Acoustic Doppler Profiler (ADP) Standard Operating Procedure

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REVISION HISTORY

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ACRONYMS

Acronym	Definition
ADCP	Acoustic Dippler Current Profiler
ADP	Acoustic Doppler Profilers
BT	Bluetooth
DEQ	Department of Environmental Quality (Montana)
DGPS	Differential GPS
GB	Gigabyte
GGA	Global Positioning System Fix Data
GPS	Global Positioning System
LED	Light-Emitting Diode
MT	Montana
NMEA	National Marine Electronics Association
PC	Personal Computer
PCM	Power and Communications Module
PDA	Personal Digital Assistant
QA	Quality Assurance
QC	Quality Control
RTK	Real Time Kinematic
SAP	Sampling and Analysis Plan
SD	Secure Digital
SOP	Standard Operating Procedure
SS	Spread Spectrum
USB	Universal Serial Bus
USGS	United States Geological Survey
VTG	Vector Track and speed over Ground
WGS	World Geodetic System
WQPB	Water Quality Planning Bureau (DEQ)
WQX	EPA's Water Quality Exchange System

1.0 INTRODUCTION TO MEASURING FLOW WITH ACOUSTIC DOPPLER PROFILERS (ADP)

1.1 SCOPE AND APPLICABILITY

Standard Operating Procedures (SOP) described in this document detail methods that will be used by the Montana Department of Environmental Quality (DEQ) for collecting, post-processing, and analyzing streamflow or velocity data collected via Acoustic Doppler Profiler (ADP). Specifically the SOP applies to discharge or velocity measurements in open channels using the Department's Sontek RiverSurveyor M9 Acoustic Doppler Profiler (ADP) instrument. However, principles can be extended to other lines of instrumentation in the future if necessary. Techniques for selection of an appropriate measurement location, configuration of the ADP, use of different deployments, diagnostic and moving-bed tests, and collection and review of ADP discharge measurements are all described. For any project using the ADP instrument, a sampling analysis plan (SAP) must be signed by the Monitoring and Assessment Section supervisor to ensure proper temporal coordination of the Bureau's field equipment.

1.2 ACOUSTIC DOPPLER PROFILING PRINCIPLES

The Doppler Shift (e.g., the shift or change in sound frequency of signals reflected off particles in the water) is a very useful principle with respect to river discharge monitoring. The ADP transmits an acoustic "ping" or pulse of sound into the water column and then listens for the return echo from the acoustic backscatterers (e.g., particles in the water). Upon receiving the return echo, the onboard acoustic doppler current profiler (ADCP) signal-processing unit calculates the Doppler shift which enables the velocity of the particles in the water to be determined. If done over a number of verticals (i.e., bins) in a transect, discharge can be computed.

The primary advantage of an ADP measurement over traditional techniques is related to both efficiency and safety. It takes significantly less time to complete a measurement and information is collected throughout the water column. Likewise, the ADP is deployed at the water surface appreciably reducing the chance of snagging by debris. Finally, the instrument can be boat-mounted, hence eliminating the need for bridge use or on manned cableways and complex flow regimes, such as vertical bi-directional flow can be accurately identified and measured (Oberg et al. 2005). Consequently, the use of the ADP by DEQ greatly enhances our ability to collect quality data on both small and large rivers systems.

1.3 SONTEK RIVERSURVEYOR® SYSTEM OVERVIEW

The Sontek RiverSurveyor® M9 ADP is a nine-beam acoustic profiling system with two sets of four profiling beams (each set having its own frequency) and one vertical beam (for depth determination). The profiling range extends from 0.06-40 m[1] with capability to measure velocities from 0-20 m/s (2 cm volume size minimum). Notable technical features of the instrumentation are shown in Table 1-1. The system is flexible enough to be deployed on rivers, canals, and other conveyance features, and includes a real time kinematic (RTK) Global Positioning System (GPS) component which allows 3 cm positioning, should such accuracy be desired. Finally, the system incorporates SmartPulseHD™ technology which is an intelligent algorithm that looks at water depth, velocity, and turbulence, and then adapts the acoustic

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[1] Actual discharge measurements must be completed in slightly deeper water (0.2-0.3 m)

pulse scheme to those conditions. This enables efficient mapping of the velocity profile, and discharge calculation with cell sizes down to 2 cm.

Table 1-1. Capabilities of the Sontek RiverSurveyor® M9

Velocity Measurement	
Profiling Range (Distance)	0.06 to 40m
Profiling Range (Velocity)	±20 m/s
Accuracy	±0.25% of measured velocity
Resolution	0.001 m/s
Number of Cells	Up to 128
Cell Size	0.02 to 4m
Transducer Configuration	Nine (9) Transducers Due 4-bean 3.0 MHz/1.0 MHz Janus to 25° Slant Angle 0.5 MHs Vertical Beam
Depth Measurement	
Range	0.20 to 80m
Accuracy	1%
Resolution	0.001 m
Discharge Measurement	
Range with Bottom-Track	0.3 to 40m
Range with RTK GPS	0.3 to 80m
Computations	Internal

The core system of the Sontenk RiverSurveyor® M9 includes the basic transducer/ADP unit, the power and communications module, the GPS components, and the hydroboard (deployment system) are described below.

1.3.1 ADP/Basic Transducer Housing

The Sontek M9 ADP unit consists of the main body transducer housing that integrates a compass/2-axis tilt sensor, temperature sensor, 8 GB internal recorder, a vertical acoustic beam (echo-sounder) for depth measurement, and the onboard computer. An 8-pin cable connection is also included for direct connection with the power and communications module. A drawing of the instrument is shown in **Figure 1-1** and there are four brass inserts on top of the ADP (top facing down in this drawing) which can be used to secure the ADP to a manned boat or to mount the optional GPS antenna.
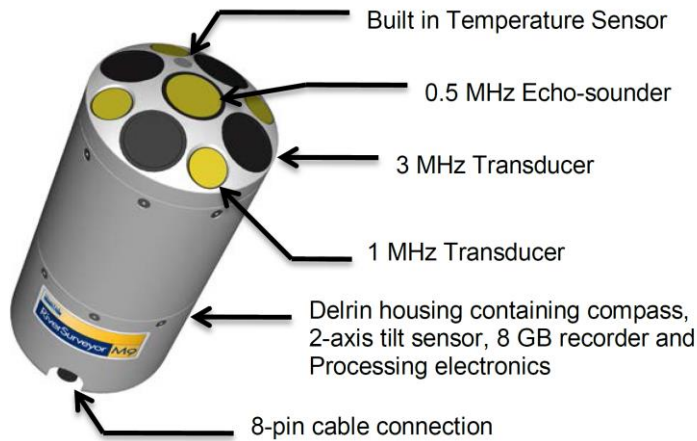
Figure 1-1. Sontek M9 RiverSurveyor ADP unit (taken from M9 user's manual).

1.3.2 Power and Communications Module (PCM)

The power and communications module (PCM) of the ADP system (Figure 1-2) connects directly to the ADP using a 1-m cable. It provides power using a rechargeable battery pack and enables communications with a personal computer (PC) or Mobile device through a radio link or bluetooth (or direct PC connection to a PC). The functionality of the PCM includes an on/off button (green in middle) and a series of status lights which show whether there is power (PWR), radio communication (Radio), differential GPS correction (DGPS), or RTK GPS lock (GPS).
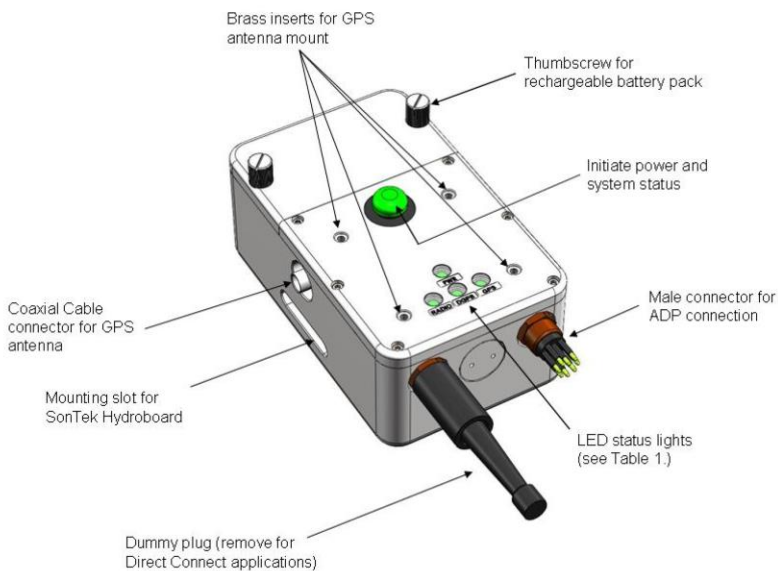
Figure 1-2. Power and communication module (PCM) of the Sontek system.

Communication between the ADP and PCM can be initiated with either a Windows PC or Windows enabled mobile device. Either of the following can be used: (1) a field Dell Toughbook notebook equipped with a Pirani Bluetooth dongle (i.e., antenna) or (2) the Motorola portable device supplied with the unit. If the field laptop is used, it must contain the RiverSurveyor Live software. The maximum

range with the laptop/Pirani Bluetooth is 200 m whereas the Bluetooth range of the Mobile device is approximately 60m. Both assume a clear line-of-sight with no obstructions or poor weather.

1.3.3 GPS Components

Two GPS options are integrated into the DEQ unit. The first provides Real Time Kinematic (RTK) quality data (±3 cm) and requires operation of a separate RTK Base Station (**Figure 1-3**) (the base station is located in a second pelican case at the DEQ water lab). The Base Station provides real-time corrections to the GPS receiver using Spread Spectrum radio with a range of about 2 km from base station to rover unit. The Base Station receives GPS data via satellite and applies an RTK correction and transmits that information to the internal GPS of the PCM. If communication between the RTK Base Station and PCM is lost, a sub-meter correction is typically valid for up to 45 minutes without having to re-establish communications.

The Differential GPS (DGPS) is the second available option and unlike the RTK method, does not require a Base Station. Rather it provides sub-meter differential GPS positioning data using a network of fixed ground-based reference stations. This is the preferred method for use by DEQ for discharge measurement. However, if bathymetric mapping, or other potential uses are forseen, the RTK option may also be used. Some general rules of thumb for connection times for the various types of GPS communications are:

- **GPS Lock:** Typically takes 5 minutes for greater than 1-m accuracy (to turn from Red to Green).
- **Differential Lock:** Typically takes up to about 5 minutes to get sub-meter accuracy (turn from Red to flashing Red/Green).
- **RTK Lock:** Typically takes up to about 10 minutes to get ±3 cm accuracy (turn from alternatively flashing Red/Green to Green).
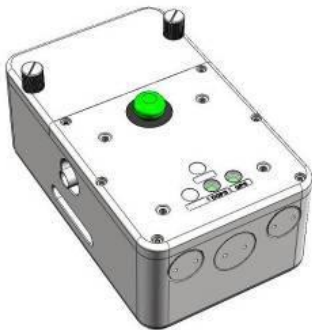
Figure 1-3. RTK base station for the GPS option of the Sontek M9 RiverSurveyor.

