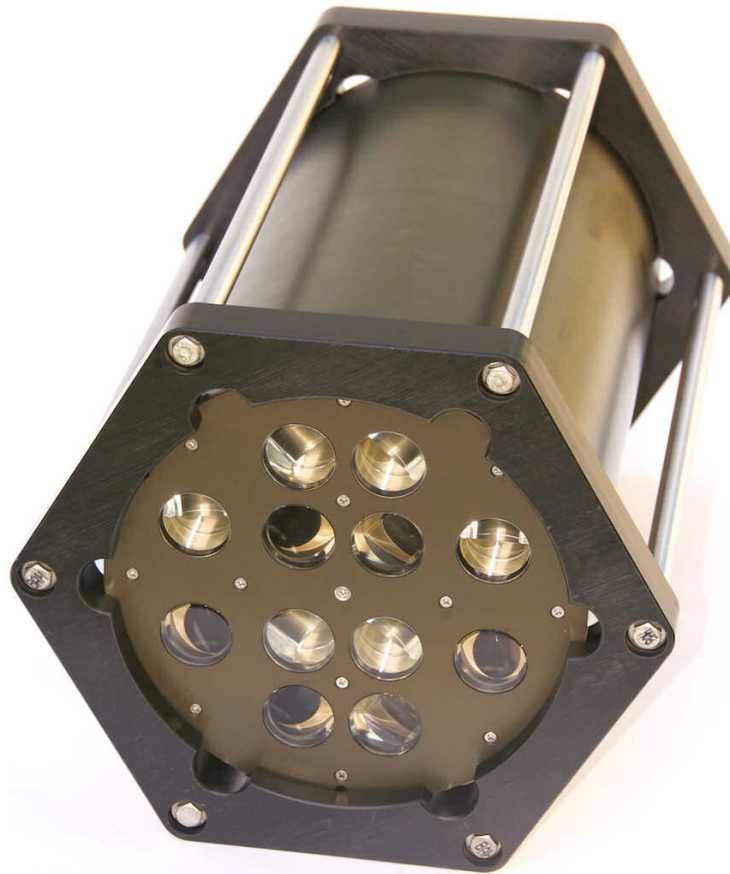


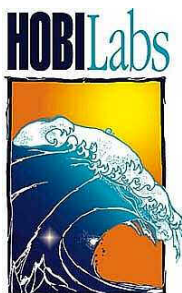
# HydroScat-6P

## *Spectral Backscattering Sensor & Fluorometer*



## **User's Manual**

*Revision J*



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**Hydro-Optics, Biology & Instrumentation  
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## **Current Firmware Version: 1.95**

*Other firmware versions may differ in some respects. Contact HOBI Labs for information on how to upgrade HydroScat firmware.*

## **Revisions**

J—August 23, 2010: Updates for Series 250 (HydroScat-6P) configuration; add Figure 5. Delete section on old deployment frame. Update example calibration file format (section 9.7). Add DELCAST command (section 8.3.9).

I—February 19, 2010: Include description of fluorescence time-sharing in section 5.5. Add deployment cage, expand troubleshooting (10)

H—June 15, 2008: Add note to avoid alcohol for cleaning acrylic windows (2.3).

G—May 14, 2008: Add note about factory maintenance (2.7)

F—June 6, 2007: Correct and clarify sigma correction, sections 9.5 and 9.6

E—October 22, 2004: Update description of Sigma correction to reflect changes in HydroSoft 2.7 (section 9.6).

D—November 17, 2003: Correct format of “time” field in “\*T” packet shown in section 9.3.2. Change “data download (DD) cable” to “power/data interface (PDI) cable”. Add description of exponential sigma correction (section 9.6). Remove description of PDI box (was section 10).

January 22, 2002: Add single-connector configuration and reorganize section 6. Add note about magnetic switch interaction with external power supply (section 5.9.1). Correct noise levels cited in section 5.5.1. Add STARTNOLOG command (8.3.20). Expand explanation of low-voltage cutoff (section 7.2).

November 6, 2001: Update HOBI Addresses

February 16, 2001: Start of revision tracking. Extensive reorganization, changes to incorporate HydroSoft, separate HydroScat-2 from HydroScat-6.

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# 1. INTRODUCTION

## 1.1. Overview

The HydroScat-6P is a self-contained instrument for measuring optical backscattering at six different wavelengths in natural waters. Its unique optical geometry also provides measurements of fluorescence. The HydroScat-6 includes a depth transducer, rechargeable batteries, a data logger with real-time clock, and an external switch for controlling logging. The data logger supports a wide range of sampling rates, as well as burst-mode sampling for collection over extended periods. Optional flash memory allows the data logger to hold many megabytes of data.

## 1.2. Optics

This brief overview introduces the key concepts necessary for understanding the HydroScat's measurements. The optical principles are covered in much greater detail in "Instruments and Methods for Measuring the Backward-Scattering Coefficient of Ocean Waters", by Robert A Maffione and David R. Dana, *Applied Optics* Vol. 36, No. 24, 20 August 1997.

The HydroScat-6 has six independent channels, each sensitive to a different narrow range of optical wavelengths. Each channel consists of separate source and receiver optics. The source produces a beam of light in the water, and the detector collects a portion of the light that is scattered out of that beam by the water.

Each source beam originates from a light-emitting diode (LED) selected to match the desired measurement wavelength. The beam from the LED goes through a lens to adjust its divergence, then through a prism that bends the beam before it enters the water. The receiver consists of an identical prism that bends the field of view toward the source beam, a band-pass interference filter that determines the exact wavelength range of the measurement, and lens that focuses the received rays onto a silicon detector.

The divergences of the source beam and receiver field of view, the angles of the prisms, and the distance between the source and receiver windows, determine the range of scattering angles over which the measurement is made. The HydroScat geometry results in a measurement centered on a scattering angle of 140°.

The fraction of the transmitted light scattered in the desired range of angles is extremely small, and one of the prime considerations in the optical design is

maximizing this inherently low throughput. Thus we maintain at least a 2 cm open aperture throughout the optical path.

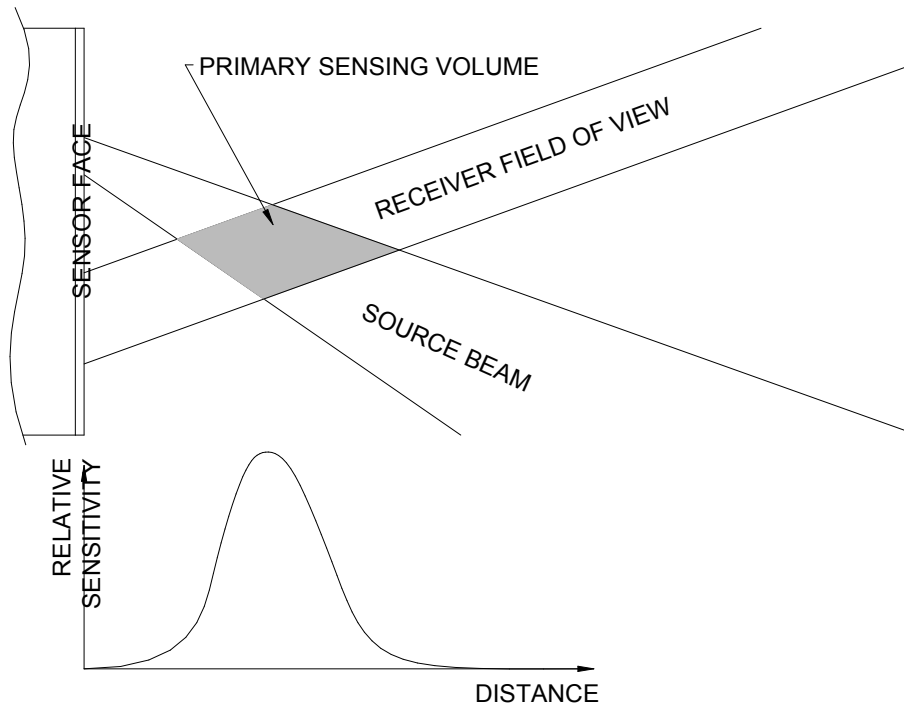


Figure 1: Side View of Backscattering Measurement Geometry

### 1.3. Electronics

The inherently low optical throughput of the backscattering measurement demands very sensitive electronics. In clear water the backscattering signals arriving on the detector may be as low as a few picowatts. At the same time, natural background light may be orders of magnitude larger.

To separate backscattering signals from background light, the LEDs are modulated at audio frequencies, and synchronous receiver electronics used to discriminate against interfering signals. Each channel has a different frequency to prevent any crosstalk between channels. This also allows us to discriminate between backscattering and fluorescence (see section 1.4).

To allow measurement in a wide range of waters, and to accommodate the requirements of our calibration procedure, the gain of each channel can be set to one of five settings spaced a decade apart. Only three of these settings are used in normal measurement situations; the lowest two are used primarily for calibration. The HydroScat normally selects the appropriate gain automatically, based on the amount of backscattering detected as well as the amount of background light.

In order to compensate for residual electronic offsets, the HydroScat periodically turns off each LED briefly to measure the receiver output in the absence of signal. The LEDs are turned off for 0.1 second approximately every 2 seconds, and the resulting offsets are continuously averaged and subtracted from the signals. Note that this is not the modulation, referred to previously, that separates the backscatter signals from each other and from background radiance; those modulations are too rapid to be visible.

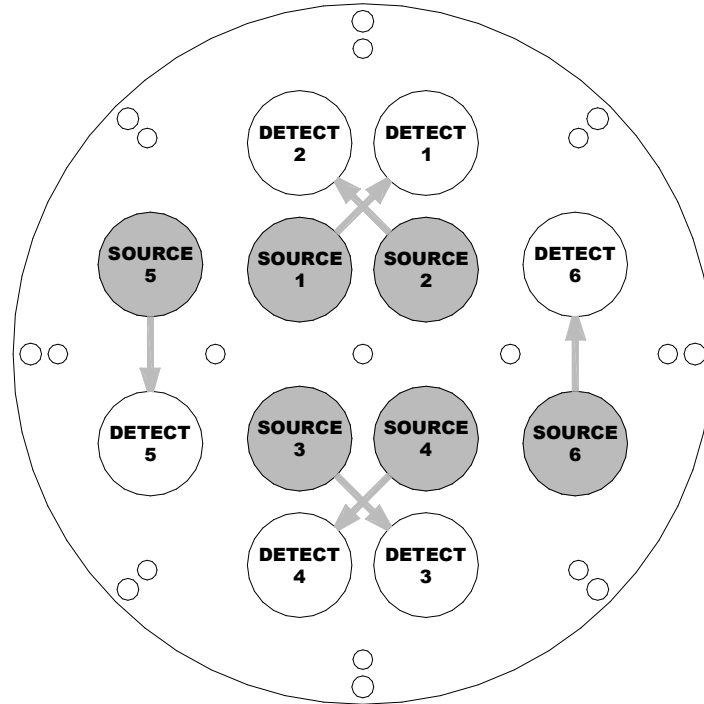


Figure 2: HydroScat-6 Front (Optics) End Cap

#### 1.4. Fluorescence Measurements

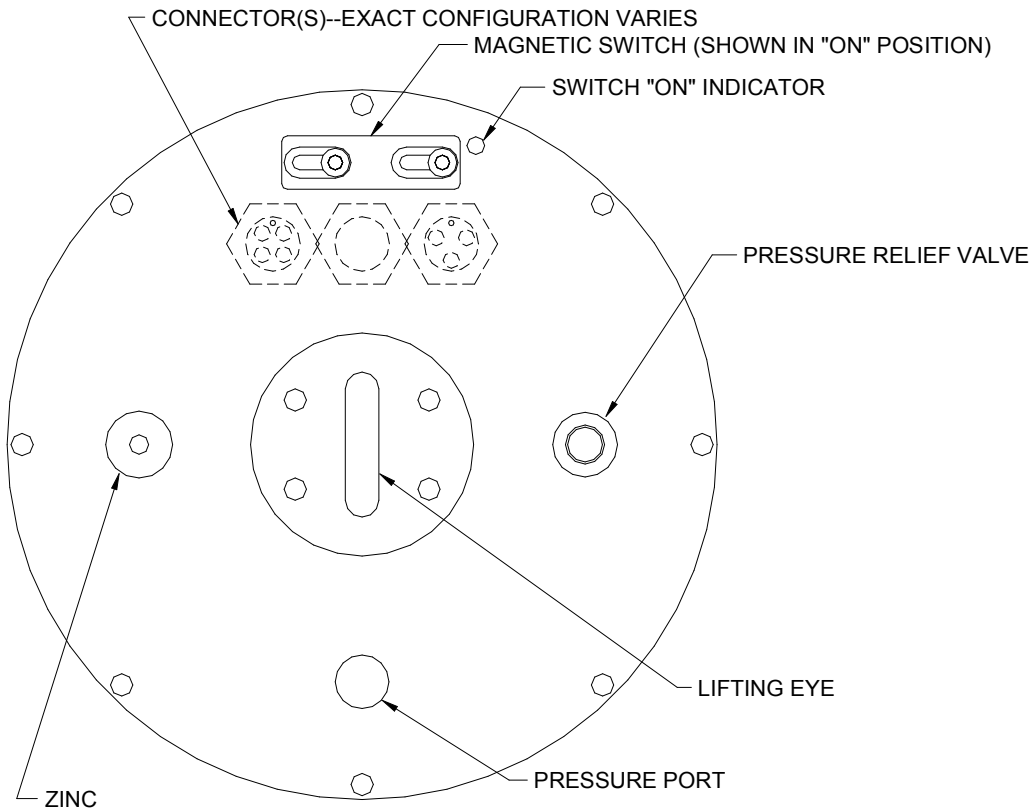
The HydroScat uses an innovative method, invented by HOBI Labs, to measure fluorescence with the same optics used for its backscattering measurements.

