SonTek®

YSI *incorporated*

FlowTracker®
Handheld ADV®
Technical Manual
Firmware Version 3.3
Software Version 2.20

featuring

SmartQC™

RECORD OF CHANGES

Effective	Description
31 AUG 2006	Initial release of Technical Manual after splitting old Operator's Manual into new Technical Manual and new Users Manual; CPU firmware version 3.0
15 NOV 2006	Support for CPU firmware version 3.1 and software version 2.10 added
05 JUL 2007	Support for CPU firmware version 3.3 and software version 2.20 added

$C\epsilon$ **Declaration of Conformity**

Manufacturer's Name: SonTek/YSI Inc.
Manufacturer's Address: 9940 Summers Ridge Road
                                       San Diego, CA 92121 U.S.A.

Sontek/YSI declares that the product(s):

Equipment Type: Water Velocity Measurement Device

Model: ADV Series

Product Name: Standard ADV 10MHz, Triton ADV 10MHz, Arg ADV
                                    10MHz, ADV 6600 10MHz, FlowTracker 10MHz, ADV
                                    Ocean 5MHz, ADV Field 16MHz.

Conforms to the following European Union Council Directives and Standards as of 7/21/04:

EMC DIRECTIVE 89/336/EEC: **-EN 61326 (1997), A1 (1998), A2 (2001), Class "A"**
                                         -EN 61000-3-2 (2000)
                                         -EN 61000-3-3 (1995)
                                         -IEC 61000-4-2 (1995), A1 (1998), A2 (2000)
                                         -IEC 61000-4-3 (2002), A1 (2002)
                                         -IEC 61000-4-4 (1995), A1 (2000), A2 (2001)
                                         -IEC 61000-4-5 (1995), A1 (2001)
                                         -IEC 61000-4-6 (1996), A1 (2000)
                                         -IEC 61000-4-11 (2001)

Director of Sales and Marketing,

Chris Ward

Release Notice

This is the July 2007 release of the *FlowTracker Handheld ADV Technical Manual*. During the creation of this manual, the following were the latest available versions of firmware/software. As such, if you are using different firmware/software versions, not all aspects of this manual may apply.

- FlowTracker firmware version 3.3
- *FlowTracker* software version 2.20

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The system you have purchased is covered under a one year limited warranty that extends to all parts and labor for any malfunction due to workmanship or errors in the manufacturing process. The warranty does not cover shortcomings that are due to the design, nor does it cover any form of incidental damage as a result of errors in the measurements.

If your system is not functioning properly, first try to identify the source of the problem. If additional support is required, we encourage you to contact us immediately, and we will work to resolve the problem as quickly as possible.

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Contact Information

Any questions, concerns, or suggestions can be directed to SonTek by telephone, fax, or email. Business hours are 8:00 a.m. to 5:00 p.m., Pacific Standard Time, Monday through Friday.

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<u>INTRODUCTION</u>

The FlowTracker® Handheld ADV® (Acoustic Doppler Velocimeter) featuring SmartQC™ provides the proven velocity performance of the SonTek ADV from a simple handheld interface. The FlowTracker is designed for a variety of current monitoring applications.

- River discharge measurements (using established USGS/ISO methods)
- Open-channel flow measurements
- Current measurements in large pipes
- Rapid, multi-point current surveys
- Current monitoring in water treatment facilities

Basic operation of the FlowTracker is described below.

- The FlowTracker is operated from a simple keypad interface, with instructions and real-time data displayed on an LCD screen. No PC is required for data collection.
- The system collects data for a fixed length of time at each location.
- For each location, you enter a few parameters to document the data set (e.g., location, water depth, measurement depth).
- For river discharge applications, these parameters are used with velocity data to compute discharge in real-time.
- All data are stored on an internal recorder. Later, you can download the data to a PC for additional processing, display, and archiving.

This operation manual is divided into the following sections.

- **Section 1 – Components, Terminology, Sampling, and Quality Control:** Definitions of terms used in this manual, and a description of all quality control parameters
- **Section 2 – Using the Keypad Interface:** Menus, setup parameters, and system functions accessed using the keypad interface
- **Section 3 – Getting Started: Operational Overview:** Basic instructions for collecting data with the FlowTracker
- **Section 4 – General Purpose Measurements:** How to use the FlowTracker to measure velocity at several locations
- **Section 5 – River Discharge Measurements:** How to make a river discharge measurement with the FlowTracker using USGS/ISO methods
- **Section 6 – PC Software:** Software used to download data files, extract data to readily usable ASCII format, and perform system diagnostics
- **Section 7 – Hardware:** Detailed descriptions of cables, connectors, and FlowTracker hardware and electronics
- **Section 8 – Operational Considerations:** Sensor mounting, velocity coordinate system, maintenance, and troubleshooting
- **Appendix A – FlowTracker Principles of Operation**
- **Appendix B – FlowTracker Direct Command Interface**
- **Appendix C – Discharge Uncertainty Calculation**
- **Appendix D – Multiple Language Keypads**

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Section 1. Components, Terminology, Sampling, and Quality Control

1.1. System Components

Figure 1 shows the FlowTracker with all major components labeled.

- **Probe** – The probe (Figure 2) contains the acoustic elements used to measure velocity. See the *FlowTracker Principles of Operation* for more information.
- **Probe cable** – The probe is mounted from a 200-cm (80-in) flexible cable. The probe cable is custom built and highly noise-sensitive; it must never be modified.
  - o A 300-cm (120-in) cable length is also available for specialized applications.
- **Handheld controller** – The handheld controller contains the processing electronics, batteries, keypad, and LCD screen. The controller is designed to withstand temporary submersion, but is not intended for underwater operation.
- **Keypad** – The FlowTracker keypad is designed for quick, efficient entry of data collection parameters and commands.
- **LCD screen** – The LCD screen displays instructions and real-time data.
- **External power/communication connector** – A waterproof connector on the bottom of the handheld controller connects to an external power/communication cable. This is used to download data from the FlowTracker to a PC. During data collection, the connector is sealed with a dummy cap.

Figure 1 – FlowTracker with 2D Probe

The following terms are commonly used with the FlowTracker probe (Figure 2).

- **Transmitter** – The acoustic transmitter generates a short pulse of sound with the majority of energy concentrated in a narrow beam (6 mm in diameter).
- **Receivers** – The acoustic receivers are mounted on arms from the central probe head. The receivers are sensitive to a narrow beam and are focused on a common volume located a fixed distance (10 cm; 4 in) from the probe. The FlowTracker uses two or three acoustic receivers for 2D or 3D probes (see §8.2).
- **Sampling volume** – The sampling volume is the physical location of the water velocity measurement. See the *FlowTracker Principles of Operation* for details.
- **Temperature sensor** – The temperature sensor is mounted inside the probe. Temperature data is used to compensate for changes in sound speed. Sound speed is used to convert the Doppler shift to water velocity. See §8.3 for details on the temperature sensor; see the *FlowTracker Principles of Operation* for details about the effect of sound speed on velocity data.
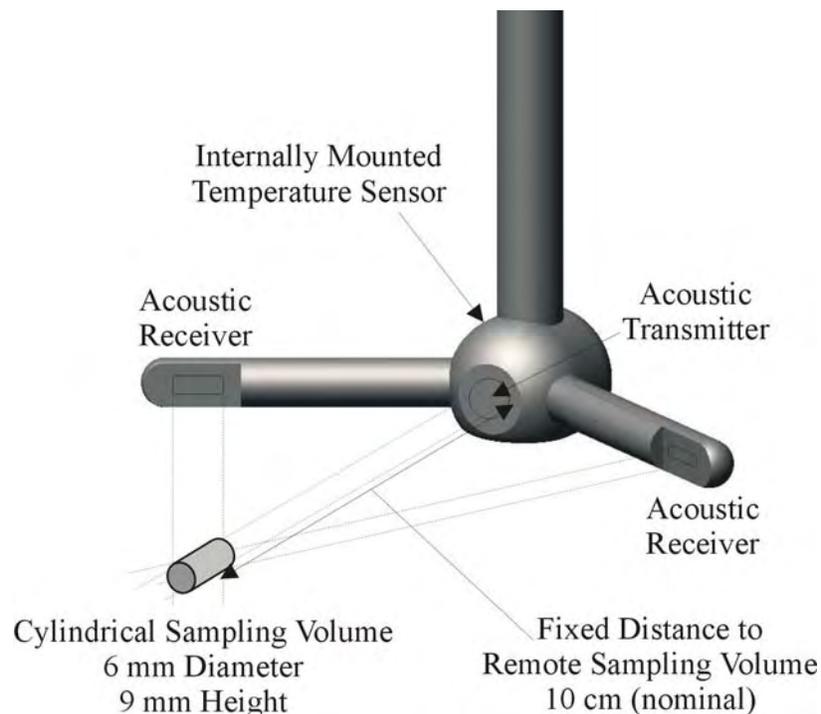
Figure 2 – 2D Side Looking FlowTracker Probe and Sampling Volume

1.2.   Definitions and Terminology

This section defines terms commonly used when working with the FlowTracker.

- **Keypad interface** – The FlowTracker is controlled from the keypad on the handheld controller. The LCD screen is used to display command options and real-time data.
- **External control** – The FlowTracker can be controlled by an external computer using the RS232 serial interface. This is accessed from the external power/communication connector. External control is used to download data from the internal recorder to a PC for further analysis, display, and archiving.
- **Quality control data** – In addition to velocity, the FlowTracker records several quality control parameters. These include signal-to-noise ratio (SNR), standard error of velocity, boundary adjustment, the number of spikes filtered from data, and velocity angle. For details about quality control data, see §1.4.
- **Signal strength** – This refers to the strength of the reflected acoustic signal. It is a function of the acoustic conditions of the water – primarily the amount and type of suspended material (scatterers) present. This is most commonly accessed as a signal-to-noise ratio (SNR).
- **Signal-to-noise ratio (SNR)** – SNR is the ratio of the received acoustic signal strength to the ambient noise level. It is expressed in logarithmic units (dB), and is the most important quality control data for the FlowTracker (§1.4).
- **Temperature** – Water temperature (in °C) is measured by the internal temperature sensor. Temperature is used for sound speed calculations.
- **Salinity** – Water salinity (in ppt) is a user-supplied value that is used for sound speed calculations. Note: If using the system in salt water, a zinc anode should be installed on the probe for corrosion protection (see §8.5.6).
- **Sound speed** – Speed of sound in water (in m/s) is used to convert the Doppler shift to velocity. See the *FlowTracker Principles of Operation* regarding the effect of sound speed on velocity data.

The FlowTracker has several QA/QC features designed to increase data integrity. Some of these features have bounds that can be set by the user, while others automatically adapt to the given situation. **SmartQC**™ refers to the collective ability of all these features towards helping you make a better measurement. Specific QA/QC features are identified in this manual with the **SmartQC** symbol.

1.3. Sampling Strategy

There are several terms specific to the FlowTracker sampling strategy.

- **Ping** – A single estimate of the 2D or 3D water velocity.
- **Ping rate** – The number of pings per second (Hz). The FlowTracker ping rate is 10 Hz.
- **Sample** – A sample refers to the mean of 10 pings to produce a measurement of the 2D or 3D water velocity. A sample includes velocity and signal strength data. The FlowTracker records one sample per second.
- **Averaging time** – The time (in seconds) in which the FlowTracker records data at each measurement location. This is a user-specified value from 10 to 1000 seconds.
- **Measurement location** – At each measurement location, the FlowTracker records one-second velocity data for the specified averaging time, location, and water depth parameters (to document the data set), and a variety of statistical and quality control data.

The basic FlowTracker data collection process, using the keypad interface, is described below.

- At the start of data collection, you are prompted for a file name.
- For **Discharge** measurements, you enter edge location data prior to data collection.
- At each measurement location, you specify location, water depth, and measurement depth data to document the data set. For **Discharge** measurements, these are used to calculate discharge in real-time.
- A fixed-length burst of velocity data is recorded at each measurement location. Velocity data is recorded once per second during the burst; mean velocity and quality control data are recorded at the end of each burst.
- Summary velocity and quality control data are displayed at the end of each measurement.
  - Quality control data is automatically reviewed. Values outside expected boundary limits generate a warning to the user.
  - You are allowed to repeat individual measurements if desired.
- The user proceeds through a series of measurement locations (up to 100 stations can be recorded with each file).
- You can scroll through previous stations to view data and edit station information.
- When done, you press **End Section** to close the file. For **Discharge** measurements, you enter ending-edge information and are then shown the final discharge data.

1.4. Quality Control Data SmartQC

The FlowTracker records quality control (QC) data with each measurement (Table 1-1). QC parameters are automatically reviewed with each measurement and at the completion of a discharge cross section (when the **End Section** key is pressed). If any value exceeds expected criteria, a warning is given. Table 1-2 lists different QC warning messages and gives guidelines for interpreting these messages. All QC review criteria can be adjusted or disabled.

1.4.1. Adjusting Quality Control Criteria SmartQC

All quality control criteria can be modified or disabled. To access quality control settings:

- From the **Main Menu**, press **1** for **Setup Parameters**.
- From **Setup Parameters**, select **4** for **QC Settings**.
  - o Select **1** to specify **SNR Threshold** (§1.4.2).
  - o Select **2** to specify **σV Threshold** (§1.4.3).
  - o Select **3** to specify **Spike Threshold** (§1.4.5).
  - o Select **4** to specify **Max Velocity Angle** (§1.4.6).
- From **Setup Parameters**, select **5** for **Discharge Settings**.
  - o Select **4** to specify **Max Section Discharge** (§1.4.7).
  - o Select **5** to specify **Max Depth Change** (§1.4.8).
  - o Select **6** to specify **Max Location Change** (§1.4.9).
- To disable any QC criteria, set that parameter to a value of **0**.

Table 1-1. Quality Control (QC) Parameters

Parameter	Description	Expected Values
SNR (§1.4.2)	**SNR** is the most important QC parameter. • It measures the strength of the acoustic reflection from particles in the water. • Without sufficient SNR, the FlowTracker cannot measure velocity.	Ideally > 10 dB Minimum ≥ 4 dB
σV (§1.4.3)	**σV** (standard error of velocity) is a direct measure of the accuracy of velocity data. • It includes the effects of turbulence in the river and instrument uncertainty.	Typically < 0.01m/s (0.03 ft/s). Higher in turbulent environment.
Boundary QC (§1.4.4)	**Boundary QC** evaluates the measurement environment for interference from underwater obstacles. • **FAIR** or **POOR** results may indicate significant interference from an underwater obstacle.	**BEST** or **GOOD**
Spikes (§1.4.5)	**Spikes** in FlowTracker velocity data are removed using a spike filter. • Some spikes are common and no cause for concern. • Too many spikes indicate a problem in the measurement environment (e.g., interference from underwater obstacles or highly aerated water).	Typically < 5% of total samples. Should be < 10% of total samples.
Angle (§1.4.6)	**Angle** is the direction of the measured velocity relative to the FlowTracker X-axis. • Used for discharge measurements only. • A good site should have small velocity angles. • Large angles may be unavoidable at some sites.	Ideally < 20º
%Q (§1.4.7)	**%Q** is the percentage of the total discharge in a single measurement station. • Most agencies have criteria for the maximum **%Q**.	Typical criteria: Ideally < 5% Maximum < 10%

Table 1-2. QC Warning Messages

Warning	QC Criteria	Description	Suggested Action
Low SNR (§1.4.2)	**None**	SNR < 4 dB	• Improve SNR (§8.6)
Beam SNR (§1.4.2)	**SNR Threshold**	Difference in SNR for any 2 beams is > **SNR Threshold**.	• Look for underwater obstacles; repeat measurement. • Check probe operation (§6.5).
SNR Variation (§1.4.2)	**None**	One-second SNR data varies more than expected during a measurement. May indicate underwater interference or a highly aerated environment.	• Look for underwater obstacles; repeat measurement. • Look for environmental sources (e.g., aerated water).
SNR Change (§1.4.2)	**SNR Threshold**	SNR more than **SNR Threshold** different previous measurements; major change in measurement conditions.	• Look for underwater obstacles or other changes in river condition. • Repeat measurement
High σV (§1.4.3)	**σV Threshold**	σV > **σV Threshold**; adjusted based on previous data and measured velocity. May indicate interference or a highly turbulent environment.	• Look for underwater obstacles or a change in conditions. • Consider real turbulence levels in river. • Repeat measurement.
Bad Boundary QC (§1.4.4)	**None**	**Boundary QC** is **FAIR** or **POOR**. Indicates possible interference from underwater obstacles.	• Consider re-locating probe and repeating test. • Measurement can proceed if results are consistent.
High Spikes (§1.4.5)	**Spike Threshold**	**Spikes** > **Spike Threshold** percent of samples. May indicate poor measurement conditions.	• Look for underwater obstacles or unusual conditions (e.g., aerated water). • Repeat measurement.
High Angle (§1.4.6)	**Max Velocity Angle**	**Angle** > **Max Velocity Angle**. May only indicate non-ideal measurement environment.	• Consider if measured angle is realistic. • Repeat measurement if needed.
High %Q (§1.4.7)	**Max Section Discharge**	**%Q** > **Max Section Discharge**. Station contains a large portion of the total discharge.	• Consider adding more stations.
Suspect Depth Value (§1.4.8)	**Max Depth Change**	Station depth differs from adjacent stations by more than **Max Depth Change** %. This may indicate a data entry problem.	• Verify station depth value. • Re-enter if needed.
Suspect Location Value (§1.4.9)	**Max Location Change**	Spacing between stations has changed by more than **Max Location Change** %. This may indicate a data entry problem.	• Verify station location value. • Re-enter if needed.
Location Out of Order / Location Outside Edge (§1.4.9)	**None**	Station location out of sequence or outside river edge. This may indicate a data entry problem.	• Verify station location value. • Re-enter if needed.

1.4.2. Signal-to-Noise Ratio (SNR) SmartQC

Signal-to-noise ratio (**SNR**) is a measure of the strength of the reflected acoustic signal relative to the ambient noise level of the FlowTracker. SNR is the most important quality control data provided by the FlowTracker.

- SNR is reported in logarithmic units (dB). It is recorded with each one-second velocity sample. Mean values are recorded for each measurement location.
- For the best operating conditions, SNR should be greater than 10 dB.
- The FlowTracker can operate reliably with SNR as low as 4 dB, although the noise in individual measurements will increase.
- The FlowTracker displays an alert at the end of a measurement if SNR of any beam is <4.0 dB. SNR data are displayed during the measurement and with the measurement summary.
  - o For 2D systems, if the SNR of either beam is low, this will affect all velocity data even if the other beam shows higher SNR values.
  - o For 2D/3D systems, if only the SNR of Beam 3 is low, vertical velocity data (Vz) are affected; the horizontal velocity data (Vx and Vy) may still be valid. This can occur if Beam 3 is out of the water in very shallow water.
- Low SNR indicates a lack of suspended material in the water. For clear water, seeding material can be introduced to increase SNR. Seeding is typically only required in large laboratory tanks. Most field applications have sufficient natural scattering material.
- The SNR data shown during data collection is the mean of the primary receivers (depending on the operating mode of the FlowTracker – either General or Discharge). Individual receiver data can be accessed after downloading the data file to a PC (see §6.3).
  - o General Mode: SNR is the mean of all receivers (2 or 3 depending on probe type).
  - o Discharge Mode: SNR is the mean of Receivers 1 and 2. Receiver 3, if installed, is not used in the mean calculation because we assume the probe is side-looking (either a 2D or 2D/3D probe), and only Vx and Vy are of interest. Receiver 3, which is only used for Vz, is irrelevant. Additionally, Receiver 3 can potentially be out of the water while Receivers 1 and 2 are submerged (and still collecting good data).

SNR data are evaluated as follows.

- SNR from all beams must be greater than 4 dB for reliable data collection.
  - o If any beam is below this threshold, an alert is given.
  - o These criteria cannot be disabled.
- The **SNR Threshold** (default 10 dB) is used for several additional tests.
  - o When the difference between any two beams is greater than **SNR Threshold**:
    - ▪ This may indicate interference from an underwater obstacle or a potential problem with the probe.
    - ▪ At the first alert, repeat the measurement (perhaps after moving probe location).
    - ▪ If the problem persists, run *BeamCheck* from a PC to evaluate FlowTracker operation in more detail (§6.5).
  - o When the variation of SNR during a measurement (as measured by the standard deviation SNR data) is greater than a fixed threshold of 5 dB:
    - ▪ This may indicate interference from an underwater obstacle, a highly turbulent environment, or highly aerated water.
    - ▪ At the first alert, repeat the measurement (perhaps after moving probe location).
    - ▪ If the problem persists, evaluate the measurement environment. In some cases, large variations may be unavoidable and may not impact the quality of velocity data.

- When SNR for a new measurement differs from the mean of all previous measurements in this file by more than **SNR Threshold**:
  - This may indicate interference from an underwater obstacle or some other dramatic change in stream conditions.
  - At the first alert, repeat the measurement (perhaps after moving probe location).
  - If the problem persists, evaluate the measurement environment to look for any potential cause for the change in SNR.
  - This criterion can be adjusted or disabled (by setting **SNR Threshold** to 0; §2.4.4).
- **SNR Threshold** is checked with each measurement and when the **End Section** key is pressed in **Discharge** mode.
  - You are notified of any stations that exceed the above criteria.
  - If desired, you can go back and delete suspect stations and repeat the measurements.

SNR is primarily a function of the amount and type of particulate matter in the water.

- While SNR cannot be immediately converted to sediment concentration, it provides an excellent qualitative picture of sediment fluctuations and, with proper calibration, SNR can be used to estimate sediment concentration. Contact SonTek for details.

1.4.3. Standard Error of Velocity (σV)   SmartQC

Standard error of velocity (**σV**) is a direct measure of the accuracy of the mean velocity data.

- **σV** can be directly interpreted as the accuracy of the mean velocity.
- **σV** is calculated by dividing the standard deviation of one-second samples by the square root of the number of samples.
- **σV** is normally dominated by real variations in the flow and will vary depending on the measurement environment (see *FlowTracker Principles of Operation*).
- **σV** shown during data collection is the standard error of Vx (**σVx**).

σVx is evaluated as follows.

- The standard error threshold for each measurement is the greater of the following:
  - **σV Threshold** (default 0.01 m/s / 0.033 ft/s).
  - If the mean **σVx** for all previous measurements is greater than **σV Threshold**, we use (**Mean σVx + σV Threshold**).
  - A fixed percentage (5%) of the X-velocity (high velocity has higher **σVx**).
- When **σVx** is greater than the standard error threshold for that measurement:
  - This may indicate interference from an underwater obstacle, a highly turbulent environment, or highly aerated water.
  - At the first alert, repeat the measurement (perhaps after moving probe location).
  - If the problem persists, evaluate the measurement environment. In some cases, large variations may be unavoidable (e.g., in highly turbulent waters).
- This criterion can be adjusted or disabled (by setting **σV Threshold** to 0; §2.4.4).
- **σV Threshold** is checked with each measurement and when the **End Section** key is pressed in **Discharge** mode.
  - You are notified of any stations that exceed the above criteria.
  - If desired, you can go back and delete suspect stations and repeat the measurements.

1.4.4. Boundary Adjustment (Boundary QC) SmartQC

The FlowTracker has a potential for acoustic interference from underwater objects. The system tries to avoid this interference, but you must be aware of system limitations.

- Reflections can occur from the bottom, the water surface, or submerged objects (e.g., rocks).
- The FlowTracker measures velocity in a sampling volume 10 cm (4 in) from the probe tip.
- If the sampling volume is on top of or beyond an underwater object, velocity data will be meaningless.

When working in very shallow water or near underwater obstacles (with the sampling volume within 15 cm (6 in) of the obstacle), acoustic reflections can potentially affect velocity data.

- At each measurement location, the FlowTracker looks for these conditions, and if necessary, adapts its operation to avoid interference.
- For most locations, any required changes do not affect system performance.
- In some environments, changes may result in a lower maximum velocity.

The FlowTracker records any changes required to avoid acoustic interference. It reports this as **Boundary QC**. This value describes the effect (if any) of boundary adjustments on performance. The **Boundary QC** variable (**Bnd**) can have the following values (0 and 1 are the most common).

- **0 (BEST)**: No boundary adjustments were necessary, or if necessary, they have minimal impact on system performance. Maximum velocity is at least 3.5 m/s (11 ft/s).
- **1 (GOOD)**: Minor boundary adjustments were necessary, with moderate impact on system performance. Maximum velocity is at least 2.5 m/s (8 ft/s).
- **2 (FAIR)**: Larger boundary adjustments were necessary, with notable impact on system performance. Maximum velocity is at least 1.2 m/s (4 ft/s).
- **3 (POOR)**: Major boundary adjustments were necessary, with significant impact on system performance. Maximum velocity is less than 1.2 m/s (4 ft/s). The FlowTracker will still provide good performance for lower flows.

The **Boundary QC** test looks for interference with underwater objects that are in or close to the FlowTracker sampling volume.

- If the **Boundary QC** results are **FAIR** or **POOR**, this indicates possible interference, and the FlowTracker will issue an alert before the measurement is made.
  - o You are prompted to consider moving the probe to avoid this interference.
  - o If the probe is moved, repeat the boundary test prior to data collection.
  - o If repeated **Boundary QC** tests do not give improved results, you can proceed with the measurement, but should carefully evaluate velocity data.

1.4.5. Spike Filtering SmartQC

Spikes in velocity data occur with any acoustic Doppler velocity sensor such as the FlowTracker. Spikes may have a variety of causes – large particles, air bubbles, or acoustic anomalies.

- Velocity data from each FlowTracker measurement are evaluated to look for spikes.
- The FlowTracker spike filter is a variation on a method called "Tukey's Outlier".
  - o A histogram of each velocity component is calculated.
  - o The FlowTracker determines the lower quartile (**Q1**; 25% of samples are less than this value), the upper quartile (**Q3**; 75% of samples are less than this value), and the inter quartile range (**IQR = Q3-Q1**).

- o If the **IQR** is less than 0.015 m/s, **IQR** is set to 0.015 m/s.
- o Any value less than (**Q1–2*IQR**) or greater than (**Q3+2*IQR**) is considered a spike and is not used for mean velocity calculations.
- Spikes are filtered based on all velocity components (Vx, Vy, and Vz). If any component falls outside the above limits, that sample is not used for the mean velocity calculation.
- The FlowTracker spike filter was updated with firmware version 3.0.
  - o The new filter commonly results in a greater number of spikes being identified.
  - o The greater number of spikes does not indicate a problem with FlowTracker operation, but just the effect of the new spike filter.
- The number of spikes is displayed and recorded at the end of each measurement.
- Raw, one-second velocity data are recorded with each measurement station. This allows you to evaluate unedited velocity data for each station.
- No other filtering or editing is done to FlowTracker velocity data.

The number of velocity spikes present in data is evaluated as follows.

- The **Spike Threshold** (default 10%) is used as follows.
  - o If the number of spikes is a greater percentage of the total number of points than specified by the **Spike Threshold**, a warning is given.
    - This may indicate interference from an underwater obstacle, a highly turbulent environment, or highly aerated water.
    - At the first alert, repeat the measurement (perhaps after moving probe location).
    - If the problem persists, evaluate the measurement environment – a large number of spikes may be unavoidable, but may not overly impact the quality of velocity data.
  - o This criterion can be adjusted or disabled (by setting **Spike Threshold** to 0; §2.4.4).
- **Spike Threshold** is checked with each measurement and when the **End Section** key is pressed in **Discharge** mode.
  - o You are notified of any stations that exceed the above criteria.
  - o If desired, you can go back and delete suspect stations and repeat the measurements.

1.4.6. Velocity Angle SmartQC

In **Discharge** mode, an additional quality control parameter is provided – *velocity angle*.

- Velocity angle is defined as the direction of flow relative to the X direction, and is calculated as `atan(Vy/Vx)`.
- For an ideal discharge measurement site, flow should be perpendicular to the tag line used to define the cross section.
- The FlowTracker's X-axis is always held perpendicular to the tag line.
- Only the X component of velocity (Vx) is used for discharge calculations. This ensures proper discharge measurements regardless of the flow direction.
- The ability of the FlowTracker to measure the 2D flow eliminates the need to estimate the flow direction with each measurement, as is required for most 1D current meters. This reduces a potential source for error in velocity measurements.
- An angle of 0° means flow direction is perpendicular to the tag line (as desired for an ideal measurement location).
- A good measurement site will typically show some flow variations, but with all angles less than about 20-30°.

The measured velocity angle is evaluated to ensure reliable data collection.

- The **Max Angle** criterion (default 20º) is used as follows.
  - Velocity angle is checked only if velocity is greater than a fixed threshold (0.02 m/s; 0.07 ft/s).
  - When measured angle is greater than **Max Angle**, a warning is given.
    - Evaluate the measurement site to verify the measured angle is reasonable.
    - Consider repeating the measurement if the angle does not appear reasonable (perhaps after moving probe location).
    - For large velocity angles, consider moving the measurement site.
  - This criterion can be adjusted or disabled (by setting **Max Angle** to 0; §2.4.4).
- **Max Angle** is active only in **Discharge** data collection mode.
- **Max Angle** is checked with each measurement and when the **End Section** key is pressed.
  - You are notified of any stations that exceed the above criterion.
  - If desired, you can go back and delete suspect stations and repeat the measurements.

1.4.7. Maximum Section Discharge SmartQC ✓

Most agencies monitoring discharge expect that no individual station should contain more than a certain percentage of the total discharge. The **Max Sect. Q** criterion (default 10%) alerts you if this standard is exceeded.

- **Max Sect. Q** is active only in **Discharge** data collection mode.
- If you have entered rated flow, the discharge from each station is checked against this rated value when the station is completed.
  - If the station discharge exceeds **Max Sect. Q** percent of the rated flow, a warning is issued; you are prompted to consider adding another station.
- **Max Sect. Q** is also checked when the **End Section** key is pressed.
  - You are warned if any station exceeds **Max Sect. Q** percent of total measured discharge.
  - If desired, you can go back and add more stations.
- This criterion can be adjusted or disabled (by setting **Max Sect. Q** to 0; §2.4.5).

1.4.8. Maximum Depth Change SmartQC ✓

The **Max Depth Change** criterion (default 50%) is intended to avoid data entry errors.

- **Max Depth Change** is active only in **Discharge** data collection mode.
- It is assumed that depth changes between stations will be gradual.
- If the entered depth is different from a reference by more than **Max Depth Change** (and at least 0.20 m; 0.66 ft) an alert is issued to be sure the depth was not incorrectly entered.
  - If only the previous station is available, the newly entered depth is compared to the depth from the previous station.
  - If depth data are available on both sides of this station, the newly entered depth is compared to an interpolated depth between the two adjacent stations.
  - You are prompted to verify the depth value or re-enter the depth.
  - This criterion can be adjusted or disabled (by setting **Max Depth Change** to 0; §2.4.5).
- **Max Depth Change** is also checked when the **End Section** key is pressed.
  - You are notified of any stations that exceed the **Max Depth Change** criterion, and are given the option to review all stations and modify any incorrectly entered data.

1.4.9. Maximum Location Change SmartQC

The **Max Location Change** criterion (default 100%) is intended to avoid data entry errors.

- **Max Location Change** is active only in **Discharge** data collection mode.
- It is assumed that the spacing of adjacent stations will be nearly constant across the river.
- If spacing between stations has changed by more than **Max Location Change**, an alert is issued to be sure the location was not incorrectly entered.
  - o A 100% **Max Location Change** means the new station spacing is more than two times the previous station spacing.
  - o This criterion can be adjusted or disabled (by setting **Max Location Change** to 0; §2.4.5).
- Any time a station location is changed, the location is compared to adjacent value(s) to see if the station is out of order.
  - o If the station is out of order, an alert is issued to ensure the location has been correctly entered.
  - o Collecting an out-of-order station is allowed. However, when an out-of-order station is entered we verify the location value since the station is sorted into the correct place within the stream.
- Any time a station location is changed, the location is compared to the starting edge location. If the new location is outside the starting edge, a warning is given.

Section 2. Using the Keypad Interface, Menus, and Display

This section describes FlowTracker's keypad interface, its menus, and the LCD display.

2.1. On/Off Switch

The **On/Off** power button is in the upper left hand corner of the keypad.

- To turn the system on, hold the button for one second until the LCD screen turns on.
- To turn the system off, hold the button for four seconds until the LCD screen resets.
- The FlowTracker draws a small amount of current when off (< 1 mA).

  o If the system is to be left idle for a long period (more than 1 month), remove the batteries to prevent unnecessary draining and potential battery leakage.

<div align="center">

IMPORTANT

</div>

Always return to the Main Menu <u>before</u> turning the system off to ensure all data has been properly saved (see last step in §4.2.2 and §5.3.2).

2.2. Keypad

Figure 3 – FlowTracker Keypad

Figure 3 shows the FlowTracker keypad.

- The function of each key is described below. Many keys have multiple functions.
- Keys are described starting at the top left, moving right and down by rows.
- Keypad overlays are available in languages supported by the FlowTracker (Appendix D).

Note: In June 2006, there were significant changes to the keypad with firmware version 3.0. A customized overlay for the keypad is available for older systems.

