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QRev—Software for Computation and Quality Assurance of Acoustic Doppler Current Profiler Moving-Boat Streamflow Measurements—User's Manual for Version 2.8

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Conversion Factors

[International System of Units to U.S. customary units]

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

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QRev—Software for Computation and Quality Assurance of Acoustic Doppler Current Profiler Moving-Boat Streamflow Measurements—User's Manual for Version 2.8

By David S. Mueller

Abstract

The software program, QRev computes the discharge from moving-boat acoustic Doppler current profiler measurements using data collected with any of the Teledyne RD Instrument or SonTek bottom tracking acoustic Doppler current profilers. The computation of discharge is independent of the manufacturer of the acoustic Doppler current profiler because QRev applies consistent algorithms independent of the data source. In addition, QRev automates filtering and quality checking of the collected data and provides feedback to the user of potential quality issues with the measurement. Various statistics and characteristics of the measurement, in addition to a simple uncertainty assessment are provided to the user to assist them in properly rating the measurement. QRev saves an extensible markup language file that can be imported into databases or electronic field notes software. The user interacts with QRev through a tablet-friendly graphical user interface. This report is the manual for version 2.8 of QRev.

Introduction

The use of acoustic Doppler current profilers (ADCPs) from a moving boat is a commonly used method for measuring streamflow. These measurements have been reviewed and post-processed using manufacturer supplied software and the user's knowledge and experience to interpret the quality of the measurement, correctly configure discharge processing settings, and set appropriate thresholds to screen out erroneous data. This dependency on the software supplied by the manufacturer has created two problems for the U.S. Geological Survey (USGS).

1. The software programs supplied by the different manufacturers have limited automated quality assessment features, and graphics and tables for user review are inconsistent among the manufacturers. Consequently, data quality assessment is not independent of the instrument used to make the measurement but rather is dependent on the capabilities of the manufacture supplied software to review and assess the data quality. The lack of automated quality assessment features leaves the assessment to the knowledge and experience of the user and may result in inconsistent assessments of data quality.
2. Software programs from different manufacturers use different algorithms for various aspects of the data processing and discharge computation. Consequently, if the same dataset could be processed by each manufacturer's software, the resulting discharges could be different.

Development of common and consistent computational algorithms combined with automated filtering and quality assessment of the data will provide significant improvements in quality and efficiency of streamflow measurements. This development will ensure that USGS streamflow measurements made using ADCPs are consistent, accurate, and independent of the manufacturer of the instrument used to make the measurement.

The USGS Office of Surface Water developed a computer program, QRev. The program can be used to compute the discharge from a moving-boat ADCP measurement using data collected with any of the Teledyne RD Instrument (TRDI) or SonTek bottom tracking ADCPs. QRev applies consistent algorithms for the computation of discharge independent of the manufacturer of the ADCP. In addition, QRev automates filtering and quality checking of the collected data and provides feedback to the user of potential quality issues with the measurement. Various statistics and characteristics of the measurement, in addition to a simple uncertainty assessment, are provided to users to assist them in properly rating the measurement. QRev saves an extensible markup language (XML) file that can be imported into databases or electronic field notes software, such as, SVMobile.

Purpose and Scope

This report is the manual for version 2.8 of QRev. The purpose of this report is to describe the user interface, features, and designed workflow of QRev. The report will present all the windows and describe the function and intended use of all the interactive controls of QRev's graphical user interface (GUI). The specific algorithms used are not discussed in this report but are documented in a technical manual (Mueller, in press).

Software Design Objectives

The general design of QRev was guided by the following criteria:

1. Process SonTek and TRDI data.
2. Use consistent algorithms.
3. Use the best available data (interpolate only what is missing or invalid).
4. Provide a logical workflow.
5. Automate data quality assessment and provide useful feedback.
6. Provide manual overrides for all automated filters.
7. Use windows with tables and graphs designed to evaluate specific problems.
8. Provide uncertainty information to the user.
9. Use a GUI and layout that is tablet friendly.

The goal is for QRev to be used for data review and processing of all moving-boat ADCP streamflow measurements. Use of QRev will ensure consistent algorithms are applied for the computation of discharge, independent of the ADCP manufacturer. QRev also provides the same automated data filters, graphs and tables, and user feedback for all data to improve consistency of data quality assessments.

Graphical User Interface

The GUI, shown in figure 1, is designed to be logical and tablet friendly. To load and review data, the user works from top to bottom along the buttons on the left. This approach leads the user through the premeasurement steps first. Navigation reference, depth, and water data are needed to compute discharge. By working top to bottom, the best navigation data are obtained, then the best depth

data, and finally the best water data, which are dependent on the navigation reference and depth. Thus, the final discharge is based on the best available data.

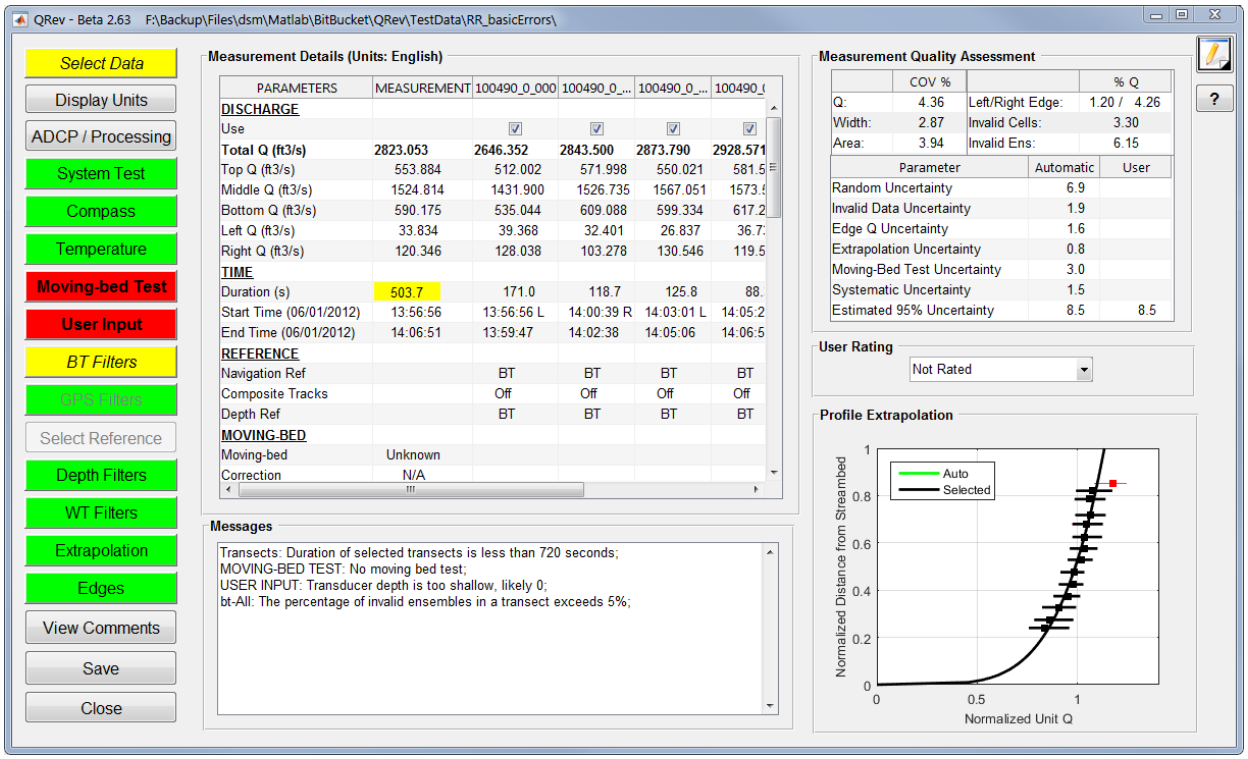


Figure 1. QRev main window. Although this window is labeled QRev Beta 2.63, the presentation is the same as in QRev version 2.8.

The buttons on the left (fig. 1) will turn green, yellow, or red based on the automated data quality assessment (ADQA). If a button is yellow or red, an associated message will be in the message box at the bottom of the main window. Buttons, check boxes, radio buttons, and pop-up menus are used in lieu of menus in an attempt to make QRev easy to use on a touch screen tablet. Each button opens a modal window that provides tables, text, options, and graphics needed to assess and process that particular aspect of the data in more detail. The modal window will not allow the user to open or work in another window until that window is closed.

QRev is designed to update the data immediately upon a changed setting. While QRev is processing, the cursor will appear with the busy shape and no other buttons or selections should be made. Once QRev has finished processing, the cursor will return to the default shape.

Common Features

The windows in QRev share several features. To avoid repeating the use of these features for each window, these common features are discussed in this section of the report and can be used in the windows where the features are present.

Comment Button

A comment button,  , is at the top right of every window in QRev. Clicking on this button will open the comment window (fig. 2). The user comment is automatically tagged with the name of the QRev modal window from which the comment button was clicked and the time and date of the comment. The user should enter comments explaining any observations associated with the data or field conditions or any changes in QRev settings. All comments can be viewed by clicking the View Comments button in the main window. Comments cannot be edited or deleted after they are entered.

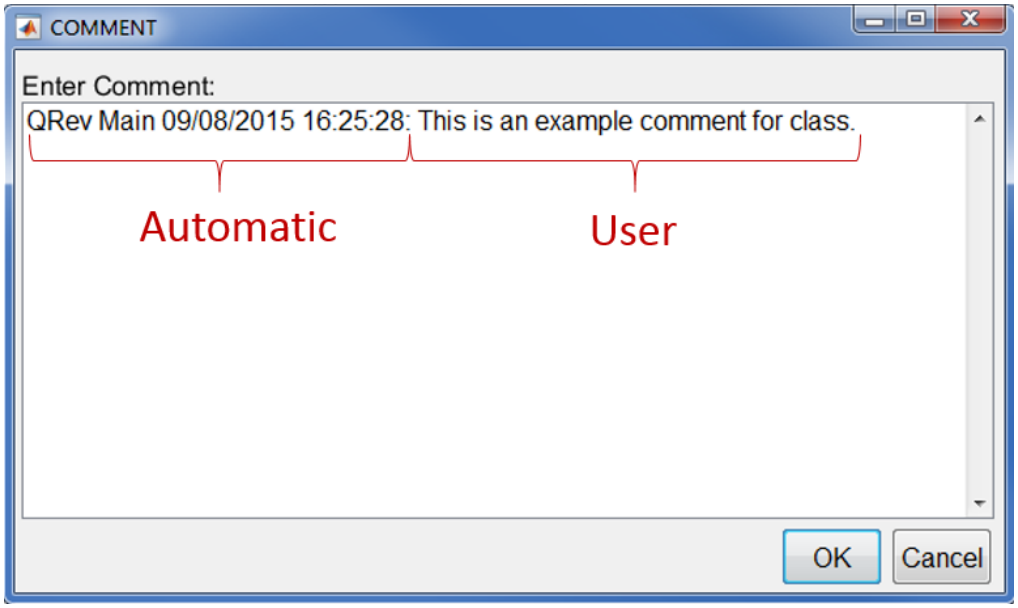
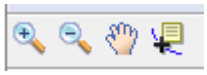


Figure 2. Comment window.

Legends

Many of the graphics in QRev have a legend associated with them. Occasionally the legend may hide important parts of the graph. The legend in any graph can be moved by left clicking on the legend and dragging it to another location. The legend can be completely removed by right clicking on the legend and selecting delete. To restore the legend, the user will have to recreate the graph by changing the transect or by changing the type of data being graphed.

Tool Bar

Each window with graphs will have a toolbar  at the upper left of the window. These tools can be used to zoom, pan, and query the data in the graphs.

- Zoom in,  , allows zooming in on data in the graph.
- Zoom out,  , allows zooming out on data in the graph.
- Pan,  , allows panning in the graphics window.

- Probe Data,  , allows data values to be probed by clicking on the data points in the graphs.

Tables

Many of the dialog windows have a table displaying each transect as a row with columns of information associated with the specific measurement characteristic being evaluated. Scroll bars at the right and bottom of the tables can be used to scroll through the data in the table. In addition, after clicking in the table the cursor keys can be used to navigate through the table.

Graphs of data in QRev typically only display data from a single transect. The transect being displayed can be changed by clicking in the table on the row or filename of the desired transect. To quickly scan graphs of data from multiple transects, click in the table and change the transect graphed by using the up and down arrow keys.

Many of the tables have data with a background colored yellow or red to associate the data with a particular ADQA message. Current (2015) limitations of MATLAB in the implementation of the table and cell coloring may result in the display of HyperText Markup Language (HTML) code when a value is edited (fig. 3). To edit the value delete all HTML code and enter the desired value.

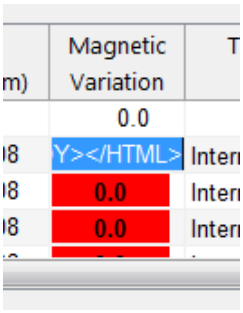


Figure 3. HyperText Markup Language (HTML) code in edited cell.

Main Window

The QRev main window (fig. 1) has the following six sections: (1) buttons down the left side, (2) Measurement Details panel, (3) Messages panel, (4) Measurement Quality Assessment panel, (5) User Rating panel, and (6) Profile Extrapolation panel. The information available from this main window provides the user an overview of the measurement quality and totals. The color highlighting and messages alert the user to any potential issues detected by the ADQA. Other modal windows to explore the data or change the processing settings are accessed from this main window using the buttons on the left.

Buttons

The buttons on the left (fig. 1) are arranged from top to bottom to lead the user through the steps of loading, reviewing, and finalizing a measurement. The buttons will display in one of four ways depending on the results of the ADQA.

Normal A normal button color after a file has been loaded indicates that no ADQA is associated with this button, but the button provides access to other functions or windows, or both.

Inactive An inactive button indicates that the data loaded do not have data associated with that specific feature.

Good A green button with normal text indicates that this aspect of the data passed all the ADQA checks.

Caution A yellow button with italic text indicates that the ADQA has identified a potential issue, but the issue is likely not critical. An associated message will be in the Message panel. The caution message will use lowercase letters in the message identifiers.

Warning A red button with bold text indicates that the ADQA has identified an issue that could have a significant effect on the measurement or that violates USGS policy. An associated message will be in the Message panel. The message identifier will be in uppercase letters for a warning message.

Measurement Details

The Measurement Details panel (fig. 1) provides a table of the measurement results and configuration settings. The units system used for the measurement is shown in the panel label and with each row label that has units associated with it. A scroll bar on the right allows the user to scroll up and down through the table. Depending on the number of transects in the measurement there may be an additional scroll bar at the bottom to allow the user to scroll left and right. Clicking in the table will allow navigation of the table with the arrow keys. The width of the columns can be changed by placing the cursor in the column labels and dragging the column divider.

The only row in this table that can be edited is the row labeled "Use". This row identifies the transects that will be used to compute the final average discharge. Clicking the check box under each transect name will change whether the transect is used (checked) or not used (unchecked) in the final average discharge computation. The ADQA will update every time a change in the transect selection is made and will report on only the data and associated computations of the selected transect.

If the ADQA identifies specific issues, some of the cells in the Measurement Details table may have a background color of yellow or red, like the buttons. For example, if an odd number of transects are selected, the "Use" label will be red. Similarly, if the duration of the measurement is less than 720 seconds, the duration of the measurement will have a yellow background.

Messages

The Messages panel displays messages reported by the ADQA (fig. 1). Each message has an initial identifier followed by a colon. Messages with an identifier that is in all uppercase are warning messages and will be associated with a red button. Messages with an identifier that has lowercase letters are caution messages and will be associated with a yellow button. The scroll bar on the right allows the user to scroll through messages if the messages exceed the panel size. The arrow keys cannot be used to scroll through the messages text box.

Measurement Quality Assessment

The Measurement Quality Assessment panel (fig. 1) consists of three tables with information to assist the user in rating the quality and uncertainty of the measurement. The table in the upper left provides the coefficient of variation in percent (COV %) for the total discharge, the cross-section width, and the cross-sectional area. The table in the upper right provides the percentage of total discharge (% Q) in the left and right edges (Left/Right Edge), in invalid cells (Invalid Cells), and in invalid ensembles (Invalid Ens.). Cells in the tables may be colored based on the results of the ADQA.

The table at the bottom of the panel has two columns for the uncertainty of the various aspects of the measurement (fig. 1). The column labeled "Automatic" contains the values generated by QRev based on assumptions and computations defined in Mueller (in press) and briefly in the following paragraphs. Because the assumptions and computations used to generate the values in the "Automatic" column are simplistic, the values may not accurately represent the uncertainty for all conditions. The column labeled "User" allows the user to override the automatic values with a user supplied value. A value entered by a user should be supported with a comment. The total estimated 95 percent uncertainty value will be recomputed each time a new "user" value is input. The uncertainty categories are defined as follows.

- ***Random Uncertainty*—**The random uncertainty expands the Q COV to a 95 percent level by applying a coverage factor from the Student's t-distribution based on the number or degrees of freedom and then dividing by the square root of the number of transects. When only 2 transect

comprise a measurement, the theoretical Student's t approach is abandoned and the 95 percent random uncertainty is computed as Q COV * 3.3.

- ***Invalid Data Uncertainty***—The 95 percent uncertainty for invalid data is assumed to be 20 percent of the sum of the percent discharge for invalid cells and ensembles.
- ***Edge Q Uncertainty***—The 95 percent uncertainty for the edge discharge is assumed to be 30 percent of the total discharge in the edges. The edge Q uncertainty accounts for uncertainty in the edge shape, roughness, distance to shore, depth, and water velocity.
- ***Extrapolation Uncertainty***—The percent extrapolation uncertainty is computed by computing the percent difference in discharge from the selected extrapolation method to other possible extrapolation methods and averaging the best four options.
- ***Moving-Bed Test Uncertainty***—If bottom track is not the navigation reference, the percent moving-bed test uncertainty is assumed to be zero. If bottom track is used and a moving-bed test is valid, the percent moving-bed test uncertainty is assumed to be 1 percent if the test indicates no moving bed is present and 1.5 percent if a moving bed is present. If the moving-bed test has warnings, is invalid, or no moving-bed test was completed, the uncertainty is set to 3 percent.
- ***Systematic Uncertainty***—Systematic uncertainty, such as biases in the components of the ADCP and beam misalignment, is assumed to be 1.5 percent.
- ***Estimated 95% Uncertainty***—The estimated 95 percent uncertainty uses the values for uncertainty from the discussed categories and combines them as the square root of the sum of the squares. The final value is only a guide because the algorithms for the various sources of uncertainty are only approximations and simple assumptions.

User Rating

The User Rating panel (fig. 1) provides a popup menu to allow the user to rate the measurement. QRev does not automatically rate the measurement. The user should consider the information provided in the Measurement Quality Assessment panel (especially the uncertainty estimate), the quality of the stage measurement, and any other factors that might affect the overall quality of the measurement when selecting the final rating.

Profile Extrapolation

The Profile Extrapolation panel (fig. 1) contains a graph of the normalized depth and discharge for the entire measurement (check transects only). The data are represented by median values of normalized Q at the mean normalized depth for all data within 5 percent increments of normalized depth. The whiskers on the data points show the range of 50 percent of the data in that median. The selected extrapolation methods are shown with a black line, and the extrapolation methods based on the automatic methods in QRev are shown with a wider green line (fig. 4). QRev defaults to the extrapolation methods based on the automatic selection algorithms; however, the user can choose to override that automatic selection.