Because each LED in the HydroScat is modulated at its own frequency, fluorescence excited by a particular channel can be identified by the excitation channel's characteristic frequency, even though its emission falls into the optical bandwidth of another channel. The HydroScat receiver channels can be "tuned" under software control to the frequency of another channel's source, allowing them to detect fluorescence instead of backscattering. If the field of view of a channel intersects the beam produced by another channel, it can collect

fluorescence from that channel as efficiently as it does backscattering from its own source.

The HydroScat-6 has two pairs of channels whose beams and fields of views cross each other (see Figure 2). For example, the 442 and 700 nm channels may be paired, allowing the 700 nm receiver to measure either 700 nm backscattering or 700 nm fluorescence excited by the 442 nm source LED. Because at any given time each receiver must be tuned to a single frequency (corresponding to a single excitation source), the HydroScat-6's fluorescence measurements are not truly simultaneous with the backscatter measurements at the same wavelength. However the sensor can be periodically set to switch between functions, providing near-simultaneous measurements. The fluorescence function may also be turned on or off full-time. See section 8.3.12 for more details.

The fluorescence channels are not calibrated to an absolute standard, so their data are reported in arbitrary units.



**Figure 3: HydroScat-6 Rear End Cap**



## **2. PRECAUTIONS AND MAINTENANCE**

### **2.1. Precautions**

- Protect the windows. Cover the instrument face whenever possible. Do not use acetone to clean any part of the instrument.
- Thoroughly clean the HydroScat with fresh water before storing it.
- Avoid letting the sensor sit in direct sun on deck. If the water temperature is very different from the temperature on deck, let the instrument stabilize in the water for 10 minutes before collecting data.
- See section 7 for information about maintaining internal batteries.

### **2.2. General Cleaning**

Upon removing the instrument from the water, rinse it thoroughly with fresh water, and rinse the windows with distilled or deionized water. Periodically inspect the windows for contamination.

### **2.3. Windows**

HydroScats have acrylic windows that are easily scratched. Minor scratches will not seriously compromise the measurements, but the windows must be treated carefully to avoid abrasion. Do not use acetone, concentrated alcohol or abrasive cleaners. Do not over-clean the windows. Unless the windows become visibly dirty during use, it is usually sufficient to rinse them with clean fresh water each time the instrument is removed from the water. If necessary, clean them with a mild liquid soap or lens-cleaning solution.

### **2.4. Pressure Transducer**

If your HydroScat-6 is equipped with an oil-filled pressure reservoir and capillary tube, the reservoir may require occasional refilling. This is part of routine maintenance performed at HOBI Labs. In older HydroScat-6's without oil reservoirs, the pressure transducer is located under a black plastic cap, flush with the rear end cap, with four small drain holes (see Figure 3 on page 4) Rinse the sensor with fresh water by gently spraying it into the drain holes.

## **2.5. Connectors**

Occasionally apply silicone lubricant to the connector pins. The connectors should mate smoothly without great force. Well-lubricated connectors also disconnect fairly easily, so use the connector locking sleeves during deployment.

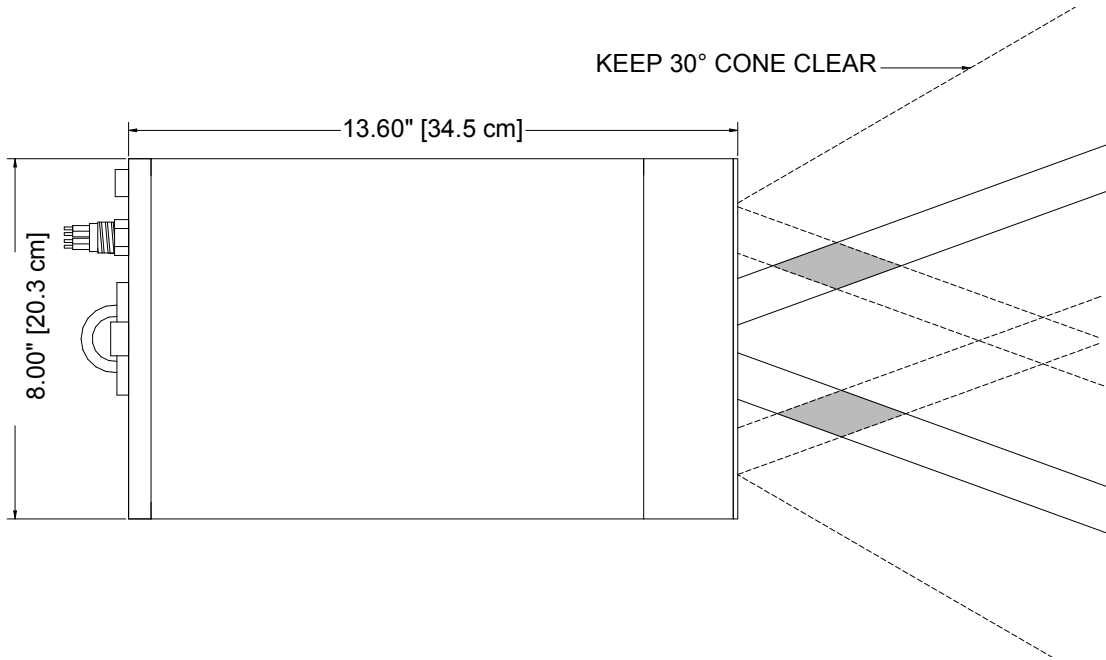
## **2.6. Mounting and Deployment**

The HydroScat can be suspended vertically from the metal eye on the connector end cap, or strapped to another support. If mounting it to another structure, protect the finish on the case from direct metal contact.

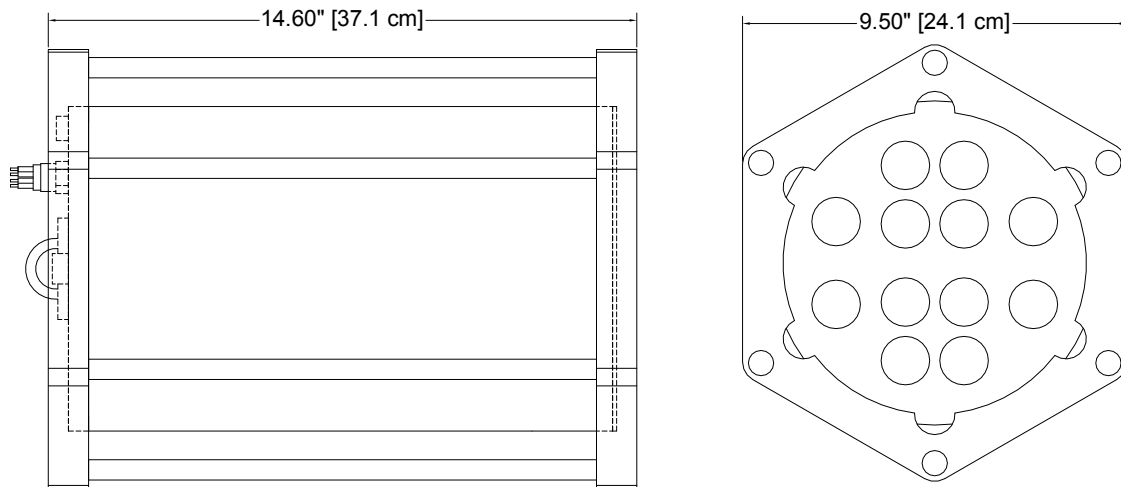
To ensure that the HydroScat does not detect reflections from any objects, keep a 30-degree cone in front of the windows clear for at least 1 meter. Even objects that appear very non-reflective, or are well out of the nominal sampling volume, can create substantial offsets in the backscattering measurement. You may find you can violate these strict limits, but you should verify by experiment that the instrument's readings are not elevated if you do so.

It is usually preferable for the sensor to face directly down in the water, to minimize the effect of background illumination. However in shallow water over a reflective bottom, under bright solar illumination, light reflected into the windows may cause high noise levels or, in extreme cases, saturation. In such situations it may be advantageous to mount the sensor horizontally so that the backscattering receivers do not face the bottom. Some experimentation may be required in such cases.

HydroScats equipped with internal batteries can be deployed with only a mechanical cable or attached to an existing package without additional cabling. If the HydroScat is attached to an existing package, make sure that the field of view of the sensor is unobstructed as mentioned above.



**Figure 4: HydroScat-6 side view without frame**



**Figure 5: HydroScat-6 Outline with frame**

## 2.7. Calibration and Maintenance


For exacting scientific applications we recommend calibrating the HydroScat-6 every six months or 200 hours of operation. At a minimum, we strongly recommend annual check-ups at HOBILabs.

With the proper equipment, available from HOBILabs, users can perform their own calibrations. For more information about the equipment and procedures involved, see the HOBILabs Backscattering Calibration Manual (available at [www.hobilabs.com](http://www.hobilabs.com)).



Even if you perform your own calibrations, it is very important to return the HydroScat-6 to HOBI Labs, preferably annually, for a complete functional test and check-out. Inspection and testing by trained factory personnel can uncover items that are not be evident to users, but which can affect the reliability or endurance of the instrument.



## 3. QUICK START

### 3.1. Setup

- 1) Install HydroSoft on your computer (see section 4.1 or the HydroSoft manual).
- 2) Connect the supplied power/data interface cable to the appropriate port on your computer.
- 3) Connect the cable to the matching connector on the HydroScat.
- 4) Run HydroSoft by selecting it on the Windows Start menu.
- 5) Click  (or select Connect from the Instrument Menu).
- 6) Click the Search button.
- 7) After a short time HydroSoft should identify the instrument, load its calibration, and close the Connect dialog box.
- 8) Select Set Date/Time... from the HydroScat menu.
- 9) Click Set Time to synchronize the HydroScat clock with your computer's clock. This will take several seconds. Then click Close to close the Date/Time dialog box.

### 3.2. Collecting Data

- 10) Select Sampling Options... from the HydroScat menu.
- 11) For testing purposes, we recommend the following settings:
  - Sample Rate: 2 per second
  - Start Delay: 0 seconds
  - Burst mode: unchecked
- 12) Select Plot Vs. Time from the Graph menu.
- 13) Click  (or select Start from the HydroScat menu). This will cause data to be logged in the HydroScat's logging memory as well as sent to HydroSoft.
- 14) If no data are visible after a short time, click , and the plot will zoom as needed to show all data.

- 15) To adjust the way data are displayed, double-click on the graph, or select Properties... from the Graph menu.
- 16) Click  (or select Stop from the HydroScat menu).
- 17) Close the open data file by selecting Close from the File menu, or clicking on the  button. If desired, save the file when prompted.

### **3.3. Downloading Data From the HydroScat**

- 18) Select Get Data From Instrument from the HydroScat menu.
- 19) After several seconds a directory of casts in memory will appear. The last cast listed should be the one you just recorded. If that cast is not already highlighted, click on it to highlight it, or click the Select All button.
- 20) Click the Browse... button to select a directory in which to save downloaded data files. In the resulting dialog box, select a directory and click the Select button.
- 21) If it is not already checked, check the Create calibrated data (.dat) files option.
- 22) Click the Download button to begin transferring data casts.

### **3.4. Disconnecting**

- 23) After you are finished communicating with the HydroScat, select Disconnect from the HydroScat menu. When asked “Put HydroScat to sleep before disconnecting?” click Yes.
- 24) Unplug the cable from the HydroScat’s underwater connector.

### **3.5. Switch-Activated Logging**

- 25) To start a cast when the HydroScat is asleep and disconnected from the computer, move the magnetic switch to the on position (see Figure 3 on page 4).
- 26) To end a cast, return the magnetic switch to the off position.

## 4. HYDROSOFT SOFTWARE

HydroSoft is HOBI Labs' Windows-based software for communicating with HydroScats as well as other instruments. Instructions in this manual assume you are using HydroSoft to communicate with your HydroScat, and cover its primary functions. You may wish to consult the separate HydroSoft manual for a more complete description and details.

### 4.1. Installing HydroSoft

HydroSoft is supplied on a CD-ROM with new instruments, and can be supplied on floppy disks by request. We also recommend you visit our web site ([www.hobilabs.com](http://www.hobilabs.com)) to check for downloadable updates to HydroSoft. It is installed using a procedure that is familiar to most Windows users.

1. Run "InstallHydroSoft.exe" from CD-ROM, or from your computer if you have received it through the internet.
2. Click the "Next" button in the installer's "Welcome" dialog box.
3. Decide whether you would like the HydroSoft application stored in the default directory shown (normally c:\program files\HOBI Labs). If not, click the "Browse" button to select a different directory, or type the name of a new directory you would like to create.
4. Click "Next" to start the installation.
5. When the installation is complete, click "Finish" to exit.

It is not normally necessary to reboot your computer unless the installer program explicitly instructs you to.

### 4.2. Removing HydroSoft

1. From the Start menu, select "Settings", then "Control Panel".
2. Double-click on the "Add/Remove Programs" icon.
3. Select HydroSoft from the list of programs.
4. Click the "Add/remove" button.

***OR***

1. Open the directory into which you installed HydroSoft.
2. Double-click on the "unwise.exe" icon, which runs the uninstaller.





## **5. COLLECTING AND HANDLING DATA**

### **5.1. Primary Data**

The primary data reported in every sample are

- date and time,
- raw scattering for each channel,
- the gain of each scattering channel,
- pressure, and
- internal instrument temperature.

### **5.2. Housekeeping Data**

HydroScats record certain “housekeeping” parameters that are not required for normal data processing, but can be valuable for troubleshooting and for evaluating the health of the sensor. They are

- battery and external supply voltages,
- background radiance on the detectors (in arbitrary units),
- reference measurements of the LED outputs, and
- signal offsets.

Normally the housekeeping data are logged at one-tenth the rate of the main data. That is, every ten samples are followed by one housekeeping sample.

### **5.3. Calibration Data**

HydroScats data are transmitted in a partially-processed hexadecimal form, which must be converted to calibrated units. The coefficients required for this conversion are unique to each instrument, and may be revised from time to time when the instrument is recalibrated. HydroSoft requires an appropriate calibration to be loaded before it can plot or store calibrated data from an instrument or raw data file.

#### **5.3.1. Loading Calibrations**

Calibrations can be loaded either directly from a connected HydroScat, or from a file on the host computer. To load an instrument’s calibration, check the Load Calibration From Instrument option while connecting to the instrument

(section 5.4). To load a calibration from a file, choose **Select Calibration File** from the File menu.

