WARRANTY

D & A Instrument Company warrants each instrument it supplies to be free of defects of materials and workmanship under normal use for a period of one year from date of shipment. In the event an instrument covered by this warranty fails to operate according to our published specifications it will be repaired by **D & A Instrument Company** if it is returned with shipping prepaid. If it is determined that the failure occurred through other than normal use, an estimate of costs will be submitted for approval before repair work is started.

This warranty is made only to the original purchaser and does not apply to expendable parts such as batteries and fuses or to underwater connectors supplied by manufacturers other than the warrantor. ***Modification and servicing of the sensor(s) or the electronics is not recommended***. If modifications are made to the instrument by persons other than the manufacturer, this warranty is void.

Shipping costs will be paid by the purchaser. No COD shipments will be accepted by the manufacturer. The warrantor accepts no responsibility for damage in shipment other than the original delivery to the purchaser.

For Technical Assistance Call: 800-437-8352

OBS-3A Serial Number ____________

CONTENTS

FIGURES

TABLES

1. INTRODUCTION

The heart of the OBS-3A monitor is an optical backscatter (OBS®) sensor for measuring turbidity and suspended solids concentrations by detecting near infrared (NIR) radiation scattered from suspended particles. With a unique optical design, OBS sensors perform better than most in situ turbidity sensors in the following ways:

1) Small size and sample volume
2) Linear response and wide dynamic range
3) Insensitivity to bubbles and organic matter
4) Rejects effects of ambient light and temperature change.

The OBS-3A includes a temperature sensor and may be equipped with pressure and conductivity sensors. Batteries and electronics are contained in a housing capable of operating at depths of up to 300 meters, depending on which pressure sensor is installed. A survey cable may be used to tow the OBS-3A and a depressor weight by clamping a cable harness to the housing.

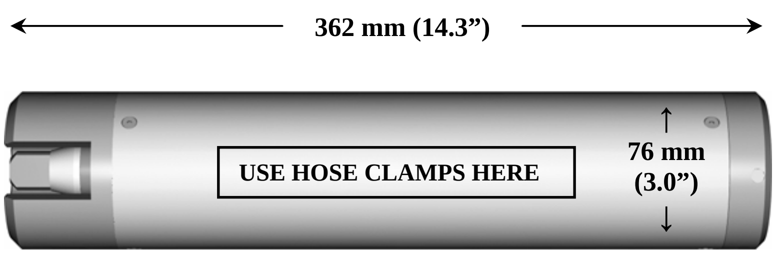


Figure 1 Dimensions

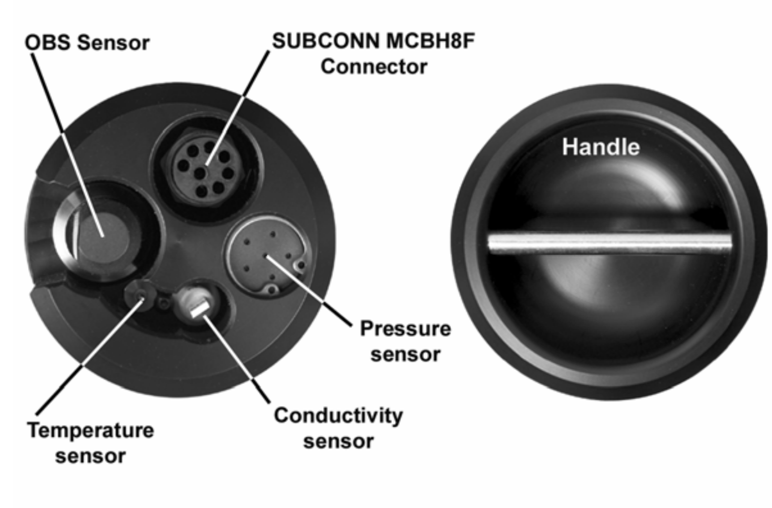


Figure 2 Components

Depending on the number of sensors and the statistics selected, the OBS-3A can log as many as 200,000 lines of data (one per hour for 23 years) including: time, date, depth, NTUs, ^{o}C, and salinity. When sampling with a full suite of sensors, the unit will run about 300 hours. When using the instrument for surveys, the data are captured by a PC running **OBS for Windows** in the log file created at initialization.

OBS Sensor

The OBS sensor consists of an infrared-emitting diode (IRED) with a peak wavelength of 875 nm, four photodiodes, and a linear temperature transducer. The IRED produces a conical beam with half-power points at 50^{o} (Figure 3). The IR scattered between 140^{o} and 160^{o} is detected after passing through a daylight-rejection filter and is proportional to turbidity and sediment concentration. See SPECIFICATIONS page 59.

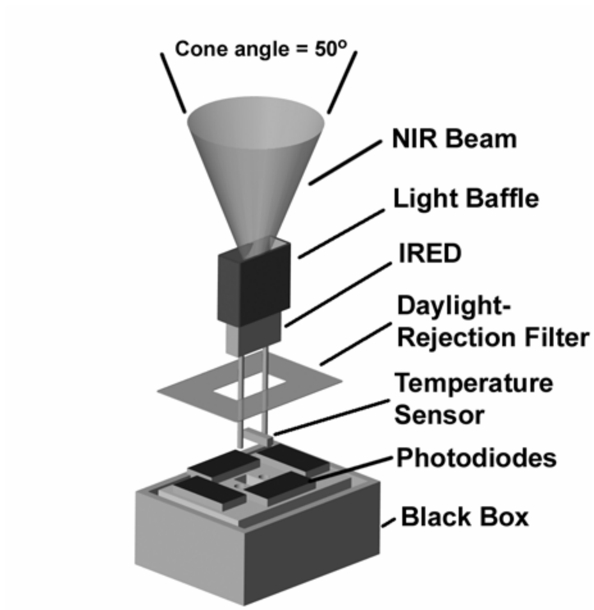


Figure 3 Anatomy of an OBS sensor

Temperature And Optional Sensors

Temperature is measured with a fast-response, stainless steel-clad thermistor. Pressure is measured with a semiconductor piezoresistive strain gage. Conductivity is measured with a four-electrode conduction-type cell. Working depths for available pressure sensors are listed in Table 1 (Page 4).

2. INSTRUMENT SETUP

Mounting Suggestions

Caution: Maximum depth for the OBS-3A housing is 300 meters. Working depths for individual instruments are limited by the installed pressure sensor. If exceeded, the pressure sensor will rupture and the housing will flood.

Table 1 Working and Maximum depths

Pressure Sensor	Working Depth	Maximum Depth
2 Bar	0 - 20 meters	30 meters
5 Bar	0 - 50 meters	75 meters
10 Bar	0 - 100 meters	150 meters
20 Bar	0 - 200 meters	300 meters

(1 Bar = 10 dBar ≅ 10 meters of fresh water)

Schemes for mounting the OBS-3A will vary with applications, however, the same basic precautions should be followed to ensure the unit is not lost or damaged.

- The most important general precaution is to ***orient the unit so that the OBS sensor "looks" into clear water*** without reflective surfaces.
- Nearly all exposed parts of the instrument are made of Delrin, a strong but soft plastic. Always ***pad the parts of the OBS-3A housing that will contact metal or other hard objects*** with electrical tape or neoprene. Expanded polyethylene tubes make excellent padding.
- ***Never mount the instrument by the end-caps or attach anything to them.*** This could stress the screws holding the unit together, cracking either the end-caps or pressure housing, and cause a leak.

Moorings

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 or 0.3" width) or stainless steel hose clamps. Use at least six cable ties or two hose clamps for redundancy. Position the clamps on the inner 2/3rds of the pressure tube, labeled "USE HOSE CLAMPS HERE", so stress is not transmitted to the ends (see Figure 1). First cover the area(s) to be clamped with tape or 1/16" (2 mm) neoprene sheet. Clamp the unit to the mounting frame or wire using the padded area. Do not tighten the hose clamps more than necessary to produce a firm grip. Over tightening may crack the pressure housing and cause a leak. Use spacer blocks when necessary to prevent chafing the unit with the frame or wire.

Surveys

The OBS-3A will usually be towed from a cable harness for surveys. The serial cable supplied with the unit is strong enough to tow the OBS-3A and a 5-kg depressor weight however; the towing forces must be transmitted to the pressure housing and not to the connector. To provide strain relief for the connector, attach a cable grip about 30 cm above the SUBCONN® connector (Figure 2) and attach a short length of 1/8" (3 mm) wire rope to the cable grip. Clamp the wire rope to the pressure housing in the clamping area with two stainless steel hose clamps. Provide a small loop of slack cable between the cable grip and connector and put chafe protection on the sensor head where it contacts the wire rope.

Battery Installation

If unit is wet, perform the following operations with the unit held sensor end up. Remove the three hex screws from the end with the handle and pull the cap down and out of the housing. Then wipe water from inside walls of the tube with a paper towel (Figure 4). Slide the battery clip back and insert the batteries with the positive terminal (+) toward the clip. Push the batteries down and slide the clip against the housing wall to hold them in place. Inspect the o-ring in the cap and replace the cap and screws.

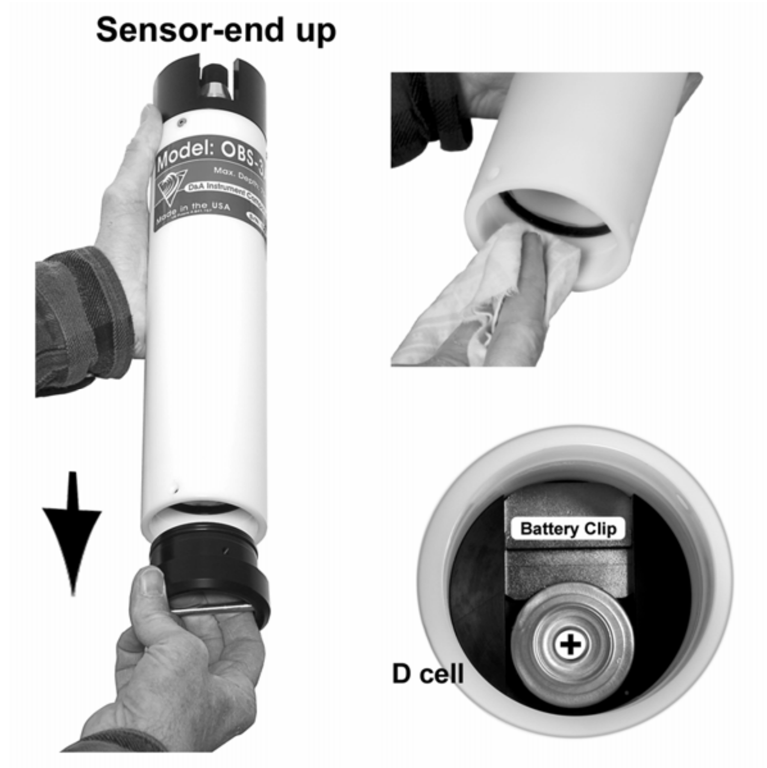


Figure 4 Battery Installation

3. OPERATIONS

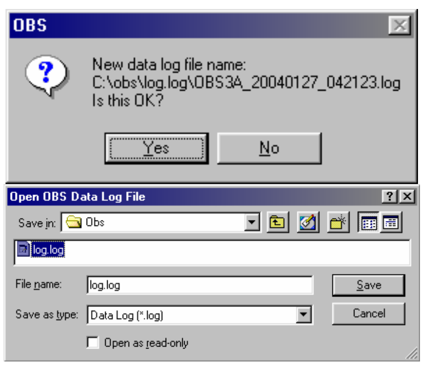
Software Installation

Before getting started, copy all of the files on the CD supplied with the unit into a directory called OBS on your PC hard drive. The program OBS for Windows (OFW) is your interface with the OBS-3A. Make a shortcut to the program OBS3A.exe on your PC. The other files on the CD include the OBS-3A firmware, a system-maintenance program, and communication drivers. The main purpose of this section is to explain how to program and operate the OBS-3A with OFW. It covers: 1) turning the OBS-3A ON and testing the sensors, 2) setting it up to sample in one of its four modes, 3) recording data with a PC or uploading data from the OBS-3A, 4) importing data into a spreadsheet, 5) plotting data with OFW, and 6) turning the OBS-3A OFF