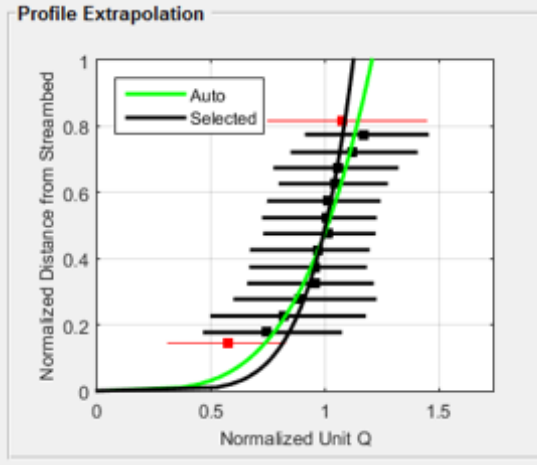


Figure 4. Example profile extrapolation showing a selected extrapolation method different from the automatically selected method.

Select Data

The Select Data button (fig. 1) is used to load data into QRev. Clicking the Select Data button opens the dialog shown in figure 5. QRev can load data from the following three sources:

1. SonTek RiverSurveyor Live (RSL) MATLAB output (*.mat),
2. TRDI WinRiver II (WR2) mmt (*.mmt) and pd0 (*.pd0) files, and
3. MATLAB file saved from QRev (*_QRev.mat).

Clicking the appropriate data type will open a file selection dialog (fig. 6).

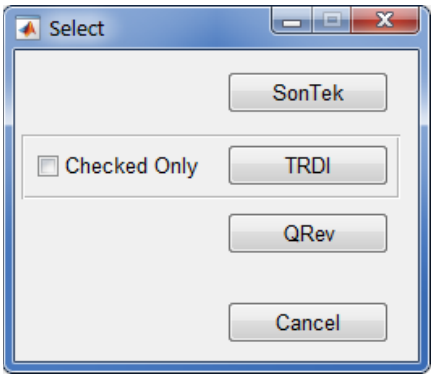


Figure 5. Select data window.

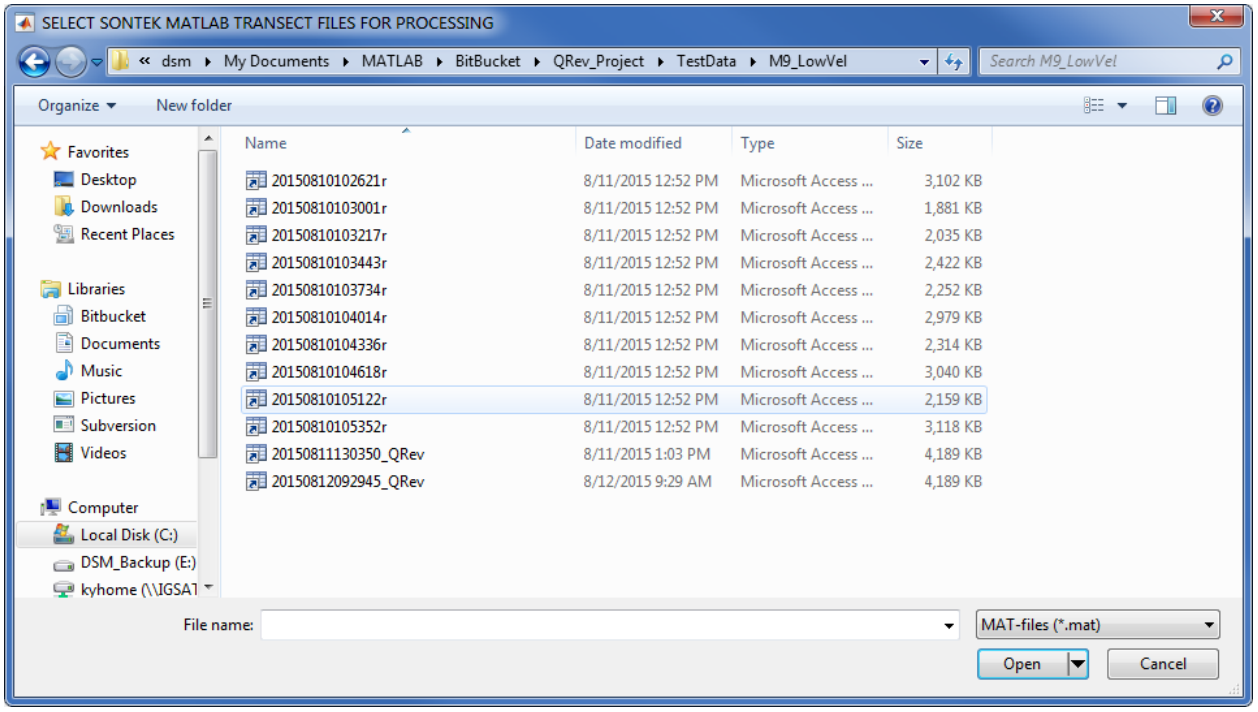


Figure 6. File selection dialog.

For RSL measurements, moving-bed tests and transects must be exported from RSL using the MATLAB export feature. These files must be output using east, north, up (ENU) coordinates and bottom track (BT), GGA, or VTG track reference. The files selected by the user from the Open File window shown in figure 6 should include the *.mat files for all transects in the measurement (Windows commonly does not display the file extension and considers *.mat files to be Microsoft Access Table Shortcuts.). QRev will automatically load associated moving-bed tests, system tests, and compass evaluations provided they follow the standard RSL naming and file storage conventions. Moving-bed tests filenames must begin with “Smba_” or “Loop_” and be exported to the MATLAB format (*.mat). The system tests and compass calibration must be stored in subfolders of the measurement folder and be named System Test and CompassCal, respectively.

For TRDI ADCPs, select the *.mmt file in the Open File dialog and the transects and supporting data will be loaded. To only load the transects that have been checked in WR2, first click the "Checked Only" box and then click on TRDI (fig. 5).

The QRev data type is for a measurement that has already been processed and saved by QRev. The file is a "*_QRev.mat" file. This file contains all the data and settings used in QRev and will present the data exactly as the file was saved.

NOTE—The user **cannot** add files to an existing QRev session; all files must be loaded at the same time.

Measurement Quality Checks

The Select Data button (fig. 1) may be colored based on the following ADQA checks.

Good (Green)

Passed all quality ADQA checks.

Caution (Yellow)

Check—Number of transects checked for use is less than 2.
Message—Transects: Only one transect selected.

Check—Number of transects checked is 2 and COV is greater than 2.
Message—Transects: Uncertainty would be reduced by additional transects.

Check—Total duration of all checked transects is less than 720 seconds.
Message—Transects: Duration of selected transects is less than 720 seconds.

Warning (Red)

Check—Number of transects checked for use is zero.
Message—TRANSECTS: No transects selected.

Check—Number of left to right and right to left transects checked for use are not equal.
Message—TRANSECTS: Transects selected are not reciprocal transects.

Check—One or more of the transects checked for use have different signs.
Message—TRANSECTS: Sign of total discharge is not consistent. One or more start banks may be incorrect.

Display Units

The Display Units button (fig. 1) opens a window that allows the user to select the desired units (English or International System of Units [SI]; fig. 7). This selection can be made at any time. This setting only affects the display of the data and does not have to be consistent with the original units of the loaded data. All data in QRev are stored internally in SI units.

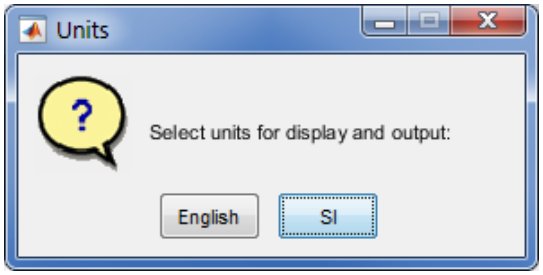


Figure 7. Display Units dialog box.

ADCP/Processing

The ADCP/Processing button (fig. 1) will open a dialog window that shows information about the ADCP (fig. 8). ADCPs with auto-adaptive water and bottom modes and frequencies may display "Variable" or a range of values representative of the data collected. If the information is not available in the data loaded, the value will be left blank.

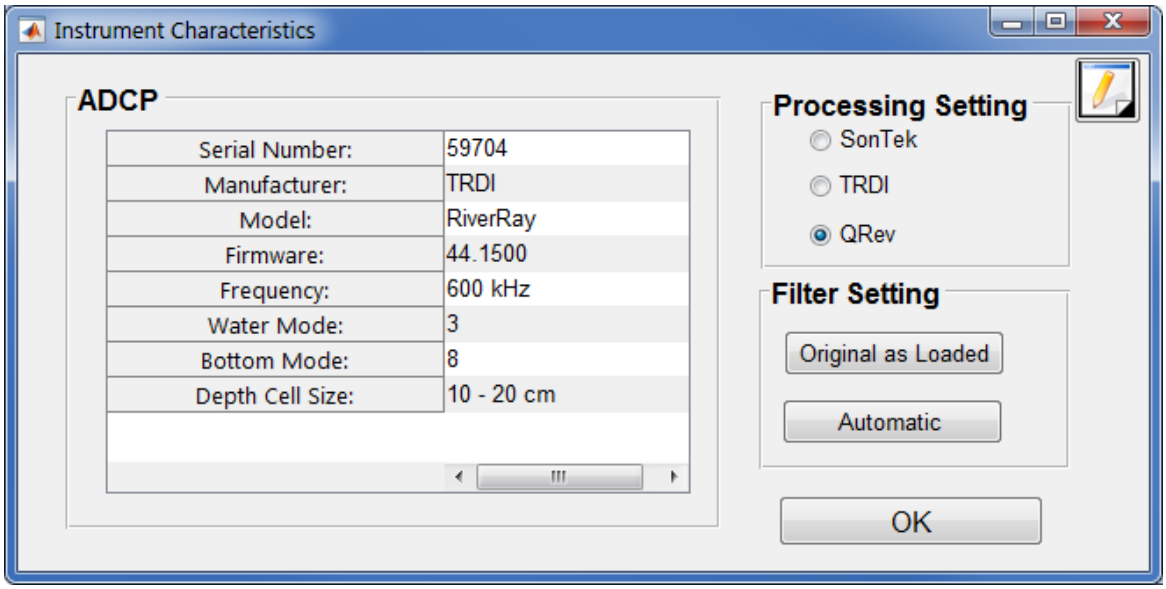


Figure 8. ADCP/Processing dialog window.

The Processing Setting panel allows the user to change the processing algorithms and global filter settings used to compute discharge (fig. 8). The Processing Setting defaults to QRev and the filter setting defaults to Automatic for all data types. The Automatic filter setting turns most of the filters in QRev to an Auto setting, meaning these filters will be applied to the data using preset values or preset

dynamic algorithms. The extrapolation is also set to the automatically selected methods. The navigation reference is set to whatever reference was set in the loaded data.

The user can switch the processing type among SonTek, TRDI, or QRev (fig. 8). Switching the processing type changes the way invalid data are interpolated and handled. The user can also change the filter settings to the filter settings used in the original data (Original as Loaded). If a filter is not supported by the manufacturer and does not have a setting, that filter is turn off. For QREV to process the data like RSL, the user would select SonTek, wait until QRev finishes processing that request, and then click on Original as Loaded. This combination will process the data similarly to RSL. Likewise, to process data like WR2, the user would select TRDI and then click on Original as Loaded. The user can use the Automatic button to turn all filters to Automatic if changes have been made using other windows in QRev.

System Test

The System Test button (fig. 1) opens a window that allows the user to review system tests that were collected with the measurement (fig. 9). System tests stored in the *.mmt file for WR2 measurements or in the System Test folder for RSL measurements will be loaded automatically. System tests loaded automatically are identified by a date and time stamp shown in the popup menu in the upper left of the System Test window. If a system test was collected outside the normal procedures and not stored in the default file and location, the user can manually load the file. Manually loaded files are identified by their filename. The manually loaded file must be an ASCII text file. If multiple tests were completed, each test can be reviewed by using the popup menu to select the test to display in the display text box. The scroll bar on the right can be used to scroll through the test results. Typically a system test is a suite of tests on different aspects of the ADCP. QRev will scan the system test and look for individual tests that “Fail”. The number of failed tests is displayed in the upper left of the System Test Window.

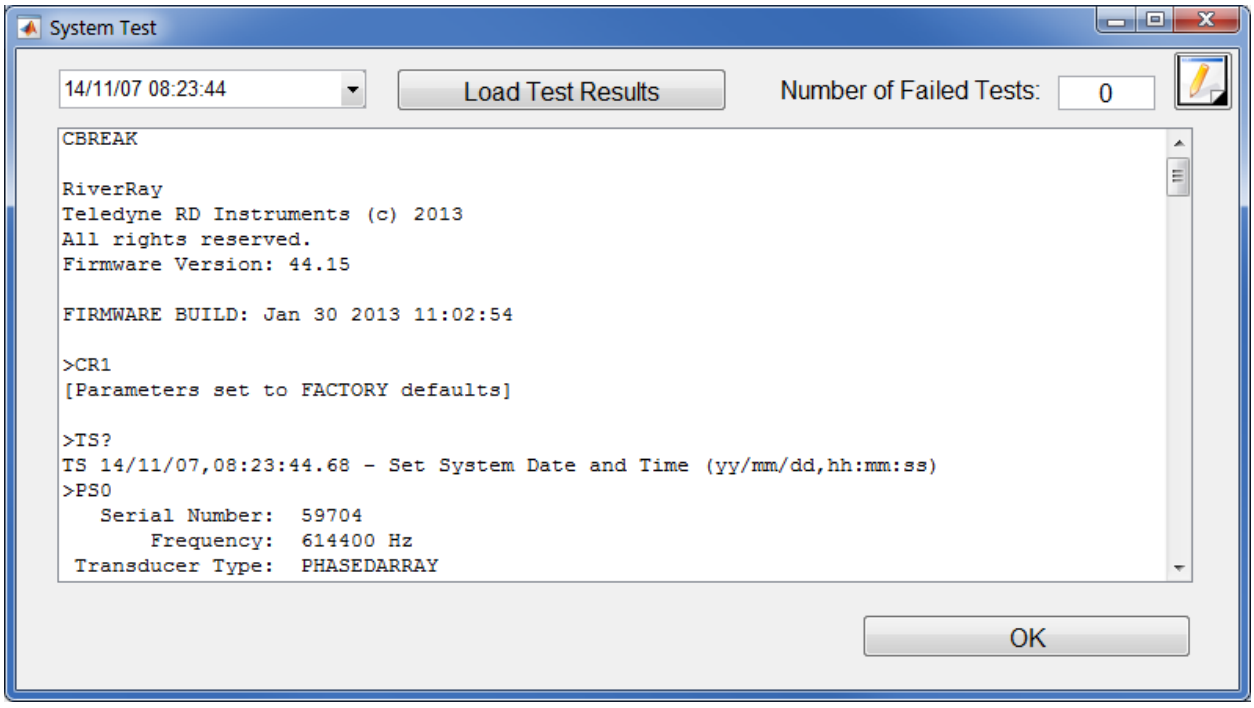


Figure 9. System Test window.

Measurement Quality Checks

The System Test button (fig. 1) will be colored based on the following ADQA checks.

Good (Green)

A system test was completed with no failures reported.

Caution (Yellow)

Check—At least one of the system tests has one or more failures.
Message—System Test: One or more system test sets have at least one test that failed.

Warning (Red)

Check—There is no system test.
Message—SYSTEM TEST: No system test.

Check—All system tests have at least one failure.
Message—SYSTEM TEST: All system test sets have at least one test that failed.

Compass

The Compass button (fig. 1) opens a window that allows the user to review compass calibrations and evaluations that were collected with the measurement (fig. 10). Compass calibrations and evaluations stored in the *.mmt file for WR2 or compass calibrations stored in the CompassCal folder for RSL measurements will be loaded automatically. However, if a compass calibration or evaluation is stored in a text file in another folder, the user can manually load the file using the Load Calibration File or Load Evaluation File buttons. Multiple calibrations and evaluations can be loaded and will be identified by date and time, if loaded automatically, or by filename, if loaded manually. To view the results, the user must select the Data Type (Calibration or Evaluation) and then select the desired time stamp or filename. QRev currently (2015) does not evaluate the quality of the calibration or evaluation.

Measurement Quality Checks

The Compass button (fig. 1) may be colored or inactive based on the following ADQA checks.

Inactive

Check—The data loaded do not have valid heading data, such as from a StreamPro with no compass.

Normal

Check—The ADCP has a compass that was not calibrated but calibration is not required because neither a loop test nor the Global Position System (GPS) are used.

Good (Green)

Check—A compass calibration and evaluation were completed.

Caution (Yellow)

Check—GPS data or the loop test is present, a compass calibration was completed but there is no compass evaluation.
Message—Compass: No compass evaluation.

Warning (Red)

Check—GPS data or the loop test is present and there is no compass calibration.
Message—COMPASS: No compass calibration.

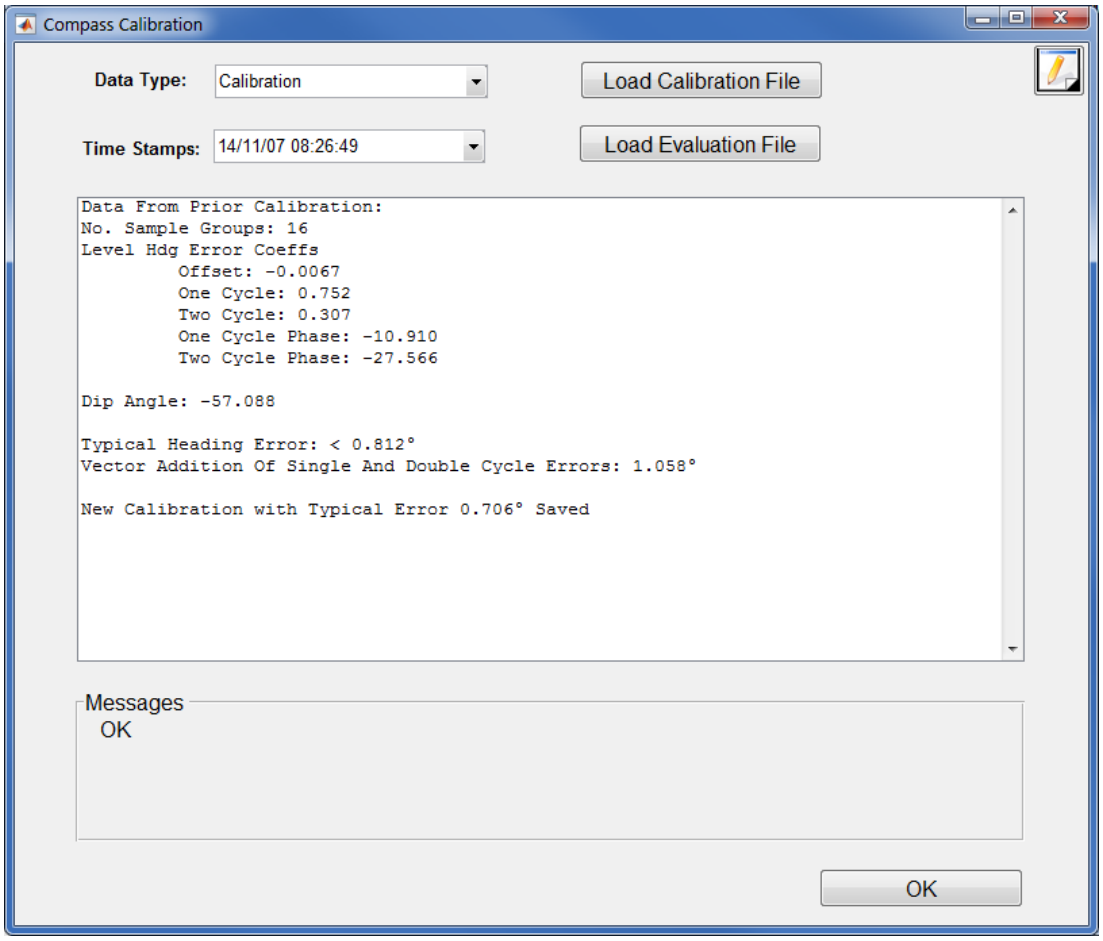


Figure 10. Compass Calibration and evaluation window.