Numbers (0-9) | . | –
- These keys are used to enter information when prompted by the FlowTracker for:
   o Menu selections
   o Filename and extension
   o Station location, depth, and other information

Letters (A-Z)
- These keys are used to enter text for the filename and for comments in the file.
- Text entry is done in the same manner as for mobile phones. For file names, the text entry assumes numbers first (i.e., for "C" press **2** button four times **2** – **A** – **B** – **C**); for all other text, it assumes letters first (i.e. for "C" press **2** button three times **A** – **B** – **C**)

On/Off ⏻

- To turn the system on, press and hold the key for one second until the LCD screen turns on.
- To turn the system off, press and hold the key for four seconds until the LCD screen resets.

IMPORTANT
Always return to the Main Menu <u>before</u> turning the system off to ensure all data has been properly saved (see last step in §4.2.2 and §5.3.2).

Back Light 🔆

- This key turns the LCD backlight on/off.
    - o If the backlight is already on, it turns the backlight off.
    - o The backlight will turn off automatically after 1 minute.
- Minimize backlight use to increase battery life (the backlight doubles power consumption).

Delete ←

- This key deletes the last character when entering parameters, and is used for deleting stations from a file.

Measure

- This key starts a measurement.
    - o It works identically in both **Discharge** and **General** data collection modes.
    - o It is only active if the FlowTracker is displaying the current station information screen. It is not active when displaying data from a previous measurement.

Corr. Factor

- This key is used to enter special correction factors.
    - o The correction factor is used only in the **Discharge** mode.
    - o The correction factor is only used for certain situations, described in §5.2.4.

Next Station

- This key is used to view the next station when scrolling through completed stations.
    - o It works identically in both **Discharge** and **General** data collection modes.
    - o It is not active during a measurement, nor from the time **Measure** is used to start a station until the time the last measurement for that station is completed.
    - o In **Discharge** mode, stations are sorted/displayed by location (regardless of the order in which they were collected).
    - o In **General** mode, stations are displayed in the order they were collected.

Set Velocity

- This key is used to enter a user-estimated velocity.
    - o It is active only in **Discharge** mode for stations using the **Input V** method (§5.2.4).

Set Location

- This key is used to set the measurement location.
    - o It sets the location value (**Loc**) in **Discharge** mode.
    - o It sets both the location 1 and location 2 values (**L1 / L2**) in **General** mode.
    - o It can be used either for the current station (before the measurement) or to edit data from a previous station.

LEW / REW
- This key is used to specify the starting or ending edge of water.
  - o It is used only in the **Discharge** mode.
  - o **LEW** means "Left Edge of Water"; **REW** means "Right Edge of Water".
  - o This is only used to document the data set and has no impact on calculations.

Prev. Station
- This key is used to view the previous station when scrolling through completed stations.
  - o It works identically in both **Discharge** and **General** data collection modes.
  - o It is not active during a measurement, nor from the time **Measure** is used to start a station until the time the last measurement for that station is complete.
  - o In **Discharge** mode, stations are sorted/displayed by location (regardless of the order in which they were collected).
  - o In **Discharge** data collection mode, it will scroll past station 1 to the starting edge and starting gauge information.
  - o In **General** mode, stations are displayed in the order they were collected.

Set Meas Depth
- This key is used to set the measurement depth.
  - o It is active in **General** mode and in **Discharge** mode only when using the **Multi Point** method (§5.2.4).
  - o It sets the measurement depth value (**MDep**).
  - o It can be used either for the current station (before the measurement) or to edit data from a previous measurement.

Set Depth
- This key is used to set the water depth (**Dep**).
  - o It works identically in both **Discharge** and **General** data collection modes.
  - o It can be used either for the current station (before the measurement) or to edit data from a previous station.

Set Ice Depth
- This key is used to set the ice depth.
  - o It is active only in **Discharge** mode.
  - o It sets the ice depth value (**Idep**) as measured from the water surface to the bottom of the ice.
  - o It can be used either for the current station (before the measurement) or to edit data from a previous station.

QC Menu SmartQC
- This key is used access the **QC Menu** during data collection (§2.6).
  - o It works identically in both **Discharge** and **General** data collection modes.
  - o The **QC Menu** includes the following functions.
    - ▪ Input supplemental data (gauge height, rated flow, and comments).
    - ▪ Accessing **QC Settings** and **Discharge Settings** (§2.4.4 and §2.4.5).
    - ▪ Changing the averaging time for each measurement.
    - ▪ Display raw velocity data (§2.5.6).
    - ▪ Run the automatic QC test (§2.5.7).

Method –
- This key sets the method used for calculating the mean velocity in discharge measurements.
  - It is active only in **Discharge** mode.
  - See a description of all methods in §5.2.
  - This key changes the method to the previous method in the list.

Method +
- This key sets the method used for calculating the mean velocity in discharge measurements.
  - It is active only in **Discharge** mode.
  - See a description of all methods in §5.2.
  - This key changes the method to the next method in the list.

Abort
- This key is used to stop data collection during a measurement.
  - It works identically in both **Discharge** and **General** data collection modes.
  - It is active only when the system is collecting velocity data.
  - After pressing **Abort**, it can take 1-2 seconds to stop data collection.
  - The FlowTracker will display a message saying that data collection was aborted and how much data were collected.
  - You can accept the aborted measurement (using the mean values of the data that were collected) or repeat the measurement.

Calculate Disch.
- This key tells the FlowTracker to perform the final discharge calculation.
  - It is active only in **Discharge** mode.
  - It is active only when all stations have been completed, and the **End Section** key has been pressed to enter the ending edge information.
  - It is active only when the ending edge screen is displayed.
  - The system will display a series of discharge screens showing final discharge data.

End Section
- This key is used to end a series of measurements.
- In **General** mode, it ends the series of measurements and displays the summary of all data collected.
  - It is active only when the current station (not yet measured) is displayed.
  - It takes a few seconds for the file to be closed before displaying the summary.
- In **Discharge** mode, this indicates that all stations have been collected.
  - It ends the section and displays the ending edge screen. After this data has been entered, the final discharge calculation can be done.
  - It is active only when the current station (not yet measured) is displayed.

ENTER
- This key serves several functions and works identically in both **Discharge** and **General** data collection modes.
  - It is used to complete the entry of any user parameter.
  - It is used to toggle between multiple display screens when available.
  - It is used to acknowledge a FlowTracker system message.

2.3. Main Menu

When turned on, the FlowTracker displays a wake up screen showing the firmware version and
the date/time from the system clock (continually updating).

```
   FlowTracker 3.0
2006/06/01  08:10:25
     Press Enter
    For Main Menu
```

Pressing **Enter** displays the **Main Menu**.

```
       Main Menu
1:Setup Parameters
2:System Functions
3:Start Data Run
```

From the **Main Menu**, press the appropriate key to access the desired function.

- Press **1** for the **Setup Parameters Menu** (§2.4).
- Press **2** for the **System Functions Menu** (§2.5).
- Press **3** to start a data run (§2.7).

<div align="center">

IMPORTANT
**Always return to the Main Menu <u>before</u> turning the system off to ensure all data has been
properly saved (see last step in §4.2.2 and §5.3.2).**

</div>

2.4. Setup Parameters Menu (Main Menu <1>)

Setup parameters determine how the FlowTracker collects data. This section describes each item in the **Setup Parameters Menu**.

```
1:Units English        4:QC Settings          7:Language English
2:Avg Time (40)        5:Discharge Settings
3:Mode Discharge       6:Salinity (0.00)
0=Exit or Enter=More   0=Exit or Enter=More   0=Exit or Enter=More
```

- The **Setup Parameters Menu** is shown above (three screens are needed to show all options).
- Press **Enter** to cycle through the screens.
- To change a setting, press the appropriate menu number.

2.4.1. Units System (Setup Parameters <1>)

The **Units** option defines the units system used for display and output data (**English** or **Metric**).

- The units system does not affect internal calculations or storage (internal units are metric).
- To change the units system, press **1** from the **Setup Parameters Menu**, and then:
  - Press **1** for **English** units.
  - Press **2** for **Metric** units.
- Table 2-1 lists the units that are used for display.

Table 2-1. FlowTracker Display Units

Parameter	English Units	Metric Units
Location	feet	meters
Depth	feet	meters
Velocity	ft/s	m/s
Standard error of velocity (σV)	ft/s	m/s
Staff/gauge height	feet	meters
Discharge	ft^3/s	m^3/s
SNR	dB	dB

2.4.2. Averaging Time (Setup Parameters <2>)

The **Avg Time** (averaging time) option specifies the amount of data (in seconds) to be collected at each measurement site.

- Averaging time is specified in 1-second intervals from 10 to 1000 seconds.
  - To change the averaging time, press **2** from the **Setup Parameters Menu**.

2.4.3. Data Collection Mode (Setup Parameters <3>)

The **Mode** option determines the procedure when collecting a series of measurement stations.

- To change the data collection mode, press **3** from the **Setup Parameters Menu**, and then:
  - Press **1** for **Discharge** mode.
  - Press **2** for **General** mode.
- **Discharge Mode**
  - In **Discharge** mode, a sequence of measurements is used to calculate river discharge.
  - See Section 5 for a complete description of discharge measurements.

- **General Mode**
  - o In **General** mode, no additional calculations are made by the FlowTracker.
  - o Location and depth information are recorded to document the data set.
  - o See Section 3 for a complete description of general measurements.

2.4.4. QC Settings (Setup Parameters <4>) SmartQC

The **QC Settings** menu sets universal quality control criteria (**Discharge** or **General** mode).

- To access the **QC Settings** menu, press **4** from the **Setup Parameters Menu**, and then:
  - o Press **1** to set the **SNR Threshold** (§1.4.2).
  - o Press **2** to set the **σV Threshold** (§1.4.3).
  - o Press **3** to set the **Spike Threshold** (§1.4.5).
  - o Press **4** to set **Max Velocity Angle** (§1.4.6).

2.4.5. Discharge Settings (Setup Parameters <5>)

The **Discharge Settings** menu specifies settings for the discharge calculations and the quality control criteria used for **Discharge** measurements.

- To access the **Discharge Settings** menu, press **5** from the **Setup Parameters Menu**. You can also access **Discharge Settings** by pressing **3** from the **QC Menu**. (Although options **1**, **2**, and **3** are not available when a data file is open.)
  - o Press **1** to set the discharge **Equation** (§5.2).
    - ▪ Press **1** to select **Mid Section**.
      - - Selecting this option sets **Repeat Depth** and **Repeat Velocity** to **NO**.
    - ▪ Press **2** to select **Mean Section**.
      - - Selecting this option sets **Repeat Depth** and **Repeat Velocity** to **NO**.
    - ▪ Press **3** to select **Japanese**.
      - - The **Japanese** equation normally involves repeating each depth and velocity measurement. This option sets **Repeat Depth** and **Repeat Velocity** to **YES**.
  - o Press **2** to toggle **Repeat Depth** (§5.2) between **YES/NO**.
    - ▪ This option is normally used with the Japanese method, and involves recording each depth value two times – once when going across the river and a second time when returning. The mean of these two readings is used.
  - o Press **3** to toggle **Repeat Velocity** (§5.2) between **YES/NO**.
    - ▪ This option is normally used with the Japanese method, and involves measuring each velocity value two times in a row. The mean of these two readings is used.
  - o Press **4** to set **Max Section Discharge** (§1.4.7).
  - o Press **5** to set **Max Depth Change** (§1.4.8).
  - o Press **6** to set **Max Location Change** (§1.4.9).
  - o Press **7** to set the discharge **Reference** value.
    - ▪ The section discharge (**%Q**) displayed for each station can be calculated based either on the user-supplied **Rated** discharge or the total **Measured** discharge.
    - ▪ Select the desired reference, **Rated** or **Measured**.
    - ▪ The default is **Rated**. If no **Rated** value is specified, the **Measured** value is used.
  - o Press **8** to select the **Methods Displayed**.
    - ▪ The FlowTracker supports several methods to determine mean velocity (§5.2.4). The method determines the number and location of velocity measurements.
    - ▪ You scroll through available methods using the **Method+** and **Method–** keys.

- If some methods will never be used, you can remove those methods from display (reducing the number of methods to scroll through).
  - Press **1** to toggle **2-6-8 Methods** (**0.6**, **0.2/0.8**, **0.8/0.2**, **.2/.6/.8**, **.8/.6/.2**) on/off.
  - Press **2** to toggle **Ice Methods** (**Ice 0.6**, **Ice 0.5**, **Ice 2/8**, **Ice 8/2**) on/off.
  - Press **3** to toggle **Kreps Methods** (**Kreps 2-**, **Kreps 2+**) on/off.
  - Press **4** to toggle **2-6-8 Methods** (**5 Point-**, **5 Point+**) on/off.
  - Press **5** to toggle **Multi Methods** (**Multi Pt**) on/off.
  - o Press **9** to select the **Uncertainty** calculation.
    - The FlowTracker supports 2 uncertainty calculations: Statistical and ISO. Each provides an estimate of the uncertainty of each discharge calculation.
    - Refer to §5.2.5 and Appendix C for details about each calculation type.

2.4.6. Salinity (Setup Parameters <6>)

The **Salinity** option specifies the salinity value (in ppt) used to compute sound speed.

- To change salinity, press **6** from the **Setup Parameters Menu**, and then:
  - o Enter the desired salinity value in ppt.
- Sound speed is used in Doppler velocity calculations (see *FlowTracker Principles of Operation* for details).
- Salinity is specified in parts per thousand (ppt). Fresh water has a salinity of 0; seawater typically has a salinity of about 35 ppt.
- As a rule of thumb, a 12-ppt error in the value of salinity will result in a 1% error in sound speed, which results in a 2% error in velocity data.
- Salinity should be specified as accurately as possible for each location.

IMPORTANT: When using the FlowTracker in salt water, a sacrificial zinc anode should be installed on the probe for corrosion protection (see §8.5.6).

2.4.7. Language (Setup Parameters <7>)

The FlowTracker firmware can operate in five different languages. Keypad labels are changed for compatibility with each language; keypad overlays are available on request for each language (and are included with each system shipped outside the United States and Canada).

- To change the language, press **7** from the **Setup Parameters Menu**:
  - o Press **1** for **English**.
  - o Press **2** for **Spanish**.
  - o Press **3** for **French**.
  - o Press **4** for **German**.
  - o Press **5** for **Italian**.

2.5.   System Functions Menu (Main Menu <2>)

The **System Functions Menu** provides access to items that should be checked periodically, but do not directly effect how data is collected. This section describes those items.

```
1:View Data File      4:Temperature Data    7:Auto QC Test
2:Recorder Status     5:Battery Data        8:Show Config
3:Format Recorder     6:Raw Velocity Data   9:Set System Clock
0=Exit or Enter=More  0=Exit or Enter=More  0=Exit or Enter=More
```

- Three screens (above) are needed to show all items.
- Press **Enter** to switch between screens.
- To change a setting, press the number shown.

2.5.1. View Data File (System Functions <1>)

The **View Data File** option allows you to view data files stored on the internal recorder.

- To view a data file stored on the internal recorder, press **1** in the **System Functions Menu**.
- The FlowTracker will display a menu of the files on the internal recorder. At most, three files are displayed on each screen.

```
31532.111    Press 1
12342.05     Press 2
872663.310   Press 3
0=Exit or Enter=More
```

- o Use **Enter** to scroll through the entire recorder directory (three files at a time).
- o Press **1**, **2**, or **3** to select the desired file.
- o Press **0** to exit the **View Data File** option without loading a file.
- After loading the file, the FlowTracker displays a summary of the data file.
  - o The summary is the same one used at the end of data collection for **General Mode** (§4.2.2) or **Discharge Mode** data collection (§5.3.2).
  - o Press **Enter** to move between the different summary display screens.
  - o Press **Previous Station** from any file summary screen to view station data.
  - o Use **Next Station** and **Previous Station** to scroll through station data (no new measurements can be added). The same station display screens are available as those used during data collection. Press **Enter** to scroll through the station data screens.
  - o Pressing **Next Station** from the last station returns you to the file summary screens.
  - o When done, press **0** to exit and return to the main menu. The **0** key is only active when the display is showing the summary data. If you have scrolled back to a previous station to view data, you will not be able to exit until you scroll forward to the summary data screen.

2.5.2. Check Recorder Status (System Functions <2>)

The **Recorder Status** option displays the number of files stored on the internal recorder, and the number of files remaining.

- To view the status of the recorder, press **2** from the **System Functions Menu**. Press any key to return to the main menu.
- The FlowTracker will have either a 2-MB or 4-MB recorder.
  - o Systems produced before about February 2002 have a 2-MB recorder. The 2-MB recorder stores at most 32 data files.
  - o Systems produced after about February 2002 have a 4-MB recorder. The 4-MB recorder stores at most 64 data files.
- The recorder is divided into blocks of 64 KB per block. No more than one file can be stored per block, but one file can occupy more than one block.
- Most data files will fit within one block. Larger data files will occupy multiple blocks (and reduce the total number of files that will fit on the recorder).
- The system will not allow you to collect data if the recorder is full.
- If recorder space is low (three or less blocks remaining), the system will prompt you at the start of a data run to see if you wish to format the recorder before data collection.

2.5.3. Format Recorder (System Functions <3>)

The **Format Recorder** option erases all data on the internal recorder.

- To format the recorder, press **3** from the **System Functions Menu**.
- The system will prompt you to enter **123** to confirm your decision to format (erase) the recorder. Entering any other value will abort the formatting process.
- Be certain that all data has been downloaded <u>before</u> formatting the recorder; data cannot be recovered after the recorder is formatted.
- Recorder formatting takes 20-60 seconds to complete.

2.5.4. Temperature Data (System Functions <4>)

The **Temperature Data** option displays the current temperature sensor data.

- To view temperature data, press **4** from the **System Functions Menu**. Press any key to return to the main menu.
- The temperature sensor is in the probe head and is accurate to ±0.1°C.

2.5.5. Battery Data (System Functions <5>)

The **Battery Data** option shows the current battery voltage and an estimate of remaining capacity.

```
   Battery 9.7 V
    Alkaline 75%
NiMH 80%  NiCad 90%
    Press Enter
```

- To view battery data, press **5** from the **System Functions Menu**. Press any key to return to the main menu.
- An estimate of remaining capacity (as a percent of total) is given for three battery types. The FlowTracker does <u>not</u> know what type of batteries are installed. Typical capacities:
  - o Alkaline: ≈25 hours
  - o NiMH: ≈15 hours
  - o NiCad: ≈7 hours
- **Battery capacity estimates are based on voltage and are only approximate.**
- **Cold weather can greatly affect battery voltage and capacity; always check battery voltage after the system has acclimated to outside temperatures.**
- See §7.2 for more information about battery types and expected battery life.

2.5.6. Raw Velocity Data (System Functions <6>)

The **Raw Velocity Data** option shows a continuous display of raw velocity and SNR data.

- To display raw data, press **6** from the **System Functions Menu**.
  - o This can also be accessed by pressing **5** from the **QC Menu**.
- Press any key to exit the raw velocity display.
- This can be done as a quick test <u>before</u> data collection or to check stream conditions during data collection.
  - o Data displayed during this function are not recorded.
- Velocity and SNR data are updated once per second.
- Velocity data can be expected to show notable variations (most of which are real), and should be indicative of the general conditions in the water.
- SNR is primarily a function of the amount of particulate matter in the water. For good conditions, SNR should be at least 10 dB. The system can operate effectively with SNR as low as 2-3 dB, although the noise in individual velocity measurements will increase.

2.5.7. Automatic QC Test (System Functions <7>) SmartQC

The Auto QC Test is an automated version of the *BeamCheck* software described in §6.5.

- This test can be run in three ways:
  - o When you are prompted to run this test at the start of each data file.
  - o When you press **7** from the **System Functions** menu.
  - o When you press **6** from the **QC Menu**.
- Follow the instructions on the LCD.
- When the test is done while a data file is open, results are recorded with the file.
- Place the probe in moving water well away from any underwater obstacles.
  - o The FlowTracker collects data for about 30 seconds.
  - o The data are analyzed based on several criteria:

- Noise level
  - Measured electronics noise level is compared to reference data. Any significant deviation causes a warning.
  - A large change in noise level may indicate damage to the probe.
- SNR
  - The SNR is checked as sufficient for reliable data collection.
  - Each beam SNR is compared to be sure all beams perform equally.
  - A warning is issued for low SNR or if beam SNR values differ.
- Peak shape
  - The shape of the sampling volume curve is compared to the expected shape. Any significant deviation causes a warning.
  - This criterion can only be checked with sufficient SNR (> 7 dB).
- Peak location
  - The physical location of the sampling volume is compared to the expected location. Any significant deviation causes a warning.
  - This criterion can only be checked for sufficient SNR (> 7 dB).
- If any warnings are issued, you are given the option to repeat the test.
  - We recommend repeating the test at least once, after you verify that the probe and sampling volume are well away from any underwater obstacles.
  - If multiple warnings are received, run *BeamCheck* from a PC (§6.5) to evaluate Flow-Tracker performance in more detail.

2.5.8. Show System Configuration (System Functions <8>)

The **Show Config** option displays basic system configuration information.

- To display system configuration information, press **8** from the **System Functions Menu**. Press any key to return to the main menu. Displayed items include:
  - Firmware version number
  - Serial number
  - Probe type
    - **Side XY 10cm** indicates a side-looking 2D probe.
    - **Side XYZ 10cm** indicates a side-looking 2D/3D probe.
    - **Down XYZ 10cm** indicates a down-looking 3D probe.

2.5.9. Set System Clock (System Functions <9>)

The **Set System Clock** option displays the date and time (continually updated) from the Flow-Tracker's internal clock.

- To change the date/time, press **9** from the **System Functions Menu**, and then:
  - Follow the menu options to change the date or time.

2.6. QC Menu SmartQC

The **QC Menu** is accessed only during data collection by pressing the **QC Menu** key (in either **Discharge** or **General** mode). It provides access to several functions.

- Input supplemental data
  - o Supplemental data is provided to allow you to further document that data set.
  - o Up to 20 different supplemental data records can be included with each file.
  - o Each record can include gauge height, rated flow, user comments, a time stamp and a location stamp.
    - ▪ The time stamp and location stamp are automatically generated with any gauge height, rated flow, or comment entries, but can be edited.
  - o Data in all records can be viewed and modified following the on-screen instructions in the **QC Menu**.
- Modify **QC Settings** (§2.4.4).
- Modify **Discharge Settings** (§2.4.5) (**Discharge** mode only).
- Change the averaging time (**Avg Time**) used for each measurement.
- Display **Raw Velocity Data** (§2.5.6) from the FlowTracker without recording to a file.
  - o One possible use for this function is to use the FlowTracker to locate the bottom of a slush layer under ice.
- Run and record an additional **Auto QC Test** (§2.5.7).

2.7. Start Data Run (Main Menu <3>)

Pressing **3** from the main menu starts a data collection run. The procedure for data collection will vary depending on the data collection mode setting (**Discharge** or **General**).

- For a detailed description of the **General** data collection procedures, see Section 4.
- For a detailed description of **Discharge** measurement procedures, see Section 5.

IMPORTANT
Always return to the Main Menu <u>before</u> turning the system off to ensure all data has been properly saved (see last step in §4.2.2 and §5.3.2).

Section 3. Getting Started: Operational Overview

For both the first-time user and the seasoned veteran, this section provides an operational overview of how to get your FlowTracker up and running.

3.1.   Power

- The FlowTracker operates on 6 to 15 VDC input power typically supplied by internal batteries. **CAUTION:** Voltages greater than 15 VDC will seriously damage the electronics.
- Ensure adequate power is available before starting a data collection run (see §2.5.5).
- See §7.2 for details about installing and checking batteries.
- An external power supply can be used; see §7.1.2.

3.2.   Pre-Deployment Diagnostics

Simple diagnostic procedures are provided to verify system operation.

- One procedure requires an external PC and should be performed before every extended field trip (or about once per week) – see §3.2.1.
- Other procedures, requiring only a few minutes, can be performed in the field from the keypad interface. These should be performed before each data run – see §3.2.2.

3.2.1. Office Diagnostic Procedures

The system software includes a program named *BeamCheck*.

- *BeamCheck* lets you evaluate all aspects of system performance and should be run before an extended field trip (about once per week).
- Using *BeamCheck* for the first time will require about 30 minutes; experienced users should need about 5 minutes.
- The system must be connected to an external PC. *BeamCheck* details are described in §6.5.

3.2.2. Field Diagnostic Procedures

Several diagnostic functions are available from the **System Functions Menu** (press **2** from the **Main Menu**). Field diagnostics should be run before every data collection run.

Recorder Status (**2** in **System Functions Menu**)
- The FlowTracker internal recorder can store up to 32 files (2-MB recorder) or 64 files (4-MB recorder).
- Check recorder status before each data collection run. Download data and format the recorder as needed (§2.5.2).

Temperature Data (**4** in **System Functions Menu**)
- Temperature data is used for sound speed calculations and can affect velocity data.
- Check temperature data to be sure it is reasonable for the environment.

Battery Data (**5** in **System Functions Menu**)
- An estimate of remaining capacity (as a percent of total) is given for three battery types. The FlowTracker does <u>not</u> know what type of batteries are installed.
- Typical expected life from fully-charged batteries:
    - o Alkaline: ≈25 hours
    - o NiMH: ≈15 hours
    - o NiCad: ≈7 hours

- These battery life estimates are at ~20° C (70° F). Cold weather will have a significant effect on voltage and capacity.
- See §7.2 for more information about battery types and expected battery life.

Display Raw Data (**6** in **System Functions Menu**)
- Place the probe in the area to be measured.
- This displays raw velocity and SNR data, updated once per second.
  - o SNR data should ideally be above 10 (units are dB), but measurements can be made as low as 3-4 dB.
  - o Velocity data should appear reasonable for the environment (short term variations are expected and are most likely real).
- See §2.5.6 for more information about the raw data display.

Auto QC Test (**7** in **System Functions Menu**) SmartQC
- You will be prompted to run this test at the start of each data file. When done collecting data, test results are recorded with the data file. The test can also be run directly from the **System Functions Menu**, although test results are not recorded.
- Place the probe in moving water well away from any underwater obstacles; follow the on screen instructions for the test.
- See §2.5.7 for more information about the automatic QC test.

System Clock (**9** in **System Functions Menu**)
- The FlowTracker uses an internal clock to record time information for all measurements.
- Verify the clock is correctly set before each data collection run. Change date/time as needed from this menu.

3.3. Data Collection Modes

The FlowTracker has two data collection modes that affect how the system collects data.

- **Discharge Mode** assumes you are measuring discharge in a river/stream. This mode follows established discharge measurement procedures. Details about this mode are in Section 5.
- **General Mode** is intended for a general series of measurements; the FlowTracker makes no calculations based on the data. Details about this mode are in Section 4.

You can switch between data collection modes using the **Setup Parameters Menu** (§2.4.3).

3.4. Other Deployment Considerations

In addition to the diagnostic routines mentioned above (§3.2), you should review the following operational considerations.

- Probe mounting, installation, and interference (§8.1)
- Routine maintenance (§8.5)
- Seeding requirements (§8.6)

IMPORTANT
Always return to the Main Menu <u>before</u> turning the system off to ensure all data has been properly saved (see last step in §4.2.2 and §5.3.2).

Section 4. General Purpose Measurements

4.1. Overview

The **General Mode** of data collection is for applications that need a series of current measurements at different locations, but that do not require a standard discharge calculation.

- The FlowTracker records the velocity data with parameters to document the data set.
- The following parameters are recorded with each measurement location.
    o Station number
    o Two location variables
    o Water depth
    o Measurement depth
- No parameters are required (station number is automatically generated). They are provided only to document the data set as desired for a particular application.

4.2. General Data Collection Procedure

This section outlines a typical procedure when collecting data in the **General Mode**. Though typical, the sequence of steps you use may vary based on your application.

4.2.1. Preparing the System for General Data Collection in the Field

Preliminary
- Run pre-deployment diagnostics before taking the instrument to the field (§3.2 and §6.5).

Mount the Probe
- Use a proper probe mounting to avoid flow interference (§8.1).

Turn the FlowTracker On
- Hold the **On/Off** key for 1 second until you see the LCD screen turn on.
- From the opening (i.e.; wakeup) screen, press the **Enter** key to view the **Main Menu**.

Field Diagnostics
- Perform field diagnostics (§3.2.2).
    o Check recorder status (**2** in **System Functions Menu**)
    o Check temperature data (**4** in **System Functions Menu**)
    o Check battery capacity (**5** in **System Functions Menu**)
    o Check raw velocity and SNR data (**6** in **System Functions Menu**)
    o Check system clock (**8** in **System Functions Menu**)

Set System Parameters
- Check the **Setup Parameters Menu** (**1** in **Main Menu**; §2.4).
    o Units system [Metric/English] (**1** in **Setup Parameters Menu**)
    o Averaging time (**2** in **Setup Parameters Menu**)
    o Data collection mode (set to **General**) (**3** in **Setup Parameters Menu**)
    o QC Settings (**4** in **Setup Parameters Menu**; §2.4.4) SmartQC
    o Salinity (**6** in **Setup Parameters Menu**)
        ▪ In salt water, a zinc anode should be installed (§8.5.6).

4.2.2. Data Collection in General Mode

Table 4-1 lists the items shown on the display screens during data collection.

Table 4-1. Items Displayed During Data Collection (General Mode)

Label	Description	English	Metric
Stn	Station number		
L1	Location value 1	ft	m
L2	Location value 2	ft	m
Dep	Water depth	ft	m
MDep	Measurement depth	ft	m
Vx	X velocity component	ft/s	m/s
Vy	Y velocity component	ft/s	m/s
Vz	Z velocity component	ft/s	m/s
SNR	Signal-to-noise ratio (mean of all receivers); §1.4.2	dB	dB
Time	Time remaining in sampling average		
σV	Standard error of velocity; §1.4.3	ft/s	m/s
Spikes	Number of spikes edited from mean; §1.4.5		
Bnd	Boundary QC value; §1.4.4		
NPts	Number of points collected (may differ from averaging time if **Abort** key used)		

The following steps describe the data collection sequence when in **General Mode**.

1. From the **Main Menu**, press **3** to **Start Data Run**.
2. The file name menu will be displayed (right).

```
   Data File Name
1:Name (none)
2:Extension (none)
9:Accept name
```

   a. Press **1** to specify file name (required).
      - A maximum of 8 characters (letters or numbers) are allowed.
      - To enter an alpha-numeric filename:
         o To enter a number, simply type the number.
         o Letters use the mobile phone method (e.g., for **C** press **2** four times: **2 – A – B – C**).
         o Press **Enter** to complete the filename.
         o Use the **Delete** key to correct mistakes.
      - After entry, the file name is shown in parentheses.
   b. Press **2** to specify file extension (optional).
      - A maximum of 3 characters (letters or numbers) is allowed
      - After entry, the extension is shown in parentheses.
   c. Press **9** when ready to start data collection. The system checks that the filename does not already exist on the recorder, and then displays station information.
   d. **Or**, press **Abort** or **End Section** to return to the **Main Menu**.
3. Input site and operator name (right). These are optional values used only to document the data set.

```
1:Site
Poudre River FC
2:Operator Billy Bob
9:Start
```

   a. Press **1** to enter site name.
   b. Press **2** to enter operator name(s).
   c. Up to 20 characters is allowed for each.
   d. Press **9** to start data collection.
4. You will be prompted (right) to conduct an automatic QC test (§2.5.7). SmartQC

```
 Automatic QC Test

1:Run Test
2:Skip Test
```

   a. Press **1** to run the automatic QC test, and follow on screen instructions.
   b. Press **2** to skip the test and begin data collection.

