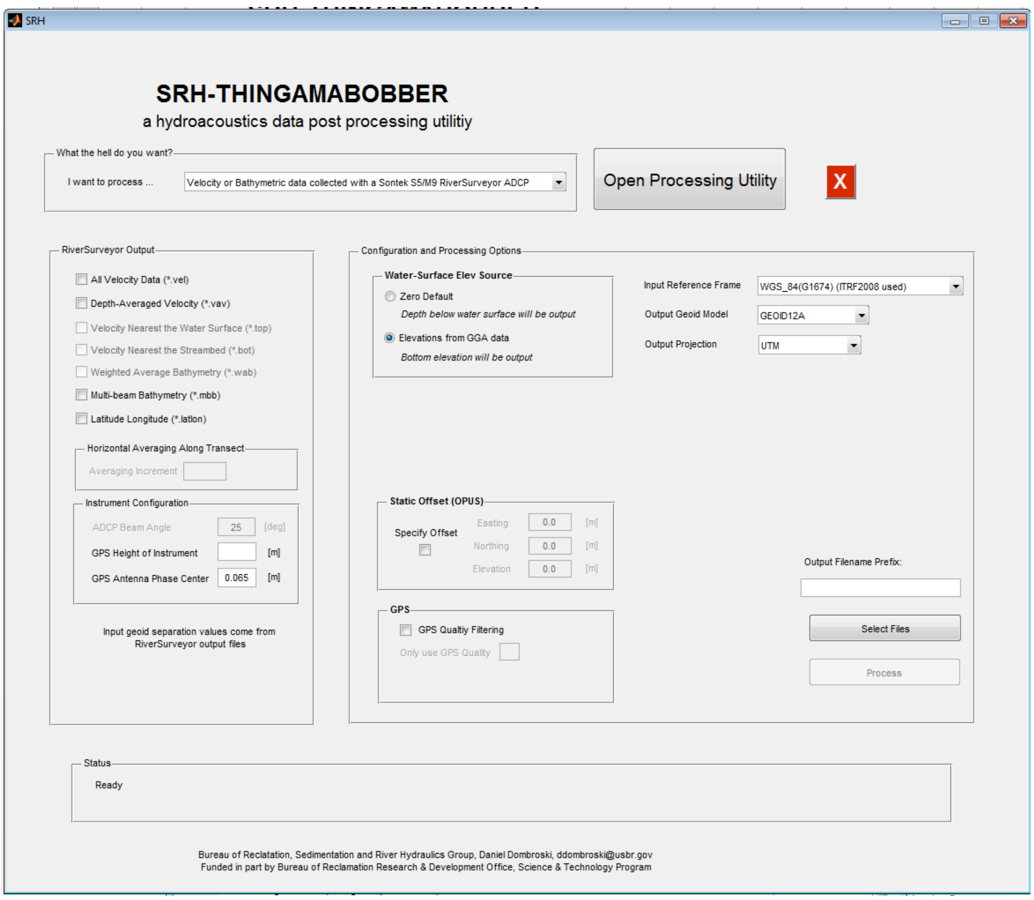
RECLAMATION

Managing Water in the West

Development of Software Tools for Efficient Processing of Bathymetry and Discharge Data

Research and Development Office
Science and Technology Program
(Final Report) ST-2017-1779-01



U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

October, 2017

Mission Statements

Protecting America's Great Outdoors and Powering Our Future

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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14. ABSTRACT Details regarding the development and guidelines for application of a software tool for processing bathymetry data are described. The computational backbone of the processing tool is comprised of several freely available geodetic source codes that have been modified and integrated under a single user interface. The software is designed to process data collected using a Sontek M9 ADCP (Acoustic Doppler Current Profiler) and either the HydroSurveyor or RiverSurveyor software package with Trimble R8 GPS receiver. The goal of the project is to provide a seamless and efficient means for producing point-based bottom bathymetry and related products from data collected using the ADCP with integrated GPS information. The methods are generally extendable to variations in equipment, data collection procedures, and end-user needs.

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Development of Software Tools for Efficient Processing of Bathymetry and Discharge Data

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Acknowledgements

Thanks to David Varyu and Kent Collins for their considerable time invested through the course of this project

Executive Summary

Details regarding the development and guidelines for application of a software tool for processing bathymetry data are described. The computational backbone of the processing tool is comprised of freely available geodetic source codes that have been modified and integrated under a single user interface. The software is designed to process data collected using a Sontek M9 ADCP (Acoustic Doppler Current Profiler) and either the HydroSurveyor or RiverSurveyor software package with Trimble R8 GPS receiver. The goal of the project is to provide a seamless and efficient means for producing point-based bottom bathymetry and related products from data collected using the ADCP with integrated GPS information. The methods are generally extendable to variations in equipment, data collection procedures, and end-user needs.

Contents

Background

Bathymetric surveys are increasingly becoming an integral part of the hydraulic studies that the Bureau of Reclamation is performing for its clients on a regular basis. Detailed bathymetry data is useful in estimating zones of sediment aggradation and degradation in rivers and reservoirs (with implications to reservoir sustainability), tracking channel and bar migration, and for setup and calibration of numerical models.

Reclamation needs to collect depth and velocity data in rivers for numerous habitat and sedimentation investigations. Numerical models of river hydraulics, sediment transport, and vegetation growth and mortality are used to predict river conditions over a range of flows. These models depend on accurate channel bathymetry and flow velocity data.

Using modern acoustic depth-sounding instruments and GPS equipment mounted to a floating raft, a small team of hydraulic engineers can map the bathymetry of 50 or more river miles in a matter of days. The newest generation of acoustic Doppler current profilers (e.g., Sontek M9 ADCP) have up to five acoustic beams acquiring spatially distributed samples of water depth, thus greatly increasing the resolution and quality of the data without any increased man-hours in the field. After the data-acquisition process is complete, post-processing and integration of data is necessary in order to glean physically-relevant information.

The Sontek RiverSurveyor ADCP was introduced in 2009 for the primary purpose of velocity and discharge measurements, although bottom bathymetry can also be derived from the instrument beam geometry (known) and orientation (pitch, roll, and heading are recorded). Algorithms originally developed by USGS scientists to process data from a similar instrument were adapted by Reclamation engineers to semi-automatically derive point bathymetric measurements from RiverSurveyor data. The Sontek HydroSurveyor software and firmware package was introduced in 2013 and designed specifically for collection of bathymetric and acoustic bottom tracking data as part of a hydrographic survey using the M9 ADCP. HydroSurveyor is offered as an alternative or upgrade from the RiverSurveyor software package. For the purpose of bathymetric surveying, the HydroSurveyor software offers several benefits over the RiverSurveyor software that aid in real-time data collection. Despite the advancements in bathymetric data collection, HydroSurveyor software falls short of providing the geodetic capabilities needed to generate a finished product. For example, the depth soundings as generated from the HydroSurveyor software are not generally referenced to the desired geographic reference frame and / or do not generally reference the most appropriate geoid model of the earth's surface. There is a general need to convert the data to an appropriate reference frame and apply a geoid model. There may be additional needs such as filtering the data to enhance quality, project the data from a geographic coordinate system to an existing reference frame for a project (such as State Plane Coordinates Systems), or to apply a correction to position data based on improved base station coordinates. The process of relating ADCP data to data from the GPS receiver is unnecessarily time-consuming. This process is commonly performed using GIS tools, and requires approximately a day of processing time per day of field data-acquisition for typical bathymetric studies. For this reason, a new post-processing tool was designed by Reclamation engineers specifically to interface with HydroSurveyor data export (Dombroski, 2013).

The purpose of the software developed herein is to (a) improve user efficiency by integrating RiverSurveyor and HydroSurveyor data processing within one tool, (b) increase the degree of automation through more robust algorithms and geodetic capabilities, and (c) decrease maintenance overhead by creating a shared collection of coded procedures. Due to the nature of the custom application of the Sontek ADCP for purposes that extend the out-of-the-box design scope of the instrument, users are challenged to develop unique and creative solutions to handling data. During the course of the project, targeted testing was performed in order to generate precise understanding of the implications varying instrument configurations may have on workflow and data quality.

Method Discussion

The first step in the project work was to develop a thorough understanding of the implications of instrument hardware configuration and GPS integration. Through a series of targeted tests that were conducted at the Denver Federal Center campus, it was discovered that the way in which the GPS hardware is physically connected to the data acquisition instrument (e.g., laptop, tablet computer, etc.) effects the type of data stream with implications to the post-processing workflow requirements and development of associated software tools. Furthermore, a hardware incompatibility related to an auxiliary GPS device installed on a tablet computer was investigated. Details of the investigation methodology and findings are provided in Appendix A.

The most significant component of the processing tool development was centered around the merging of two existing processing tools into a single framework. Specific user guidance regarding the processing workflow for data exported from the Sontek RiverSurveyor and HydroSurveyor packages can be found in Appendix B. In a test of the processing tool accuracy, bathymetry results from data collected using HydroSurveyor were compared to a conventional, and more time consuming, form of processing (Appendix C).

The primary motives for creating a single platform tool were to (1) decrease maintenance overhead by consolidating coded algorithms into one thread of development and (2) improve user efficiency by eliminating uncertainty surrounding tool selection. Creating a single framework required a large investment in time and effort; consensus among the main user base at the TSC was that the long term projected benefits justified the expense.

In parallel with the process of creating a single framework processing tool, a series of changes and improvements were made with a focus on increasing the automation and capability which, ultimately, will save staff time:

- An output file is automatically generated that includes date and time of acquisition, user selections and processing configuration, and an error log.
- Users may specify a search directory for geoid coordinate files, necessary for estimating geoid separation in computing orthometric height
- Users may specify a block (X,Y,Z) shift to output Cartesian coordinates

Future work

Combined funding provided by various project offices will support the continued development of the processing tool. Among the highest priority items for future development is the inclusion of optional State Plane coordinate conversion to the output options.

Processing Tool

For access to the processing tool or for further guidance on use, contact the principal investigator:

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303-445-2570

References

Dombroski, D. E. (2013). *Development of Software Tools for Efficient Processing of Bathymetry and Discharge Data.* Denver: Bureau of Reclamation Research and Development Office, Science and Technology Program.

Appendix A – Instrument Testing

Test 1

Purpose

A test was conducted on 7 October, 2016 in order to compare HydroSurveyor data to Trimble Business Center survey data. This test was intended to help us understand potential systematic errors occurring in position/elevation data from the two data sources (NMEA string feeding HydroSurveyor and TBC continuous topo).

Setup

Two tripods were set up; one over the point “HARD” near building 810, and one over “DFC1” near the post office (both on Denver Federal Center). The base station was set on the tripod over the point “HARD” and the point over “DFC1” was the rover.

Survey base station was set up using 2 different job files (and 2 job files on controller for rover):

1) a job with no projection / no transformation (should give us WGS84 lat longs)
2) a job as NAD83 Colorado Central SPCS.

In both cases, known coordinates were entered for the base point “HARD”. For the first job file (WGS 84) Lat/Longs were entered. For the second job file, State Plane eastings and northings were entered. All data comparisons are based on Lat/Long comparisons.

Data Comparisons

1) Continuous Topo points collected on the TBC controller (we collected ~13 points at a fixed time interval of 5? seconds)
2) HydroSurveyor data. At first we had no bucket of water, we tried to collect soundings and failed. We then got a bucket of water and collected soundings.
3) NMEA string data. This was captured using HyperTerminal or similar program. We were unable to collect NMEA string data concurrently with collecting HydroSurveyor data.

Summary of Data Files

1) Continuous Topo. We have one set of 13 points for WGS84 and one set of 13 points for NAD83. Lat/Longs (global) were exported from TBC as text files.
2) HydroSurveyor.
   a. Soundings; one for WGS84 and one for NAD83. Soundings were exported from HydroSurveyor as text files.
   b. GPS log files; six total files (already text files stored on local disk)
      i. Four files with WGS84 with no soundings associated.
      ii. Two files associated with soundings, one for WGS84 (fileID 195629) and one for NAD83 (fileID 202326).
3) NMEA string. Three files; two of WGS84 (one on laptop and one on tablet) and one of NAD83 captured using tablet.

Results

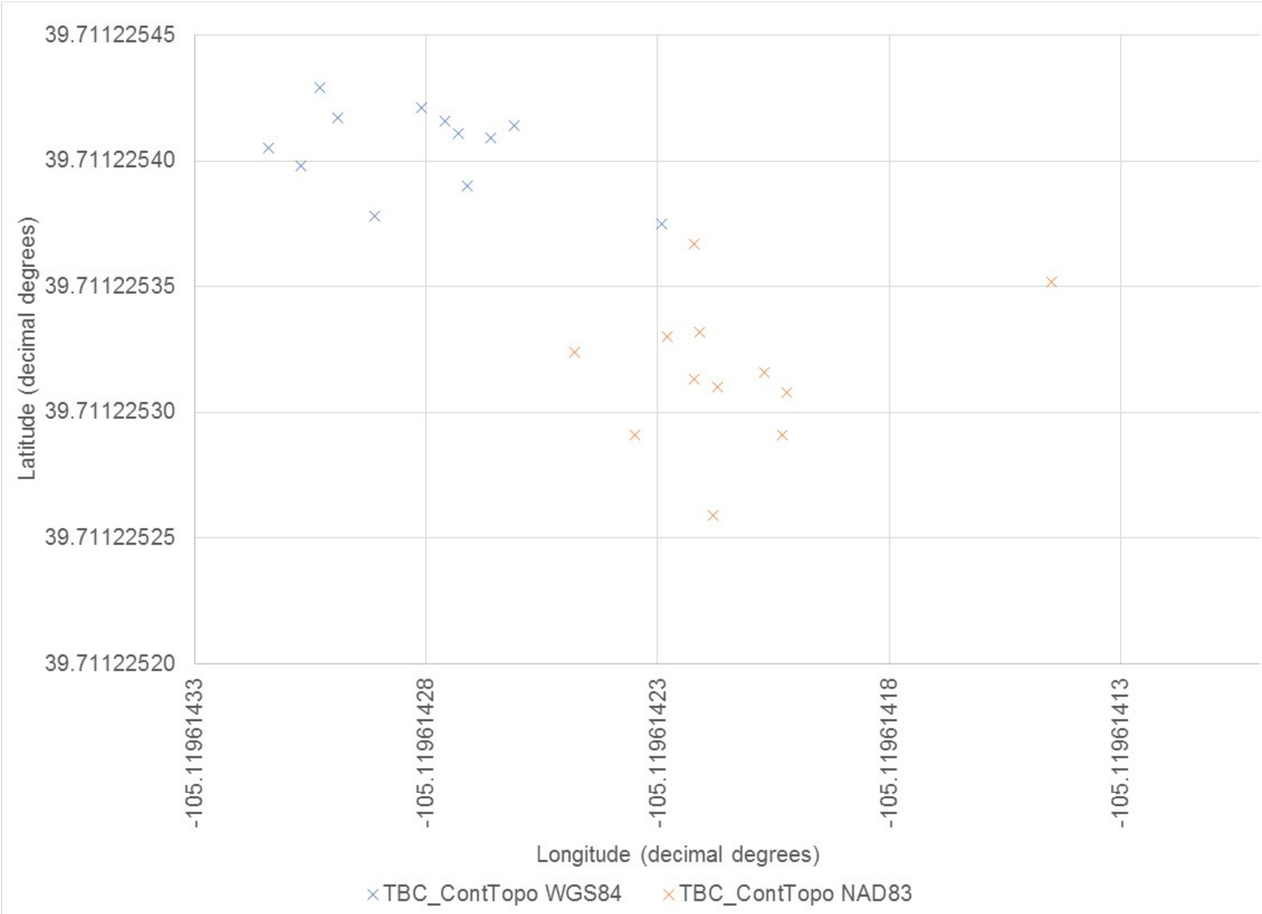


Figure A 1. Continuous Topo Points. There does seem to be two distinct groupings of data. Horizontal and vertical axes span 2.3e-7 and 2.5e-7 decimal degrees, respectively