Temperature

The Temperature button (fig. 1) opens a window that allows the user to review the change in water temperature during the entire measurement and to enter an independent water temperature and associated ADCP water temperature (fig. 11). The Units panel at the top left allows the user to change the temperature units. The External Temperature Check panel at the top right provides an area where the user can enter the temperature check information collected before the measurement. The User temperature is a temperature measured using an independent temperature sensor, and the ADCP temperature is the temperature measured at the same time by the ADCP. In the absence of the ADCP

temperature, the User temperature will be compared to the average temperature for the entire measurement.

Measurement Quality Checks

The Temperature button (fig. 1) may be colored and messages provided based on the following ADQA checks.

Good (Green)

Check—Difference between the user recorded independent temperature reading and either the mean ADCP temperature for the measurement or a user recorded ADCP temperature is less than 2 degrees Celsius.

Caution (Yellow)

Check—Temperature range for the entire measurement exceeds 1 degree Celsius.
Message—Temperature: Temperature range is xx degrees Celsius, which is greater than 1 degree Celsius.

Check—There is no independent user measured temperature recorded.
Message—Temperature: No independent temperature reading.

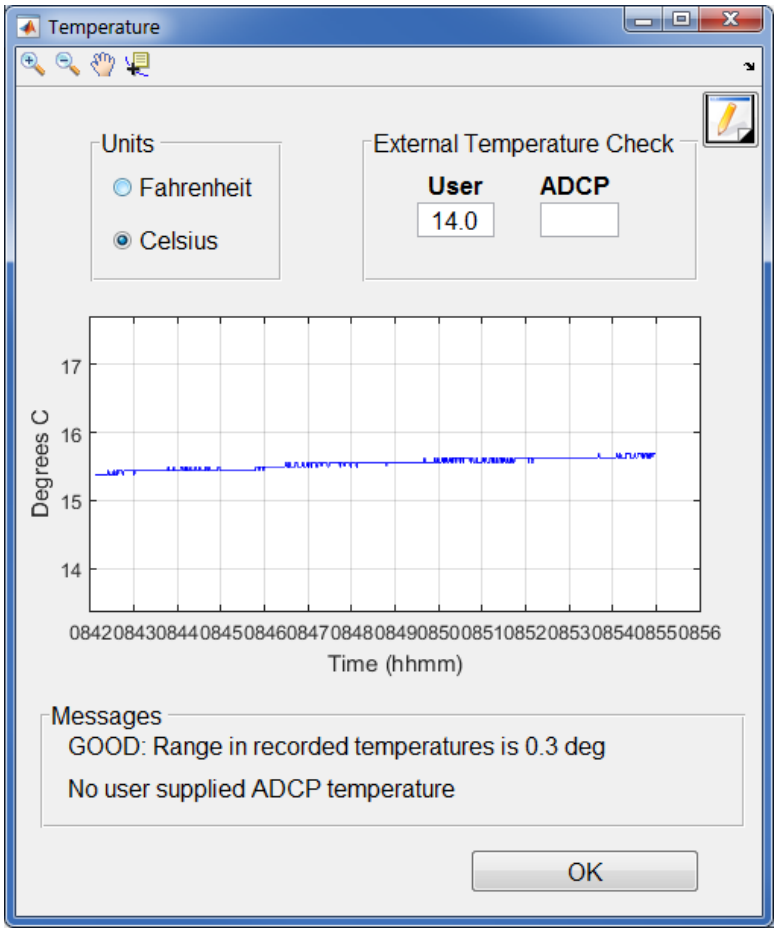


Figure 11. Temperature window.

Warning (Red)

Check—Temperature range for the entire measurement exceeds 2 degrees Celsius.
Message—TEMPERATURE: Temperature range is xx degrees Celsius, which is greater than 2 degrees Celsius.

Check—Difference between the user recorded independent temperature reading and user recorded ADCP temperature is 2 degrees Celsius or greater.
Message—TEMPERATURE: The difference between the ADCP and independent temperatures is: xx degrees Celsius, which is not within 2 degrees Celsius.

Check—Difference between the user recorded independent temperature reading and average ADCP temperature is 2 degrees Celsius or greater.
Message—TEMPERATURE: The difference between the ADCP and independent temperatures is: xx degrees Celsius, which is not less than 2 degrees Celsius.

Moving-Bed Test

The Moving-bed Test button (fig. 1) opens a window that allows the user to review moving-bed test results, mark tests invalid, and decide if any of the moving-bed tests should be used to correct the measured discharge (fig. 12).

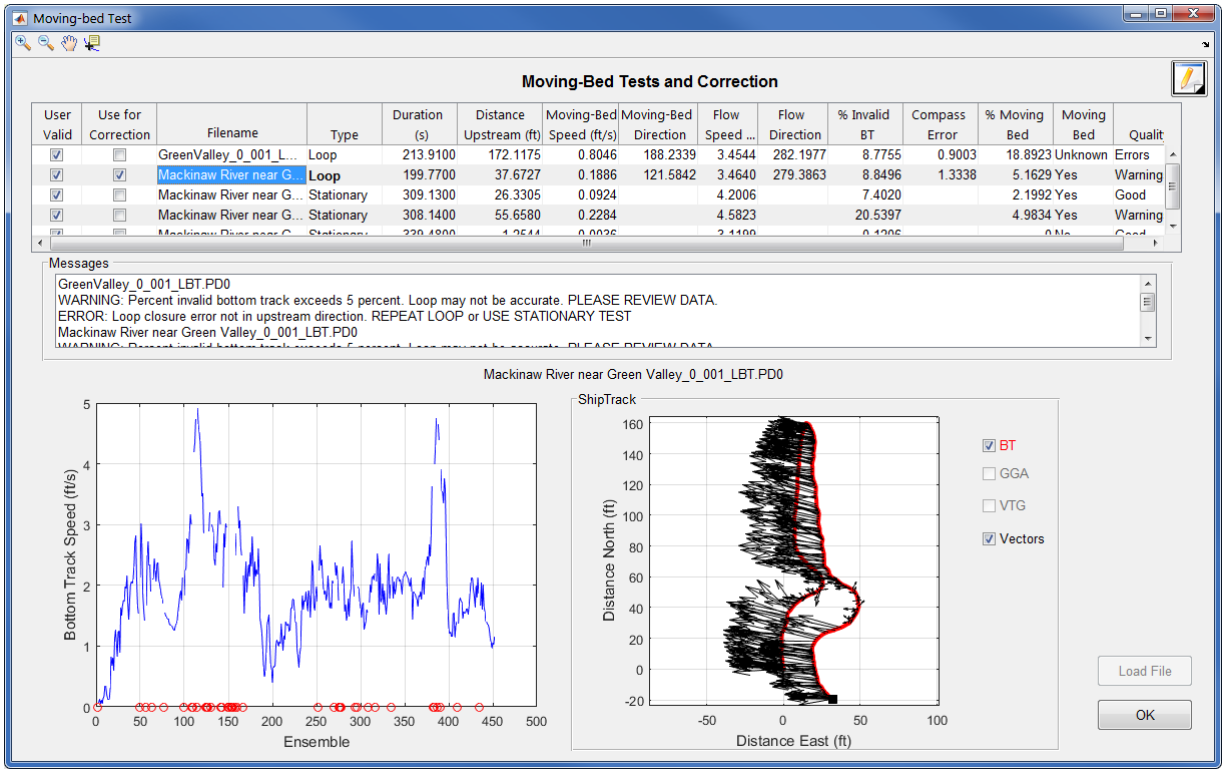


Figure 12. Moving-bed Test window displaying a loop moving-bed test.

Moving-Bed Tests and Correction Table

The table at the top of the window lists all the moving-bed tests associated with the measurement (fig. 12). Scroll bars on the right and bottom of the table can be used to scroll through the data. The columns of the table contain the following information:

- ***User Valid*—**This column identifies tests that the user considers valid moving-bed tests. QRev assumes that all loaded tests are valid tests; for example, tests that were completed using proper technique. If a test is not valid because of an aborted test or because of something that happened during the test that indicates the test should not be used, the user should uncheck that test. Unchecking the User Valid column tells QRev that this test should not be used to determine if a moving-bed condition exists or to correct the discharge.
- ***Use for Correction*—**This column identifies the test or test(s) that will be used to correct the discharge for a moving-bed condition. If bottom track is the navigation reference and a moving bed exists, QRev will automatically select the moving-bed test to use to correct the final discharge; however, the user can override the selection by checking or unchecking the tests that do not have critical errors. QRev does not permit the combined use of loop and stationary tests. No test can be checked or will be applied if a moving-bed condition does not exist or if GGA or VTG are the navigation reference.
- ***Filename*—**The filename containing the moving-bed test.
- ***Type*—**The type of test (Loop or Stationary).
- ***Duration*—**The duration of the test in seconds.
- ***Distance Upstream*—**The distance the test showed the boat moved upstream from its starting location. This distance is the closure error for a loop test.
- ***Moving-Bed Speed*—**The computed speed of the bed (Distance Upstream/Duration).
- ***Moving-Bed Direction*—**The direction (azimuth) the boat moved relative to its starting location. For a moving-bed condition, this value should be approximately 180 degrees from the flow direction. This value is only computed for the loop moving-bed test.
- ***Flow Speed*—**The magnitude of the average water velocity vector for all data in the test.
- ***Flow Direction*—**The direction (azimuth) of the average water velocity vector for all data in the test. This value is only computed for the loop moving-bed test.
- ***% Invalid BT*—**The percentage of ensembles that have invalid bottom track data.
- ***Compass Error*—**The difference in the flow direction between the outgoing and returning portions of the loop moving-bed test.
- ***% Moving Bed*—**The ratio of the moving-bed speed to flow speed expressed as a percentage.
- ***Moving Bed*—**Using the criteria for a moving-bed condition documented in Mueller and others (2013), QRev determines if a moving-bed condition exists. If the quality of the moving-bed test results in errors, this field is set to Unknown because the moving-bed test is unreliable.
- ***Quality*—**QRev completes a quality assessment of every moving-bed test. Based on criteria documented in Mueller (2016), the quality of the measurement is set to Good if all the quality checks pass, to Warnings if some quality checks fail but are not critical failures, or to Errors if critical errors in the moving-bed test are identified.

Messages Panel

The Messages panel lists the warning and error messages from the quality assessment for each moving-bed test (fig. 12). The scroll bar at the right can be used to scroll through the messages.

Graphs

When the Moving-bed Test window is first opened, the first file in the table is the file displayed in the graphs at the bottom of the window. To display a different file, click in the table on the filename to be displayed. The filename of the moving-bed test displayed is shown immediately above the graphs. The graphs at the bottom change depending on whether the displayed test is a loop test (fig. 12) or a stationary test (fig. 13).

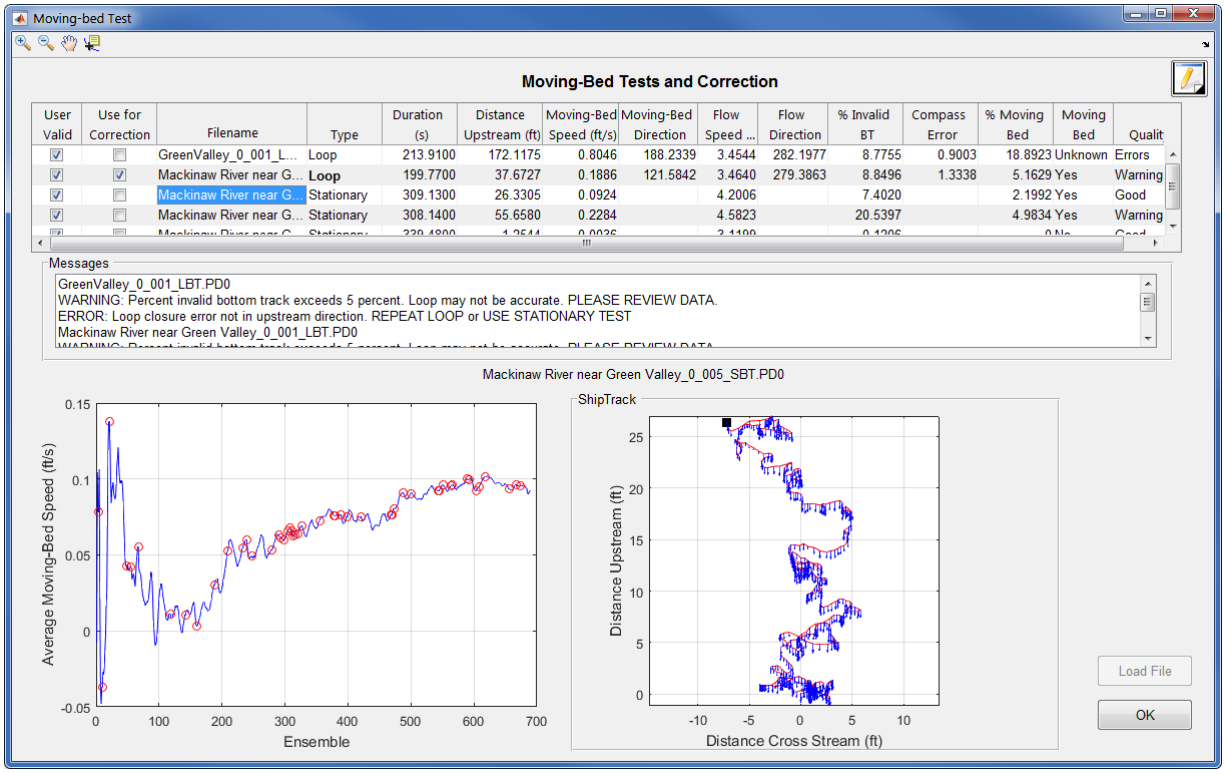


Figure 13. Moving-bed Test window displaying a stationary moving-bed test.

Loop Moving-Bed Test Graphs

The two graphs for the loop moving-bed test (fig. 12) are a time series of boat speed on the left and a ship track graph on the right. Red circles in the time series graphs identify ensembles with invalid bottom track. Check boxes in the Ship Track panel for the loop moving-bed test can be used to control what data are displayed on the ship track.

Stationary Moving-Bed Test Graphs

The two graphs for a stationary moving-bed test (fig. 13) are a time series of the average moving-bed speed on the left and a ship track graph on the right. By the end of a stationary moving-bed test the average moving-bed speed should reach equilibrium, so the line in the left graph should be horizontal or oscillating slightly about a horizontal trend. Red circles in the time series graphs identify ensembles with invalid bottom track. The ship track is graphed so that the horizontal axis is the cross stream distance and the vertical axis is the upstream distance. All velocity vectors should be pointing down. A moving-bed condition would present itself as a ship track in the upstream direction.

Moving-Bed Test Quality Assessment

The quality assessment of moving-bed tests is completed in three steps as follows: (1) a detailed step evaluates the actual moving-bed test based on specific criteria for loop or stationary tests; (2) on the basis of the results of that detailed evaluation, QRev selects the moving-bed test(s) to use in determination of a moving-bed condition; and (3) the ADQA is completed on the results of the selected moving-bed test and provides the color coded and textual feedback to the user in the main QRev window.

The detailed evaluation for loop tests uses that same criteria and algorithms used in LC (Mueller and others, 2013) and gives the loop moving-bed test a quality rating of good, warnings, or errors. The specific messages related to each loop moving-bed test are displayed in the Messages panel (fig. 12).

Unlike WR2, RSL, or SMBA, QRev evaluates the quality of individual stationary moving-bed tests. The evaluation examines the percentage of ensembles with invalid bottom track velocities, examines the duration of the test, and determines if the test appears to have reached equilibrium (Mueller, in press).

Test Selection

If more than one loop test or a loop test(s) and stationary test(s) are completed, QRev automatically determines which test(s) are used to determine if there is a moving-bed and to compute any required moving-bed corrections. If more than one valid loop test is present, then the last valid loop test is selected. If no valid loop tests are present, then all valid stationary tests are selected. If any of the selected tests indicate a moving bed, then a moving-bed condition exists, and the selected test(s) is used to correct the bottom track referenced discharge.

Measurement Quality Checks

The ADQA uses the selected moving-bed test to set the button color and provide messages to the user.

Good (Green)

A valid moving-bed test was recorded and indicates no moving bed.

Caution (Yellow)

***Check*—**Valid moving-bed test indicates a moving bed.
***Message*—**Moving-Bed Test: A moving bed is present, use GPS or moving-bed correction.

***Check*—**Moving-bed test completed but moving-bed test quality checks indicate warnings.
***Message*—**Moving-Bed Test: The moving-bed test(s) has warnings, please check validity of tests.

Warning (Red)

***Check*—**No moving-bed test recorded.
***Message*—**MOVING-BED TEST: No moving-bed test.

***Check*—**All loaded moving-bed tests have been marked invalid by the user.
***Message*—**MOVING-BED TEST: No valid moving-bed test based on user input.

***Check*—**Moving-bed test completed but moving-bed test quality check indicate the test has critical errors.
***Message*—**MOVING-BED TEST: The moving-bed test(s) have critical errors and will not be used.

***Check*—**A stationary moving-bed test indicates a moving bed, but GPS data are not present and fewer than three stationary moving-bed tests were recorded.
***Message*—**MOVING-BED TEST: Fewer than three stationary tests available for moving-bed correction.

User Input

The User Input button (fig. 1) opens a window that allows the user to review and change general user settings of draft, magnetic variation, water temperature source, water temperature, salinity, speed of sound source, and speed of sound (fig. 14). The Station Name, Station Number, and all values and settings in the table are read from the data files. The RSL *.mat files created prior to RSL version 3.9.4 do not contain the station name or number; therefore, the station name and number have to be entered in QRev by the user. The table contains the following data:

- ***Filename*—**Name of the file for each transect. The top row contains "All Transects", and data entered in this row will be applied to all transects.
- ***Draft*—**The depth of the ADCP transducers below the water surface.
- ***Magnetic Variation*—**The magnetic variation or declination from magnetic north to true north.
- ***Temperature Source*—**The source of the temperature data; Internal (ADCP) or Manual.
- ***Temperature Units*—**The units for the displayed temperature; Celsius or Fahrenheit.
- ***Average Temperature*—**The average temperature from all ensembles in the transect or the temperature to use for all ensembles if entered manually.
- ***Average Salinity*—**A user supplied average salinity that will be applied to all ensembles in the transect.
- ***Speed of Sound Source*—**The source of the speed of sound:
  - Internal (ADCP)—Speed of sound computed for each ensemble internally in the ADCP and used in the raw data.
  - Manual—A manually entered speed of sound that will be used for all ensembles in the transect.
  - Computed—The speed of sound is computed by QRev based on user provided salinity or average temperature, or both.
- ***Speed of Sound*—**The average speed of sound from all ensembles in the transect or the manually entered speed of sound that will be used for all transects.
- ***Discharge*—**The total discharge for the transect.