If you select a new calibration file while an instrument is connected, or while a raw data file is open, HydroSoft will only load it if it is of a matching type. HydroSoft will inform you if the type does not match. It will also warn you if the serial number of the instrument does not match that contained in the calibration file, but it will offer you the option of loading it even if the serial numbers do not match.

Once a calibration file is loaded, it remains in effect until a different one is loaded. When you exit HydroSoft, it stores the name of the current calibration file. If the **Automatically recall last selected calibration file** option is selected in the Preferences dialog box, the file will be reloaded the next time HydroSoft starts up. If you have more than one data window open in HydroSoft, you can select a different calibration file for each one. The most recently selected file in any window will be saved as the default.

### **5.3.2. Viewing And Editing Calibration Data**

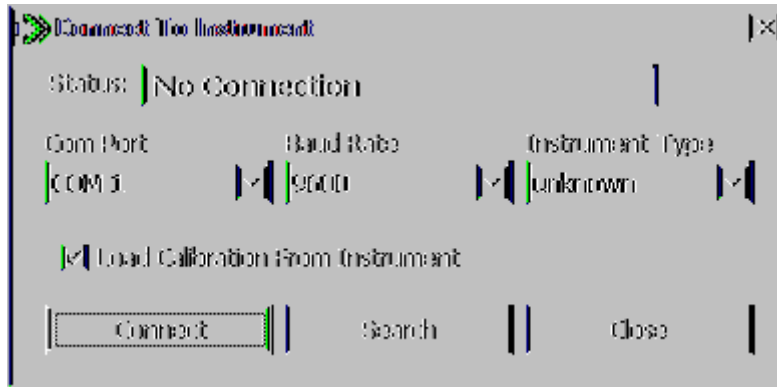
You can see the details of the current calibration by selecting **View Calibration** from the File Menu. Normally you should not need to modify calibration data for an instrument, and the fields in the Calibration dialog box are locked to discourage casual changes. However you can unlock most fields by clicking on the lock icon in the dialog box. Because correct calibration files are critical to the accuracy of your data, use care when modifying them. To reduce confusion we encourage you to enter a description, in the comment field provided, of any changes you make.

To save a copy of the currently loaded calibration, select **Save Calibration** from the File menu.

## **5.4. Connecting**

To communicate with a HydroScat, HydroSoft must open the appropriate computer port at the correct baud rate. The following dialog box allows you to control this process.

### 5.4.1. Connection Dialog Box



This dialog box appears each time you

- select Connect from the Instrument menu,
- click on the Connect button in a data window,
- attempt an operation that requires a connection, if a connection has not yet been established.

### 5.4.2. Manual Connection

If you click the Connect button, HydroSoft will open the currently selected port at the selected baud rate. Normally you need not select an instrument type, because HydroSoft will always request identification information from the instrument. If it receives a reply sufficient to identify the instrument, it will proceed with the connection and close the dialog box. If not, it will notify you and ask whether to open the connection anyway. In you instruct it to, it will proceed on the assumption that an instrument of the type you designate is connected.

### 5.4.3. Search Connection

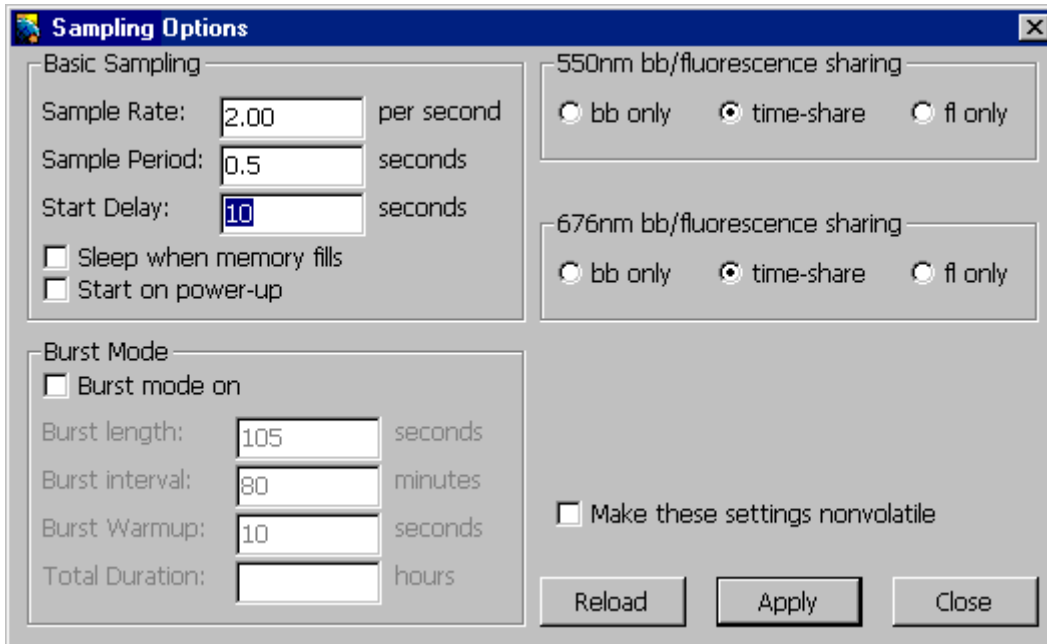
If you click Search, HydroSoft will ignore the selected port and baud rate, and attempt a connection to each port, at each baud rate (from 4800 to 57600), until it receives valid identifying information from an instrument. The dialog box will automatically close if a valid connection is found.

### 5.4.4. Load Calibration From Instrument Option

If Load Calibration From Instrument is checked at the time an instrument is connected, HydroSoft will prompt the instrument to transmit the calibration information stored in the instrument's memory. This will override the currently selected calibration file, if any. See section 5.3 for more information about calibration files.

## 5.5. Logging Setup

HydroScats can be programmed to collect data continuously at rates from 0.1 Hz to 10 Hz, or intermittently to allow autonomous logging for long periods. In HydroSoft, you can set these parameters in the following dialog box, which appears when you select **Sampling Options...** from the HydroScat menu.



When the Sampling Options dialog is first open, it may take several seconds for the current settings to be retrieved from the HydroScat. Similarly, when you click the **Apply** button there will be a noticeable delay while HydroSoft transmits, then confirms, the new settings. This confirmation is important because it allows you to check that the settings were entered as you intended. The HydroScat may reject settings it cannot support—for example, burst lengths that are longer than the burst interval.

Sample Rate and Sample Period, by definition, have an inverse relationship. Changes you make to one will automatically affect the other. Note however that the period, which has a resolution of 0.01 second, is the controlling parameter. Therefore some exact sample rates are not available. For example, if you enter a rate of 3 per second, the calculated period will be rounded to 0.33 s, and the rate will be set to 3.03 per second.

When logging is started, either by software command or by turning on the external switch, the HydroScat will wait for the number of seconds specified by **Start Delay**, then data will be logged according to the given **Sample Period**. If burst mode is on, the sampling continues until the **Burst Length** has elapsed, at which time the sensor goes into its low-power sleep state. The bursts repeat according to the period set by **Burst Interval**. At the beginning of each burst, the HydroScat will wait for the number of seconds specified in **Burst Warmup** before

collecting its first sample. Whether or not burst mode is on, sampling stops upon receipt of a software stop command, when the external switch is turned off, or when the battery becomes exhausted.

In the example above, the burst-mode parameters are inactive because burst mode is not on. To edit the burst-mode parameters you must first check the **Burst Mode On** option.

If **Start on power-up** is checked, the HydroScat will begin logging each time power is applied. Note, however that this setting is only relevant after all power sources, including internal batteries, are turned off. For HydroScats with internal batteries (i.e. most HydroScats), this only affects what happens after you intentionally disable the batteries (see section 7.4).

The **bb/fluorescence sharing** settings control the two dual-function channels of the HydroScat-6 (also see sections 1.4 and 8.3.12). These channels can either measure backscattering or fluorescence, or can time-share between them. In the time-share mode, they alternate between backscattering and fluorescence, switching every 0.4 seconds. This gives the appearance of simultaneously measuring both parameters, but the actual sampling rate is limited by the time required to switch between them. We recommend setting the sample period to no less than 0.5 seconds if you use time sharing.

If time-sharing is on and the sample period is set to less than 0.5 seconds, some samples will not include measurements of both parameters for the dual-function channels. If one sample of a parameter is skipped because of time-sharing, the HydroScat-6 output will repeat the last measured value of the skipped parameter, giving the appearance of continuous measurements. If the sample period is less than 0.3 seconds, however, several samples may pass without an actual measurement, and zeros will appear in place of any missing measurements. If you choose sampling settings that will result in missing data, the HydroScat-6 will send a warning message, but will not prevent the settings from taking effect.

If **Make these settings nonvolatile** is checked, the settings will be stored in semi-permanent memory and will remain in effect even if the internal computer is reset or all power is removed from the instrument.

Before logging you may wish to download and clear data from the HydroScat's memory (see section 5.10).

### **5.5.1. Noise Levels and Sampling Rates**

The backscattering measurement involves extremely low light levels, and several factors can contribute to noticeable noise in the measurements, especially in clear water. However, noise in the measurements is unbiased, and uncertainty can be reduced by averaging samples together, or equivalently, lowering the instrument's sampling rate. In conditions with low background light, at a

sampling rate of 1 Hz, the RMS noise level is typically from about 0.00002 m<sup>-1</sup> to 0.0002 m<sup>-1</sup> depending on wavelength. High background light levels can introduce shot noise that degrades these figures.

In many circumstances natural variability exceeds the measurement noise. In water containing significant numbers of very large particles—even schools of fish—the data may show a background scattering level punctuated by spikes of increased scattering (as individual large particles pass through the sampling volume). Depending on your application, you may or may not wish to include such spikes in averaged measurements. Higher sampling rates preserve the option of evaluating the character of the data before averaging or other processing.

## **5.6. Setting the HydroScat's Real-Time Clock**

Although it is not necessary for the sensor's operation, you may wish to set the real time clock before logging. Select **Set Date/Time...** from the HydroScat menu. Click **Set Time** to synchronize the HydroScat clock with your computer's clock. If you wish to set the clock to a different time reference, select the **Set Manually** option and enter the correct date and time before clicking **Set Time**. It takes several seconds for HydroSoft to set the clock and reconfirm the setting. When it is finished, click the **Close** button to close the dialog box.

## **5.7. Logging Versus Real-Time Data**

Whenever collecting data in response to a **Start** command from HydroSoft, or from its magnetic switch, HydroScats simultaneously transmit them from their serial port. Data can also be collected on demand, without internal logging, by sending “D”, “T” or “H” commands each time data are required (see section 8 for information about the commands, and section 9 for the data formats).

## **5.8. Log Memory Capacity**

The base memory for a HydroScat includes 256K of RAM, of which most is reserved for data logging. This provides a capacity of about 7,000 HydroScat-6 samples (we use the terms “sample” and “packet” interchangeably to indicate a set of simultaneous measurements from all the channels). The optional flash memory has a base size of 128 MB, where each megabyte can hold about 30,000 samples. The flash memory also prevents loss of data in case of battery failure.

## **5.9. Using The Magnetic Switch**

The magnetic switch located on the back end cap of the HydroScat (see Figure 3 on page 4) signals the sensor when to start and stop data logging. When switched on, the HydroScat will wake and begin collecting data as if the **START**

command were sent to it. When switched off, it will stop sampling and go to sleep, as if the STOP and SLEEP commands were sent.

By using the magnetic switch, one can collect an extended series of casts without connecting to a computer. The starting and ending times of each cast are recorded in the log memory so that casts can be later downloaded individually or as a group. The sensor may be wakened from sleep by command from the serial port regardless of whether the switch is “on” or “off”. However the software SLEEP command will not work if the switch is “on.”

Some early HydroScat-6’s that were retrofitted with batteries do not have a magnetic actuator attached to the end cap; instead a separate magnet is used to actuate the switch, which is located directly between the two electrical connectors. Momentarily placing the magnet between the connectors toggles the instrument between the logging and sleeping states. On instruments with separate magnets, do not leave the magnet in place more than 1 second. Leaving it too long after waking the sensor could cause it to go back to sleep when the magnet is withdrawn.

#### **5.9.1. Important Note On Using External Power Sources**

Because the switch was designed specifically for use with the internal battery, it may not function as expected when the HydroScat is powered by an external source. If the external voltage exceeds the voltage of the internal battery, the HydroScat-6 cannot detect that the switch is on. Similarly, if the voltage of the internal battery falls below the external source during a cast and the switch is on at the time, it will be interpreted as if the switch were turned off, prematurely ending the cast.

You can avoid this situation in two ways. One is to start and stop casts with commands sent by a computer, rather than the magnetic switch.

The second is to operate the switch while the external power source is off or disconnected, and start casts by turning the switch on only momentarily (for less than one second). When it is wakened by the switch, but the switch is then rapidly turned off, the HydroScat ignores the off transition and continues logging indefinitely as if the switch were still on (this allows it to accommodate a detached magnet as an actuator). When using this technique you can verify that a cast has been started by checking that the lights have turned on (although they may not turn on immediately if you have programmed a start-up delay).

