Summary Workflow for CEE-USV™ Hydrographic Projects

The CEE-USV™ remotely-operated survey boat is used to generate accurate bathymetric data to support construction or modeling projects, water volume determination and flood control. Often the hydrographic data are merged with land surveys to produce a complete digital elevation model. An overview of the process of using the USV is described, allowing potential users to better understand the workflow involved.

Step 1: Set Up Project Job in the Hydrographic Acquisition Software

Background map images may be imported into the project for reference, survey boundary polygons and planned survey lines / background DXFs can be added to indicate the desired survey pattern to the field crew. Waypoint navigation routes can be loaded if using a robotic navigation system. Previous survey data may be imported if necessary. Geodesy is set as required by the project, and geoid model selected if using RTK.

Step 2: Configure GNSS Inputs

For CEE-USV systems that have an RTK-enabled CEESCOPE™ echo sounder on board, or those that operate in differential mode only, then no configuration is needed. The internal GNSS receiver will be set to match the base station UHF frequency and modulation and will receive RTK corrections automatically. For CEE-USV systems that use a third party GNSS, such as a Trimble R10, Leica GS16 or Topcon Hiper, this rover receiver must first be reconfigured to output the correct NMEA0813 messages and the data link with the CEESCOPE echo sounder in the CEE-USV must be established. Once the corrected GNSS data are visible on the CEESCOPE LCD display, and the appropriate fix quality is achieved, GNSS hardware setup is complete.

Step 3: Start Telemetry Link and Test RC Range

Powering up the CEE-LINK™ shore radio automatically establishes a connection between the shore laptop or tablet and the CEE-USV. The hydrographic software may be started to show the water column echogram, position and depth data streaming from the USV. The remote operation of the echo sounder using the CEE CONNECT utility is checked and the appropriate maximum depth for the survey is entered. Appropriate checks on telemetry performance should be undertaken and RC control should be established as normal.

Step 4: Measure Offsets and Cross Check GNSS

The static transducer draft and (if present) RTK GNSS antenna height above the waterline are measured and entered in the hydrographic software. The appropriate coordinate system (eg. State Plane NAD83) and geoid model are checked. For RTK surveys, the water elevation as shown by the hydrographic "tide" indication in the acquisition software should match a "point shot" using land GPS equipment, or a known elevation determined by other means. This is a key cross check to complete when merging land survey and hydrographic datasets.

Step 5: Cross Check Echo Sounder Output and Estimate Sound Velocity

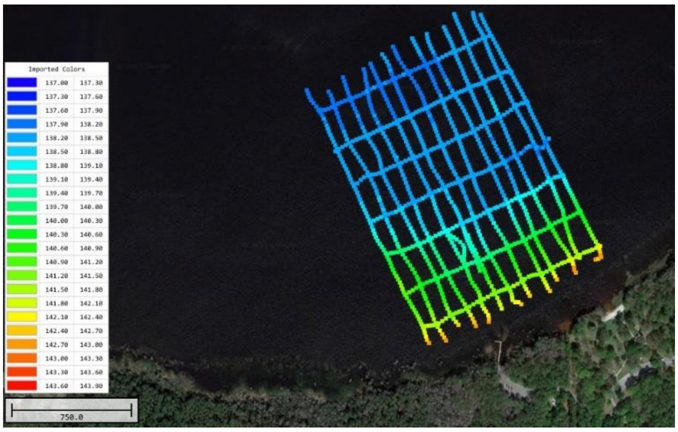
The bottom depth or elevation measurements from the CEE-USV may be checked with a range pole at a convenient location. If possible, a bar check may be performed at a dock. The sound velocity is entered in the CEESCOPE echo sounder on board, from a bar check or temperature and salinity estimate.

Step 6: Mark Survey Boundary

If the boundary of the survey is not known and not already loaded in the hydrographic software project, the USV may be driven round the safe boundary to mark the extent of the survey. From this boundary, survey lines and/or a robotic waypoint navigation route may be generated in the hydrographic software or the boat may be driven manually "on the fly". This route may be uploaded to the CEE-PILOT™ navigation controller in case of the autonomous system or used by an operator for manual surveys. Equally, the survey may be conducted without establishing any boundary or survey lines.

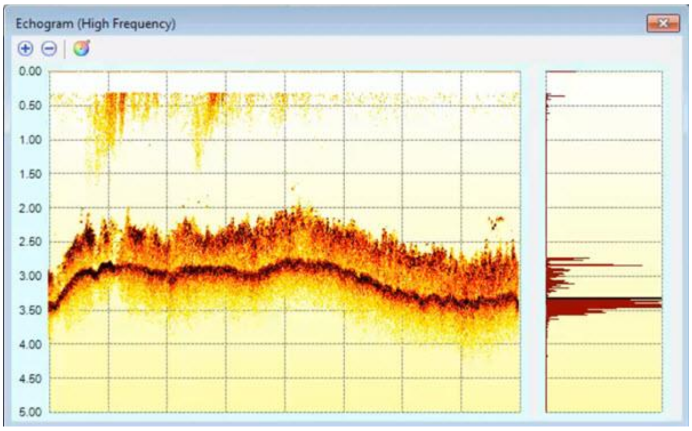
Step 7: Conduct Survey

The USV is usually driven in parallel lines with an appropriate spacing for the job size and bathymetry complexity; survey data are recorded in the hydrographic software for each line. At the same time the complete dataset for the survey may simultaneously be recorded on the CEESCOPE echo sounder onboard the CEE-USV for redundancy. Where possible, most lines should run perpendicular to slopes and the main survey pattern should not run parallel to slopes. Typically, fewer lines are run perpendicular to the main line set to provide cross lines for quality control checks.