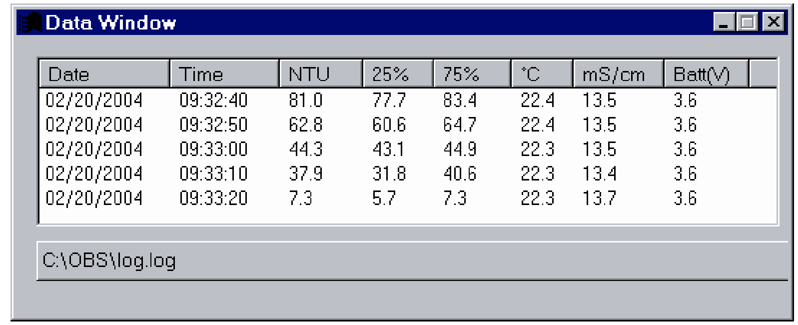
Running OBS For Windows

1) Double click the icon to start **OBS for Windows** and open the Data window and toolbar.

2) **OBS for Windows** will create a new data log file and prompt you to accept the name. Files are automatically named with Greenwich Date and Time as follows: OBS3A_20010808_172433.log. Or you can designate your own file name and destination by choosing **No.**



Data received from OBS-3A while it is connected to the PC will be stored in this file.



Date	Time	NTU	25%	75%	°C	mS/cm	Batt(V)
02/20/2004	09:32:40	81.0	77.7	83.4	22.4	13.5	3.6
02/20/2004	09:32:50	62.8	60.6	64.7	22.4	13.5	3.6
02/20/2004	09:33:00	44.3	43.1	44.9	22.3	13.5	3.6
02/20/2004	09:33:10	37.9	31.8	40.6	22.3	13.4	3.6
02/20/2004	09:33:20	7.3	5.7	7.3	22.3	13.7	3.6

3) Connect the OBS-3A to a PC with the test cable (Figure 5).

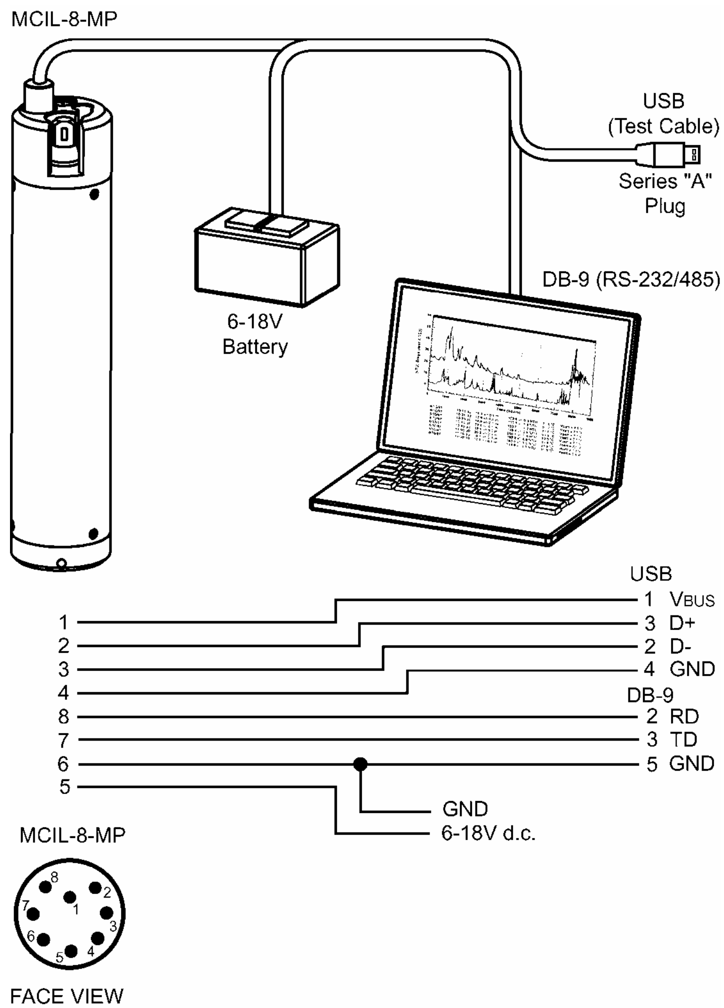
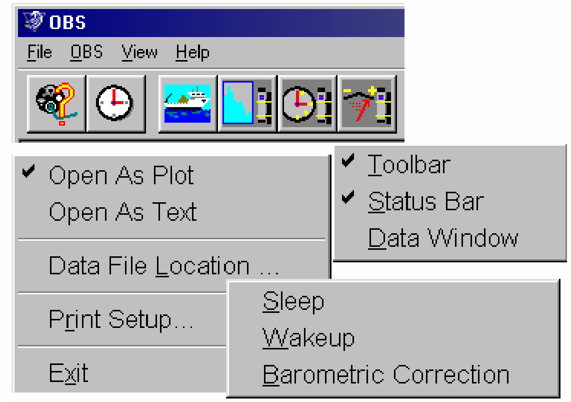


Figure 5 Connections and wiring of field cable

4) Click  **Connect/Disconnect** to get a green light and synchronize the OBS-3A clock with your PC by clicking 

Pull-Down Menus

OBS for Windows has four pull-down menus for **Files**, **OBS, View**, and **Help**.



The **File**s menu allows you to select the location and formatting for OBS files. Files can be opened as plots or ASCII text that can be brought into spreadsheet programs or text editors. Plot files are displayed graphically.

The **View Menu** controls the display on your PC. Switches are provided for:

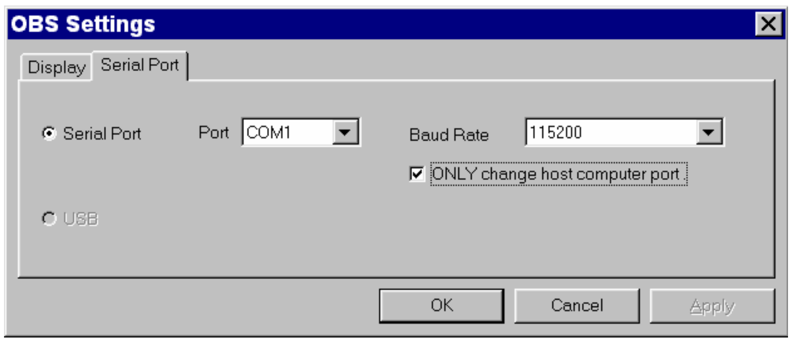
- **Toolbar** toggles the icons to ON or OFF.
- **Status bar** toggles the Status Bar at the bottom of the screen to ON or OFF.
- **Data Window** pops the data window into view

The **OBS menu** allows you to put the instrument into a low power **Sleep,** or have the instrument make a **Barometric Correction.**

Communication Settings

The **Plot and Port Settings** button has a serial port tab that is used to configure the PC communication settings. The default communication settings are: 115 kbs, 8 data bits, no parity, no flow control. These settings will work for most applications and with most PCs. In order to pick a slower baud rate for an older PC or to avoid data-transfer errors, select the desired rate from the dialog box and click **Apply.** The rate adjustment takes two seconds. If your PC is set to the wrong rate for some reason, use the check box to select **ONLY change host computer port**. Then click **Apply** and the button.

If you get the OBS-3A information box, the baud rate of the unit is synchronized with your PC. If you don’t get an information box, repeat the above procedure.



Testing Sensors

1) Before daily operations and deployments, verify the instrument works by clicking **Open Plot**, and then clicking **Survey**. Select all installed sensors and click **Start Survey**.

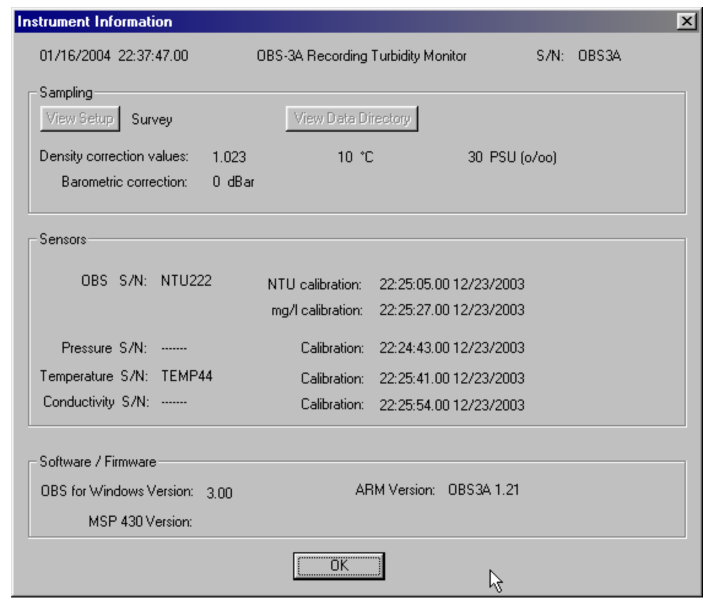
2) Wave your hand in front of the OBS sensor; the turbidity signal on the top plot will fluctuate and data will scroll.

3) Blow on the temperature sensor to observe an increase in temperature (red trace on the middle plot).

4) Blow into the pressure sensor and a small elevation in the pressure signal will occur (bottom plot).