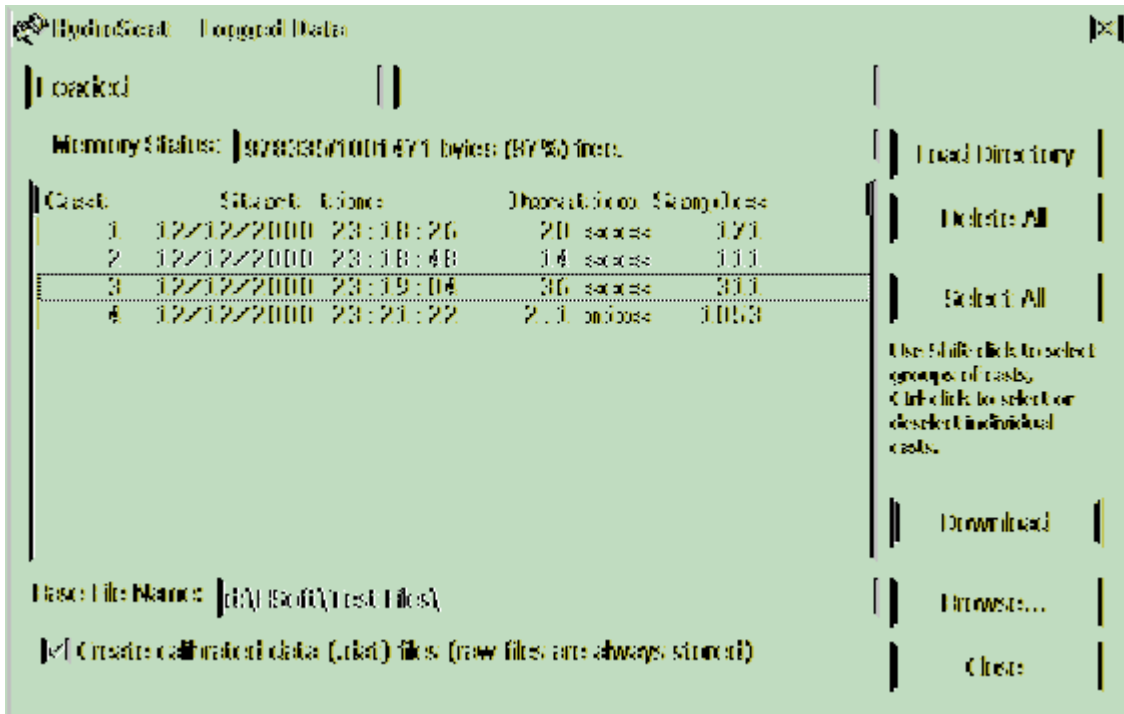
Even if the switch operates normally with your external power source connected, you should use the “momentary-on” action of the switch to start long-term casts, to avoid possible premature termination.

## 5.10. Downloading Logged Data

HydroSoft's Get Data From Instrument command enables you to view a list of casts stored in an instrument's memory, transfer casts from the instrument to files on your computer, and erase the instrument's memory. Casts you transfer are stored in individual files whose location and base name you specify. The cast number is appended to the name of each file.

### 5.10.1. Basic Procedure

- Connect the HydroScat to your computer's com port using the supplied power/data interface cable, start HydroSoft, and use HydroSoft's Connect command to establish communication.
- Select Get Data From Instrument on the HydroScat menu.
- A dialog box like the following will appear.



- After the directory is loaded, select the cast or casts you wish to retrieve.
- Enter a base file name for the downloaded files. The cast number will be appended to this base name to create a unique name for each cast you download.
- If necessary, click Browse and select a destination directory for the downloaded files.



- Click **Download**. Depending on the quantity of data and baud rate, downloading may take some time. Status messages and a graphical indicator will show the download progress.
- To clear the instrument's memory after verifying the desired casts were downloaded, click **Delete All**.
- Click **Close** to dismiss the dialog box.

### **5.10.2. Details**

Depending on the number of casts stored, loading the directory may take a number of seconds. The status message in the upper left corner indicates if the directory is loaded, as above, or if it is in the process of loading.

The memory status line indicates how much of the instrument's memory is presently used.

You can select arbitrary groups of casts for downloading. To select a contiguous group of casts, click on the first item in the group, then shift-click on the last item; or hold down the shift key while using the arrow keys. To select or unselect non-contiguous casts, control-click on them; or hold down the control key while using the arrow keys to move through the directory, and press the space bar to select or unselect casts.

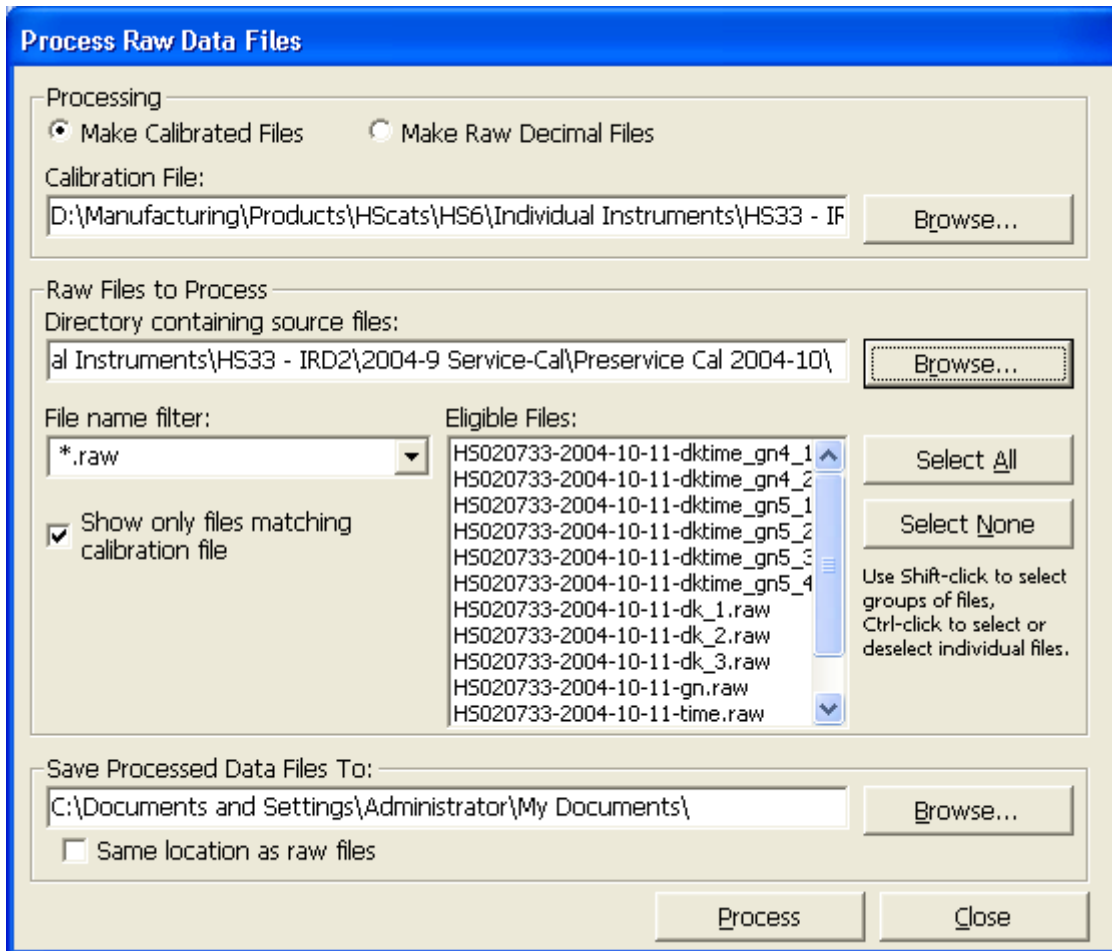
Data are always collected in raw form. If the **Create calibrated data (.dat) files** option is checked, a calibrated file will also be created for each downloaded cast. The calibration currently in effect for the main data window will be applied to these data (see section 5.3 for more information about calibrations).

Because of the way the HydroScat's memory is configured, it is not possible to delete individual casts—you can only erase the instrument's entire memory.

## **5.11. Processing Downloaded Data**

While HydroSoft allows you to save calibrated data automatically at the time you collect or download data from a HydroScat, you can also process raw data files using HydroSoft's **Process Raw Files** command. This command also allows you to convert raw hexadecimal data to decimal form without calibrating them.

When you select **Process Raw Files**, the following dialog box appears:



### 5.11.1. Making Calibrated Data Files

When Make Calibrated Files is selected, you need to specify a calibration file to be used (see section 5.3 for more information about calibration files). You can type the path and name of the file directly, or use the **Browse...** button to open an Open File dialog box. You must also select the file or files you wish to process, using the familiar browse controls. The list in the center right of the dialog box shows those files that are contained in the drive and directory you specify, and whose names match the File name filter you specify. If Show only files matching calibration file is checked, as it is by default, HydroSoft will check the contents of the files and list only those that contain data from the instrument type and serial number specified by the selected calibration file.

You can select a single file or an arbitrary group of files from the list. Select a contiguous group of files by shift-clicking, and select or deselect individual files by Ctrl-clicking. Once you start processing, all the selected files will be processed.

The processed files will use the same base names as the source files, with their extensions set to “.dat”. They will be saved in the directory you specify. If

you wish to save them in the same directory as the raw files from which they are generated, you can avoid having to select that directory manually by checking the Same location as raw files option.

### 5.11.2. Making Raw Decimal Files

The process for making raw decimal files is identical to that described above, except that there is no need for a calibration file. Controls relating to the calibration file will thus be disabled.

When you select the Make Raw Decimal Files option, an additional Include Housekeeping checkbox will appear, allowing you to control whether housekeeping data will be included in the file in addition to the primary optical data.

## 5.12. Raw Data File Format

HydroSoft names raw data files with the extension “.RAW”. Raw files start with a header like the following:

```
[Header]
HydroSoftVersion=2.02
CreationDate=02/12/01 23:00:55
FileType=raw
DeviceType=HydroScat-6
DataSource=HydroScat-6
CalSource=D:\Program Files\HOBI Labs\temp.cal
Serial=HS000123
Config=S2B3
[EndHeader]
```

Future versions of HydroSoft may include additional information between the [Header] and [EndHeader] markers. In any case, everything following the end marker is included in the exact form in which it was received from the HydroScat. For information on the raw data formats, see section 9.

## 5.13. Calibrated Data File Format

HydroSoft normally names calibrated data files with the extension “.DAT”. Calibrated data files start with a header like the following:

```
[Header]
HydroSoftVersion=2.02
CreationDate=02/12/01 23:28:42
FileType=dat
DeviceType=HydroScat-6
DataSource=Instrument Cast 3
```

```

CalSource=D:\Program Files\HOBI Labs\temp.cal
Serial=HS00001
Config=S2B3
[SigmaParams]
ad400=.01
aStarFile=D:\Program Files\HOBI Labs\aStar.csv
awFile=D:\Program Files\HOBI Labs\aw.csv
bbTildeValue=.015
C=.1
gammad=.011
gammay=.014
[Channels]
"bb440"
"bb676"
"f1676"
[ColumnHeadings]
Time,Depth,bb440,bb676,f1676,bb440uncorr,bb676uncorr,f1676uncorr
[Data]

```

```

36872.9715856481,-29.388,0,1.5536E-04,0,0,1.5536E-04,0,

```

Future versions of HydroSoft may include additional information between the [Header] and [Data] markers.

The lines following [SigmaParams] are the parameters used for “sigma” correction of the calibrated backscattering, described in section 9.6.

The line following [ColumnHeadings] names the parameters included in the calibrated data lines. Future HydroSoft files may include additional column headings and data parameters, but if so the parameters shown here will remain in the same order.

Times are stored as double-precision real numbers corresponding to the number of days since midnight, January 1, 1900. This is the native format of dates and times in Microsoft Excel.

Depth is in meters,  $b_b$  is in inverse meters, and is shown first in its “sigma-corrected” form, then in uncorrected form.  $\beta(140^\circ)$  values, with and without sigma correction, are also included if the “include beta in .dat files” option is selected in the Backscattering Parameters dialog (section 9.5).

## 6. ELECTRICAL CONNECTIONS

HydroScat-6's have been produced with three different connector configurations, depending on their date of manufacture. The connection functions as described below have remained the same in each configuration. See the following sections for the exact connector specifications and pin assignments.

### 6.1. Power Inputs

A HydroScat-6 can be powered from three sources:

- 1) external 10V to 15V supply,
- 2) internal battery,
- 3) battery charger.

Any combination of these source may be safely connected simultaneously. Power for operating the instrument will be drawn from the source with the highest voltage, but the batteries are charged only through the separate charging input. The external power input can be used to connect additional battery packs to the HydroScat. **If you plan to use the magnetic switch to activate logging while powering the instrument from an external source, see the important note in section 5.9.1.**

Whereas the operating voltage is limited to a maximum safe level of 15V (at a maximum power level of 3W), the charging voltage must be regulated at 24V and capable of supplying up to 1.8A of current. The HydroScat-6 is supplied with an appropriate charging supply. See section 7 for more details about charging the internal batteries.

### 6.2. Battery Disconnect

Shorting the battery disconnect pin to the common pin electronically disconnects the internal batteries from the HydroScat circuitry. **Note that disconnecting the batteries will cause the loss of any data in RAM.** Data stored in flash memory, for HydroScats so equipped, will not be affected.

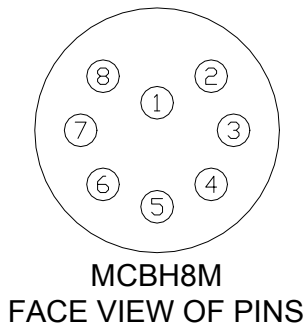
### 6.3. Data Connections

HydroScats can be configured to use either RS232 or RS485 protocols for communication. In the RS232 configuration the HydroScat can communicate directly through a standard computer serial port. In the RS485 configuration, a converter or interface card must be provided to allow communication with an

RS232 port. If the optional PDI is purchased with the HydroScat, it will be configured according to the appropriate protocol.

#### 6.4. Single-Connector Configuration

Starting in January 2002, HydroScat-6's have been equipped with a single MCBH8M connector that matches that used for most other HOBI Labs instruments:



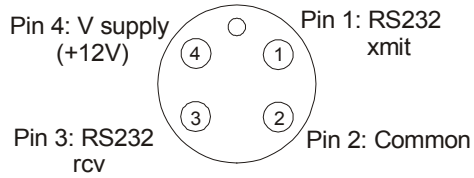
PIN	FUNCTION
1	Supply voltage (10 to 15 V)
2	Common
3	RS232 Receive or RS485A
4	RS232 Transmit or RS485B
5	Battery charging input (24 V, 1.7A)
6	Reserved
7	Reserved
8	Battery Disconnect

Instruments having this configuration are supplied with a standard power/data interface (PDI) cable. One end of the cable has an MCIL8F connector that mates with the bulkhead connector. The other end breaks out into a DB9 for serial communications with a computer, a female “barrel” connector for the battery charger input, and a BNC connector with binding post adapter for connecting an external supply.