5. Station information will be displayed (right).
   a. Data are in meters or feet based on the units selection.
   b. Press **Set Location** to set location 1 (**L1**) and location 2 (**L2**) values.
   c. Press **Set Depth** to set water depth (**Dep**).
   d. Press **Set Meas Depth** to set measurement depth (**MDep**).

```
Station 1
L1 0.00     Dep 0.00
L2 0.00    MDep 0.00
Press Meas to Start
```

6. When the probe is located at the desired station, press **Measure** to start data collection. The display (right) shows a running mean of velocity and SNR data. The displayed values represent the running mean of data collected at the selected station.

```
Stn 1      MDep 0.00
Vx 0.00    Vy 0.00
Vz 0.00    SNR 0.0
Time (sec) 19
```

7. When the station is complete, a summary of velocity and quality control data are shown (right).
   a. The data represent the mean over the entire averaging period after removing any spikes.
   b. Press **1** to accept the measurement and move on to the next station.
   c. Press **2** to repeat the measurement (using the same station number).
      Note: When a measurement is repeated, data are not lost. However, you can longer view the *old* data using the keypad interface. The *old* data are still recorded. Later, you can extract the data from the raw data file (`*.dat`) and the measurement summary file (`*.sum`).

```
Vx 2.25     σV 0.02
Vy 0.42     SNR 15.1
Spikes 0   Bnd BEST
1:Accept    2:Repeat
```

8. When a measurement is accepted, the FlowTracker displays the next station.
   a. Location and depth data for new stations are predicted based on previous stations.
   b. At this point, you would repeat Steps 3 through 8 to add additional stations; otherwise, continue with Step 9 below.
      Note: In **General Mode**, the maximum number of stations for a data file is 100. Measurements that are repeated (Step 7.c.), do <u>not</u> count towards the maximum number of stations.
9. Use the **Previous Station** and **Next Station** keys to scroll through completed stations.
   a. Three screens (below) are available for each completed station; press **Enter** to scroll through the screens for each station.
   b. You can edit station information using **Set Location**, **Set Loc. 2**, **Set Depth**, and **Set Meas Depth**.

```
Station 3
L1 4.00     Dep 2.25
L2 6.50    MDep 1.50
Press Enter For More
```
```
Stn 3      MDep 1.50
Vx 2.25    Vy 0.42
Vz 0.05    Npts 40
Press Enter For More
```
```
Stn 3      MDep 1.50
SNR 14.5    Bnd BEST
σV 0.02     Spikes 0
Press Enter For More
```

10. At any point, press **QC Menu** to access a variety of special functions (§2.6). SmartQC✓
    a. Enter supplemental data (gauge height, rated flow, user comments).
    b. Modify **QC Settings** (§2.4.4).
    c. Change averaging time (**Avg Time**) used for each measurement.
    d. Display **Raw Velocity Data** (§2.5.6).
    e. Run and record an additional **Auto QC Test** (§2.5.7).
11. When all stations are done, press **End Section** to close the file and view summary data (this process may take a few seconds). Note: The **End Section** key is only active when the display is showing the last station in the file. If you have scrolled back to a previous station to view data, you will not be able to end the section until you scroll forward to the ending station.

12. After the file has been closed, seven screens of file summary data are available (below). Table 4-2 lists the items shown on the summary screens.

a. Press **Enter** to move between the different file summary screens.

b. Press **Previous Station** from any file summary screen to view the station data. You can then scroll through all station data using the **Next Station** and **Previous Station** keys. Press **Next Station** from the last station screen to return to the file summary screens.

c. When done, press **9** to exit and return to the main menu. The **9** key is only active when the display is showing the file summary data. If you have scrolled back to a previous station to view data, you cannot exit until you scroll forward to the summary data.

d. **IMPORTANT: Always return to the Main Menu <u>before</u> turning the system off to ensure all data has been saved.**

```
File 555312.100
Mode: General
2001/06/25  14:24:15
0=Exit or Enter=More
```

```
Site
Poudre River FC
Operator Billy Bob
0=Exit or Enter=More
```

```
File 555312.100
Num Stations 15

0=Exit or Enter=More
```

```
Vx Mean 1.05 ft/s
Vy Mean 0.08 ft/s

0=Exit or Enter=More
```

```
Vx Min 0.88 ft/s
Vy Min −0.10 ft/s

0=Exit or Enter=More
```

```
Vx Max 1.63 ft/s
Vy Max 0.34 ft/s

0=Exit or Enter=More
```

```
SNR Mean 16.5 dB
σV Mean 0.05 ft/s
Temperature 63.2°F
0=Exit or Enter=More
```

Table 4-2. Items Displayed on Summary Screens (General Mode)

Label	Description	English Units	Metric Units
Stations	Total number of stations (including edges)	-	-
Site	Site name	-	-
Operator	Operator name	-	-
Vx Mean	Mean X velocity	ft/s	m/s
Vy Mean	Mean Y velocity	ft/s	m/s
Vz Mean	Mean Z velocity (if present)	ft/s	m/s
Vx Min	Minimum X velocity	ft/s	m/s
Vy Min	Minimum Y velocity	ft/s	m/s
Vz Min	Minimum Z velocity (if present)	ft/s	m/s
Vx Max	Maximum X velocity	ft/s	m/s
Vy Max	Maximum Y velocity	ft/s	m/s
Vz Max	Maximum Z velocity (if present)	ft/s	m/s
SNR Mean	Mean signal to noise ratio; §1.4.2	dB	dB
σV Mean	Mean standard error of velocity; §1.4.3	ft/s	m/s
Temperature	Mean water temperature	°F	ºC

Section 5. River Discharge Measurements

5.1. Overview

Discharge Mode is for applications where the primary goal is to measure river/stream discharge. The technique involves taking a series of velocity measurements at different locations throughout the cross section. These measurements are combined with location and water depth information to compute the total discharge.

- Section 5.2 describes the measurement methodology and discharge calculations in detail.
- Section 5.3 describes how to make discharge measurements with the FlowTracker.

5.2. Discharge Calculation Equation

The basic procedure for making a discharge measurement is as follows.

- A site is selected. Site selection is a crucial part of collecting discharge measurement data.
  - In an ideal measurement site, the flow should be perpendicular to the tag line at all points with no flow reversals or obstructions.
  - Look for sites with reasonably smooth, consistent bottom conditions.
  - Flow conditions at the site are the most important factor in determining overall accuracy of measurements at that site (§5.2.5).
- A graduated tag line is strung across the river.
- The operator starts at one edge, recording the starting-edge location and water depth.
- The river cross section is split into several stations. At each station, the operator records the station location and water depth, and then takes velocity measurements at one or more depths to determine the mean velocity at that station.
- During velocity measurements, the probe's X-axis is maintained perpendicular to the tag line (Figure 4); the red band (receiver arm #1) should face downstream. Only the X-component of velocity (**Vx**) is used to ensure proper discharge calculation, regardless of the flow direction (flow direction is also measured and recorded).
- When complete, the operator records the ending-edge location and water depth.
- The total discharge is the sum of all station discharge values.

The FlowTracker supports several equations for calculating discharge following the basic procedure outlined above.

- **Mid Section** equation (§5.2.1)
- **Mean Section** equation (§5.2.2)
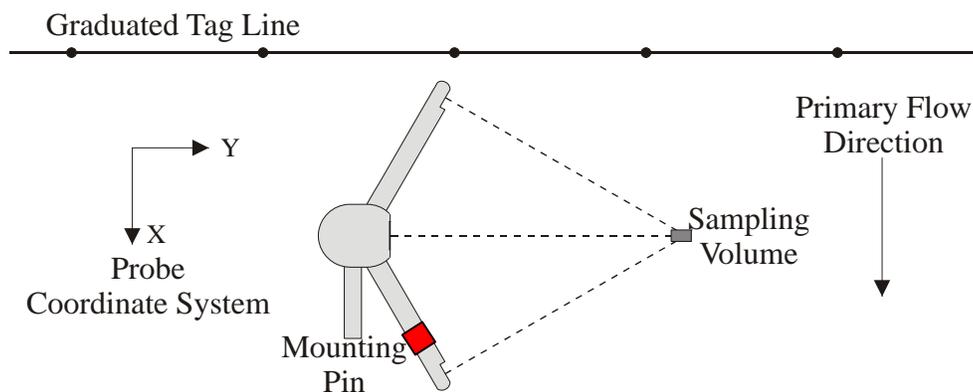- The **Japanese** equation (§5.2.3)

Figure 4 – FlowTracker Probe Orientation Relative to Stream Flow

5.2.1. Mid Section Discharge Equation

The **Mid Section** discharge equation is the default used by the FlowTracker.

- This method is used by the U.S. Geological Survey (USGS), the primary U.S. government agency responsible for river discharge monitoring.
- The same methodology is described in ISO standards 748 (1997) and 9196 (1992).
- Figure 5 shows the **Mid Section** equation. In this figure:
  - Loc_i represents the location of measurement station **i**.
  - Dep_i represents the measured water depth at station **i**.
  - Vel_i represents the mean velocity at station **i** (§5.2.4).

There are a few special cases to consider.

Edges
- Velocity from the adjacent station is used, scaled by a user-supplied correction factor.

Multiple channels (internal islands)
- If a river is split into multiple channels, any internal island(s) must be accounted for in the discharge calculation.
- The stations at each edge of the internal island(s) are treated like the river edges.
- Enter station location and water depth, and then select the velocity measurement method **None** to indicate an internal island. For an internal island, there should be two method **None** stations in a row (one for each edge).

Ice covered water
- For under ice measurements, calculations must take into account the thickness of the ice.
- Holes are cut through the ice at each measurement station.
- The operator enters station location and water depth as normal.
- The operator enters an ice depth parameter (**Ice**), which is the distance from the water surface to the bottom of the ice or bottom of the slush (if present).
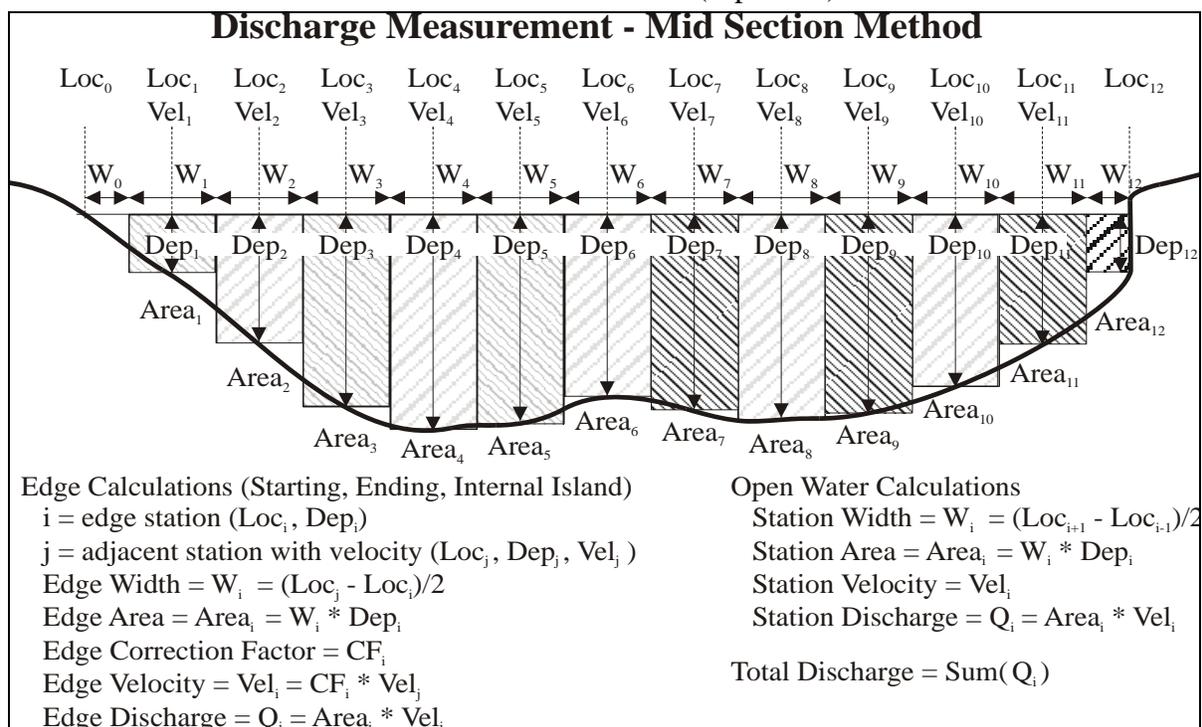

Figure 5 – Mid Section Discharge Equation

- Station width is calculated as normal.
- Effective depth is calculated as **EffD$_i$ = Dep$_i$ – Ice$_i$**.
- Station area is the effective depth times station width **Area$_i$ = W$_i$ * EDep$_i$**.

5.2.2. Mean Section Discharge Equation

The **Mean Section** discharge equation uses the same data collection procedure as the **Mid Section** equation, but differs in the details of how discharge is calculated.

- The **Mean Section** methodology is described in ISO standards 748 (1997) and 9196 (1992).
- Figure 6 shows the **Mean Section** equation. In this figure:
  - **Loc$_i$** represents the location of measurement station **i**.
  - **Dep$_i$** represents the measured water depth at station **i**.
  - **Vel$_i$** represents the mean velocity at station **i** (§5.2.4).

There are a few special cases to consider.

Edges
- Velocity from the adjacent station is used, scaled by a user-supplied correction factor.

Multiple channels (internal islands)
- If a river is split into multiple channels, any internal island(s) must be accounted for in the discharge calculation.
- The stations at each edge of the internal island(s) are treated like the river edges.
- Enter station location and water depth, and then select the velocity measurement method **None** to indicate an internal island. For an internal island, there should be two method **None** stations in a row (one for each edge of the internal island).
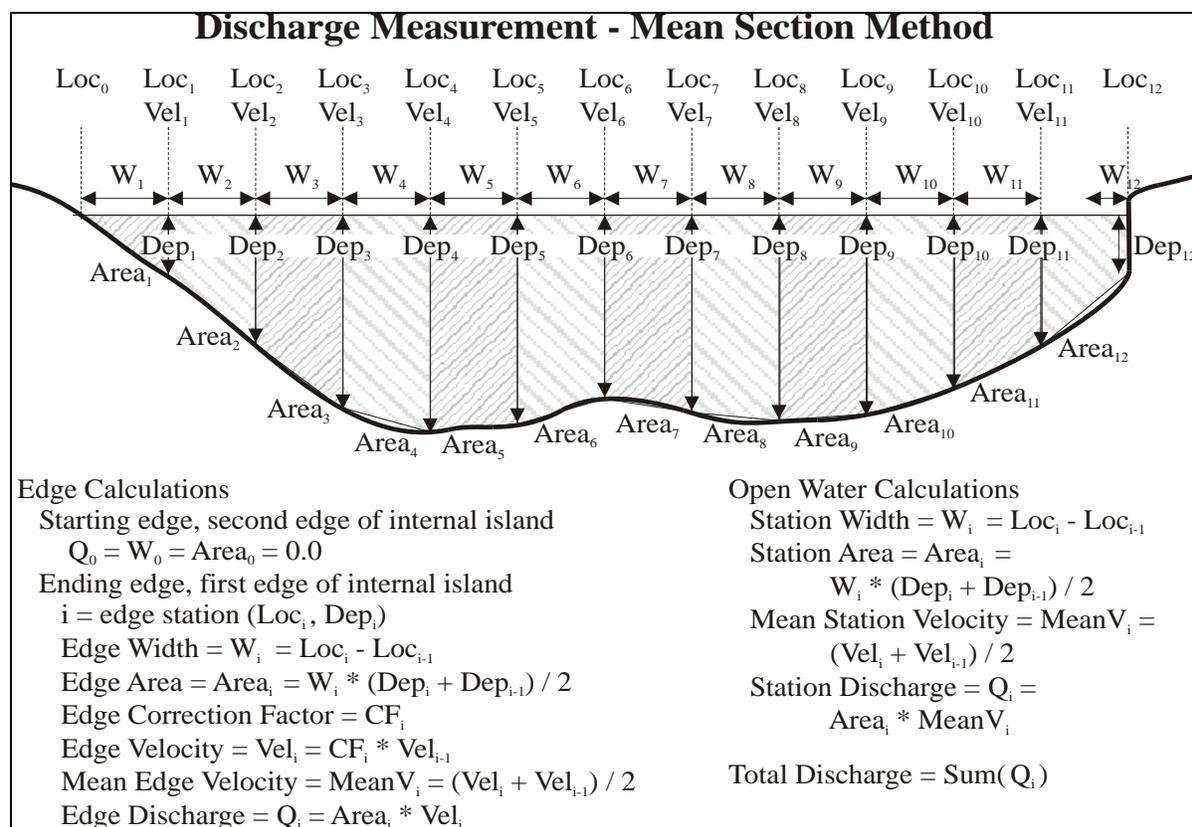

Figure 6 – Mean Section Discharge Equation

Ice covered water
- For under ice measurements, calculations must take into account the thickness of the ice.
- Holes are cut through the ice at each measurement station.
- The operator enters station location and water depth as normal.
- The operator enters an ice depth parameter (**Ice**), which is the distance from the water surface to the bottom of the ice or bottom of the slush (if present).
- Station width is calculated as normal.
- Effective depth is calculated as **EffD$_i$ = Dep$_i$ – Ice$_i$**.
- Station area is the effective depth times station width **Area$_i$ = W$_i$ * EDep$_i$**.

5.2.3. Japanese Discharge Equation

The **Japanese** discharge equation includes several modifications to the two other data collection procedures described above.

- Location and water depth are recorded for every station; however, velocity is only measured at every second station.
  - o Stations without a velocity measurement use velocity method **None** (§5.2.4).
- Depth for each station is recorded twice, once when going across the river and a second time on the return trip. The mean of the two values is used for discharge calculations.
  - o When the **Japanese** equation is selected, the FlowTracker automatically supports two depth values using the **Set Depth** key; the mean value is displayed.
- Each velocity measurement is repeated twice. The mean of the two values is used for discharge calculations.
- Figure 7 shows the **Japanese** equation. In this figure:
  - o **Loc$_i$** represents the location of measurement station **i**.
  - o **Dep$_i$** represents the measured water depth at station **i**.
  - o **Vel$_i$** represents the mean velocity at station **i** (§5.2.4).

There are a few special cases to consider.

Discharge Measurement - Japanese Method

Width, area and discharge are calculated only for stations that include a velocity measurement.
Station Width $W_i = Loc_{i+1} - Loc_{i-1}$
Station Area = $Area_i = ((Loc_i - Loc_{i-1})*(Dep_i+Dep_{i-1}) / 2) + ((Loc_{i+1} - Loc_i)*(Dep_{i+1}+Dep_i) / 2)$
Station Discharge = $Q_i = Area_i * Vel_i$
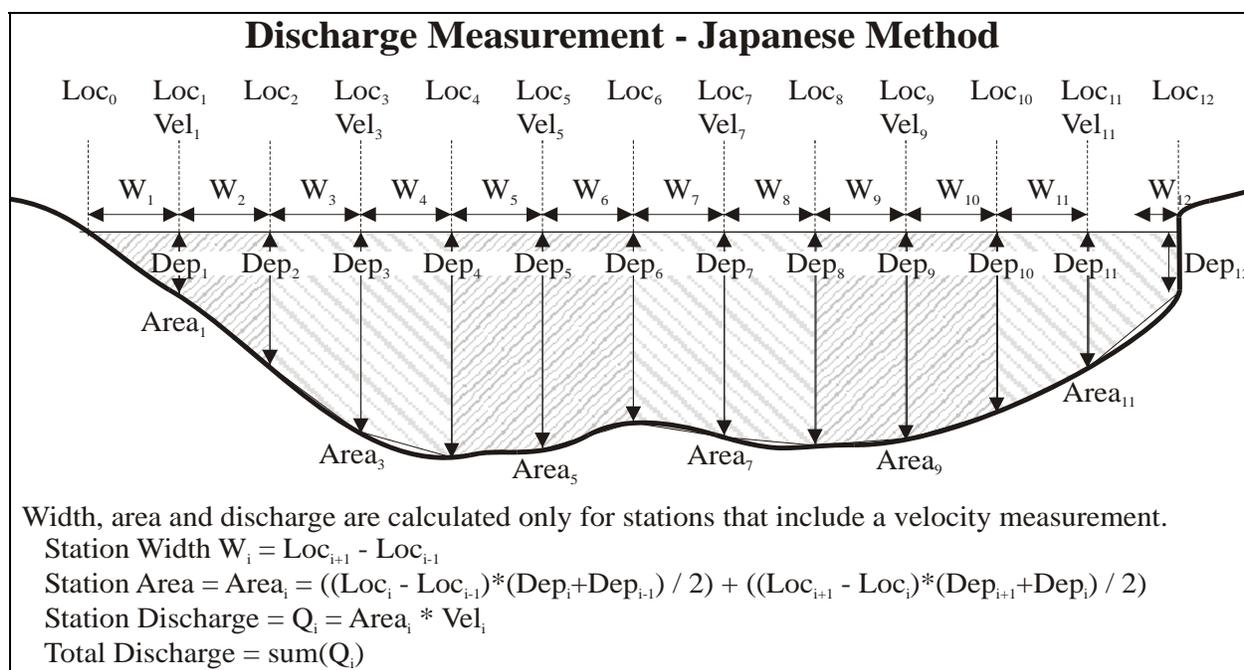Total Discharge = $sum(Q_i)$

Figure 7 – Japanese Method Discharge Equation

Multiple channels (internal islands)
- If a river is split into multiple channels, any internal island(s) must be accounted for in the discharge calculation.
- The stations at each edge of the internal island(s) are treated like the river edges.
- Enter station location and water depth, and then select the velocity measurement method **None** to indicate an internal island. For an internal island, there should be two method **None** stations in a row (one for each edge of the internal island).

Ice covered water
- For under ice measurements, calculations must take into account the thickness of the ice.
- Holes are cut through the ice at each measurement station.
- The operator enters station location and water depth as normal.
- The operator enters an ice depth parameter (**Ice**), which is the distance from the water surface to the bottom of the ice or bottom of the slush (if present).
- Station width is calculated as normal.
- Effective depth is calculated as $\textbf{EffD}_i = \textbf{Dep}_i - \textbf{Ice}_i$.
- Station area is the effective depth times station width $\textbf{Area}_i = \textbf{W}_i * \textbf{EffD}_i$.

5.2.4. Determining Mean Station Velocity (Discharge Measurement Method)

The discharge measurement **Method** specifies how the FlowTracker determines mean velocity at each station.

- The **Method** involves variations in the number of velocity measurements, measurement depths, and how data are combined.
- Table 5-1 lists all **Methods** supported by the FlowTracker.
- **Methods** involving more than one measurement can be done in either direction (from surface to the bottom, or from the bottom towards the surface).
  - o The FlowTracker automatically alternates between directions at adjacent stations to make setting the probe location easier.
- Select the method using the **Method +** and **Method −** keys.
- If some **Methods** will never be used, you can specify which methods to display (§2.4.5)
  - o From the **Main Menu**, press **1** for **Setup Parameters**.
  - o Select **5** for **Discharge Settings**.
  - o Select **9** to specify **Methods Displayed**.
- Both fractional and actual measurement depths are shown on the FlowTracker display.
  - o Fractional measurement depth is referenced from the surface down (e.g., 0.6*depth down from the surface).
  - o Actual measurement depth is referenced from the bottom up (e.g., 0.23 ft above bottom).

There are a few special cases to consider.

Method **None**
- Method **None** is used in two different situations:
  - o When no measurement is possible (perhaps due to weed growth) and velocity will be estimated based on velocity from the adjacent station(s).
  - o To specify the banks of an internal island (for a multiple channel river).
- If *one* method **None** station is recorded, it is assumed that no measurement was possible.
  - o Velocity for this station is based on the mean station velocity from the adjacent station(s) with velocity measurements multiplied by the user-specified correction (**CF**) factor for this station. The default **CF** is 1.00.
- If *two* method **None** stations are recorded together, they are assumed to represent an internal island and discharge is calculated accordingly (§5.2.1, §5.2.2, §5.2.3).

Method **Multi Pt**
- This is a general-purpose method that lets you make any number of velocity measurements at any location in the water column.
  - o For each measurement, you must manually enter the measurement depth (using the **Set Meas Depth** key).
  - o When all measurements for a station have been made, press the **End Section** or **Abort** key to complete the station.
- The mean velocity is calculated by integrating all velocity measurements considering their location as illustrated in Figure 8.
  - o If multiple measurements are made at the same measurement depth, these measurements are averaged prior to calculating the velocity integration.

Table 5-1. FlowTracker Discharge Measurement Methods

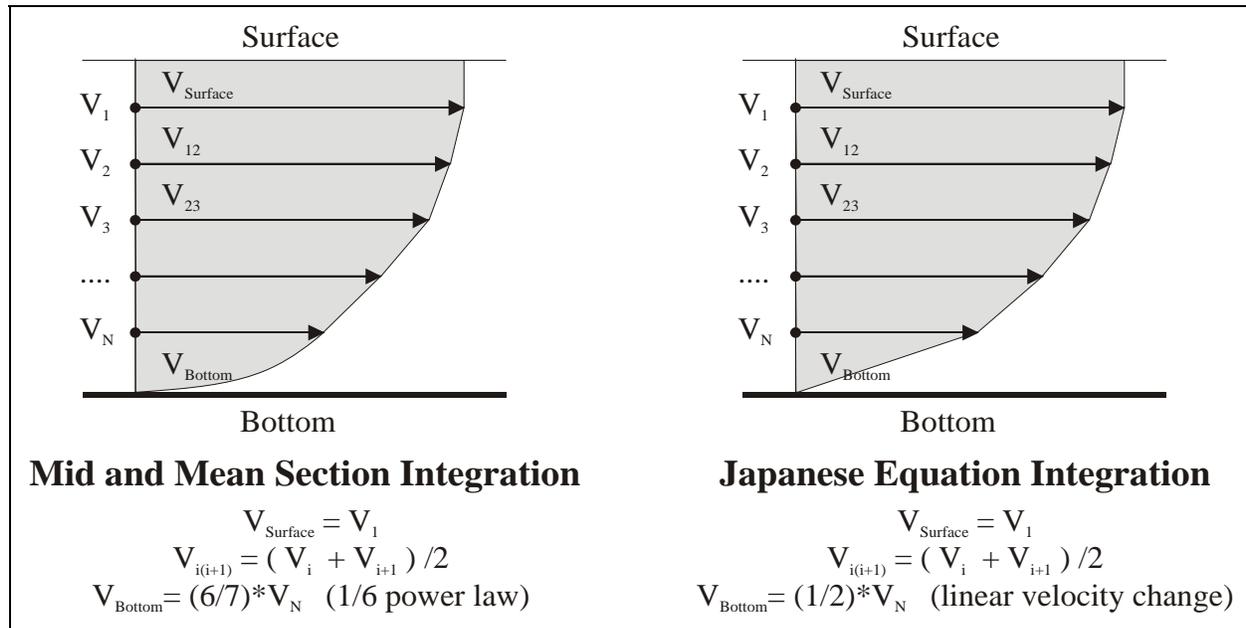| Method	Measurement Locations	Mean Velocity Equation
0.6	0.6 * depth	$V_{mean} = V_{0.6}$
0.2/0.8 **0.8/0.2**	0.2 * depth 0.8 * depth	$V_{mean} = (V_{0.2} + V_{0.8}) / 2$
.2/.6/.8 **.8/.6/.2**	0.2 * depth 0.6 * depth 0.8 * depth	$V_{mean} = (V_{0.2} + 2*V_{0.6} + V_{0.8}) / 4$
Ice 0.6	0.6 * effective depth	$V_{mean} = 0.92*V_{0.6}$ (Correction Factor 0.92 can be changed by user)
Ice 0.5	0.5 * effective depth	$V_{mean} = 0.89*V_{0.5}$ (Correction Factor 0.89 can be changed by user)
Ice 2/8 **Ice 8/2**	0.2 * effective depth 0.8 * effective depth	$V_{mean} = (V_{0.2} + V_{0.8}) / 2$
Kreps 2- **Kreps 2+**	0.0 (near surface) 0.62 * depth	$V_{mean} = 0.31*V_{0.0} + 0.634*V_{0.62}$
5 Point+ **5 Point-**	0.0 (near surface) 0.2 * depth 0.6 * depth 0.8 * depth 1.0 (near bottom)	$V_{mean} = (V_{0.0} + 3*V_{0.2} + 3*V_{0.6} + 2*V_{0.8} + V_{1.0}) / 10$
Multi Pt	Any number of points at user-specified depths	Integrated velocity average (Figure 8) Measurements can be made in any order; they are sorted by depth to calculate the integrated mean velocity. Repeat measurements at the same depth are averaged prior to calculating the integrated velocity.
None	No velocity measurement	$V_{mean} = CF * V_{adjacent}$ Mean velocity is based on the velocity from the adjacent station(s), multiplied by a user-specified correction factor. This method is used when velocity measurements cannot be made, and to specify the edges of an internal island in a multiple channel river.
Input V	User input velocity	$V_{mean} = V_{input}$ User enters an estimated velocity value. This method is used when velocity measurement is not possible, most commonly due to weed growth along a riverbank.

Surface	Surface
V_1 $V_{Surface}$	V_1 $V_{Surface}$
V_2 V_{12}	V_2 V_{12}
V_3 V_{23}	V_3 V_{23}
....	....
V_N	V_N
V_{Bottom}	V_{Bottom}
Bottom	Bottom
Mid and Mean Section Integration	**Japanese Equation Integration**
$V_{Surface} = V_1$	$V_{Surface} = V_1$
$V_{i(i+1)} = (V_i + V_{i+1}) /2$	$V_{i(i+1)} = (V_i + V_{i+1}) /2$
$V_{Bottom}= (6/7)*V_N$ (1/6 power law)	$V_{Bottom}= (1/2)*V_N$ (linear velocity change)

Figure 8 – Multiple Point Mean Velocity Integration

*Correction Factor (**CF**)*

- The correction factor (**CF**) is a user-supplied parameter used to scale the mean station velocity; it is entered using the **Corr. Factor** key.
- The **CF** is most commonly used at edges, internal islands, and other method **None** stations to scale the velocity from the adjacent station(s).
  - o The default **CF** value is 1.00.
  - o Any value from -1.00 to 1.00, except 0.0, is allowed.
- The **CF** can be entered for any station and mean velocity will be multiplied by the **CF**.
  - o One possible use is near the edges in very narrow streams.
  - o In these cases, the orientation of the FlowTracker probe can be reversed 180° to allow measurement closer to the edge.
  - o A **CF** of -1.00 should be entered to correct the FlowTracker X-velocity.
- Be careful when entering the **CF**, as mean velocity is always scaled by this value. Incorrect use of this parameter will affect the final discharge measurement.

5.2.5. *Discharge Uncertainty Calculation* SmartQC

The FlowTracker estimates the uncertainty of every discharge measurement. This calculation can be done using two different ways: **Statistical** or **ISO**.

- The **Statistical** (abbreviations **Stats**) uncertainty calculation uses a method developed by researchers at the U.S. Geological Survey; this is the default calculation as it provides the most reliable indicator of measurement quality.
- The **ISO** method is based on the international standard. It provides users with the results of a published, standard technique; however, in some cases this calculation may not provide a reliable indicator of data quality.

The uncertainty calculations are based on several different parameters. In addition to overall uncertainty, the FlowTracker also looks at the contribution of each parameter.

- **Accuracy**: the accuracy of the FlowTracker calibration (this is generally negligible).
- **Depth**
  - o In the **Statistical** calculation, this term includes both uncertainty in the depth measurement and the effect of changes in depth between stations.
  - o In the **ISO** calculation, this term includes only the uncertainty in depth measurements.
- **Velocity**
  - o In the **Statistical** calculation, this term includes both uncertainty in the velocity measurement and the effect of changes in velocity between stations.
  - o In the **ISO** calculation, this term includes only the uncertainty in velocity measurements.
- **Width**
  - o Estimated uncertainty in width measurements.
- **Method**: Discharge measurement method (§5.2.4)
  - o Use for the **ISO** method only.
- **Number of stations**
  - o Use for the **ISO** method only.

In the FlowTracker real time display, uncertainty is shown with the calculated discharge; the largest individual source of uncertainty is also shown. The *FlowTracker* software program shows both uncertainty calculations and the contribution of each parameter to the overall uncertainty. A complete description of the discharge uncertainty calculations can be found in Appendix C – Discharge Uncertainty Calculation.

5.3. Discharge Data Collection Procedure

This section outlines a typical procedure when collecting data in the **Discharge Mode**. Though typical, the sequence of steps may vary based on your application.

5.3.1. Preparing the System for Discharge Data Collection in the Field

Preliminary
- Use §5.2 to determine the discharge procedure and equation you will use.
- Run pre-deployment diagnostics before taking the instrument to the field (§3.2 and §6.5).

Mount the Probe
- Mount the probe properly to avoid flow interference (§8.1).
- Be sure to keep the X direction perpendicular to the tag line being used to define the cross section at all times (see §5.2 and 8.1).

Turn the FlowTracker On
- Hold the **On/Off** key for one second until you see the LCD screen turn on.
- From the opening (i.e.; wakeup) screen, press the **Enter** key to view the **Main Menu**.

Field Diagnostics
- Perform field diagnostics (§3.2.2).
  - o Check recorder status (**2** in **System Functions Menu**)
  - o Check temperature data (**4** in **System Functions Menu**)
  - o Check battery capacity (**5** in **System Functions Menu**)
  - o Check raw velocity and SNR data (**6** in **System Functions Menu**)
  - o Check system clock (**9** in **System Functions Menu**)

Set System Parameters
- Check the **Setup Parameters Menu** (**1** in **Main Menu**; §2.4).
  - o Units system [Metric/English] (**1** in **Setup Parameters Menu**)
  - o Averaging time (**2** in **Setup Parameters Menu**)
  - o Data collection mode (set to **Discharge**) (**3** in **Setup Parameters Menu**)
  - SmartQC o QC Settings (**4** in **Setup Parameters Menu**) (§2.4.4)
  - o Discharge Settings (**5** in **Setup Parameters Menu**) (§2.4.5)
  - o Salinity (**6** in **Setup Parameters Menu**)
    - ▪ In salt water, a zinc anode should be installed (§8.5.6).

5.3.2. Data Collection in Discharge Mode

Table 5-2 lists the items shown on the display screen during data collection.