5) Dip the sensor in salty water and conductivity will increase (blue trace on middle plot).

6) Click **OBS-3A Settings** to view time, serial numbers, depth corrections, and software versions.



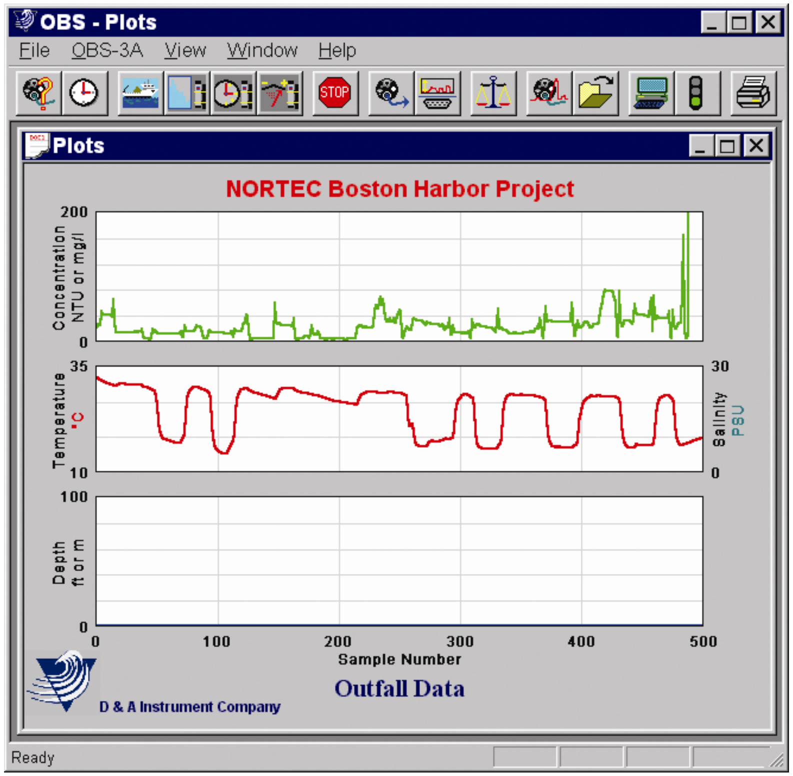


Figure 6 Test data sample

Water-Density & Barometric Corrections

Since depths are estimated from pressure measurements, it is important to set the water temperature and salinity so the OBS-3A can correct for water density and calculate depth in meters or feet (this will not affect temperature or salinity measurements). Also, the sensor measures absolute pressure so another correction must be made for barometric pressure. **Be sure to do this while the OBS-3A is at the surface.** Doing so when the instrument is submerged will result in large errors in the depth measurement. The error will be approximately equal to the instrument depth when the correction is made. Depending on the magnitude of barometric pressure fluctuations at the sampling site and the desired accuracy, you may want to correct data for atmospheric effects using barometric pressure simultaneously recorded at a nearby site.

Sample Statistics

Three types of statistics can be selected for the OBS-3A measurements.

1) Measures of central tendency, the mean and median.

2) Measures of variation or spread within a sample, the standard deviation (σ) and cumulative percentages, such as X_{25} and X_{75} (where X is the measured depth or NTU)

3) Wave statistics, significant height and dominant period.

Statistics are computed for each sample and logged in the FLASH. The raw data are not saved. The mean is the arithmetic average of the values ($\sum x / n$), where $\sum x$ is the sum of the sample values (x) and n is the number of values (sample size). The median (X_{50}) is the value that exceeds 50% of the sample values and is the best measure of central tendency when a sample has outliers. The percentages, X_{25}, X_{50}, X_{75}, etc. exceed 25, 50, and 75% of the sample values. The OBS-3A uses a spectral method developed by the U.S. Army Corps of Engineers to calculate wave heights in depth units and periods (H_s and T_s). H_s is the average height of the one-third largest waves, and reports it in the selected depth units (meters or feet). T_s, is the time in seconds associated with the peak spectral-density in the wave spectrum.

Definitions

The following definitions are useful when programming the OBS-3A.

Interval: The time in seconds between the start of one sample and the beginning of the next. In cyclic mode, this is the time between samples, and in setpoint mode, there are two intervals, one slow and the other fast. The interval must be longer than the duration plus some time for statistical computations. OFW will prompt you if too short an interval is selected.

Duration: This is the length of time in seconds that the OBS-3A is measuring its sensors. The duration must always be less than the interval. The minimum duration is five seconds and the maximum is the longer of the wave record length or the 2048 / rate. Note: the product of the rate and the duration can not exceed 2048.

Rate: Rate is the frequency of sampling for the duration of measurements. All sensors are sampled at the same rate, typically 2, 5, 10, or 25 times per second (Hz). For example, a rate of 25 Hz for a 60-second duration will produce a sample with 1500 measurements for each sensor. When wave statistics are chosen, the rate must be selected in the **Wave Setup** box.

Power: This indicates the percentage of time over the duration of a sample that sensors are ON. Higher power levels mean larger samples, better statistics, and shorter battery life. Lower levels spare the batteries but result in more random noise in sample statistics.

Record Length: When wave measurements are selected, this sets the time in seconds for which depth measurements are made for the wave-spectral computations. Use a record length of 512 seconds for inshore waters (lakes and rivers), protected bays and estuaries. For coastal waters with intermediate periods (6 to 9 seconds) use 1024 seconds. For the open ocean select a record length of 2048 seconds to record long period waves (T_s > 10 seconds).

Depth: This is the user's best estimate of the water depth when the OBS-3A is deployed. It is an initial value needed by the unit to compute wave heights and correct for the attenuation of dynamic pressure with depth. When depth is specified in the **Wave Setup** box, the OBS-3A automatically measures height above bottom after reaching the deployment depth.

Height Above Bottom: This is distance above the bottom in meters or feet where the OBS-3A will come to rest after it is deployed. It is an alternative initial value used by the unit to correct for pressure attenuation. When height above bottom is selected, depth is automatically computed once the unit has come to rest.

Sampling Schedules

The main factors that need to be considered when setting up OBS-3A sampling schedules include:

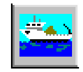
- Sampling interval needed to characterize the processes of interest (e.g. water-level fluctuations, flood and transport duration, tidal and surf conditions, etc.).
- Maximum sediment concentration.
- Statistical requirements, such as sample size and sampling rates.
- Battery capacity.

The goal is to pick a sampling scheme that gets essential information without taking too many samples or sampling too often. Inefficient sampling produces a data avalanche, unnecessary processing, and excessive battery consumption. Sampling schedules are set with the **interval**, **duration**, and **rate** parameters. **Interval** sets the time in seconds between the start of one sample and the beginning of the next, e.g. how often data are recorded. Select the longest interval that will show the changes in turbidity and water depth that you wish to investigate. **Rate** sets the number measurements per second, in Hz, taken during a sample. The quicker turbidity and depth change, the higher the sampling rate should be to get a stable average value for a sample. Finally, **Duration** sets the period of time for measurements and how long sensor outputs will be averaged. For example, with an interval of 30 seconds and a duration of five seconds, the OBS-3A will make measurements for five seconds starting every 30 seconds. The number of measurements in a sample (sample size) is the product of the duration and the rate. So if the rate was 25 Hz in the prior example, the sample size would be 5 X 25 = 125 measurements. Table 2 provides some recommended ranges for these parameters in various sampling environments. Always select duration and rate to give a sample size of at least 30, and to reduce random sampling noise below 50% of its maximum value, select them to give a size greater than 200.

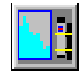
Table 2 Sampling Schedules

Environment	Rate (Hz)	Duration (sec)	Interval
River/Stream	2-5	30-100	300-900
Beach	5-25	30-200	60-900
Estuary	5-10	10-60	600-3600

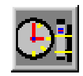
Sampling Modes



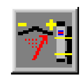
Survey: Select the survey mode when operating the unit with a cable connection to a PC and when high data rates are desired. Data can be logged with a PC at rates up to 120 lines per minute (2 Hz).



Cyclic sampling: Use cyclic sampling to record data internally in the 8 Mb, non-volatile FLASH memory at regular intervals, e.g. every 1, 5, 15, or 30 minutes. Depending on the number of sensors measured and the statistics selected, the OBS-3A can log as many as 200,000 lines of data (one per hour for 23 years) including: time, date, depth, NTUs, ^{o}C, and salinity.



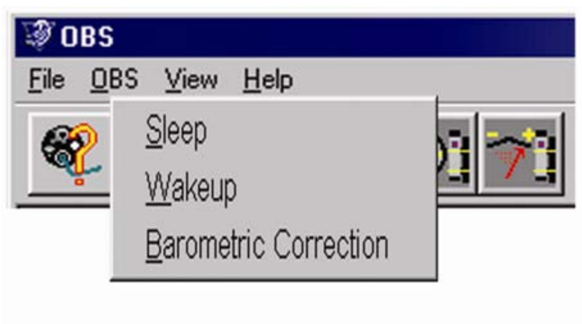
Scheduled sampling: The OBS-3A can be scheduled to sample at specific times in hours and minutes on a 24-hour clock using this mode.



Setpoint sampling: Use this mode for fast sampling of events such as storms, floods, dredging operations, and construction activities. The unit will revert to slow recording between events. Sample events two to five times faster than the rate chosen for the periods between events. For example, program the OBS-3A to sample slowly for a duration of 30 seconds every 900 seconds (15 minutes), and to sample at a fast rate every 180 seconds (three minutes), when the turbidity level exceeds a specified setpoint.

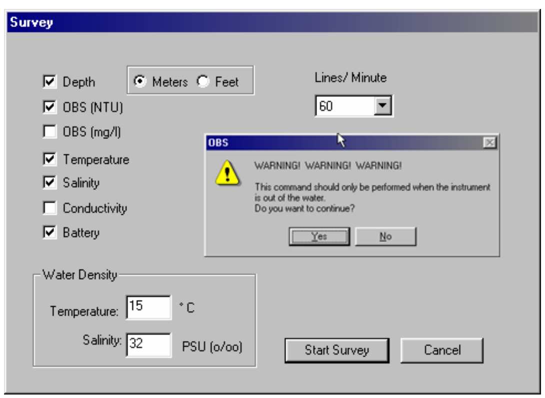
Surveying

If you have a pressure sensor, click the OBS menu and select **Barometric Correction** (***do not do this when the OBS-3A is submerged***). The OBS-3A takes about five seconds to measure the surface pressure and compute a barometric correction.

