

# OPERATOR'S MANUAL



## ***OBS501 Smart Turbidity Meter with ClearSensor® Technology***

Revision: 10/17



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# Safety

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**DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.**

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at [www.campbellsci.com](http://www.campbellsci.com) or by telephoning (435) 227-9000 (USA). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

## General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

## Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

## Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

## Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

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# OBS501 Smart Turbidity Meter with ClearSensor<sup>®</sup> Technology

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## 1. Introduction

The OBS501 is a submersible turbidity meter that includes dual backscatter and sidescatter sensors, shutter mechanism that keeps the lenses clean, and a refillable biocide chamber that prevents fouling. It's designed to prevent sand grains or packed sediment from getting wedged between the shutter and the sensor body, which inhibits the shutter's movement.

The OBS501 has three communication modes: SDI-12, RS-232, or simple analog output. The mode defaults to SDI-12/RS-232 but can be set in our *Device Configuration Utility (DevConfig)* to analog. As an SDI-12/RS-232 sensor, the OBS501 is shipped with an address of 0.

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### NOTE

This manual provides information only for CRBasic dataloggers. It is also compatible with most of our retired Edlog dataloggers. For Edlog datalogger support, see an older manual at [www.campbellsci.com/old-manuals](http://www.campbellsci.com/old-manuals).

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## 2. Precautions

- READ AND UNDERSTAND the [Safety](#) section at the front of this manual.
- The OBS501 needs to be sent in after two years or 70,000 cycles for drive shaft seal replacement. (See **aM9!** command in TABLE 8-2, *SDI-12 and RS-232 Measurement Commands* (p. 21)).
- The sensor may be damaged if it is encased in ice. Damages caused by freezing conditions will not be covered by our warranty.
- Campbell Scientific recommends removing the sensor from the water for the time period that the water is likely to freeze.
- Minimize temperature shock. For example, do not take sensor from sunny dashboard and immediately drop it in frigid water.
- Ensure that obstructions are not in the backscatter sensor's large field of view. See Section 7.5, *Mounting Suggestions* (p. 15), for more information.
- Maximum depth for the OBS501 is 100 m.
- For sediment concentration, the probe should be calibrated with sediments from the waters to be monitored. The procedure for calibrating the probe is provided in Section 8.6, *Calibration* (p. 24).

- Special care should be taken for sites with high sediment loads or large sand grains. Refer to Section 8.7, *Operation in High Sediment Loads and Sandy Sediments* (p. 30), for more information.
- Remember that although the OBS501 is designed to be a rugged and reliable device for field use, it is also a highly precise scientific instrument and should be handled as such.

## 3. Initial Inspection

- Upon receipt of the OBS501, inspect the packaging for any signs of shipping damage, and, if found, report the damage to the carrier in accordance with policy. The contents of the package should also be inspected and a claim filed if any shipping-related damage is discovered.
- When opening the package, care should be taken not to damage or cut the cable jacket. If there is any question about damage having been caused to the cable jacket, a thorough inspection is prudent.
- The model number is engraved on the housing. Check this information against the shipping documentation to ensure that the expected model number was received.
- Refer to the Ships With list to ensure that all parts are included (see Section 3.1, *Ships With* (p. 2)).

### 3.1 Ships With

- (1) Calibration Certificate
- (1) 27752 OBS501 Spare Parts Kit
- (1) *ResourceDVD*

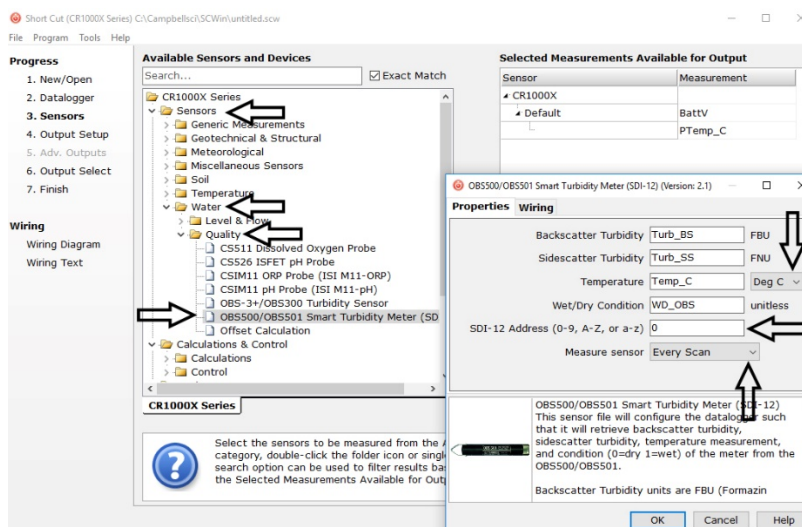
## 4. QuickStart

*Short Cut* is an easy way to program your datalogger to measure the sensor and assign datalogger wiring terminals. *Short Cut* is available as a download on [www.campbellsci.com](http://www.campbellsci.com) and the *ResourceDVD*. It is included in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ*.

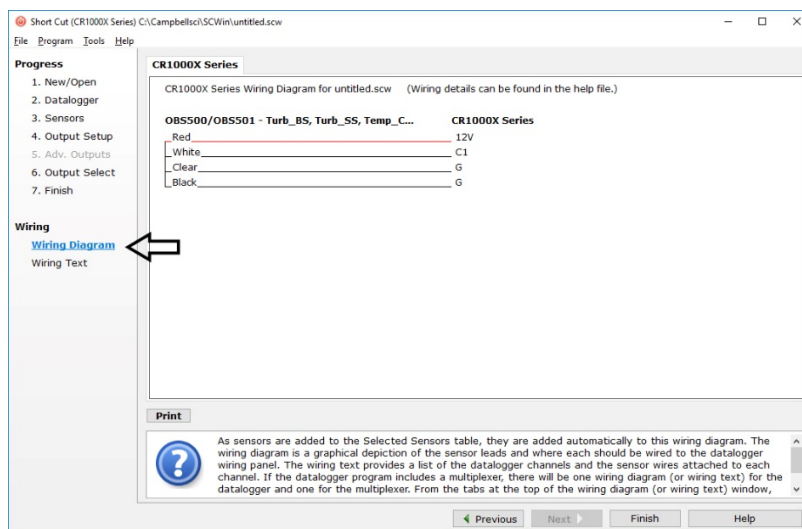
The following procedure shows using *Short Cut* to program the OBS501.

1. Open *Short Cut* and create new program.
2. Double-click the datalogger model.

- Under the **Available Sensors and Devices** list, select the **Sensors | Water | Quality** folder and double-click **OBS500/OBS501 Smart Turbidity Meter (SDI-12)**. Temperature defaults to degrees Celsius and the sensor is measured every scan. These can be changed by clicking the **Temperature** or **Measure Sensor** box and selecting a different option. Typically, the default SDI-12 address of 0 is used.



- After selecting the sensor, click **Wiring Diagram** to see how the sensor is to be wired to the datalogger. The wiring diagram can be printed now or after more sensors are added.



- Select any other sensors you have, then finish the remaining *Short Cut* steps to complete the program. The remaining steps are outlined in *Short Cut Help*, which is accessed by clicking on **Help | Contents | Programming Steps**.
- If *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ* is running on your PC and the PC to datalogger connection is active, click **Finish** in *Short Cut* and you will be prompted to send the program just created to the datalogger.

7. If the sensor is connected to the datalogger, as shown in the wiring diagram in step 4, check the output of the sensor in the datalogger support software data display to make sure it is making reasonable measurements.

## 5. Overview

### 5.1 Applications

Turbidity sensors are used for a wide variety of monitoring tasks in riverine, oceanic, laboratory, and industrial settings. They can be integrated in water-quality monitoring systems, CTDs, laboratory instrumentation, and sediment-transport monitors. The electronics of the OBS501 are housed in a Delrin® package, which is ideal for salt water or other harsh environments.

Applications include:

- Compliance with permits, water-quality guidelines, and regulations
- Determination of transport and fate of particles and associated contaminants in aquatic systems
- Conservation, protection, and restoration of surface waters
- Assess the effect of land-use management on water quality
- Monitor waterside construction, mining, and dredging operations
- Characterization of wastewater and energy-production effluents
- Tracking water-well completion including development and use

### 5.2 Backscatter and Sidescatter Sensors

The heart of the OBS501 sensor is a near-infrared (NIR) laser and two photodiodes for detecting the intensity of light scattered from suspended particles in water. One detector measures the backscatter energy and the second is positioned at 90 degrees to the emitter to measure the sidescatter energy.

Backscatter and sidescatter sensors have unique strengths and weaknesses. Generally speaking, backscatter provides high-range (HR) measurements, and sidescatter provides low-range (LR) measurements. The OBS501 combines both in one sensor to provide unequalled performance in a field turbidity sensor. With their unique optical design (U.S. Patent 4841157), backscatter sensors perform better than most in situ turbidity monitors in the following ways:

- Measure turbidity to 4000 TU (compared to 1000 TU typically for sidescatter sensors)
- Insensitivity to bubbles and organic matter
- Ambient-light rejection
- Low temperature coefficient

Sidescatter sensors have the following advantages:

- More accurate in very clean water
- Fixed measurement volume

### 5.3 ClearSensor® Antifouling Method

The OBS501 incorporates the ClearSensor® (U.S. Patent 8429952) anti-fouling method to prevent biofouling, which ensures better measurements in biologically active waters. This method uses a shutter/wiper mechanism to

protect and clean the optics (see FIGURE 5-1). Additionally, biocide, stored in a refillable chamber, continuously leaches over the optics while the shutter is in the closed position.



FIGURE 5-1. OBS501 sensor with the shutter open (top) and closed (bottom)

## 5.4 Comparison of OBS500 and OBS501

The OBS501 provides the same functionality as the OBS500 but performs better in heavy sediment load environments. This was accomplished by using a shutter and body design that eliminates parallel surfaces between moving parts (wherever possible), which prevents sand grains or packed sediment from getting wedged between the shutter and the sensor body. The OBS501 also uses a flushing action that moves the sediment down and out of the cavity behind the shutter.

The OBS501 can sense if the shutter's motor is working harder than normal. If it is, the shutter moves slightly back and forth to dislodge sand grains before fully opening or closing. Users who are particularly concerned about the sediment load can use SDI-12 instructions to place the shutter in the normally open mode.

## 6. Specifications

### Features:

- Designed to perform better in heavy sediment load environments
- Dual backscatter and sidescatter sensors used to measure turbidity
- ClearSensor® antifouling method for better measurements in biologically active water
- Disposable plastic sleeve facilitates cleanup
- Optional copper sleeve for additional protection (especially for sea water) or disposable plastic sleeve facilitates easy cleanup
- Compatible with Campbell Scientific CRBasic dataloggers: CR200(X) series, CR300 series, CR6 series, CR800 series, CR1000X, CR1000, CR3000, and CR5000

<b>Dual Probe:</b>	Backscatter and 90-degree sidescatter
<b>Turbidity Units (TU) Range:</b>	0 to 4000 TU (see Section 8.1, <i>Turbidity Units</i> (p.17), for information about turbidity units)
<b>Active and Passive Antifouling:</b>	Shutter, wiper, biocide, copper, optional removable sleeve
<b>Accuracy:</b>	0.5 TU or $\pm 2\%$ of reading, whichever is greater
<b>Temperature Accuracy:</b>	$\pm 0.3$ °C, 0 to 40 °C
<b>Temperature Range:</b>	0 to 40 °C, non-freezing, ice may destroy the sensor
<b>Storage Temperature:</b>	0 to 40 °C
<b>Emitter Wavelength:</b>	850 nm
<b>Power Requirements:</b>	7 to 18 Vdc
<b>Power Consumption</b>	
<b>Quiescent Current:</b>	< 200 $\mu$ A
<b>Measurement/Communication Current:</b>	< 40 mA
<b>Shutter Motor Active Current:</b>	< 380 mA
<b>Cycle Time:</b>	Open, measure, close, < 20 s
<b>Measurement Time:</b>	< 4 s
<b>Outputs:</b>	SDI-12 (version 1.3) 1200 bps RS-232 9600 bps, 8 data bits, 1 stop bit, no parity, no flow control  Analog 0 to 5 V
<b>Submersion Depth:</b>	100 m (328 ft)
<b>Diameter:</b>	4.76 cm (1.875 in)
<b>Length:</b>	27.54 cm (10.84 in)
<b>Weight:</b>	0.74 kg (1.62 lb)
<b>Maximum Cable Length:</b>	116 m (380 ft) (1 channel SDI-12 or Analog); 15 m (50 ft) (RS-232)

## 7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.3, *Datalogger/RTU Connection* (p. 12), and Section 7.4, *Programming* (p. 14). *Short Cut* does this work for you. See Section 4, *QuickStart* (p. 2), for a *Short Cut* tutorial.



## 7.1 Default Settings

The OBS501 is configured at the factory with the default settings shown in TABLE 7-1. For most applications, the default settings are used.

TABLE 7-1. Factory Settings	
SDI-12/Analog	SDI-12
SDI-12 Address	0
RS-232 Baud Rate	9600
Turbidity Units	TU
Temperature Units	Celsius
Side Scatter Ratio Top	1200 TU

## 7.2 Device Configuration Utility

*Device Configuration Utility (DevConfig)* is used to change settings, set up the analog sensor, enter RS-232 commands, and update the operating system.

Use the OBS501 test cable or A200 to connect the OBS501 to a computer running *DevConfig*. Connect the red wire to a 12 Vdc power supply and the black wire to ground. The datalogger power supply is a good choice to use for the power supply. *DevConfig* software is shipped on the Campbell Scientific *ResourceDVD* included with the OBS501.

Alternatively, you can attach an A200 (pn 25982) to the field cable of the OBS501, which also powers the sensor. The first time the A200 is connected to your computer may require you to wait for the USB drivers to be installed. This installation should happen automatically through Windows update. If that fails, you can find the drivers on the *ResourceDVD* or on Campbell Scientific's website at [www.campbellsci.com](http://www.campbellsci.com). TABLE 7-2 provides the field cable wiring.

### CAUTION

The A200 does not provide enough current to open and close the OBS501's shutter. Therefore, to use the A200 to run these commands in the terminal mode, connect the field cable's red wire to the datalogger's 12 V and the field cable's black wire to the datalogger ground.

TABLE 7-2. Wiring an OBS501 Cable to an A200	
Field Cable Wire	A200 Port
Red	+12 VDC
Black	G (ground)
White	Tx
Blue	Rx

**NOTE**

The OBS501 is supported in *DevConfig* version 1.16 or higher.

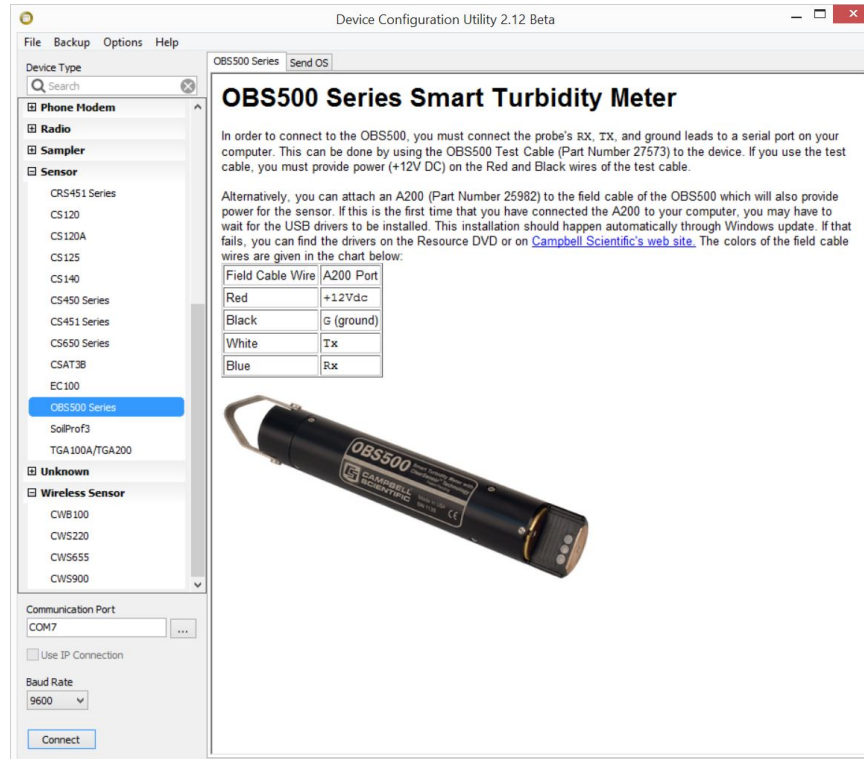


FIGURE 7-1. Device Configuration Utility

After installing *DevConfig*, select the OBS500 Series in the Device Type – Sensor selection. Select the correct **PC Serial Port** and then click **Connect** (see FIGURE 7-1).

## 7.2.1 Setting Editor Tab

*DevConfig* allows you to change the configuration of the OBS501 by selecting the **Settings Editor** tab.