The other connection signals are Bluetooth/Spread Spectrum (BT/SS) LED which lights green as soon as connection is established between PC/Phone and the system (assuming you are within range), and the Base Station Radio Link which is red when established.

1.3.4 Sontek Hydroboard

The SonTek Hydroboard (**Figure 1-4**) is an unmanned tethered boat designed to be used specifically with the RiverSurveyor™ M9 ADP when making bridge measurements, or alternatively, to affix to a manned boat via the boom and winch of the DEQ jet boat (as described later in this SOP). The hydroboard has mounts for both the ADP and PCM along with two embedded towing mounts near the front and one in the rear for an optional drag chute to increase boat track stability (e.g., sea anchor, also included with

the DEQ measurement equipment). Two hydro-fins in the rear of the vessel provide increased stability. A description of the mounting procedure for the Hydroboard is explained later in **Section 2.0**.

Figure 1-4. Sontek Hydroboard for use with the Sontek RiverSurveyor™ M9 ADP and PCM.

2.0 DISCHARGE MEASUREMENT PROCEDURES

The last section (Section 1.0) provided familiarization with the Sontek RiverSurveyor™ M9 ADP that DEQ will use for discharge measurement. This section presents a general overview of how to conduct a discharge measurement with the system. Included is information on training, pre-field preparation, instrument and PC setup, selecting an appropriate site for discharge measurement, instrument configuration and compass calibration, and discharge measurement.

2.1 TRAINING REQUIREMENTS

Each person responsible for ADP operation will be trained such that they understand the principles of the technology and how to successfully complete quality measurements. Training will be conducted annually prior to each field season, such as typically done in other DEQ monitoring programs. In addition, completion of the United States Geological Survey (USGS) class Measurement of Streamflow using ADPs at the following weblink is recommended: http://hydroacoustics.usgs.gov/training/SW1321TEL.shtml. Finally two papers, Simpson (2001) and Mueller and Wagner (2009) are valuable resources for ADP users which describes ADP operating techniques, fundamental ADP theory, ADP discharge-measurement theory, vessel mounts, and operating techniques required for ADP measurements, and should be reviewed. A significant amount of content from this SOP was based on those documents.

2.2 PRE-FIELD PREPARATION

Prior to doing any field activities, it is recommended that the software and firmware are updated on the field PC and ADP system to ensure complete and accurate data collection. While upgrades to the system may or may not improve discharge measurement/post-processing capability (Oberg et al. 2005), they still should be completed. The lead field personnel will ensure that the most recent software and firmware are installed on the primary field computer and ADP system each year before going out to the field. Updates can be found at the SonTek website: http://www.sontek.com/.

RiverSurveyor Live for PC is the primary operational software and must be installed on the field PC prior to making a discharge measurement (as well as post-process the data). The following specifications are required for installation on Windows Vista or Windows XP (or higher) machines, 1.6 GHz processor, 1 GB memory, 1 GB disk space, and 1024 x 768 Screen Resolution. To install the software or perform an update, download the most recent installation files and follow the instructions in the user's manual. Staff from the DEQ Monitoring and Assessment section will ensure that updates are completed as appropriate.

2.3 SITE SELECTION

After arriving in the field, site selection is an integral part of the discharge measurement process. Similar to traditional methods, many ADP measurement problems can be solved by simply moving to a better measurement location. Guidelines for site selection are provided in DEQ (2012) and USGS Water-Supply Paper 2175 (Rantz et al. 1982, p. 139), and generally include:

- Choose a location in a straight reach with uniform laminar flow where streamlines are parallel to each other. The location should be free of disturbances (i.e., boulders, aquatic growth, pipe joints), inflowing/outflowing side channels or tributaries, eddies, vortices, backward flow, excessive turbulence, dead zones (although the ADP can account for 3-dimensional velocities), or other obstructions. Desirable measurement sections are roughly parabolic, trapezoidal, or rectangular and asymmetric channel geometries. Non-typical cross-sections (for example, deep on one side and shallow on the other) should be avoided if possible (Simpson, 2001).
- Ensure that velocities and depths are within the operating limits of the ADP instrument, primarily >0.3m in depth (which is required for depth measurements). In addition, if velocities are <0.30 ft/s, boat speeds must be kept extremely slow (if possible, less than or equal to the average water velocity).
- Avoid areas downstream of sharp bends, upstream or downstream of vertical drops or where the stream empties into a stationary body of water. Sites with turbulent flow, as evidenced by standing waves (e.g., hydraulic jumps), should also be avoided. This is often indicative of non-homogenous flow, a condition that violates assumptions for ADP velocity measurements.
- Avoid locations having strong local magnetic fields (in comparison to the Earth's magnetic field). Large steel structures, such as overhead truss bridges or power lines are a common source for these large local magnetic fields and may result in ADCP compass errors.
- When using DGPS, avoid locations where multi-path interference is possible (signals from the satellites bounce off structures and objects such as trees along the bank or nearby bridges or buildings), or where reception of signals from GPS satellites is blocked. It would be best to use the bottom track feature in these instances (which does not require the GPS).

Finally, DEQ will use best judgment in site selection when all of the above criteria do not exist. Note that it may not be possible to find measurement locations in sections that do not violate one or more of the above guidelines. Whenever possible, we will locate and use a better measurement section. This is possible when using manned boat measurements, however is not if using a tethered boat from a bridge.

2.4 INSTRUMENT SETUP/PRE-MEASUREMENT ACTIVITIES

The general setup for the ADP will be similar regardless of whether a manned and unmanned boat measurement is made. In all cases, a pre-field inspection is recommended to ensure that the equipment is available and functioning. For example, ADP cables, connections, batteries, and mounts should be inspected prior to use. In addition, the ADP should be connected to the field PC (via Bluetooth) to ensure communications are established. If problems are encountered during any of these checks, the problems will be resolved before commencing a measurement. If the issue still cannot be resolved, the technician will consult with the Monitoring Section supervisor, or contact vendor technical support. Specifics about the setup configurations and pre-measurement tests are below.

2.4.1 Configuration 1 – Differential GPS Setup

Flow measurements can be made by the DGPS method (**Figure 2-1**) which requires use of a Dell Toughbook laptop (or equivalent), Pirani Bluetooth dongle, core ADP system (no Base Station), and the Hydroboard. For the wireless communications option (which should be used for all DEQ measurements), the dummy plug (8-pin plug) must be inserted into the Power Command Module (PCM) in order to complete internal circuitry and to prevent water damage. Setup of the Hydroboard should be completed as described in the next section (Sontek, 2012) along with the general DGPS setup:

1. Open the battery pack of the PCM by loosening the thumb screws. Insert the rechargeable battery pack by aligning the cells with the contacts and make sure the O-ring seal is clear of debris. Close the battery cover and securely tighten the thumb screws to maintain a water-proof seal. Set the PCM into position on the Hydroboard (the rectangular cut-out in the mounting bracket) and tighten its thumb screws. Four separate battery packs are available and these should be kept in a charged condition as possible. Both a 110 volt and lighter plug version of the charger is kept in the pelican case of the ADP unit.

2. Insert the ADP face (transducers looking down) into the circular hole in the Hydroboard. Start from the topside of the Hydroboard and move the ADP downward (be sure the top of the ADP coincides with the top of the Hydroboard). If needed, slightly rotate the ADP left and right to raise and lower the ADP to the proper level. A sharpie mark has been made on the top of the ADP unit and this should be set level with the mounting surface (so the line barely shows).

3. To properly align the transducers, make sure the female plug-in of the ADP lines up with the female plug-in of the PCM. Tighten the clamp around the transducer by rotating the thumb screw until the ADP is held firmly in place. The ADP should be installed so that the transducer head is flush with the fairing and as described previously.

4. After the PCM and the ADP are in place, connect the data cable between them. Start by connecting the cable's underwater 8-pin male connector to the female ADP connector until the face of the cable is flush with the connector; now tighten the connection with the protective locking sleeve. All of these activities should be completed away from water. Next, repeat the same procedure to connect the data cable to the PCM. Connect the 8-pin male cable connector by pushing the connector into the female connector embedded in the PCM until the face of the cable is flush with the female connector; tighten the connection with the protective locking sleeve.

5. Attach the GPS receiver and antenna mast to the ADP (if not already connected) by inserting the four thumb screws into the brass holes in the ADP. Connect the female connector of the GPS coaxial cable to the male connection on the receiving antenna. Run the coaxial cable through

the antenna mast to the bottom, collecting all excess cable from the antenna mast and connect the female connector of the coaxial cable to the male connection on the PCM.

6. Turn the system on by pressing the power button on the PCM. The button should then glow solid green. Follow the instructions later in this section to complete the discharge measurement. The SonTek GPS options use the World Geodetic System (WGS) 84 horizontal datum. Recall the DGPS option has sub-meter precision for positional accuracy (<1 m).
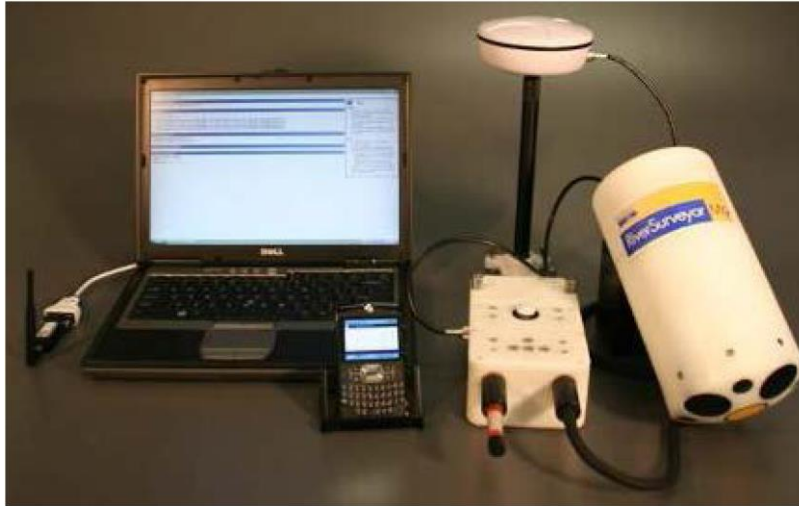

Figure 2-1. ADP setup for DGPS configuration including computer and Bluetooth Pirani dongle.