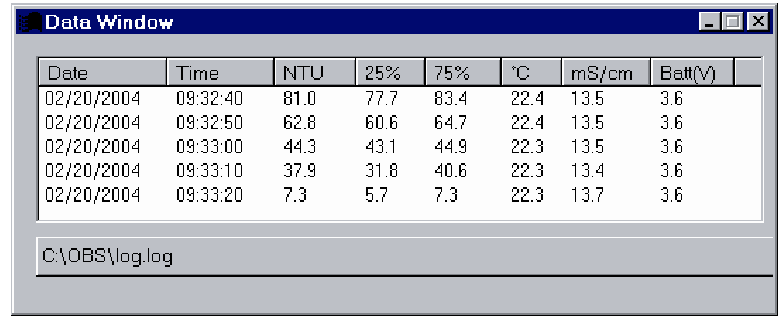


1) **C**onnect OBS-3A to PC with survey cable.

2) Use to select: sensors, lines per minute, depth units (**Meters** or **Feet**), water **Temperature**, and **Salinity**. Selection of temperature and salinity only affects the depth calculation. It does not influence temperature or salinity measurements.



3) Click **Start Survey** and check data flow in data window.


Data Window

Date	Time	NTU	25%	75%	°C	mS/cm	Batt(V)
02/20/2004	09:32:40	81.0	77.7	83.4	22.4	13.5	3.6
02/20/2004	09:32:50	62.8	60.6	64.7	22.4	13.5	3.6
02/20/2004	09:33:00	44.3	43.1	44.9	22.3	13.5	3.6
02/20/2004	09:33:10	37.9	31.8	40.6	22.3	13.4	3.6
02/20/2004	09:33:20	7.3	5.7	7.3	22.3	13.7	3.6

C:\OBS\log.log

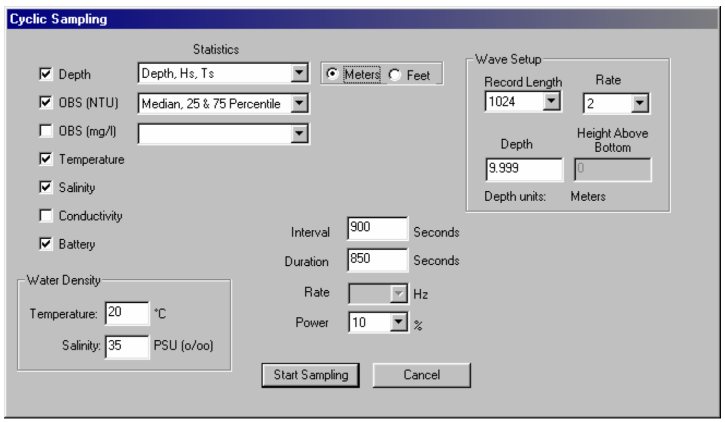
4) A file for logging data was created when you started **OBS For Windows**. You can review data at any time with **Open** and import the log file directly into an Excel spreadsheet for post-survey processing and plotting (see "Excel Spreadsheets" page 27)

Cyclic Sampling

This mode is for logging data at regular time intervals such as 1, 10, 15, 30, etc. minutes for example.

1) Request **Barometric Correction** from the OBS menu. **Be sure to do this while the OBS-3A is at the surface.** Doing so when the instrument is submerged will result in large depth errors.

2) Click  and select sensors, statistics, depth units (meters or feet), water temperature, and salinity**.** Selection of temperature and salinity only affects the depth calculation. It does not influence temperature or salinity measurements



3) Configure the **Wave Setup** if you want to measure wave heights and periods (see "Definitions" page 15). Do this before scheduling the other sample parameters.

4) Select **Interval, Duration, Rate**, and **Power** level; see recommendations in "Sampling Schedules" page 16. The duration must be longer than the **Record Length**. The minimum duration for the **Record Length** will be computed and displayed by OFW.

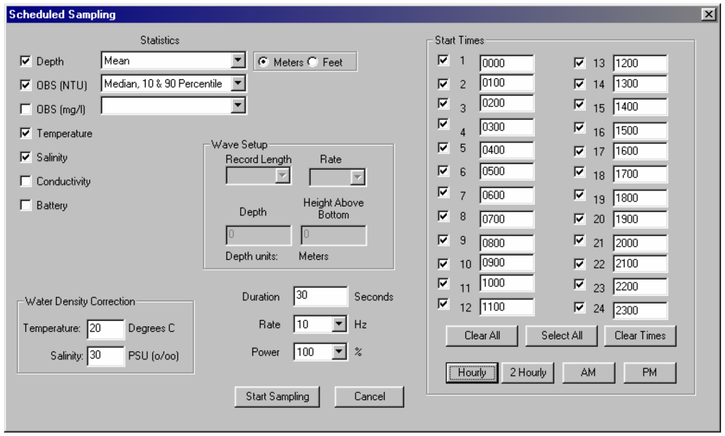
5) Click **Start Sampling** to begin logging data. Unplug test cable; install dummy plug and locking sleeve. The instrument is ready for deployment.

Scheduled Sampling

Use this mode when you want the OBS-3A to sample at specific times, scheduled by hours and minutes, on a 24-hour clock.

1) Request **Barometric Correction** from the OBS menu. **Be sure to do this while the OBS-3A is at the surface.** Doing so when the instrument is submerged will result in large depth errors.

2) Click and select items as described in Cyclic sampling section**.**



3) Use the **Start Times** block to schedule sampling.

4) Click **Start Sampling** to record data. Monitor the data window to verify that data are being logged.

5) Switch the COM port off (red) with the icon

6) Unplug test cable; install dummy plug and locking sleeve. The instrument is ready for deployment.

Setpoint Sampling

Use this mode when you want the OBS-3A to sample at a faster rate during events such as storms, floods, dredging operations, and construction. The OBS-3A will switch from the slow to fast sampling rate when the setpoints and logical conditions you select are exceeded. It will return to the slower rate when the selected setpoints and logical conditions are met.

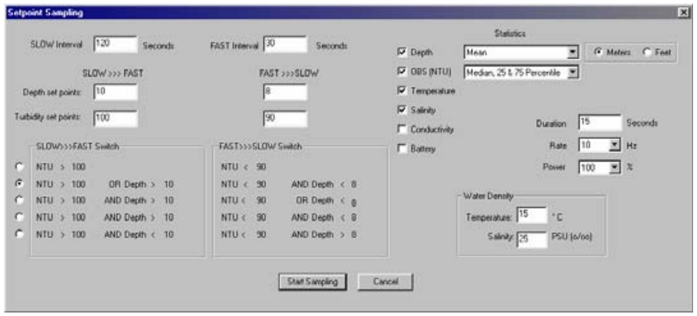
1) Request **Barometric Correction** from the OBS menu. **Be sure to do this while the OBS-3A is at the surface.** Doing so when the instrument is submerged will result in large depth errors.

2) Click and select items as described in Cyclic sampling section.

3) Select **SLOW Interval** and **FAST Interval** in seconds.

4) Select setpoint values for transitions to fast sampling (**SLOW>>>FAST**) and slow (**FAST>>>SLOW**) rates**.**

5) Select one of the five logic criteria with the radio buttons.



6) Click **Start Sampling** to record data. Monitor the data window to verify that data are being logged.

7) Switch the COM port off (red) with the icon

8) Unplug test cable; install dummy plug and locking sleeve. The instrument is ready for deployment.

Data Retrieval

1) Remove dummy plug and connect OBS-3A to PC with test cable.

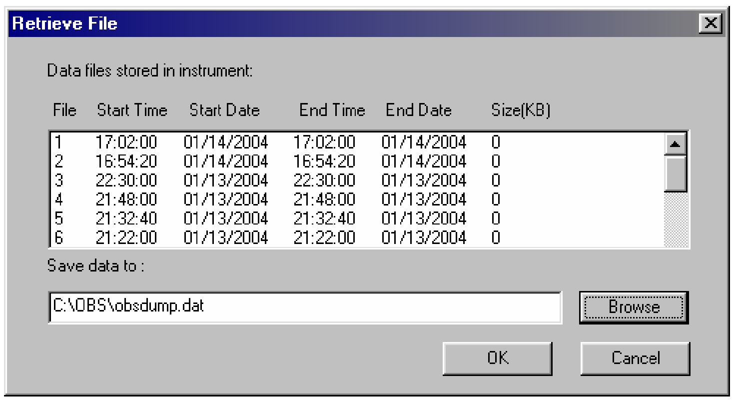
2) Run **OBS for Windows** (see page 7).

3) Check the Data Window to verify the instrument is transmitting data.

4) Click  to end data collection and use  **Offload Data** to save data in a file.

5) Highlight the data with the start and end times you want.

6) Click **Browse,** select a destination file and click **OK**.



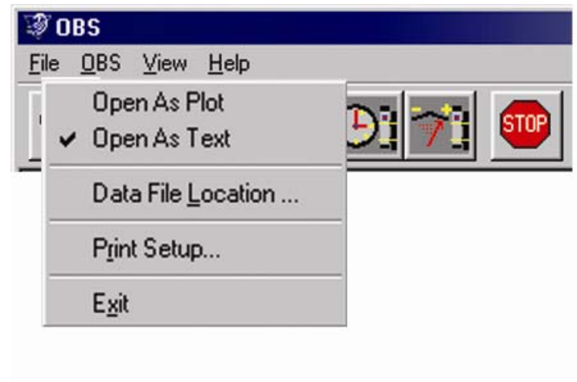
7) Wait for the progress bar to disappear and examine data as a plot or test file (page26).

Shutdown

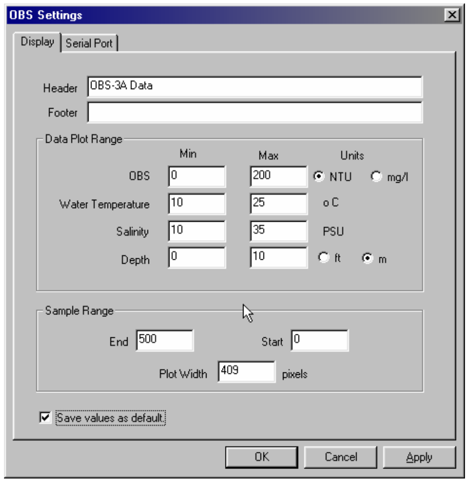
From the **OBS** menu (see page 19), select **Sleep**. See menus shown in the following section.

Graphing And Printing

1) Use **File** menu to select how data file will be opened.



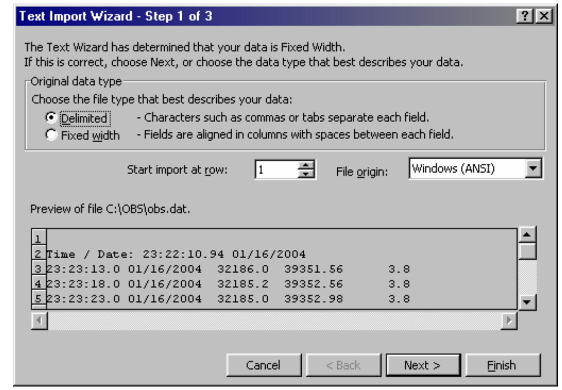
2) Click  and select a file to view.  **Print** will print a graph when data file is **Open As Plot**. To print a text file, **Open As Text,** and use the Word Pad file print functions. For spreadsheet operations, see next section. The Plot and Port Settings  button is also used for communication settings (see page 11).