Generally, unless the ADCP has a malfunctioning temperature sensor, only the draft, magnetic variation, and salinity may need to be changed by the user. Selections made or values entered in the top row of the table are applied to all transects.

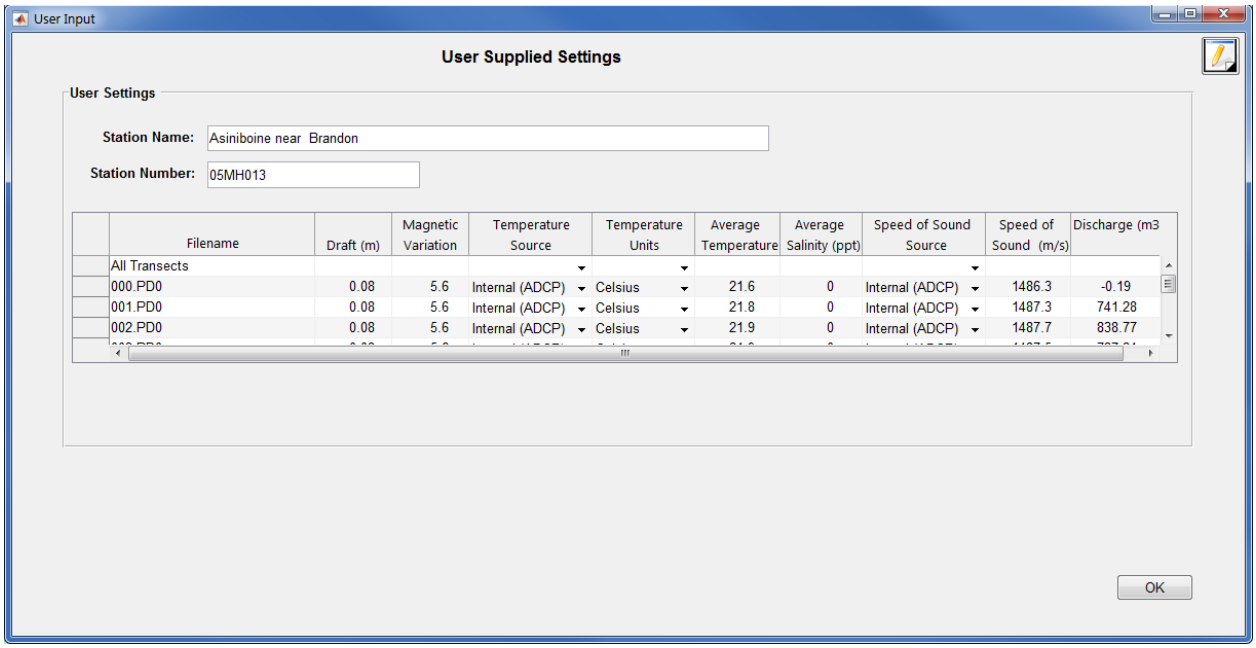


Figure 14. User Input window.

Measurement Quality Checks

When the ADQA results in a caution or warning, the associated data cells in the table are appropriately colored to help the user identify and correct the issue.

Good (Green)

User input passed all quality checks.

Caution (Yellow)

Check—Transducer depth (draft) is not consistent for all transects.
Message—User Input: Transducer depth is not consistent among transects.

Check—Magnetic variation is not consistent for all transects.
Message—User Input: Magnetic variation is not consistent among transects.

Check—A station name has not been entered.
Message—User Input: Station name not entered.

Check—A station number has not been entered.
Message—User Input: Station number not entered.

Warning (Red)

Check—GPS data are recorded and the magnetic variation is zero.
Message—USER INPUT: Magnetic variation is zero and GPS data are present.

Check—Transducer depth (draft) is less than 0.01 meter.
Message—USER INPUT: Transducer depth is too shallow, likely zero.

Bottom Track (BT) Filters

The BT Filters button (fig. 1) opens a window that allows the user to evaluate the bottom track data for each transect and change the filter settings (fig. 15). Filter settings are applied to all transects and cannot be set for individual transects.

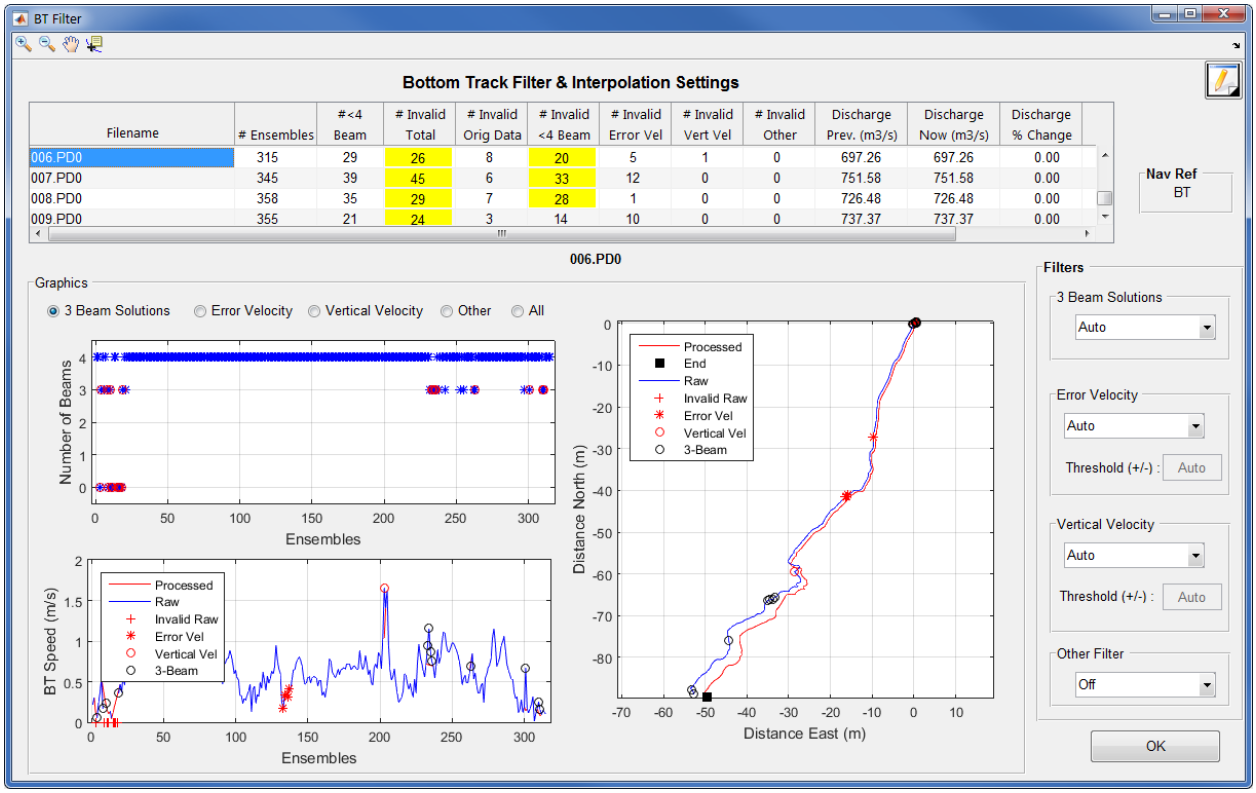


Figure 15. Bottom track (BT) Filter window.

Bottom Track Filter and Interpolation Settings Table

The table at the top of the window (fig. 15) allows the user to select which transect to graph (by clicking on the desired row), provides information on the number of ensembles that have been determined to be invalid by the various filters, and shows the effect of a filter change on the computed discharge. Cells in the table contain color codes associated with cautions or warnings generated from the ADQA. This table does not have any editable cells. The columns in the table are as follows:

- ***Filename***—Filename of the transect.
- ***# Ensembles***—Total number of ensembles in the transect.
- ***# <4 Beam***—Number of ensembles that had valid bottom track but less than 4 valid beams.
- ***# Invalid Total***—Number of ensembles with invalid bottom track velocity.
- ***# Invalid Orig Data***—Number of ensembles that had invalid bottom track velocity prior to any filtering.
- ***# Invalid <4 Beam***—Number of ensembles with valid bottom track but less than 4 beams for which the bottom track velocity has been determined to be invalid by the 3 Beam Solutions Filter.

- **# *Invalid Error Vel*—**Number of ensembles that have been determined to be invalid due to filtering based on the bottom track error velocity.
- **# *Invalid Vert Vel*—**Number of ensembles that have been determined to be invalid due to filtering based on the bottom track vertical velocity.
- **# *Invalid Other*—**Number of ensembles that have been determined to be invalid due to filtering using other filters.
- ***Discharge Prev.*—**Total discharge prior to most recent filter change.
- ***Discharge Now*—**Total discharge after applying the most recent filter change. If no filters have been changed, the discharge now will equal the discharge previous.
- ***Discharge % Change*—**The percent difference between the discharge previous and the discharge now due to the last filter change.

Nav Ref Panel

To the immediate right of the table is the Nav Ref panel that shows the current navigation or boat velocity reference (fig. 15). If this reference is not BT, then changes to the BT filters will not change the discharge.

Graphics Panel

The Graphics panel below the table consists of two or three graphs depending on the type of data graphed. The filename of the transect being graphed is shown just above the Graphics panel (fig. 15).

The right portion of the Graphics panel is always a ship track graph. The ship track graph displays the raw (unfiltered and without interpolation) ship track and the processed (filtered and interpolated) ship track. The location and source of invalid data are indicated by symbols shown in the graph legend. The end of the transect is indicated by a black square so the user can determine the direction of boat travel.

The configuration of the left portion of the Graphics panel is determined from the type of data graphed, which is selected by the user using the radio buttons at the top left of the Graphics panel. For 3 Beam Solutions, Error Velocity, and Vertical Velocity, the left portion of the Graphics panel will display two graphs. The top graph will display a time series graph for the type of data selected—3 Beam Solutions (fig. 15), Error Velocity (fig. 16), or Vertical Velocity (fig. 17). Invalid data are identified by red circles. The bottom graph is a time series of the raw and processed boat speed with the source of invalid data indicated by symbols identified in the graph legend (fig. 15). If Other or All are selected from the radio buttons, the left graph is a single graph (figs. 18 and 19). The Other graph is only valid if the Other Filter is set to Smooth.

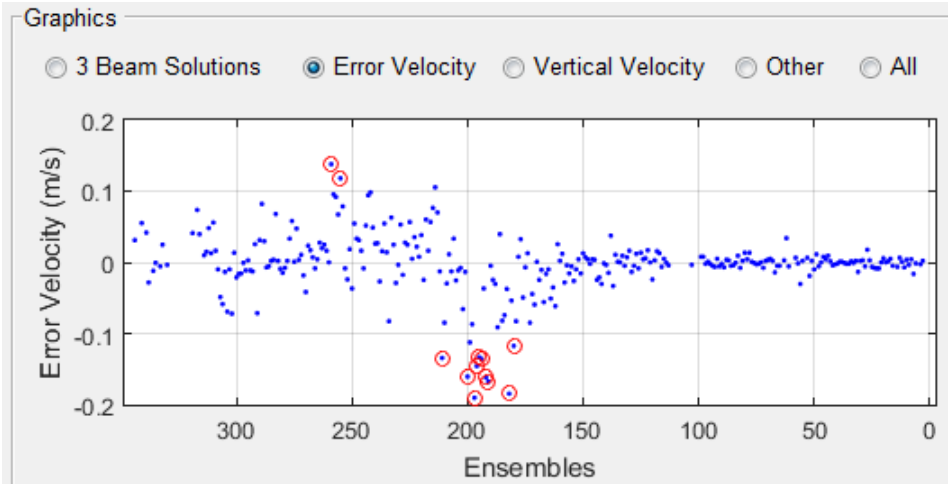


Figure 16. Example of top left graph with Error Velocity selected.

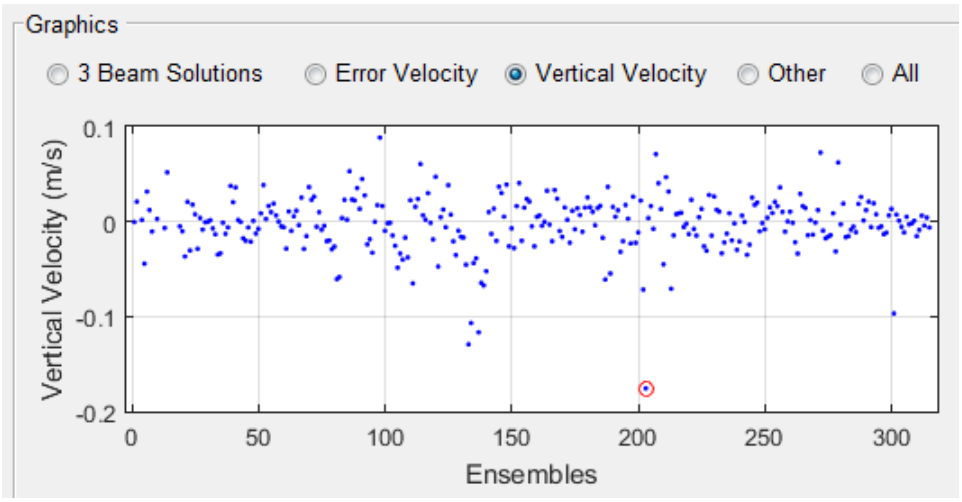


Figure 17. Example of top left graph with Vertical Velocity selected.

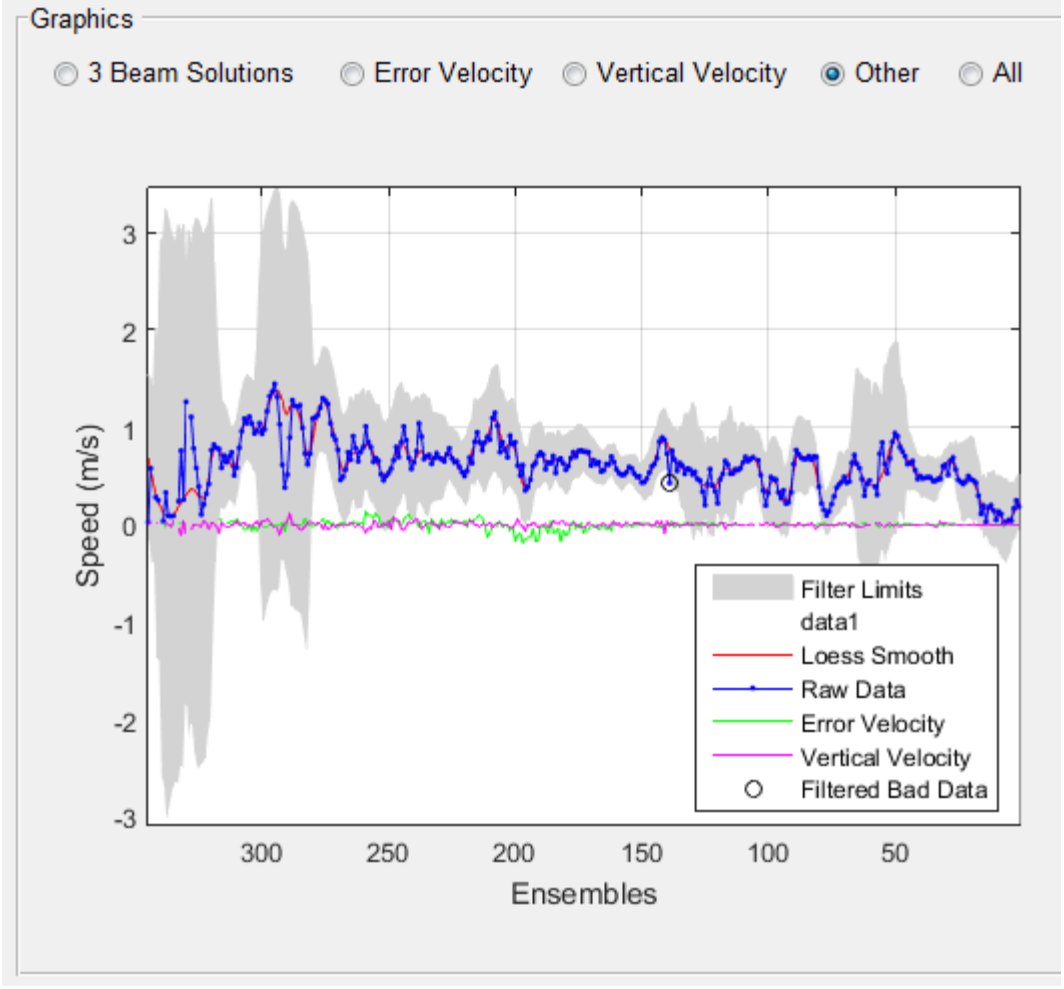


Figure 18. Example of left graph with Other selected.

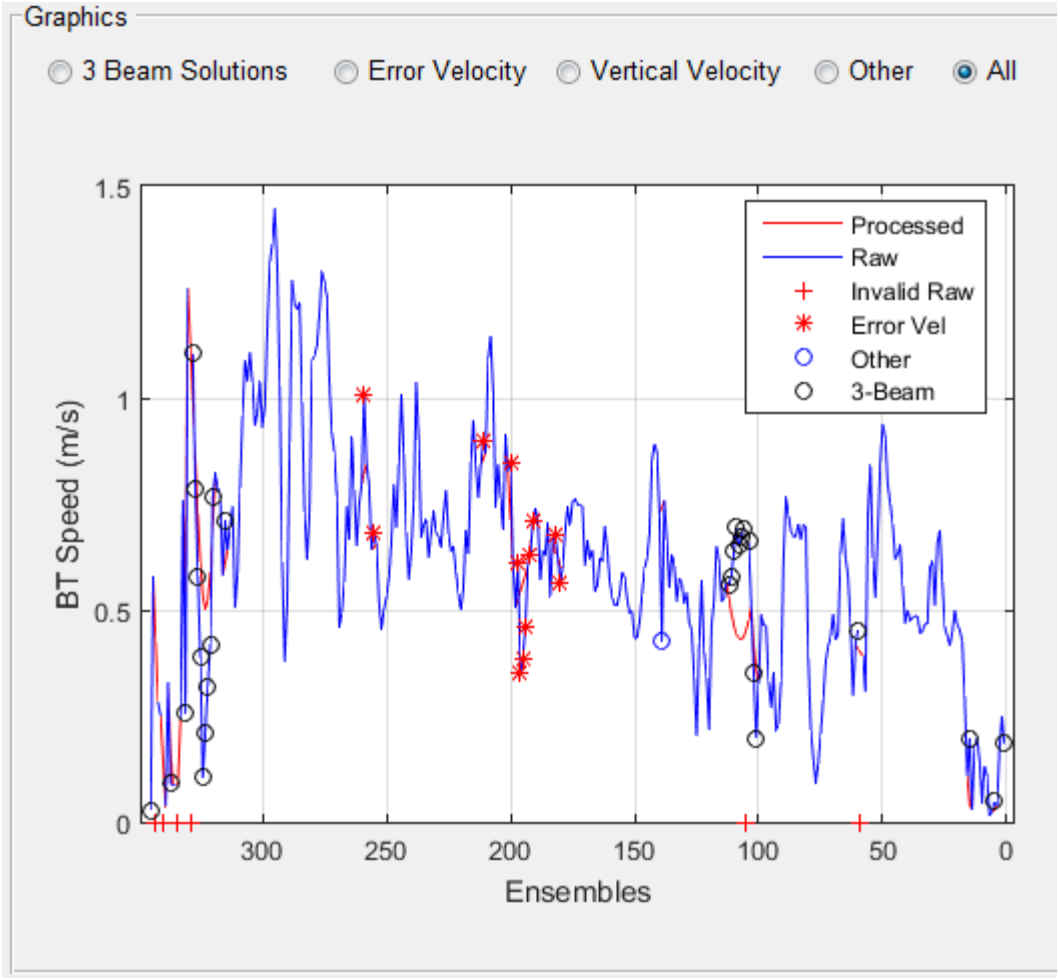


Figure 19. Example of left graph with All selected.