2.4.2 Configuration 2 – RTK Setup

The RTK setup is no different than the DGPS procedures described previously, however, it requires the setup of an RTK base station (**Figure 2-2**). The Base Station should be installed within 2 kilometers of the PCM and away from nearby obstructions such as bridges, buildings, or large trees which limit the number of useful satellites and increase the required time to obtain an RTK correction. Instructions for setup of the Base Station are:

1. Attach the tripod adaptor (round plastic disk) to the RTK Base Station and then the tripod adaptor to the tripod. Attach the Base Station antenna mount to the top of RTK Base Station. Screw in the Base Station antenna to the top of the mast. Connect the SS Radio antenna male connector to the female connector in the RTK Base Station. Plug the male connector of the Base Station antenna cable to the female connector embedded in the RTK Base Station.
2. Open the RTK Base Station battery cover by loosening the two thumb screws on the battery cover. Insert the rechargeable battery pack by aligning the exposed cells with the spring contacts. Check to make sure the O-ring seal is clear of all debris. When closing the battery cover, securely tighten both thumb screws to maintain a waterproof seal.
3. Align the tripod so it is level and stable and adjust the height of the tripod for the best line of sight to the remote PCM. Make sure the antenna is high enough to avoid interference from nearby obstructions like overhead trees, bridges, or buildings. The antenna is typically mounted directly on top of the RTK Base Station; however, it can be dismounted and placed in a more ideal location as long as the antenna's coaxial cable remains connected to the RTK Base Station. If possible, avoid line of sight obstructions as they may decrease the communication range between the RTK Base Station and the PCM (on the boat).

4. Turn on system power by pressing the circular button on top of the communications box: it should turn solid green once turned on. The RTK Base Station has two LEDs. In all cases, a green light would indicate that the component is functioning while a red/orange light would indicate that the system is not functioning.
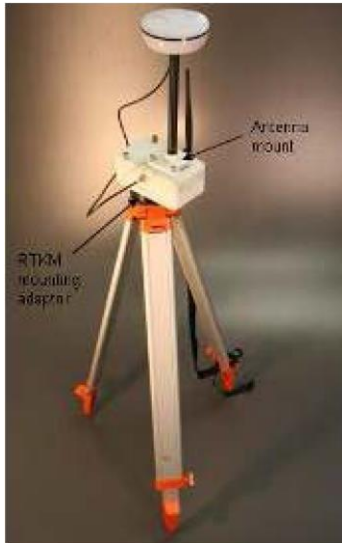

Figure 2-2. ADP setup for the RTK GPS configuration.

2.4.3 Check cables and connections

Prior to making a discharge measurement, the structural integrity of all cables and connectors attaching hardware to the RiverSurveyor (e.g., cables, GPS antennae, etc.) should be evaluated to ensure that there are no defects. This should be done every time the unit is setup. During connection of cables, the faces of the connectors should be ensured to be flush/secure before screwing down the locking sleeves or damage may occur to the connections. When using the SonTek Hydroboard or other remote device, be sure that all knots and clamps are sound and that the rope/cord is strong enough to withstand the onsite conditions. It is also important to ensure battery packs adequately charged and spares are available.

2.4.4 Communications Check

The communications check is a critical part of the measurement process and the first part in implementing a measurement. There are three types of ways the Sontek M9 ADP can communicate with the PC/field personnel. DEQ will use only the Bluetooth connection (i.e., the Parani Bluetooth dongle with 200m range). This is an external Bluetooth radio that plugs into the PC through the USB to serial adapter. It is automatically configured to 57600 baud by the RiverSurveyor Live software.

After selecting initiating a connection, a popup window will open prompting which Com port should be selected. Check the Parani Bluetooth connection box highlighted in **Figure 2-3**. This automatically connects to the Parani Bluetooth dongle at 57600 baud. The PC is now connected to the ADP through the Bluetooth connection.
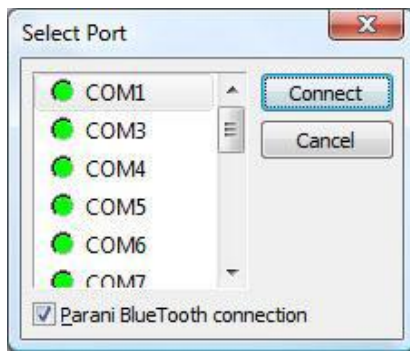
Figure 2-3. Communication port selection window for making a connection between the ADP and PC.
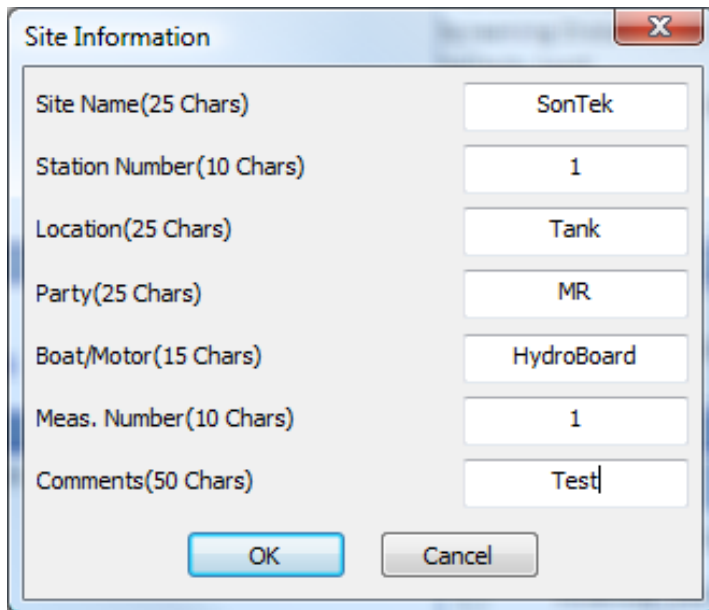
2.5 LAPTOP/PC PROCEDURES FOR DISCHARGE MEASUREMENT

When the connection is established, the System Tab is displayed as shown in Figure 2-4. This is where DEQ will enter site information, set system/measurement settings, download files from the recorder, and perform pre-measurement tests. This window is the primary point of interaction with the software.

2.5.1 Entering Site Information

Site information can be entered at the top of the System Tab by clicking Change Site Information at the top of the page. This opens a popup window that allows you to enter site specific details (**Figure 2-5**) which would include information on the site name/ID, site visit code, personnel, etc. The maximum number of characters allowed for each data field is in parentheses. Entering more than the maximum allowable characters will display an error message that will prompt you to enter the information within the allotted number of characters. This information can be changed during post processing.

Figure 2-4. System Tab following communication connection

Figure 2-5. Site Information Form

2.5.2 Entering System Settings

System settings are specific to the measurement site. The information is entered by clicking Change System Settings. This is where DEQ will enter setup information for the site such as the transducer offset, track reference, depth reference, coordinate system, etc. **Figure 2-6** presents the System Settings menu. This information can be changed before the measurement, or during post processing (i.e., the raw data is stored from each measurement). The data changed in post-processing will be indicated with green text. Below is an explanation of each field in the System Settings menu.

Figure 2-6. System Settings Menu

Transducer depth (m) – The line on the side of the Hydroboard can be used to calculate the transducer depth. The transducer depth is defined as the distance from the vertical beam to the water surface. The distance for the DEQ M9 unit with the GPS unit attached has been premeasured to be 0.275 inches. This value should be verified in the field before use.
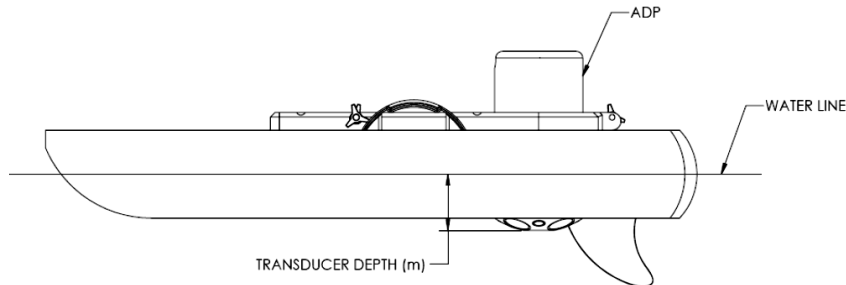
Figure 2-7. Explanation of transducer depth measurement on ADP

Screening Distance – This is the distance below the face of the ADP that you want to start collecting data rather than relying on the default setting of the instrument. In all instances, the screening distance should be set to zero, unless over-the-boat applications are shown to cause flow disturbance from the boat wake. In the latter case, it should be set to a different value determined by the lead field investigator.

Salinity – This user-defined parameter allows for correction of the speed of sound in water based on the salinity in parts per thousand (ppt). For most Montana waters, the value will be 0 ppt (freshwater). Water temperature is also a factor for speed of sound in water calculations. The ADP has a built-in temperature sensor that automatically compensates for this effect.

Magnetic Declination – On the earth's surface, a calibrated compass points toward magnetic North rather than true (geographic) North. The angular difference between these two directions is called magnetic declination. The magnetic declination varies across the earth's surface and over time and will be calibrated at each site to remove any local magnetic interference. The magnetic declination angle (θ) can be found on maps, like the one presented in **Figure 2-8**, however DEQ will use a different procedure.
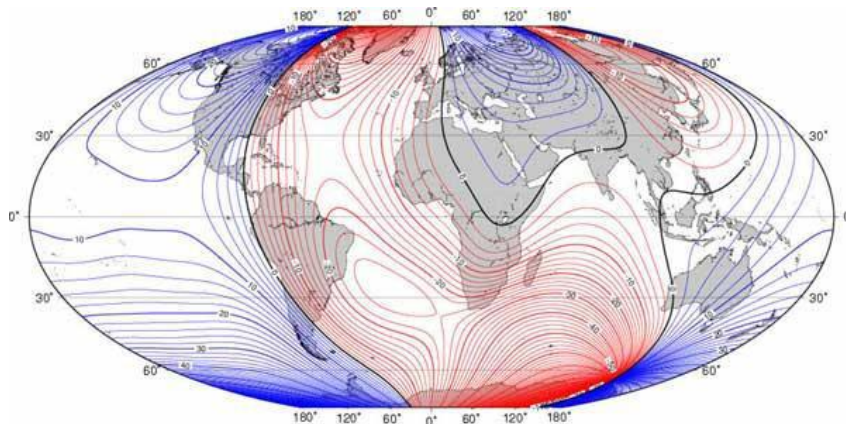
Figure 2-8. Magnetic declination of the world map (from the Sontek User's manual).

Site-specific magnetic declination will be determined using the resources at the National Geophysical Data Center (web address is http://www.ngdc.noaa.gov/geomag-web/#declination). Using position (latitude and longitude) and date, magnetic declination (in degrees, minutes, and seconds) can be computed for a given site. This is most easily done in the field using a smart-phone although it can also be done prior to going out in the field should the measurement location be known *a priori*. The appropriate value will then entered in the software to make the appropriate corrections.

Track Reference – When the ADP is in motion, the water velocity measured by the ADP is a combination of boat velocity and water velocity. In order to determine true water velocity the boat speed must be known and then subtracted from the actual water velocity measurement. Several methods are available to make these corrections:

1. **Bottom-Track:** The ADP itself is capable of determining boat speed using a technique called "Bottom-Track". In this case, bottom-track velocity is calculated using the Doppler shift received from multiple acoustic pulses transmitted from the ADP that have reflected off of the riverbed. Since DEQ unit is GPS enabled, this method is not recommended.
2. **GGA (Global Positioning System Fix Data) GPS-referenced velocity:** refers to a specific National Marine Electronics Association (NMEA)-0183 protocol for outputting GPS position data. In this case, the GGA "string" contains actual position (latitude/longitude) information along with several other GPS quality parameters. Boat velocity is calculated by measuring the distance between two successive GGA positions divided by the travel time between those two positions. Differential corrections are required for the GGA data to reduce the amount of position error associated with each measurement.
3. **VTG (Vector Track and speed over Ground) GPS-referenced velocity:** refers to a specific NMEA-0183 protocol for outputting GPS velocity data. In this case, the VTG string contains the actual boat speed information along with several other GPS parameters. The GPS velocity is calculated based on the Doppler shift of the received satellite signals and does not require differential correction.