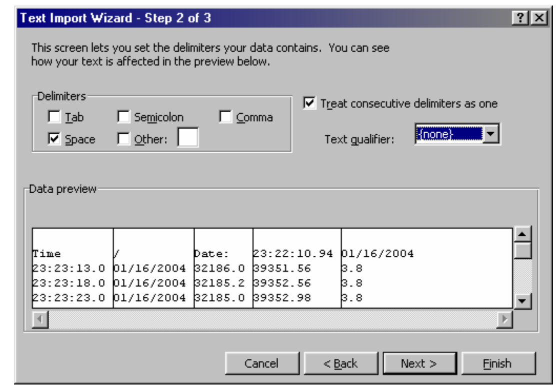


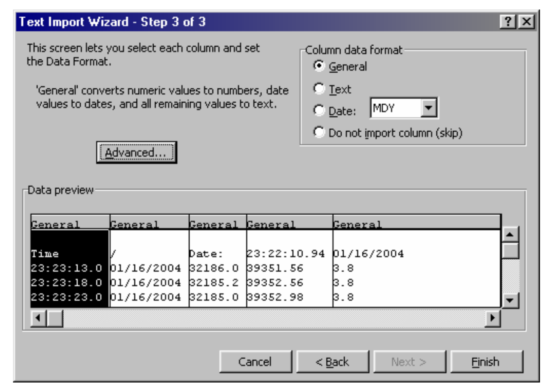
3) Use the **Min** and **Max** and **Sample Range** (**Start** and **End**) values to bracket the data you need on the graph. **Plot Width** allows the graph to be sized to fit a PC screen. On the depth plot, select **Max** = 0 and **Min** = the maximum depth to display depth increasing downward.

Excel Spreadsheets

To make an Excel spreadsheet from OBS-3A data, start Excel and set file type to **All**. Open a data file and select **Delimited** in Step 1 of 3 of the Text Import Wizard. Click **Next >** and select the delimiter **Space**; **Treat consecutive delimiters as one**; and {none} for **Text qualifier**. In Step 3 of 3, select the **General Column data format** and click **Finish**.







4. TROUBLE SHOOTING

This section will help you isolate problems that can be easily fixed such as cable-continuity, processor reset, and battery replacement from serious ones such as sensor, computer and electronic malfunctions, and damaged mechanical parts that will require our help. The problem symptoms are shown with underlined, bold text.

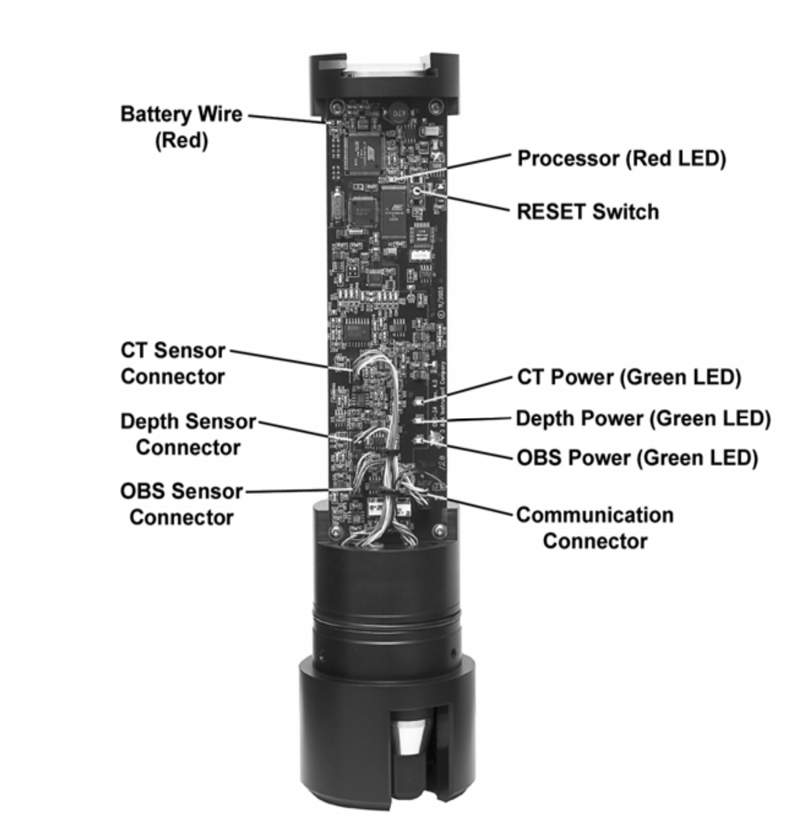
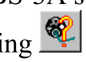


Figure 7 Component locations

Unit does not communicate with PC.

There are several possible causes for this symptom.

1. The test/umbilical cable is damaged or improperly connected.
2. The OBS-3A is sleeping and will not wake up.
3. The batteries are dead.
4. The OBS-3A and PC are not set to the same baud rate or communication protocol (e.g. RS-232, USB, RS-485).

- Click  and check port settings on the serial port tab. The default baud rate is 115.2 kb. If the PC is not set to this speed, follow the steps on page 11 to set it.
- If the OBS-3A still fails to respond, try changing PC speeds and clicking  until communication is established (e.g. 57.6, 38.4, 19.6, 9.6 kb, etc.). If this fails, switch the PC back to 115.2 kb and go to the next step.
- Reconnect the cable and try .
- Replace the main batteries; see page 5 and try .
- If you have a survey cable, connect instrument to external power and try .
- Remove the unit from the pressure housing and press and release the RESET button. Try .

Power failed due to battery clip corrosion or a broken power wire.

Check for a broken red wire connecting the battery tube and circuit board. Green powder or tarnish on the battery contact parts indicates salt-water corrosion. Remove the electronics from the pressure housing. Pull battery-clip-retainer pin out with needle-nose pliers and slide the clip from its track. Clean the corroded surfaces of clip and track with a Scotch-brite® pad and reassemble unit.

OBS or other sensor malfunction.

- Inspect for physical damage such as a broken or bent thermistor, a dirty conductivity sensor, or an OBS sensor fouled with marine growth.
- Open unit and inspect for broken sensor and communication wires and loose connectors (Figure 7).
- Check sensor power by starting Survey mode  and selecting all sensors. Green LEDs should illuminate for installed sensor.
- If the depth sensor reads high and does not change, it may need to be cleaned (see pressure-sensor maintenance, page 34).
- If the sensors appear to be in working order, the digitizer or microcontroller may be damaged. Such problems usually require factory service.

Bright sun near the surface (< 2 meters) or black-colored sediments cause erroneous OBS readings.

Do not survey in shallow water between 10:00 and 14:00 local time and avoid areas with suspended black mud.

Changing the water temperature in the setup dialog box does not change the temperature measurement.

This is normal. Temperature inputs only change the water density correction used to convert pressure to depth.

OBS-3A indicates different NTU values in the field than other turbidimeters.

Not all turbidity meters read the same! OBS sensors are checked with a Hach 2100N laboratory instrument, using U.S. EPA-approved, formazin turbidity standards before leaving our factory.

Turbidimeters other than the 2100N will read different NTU values on natural water samples.

OBS-3A indicates different suspended sediment levels in the field than in the laboratory.

This results from a change in sediment size or color (see Section 8, page 49). You may have to perform a field calibration with water samples.

5. MAINTENANCE

OBS Sensor

The OBS sensor must be kept clean to measure sediment concentration or turbidity accurately. A gradual decline in sensitivity over a period of time indicates fouling with mud, oil, or biological material. Regular cleaning with a water jet, mild detergent and warm water, or a Scotch-bite abrasive pad will remove most contaminants encountered in the field. Solvent or mineral spirits on cloth can be used to remove oil or grease however, **<u>do not use MEK, benzene, toluene, or electronic cleaners</u>** as they could damage the OBS window. At the conclusion of each survey or deployment, clean the OBS. If thick bio-fouling has developed:

1) Scrape the material off the window with a flexible knife, taking care not to scratch it.
2) Tape a strip of 400 to 600-grit wet/dry sandpaper on the edge of a bench top.
3) Add a few drops of water and rub the sensor window on the wet sandpaper, using the counter edge for a guide.
4) Continue until the sensor is smooth and pit-free.

Polishing with abrasives can be done as needed until approximately 1 mm of epoxy has been removed. Deeper polishing may damage the IR source.

Check the calibration of the sensor with formazin after cleaning with abrasives; see CALIBRATION, page 37.

Pressure Sensor

The strain gage sensor is located under a perforated disk and spring-clip (Figure 2) that protects the Hastelloy diaphragm isolating it from water. Do not touch the diaphragm with tools or pointed objects, as the instrument will leak if it is pierced. Clean the sensor with a water jet directed at the disk after each survey or deployment to flush sediment from between the disk and the sensor. Do not allow sediment to dry on the sensor diaphragm, as it is difficult to clean and will influence accuracy. If this occurs, remove the spring clip and disk with plastic tweezers then gently wipe sediment off the diaphragm with a cotton-tipped swab. Replace the disk and spring clip then flush with a water jet.

Conductivity Sensor

The conductivity sensor is very fragile and is enclosed in a hole behind the OBS sensor. Do not poke it with any tool or object as the electrodes may be damaged. Routine cleaning should only be done with a water jet directed alternately from the side and top of the sensor well. This should be done daily during surveys or after each deployment. A sensor that has been stored dry should be soaked in water for 15 minutes prior to use.

If the sensor becomes fouled with sediment, oil, or biological material, conductivity will decline over a period of time indicating cleaning is necessary. If a water jet fails to remove contaminants, the sensor can be flushed with hot soapy water or warm alcohol. Do not use solvents. The last step in the cleaning process should always be to flush with clean water.

Batteries

The unit runs on three D-size alkaline batteries. Buy the expensive ones with the most distant pull date (“use before May 2008’). With all sensors installed, the OBS-3A will run 400 hours in survey mode and for as long as 8000 hours in one of the logging modes.