Filters Panel

The Filters panel shows the current settings of all filters and allows the user to change the filters as necessary (fig. 15). By default, the 3 Beam Solutions, Error Velocity, and Vertical Velocity filters are set to Auto and the Other Filter is set to Off. The user can change the filter settings by clicking on the popup menu and selecting a different option.

- ***3 Beam Solutions***
  - Auto—Evaluates 3 beams solutions using neighboring data to determine the validity of the 3 beam solution. Details are documented in Mueller (in press).
  - Allow—Allows 3 beam solutions
  - 4 Beam—Allows only 4 beam solutions
- ***Error Velocity***
  - Auto—Use the variance of the error velocity data to automatically set threshold limits for each transect. Details are documented in Mueller (in press).
  - Manual—Allows the user to enter a threshold value that will be applied to all transects in the measurement.
  - Off—No error velocity filter is applied.

- ***Vertical Velocity***
  - Auto—Use the variance of the vertical velocity data to automatically set threshold limits for each transect. Details are documented in Mueller (in press).
  - Manual—Allows the user to enter a threshold value that will be applied to all transects in the measurement.
  - Off—No vertical velocity filter is applied.
- ***Other Filter***
  - Off—No spike detection type filter is applied.
  - Smooth—A locally weighted scatterplot smoothing (LOWESS) filter with a dynamic moving window is applied. Details are documented in Mueller (in press).

Measurement Quality Checks

The ADQA checks are associated with the bottom track filters. The effect of the data marked invalid on the computed discharge is evaluated using the total discharge estimated for all invalid ensembles, the discharge estimated in consecutive invalid ensembles, and the percent of invalid ensembles. The resulting messages are preceded by BT- and the filter resulting in the warning message and by bt- and the filter resulting in the caution message. For example, All (BT-All), Original (BT-Original), Difference Velocity (BT-ErrorVel), Vertical Velocity (BT-VertVel), Other (BT-Other), and 3 Beams (BT-3Beams).

Good (Green)

Check—No filters exceeded prescribed thresholds.

Caution (Yellow)

Check—More than 5 percent of ensembles have an invalid BT velocity due to specified filter.
Message—bt-filter: The percentage of invalid ensembles in a transect exceeds 5 percent.

Check—More than 3 percent of the discharge is interpolated for consecutive ensembles with an invalid BT velocity due to specified filter.
Message—bt-filter: Interpolated discharge for consecutive invalid ensembles exceeds 3 percent.

Warning (Red)

Check—More than 25 percent of the discharge is interpolated for ensembles with an invalid BT velocity due to specified filter.
Message—BT-filter: Interpolated discharge for invalid ensembles in a transect exceeds 25 percent.

Check—More than 5 percent of the discharge is interpolated for consecutive ensembles with an invalid BT velocity due to specified filter.
Message—BT-filter: Interpolated discharge for consecutive invalid ensembles exceeds 5 percent.

GPS Filters

The GPS Filters button (fig. 1) opens a window that allows the user to evaluate the GGA and VTG data for each transect and change the filter settings (fig. 20). Filter settings are applied to all transects and cannot be set for individual transects.

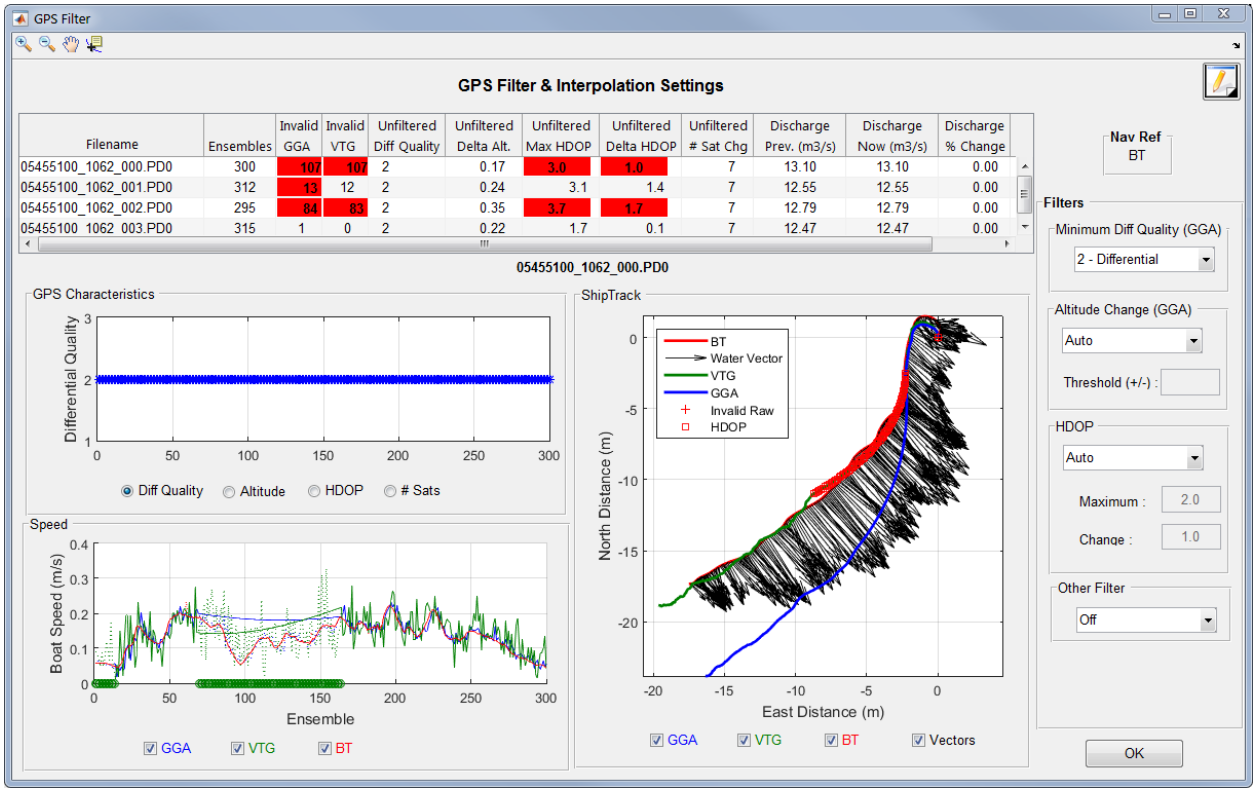


Figure 20. Global Position System (GPS) Filter window.

GPS Filter and Interpolation Settings Table

The table at the top (fig. 20) allows the user to select the transect to be graphed (by clicking on the desired row) and provides information about the quality of the GPS data. Because setting the thresholds for the GPS filters is based on best assumptions rather than statistical analysis of the data, the table lists the information about GPS quality indicators rather than the number of invalid ensembles based on each indicator. This table has no editable cells. The columns in the table are defined as follows:

- ***Filename***—Filename of the transect.
- ***Ensembles***—Total number of ensembles in the transect.
- ***Invalid GGA***—Total number of ensembles with invalid GGA data.
- ***Invalid VTG***—Total number of ensembles with invalid VTG data.
- ***Unfiltered Diff Quality***—A list of all unique differential quality values for unfiltered data.
  - 0—no position fix
  - 1—autonomous
  - 2—differential correction (DGPS)

    - 4—real-time kinematic (RTK)
    - 5—float RTK
- ***Unfiltered Delta Alt.*—**The maximum difference in altitude for an individual ensemble and the mean altitude of all ensembles using unfiltered data.
- ***Unfiltered Max HDOP*—**The maximum horizontal dilution of precision (HDOP) value for all ensembles using unfiltered data.
- ***Unfiltered Delta HDOP*—**The difference between the maximum and mean HDOP for all ensembles using unfiltered data.
- ***Unfiltered # Sat Chg*—**The number of times the number of satellites used in the position fix changed.
- ***Discharge Pre.* —**Total discharge prior to most recent filter change.
- ***Discharge Now*—**Total discharge after applying the most recent filter change. If no filters have been changed, the discharge now will equal the discharge previous.
- ***Discharge % Change*—**The percent difference between the discharge previous and the discharge now due to the last filter change.

Nav Ref Panel

To the immediate right of the table is the Nav Ref panel that shows the current navigation or boat velocity reference (fig. 20). If this reference is not GGA or VTG, then changes to these filters will not change the discharge.

GPS Characteristics Panel

The GPS Characteristics panel below the table on the left provides a time series graph of the GPS characteristics provided in the table above the panel (fig. 20). Radio buttons below the graph are used to determine what data are graphed (figs. 20–23). Data determined to be invalid by the filters are marked with a red circle.

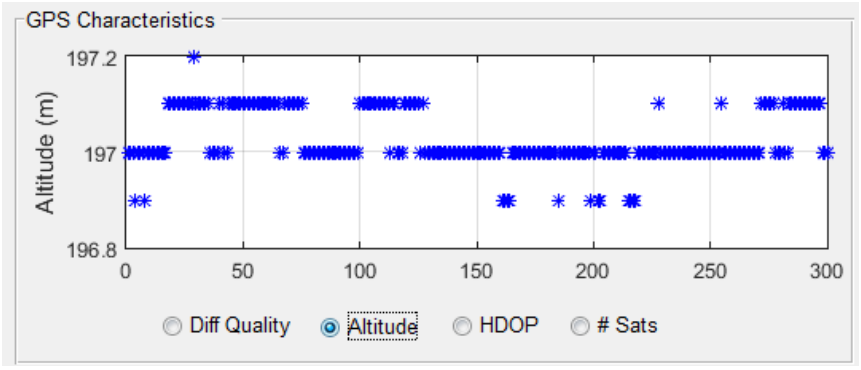


Figure 21. Example of altitude graph.

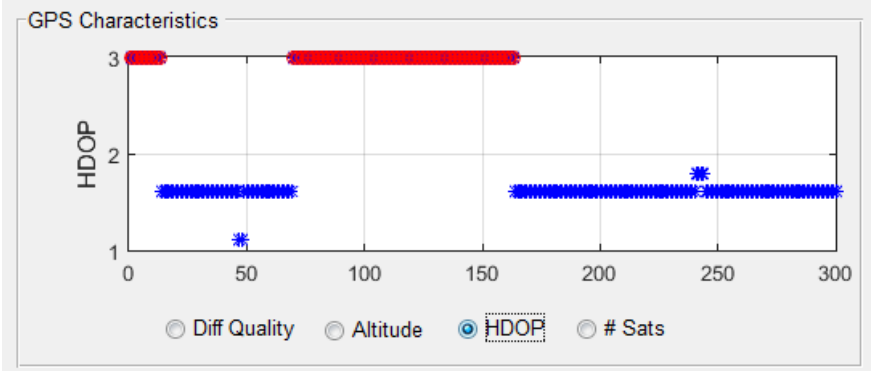


Figure 22. Example of horizontal dilution of precision (HDOP) graph.

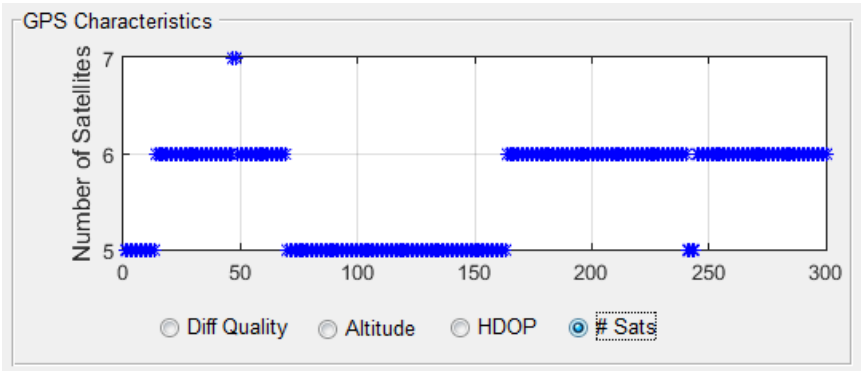


Figure 23. Example graph of number of satellites.

Speed Panel

The Speed panel below the GPS Characteristics panel provides a time series graph of the boat speed based on GGA, VTG, and BT data. The data displayed on the graph are controlled by the three check boxes at the bottom of the panel. Processed data (used to compute discharge) are shown in the graph as a solid line and raw data as dashed lines (fig. 20).

Ship Track Panel

The ShipTrack panel allows the GGA, VTG, and BT ship tracks to be compared. Invalid data are identified with a symbol, which is defined in the legend. The water vectors are only graphed on the navigation reference currently selected for discharge computation. The data shown in the graph are controlled by check boxes at the bottom of the panel (fig. 20).

Filters Panel

The Filters panel is on the right side of the window (fig. 20) and allows the user to review and change the filter settings.

- ***Minimum Diff Quality (GGA)*** —Applies to GGA data only and allows the user to set the minimum allowable differential correction quality.
  - 1 - Autonomous
  - 2 - Differential
  - 4+ - RTK

- ***Altitude Change (GGA)*** **—**Applies to GGA data only.
  - Auto—The threshold for altitude change is set to 3 meters.
  - Manual—The user can enter a user-specified threshold.
  - Off—No altitude filter is applied.
- ***HDOP*—**Applies to GGA and VTG data if GGA data are available.
  - Auto—Sets the maximum allowable HDOP to 2.0 and the maximum allowable change in HDOP to 1.0.
  - Manual—Allows the user to specify the maximum allowable HDOP and the maximum allowable change in HDOP.
  - Off—No HDOP filter is applied.
- ***Other Filter***
  - Off—No other filter is applied.
  - Smooth—A smooth filter is applied to identify spikes in the boat speed.

The values used for the automatic settings were chosen to ensure high-quality data, and experience has indicated that most valid data fit within these thresholds. However, the default thresholds for the HDOP filter are occasionally too tight and filter out what appears to be valid boat velocity data (fig. 24). When the HDOP filter is set to Auto, data with an HDOP of 3 are marked invalid and the boat velocity is linearly interpolated. An evaluation of the interpolated GGA based boat speed (solid blue line) and the raw GGA referenced boat speed (fig. 24) indicates that the raw data are more realistic than the interpolated data. In such a case, the user should change the filter to manual and adjust the threshold or turn the filter off. Figure 25 shows the data with the filter turned off, which in this case provides the best data.

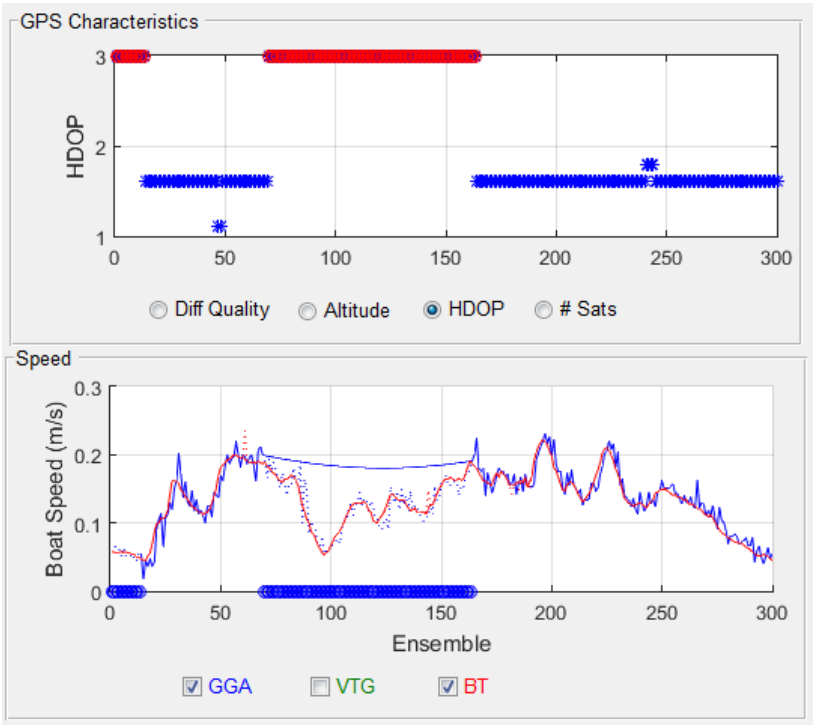


Figure 24. Example of horizontal dilution of precision (HDOP) filtering apparently valid data.

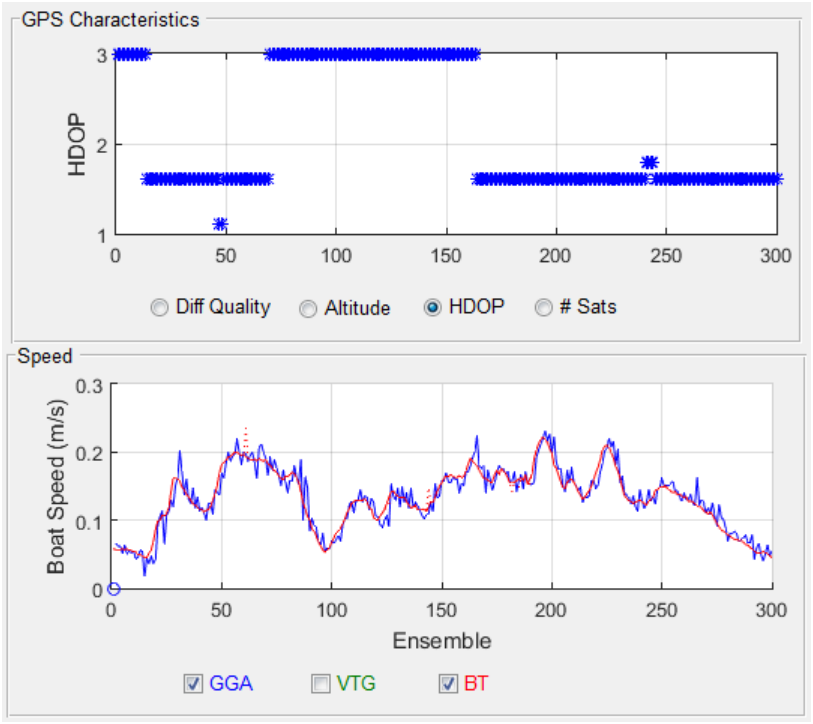


Figure 25. Example with horizontal dilution of precision (HDOP) filter turned off.

Measurement Quality Checks

The ADQA evaluates the effect of the data marked invalid on the computed discharge using the total discharge estimated for all invalid ensembles, the discharge estimated in consecutive invalid ensembles, and the percent of invalid ensembles. The resulting messages are preceded by GGA- or VTG- and the filter resulting in the warning message and by gga- or vtg- and the filter resulting in the caution message. For example, GGA All (GGA-All), GGA Original (GGA-Original), GGA Differential Correction Quality (GGA-DGPS), GGA Altitude (GGA-Altitude), GGA Other (GGA-Other), GGA HDOP (GGA-HDOP), VTG All (VTG-All), and VTG Original (VTG-Original).

Good (Green)

Check—No filters exceeded prescribed thresholds.