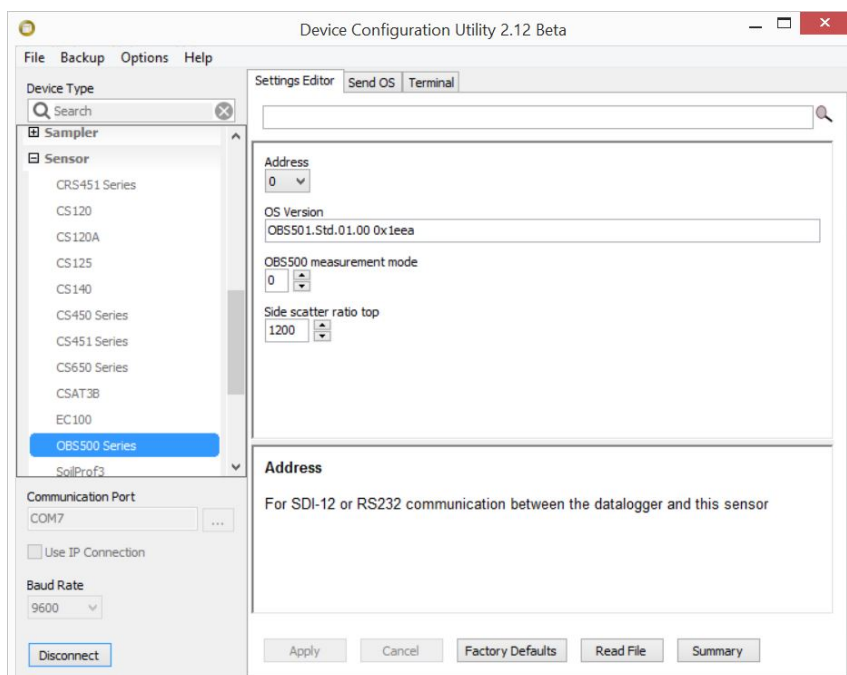


FIGURE 7-2. Settings Editor screen

There are three settings that can be changed: SDI-12 address, measurement mode, and sidescatter ratio top. Select the desired values and press the **Apply** button.

Measurement mode sets the sensor to a specific communication mode (SDI-12/RS-232 = 0; Analog (0 to 5 V) = 1).

Sidescatter ratio top: Two measurement commands return a weighted ratio of backscatter to sidescatter (**aM2!** and **aM6!**). As water gets cloudier, backscatter is the more accurate reading due to the large sample volume. This setting specifies the TU value at which the ratio is 100% backscatter. So your backscatter output from the command will be equal to the ratio value.

### NOTE

The SDI-12 address is not used while in analog mode.

## 7.2.2 Downloading a New Operating System

Use *DevConfig* to download a new operating system (OS) to the OBS501. Select the **Send OS** tab and follow the directions on the screen.

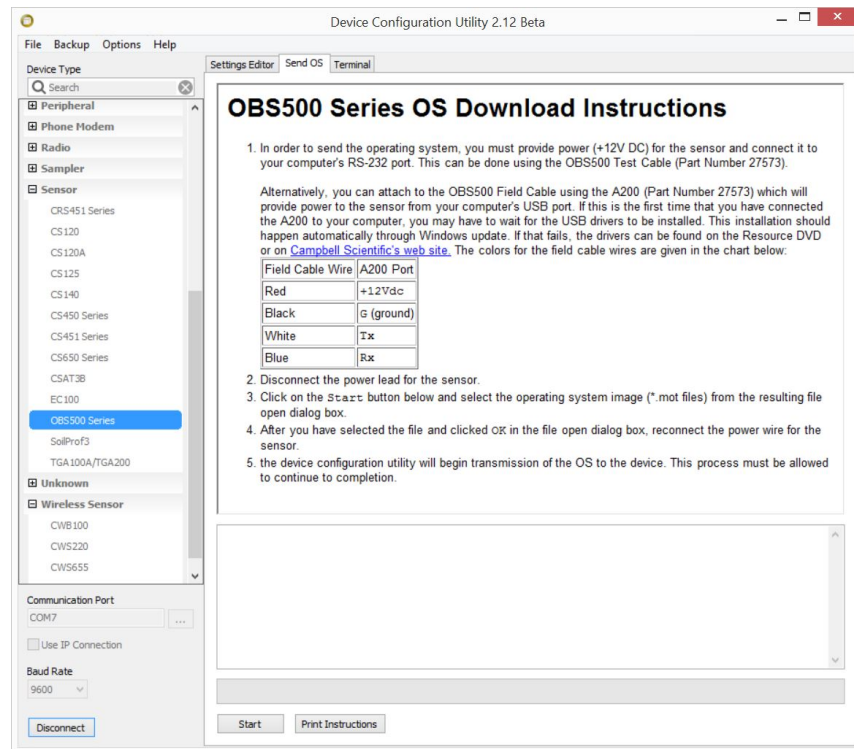


FIGURE 7-3. DevConfig, Send OS

## 7.2.3 Terminal Tab

Use the **Terminal** tab to verify the setup of the OBS501. In the **Terminal** window, press the **Enter** key several times to wake up the RS-232 mode of the sensor. Once successfully connected, you see an **OBS\_501>** prompt. FIGURE 7-4 shows *DevConfig* after pressing **1** (one) to identify the OBS501. By default, the OBS501 is in the SDI-12 mode for communication. Once in the RS-232 mode, if there is no communication for 20 s, the sensor returns to the SDI-12 mode.

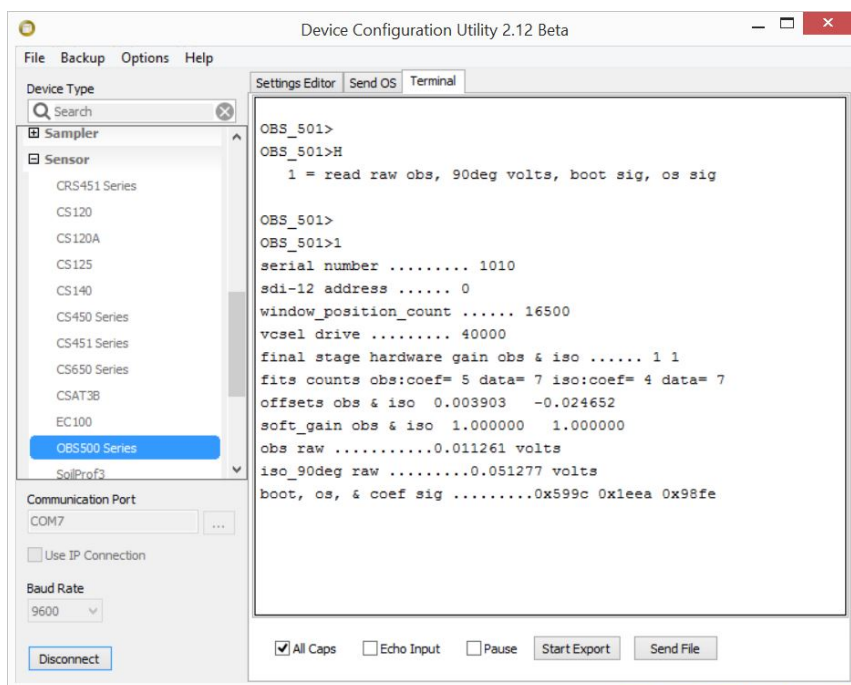


FIGURE 7-4. Terminal Mode using 1 and H commands

TABLE 7-3. RS-232 Terminal Commands	
Terminal Commands	Values Returned
1 Identify	Serial Number, SDI-12 address, etc.
2 Open Wiper	Command to open wiper started – please wait Wiper now open – average current was xxx mA
3 Close Wiper	Command to close wiper started – please wait Wiper now closed – average current was xxx mA
H or h	Help menu
U	Burst measurement command: returns temperature (deg C), backscatter (FBU), sidescatter (FNU), bs standard deviation, ss standard deviation. It will take measurements until you hit enter to stop the command.

**CAUTION**

The A200 does not provide enough current to open and close the OBS501's shutter. Therefore, to use the A200 to run these commands in the terminal mode, connect the field cable's red wire to the datalogger's 12 V and the field cable's black wire to the datalogger ground.

## 7.3 Datalogger/RTU Connection

The OBS501CBL-L Field Cable connects the OBS501 to a datalogger or RTU (see Section 8.3, *OBS501CBL-L Connector Pin Out* (p. 19)). TABLE 7-4, *SDI-12 Wiring* (p. 12), TABLE 7-5, *RS-232 Wiring* (p. 13), and TABLE 7-6, *Analog 0 to 5 Volt Wiring* (p. 13), provide wiring for connecting the OBS501CBL-L Field Cable to a Campbell Scientific datalogger. Wiring to dataloggers or RTUs manufactured by other companies is similar.

### NOTE

Campbell Scientific recommends powering down the system before wiring the OBS501. The shield wire plays an important role in noise emissions and susceptibility as well as transient protection.

### 7.3.1 SDI-12 Wiring

TABLE 7-4. SDI-12 Wiring				
Color	Description	CR300 CR800 CR5000 CR3000 CR1000	CR200X Series	CR6
Red	Power	12V	Battery+	12V
Black	Power Ground	G	G	G
White	SDI-12 Signal	Control Port <sup>1</sup>	C1/ SDI-12	Control Port <sup>1</sup> or Universal Channel <sup>1</sup>
Brown	not used	not used	not used	not used
Blue	not used	not used	not used	not used
Green	not used	not used	not used	not used
Clear	Shield	G	G	G
<sup>1</sup> Only odd control ports or universal channels can be used for SDI-12 (for example, C1, C3...)				

### 7.3.2 RS-232 Wiring

The CR800 series, CR1000, and CR3000 dataloggers support serial communications with dedicated UART hardware on their control ports. They use two control ports configured as a single communications (COMn) port. The CR6 uses two control ports or two universal channels configured as a single communication port.

**TABLE 7-5. RS-232 Wiring**

<b>Color</b>	<b>Description</b>	<b>CRBasic Datalogger</b>	<b>RS-232 9-pin</b>
Red	Power	12V	
Black	Power Ground	G	
White	RS-232 Transmit (OBS501 Tx Output)	Rx (COM $n$ , C $n$ , or U $n$ )	Pin 2 Rx (Input)
Blue	RS-232 Receive (OBS501 Rx Input)	Tx (COM $n$ , C $n$ , or U $n$ )	Pin 3 Tx (Output)
Brown		not used	
Green		not used	
Clear	Shield	G	

### 7.3.3 Analog 0 to 5 Volt Wiring

**TABLE 7-6. Analog 0 to 5 Volt Wiring**

<b>Color</b>	<b>Description</b>	<b>CR6, CR300, CR800, CR850, CR1000, CR3000, CR5000</b>
Blue	Shutter Open – Control High	Control Port or Universal Channel
White	Backscatter (Low) or Sidescatter (High) Control	Control Port or Universal Channel
Green	Signal	Differential High or Single-Ended Input
Brown	Analog Ground	Differential Low or Analog Ground
Black	Power Ground	G
Red	Power	SW12V
Clear	Shield	G

The measurement sequence is to raise the blue wire from ground to 5 volts to open the shutter, delay 6 seconds, and then measure the backscatter analog output on the green wire. If sidescatter is desired, then raise the white wire from ground to 5 volts, delay 3 seconds, and then measure the sidescatter analog output on the green wire. In either case, lower the blue wire to ground to close the shutter. Note that measurements can be differential or single-ended. Differential measurements are recommended.

The output is scaled as 1 mV per TU. For example, 100 mV = 100 TU, 4000 mV = 4000 TU.

## 7.4 Programming

*Short Cut* is the best source for up-to-date datalogger programming code. Programming code is needed when:

- Creating a program for a new datalogger installation
- Adding sensors to an existing datalogger program

If your data acquisition requirements are simple, you can probably create and maintain a datalogger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great source for programming code to start a new program or add to an existing custom program.

### NOTE

*Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in Section 4, *QuickStart* (p. 2). If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code Into CRBasic Editor* (p. A-1).

Programming basics for CRBasic dataloggers are provided in the following sections. Complete program examples for select CRBasic dataloggers can be found in Appendix B, *Example Programs* (p. B-1). Programming basics and programming examples for Edlog dataloggers are provided at [www.campbellsci.com/old-manuals](http://www.campbellsci.com/old-manuals).

### 7.4.1 SDI-12

The **SDI12Recorder** instruction is used to read the OBS501 in SDI-12 mode. See the CRBasic help for more information about this command. Refer to Appendix B.2, *CR1000 SDI-12 Program* (p. B-2), for an example of using this CRBasic instruction. More information about using the SDI-12 protocol is provided in Section 8.5.1, *SDI-12* (p. 20), and Appendix D, *SDI-12 Sensor Support* (p. D-1).

### 7.4.2 RS-232

The **SerialOut()** instruction sends strings over the Tx COM port and the **SerialIn()** instruction receives strings from the Rx COM port.

Refer to Appendix B.3, *CR1000 RS-232 Program* (p. B-3), for an example of using these CRBasic instructions. More information about using the RS-232 protocol is provided in Section 8.5.2, *RS-232* (p. 24).

### 7.4.3 Analog

The **PortSet()** instruction is used to open the shutter. Either the **VoltDiff()** (recommended) or **VoltSe()** instruction is used to measure the analog voltage output.



Refer to Appendix B.4, *CR1000 Analog Program (p. B-8)*, for an example of using these CRBasic instructions.

## 7.5 Mounting Suggestions

Maximum depth for the OBS501 housing is 100 meters.

Schemes for mounting the OBS501 will vary with applications; however, the same basic precautions should be followed to ensure the unit is able to make a good measurement and that it is not lost or damaged.

- The most important general precaution is to **orient the unit so that the OBS501 looks into clear water** without reflective surfaces. This includes any object such as a mounting structure, a streambed, or sidewalls. The backscatter sensor in the OBS501 can see to a distance of about 50 cm (20 in) in very clean water at angles ranging from 125° to 170°. The sidescatter (SS) sensor can only “see” to about 5 cm (2 in) at 90°.
- The sensor has ambient-light rejection features, but it is still best to orient it away from the influence of direct sunlight. Shading may be required in some installations to totally protect from sunlight interference.
- Nearly all exposed parts of the instrument are made of Delrin®, a strong but soft plastic.

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### CAUTION

Always pad the parts of the OBS501 housing that will contact metal or other hard objects with electrical tape or neoprene.

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- Mounting inside the end of a PVC pipe is a convenient way to provide structure and protection for deployments. The OBS501 will fit inside a 2-in. schedule 40 PVC pipe.

The most convenient means for mounting the unit to a frame or wire is to use large, high-strength nylon cable ties (7.6 mm (0.3 in) width) or stainless steel hose clamps. First cover the area(s) to be clamped with tape or 2 mm (1/16 in) neoprene sheet. Clamp the unit to the mounting frame or wire using the padded area.

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### CAUTION

Do not tighten the hose clamps more than is necessary to produce a firm grip. Overtightening may crack the pressure housing and cause a leak. Use spacer blocks when necessary to prevent chafing the unit with the frame or the wire.