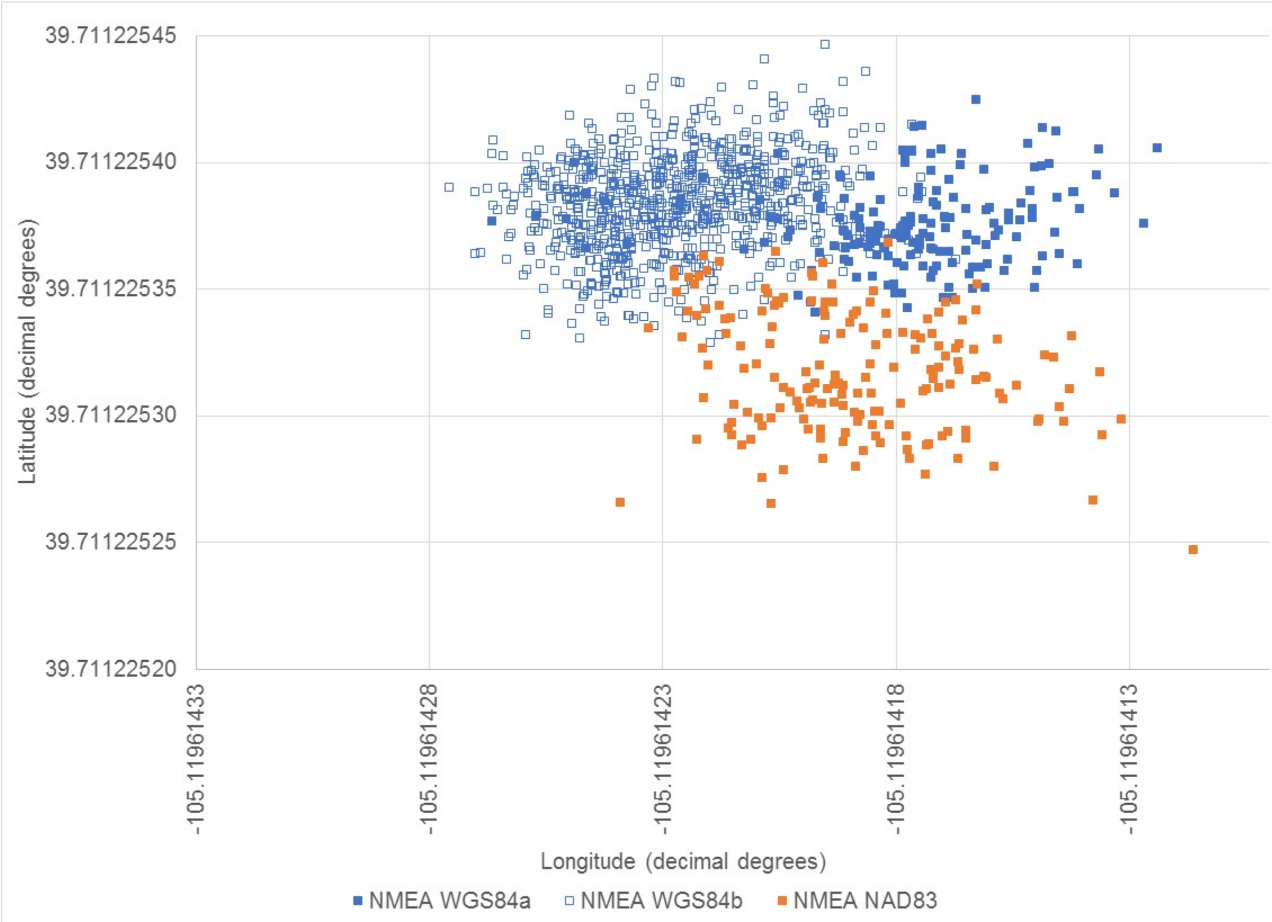


Figure A 2. NMEA string data. There does seem to be two distinct groupings of data. Horizontal and vertical axes span 2.3e-7 and 2.5e-7 decimal degrees, respectively

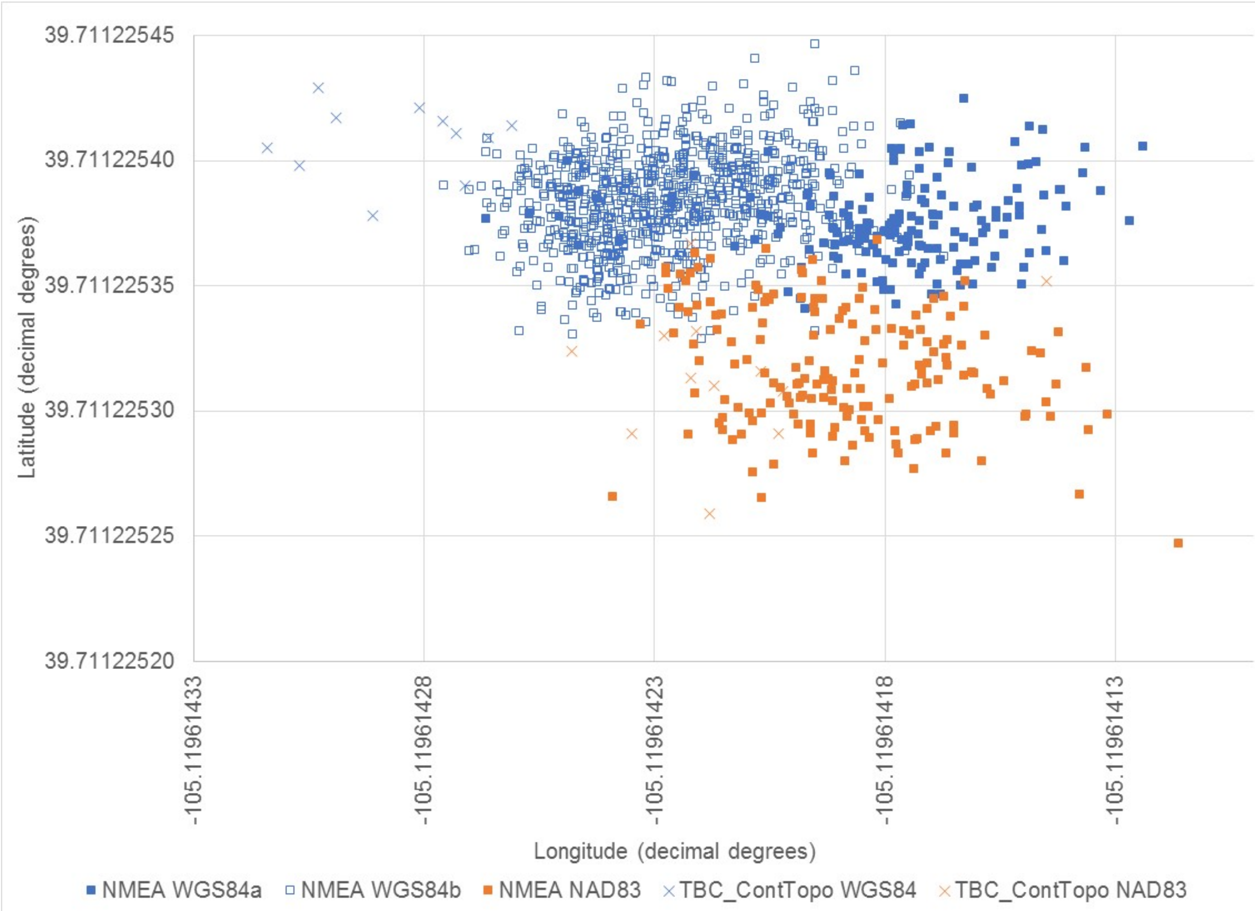


Figure A 3. Continuous Topo Points compared to NMEA string. There does seem to be two distinct groupings of data. Horizontal and vertical axes span 2.3e-7 and 2.5e-7 decimal degrees, respectively.

Figure A 4. HydroSurveyor data. There are two distinct groupings of data. NMEA data and Continuous topo data exist in the black box between the data sets. Horizontal and vertical axes span 8e-5 and 7e-5 decimal degrees, respectively.

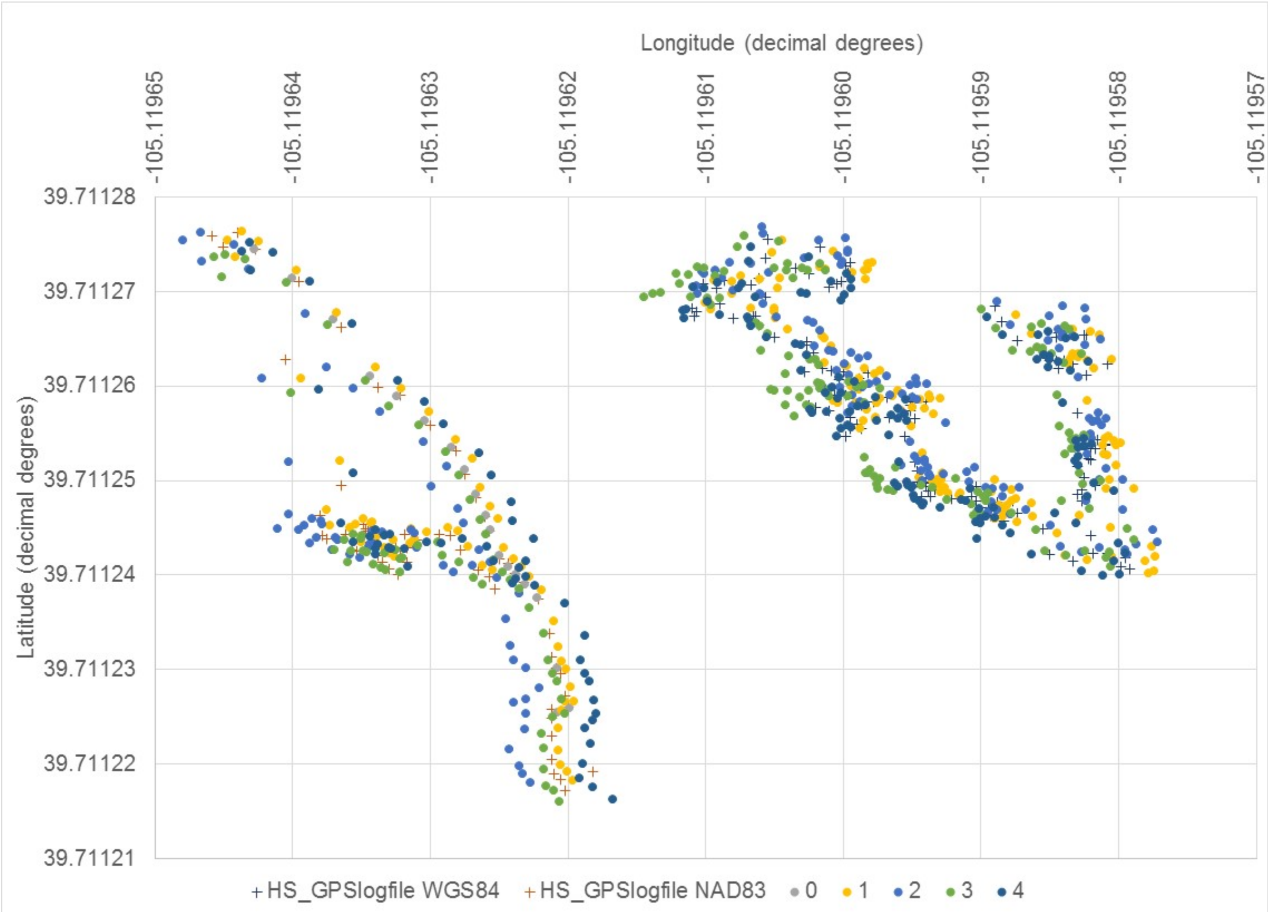


Figure A 5. Comparison of GPS log file data to soundings export to confirm the amount of variability in the data.

Test 2

Purpose

A test of data the hardware and software for Sontek M9 HydroSurveyor setup with Trimble GPS system was conducted by D. Varyu and D. Dombroski (N. Holste observing) on December 2nd, 2016 at the Denver Federal Center Campus.

Setup

The Sontek M9 was held over a 20 gallon bucket of water during the test. A RTK base station and receiver were setup in order to simulate the configuration used during real data acquisition on the raft during bathymetric surveying. See setup photos below.

Data Comparisons

A series of six trials were performed using a combination of "Auxiliary" mode and "Generic" mode configurations of the GPS integration with the HydroSurveyor software for differing implementation of cable setup. The matrix below indicates the hardware and software setup used for each trial. Additionally several sets of NMEA string data were collected directly from the GPS receiver using hyperterminal.

Test ID	M9 connection to computer	R8 serial cable	Device Connection Description	notes
1	with usb to serial	directly to computer	Generic GPS	
2	with usb to serial	directly to computer	Auxiliary HydroSurveyor GPS	HydroSurveyor Can't see GPS in this configuration; no data collection
3	with usb to serial	to m9 cable	Generic GPS	
4	with usb to serial	to m9 cable	Auxiliary HydroSurveyor GPS	
5	without usb to serial	to m9 cable	Generic GPS	
6	without usb to serial	to m9 cable	Auxiliary HydroSurveyor GPS	
7	~~without usb to serial~~	~~directly to computer~~	~~Generic GPS~~	not possible, one com port on computer/tablet
8	~~without usb to serial~~	~~directly to computer~~	~~Auxiliary HydroSurveyor GPS~~	not possible, one com port on computer/tablet

Observations and conclusions

The overall conclusion reached was that there is a problem associated with acquisition in "Generic" mode GPS by which the positioning data appears to have increased scatter, offset, and drift over that of the data collected in "Auxiliary" mode. The conclusions were not affected by the specifics of the cabling setup; only by whether the mode was selected as "Auxiliary" or "Generic".

It was noted that the GPS quality was generally of value 1 for each of the tests conducted under "Generic" mode, while data collected under "Auxiliary" mode was generally of quality 4. GPS quality 1 corresponds to standard positioning service (SPS), consistent with handheld GPS units, while GPS quality 4 is real time kinematic (RTK), consistent with survey-grade positioning. Although the difference in GPS quality is likely tied to the difference in scatter and error in the data, it is unclear why there is a difference in GPS quality related to the instrument configuration ("Generic" vs "Auxiliary"). The GPS configuration did not change during the course of the tests.

Figure A 6. Overall site view with horizontal positioning of collected points shown for each test and acquisition mode.

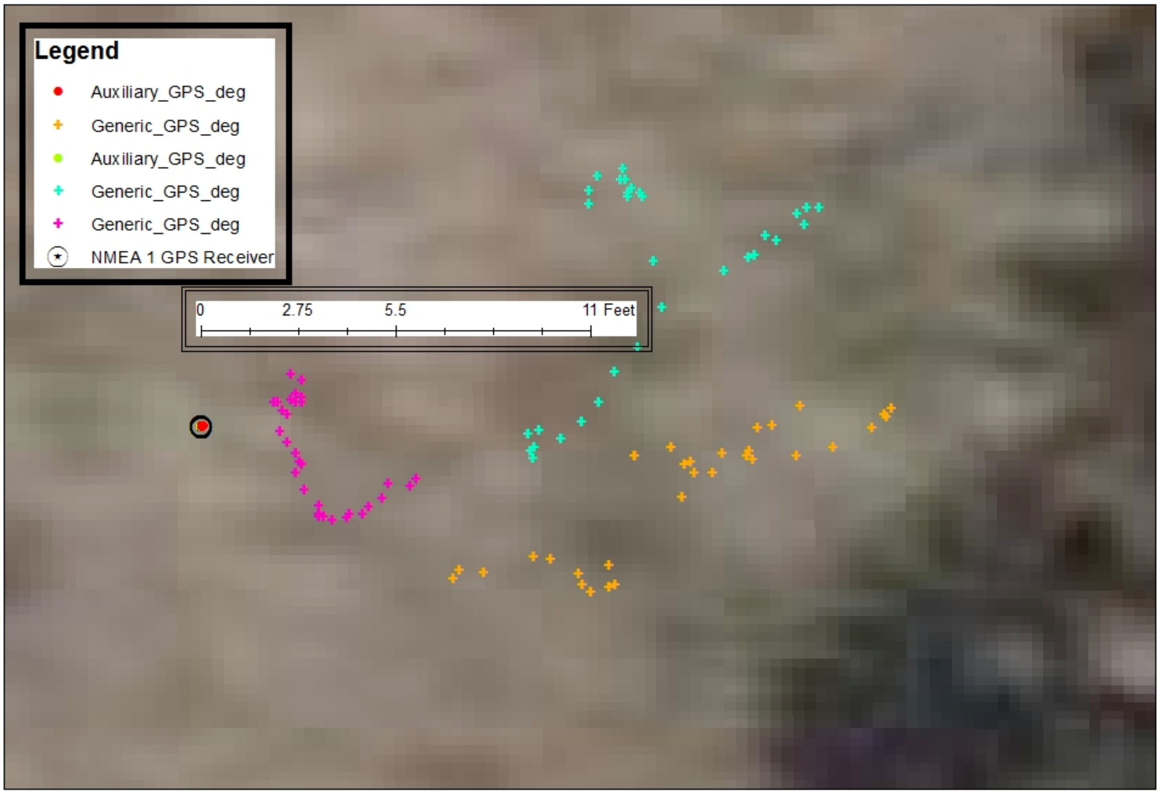


Figure A 7. View of all data collected. Scatter of NMEA and Auxiliary mode horizontal positioning is small relative to Generic mode GPS horizontal positioning and appears as a single point.