Table 5-2. Items Displayed During Data Collection (Discharge Mode)

Label	Description	English	Metric
RatedQ	Rated discharge (as input by the user)	ft^3/s	m^3/s
TotalQ	Computed discharge (based on FlowTracker measurements)	ft^3/s	m^3/s
Loc	Location	ft	m
Dep	Water depth	ft	m
0.6 0.2/0.8, etc.	Velocity method used; §5.2.4, Table 5-1	-	-
0.6(0.32)	Measurement depth • First is the fractional depth (e.g., **0.6** indicates 0.6 * depth), referenced from the surface down. • Second (in parenthesis) is the actual depth, referenced from the bottom up. This calculated depth includes the effect of ice, if present.	ft	m
Vel	X velocity component	ft/s	m/s
SNR	Signal-to-noise ratio; §1.4.2	dB	dB
Time	Time remaining in sampling average		
σV	Standard error of velocity; §1.4.3	ft/s	m/s
Spikes	Number of spikes removed from mean; §1.4.5	-	-
Bnd	Boundary QC value; §1.4.4	-	-
NPts	Number of points collected (may differ from averaging time if **Abort** key used)	-	-
Ang	Flow angle relative to X direction; §1.4.6	°	°
StnQ	Station discharge	ft^3/s	m^3/s
StnV	Mean station velocity; §5.2.4	ft/s	m/s
%Q	Station discharge as percent of either rated or measured discharge, based on the discharge **Reference** value (§2.4.5).	%	%

The following steps describe the data collection sequence when in **Discharge Mode**.

1. From the **Main Menu**, press **3** to **Start Data Run**.
2. The file name menu will be displayed (right).
   a. Press **1** to specify file name (required).
      ▪ A maximum of eight characters (letters or numbers) are allowed.
      ▪ To enter an alpha-numeric filename:
         o To enter a number, simply type the number.
         o Letters use the mobile phone method (e.g., for **C** press **2** four times: **2–A–B–C**).
         o Press **Enter** to complete the filename.
         o Use the **Delete** key to correct mistakes.
      ▪ After entry, the file name is shown in parentheses.
   b. Press **2** to specify file extension (optional).
      ▪ A maximum of 3 characters (letters or numbers) is allowed
      ▪ After entry, the extension is shown in parentheses.
   c. Press **9** when ready to start data collection.
      ▪ The system checks that the filename does not already exist on the recorder, and then displays starting gauge information.
   d. **Or**, press **Abort** or **End Section** to return to the **Main Menu**.

```
   Data File Name
1: Name (none)
2: Extension (none)
9: Accept name
```

3. Enter site and operator name (right). These are optional values used only to document the data set.
   a. Press **1** to enter site name.
   b. Press **2** to enter operator name(s).
   c. Up to 20 characters are allowed for each entry.
   d. Press **9** to start data collection.

```
1:Site
Poudre River FC
2:Operator Billy Bob
9:Start
```

4. At any point, press **QC Menu** to access a variety of special functions (§2.6). SmartQC
   a. The operator is prompted to do so at the start and end of each data file; this is typically to enter starting and ending gauge height values.
   b. Enter supplemental data (gauge height, rated flow, user comments).
   c. Modify **QC Settings** (§2.4.4) or **Discharge Settings** (§2.4.5).
   d. Change averaging time (**Avg Time**) for each measurement.
   e. Display **Raw Velocity Data** (§2.5.6).
   f. Run and record an additional **Auto QC Test** (§2.5.7).

```
  Press QC Menu
   At Any Time
  For Gauge Data
 ENTER = Continue
```

5. You will be prompted (right) to conduct an automatic QC test (§2.5.7). SmartQC
   a. Press **1** to run the automatic QC test; follow the on-screen instructions.
   b. Press **2** to skip the test and begin data collection.

```
 Automatic QC Test

1:Run Test
2:Skip Test
```

6. Starting-edge information will be displayed (right).
   a. Press **Set Location** to set starting-edge location (**Loc**).
   b. Press **Set Depth** to set starting-edge water depth (**Dep**).
   c. If needed, press **Set Ice Depth** (**Ice**); this is displayed only if non-zero.
   d. Press **Corr. Factor** to set any required correction factor (**CF**); see §5.2.4.
   e. Press **LEW/REW** to toggle the starting edge of water – left or right (this is used to document the data set and is not required).
   f. When complete, press **Next Station** to continue.

```
  Starting Edge
Loc 1.00   Dep 0.50
LEW        CF 1.00
 Press Next Station
```

7. Station information will be displayed (right).
   a. Press **Set Location** to set station location (**Loc**).
   b. Press **Set Depth** to set water depth (**Dep**).
   c. If needed press **Set Ice Depth** (**Ice**); this is displayed only if non-zero.
   d. Use **Method+** and **Method–** to select the method used for velocity at that station (§5.2.4). Note that the measurement depth will change at the same time.
   e. If needed press **Corr. Factor** to set the correction factor (**CF**), this is displayed only if the value is something other than **1.00**.

```
Stn 1      Loc 2.00
0.6        0.6(0.54)
           Dep 1.35
         Enter=More
```

8. When all values are correctly set, and the probe is located as desired, press **Measure** to start data collection. Make sure you keep the probe's X direction perpendicular to the tag line being used to define the stream cross section (see Figure 4, §5.2, and §8.1).
   Note: You can recover if you mistakenly press **Measure** with an incorrect parameter or **Method**. Press **Abort** to terminate the measurement (or let the measurement finish), and press **2** to repeat the measurement. Until one measurement is accepted at a station, you have the ability to change all parameters. After one measurement has been accepted, **Method** can no longer be changed (although other parameters can still be changed).

9. An updating display (right) shows velocity and SNR data. Displayed values represent the running mean of data at that station.

```
Loc 2.00   MDep .6D
Vel     2.23
SNR     14.3
Time    19
```

10. When the station is complete, a summary of velocity and quality control data is shown (right).

```
Vel 2.25    σV 0.04
Ang 5°      SNR 15.1
Spikes 0    Bnd BEST
1:Accept    2:Repeat
```

   a. Prior to the summary screen, the data are reviewed using a variety of quality control criteria (§1.4). If any data are outside expected values, a warning is issued.
   b. The values represent the mean over the entire averaging period after removing any spikes.
   c. Press **1** to accept the measurement and move on to the next measurement (or to the next station if this is the last measurement for this station).
   d. Press **2** to repeat the measurement (using the same station number).
      Note: When a measurement is repeated, data are not lost. However, you will no longer be able to view the *old* data from the keypad interface. The *old* data are still recorded. Later, the data can be extracted in the raw data file (***.dat**) and the measurement summary file (***.sum**), but not in the discharge summary file (***.dis**).
11. If there is more than one measurement at a station (e.g., 0.2 and 0.8 times the water depth), the system will proceed to the next measurement in the series.
   ▪ When using method **Multi Pt**, any number of measurements for each station is allowed. When the last measurement is complete, press **End Section** or **Abort** to end that station.
12. When a station is completed, the FlowTracker displays the next station.
   a. Location, depth, and method data for new stations are predicted using previous stations.
   b. If a multiple measurement method was used (e.g., 0.2 and 0.8 times water depth), the next station will use the same method in the opposite order (i.e.; 0.8 then 0.2 times depth).
   c. To add more stations, repeat Steps 7 through 12; otherwise, continue with Step 13.
      Note: In **Discharge Mode**, the maximum number of stations for any data file is 100, and the maximum number of measurements is 300. The starting and ending edges are considered stations. Station measurements that are repeated (Step 10.d.), do <u>not</u> count towards the maximum number of stations.
13. Use **Previous Station** and **Next Station** to scroll through the completed station(s).
   a. Stations are sorted based on location and displayed in that order.
   b. Four screens are available for each completed station; use **Enter** to scroll through screens.

```
Stn 1       Loc 2.00     Stn 1       Loc 2.00
0.6         0.6(0.54)    Npts 40     0.6(0.54)
            Dep 1.35     Vel 2.25
            Enter=More   Ang 5°      Enter=More
```

```
Stn 1       Loc 2.00     Stn 1       Loc 2.00
SNR 14.5    0.6(0.54)    StnQ 2.523 cfs
σV 0.04     Bnd BEST     StnV 2.25 ft/s
Spikes 0    Enter=More   %Q 4.5%     Enter=More
```

   c. You can edit station information using **Set Location**, **Set Depth**, **Corr.Factor**, **Set Ice Depth**.
   d. **Next Station** and **Previous Station** are not active from the time the **Measure** key is used to start a station until the time the last measurement for that station is complete.
   e. **Measure** is active only on the current (uncompleted) station.

f. Use **Calculate Disch.** to view (right) the total discharge for all completed stations. This is a temporary calculation and does not affect ongoing data collection.

```
TotalQ 44.234 cfs
RatedQ 45.000 cfs
Difference -1.7%
    Press Enter
```

14. It is possible to delete or repeat a station if desired.
   a. To delete an existing (completed) station:
      ▪ All measurements at that station will be deleted. You cannot delete only one measurement at a station.
      ▪ Use **Next Station** and **Previous Station** to scroll to the desired station.
      ▪ Press **Delete**.
      ▪ When prompted, enter **123** to confirm; any other entry keeps the station intact.
      ▪ The station is deleted, and the display returns to the current station.
   b. To repeat a station:
      ▪ **Delete** the desired station.
      ▪ At the current station, enter the location, depth, and measurement method of the station to be repeated. Follow standard measurement procedures for that station.
      ▪ The new station data will automatically be sorted into the correct position so that discharge calculations are accurate.
   c. Data from a deleted station is not lost. However, you will no longer be able to view the *old* data from the keypad interface. The *old* data are still recorded. Later, the data can be extracted in the raw data file (***.dat**) and the measurement summary file (***.sum**), but not in the discharge summary file (***.dis**).
15. When all stations are completed, press **End Section**.
   a. The FlowTracker reviews all data using several quality control criteria (§1.4). **SmartQC**
      ▪ If any stations / measurements are outside expected values, a warning is issued and these measurements are displayed.
      ▪ You can review data and repeat or add measurements to ensure optimal data quality.
   b. When the review is complete, the ending-edge screen is shown. At this point, enter the ending-edge information. This screen works just like the starting-edge screen (Step 6).
   c. **Next Station** and **Previous Station** can be used to view/edit other stations.
      ▪ To add new measurements, press the **Measure** key and confirm when prompted that you wish to re-open the file and add measurements.
   d. When all values are correctly set, press **Calc. Disch.** to complete discharge calculations and close the file.
16. After final discharge calculations are complete, nine data screens are available (next page and Table 5-3).
   a. Press **Enter** to move between the different display screens.
   b. Press **Previous Station** from any file summary screen to view the station data. You can then scroll through all station data using the **Next Station** and **Previous Station** keys. Press **Next Station** from the ending edge screen to return to the file summary screens.
17. Press **0** to return to the main menu. Note: The **0** key is only active when the display is showing the discharge summary. If you have scrolled back to a previous station to view data, you will not be able to exit until you scroll forward to the discharge summary.

IMPORTANT:
Always return to the Main Menu <u>before</u> turning the system off to ensure all data has been saved.

```
TotalQ 44.234 cfs        Q Uncertainty 3.5%       Num Stations 27
RatedQ 45.000 cfs        Largest Source           V Mean 1.43 ft/s
Difference -1.7%           Num Stations           V Max 2.21 ft/s
0=Exit or Enter=More     0=Exit or Enter=More     0=Exit or Enter=More


Width 23.000 ft          Depth Mean 2.77 ft       SNR Mean 16.5 dB
Area 47.350 ft^2         Depth Max 3.15 ft        σV Mean 0.05 ft/s
                                                  Temperature 61.2°F
0=Exit or Enter=More     0=Exit or Enter=More     0=Exit or Enter=More


Start Height 4.900       File 555312.100          Site
End Height 5.000         Mode: Discharge          Poudre River FC
Change 0.100 ft          2001/06/25  14:24:15     Operator Billy Bob
0=Exit or Enter=More     0=Exit or Enter=More     0=Exit or Enter=More
```

Table 5-3. Items Displayed on Summary Screens (Discharge Mode)

Label	Description	English Units	Metric Units
RatedQ	Rated discharge	ft^3/s	m^3/s
TotalQ	Calculated discharge	ft^3/s	m^3/s
Q Uncertainty	Uncertainty in discharge measurement (§5.2.5)	%	%
Stations	Total number of stations (including edges)	-	-
MeanV	Mean velocity (equals discharge / area)	ft/s	m/s
Max V	Maximum station velocity	ft/s	m/s
Width	Total width	ft	m
Area	Total area	ft^2	m^2
Mean Depth	Mean river depth (area / width)	ft	m
Max Depth	Maximum station depth	ft	m
MeanSNR	Mean signal to noise ratio; §1.4.2	dB	dB
MeanσV	Mean standard error of velocity; §1.4.3	ft/s	cm/s
Temperature	Mean water temperature.	ºF	°C
Start / End Height, Change	First and last gauge height values, and the difference between the two; §2.6	ft	m
Site	Site name	-	-
Operator	Operator name		

Section 6. PC Software for the FlowTracker

The *FlowTracker* software (Figure 9) is intended to be largely self-explanatory; this section is provided for reference purposes. The software can be found on the CD included with the system or downloaded from the SonTek/YSI website at www.sontek.com.

6.1. Installing Software

To install the PC-based FlowTracker software on your computer:

- *FlowTracker* software is compatible with Windows 2000 and XP.
- Insert the distribution CD in your computer.
- An installation menu should automatically appear after the CD has been inserted.
  - If the installation window does not appear in a few seconds, click **Start | Run** and type **d:\install.exe** where **d:** is the letter of your CD-ROM drive.
- Click the **FlowTracker Software Installation** button from the software installation menu.
- Follow the on-screen installation instructions.
- We also recommend installing *SonUtils*.
- Click the **SonUtils Software Installation** button from the software installation menu.
- Follow the on-screen installation instructions.

Links to the FlowTracker User's and Technical manuals are provided in the software.
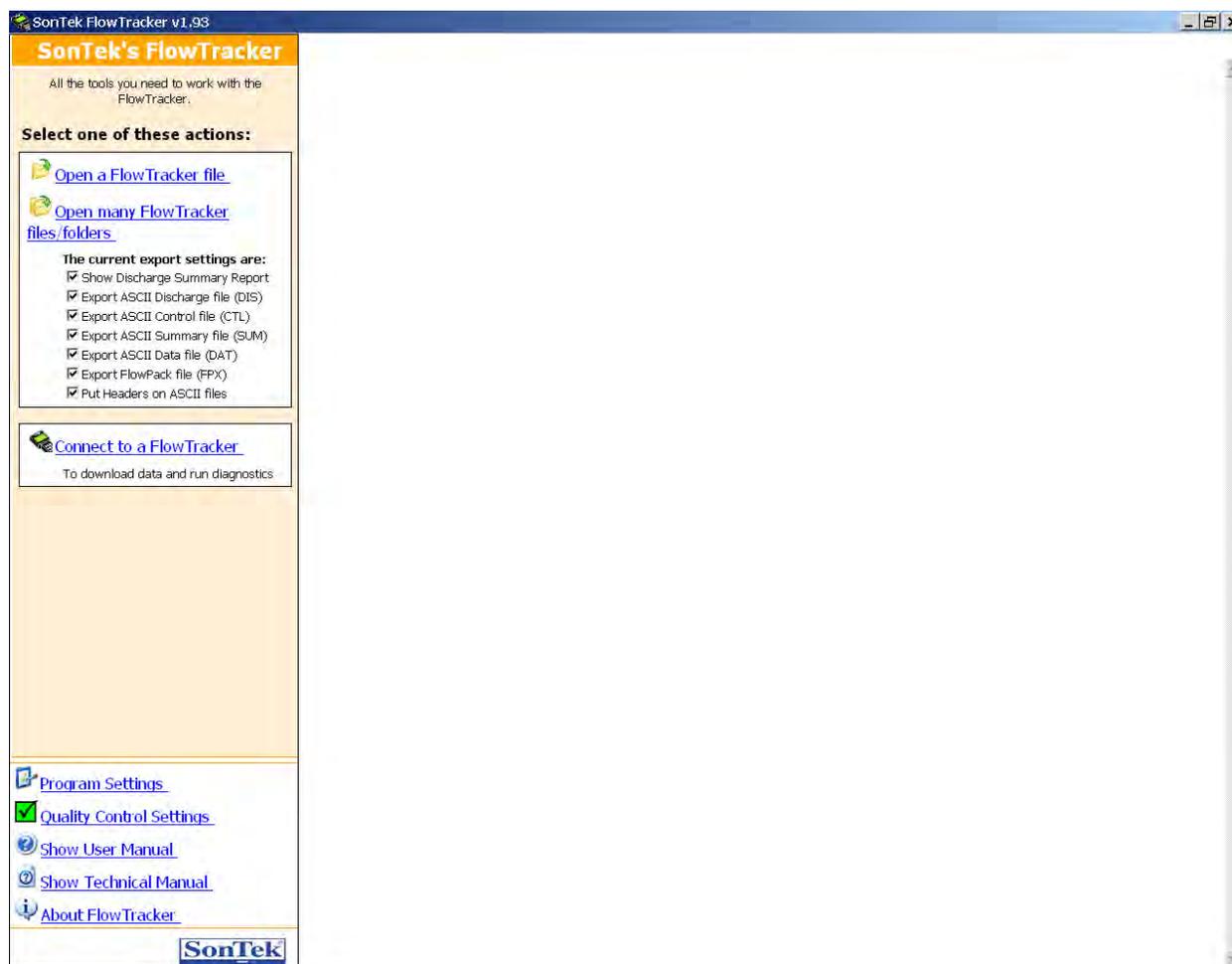
Figure 9 – FlowTracker Launch Window

6.2. FlowTracker Windows Software

The *FlowTracker* Windows software package is used for all major FlowTracker functions.

- To run *FlowTracker*, click **Start | Programs | SonTek Software | FlowTracker**.

Figure 9 shows the *FlowTracker* software launch window. From the launch window:

- Click **Open a FlowTracker File** to display and export data from a single data file, see §6.3.
  - o Select data export options using **Program Settings**.
  - o Select the desired output data and file formats; several are available.
    - **Discharge Summary Report**: A graphical report for easy viewing and printing.
    - **ASCII Discharge File** (**DIS**): Final data results in a self-explanatory form that is easy to integrate with database utilities.
    - **ASCII Summary File** (**SUM**): Velocity and quality control data from all measurements.
    - **ASCII Raw Data File** (**DAT**): Raw, one-second velocity and SNR data.
    - **ASCII Control File** (**CTL**): System configuration data.
  - o Output formats should be self-explanatory and can include optional column headers.
- Click **Open many FlowTracker files/folders** to display and export data from multiple Flow-Tracker files or folders. This operation is referred to as Batch Export. When this item is selected, the **Batch Export** window is displayed (Figure 10). Use the **Add File** and **Add Folder** buttons to add files/folders for processing. When a folder is added, all FlowTracker files in that folder are processed. Items may be removed from the list by selecting them and clicking **Remove**. When **Export** is clicked, all the listed files/folders are processed using the options selected from the main menu. If **Show Discharge Summary Report** is selected, all files will be added as tabs to the main window.
- Click **Connect to a FlowTracker** to establish communications with a FlowTracker connected to a COM port on your computer. After clicking **Connect**, you have the following options.
  - o **Recorder** – Download data files from the FlowTracker to your computer; see §6.4.
  - o **BeamCheck** – Perform detailed system diagnostics; see §6.5.
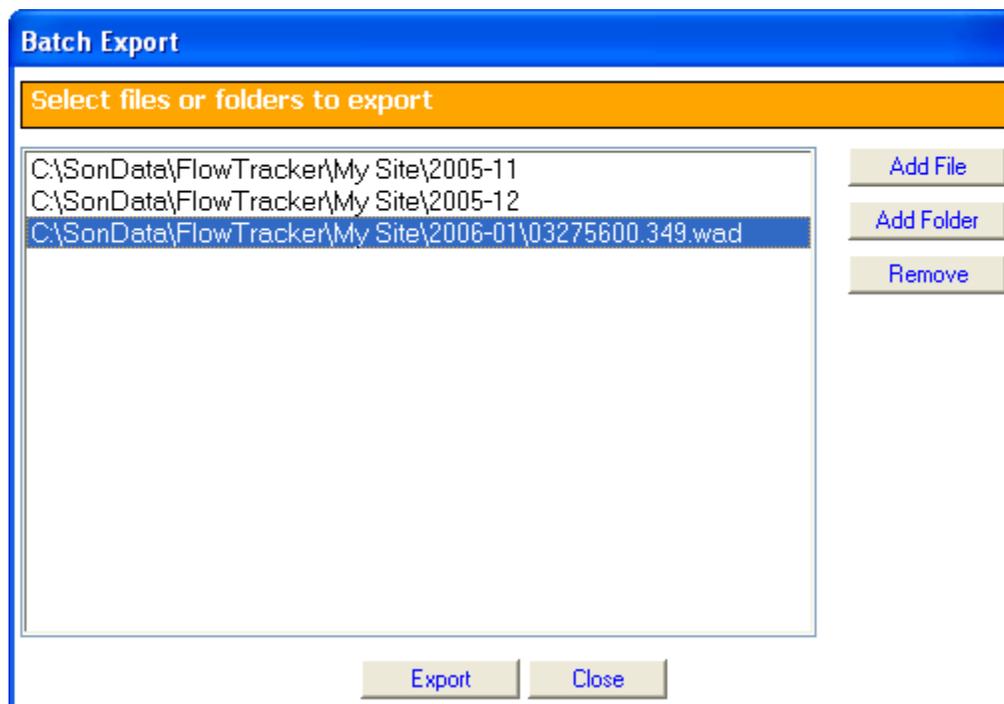
Figure 10 – Batch Export Window

6.3. Data Display and Export

FlowTracker data files are recorded in a compact binary format. The *FlowTracker* software is used to access these files, generating a graphical data report and various ASCII output files, each containing a particular type of data. To access the binary data files, use the following steps.

- Run the *FlowTracker* software (click **Start | Programs | SonTek Software | FlowTracker**).
- Download data from the FlowTracker to your computer as described in §6.4.
- Click **Program Settings** to specify the output units system, language settings, and (if desired) a fixed output directory for all ASCII output files (Figure 11). Click **OK** when done.
  - o Language settings affect the software display, data report, and all ASCII output files.
  - o Specify a different output directory for the ASCII files (if desired) using the **Browse** button in the **Export Settings** section (Figure 11).
  - o You can include a logo to be added to all FlowTracker data reports if desired. Click **Browse** in the **Report Logo** section.
- Select the desired output file types (Figure 12).
  - o **Show Discharge Summary Report**: Figure 13 and Figure 14 show the final discharge calculation and measurement summary report in tabular and graphic form. This includes automatic quality control analysis to flag measurements that may include suspect data.
  - o **Export ASCII Discharge file (DIS)**: Final discharge calculation data and overall measurement summary. The most widely used output file, especially for database integration.
  - o **Export ASCII Control file (CTL)**: System configuration data.
  - o **Export ASCII Summary file (SUM)**: All mean data recorded with each measurement.
  - o **Export ASCII Data file (DAT)**: Raw one-second velocity and SNR data.
  - o **Export FlowPack file (FPX)**: Binary file for use with SonTek's *FlowPack* software.
  - o **Put Headers on ASCII files**: Adds/removes column headers from above ASCII files.
- Click the **Open a FlowTracker file** or **Open many FlowTracker files/folders** button; use the browse window to select FlowTracker binary files/folders (file extension ***.wad**).
- *FlowTracker* looks for data files with the ***.wad** file extension and generates the selected reports and output files selected (Figure 12). All output files use the same base file name with different extensions based on the content of the files. **Important: *FlowTracker* does NOT prompt before overwriting the ASCII output files. Be sure any modified files, or files using the same file name, have been moved to a different folder before extracting the ASCII data.**

Table 6-1 describes the parameters reported in FlowTracker output files.
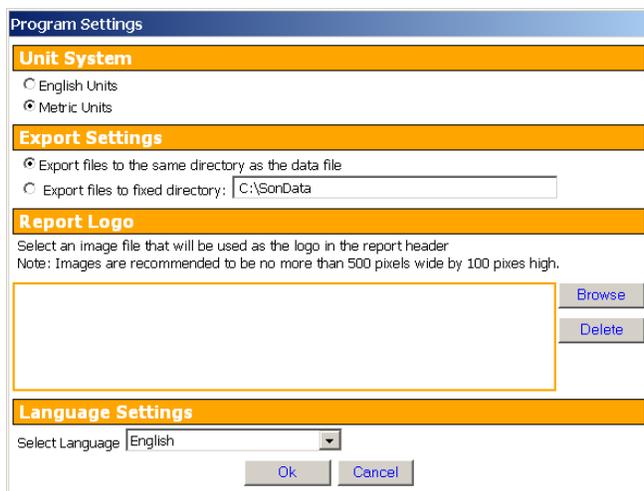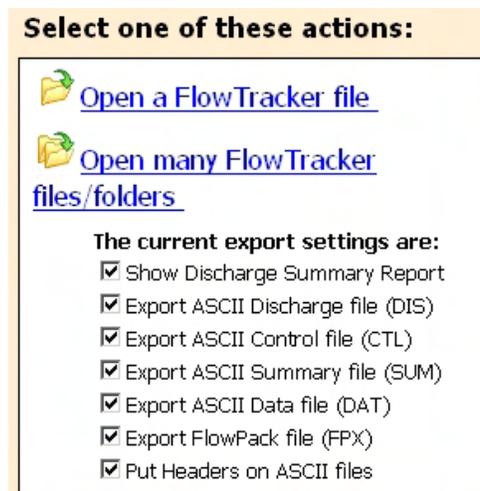

Figure 11 – FlowExporter Options Window

Figure 12 – Output File Options

Discharge Measurement Summary

Date Generated: Fri Aug 25 2006

File Information

File Name	DemoData.wad
Start Date and Time	2001/08/15 12:58:16

Site Details

Site Name	
Operator(s)	

System Information

Sensor Type	FlowTracker
Serial #	P63
CPU Firmware Version	2.0
	1.95

Units (Metric Units)

Distance	m
Velocity	m/s
Area	m^2
Discharge	m^3/s

Discharge Uncertainty

Category	ISO	Stats
Accuracy	1.0%	1.0%
Depth	0.1%	1.2%
Velocity	0.5%	1.6%
Width	0.1%	0.1%
Method	1.8%	-
# Stations	2.0%	-
Overall	**2.9%**	**2.3%**

Summary

Averaging Int.	40	# Stations	25
Start Edge	LEW	Total Width	73.762
Mean SNR	24.3 dB	Total Area	31.111
Mean Temp	27.12 °C	Mean Depth	0.422
Disch. Equation	Mid-Section	Mean Velocity	0.2783
		Total Discharge	**8.6585**

Measurement Results

St	Clock	Loc	Method	Depth	%Dep	MeasD	Vel	CorrFact	MeanV	Area	Flow	%Q
0	12:58	3.05	None	0.000	0.0	0.000	0.0000	1.00	0.0000	0.000	0.0000	0.0
1	12:58	6.10	0.6	0.186	0.6	0.074	0.2264	1.00	0.2264	0.567	0.1283	1.5
2	12:59	9.14	0.6	0.305	0.6	0.122	0.2748	1.00	0.2748	0.929	0.2553	2.9
3	13:02	12.19	0.6	0.433	0.6	0.173	0.3781	1.00	0.3781	1.319	0.4988	5.8
4	13:03	15.24	0.6	0.518	0.6	0.207	0.4307	1.00	0.4307	1.579	0.6801	7.9
5	13:04	18.29	0.6	0.491	0.6	0.196	0.4748	1.00	0.4748	1.496	0.7101	8.2
6	13:05	21.34	0.6	0.515	0.6	0.206	0.3789	1.00	0.3789	1.570	0.5949	6.9
7	13:06	24.38	0.6	0.619	0.6	0.247	0.2571	1.00	0.2571	1.886	0.4848	5.6
8	13:08	27.43	0.6	0.710	0.6	0.284	0.2429	1.00	0.2429	2.164	0.5257	6.1
9	13:09	30.48	0.6	0.680	0.6	0.272	0.2553	1.00	0.2553	2.072	0.5289	6.1
10	13:10	33.53	0.6	0.671	0.6	0.268	0.2436	1.00	0.2436	2.044	0.4978	5.7
11	13:11	36.58	0.6	0.640	0.6	0.256	0.2644	1.00	0.2644	1.951	0.5158	6.0
12	13:12	39.62	0.6	0.607	0.6	0.243	0.3181	1.00	0.3181	1.849	0.5880	6.8
13	13:13	42.67	0.6	0.509	0.6	0.204	0.3704	1.00	0.3704	1.551	0.5747	6.6
14	13:14	45.72	0.6	0.451	0.6	0.180	0.3675	1.00	0.3675	1.375	0.5053	5.8
15	13:15	48.77	0.6	0.372	0.6	0.149	0.3421	1.00	0.3421	1.133	0.3877	4.5
16	13:16	51.82	0.6	0.317	0.6	0.127	0.2935	1.00	0.2935	0.966	0.2835	3.3
17	13:18	54.86	0.6	0.271	0.6	0.108	0.2303	1.00	0.2303	0.827	0.1904	2.2
18	13:19	57.91	0.6	0.256	0.6	0.102	0.1952	1.00	0.1952	0.780	0.1523	1.8
19	13:20	60.96	0.6	0.259	0.6	0.104	0.1314	1.00	0.1314	0.789	0.1037	1.2
20	13:21	64.01	0.6	0.293	0.6	0.117	0.1193	1.00	0.1193	0.892	0.1064	1.2
21	13:22	67.06	0.6	0.351	0.6	0.140	0.1196	1.00	0.1196	1.068	0.1278	1.5
22	13:23	70.10	0.6	0.421	0.6	0.168	0.1147	1.00	0.1147	1.282	0.1470	1.7
23	*13:25*	*73.15*	*0.6*	*0.305*	*0.6*	*0.122*	*0.0696*	*1.00*	*0.0696*	*1.022*	*0.0711*	*0.8*
24	13:25	76.81	None	0.000	0.0	0.000	0.0000	1.00	0.0000	0.000	0.0000	0.0

Rows in italics indicate a QC warning. See the Quality Control page of this report for more information.