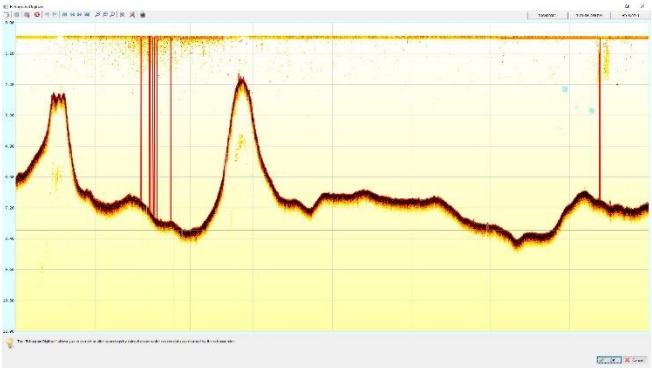
Step 8: Conduct Quality Control Assessment

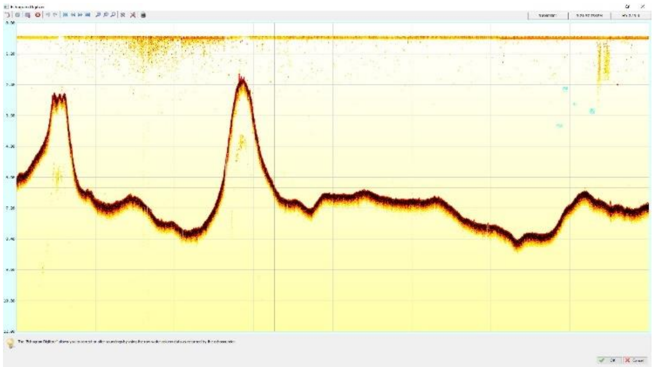
While performing the survey, the water column echogram should be monitored to ensure sounding data are accurate. If necessary, adjustments to the echo sounder parameters may be made to ensure accurate final soundings. The data should be reviewed at periods during the survey to ensure constent results are achieved, by examining the consistency of color patterns and sounding intersections should be within a few cm (<0.2ft).



Step 9: Edit Dataset

After the survey is concluded, the raw data are edited to generate a final sounding file. The typical raw data file from the CEESCOPE in the CEE-USV has 20 soundings per second. Any spiking is removed by filter tools or manual deletion and unusual effects from vegetation or soft sediments may be removed by manipulation using the manual digitizer tool to re-draw soundings to the correct level.