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### 7.5.1 Mounting Example

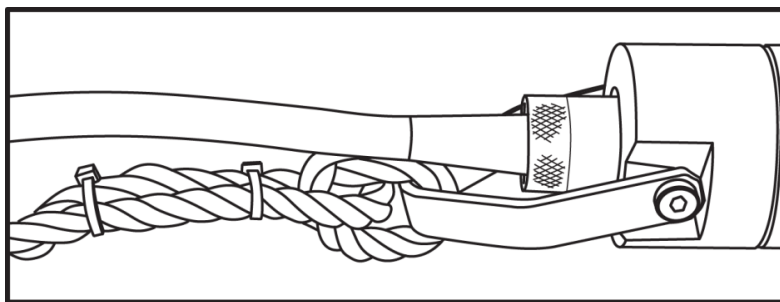


FIGURE 7-5. Use strain relief to keep stress off the cable and provide extra security

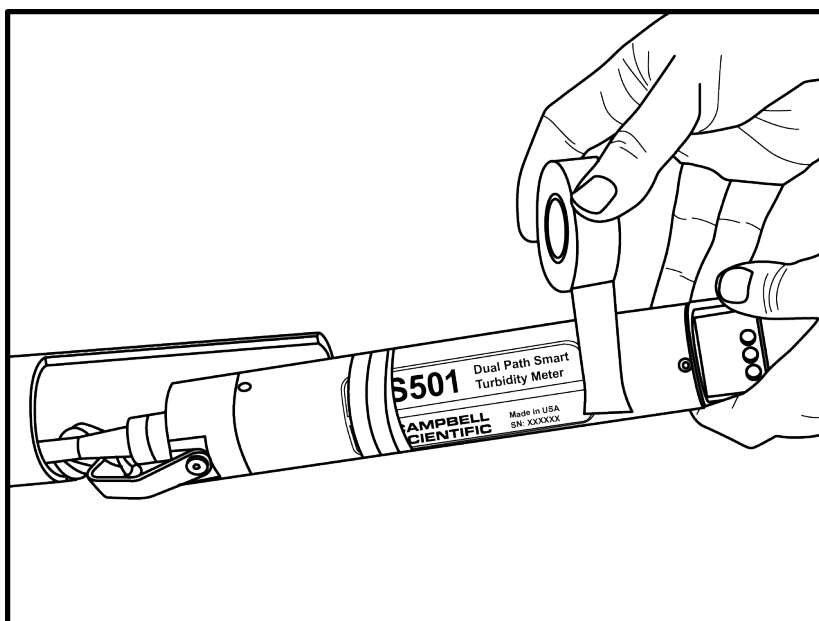


FIGURE 7-6. Apply tape to protect sensor

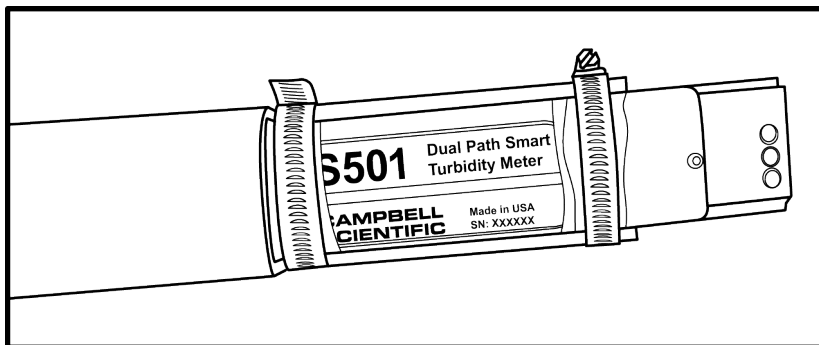


FIGURE 7-7. Secure with hose clamps; do not overtighten

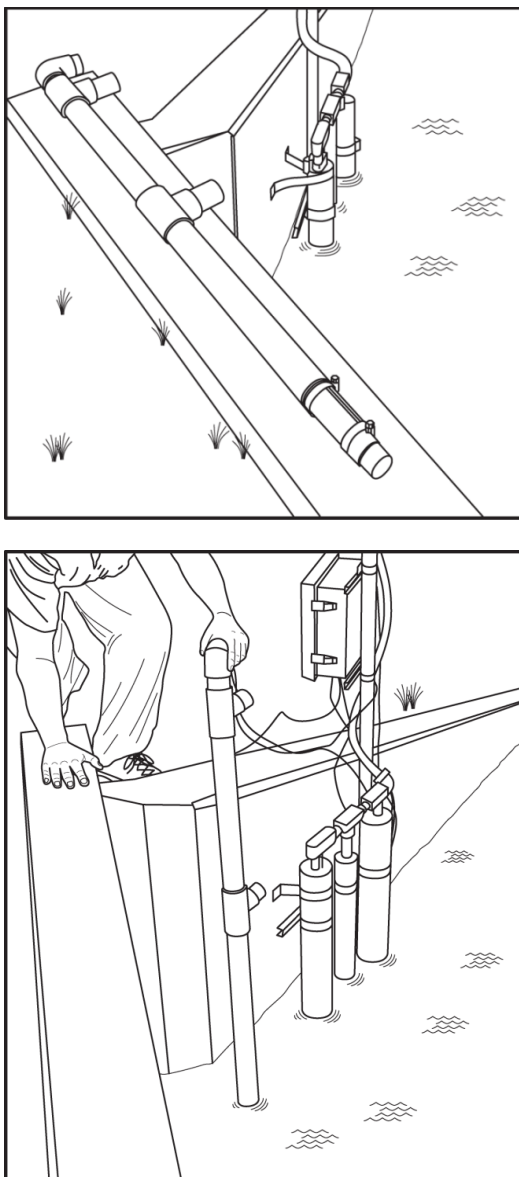


FIGURE 7-8. Place and secure mounting fixture

## 8. Operation

### 8.1 Turbidity Units

Conceptually, turbidity is a numerical expression in turbidity units (TU) of the optical properties that cause water to appear hazy or cloudy as a result of light scattering and absorption by suspended matter. Operationally, a TU value is interpolated from neighboring light-scattering measurements made on calibration standards such as Formazin, StablCal®, or styrene divinylbenzene (SDVB) beads. Turbidity is caused by suspended and dissolved matter such as sediment, plankton, bacteria, viruses, and organic and inorganic dyes. In general, as the concentration of suspended matter in water increases, so will its turbidity; as the concentration of dissolved, light-absorbing matter increases, turbidity will decrease.

Descriptions of the factors that affect turbidity are given in Appendix E, *Factors that Affect Turbidity and Suspended-Sediment Measurements* (p. E-1). Like all other optical turbidity monitors, the response depends on the size, the composition, and the shape of suspended particles. For this reason, for monitoring concentrations, ***the sensor must be calibrated with suspended sediments from the waters to be monitored.*** There is no “standard” turbidimeter design or universal formula for converting TU values to physical units such as mg/l or ppm. TU values have no intrinsic physical, chemical, or biological significance. However, empirical correlations between turbidity and environmental conditions, established through field calibration, can be useful in water-quality investigations.

The USGS has an excellent chapter on turbidity measurements in their “National Field Manual for the Collection of Water-Quality Data”:

[http://water.usgs.gov/owq/FieldManual/Chapter6/Section6.7\\_y2.1.pdf](http://water.usgs.gov/owq/FieldManual/Chapter6/Section6.7_y2.1.pdf)

Historically, most turbidity sensor manufacturers and sensor users labeled the units NTUs, for Nephelometric Turbidity Units. ASTM and the USGS have come up with the following unit classifications that are applicable to the OBS501:

Optical Backscatter	FBU	Formazin Backscatter Unit
Sidescatter	FNU	Formazin Nephelometric Unit
Ratio Back and Sidescatter	FNRU	Formazin Nephelometric Ratio Unit

The document “U.S. Geological Survey Implements New Turbidity Data-Reporting Procedures” details the units:

<http://water.usgs.gov/owq/turbidity/TurbidityInfoSheet.pdf>

## 8.2 Vertical-Cavity Surface-Emitting Laser Diode

OBS501 sensors detect suspended matter in water and turbidity from the relative intensity of light backscattered at angles ranging from 125° to 170° and at 90° for the sidescatter measurement. A 3D schematic of the main components of the sensor is shown in FIGURE 8-1. The OBS501 light source is a Vertical-Cavity Surface-Emitting Laser diode (VCSEL), which converts 5 mA of electrical current to 2000 µW of optical power. The detectors are low-drift silicon photodiodes with enhanced NIR responsivity. NIR responsivity is the ratio of electrical current produced per unit of light power in air or water. A light baffle prevents direct illumination of the detector by the light source and in-phase coupling that would otherwise produce large signal biases. A daylight-rejection filter blocks visible light in the solar spectrum and reduces ambient-light interference. In addition to the filter, a synchronous detection circuit is used to eliminate the bias caused by ambient light. The VCSEL is driven by a temperature-compensated Voltage-Controlled Current Source (VCCS).

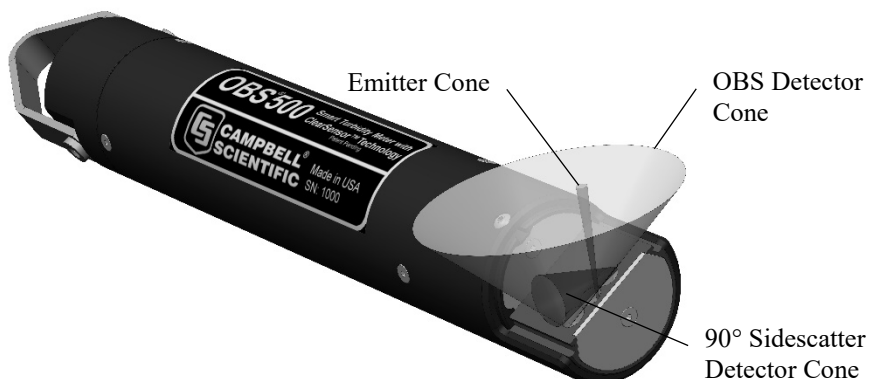


FIGURE 8-1. Orientation of emitter cone (source beam) and OBS and sidescatter detector (acceptance) cones

The beam divergence angle of the VCSEL source is 4° worst case and 2° typical (95% of the beam power is contained within a 5° cone).

### 8.3 OBS501CBL-L Connector Pin Out

The OBS501CBL-L Field Cable terminates with an MCIL wet pluggable underwater terminator. TABLE 8-1, shows the contact numbers for the MCIL/MCBH-8 connectors and the electrical functions and wire colors.

TABLE 8-1. OBS501CBL-L Connector Pin-Out		
MCIL-8-MP/MCBH-8-FS Contact Number	Electrical Function	Wire Color
1	Power Ground	Black
2	SDI-12/RS-232 TX/Analog SS-BS Control	White
3	Power (7 to 15 V)	Red
4	Analog Signal	Green
5	RS-232 RX/Shutter Open	Blue
6	NC	
7	Analog Ground	Brown
8	NC	
No Connection		Clear/Braid

### 8.4 Measurements

The OBS501 design combines the sensor, analog measurement, and signal processing within a single housing resulting in the integration of state-of-the-art sensor and measurement technology. The 24-bit A/D has simultaneous 50/60 Hz rejection and automatic calibration for each measurement. A number of additional advanced measurement techniques are employed to harness the best possible performance available from today's state-of-the-art sensor

technology. The sensor reverts to a low-power sleep state between measurements. A series of measurements is performed, yielding two turbidity and one temperature value. This measurement cycle takes about 20 seconds. The measurement cycle is activated by commands via SDI-12, RS-232 terminal commands, or a control line(s) going high (analog measurements).

With SDI-12 and RS-232, the basic values output by the OBS501 are backscatter turbidity, sidescatter turbidity, and temperature. The OBS501 can also output a ratiometric measurement that combines the backscatter and sidescatter measurements. See TABLE 8-3, *Variables Returned by the SDI-12 and RS-232 Commands* (p. 23), and Equation 8-1 for more information regarding the ratiometric measurement. Other diagnostic information is available (see TABLE 8-2, *SDI-12 and RS-232 Measurement Commands* (p. 21)) including the raw voltage output from the backscatter and the sidescatter sensors, the current to open and close the shutter, an open and close position count, total open and close cycles, and a moisture alarm. The moisture alarm returns a zero when the circuit board inside is dry, but if there is ever a leak past the shaft seals, the moisture alarm will begin to increment each time the shutter moves and moisture is detected (the variable is called *wet dry* in TABLE 8-3, *Variables Returned by the SDI-12 and RS-232 Commands* (p. 23)). The unit will also stop opening and closing to prevent damage to the circuit board. Not all SDI-12 measurement commands return the moisture alarm during the measurement. See TABLE 8-2, *SDI-12 and RS-232 Measurement Commands* (p. 21), to determine which command is right for your application. If an OBS501 returns a 1 or greater to the moisture alarm, then the unit should be returned to Campbell Scientific for maintenance. The OBS501 is shipped from the factory to output turbidity in TU and temperature in degrees Celsius. The analog output supports backscatter and/or sidescatter according to the status of a control line.

## 8.5 Communication Modes

### 8.5.1 SDI-12

The OBS501 uses an SDI-12-compatible hardware interface and supports a subset of the SDI-12 commands. The most commonly used command is the **aM!** command, issued by the datalogger. Here, *a* represents the sensor address (0–9, a–z, A–Z). The communication sequence begins with the datalogger waking the sensor and issuing the **aM!** command. In the case of this command, the sensor responds to the datalogger indicating that four measurements will be ready within 35 seconds. Subsequent communications handle data reporting from the sensor to the datalogger.

The SDI-12 protocol has the ability to support various measurement commands. The OBS501 supports the measurement commands that are listed in TABLE 8-2. For more SDI-12 commands that return diagnostic information and additional explanation regarding the types of measurement commands, see Appendix D, *SDI-12 Sensor Support* (p. D-1). Also, for an explanation of variables in TABLE 8-2, see TABLE 8-3.

**TABLE 8-2. SDI-12 and RS-232 Measurement Commands**

Commands <sup>1</sup>	Process	Values Returned	Time to Respond (s)	
			Maximum	Typical
<b>aM!</b> <b>aMC!</b> <b>aC!</b> <b>aCC!</b> a = address	Open Wiper Measure Close Send Data	bs (TU) ss (TU) temperature (°C) wet dry (0=dry 1=wet)	35	20
<b>aC1!</b> <b>aCC1!</b>	Burst Data Open Wiper Measure 100 Times Close Send Data	bs median bs mean bs standard deviation bs minimum bs maximum ss median ss mean ss standard deviation ss minimum ss maximum	54	54
<b>aM2!</b> <b>aMC2!</b> <b>aC2!</b> <b>aCC2!</b>	Open Wiper Measure Close Send Data	bs (TU) ss (TU) ratio (TU) temperature (°C) raw bs (V) raw ss (V) open current (mA) close current (mA) wet dry (0=dry 1=wet)	35	20
<b>aM3!</b> <b>aMC3!</b> <b>aC3!</b> <b>aCC3!</b>	Open Wiper Send Data	open wiper position count open max current count open timeout count open current (mA) total open/close count	20	10
<b>aM4!</b> <b>aMC4!</b> <b>aC4!</b> <b>aCC4!</b>	Measure Send Data	bs (TU) ss (TU) temperature (°C) wet dry (0=dry 1=wet)	6	4
<b>aC5!</b> <b>aCC5!</b>	Burst Data Measure 100 Times Send Data	bs median bs mean bs standard deviation bs minimum bs maximum ss median ss mean ss standard deviation ss minimum ss maximum	50	50

TABLE 8-2. SDI-12 and RS-232 Measurement Commands

Commands <sup>1</sup>	Process	Values Returned	Time to Respond (s)	
			Maximum	Typical
<b>aM6!</b> <b>aMC6!</b> <b>aC6!</b> <b>aCC6!</b>	Measure Send Data	bs (TU) ss (TU) ratio (TU) temperature (°C) raw bs (V) raw ss (V) open current (mA) <sup>2</sup> close current (mA) <sup>2</sup> wet dry (0=dry 1=wet)	6	4
<b>aM7!</b> <b>aMC7!</b> <b>aC7!</b> <b>aCC7!</b>	Close Wiper Send Data	close wiper position count close max current count close timeout count close current (mA) total open/close count	20	10
<b>aC8!</b> <b>aCC8!</b>	Raw Burst Data in Volts Measure 100 Times Send Data	bs median bs mean bs standard deviation bs minimum bs maximum ss median ss mean ss standard deviation ss minimum ss maximum	50	50
<b>aM9!</b> <b>aMC9!</b>	Wipe Leave Open	total open/close count open wiper position count open max current count open timeout count close wiper position count close max current count close timeout count	35	20
<sup>1</sup> RS-232 communication does NOT support the <b>aMC!</b> and <b>aCC!</b> measurement commands. <sup>2</sup> The open and close current returned with the <b>M6!</b> is from the last time the shutter opened and closed. This command is for running in open mode, so the values may be repetitive if you wipe less frequently than you measure.				

**NOTE**

With the SDI-12 concurrent measurements (**aCx!**), the datalogger does not request the data until the next interval hits. For example, if you have a 30-minute interval, you will not see the data for 30 minutes. There is not an equivalent **M** command to the **aC1!**, **aC5!**, and **aC8!** commands since the **M** command is limited to returning nine values.

As the measurement data is transferred between the probe and the datalogger digitally, there are no offset errors incurred with increasing cable length as seen with analog sensors. However, with increasing cable length, there is still a point when the digital communications will break down, resulting in either no



response or excessive SDI-12 retries and incorrect data due to noise problems. In these circumstances, use the **aMC!** or **aCC!** command to do a cyclic redundancy check (CRC). For more information regarding cyclic redundancy check commands, refer to Appendix D, *SDI-12 Sensor Support (p. D-1)*, a datalogger manual, or CRBasic help.