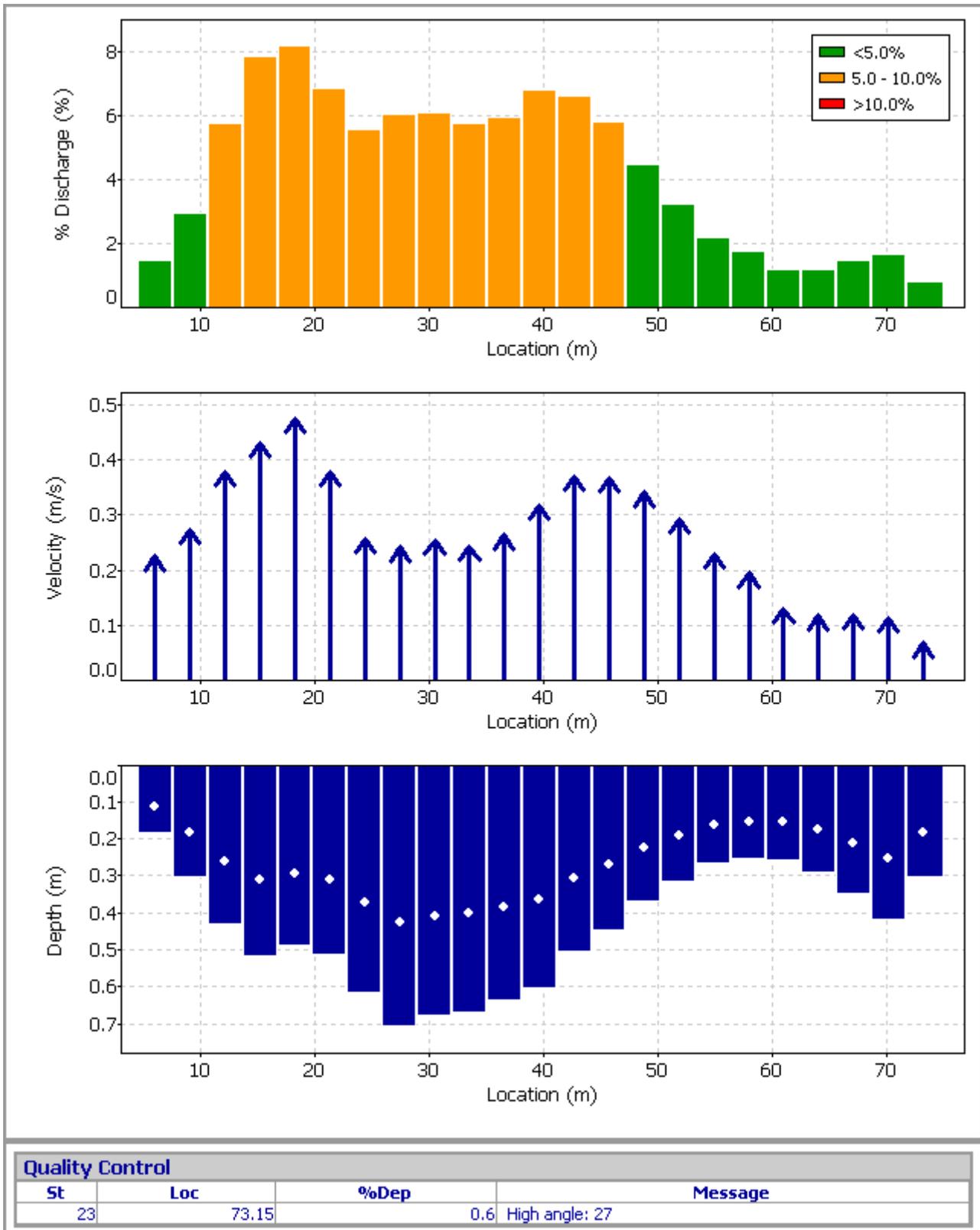**Figure 13 – FlowTracker Discharge Measurement Summary Report (Top Half)**

Figure 14 – FlowTracker Discharge Measurement Summary Report (Bottom Half)

Table 6-1. Description of Output Parameters

Label	Description	English	Metric
St	Station number. Note: Stations may include more than one measurement.		
#	Burst or measurements number. Even measurements not used for final calculations are recorded and output in the .sum and .dat files.		
Clock	Measurement time from FlowTracker clock		
Loc	Station location	ft	m
Loc1	Station location value 1 (general mode only)	ft	m
Loc2	Station location value 2 (general mode only)	ft	m
Method	Discharge measurement method (§5.2.4)		
Depth	Water depth	ft	m
Depth1	Water depth 1 (when RepeatDepth enabled, normally with Japanese discharge equation)	ft	m
Depth2	Water depth 2 (when RepeatDepth enabled, normally with Japanese discharge equation)	ft	m
MeanD	Mean water depth (when RepeatDepth enabled, normally with Japanese discharge equation)	ft	m
IceD	Ice depth, water surface to bottom of ice or slush	ft	m
%D	Measurement depth location, as fraction of the effective depth. Effective depth is water depth minus ice depth. This value is referenced from the surface down (e.g., 0.6 indicates 0.6*depth down from the surface).		
MeasD	Measurement depth location, in depth units. This value is referenced from the bottom (e.g., 0.40 m up from the bottom).	ft	m
Vel	Mean X velocity	ft/s	m/s
MeanV	Mean station velocity	ft/s	m/s
Vx	Mean X velocity	ft/s	m/s
Vy	Mean Y velocity	ft/s	m/s
Vz	Mean Z velocity	ft/s	m/s
VelX	Raw 1 second X velocity	ft/s	m/s
VelY	Raw 1 second Y velocity	ft/s	m/s
VelZ	Raw 1 second Z velocity	ft/s	m/s
CorrFact	Correction factor used to scale measured velocity		
Area	Station area	ft^2	m^2
Flow	Station discharge	ft^3/s	m^3/s
%Q	Percent of total discharge	%	%
Npts	Number of samples in measurement; one sample collected per second		
Spike	Number of spikes removed before calculating mean values		
SNR	Mean Signal-to-Noise Ratio	dB	dB
SNR1	Signal-to-Noise Ratio beam 1	dB	dB
SNR2	Signal-to-Noise Ratio beam 2	dB	dB
SNR3	Signal-to-Noise Ratio beam 3	dB	dB
Angle	Velocity angle calculated as atan(Vy/Vx)	°	°
Verr	Standard error of X velocity (§1.4.3)	ft/s	m/s
VxErr	Standard error of X velocity (§1.4.3)	ft/s	m/s
VyErr	Standard error of Y velocity (§1.4.3)	ft/s	m/s
VzErr	Standard error of Z velocity (§1.4.3)	ft/s	m/s
Bnd	Boundary QC measurement (§1.4.4); 0=Best, 1=Good, 2=Fair, 3=Poor		
Temp	Water temperature	°F	°C
ASD1	Standard deviation of SNR data, beam 1	dB	dB
ASD2	Standard deviation of SNR data, beam 2	dB	dB
ASD3	Standard deviation of SNR data, beam 3	dB	dB
Batt	Battery voltage	V	V

6.4. Download Data Files (Recorder)

When you have connected to a FlowTracker system, the *Recorder* module (Figure 15) becomes available. *Recorder* is used to download binary data files from the internal recorder (§6.4.1), and to format (erase) data files from the internal recorder (§6.4.2).

- It establishes communication with the FlowTracker.
- It downloads a directory of files on the internal recorder.
- The user specifies which files to download and a destination directory.
- The software enters a special download mode at a higher baud rate (usually 57600) and downloads the specified files at this rate.
- It allows you to format (erase) the recorder.

6.4.1. Recorder Downloading Steps

The following steps describe how to download data files from the FlowTracker's internal recorder to your computer. Note: Files are downloaded with the `*.wad` file extension.

- Click **Recorder** to open the dialog box (Figure 15). This action will establish communication and display the recorder's directory. Note: The **Recorder** option is only available after you have successfully connected to a FlowTracker system.
- Select one or more files from the display list. You can:
  - o Click one file to select it.
  - o Hold **Control** or **Shift** and click a series of files.
  - o Click **Select All** to select all files on the recorder.
- Set the download **Baud rate**.
  - o **Recorder** uses a higher rate to download files (compared to the standard system communication rate). The default download baud rate is 57600.
  - o If you have trouble downloading data, try using a slower download baud rate.
- Specify a **Destination folder** (or use the **Browse** control).
- Click **Download** to copy all the selected files to the specified folder. Note: A **Cancel** control will appear to let you abort the download process.
- Watch the status area at the bottom of the dialog box to view the download progress.
- Select more files to download, or **Close** the **Recorder** dialog box.
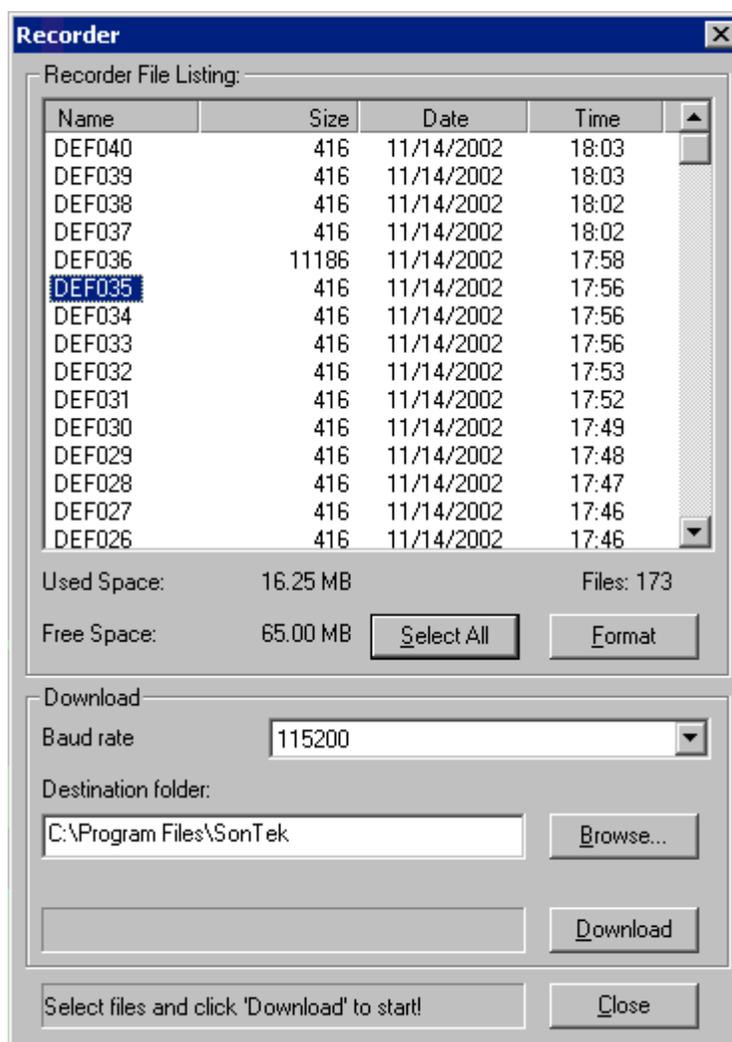
Figure 15 – Recorder Dialog Box

6.4.2. Recorder Formatting Steps

The following steps describe how to format (erase) the FlowTracker's internal recorder.

- Click **Recorder** to open the dialog box. This action will establish communication and display the recorder's directory. Note: The **Recorder** option is only available after you have successfully connected to a FlowTracker system.
- <u>Caution</u>: Ensure that all desired data files have been downloaded to your computer (§6.4.1) <u>before</u> executing the **Format** command. Note that all files will be erased from the recorder; that is, there is no option to erase individual files from the recorder. Files cannot be recovered from the recorder after it has been formatted.
- Click **Format**, and then **OK** (or **Cancel**) to verify your decision to format/erase the recorder.
- **Close** the **Recorder** dialog box.
- The recorder can also be formatted from the keypad interface (see §2.5.3).

6.5. Diagnostic Software (BeamCheck)

BeamCheck (Figure 16) is a diagnostic program used to verify FlowTracker performance.

- This is the same diagnostic program used at SonTek. It provides you with a powerful tool for understanding and verifying system performance.
- We recommend you become familiar with this software and use it on a regular basis.

Typically, *BeamCheck* operates by sending a pulse of sound into the water, and then plots the signal strength of the return signal versus range for each of the FlowTracker's receivers. This information can be evaluated to determine the effective measurement range, to look for interference from boundaries/structures, to survey a deployment site, or to observe the quality of the returned signal. General program information is provided in §6.5.1 through §6.5.4. Example *BeamCheck* outputs are provided in §6.5.5 and §6.5.6.
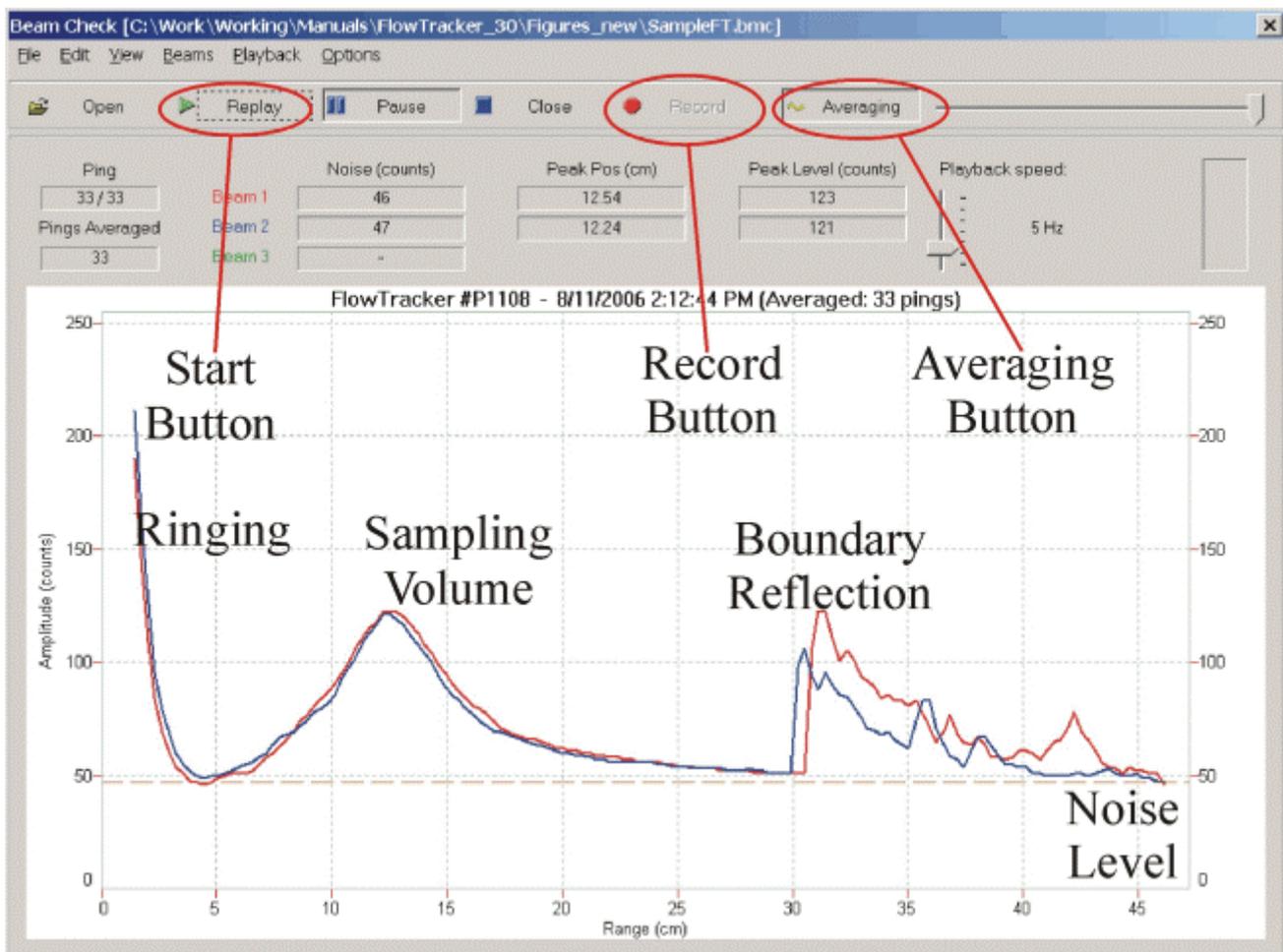
Figure 16 – BeamCheck Main Window with Sample Output

6.5.1. BeamCheck Overview

In *BeamCheck*, the FlowTracker sends a pulse of sound and outputs the return signal strength for each receiver as a function of time. Features in the signal strength profile verify different aspects of system performance (Figure 16).

- The horizontal axis indicates the range from the FlowTracker probe (in cm).
- The vertical axis is in internal signal strength units called counts (1 count = 0.43 dB).
- *Ringing* from the transmit pulse appears on the left side of the graph.
- The location of the *sampling volume* is indicated by increased signal strength in a bell-shaped curve.
    - o The sampling volume curve corresponds to the transmit pulse passing through the focal point of the receivers.
    - o The peak of this curve corresponds to the center of the sampling volume.
    - o The location of the sampling volume varies, but is typically 10-12 cm.
    - o All receivers (2 or 3) should see the peak in the same location, although there will be variation in the height and shape of the curve.
- A sharp spike indicates a *boundary reflection* (if a boundary is within range).
    - o If the probe is close to a boundary, a sharp reflection should be seen.
    - o The size and shape of this reflection will vary depending on the nature of the boundary and its distance from the FlowTracker.
- Signal strength decreases to the electronic *noise level* past the boundary.

When using *BeamCheck*, it is important to understand that the output plot will vary considerably because of the nature of acoustic scattering.

- Each of the items described above should be visible (Figure 16).
- If no sampling volume peak can be seen, try adding some fine dirt or other seeding material and stirring the water to increase the signal strength (§8.6).
- If the *BeamCheck* output differs significantly from the sample shown here, refer to §6.5.5 and §6.5.6 for more details about interpreting this data.

6.5.2. BeamCheck Menu and Control Items

This section describes *BeamCheck* menu and control items.

- File Menu
  - o **Open** – Opens a previously recorded beam check file (**.bmc**) for playback and review.
  - o **Record** – Starts the data recording process if you wish to store the real-time information being displayed to a data file. You will be prompted for a file name and location.
  - o **Print** – Sends the currently displayed graph to a selected printer.
  - o **Close** – Closes the currently selected beam check file (**.bmc**), but not the main window.
  - o **Exit** – Stops the beam check process and closes the **Beam Check** window.
- Edit Menu
  - o **Copy** – Sends the currently displayed graph to the Windows clipboard. You can then "paste" the graph in another program such as Microsoft Word.
- View Menu
  - o **Amplitude** – Sets the graph to display a representation of signal strength versus time.
  - o **Sine/Cosine** – Not used.
  - o **Show range as X-Axis** – Sets the X-axis of the graph to display signal strength data in meters rather than number of samples.
  - o **Show decay curve** – Not used.
- Beams Menu
  - o **Beam 1/2/3** – Lets you select which combination of beams to display. **Beam 3** is disabled on 2-beam systems.
  - o **All beams** – Displays data for all the beams.
- Playback Menu
  - o **Start/Replay** – Begins the process of displaying either real-time (**Start**) or previously recorded (**Replay**) data to the graph and tabular displays.
  - o **Pause** – Toggles between either pausing or continuing the display of data.
  - o **Stop/Close** – Ends the process of displaying real-time data or closes a file being replayed.
- Options Menu
  - o **Averaging** – Smoothes the display of data by continually averaging successive pings. The number of pings that have been averaged is shown in the **Pings Averaged** box. By averaging the pings, a more representative display of the data is shown.
  - o **Force high-speed connection** – Sets the computer-to-instrument interface to a higher baud rate so that data updates occur more quickly. The default for this feature is ON. You should only turn this feature OFF if you experience communication problems.
- Controls (e.g., buttons, slide switches)
  - o **Open** – Opens a previously recorded beam check file (**.bmc**) for playback and review.
  - o **Start** / **Replay** – Begins the process of displaying either real-time (**Start**) or previously recorded data (**Replay**) to the graph and tabular displays. If no previously recorded data file has been opened, the button says **Start**; if a file has been opened, the button says **Replay**.
  - o **Pause** – Toggles between either pausing or continuing the display of data.
  - o **Stop** / **Close** – Ends the process of displaying data. If no previously recorded data file has been opened, the button says **Stop**. If a file has been opened, the button says **Close**, and will now function to both stop the display of data and to close the data file.
  - o **Record** – Starts the data recording process if you wish to store the real-time information being displayed to a data file. You will be prompted for a file name and location. From that point on, the data that is being displayed will be recorded until you click **Stop**.

o **Averaging** – Smoothes the display of data by continually averaging successive pings. The number of pings that have been averaged is shown in the **Pings Averaged** box. By averaging the pings, a more representative display of the data is shown.

o **Ping Selector** (slide control next to **Averaging** button) – Lets you select an individual "ping" to display. Click and drag the slider to select the desired ping number (shown in the **Ping** box). When used, the **Averaging** feature is disabled.

o **Playback Speed** (slide control) – Lets you change the rate at which playback data is displayed. Click and drag the slider to the desired playback speed. Values in Hz display data faster than values in seconds. For example: a setting of **50 Hz** will replay data at a rate of 50 pings per second, while a setting of **10 s** will display a ping every 10 seconds. The default for this setting is **5 Hz** (i.e., data replayed at a speed of 5 pings per second).

o **Zoom In/Out** (mouse control) – To zoom-in on a particular area of the graphic display, use your mouse to click-and-drag a box around the desired area (see Figure 17). You can also zoom-in just by clicking on a particular feature within the graph. To zoom-out, right-click your mouse anywhere on the graph to step through the zoom-out levels. The click point will coincide with the center of the zoom.
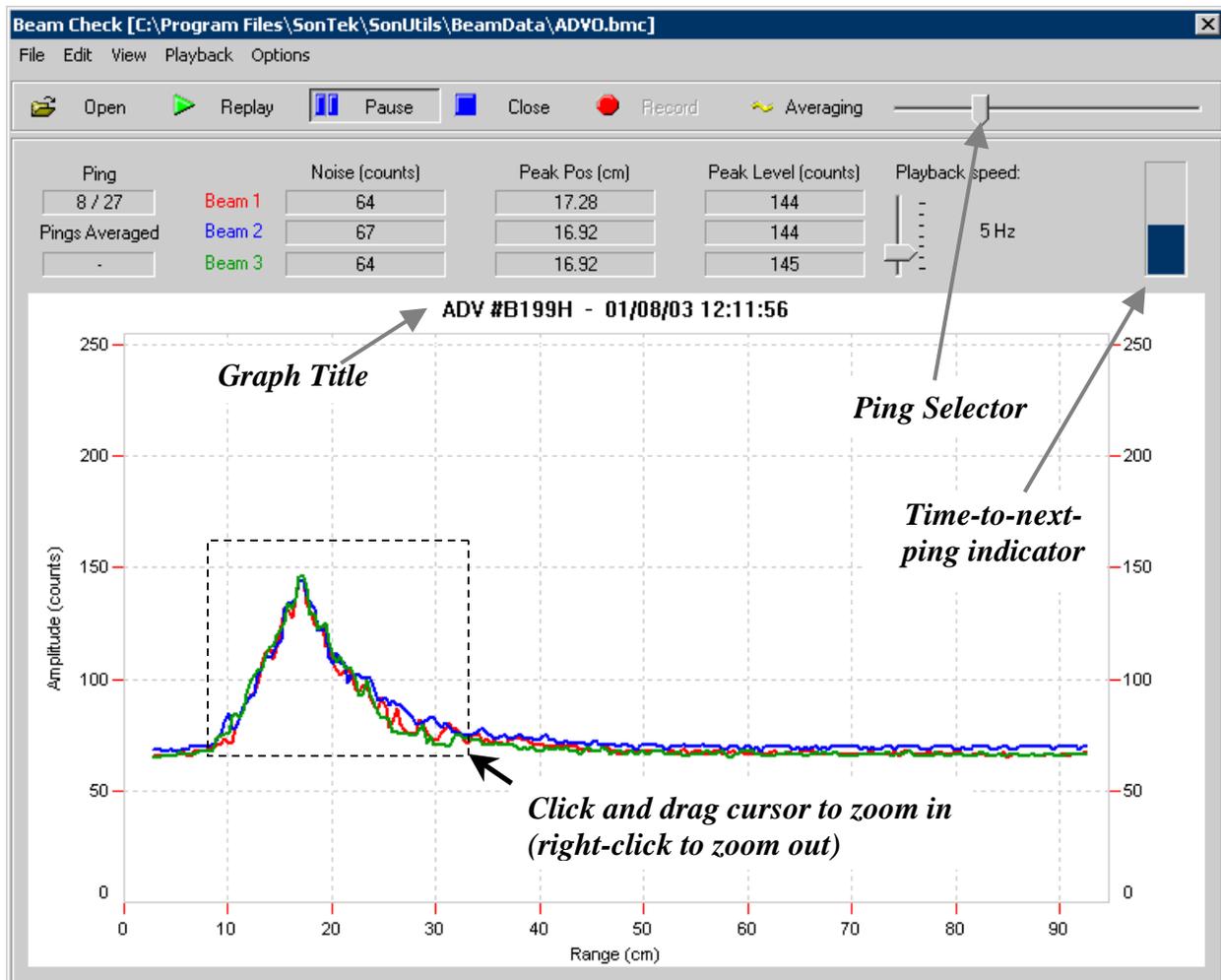
Figure 17 – BeamCheck Playback Example

6.5.3. BeamCheck Display Features

This section describes *BeamCheck* display features (Figure 17).

- **Ping** – Indicates the number of the transmitted pulse (i.e., "ping") that is currently being displayed on the graph and in the tabular data boxes. If real-time data is being displayed, only the current ping number is displayed. If previously recorded data is being displayed, both the current ping and the total number of recorded pings are displayed. For example, **3 / 27** means ping number 3 from a data set containing 27 pings is being displayed.
- **Pings Averaged** – When **Averaging** has been selected, this box indicates the number of pings that have been averaged together for the currently displayed graph and tabular data.
- **Noise** – Shows the electronics noise level for the receiver of each beam. This value is determined by the signal strength when the instrument is not receiving any return reflections from the water. This value should match the signal strength for the flat portion of the graph. The noise value is displayed in "counts".
- **Peak Pos** – This is the location of the center of the peak for the sampling volume for each of the receivers. The displayed value can be in either centimeters (cm) or counts, depending on the setting of the **Show range as X-Axis** option. The position of the peak should be about the same for each receiver.
- **Peak Level** – This is the height of the peak for the sampling volume for each of the receivers. This will vary depending on the amount of scattering material in the water.
- **Graph Title** – A title bar appears within the graph itself (Figure 17). This title bar shows the type of instrument (e.g., ADV, FlowTracker), its serial number, and the date/time that data collection began. Time is displayed in the format set within the Windows Control Panel (**Start|Settings|Control Panel|Regional Options|Time**).
- **Graph Range/Samples** (X-axis) – The graph itself shows a plot of the return signal strength for each beam as a function of time following the transmit pulse. The "time" portion is shown along the graph's X-axis. This value can be shown as a function of range (in meters) or as a function of samples depending on the setting of the **Show range as X-Axis** option.
- **Graph Amplitude** (Y-axis) – The graph itself shows a plot of the return signal strength for each beam as a function of time following the transmit pulse. The "signal strength" portion is shown along the graph's Y-axis. This value is shown in "counts".

6.5.4. BeamCheck Operation

To run *BeamCheck*:

- Hold the FlowTracker in a small tank or bucket of water (or in a natural environment) such that the probe is submerged and there is a boundary (surface, side, or bottom) within view.
  - o Ideally, the boundary should be placed 20-30 cm (8-12 in) from the probe.
  - o You may need to add a small amount of fine dirt or other seeding material and stir the bucket well for good test conditions. Regular tap water usually does not have enough scatterers (seeding) for a valid test.
- Connect the FlowTracker to the computer and turn the system on.
- Run the *FlowTracker* software (click **Start | Programs | SonTek Software | FlowTracker**).
- Click **Connect to a FlowTracker**. Select the correct COM port and click **Connect**.
- Click **BeamCheck**.
- To view real-time beam check data:
  - o Click **Start**. This establishes communication with the instrument and starts data display.
  - o Use the menu and control items (§6.5.2) to alter the display of data as desired.
  - o See §6.5.5 and §6.5.6 for examples of how to interpret the data.
  - o Click **Stop** to end the display of data.
  - o Use **File|Exit** to close the **Beam Check** window.
- To record real-time beam check data for later playback:
  - o Start the display of real-time data as described above.
  - o Click **Record** to save all data to a file. You will be prompted for a file name and storage location. Typically, a minimum of 20 pings is required for proper data analysis.
  - o Use the menu and control items (§6.5.2) to alter the display of data as desired. The recorded data is not affected; only the display of data is affected.
  - o Click **Pause** or **Stop** to interrupt or end data collection.
- To play back previously recorded beam check data (using a .bmc data file):
  - o Click **Open** to select a previously recorded beam check file (**.bmc**).
  - o Click **Replay** (or **Pause**) to start the playback of data.
  - o Use the menu and control items (§6.5.2) to alter the display of data as desired. The recorded data is not affected; only the display of data is affected.

6.5.5. Sample Program Output

BeamCheck operates in the following manner.

- The FlowTracker transmits a pulse of sound. It then receives the return signal strength for each of the 2 (or 3) receivers as a function of time following the transmit pulse.
- Features in the return signal strength profile are used to verify different aspects of system performance.
- The software also plots sine and cosine channel versus time for each receiver. These are used for internal diagnostics at SonTek and are not needed for user diagnostics. The sine and cosine outputs are not discussed in this manual.

The plot of signal strength versus time shows several features (Figure 18):

- Ringing from the transmit pulse.
- Increased signal strength in a bell-shaped curve corresponding to the sampling volume.
- A sharp spike from the boundary reflection, if within range.
- Signal strength leveling to the electronic noise level past the boundary.
- The display is updated every ≈5 seconds (each plot is the average of a number of samples).
- The horizontal axis is in FlowTracker timing units; time corresponds to the distance from the transmitter. One count axis equals 0.06 cm (0.15 in).
- The vertical axis is in internal signal strength units called counts (1 count = 0.43 dB).

Each feature of the *BeamCheck* signal strength plot is described in detail below.
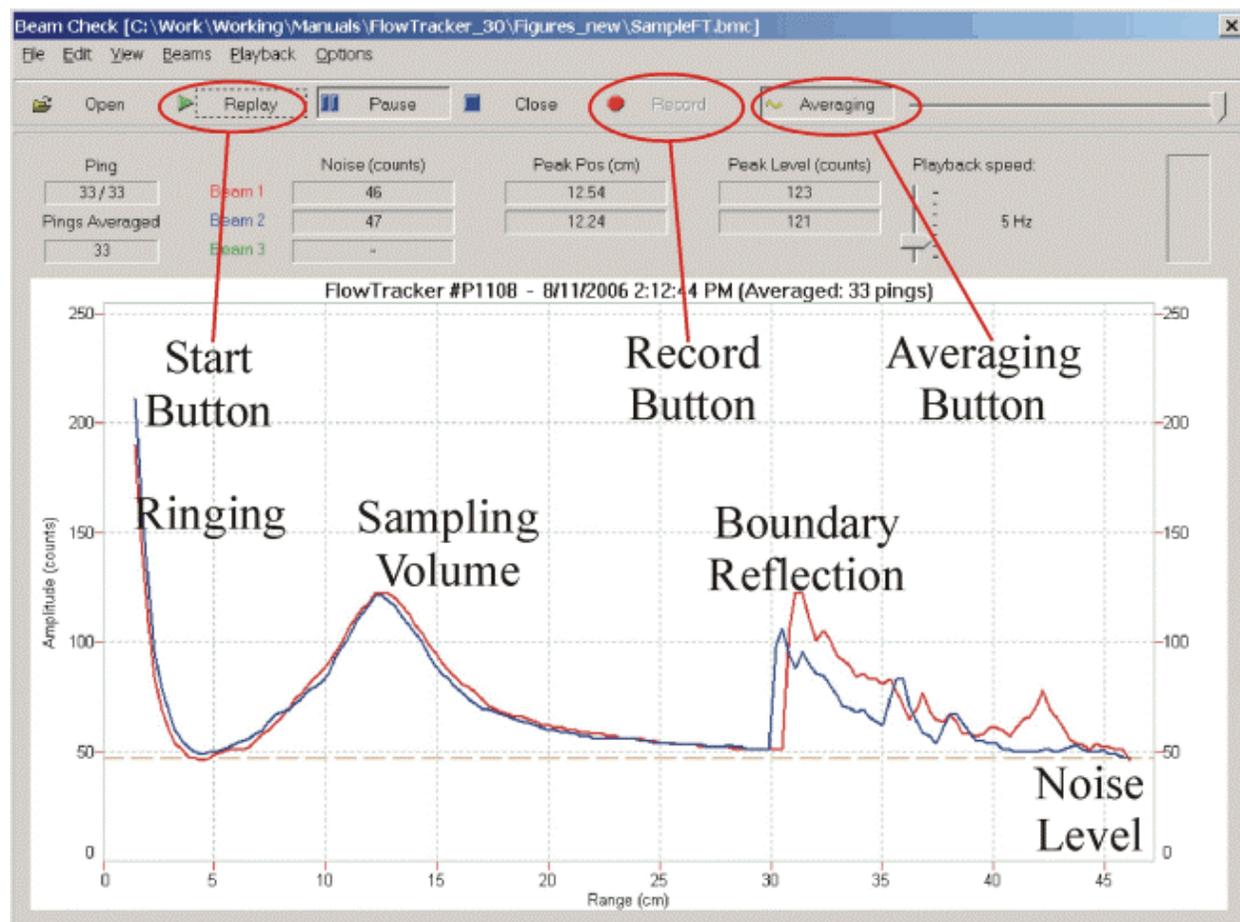
Figure 18 – BeamCheck Sample Output Screen

- The first ≈5 cm of the horizontal axis is electronic "ringing" following the transmit pulse. The transmit pulse is generated by a strong electrical signal, and requires some time for the electronics and transducers to recover.
- If there is sufficient scattering material in the water, there will be an increase in signal strength in a bell-shaped curve that corresponds to the transmit pulse passing through the focal point of the receivers. The peak of this curve corresponds to the center of the sampling volume. The location of the center of the sampling volume varies from probe to probe but typically is in the range of 10-12 cm. All receivers (2 or 3) should see the peak in the same location, although there will be variation in the height and shape of the curve.
- If the probe is close to a boundary (bottom, surface, or side), a sharp reflection should be seen. The size and shape of this reflection will vary depending on the nature of the boundary, its distance from the FlowTracker, and the acoustic conditions of the water. We can estimate the distance from the probe to the boundary by the location of the boundary reflection. In Figure 18, this occurs at about 30 cm from the probe.
- After the boundary reflection, the signal strength flattens out in the region where there is no reflected signal from the water. The value at which it flattens out is the electronics noise level. This noise level is typically about 30-70 counts; it is also shown in the tabular display at the top of the screen. An easy way to measure the instrument noise level is to run *Beam-Check* when the probe is not in the water. In this case, the entire plot should show a constant return at the instrument's noise level.
- When using *BeamCheck*, it is important to understand that the output plot will vary considerably because of the nature of acoustic scattering. The shape and height of the return signal, particularly the bell curve for the sampling volume, will show considerable variation between updates. When using the program for diagnostics, look at the general shape of the curve and for features that are consistently present.

6.5.6. Diagnosing Hardware Programs with BeamCheck

BeamCheck can be used to detect most problems that can occur with a FlowTracker. This section describes the program output for some possible situations.