Caution (Yellow)

Check—More than 5 percent of ensembles have an invalid GGA or VTG velocity due to specified filter.
Message—gga- or vtg-filter: The percentage of invalid ensembles in a transect exceeds 5 percent.

Check—More than 3 percent of the discharge is interpolated for consecutive ensembles with an invalid gga or vtg velocity due to specified filter.
Message—gga- or vtg-filter: Interpolated discharge for consecutive invalid ensembles exceeds 3 percent.

Warning (Red)

Check—More than 25 percent of the discharge is interpolated for ensembles with an invalid GGA or VTG velocity due to specified filter.
Message—GGA- or VTG-filter: Interpolated discharge for invalid ensembles in a transect exceeds 25 percent.

Check—More than 5 percent of the discharge is interpolated for consecutive ensembles with an invalid gga or vtg velocity due to specified filter.
Message—GGA- or VTG-filter: Interpolated discharge for consecutive invalid ensembles exceeds 5 percent.

Select Reference

The Select Reference button (fig. 1) opens a window that allows the user to select the navigation reference and select whether or not to use composite tracks (fig. 26). Composite tracks is a feature that will automatically substitute one of the other valid navigation references for the selected navigation reference if the selected reference is invalid. The approach used for composite tracks in QRev is summarized in table 1. These settings apply to all transects and cannot be set differently for individual transects.

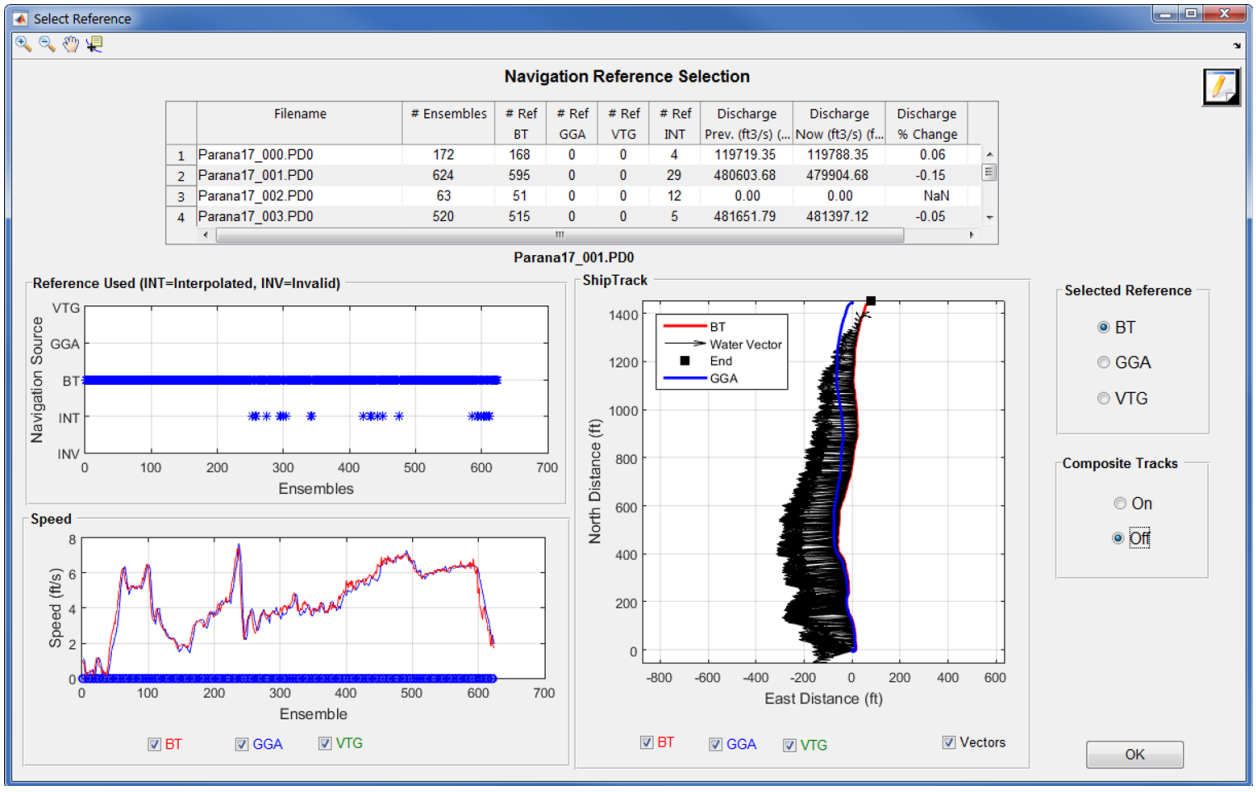


Figure 26. Select Reference window.

Table 1. Progression of navigation reference in QRev with composite tracks enabled.

Reference quality	Reference used
Bottom track (BT) selected	
BT valid	BT
BT invalid	VTG
BT invalid, VTG invalid	GGA
BT invalid, VTG invalid, GGA invalid	Interpolate from BT data
GGA selected	
GGA valid	GGA
GGA invalid	VTG
GGA invalid, VTG invalid	BT
GGA invalid, VTG invalid, BT invalid	Interpolate from GGA data
VTG selected	
VTG valid	VTG
VTG invalid	GGA
VTG invalid, GGA invalid	BT
VTG invalid, GGA invalid, BT invalid	Interpolate from VTG data

Navigation Reference Selection Table

The table at the top of the window (fig. 26) allows the user to select which transect is displayed in the graphs (by clicking on the desired row) and provides information on the number of ensembles referenced to each navigation reference.

- ***Filename*—**Filename of the transect.
- **# *Ensembles*—**Total number of ensembles in the transect.
- **# *Ref BT*—**Number of ensembles referenced to bottom track.
- **# *Ref GGA*—**Number of ensembles referenced to GGA.
- **# *Ref VTG*—**Number of ensembles referenced to VTG.
- **# *Ref INT*—**Number of ensembles for which the boat velocity has been interpolated.
- ***Discharge Prev.*—**Total discharge prior to most recent filter change.
- ***Discharge Now*—**Total discharge after applying the most recent filter change. If no filters have been changed, the discharge now will equal the discharge previous.
- ***Discharge % Change*—**The percent difference between the discharge previous and the discharge now due to the last filter change.

Graphs

Three graphs are available to assist the user in selecting the best navigation reference settings. Immediately below the table is the filename of the transect being displayed in the graphs (figs. 26 and 27). The Reference Used panel on the left, below the table, displays a time series of the reference used for each ensemble of the selected transect. The Speed panel below the GPS Characteristics panel provides a time series graph of the boat speed based on GGA, VTG, and BT data. The data displayed on the graph are controlled by the three check boxes at the bottom of the panel. The Ship Track panel allows the GGA, VTG, and BT ship tracks to be compared. The water vectors are graphed only on the navigation reference currently selected for discharge computation. The data shown in the graph are controlled by check boxes at the bottom of the panel.

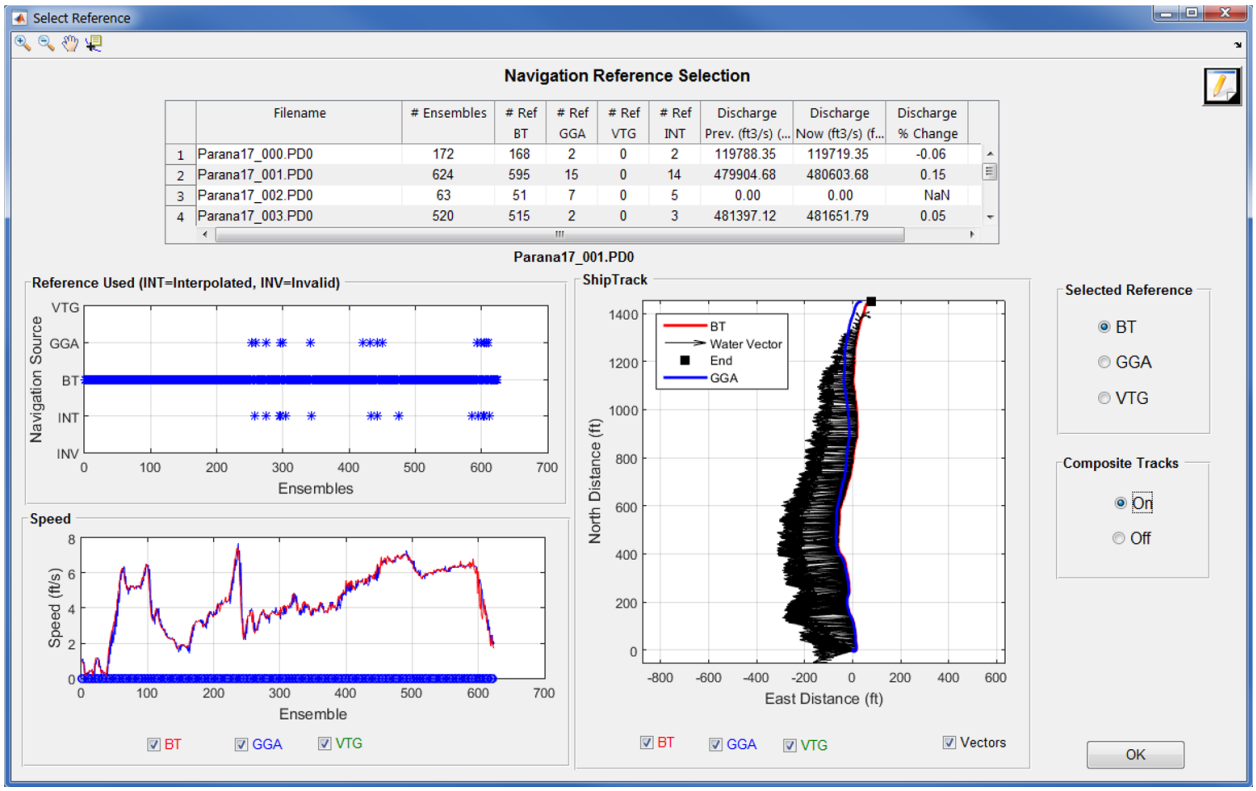


Figure 27. Example of data with some invalid bottom track (BT) and Composite Tracks turned on.

Selected Reference and Composite Tracks Panels

The selected reference and whether or not composite tracks are used are set by the user using the radio buttons in the Selected Reference and Composite Tracks panels (figs. 26 and 27). QRev defaults the navigation reference to that used in the raw data. Composite tracks defaults to off. Setting composite tracks to on will result in changes to the boat velocities if the selected reference has invalid boat velocities. When Composite Tracks is turned on, some of the ensembles are referenced to GGA (fig. 27), and some ensembles are still interpolated. Some of the ensembles with invalid BT had valid GGA data that could be used; however, other ensembles with invalid BT did not have valid GGA or VTG data, and the boat velocity had to be interpolated.

Depth Filters

The Depth Filters button (fig. 1) opens a window that allows the user to review the measured depths from each beam and the final mean depth (fig. 28). The user can also change the primary depth reference and indicate whether or not to use composite depths. QRev defaults to using inverse depth weighting to compute the mean depth when the 4 slant beams are used. The user can also change the filter type to try and eliminate unreasonable and erroneous spikes in the data.

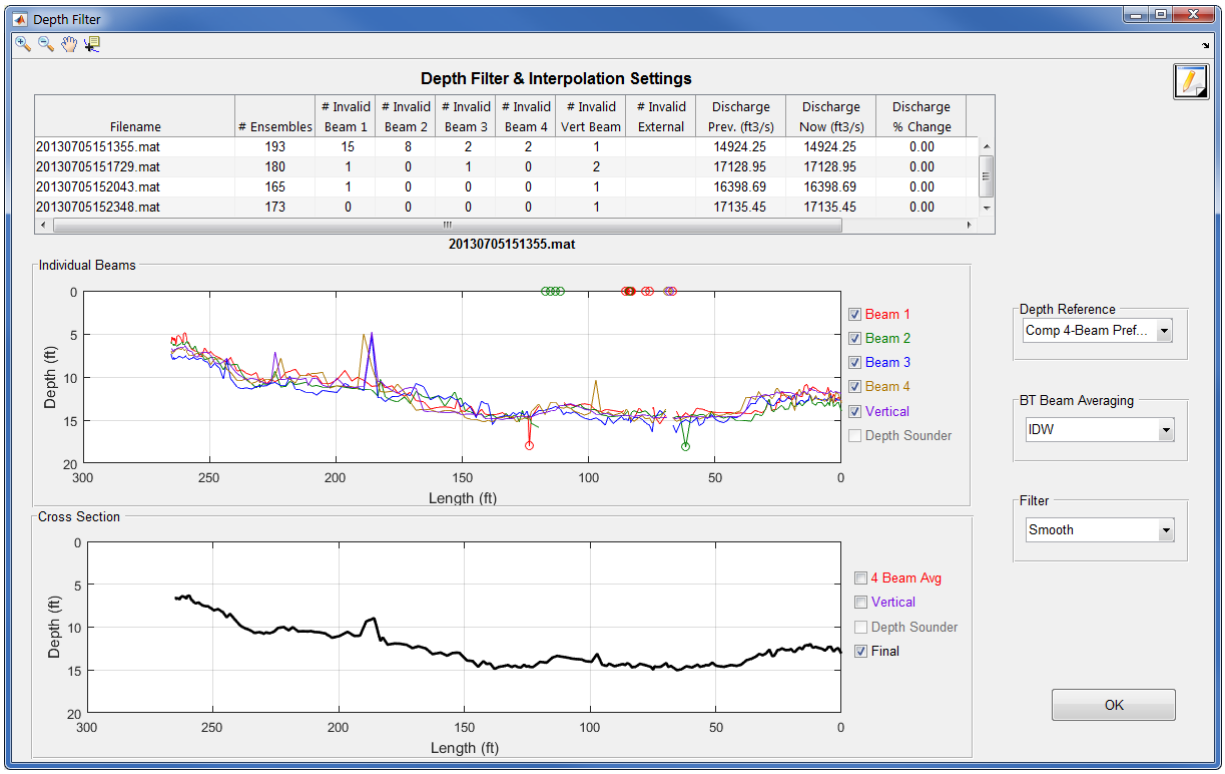


Figure 28. Depth filter window.

Depth Filter and Interpolation Settings Table

The table at the top (fig. 28) allows the user to select which transect is displayed in the graphs (by clicking on the desired row) and provides information on beams with invalid depths.

- ***Filename***—Filename of the transect.
- ***# Ensembles***—Number of ensembles in the transect.
- ***# Invalid Beam 1***—Number of ensembles where the depth in beam 1 is invalid.
- ***# Invalid Beam 2***—Number of ensembles where the depth in beam 2 is invalid.
- ***# Invalid Beam 3***—Number of ensembles where the depth in beam 3 is invalid.
- ***# Invalid Beam 4***—Number of ensembles where the depth in beam 4 is invalid.
- ***# Invalid Vert Beam***—Number of ensembles where the depth in the vertical beam is invalid.
- ***# Invalid External***—Number of ensembles where the depth from the external depth sensor is invalid.
- ***Discharge Prev.*** —Total discharge prior to most recent filter change.
- ***Discharge Now***—Total discharge after applying the most recent filter change. If no filters have been changed, the discharge now will equal the discharge previous.
- ***Discharge % Change***—The percent difference between the discharge previous and the discharge now due to the last filter change.

Individual Beams Panel

The Individual Beams panel below the table displays the cross section as measured by each individual beam (fig. 28). All available beams or depth sources are active in the graphs. The user can

check or uncheck the check box associated with each beam to display or hide that beam; this action does not affect the computations. The circles at the top of the graph identify ensembles that have no depth. Circles on the lines of the individual beams indicate a depth that has been determined to be invalid based on the selected filters. The color of the line or circle corresponds to the beam or depth source.

Cross Section Panel

The Cross Section panel displays the final cross section (fig. 28). The final cross section is based on the selected depth reference and the results of the filters and interpolation. The check boxes to the right can be used to compare the final cross section to other alternatives.

Depth Reference Panel

The Depth Reference is a popup menu that allows the user to select from all available depth sources.

- ***4 Beam Avg—***The ensemble depth is computed as the average of the 4 slant beams.
- ***Comp 4 Beam Preferred—***The ensemble depth is computed as the average of the 4 slant beams, but if that results in an invalid depth, other available valid depth sources will be substituted according to the priority defined in table 2.
- ***Vertical—***The depth from the vertical beam is used as the ensemble depth.
- ***Comp Vertical Preferred—***The ensemble depth is the vertical beam depth, but if the vertical beam depth is invalid, other available valid depth sources will be substituted according to the priority defined in table 2.
- ***Depth Sounder—***The depth from an external depth sounder is used as the ensemble depth.
- ***Comp DS Preferred—***The ensemble depth is the external depth sounder depth, but if the depth from the external depth sounder is invalid, other available valid depth sources will be substituted according to the priority defined in table 2.

Table 2. QRev priority for composite depths

[BT, average depth from four slant beams; DS, depth from external depth sounder; VB, depth from vertical beam]

Primary	BT	VB	DS
1st option	DS	DS	VB
2d option	VB	BT	BT
3d option	Interpolated BT	Interpolated VB	Interpolated DS

BT Beam Averaging Panel

BT Beam Averaging determines if the average depth from the 4 slant beams is computed using a simple average or an inverse depth-weighted method. The inverse depth-weighted method is preferred and the QRev default. However, to allow duplication of RSL computations, the simple average option is available.

Filter Panel

The two options available to filter out spikes in the depths are the method used in WR2 and a method based on a LOWESS smooth. The method used in WR2 will tend to filter out the lowest (deepest) data because the method was designed to filter out multiple reflections. The LOWESS smooth

filter only works well with continuous data. Gaps in the data can cause the LOWESS smooth filter to miss what appear to be obvious spikes. The filter can also be turned off.

Measurement Quality Checks

The ADQA evaluates the effect of invalid depths on the computed discharge using the total discharge estimated for all invalid ensembles, the discharge estimated in consecutive invalid ensembles, and the percent of invalid ensembles.

Good (Green)

***Check*—**No filters exceeded prescribed thresholds.

Caution (Yellow)

***Check*—**More than 5 percent of ensembles have an invalid average depth.
***Message*—**Depth: The percentage of invalid ensembles in a transect exceeds 5 percent.

***Check*—**More than 3 percent of the discharge is interpolated for consecutive ensembles with an invalid average depth.
***Message*—**Depth: Interpolated discharge for consecutive invalid ensembles exceeds 3 percent.

Warning (Red)

***Check*—**More than 25 percent of the discharge is interpolated for ensembles with an invalid average depth.
***Message*—**DEPTH: Interpolated discharge for invalid ensembles in a transect exceeds 25 percent.

***Check*—**More than 5 percent of the discharge is interpolated for consecutive ensembles with an invalid average depth.
***Message*—**DEPTH: Interpolated discharge for consecutive invalid ensembles exceeds 5 percent.

Water Track (WT) Filters

The WT Filters button (fig. 1) opens a window that allows the user to evaluate the water track data for each transect and change the filter settings (fig. 29). Filter settings are applied to all transects and cannot be set for individual transects.