Caution: Always put OBS-3A to sleep when it will not be used for a while to conserve battery capacity (see Shutdown page 26)

Refer to Figure 4 for installing batteries. Put the unit on a padded surface and remove the three screws from the end with the handlebar using the 5/64" hex wrench provided in the spares kit. Grasp the handlebar, turn the sensor end up and pull the cap straight out of the pressure-housing tube. Immediately wipe up any water from inside the tube. Stand the unit up on the sensor end and remove the desiccant bags. Slide the clip away from the batteries until the spent cells pop up and can be slid out of the tube. Insert fresh batteries in the tube with the positive terminal (+) up. Press them down and slide the clip over the batteries until it contacts the tube wall. Replenish the desiccant bags and clean and regrease the O-ring. Replace the end cap. ***Do not over tighten the screws***.

Battery life will depend on the percentage of time the unit is sampling. Table 3 shows battery life as a function of sample duration and interval to assist with planning your setup. Pick a power-efficient sampling schedule that meets your scientific objectives.

Table 3 Battery life

	Duration in seconds (% Power)							
Interval (Sec.)	10^1 100%	60^2 50%	60^1 100%	120^2 50%	120^1 100%	256^3 10%	256^1 100%	1024^3 10%
60	1300	NO	NO	NO	NO	NO	NO	NO
600	> 8000	5450	2080	3150	1100	1460	530	NO
900	> 8000	> 8000	2970	5450	1600	2110	785	NO
1800	> 8000	> 8000	5160	> 8000	2950	3815	1510	1120
3600	> 8000	> 8000	> 8000	> 8000	5150	6400	2810	2110

NO = Not possible; 1 = All sensors; 2 = OBS & depth sensors; 3 = Wave calculations.

Pressure Housing

The pressure housing and O-ring seals require little maintenance unless the housing has been opened since the last service. However, it should be carefully inspected every six months and serviced before all deployments longer than one month.

1) Disassemble O-ring seals and inspect mating surfaces for pits and scratches.

2) Inspect O-rings for cuts and nicks; replace if necessary using spares provided.

3) Clean O-rings and mating surfaces with a cotton swab and alcohol. Remove fibers from groove and mating surfaces then grease O-rings with DOW Compound 55 and reassemble.

Antifoulant Coatings

Clear TBTA antifoulant coating or toxin-impregnated collars can be used for monitoring in biologically active waters. TBTA prevents most marine algae and encrusting animals from growing on optical surfaces for up to two months with minimal loss of IR transmission. It is illegal to use TBTA in many places so check applicable water quality regulations in your area before using TBTA coated OBS sensors. Use of TBTA is the sole responsibility of the user.

User-serviceable Parts

See SPECIFICATIONS on page 59 for a list of user-serviceable parts.

6. CALIBRATION

Turbidity

This section briefly describes the materials and equipment you will need and the basic procedures for calibrating OBS sensors with formazin and sediment. All sensors are factory calibrated with formazin and include a calibration certificate expressed in nephelometric turbidity units (NTU). Formazin can be purchased from the Hach Company (800-227-4224; www.hach.com)); request the certificate of analysis when ordering it. Hach also supplies premixed, StablCal which is like formazin except that it can be stored for two years while maintaining +/- 5% of its nominal NTU value. A third U.S. EPA-approved calibration standard is AMCO Clear (GFS Chemicals Inc., 800-858-9682; www.gfschemicals.com) It is approximately three times more expensive per NTU-liter, however: 1) it is guaranteed to be stable for one year and has < 1% initial lot-to-lot accuracy; 2) AMCO particles are small and uniform in size and shape (0.31 ±0.1µm versus 1.3 ±0.6µm for formazin); and 3) it does not flocculate or settle so stirring is not required. AMCO Clear must be made specifically for the OBS sensor.

We strongly advise that the same turbidity standard be used throughout a study (e.g. do not switch between formazin and AMCO standards). Also, AMCO is premixed by the manufacturer and must be used in the container it was shipped in.

Turbidity calibration is organized into steps for Preparation; recording values with OFW; and Production of Standards. After completing the preparations and starting OFW, you must alternate between the OFW and standard-production procedures.

Equipment and Materials

- 4000 NTU formazin, StablCal, or AMCO Clear,
- 4” and 6” diameter black polyethylene containers. Concrete sample containers (Cat. # TC-4, Deslauriers Inc., 800-743-4106; www.deslinc.com) work well for this.
- 2-liter, Class A volumetric flask,
- 100 ml TD volumetric pipette
- 25 ml TD measuring pipette
- 2 gallons filtered distilled water (purified water from the super market works fine)
- Slotted stainless steel stirring spoon.

Preparation

1) Experience has shown that only three calibration points are needed to get sub-1% accuracy. It is recommended to do one for clean filtered water, a midrange value (e.g. 125, 250, 500 or 1000 NTU) and one at the high end of the desired measurement range (e.g. 250, 500, 1000, or 2000 NTU).

2) Scrub the sensor, container, spoon, and glassware with detergent and water and rinse everything twice with filtered water.

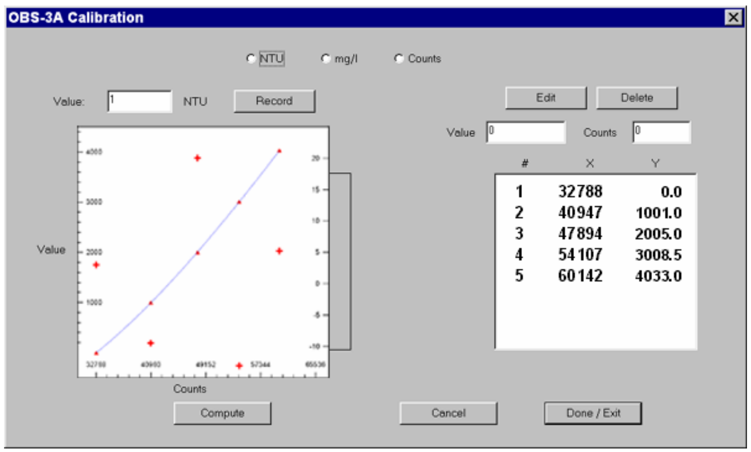
3) To avoid interference from incandescent and solar IR, perform calibrations under fluorescent lighting and make field checks in the shade.

4) Start OBS For Windows and wake the OBS-3A.

OFW Steps

1) Open the calibration dialog box with and click the **NTU** button. Follow the instructions to place the OBS-3A in a turbidity standard.

WARNING: <u>You cannot change the OBS-3A calibration after exiting the calibration dialog box.</u>



2) Enter the standard value in the **Value** box of the calibration dialog and click the **Record** button. If **mg/l** or **ppm** are selected, choose a sample duration from Table 5 (see page 45).

3) After the sample has been logged, the table and plot of calibration data will be updated. Verify that the calibration value is what you intended it to be.

4) Prepare the next NTU standard and put the OBS-3A in it. Repeat steps 1 and 2 for all calibration values.

5) After the calibration is complete, click the **Compute** button and inspect the plot to verify that it resembles the example shown above

Warning: There is <u>no way to cancel a calibration after the Compute button is clicked.</u>

Review the quality assurance checks discussed later in this section. Look at the plot of residuals, which show the differences between the standard and computed NTU values. The average residual magnitude should be less than 1% of the calibration range. For example, a calibration range of 2000 NTU (maximum minus minimum NTU values) should produce an average residual less than 20 NTU. Residuals higher than 1% of the calibration range indicate that errors were made in the procedure. By inspecting the plot of residuals, you can decide which values to repeat, edit, or delete. Repeat values using the procedures described above. To edit a value,

6) Click the **Edit** button; select the number of the calibration value you want to change from the data table; enter the revised calibration value; and click **OK**.

7) The data table and plot will be updated. Use the **Delete** button to remove a calibration value by number from the data table.

8) Once satisfied with the calibration, click the **Compute** button and make a final quality check.

9) Use the **Done / Exit** button to return to the OFW.

Making Turbidity Standards

1) For the zero NTU calibration point you will need a black 20”X14”X16” container filled with clean tap water. A Rubbermaid plastic storage box makes a suitable container.

2) For calibrations from 50-250 NTU use a 6” diameter container with 2 liters of filtered water or a premixed standard. Hold the sensor in the container so that the beam looks down and across the diameter to prevent the beam from reflecting off the wall.

3) A 4” diameter container can be used for solutions of ≥250 NTUs. Add one liter of filtered water and the necessary amount of formazin. See Table 4 or the formula below for the preparation of standards.

4) Stir the formazin solution with the spoon and position the OBS-3A in the standard.

5) Go to Step 2 of OFW procedure.

The formula for preparing turbidity standards other than shown in Table 4 is:

$$T_{std} = T_{stk}\left[\frac{V_{stk}}{V_{dw} + V_{stk}}\right] \quad \text{or} \quad V_{stk} = \left[\frac{T_{std} \times V_{dw}}{T_{stk} - T_{std}}\right]$$

Where:
T_{std} = Turbidity of the standard solution;
T_{stk} = Turbidity of the stock solution, usually 4000 NTU;
V_{stk} = Cumulative volume of stock solution at each calibration point;
V_{dw} = Initial volume.

Table 4 Mixing volumes for formazin standards

Formazin Volume V_{stk} (ml)	**Solution Turbidity** T_{std} (NTU)
12.7	50
32.3	125
66.7	250
143	500
333	1000
1000	2000

Sediment

The procedure for sediment calibration is more involved than for turbidity. For a modest charge we will pre-calibrate OBS sensors with sediment provided by users. Call us for a quotation to perform this service.

Caution: The most common cause of errors in OBS data is improper calibration.

Before proceeding with a sediment calibration, review Section 8 to learn about factors that can influence the quality of your results. The most difficult part of the procedure is maintaining a stable sediment concentration while the OBS logs calibration values. This is straightforward when the material is dry, completely disaggregated mud with particles smaller than ~20µm. It becomes more difficult the larger the sediment gets and special calibration equipment may become necessary (see REFERENCES, page 57).

Equipment and Materials

- Dry, completely disaggregated bottom sediment or suspended matter from the monitoring site,
- 1-gallon (4 L) brown Nalgene polypropylene bottle with top cut off,
- 1-liter, Class A volumetric flask,
- 2 gallons filtered distilled water (purified water from the super market works fine)
- Hand-drill motor,
- Paint stirrer.

Sediment Preparation

Sediment preparation is a critical factor in calibration quality. It is most convenient to use dry material because it can be accurately weighed with an electronic balance. However, this only works well for clean sand because disaggregation produces a sediment size different than existed in the field. For example, deep harbors with weak currents often have cohesive (sticky) mud with high organic-rich flocculation. Disaggregation of the flocs will reduce the particle size and change the OBS response. Sediment or suspended solids concentration is the dry weight of sediment divided by the weight of the sample (expressed in ppm) or by the volume of sample in liters (expressed as mg/l). Usually the disaggregated particles will be finer than untreated sediment. When dried sediment is used, verify that field estimates are accurate by comparing the OBS results with direct samples of suspended matter. (See REFERENCES: USGS Book 9, page 57).