**TABLE 8-3. Variables Returned by the SDI-12 and RS-232 Commands**

Variable Name	Parameter	Units	Description
bs	Backscatter	FBU	Optical backscatter reading
ss	Sidescatter	FNU	Optical sidescatter reading
ratio	Weighted ratio		Weighted ratio of backscatter to sidescatter. The threshold where the ratio becomes 100% backscatter is set in <i>DevConfig (ratio_top)</i> . The default is 1200 FNU. (See equation 1.)
temperature	VCSEL temperature	°C	The temperature of the VCSEL. Once a sensor has equilibrated to the water temperature, this value will track water temperature.
raw bs	Raw backscatter	V	Voltage reading of backscatter. This is the raw reading before the value is converted via the calibration equation to FBU.
raw ss	Raw sidescatter	V	Voltage reading of sidescatter. This is the raw sidescatter reading before it is converted to FNU via the calibration equation.
wet dry	Wet dry	0 or 1	Binary indicator if the shaft seals have leaked and water has made it to the circuit board. A 0 will be returned until a leak occurs. Once a leak occurs, the sensor will stop moving the shutter but continue to make measurements.
open/close current	Open or close current	mA	The average current draw the last time the shutter opened or closed.
wiper position count	Wiper position	Count	When the motor rotates, it outputs pulses that are counted by the processor and returned via open/close/wipe commands. The count should be near 16400. A value << 16400 could mean the shutter is jammed.
max current count	Maximum current	Count	The motor shuts off if the maximum current occurs while trying to move the shutter. The max current count will increment. This could also indicate the shutter is jammed.
timeout count	Time out	Count	It is very unusual for this to be non-zero. This value will increment if the processor goes through the process of applying power to the motor and not detecting any pulses from the motor moving after a set time period.
total open/close count	Total open/close cycles	Count	Every time the sensor detects that it is back in the home position (closed), it increments a count.

$$ratio = bs \left( \frac{ss}{ratio\_top} \right) + ss \left( 1 - \frac{ss}{ratio\_top} \right) \quad (8-1)$$

### 8.5.1.1 Measuring Multiple SDI-12 Sensors

Up to ten OBS501s or other SDI-12 sensors can be connected to a single datalogger control port. Each SDI-12 device must have a unique SDI-12 address of 0 and 9, A to Z, or a to z. See Appendix D, *SDI-12 Sensor Support (p. D-1)*, for more information.

## 8.5.2 RS-232

RS-232 measurements of the OBS501 are typically made by a CR300, CR800, CR850, CR1000, CR3000, or CR6 datalogger or an RTU device. The OBS501CBL-L Field Cable is used and wired appropriately for the measurement device. See TABLE 8-4 for settings. Measurement commands for RS-232 are shown in TABLE 8-2, *SDI-12 and RS-232 Measurement Commands (p. 21)*. RS-232 measurement commands do not include the **aMC!** or **aCC!** variations shown in TABLE 8-2.

TABLE 8-4. RS-232 Settings	
Bits Per Second	9600
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None

## 8.6 Calibration

### 8.6.1 Turbidity

Field recalibration is not recommended and usually not needed until the OBS501 is sent back to Campbell Scientific for the two-year service. We recommend checking the calibration in the field as described below. If a 9-point calibration is needed, the OBS501 should be sent to Campbell Scientific to perform the calibration.

The normalized response of an OBS501 sensor to SDVB turbidity over the range from 0 to 4,000 TU is shown in FIGURE 8-2. As shown on the inset, the response function is contained within region A, the linear region, of the universal response curve. However, there is residual nonlinearity that is removed by calibration and by computation of a TU value with a 2nd-order polynomial. This section explains how to do a turbidity calibration.

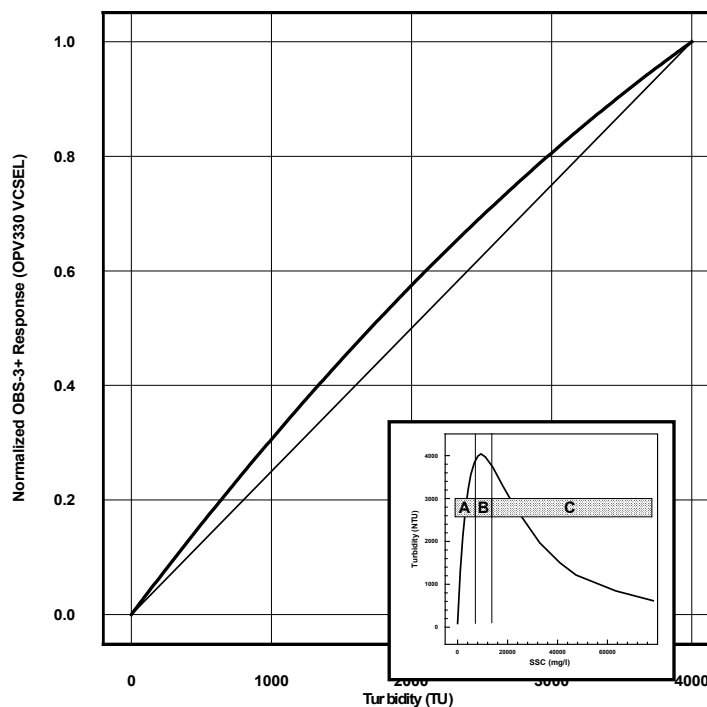


FIGURE 8-2. Normalized response of OBS501 to AMCO Clear® turbidity. The inset shows the response function of a turbidity sensor to high-sediment concentrations.

AMCO Clear® SDVB turbidity standards are used to calibrate an OBS501 sensor. SDVB standards are made for individual instruments. Standards made for one model of turbidity meter cannot be used to calibrate a different model.

TABLE 8-5. Calibration Materials and Volumes	
Sidescatter 90-Degree Materials	Calibration Cup Diameter (mm/inches)
8594 – 20 TU	100 (~4)
8595 – 40 TU	100 (~4)
8596 – 125 TU	100 (~4)
8597 – 250 TU	100 (~4)
8598 – 500 TU	100 (~4)
8599 – 1000 TU	100 (~4)
<b>OBS501 Material</b>	
8600 – 125 TU	200 (~7.9)
8601 – 250 TU	200 (~7.9)
8602 – 500 TU	200 (~7.9)
8603 – 1000 TU	100 (~4)
8604 – 2000 TU	100 (~4)
8605 – 4000 TU	100 (~4)

The GFS item numbers, standard values, and volumes required for the standard low ranges are given in TABLE 8-5. SDVB standards have a shelf life of two years provided that they are stored in tightly sealed containers and evaporation is minimized.

The TU values of the standards will remain the same as long as the ratio of particle mass (number of particles) to water mass (volume) does not change. Evaporation causes this ratio to increase and dust, bacteria growth, and dirty glassware can also cause it to increase. Therefore, take the following precautions.

1. Always use clean glassware and calibration containers.
2. Don't leave standards on the bench in open containers or leave the standard bottles uncapped. Perform the calibration as quickly as possible and return the AMCO solutions to their bottles.
3. Clean dirty sensors with a clean, alcohol-soaked cloth to sterilize them before dipping them into the standards.
4. Transfer entire bottles between containers. To avoid aeration, do not shake excess fluid off the glassware.

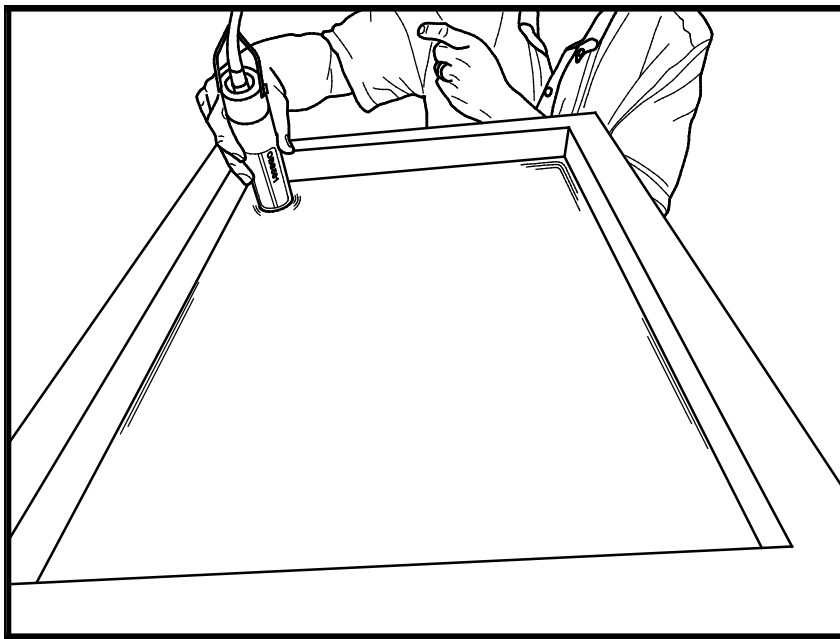
Because of the intrinsic errors in the TU value of formazin used by the SDVB manufacturer (GFS Chemicals) and the dilution procedures, the uncertainty in the TU value of an SDVB standard is  $\pm 1.2\%$  of the value indicated on the standard bottle. Consequently, the TU value of one liter of standard in an uncovered 100-mm calibration cup will increase  $\sim 1\%$  in 10 hours on a typical summer day (relative humidity = 90% and air temperature = 18 °C). For example, the TU value of a 2000 TU standard in a 100-mm cup will increase by about 2 TU (0.1%) per hour. TABLE 8-6 gives the increases for some other commonly used standards.

<b>TABLE 8-6. Change in TU value resulting from one hour of evaporation of SDVB standard</b>				
<b>Calibration-cup Size <math>\phi</math> mm (<math>\phi</math> in)</b>	<b>250 TU</b>	<b>500 TU</b>	<b>2000 TU</b>	<b>4000 TU</b>
100 (4)	+0.26	+0.52	+2.10	+4.20
150 (6)	+0.60	+1.20	+4.80	+9.70

**Materials and equipment used in the procedure:** OBS501 with cable, datalogger, large black polyethylene plastic tub (0.5 M I.D. X 0.25 M deep) for measuring the clear-water points, and 100-mm and 200-mm black PE (polyethylene) calibration cups.

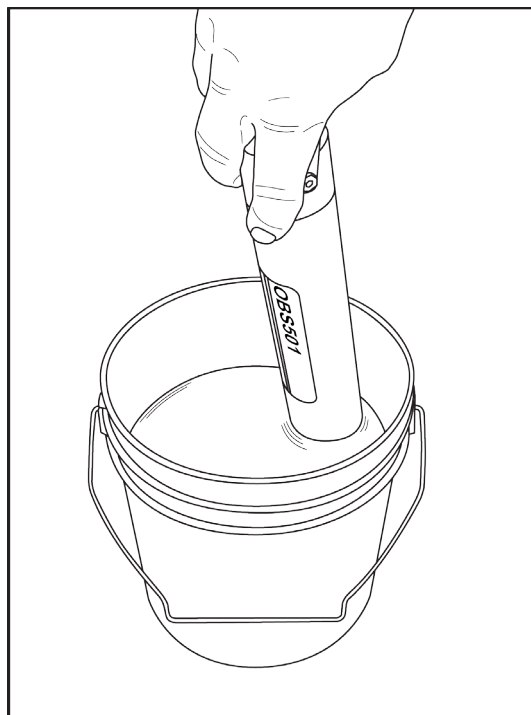
### Procedure

1. Swab sensor with an alcohol-soaked towel to sterilize it. Position the OBS501 in a large, black tub of fresh tap water as shown in FIGURE 8-3 and record a 10 s average of the low-range output. Record the average output on the calibration log sheet.



*FIGURE 8-3. Position of OBS501 in clean tap water in big black tub*

2. Pour the first SDVB standard into the appropriately sized cup (see TABLE 8-6).
3. Position the OBS501 in the cup or bucket as shown in FIGURE 8-4 and record the average output on the calibration log sheet.
4. Pour the standard back into its container.
5. Wipe sensor with a clean, dry towel to remove residual standard.
6. Repeat steps 2, 3, 4, and 5 for the other standards.
7. Perform second order polynomial regressions on the calibration data to get the coefficients for converting OBS signals to TU values.



**FIGURE 8-4.** OBS501 in 500-TU AMCO Clear® turbidity standard in 100-mm black polyethylene calibration cup

## 8.6.2 Sediment

The following sections show three basic methods for calibrating an OBS501 with sediment. However, only the procedures for dry-sediment are explained in detail in this manual. Typically, the sensor records in turbidity units and the relationship to suspended-sediment concentration is calculated in a spreadsheet or database after the data is retrieved to a computer.

### 8.6.2.1 Dry-Sediment Calibration

This calibration is performed with sediment that has been dried, crushed, and turned to powder. This is the easiest calibration to do because the amount of sediment can be determined accurately with an electronic balance and the volume of water in which it is suspended can be accurately measured with volumetric glassware. Of the three methods, dry-sediment calibration causes the greatest physical and chemical alteration of the sediment. Alteration of the sediment size as a result of processing can significantly affect the calibration slope. FIGURE 8-2, *Normalized response of OBS501 to AMCO Clear® turbidity (p. 25)*, shows, for example, that reducing the grain size by a factor of two during grinding can increase OBS sensitivity by a factor of two.

### 8.6.2.2 Wet-Sediment Calibration

Wet-sediment calibration is performed with sediment obtained from water samples or from the bed of a river that has not been dried and pulverized. Consolidation and biochemical changes during storage and processing cause some alteration of wet sediment, and for this reason, sediment and water samples should be stored at about 4 °C prior to use. The wet sediment is introduced into the sediment suspender as it comes from the field. This kind of

calibration requires that water samples be withdrawn from the suspender after each addition of sediment for the determination of SSC (suspended-sediment concentration) by filtration and gravimetric analysis.

#### 8.6.2.3 In situ Calibration

In situ calibration is performed with water samples taken from the immediate vicinity of an OBS501 in the field over sufficient time to sample the full range of SSC values to which a sensor will be exposed. SSC values obtained for these samples with concurrent recorded OBS501 signals and regression analysis establishes the mathematical relation for future SSC conversions by an instrument. This is the best sediment-calibration method because the particles are not altered from their natural form in the river (see Lewis, 1996). It is also the most tedious, expensive, and time-consuming method. It can take several years of water sampling with concurrent OBS measurements to record the full range of SSC values on a large river.

#### 8.6.2.4 Performing a Dry-Sediment Calibration

**Materials and equipment:** OBS501 with test cable; dry, disaggregated sediment from the location where the OBS501 will be used (sediment should be in a state where grinding, sieving, or pulverization does not change its particle-size distribution); datalogger with 12 V power supply; sediment suspender (if a suspender is not available, use a 200 mm I.D. dark plastic container and a drill motor with paint-mixing propeller); electronic balance calibrated with 10 mg accuracy; 20 ml weigh boats; large, black polyethylene plastic tub for measuring the clear-water points; 1 liter, class A, volumetric flask; tea cup with round bottom; and teaspoon.

1. Check the balance with calibration weights; recalibrate if necessary.
2. Connect the OBS501 to a computer or a datalogger so that the measured values can be observed.
3. Add three liters of tap water to the suspender tub with the volumetric flash.
4. After measuring the clear-water signal (Step 1, Section 8.6.1, *Turbidity* (p. 24)), mount the OBS501 so that the sensor end is 50 mm above the bottom of the suspender tub and secure it in the position that minimizes reflections from the wall; see FIGURE 8-5.



FIGURE 8-5. Portable Sediment Suspender

$SSC = W_{ts} [V_w + W_{ts}/\rho_s]^{-1}$ , where  $W_{ts}$  = total sediment weight in tub in mg,  $V_w$  = volume of water in liters, and  $\rho_s$  = sediment density (assume  $2.65 \times 10^3 \text{ mg L}^{-1}$ )

### Procedure

1. Record and log the clean-water signal as in Step 1, Section 8.6.1, *Turbidity* (p.24); see FIGURE 8-3, *Position of OBS501 in clean tap water in big black tub* (p. 27). Use the same value, such as, sidescatter, backscatter, or ratio throughout the calibration.
2. Move the OBS501 to the suspender as described in setup.
3. Weigh  $500 \pm 10$  mg of sediment in a weigh boat and transfer it to the teacup. Record the weight on the calibration log sheet and add about 10 cc of water from the suspender tub to the teacup and mix the water and sediment into a smooth slurry with the teaspoon.
4. Add the sediment slurry to the tub and rinse the teacup and spoon with tub water to get all the material into the suspender.
5. Turn the suspender on and let it run for 10 minutes or until the OBS signal stabilizes.
6. Take averages of signals with the computer or datalogger and enter them on the calibration log sheet.
7. Calculate the sediment-weight increment as follows:  $W_i = 2500 \text{ mg}$  ( $4000/V_x$ ), where  $W_i$  = the incremental weight of sediment and  $V_x$  = the average output signal from step 6. The resulting weight gives the amount of sediment to add to have evenly spaced calibration points.
8. Add enough additional sediment to get one full increment of sediment,  $W_i \pm 5\%$ . Repeat steps 4, 5, and 6.
9. Repeat step 8 until five full increments of sediment have been added or until the OBS signals exceed the output range.
10. Perform 3<sup>rd</sup> order polynomial regressions on the data to get the coefficients for converting OBS output to SSC.

## 8.7 Operation in High Sediment Loads and Sandy Sediments

Sites with high sediment loads and large sand grains can be problematic for the shutter and its motor. The recommendations provided in this section should help reduce these problems.

### NOTE

Typically sites with high biological growth have relatively low sediment loads.

1. Run the OBS501 in a normally open mode. For example, close then open the wiper once every four hours. This reduces the wear on the motor significantly, and saves power. The interval can be adjusted over time. Increase the interval if experiencing fouling. If the windows are staying



clean, slow it down even more. Example CRBasic programs are provided at Appendix B.5, *Examples for High Sediment Loads* (p. B-9). For specific information on each command referenced below, see TABLE 8-2, *SDI-12 and RS-232 Measurement Commands* (p. 21).