It will be acceptable for DEQ will to use either GPS option. We have found very little difference during field evaluations of the instrument. However, all available track references will be evaluated during post-processing to determine the validity of the measurement.

Depth Reference – Depth can be calculated in one of two ways, the single depth transducer (vertical beam) or through use of multiple transducers (e.g., bottom track). DEQ will use the bottom-track average for computation of discharge as data from the four angled beams is less influenced by anomalies on the riverbed unless single bean depth is justified in a given project plan or SAP.

Coordinate System - This drop down menu has three options. For DEQ use, the traditional East, North, and Up (ENU) coordinate system will be used.

2.5.3 System Test
After establishing communication with the ADP, a handful of system tests will be completed to verify hardware is functioning properly. The system test takes approximately 60 seconds in which the battery voltage, compass, SD memory card and temperature sensor are all evaluated to ensure they are functioning properly. A system pass would indicate that all systems are sound for use, while a fail would require further user action. Possible fail messages include: (1) that the system battery voltage is less

than 12 volts (meaning insufficient battery is available to make a measurement), (2) that the system compass is not working, (3) that the system SD card (memory) is not working, or (4) that the temperature sensor is not working. If one of these errors is encountered, DEQ will reinitiate a second system test. If the problem is not reconciled, the discharge measurement will be aborted and the manufacturer of the instrument will be contacted.

2.5.4 Compass Calibration

Compass calibration is necessary to compensate for magnetic fields specific to the site so that water direction (in relation to boat motion/position) can be determined. Hence this information is used to compensate for local magnetic interference in the vicinity of the ADP. For example, a battery or steel clamp right next to the unit, or a steel bridge 200 m away, will all have varying effects on the local magnetic field.

To perform a compass calibration, the ADP will be rotated through two complete revolutions (720°) while varying pitch and roll angles as much as is expected in the measurement. The required duration of the compass calibration will be 1- 2 minutes. Also, the calibration will be constrained within the range of pitch and roll that the ADP will be used as this results in a better calibration (Mueller, 2012). The instrument will only be operated provided the calibration passes. If it fails, the calibration will be repeated. The following will be adhered to during the calibration process:

1. The compass will be calibrated in as magnetically clean environment as is possible. Before calibrating the compass, all small ferrous objects (i.e. hand tools, cell phones, keys, etc.) will be removed at least several feet from of the instrument. DEQ will avoid calibrating on or near a bridge or near steel posts or guard rails when possible.
2. Calibrations will occur for at least 1 minute (maximum of 2 minutes). It is important to note that RiverSurveyor Live 3.5 will not permit calibrations less than 1 minute nor greater than 2 minutes.
3. If the ADP is mounted on a boat, the entire boat needs to be rotated for the calibration, along with everything that is physically attached to the system, while varying the pitch and roll angles as much as possible (within the limitations of the vessel). Changes to ferrous components on the boat (such as toolboxes, engines or mounts) will not be made after the calibration is done. On a manned boat prior to the calibration move batteries, all ferrous/metalic objects (tools), and other sources of magnetic interference as far from the ADP as is practical.
4. Two 360-degree rotations of the instrument will be completed during the calibration while smoothly pitching and rolling the instrument and deployment platform about +/- 10-15 degrees. The goal is to achieve a uniform distribution of the pitch and roll angles for the complete rotation. RiverSurveyor Live 3.5 provides graphical aids that should help the user ensure a uniform distribution of data (an example is shown in Figure 2-9).
5. Once the calibration is complete, any data collected will be carefully monitored for errors in compass heading. These errors often appear as a difference in the ship track direction based on orientation of the instrument.
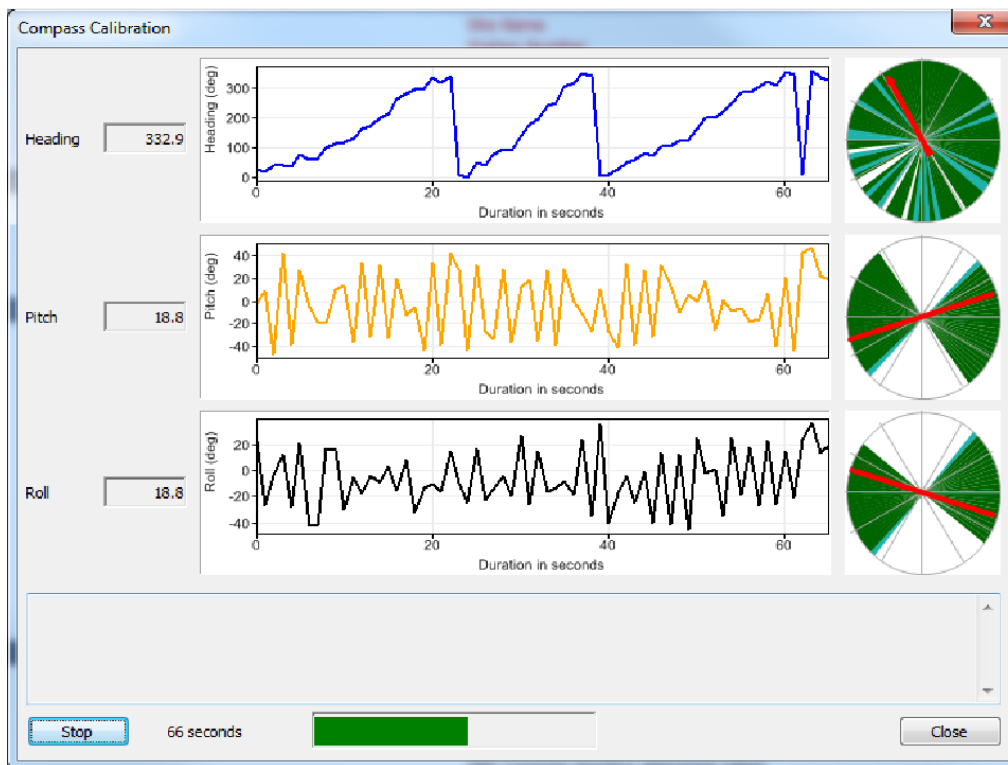
Figure 2-9. Example of compass calibration feedback.

Note: If the discharge or velocity data being collected will require use of GGA or VTG as the reference (i.e., GPS methods), the accuracy of the compass is critical (i.e., the compass is used to relate the water velocity coordinate system to the GPS boat coordinate system).

2.5.5 Check Storage Capacity of Recorder

Before a measurement is initiated, DEQ will ensure that there is adequate memory available on the recorder prior to making a discharge measurement. The Recorder Menu is provided on the Systems Tab and provides a way of managing files stored on the 8 GB memory card. DEQ will download files and format the recorder between measurement sites.

2.5.6 Moving Bed Test

The Sontek RiverSurveyor can measure velocity using either the method of bottom tracking (which computes the Doppler shift of acoustic pulses relative to the streambed) or using the VTG/GGA GPS system as described previously. For all DEQ measurements, we will use the GPS method which eliminates the need to assess moving bed conditions. As such, these tests are not described in this SOP short of noting that such effects can influence the computed discharge.

2.6 MEASUREMENT PROCEDURE

2.6.1 Steps for Completing an ADP Discharge Measurement

After completing the pre-measurement tests and initial site specific entries to configure the system, the actual measurement will be done as described in the user's manual (Sontek, 2012). **Figure 2-10**

illustrates key concepts of a discharge measurement including starting and ending edges, and the transect itself. General procedures toward to completing these parts of the measurement follow.

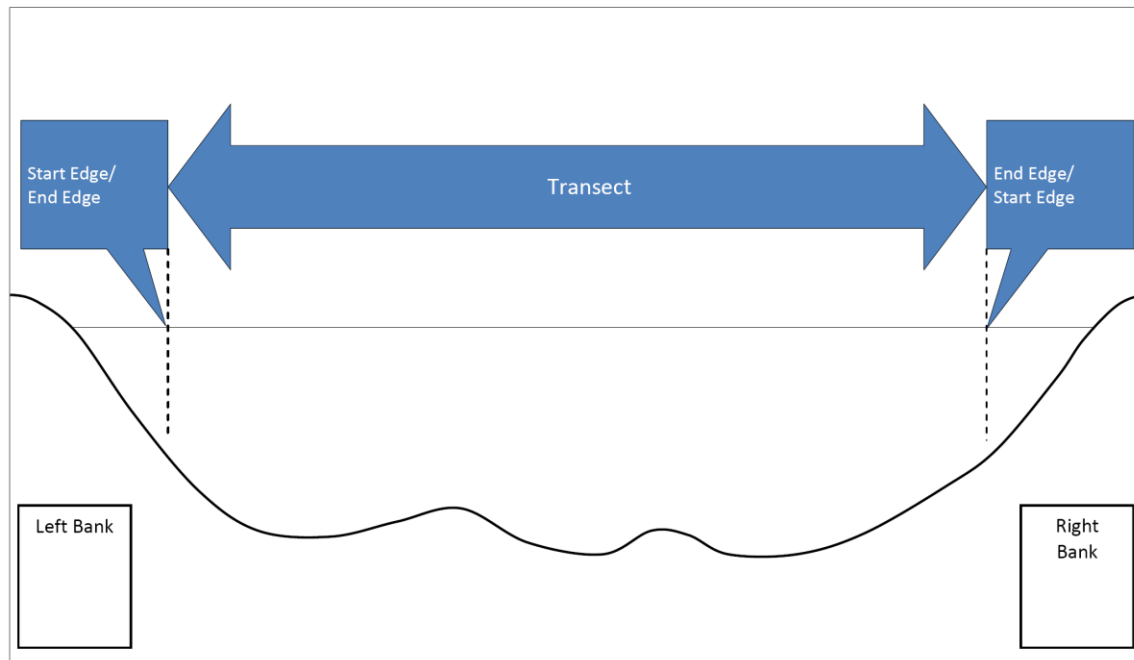**Figure 2-10. Steps for making a discharge measurement using a RiverSurveyor™ M9.**

1. **Start Edge –** Position the vessel at the beginning edge of the transect and collect at least 10 edge samples keeping the vessel as stationary as possible (so this can be applied to unmeasured edge areas). Enter the edge distance and shape information. Distances from the edge of water to the starting and stopping point of each transect must be measured using a distance-measurement device (such as a laser or optical rangefinder), tagline, or some other accurate measurement device.

2. **Transect –** Begin the transect and try to keep the vessel speed and direction constant progressing toward the other river edge. Average boat speed for each transect normally should be less than or equal to the average water speed. In certain conditions, it may not be possible to keep the boat speed less than the water speed. Placing marker buoys at the start and end points of transects is recommended where possible.