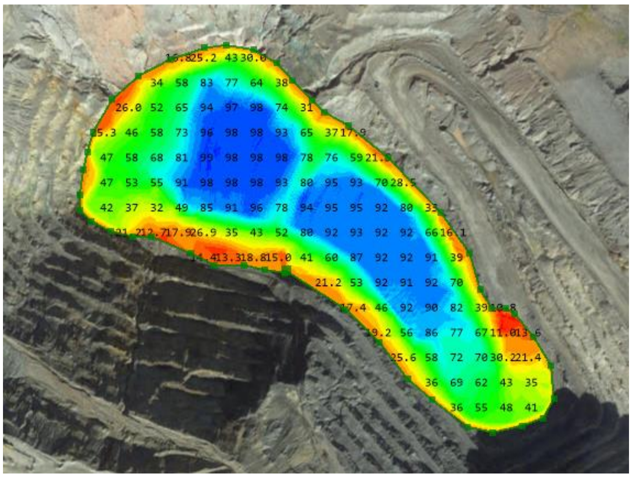


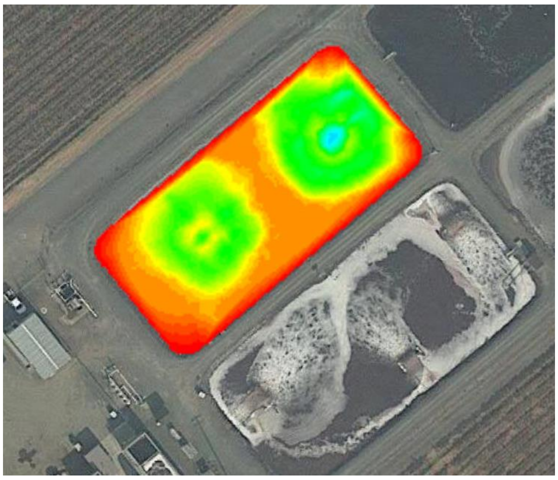


Step 10: Generate Survey Output

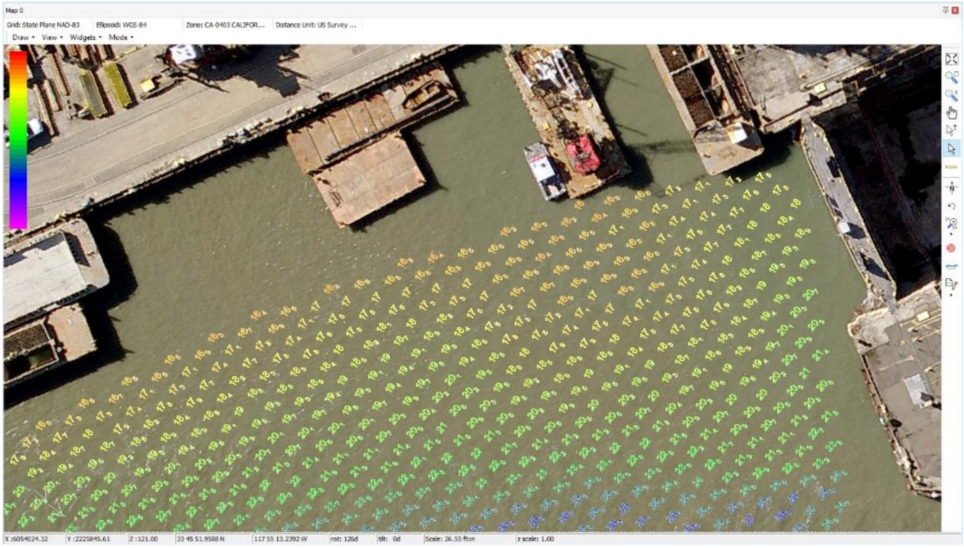
The sounding data now contains up to 20Hz edited soundings accurately positioned in the required coordinate system, either depth values or depth values and bottom elevations. The following outputs are commonly used, either from HYPACK or Hydromagic software (or others), although more options are available depending on the package. The common goal is to export XYZ data to merge with land survey, drone, or LiDAR datasets. This is possible as the geodetic framework is identical, and calibration has been performed to ensure data line up.

- Export edited XYZ for all sounding points. These data may be reduced or manipulated in third party software.
- Export edited and thinned / reduced XYZ (for example reduced to 4 points per sec or 1 point per ft spacing).
- Generate and export TIN model surface and DXF contours. Hydromagic data examples:

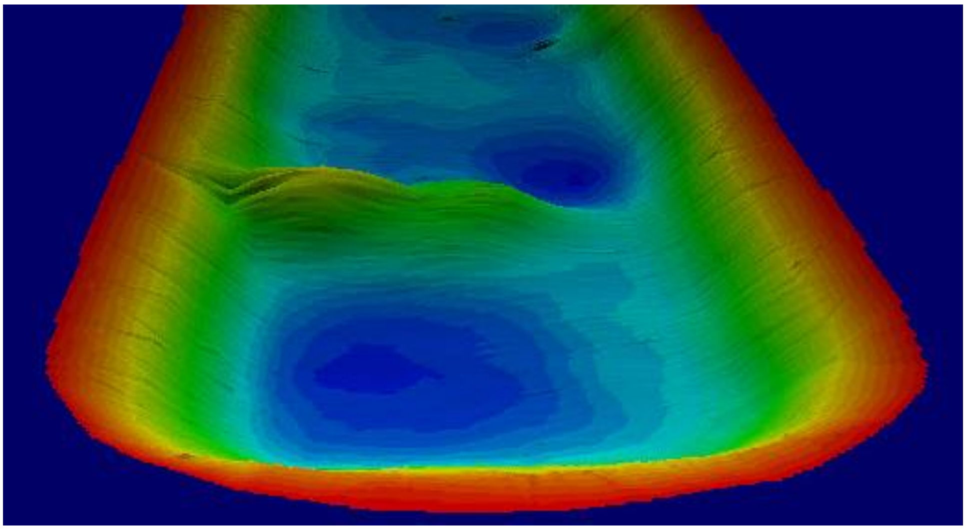




- Export XYZ with equidistant data points calculated from TIN model surface, for example a XYZ data point every 3ft (X) x 3ft (Y). HYPACK data example:



- Export 3D view of data for presentations. Hydromagic data example:



- Export KMZ for easy reference when emailing survey data.

Other Procedures.

In case post processing of GNSS data is required to meet precision standards, augmented PPK position data may be used in place of real time data when using HYPACK software, and others.

Geodetic transformations are possible within the hydrographic software to correct setup errors or to change the geodesy of the project data as required.

Dual frequency sounding data may be simultaneously acquired and edited to give two separate XYZ surfaces for the high and low frequency echo sounder channels.