Low Scattering Strength (Figure 19)

If there is insufficient scattering material (e.g., very clear water), the sampling volume peak will be small or non-existent. This situation can be confused with a malfunctioning transmitter (see Figure 20) unless the boundary is in view. Note that in Figure 19 we clearly see the boundary reflection at ≈23 cm, but do not see a sampling volume peak around 10 cm. In this situation, place a small amount of seeding material in the water to act as scattering material (fine dirt or clay will work quite well; see §8.6).
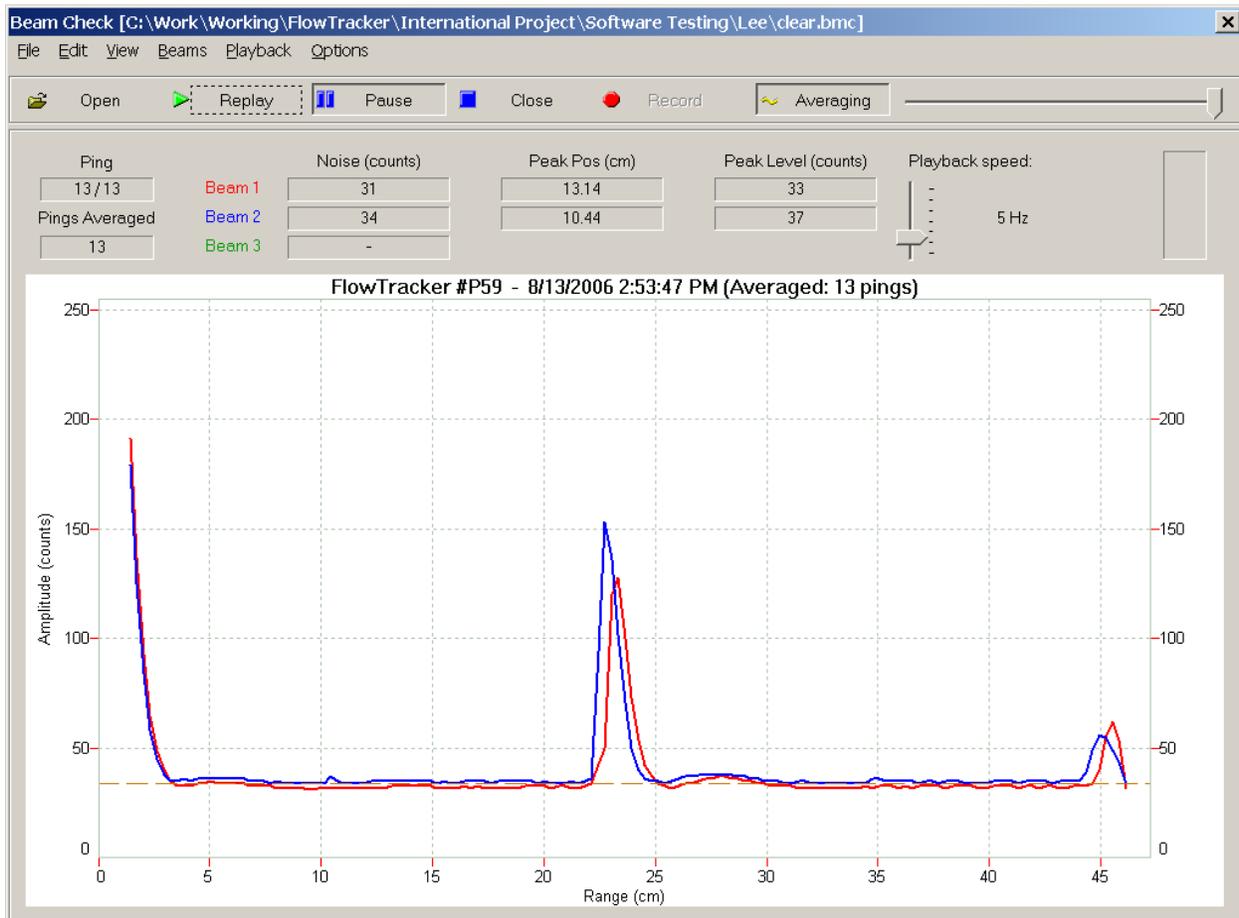
Figure 19 – BeamCheck Output with Low Scattering Strength

Malfunctioning transmitter (Figure 20)

This appears as a flat response with signal strength at the normal noise level. This can be confused with a disconnected probe or low scattering levels (see Figure 19). Note the absence of a boundary reflection to distinguish this from low scattering levels.
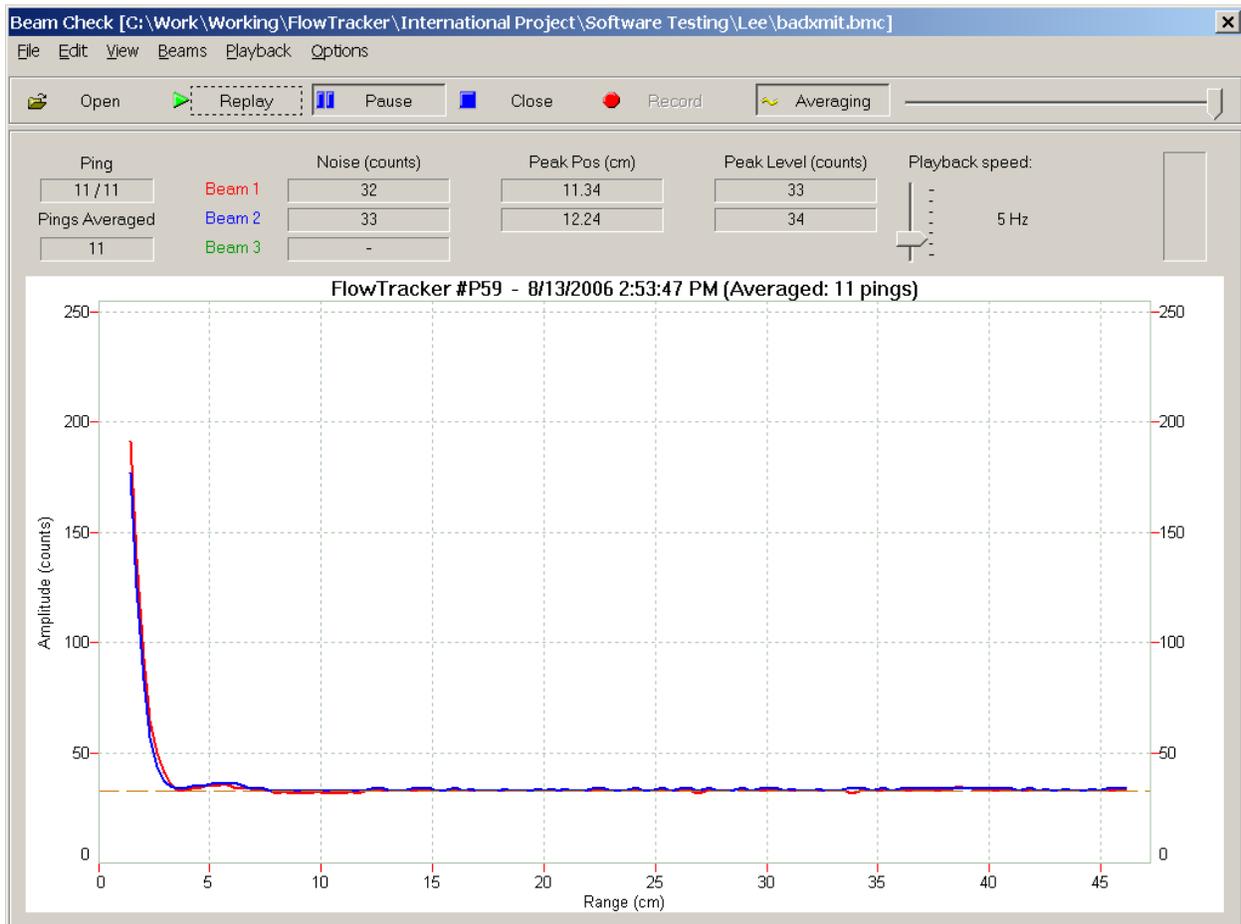
Figure 20 – BeamCheck Output with Malfunctioning Transmitter

Malfunctioning receiver(s) (Figure 21)

The signal from each receiver should have approximately the same strength as the sampling volume. If the differences exceed 10-20 counts, clean off the each transducer and make sure the beams are not physically blocked before calling SonTek.

Damaged receiver arm (no Figure provided)

If the sampling volume in one receiver is offset along the horizontal axis, it means the receiver arm has been physically bent. A bent arm will change the FlowTracker calibration and will affect the accuracy of velocity data. Contact SonTek if you have a damaged probe for details about repair options.
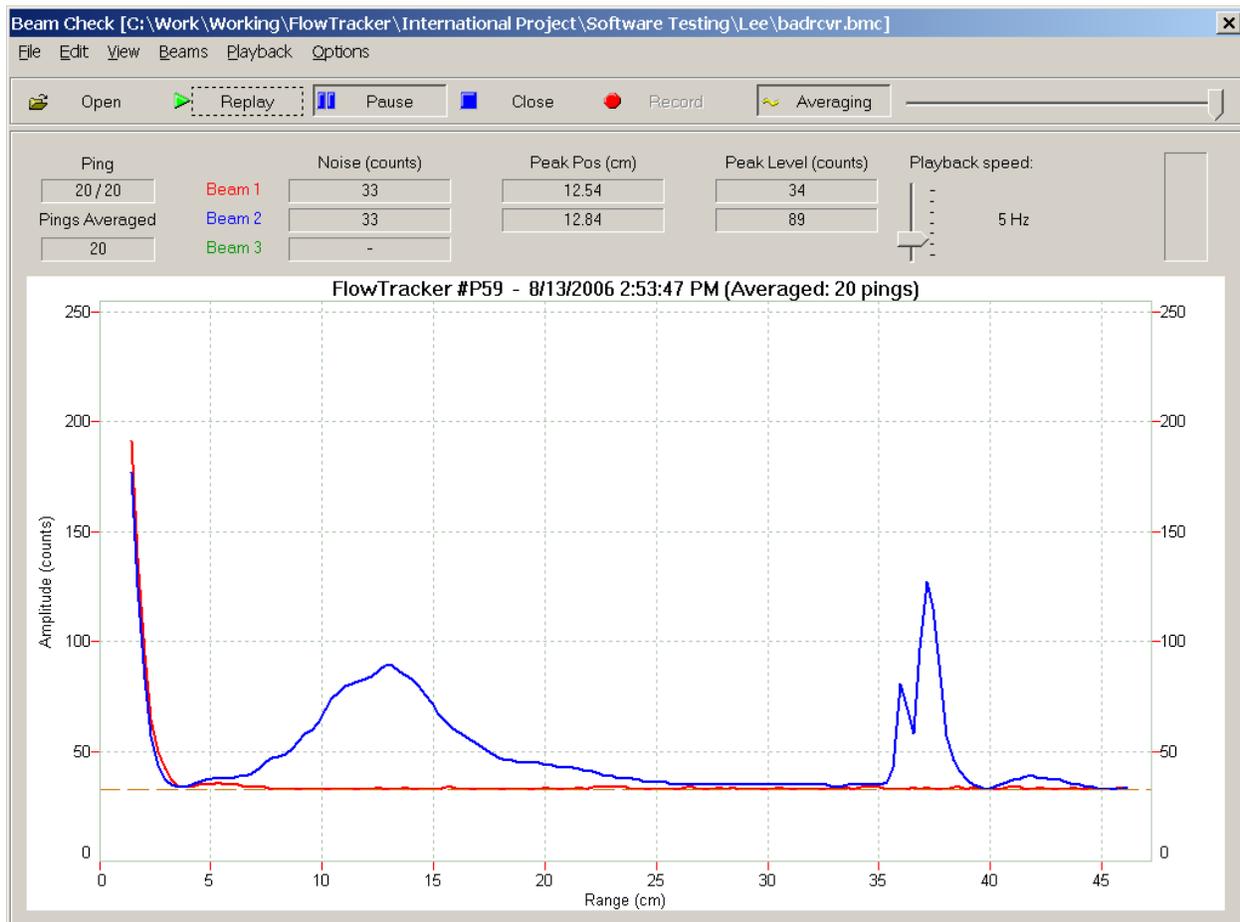
Figure 21 – BeamCheck Output with Malfunctioning Receiver

Excessive noise (Figure 22)

If the electronics noise level is more than 10 counts above its normal level, it may be a sign that something is wrong. Likewise, if the noise level between beams is significantly different (as in Figure 22), this may indicate a system problem. The noise level may also be higher than normal because of external electromagnetic interference, or because water has condensed on the receiver electronics.
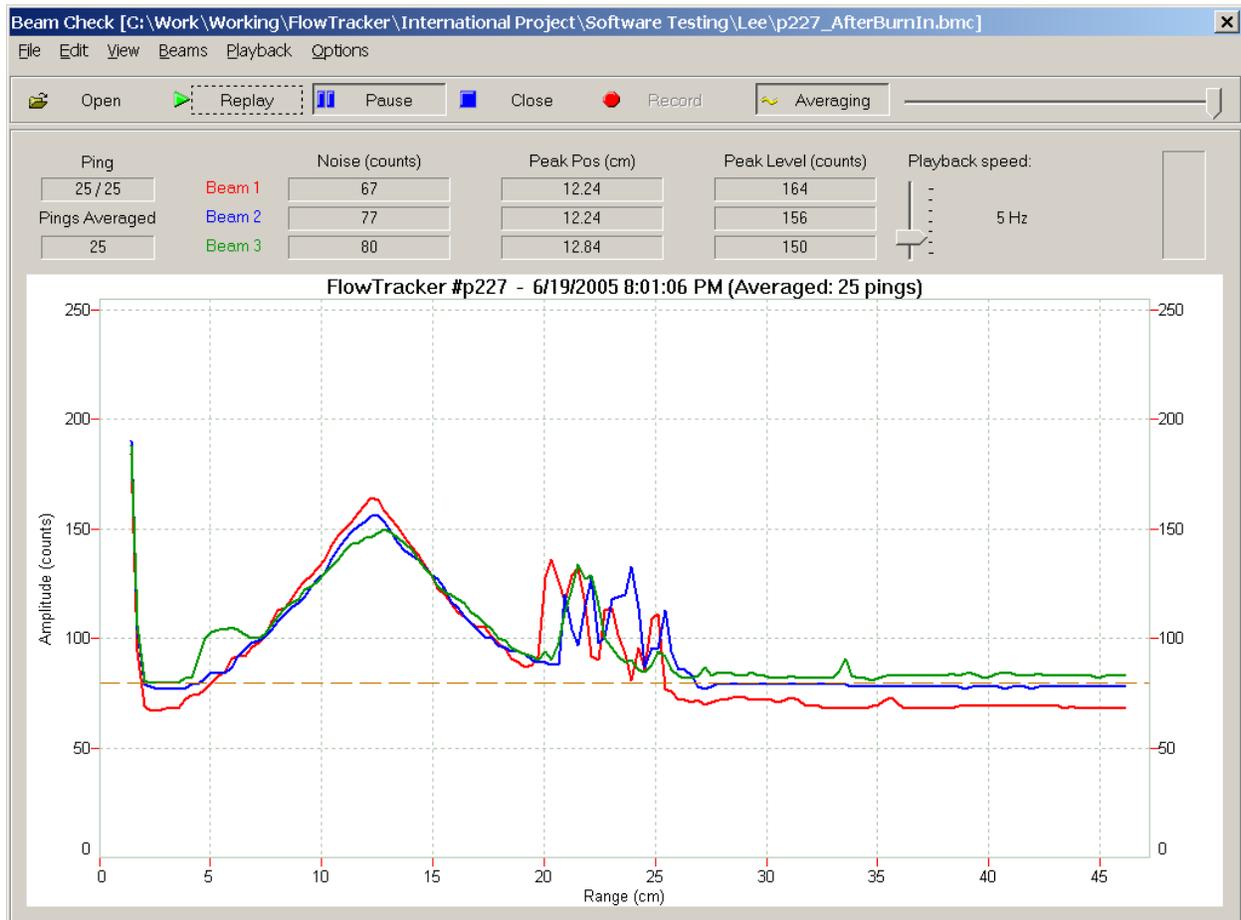
Figure 22 – BeamCheck Output with Excessive Noise

High signal strength past the boundary (Figure 23)

If the signal strength does not fall off rapidly past the boundary, the additional acoustic noise can potentially increase the noise in velocity measurements. This additional acoustic noise is most commonly seen in small tanks, particularly when built from acrylic or glass. While it may occur during testing in the office or laboratory, it is rarely a factor during field operations with the FlowTracker.
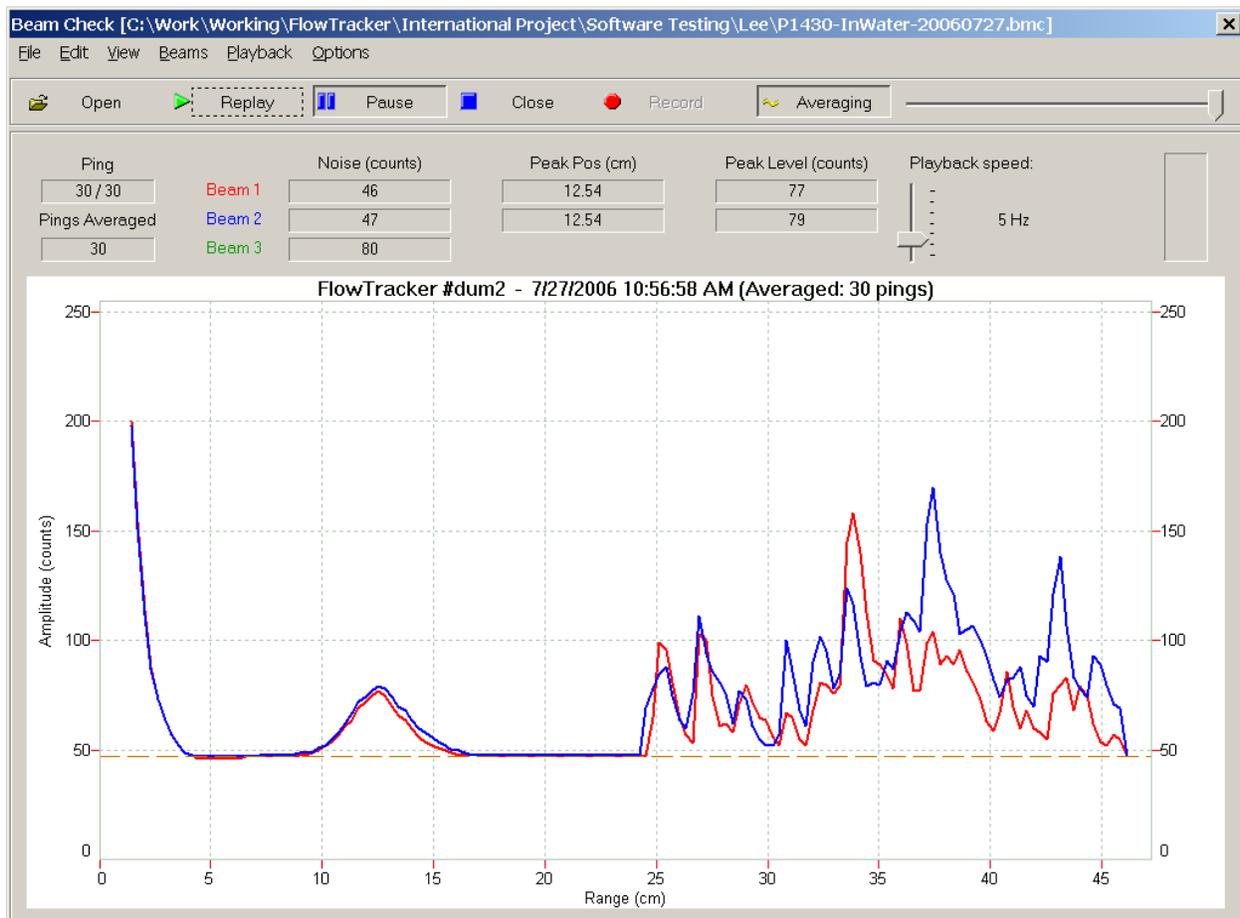
Figure 23 – BeamCheck Output with Noise Past Boundary

Section 7. Hardware

7.1. Cables and Connectors

7.1.1. Probe Cable

The ADV probe is connected to the handheld controller by a 200-cm (80-in) cable.

- This is a custom built, highly noise-sensitive cable.
- It is permanently attached to the handheld controller.
- Avoid damage to the cable, especially cuts to the jacket or sharp bends that could damage internal conductors. Damage to the cable can severely affect FlowTracker operation.
- A longer cable (300 cm; 120 in) is available for special applications. It is not possible to up-grade an existing system to a different cable length.

7.1.2. External Power/Communication Cable

A cable is supplied that lets you interface the handheld controller to an external PC and power supply. This cable has three connectors.

- A 5-pin waterproof connector matches the connector on the handheld controller.
- A female DB9 connector matches the serial port on a standard PC.
- A 2-pin connector matches the FlowTracker external power supply (optional). You can use the external supply to conserve battery power when downloading data or when testing the system.

Table 7-1 shows the wiring of the power/communication connector.

Table 7-1. Power/Communication Cable Connector Wiring

5-Pin Connector	Function	DB9 Female	2-Pin Connector
Pin A	Power (6-15 VDC)	Not connected	Pin 1
Pin B	RS232 Data Out	Pin 2	Not connected
Pin C	RS232 Data In	Pin 3	Not connected
Pin D	RS232 Ground	Pin 5	Not connected
Pin E	Power Ground	Not connected	Pin 2

7.2. Power Supply

7.2.1. Input Power

The FlowTracker operates on 6-15 VDC input power.

- An input voltage greater than 15 V will seriously damage the electronics.
- The FlowTracker draws about 1.0 W during data collection (with the LCD backlight off).
  - o The LCD backlight increases total power consumption to about 2.0 W.
- When off, the FlowTracker draws a small residual current (≈0.5 mA).

The FlowTracker will not start data collection unless the input voltage is at least 7.0 V.

- Voltage less than 7.0 V indicates the batteries are drained.
- If voltage is below 7.0 V when the FlowTracker is turned on, it will display a low battery warning and force the system to power down.
- If voltage is less than 7.0 V when a data collection run is started, the FlowTracker will display a low battery warning and force the system to power down.
- If voltage is less than 8.0 V when a data collection run is started, the FlowTracker will display a warning but allows you to continue data collection if desired.
- If voltage drops below 8.0 V during data collection, the FlowTracker will display a warning message. Data collection should be stopped and batteries replaced to prevent loss of data.

To Avoid Draining of Batteries When System is Not in Use
- Always turn the system off before storing the system.
- When off, the FlowTracker draws a small amount of current from the batteries (≈0.5 mA).
- The current would drain a new set of alkaline batteries is 6-8 months.
- If the system will be left unused for a long period (more than 1 month), remove the batteries to prevent them from being drained unnecessarily.

7.2.2. Batteries

The FlowTracker uses eight AA batteries: alkaline, NiMH, or NiCad. Table 7-2 compares the three types of batteries.

Table 7-2. Comparison of Battery Types

	Alkaline	NiMH	NiCad
General description	Single use	Rechargeable	Rechargeable
Nominal battery capacity (typical)	2.85 Ah	1.60 Ah	0.70 Ah
New battery voltage	12.0 V	10.5 V	10.0 V
Drained battery voltage	7.0 V	8.0 V	8.5 V
Approximate operating life	25 hours	15 hours	7 hours

To access FlowTracker battery data:

- Press **2** from the main menu to access the **System Functions Menu**, and then press **5** for battery data.
- The FlowTracker will display battery voltage and estimated remaining capacity (percent of total) based on voltage for all three battery types.
- The FlowTracker has no way to determine what types of batteries are installed.
- **Predicting capacity based on voltage is only approximate, particularly for rechargeable batteries where voltage characteristics can change significantly over the life of the batteries.**
- These battery life estimates are at ≈20° C (70° F); cold weather will have a significant effect on voltage and capacity. Always check battery capacity with the system acclimated to the outside temperature.

To Avoid Draining of Batteries When System is Not in Use
- Always turn the system off before storing the system.
- When off, the FlowTracker draws a small amount of current from the batteries (≈0.5 mA).
- The current would drain a new set of alkaline batteries in 6-8 months.
- If the system will be left unused for a long period (more than 1 month), remove the batteries to prevent them from being drained unnecessarily.

7.2.3. Changing the Batteries

The batteries are accessed from the back of the FlowTracker handheld controller.

- Turn the system off.
- Remove the six screws holding the battery compartment lid to the main housing.
- Remove the old batteries from the battery holder.
- Install the new batteries, matching the orientation shown on the battery holder.
- Secure the battery compartment lid using the six screws.
- Turn the system on and check the battery voltage level to ensure proper installation. From the main menu, press **2** for the **System Functions Menu**, and then **5** for battery data.
  - New alkaline batteries should show about 12.0 VDC.
  - Fully charged NiMH batteries should show about 10.5 VDC.
  - Fully charged NiCad batteries should show about 10.0 VDC.

7.3.   Internal Electronics and Wiring Overview

Under normal conditions, you should never need to open the FlowTracker (except for battery replacement). The information provided here is for reference only.

This section provides information about the internal layout of the FlowTracker. The handheld controller is described from the view of being opened and looking at the inside of the housing and lid.

- The LCD screen is mounted to the inside of the lid.
- The keypad is mounted to the outside of the lid, and is connected to the LCD.
- The o-ring seal is exposed on the top of the housing. When opening the system, take care to avoid damage to o-rings and surfaces. Clean and inspect the o-ring and surfaces before closing the system.
- The receiver board is mounted at the narrow end of the housing. The probe is permanently wired to the receiver board.
- The FlowTracker Processor (Analog and CPU boards) is mounted in the wide end of the housing. The two boards are connected using an edge connector at one end. See §7.4 for a detailed description of the FlowTracker Processor.
- The batteries are installed below the Receiver board and are accessed from the back of the housing.

Cables used to connect the different portions of the FlowTracker are described below.

- A 16-pin ribbon cable connects the Receiver board to the Analog board. The cable uses the same connectors at each end with pin-to-pin wiring. The ribbon cable can be installed at either end. However, the connectors are keyed and can be installed in only one direction.
- A 2-wire cable from the temperature sensor (in the probe) connects to a red, 2-pin, keyed connector on the Analog board (labeled **Temperature**).
- The batteries and external power supply (via the external power/communication connector) are connected to a red, 3-pin, keyed connector on the Analog board (labeled **Power**).
- RS232 serial communication is wired from the external power/communication connector to a red, 5-pin, keyed connector on the CPU board (labeled **User**).
- The 5-pin connector attached to the LCD is wired to two connectors: a red, 3-pin, keyed connector on the CPU board (labeled **CTD**), and a red, 5-pin, keyed connector on the CPU board (labeled **Compass**).

7.4. FlowTracker Processor

The FlowTracker processor consists of two printed circuit boards – the Analog board (Figure 24) and the CPU board (Figure 25).

Figure 24 – FlowTracker Analog Board

Figure 24 shows the layout of the Analog board.

- A 16-pin, keyed connector (not labeled) connects to a ribbon cable to the Receiver board.
- The board name and revision is printed next to the pressure sensor connector.
- A red, 5-pin connector (labeled **Pressure**) is not used in the FlowTracker.
- A red, 2-pin, keyed connector (labeled **Temp**) connects to the temperature sensor in the probe.
- A red, 3-pin, keyed connector (labeled **Power**) is connected to the input power wiring. See §7.2 for input power specifications.
- A 40-pin edge connector mates below to the CPU board (Figure 25).
- The Analog board includes four holes for mounting, which match the mounting holes on the CPU board and are used with a set of #4-40 screws and standoffs.
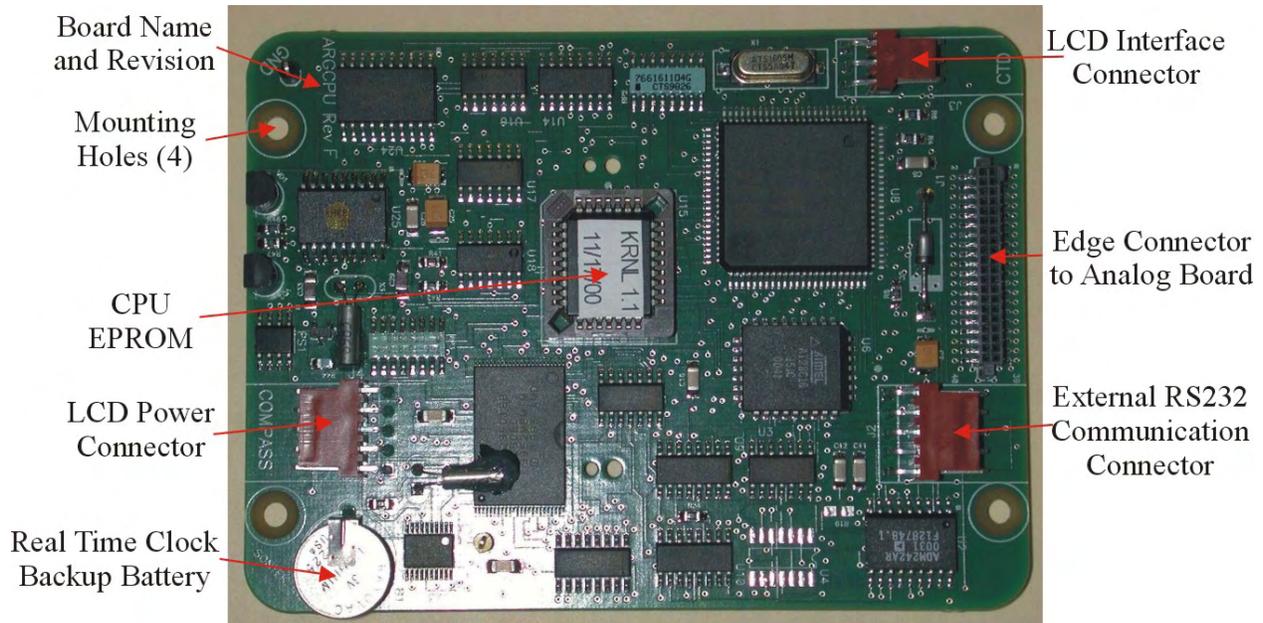
Figure 25 – FlowTracker CPU Board

Figure 25 shows the layout of the CPU board.

- The board name and revision are printed in the upper left corner.
- The EPROM containing the software to control FlowTracker operation is installed in a socket at the center of the board. Upgrades for the EPROM may be periodically available; see §7.6 for details.
- A 5-pin connector (labeled **Compass**) provides power to the LCD screen.
- The backup battery is installed in the corner of the board. This battery is used to supply the real-time clock when main power is not available. See §8.4 for details.
- A red, 3-pin connector (labeled **CTD**) connects to the interface of the LCD screen.
- A 40-pin edge connector mates above to the Analog board (Figure 24).
- A red, 5-pin connector (labeled **User**) connects to the external power/communication connector for external serial communications (RS232).

7.5.   Accessing Electronics

Under normal conditions, you should never need to open the FlowTracker (except for battery replacement). The instructions here are provided for reference only. The system should only be opened after receiving instructions from SonTek/YSI personnel.

To open the FlowTracker handheld controller, use the following steps.

1. Perform all maintenance in a static-safe environment.
2. See §7.3 for a description of the internal layout of the FlowTracker. See §7.4 for a description of the FlowTracker Processor.
3. Open the battery compartment and remove all batteries (§7.2.3).
4. Loosen the dummy cap on the external power/communication connector to allow the inside of the housing to equalize to atmospheric pressure.
5. From the back of the handheld controller, remove the six screws holding the housing to the lid (these screws are accessed from recessed holes on the edge of the housing).
6. Carefully lift the lid from the housing.
7. Take care to avoid any damage to the o-ring and o-ring surfaces.

To close the FlowTracker handheld controller, use the following steps.

1. Clean and inspect all o-rings and o-ring surfaces for damage; replace o-rings if necessary.
2. Reconnect all internal wiring (if removed).
3. Inspect the desiccant pack installed inside the handheld controller. Replace if necessary.
4. If the o-ring was removed, lay it back into the o-ring groove on the housing.
5. Lay the lid on top of the housing.
6. From the back of the controller, secure the lid to the housing using the six screws.
7. Reinstall the batteries (§7.2.3).

7.6.   Upgrading the CPU EPROM

Downloadable CPU firmware
- All FlowTracker systems have downloadable firmware.
- Firmware upgrades may be periodically available; check the SonTek web site for details (http://www.sontek.com).
- For firmware upgrades, all software and instructions will be provided with the upgrade. Contact SonTek for details.

Verifying system operation after a change
- Following any EPROM change, you should verify basic system operation.
- Turn the system off and on.
- From the keypad interface, use the raw data display (see §2.5.6) in a small tank of water to verify basic velocity and SNR data.
- Perform full system diagnostics as described in §3.2.

Section 8. Operational Considerations

8.1. Mounting and Installation

The FlowTracker is commonly mounted on a top-setting wading rod. The probe and controller mounting have been designed with wading rod use in mind, but the design is flexible enough to allow a variety of mounting arrangements. Top-setting wading rods are available from SonTek.

8.1.1. Handheld Controller Mounting

Mounting the handheld controller to the top of a wading rod can simplify data collection.

- A mounting bracket compatible with the mounting pin on a top-setting wading rod is available from SonTek (Figure 26).
- The handheld controller includes two threaded inserts on the back, which can be used to secure a user-supplied mounting bracket.
- User-supplied mounting brackets can also be constructed using Velcro® adhered to the back of the controller, or a strap around the controller.
- User-supplied mounting brackets should avoid direct contact with the keypad and LCD.