3. **End Edge –** After moving across the channel and arriving at an opposite edge location, again collect at least 10 samples/profiles with the vessel as stationary as possible and enter the end edge distance and shape. Accurate edge discharge estimates require the ADP operator to select the correct edge-shape coefficient for the type of edge (sloping or vertical).

After entering the end edge information, the measurement is complete. Another pass with the instrument can then be started from the same location until the appropriate contact time is obtained (see **Section 2.6.2**), or alternatively, if the transect is finished, the system can be shut down.

During the measurement, DEQ will continuously monitor the data in the Transect Window (**Figure 2-11**). If a critical data-quality problem is observed, the measurement will be terminated and the issue remedied. Potential problems include configuration errors such as an insufficient number of depth cells to profile to the channel bed, appreciable area with invalid or missing data, unusual boat or water velocities, or excessive boat speed. When using DGPS, it is especially important to keep the boat speed as low as practical because errors in the compass readings are additive and increase with boat speed. Rapid boat course changes should be avoided and smooth operation will give more consistent results (Simpson, 2001). If the problem was related to undesirable measurement section, a new measurement section will be located and the discharge from the transect not be used in the computation of measurement discharge.
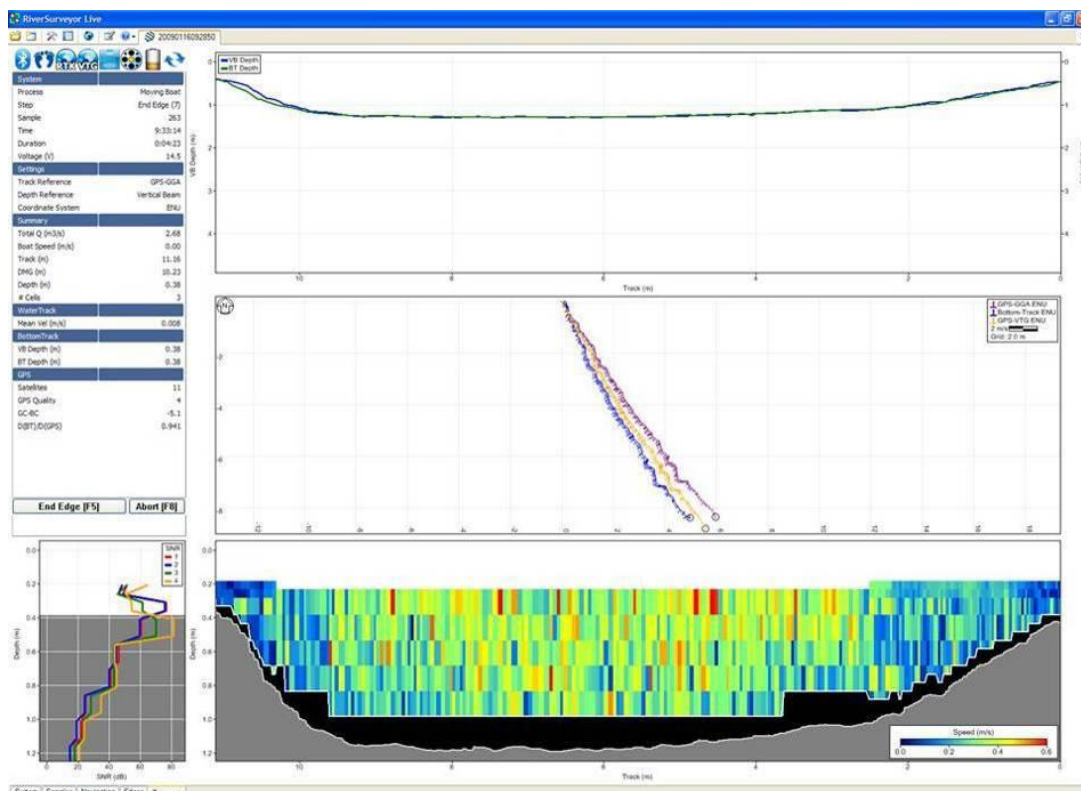
Figure 2-11. Transect window for evaluating measurement progress.

It is important to note that during data collection, not the entire transect is measured. At depths lower than the minimum operating depth, the water velocity and discharge must be estimated. Likewise there is a blanking distance which is the mounting depth plus a short unmeasured distance from the profiler which leaves a section of the water at the surface unmeasured. Finally, there may be potential data contamination in the last cell (i.e., the cell is partially or fully "touching" the riverbed) or side-lobe interference at the end of the profile leaving a section of water at the bottom unmeasured. As such, estimates are made at the top and bottom of the profile (**Figure 2-12**) and then discharge is calculated by summing the Start Edge, Top Estimate, Measured Area, Bottom Estimate and End Edge. Unmeasured areas are calculated using the power law velocity profile (Sontek, 2012).

Figure 2-12. Areas not measured by the ADP (cross-sectional view).

When measuring in channels with vertical walls at the edges, start and stop points for transects will be no closer to the wall than the depth of water at the wall to prevent acoustic interference from the main beam or side lobes impinging on the wall. For example, if the depth at a vertical wall is 10 ft, transects should start/stop at least 10 ft away from the wall.

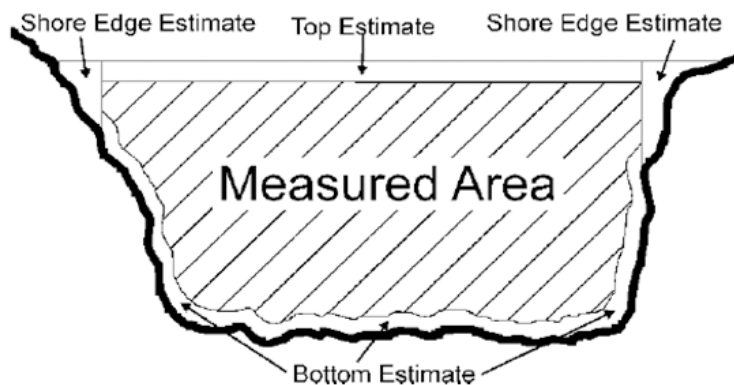## 2.6.2 Contact Time Required/Number of Transects

A minimum of two and a maximum of 4 transects will be made in reciprocal pairs , 2 passes in opposite directions, per site by DEQ such that an appropriate contact time with the water is achieved (5-10 minutes). Individual transect discharges will then be averaged to obtain the measured discharge. If the discharge for any of the four transects differs by more than 5-percent from the measured discharge, additional transects (in reciprocal) will be added until all are within the 5-percent threshold, or alternatively, until 4 total transect measurements are made (whereby all 4 are averaged). Reciprocal transects are required to reduce directional biases. Directional biases may occur when the discharges measured for transects from the left bank to the right bank are consistently either greater than or less than discharges measured for transects made from the right bank to the left bank.

2.6.3 Manned Boat Measurements

Before a manned boat discharge measurement begins, all DEQ boat-safety requirements should be met including required life jackets, throwable devices, fire extinguishers, horns, etc. as outlined in the DEQ Small Boat Operations and Safety Manual. According to Simon (2002), boat-maneuvering techniques for discharge measurements using ADP do not require the precision once needed for conventional moving-boat discharge measurements. For a typical measurement, the operator must maneuver the boat close to, and parallel with, the Riverbank, as close as possible to the bank without bottoming out the ADP transducer assembly or the boat motor. For jet drives, trimming the jet up allows operating in shallower water and near the bank. Boat measurements in rivers are not recommended with propeller propulsion systems but could be implemented with a kayak or other shallow water vessel.

The operator should start the transect and set the edge while the boat is stationary. At this point, the software operator begins the discharge measurement and the boat operator must maneuver the boat across the transect "crabbing" sideways until the finish of each cross section. Picking two points on each side of the river at shoreline (for which to draw a transect perpendicular to flow) greatly helps in better boat operation. Maintaining a uniform boat speed is more important than steering a straight course however. Rapid course and boat heading changes can introduce errors into the measurement. The key element is to move the vessel slowly, including course changes, control the speed of the vessel itself,

and even the speed of persons moving around onboard the measurement vessel. Sharp accelerations of the measurement vessel in any direction should be minimized or eliminated, all the while keeping the boat itself oriented parallel to the river channel/shoreline.

As the vessel approaches the opposite edge of the measuring section, the boat should be slowed by slowly changing the heading to a more upstream direction and slowing the boat motor. The boat then can edge toward the bank. When the operator decides that the approach cannot be continued further, an edge value is determined and the transect is ended by the PC operator.

2.6.4 Tethered Boat Measurements

Hydroboard control and speed is often more difficult from a bridge than in a manned boat. Certain considerations therefore need to be made when making tethered ADP measurements (e.g., using the Hydroboard). In the case of the DEQ program, tethered boats will be used primarily from the downstream side of bridges for convenience. Bridge piers can cause excessive turbulence during high streamflow, especially if debris accumulations are present on the piers and the piers are skewed to the flow. The effect of bridge pier-induced turbulence may be reduced by lengthening the tether to increase the distance between the bridge and the tethered boat. An alternative is to have a person on each bank with a rope attached to the platform, pulling it back and forth across the river. Bank-operated cableways may be as simple as a temporary "rope and pulley" apparatus.

When the water velocity is slow (usually less than 0.5 ft/s), it may become difficult to control the tethered boat. This lack of control may be exacerbated by wind, which may push the boat in an undesirable direction. In these instances, boat handling can be improved by attaching a floating sea anchor to the back side of the boat, to increase the effect of the current and its pull on the tether. One has been modified by DEQ for use in rivers and has been included as part of the equipment. The anchor will be set far enough behind the boat so as to not disturb the flow and potentially bias the velocity measurements. When the water velocity is fast (usually greater than 5 ft/s), it is not uncommon for a tethered boat to be pitched upward at the bow. This increased pitch is caused by increased vertical tension on the tether in faster flows. Large pitch angles may introduce some bias in depth measurements and will be minimized by DEQ by increasing the length of the tether to help reduce the pitch angle.