- a. **aM3!/aC3!** opens the wiper
  - b. **aM4!/aC4!**, **aC5!**, **aM6!/aC6!**, or **aC8!** perform measurements when the wiper is open
  - c. **aM7!** closes the wiper or use **aM9!** to wipe the shutter
2. Clean the shutter assembly. The frequency that the shutter should be cleaned depends on the sediment load and can vary from weeks to months (step 3 can help you determine the required frequency for cleaning). Two levels of cleaning should be done:
    - a. flush the wiper as it opens and closes with a stream of clean water, or
    - b. remove the wiper from the OBS501 by removing one screw and follow the directions provided in Section 8.7.1, *Wiper Removal Procedure* (p. 31). Flush and clean.
  3. Store the current used to open and close the slider. The open and close SDI-12 instructions (**M3!** and **M7!**) output the current. Normally the current is around 175 mA. As sand grits lodge in the grooves, the resistance to movement increases and the motor has to work harder. This increases the current usage. Therefore, increased current usage indicates the wiper needs to be cleaned (see step 2). However, open/close currents also increase with decreasing temperature, independently of sediment concentration. The best way to determine if a sensor is having trouble with sediment is to monitor current usage regularly so you can detect an increase.
  4. Mount the sensor between 45 degrees pointing down to vertical hanging down.

### 8.7.1 Wiper Removal Procedure

1. Remove the stop screw in the OBS501 housing at the end of the shutter/wiper slot.
2. Remove the 4-40 flat head screw and copper plate to expose the drive shaft access port (FIGURE 8-6).
3. Insert a slot screw driver (2.5 mm (0.1 in.) wide blade) into the access port (FIGURE 8-7).
4. Engage the end of the drive shaft and then rotate clockwise until the shutter is free (FIGURE 8-7 and FIGURE 8-8).

---

#### CAUTION

Keep track of all of the components (FIGURE 8-9).

---

5. Reassemble by reversing the steps.

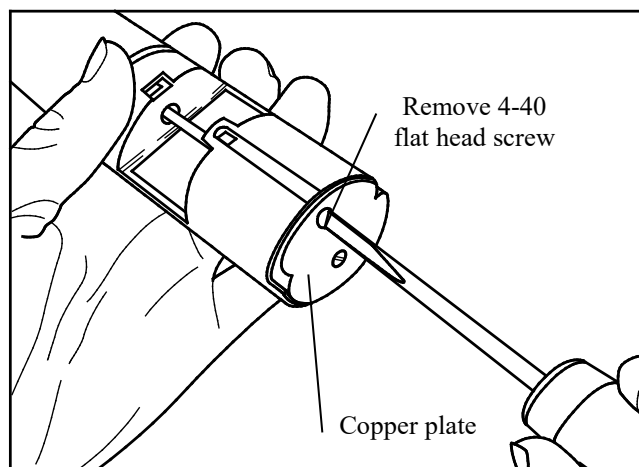


FIGURE 8-6. Remove the screw

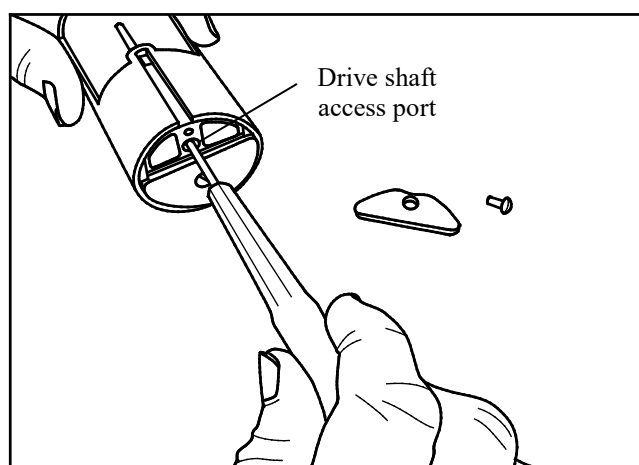


FIGURE 8-7. Insert screwdriver and rotate clockwise

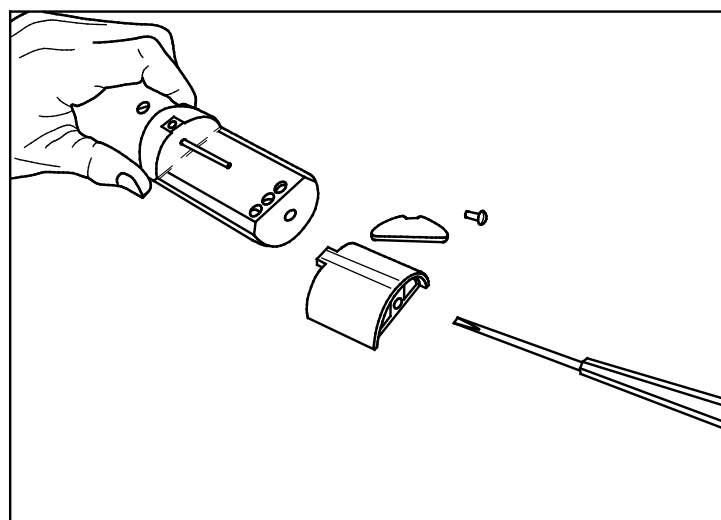


FIGURE 8-8. Shutter disassembled

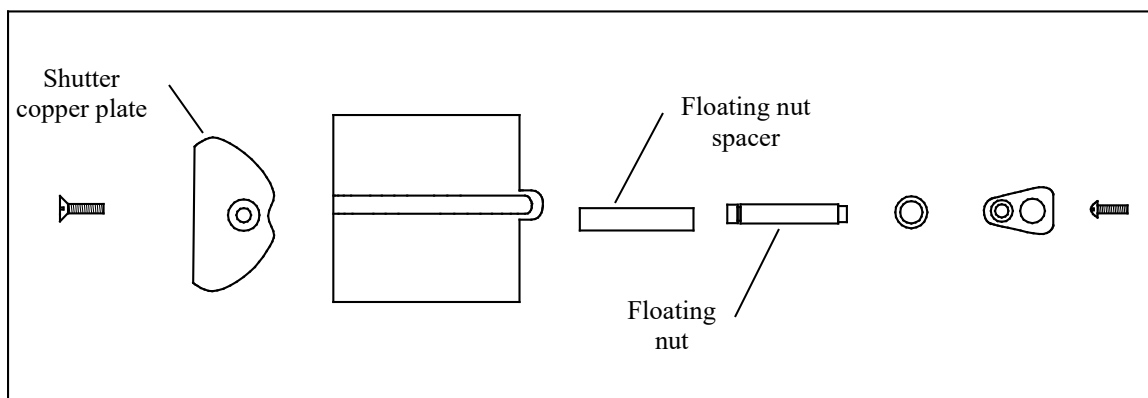


FIGURE 8-9. Shutter components

## 9. Maintenance

The biocide chamber in the slider is refillable. The default biocide from the factory is copper braid. The braid lasts for many years, but can be replaced as desired. You can use other solid biocides in the chamber. To be effective over time, the biocide should dissolve slowly.

Send the OBS501 for service (seal, shaft, and nut replacement) after two years or 70,000 shutter cycles, whichever occurs first. The sensor has a cycle count and a moisture alarm (wet/dry) in the data string (SDI-12 and RS-232 only). If the seals are not replaced, the sensor eventually leaks, potentially causing damage to the sensor. Campbell Scientific recommends regularly recording the cycles and moisture alarm. If the moisture alarm is detected (returns a 1 or higher instead of a 0), take the sensor out of the water and return it for repair as soon as possible. If the OBS501 detects water leaking past the shaft seals, the shutter remains open and won't respond to close commands. However, the sensor will continue to make measurements. TABLE 8-2, *SDI-12 and RS-232 Measurement Commands* (p. 21), discusses the moisture alarm as the wet/dry variable. The wet/dry variable is returned for commands **M1/C!**, **M2/C2!**, **M4/C4!**, **M6/C6!** (0=dry, 1=wet).

### WARNING

**Other than the sleeve and the biocide chamber on the sensor tip, there are no user-serviceable parts inside the sensor housing. Do not remove the sensor or connector from the pressure housing. This will void the warranty and could cause a leak.**

Plastic (pn 31570) and copper (pn 31569) sleeves are available for the OBS501 to reduce required cleaning. The plastic sleeve is intended to be disposable. The copper sleeve should slow fouling growth, but it may need to be cleaned. If the sleeve becomes encrusted with organisms, such as barnacles or tube worms, remove the sleeve. Soak the sleeve in weak acids or other cleaning products that are compatible with copper. The sleeve may have to be gently scraped with a flexible knife blade followed by a scouring pad such as ScotchBrite®. For more information, see Appendix C, *Sleeve Installation* (p. C-1).

**WARNING**

**Do not use solvents such as MEK, Toluene, Acetone, or trichloroethylene on OBS501s. Solvents like these will cause the optics housing to swell and will permanently damage the sensor. When cleaning the optics do NOT soak the sensor in vinegar (acetic acid). You can wipe the windows gently with a vinegar solution and rinse.**

## 10. Troubleshooting

A common cause for erroneous, turbidity-sensor data is poor sensor connections to the datalogger.

*Problem:*

Unit will not respond when attempting serial communications.

*Suggestion:*

Check the power (red is +V and black is ground) and signal (white is SDI-12 data) lines to ensure proper connection to the datalogger. Check the datalogger program to ensure that the OBS501 is connected to the correct SDI-12 port on the datalogger.

The following three tests are used to diagnose malfunctions of an OBS501:

1. **Finger-Wave Test** determines if an OBS501 is ‘alive’. Power the OBS501 and connect the datalogger (see Section 7.2, *Device Configuration Utility* (p. 7)). Wave your finger across the sensor window about 20 mm away from it. The datalogger should show the output fluctuating from a few TU to the full-scale signal. If this does not occur, the sensor is not functioning properly.
2. **Calibration Check** indicates whether a working OBS501 needs to be recalibrated. To be meaningful, the user must have a criterion for this test. For example, this criterion might be 5%. The sensor is placed in calibration standards with the first and second TU values listed in FIGURE 8-2, *Normalized response of OBS501 to AMCO Clear® turbidity* (p. 25), and the datalogger readings are logged. Recalibrate the sensor when either reading differs by more than 5% from the readings reported on the factory calibration certificate or the user’s calibration data. If the first two calibration points fall within the acceptance criterion, the third value can be tested. The recommended frequency for calibration checks is quarterly when an OBS501 is in regular use. Otherwise, it should be performed prior to use. Calibration checks can be done in the field.

TABLE 10-1. Troubleshooting Chart		
Fault	Cause of Fault	Remedy
Fails finger-wave test	No power, dead battery	Replace battery and reconnect wires
	Plug not fully seated	Disconnect and reinsert plug
	Sensor broken	Visually inspect for cracks; return OBS501 to manufacturer if cracks are found
	Electronic failure. Unit draws 0 mA or more than 40 mA.	Return OBS501 to manufacturer
Fails calibration check	Aging of light source causes it to become dimmer with time	Recalibrate (see Section 8.6, <i>Calibration</i> (p. 24))

## 11. References

- Anderson, C.W., 2005, Turbidity (ver. 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., sec. 6.7, Sept 2005, accessed December 8, 2011, from <http://pubs.water.usgs.gov/twri9A6/>.
- Boyd Bringham and Jeff Adams. “Innovative Sensor Design for Prevention of Bio-fouling.” Oceans 2011, September 2011.
- Lewis, Jack. 1996. Turbidity-controlled Suspended Sediment Sampling for Runoff-event Load Estimation. Water Resources Research, 32(7), pp. 2299-2310.
- “U.S. Geological Survey Implements New Turbidity Data-Reporting Procedures.” U.S. Geological Survey. <http://water.usgs.gov/owq/turbidity/TurbidityInfoSheet.pdf>.



# Appendix A. Importing Short Cut Code Into CRBasic Editor

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This tutorial shows:

- How to import a *Short Cut* program into a program editor for additional refinement
- How to import a wiring diagram from *Short Cut* into the comments of a custom program

*Short Cut* creates files, which can be imported into *CRBasic Editor*. Assuming defaults were used when *Short Cut* was installed, these files reside in the C:\campbellsci\SCWin folder:

- .DEF (wiring and memory usage information)
- .CR2 (CR200(X)-series datalogger code)
- .CR6 (CR6-series datalogger code)
- .CR8 (CR800-series datalogger code)
- .CR1X (CR1000X datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Use the following procedure to import *Short Cut* code and wiring diagram into *CRBasic Editor*.

1. Create the *Short Cut* program following the procedure in Section 4, *QuickStart* (p. 2). Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.
2. Open *CRBasic Editor*.
3. Click **File | Open**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has the .CR2, .CR6, .CR8, .CR1X, .CR1, .CR3, or .CR5 extension. Select the file and click **Open**.
4. Immediately save the file in a folder different from C:\Campbellsci\SCWin, or save the file with a different file name.

---

## NOTE

Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program. Change the name of the program file or move it, or *Short Cut* may overwrite it next time it is used.

---

5. The program can now be edited, saved, and sent to the datalogger.
6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading “-Wiring for CRXXX-” into the CRBasic program, usually at the head of the file. After pasting, edit the information such that an apostrophe (') begins each line. This character instructs the datalogger compiler to ignore the line when compiling.





# Appendix B. Example Programs

## B.1 CR6 SDI-12 Program

### CRBasic Example B-1. CR6 SDI-12 Program

```
'CR6 Series
'Must be running OS 4 or higher

'Declare Variables and Units
Public BattV
Public PTemp_C
Public OBS501(4)

Alias OBS501(1)=Turb_BS
Alias OBS501(2)=Turb_SS
Alias OBS501(3)=Temp_C
Alias OBS501(4)=WD_OBS

Units BattV=Volts
Units PTemp_C=Deg C
Units Turb_BS=FBU
Units Turb_SS=FNU
Units Temp_C=Deg C
Units WD_OBS=unitless

'Define Data Tables
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,Turb_BS,FP2)
  Sample(1,Turb_SS,FP2)
  Sample(1,Temp_C,FP2)
  Sample(1,WD_OBS,FP2)
EndTable

DataTable(Table2,True,-1)
  DataInterval(0,1440,Min,10)
  Minimum(1,BattV,FP2,False,False)
EndTable

'Main Program
BeginProg
'Main Scan
Scan(5,Sec,1,0)
'Default Datalogger Battery Voltage measurement 'BattV'
Battery(BattV)
'Default Wiring Panel Temperature measurement 'PTemp_C'
PanelTemp(PTemp_C,60)
'OBS501 Smart Turbidity Meter (SDI-12) measurements 'Turb_BS', 'Turb_SS', 'Temp_C', and 'WD_OBS'
SDI12Recorder(OBS501(),C1,"0","M!",1,0,-1)
'Call Data Tables and Store Data
CallTable Table1
CallTable Table2
NextScan
EndProg
```

## B.2 CR1000 SDI-12 Program

### CRBasic Example B-2. CR1000 SDI-12 Program

```

'CR1000 Series DataLogger
'Must be running OS 29 or higher

'Declare Public Variables

Public SDI (4)

'Declare Other Variables

Alias SDI(1) = OBS
Alias SDI(2) = SS
Alias SDI(3) = Temp
Alias SDI(4) = WetDry

'Define Data Tables
DataTable (Test,1,1000)
  DataInterval (0,15,Min,10)
  Sample (1,OBS,FP2)
  Sample (1,SS,FP2)
  Sample (1,Temp,FP2)
  Sample (1,WetDry,FP2)
EndTable

'Main Program
BeginProg
  Scan (30,Sec,0,0)

    SDI12Recorder (SDI(),1,0,"M!",1.0,0,-1)

'Call Output Tables
  CallTable Test
  NextScan
EndProg

```

## B.3 CR1000 RS-232 Program

### B.3.1 RS-232 Common Measurement Commands

Although this is a CR1000 program, other CRBasic dataloggers are programmed similarly.