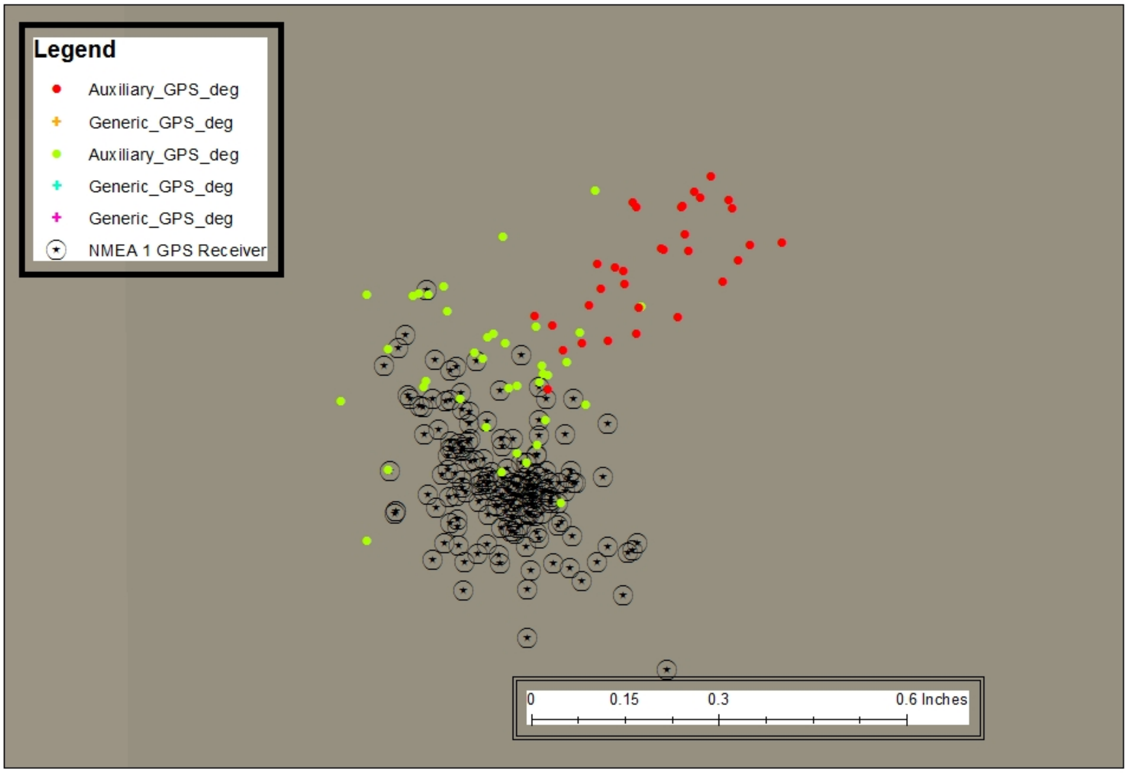


Figure A 8. Zoom image of scatter amongst NMEA and Auxiliary Mode GPS horizontal positioning. Generic Mode data not shown at this scale.

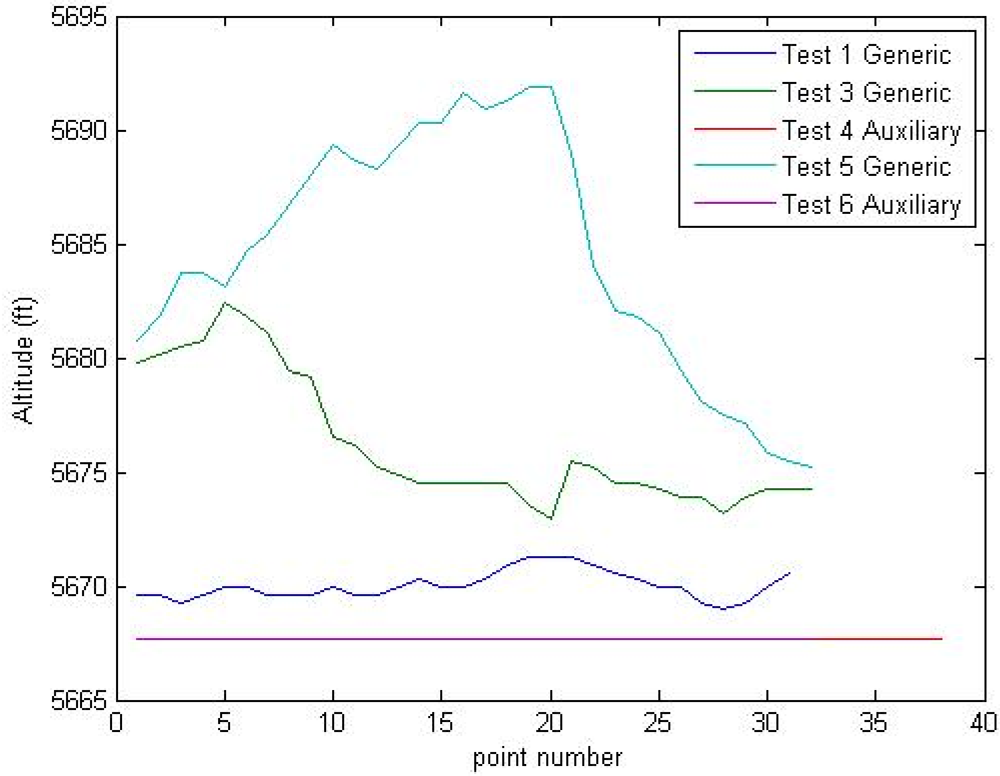


Figure A 9. Vertical positioning comparison amongst acquisition mode (Generic vs Auxiliary) for each test. The results show that the vertical positioning in Generic mode contains dramatically more scatter than the vertical positioning in Auxiliary mode.

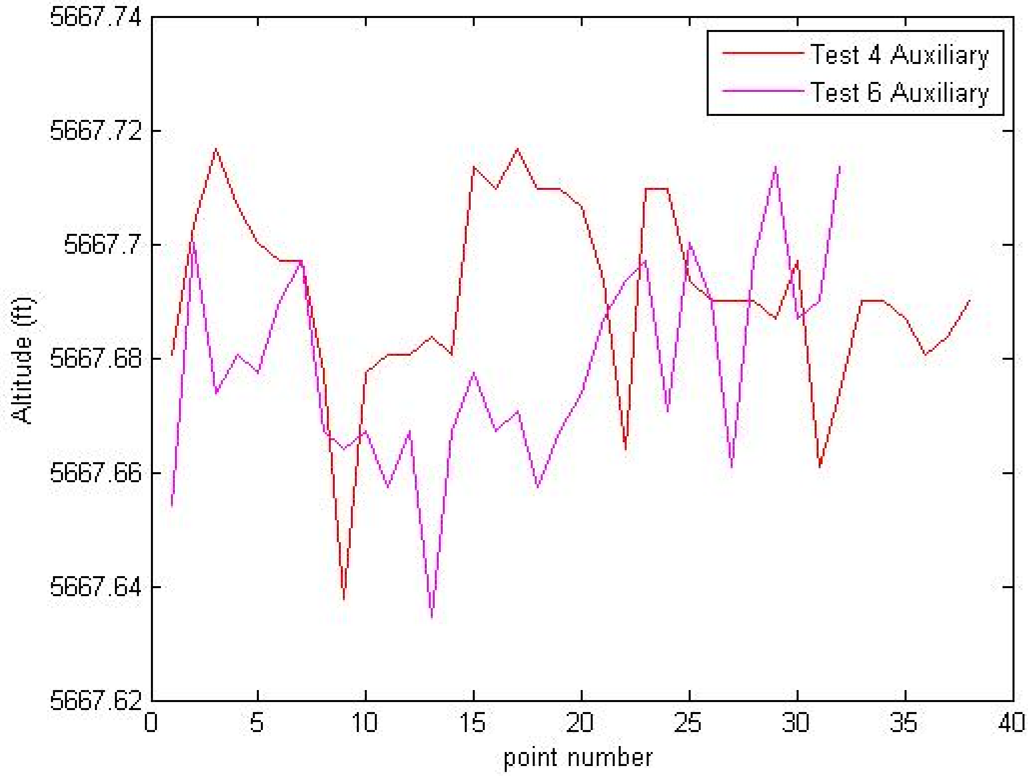


Figure A 10. Vertical positioning comparison for data collected in Auxiliary mode. The scatter in auxiliary mode is much less than that in Generic mode (Figure A 9)

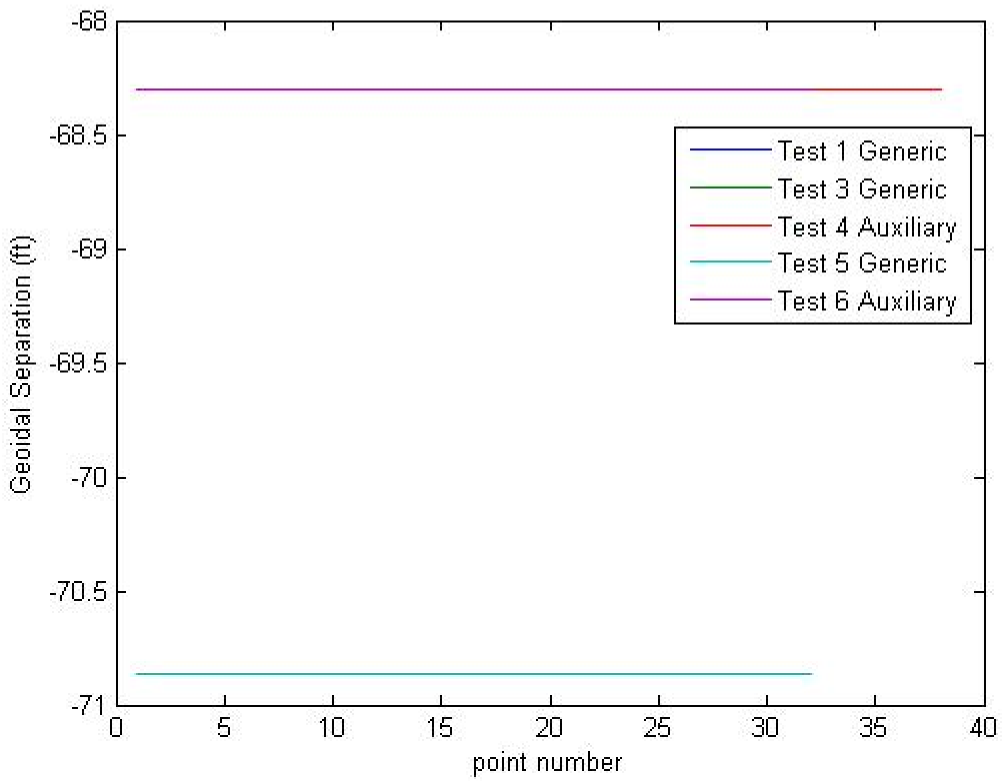


Figure A 11. Comparison of Geoidal separation value for trials in Auxiliary mode vs Generic mode. The geoidal separation value is consistent and constant amongst trials conducted with in each mode, however the values are different between modes (Auxiliary vs Generic).

Test 3

Purpose

The overarching question seems to be why the horizontal and vertical positioning data is dependent on the mode of acquisition and why the performance of the GPS data reported from the software is poor in Generic mode compared to Auxiliary mode?

Experiment Description

Following the December 2nd, 2016 test of the Sontek M9 HydroSurveyor setup in which it was discovered that GPS data was of low quality when collected with the system in “Generic GPS” mode, it was discovered that additional GPS hardware connected to the tablet computer may be causing the issues experienced. The tablet computer has GPS hardware installed that provides low quality (hand-held GPS) data for approximate positioning and was not intended to communicate with the HydroSurveyor software. It is believed, however, that when in “Generic GPS” mode, the HydroSurveyor software may be connecting to this GPS device instead of the Trimble GPS system providing RTK fix GPS data. In order to test the hypothesis, a further set of tests were derived. The test used the tablet computer with the low-quality GPS hardware removed and also the ruggedized laptop (which contains no additional GPS hardware) for data acquisition.

The follow-up test of the hardware and software for Sontek M9 HydroSurveyor setup with Trimble GPS system was conducted by D. Varyu, K. Collins, and D. Dombroski on December 16th, 2016 at the Denver Federal Center Campus.

Setup

Mirroring the December 2nd test, the Sontek M9 was held over a 20 gallon bucket of water during the test. A RTK base station and receiver were setup in order to simulate the configuration used during real data acquisition on the raft during bathymetric surveying. See setup photos below.

Data Comparisons

A series of trials were performed using a combination of “Auxiliary” mode and “Generic” mode configurations of the GPS integration with the HydroSurveyor software for differing implementation of cable setup and for both the tablet computer and laptop computer. The matrix below indicates the hardware and software setup used for each trial as well as which setup configurations were invalid. Note that inability of the system to connect to GPS or HydroSurveyor does not generally indicate a defect in the hardware or software but instead that the specific configuration is not valid. Additionally, several sets of NMEA string data were collected directly from the GPS receiver using hyperterminal.

Logging on the tablet will be completed without the GPS attached to Port 4.
Columns G & H will be populated after the test with information from the "device connection" dat file

Logging Device	Test ID	M9 connection to computer	R8 serial cable	Device Connection Description	notes	M9 Port	R8 Port
Tablet 1	T1	with usb to serial	directly to computer	Generic GPS	Tablet was sluggish and kept locking up when not plugged into inverter. For this test, mouse in bottom USB port and USB to Serial converter in the top USB port. Boat did not appear to be drifting in HydroSurveyor.	COM 5	COM 1
Tablet 1	T2	with usb to serial	directly to computer	~~Auxiliary HydroSurveyor GPS~~	Cannot connect with this configuration in Auxiliary mode. Tried auto detect with no success. No option of	COM 5	COM 1

					specifying M9 comport in Auxiliary mode.		
Tablet 1	T3	with usb to serial	to m9 cable	~~Generic GPS~~	Cannot connect with this configuration in Generic mode. Tried auto detect with no success.	COM 5	COM 5
Tablet 1	T4	with usb to serial	to m9 cable	Auxiliary HydroSurveyor GPS	Had to power cycle M9 to connect. Shutting and restarting HS did not work. Boat did not appear to be drifting in HydroSurveyor. Beam positions appeared reasonable with minimal scatter.	COM 5	COM 5
Tablet 1	T5	without usb to serial	to m9 cable	~~Generic GPS~~	Cannot connect with this configuration in Generic mode. Tried auto detect with no success. Also tried to power cycle M9. Connected to	COM 1	COM 1

					M9, but not GPS.		
Tablet 1	T6	without usb to serial	to m9 cable	Auxiliary HydroSurveyor GPS	Manually connected, but auto detect should work as well. Boat did not appear to be drifting in HydroSurveyor. Beam positions appeared reasonable with minimal scatter.	COM 1	COM 1
Tablet 1	T7	~~without usb to serial~~	~~directly to computer~~	~~Generic GPS~~	not possible, one com port on computer/tablet		
Tablet 1	T8	~~without usb to serial~~	~~directly to computer~~	~~Auxiliary HydroSurveyor GPS~~	not possible, one com port on computer/tablet		
Logging Device	**Test ID**	**M9 connection to computer**	**R8 serial cable**	**Device Connection Description**	**notes**	**M9 Port**	**R8 Port**

Ruggedized Laptop	L1	with usb to serial	directly to computer	Generic GPS	Change connections for GPS and M9 in HS Configluration. SS USB on left side of laptop is COM12.	COM 12	COM 1
Rugged Laptop	L2	with usb to serial	directly to computer	~~Auxiliary HydroSurveyor GPS~~	Cannot connect with this configuration in Auxiliary mode. Tried auto detect with no success. No option of specifying M9 comport in Auxiliary mode.	COM 12	COM 1
Rugged Laptop	L3	with usb to serial	to m9 cable	~~Generic GPS~~	Cannot connect with this configuration in Generic mode. Tried auto detect with no success.	COM 12	COM 12
Rugged Laptop	L4	with usb to serial	to m9 cable	Auxiliary HydroSurveyor GPS	had to use autodetect to recognize	COM 12	COM 12
Rugged Laptop	L5	without usb to serial	to m9 cable	~~Generic GPS~~	Cannot connect with this configuration in Generic mode. Tried	COM 1	COM 1

					auto detect with no success. Also tried to power cycle M9. Connected to M9, but not GPS.		
Rugged Laptop	L6	without usb to serial	to m9 cable	Auxiliary HydroSurveyor GPS	Manually connected, but auto detect should work as well. Boat did not appear to be drifting in HydroSurveyor. Beam positions appeared reasonable with minimal scatter.	COM 1	COM 1
Rugged Laptop	L7	~~without usb to serial~~	~~directly to computer~~	~~Generic GPS~~	not possible, one com port on computer/tablet		
Rugged Laptop	L8	~~without usb to serial~~	~~directly to computer~~	~~Auxiliary HydroSurveyor GPS~~	not possible, one com port on computer/tablet		

Observations and conclusions

The overall conclusion of the tests was that good performance of the GPS systems and quality of horizontal and vertical positioning was achieved in both “Generic” and “Auxiliary” modes and for *both tablet and laptop, confirming that the prior source of erroneous positioning was the secondary low-quality GPS device installed on the tablet computer.*

- It is the opinion at the time of writing that satisfactory data may be acquired with either the tablet or laptop computer and in either “Generic” or “Auxiliary” configuration, so long as no secondary GPS devices are installed and communicable within the system.
- Although the post-processing approach applied may depend somewhat on the mode of operation, data from any setup configuration should be able to be equally well post-processed into finished bathymetric data.
- Collection of regularly spaced topo shots (water surface elevations) stored by the GPS receiver is good practice, as this provides an independent backup source of data.