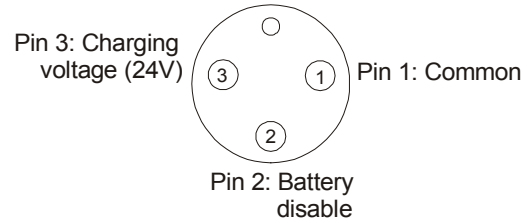
#### 6.5. Dual-Connector Configurations

HydroScat-6's made between mid-1998 and the beginning of 2002 used a Subconn MCBH4M (mate: MCIL4F) for power and data connections, and a Subconn MCBH3M (mate: MCIL3F) for charging and disconnecting the battery. HydroScats with this connector configuration were supplied with suitable cables for the two connectors.

Power and data connector  
MCBH4M  
Face view of pins



Battery charger connector  
MCBH3M  
Face view of pins



## 6.6. Early Dual-Connector Configuration

HydroScat-6's manufactured before mid-1998 had an XSG-4-PBCLM connector for power and data, and XSG-3-PBCLM for battery connections. The pin number assignments for these connectors were the same as for the MCBH connectors used in later instruments.





## 7. INTERNAL BATTERY

HydroScats manufactured since December 1998 are equipped with an internal rechargeable battery, except upon special request. Earlier instruments may have had a battery added as an option. If you are not sure whether a HydroScat has an internal battery, connect to it and use the ‘GCF’ command (see section 8.4.6).

The battery provides capacity sufficient for a day of intensive data collection. With intermittent sampling and proper use of the HydroScat’s low-power modes, it is possible to operate for days or weeks between charges.

### 7.1. Battery Capacity

The actual capacity of the battery depends on the temperature at which it is charged, stored, and discharged. Charging and storage at temperatures of 20 C or less improve capacity. On the other hand, low temperatures during discharge lower the realized capacity. Peak capacity for a battery charged and discharged at room temperature is over 20 hours of continuous operation. When discharged at 0 C, the same charge provides at least 14 hours of operation.

Internal leakage causes the battery to slowly discharge even with no load. The self-discharge rate is highly temperature-dependent. After one month at 0 C, the battery may lose 10% of its charge. The loss at least doubles at 20 C, and continues to increase at higher temperatures. Capacity also decreases slowly as the battery ages. The capacity loss depends greatly on charging conditions, but is typically less than 10% after 200 charge/discharge cycles, and 20% after 500 cycles.

Approximate discharge time for the battery can be calculated as follows. **Please note** that it is not possible to accurately account for all the factors that affect battery capacity, so you should use these calculations with caution and temper them with your own experience.

First, calculate the equivalent total current drain for your sampling schedule:

$$I_{equiv} = I_{standby} + I_{sample} \frac{t_{active}}{t_{total}}$$

where  $t_{active}/t_{total}$  is the fraction of the deployment time during which the sensor will be active. In burst mode, this will be the sum of the burst warmup time and burst length, divided by the burst interval. For continuous collection, its value is 1.

$I_{sample}$  typically averages 270 mA over the course of the battery's discharge. Given  $I_{equiv}$ ,

$$t_{total} = \frac{C_B}{I_{equiv}}$$

where  $C_B$  is the battery capacity, with units of current \* time.  $I_{standby}$  and  $C_B$  both vary with temperature. The following table shows typical values for a new battery.

Temperature	$C_B$	$I_{standby}$
0 C	4200 mAh	1.8 mA
10 C	4800 mAh	2.1 mA
20 C	5400 mAh	2.4 mA
30 C	5700 mAh	3.1 mA

For example, in continuous use at 10 C we would predict endurance of about 4800 mAh / 272 mA = 17.6 hours.

For a burst-mode application with active time of 20 seconds per hour, at 30 C,  $I_{equiv}$  would be 3.1 mA + 270 mA \* (20/3600) = 4.8 mA. Total duration would be 5700 mAh / 4.8 mA = 1190 hrs or about 49 days.

## 7.2. Low-Voltage Cutoff

When the battery voltage falls to 9.9V, indicating it is nearly exhausted, the firmware will automatically put the HydroScat into an indefinite low-power sleep state. In this state the contents of the RAM will be preserved, but no further data will be collected. With its load thus reduced, the battery voltage will typically recover and the battery will usually be able to preserve the memory for several weeks or longer. HydroScats equipped with flash memory will retain their data even if the batteries fail completely.

In addition to the low-voltage sleep, which is controlled by software, the battery control circuit will disconnect it completely if the voltage falls below about 8 volts. This is unlikely under most circumstances, but may happen after very long periods with no charging. If this happens, the battery will remain disconnected until the charging supply is connected.

### 7.3. Charging

The HydroScat-6 contains a sophisticated three-stage charger that fully recharges the battery in less than 3 hours. It also closely monitors the cumulative charging and discharging of the battery to allow tracking of battery capacity.

The HydroScat-6 includes an external power supply that converts 95 to 250 VAC to the  $24 \pm 1$  VDC required by the charging circuitry. The internal charger regulates the current from the charging supply and selects either a low “trickle” current, a high fast-charging current, or a pulsed “top-off” current, depending on the temperature and state of charge of the battery.

Charging starts whenever the charging supply is connected. This also causes the HydroScat-6 to wake if it is asleep (see section 8.3.17) and to halt any data collection in progress. Then, and throughout charging, the six beams of the sensor flash in one of two patterns to indicate the charge status:

- Fast: always one color on, changing colors at 3 Hz
- Trickle or top-off: one quick cycle through the colors every 5 seconds

This permits one to monitor the charging without requiring direct communication to the sensor. However it is also possible, if connected, to communicate and send commands. The HydroScat-6 also announces changes in charging status with brief messages via the communications port. For example:

- “Charge starting”
- “Trickle charging”
- “Starting fast charge”
- “Fast charge terminated”
- “Charger disconnected”

The battery can only be fast-charged if its temperature is between 10 C and 45 C. When the charging supply is first connected, a trickle current flows while the charger checks the temperature of the battery. If the temperature is appropriate, fast charging will begin within 30 seconds. If not, the trickle charge will continue until the temperature comes within range. Note that the battery temperature may change very slowly compared to the HydroScat-6’s case temperature.

A completely discharged battery will reach full charge after a fast charge of about three hours. Partial charges require proportionately less time.

Ideally, fast charge will continue until full charge is detected, as indicated by a drop in voltage or a rapid rise in temperature. Fast charge will also terminate if the temperature goes out of the safe range. Note that it is normal for the battery temperature to gradually rise during charging. If a charge is started when the

temperature is near the high limit, the fast charge may terminate prematurely due to this normal rise.

After the termination of a fast charge, the charger goes into a “top-off” mode during which it pulses the fast current for roughly two seconds out of every 30. This mode lasts a maximum of two and a half hours, after which it switches to the low trickle current. Both trickle and top-off modes are referred to as “slow charge” in the HydroScat-6’s status messages.

While it is safe to continue trickle charging indefinitely, repeated, prolonged charges can eventually degrade capacity. Under normal circumstances we recommend you disconnect the charging supply within 8 hours after a full charge is completed. Also avoid charging the battery much more frequently than necessary. Even with near-constant use, charging once or twice a day should be adequate. It is best to allow the battery to discharge substantially between charges.

**IMPORTANT NOTE:** It is possible to damage the battery, and to create a safety hazard, by repeatedly initiating new charges when the battery is fully charged. Do not attempt to “top off” the battery by forcing a new fast charge after a normal charge termination.

#### **7.4. Battery Disconnect**

The internal battery can be disconnected from the circuitry by shorting the appropriate pin on the bulkhead connector (for the connector pin assignments, see section 6) to ground, using the special dummy plug supplied. This special plug, distinguished by a red handle, must be removed and replaced with the black generic dummy plug to permit battery-powered operation. The battery disconnect capability is useful to prevent loading of the batteries during long periods of storage, or if it is necessary to reset the instrument’s internal computer.

## 8. DIRECT COMMUNICATION AND COMMANDS

HydroScats are configured and controlled with commands sent via their serial communication port. When you use HydroSoft, the commands needed for routine operation are generated automatically and you do not need to know the details. However you can type commands manually, and view the HydroScat's replies directly, via HydroSoft's terminal window or a generic terminal program. Some less-common commands are accessible only through this method.

### 8.1. Communication Protocol

HydroScats communicate through a standard RS-232 serial connection, with 8 data bits, no parity, one stop bit, and no handshaking. The default baud rate is 9600, but it can be set to other standard rates up to 57600 (see section 8.4.1).

### 8.2. Command Conventions

The HydroScat waits until it receives a carriage return, line feed, or other control character before responding to a command. It responds to every command, but does not echo characters when it receives them. If it receives a command it does not understand, it will echo the command followed by a question mark.

The HydroScat's responses usually start with an apostrophe ('). Error messages start with an exclamation point, and primary data messages start with an asterisk (\*).

Commands are insensitive to case. They are shown below in upper case for clarity.

Some commands accept arguments, which are separated from the base command, and from each other, by commas. Arguments may be individually omitted, in which case they will have no effect. For example, if a command accepts three arguments, in the form `COMMAND,arg1,arg2,arg3`, you may adjust only *arg3* by entering `COMMAND,,,arg3`.

### 8.3. Routine Commands

#### 8.3.1. BATT

BATT displays a brief subset of the data displayed by CHARGE, including the battery voltage and current, and the charging rate, if any. If a charge is in progress, the duration of the charge, and the cumulative charge and energy are

shown. If not, the cumulative charge and energy consumed since the last charge (if any) are shown.

### **8.3.2. BURST,*on,warmup,duration,cycle,totalDuration,logPeriod,startDelay,autoStart,sleepOnMemFull***

Similar to LOG, but lists the burst parameters first to make them easier to enter.

In burst mode (i.e. if *on* is nonzero), upon receipt of the START command (or activation of the magnetic switch) the HydroScat waits for the number of seconds specified by the LOG command's *startDelay* parameter. It then collects data until *duration* seconds have passed. At the end of the burst it goes into low-power sleep mode until *cycle* minutes have passed since the beginning of the previous burst. At the beginning of each subsequent burst it waits for *warmup* seconds before resuming collection. When *totalDuration* hours have passed since the beginning of the first burst, the HydroScat will go into an indefinite low-power sleep.

If *duration* is zero, burst mode will be disabled regardless of the value of *on*. If *cycle* is zero, the HydroScat will sleep indefinitely after only one burst. If *totalDuration* is zero, the total duration will not be limited.

```
'Burst mode: 1 (ON)
' Warmup time: 5 seconds
' Burst duration: 15 seconds
' Burst cycle: 10 minutes
' Total duration: 0 hours (not in effect)
'Sampling and Logging Parameters:
' Log Period: 1 seconds
' Start delay: 60 seconds
' Sleep when memory full: 1
' Start on power up: 0
```

### **8.3.3. CHANNELS**

Lists the wavelengths and functions of the 8 data channels of a HydroScat-6, in the order in which the HydroScat produces them.

```
Reply:
`1: bb442
`2: bb671
`3: bb470
`4: bb510
`5: bb589
`6: bb671
`7: f1510 (excitation: bb470)
```

`8: fl671 (excitation: bb442)

### 8.3.4. CHARGE

CHARGE takes no arguments, and displays a summary of the battery's charge and discharge status. This includes information about the most recent (or current) charge and discharge, as well as cumulative information about past charges.

Example reply:

Voltage: 11.09 v

The voltage of the battery at the time of the status report. This could range from 16V during fast charge to 10V near the end of the discharge (the sensor goes to sleep automatically when the voltage falls below 10).

Current: -0.30 A (discharge)

The current flowing into or out of the battery at the time of the status report. A negative current means the battery is being discharged. The maximum normal discharge current is about -0.32 A. The maximum charge current is about 2.5A.

Present dschg: 0.21 Ahr, 2.4 WHr

The total charge and energy drawn from the battery since the end of the last charge. This is your best indication of how close you are to needing a charge. After a full charge you will be able to get roughly 60 WHr out of the battery, depending on the temperature at which it was charged and discharged. In this case, only 2.4 WHr, a small fraction of the total capacity, has been used. If a charge is in progress, this will indicate the energy drawn before the start of the present charge, and the label will change to "previous dschg."

Last charge: 1.23 Ahr, 17.4 WHr

The total charge and energy put into the battery during the previous charge, or if a charge is in progress, the present charge (the label will change to reflect this). The charge required for a completely discharged battery may be as much as 80 WHr. This is higher than the maximum discharge capacity because of inefficiencies in the electro-chemical process of charging the batteries. In this example, the energy is fairly low, presumably because the battery was mostly charged before the charge was begun.

Charge Start: none

If a charge is in progress, this will show the date and time (according to the internal clock) at which it started.

Duration: 16 min fast, 114 min total

The duration of the present or previous charge. In this case, the fast charge lasted only 16 minutes, which indicates the batteries were near full charge before the charge started. The charger was unplugged 114 minutes after the charge started.

Peak voltage: 15.82 v at 16 min

The highest voltage reached during the present or previous charge, and how long after the start of charge it was reached.

Fast end voltage: 14.45

The voltage at the time the previous fast charge ended.

Charges: 10

How many times the batteries have been charged since the sensor's final assembly.

Total Charge: 80.3 Ahr, 820.0 Whr

The cumulative charge and energy of all recorded charges.

Total dischg: 43.2 Ahr, 452.4 Whr

The cumulative charge and energy of all recorded discharges. Note that the total discharge will always be less than the total charge because the charging process is not perfectly efficient, and also because the batteries can safely tolerate a considerable amount of overcharging. However if the cumulative charge is more than 3 times the cumulative discharge after a large number of charges, you should considering reducing the frequency and duration of charges.

### **8.3.5. CLEARRAM**

Erases the contents of the log memory. Before proceeding, displays the memory status (the same information as displayed by the ram command) and asks for confirmation.