#### CRBasic Example B-3. CR1000 RS-232 Program

```
'This is an example program for running an OBS501 sensor over RS-232.
'There is 1 subroutine available in this program.
'The routine (OBS501_MEAS) allows the user to enter the measurement commands identified in
'the manual (Table 8-2).
'The table shows both SDI-12 and RS-232 measurement commands and the number of
'measurement values returned once the measurement is complete. RS-232
'measurement commands will include all of the M! and C! varieties.
'You must enter the SDI-12 address of the sensor first.
'For example aM! or 1C2!
'RS-232 does not support the CRC type commands (MC! or CC!)
'The data table set up in this example is for the M! command that returns 4 values.

SequentialMode

Public CMD As String * 7 = "OM!" 'Measurement command aM#! See table 8-2 for options
Const OBS501_ComPort = Com1 'enter the com port that the sensor is connected to
Const ScanRate = 10 'seconds
Public LoggerTemp, BattV
Public Dest(4) 'Destination array for OBS501_MEAS routine. Currently it is set to 4 values.

Alias Dest(1) = turb_bs
Alias Dest(2) = turb_ss
Alias Dest(3) = tempC_OBS501
Alias Dest(4) = wet_dry

Units turb_bs = fbu
Units turb_ss = fnu
Units tempC_OBS501 = degC
Units wet_dry = YesNo

DataTable (Test,1,-1) 'All four values returned from the M! command are stored every 5 minutes
DataInterval (0,5,Min,10)
Sample (1,turb_bs,FP2)
Sample (1,turb_ss,FP2)
Sample (1,tempC_OBS501,FP2)
Sample (1,wet_dry,Long)
EndTable

BeginProg
SerialOpen (OBS501_ComPort,9600,3,0,5000)

Scan (ScanRate,Sec,0,0)

    PanelTemp (LoggerTemp,250)
    Battery (BattV)
    If IfTime (0,15,Min) Then
        'Call the measurement subroutine
        Call OBS501_MEAS(Dest,OBS501_ComPort,CMD)
    EndIf
    'Call Output Tables
    CallTable Test
NextScan

'#####
Sub OBS501_MEAS(Dest(20),ComPort,CMD As String * 31)
    Dim SerOut As Long
    Dim SerIn As String * 100
```

```

Dim EndOfData As Long

'assume failure, make first element = NAN
Dest(1) = NAN

'get OBS501 attention with CR, up to 10 times, waiting for OBS_501> prompt
'must have delay between rx of prompt and issue of measurement command
'OR, you need to get the prompt at least twice - one or the other
SerialOut (ComPort,CHR(13),"OBS_501>",10,10)
'SerialOut (ComPort,CHR(13),"OBS_501>",10,10)
Delay (1,1,Sec)

'for good measure, flush serial input buffer
SerialFlush (ComPort)

'output command to sensor
'example commands: "aM0!" , "aM1!" , "aM2!"
'the sensor echos the command immediately
SerOut = SerialOut (ComPort,CMD & CHR(13),CMD,1,100)

'if we do not receive echo of command, then
'sensor is not responding, so exit sub routine now
If SerOut < 1 Then ExitSub

'wait for up to 300 seconds (5 minutes) for "CR LF OBS_501>" to be returned by sensor
'when we have received "CR LF OBS_501>" we know measurement data is starting to be returned
'data returned looks like: "CR LF OBS_501>1+1.234+56.7 CR LF"
SerialIn (SerIn,ComPort,30000,CHR(13) & CHR(10) & "OBS_501>",100) 'wait for and gobble
                                                                    'up start of data
SerialIn (SerIn,ComPort,200,CHR(13) & CHR(10),100) 'wait for and pull in rest of CR LF
                                                                    'terminated data

'find the end of the data, marked by CR LF
EndOfData = InStr(1,SerIn,CHR(13) & CHR(10),2)

If EndOfData > 0 Then
    'purposefully omitting the first character, which is the sensor address
    SerIn = Mid (SerIn,2,EndOfData-1)
    SplitStr (Dest,SerIn,0,20,0)
EndIf

EndSub

EndProg

```

### B.3.2 RS-232 Burst Measurement Mode

Running an OBS501 via RS-232 allows the user to run in a burst mode that returns calibrated turbidity values as fast as possible. In this mode, you need to tell the sensor to open, burst measure, and then close. RS-232 burst mode is different than the SDI-12 burst measurement returned via C! commands. Over SDI-12, only statistics of 100 measurements are returned to the user. In the RS-232 burst mode, you get the actual backscatter and sidescatter readings. Below is sample program for collecting bursts of data every 15 minutes.

**CRBasic Example B-4. CR1000 RS-232 Program**

```

'This is an example program for running an OBS501 sensor over RS-232.
'There are two subroutines available in this program.
'The first routine (OBS501_MEAS) is used to tell the sensor to open (aM3!) and close (aM7!)
'and returns the five values to a destination array. See Table 8-2 for those values.
'The second routine (OBS501_U) allows the user to work in a burst or profile mode.
'OBS501_U routine will return 5 readings: temperature, BS, SS, BS_stddev, SS_stddev

SequentialMode

Const OBS501_ComPort = Com1 'enter the com port that the sensor is connected to
Const ScanRate = 10 'seconds
Public LoggerTemp, BattV
Public Dest_open(5) 'Open destination array for OBS501_MEAS routine.
Public Dest_close(5) 'Close destination array for the OBS501_MEAS routine
Public U(100,5) 'Destination array for OBS501_U routine/burst mode. Currently it is set to 100 records.
'This program limits the array to 200 records.
Alias Dest_open(1) = open_wiper_position
Alias Dest_open(2) = open_max_current
Alias Dest_open(3) = open_timeout
Alias Dest_open(4) = open_current
Alias Dest_open(5)= open_total

Alias Dest_close(1) = close_wiper_position
Alias Dest_close(2) = close_max_current
Alias Dest_close(3) = close_timeout
Alias Dest_close(4) = close_current
Alias Dest_close(5)= close_total

'Data tables are called every time the measurements are completed.
DataTable (Shutter,1,1000) 'All four values returned from the M! command are stored every 5 minutes
'DataInterval (0,15,Min,10)
Sample (5, Dest_open(), FP2)
Sample (5, Dest_close(), FP2)
Sample (1, LoggerTemp, FP2)
Sample (1, BattV, FP2)
EndTable

DataTable (Burst,1,-1) 'All four values returned from the M! command are stored every 5 minutes
'DataInterval (0,15,Min,10)
Sample (500,U(), FP2)
EndTable

BeginProg
SerialOpen (OBS501_ComPort,9600,3,0,5000)

Scan (ScanRate,Sec,0,0)
PanelTemp (LoggerTemp,250)
Battery (BattV)

If IfTime (0,15,Min) Then
'Call the measurement subroutine
Call OBS501_MEAS(Dest_open,OBS501_ComPort,"3M3!") '(destination for values, Comport,
'open the sensor command)
Call OBS501_U(U,100,OBS501_ComPort) '(destination, number or measurements, com port)
Call OBS501_MEAS(Dest_close,OBS501_ComPort,"3M7!") 'close the sensor

CallTable Burst
CallTable Shutter

EndIf
NextScan

'Subroutine 1: OBS501_MEAS This routine runs the standard measurement commands outlined in
'Table 8-2 in the manual.
'It will return the parse and return the values to the Destination (Dest), it will make
'the measurement on Comport,

```

```

'and send a comand identified in the CMD as a string.
Sub OBS501_MEAS(Dest(20),ComPort,CMD As String * 31)
    Dim SerOut As Long
    Dim SerIn As String * 100
    Dim EndOfData As Long

    'assume failure, make first element = NAN
    Dest(1) = NAN

    'get OBS501 attention with CR, up to 10 times, waiting for OBS_501> prompt
    'must have delay between rx of prompt and issue of measurement command
    'or, you need to get the prompt at least twice - one or the other
    SerialOut (ComPort,CHR(13),"OBS_501>",10,10)
    'SerialOut (ComPort,CHR(13),"OBS_501>",10,10)
    Delay (1,1,Sec)

    'for good measure, flush serial input buffer
    SerialFlush (ComPort)

    'output command to sensor
    'example commands: "aM0!", "aM1!", "aM2!"
    'the sensor echos the command immediately
    SerOut = SerialOut (ComPort,CMD & CHR(13),CMD,1,100)

    'if we do not receive echo of command, then
    'sensor is not responding, so exit sub routine now
    If SerOut < 1 Then ExitSub

    'wait for up to 300 seconds (5 minutes) for "CR LF OBS_501>" to be returned by sensor
    'when we have received "CR LF OBS_501>" we know measurement data is starting to be returned
    'data returned looks like: "CR LF OBS_501>1+1.234+56.7 CR LF"
    SerialIn (SerIn,ComPort,30000,CHR(13) & CHR(10) & "OBS_501>",100) 'wait for and gobble up
                                                                    'start of data
    SerialIn (SerIn,ComPort,200,CHR(13) & CHR(10),100) 'wait for and pull in rest of CR LF
                                                                    'terminated data

    'find the end of the data, marked by CR LF
    EndOfData = InStr(1,SerIn,CHR(13) & CHR(10),2)

    If EndOfData > 0 Then
        'purposefully omitting the first character, which is the sensor address
        SerIn = Mid (SerIn,2,EndOfData-1)
        SplitStr (Dest,SerIn,0,20,0)
    EndIf
EndSub

'Subroutine 2: Burst measurement mode. This subroutine
'puts the sensor into a burst mode that will let it return values as fast
'as possible for up to 200 records.
'The sensor responds to the U command with temperature, BS, SS, BS_stdev, and SS_stdev
Sub OBS501_U(Dest(200,5),NumVals,ComPort)
    Dim i As Long,j As Long
    Dim SerOut As Long
    Dim SerIn As String * 100

    'assume failure, make first element = NAN
    Dest(1) = NAN

    'get OBS501 attention with CR, up to 10 times, waiting for OBS_501> prompt
    'must have delay between rx of prompt and issue of measurement command
    'OR, need to get the prompt at least twice - one or the other
    SerialOut (ComPort,CHR(13),"OBS_501>",10,10)
    'SerialOut (ComPort,CHR(13),"OBS_501>",10,10)
    Delay (1,1,Sec)

    'for good measure, flush serial input buffer
    SerialFlush (ComPort)

```

```

'output U command to sensor
'the sensor echos the command immediately
SerOut = SerialOut (ComPort,"U" & CHR(13),"U",1,100)

'if we do not receive echo of command, then
'sensor is not responding, so exit sub routine now
If SerOut < 1 Then ExitSub

'Discard the first five measurements to make sure the sensor has stabilized.
For i = 1 To 5
    SerialIn (SerIn,ComPort,200,CHR(13) & CHR(10),100)
Next i

'wait for, parse, and return the number of values specified
For i = 1 To NumVals
    SerialIn (SerIn,ComPort,200,CHR(13) & CHR(10),100)
    If SerIn = "" Then
        'no response
        'make the rest of the array NAN
        'and give up / exitfor
        For j = i To NumVals
            Dest(j,1) = NAN
            Dest(j,2) = NAN
            Dest(j,3) = NAN
            Dest(j,4) = NAN
            Dest(j,5) = NAN
        Next j
    Else
        SplitStr (Dest(i,1),SerIn,0,5,0)
    EndIf
Next i

'send CRLF to cease output
SerialOut(ComPort,CHR(13),CHR(13),3,100)
EndSub

EndProg

```

## B.4 CR1000 Analog Program

Although this is a CR1000 program, other CRBasic dataloggers are programmed similarly.

### CRBasic Example B-5. CR1000 Analog Program

```
'CR1000 Series Datalogger
'OBS501_analog_O&M.CRI for the CR1000
'wiring: Green to 1H; Brown to 1L; Red to SW12; Black to Grnd; Blue to C1; and White to C2

'Declare Public Variables
Public PTemp, batt_volt
Public Results (2)
Alias Results(1)=obs
Alias Results(2)=ss

Units obs=NTU
Units ss=NTU

DataTable (OBS501_analog,1,-1)
  DataInterval (0,3,min,10)
  Minimum (1,batt_volt,FP2,0,False)
  Sample (1,PTemp,FP2)
  Sample(1,obs,FP2)
  Sample(1,ss,FP2)
EndTable

'Main Program
BeginProg

  Scan (30,sec,3,0)
    PanelTemp (PTemp,250)
    Battery (batt_volt)
    PortSet (1 ,1 )
    PortSet (2,0)
    Delay (0,9500,msec)
    VoltDiff (obs,1,0,1,1,0,_60Hz,1,0)
    PortSet (2 ,1 )
    Delay (0,800,msec)
    VoltDiff (ss,1,0,1,1,0,_60Hz,1,0)
    PortSet (1,0)
    CallTable(OBS501_analog)
  NextScan

  'blue wire -- drive high to open shutter
  'white wire selects obs (0) or ss (1)
  '6 secs (shutter open) + 3.5 secs
  '1 mV = 1 TU
  'white wire to +5 volts for ss meas
  'wait until meas is done

  'blue wire -- drive low to close shutter

EndProg
```



## B.5 Examples for High Sediment Loads

### B.5.1 Normally Open CR1000 Example

#### CRBasic Example B-6. Normally Open CR1000 Example

```
'CR1000 Series Datalogger with OS29 or higher
'If you do not have OS29 or higher, there will be a compile error due to the new optional
'parameters in the SDI12recorder instructions.
'OBS501 normally open

'In normally open mode, the OBS501 can make measurement multiple times per minute but the wiper
'interval could be set to as low as a time or two a day. This mode is also beneficial where the
'power budget is critical since opening and closing the wiper consumes considerably more power
'than making the turbidity measurement.

'Declare Public Variables

Public OBS501(4)
Public TimeCounter
Public obsDatOpen(5), obswipe(7)

'Declare Other Variables
Alias OBS501(1) = turb_bs
Alias OBS501(2) = turb_ss
Alias OBS501(3) = tempC_OBS501
Alias OBS501(4) = wet_dry

Alias obsDatOpen(1) = OpenPos_cnts      'Full movement of slider is about 20,000 counts.
                                         'If it jams, this # will be smaller
Alias obsDatOpen(2) = Open_Max_mA_cnts  'Number of times the shutter stops while opening
                                         'because of max current
Alias obsDatOpen(3) = Open_timeout_cnts 'Open timeout count. If the threads are stripped, the slide
                                         'will not move and this count will increase
Alias obsDatOpen(4) = Open_mA           'mA current of the motor
Alias obsDatOpen(5) = Total_Open_cnts   'Total times the sensor has opened (count)

Alias obswipe(1) = Total_open_close     'Total number of times the unit has open and closed (count)
Alias obswipe(2) = Wipe_open_pos_cnt    'Full movement of slider is about 16,400 counts.
                                         'If it jams, this # will be smaller
Alias obswipe(3) = Wipe_open_MaxmA_cnt  'Number of times the shutter stops while opening
                                         'because of max current
Alias obswipe(4) = Wipe_open_timeout_cnt 'Open timeout count. If threads are stripped,
                                         'the slide will not move and this count will increase
Alias obswipe(5) = Wipe_close_pos_cnt   'Full movement of slider is about 16,400 counts.
                                         'If it jams, this # will be smaller
Alias obswipe(6) = wipe_close_MaxmA_cnt 'Number of times the shutter stops while closing because
                                         'of max current
Alias obswipe(7) = wipe_close_timeout_cnts 'Close timeout count. If the threads are stripped, the
                                         'slide will not move and this count will increase

Units turb_bs = fbu
Units turb_ss = fnu
Units tempC_OBS501 = degC
Units wet_dry = YesNo

'Define Data Tables
DataTable (Test,1,1000)
  DataInterval (0,5,Min,10)
  Sample (1,turb_bs,FP2)
  Sample (1,turb_ss,FP2)
  Sample (1,tempC_OBS501,FP2)
EndTable

'Main Program
```

## BeginProg

```
SDI12Recorder (obsDatOpen(),1,0,"M3!",1,0,-1) 'Start with shutter open
'The last parameter tells the datalogger to put a "nan" inside all the elements of the
'destination array. This is one of a few new features. If you are running and OS older than 29,
'you will need to remove the ",-1" before the last parenthesis. Also need to remove the -1
'from the next two sdi12recorder instructions.
```

```
Scan (1,Min,0,0)
```

```
TimeCounter = TimeCounter + 1
```

```
'Wipe at a slower interval than the scan interval
```

```
If TimeCounter >= 60 Then 'This value, 60, will wipe once every 60 scan intervals.
'60 min. in this case
```

```
SDI12Recorder (obswipe(),1,0,"M9!",1,0,-1) 'This will issue the wipe command
TimeCounter = 0
```

```
EndIf
```

```
'Read OBS501 each scan interval
```

```
SDI12Recorder(OBS501(),1,0,"M4!",1,0,-1) 'Measure without moving the wiper
```

```
'Call Output Tables
```

```
CallTable Test
```

```
NextScan
```

```
EndProg
```

## B.5.2 Cycle Shutter/Wiper for Each Measurement CR1000 Program

The following CRBasic program:

- Opens the shutter if closed, then makes a measurement
- Makes a measurement if open, then close

The program cuts shutter/wiper cycles by 50%, which reduces wear and 50% of power consumption, and leaves the optics shuttered 50% of the time.