Oddities:

- The last NMEA collection file directly from the receiver contained no data.
- Test 1 acquired using tablet computer contained no soundings and therefore no data to export from the session. There was a gps log file and so data was taken from the gps log file instead of the session export file.

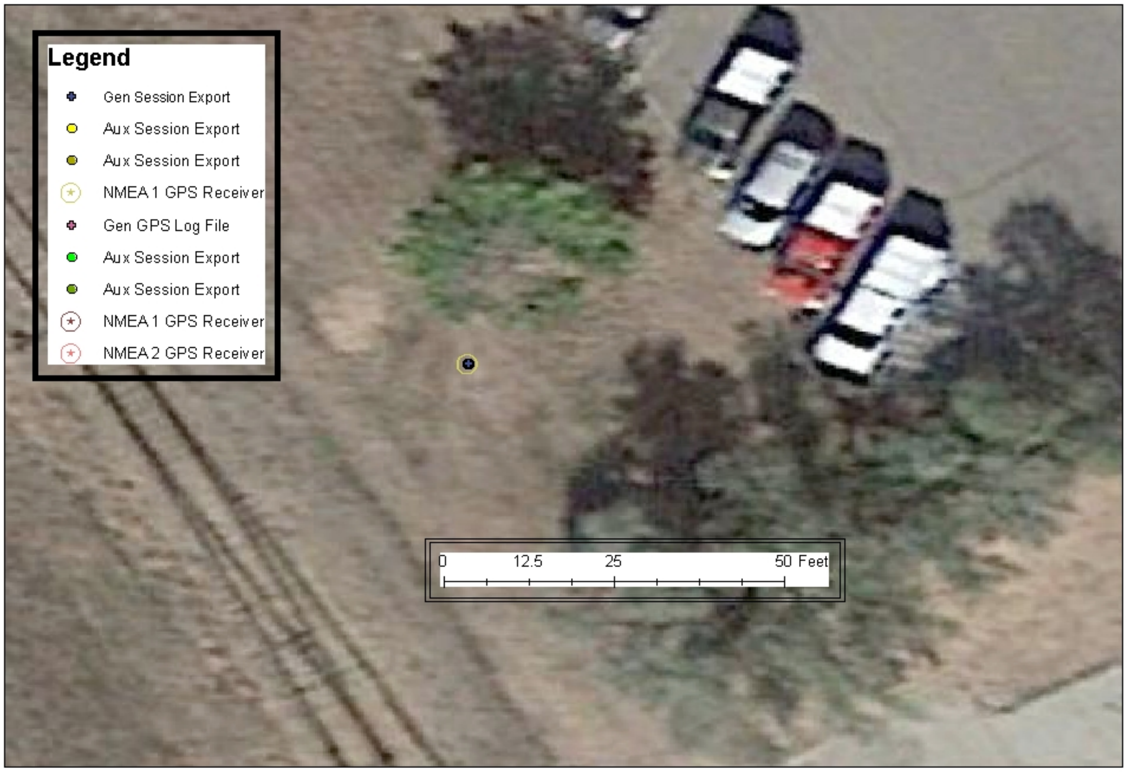


Figure A 12. Overall site view with horizontal positioning of collected points shown for each test and acquisition mode. The scatter of the data (O~1 in) appears consistent among all tests. This is in contrast to the December 2nd test that was conducted in which all tests conducted in "Generic" mode exhibited scatter O~10 ft.

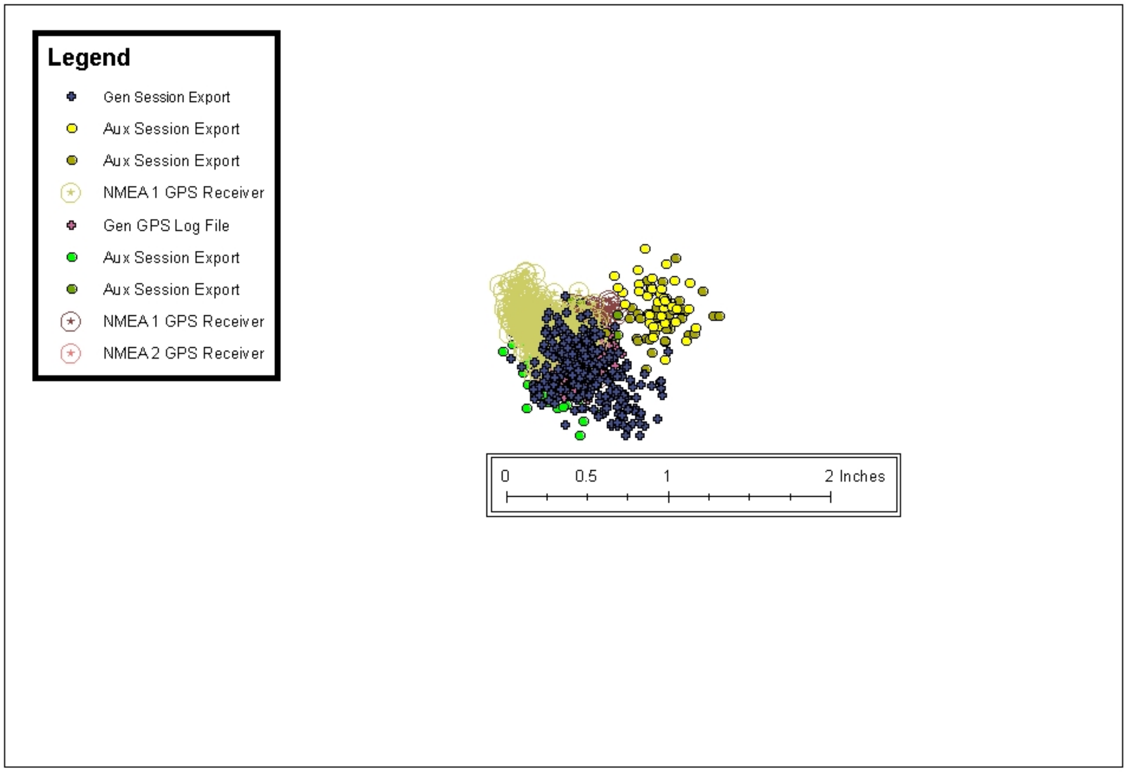


Figure A 13. Close up view of all data collected. Scatter of NMEA, Auxiliary mode, and Generic mode horizontal positioning is small and consistent, indicating that the Generic mode is operating correctly.

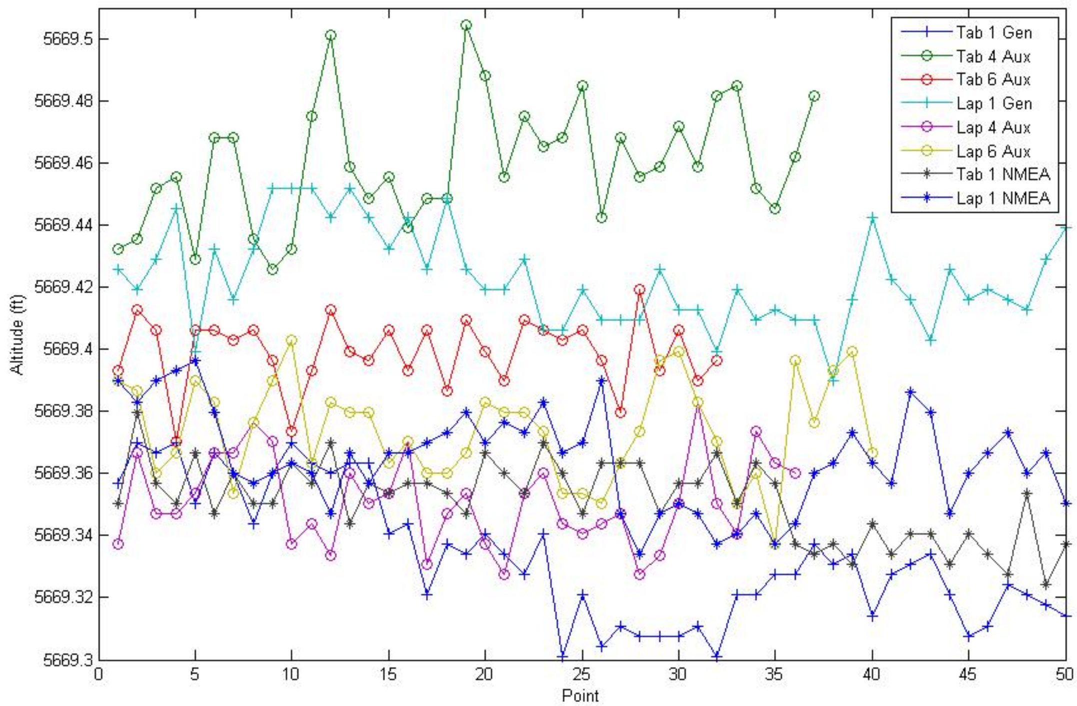


Figure A 14. Vertical positioning comparison amongst acquisition mode (Generic vs Auxiliary) for each test. Also shown are two results pulled from the NMEA string collected directly from the GPS receiver. Generic mode data denoted with crosses, Auxiliary mode data denoted with circles, and NMEA data denoted with asterisk. The results show that the vertical positioning is consistent among varying types of data.

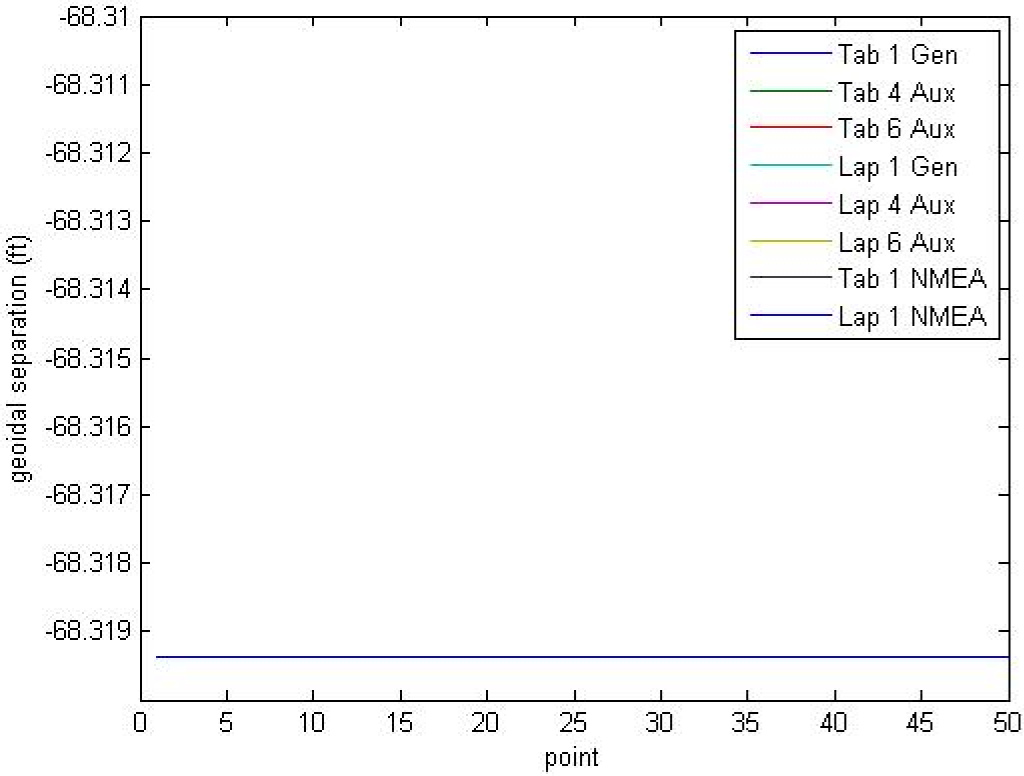


Figure A 15. Comparison of Geoidal separation value for trials in Auxiliary mode vs Generic mode and directly from the GPS receiver. The geoidal separation value is consistent and constant amongst trials conducted with in each mode.

Implications and uncertainties

It appears from these tests that high quality data can be acquired either using Generic or Auxiliary mode and with either the laptop or the tablet (assuming secondary gps devices are removed). So for the purposes of establishing good practices in the field and in post-processing, what are our specific recommendations for both acquisition and production of finish quality bathymetric data?

Appendix B – User Guide for Data Processing

RiverSurveyor Data Export and Processing

AdMap is a tool for post-processing velocity data and depth soundings using the Sontek M9 ADCP with GPS when operated in RiverSurveyor mode.

Purpose

The purpose of AdMap is to improve the capability and efficiency of developing finished bathymetric and velocity mappings by expanding the breadth of products produced and partially automating the task of post-processing and integration of GPS information.

Need

- The depth soundings as generated from the RiverSurveyor software are referenced only to the nadir beam of the ADCP even though there are a total of 5 beams available for any measurement. Higher-quality and more efficient bathymetry can be produced by using depth soundings from all available beams. Because the RiverSurveyor software does not provide positioning information for the depth measurement associated with each beam, it is necessary to calculate locations based on the geometry, pitch, and roll of the instrument.
- The RiverSurveyor software does not provide a full suite of velocity products, such as depth-averaged velocity.
- Measurements from RiverSurveyor are positioned according to latitude and longitude, while it is generally desirable to express data in a projected coordinate system.
- There may be additional needs such as filtering the data to enhance quality.

Workflow

Processing with AdMap is generally conducted in the office after the data acquisition trip has been completed.

RiverSurveyor Data Export

After field data acquisition using the Sontek ADCP and RiverSurveyor software is complete, the input dataset for the AdMap tool can be generated. Click on the “Show/Hide Processing Tools” icon (looks like a hammer and wrench). Within the “Processing Toolbox”, select “Matlab Export All” (Figure B 1).

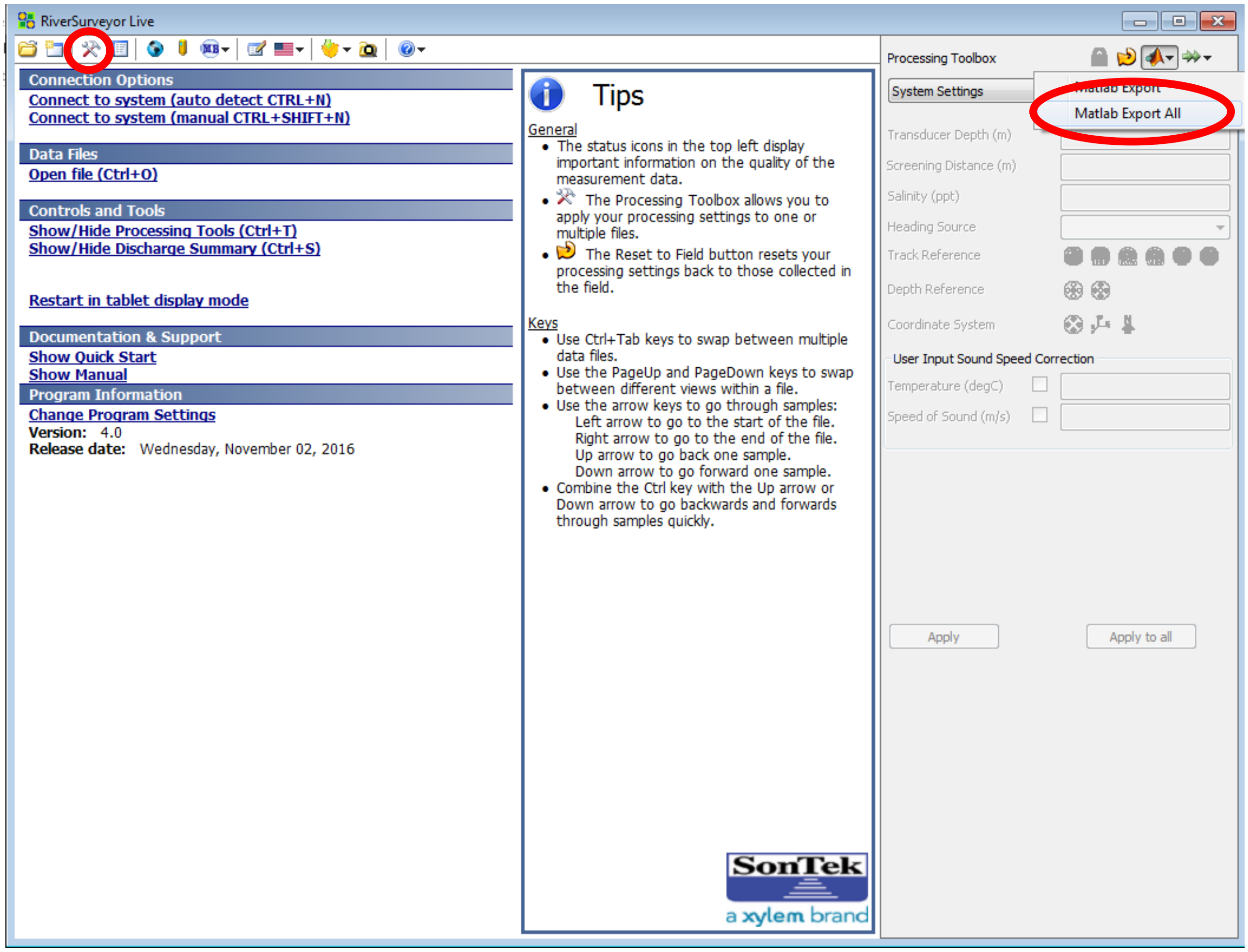


Figure B 1. Export data from RiverSurveyor by showing the “Processing Toolbox” and selecting “Matlab Export All”