Reply:

```
`339960/1017856 bytes (33%) used in log RAM
`10059/29976 packets logged
`First packet logged 05/01/97 13:40:42
`Last packet logged 05/01/97 14:28:02
```

`ERASE ALL DATA IN RAM (Y/N) [N]?

Press “y” to clear the memory, or any other key to abort.

### **8.3.6. CLEARLOG**

Identical to CLEARRAM.

### **8.3.7. D**

Transmits a “D” packet of hexadecimal data. See section 9.2 for a description of the format.

### **8.3.8. DATE,mm/dd/yyyy hh:mm:ss**

Sets the real-time clock to the given date (and time if provided). If no date is given, simply reports the current setting. The year may be entered either as two or four digits. If only two digits are entered, years from 00 to 43 will be assumed



to be in the 21<sup>st</sup> century. The real-time clock is reset whenever power is turned off to the sensor. Setting it accurately is not necessary to the operation of the sensor, but may be useful for keeping track of logged data.

In the Crosscut terminal program, the host computer's date and time for this command can be entered by pressing Alt-D.

```
Reply:
`05/01/97 14:51:02
```

### **8.3.9. DELCAST, *cast* [flash memory only]**

Deletes the given numbered cast from flash memory. Has no effect on instruments equipped with RAM logging.

### **8.3.10. DIR**

Displays a directory of the casts currently stored in memory.

```
Reply:
`Cast          Start Time          Duration Samples
`  1    mm/dd/yyyy hh:mm:ss    2.3 hrs  12,345
`  2    mm/dd/yyyy hh:mm:ss   23.1 mins  3,456
```

Note that the duration is calculated from the time tags associated with the first and last packets in the cast. If the user changed the setting of the HydroScat clock while a cast was in progress, the duration displayed may not make sense.

### **8.3.11. DOWNLOAD, *cast***

Causes the HydroScat to transmit data stored in its log RAM. *Cast* is the number of a cast to transmit. Use DIR to view the available casts. If no argument is given, transmits the entire contents of memory. This command does not change the contents of the log memory.

Reply: If a valid cast number is specified, raw data packets in the same form as produced by the sensor in real time.

You can interrupt a download in progress, without affecting the contents of memory, by sending a control-C character to the HydroScat. (Because RS485 cannot support simultaneous two-way transmission, this works only on sensors with RS232 interfaces).

### **8.3.12. FL, *on***

FL controls the function of the two dual-function (backscattering and fluorescence) channels of the HydroScat-6 (also see sections 1.4 and 5.5). Whether or not you include an argument, FL reports the configuration of the fluorescence channels.

```
Reply:
```

```
`fl510
` excitation: bb470
` receiver: bb510
` status: 1 (fl510 on, bb470 off)

`fl671
` excitation: bb442
` receiver: bb671
` status: 0 (fl671 on, bb671 off)
```

The argument *on* is a numeric value (the same as the *status* value shown above) indicating which function is active. The value 1 turns on the fluorescence full time; 0 (zero) turns fluorescence off (leaving backscattering on). The value 2 turns on time-sharing, causing the backscattering and fluorescence functions to alternate. In the time-sharing mode the function changes every 0.4 seconds. Note that this means the sensor will require somewhat more than 0.4 seconds to make a complete measurement of all parameters. For shorter sample periods, some samples will not include measurements of both parameters. If one sample of a parameter is skipped because of time-sharing, the sensor will repeat the last measured value. If the sample period is short enough that several samples pass without an actual measurement, zeros will appear in place of the missing measurements. When you enter a combination of sample period (entered with the LOG command) and FL mode that will lead to skipped measurements, the sensor will provide a warning message, but will not prevent the settings from taking effect.

The two fluorescence channels need not operate in the same mode. To specifically address one of the fluorescence channels, you can type its full name as the command. For example, `FL510,1` turns on fl510 without affecting fl671.

**NOTE:** Changes you make with the FL command are not saved when power is disconnected from the sensor, unless you first use the STOREFL command (section 8.3.22).

### **8.3.13. H**

Transmits a hexadecimal packet of housekeeping information. See section 9.4 for details of the packet format.

### **8.3.14. ID**

ID displays identifying information about the sensor. This information can only be set at the factory, except for the address, which can be set with the GCF command (section 8.4.6). It replies in this format:

```
`Identification:
` Model: HS6
` S/N: HS97074
` Config: W1B2R1I2P2
```

```
` ID: Hobi One
` Address: *
` Maximum Depth: 200 m
` Firmware: 1.77
` Cal Time: 13660
```

Model and serial number are self-explanatory. The “config” string describes the sensor’s hardware configuration. Among other things, it indicates the wavelength set, quantity of RAM, communication protocol, and whether it has an internal battery. ID is simply an identifying name, which we usually fill with the name of the purchasing institution.

Address is used when several instruments share communication lines. The default setting for all HydroScats is \*, which indicates no address is required. If an address other than \* is specified, the HydroScat will respond only to commands that begin with that address.

Not all HydroScats have the same warranted depth rating, so maximum depth is recorded here along with the sensor’s other attributes.

The firmware version number displayed is programmed into the firmware’s source code, and therefore cannot be changed except by installing different firmware.

The calibration time shown is in the real-time clock’s raw reading (in seconds since midnight Jan 1, 1970) at the time the calibration or configuration parameters were last changed. This cannot be directly entered, but is updated automatically.

### **8.3.15. LOG,period,delay, sleepOnMemFull,autostart,burstMode,burstWarmup,burstDuration,burstCycle,totalDuration**

*Period* is the time, in seconds, between samples that are logged (and transmitted on the serial port). *Delay* is the number of seconds the instrument will wait after a START command, power-on, or magnetic switch activation before the first sample is logged. A nonzero *sleepOnMemFull* value indicates that the sensor will stop logging and go into a low-power sleep when the log memory fills. *Autostart*, if non-zero, indicates that logging will start (with the given delay) automatically when power is applied to the sensor. *Autostart* applies primarily to HydroScats without batteries; those with batteries are usually powered continuously, even in sleep mode.

The burst mode parameters are described under the BURST command, although they can also be modified using LOG.

The reply to the LOG command shows the settings of all the applicable parameters:

```
'Sampling and Logging Parameters:
```

```
' Log Period: 1 seconds
' Start delay: 60 seconds
' Sleep when memory full: 1
' Start on power up: 0
'Burst mode: 1 (ON)
' Warmup time: 5 seconds
' Burst duration: 15 seconds
' Burst cycle: 10 minutes
' Total duration: 0 hours (not in effect)
```

**NOTE:** Changes you make to the log parameters remain in effect only as long as the sensor is powered, unless you make them permanent with the STORELOG command (section 8.3.23).

### **8.3.16. RAM**

Displays information about the log memory, in the following form:

```
`339960/1017856 bytes (33%) used in log RAM
`10059/29976 packets logged
`First packet logged 05/01/97 13:40:42
`Last packet logged 05/01/97 14:28:02
```

The first line shows how many bytes are used and the total memory in the system.

The second line shows how many packets (samples) are stored, and the approximately maximum number of packets that can be stored.

If the memory is empty, the last two lines are omitted. The accuracy of the dates and times presented depends on the HydroScat's real-time clock being set accurately. See DATE (8.3.8) and TIME (8.3.25).

### **8.3.17. SLEEP,secs**

The SLEEP command causes the HydroScat to immediately cease any data collection and go into a low-power sleeping state. In this state the current consumption is reduced to a level similar to the battery's self-discharge rate. The *secs* argument, if included, specifies the duration of the sleep in seconds. If no duration is specified, the sleep interval defaults to an essentially infinite 200,000,000 seconds (about six years).

The HydroScat-6 wakes from its sleep when:

- the specified number of seconds has passed, or
- it receives characters through its communication port,
- the charging supply is connected to the battery charger, or
- the magnetic switch is moved to the "on" position.

The HydroScat-6 wakes automatically when the battery charging supply is connected so that the internal computer can monitor charging and signal charge status with the LEDs.

### **8.3.18. SLEEPINFO**

SLEEPINFO displays the time and cause of the HydroScat's last sleep, and of its subsequent waking. Possible causes of sleep include:

- receipt of the SLEEP command,
- movement of the magnetic switch to its off position,
- log memory filling up,
- battery voltage falling too low,
- scheduled sleep during burst-mode logging.

### **8.3.19. START,*delay***

Causes the HydroScat mark the beginning of a new cast in log memory, and to begin logging and transmitting data according to the parameters set with the LOG or BURST command. Logging will start after *delay* seconds, or if no *delay* is specified, after the start delay specified by the LOG command. START has no effect if the HydroScat is already logging.

Reply:

```
`Sampling starts in [delay] seconds.
```

### **8.3.20. STARTNOLOG,*delay* [added in firmware 1.80]**

Identical to START, except that data collected will not be logged in internal memory.

### **8.3.21. STOP**

Causes the HydroScat to immediately cease logging and transmitting data. Also marks the end of the current cast (if any) in the log directory.

Reply:

```
`Sampling stopped.
```

### **8.3.22. STOREFL**

Stores the current settings of the fluorescence channels (see the FL command on page 21 in non-volatile memory, so they will remain in effect even when power is removed from the sensor.

Reply:

```
`Storing...OK
```

### 8.3.23. STORELOG

Stores the current settings of the log parameters (see the LOG command on page 22) in non-volatile memory, so that they will remain in effect even when power is removed from the sensor.

Reply:

```
`Storing...OK
```

### 8.3.24. T

Transmits a “T” packet of hexadecimal format. See section 9.3 for details of the data format.

### 8.3.25. TIME,*hh:mm:ss*

Sets the real-time clock to the given time (does not affect the date). If no time is given in the command, simply reports the current setting. The real-time clock is reset whenever power is turned off to the sensor. Setting it accurately is not necessary to the operation of the sensor, but may be useful for keeping track of logged data.

Reply:

```
`05/01/97 14:51:02
```

### 8.3.26. TIMERES,*mode*

Causes the HydroScat to report time in high-resolution (0.01 s) or low-resolution (1 s) mode. Specifying a *mode* of H (“high”) or 1 (“on”) will enable the high-resolution mode. Specifying a *mode* of L (“low”) or 0 (“off”) will disable the high-resolution mode. In high-resolution mode, the data packet format is slightly different and is denoted by “\*T” instead of “\*D” at the beginning of the line. See section 9.1 for details of the data formats.

Reply (to TIMERES,H or TIMERES,1):

```
`Time Resolution: high (0.01 second)
```

Reply (to TIMERES,L or TIMERES,0):

```
`Time Resolution: low (1 second)
```

## 8.4. Special-Purpose Commands

The following commands are not needed for routine operations and should be used with great care.

### 8.4.1. BAUD,*rate*

Immediately sets the baud rate at which the instrument communicates. If sent without an argument, reports the current baud rate setting. Valid rates are 4800, 9600, 19200, 38400 and 57600. The actual baud rate set by the instrument

is usually slightly different from these rates, although you must specify one of the standard rates exactly. When the HydroScat states a baud rate, it shows both the nominal and actual values. The deviation in actual baud rates is well within the acceptable tolerances for communication with a computer.

Reply (if no rate specified):

```
`Baud rate: 9583 (9600)
```

Reply (if rate is 19200):

```
`Changing rate to: 19166 (19200)
```

#### **8.4.2. AGAIN,channel,auto**

Turns automatic gain control on (if *auto* is nonzero) or off (if *auto* is zero). The *channel* argument specifies to which channel the auto argument applies. The channels are numbered 1 through 8. Setting *channel* to zero causes the auto argument to apply to all channels.

Note that automatic gain control only works for gain settings of 3, 4 and 5 (see the gain command). Even if it is enabled, automatic gain control will have no effect if the gain is set to 1 or 2.

Reply (for the default setting of autogain active for all channels):

```
`autogains: 11111111
```

#### **8.4.3. ECHOOFF**

Turns off character echo, so that characters received by the HydroScat are not automatically retransmitted to the computer. This is the HydroScat's default setting.

#### **8.4.4. ECHOON**

Turns on character echo. That is, the HydroScat will automatically retransmit every character it receives back to the computer. Echo is off by default.

#### **8.4.5. GAIN,channel,gain**

Sets the given *channel* (1 through 8) to the given *gain* (1 through 5). If *channel* is zero, all channels are set to the given *gain*.

The channels are not completely independent with regard to gain settings, and gain settings 1 and 2, the lowest, behave differently from the higher three gains. Gains 1 and 2 are ordinarily only needed during calibration procedures using a highly reflective target. If any channel is set to a gain of 3 or higher, gain settings 1 and 2 (the lowest) will not take effect. In order to use gain settings 1 and 2, all channels must be set to gain 1 or 2. Also, setting a channel's gain to 1 or 2 will disable automatic gain control for that channel.

Reply:

```
`gains: 54555500
```

*Gain* is reported as zero when a channel is disabled. For example, channels 7 and 8 are reserved for reporting fluorescence measurements, and are disabled by default.

#### **8.4.6. GCF,*address*,*Baudrate***

GCF stands for global configuration. This command displays and sets certain parameters that pertain to the HydroScat-6 as a whole. Note that not all the parameters displayed can be set with this command.

Reply:

```
'Global Configuration:
' Address: *
' Baud Rate: 9600
' Data prefix: *
' Info prefix: '
' Error prefix: !
' Cal Temp: 0.000000
' Depth Offset: 14.1
' Depth Coefficient: 0.0089
' Maximum Depth: 200 m
' ID: Institution
' Model: HS6
' S/N: HS97074
' Config: W1B0R1I2P2
' Firmware: 1.10/256K
' RAM size: 256K
' Config Version: 2
' Cal Time: 10/01/97 11:03:41
```

The address should normally be set to \*. If it is set to any other character or string, the HydroScat will only acknowledge commands that begin with that string.

Baud rate is the rate to which the sensor is set upon startup, not necessarily the current rate. Use BAUD to view or adjust the current rate.

The three prefix characters are used to distinguish almost all messages produced by the HydroScat-6. The Data Prefix character precedes all standard data messages (see D, H and T), and is used by the HydroScat Windows software to identify them as such. The Info Prefix precedes most informational displays (including those shown in this example). The Error Prefix marks important warnings that demand the user's attention.