### CRBasic Example B-7. Cycle Shutter/Wiper for Each Measurement CR1000 Program

```
'CR1000 Series Datalogger
'OBS501 cycle shutter each measurement

'Declare Public Variables

Public OBS501(4)
Public obsDatOpen(5),obsDatClose(5)
Public Open

'Declare Other Variables
Alias OBS501(1) = turb_bs
Alias OBS501(2) = turb_ss
Alias OBS501(3) = tempC_OBS501
Alias OBS501(4) = wet_dry
Alias obsDatOpen(1) = Open_wiper_position 'Full movement of slider is about 20,000 counts.
                                         'If it jams, this # will be smaller
Alias obsDatOpen(2) = Open_Max_mA_cnts 'Number of times the shutter stops while opening
                                         'because of max current
Alias obsDatOpen(3) = Open_timeout 'Open timeout count. If the threads are stripped the slide
                                     'will not move and this count will increase
Alias obsDatOpen(4) = Open_mA 'mA current of the motor
Alias obsDatOpen(5) = Open_total_counts 'total number of open and close cycles
Alias obsDatClose(1) = Close_wiper_position 'Full movement of slider is about 20,000 counts.
                                         'If it jams this # will be smaller
Alias obsDatClose(2) = Close_Max_mA_cnts 'Number of times the shutter stops while opening
                                         'because of max current
Alias obsDatClose(3) = Close_timeout 'Close timeout count. If the threads are stripped the
                                     'slide will not move and this count will increase
Alias obsDatClose(4) = Close_mA 'mA current of the motor while the shutter is closing
Alias obsDatClose(5) = Close_total_counts 'total number of open and close cycles
Units turb_bs = fbu
Units turb_ss = fnu
Units tempC_OBS501 = degC
Units wet_dry = YesNo

'Define Data Tables
DataTable (Test,1,1000)
  DataInterval (0,5,Min,10)
  Sample (1,turb_bs,FP2)
  Sample (1,turb_ss,FP2)
EndTable

'Main Program
BeginProg

  Scan (60,Sec,0,0)

  'If open make measurement and close. If closed, open then make measurement.

  If Open = 1 Then 'If open the make measurement, then close
    SDI12Recorder(OBS501(),1,0,"M4!",1,0,-1) 'Measure without moving the wiper
    SDI12Recorder(obsDatClose(),1,0,"M7!",1,0,-1) 'Close wiper
```

```
    Open = 0
Else 'if closed
    SDI12Recorder (obsDatOpen(),1,0,"M3!",1,0,-1) 'Open wiper
    Delay (0,11,Sec)
    SDI12Recorder(OBS501(),1,0,"M4!",1,0,-1) 'Measure without moving the wiper
    Open = 1
EndIf

'Call Output Tables
CallTable Test
NextScan
EndProg
```

## ***Appendix C. Sleeve Installation***

---

Campbell Scientific offers plastic and copper sleeves. The OBS501 Copper Sleeve (pn 31569) was released in October 2015. Prior to that, the OBS500 Copper Sleeve (pn 27803) was used. The newer copper sleeve was designed specifically for the OBS501.

The following procedure is used to install the plastic (pn 31570) or OBS501 Copper Sleeve (pn 31569). The installation of the older OBS500 Copper Sleeve (pn 27803) is slightly different; refer to an older manual at [www.campbellsci.com/old-manuals](http://www.campbellsci.com/old-manuals) for more information.

1. Ensure that the 4-40 x ¼ SS Slot Head Screw is fully tightened into the OBS501.
2. Slide the copper (shown) or plastic sleeve over the OBS501 and line up the hole in the sleeve with the screw.



3. Loosen the 4-40 x ¼ SS Slot Head Screw so that it secures the sleeve to the OBS501.





# Appendix D. SDI-12 Sensor Support

## D.1 SDI-12 Command Basics

SDI-12 commands have three components:

*Sensor address (a)* – a single character, and is the first character of the command. The default address of zero (0) can be used unless multiple sensors are connected to the same port.

*Command body (M1)* – an upper case letter (the “command”) followed by alphanumeric qualifiers.

*Command termination (!)* – an exclamation mark.

An active sensor responds to each command. Responses have several standard forms and terminate with <CR><LF> (carriage return – line feed). Standard SDI-12 commands supported by the OBS501 are listed in TABLE D-1.

TABLE D-1. OBS501 SDI-12 Command and Response Set		
Name	Command	Response
Acknowledge Active	<b>a!</b>	a<CR><LF>
Send Identification	<b>aI!</b>	allccccccmmmmmmmvvxxx...xx <CR><LF>
Start Verification	<b>aV!</b>	atttn <CR><LF>
Address Query	<b>?!</b>	a<CR><LF>
Change Address	<b>aAb!</b>	b<CR><LF>
Start Measurement	<b>aM!</b> <b>aM1!...aM9!</b>	atttn<CR><LF>
Start Measurement and Request CRC	<b>aMC!</b> <b>aMC1!...aMC9!</b>	atttn <CR><LF>
Start Concurrent Measurement	<b>aC!</b> <b>aC1!...aC9!</b>	atttnn<CR><LF>
Start Concurrent Measurement and Request CRC	<b>aCC!</b> <b>aCC1!...aCC9!</b>	atttnn<CR><LF>
Send Data	<b>aD0!</b> . . . <b>aD9!</b>	a<values><CR><LF> or a<values><CRC><CR><LF>

### D.1.1 Acknowledge Active (a!)

This command allows the user to determine if a sensor is responding to a datalogger or another SDI-12 device. It asks the sensor to acknowledge its presence on the SDI-12 bus.

### D.1.2 Send Identification command (a!)

This command is used to determine SDI-12 communication compatibility, model number, and firmware version number.

Send Identification	<b>a!</b>	allccccccmmmmmmvvvxxx...xx<CR><LF>
	a	Sensor's SDI-12 address
	ll	SDI-12 version number (indicates compatibility)
	cccccccc	8-character vendor identification
	mmmmmm	6 characters specifying the sensor model
	vvv	3 characters specifying the sensor version (OS)
	xxx...xx	An optional field up to 13 characters in length, used for a serial number or the specific sensor information that is not relevant for operation of the data recorder
	<CR><LF>	Terminates the response.

In the case of the OBS501 the response to the Identification command is shown below:

Response to **I!** command: 013CAMPBELLOB5012.0

Sensor Address: 0

SDI-12 Version: 1.3

Vendor Identification: CAMPBELL

Sensor Model: OBS501

Sensor Version: 2.0

Optional Field: There are no optional characters in the OBS501 response to the **a!** command.

### D.1.3 Start Verification Command (aV!)

This command tells the sensor to return a verification response to a subsequent D command. A verification sequence may include ROM signatures, CRC's, RAM test results, or the results of other diagnostics in the sensor. A standard response to the V command is not specified.

Command: **aV!**

Response: atttn<CR><LF>



The OBS501 responds as follows:

```
0V!
00013<CR><LF>
0D0!
0+0+9+4<CR><LF>
```

The three values returned at this time are meaningless for the OBS501.

#### D.1.4 Address Query Command (?!)

Command **?!** requests the address of the connected sensor. The sensor replies to the query with the address, *a*. This command should only be used if there is only one sensor on the bus at a time.

#### D.1.5 Change Address Command (aAb!)

Sensor address is changed with command **aAb!**, where *a* is the current address and *b* is the new address. For example, to change an address from 0 to 2, the command is **0A2!**. The sensor responds with the new address *b*, which in this case is 2.

SDI-12 communications can talk to multiple sensors on one bus; however, those sensors must be uniquely addressed ahead of time. So if you want to have three SDI-12 sensors on the same bus and they all have a default address of 0, you will need to wire up one sensor, connect to the sensor via terminal mode, and change its address. Then connect the next sensor and change that address. You will NOT be able to change the address of sensor 0 to something else if all three sensors are on the bus and all three have an address of 0.

Alternatively, for Campbell Scientific sensors you can use an A200 and *Device Configuration Utility* to change the address from the default (see Section 7.2, *Device Configuration Utility* (p. 7), for more instructions).

#### D.1.6 Start Measurement Commands (aM!)

A measurement is initiated with **M!** commands. The response to each command has the form *attn*, where

*a* = sensor address

*ttt* = time, in seconds, until measurement data are available. The time period begins upon completion of the line feed character. If the sensor has the data ready before *ttt* seconds has elapsed, the sensor will send a service request to the data recorder. This service request tells the recorder to stop marking time and issue the D0 command.

*n* = the number of values to be returned when one or more subsequent **D!** commands are issued; *n* is a single digit integer with a valid range of 0 to 9.

When issuing an **M!** it is important to know that the data recorder must complete the command/response sequence with the sensor before the recorder can send commands to any other sensor. Depending on the scan interval in your datalogger program and the response time of the sensor, this may cause skipped scans to occur. In this case, make sure your scan interval is longer than

the longest measurement time (*ttt*). For measurement response times of the OBS501, see TABLE 8-2, *SDI-12 and RS-232 Measurement Commands* (p. 21).

Example of response of an OBS501 in transparent mode to a **M!**

0M!

00354<CR><LF>

The **M!** command sent to address 0 will return 4 values in 035 or once the service request is sent to the datalogger. The datalogger will collect the data by issuing a send data command as follows:

0<CR><LF>

Service request sent by the sensor once the measurement is done or at the time reported earlier. In transparent mode with the terminal emulator, with a CSI datalogger, you will not see a service request come from the sensor. However, if you are watching SDI-12 traffic in the terminal emulator, you should see the service requests in the communication traffic. For more information about working with a sensor via Campbell Scientific terminal modes, watch the *SDI-12 Sensors | Transparent Mode* video at [www.campbellsci.com/videos?video=25](http://www.campbellsci.com/videos?video=25).

0D0!

0+.8590414+3.543704+8.902214+0<CR><LF>

The sensor will respond with the sensor address and the four values.

#### D.1.6.1 Aborting a Measurement Command

A measurement command (**M!**) is aborted when any other valid command is sent to the sensor.

#### D.1.7 Start Concurrent Measurement Commands (**aC!**)

A concurrent measurement (**aC!**) is a measurement that occurs while other SDI-12 devices on the same bus are also taking measurements. The sensor will NOT issue a service request to the data recorder to come get the data. The recorder will come back and pick up the data on the next scan or if the scan is long enough after the time stated has expired. The command and response have the following format:

Command: **aC!**

Response: attnn <CR><LF>

*a*: the sensor address

*ttt*: the specified time, in seconds, until the sensor will have the measurements ready

*nn*: The number of measurement values the sensor will make and return in response to one or more subsequent D commands.

See the following example for an explanation. A datalogger has three sensors wired into com port 1 (C1). The sensors are addresses X, Y, and Z. The datalogger will issue the following commands and receive the following responses:

T: XC!

R: X03005

This means address X will have 5 values in 30 seconds.

T: YC!

R: Y04006

This means the sensor at address Y will have 6 values in 40 seconds.

T: ZC!

R: Z02010

This means the sensor at address Z will have 10 values ready in 20 seconds.

After 20 seconds the datalogger will issue **ZD0!** through **ZD9!** to collect the data.

T:ZD0!

R: Z+1+2+3+4+5

T:ZD1!

R: Z+6+7+8+9+10

10 seconds later the datalogger will issue **XD0!** through **XD9!** to collect the data.

T: XD0!

R:X+1+2+3+4+5

10 seconds later the datalogger will issue **YD0!** through **YD9!** to collect the data from sensor.

T: YD0!

R: Y+1+2+3+4+5+6

### D.1.8 Start Measurement Commands with Cyclic Redundancy check (aMC! and aCC!)

To take advantage of the error detection capability within SDI-12 communication users should issue measurement commands (**aMC!** or **aCC!**) with cyclic redundancy checks. This is most commonly implemented when long cable lengths or electronically noises environment may impact measurement transmission to the datalogger. When these commands are used, the data returned in response to the D commands or R commands must have a CRC code appended to it. The CRC code is a 16-bit value appended before the <CR><LF>. This code will not be returned in the data table but checked by the recorder as it comes. The code returned is based on the SDI-12 protocol. See the SDI-12 communication specification for version 1.3 to learn more about how the CRC code is developed. In order for a datalogger or recorder to be SDI-12 version 1.3 compliant, it will be able to anticipate the CRC code to check the value once it is returned to the datalogger.

The number of measurements returned in response to a CRC command should be the same as the measurement command that was made in response to a non-CRC command.

Below are examples of the OBS501 response to measurement commands with CRC code appended at the end.

```

0MC!
00354<CR><LF>
0D0!
0+5.004837+4.082218+9.139377+0KHs<CR><LF>

0CC!
003504<CR><LF>
0D0!
0+4.905411+3.350808+9.234887+0Hlc<CR><LF>

```

### D.1.9 Send Data Command (aDv!)

The send data command requests groups of data from the sensor and is issued in conjunction with every type of measurement command (**aM!**, **aMC!**, **aC!**, **aCC!**). When the measurement command is **aM!** or **aMC!**, the data recorder will issue the **aDv!** once a service request has been received from the sensor. When the recorder is issuing concurrent commands (**aC!** or **aCC!**), the send data command will be issued after the required time has elapsed (no service request will be sent by the sensor). In transparent mode, the user asserts this command to obtain data.

Depending on the data type of the returning data (integer, long, double, etc.) and the number of values a sensor returns, the recorder may need to issue **aD0!**, **aD1!** up to **aD9!** to get all of the data back to the recorder. The **aM!** and **aMC!** commands will return up to 35 characters. The **aC!** or **aCC!** commands can return up to 75 characters.

Command: **aD0!** (**aD1!...aD9!**)

Response: a<values><CR><LF> or  
a<values><CRC><CR><LF>

where:

a = sensor address; this will be returned for each D0, D1, D2...

values = pd.d

p = the polarity sign (+ or -)

d = numeric digits before the decimal place

. = the decimal point (optional)

d = numeric digits after the decimal point

The maximum number of digits for a data value is 7, even with the decimal point. The minimum number of digits for a data value (excluding the decimal point) is 1. The maximum number of characters in a data value is 9 (parity sign+7 digits+decimal point).

<CR><LF> = terminates the response

<CRC> 16 bit CRC code, appended if data was requested with the **aMC!** or **aCC!**.

For example, see the data below for the OBS501 in transparent mode.

```

0M6!
00069<CR><LF>
0D0!
0+4.675679+3.548918+3.552251<CR><LF>
0D1!
0+8.997965+.0028316+.00225+176.<CR><LF>

```

```
0D2!
0+149.+0<CR><LF>
```

## D.2 SDI-12 Transparent Mode

System operators can manually interrogate and enter settings in probes using transparent mode. Transparent mode is useful in troubleshooting SDI-12 systems because it allows direct communication with probes. Datalogger security may need to be unlocked before transparent mode can be activated.

Transparent mode is entered while the PC is in telecommunications with the datalogger through a terminal emulator program. It is easily accessed through Campbell Scientific datalogger support software, but is also accessible with terminal emulator programs. Datalogger keyboards and displays cannot be used.

The terminal emulator is accessed by navigating to the **Datalogger** menu in *PC200W*, the Tools menu in *PC400*, or the **Datalogger** menu in the *Connect* screen of *LoggerNet*.

The following examples show how to use *LoggerNet* software to enter transparent mode and change the SDI-12 address of an OBS501 sensor. The same steps are used to enter transparent mode with *PC200W* and *PC400* software after accessing the terminal emulator as previously described.

### D.2.1 CR200(X) Series Datalogger Example

1. Connect a single OBS501 to the CR200(X) (see TABLE 7-4)
2. In the *LoggerNet Connect* screen navigate to the **Datalogger** menu and select **Terminal Emulator**. The terminal emulator window will open. In the **Select Device** menu, located in the lower left-hand side of the window, select the CR200Series station.
3. Click on the **Open Terminal** button.
4. Press the <enter> key until the datalogger responds with the *CR2XX>* prompt. At the *CR2XX>* prompt, make sure the **All Caps Mode** box is checked and enter the command *SDI12* <enter>. The response *SDI12>* indicates that the OBS501 is ready to accept SDI-12 commands.
5. To query the OBS501 for its current SDI-12 address, key in *?! <enter>* and the OBS501 will respond with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply enter the command *SDI12* again and press <enter>.
6. To change the SDI-12 address, key in *aAb! <enter>*, where *a* is the current address from the above step and *b* is the new address (see FIGURE D-1). The OBS501 will change its address and the datalogger will respond with the new address. To exit SDI-12 transparent mode select the **Close Terminal** button.