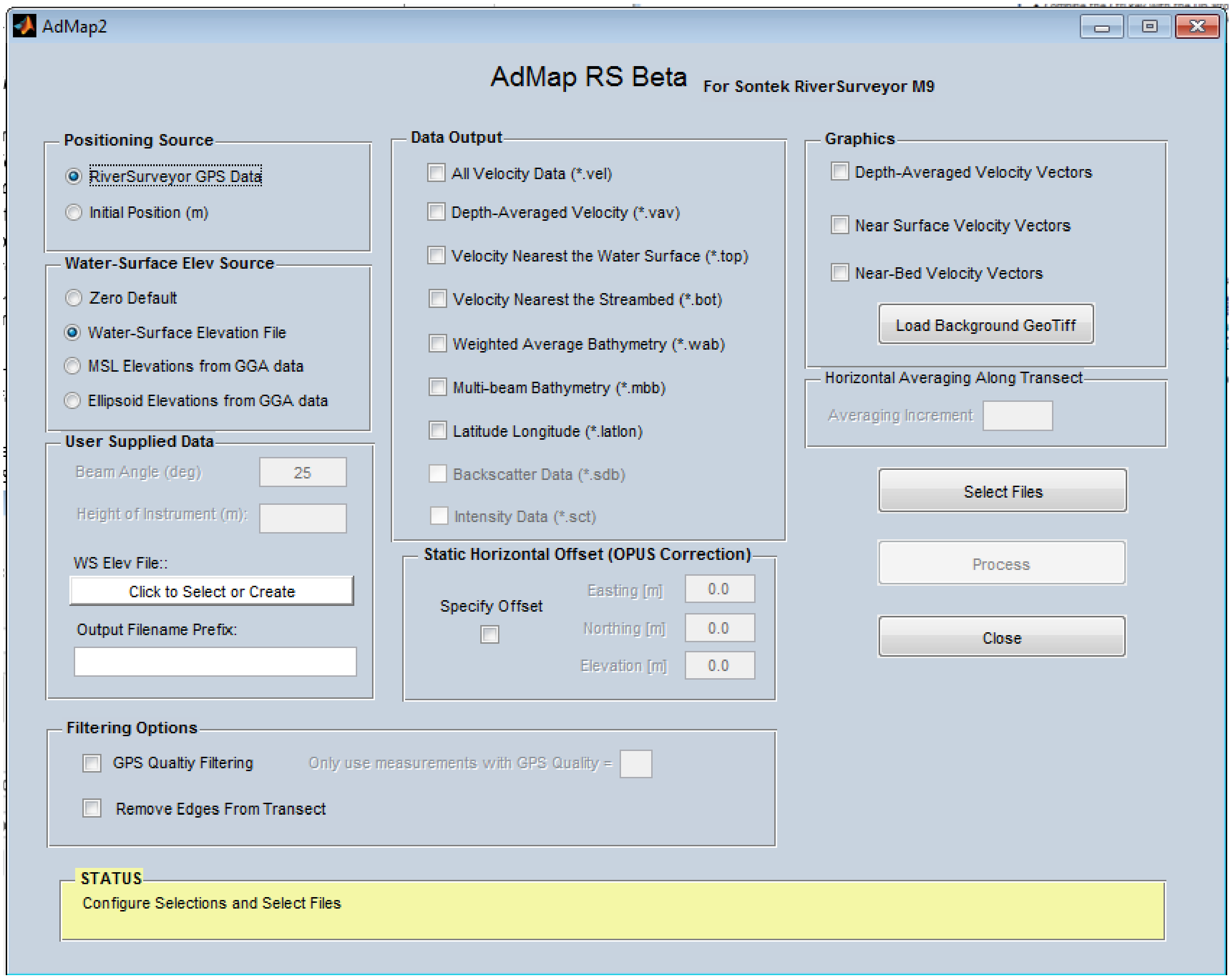


Figure B 2. AdMap graphical user interface

AdMap Interface

The AdMap graphical user interface (GUI) is shown in Figure B 2.

Units

Input units from RiverSurveyor can be either English or Metric. AdMap checks the units tag within the input file, and runs units conversions appropriately. Horizontal positioning is always taken from the Latitude & Longitude information in the input file, and converted to UTM (meters). If using initial position capability (instead of RiverSurveyor GPS output), the initial positions need to be specified in meters, regardless of whether RiverSurveyor input units are English or Metric.

Water Surface Elevation Source

Zero Default: References all elevations from zero water surface elevation so that the resulting bathymetry represents depth values instead of elevation.

Water-Surface Elevation File: This option requires the creation of an Excel file that has the transect name in column A and the water-surface elevation in column B. The WS Elev File box in the next section will allow you to create this file from within AdMap or pick a preexisting file.

MSL Elevation from GGA data: This option uses the elevation from the GGA string. This is only recommended if you are using RTK and do not wish to do a local adjustment.

Ellipsoid Elevation from GGA data: This option uses the ellipsoid elevation from the GGA string so the user can adjust the elevation using local datum and adjustments.

User Supplied Data

Beam Angle (deg): Default is 25 for Sontek M9 systems.

Height of Instrument (m): Refers to the height of the GPS receiver relative to the water surface in meters. Thus all geographic coordinates (horizontal and vertical) are referenced from the GPS receiver. Entering a ”Height of instrument” value into AdMap will remove the instrument height from the elevation measured by the GPS, thus reflecting the water surface elevation.

WS Elev File: When you click the button below this label you will get a dialog that asks you to either open an existing file or create a new file. If you have an existing file then a file selection dialog will allow you to select that file. If you need to create a new file then the dialog will prompt you to select all the files that you want to include in this water-surface specification file. The software will automatically put the filenames in column A of an Excel spreadsheet and open Excel for you. You will have to expand column A so that you can enter the elevations in column B.

Output Filename Prefix: Enter the name you would like the output to be called. The different types of output will be identified with a three character suffix see labels in () under Data Output.

TransNo	EnsNo	Easting(m)	Northing(m)	Elev(m)	u(cm/s)	v(cm/s)	w(cm/s)	hmag(cm/s)	mag(cm/s)	hdir(deg)	vdir(deg)
0	549	740230.81	4617063.64	99.31	38.80	-74.30	-7.30	83.82	84.14	152.43	-0.09
0	549	740230.81	4617063.64	99.21	58.70	-55.20	-8.20	80.58	80.99	133.24	-0.10
0	549	740230.81	4617063.64	99.11	13.00	-36.20	-13.30	38.46	40.70	160.25	-0.33
0	549	740230.81	4617063.64	99.01	60.40	-28.20	0.10	66.66	66.66	115.03	0.00
0	549	740230.81	4617063.64	98.91	60.60	-37.00	8.70	71.00	71.53	121.41	0.12
0	549	740230.81	4617063.64	98.81	34.10	-71.40	3.20	79.13	79.19	154.47	0.04
0	549	740230.81	4617063.64	98.71	57.30	-58.30	-4.80	81.74	81.89	135.50	-0.06
0	549	740230.81	4617063.64	98.61	73.30	-75.70	-4.40	105.37	105.46	135.92	-0.04
0	549	740230.81	4617063.64	98.51	72.70	-45.00	-1.30	85.50	85.51	121.76	-0.02
0	549	740230.81	4617063.64	98.41	80.80	-43.80	-1.40	91.91	91.92	118.46	-0.02
0	549	740230.81	4617063.64	98.31	58.50	-27.30	0.50	64.56	64.56	115.02	0.01
0	549	740230.81	4617063.64	98.21	60.50	-39.30	3.70	72.14	72.24	123.01	0.05

Data Output

Note: The northing and easting (UTM) are always in meters. The other data are in whatever units were used in the output from RiverSurveyor. The UTM zone is picked based on the first latitude and longitude coordinate read from the files.

All Velocity Data (.vel):* Outputs an ASCII tabular file for all velocity data for every bin and every ensemble.

Depth-Averaged Velocity (.vav):* Outputs the average velocity for each ensemble using the average of all the bins in that ensemble but ignoring the unmeasured areas.

TransNo	EnsNo	Easting(m)	Northing(m)	u(cm/s)	v(cm/s)	hmag(cm/s)	hdir(deg)
0	549	740230.81	4617063.64	49.17	-45.65	67.09	132.87
0	550	740230.49	4617063.89	66.66	-54.19	85.91	129.11
0	551	740230.19	4617063.93	48.90	-63.64	80.26	142.46
0	552	740229.85	4617063.89	58.44	-54.74	80.07	133.12

Velocity Nearest the Water Surface (.top):* Outputs the velocity in the 1st valid bin from the water surface.

TransNo	EnsNo	Easting(m)	Northing(m)	Elev(m)	Depth(m)	u(cm/s)	v(cm/s)	w(cm/s)	hmag(cm/s)	mag(cm/s)	hdir(deg)	vdir(deg)
0	549	740230.81	4617063.64	99.31	0.69	38.80	-74.30	-7.30	84.14	83.82	152.43	-0.09
0	550	740230.49	4617063.89	99.31	0.69	67.90	-96.70	-7.00	118.37	118.16	144.92	-0.06
0	551	740230.19	4617063.93	99.31	0.69	82.20	-51.50	-8.80	97.40	97.00	122.07	-0.09
0	552	740229.85	4617063.89	99.31	0.69	68.00	-87.60	-9.10	111.27	110.90	142.18	-0.08
0	553	740229.60	4617063.94	99.31	0.69	80.30	-42.40	-19.40	92.86	90.81	117.83	-0.21
0	554	740229.36	4617064.17	99.31	0.69	63.60	-77.20	-4.80	100.14	100.02	140.52	-0.05
0	555	740229.14	4617064.34	99.31	0.69	79.90	-51.10	-4.50	94.95	94.84	122.60	-0.05
0	556	740228.88	4617064.30	99.31	0.69	72.60	-50.50	3.20	88.49	88.44	124.82	0.04

Velocity Nearest the Streambed (.bot):* Outputs the velocity and location of the last valid bin in each ensemble.

TransNo	EnsNo	Easting(m)	Northing(m)	Elev(m)	Depth(m)	u(cm/s)	v(cm/s)	w(cm/s)	hmag(cm/s)	mag(cm/s)	hdir(deg)	vdir(deg)
0	549	740230.81	4617063.64	97.71	2.29	2.00	-37.20	2.80	37.36	37.25	176.92	0.08
0	550	740230.49	4617063.89	97.71	2.29	23.60	-40.00	-2.90	46.53	46.44	149.46	-0.06
0	551	740230.19	4617063.93	97.81	2.19	1.80	-37.70	0.20	37.74	37.74	177.27	0.01
0	552	740229.85	4617063.89	98.01	1.99	73.80	-48.50	1.20	88.32	88.31	123.31	0.01
0	553	740229.60	4617063.94	98.11	1.89	37.30	-44.00	1.70	57.71	57.68	139.71	0.03
0	554	740229.36	4617064.17	98.11	1.89	29.60	-90.80	6.80	95.74	95.50	161.94	0.07
0	555	740229.14	4617064.34	98.21	1.79	2.30	-67.60	-4.70	67.80	67.64	178.05	-0.07
0	556	740228.88	4617064.30	98.31	1.69	45.30	-48.30	11.80	67.26	66.22	136.84	0.18
0	557	740228.68	4617064.33	98.31	1.69	73.10	-54.40	-2.90	91.17	91.12	126.66	-0.03
0	558	740228.64	4617064.67	98.41	1.59	41.80	-37.00	-2.40	55.87	55.82	131.51	-0.04
0	559	740228.84	4617065.27	98.31	1.69	72.50	-55.10	-5.00	91.20	91.06	127.23	-0.05
0	560	740229.25	4617066.06	97.61	2.39	54.70	-6.80	6.30	55.48	55.12	97.09	0.11

Weighted Average Bathymetry (.wab):* Outputs a single depth for each ensemble based on the inverse weighted average of the four beams.

TransNo	EnsNo	Easting(m)	Northing(m)	Elev(m)	Depth(m)
0	549	740230.81	4617063.64	-2.71	2.71
0	550	740230.49	4617063.89	-2.71	2.71
0	551	740230.19	4617063.93	-2.71	2.71
0	552	740229.85	4617063.89	-2.38	2.38
0	553	740229.60	4617063.94	-2.35	2.35
0	554	740229.36	4617064.17	-2.38	2.38

Multi-beam Bathymetry (.mbb):* Outputs the position and elevation of the streambed for each of the four beams.

TransNo	EnsNo	Easting(m)	Northing(m)	Elev(m)
0	549	740230.38	4617062.86	97.89
0	549	740231.43	4617064.26	97.89
0	549	740230.20	4617064.08	97.85
0	549	740231.61	4617063.04	97.94
0	550	740230.13	4617063.06	97.90
0	550	740231.05	4617064.56	97.89
0	550	740229.84	4617064.27	97.85

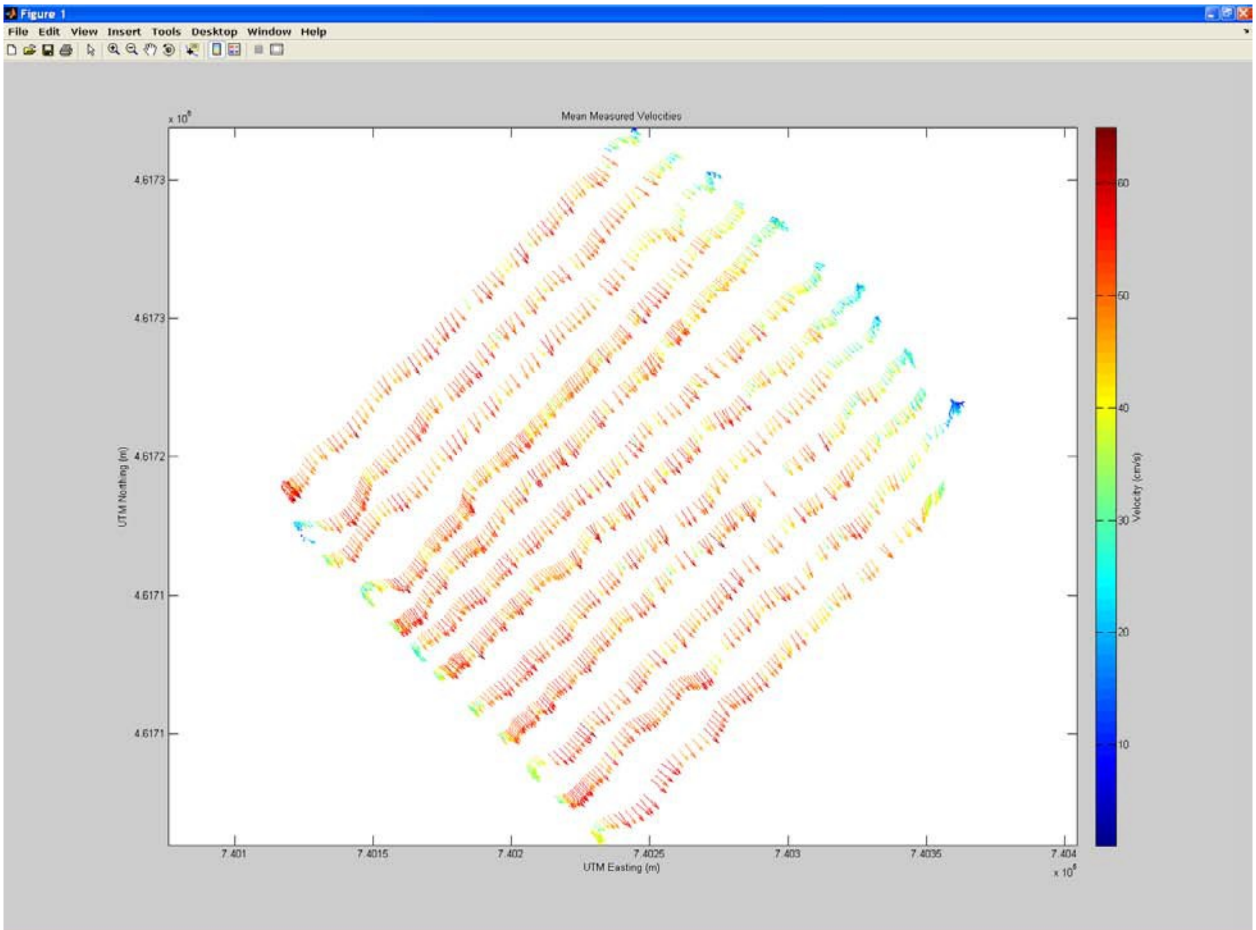
Static Horizontal Offset (OPUS Correction)

Offsets between the GPS reciever and the ADCP due to the mounting configuration within the boat, hydroboard, or other structure should be accounted for within the configuration settings in the RiverSurveyor Live software. This is because this correction must follow the instrument heading.