The tether line should be visible from the water surface to minimize the risk of collision with river traffic. Orange plastic flags tied along the tether will enhance its visibility. The operator should also be capable of releasing the tether quickly in case the boat becomes entangled in debris or collides with river traffic. Never wind the tether around your hand to hold the boat as this action is a safety hazard. In addition, standard safety practices, site-specific traffic safety plans, and the local highway traffic regulations should be followed. Finally, for tethered boats, it is possible to lose control of the boat because of a system component failure. For example, a boat tether or tether attachment point could break. It is recommended that a contingency plan for retrieving the boat in the event of a failure that causes a loss of boat control. An example of a contingency plan would be to carry a small manned boat that could be quickly and safely launched to retrieve the tethered or remote-controlled boat.
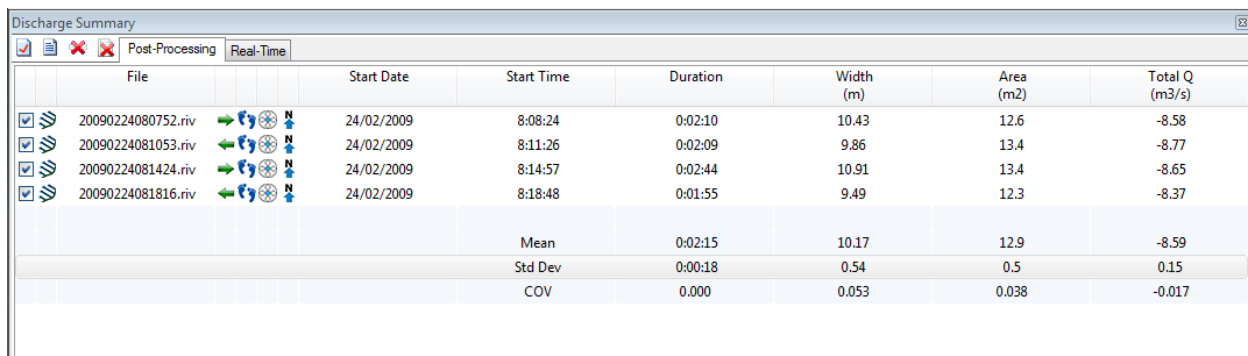
2.7 FIELD SHEETS

All information on the ADP measurement note sheets will be filled out either prior to, during, or immediately after the measurement. The operator should note any conditions that potentially could

affect the measurement, including wind speed and direction, bi-directional or unusual flow patterns, excessive waves, or passing boats. An example of a completed ADP discharge site visit form is shown in Appendix A1.

2.8 FIELD-EVALUATION OF DISCHARGE MEASUREMENT

Following the measurement, an assessment of the discharge results will be made. While a thorough review of all measurement data often is not practical in the field, a cursory review can be made to ensure no critical data-quality problems occurred. DEQ will diagnose problems by: (1) reviewing transect widths and discharges in the measured (middle) and unmeasured (top, bottom, and edge) sections noting that these should be consistent if made at the same location), (2) review of other indicators such as the track reference, and (3) review of the computed discharges for each transect. If transect widths or discharges are not consistent with the other transects, the transect data will be scrutinized in the Discharge Summary window (**Figure 2-13**) to determine if a critical data-quality problem occurred.

	File	Start Date	Start Time	Duration	Width (m)	Area (m2)	Total Q (m3/s)
☑	20090224080752.riv	24/02/2009	8:08:24	0:02:10	10.43	12.6	-8.58
☑	20090224081053.riv	24/02/2009	8:11:26	0:02:09	9.86	13.4	-8.77
☑	20090224081424.riv	24/02/2009	8:14:57	0:02:44	10.91	13.4	-8.65
☑	20090224081816.riv	24/02/2009	8:18:48	0:01:55	9.49	12.3	-8.37
			Mean	0:02:15	10.17	12.9	-8.59
			Std Dev	0:00:18	0.54	0.5	0.15
			COV	0.000	0.053	0.038	-0.017

Figure 2-13. Discharge Measurement Summary window

If a critical data-quality problem is identified, the data from that transect will not be used in the computation of discharge. Likewise, to meet the contact time requirements (e.g., 12 minutes approximately), a new transect will then be initiated starting from the same side as the discarded transect, if flow conditions have remained steady. If the flow has changed, a new set of transects will have to be collected (a minimum of four transects if the flow is stable when the new transects are collected). It is emphasized that a transect should be discarded only if a critical data-quality problem is identified and documented on the field note sheet.

2.9 FILE UPLOAD TO PC

Immediately after completion of a measurement, all files including raw data files, configuration files, instrument test files, compass calibration files, and any electronic measurement forms will be uploaded to the PC (such that a copy of the record exists on both the PC and the ADP). Files should not be removed from the ADP until a suitable backup copy is made on network servers as described in **Section 4.0**.The purpose of this redundant backup is to preserve the data in the event of loss or failure of the field computer of ADP. Once the files are open, they are available for post-processing as described in **Section 3.0**.

3.0 MEASUREMENT POST-PROCESSING

ADP data collected in the field will be reviewed and post-processed as soon as practical in the office by the person that made the measurements. Steps necessary to complete the post-processing including (1) transfer of files to the network server, (2) quality control (QC) of the measurement data, (3) measurement post-processing, and (4) the final discharge computation. These are briefly outlined in the following sections.

3.1 TRANSFER OF ELECTRONIC FILES TO NETWORK DRIVES

Per Section 2.0, electronic files will be stored on both the ADP and field computer; however, all measurement files should be moved from the field computer to a permanent storage location for archival and backup within 2 working days of returning to the office. Once uploaded, file system must be defined such that the location of the measurement is known, data is coincident with the field forms, and electronic files are properly organized on the shared network drive. Most often, DEQ has separate project folder files on the shared network drive (i.e., G drive), and files will be transferred to that location based on the project requirements. All of the files in a discharge-measurement series should be identified uniquely.

3.2 OPENING FILES

Discharge measurement files can only be opened in RiverSurveyor Live for PC (.riv extension). Once a file or series of files are opened, the application layout is shown (**Figure 3-2**), which has a number of toolbars and windows that will be used by DEQ to post-process the measurement.
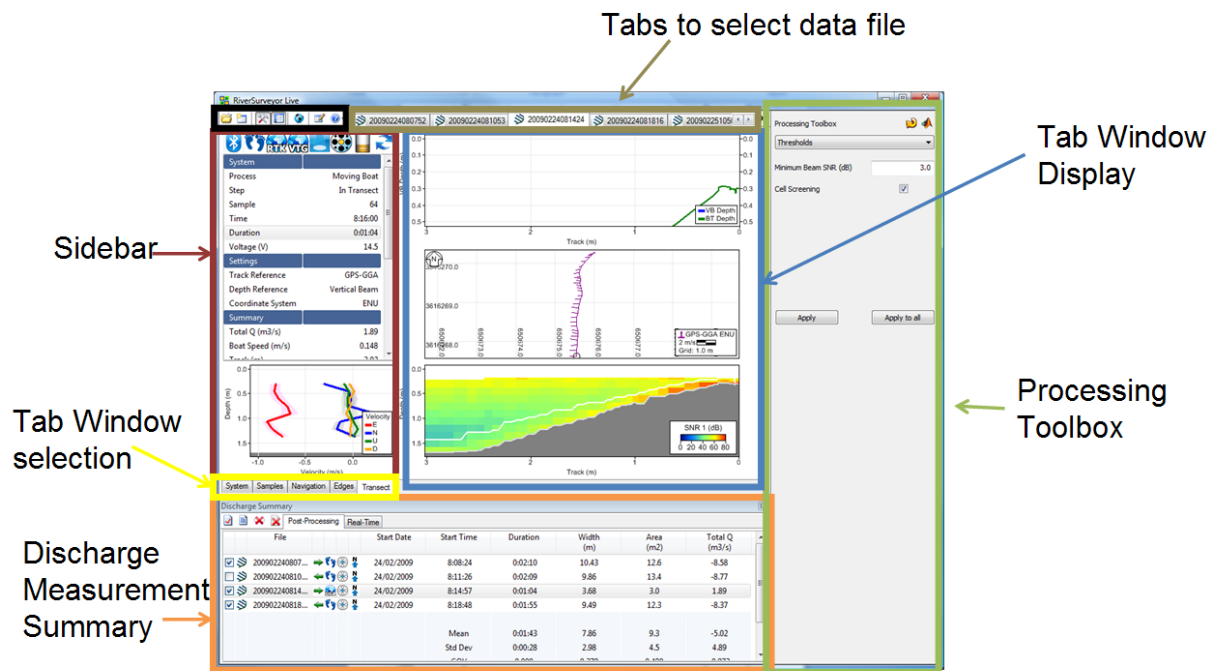

Figure 3-2. Application layout window RiverSurveyor Live for PC.

3.3 POST-PROCESSING

Data post-processing will be done by DEQ using the Processing Toolbox. To initiate post-processing, recorded data file(s) must be opened in the RiverSurveyor Live for PC software and the following post-processing steps will be completed:

1. Ensure transducer depth, screening distance, salinity, magnetic declination, and track or depth reference (**Figure 3-3a**) are all correct in the System Settings Tab. A primary error here is that the analyst forgot to enter the transducer depth or magnetic declination.

2. Check the Edge Estimates to ensure that are correct and appropriately entered. Check to make sure left/right bank settings appropriately describe the field-observed channel conditions.

3. Verify the Exptrapolation Procedure by checking the top/bottom estimates (**Figure 3-3b**). A more refined procedure for extrapolation is also described in the next section using the Extrap Matlab tool developed by U.S. Geological Survey.

4. Evaluate quality information such as duration of the measurement and GPS quality. Be sure the number of GPS satellites is good (>6) and the GPS quality is valid. An angle of average GPS course from start of transect minus ADP bottom-track course value (GC-BC) near 0 is desired (although less than 2 degrees is acceptable). The D(BT)/D(GPS) (Ratio of Bottom Track distance to GPS track distance) is approximately 1. Both these values can be found on the sidebar. If necessary, change the Track and Depth reference to best represent the best field measurement.

5. Visually review each measurement to ensure the depth measured by the Vertical Beam and Bottom Track are reasonably consistent. Similarly, Boat Speed /Water Speed can be plotted on the same graph. Ideally, the Boat/Water Speed should be <1. Finally, evaluate BottomTrack vs. GPS (if applicable) to observe any compass, GPS or moving bed issues.

6. Check the discharge measurement summary to ensure consistencies among all of the measurements. This includes making sure that channel width and discharge areas, and calculated discharges are similar, and that the duration of measurements are similar. In addition, use the Statistics to identify any outliers and uncheck or delete problematic records.
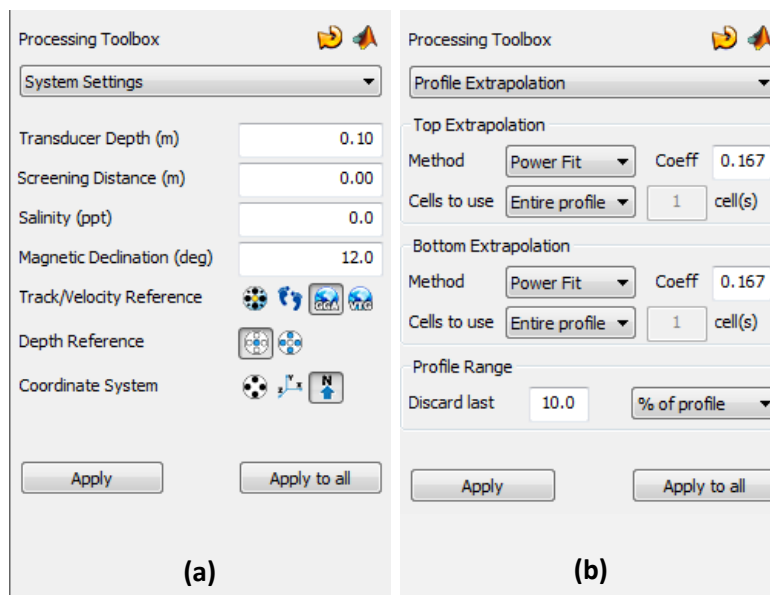

(a) (b)

Figure 3-3. Post-processing toolbars for (a) System Settings and (b) Profile Extrapolation

3.3.1 Profile Extrapolation

The extrapolation method for the top and bottom discharges will be reviewed as part of the measurement post-processing. If the data shows the need for a different extrapolation method than that chosen for use in the field, the extrapolation method should be corrected. The compiled Matlab software Extrap (**Figure 3-1**) from the U.S. Geological Survey will aid in the selection of the appropriate top and bottom discharge extrapolation methods and coefficients. It can be downloaded at: http://hydroacoustics.usgs.gov/movingboat/extrap1.shtml.