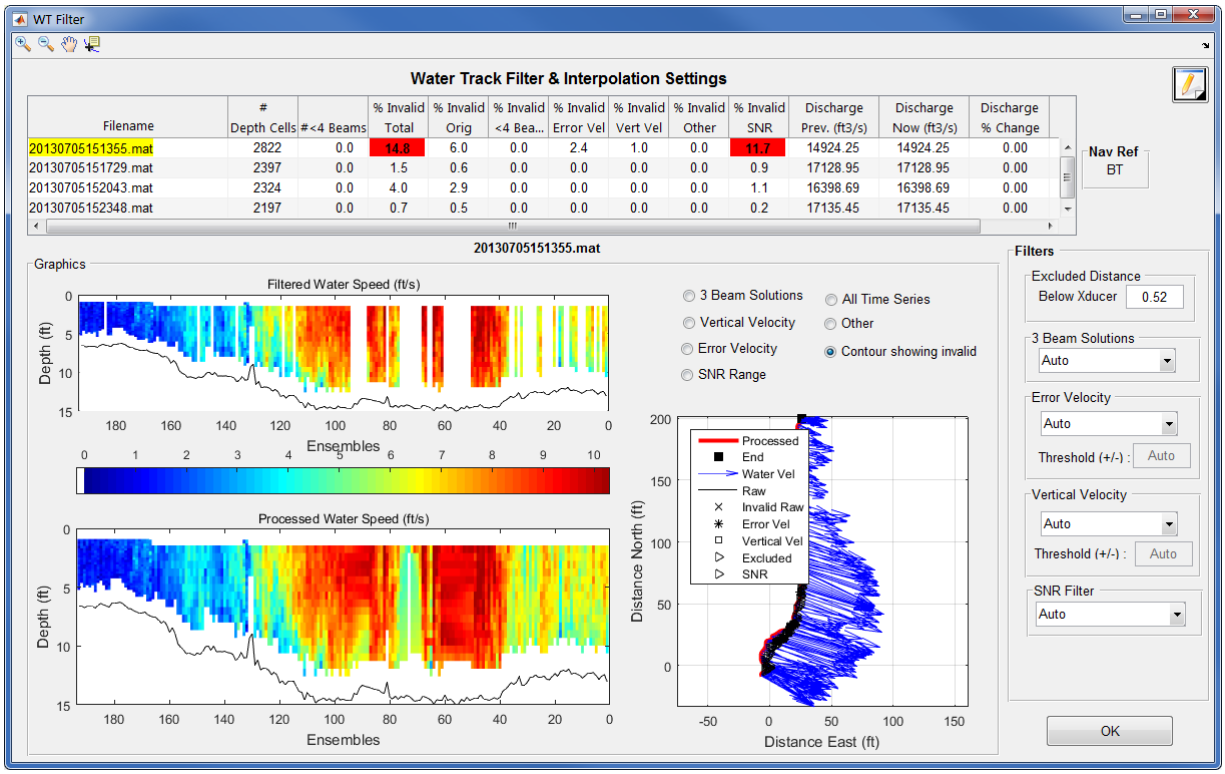


Figure 29. Water Track (WT) Filter window.

Water Track Filter and Interpolation Settings Table

The table at the top of the window allows the user to select which transect to graph (by clicking on the desired row), provides information on the number of depth cells that have been determined to be invalid by the various filters, and shows the effect of a filter change on the computed discharge (fig. 29). Cells in the table contain color codes associated with cautions or warnings generated from the ADQA. No editable cells are in this table. The columns in the table are as follows:

- ***Filename***—Filename of the transect.
- ***# Depth Cells***—Total number of depth cells in the transect.
- ***% <4 Beams***—Number of ensembles that had valid water track in less than 4 beams.
- ***% Invalid Total—N***umber of ensembles with invalid water track velocity.
- ***% Invalid Orig***—Number of ensembles that had invalid water track velocity prior to any filtering.
- ***% Invalid <4 Beams***—Number of ensembles with valid water track in less than 4 beams for which the water track velocity has been determined to be invalid.
- ***% Invalid Error Vel***—Number of ensembles that have been determined to be invalid due to filtering based on the water track error velocity.
- ***% Invalid Vert Vel***—Number of ensembles that have been determined to be invalid due to filtering based on the water track vertical velocity.
- ***% Invalid Other***—Number of ensembles that have been determined to be invalid due to filtering using other filters. Currently (2015) other filters are not implemented.
- ***% Invalid SNR***—Number of ensembles that have been determined to be invalid due to filtering of the signal to noise ratio (SNR) range. This filter applies to SonTek data only.

- ***Discharge Prev.*** —Total discharge prior to most recent filter change.
- ***Discharge Now***—Total discharge after applying the most recent filter change. If no filters have been changed, the discharge now will equal the discharge previous.
- ***Discharge % Change***—The percent difference between the discharge previous and the discharge now due to the last filter change.

Nav Ref Panel

To the right of the table is the Nav Ref panel (fig. 29), which shows the current navigation reference.

Graphics Panel

The Graphics panel below the table consists of two or three graphs depending on the type of data graphed. The filename of the transect being graphed is shown just above the Graphics panel (fig. 29).

The right portion of the Graphics panel is always a ship track graph (fig. 29). The ship track graph displays the processed ship track for the selected navigation reference. The location and source of invalid data are indicated by symbols shown in the graph legend. The end of the transect is indicated by a black square so the user can determine the direction of boat travel.

The configuration of the left portion of the Graphics panel is determined from the type of data graphed, which is selected by the user using the radio buttons above the ship track graph (fig. 29). For 3 Beam Solutions, Error Velocity, Vertical Velocity, SNR Range, and Contour showing invalid, the left portion of the Graphics panel will display two graphs. The default is to display a color contour graph showing only valid data without interpolation (fig. 29). The top graph will display a time series graph for the other types of data selected—3-Beam Solutions (fig. 30), Vertical Velocity (fig. 31), Error Velocity (fig. 32), and SNR Range (fig. 33). With the exception of 3 Beam Solutions, the time series shows every valid depth cell. Showing every depth cell allows the user to visually evaluate the magnitude and variance of the data. Invalid data are identified by red circles. The bottom graph will be a color contour graph showing full processed data including interpolation (fig. 29). These data will be used to compute discharge. If All Time Series or Other is selected from the radio buttons (fig. 29), the left graph is a single time series graph (figs. 34 and 35, respectively). Currently, other filters have not been implemented; therefore, the other graph is a times series of the average water speed for each ensemble.

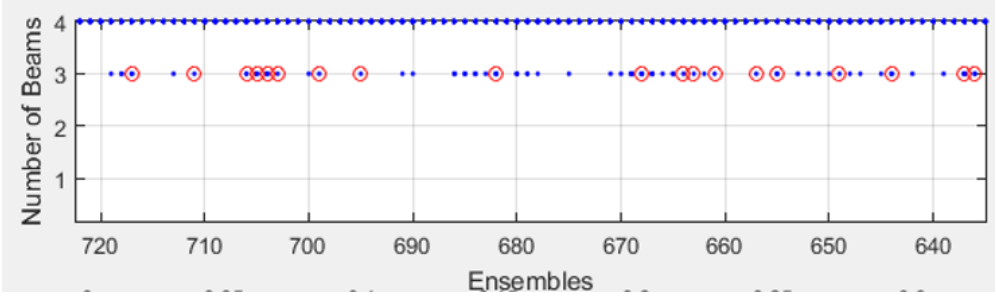


Figure 30. Water track 3 Beam Solutions graph.

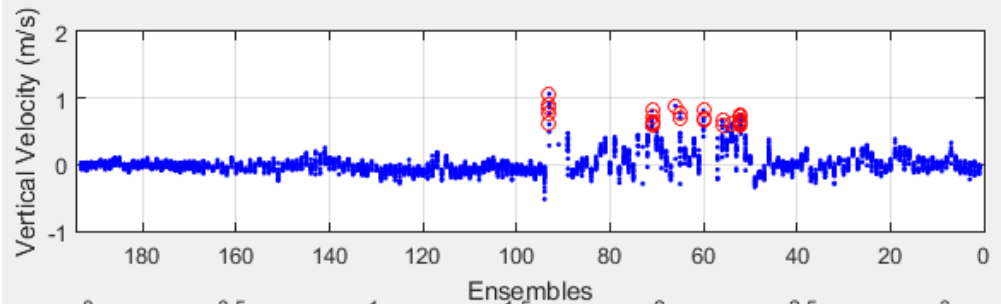


Figure 31. Water track Vertical Velocity graph.

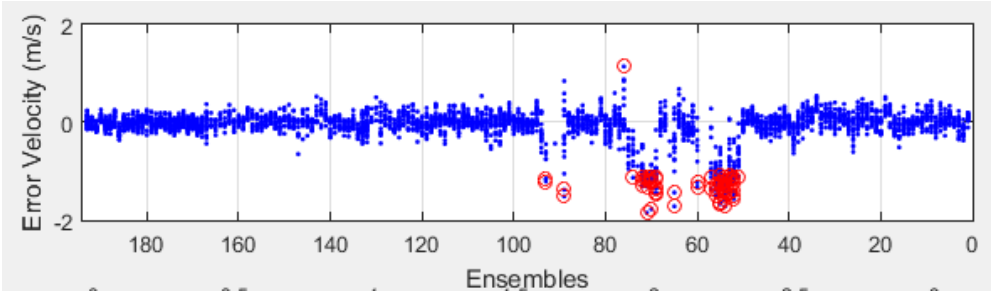


Figure 32. Water track Error Velocity graph.

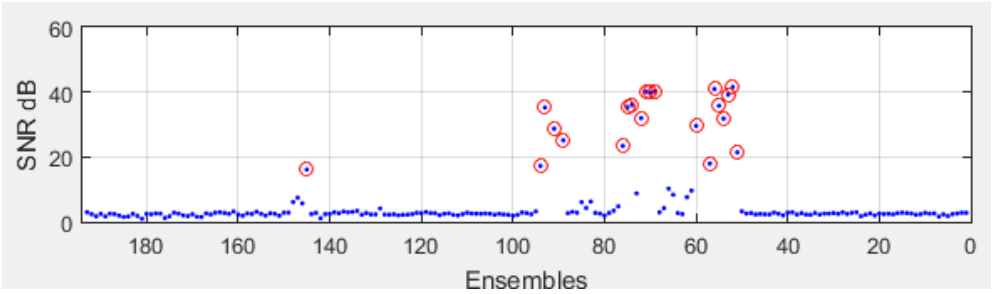


Figure 33. Water track signal to noise ratio (SNR) graph.

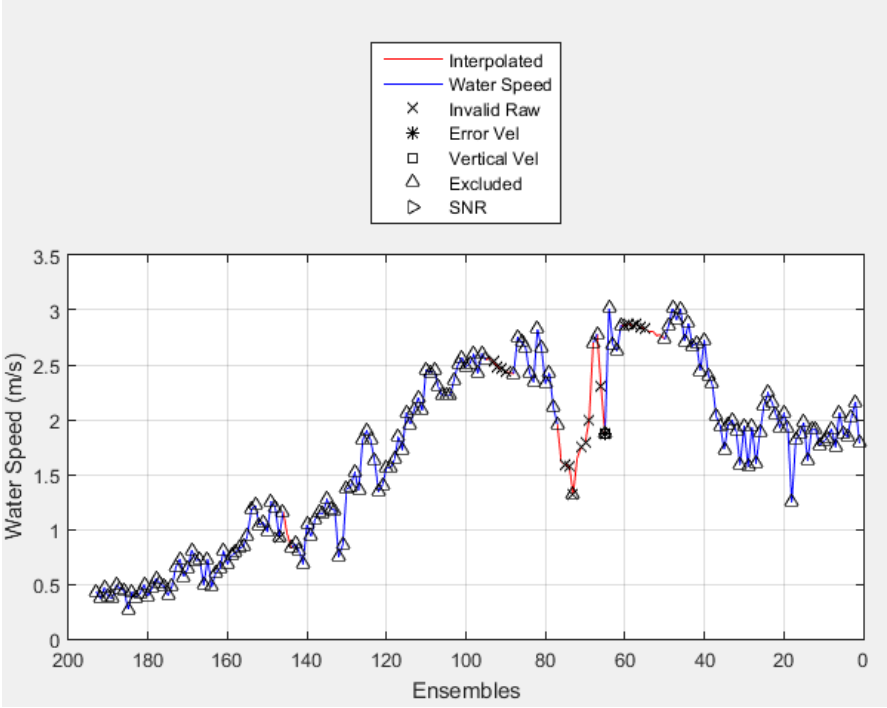


Figure 34. Water track All Time Series graph.

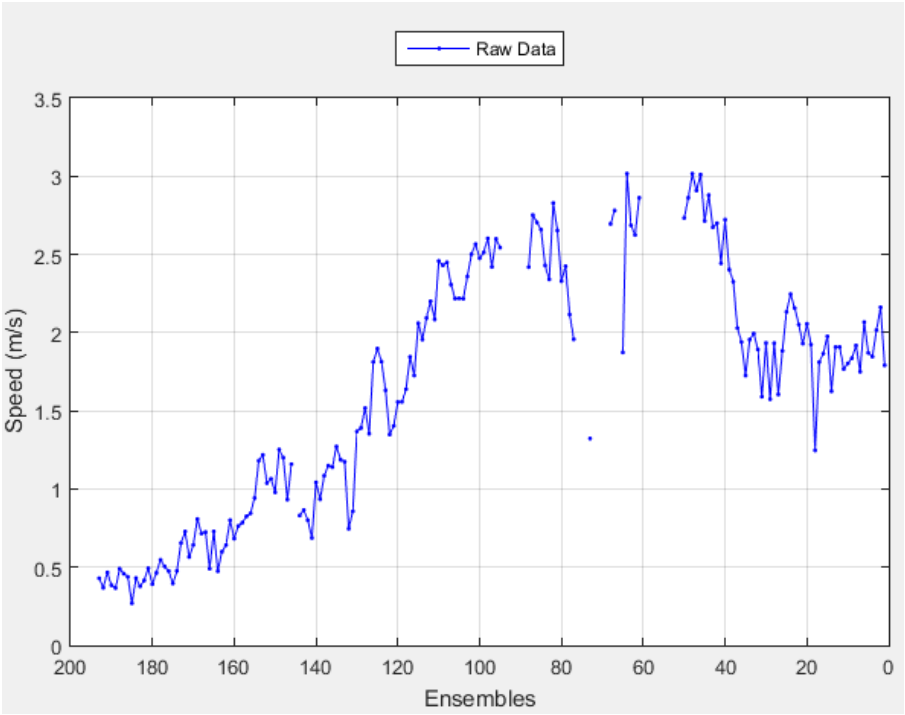


Figure 35. Water track Other graph.

Filters Panel

The Filters panel shows the current settings of all WT filters and allows the user to change the filters as necessary (fig. 29). The Excluded Distance is the distance below the transducer for which measured WT data will not be used and defaults to 16 centimeters for SonTek M9 ADCPs (U.S. Geological Survey, 2014) and to zero for TRDI ADCPs. By default, the 3 Beam Solutions, Error Velocity, and Vertical Velocity filters are set to Auto. The SNR filter is set to Auto for RSL data but is inactive for WR2 data. The user can change the filter settings by clicking on the popup menu and selecting a different option.

- ***3 Beam Solutions***
  - Auto—Evaluates 3-beams solutions using neighboring data to determine the validity of the 3 beam solution. Details are documented in Mueller (in press).
  - Allow—Allows 3 beam solutions.
  - 4 Beam Only—Allows only 4 beam solutions.
- ***Error Velocity***
  - Auto—Uses the variance of the error velocity data to automatically set threshold limits for each transect. Details are documented in Mueller (in press).
  - Manual—Allows the user to enter a threshold value that will be applied to all transects in the measurement.
  - Off—No error velocity filter is applied.
- ***Vertical Velocity***
  - Auto—Uses the variance of the vertical velocity data to automatically set threshold limits for each transect. Details are documented in Mueller (in press).
  - Manual—Allows the user to enter a threshold value that will be applied to all transects in the measurement.
  - Off—No vertical velocity is applied.
- ***SNR Filter***
  - Auto—The SNR filter is applied with predetermined thresholds to RSL data only. Details are documented in Mueller (in press).
  - Off—No SNR filter is applied.

Measurement Quality Checks

The ADQA evaluates the effect of the data marked invalid on the computed discharge using the following: the total discharge estimated for all invalid ensembles, the discharge estimated in consecutive invalid ensembles, and the percent of invalid ensembles. The resulting messages are preceded by WT- and the filter resulting in the warning message and by wt- and the filter resulting in the caution message. For example, All (WT-All), Original (WT-Original), Error Velocity (WT-ErrorVel), Vertical Velocity (WT-VertVel), Other (WT-Other), and 3 Beams (WT-3Beams).

Good (Green)

Check—No filters exceeded prescribed thresholds.

Caution (Yellow)

Check—More than 5 percent of ensembles have an invalid WT velocity due to specified filter.
Message—wt-filter: The percentage of invalid ensembles in a transect exceeds 5 percent.

Check—More than 3 percent of the discharge is interpolated for consecutive ensembles with an invalid WT velocity due to specified filter.
Message—WT-filter: Interpolated discharge for consecutive invalid ensembles exceeds 3 percent.

Warning (Red)

Check—More than 25 percent of the discharge is interpolated for ensembles with an invalid WT velocity due to specified filter.
Message—WT-filter: Interpolated discharge for invalid ensembles in a transect exceeds 25 percent.

Check—More than 5 percent of the discharge is interpolated for consecutive ensembles with an invalid WT velocity due to specified filter.
Message—WT-filter: Interpolated discharge for consecutive invalid ensembles exceeds 5 percent.

Extrapolation

The Extrapolation button (fig. 1) opens a window that is similar to the extrap program (Mueller, 2013), except the extrapolation window has been redesigned with buttons instead of menus (fig. 36). QRev defaults to the extrapolation settings determined automatically from the extrap algorithms. The user can use the Extrapolation window to switch to or explore other extrapolation settings, apply manually selected extrapolation settings, and evaluate the sensitivity of the discharge to the extrapolation settings. The user can explore different extrapolation settings without applying them to the measurement if "Cancel" is selected to close the window.

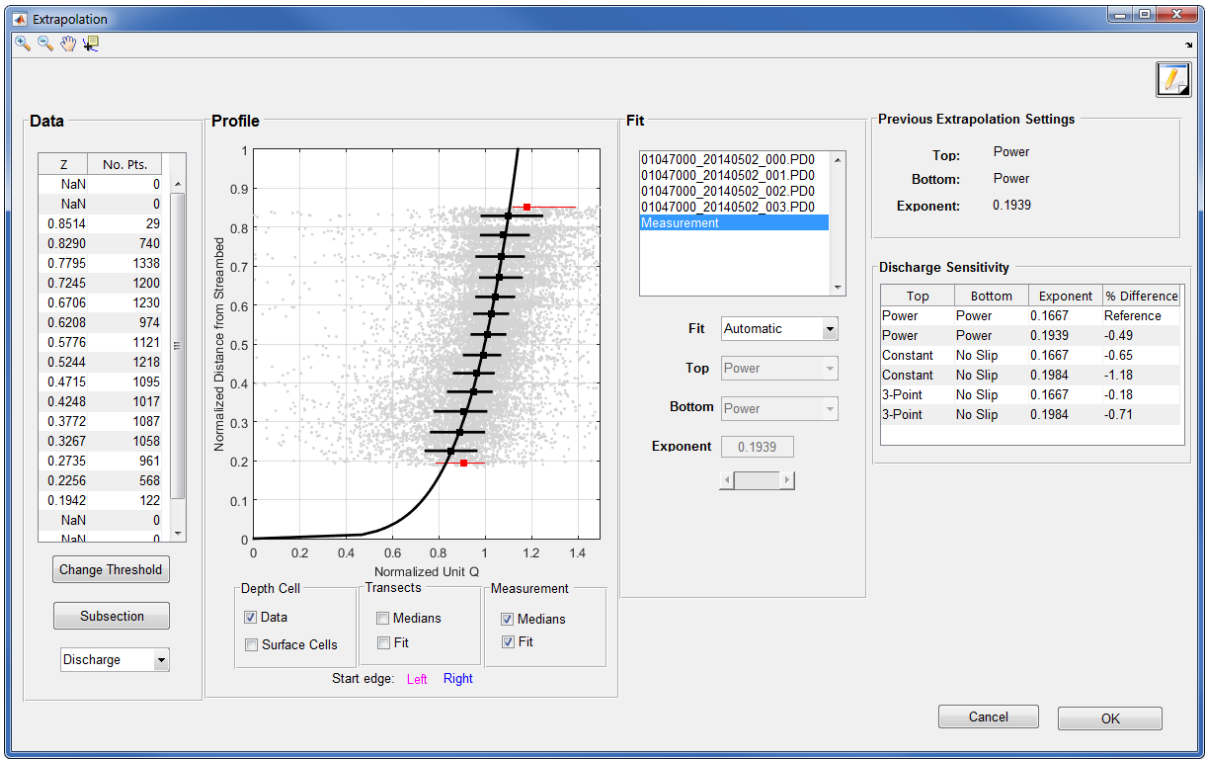


Figure 36. Extrapolation window.