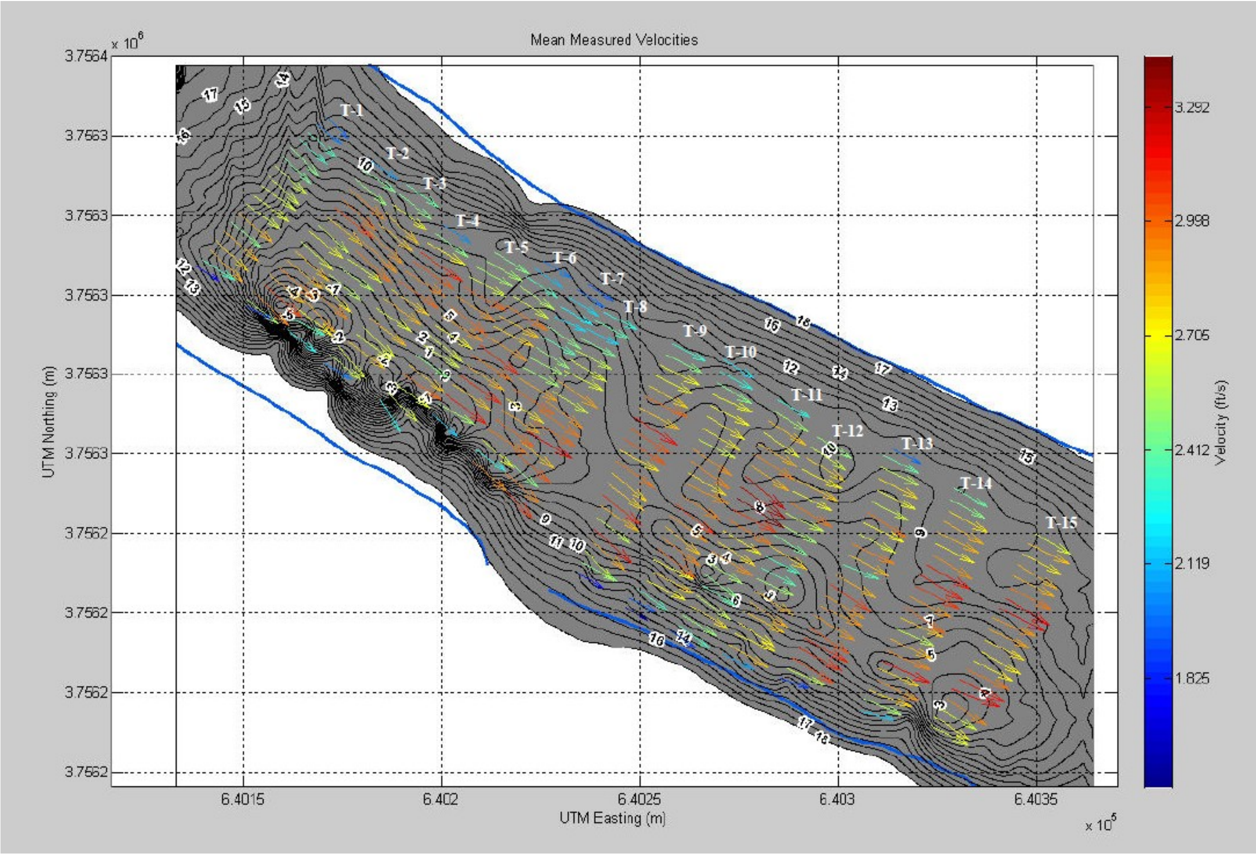
Offsets that are related to global positioning (namely, the OPUS correction of the base station location) should be applied using the static offset option in the AdMap GUI. This is because this type of offset is independent of the instrument heading.

Graphic

Selecting any or all of the three options will create a vector plot of the respective velocity vectors and turn on the data output for these options.



You can also load a background GeoTiff file and plot the vectors on this background.



Horizontal Averaging Along Transect

Averaging Increment: Often the raw data vectors are so close together that they do not make a good presentation of the flow. The value entered here will create average vectors spaced at this increment along the curvilinear path of the transect.

Select Files Button

Opens a dialog to select all files for processing. Using SHIFT-CLICK and CNTRL-CLICK to select multiple files.

Process Button

Begins processing the files. The status window will show which file is being processed.

Close Button

Closes the program.

Filtering Options

GPS Quality Filtering: Filters out data with poor GPS quality. Only keep data with specified quality (typically quality 4).

Dealing with Bad Data

Bad depth readings collected by the ADCP are assigned a value of zero when output to file. Because the instrument takes measurements from multiple beams simultaneously, any combination of beams may be bad for any given sample. Accordingly, the file output depth readings (*.mat) may contain any combination of zeros at each sample. In the event that the instrument does not recieve a valid depth reading from at least one or two out of the possible five beams, the RiverSurveyor Live software tags the sample as ’invalid’ in the ’Depth Reference’ column of the display. However, the file output will still contain the appropriate number of zeros for each beam in the sample. Apparently, it is also possible for a ”very large” number to be written to file instead of a zero, although I have not observed this behavior yet.

In principal, a bad depth reading could be the result of the water being too shallow (in which case the actual depth is close to zero anyways), a double-return (in which the acoustic signal actually travels down and back twice, resulting in a reported depth that is twice the actual depth) or for some other unknown system malfuction. Due to the uncertainty associated with the source of ”bad” data, we decided not to implement some sort of zero filtering function, so that more awareness of the data is forced upon the user.

AdMap Code Development

The content in this section will not likely be needed for most users of AdMap, but is provided for documentation and for any users that are interested in a deeper understanding of how the tool works.

AdMap was originally developed by Dave Mueller of the USGS (Figure B 3) for use in processing data from the WinRiver software RDI ADCP. Significant changes were required regarding the data format and instrument geometry in order to allow the tool to work in processing data from RiverSurveyor. Along a parallel path, features and capabilities have been added that were not included in the original AdMap.

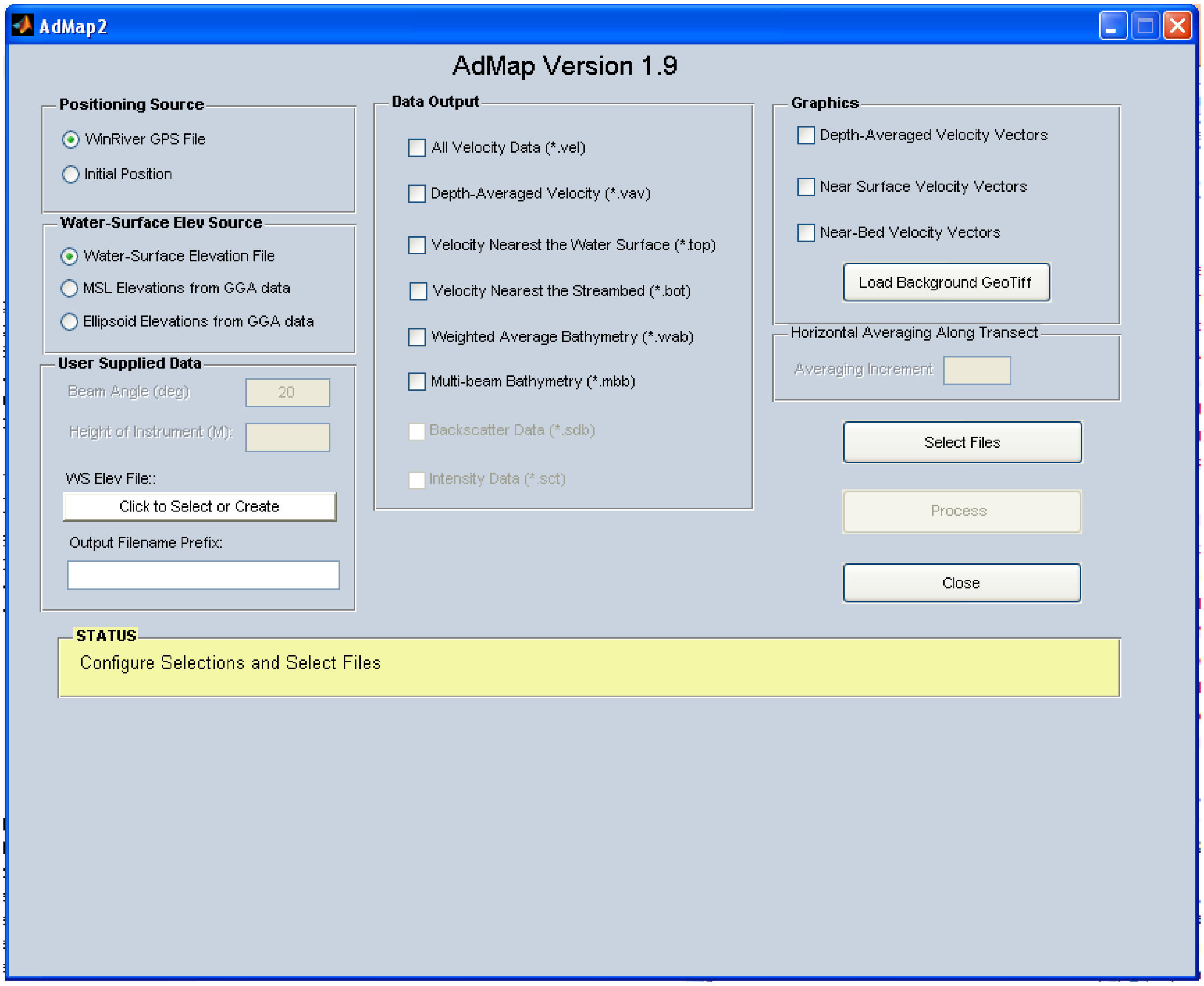


Figure B 3. Original AdMap graphical user interface as developed and provided by Dave Mueller, USGS, for use with WinRiver and RDI ADCP. The original AdMap was not compatible with the Sontek format.

Frequency Output

RiverSurveyor outputs several different types of frequency information associated with the mesurements.

- There is a bottom track frequency (BT-Frequency) array that contains the frequency tag associated with each depth measurement. It indicates whether the 1 MHz or 3 MHz beams were used for the multi-beam depth measurements. This information is used by AdMap to calculate the beam positioning since the geometry calculations are slightly different depending on which beam set is used for a given sample.
- There is also a water track, or profiling, frequency (WT Frequency) array that contains the frequency tag associated with each velocity measurments. It indicates whether the 1 MHz or 3MHz beams were used for the velocity measurements at each sample.
- Finally, there is a column ’Depth Reference’ which can be viewed in the RiverSurveyor Live output table. This information indicates where the depth measurement displayed is

the vertical beam (representing the nadir beam alone) or bottom track (an arithmetic average of the four outer beams)

HydroSurveyor Data Export and Processing

HydroProc is a tool for post-processing depth soundings and GPS data collected using the Sontek M9 ADCP when operated in HydroSurveyor mode.

Purpose

The purpose of HydroProc is to improve the efficiency of developing finished bathymetric mappings by partially automating the task of post-processing and integration of GPS information.

Need

The depth soundings as generated from the HydroSurveyor software are not generally referenced to the desired geographic reference frame and / or do not generally reference the most appropriate geoid model of the earth's surface. There is a general need to convert the data to an appropriate reference frame and apply a geoid model. There may be additional needs such as filtering the data to enhance quality or project the data from a geographic coordinate system in order to produce finished bathymetric data for a project.

Workflow

Processing with HydroProc is generally conducted in the office after the data acquisition trip has been completed.

GPS Configuration

GPS positioning is provided with the Trimble R8 system (the Trimble R10 could theoretically be used but has not yet been tested). The GPS hardware can be operated either in "generic GPS" or "auxiliary GPS" configuration, as defined by the HydroSurveyor data collection software. There are implications to the data processing workflow within the HydroProc tool depending on which GPS configuration is implemented during the data collection process. According to Dave Velasco of Sontek, "auxiliary GPS" is the preferred configuration, although there is uncertainty as to why that is the case. However, when using the "generic GPS" configuration, a NMEA log file for each data collection session is produced by the Sontek HydroSurveyor software, which contains geodetic information that can be useful in post-processing data. In "auxiliary GPS" configuration, a NMEA log file is not recorded, which puts some additional constraints on data processing using the HydroProc tool. However, HydroProc is setup to be able to perform the processing of data in either mode of operation, with or without the NMEA log files.

HydroSurveyor Data Export

After field data acquisition using the Sontek ADCP and HydroSurveyor software is complete, the input dataset for the HydroProc tool can be generated using the "Export Soundings" and "Export" utility within the HydroSurveyor software.

1. Soundings must be exported as elevations, not depths. First verify that the "Fixed Altitude" option is *not* selected in the "Project Settings" tab within the "Config" menu (Figure B 4).

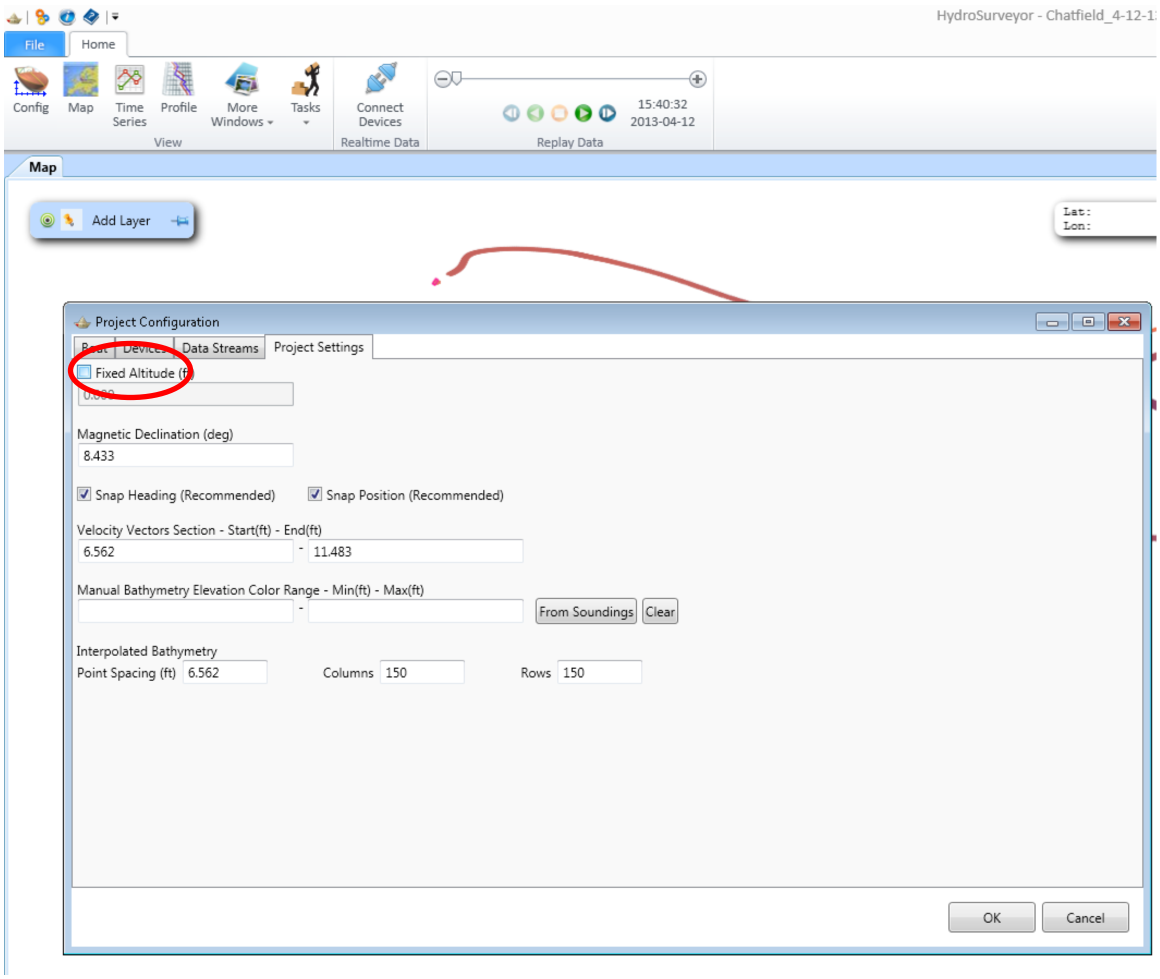


Figure B 4. Verify that "Fixed Altitude" is *not* selected prior to Soundings Export

2. Export the soundings within the soundings data layer by clicking the "Export Soundings" button in the expandable drop-down menu (Figure B 5).