Extrap provides an automated approach to selecting common top (power or constant) and bottom (power and no slip) extrapolation methods based on an assumed logarithmic velocity profile. These values must then be manually entered into the post-processing software by DEQ. A text file documenting the selected fit along with the discharge sensitivity analysis and any comments the user can also be generated. This will be printed and saved electronically in the DEQ files.
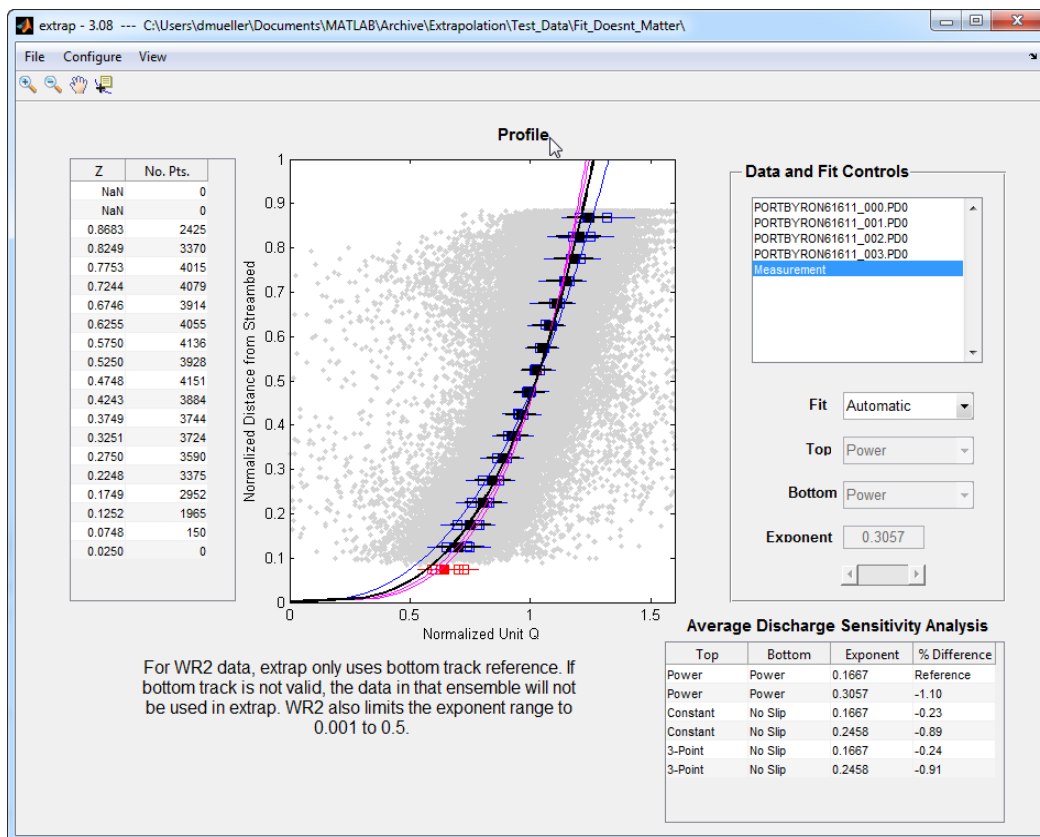

Figure 3-1. Example of USGS Extrap software for calculating appropriate extrapolation method.

3.4 QUALITY-CONTROL (QC) OF THE MEASUREMENT

Important aspects of ADP discharge-measurement review (i.e., QC) are listed below. DEQ will complete each of these checks as part of a final quality control of a measurement. It is recommended that these be completed by a party rather than who made the original measurement.

- Discharge-measurement note sheets will be checked for completeness, clarity, and legibility.

- The number of transects collected will be evaluated to ensure it is appropriate for the flow conditions and that they are collected in reciprocal pairs.
- Configuration files will be checked for errors and for consistency with field notes. ADP depth, edge distances, edge shapes, extrapolation methods, and configuration parameters shown on the field notes should match those in the configuration file.
- The average boat speed for the measurement will be checked to ensure that it has not exceeded the average water speed over a large part of the measurement (unless it was impractical or unsafe to do so). Excessive boat pitch-and-roll will also be evaluated.
- The measured edge distances and shapes recorded on the ADP measurement note sheet will be evaluated to ensure they match those electronically logged. Samples at transect stop/start points should exceed 10, and if a vertical wall(s) were present, then the start and/or end points for the transect should be located such that the distance from the wall(s) is equivalent to the water depth at the wall or greater.
- Results will be checked to ensure there is not excessive loss of ensembles/profiles. The loss of more than 10 percent of ensembles/profiles is acceptable, however, when more than 25 percent of the depth cells in one or more transects are marked invalid or missing, the quality of the measurement is in question.

Following this quality review, the measurement will receive a second level of QC to ensure its validity. It may be necessary for the person who collected the data or the reviewer to change some configuration parameters. If the measurement reviewer makes changes, these changes should be discussed with the person who made the measurement. Any changes to the configuration parameters and the reasons for the changes must be documented on (or attached to) the ADP measurement note sheets.

4.0 DATA ARCHIVING

An important part of a good quality-assurance program is the archival of data. DEQ will retain all information in both hardcopy and electronic archive according to the policy in our records management system. A nice attribute of the RiverSurveyor™ measurement system is that the raw data from the sensor is left in an unaltered state and always can be re-processed. As such, a record of the original information is always present regardless of the post-processing done previously. In addition to archiving all of the electronic measurement data, discharge-measurement summary data (hard copy) will also be retained in DEQ files.

4.1 REPORTS AND REPORTING

Reporting includes the use of both field forms and office procedures pertinent to the ADP measurement protocol. This includes logs of annual ADP instrument checks (at a site having a known discharge from USGS), firmware/hardware upgrade descriptions and dates, system tests and compass calibrations (stored as electronic files), and the actual discharge measurement itself. An example site visit form (paper copy) is included in the Appendix B. All electronic data files associated with the measurement will be backed up in the field and archived on an office server.

4.2 DATA MAINTENANCE/MT E-WQX REPORTING REQUIREMENTS

ADP data is managed through the data life cycle from project planning to long-term storage and archiving by Water Quality Planning Bureau (WQPB) data management staff. The results of the measurements (final reported value only) will be entered on the Site Visit Form and uploaded to the EQUIS database as part of standard internal data flow process.

4.3 CHECKLISTS

Checklists for pre-measurement preparation, discharge measurement procedures, post-measurement procedures, and office procedures are shown in Appendix C.

5.0 SYSTEM MAINTENANCE

Under normal conditions, the ADP requires little maintenance. This section discusses some routine maintenance procedures that should be followed to ensure long-term quality operation.

5.1 STORAGE

The ADP should be dried after use and stored in its protective case for transport. Failure to dry the ADP may result in corrosion of the ADP connectors, mounting brackets, and any ADP accessories stored in the protective case. Ensure the protective case is snapped shut such that it does not come open during transport. If it possible to do safely, the ADP unit may be transported in the Hydroboard if going short distances (e.g., to a new site for example not far away), or when launching a manned boat or travelling distances up- or down-river for powerboat measurements.

5.2 MAINTENANCE

5.2.1 Cleaning the transducers

Periodic cleaning of the ADP transducer face may be needed to maintain optimal performance in areas of high biological activity or mineral build-up. To remove material build-up on the transducer faces, simply clean with a stiff (non-metallic) brush or apply soapy water and clean with a sponge. The transducers themselves are protected in a hard epoxy-resin and are very durable. Minor scratches on the transducer face are normal over a period of time and will not harm them or affect their performance. Direct impacts to the face should be avoided as this might crack the face of the transducer and allow moisture into the electronics housing as well as causing damage to the transducer itself.

5.2.2 Cables and connectors

Cables and connectors used with the ADP are often the most vulnerable portion of the system. All SonTek cables use a durable polyurethane jacket that provides excellent long-term wear and abrasion resistance. Rugged underwater flexible connectors are also used along with high-grade metal connectors to prevent connection failures. However, any cable or connector used in the field is susceptible to damage and reasonable precautions should be taken as a consequence. DEQ will inspect all ADP cables and connectors for damage on a regular basis and replace if necessary.

For connectors, a light coat of silicone grease or spray is useful in facilitating the connections. However, make sure the silicone does not contain cleaners or solvents that could damage the rubber part of the connector. Inspect both male and female connector pins to make sure they are clear of debris and excess grease, which could interfere with the connection or make it difficult to fully mate the connectors.

5.2.3 O-rings

O-rings should be inspected on the battery compartment of the PCM and Base Station to ensure they are completely clean and free of debris. Be sure that the O-ring is seated correctly, and that it is not twisted or broken. It is important to maintain a water-tight seal for the integrity of the instrument.

5.2.4 Batteries

To charge the batteries, use the SonTek charger only. Follow these steps (SonTek, 2012):
1. Plug the charger into the wall and wait for the LED to turn orange.
2. Insert the battery pack into the charging cradle. Be sure the metal contacts on the battery pack are aligned with the metal springs in the charging cradle. The LED will be red while it is charging. Charging is complete when the LED turns green. A full charge will take about 1-2 hours.
3. Remove the battery from the cradle.
4. Wait for the LED to turn orange to charge another battery.
5. Repeat steps 2 through 3 to charge another battery

A description of all of the possible light patterns can be found on the bottom of the charger. It is important to use only completely charged SonTek battery packs. A completely charged battery pack should have about 16-18 volts if you check it with a voltmeter. Be sure the battery pack is completely dry before placing it in the charging cradle. Also be sure the battery compartment in the PCM is completely dry before inserting the charged battery pack. Do not try to modify the battery packs shipped with the product. Third party battery packs are not supported by SonTeK. Any damage incurred from using a third party battery pack will void the warranty.

5.3 FACTORY CALIBRATION

Each SonTek M9 system is individually calibrated during the manufacturing process. Since there are no moving parts and the beams are built into the ADP head, recalibration is not necessary unless the unit is physically damaged. It is suggested however, (but not required) that an annual instrument check be completed as described by Lipscomb (1995). This can be done where the ADP-measured discharge is compared with a known discharge derived from some other source, such as the rating discharge from a site with a stable stage discharge rating. The discharge obtained from the ADP should be within 5 percent of the known discharge. In addition, since the DEQ ADP is equipped with more than one water- or bottom-tracking mode, it is desirable, though not required, to periodically conduct these test using different modes. The instrument check should be fully documented and archived in a log.