Previous Extrapolation Settings Panel

The extrapolation settings when the window was opened are shown in the upper right panel labeled "Previous Extrapolation Settings" (fig. 36) and are the extrapolation settings that will be used when exiting with "Cancel". Selecting "OK" exits the window and applies the currently selected settings.

Data Panel

The normalized distance from the streambed is divided into 5 percent segments (0.05; from 0 to 1). A median value of the normalized unit discharge is then computed for each segment, and the result is assigned to the average normalized depth of the data in that segment. The location of the mean normalized depth for each segment and number of points used in each segment are reported in the Data panel (fig. 36). To help ensure that the median profile is representative of the data and not overly influenced by a few points in the top or bottom segments, only median values with sufficient points to exceed a specified threshold are used in the computation of the extrapolation. The default threshold is set to 20 percent of the median number of points for all segments. The threshold can be changed by the user using the Change Threshold button in the Data panel. The median points for an individual transect are colored blue if the number of points in the segment exceeds the threshold.

At the bottom of the Data panel, a drop down menu is available that allows the user to select discharge or velocity data (fig. 36). Discharge is the default and is recommended for all moving-boat measurements. The other two options in the Data panel are explained as follows:

- ***Change Threshold—***Allows the user to change the cutoff threshold from the default value of 20 percent of the median number of points in all the segments to a user defined value.
- ***Subsection—***Allows the user to look only at a subsection of the data by entering a lower and upper discharge range. The range is applied from the beginning of the transect independent of the starting bank. This range is only applied to the profile evaluation and does not affect the discharge sensitivity analysis. For example, if the user wanted to look at the profile for the center 50 percent of the discharge, 25 should be entered for the lower limit and 75 for the upper limit.

Profile Panel

The primary panel in the extrapolation dialog window is the Profile panel (fig. 36). The graph in the profile panel displays the following data depending on the selections made in the check boxes below the graph.

- ***Data (Gray Dots)***—The raw data represent the normalized discharge or velocity in each depth cell for all transects selected in the Fit panel.
- ***Surface Cells (Green circles)—***Cells that are the top cell for each ensemble.
- ***Median Points (Blue/Red/Black Squares)—***If the number of points in a segment does not exceed the threshold value, the median point is colored red and is not used in the computation of the extrapolation. Solid black squares represent the median values of the composite of all transects in the measurement.
- ***Whiskers (Horizontal Blue/Red/Black Lines)—***The whiskers on each median value represent the 25th and 75th percentile of all the data in that 5 percent increment. Thus, 50 percent of the data for that increment fall within the limits of the whiskers. Colors are representative of the type of median value.
- ***Extrapolation (Solid Blue/Magenta/Black Line)—***The extrapolation fits are color coded such that magenta lines represent transects collected in the left to right direction, blue lines represent

transects collected in the right to left direction, and the black line represents the composite of all transects in the measurement.

The controls at the bottom of the graph are described below:

- ***Depth Cell***
  - Data—Turns on and off the display of the cell data (gray dots).
  - Surface Cells—Highlights the cells that are the top cell for each ensemble.
- ***Transects***
  - Medians—Turns on and off the display of the median points for each transect.
  - Fit—Turns on and off the display of the extrapolation fit for each transect.
- ***Measurement***
  - Median—Turns on and off the display of the median points for the composite measurement.
  - Fit—Turns on and off the display of the extrapolation fit for the composite measurement.

Fit Panel

The Fit panel (fig. 36) provides the user the ability to control what data are shown in the Profile and Data panels and change the fit type, extrapolation methods, and exponent. The transect selection list shows the filename of the transects loaded and the composite for the measurement ("Measurement"). The default is for the composite measurement to be shown. To view a specific transect, click on the transect filename, and the graph and fit characteristics for that transect will be shown. The fit characteristics of an individual transect can be changed; however, because QRev uses only one set of fit characteristics for the measurement, only the settings for "Measurement" are used in the discharge computation.

- ***Fit—***The fit popup menu allows the user to change the fit type from the default automatic algorithms to Manual. If Manual is selected, the Top, Bottom, Exponent, and slider will become active.
- ***Top—***The Top popup menu displays the top extrapolation method. This popup menu cannot be changed unless Fit is changed to Manual. The options are Power and Constant.
- ***Bottom—***The Bottom popup menu displays the bottom extrapolation method. This popup menu cannot be changed unless Fit is changed to Manual. The options are Power and No Slip.
- ***Exponent—***The Exponent edit box displays the exponent for the power or no slip extrapolations. The exponent cannot be changed unless Fit is changed to Manual. If fit is changed to manual, the exponent can be changed by manually typing a value in the edit box or by using the slider below the box to incrementally change the value.

Discharge Sensitivity Panel

The sensitivity of the extrapolation method for the top and bottom extrapolation is evaluated by computing the discharge for each combination of top and bottom extrapolation methods with a default and with least squares fit exponents and reporting the percent difference from the one-sixth power/power fit. If a manual fit is used for the composite measurement, then an additional line will be added to the table that represents the manual fit. This table can be used to help determine the effect of extrapolation choices on the final discharge.

Measurement Quality Checks

Good (Green)

Check—Selected extrapolation methods results in a mean discharge with an uncertainty due to extrapolation of less than 2 percent.

Caution (Yellow)

Check—Selected extrapolation methods results in an uncertainty in discharge due to extrapolation methods of greater than 2 percent.
Message—Extrapolation: The extrapolation uncertainty is more than 2 percent. Carefully review the extrapolation.

Edges

The Edges button (fig. 1) opens a window that allows the user to review and change settings associated with the discharge computations (fig. 37). This window has a table containing the edge setting and graphs to evaluate The Edges window displays a table that lists the edge settings and graphs that show the data used to compute the left and right edge discharges.

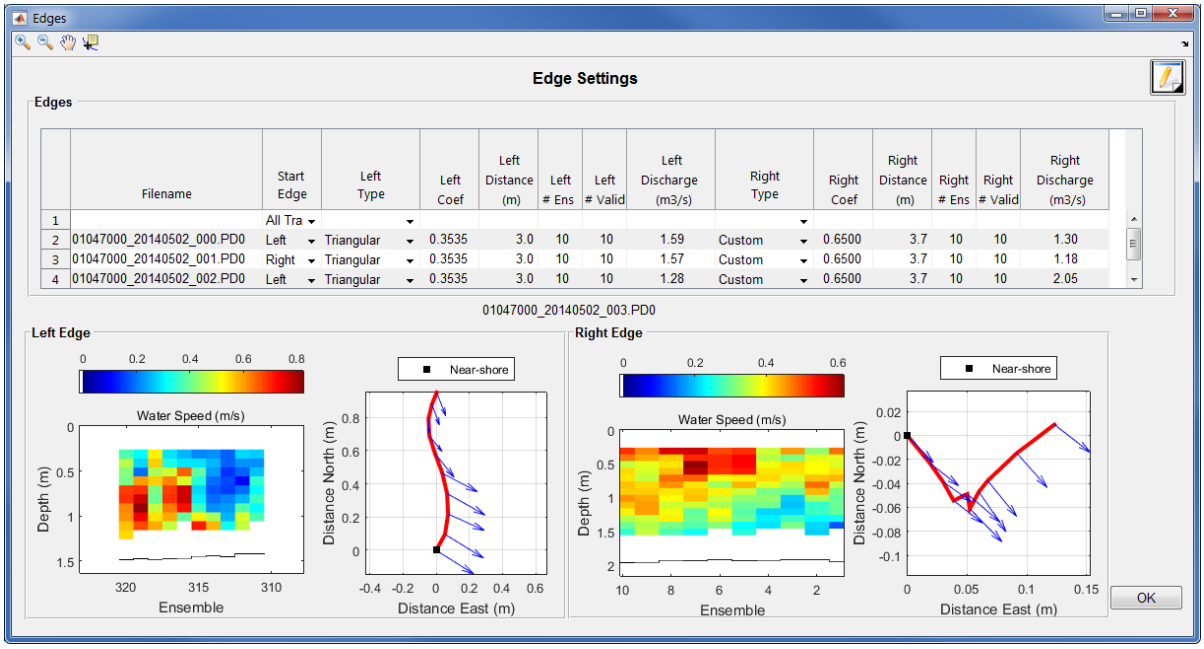


Figure 37. Edges window.

Edge Settings Table

The table at the top of the window (fig. 37) allows the user to select what transect is graphed (by clicking on the desired row) and allows the user to change edge settings. The table contains the following information:

- ***Filename*—**Filename of transect.
- ***Start Edge*—**Specifies at what edge the transect was started (Left or Right).
- ***Left Type*—**Specifies the type of edge for the left bank.
  - *Triangular*—Sets the left coefficient to 0.3535.
  - *Rectangular*—For TRDI and QRev processing (WR2 and RSL data), sets the left coefficient to 0.91. For SonTek processing, an equation is used to set the coefficient (Mueller, in press).
  - *Custom*—Allows the user to type a custom coefficient in the Left Coef column.
  - *User Q*—Allows the user to not specify a coefficient but rather to specify the discharge in the left edge by entering the discharge in the Left Discharge column.
- ***Left Coef*—**Coefficient, C, in the equation ($Q_{edge} = C * L * D * V$) for computing the left edge discharge.
- ***Left Distance*—**The user measured distance (L) from the end of the transect to the water's edge on the left bank.
- ***Left # Ens*—**The number of ensembles specified to determine the water velocity (V) and depth (D) for the edge discharge equation.
- ***Left # Valid*—**The number of left edge ensembles that contain valid data that are used to determine the water velocity (V) and depth (D) for the edge discharge equation.
- ***Left Discharge*—**The discharge computed or entered (User Q) for the left unmeasured edge.
- ***Right Type*—**Specifies the type of edge for the right bank.
  - *Triangular*—Sets the right coefficient to 0.3535.
  - *Rectangular*—For TRDI and QRev processing (WR2 and RSL data), sets the right coefficient to 0.91. For SonTek processing, an equation is used to set the coefficient (Mueller, in press).
  - *Custom*—Allows the user to type a custom coefficient in the Right Coef column.
  - *User Q*—Allows the user to not specify a coefficient but rather to specify the discharge in the right edge by entering the discharge in the Right Discharge column.
- ***Right Coef*—**Coefficient, C, in the equation ($Q_{edge} = C * L * D * V$) for computing the right edge discharge.
- ***Right Distance*—**The user measured distance (L) from the end of the transect to the water's edge on the right bank.
- ***Right # Ens*—**The number of ensembles specified to determine the water velocity (V) and depth (D) for the edge discharge equation.
- ***Right # Valid*—**The number of right edge ensembles that contain valid data that are actually used to determine the water velocity (V) and depth (D) for the edge discharge equation..
- ***Right Discharge*—**The discharge computed or entered (User Q) for the right unmeasured edge.

A setting for an individual transect can be changed by clicking on the setting and selecting or entering the desired setting. Changing the setting for all transects can be accomplished by clicking in the appropriate column in the top row of the table and selecting or entering the desired setting, which will then be applied to all transects.

Left and Right Edge Panels

The data used in the computation of the left and right edge discharges are displayed in the Left Edge and Right Edge panels below the table (fig. 37). The transect data displayed are selected by clicking on the filename in the table. The filename of the transect being displayed is below the table and just above the left and right edge panels. Each edge panel contains a color contour graph of the water speed and a ship track graph. These graphs only contain data from the edge ensembles. The color contour graph should be used to evaluate the consistency of the depth and water speed. The ship track graph should be used to evaluate boat movement during the collection of the edge ensembles. The black square also indicates the end of the transect closest to shore. The blue arrows represent the depth averaged velocity vectors.

Measurement Quality Checks

The Edges button (fig. 1) may be colored and messages provided based on the following ADQA checks.

Good (Green)

Edges pass all quality checks.

Caution (Yellow)

***Check*—**Edge discharges have inconsistent signs.
***Message*—**Edges: Sign of edge discharge is not consistent.

Warning (Red)

***Check*—**Discharge in each edge is nonzero.
***Message*—**EDGES: An edge has zero discharge.

***Check*—**Edge type is inconsistent for the left edge.
***Message*—**EDGES: Left edge type is not consistent.

***Check*—**Edge type is inconsistent for the right edge.
***Message*—**EDGES: Right edge type is not consistent.

View Comments

The View Comments button (fig. 1) opens a window that allows the user to see comments that were either imported from the data files or have been added in QRev (fig. 38). Remarks made in WR2 are prefaced by "MMT Remarks". Notes associated with transects in WR2 are prefaced by the file number, the date, and the time. QRev comments are prefaced by the dialog or window name, date, and time. Comments cannot be edited or deleted and are considered original data. To change a comment, add an additional comment to correct an earlier comment.

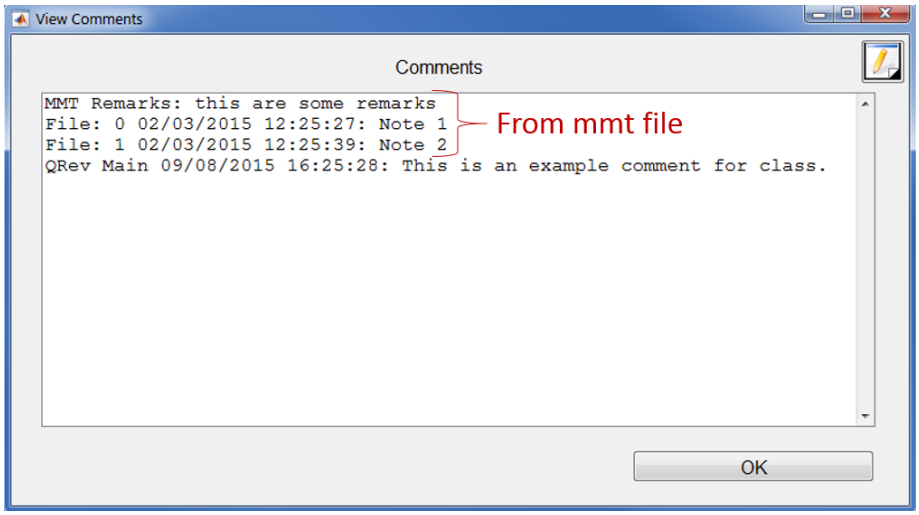


Figure 38. Example of View Comments window.

Save

The Save button (fig. 1) allows the user to save a MATLAB file of the measurement as processed in QRev and an XML file that can be loaded into other software, such as SV Mobile. A save file dialog window provides a default name for the MATLAB file, which can be changed by the user prior to saving (fig. 39). The same name with an xml suffix will be used for the XML file. The default filename is based on the date and time of the save (yyyymmddHHMMSS_QRev.mat or yyyymmddHHMMSS_QRev.xml). If the user attempts to overwrite an existing file, a dialog is displayed indicating a file with the same name exits and asking the user if they wish to overwrite the existing file.

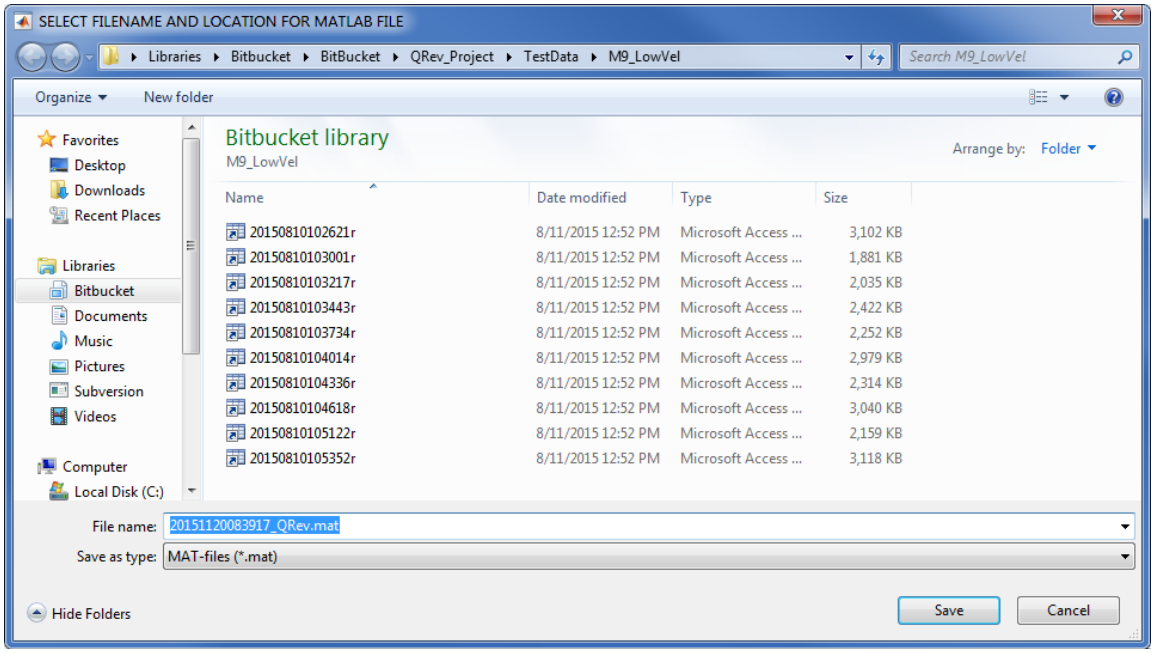


Figure 39. Save window.

Close

The Close button (fig. 1) closes QRev. If the data were loaded from a WR2 or RSL file and the data have not been saved in QRev, clicking the Close button will display a dialog warning to the user that the loaded data have not been saved and giving the user an opportunity to save the data (fig. 40). This dialog will not appear if the data were loaded from a previously saved *_QRev.mat file.

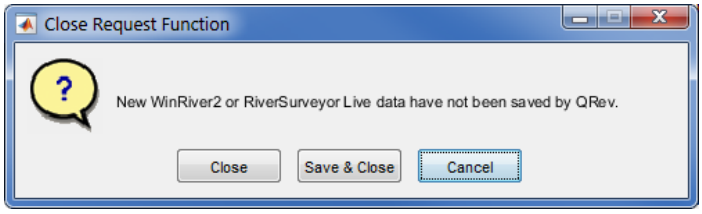


Figure 40. Close request dialog.

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