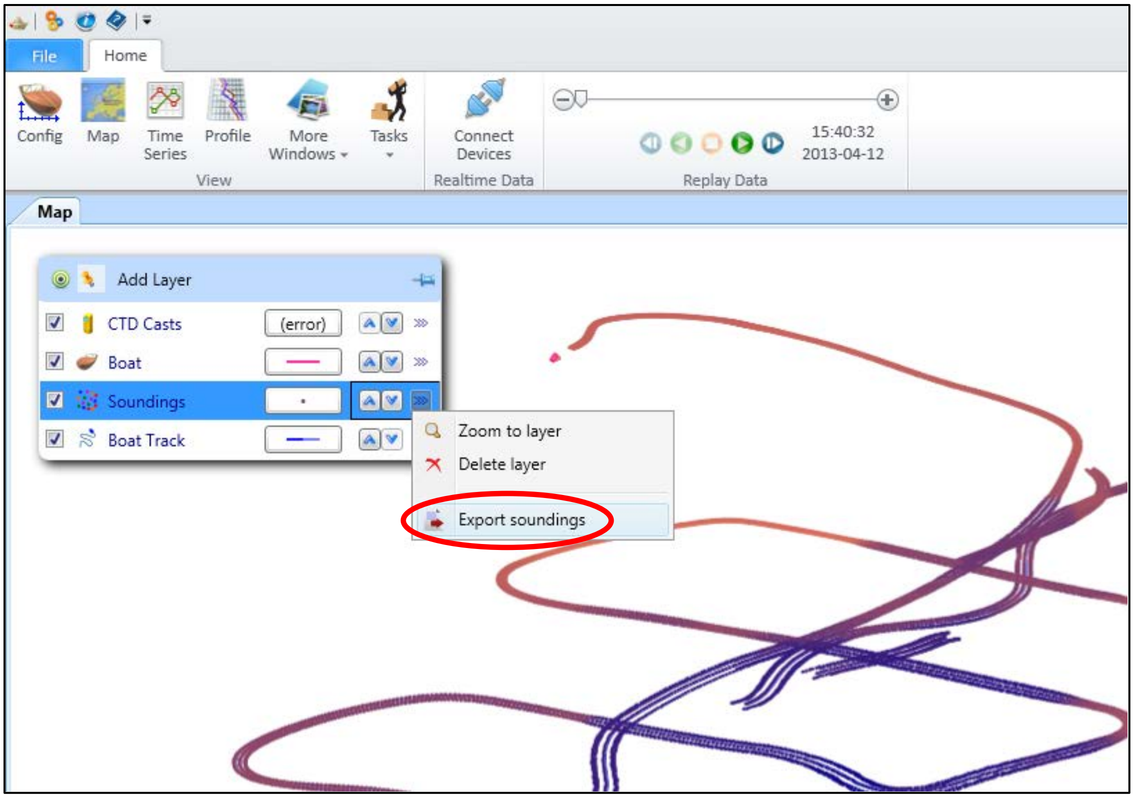


Figure B 5. Export soundings within Sontek HydroSurveyor Software

3. Export the session files in .mat Matlab format by selecting “Tasks” then “Export Session” (Figure B 5). In the “Export Data” dialogue box, select export “All” sessions from the drop-down menu Figure B 6).

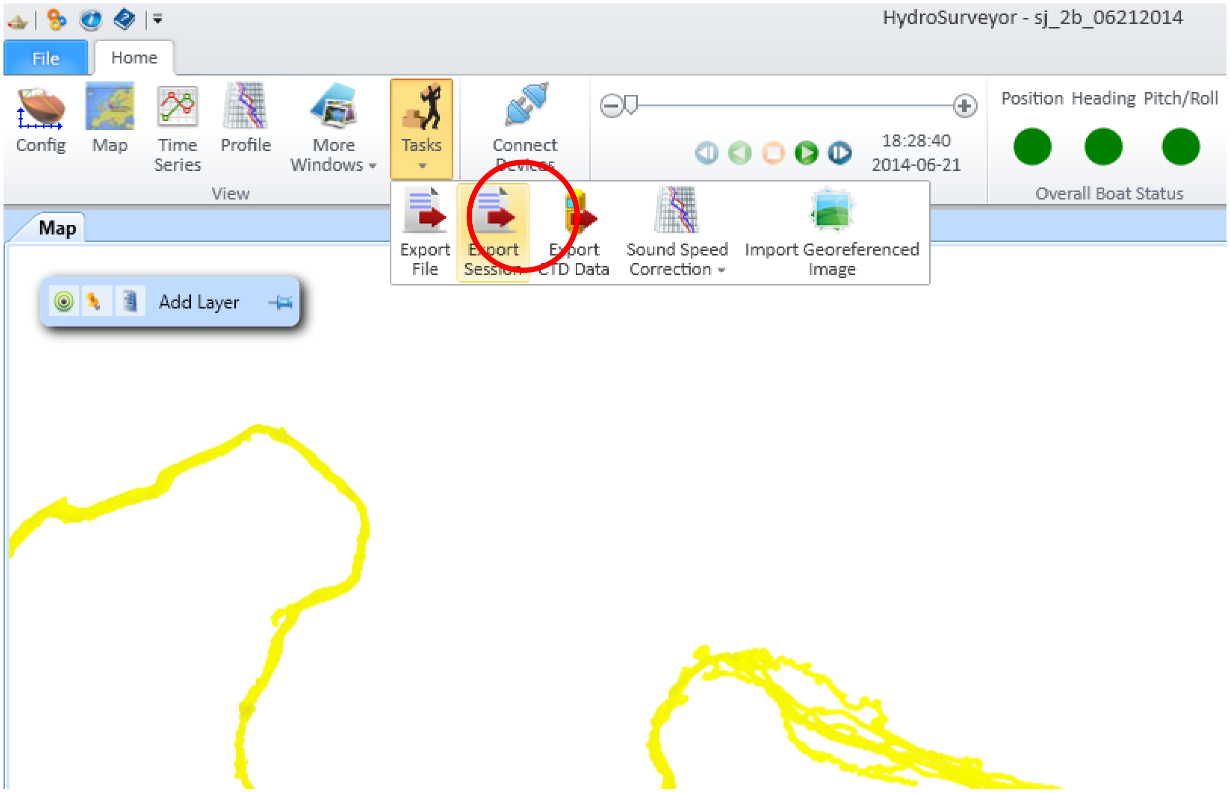


Figure B 6. Export session files by clicking "Export Session" under the "Tasks" drop-down menu

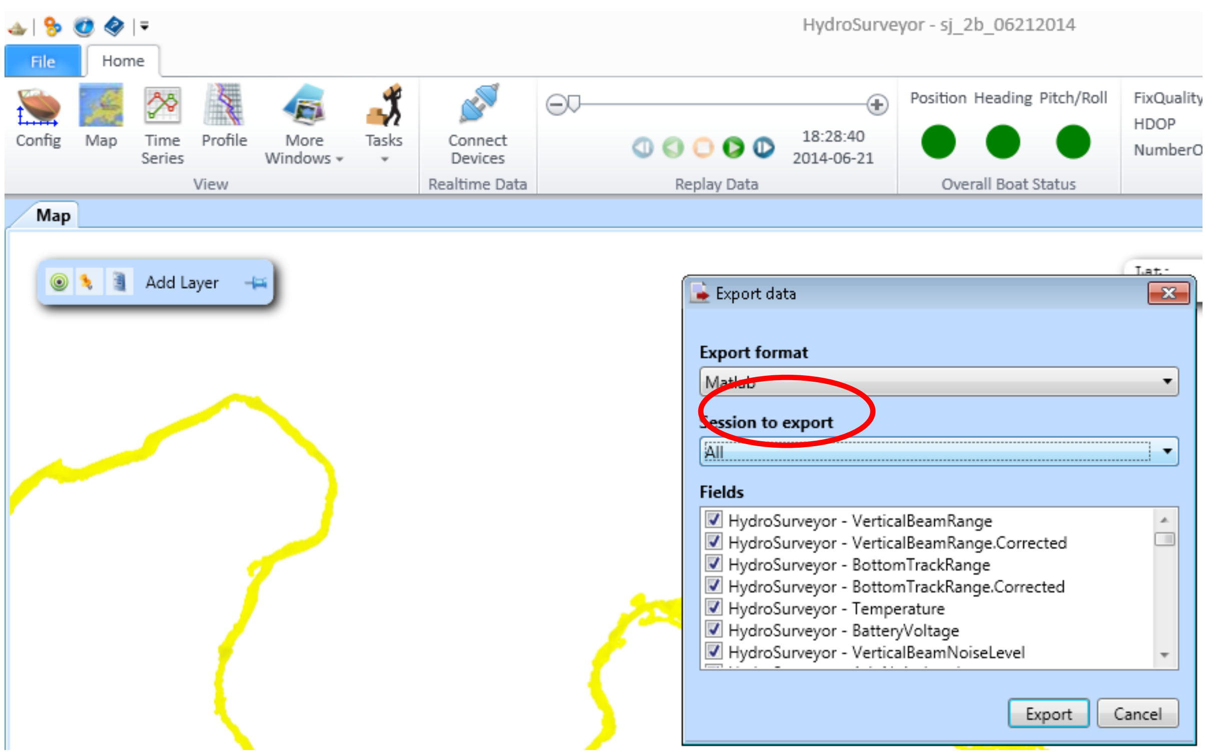


Figure B 7. Select "All" sessions for export in the "Export Data" dialogue box

HydroProc Interface

The HydroProc graphical user interface (GUI) is shown in Figure B 8.

- The “Soundings” button opens a file browser for selection of the exported soundings file from HydroSurveyor. See HydroSurveyor Data Export above. *In future versions a radio button may be added for the user to specify whether the soundings longitude is positive east or west convention.*
- “Date of Acquisition” is a necessary input but can be approximate since the program is not updating coordinates temporally. *In future versions, the date of acquisition may simply be pulled from the time stamp in the soundings data or GPS information loaded.*
- The pull-down menu “Geoid Input Source” specifies how the geoid separation that is to be removed from the soundings elevation data is to be determined (details below).
- The “Input Reference Frame” and “Output Reference Frame” specify the geographic reference frame on the input soundings and the desired output reference frame of the finished bathymetric data. HydroProc performs transformations between reference frames (details below).
- The “Output Geoid Model” is the desired geoid model to be applied to the finished bathymetry; it is left to the user to ensure that the output reference frame and output geoid model are compatible.
- The “GPS Quality” check box under “Filtering” determines whether or not filtering is performed on the data. If checked, only soundings with GPS quality values of 4 (four) are used.

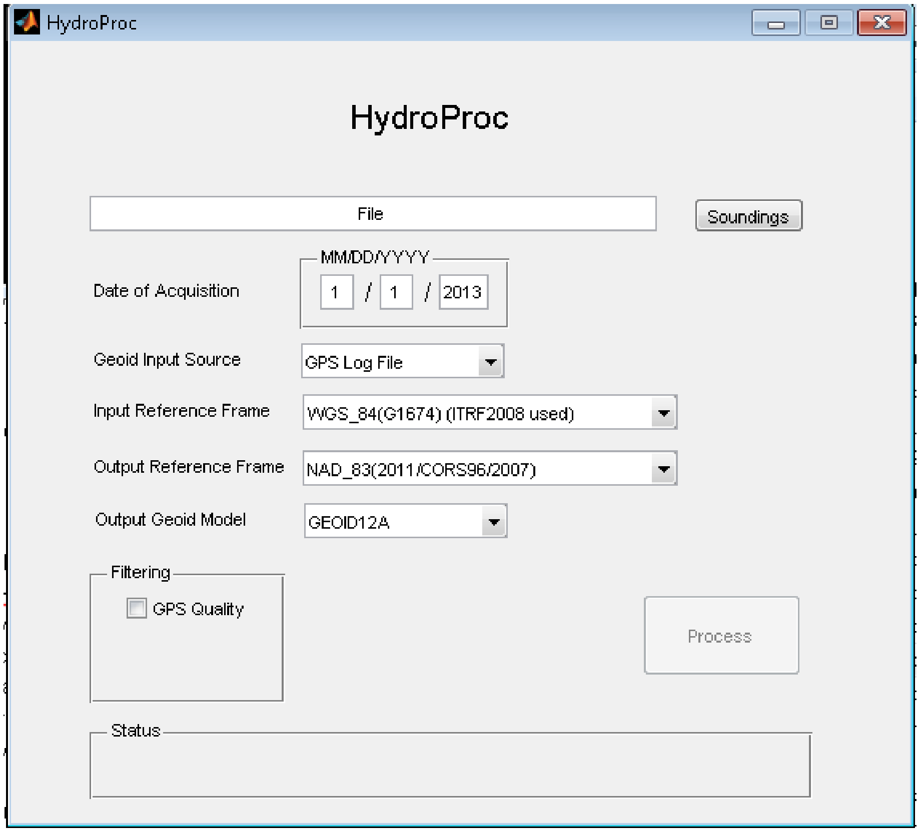


Figure B 8. HydroProc graphical user interface (GUI)

Feature Descriptions

Geoid Input Source

The geoid separation distance must be removed from the orthometric heights (elevations) given in the soundings file so that the coordinate system may be updated and a new geoid separation applied. Removing the geoid separation from the orthometric height produces the ellipsoid height (height above the model ellipsoid). The pull-down menu "Geoid Input Source" specifies how the geoid separation that is to be removed from the soundings elevation data is to be determined.

- If "GPS Log File" is selected, then the geoid separation values are pulled from the GGA string in the NMEA sequences contained within the GPS log files ("Generic GPS" configuration is required in order for GPS log files to be created during data acquisition). The HydroProc program will ask for the parent folder where the GPS log files reside. The appropriate GGA string information is paired to each soundings point based on a nearest neighbor search of a spatial triangulation of the data.
- If "Session File" is selected, then the geoid separation values are pulled from the Matlab (___SessOut#.mat) session output files that can be exported from HydroSurveyor. The HydroProc program will ask for the .mat session files. The appropriate geoid separation value is paired to each soundings point based on a time stamp interpolation. *In future versions, may add ability to use .csv session export files instead of .mat.*
- If "Calculated (EGM96)" is selected, the geoid separation is calculated based on the latitude, longitude pair at each soundings point using the NGA F477 tool (details below).

HydroProc Code Development

The content in this section will not likely be needed for most users of HydroProc, but is provided for documentation and for any users that are interested in a deeper understanding of how the tool works.

User Interface

The HydroProc user interface and driver is written in the Matlab language and compiled into a PC-executable using the Matlab Compiler. This allows the tool to be used on computers without a full Matlab installation. It is necessary to run the MCR (Matlab Compiler Runtime) installer which provides the underlying Matlab engine to run the executable.

Longitude East / West Convention

Soundings are expected to be in positive east convention when exported from HydroSurveyor software, which is the default convention used by HydroSurveyor at the time this was written. In positive east convention, California longitude is approximately -120 or +240. Longitude is then stored as both an east convention array and west convention array within the code in order to ensure that the appropriate convention is used at each stage in the processing (see NGS tools below).

NGS INTG

The INTG (INTerpolate Geoid) tool was developed by Dan Roman of NGS for interpolating geoid height given a user specified position and geoid model. Interpolation is performed using either spline or bilinear interpolation. Gridded data model files (*.bin) are direct access, unformatted, binary format, and must be located within the search directory. The gridded data files are available for download from the NGS website, and are specific to each geoid model (e.g., Geoid09 vs. Geoid12A).

The INTG code was written in C/C++ language. Integration into HydroProc was performed by building a Matlab gateway routine and compiling the code into a MEX (Matlab Executable) file. This allows the INTG program to be called as a function at the Matlab command line or in script.

HydroProc is using INTG version 3.17, which is the latest release as of the time of writing this document.

The INTG source code can be found here:

http://www.ngs.noaa.gov/GEOID/GEOID12A/GEOID12A_data.shtml

The INTG readme file (specific to GEOID12A) can be found here:

http://www.ngs.noaa.gov/GEOID/GEOID12A/g2012Arme.txt

NGS HTDP

The HTDP (Horizontal Time-Dependent Positioning) tool was developed by Richard Snay and Christopher Pearson of the NGS for transforming positional coordinates across time and between spatial reference frames.