6.0 REFERENCES

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APPENDIX A. ADP DISCHARGE FORM

Discharge Measurement Summary

Date Measured: Tuesday, September 11, 2012

Site Information

Site Name	Yellowstone River
Station Number	70
Location	Otter Creek FAS

Measurement Information

Party	Flynn, Makus
Boat/Motor	Roughneck Jet
Meas. Number	1

System Information

System Type	RS-M9
Serial Number	2006
Firmware Version	1.02
Software Version	3.50

System Setup

Transducer Depth (ft)	0.28
Salinity (ppt)	0.0
Magnetic Declination (deg)	12.0

Units

Distance	ft
Velocity	ft/s
Area	ft2
Discharge	cfs
Temperature	degF

Discharge Calculation Settings

Track Reference	GPS-VTG	Left Method	Sloped Bank
Depth Reference	Bottom-Track	Right Method	Sloped Bank*
Coordinate System	ENU	Top Fit Type	Power Fit
		Bottom Fit Type	Power Fit

Discharge Results

Width (ft)	209.08
Area (ft2)	503.5
Mean Speed (ft/s)	3.777
Total Q (cfs)	1,901.865

Measurement Results

Tr #		Time			Distance				Mean Vel			Discharge						%
		Time	Duration	Temp.	Track	DMG	Width	Area	Boat	Water	Left	Right	Top	Middle	Bottom	Total	MBTotal	Measured
1	L	7:25:02 AM	0:03:12	57.1	191.52	182.19	209.19	504.5	0.997	3.722	13.55	6.73	439.75	1,022.38	395.12	1,877.527	--	54.5
2	R	7:28:28 AM	0:02:49	57.7	191.98	182.98	209.98	502.2	1.136	3.813	9.71	18.28	441.94	1,062.36	382.41	1,914.713	--	55.5
3	L	7:31:43 AM	0:03:40	57.3	195.71	181.13	208.13	510.0	0.890	3.823	9.98	15.58	444.90	1,054.92	424.38	1,949.754	--	54.1
4	R	7:35:35 AM	0:03:07	57.9	190.33	182.04	209.04	497.5	1.018	3.750	8.12	16.49	438.23	1,043.49	359.14	1,865.467	--	55.9
			Mean	57.5	192.39	182.08	209.08	503.5	1.010	3.777	10.34	14.27	441.20	1,045.79	390.26	1,901.865	0.000	55.0
			Std Dev	0.3	2.01	0.66	0.66	4.5	0.087	0.042	1.98	4.46	2.51	15.09	23.55	33.074	0.000	0.7
			COV	0.0	0.010	0.004	0.003	0.009	0.087	0.011	0.192	0.312	0.006	0.014	0.060	0.017	0.000	0.014

Exposure Time: 0:12:48

Tr1=20120911072521.riv-Locked; Tr2=20120911072848.riv-Locked; Tr3=20120911073202.riv-Locked; Tr4=20120911073556.riv-Locked;

Comments

Tr1=20120911072521.riv - time=7:30, exp=default; Tr2=20120911072848.riv - time=7:30, exp=default;
Tr3=20120911073202.riv - time=7:30, exp=default; Tr4=20120911073556.riv - time=7:30, exp=default;

Compass Calibration

File name: CompassCal20120911072214.txt

Results: PASS
Score is excellent.
Magnetic interference is fairly low.

Calibration score: M14.00Q9

System Test

File name: SystemTest20120911072340.txt

System Test: PASS

Parameters and settings marked with a * are not constant for all files.   Report generated using SonTek RiverSurveyor Live v3.50

APPENDIX B. STANDARD SITE VISIT FORM

SITE VISIT FORM   Project ID:_____

(One Station per page)

Date: _____   **Time:** _____   **Personnel:** _____

Waterbody: _____   Location: _____

Station ID: _____   Visit #: _____   HUC: _____   County: _____

Lat/Long Verified? ☐

Latitude: __ __ . __ __ __ __   Longitude: __ __ . __ __ __ __   By: _____

Elevation: _____ ft   m   Geo Method: **GPS** Other:_____   Datum: NAD27 **NAD83** WGS84

Samples Collected:		Sample ID:	Sample Collection Information/Preservation:
Water	☐		GRAB EWI
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Analysis:			Preserved: HNO₃ H₂SO₄ H₃PO₄ HCL Ice Frozen None
Sediment	☐		SED-1
Analysis:			Preserved: None Other:
Benthic Chl-*a*	☐		Sample Method: C=Core H=Hoop T=Template N=None
Composite at Lab ☐ AFDW ☐ Visual <50 mg/m2 ☐			Sample Location: R=Right C=Center L=Left
Transect: A__ -__ B__ -__ C__ -__ D__ -__ E__ -__ F__ -__ G__ -__ H__ -__ I__ -__ J__ -__ K__ -__			
Phytoplankton Chl-*a*	☐		D1 Filtered:_____ mL D2 Filtered:_____ mL
Phytoplankton CNP	☐		D1 Filtered:_____ mL D2 Filtered:_____ mL
Algae	☐		PERI-1-MOD PERI-1 OTHER:
Macroinvertebrates	☐		MAC-R-500 HESS # of Jars:

Field Measurements:		Time: _____ am pm	Field Assessments:	
Water Temp: ____ °C °F		Air Temp: ____ °C °F	Field Forms: Fish Cover Form ☐ Photographs ☐	
Bar. Pressure: ____ mm/Hg		SC: ____ uS/cm	Aquatic Plant Tracking Form ☐ Rosgen Form ☐	
pH: ____	DO: ____ mg/L	Turbidity: ____ NTU	NRCS Form ☐ EMAP Forms ☐ Summary Form ☐	
Turbidity: Clear ☐ Slight ☐ Turbid ☐ Opaque ☐			Channel Cross-Section ☐ Total Discharge ☐	
Flow: ____ cfs (Dry Bed ☐ Stranded Pools ☐)			Data Loggers: Temp ☐ YSI ☐ TruTrack ☐ DOT ☐	
Meter ☐ Doppler ☐ Float ☐ Gage ☐ Visual Est. ☐			AquaRods ☐ Weather Station ☐ Surveyor ☐	

Comments:	Only Transect F ☐ Total Site Length_____m Average Wetted Width_____m Transect Length__m

Chemistry Lab Information:		
Lab Samples Submitted to:	Account #:	Term Contract Number:
Invoice Contact:		
Contact Name & Phone:	EDD ☒ Format: MT-eWQX Compatible	
1) Relinquished By & Date/Time:	1) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	1) Received By & Date/Time:
2) Relinquished By & Date/Time:	2) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	2) Received By & Date/Time:

Lab Use Only - Delivery Temperature: Wet Ice_____ °C   Dry Ice_____ °C

Rev. 12/28/2012

Place Site Visit Label Here

Site Visit Form Instructions

1. Place a Site Visit Code label in the upper left corner (ONLY 1 SITE VISIT CODE PER FORM).

2. Place a Trip Label in the upper right corner. (Covering Project ID and Trip ID with label is alright.)

3. **Project ID**: If you do not have a Trip Label, enter the Project ID assigned by Data Management. If Project ID is not assigned, leave blank for Water Quality Database Manager.

4. **Trip ID:** If you do not have a Trip Label, enter the Trip ID assigned by Data Management. If Trip ID is not assigned, leave blank for Water Quality Database Manager.

5. **Date/Time**: Enter the date and time of the station visit.

6. **Personnel**: Enter the first and last name(s) of the personnel conducting field activities.

7. **Waterbody**: Enter the name of the waterbody such as "Missouri River".

8. **Location**: Description of sample location such as "upstream from bridge on Forest Service road 100". For confidentiality please <u>DO NOT</u> use proper names of people in the location field.

9. **Station ID**: If you have a Trip Label, enter the established ID. If there is no ID on the Trip Label, leave the field blank and Data Management will generate a Station ID when the SVF is submitted.

10. **Visit #**: Enter "1" if this is a new station. Leave blank if visit number is unknown.

11. **HUC**: If you do not have a Trip Label, enter the fourth code (8 digit) HUC the station falls within.

12. **County**: If you do not have a Trip Label, enter the county in which the station falls within.

13. **Lat/Long**: Latitude and Longitudes should be obtained in decimal degrees using a GPS unit reading **NAD83** whenever possible. If a lat/long is obtained by another method, the datum and method must be recorded in the Site Visit Comments.

14. **Lat/Long Verified**: Latitudes and Longitudes should be verified <u>immediately</u> upon return from the field. Verify by plotting on a paper map or using a mapping website. Once the lat/long has been verified check the Verified box and enter initials after "By".

    - Do not make minor adjustments to measured values during verification; they are assumed to be correct within the limitations of the measurement system.

    - Gross errors should be corrected as follows: 1) Draw a single line through the erroneous value(s) and initial. Do not erase the original reading. 2) Write the corrected value in the comment field along with the method and datum used to derive the corrected value.

15. **Elevation:** Record elevation collected by GPS and circle the GPS datum used. If elevation is obtained by another method, the datum and method must be recorded in the Site Visit Comments.

16. **Samples Collected**: Check the box next to each activity that is collected during the station visit.

17. **Sample ID**: Write the Sample ID (Site Visit Code-sample identifier) for all of the samples collected.

18. **Sample Collection Procedure**: Circle the appropriate Sample Collection Procedure ID.

    - For each Chlorophyll-*a* transect, record the sample collection method in the first space provided and the sample location in the second space provided (example: A:_T_-_R_).

    - For Phytoplankton, record the volume filtered for each sample collected.

19. **Analysis Requested**: Record the requested laboratory analysis for each chemistry sample and circle the preservative used.

20. **Field Measurements**: Record your field measurements in the spaces provided.

21. **Field Assessments**: Check the boxes next to each type of field assessment completed.

22. **Site Visit Comments**: Record general comments about the station visit, samples, and field measurements.

23. **Chemistry Lab Information**: If chemistry lab samples were taken, complete this section.

    - Lab Samples Submitted to: Enter name of laboratory where samples will be sent.

    - Account #: Enter account number at laboratory where samples will be sent.

    - Date Submitted: Record date the samples were received by the laboratory.

    - Sign and date the form each time the samples change possession.

APPENDIX C. EQUIPMENT CHECKLIST FOR ADP MEASUREMENT

- Field computer (Dell Toughbook) with RiverSurveyor Live PC installed, chargerm and power invertor
- Pirani BlueTooth Dongle (in ADP pelican case)
- Handheld PDA as backup for field computer (procedures for using the personal digital assistant (PDA) are not described in this SOP)
- ADP System (1 large pelican case) including all cables, connections, PCM, GPS antenna, batteries, and survey tripod
- Base Station (1 large pelican case) all cables, connections, PCM, GPS antenna and batteries
- Hydroboard
- Tether Rope (plus backup) with carabineer clip (plus backup)
- Five gallon bucket (to store tether rope)
- Sea anchor (modified for use in rivers)
- Flagging
- Walkie Talkies
- Safety Cones
- Lifejackets
- Waders
- Field Measurement Forms
- DEQ jetboat (for manned boat measurements)
- Boom assembly (for manned boat measurements)
- Kayak or other small boat for emergency retrieval during bridge measurements