8.1.2. Probe Cable

The cable from the probe to the handheld controller is highly noise-sensitive and should be treated with care.

- The cable should be protected from cuts, abrasions, and other damage.
- In any mounting arrangement, secure the cable to prevent excessive motion or damage.
- Avoid sharp bends in the cable, particularly near the probe.

Figure 26 – Handheld Controller Mounting

8.1.3. Probe Mounting

2D and 2D/3D Side-Looking Probes
- An adaptor bracket (Figure 27) is available for mounting the probe from a top-setting wading rod. Both the bracket and complete wading rods are available from SonTek.
- The adaptor replaces the standard wading rod current meter mount.
- The bracket offsets the probe to one side of the wading rod, placing the sampling volume closer to the wading rod, approximately 5 cm (2 in) to one side.
- The bracket allows the wading rod to be used in its standard "forward" orientation.
- Installation and mounting instructions are in-cluded with the mounting bracket.

Figure 27 – Probe Mount Adaptor Bracket

Probe Orientation
- Figure 28 shows the proper orientation of the probe for discharge measurements.
- The tag line is installed perpendicular to the primary flow direction, although the flow direc-tion may vary at different points across the stream.
- At each station, the X-axis should be perpendicular to the tag line. It should **not** be kept in line with the true flow direction. The red band (which marks receiver arm #1) should face downstream.
- The FlowTracker uses the X component of velocity (Vx) for discharge measurements, and calculates flow direction for each measurement as a quality parameter (see §1.4.6).

3D Down-Looking Probes
- 3D down-looking probes are not normally used from a wading rod.
- Mounting arrangements are user-constructed to meet the requirements of the application.
- Probe mounting should be done to avoid flow interference in the sampling volume (§8.1.4).
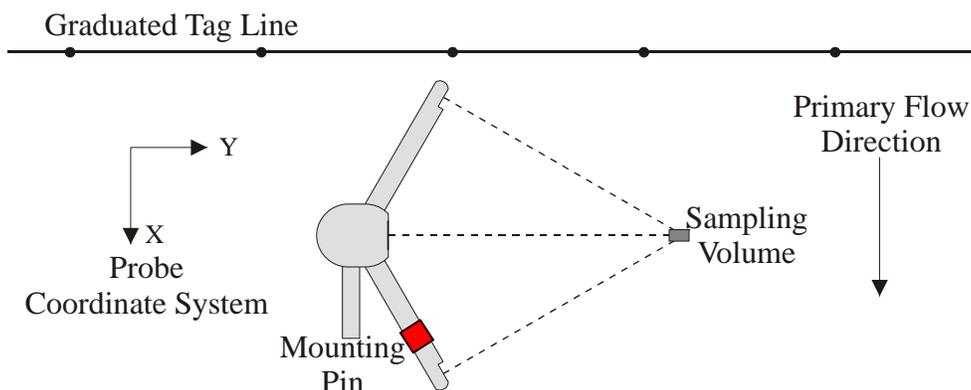
Figure 28 – FlowTracker Probe Orientation Relative to Stream Flow

8.1.4. Flow Interference

The FlowTracker measures velocity in a small sampling volume nominally located 10 cm (4 in) from the tip of the probe (see *FlowTracker Principles of Operation*). The placement of the sampling volume relative to other structures in the water must be considered when measuring velocity to avoid flow interference.

Structures

- The FlowTracker probe should be located away from any underwater structures or obstacles, particularly those upstream.
- Consider the size and location of nearby structures and obstacles, and the probable magnitude and direction of flow, when choosing a measurement location.

Probe orientation relative to flow

- The FlowTracker should be oriented so the axis of the transmit transducer is roughly perpendicular to the expected direction of flow (Figure 29).
- For side-looking probes (2D and 2D/3D), the probe should be oriented looking across the expected direction of flow (so the X-axis aligns with the expected flow).
- For 3D down-looking probes, this is usually simple since the probe is most commonly looking vertically down in a region of horizontal flow.
- FlowTracker probes have been tested and have shown negligible flow interference with the probe as much as 40-50° away from the preferred alignment. At higher angles, the FlowTracker may see flow interference in the sampling volume.
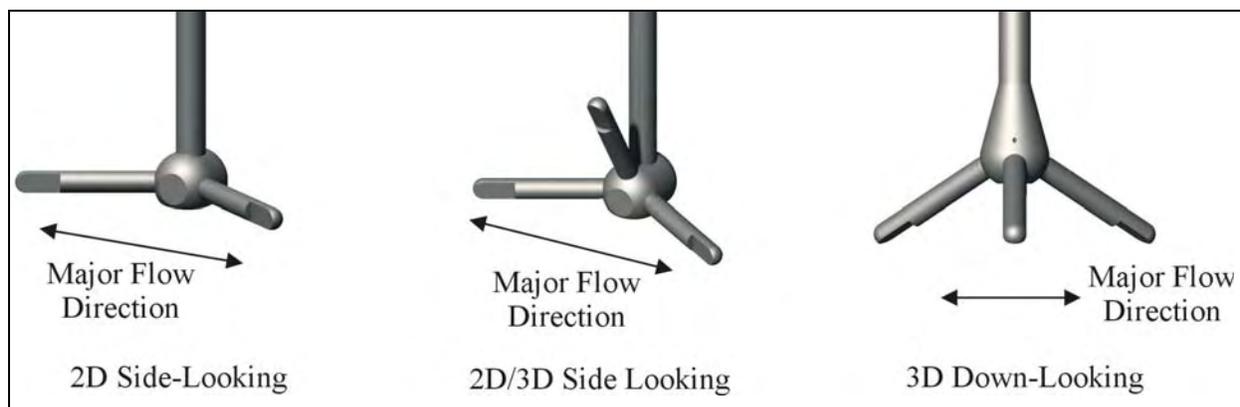
Figure 29 – Preferred Flow Direction to Avoid Flow Interference

8.2.   Velocity Data Coordinate System

FlowTracker velocity measurements are reported using a right-hand Cartesian coordinate system relative to the probe. The XYZ coordinate systems for each probe type are shown below.
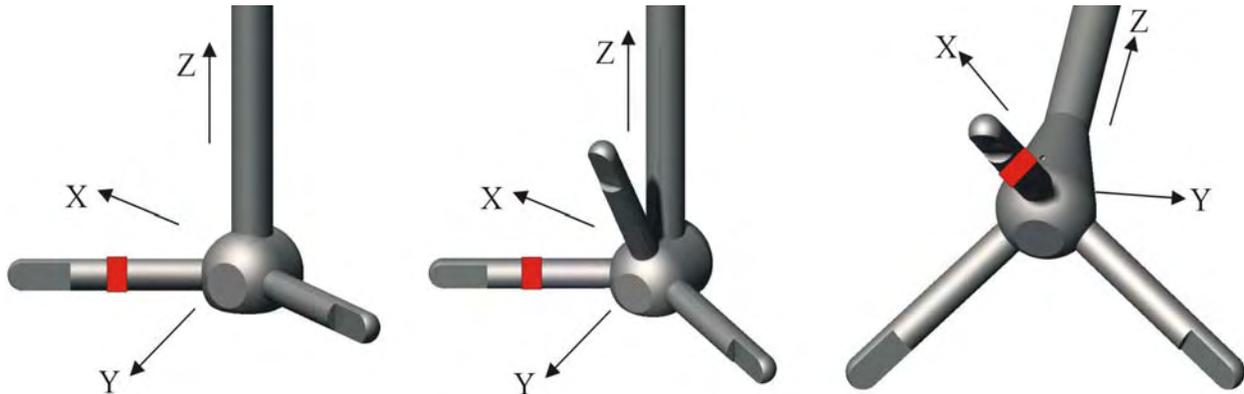
Figure 30 – FlowTracker Looking Probe XYZ Coordinate Systems

2D Side-Looking Probe (Figure 30a)
- The positive Z-axis is defined as vertically up in the direction of the probe's stem.
- The positive X-axis is defined perpendicular to both the probe's stem and the axis of the transmit transducer in the direction of receiver arm #1 (marked with a red band).
- The positive Y-axis is defined along the axis of the transmit transducer from the transmitter towards the sampling volume (making a right-handed coordinate system).

2D/3D Side-Looking Probe (Figure 30b)
- The positive Z-axis is defined as vertically up in the direction of the probe's stem.
- The positive X-axis is defined perpendicular to both the probe's stem and the axis of the transmit transducer in the direction of receiver arm #1 (marked with a red band).
- The positive Y-axis is defined along the axis of the transmit transducer from the transmitter towards the sampling volume (making a right-handed coordinate system).

3D Down-Looking Probe (Figure 30c)
- The positive Z-axis is defined as vertically up in the direction of the probe's stem, which for this probe is the same as the axis of the transmit transducer.
- The positive X-axis is defined perpendicular to probe's stem in the direction of receiver arm #1 (marked with a red band).
- The positive Y-axis is defined based on the X and Z-axes to make a right-handed coordinate system.

8.3. Temperature Sensor

The FlowTracker uses a thermistor mounted inside the probe head to measure temperature.

- The coupling of the thermistor to the metal probe head gives good response to changes in temperature and ensures the temperature data accurately reflect the water temperature at the location velocity measurements are being made.
- The temperature sensor has a specified accuracy of ±0.1°C (±0.2°F).
- Temperature data are sampled once per second (with each velocity sample) during each measurement burst. Mean temperature is recorded with each measurement burst.

8.4. Real-time Clock Backup Battery

The FlowTracker has a backup battery to run the system clock when main power is not available.

- The battery is installed on the processor CPU board (see §7.4).
- The battery can be expected to last for many years with no maintenance.
- If the backup battery dies, the system clock will reset when power is disconnected.
- Contact SonTek before attempting to replace the battery.

8.5.   Routine Maintenance

The FlowTracker requires little maintenance for years of reliable performance.

- Normal use does not change instrument performance.
- The FlowTracker never requires recalibration for velocity data (unless the probe is physically damaged).
- This section describes the suggested maintenance procedures.

8.5.1. Regular Diagnostic Procedures

In addition to the diagnostic procedures available from the handheld interface, the FlowTracker software includes a diagnostic program named *BeamCheck*.

- This is the same program used at SonTek for system testing and diagnostics.
- The program lets you verify all major aspects of system performance and probe condition.
- Use of the program is described in §6.5.
- We recommend running this program on a regular basis (e.g., once per week).

8.5.2. Cleaning the Transducers

Biological growth on the transducers does not affect velocity measurements, but can decrease acoustic signal strength and potentially increase noise in velocity data in clear water.

- Periodic cleaning of the FlowTracker transducers may be needed to maintain optimal performance in areas of high biological activity.
- FlowTracker transducers are encapsulated in an epoxy that is impervious to damage from barnacles or other types of growth.
- To remove growth, simply clean with a cloth or stiff (non-metallic) brush. The transducer epoxy is very durable and cannot be easily damaged except by direct impact.

8.5.3. Cable Maintenance

The FlowTracker probe cable is often the most vulnerable part of the system.

- The cable uses a durable polyurethane jacket that provides excellent long-term wear and abrasion resistance.
- Any cable is susceptible to damage and reasonable precautions should be taken.
- Inspect the cable and all connectors on a regular basis.
- This cable is highly noise-sensitive and should not be modified by the user.

8.5.4. O-rings

The FlowTracker handheld controller uses an o-ring seal.

- The controller is designed to withstand temporary submersion, but is not intended for underwater operation.
- We do not recommend opening the system without specific instructions from SonTek/YSI.

8.5.5. Condensation in FlowTracker Housing

Moisture in the air can potentially damage FlowTracker electronics if allowed to condense inside the controller housing.

- The housing is shipped with a desiccant pack inside to absorb moisture.
- We do not recommend opening the system without specific instructions from SonTek/YSI personnel. If the housing has not been opened, the desiccant should not need to be replaced.

8.5.6. Zinc Anodes for Corrosion Protection

When using the FlowTracker in salt water, additional precautions must be taken to prevent corrosion.

- A sacrificial zinc anode should be installed on the probe (attached to the metal portion of the probe stem).
- Anode condition should be inspected regularly, and the anode should be replaced when necessary. Zinc anodes are available from SonTek.
- To check anode condition, try to chip away part of the anode with a screwdriver. If large portions of the anode easily fall away, the anode should be replaced.
- The probe and cable should be thoroughly rinsed with fresh water after each use.

8.6. Seeding

If FlowTracker velocity data appears "noisy", the most common cause is a lack of scattering material in the water.

- See the *FlowTracker Principles of Operation* (§A-7.3) for details about how/why the Flow-Tracker uses scattering material for velocity measurements.
- A lack of scattering material can increase noise in velocity data. If insufficient scattering material is present, the FlowTracker will not be able to accurately measure velocity.
- In most field applications, there is sufficient scattering material naturally present.
- Large, quiet laboratory tanks often have insufficient natural scattering material.
- To evaluate seeding requirements, use the raw data display from the handheld interface (see §2.5.6).
  - o For ideal operating conditions, the SNR should be above 10 dB.
  - o The FlowTracker can operate reliably with SNR as low as 3-4 dB.
- A lack of scattering material can be remedied by adding seeding.

For field applications, seeding can be introduced by stirring the bottom (e.g., walking across the river upstream of the measurement location). In some situations, seeding material will need to be introduced. An ideal seeding material should have the following qualities.

- Neutrally buoyant (to remain in suspension for a long period)
- Mean particle diameter of 10-20 µm (for peak sensitivity of the acoustic signal)
- Inexpensive, readily available, with no adverse effects on the operating environment

The best seeding material we have found (from an acoustics point of view) are hollow glass spheres with a mean diameter about 10 µm and a mean density close to that of water.

- Small quantities of this material are available from SonTek.
- Larger quantities can be purchased from the manufacturer at the address below.

> Potters Industries
> Valley Forge PA USA
> Phone: +1-610-651-4700
> Internet: www.pottersbeads.com
> Part name: Potters Sphericel

For most applications, a more practical seeding material is lime or pulverized limestone (the chalk commonly used on athletic fields).

- Large bags are inexpensive and readily available from most hardware stores.
- While not perfect, the acoustic performance is sufficient for most applications.
- A variety of distribution arrangements can be arranged to seed even very large tanks.
- A note of caution: repeated addition will gradually increase the pH in a tank (in addition to creating a layer of lime/limestone on the bottom of the tank).

8.7. Troubleshooting

This section provides suggestions for diagnosing problems with the FlowTracker. If you have trouble finding the source of a problem, please contact SonTek.

8.7.1. Cannot Turn System On

FlowTracker power-up problems are usually related to the batteries or power supply.

- Check/replace the existing batteries (§7.2.3).
- Verify that all batteries are correctly oriented as shown on the battery holder.
- Try operating the system with the SonTek external power supply, if available.

If the system still will not turn on, try the following.

- Hold the **On/Off** key down for at least four seconds.
- Release the **On/Off** key, and then hold down the key again for at least one second.
- Try to establish direct serial communication (see Appendix B).

8.7.2. Cannot Communicate with the FlowTracker

If you are unable to establish external communications with the FlowTracker (typically using the data download software), the following may be helpful in identifying the cause.

- Verify all cables to the FlowTracker are securely connected.
- Verify the batteries are correctly installed (or the external supply is connected) and that you can turn on the system.
- Try to establish direct communications with the FlowTracker using *SonUtils* (Appendix B).
- Verify the computer serial port is functioning correctly. Try using another computer.
- Inspect the external power/communications cable. Verify all cable connections match the wiring diagram listed in §7.1.2.

8.7.3. Cannot Retrieve Data from Internal Recorder

The following are common causes of communication errors when retrieving data from the Flow-Tracker's internal recorder (using the *Recorder* software described in §6.4).

- Verify you can establish direct communication with the FlowTracker using *SonUtils* (Appendix B).
- The data-extraction baud rate may be too high (default is 57600). The maximum baud rate is a function of the length and quality of cables, the computer, and the operating environment. Run *Recorder* using a lower extraction rate (§6.4).
- Some computers have poor quality serial ports and cannot retrieve large amounts of data at high baud rates. Try using another computer or lower the extraction baud rate.

8.7.4. Velocity Data Appears Noisy or Unreasonable

If the velocity data from the FlowTracker does not seem reasonable, the following list may help establish the cause.

- Lack of scattering material in the water is the most common problem (particularly in large laboratory tanks). See §8.6 and the *FlowTracker Principles of Operation* for details about seeding requirements.
- Run *BeamCheck* as described in §6.5. This can address all aspects of FlowTracker operation, in particular, signal strength (scattering/seeding issues) and probe operation.
- Inspect the FlowTracker to be sure debris is not fouling the probe.
- Verify the FlowTracker mounting is stable and that instrument motion is not causing noise in the velocity data.
- Consider any possible environmental influences, particularly flow interference from underwater structures or obstacles.
- Consider the measurement environment. Highly turbulent or highly aerated water will greatly affect FlowTracker operation. In highly aerated water, the FlowTracker may not be able to operate reliably.
- Consider the orientation of the probe with respect to the flow direction to be sure the probe is not causing flow interference in the sampling volume (see §8.1.4).

8.7.5. Keypad Does Not Operate Reliably

The handheld controller is fully sealed; this can potentially affect operation of the keypad.

- Changes in temperature or atmospheric pressure may affect the keypad because of a difference in internal and external pressure.

Significant changes in pressure can affect system operation. To avoid problems, the controller must be vented to equalize pressure.

- To vent the keypad, simply loosen the dummy cap on the external communication connector a few turns (it is not necessary to completely remove the cap).
- Pressure will equalize within a few seconds.
- When pressure has equalized, tighten the dummy cap.
- When storing or shipping the system, leave the dummy cap loose to allow the system to adapt to changes in pressure.

Appendix A. FlowTracker Principles of Operation

A-1. Introduction

The FlowTracker Handheld ADV is a single-point Doppler current meter designed for field ve-locity measurements. The FlowTracker uses the proven Doppler technology of the SonTek/YSI Acoustic Doppler Velocimeter (ADV), the leading high-resolution velocity sensor. ADV tech-nology provides several advantages.

- Accurate velocity measurements in a remote sampling volume
- 2D or 3D velocity measurements (depending on probe configuration)
- Invariant factory calibration – no periodic recalibration required
- Rapid response time
- Simple operation
- Excellent performance for low and high flows – accuracy 1% of measured velocity
- Built-in temperature sensor

The FlowTracker offers ADV performance from a simple handheld interface, allowing rapid data collection without the use of a computer. Some common applications include:

- River discharge measurements (using established methodology, including USGS/ISO)
- Open-channel flow measurements
- Current measurements in large pipes
- Rapid, multi-point current surveys
- Current monitoring in water treatment facilities

This appendix presents the operating principles of the FlowTracker. It does not attempt to pro-vide a detailed discussion of all technical issues, nor a detailed description of FlowTracker op-eration. To learn more about specific applications, please contact SonTek/YSI.

A-2.   The Doppler Shift

The FlowTracker uses an adaptation of the Doppler principle to measure water velocity.

- Velocity can be determined by measuring the change in pitch of sound coming from (or reflected from) a moving target.
- A common example is the pitch of a whistle from a moving train. The pitch is higher when the train is approaching, and lower when it is going away.
- Some common implementations of the Doppler principle include police radar sets for tracking automobile speeds and Doppler weather radar that tracks the speed of water particles suspended in the air (clouds).
- The FlowTracker uses a highly sophisticated form of this technique, which processes underwater sound (sonar) reflected from particulate matter suspended in the water.

The Doppler principle says that if a source of sound is moving relative to the receiver, the frequency of the sound at the receiver is shifted from the transmit frequency.

$$F_{doppler} \; = \; -F_{source} \, (V \, / \, C)$$

where

$F_{doppler}$ = change in received frequency (Doppler shift)
F_{source} = frequency of transmitted sound
V = velocity of source relative to receiver
C = speed of sound

The velocity, V, represents the relative speed between source and receiver (motion that changes the distance between the two).

- If the distance between the two objects is decreasing, frequency increases.
- If the distance is increasing, frequency decreases.
- Motion perpendicular to the line connecting source and receiver does not introduce a Doppler shift.

A-2.1. Bistatic Doppler Current Meters

Figure 31 shows the FlowTracker probe. The FlowTracker is a *bistatic* Doppler current meter.

- Bistatic means separate acoustic transducers are used for transmitter and receiver.
- The transmitter generates sound concentrated in a narrow beam.
- The receivers are sensitive to sound coming from a narrow beam.
- The receivers are mounted such that the beams intersect at a volume of water located a fixed distance (10 cm; 4 in) from the tip of the probe.
- The beam intersection determines the location of the *sampling volume* (the volume of water in which measurements are made).

The FlowTracker measures velocity as follows.

- The transmitter generates a short pulse of sound at a known frequency.
- The sound travels through the water along the transmitter beam axis.
- As the pulse passes through the sampling volume, sound is reflected in all directions by particulate matter (sediment, small organisms, bubbles).
- Some portion of the reflected energy travels back along the receiver beam axes.
- The reflected signal is sampled by the acoustic receivers.
- The FlowTracker measures the change in frequency (Doppler shift) for each receiver.
- The Doppler shift is proportional to the velocity of the particles along the bistatic axis of the receiver and transmitter. The bistatic axis is located halfway between the transmit and receive axes.
- Knowing the relative orientation of the bistatic axes allows the FlowTracker to calculate 2D or 3D water velocity.
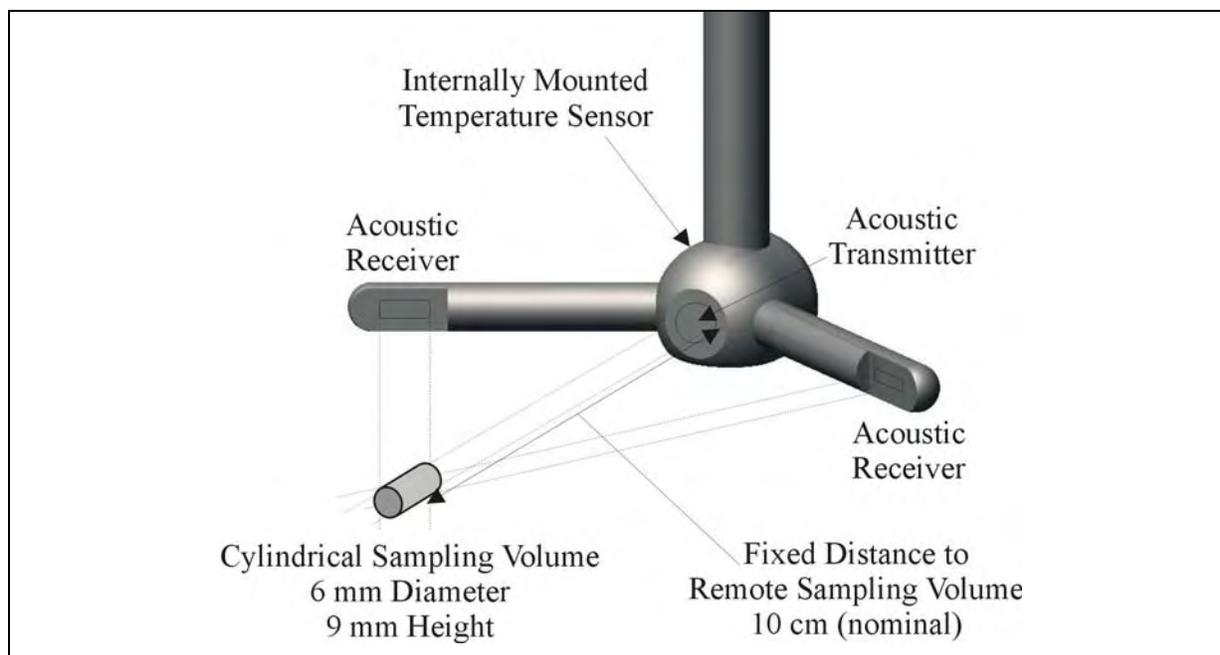
Figure 31 – FlowTracker 2D Side Looking Probe and Sampling Volume

Figure 32 shows a profile of signal strength versus time for the FlowTracker.

- The horizontal axis shows time after the transmit pulse
- The vertical axis shows the return signal strength measured by one receiver.
- As the transmit pulse travels through the water, sound is reflected in all directions.
- Immediately following the transmit pulse, reflections come from outside the receiver beam. The receiver measures only the ambient noise level.
- As the pulse propagates along the transmit axis, it moves closer to the receiver beam. The receiver sees an increase in signal strength.
- Signal strength reaches a maximum at the intersection of the transmit and receive beams.
- By sampling the return signal at its peak, the FlowTracker makes measurements in the sampling volume defined by the intersection of the transmit and receive beams.
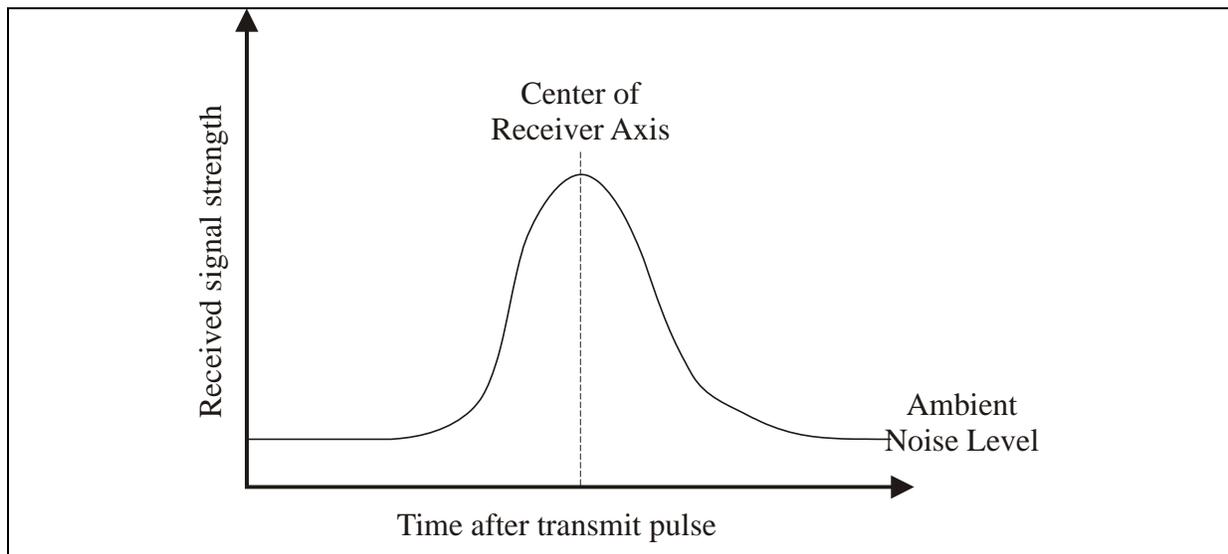
Figure 32 – FlowTracker Signal Strength Profile

A-3.   Beam Geometry and 3D Velocity Measurements

A single transmit/receive pair measures the projection of the 3D water velocity onto the bistatic axis.

- The bistatic axis is halfway between the transmit and receive beam axes (see Figure 33).
- The velocity measured by each receiver is called the bistatic velocity.
- The FlowTracker uses one transmitter and two or three receivers (for 2D or 3D probes).
- See §A-7 for other FlowTracker probe configurations.
- Receivers intersect with the transmit beam pattern at a common sampling volume.
- Bistatic velocities are converted to Cartesian (XYZ) velocities using the probe geometry (the relative angles of transmit and receive beams). Cartesian velocities give the 2D or 3D velocity relative of the FlowTracker probe.
- During the manufacturing process, probe geometry is precisely determined by a calibration procedure.
- This calibration only needs to be performed once.
- No periodic re-calibration is required.
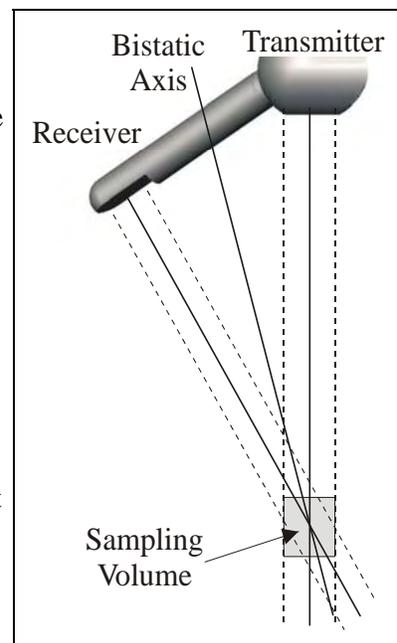
Figure 33 – Bistatic Axis

A-4.   Sampling Volume Definition

The FlowTracker sampling volume is specified as follows.

- The sampling volume is nominally 10 cm (4 in) from the tip of the probe.
- The exact location varies ±1.0 cm (±0.4 in) from probe to probe.
- Precise sampling volume location is fixed for any given probe.
- The physical size of the sampling volume is a cylinder 6 mm (0.24 in) in diameter by 9 mm (0.35 in) in length (see Figure 31).

A-5.   Pulse-Coherent Processing

This section does not attempt to provide a detailed description of pulse-coherent processing. It presents a simple overview with a focus on how this affects FlowTracker operation. SonTek can provide additional information on request.

The description of FlowTracker operation given in §A-2 is an oversimplification.

- §A-2 describes incoherent Doppler processing in which the transducer sends a single pulse of sound and measures the frequency change of the return signal.
- The FlowTracker uses a technique called *pulse-coherent processing*.

Pulse-coherent processing provides the best possible performance of any Doppler processing technique. In the simplest terms, pulse-coherent processing works as follows.

- The FlowTracker sends two pulses of sound separated by a time lag (τ).
- Each receiver measures the phase (ϕ) of the return signal from each pulse.
- The change in phase ($\phi_2 - \phi_1$) divided by the time lag (τ) is proportional to velocity.
- Because of the nature of the phase measurement (which can only be determined from -180° to +180°), the system has an inherent maximum velocity limitation.
- The FlowTracker velocity algorithms have been optimized to give the best possible performance over a wide velocity range of ±4.5 m/s (±15 ft/s).
- FlowTracker processing provides unmatched results for low flows (<1 cm/s; <0.03 ft/s).

FlowTracker processing has been designed to give the best possible performance in all environments. However, there is a situation where system performance may be affected by operating conditions.

- When working near boundaries or underwater obstacles, the system may need to adapt its operation to avoid acoustic interference.
- This is called *boundary adjustment* and is performed automatically by the system at each measurement location.
- The system reports a quality parameter with each measurement location that tells you if the environment has any effect on FlowTracker performance. This quality parameter is described in §1.4.4.

A-6. FlowTracker Data

A-6.1. Basic Sampling Strategy

The FlowTracker collects a burst of velocity data at each measurement location.

- All data are recorded to the FlowTracker internal recorder.
- You are prompted to enter location, depth, and other data at each measurement location to document the data set.
- For river discharge applications, measurements follow a prescribed sequence. This allows the FlowTracker to calculated river discharge in real-time.
- The system collects a fixed-length time-series of velocity at each measurement location.
- The *averaging time* at each location is user-specified (10 to 1000 seconds).
- Velocity data are recorded once per second during the averaging time.

When each measurement location is complete, you are presented with a summary of the velocity and quality control data. All data are stored to the internal recorder for later downloading to a computer for display, archiving, and further analysis.

A-6.2. Velocity Data

The FlowTracker provides several important performance advantages.

- It can measure 2D or 3D water velocities from 0.0001 to 4.5 m/s (0.0003 to 15 ft/s).
- Velocity data are accurate to 1% of the measured velocity in a one-second sample.
- Velocity data can be used immediately without any postprocessing corrections.
- True 2D or 3D velocity data are output in Cartesian coordinates (XYZ) relative to probe orientation.
- The FlowTracker calibration will not change unless the probe is physically damaged. No periodic calibration is required.
- Diagnostic software is included to evaluate system performance periodically.

The following describes the basic FlowTracker sampling strategy.

- An individual measurement of the 2D or 3D velocity is referred to as a *ping*.
- The FlowTracker pings 10 times per second, averaging these pings for a single velocity *sample*.
- One velocity sample is recorded each second.
- Velocity data are collected at each measurement location over the user-specified time. Raw one-second velocity, mean velocity, and quality control data are recorded with each station.
- For river discharge measurements, the FlowTracker combines velocity data with station location, water depth, and other data to determine total discharge in real-time.
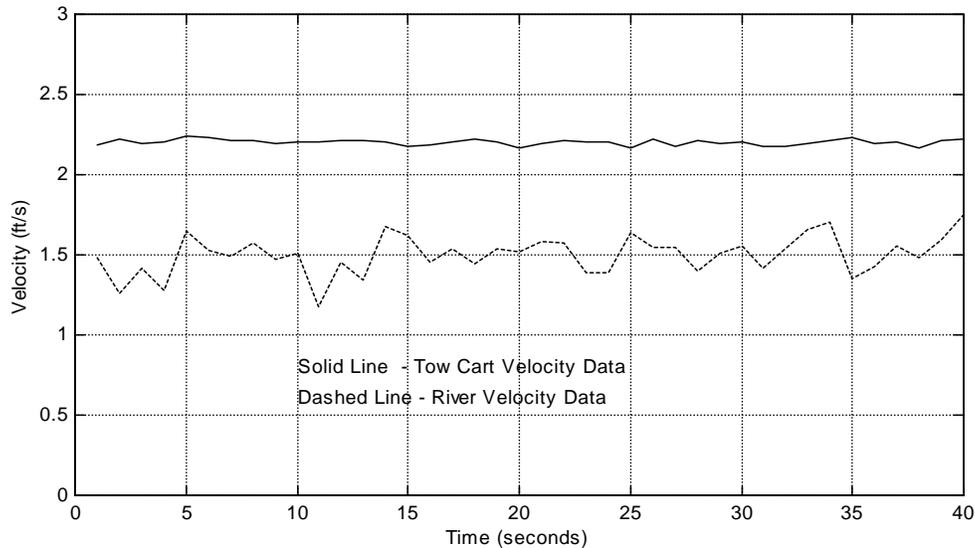
Figure 34 – FlowTracker Velocity Comparison

Accuracy of Velocity Data
The FlowTracker has been optimized to provide the best possible velocity data.