The HTDP code was written in the FORTRAN fixed-format style language. Integration into HydroProc was performed by building a Matlab gateway routine and compiling the code into a MEX (Matlab Executable) file. This allows the HTDP program to be called as a function at the Matlab command line or in script.

HydroProc is using HTDP version 3.2.3, which is the latest release of the time of writing this document.

The HTDP source code, User's Guide, and revision log can be found here:

http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.shtml

NGA F477

The F477 tool was developed by Richard Rapp of Ohio State University in collaboration with NGA/NASA. The program calculates geoid undulation at a user specified location using the EGM96 geo-potential model. The undulation is relative to the WGS84(G873) ellipsoid.

The F477 source code was written in the FORTRAN fixed format style language. Integration into HydroProc was performed by building a Matlab gateway routine and compiling the code into a MEX (Matlab Executable) file. This allows the F477 program to be called as a function at the Matlab command line or in script.

The F477 program was developed in December 1996.

The F477 source code, User Instructions, and EGM96 Coefficients files can be found here:

http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm96/egm96.html

Future Work

It is likely that future work will be required to maintain the HydroProc capabilities while updates to ADCP and GPS hardware and software progress. Bathymetry mapping utilizes rapidly changing technology and it will be important for users to remain current in order to maintain efficient workflow, particularly as data requirements increase in routine project work. In the future, the HydroProc tool may be extended to complement the RiverSurveyor data export as well.

Appendix C – HydroProc Performance Assessment

Funded by Four Corners Construction Office (FCCO) in cooperation with the Navajo-Gallup Water Supply Project (NGWSP)

Purpose

A test was conducted in 2016 in order to evaluate the effectiveness of the processing tool in handling data export from the HydroSurveyor software. A comparison was made between data processed using the newly developed tool and data processed using conventional GIS methods. Conceptually, if the data processed by both methodologies is well-aligned, then a high degree of confidence can be had in the effectiveness of the new processing tool.

Methods

The following steps were conducted to determine HydroProc performance.

In HydroSurveyor:

1. Ensure that all boat dimensions and distances relative to the CRP are correct.
2. Export soundings as:
    a. Depths
    b. Elevations
3. Export all Sessions to MatLab files (under "Tasks")

In HydroProc

4. Identify soundings file as the 'elevation' export from 2.b
5. Set Input Reference Frame as WGS_84(transit)(NAD_83(2011)used)
6. Set Output Reference Frame as NAD_83(2011/CORS96/2007)
7. Set Geoid Model to be consistent with TBC/project data
8. Check the GPS Quality box.
9. When Prompted, select all session export (.mat) files

In ArcMap:

10. Digitize a channel centerline and make it a route (linear referencing)
11. Create the following shapefiles (Feature Class from XY Table)
    a. Water surface points: these are from TBC export. Should have Eastings and Northings in the appropriate SPCS using NAD83(Conus) as reference frame
    b. HydroSurveyor Soundings
        i. For both depths and elevations.
            1. Assign XY Coordinate system as "NAD 1983" (GCS_North_American_1983; WKID 4269). Using other

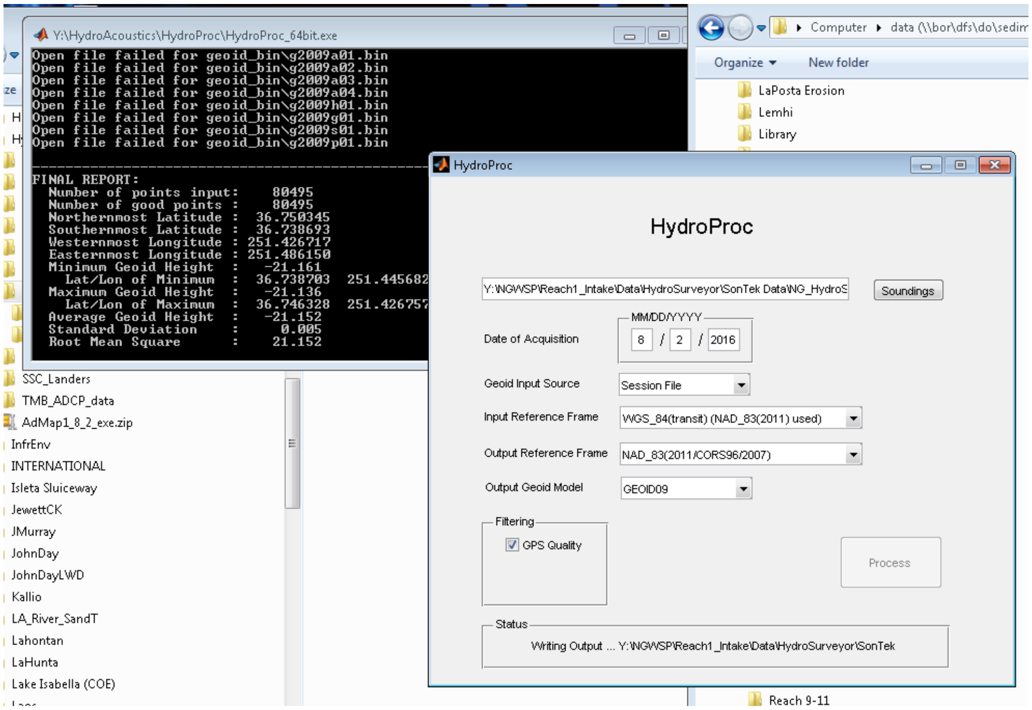
Coordinate systems (2011, WGS84) will cause position to be WRONG.
2. Project shapefile to appropriate SPCS (same as TBC export definition)

c. HydroProc output
    i. First changes longitudes from (+) to (-) in text editor (find/replace)
    ii. Assign XY Coordinate system as “NAD 1983” (GCS_North_American_1983; WKID 4269).
    iii. Project shapefile to appropriate SPCS (same as TBC export definition)

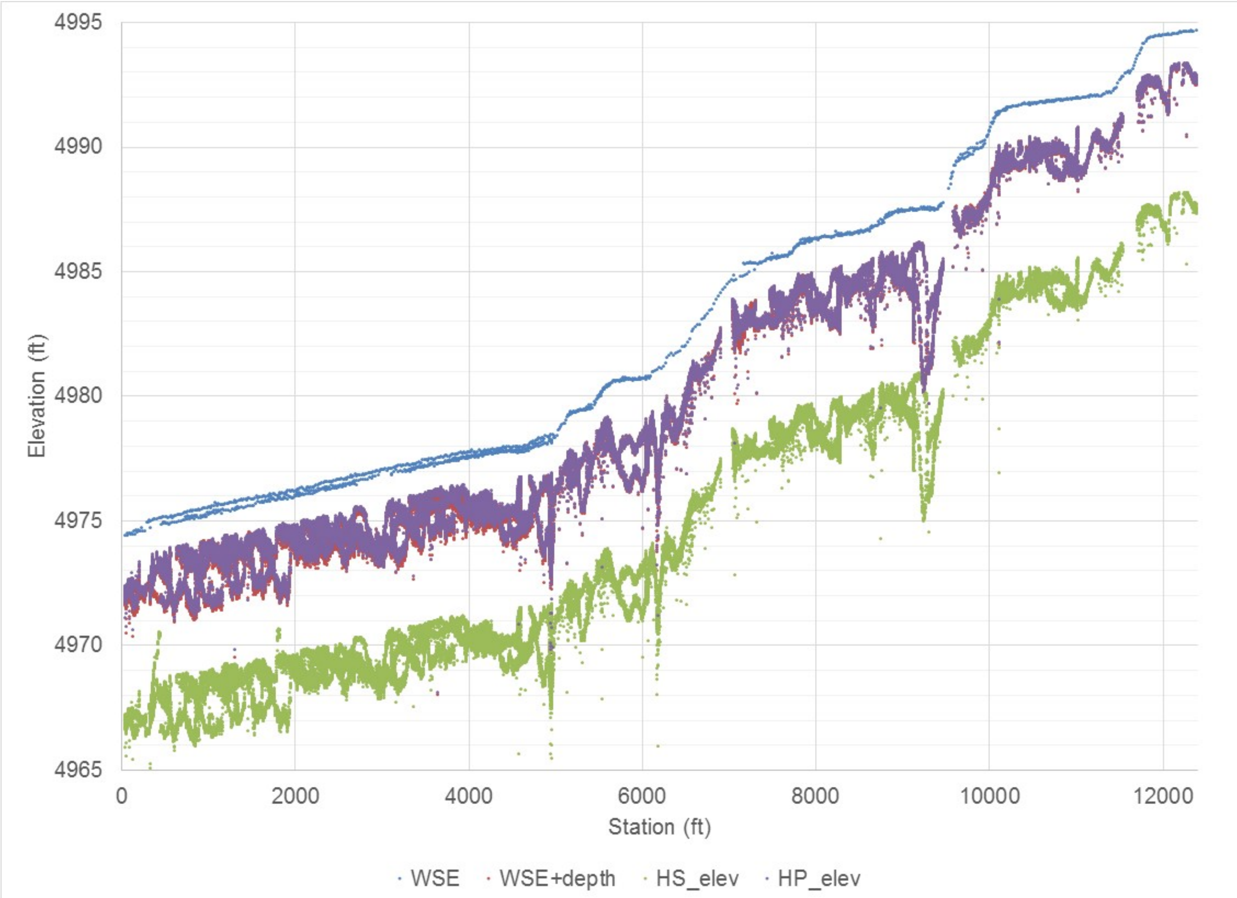
12. Locate Features Along Routes
    a. Use route created in step 10
    b. Locate 4 shapefiles along routes (Linear Referencing Toolbox)
        i. 1 WSE file from TBC
        ii. 2 HydroSurveyor exports (depths and elevations)
        iii. 1 HydroProc output
13. Export each output table from Linear Referencing to Text File for manipulation in Excel (or R or what have you)

In Excel (or other)

14. Plot data as a longitudinal profile
15. Calculate bed elevations as WSE + depth (depths are exported as negative numbers from HydroSurveyor). One option is to linearly interpolate WSE based on nearest up/downstream survey points. Other methods are available.
16. Create a column that rounds route station (MEAS) to integer value
17. Summarize elevations from various sources based on integer station, which is essentially a moving average
18. Develop simple statistics: mean, median, min, max, IQR. This calculation is a difference between HydroProc output and the elevations calculated as WSE plus (negative) depth.


Y:\HydroAcoustics\HydroProc\HydroProc_64bit.exe
Open file failed for geoid_bin\g2009a01.bin
Open file failed for geoid_bin\g2009a02.bin
Open file failed for geoid_bin\g2009a03.bin
Open file failed for geoid_bin\g2009a04.bin
Open file failed for geoid_bin\g2009h01.bin
Open file failed for geoid_bin\g2009g01.bin
Open file failed for geoid_bin\g2009s01.bin
Open file failed for geoid_bin\g2009p01.bin
FINAL REPORT:
Number of points input: 80495
Number of good points : 80495
Northernmost Latitude : 36.750345
Southernmost Latitude : 36.738693
Westernmost Longitude : 251.426717
Easternmost Longitude : 251.486150
Minimum Geoid Height : -21.161
Lat/Lon of Minimum : 36.738703 251.445682
Maximum Geoid Height : -21.136
Lat/Lon of Maximum : 36.746328 251.426757
Average Geoid Height : -21.152
Standard Deviation : 0.005
Root Mean Square : 21.152
Computer
data (\\bor\dfs\do\sedim
Organize
New folder
LaPosta Erosion
Lemhi
Library
SSC_Landers
TMB_ADCP_data
AdMap1_8_2_exe.zip
InfrEnv
INTERNATIONAL
Isleta Sluiceway
JewettCK
JMurray
JohnDay
JohnDayLWD
Kallio
LA_River_SandT
Lahontan
LaHunta
Lake Isabella (COE)
Reach 9-11
HydroProc
HydroProc
Y:\NGWSP\Reach1_Intake\Data\HydroSurveyor\SonTek Data\NG_HydroS
Soundings
MM/DD/YYYY
Date of Acquisition
8 / 2 / 2016
Geoid Input Source
Session File
Input Reference Frame
WGS_84(transit) (NAD_83(2011) used)
Output Reference Frame
NAD_83(2011/CORS96/2007)
Output Geoid Model
GEOID09
Filtering
GPS Quality
Process
Status
Writing Output ... Y:\NGWSP\Reach1_Intake\Data\HydroSurveyor\SonTek

Results



Metric	Δ HPelev - (WSE+Hsdepth)
min	-1.320
0.25%	-0.142
mean	-0.085
0.50%	-0.058
0.75%	-0.025
max	1.120

Figure C 1. Comparison of bathymetry computed by conventional methodology (red) to bathymetry computed using the HydroProc processing tool (purple). The overlap of the data indicates that the processing tool is performing effectively.

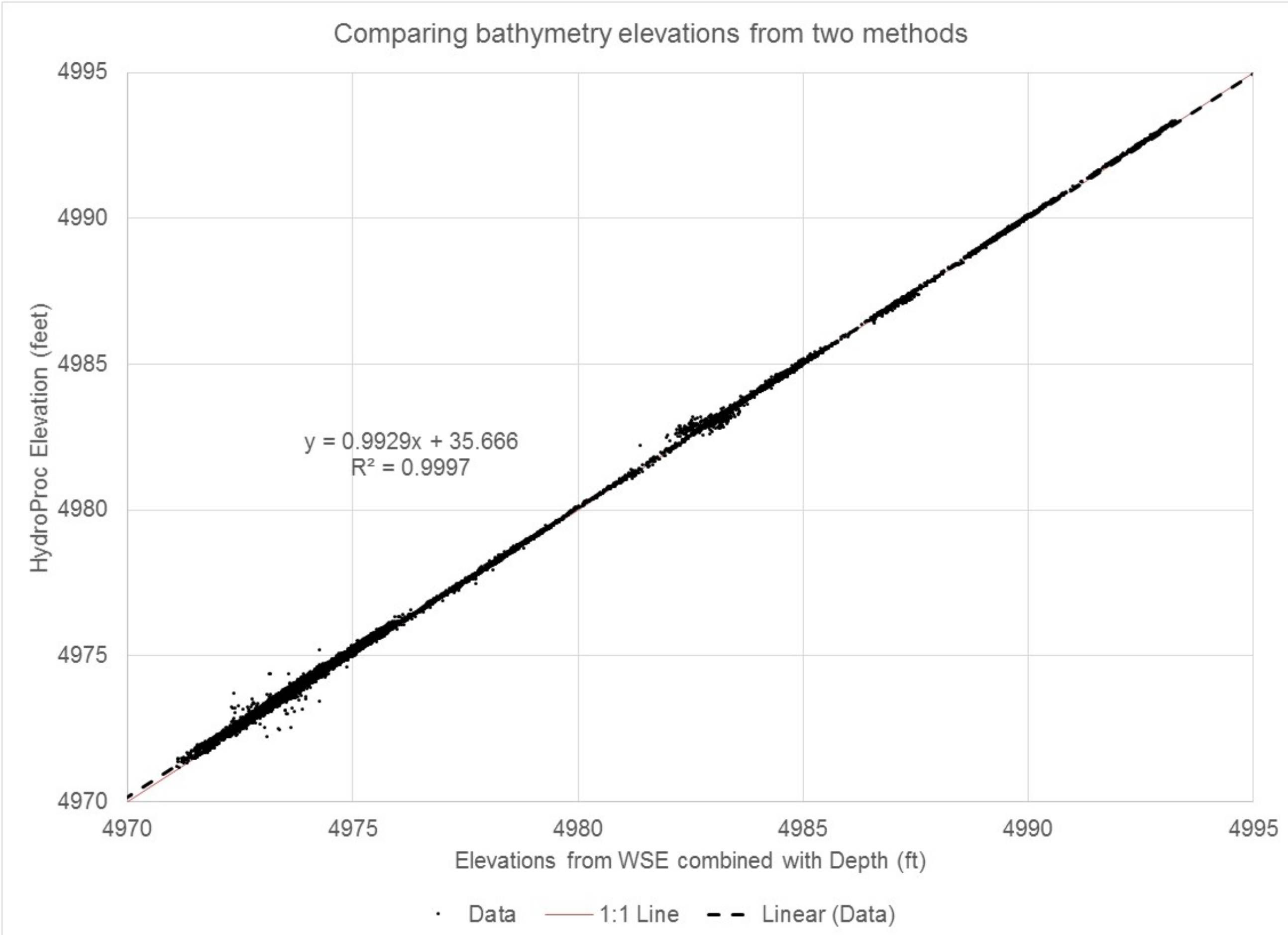


Figure C 2. Comparison of bathymetry computed by conventional methodology (x axis) to bathymetry computed using the HydroProc processing tool (y axis). The data plots along a 1:1 fitted line, indicating good agreement.