Figure 8 shows how different methods of disaggregating sediment can change the relationship between turbidity and the concentration of suspended material. This occurs because vigorous disaggregation produces more small particles than less vigorous methods as well as more OBS signal per unit of mass concentration. The result is higher signal levels for a given concentration.

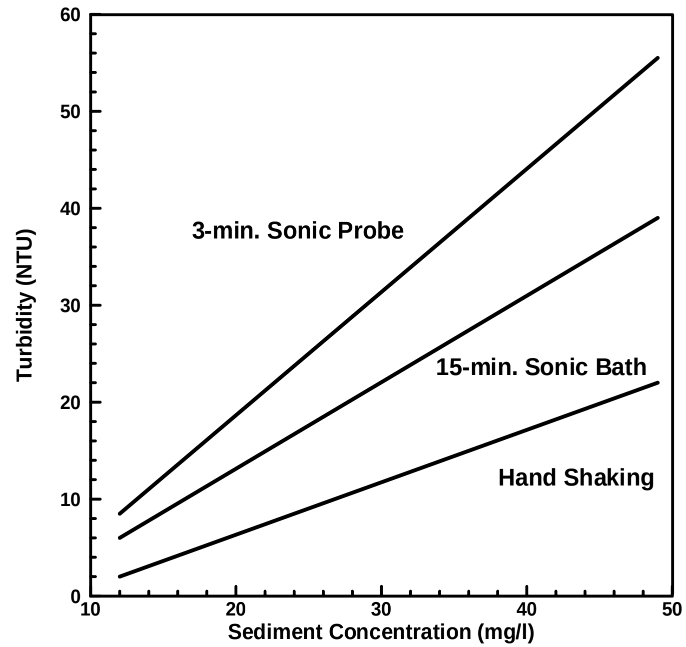


Figure 8 Effects of disaggrgation

Preparation

1) Clean containers and glassware with detergent and rinse with filtered water.

2) Perform the calibration under fluorescent lighting.

3) Based on the material, select the appropriate sample duration from Table 5.

4) Refer to the OFW step explaining the dialog box on page 49. Instead of entering NTU values, enter sediment concentration values.

5) After each addition of sediment compute mg/l or ppm with the equations given on the following page.

6) Start OBS for Windows and wake OBS-3A. Click the **mg/l or ppm** button.

Table 5 Sample durations for sediment calibrations

Sediment	Seconds
Clay	10
Silt	20
Fine Sand	40

Sediment concentrations are calculated with the following equations:

$$\frac{M_s}{V_i + \left[\frac{M_s}{\rho_s}\right]} = mg/L \quad ; \quad \frac{M_s}{M_i + M_s} = ppm$$

Where:
M_s = Mass (mg) of sediment in suspension
M_i = Initial water mass, $1 \times V_i(kg)$
V_i = Initial volume (L)
ρ_s = Sediment density (usually $2.65 \times 10^3\ mg/L$)

7) For the zero calibration point you will need a clean black 20” x 14” x 16” container filled with clean tap water. A Rubbermaid plastic storage box is suitable.

8) Add 2L of filtered water to the 1 gallon container submerging the sensor at least 5 cm; tap bubbles off container walls.

9) Weigh 5 to l0 equal increments of the sediment so that the total dry weight will produce the maximum concentration expected at the monitoring site.

10) Repeat OFW Steps 2-4 (page 39) for each sediment standard.

11) After all sediment values have been logged, follow OFW Steps 6-9 to complete the calibration.

Salinity, Pressure and Temperature Calibrations

Due to the specialized equipment involved for salinity, pressure and temperature calibration, it is recommended that the instrument be returned to D & A Instrument Company if any of these sensors are not operating with specified accuracy.

7. OPTICS AND TURBIDITY MEASUREMENTS

Turbidity is the cloudy appearance of a liquid produced by light scattered from suspended matter. It is an *apparent* optical property that depends on the size, color, and shape of scattering particles, and the instrument used to measure it. In accordance with standard method 2130B and ISO 7027, turbidity is usually measured with a 90^{o}-scatterance nephelometer and reported in nephelometric turbidity units (NTUs). Turbidity standards are discussed in Section 6.

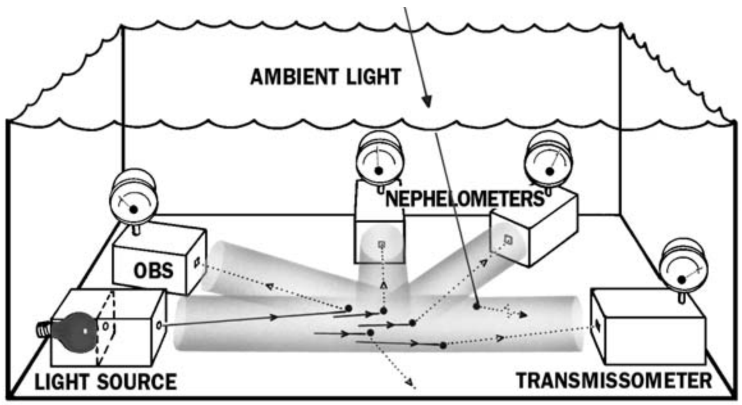


Figure 9 Optical particle detectors

Light transmission in water is attenuated by scattering (deflection by water molecules, and suspended matter) and absorption, which converts light to heat. Attenuation, absorption, and scattering are inherent properties of water that are affected only by impurities such as color and suspended organic matter. Optically pure water is not readily available; however deionized water that has passed through a 0.2 µm filter is adequate for most practical purposes.

There are dozens of turbidimeter designs, however most are configured in one of the ways shown in Figure 9. These include: forward-scatterance, 90^{o} scatterance, and backscatterance nephelometers. Some instruments combine two or more of these configurations and blend signals to produce a useful output. The transmissometer measures attenuation, an inherent optical property but is not approved for turbidity measurements except by ISO 7027. OBS sensors have superior linearity in turbid water but a transmissometer is more sensitive at low concentrations (<~25mg/L). Data from turbidimeters made by different companies should be compared cautiously. Inconsistencies between instruments results from variations in light sources, detectors, optical configurations and turbidity standards.

Can turbidity be converted to suspended solids concentrations and vise-versa?

In most situations, conversions between turbidity and suspended solids concentrations will give misleading results because the conversion equates to an apparent optical property, in relative units, with one precisely defined in terms of mass and volume; these are "apples and oranges".

Conversion of turbidity to suspended solids concentration is recommended only when:

- Measurements are made with the same turbidimeter.
- The turbidimeter is intercalibrated with a turbidity standard and suspended matter from the waters to be monitored.
- Particle size and composition do not change over the monitoring period.

Compliance with the last condition is crucial but virtually impossible to verify in the field because it is difficult to sample particles in their natural state and preserve them for laboratory analysis in a consistent and meaningful way.

8. FACTORS AFFECTING OBS RESPONSE

This section summarizes some of the important factors that affect OBS-3A 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 over looked.

Particle Size

The size of suspended sediment particles typically ranges from about 0.2 to 500µm in surface water (streams, estuaries and the ocean). Everything else being equal (size, shape, and color), particle area normal to a light beam will determine the intensity of light scattered by a volume of suspended matter. Results from laboratory experiments and natural material support this and indicate a wide range of backscatter associated with very fine mud and coarse sand (about two orders of magnitude). Laboratory tests with coarse silt to medium sand material show that sensitivity changes by a factor of about 3.5 (see Figure 11). The significance is that size variations between the field and laboratory and within in a survey area cannot be ignored

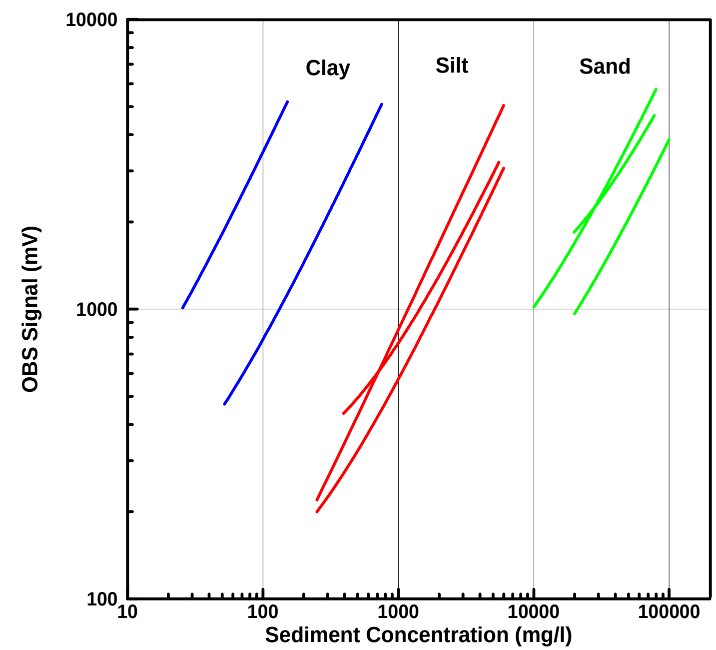


Figure 10 Response to sand, silt and clay

Suspensions with Mud and Sand

As mentioned earlier, backscattering from particles is inversely related to particle size on a mass concentration basis (see Figure 11). 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. An OBS 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. The obvious thing to do is to take a lot of water samples and analyze them in the laboratory. This is not always practical during storms when the errors are likely to be largest. Do not rely solely on OBS sensors to monitor suspended sediments when particle size or composition are expected to change with time at a monitoring site.

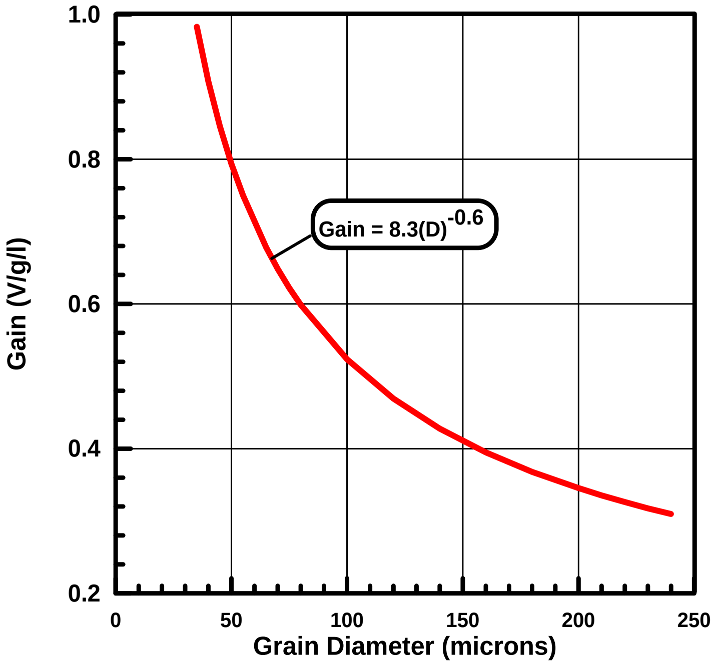


Figure 11 Effects of particle size

High Sediment Concentrations

At high sediment concentrations, particularly in suspensions of high 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 with increasing sediment concentration. For mud, this occurs at concentrations greater than about 5,000 mg/l. Figure 12 shows a calibration in which sediment concentrations exceed 6 g/L cause the output signal to decrease. It is recommended not to exceed the specified turbidity or suspended sediment ranges unless calibrations extend over range "A" on Figure 12.