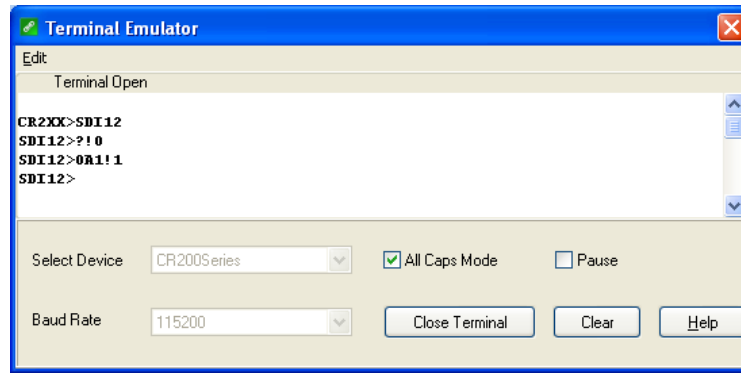
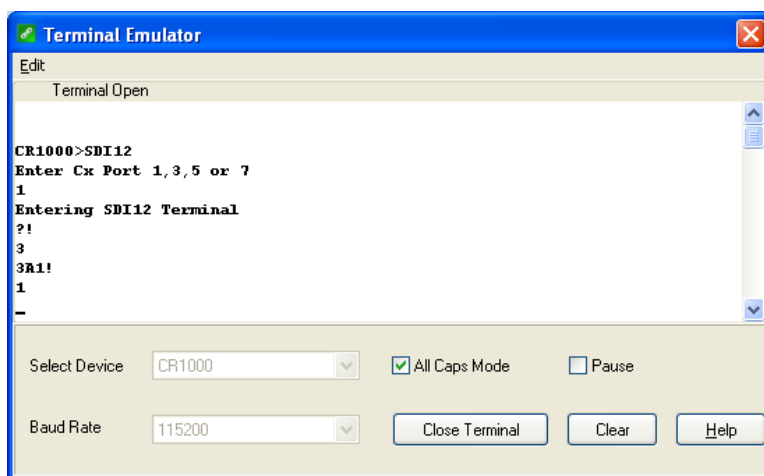


FIGURE D-1. CR200(X) example of using the SDI-12 transparent mode to change the SDI-12 address from 0 to 1

## D.2.2 CR1000 Datalogger Example

1. Connect an OBS501 to the CR1000 (see TABLE 7-4).
2. In the *LoggerNet Connect* screen navigate to the **Datalogger** menu and select **Terminal Emulator**. The terminal emulator window will open. In the **Select Device** menu, located in the lower left-hand side of the window, select the **CR1000** station.
3. Click the **Open Terminal** button.
4. Press the <enter> key until the datalogger responds with the *CR1000>* prompt. At the *CR1000>* prompt, make sure the **All Caps Mode** box is checked and enter the command *SDI12* <enter>. At the *Enter Cx Port 1, 3, 5, or 7* prompt, key in the control port number where the OBS501 is connected and press <enter>. The response *Entering SDI12 Terminal* indicates that the OBS501 is ready to accept SDI-12 commands.
5. To query the OBS501 for its current SDI-12 address, key in *?!* <enter> and the OBS501 will respond with its SDI-12 address. If no characters are typed within 60 seconds, the mode is exited. In that case, simply enter the command *SDI12* again, press <enter>, and key in the correct control port number when prompted.
6. To change the SDI-12 address, key in *aAb!* <enter>, where *a* is the current address from the above step and *b* is the new address (see FIGURE D-2). The OBS501 will change its address and the datalogger will respond with the new address. To exit SDI-12 transparent mode, select the **Close Terminal** button.



*FIGURE D-2. CR1000 example of using the SDI-12 transparent mode to change the SDI-12 address from 3 to 1. Sensor is connected to control port 1.*





# Appendix E. Factors that Affect Turbidity and Suspended-Sediment Measurements

This appendix summarizes some of the factors that affect OBS measurements and shows how ignoring them can lead to erroneous data. If you are certain that the characteristics of suspended matter will not change during your survey and that your OBS was factory-calibrated with sediment from your survey site, you only need to skim this section to confirm that no problems have been overlooked.

## E.1 Particle Size

The size of suspended-sediment particles typically ranges from about 0.2 to 500  $\mu\text{m}$  in surface water (streams, estuaries, and ocean). With size, shape, and color remaining constant, particle area normal to a light beam will determine the intensity of light scattered by a volume of suspended matter. Results of tests with sediment shown in FIGURE E-1 indicate a wide range of sensitivity is associated with fine mud and coarse sand (about two orders of magnitude). The significance of these results is that size variations between the field and laboratory and within a survey area during monitoring will produce shifts in apparent TU and SSC values that are unrelated to real changes in sediment concentration.

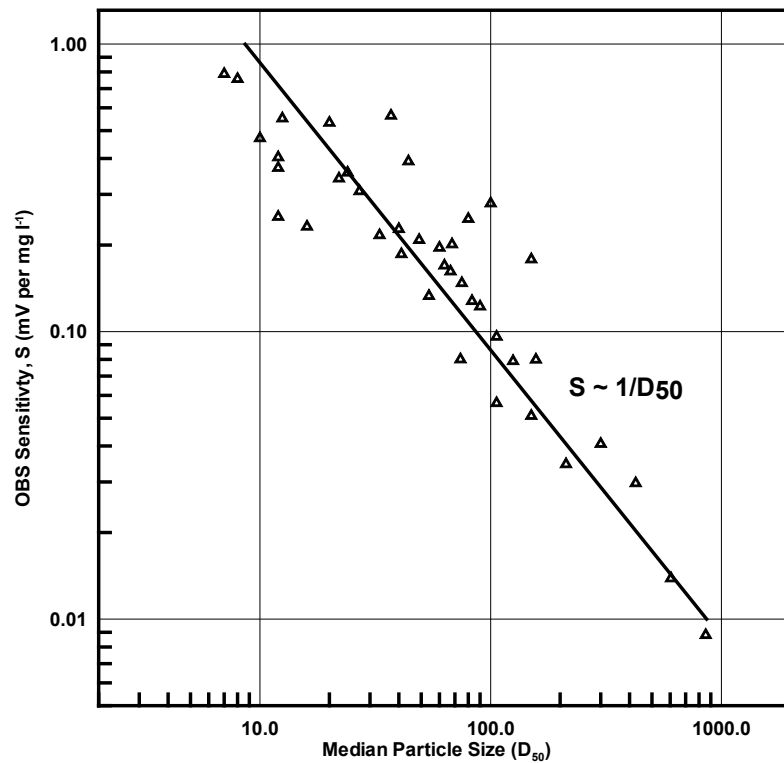


FIGURE E-1. Normalized sensitivity as a function of grain diameter

FIGURE E-2 shows the difference in apparent turbidity that can result from different ways of disaggregating sediment.

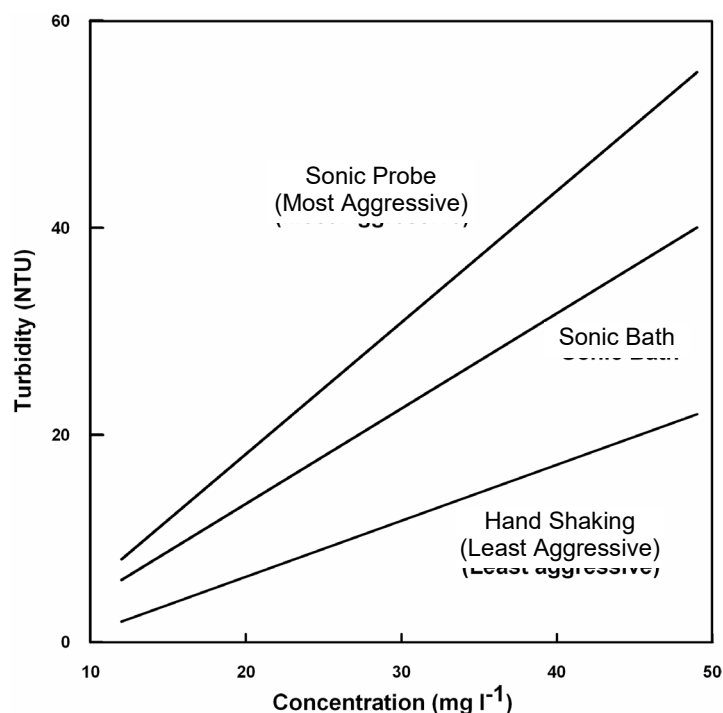


FIGURE E-2. The apparent change in turbidity resulting from disaggregation methods

## E.2 Suspensions with Mud and Sand

As mentioned in Appendix E.1, *Particle Size (p. E-1)*, light scattering from particles is inversely related to particle size on a mass concentration basis. This can lead to serious difficulties in flow regimes where particle size varies with time. For example, when sandy mud goes through a cycle of suspension and deposition during a storm, the ratio of sand to mud in suspension will change. A turbidity sensor calibrated for a fixed ratio of sand to mud will, therefore, indicate the correct concentration only part of the time. There are no simple remedies for this problem. One solution is to take many water samples and analyze them in the laboratory; however, this is not always practical during storms when the errors are likely to be largest. Do not rely solely on turbidity sensors to monitor suspended-sediment particles when particle size or composition is expected to change with time at a monitoring site.

## E.3 Particle-Shape Effects

In addition to size and flocculation/aggregation, particle shape has a significant effect on the scattering intensity from a sample and calibration slope of a turbidity sensor. As the graph in FIGURE E-3 shows, plate-shaped particle (clay-mineral particles, for example) backscatter light about ten times more efficiently than spherical particles, while angular shapes have intermediate scattering efficiency. Turbidity sensors are very sensitive to shape effects and this makes it very important to calibrate with material from the monitoring site.

It is also essential that particle shape remains constant during the monitoring period.

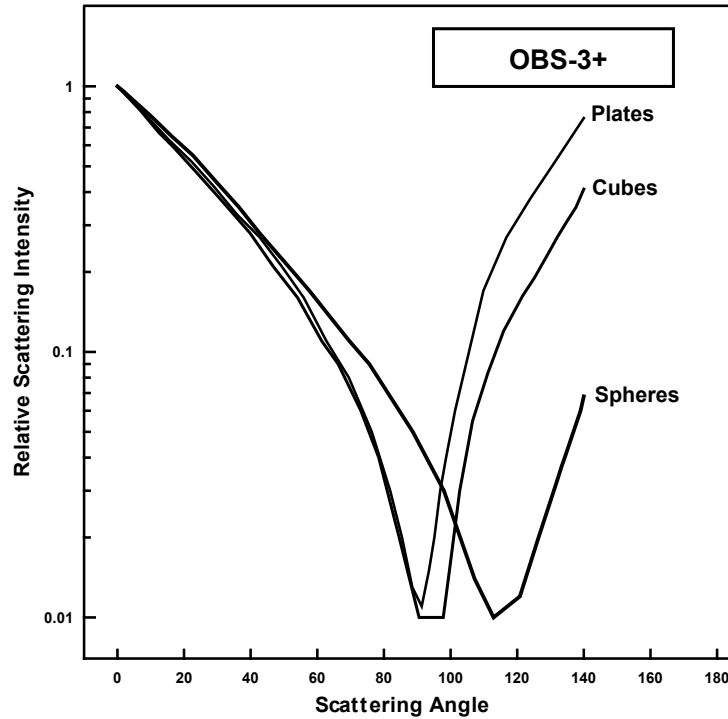


FIGURE E-3. Relative scattering intensities of grain shapes

## E.4 High Sediment Concentrations

At high sediment concentrations, particularly in suspensions of clay and silt, the infrared radiation from the emitter can be so strongly attenuated along the path connecting the emitter, the particle, and the detector, that backscatter decreases exponentially with increasing sediment concentration. For mud, this occurs at concentrations greater than about 5,000 mg/l. FIGURE E-4 shows a calibration in which sediment concentrations exceeding 6,000 mg/l cause the output signal to decrease. It is recommended not to exceed the specified turbidity or suspended-sediment ranges, otherwise the interpretation of the signal can be ambiguous. For example, a signal level of 2,000 mV (FIGURE E-4) could be interpreted to indicate SSC values of either 3,000 or 33,000 mg/l. Factory calibrations are performed in the linear region designated 'A' on the graph.

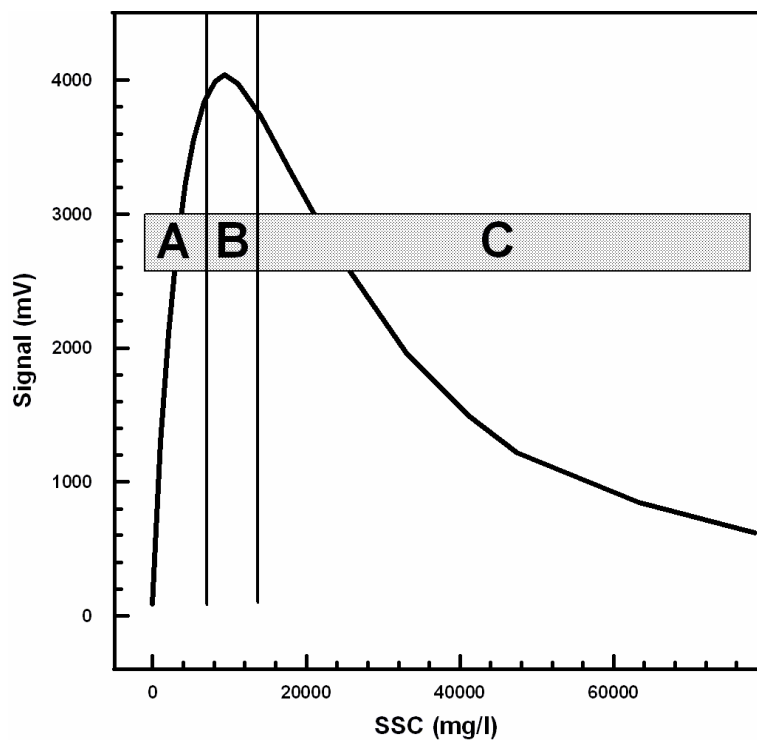


FIGURE E-4. Response of an OBS501 to a wide range of SSC

## E.5 IR Reflectivity—Sediment Color

Infrared reflectivity, indicated by sediment color, has a major effect on sensitivity because with other factors remaining constant, it changes the intensity of light scattering. Although turbidity sensors are color blind, tests have shown that “whiteness”, color, and IR reflectivity are correlated. Calcite, which is highly reflective and white in color, will produce a much stronger turbidity signal on a mass-concentration basis than magnetite, which is black and IR-absorbing. Sensitivity to colored silt particles varies from a low of about one for dark sediment to a high of about ten for light gray sediment; see FIGURE E-5. In areas where sediment color is changing with time, a single calibration curve may not work. Resulting errors will depend on the relative concentrations of colored sediments.

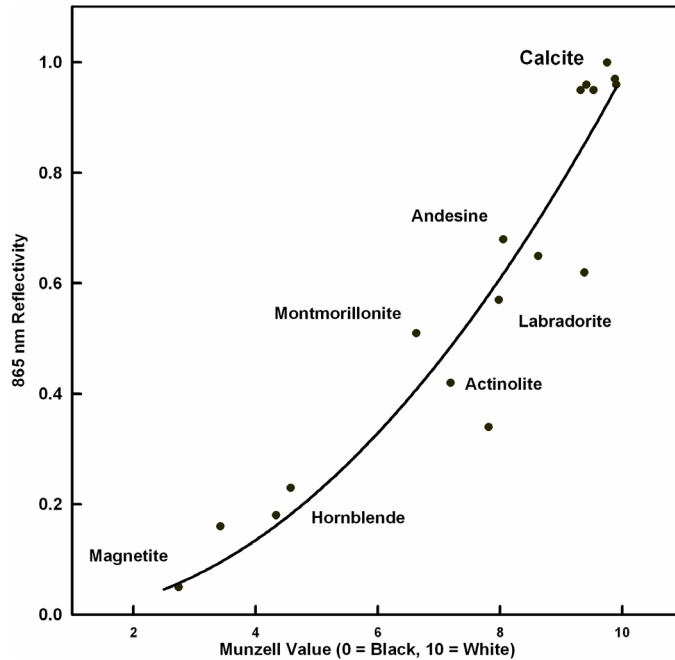


FIGURE E-5. Infrared reflectivity of minerals as a function of 10-Munzell Value

## E.6 Water Color

Some OBS users have been concerned that color from dissolved substances in water samples, not colored particles as discussed in Appendix E.5, *IR Reflectivity—Sediment Color* (p. E-4), produces erroneously low turbidity measurements. Although organic and inorganic IR-absorbing, dissolved matter has visible color, its effect on turbidity measurements is small unless the colored compounds are strongly absorbing at the sensor wavelength (850 nm) and are present in high concentrations. Only effluents from mine-tailings produce enough color to absorb measurable IR. In river, estuary, and ocean environments, concentrations of colored materials are too low by at least a factor of ten to produce significant errors.

## E.7 Bubbles and Plankton

Although bubbles efficiently scatter light, monitoring in most natural environments shows that OBS signals are not strongly affected by bubbles. The sidescatter measurement may be more affected. Bubbles and quartz particles backscatter nearly the same amount of light to within a factor of approximately four, but most of the time bubble concentrations are at least two orders of magnitude less than sand concentrations. This means that sand will produce much more backscatter than bubbles in most situations and bubble interference will not be significant. Prop wash from ships and small, clear, mountain streams where aeration produces high bubble concentrations are exceptions to this generality and can produce erroneous turbidity values resulting from bubbles.

OBS501s detect IR backscattered between 90° and 165° where the scattering intensities are nearly constant with the scattering angle. Particle concentration

has the most significant effect in this region. OBS501s are more sensitive, by factors of four to six, to mineral particles than particulate organic matter, and interference from these materials can, therefore, be ignored most of the time. One notable exception is where biological productivity is high and sediment production from rivers and re-suspension is low. In such an environment, OBS signals can come predominately from plankton.



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