- Velocity data are accurate to 1% of measured velocity for each one-second sample.
- Variations in velocity data are dominated by true variations in water velocity.
- Instrument noise does not normally have an impact on velocity data.
- The averaging time required to determine the true mean velocity at a given location is a function of the real variations in velocity at that site.

FlowTracker velocity performance is shown in Figure 34.

- The solid line is data from a tow carriage test (the FlowTracker was towed at a known speed). Variations represent instrument noise and are less than 1% of the true velocity.
- The dashed line is data collected in a small stream. Variations represent real changes in the flow field (at this site they are about 8% of the mean velocity).

Two factors influence accuracy of FlowTracker velocity data – sound speed and probe geometry.

- The effect of sound speed is discussed in §A-7.2. With properly specified salinity data, sound speed errors are negligible (less than 0.25%).
- Probe geometry is calibrated at the factory for each FlowTracker; no recalibration is required unless the probe has been physically damaged.
- The FlowTracker calibration procedure is specified to ±1.0% of the measured velocity.
- There is no potential for zero offset or zero drift in velocity measurements. There is no inherent minimum measurable velocity.
- The FlowTracker is very well suited to low-flow applications to less than 1 cm/s (0.03 ft/s).

A-6.3. Quality Control Data

In addition to velocity, the FlowTracker records quality control data with each measurement station to quickly evaluate velocity data quality. Parameter details are in the FlowTracker manual.

- Standard Error of Velocity – §1.4.3
- Signal-to-Noise Ratio (SNR) – § 1.4.2
- Boundary Adjustment – §1.4.4
- Spike Filtering – §1.4.5
- Flow Angle – §1.4.6

A-7. Special Considerations

A-7.1. Probe Configurations

Several FlowTracker probe configurations (Figure 35) are available for different applications.

Probe mounting

- The probe is mounted from a 200 cm (80 in) flexible cable.
  - o A 300 cm (120 in) cable is available for special applications. However, it is not possible to upgrade an existing system to a different cable length.
- The cable is custom built to reduce electronic noise. It should not be modified by the user.
- Cable length is limited to a maximum of 200 cm (80 in).
- Take care to avoid damage to the cable, as this can affect system operation.

3D Down-Looking   2D Side-Looking   2D/3D Side Looking
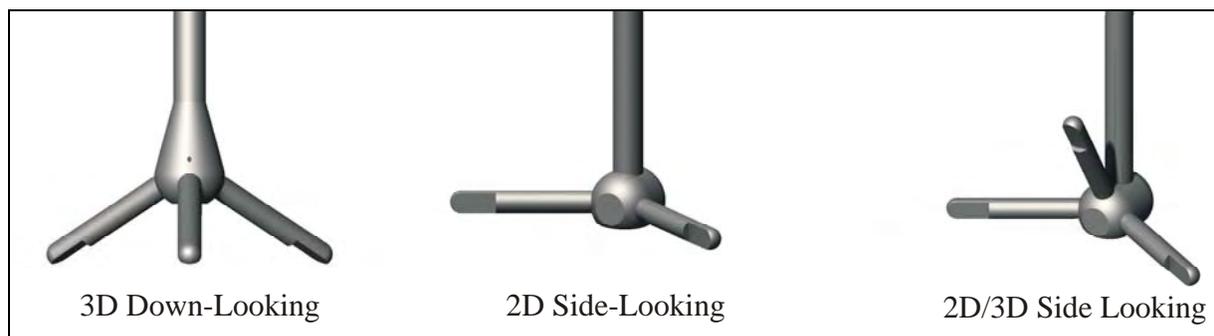
Figure 35 – FlowTracker Probe Configurations

Probe type

- Three probe types are available (Figure 35).
- The standard FlowTracker uses a 2D side-looking probe. The sampling volume is located 10 cm (4 in) to the side of the probe, and can operate in as little as 2 cm (1 in) of water.
- To work in both shallow and deeper water, a combination 2D/3D side-looking probe is available. This has a sampling volume located 10 cm (4 in) to the side of the probe, and can operate in as little as 2 cm (1 in) of water. It measures 2D velocity in shallow water (with only two arms submerged), and 3D velocity in deeper water (with all three arms submerged).
- For some applications, the 3D down-looking probe is preferred based on the location of the sampling volume, which is 10 cm (4 in) below the probe. It has a minimum operating depth of about 12 cm (5 in).

A-7.2. Sound Speed

The FlowTracker uses sound speed to compute velocity from the measured Doppler shift, and to precisely determine the location of the sampling volume. The speed of sound in water is primarily a function of temperature and salinity.

- A temperature change of 5°C (9°F) results in a sound speed change of ≈1%.
- A salinity change of 12 ppt results in a change in sound speed of ≈1%.
- A 1% error in sound speed results in a ≈2% error in velocity data.

To compensate for changing sound speed, the FlowTracker does the following.

- The FlowTracker includes a temperature sensor for automatic sound speed corrections. Resolution is ±0.1°C (±0.2°F).
- A user-input value of salinity is used for sound speed calculations.
- If accurate salinity data has been specified by the user (±2 ppt), sound speed changes can be assumed to have no impact on velocity data.

A-7.3. Environmental Conditions

Doppler current meters, such as the FlowTracker, do not measure movement of water, but actually the movement of particles **in** the water. We must assume that the movement of the particles in the water is representative of the movement of the water itself. This actually turns out to be a very safe assumption. As such, if you have a body of water where no particles (other than the water molecules themselves) are present, Doppler current meters will not work. Thankfully, natural streams almost always have something else other than just "water" (even if just tiny air bubbles), and the technology is such that even a small amount of particles in the water is usually enough for good measurements.

Two questions quickly come to mind: (1) how many particles does it take for the instrument to work, and (2) how small can these particles be? The short answers to these questions are: (1) just a few and (2) very small.

Visual inspection is **not** an acceptable method for determining the amount of particles in the water and no simple relationship exists with turbidity. We cannot say that for a given turbidity level your water is too clear for a Doppler-based measurement. The amount of particles in the water is not the only factor affecting signal amplitudes. Particle size, shape, distribution, and type also control these values, and these conditions vary from site to site. Therefore, one stream may meet these conditions, but another with the same turbidity may not.

Our best recommendation is that if you are unsure as to whether a stream will be "too clear" for a FlowTracker, simply take one and place it in the water to check the SNR values (signal-to-noise ratio; §1.4.2). The FlowTracker can return reliable measurements down to about 3 dB (in SNR), although we recommend 10 dB and above for best operating conditions.

Appendix B. FlowTracker Direct Command Interface

It is possible to establish direct communication with the FlowTracker using its RS232 serial interface.

- The serial interface is accessed through the external power/communication connector on the handheld controller.
- The serial interface is most commonly used to download data files from the internal recorder (see §6.4).
- A terminal emulator program (*SonUtils*) is included with the system to allow direct serial communication with the system.
- Direct communications are not commonly required, but can be a good diagnostic tool for verifying external communication with the FlowTracker.

Use the following steps to establish direct serial communications.

- Run *SonUtils*. Select COM1 and set the baud rate to 9600.
- Connect the external power/communication cable from the FlowTracker to COM1 of the computer.
- Turn on the FlowTracker.
- Send a **BREAK** to wake up the FlowTracker.
  - o A **BREAK** is sent either by clicking the **BREAK** icon or by pressing **Alt+B**.
  - o The **BREAK** is a serial communications signal that consists of holding the transmit line high for a period of at least 300 ms.
  - o The **BREAK** causes a hardware reset in the FlowTracker, and should cause it to output a wake up message (e.g., "SonTek FlowTracker Handheld ADV …").
  - o After the wake-up message, you should see the command prompt ">".
- You have now established direct communications and can send and receive commands.

A variety of commands are available from the direct command interface. They are not documented here as they are not required for FlowTracker operation.

- Type `show <CR>` to see a list of functions used to display all major system settings.

Appendix C. Discharge Uncertainty Calculation

C-1.   Overview

The FlowTracker estimates the uncertainty of every discharge measurement. This calculation can be done using two different methods – **Statistical** or **ISO**.

- The **ISO** uncertainty calculation (§C-2) is based on the international standard[1]. It provides users with the results of a published, standard technique. However, in some cases, this calculation does not provide a reliable indicator of data quality.
- The **Statistical** uncertainty calculation (§C-3) uses a method developed by researchers at the U.S. Geological Survey[3]. This is the default calculation as it provides the most reliable indicator of measurement quality.
- The FlowTracker software displays the results of both uncertainty calculations.
- In the FlowTracker firmware, you can select the discharge uncertainty calculation from the Discharge Settings menu (§2.4.5).
- A comparison of the uncertainty results from the two calculations is shown in §C-4.

C-2.   ISO Uncertainty Calculation

The ISO uncertainty calculation is based on a working version of ISO Standard 748[1]. While it is normally not appropriate to use a working version, an exception was made since the working version provides a more thorough calculation than the released ISO standard (1997). Equation 1 shows the ISO method to calculate uncertainty applied to a FlowTracker discharge measurement.

$$u_Q{}^2 = u_m{}^2 + u_s{}^2 + \frac{\sum_{i=1}^{m}\left((b_i d_i v_i)^2\left(u_{bi}{}^2 + u_{di}{}^2 + u_{pi}{}^2 + \left(\frac{u_{ci}{}^2 + u_{ei}{}^2}{n_i}\right)\right)\right)}{\left(\sum_{i=1}^{m}(b_i d_i v_i)\right)^2} \qquad \text{(Eq. 1)}$$

Where:
- u_Q = relative (percentage) uncertainty in discharge calculation
- u_m = relative uncertainty due to the number of verticals (stations); §C-2.1
- u_s = relative uncertainty due to calibration errors in measurements of width, depth and velocity. This is assumed to be accuracy of the FlowTracker calibration (1%).
- m = number of verticals across the width of the stream
- b_i = width at vertical i
- d_i = depth at vertical i
- v_i = mean velocity at vertical i
- u_{bi} = relative uncertainty in the width measurement at vertical i. From the ISO standard, this is assumed to be 0.5%.
- u_{di} = relative uncertainty in the depth measurement at vertical i. From the ISO standard, this is assumed to be 0.5% for depth > 0.30 m (1 ft), and 1.5% for depth < 0.30 m (1 ft).
- u_{pi} = relative uncertainty due to limited number of velocity measurements at vertical i; §C-2.2
- $u_{ci}+u_{ei}$ = relative uncertainty in velocity measurements at vertical i, with contributions from instrument uncertainty (u_{ci}) and real fluctuations in the river (u_{ei}). The combination of these two terms is directly measured by the FlowTracker as the standard error of velocity (v_{i_err}), and is calculated as ($u_{ci} + u_{ei} = v_{i\_err} / v_i$)
- n_i = number of velocity measurements at vertical i

In Equation 1, the ISO calculation breaks the sources of uncertainty into two groups. The first group contains uncertainty sources that are applied for each vertical – width (u_{wi}), depth (u_{di}), method (u_{pi}, for the number of velocity measurements at each vertical), and velocity ($u_{ci} + u_{ei}$). These uncertainty sources are assumed to be independent, and are being weighted based on the discharge of each vertical.

The second group contains those values applied to the measurement as a whole – the accuracy of instrument calibration (u_s), and the number of verticals (u_m) (see §C-2.1).

In addition to overall uncertainty, the FlowTracker looks at the contribution of each parameter. To calculate the contribution of each parameter, the calculation is repeated while setting all other parameters to zero. At the end of each discharge measurement, the FlowTracker displays the overall uncertainty and the largest individual source of uncertainty. The FlowTracker software shows the contribution of each parameter.

- **Accuracy** (u_s): uncertainty due to the accuracy of the FlowTracker calibration
- **Depth** (u_{di}): uncertainty due to depth measurements
- **Velocity** ($u_{ci} + u_{ei}$): uncertainty due to velocity measurements (instrument uncertainty and real fluctuations in the flow)
- **Method** (u_{pi}): uncertainty due to number and location of velocity measurements at each vertical
- **Number of verticals** (u_m): uncertainty due to a limited number of verticals
- **Width** (u_{wi}): uncertainty due to width measurements

C-2.1. Number of Verticals

Velocity and depth are measured at a limited number of verticals across the stream, and are assumed to vary linearly between them. To estimate the uncertainty of this assumption, the ISO provides a guideline based on the number of verticals in Table C-1.

Table C-1. Number of Verticals vs. Uncertainty

Number of Verticals	Uncertainty % (u_m)
5	7.5
10	4.5
15	3.0
20	2.5
25	2.0
30	1.5
35	1.0
40	1.0
45	1.0

Sauer and Meyer[2] provide the same data and Equation 2 below to calculate this uncertainty for any number of verticals. In this equation, u_m is given in percent and m is the number of verticals. This is the equation used by the FlowTracker when calculating the ISO uncertainty estimate.

$$u_m = 32 * m^{-0.88}$$ (Eq. 2)

This estimate is based on a statistical analysis of many streams. It does not take into account the data available with an individual stream that could strongly influence the overall uncertainty. For example, it might be possible with five verticals to accurately measure the flow in a broad concrete lined channel of constant depth, as the velocity distribution across the width of the channel will likely be very consistent. In comparison, a natural stream can show large velocity and depth changes, so the accuracy of a discharge measurement with five verticals would be much lower. The ISO calculation would not account for this difference. This is perhaps the most significant shortcoming of the ISO calculation.

C-2.2. Limited Velocity Measurements at Each Vertical (Discharge Method)

A limited number of velocity measurements are made at each vertical; the mean velocity is calculated using assumptions about the velocity distribution. The ISO standard provides an estimate of the uncertainty associated with these assumptions in Table C-2.

Table C-2. Measurement Method vs. Uncertainty

Measurement Method	Uncertainty (u_{pi}) %
1 point (0.6 * depth)	7.5
2 points (0.2 and 0.8 * depth)	3.5
5 points (near surface, near bottom, and 0.2 / 0.6 / 0.8 * depth)	2.5
Velocity distribution method (multiple points with the change between points not to exceed 20% of the higher value)	0.5

For the FlowTracker calculations, we have simplified Table C-2 above to estimate the uncertainty based only on the number of measurements in the vertical as shown in Table C-3 below.

Table C-3. Number of Measurements vs. Uncertainty

Number of Measurements	Uncertainty (u_{pi}) %
1	7.5
2	3.5
3	3.0
4	2.7
5 or more	2.5

C-3. Statistical Uncertainty Calculation

The technique we refer to as the **Statistical** uncertainty calculation was developed by researchers at the U.S. Geological Survey (USGS): Tim Cohn, Julie Kiang, and Robert Mason [3]. It has also been called the interpolated difference technique, though no final name has been selected. As of August 2006, they have not published the technique, but have plans to do so in the future. The calculation described here should be considered preliminary, and may be subject to change.

The **Statistical** technique takes a very different approach from the ISO method. The ISO looks at the physical characteristics of the measurement and discharge calculation to estimate uncertainty. The **Statistical** technique is a strictly statistical approach, using adjacent values of each measured variable to estimate the uncertainty in these measurements. This appendix presents a brief overview of the **Statistical** technique, deferring a full description to future publications of Cohn, Kiang, and Mason. The basic form of the **Statistical** calculation is similar to the ISO calculation.

$$u_Q{}^2 = u_s{}^2 + \frac{\sum_{i=1}^{m} \left((b_i d_i v_i)^2 \left(u_{bi}{}^2 + u_{di}{}^2 + u_{vi}{}^2 \right) \right)}{\left(\sum_{i=1}^{m} (b_i d_i v_i) \right)^2} \qquad \text{(Eq. 3)}$$

Where:

- u_Q = relative (percentage) uncertainty in overall discharge calculation
- u_s = relative uncertainty due to calibration errors in measurements of width, depth and velocity. This is assumed to be accuracy of the FlowTracker calibration (1%).
- m = number of verticals across the width of the stream
- b_i = width at vertical i
- d_i = depth at vertical i
- v_i = mean velocity at vertical i
- u_{bi} = relative uncertainty in the width measurement at vertical i. This is not specifically calculated by the Statistical technique; it uses the same 0.5% value as the ISO calculation.
- u_{di} = relative uncertainty in the depth measurement at vertical i.
- u_{vi} = relative uncertainty in the velocity measurement at vertical i.

As with the ISO, this calculation breaks the sources of uncertainty into two groups. The first are uncertainty sources that are applied for each vertical: width (u_{wi}), depth (u_{di}), and velocity (u_{vi}). These uncertainty sources are weighted based on the discharge of each vertical. The other source is applied to the measurement as a whole: the accuracy of instrument calibration (u_s). All uncertainty sources are assumed to be independent.

To estimate the uncertainty in depth and velocity, the **Statistical** technique uses adjacent measurements. The calculation is the same for depth or velocity (only depth is shown here).

A basic assumption of a discharge measurement is that velocity and depth change linearly between verticals. Following this assumption, we can estimate the depth at vertical i (d_i) by using depth values from the adjacent vertical (d_{i-1} and d_{i+1}). For simplicity, the calculation here assumes equal spacing of verticals. The FlowTracker implementation does a linear interpolation based on the location of each vertical.

$$d_{i\_est} = (d_{i-1} + d_{i+1}) / 2 \qquad \text{(Eq. 4)}$$

An estimate of the uncertainty in depth for vertical i can be calculated as the difference between the estimated and measured depth.

$$\Delta_i = d_{i\_est} - d_i \qquad \text{(Eq. 5)}$$

Any individual uncertainty estimate (Δ_i) is subject to considerable variability; combining all estimates from a given measurement gives a better overall estimate of uncertainty. Equation 6 calculates an overall estimate of the uncertainty in depth measurements (σ_d), a statistical average of the individual uncertainty estimates (Δ_i). This value (σ_d) is in depth units (m or ft). (The derivation of Equation 6 is deferred to future publications of Cohn, Kiang, and Mason.)

$$\sigma_d^{\ 2} = \left(\frac{2}{3}\right)\left(\frac{1}{(m-2)}\right)\sum\nolimits_2^{m-1}\left(\Delta_i^{\ 2}\right) \qquad \text{(Eq. 6)}$$

The relative depth uncertainty for each vertical is calculated below in Equation 7. This relative depth uncertainty (u_{di}) is used directly in Equation 3. A similar term can be calculated for velocity (u_{vi}; not shown here).

$$u_{di} = \sigma_d / d_i \qquad \text{(Eq. 7)}$$

Perhaps the primary advantage of the **Statistical** technique is that the estimated uncertainty takes into account variability in depth/velocity across the stream, and as such, includes measurement uncertainty, natural stream conditions (e.g., different bottom types), and the assumption that depth and velocity change linearly between stations.

In addition to overall uncertainty, the FlowTracker looks at the contribution of each parameter. To calculate the contribution of each parameter, the calculation is repeated while setting all other parameters to zero. At the end of each discharge measurement, the FlowTracker displays the overall uncertainty and the largest individual source of uncertainty. The *FlowTracker* software shows the contribution of each parameter.

- **Accuracy** (u_s) – uncertainty due to the accuracy of FlowTracker calibration
- **Depth** (u_{di}) – this term includes both uncertainty in the depth measurement and the effect of changes in depth between verticals.
- **Velocity** (u_{vi}) – this term includes both uncertainty in the velocity measurement and the effect of changes in velocity between verticals.
- **Width** (u_{wi}) – uncertainty due to width measurements

C-4.   Uncertainty Comparison: ISO and Statistical

Why offer two different uncertainty calculations – should not one be sufficient? To answer this, we need to look at the results of each method.

The ISO calculation seems a natural choice – it is well documented and from an internationally recognized agency. However, analysis shows the ISO does not always provide a meaningful indication of the measurement quality. In comparison, the **Statistical** technique appears to provide a good indicator of measurement quality, particularly at sites with variable flow conditions. However, it is currently (August 2006) an unpublished technique and may be subject to change. Since there are drawbacks to each calculation, we decided to present results from both calculations.

To compare the two uncertainty calculations, we used a set of 24 real discharge measurements made with a FlowTracker. These represent a range of conditions – discharge values from 0.004 to 8.6 m^3/s (0.13 to 300 ft^3/s) and mean velocity from 0.01 to 0.50 m/s (0.03 to 1.6 ft/s). All measurements are in natural rivers in North America.

Figure 36 compares the **Statistical** and ISO calculations from all 24 files.

- The **Statistical** calculation shows uncertainty values from 2.1 to 19%; the ISO calculation shows values from 2.4 to 8.4%.
- If you remove one outlier (with very low velocity and high uncertainty), the **Statistical** calculation varies from 2.1 to 15% while the ISO varies only from 2.4 to 4.3%.
- Since uncertainty under 5% is considered a "Good" measurement by many agencies, the ISO equation would rate all of these measurements as Good, which is clearly not the case on closer analysis of some files.
- To understand this better, we will also look at two individual files in detail.
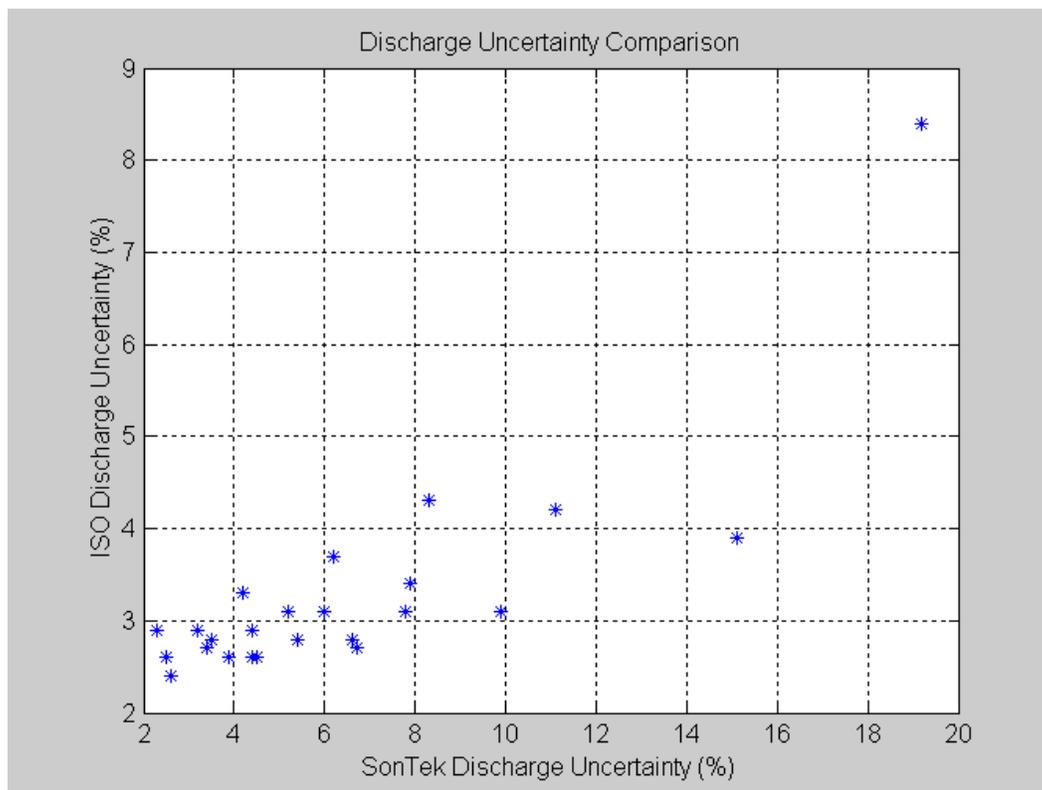
Figure 36 – Statistical and ISO Calculation Comparison

Figure 37 shows depth and velocity profiles from a file where **Statistical** shows 2.5% uncertainty, while ISO shows 2.6%. As both calculations indicate, this is a good measurement with smooth, linear variations in depth and velocity with few large inconsistencies. Both calculations correctly represent this.

Figure 38 shows depth and velocity profiles from a file where the **Statistical** calculation shows 15.1% uncertainty, while the ISO calculation shows 3.9%. Looking closely at the measurement, there are several large and dramatic changes in both depth and velocity (particularly velocity; for example, look at the verticals at location 5.5 and 8.1 m). This indicates either unusual flow conditions (which would require more verticals to resolve) or measurement problems. The ISO calculation still reports an uncertainty (3.9%) that would be considered good by most users. The **Statistical** calculations report a much higher uncertainty (15.2%), correctly indicating there are areas that are cause for concern in the quality of this measurement.

Because of the ability of the **Statistical** calculation to distinguish data quality issues as shown here, we recommend using the **Statistical** uncertainty calculation. It is hoped that additional publications and data analysis will help further the development of uncertainty calculations, leading to a single accepted method in the future.

It is also interesting to look at the contribution of each parameter to the estimated uncertainty. For the ISO calculation, six different parameters contribute to the overall uncertainty – width, depth, velocity, method, number of stations, and accuracy (FlowTracker calibration). For the **Statistical** calculation, there are four parameters – width, depth, velocity, and accuracy (FlowTracker calibration again).

For the ISO calculation, the number of stations is the largest single component of uncertainty for 22 of 24 files; method and velocity are each the largest source in one file. Since the number of stations parameter is essentially based on a statistical analysis of many rivers, rather than data from the specific measurement site, this raises significant concerns if it is the largest source of uncertainty. The contribution of velocity is generally small, except in cases where the mean velocity is very low (velocity is the largest component of uncertainty in a file where the mean velocity is 0.01 m/s (0.04 ft/s)). The measurement method is generally a modest contributor to overall uncertainty, but can be significant in files with low overall uncertainty (<3%). The contribution of width, depth, and accuracy to the overall ISO uncertainty is small to negligible.
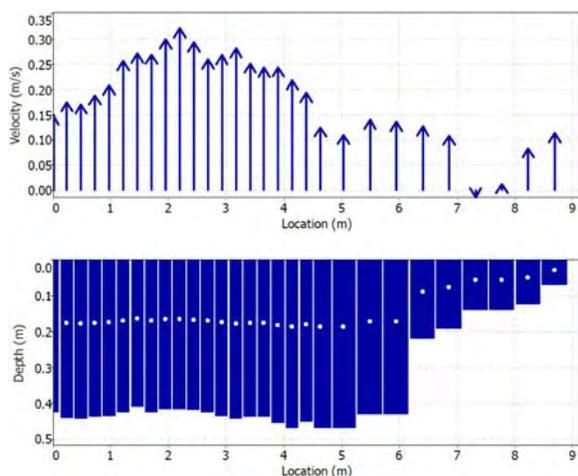
Figure 37 – Uncertainty Comparison:
Good Discharge Measurement
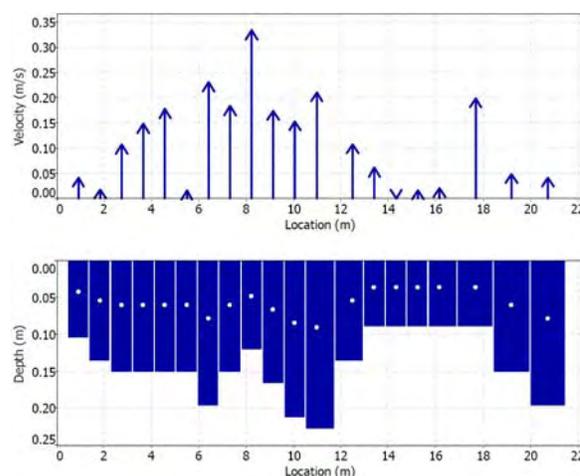
Figure 38 – Uncertainty Comparison:
Poor Good Discharge Measurement

For the Statistical calculation, the velocity term is the largest individual source of uncertainty in all 24 files. Keep in mind that this term includes not only uncertainty in the velocity measurement, but also variation in velocity between stations (which is typically the dominating factor). Depth adds a small but notable amount to the Statistical uncertainty calculation; again, this is dominated by the variation in depth between stations. The contributions of width and accuracy are small to negligible. Analysis of this data tends to indicate that variation between stations, both of depth and velocity, are the most important factor in overall measurement uncertainty.

C-5. References

[1] ISO 748, Hydrometry - Measurement of liquid flow in open channels using current meters or floats. Working version 2003.

[2] V.B. Sauer, and R.W. Meyer, Determination of Error in Individual Discharge Measurements. U.S. Geological Survey, Open File Report 92-144. 1992.

[3] Tim Cohn, Julie Kiang, and Robert Mason, U.S. Geological Survey. Personal communication, June-August 2006.

Appendix D. Multiple Language Keypads

The FlowTracker supports operation in five languages using translated keypad overlays for each language. The keypads are shown in actual size within the document, so they can be printed and temporarily taped over the keypad for testing purposes. High quality, embossed decals to overlay onto existing keypads are available as a permanent way to show the different key labels.
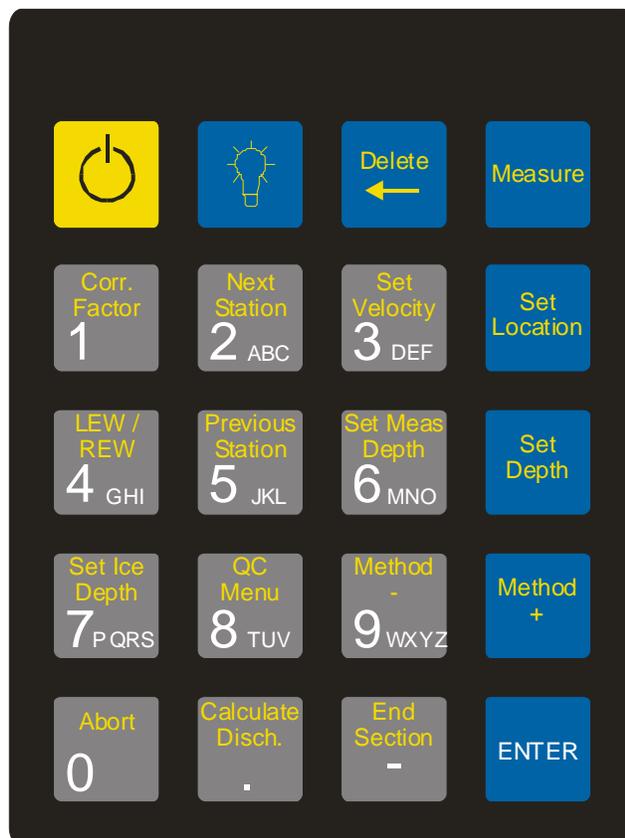
English Keypad

Spanish Keypad
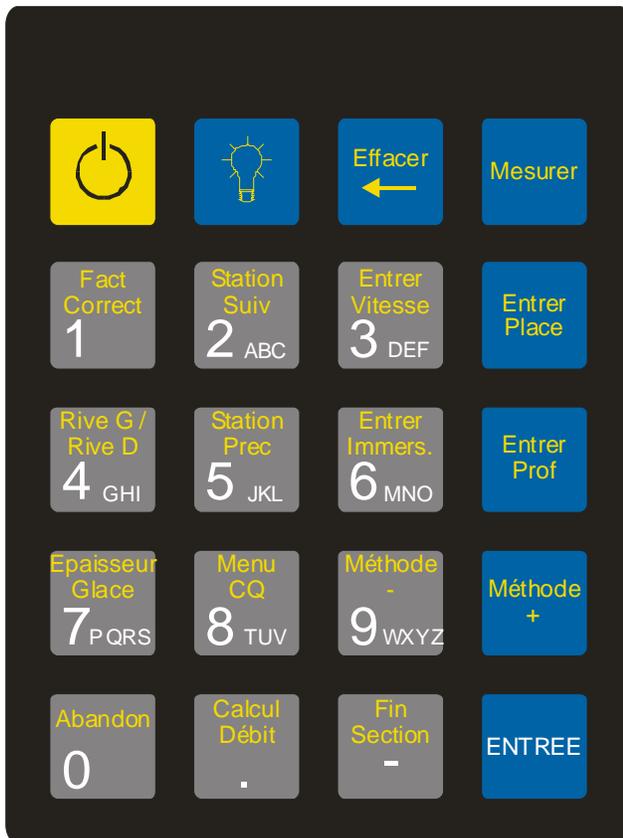
French Keypad

German Keypad

Italian Keypad

Z

zinc anodes, 85

zoom in/out (beam check), 60