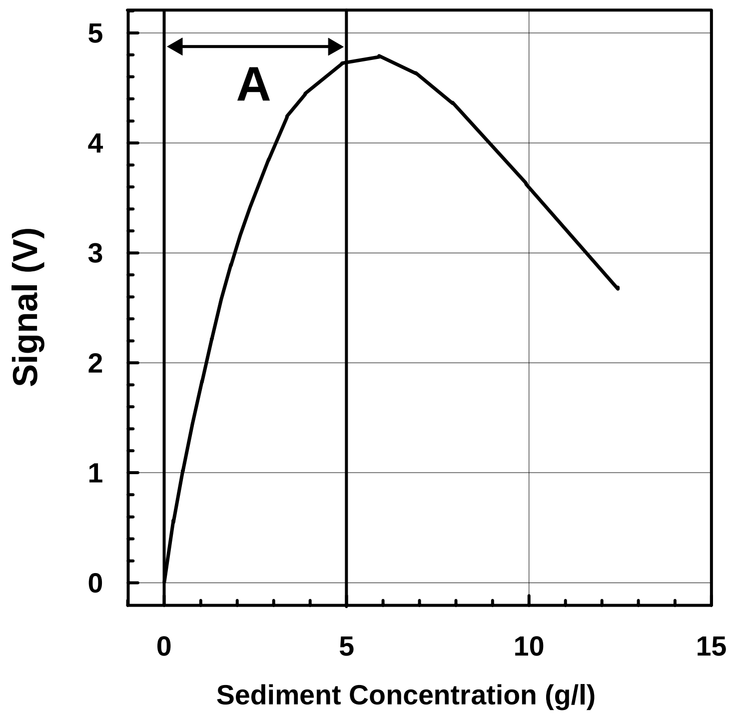


Figure 12 Response at high sediment concentrations

Sediment Color

Sediment color, after particle size, has a major effect on OBS sensitivity, and if it changes, it can degrade the accuracy of measurements. Although OBS sensors are "color blind", "whiteness", color, and IR reflectivity (measured by an OBS sensor) are well correlated. Calcite, which is highly reflective and white in color, will produce a much stronger OBS 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 13. 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.

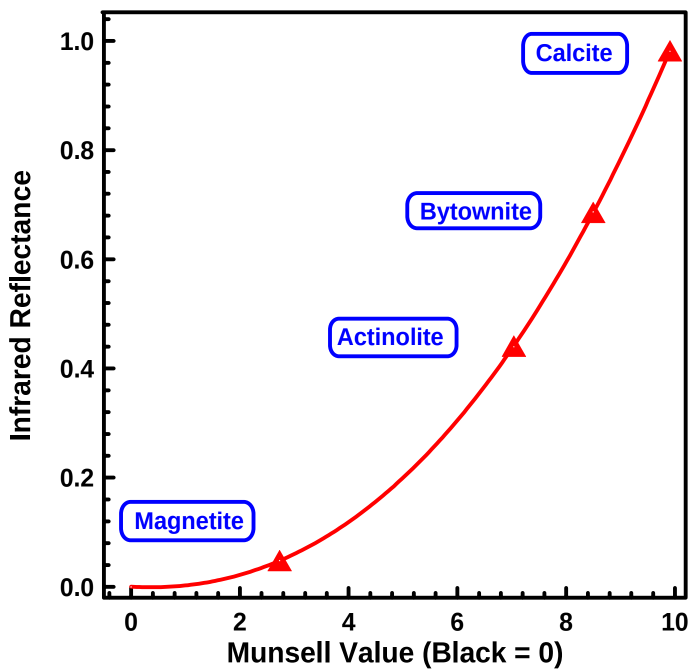


Figure 13 IR reflectance of minerals.

Water Color

Several OBS users have been concerned that color from dissolved substances in water samples (not colored particles discussed in the previous section) produces erroneously low turbidity measurements. Although organic and inorganic IR-absorbing dissolved matter has visible color, its effect on OBS measurements is small unless the colored compounds are strongly absorbing at the OBS wavelength (875 nm) and are present in very high concentrations. Only effluents from mine-tailings appear to 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.

Bubbles

Although bubbles efficiently scatter IR, monitoring in most natural environments shows that OBS signals are not strongly affected by bubbles. 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 in most environments. This means that sand will produce much more backscatter than bubbles in most situations and bubble interference will not be significant.

The scattering intensity of mineral particles, bubbles, and suspended organic material are shown in Figure 14 . OBS sensors detect IR backscattered between 140^{o} and 160^{o}, and where the scattering intensities are nearly constant with the scattering angle. Particle concentration has the most important effect in this region. OBS sensors are also more sensitive to mineral particles than either bubbles or particulate organic matter by factors of four to six. In most environments, interference from these materials can therefore be ignored. One notable exception is where biological productivity is high and sediment production from rivers and resuspension is low. In such an environment, OBS signals can come predominately from plankton. Prop wash from ships and small, clear mountain streams where aeration produces high bubble concentrations are another probable source of erroneous turbidity readings.

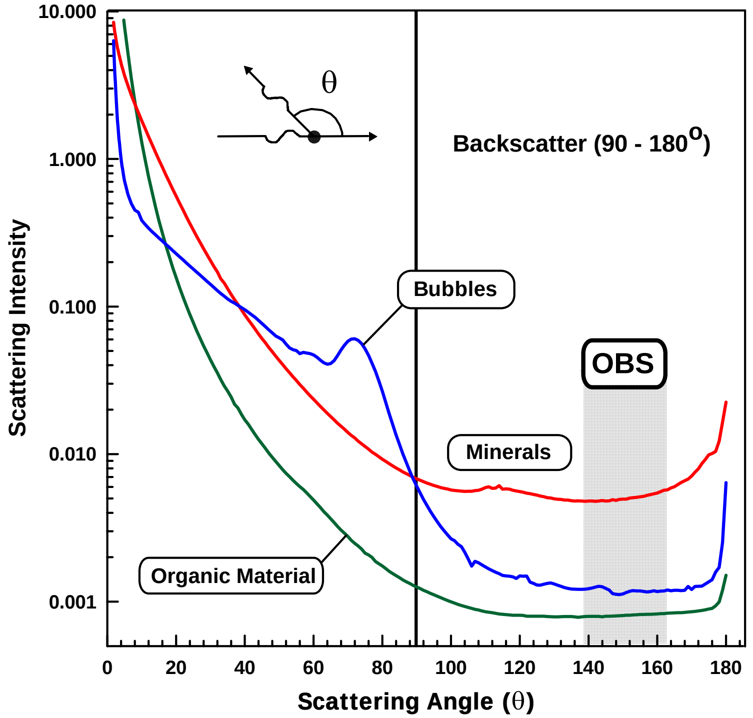


Figure 14 Scattering intensity vs. angle

Biological and Chemical Fouling

Sensor cleaning is essential during extended deployments. In salt water, barnacle growth on an OBS sensor can obscure the IR emitter and/or detectors and produce an apparent decline in turbidity. Algal growth in marine and fresh waters has caused spurious scatter and apparent increases of OBS output. The reverse has also been noted in fresh water where the signal increases after cleaning the sensor window.

Prolonged operation in freshwater with high tannin levels can cause a varnish-like coatings to develop on an OBS sensor that obscure the IR emitter and caused an apparent decline in turbidity. Cleaning algal and tannin accumulation off OBS sensors is required more often during the summer because warm water and bright sunlight increase

biological and chemical activity. See Antifoulant Coatings for alternatives to cleaning.

9. REFERENCES

See www.D-A-Instruments.com for a complete list of references.

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10. SPECIFICATIONS

RANGE

Turbidity (Formazin)................................0.2 - 4,000 NTU[1]
Mud (D_{50}=20µm) ....0.1 - 5,000 mg/l
Sand (D_{50}=250µm) ....2 -100,000 mg/l
Pressure[2]...0-2 / 0-20 bar
Temperature ....0-40 °C
Conductivity (Salinity)..............................65mS/cm (40 PSU, o/oo)

ACCURACY

Turbidity (formazin, 0-2,000 NTU)...........2.0%
Mud (0-4,000 mg/l) 2.0%
Sand (0-60,000 mg/l) 3.5%
Pressure[3]..+/-0.2% full scale
Temperature ....+/-0.05 °C
Conductivity..+/-0.07 mS/cm

OBS SENSOR

Frequency..5 Hz
Time drift ....-3.5% 1st 2000 hours
Temperature drift ....0.05%/°C

OTHER DATA

Maximum size sample 2048
Sampling rate ....1-25 Hz
Maximum data rate ....2 Hz
Data Capacity..8 Mbytes
Maximum number of data lines 200,000
Battery capacity 18Ah
Maximum battery life ....8,000 hours
Data protocols ....RS-232 / RS-485 / USB
Maximum Housing Depth ....300 meters

DIMENSIONS

Length / diameter ....362 mm (14.3") / 76 mm (3.0")
Weight ....1.5kg (3.4#)
Weight (submerged) ....0.2 kg (0.5#)

USER SERVICEABLE PARTS

End Cap O-Ring.......................................Parker 2-141
OBS Sensor O-Rings ....Parker 2-013 & 2-017
Temperature Sensor O-Ring ....Parker 2-007
Conductivity Sensor O-Ring[4]....................ARP 7.5 X 1.2 mm 70BN
Pressure Sensor O-Ring[4]...........................ARP 0.67 X 0.04 70BN
Pressure Sensor Spring clip.......................#HO-75
End Cap Screws ....8-32 X 3/8", socket (5/64")
Dummy plug ....Subconn® MCDC8M
Plug locking sleeve ....Subconn® MCDLSF
Batteries ....Three alkaline D-Cells

1 0-100, 0-250, 0-500 and 0-1000 NTU ranges are available on request.
2 Range depends on sensor selection (one dBar of pressure equals a freshwater depth of 1.0 meter). *Note: See Table 1 for a list of working depths for different pressure sensors.*
3 Pressure accuracy corresponds to about 4-20 cm of water depth.
4 Apple Rubber Products.