Cal Temp is not used in present HydroScat-6's. It is intended to serve as a reference temperature for correcting temperature-related drift, should such corrections be needed.



Depth offset and depth coefficient are used to translate raw depth data to units of meters. These are not used within the HydroScat-6 firmware, but are stored there for reference.

The maximum depth, ID, model, S/N and Config fields are described under ID (section 8.3.14).

The firmware version shows not only the sequential version number, but which memory configuration it is compiled for. This should match the RAM size displayed on the next line.

The calibration and configuration data that are unique to each HydroScat-6 are stored in nonvolatile memory in a format that has changed as more information was added in successive firmware versions. The configuration version number identifies the format in which the current information was stored.

Finally, the cal time shows the date and time at which the configuration and calibration data were last altered. This is updated automatically and cannot be edited. The same parameter is displayed in raw form by the ID command.

#### 8.4.7. X

X is used extensively during testing and troubleshooting, since it displays a comprehensive report of the HydroScat-6's most recent raw data as follows. Raw data are also discussed in section 9.1).

```
'time: 2856 error: 2
'samples: 733 on, 11 off
'bb440 4611 4546 8840 2393 -4 47
'bb670 13110 1707 12730 1557 -1 8128
'bb470 10724 1722 16239 2031 -3 5068
'bb510 6761 1616 13869 1604 -2 3233
'bb590 14818 1910 17587 1865 -7 6528
'bb620 11472 2003 12729 1650 -3 6396
'fl510 0 0 0 0 0 0
'fl670 0 0 0 0 0 0
'gains: 555555(5)(5)
'depth:1661 temp:176 VA:135 VB:79 VBk:53 Aux:5888
'gain status: -1 0 -1 0 -1 0 0 0
```

Time is the current raw setting of the real-time clock (in seconds since midnight, 1/1/1970). Error is a one-byte variable in which each bit is a flag for a particular error condition (described in section 9.2.10). In the display above, error has the value 2, indicating that one or more of the signal channels saturated at some point during the sampling time.

The second line shows how many samples were averaged to produce the displayed data. In this case, the signals were averaged over 733 samples (about 7 seconds at the sensor's internal 100 Hz rate), and 11 samples were averaged to produce the offset figures. Since the LEDs must be turned off to measure offsets,

only about 5% of the sensor’s time is devoted to them, and the number of offsets averaged is usually smaller than the number of signals. In general, the number of samples differs slightly from channel to channel. The sample quantities shown are averaged over all channels.

The next eight lines show the name of each channel, followed by its signal, signal offset, reference, reference offset, background radiance, and normalized signal (*SNorm*). The background radiance is usually small in laboratory conditions. The background saturates at approximately 85 on some sensors, and 120 on others, depending on which components are installed on the motherboard. *SNorm* is the normalized signal sent in the standard data packets (see section 9.2.6). It is calculated by

$$S_{norm} = R_{nom} \frac{Sig - SigOff - SigDark}{Ref - RefOff}$$

where *Rnom* and *SigDark* are parameters from the channel calibration record. *Snorm* is a 16-bit signed integer.

Note that in this case the fluorescence channels are turned off, so their data are all zero.

The next line shows the gain settings of all the channels. Gains may range from 1, the lowest, to 5. The last two are shown in parentheses to show that channels 7 and 8 were turned off in this instance.

The depth value shown is in raw digital counts. The temperature shown is scaled to fit into an unsigned byte, as when it is transmitted in the normal “D” data packet. To convert it to degrees C, divide by 5 and subtract 10. For example, 176 corresponds to 25.2 C.

VA is the voltage supplied via the HydroScat-6’s main 4-pin connector. VB is the voltage of the internal battery. VBk is used to detect when the charging supply is connected. All these voltages are expressed in hundredths of volts. For example, VA above is 13.5V.

Aux is used to measure the battery charge or discharge current in sensors with batteries. The value shown is 840 times the current in amps. In sensors without batteries, Aux is not used.

Gain status indicates whether the current gain settings are appropriate to the measurement conditions. A value of zero indicates the gain is suitable. Positive one means it should be increased, and negative one means it should be reduced. In this example, channels 1, 3 and 5 are judged to have too much gain, and will be reduced by the autogain algorithm if it is enabled. The next sample displayed would show those channels set to gain 4. The averaged signal levels in this example are well below saturation, but, as indicated by the error value of 2, some

channels must have received excessive signals at some point during the sampled interval.



## 9. DATA PROCESSING REFERENCE

### 9.1. Raw Data Formats

HydroScats can produce several data packet formats, as well as reply to many commands (see section 8). The “D” data packet described below contains the primary optical and supporting data for routine data collection. The “T” packet, which was introduced in firmware version 1.60, is identical to the “D” packet except that it includes higher-resolution time values. “H” packets contain housekeeping data that are not needed for normal data processing, but provide extra information that could be useful for trouble-shooting. It is advisable to save all the raw data in case any special post-processing is needed.

For troubleshooting purposes you can view raw data in decimal form by using the X command (section 8.4.7).

Packets consist of ASCII characters. Numbers are represented in hexadecimal notation. Signed numbers are in 2’s complement format. Transmissions always end with carriage return and line feed characters.

### 9.2. “D” Packet Format

#### 9.2.1. Example “D” Packet:

```
*D346A023C055613CC160615DE13232034FB24F952555555000648870042<CR><LF>
```

#### 9.2.2. “D” Packet Structure

Parameter	Type	ASCII	ASCII Bytes	Example
Packet Flag		*	1	*
Packet ID	char	D	1	D
Time	signed	HHHHHHHH	8	346A023C
Snorm1	signed	HHHH	4	0556
Snorm2	signed	HHHH	4	13CC
Snorm3	signed	HHHH	4	1606
Snorm4	signed	HHHH	4	15DE
Snorm5	signed	HHHH	4	1323
Snorm6	signed	HHHH	4	2034
Snorm7	signed	HHHH	4	FB24
Snorm8	signed	HHHH	4	F952
Gain/Status1	nibble	H	1	5
Gain/Status2	nibble	H	1	5
Gain/Status3	nibble	H	1	5
Gain/Status4	nibble	H	1	5
Gain/Status5	nibble	H	1	5
Gain/Status6	nibble	H	1	5

Gain/Status7	nibble	H	1	0
Gain/Status8	nibble	H	1	0
DepthRaw	signed	HHHH	4	0648
TempRaw	unsigned	HH	2	87
Error	byte	HH	2	00
Checksum		HH	2	42
Terminator		<CR><LF>	2	
<b>TOTAL:</b>			<b>62</b>	

### 9.2.3. Packet Flag

Each data packet with an asterisk character. Other transmissions, for example replies to commands, may begin with other characters.

### 9.2.4. Packet ID

The packet described here is identified by a 'D' in this position. HydroScats may produce other packets, of various lengths, with other identifiers.

### 9.2.5. Time

TIME is in seconds. If the HydroScat's real-time clock has been set accurately (See the description of the TM and DT commands in the User's Manual), a time of zero represents Midnight, January 1, 1970. The time shown in the example above, 346A023C, corresponds to November 12, 1997 at 19:23:40.

When power is first applied to the HydroScat the time may proceed from a random value. It is not necessary to set the time if absolute time data are not required.

### 9.2.6. Snorm

There is one 16-bit Snorm value for each of the 8 optical data channels. Note that some channels may be disabled, as indicated by their Gain/Status values, in which case the Snorm value is meaningless. It is calculated by the HydroScat from

$$S_{norm} = R_{nom} \frac{Sig - SigOff - SigDark}{Ref - RefOff}$$

where *Sig* and *Ref* are the raw signal and LED reference measurements. *SigOff* and *RefOff* are the signal and reference measured during the time when the LED is off. *Rnom* and *SigDark* are parameters from the HydroScat's calibration record. *Snorm* is a 16-bit signed integer.

Snorm is used to calculate backscattering as shown in section 9.5.

### 9.2.7. Gain/Status

There is one 4-bit gain/status value for each of the optical data channels. The three LSB's comprise a gain setting, and the MSB indicates status.

A gain setting of zero indicates that the channel is disabled and its data should be ignored. Gains of 1 to 5 are used to select one of five coefficients to be applied to Snorm. Gains 6 and 7 are undefined.

The status bit is zero under normal conditions. The status bit for a channel may be set to 1 if the HydroScat detects a condition that may affect the quality of the data on that channel. However a status value of 1 does not necessarily indicate invalid data.

### 9.2.8. DepthRaw

DepthRaw is reported as a signed 16-bit integer. The depth in meters is calculated by

$$\text{depth (m)} = \text{DepthRaw} * \text{depthCal} - \text{depthOff}$$

The values of depthCal and depthOff are specified in the calibration file provided with each instrument.

### 9.2.9. TempRaw

TempRaw indicates the HydroScat's internal temperature. The actual temperature is calculated by

$$\text{Temp (C)} = \text{TempRaw} / 5 - 10$$

Note that TempRaw is an unsigned byte with a range of 0 to 255, giving the calibrated temperature a range of -10 to 41 C.

### 9.2.10. Error

Each bit in the one-byte error code corresponds to a particular error condition:

<b>weight</b>	<b>condition</b>
1	high background
2	high signal
4	reference out of range (not yet implemented)
8	temperature out of range (not yet implemented)
16	primary voltage out of range (not yet implemented)
32	battery voltage out of range
64	log memory full
128	undefined

### 9.2.11. Checksum

Checksum is the least significant byte of the unsigned sum of all the ASCII bytes preceding the checksum in the packet, not including the packet flag (\*).

### 9.2.12. Terminator

This packet and all other transmissions are terminated with a carriage return and line feed.

## 9.3. “T” Packet Format (firmware 1.60 and later)

The “T” packet is identical to the “D” packet, except that the resolution of the time value is extended by 2 hex digits. The added digits indicate the fractional time in hundredths of seconds. In the example below, the fractional time of 1A indicates 0.26 seconds. Fractional time values greater than 99 decimal, 63 hex, are undefined.

### 9.3.1. Example “T” Packet:

\*T346A023C1A055613CC160615DE13232034FB24F9525555550006488700B4<CR><LF>

### 9.3.2. “T” Packet Structure

Parameter	Type	ASCII	ASCII Bytes	Example
Packet Flag		*	1	*
Packet ID	char	T	1	T
Time	signed	HHHHHHHH	8	346A023C1
Fractional Time	Unsigned	HH	2	1A
Snorm1	signed	HHHH	4	0556
Snorm2	signed	HHHH	4	13CC
Snorm3	signed	HHHH	4	1606
Snorm4	signed	HHHH	4	15DE
Snorm5	signed	HHHH	4	1323
Snorm6	signed	HHHH	4	2034
Snorm7	signed	HHHH	4	FB24
Snorm8	signed	HHHH	4	F952
Gain/Status1	nibble	H	1	5
Gain/Status2	nibble	H	1	5
Gain/Status3	nibble	H	1	5
Gain/Status4	nibble	H	1	5
Gain/Status5	nibble	H	1	5
Gain/Status6	nibble	H	1	5
Gain/Status7	nibble	H	1	0
Gain/Status8	nibble	H	1	0





Back8	signed	HH	2	00
VsupA	unsigned	HH	2	77
VsupB	unsigned	HH	2	21
Vback	unsigned	HH	2	0B
Aux	signed	HHHH	4	0691
Checksum		HH	2	20
Terminator		<CR><LF>	2	
<b>TOTAL</b>			<b>136</b>	

#### 9.4.2. Time

Same as “D” packet time.

#### 9.4.3. SigOff, Ref, RefOff

These three values (one set for each of the optical channels) are incorporated into the calculation of Snorm, and are not needed for normal post-processing.

#### 9.4.4. Back

This signed integer indicates the amount of background radiance incident on the detectors. Its value is normally zero or negative from the HydroScat-6. A large value indicates bright background light (presumably sunlight), which may contribute to noise in the backscattering data.

#### 9.4.5. VsupA, VsupB, Vback

These show the voltages of up to three power supplies for the instrument. The HydroScat only draws power from the source with the highest voltage, and only one need be supplied for normal operation. Different sensor configurations may assign the voltages differently. The value reported is 10 times that actual applied voltage. For example, VsupA above is 77 Hexadecimal, 119 Decimal, representing 11.9 Volts.

#### 9.4.6. Aux

Not presently used.

#### 9.4.7. Checksum

Same as “D” packet.

#### 9.4.8. Terminator

Same as “D” packet.

## 9.5. Calculating $\beta$ and $b_b$

Each optical channel of each HydroScat has a unique set of calibration coefficients needed to convert its data to engineering units. These coefficients are measured at the factory and stored in the instrument's memory, as well as supplied in a “.CAL” file that can be used by HydroSoft or other software. The file format is described in section 9.7.

The first step in processing is to convert the raw signal to the value of the volume scattering function,  $\beta(140^\circ)$ , using

$$\beta_u = \frac{S_{norm} \cdot \mu}{(1 + k_T(T - T_{cal})) \cdot G_g \cdot R_{nom}}$$

with the following input variables

$S_{norm}$	Normalized backscatter value from HydroScat
$\mu$	Mu from .cal file
$k_T$	TempCoeff in .cal file
$T$	Instrument temperature (calculated as shown above)
$T_{cal}$	CalTemp from .cal file
$G_g$	Gain ratio for gain g, (Gain1 – Gain5 from .cal file)
$R_{nom}$	Nominal reference value (Rnom from .cal file)

The  $u$  subscript here stands for “uncorrected”, indicating that the sigma correction described in section 9.6 has not yet been applied.

The backscattering coefficient  $b_b$  is estimated from  $\beta(140)$  using the method described in “Instruments and Methods for Measuring the Backward-Scattering Coefficient of Ocean Waters”, by Robert A Maffione and David R. Dana, *Applied Optics* Vol. 36, No. 24, 20 August 1997, according to the following expression.

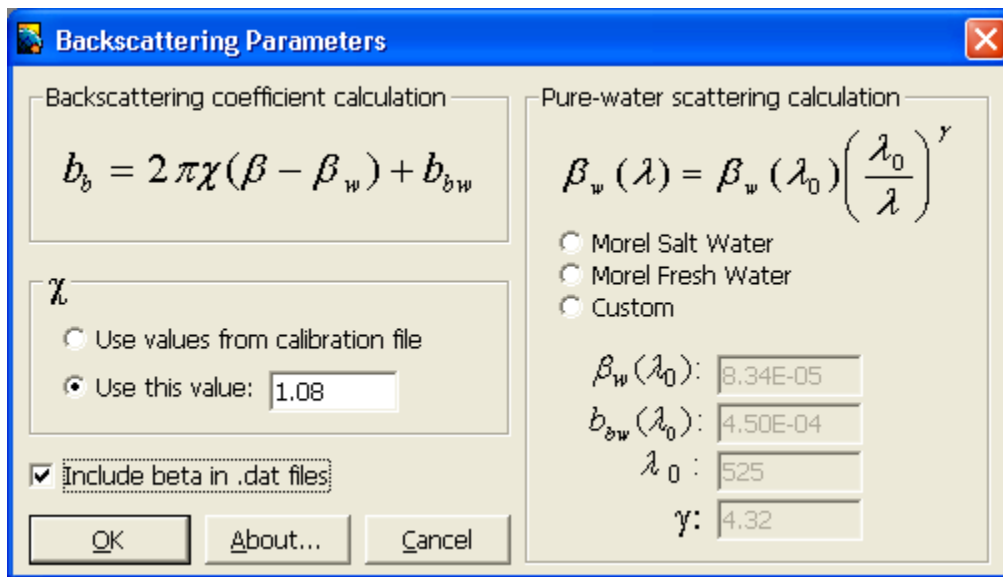
$$b_b = 2\pi\chi_{bb} [\beta(140) - \beta_w(140)] + b_{bw}$$

with the following additional inputs

$\chi_{bb}$	Constant of proportionality between $\beta(140)$ and $b_b$ for particle scattering. The default value is appropriate for most cases, but can be changed in the backscattering parameters dialog box shown below. In .cal files, the value $2\pi\chi_{bb}$ is stored with the name Beta2Bb.
$\beta_w(140)$	Volume scattering of pure water at 140 degrees
$b_{bw}$	Backscattering coefficient of pure water

Normally the value of  $\beta(140)$  used in this equation would include the sigma correction explained in the following section.

The pure-water scattering values  $\beta_{140w}$  and  $b_{bw}$  are calculated by HydroSoft, according to parameters set in the dialog shown below. This is displayed in response to the Backscattering Parameters command on the File menu. The default values are from A. Morel, "Optical Properties of Pure Water and Pure Sea Water," *Optical Aspects of Oceanography*, M. G. Jerlov and E. S. Nielsen (eds.), Academic Press, New York, 1974, chap. 1, pp 1-24. However by selecting the "custom" option you can modify the model. For special applications you can also remove the pure water factor entirely by setting the custom parameters to zero.



## 9.6. Sigma Correction

Sigma correction is an adjustment to improve the accuracy of backscattering measurements in highly-attenuating water. Some light that would otherwise be detected as backscattering is lost to attenuation in the water between the instrument and the detection volume, causing backscattering to be underestimated. We compensate for this applying the following correction<sup>1</sup>:

$$\beta = \sigma(K_{bb}) \cdot \beta_u$$

where  $\beta_u$  is the uncorrected backscattering. The sigma-corrected  $\beta$  can be used in the equation for  $b_b$  above, to produce sigma-corrected  $b_b$ .

<sup>1</sup> Versions of HydroSoft prior to 2.5 used a third-order polynomial approximation for sigma, and the current version still uses this if the constant  $k_{exp}$  is not present in an instrument's calibration data.

$\sigma(K_{bb})$  is a complicated function of the sensor's optical geometry, but can be closely approximated by

$$\sigma(K_{bb}) = k_1 \exp(k_{exp} K_{bb})$$

where  $K_{bb}$  is the coefficient of attenuation for light traveling from the sensor to the sensing volume and back.  $k_{exp}$  is characteristic of the specific instrument, and is included in its calibration file.  $k_1$  is set so as to satisfy the requirement that

$$\sigma(K_{bbw}) = 1$$

where  $K_{bbw}$  is the attenuation, excluding that of pure water<sup>2</sup>, of the water in which the instrument was calibrated. That is,

$$k_1 = \exp(-k_{exp} K_{bbw})$$

When the calibration is performed with well-filtered water,  $K_{bbw}$  is near zero and  $k_1$  is for practical purposes 1 at all wavelengths.

Since HydroScats do not make a direct measurements of attenuation, their  $K_{bb}$  is estimated from

$$K_{bb} = a + 0.4b .$$

If measurements of  $a$  and  $b$  are available, they can be used to calculate sigma corrections with the best possible accuracy. However within HydroSoft,  $a$  is estimated from *a priori* data, and  $b$  is estimated from the measured  $b_b$ .  $a$  is calculated from the following model:<sup>3</sup>

$$a(\lambda) = 0.06a^*(\lambda)C^{0.65} \left[ 1 + 0.2 \exp(-\gamma_y(\lambda - 440)) \right] \\ + a_d(400) \exp(-\gamma_d(\lambda - 400))$$

where the first term accounts for the contribution of chlorophyll and other factors that correlate with chlorophyll, and the second term accounts for detrital material.  $a^*(\lambda)$  is a function determined empirically by Prieur and Sathyendranath<sup>4</sup> and modified by Morel<sup>5</sup>.  $C$  is the chlorophyll concentration in  $\text{mg}/\text{m}^3$  which can be set by the user, as can  $\gamma_y$ ,  $\gamma_d$ ,  $a_d(400)$ .

<sup>2</sup> Prior to HydroSoft 2.7,  $K_{bb}$  was reckoned including the contribution of pure water. Thus it, and  $k_1$ , differed considerably at different wavelengths and the value of  $k_1$  appropriate to each channel was included in the calibration file. Starting with version 2.7,  $K_{bb}$  is defined to include only attenuation above and beyond that of pure water.

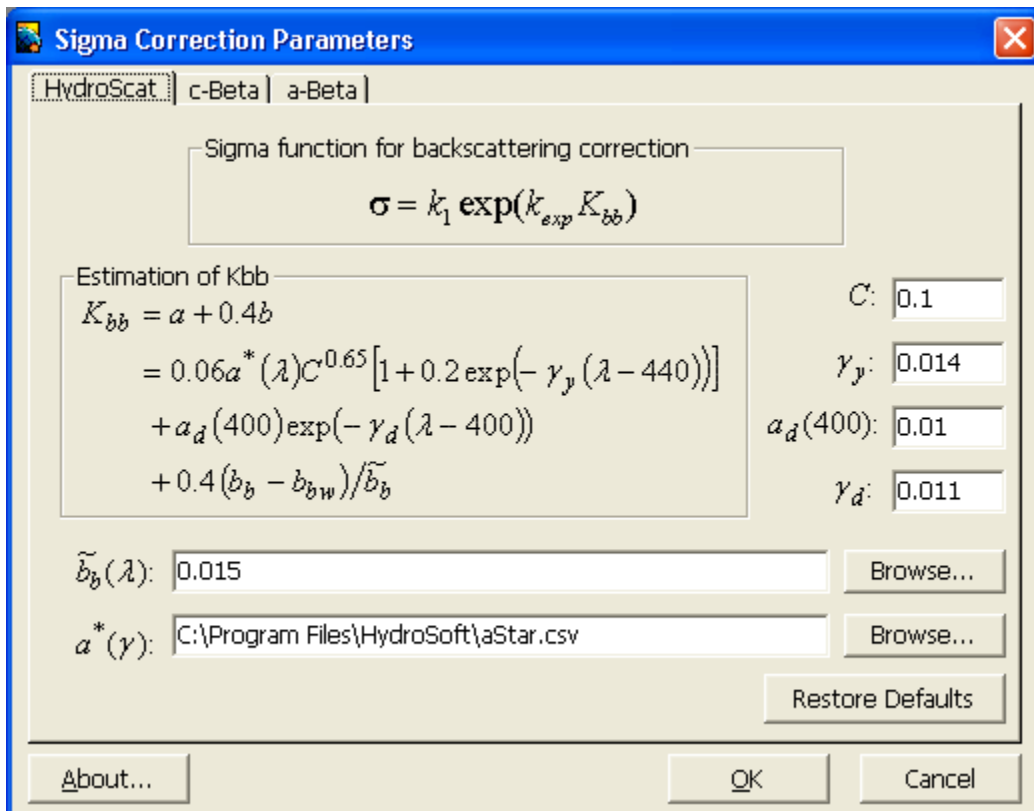
<sup>3</sup> Prior to HydroSoft 2.7, the equation for absorption also included a term for pure water.

<sup>4</sup> "An optical classification of coastal and oceanic waters based on the specific spectral absorption curves of phytoplankton pigments, dissolved organic matter, and other particulate materials, *Limnol. Oceanogr.*, 26(4), 671-689

<sup>5</sup> "Light marine photosynthesis: a spectral model with geochemical and climatological implications," *Prog. Oceanogr.*, 26, 263

$b$  is estimated from  $b = (b_{bu} - b_{bw}) / \tilde{b}_b$ , where  $\tilde{b}_b$  is the backscattering probability, which can be set by the user. The numerator of this expression is the uncorrected  $b_b$  excluding that of pure water.

The Sigma Correction Parameters dialog box is shown below, with typical settings for a HydroScat sensor. The default settings are appropriate for most cases. The main exception is it may be appropriate to adjust the value of  $C$  if Chlorophyll levels are high and can be estimated. HydroScats that are appropriately configured may provide this information, but the user must provide a calibration to translate the HydroScat's readings into Chlorophyll concentrations.



## 9.7. CAL file format

Note that not all the parameters included in the CAL file are needed for the calibration procedure described above. Some parameters not shown here may also appear, and the sequence of parameters may change, depending on the firmware version. Each line may also include a comment, preceded by a double slash (“//”).

```
[Start]
[General]          //Comment
Serial=HS991014
Config=W4B0R0F0S0I2
Label=U South Florida-4
CalTime=940441065 (10/20/99 17:37:45)
CalTemp=25.1
DepthCal=0.011509
DepthOff=27.776199

[Channel1]
Name=bb470
Gain1=0.105786
Gain2=1.000000
Gain3=9.814222
Gain4=97.364861
Gain5=994.677307
Mu=11.57230
Sigma1=0.998000      // not used by v2.7 and later
Sigma2=0.128000
Sigma3=0.012800
SigmaExp=.132
RNominal=8000
SOutOff=0.000000
SInOff=0.000000
ROutOff=0.000000
RNominal=10000.000000
Beta2Bb=6.790000
Bb2c=64.000000
TempCoeff=0.0013
Offset1=4
Offset2=51
Offset3=5
Offset4=3
Offset5=-15
NomOffset1=1748
NomOffset2=1704
NomOffset3=1747
NomOffset4=1743
NomOffset5=1730
```

F1Offset1=0  
F1Offset2=0  
F1Offset3=0  
F1Offset4=0  
F1Offset5=0

[Channel2, etc. in same format]

.

.

.

[End]



## 10. TROUBLESHOOTING

### 10.1. HydroScat-6 is unresponsive; HydroSoft is unable to detect it.

- Connect the battery charger or another external power source.
- Check that the HydroScat is properly connected to the computer.
- Select the Reset command from HydroSoft's Instrument (or HydroScat) menu, making sure that it is addressing the port to which the HydroScat is connected.
- Wait for 10 seconds after the reset completes, then attempt to reconnect.

### 10.2. HydroScat-6 still does not respond after the above steps.

- **Note that this procedure will erase any data in the HydroScat-6 RAM, but will not affect data in flash memory, if your instrument is so equipped.**
- If it is possible the battery is discharged, connect the charger for at least 5 minutes (but DO NOT repeatedly connect the charger if the battery fails to hold charge – this can cause damage).
- Disconnect the charger from AC power.
- Disconnect the charging cable from the HydroScat's underwater connector.
- Plug the battery-disconnect plug (designated by a red handle) into the HydroScat-6 for 10 seconds. If the special plug is not available, directly short together the battery disconnect and common pins on the bulkhead detector (see connector diagrams in section 6).
- Attempt to connect with HydroSoft.

### 10.3. Communication OK, but external switch does not function as expected.

- If you are powering the sensor from an external source, see the note in section 5.9.1.
- If switch operation is intermittent, look for signs of corrosion around the external actuator. If corrosion is evident, the magnet may be damaged.

#### **10.4. HydroScat-6 batteries do not sustain operation as long as expected.**

- Check for damage to the charger or charging cable.
- If the batteries do not respond to charging or their endurance is very short (less than an hour), **do not attempt to compensate with frequent or prolonged charging**. Drastically reduced capacity indicates a battery failure, and prolonged charging of a faulty battery can damage the instrument and possibly create hazardous venting from the batteries. Contact HOBI Labs about repairs.

## 11. CUSTOMER SERVICE

If your HydroScat-6 needs to be returned to HOBI Labs for repair, maintenance or calibration, contact HOBI Labs customer service ([service@hobilabs.com](mailto:service@hobilabs.com), or go to the support section at [www.hobilabs.com](http://www.hobilabs.com)) with the following information at hand:

- Instrument Serial Number
- Reason for return
- Method of return (Federal Express, United Parcel Service, etc.)
- Point of contact
- Date needed
- Delivery address

HOBI Labs will provide you with a returned material authorization (RMA) number so that your instrument will be properly identified when we receive it. PLEASE DO NOT RETURN ANY EQUIPMENT TO HOBI LABS WITHOUT AN RMA NUMBER.

As soon as possible after receiving the instrument, HOBI Labs will inspect it and provide you with an estimated cost for required or recommended repairs (if any). Repairs will not be started until you approve the cost estimate and turnaround time.

For technical support or questions about your instrument, contact our technical support department at [support@hobilabs.com](mailto:support@hobilabs.com), or consult the support section of [www.hobilabs.com](http://www.hobilabs.com).