ETRAC'S EVALUATION OF QIMERA:
Accomplishing the NOAA Workflow

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Abstract

eTrac's 2017 NOAA task orders in the state of Florida cover over 100 miles, from Sarasota to Naples, with area coverage requirements prioritized per NOAA's hydrographic health model. These include inlets, ferry routes, and over 100 feature investigations, which are particularly important after the passage of Hurricane Irma. eTrac, with their considerable resources and skilled personnel, is well-suited to handle such a project, and at the same time prides itself in their ability to be on the leading edge of new tools and capabilities.

QPS Qimera emphasizes above all a clean and streamlined workflow, one that minimizes the error-prone human tasks that traditionally have been required in hydrographic data processing. With eTrac operating three survey vessels daily, each with dual-head multibeam echo sounders, plus with the considerable feature requirements, there is excellent opportunity to evaluate Qimera's data throughput capabilities, dynamic workflows, and finally, its latest functionality—S-57 feature management. Additionally, eTrac showcases the benefit of QPS QINSy for acquisition—with real-time integration capabilities and seamless project migration to Qimera, there is potential for significant gains in efficiency.

Qimera will be evaluated during this project, with particular attention paid to the rapid data processing turnaround that is required by eTrac to ensure quality standards per NOAA specifications. Furthermore, the benefits of Qimera's processing state management and guided workflows for the eTrac personnel on-scene with varying experience levels will be assessed. Lastly, Qimera's S-57 capabilities—built with new, innovative methodology, in-spirit with the Qimera philosophy of removing human error from what is traditionally a quite tedious process—will be introduced. Both advantages and lessons learned will be included, and the benefits measurably delivered by Qimera—for eTrac and NOAA alike—will be presented.

Background

The NOAA Office of Coast Survey Project OPR-H358-KR-17 was awarded to eTrac in 2017 and is one of the first with survey area prioritized based on the NOAA Hydrographic Health Model (Fandel et al., 2017). As such, the area includes corridors to support high vessel traffic routes, inlets, and over 100 feature investigations. Altogether the project covers over 100 miles along the west coast of Florida, from Sarasota to Naples.

NOAA's complete coverage was required for all corridors, passes, and feature investigation, while also there were expansive areas of set line spacing multibeam over areas where previous lidar data collected in 2015 by the Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) did not achieve bottom detection due to water clarity or extinction depth. Feature investigations were particularly important after the passage of Hurricane Irma, which impacted the assigned project area as well as eTrac's mobilization efforts. The required feature investigation radius of complete coverage multibeam depended upon how each feature was charted, whether its position was known, approximate, reported, or doubtful.

The project was delayed by the passage of Hurricane Irma, as facilities critical to the mobilization of the project remained without power and a gasoline shortage hindered continuous vessel operation. eTrac mobilized as quickly as possible once facilities became available.

Three 30 foot Armstrong Catamaran Vessels were mobilized simultaneously with a suite of sensors on each vessel. Each vessel was mobilized with a different compliment of equipment tailored to that particular vessels survey tasks. *R/V Taku* was mobilized with Dual Head R2Sonic 2024 MBES sonars and was assigned primarily to complete coverage corridors and inlets. *R/V Benthos* was mobilized with a Dual Head Kongsberg 2040c system and was also assigned primarily to complete coverage corridors and inlets. *R/V 505* was mobilized with a single head R2Sonic 2024 and was assigned primarily to 100 meter set line spacing areas as well as feature investigations.

Figure 1. Three survey vessels mobilized, calibrated and prepared for survey operations (Naples, FL, September 20, 2017)

Acquisition

eTrac utilized QPS QINSy (Quality Integrated Navigation System) for data acquisition on each vessel. Each vessels survey system is a complement of sensors integrated within QINSy including Multibeam Echosounders and Inertially aided GNSS Navigation Systems. These systems were mounted statically on each vessel and remained in place for the duration of the project. Sensor lever arms and measurement offsets were measured to millimeter precision using a total station. A patch test was performed on each vessel to determine mounting angle biases.

As the project spanned a long stretch of shoreline, in order to efficiently task 3 vessels simultaneously the project area was segmented into 74 “tasking squares”. Each tasking square was 4 nautical miles by 4 nautical miles square, which was determined to be approximately the amount of area that could be completed by 1 vessel in 1 day. These tasking squares proved to be highly efficient for communication of tasks to the multiple field crews, as field hydrographers were able to overlay the tasking squares in QINSy’s online navigation display and monitor progress in real time.

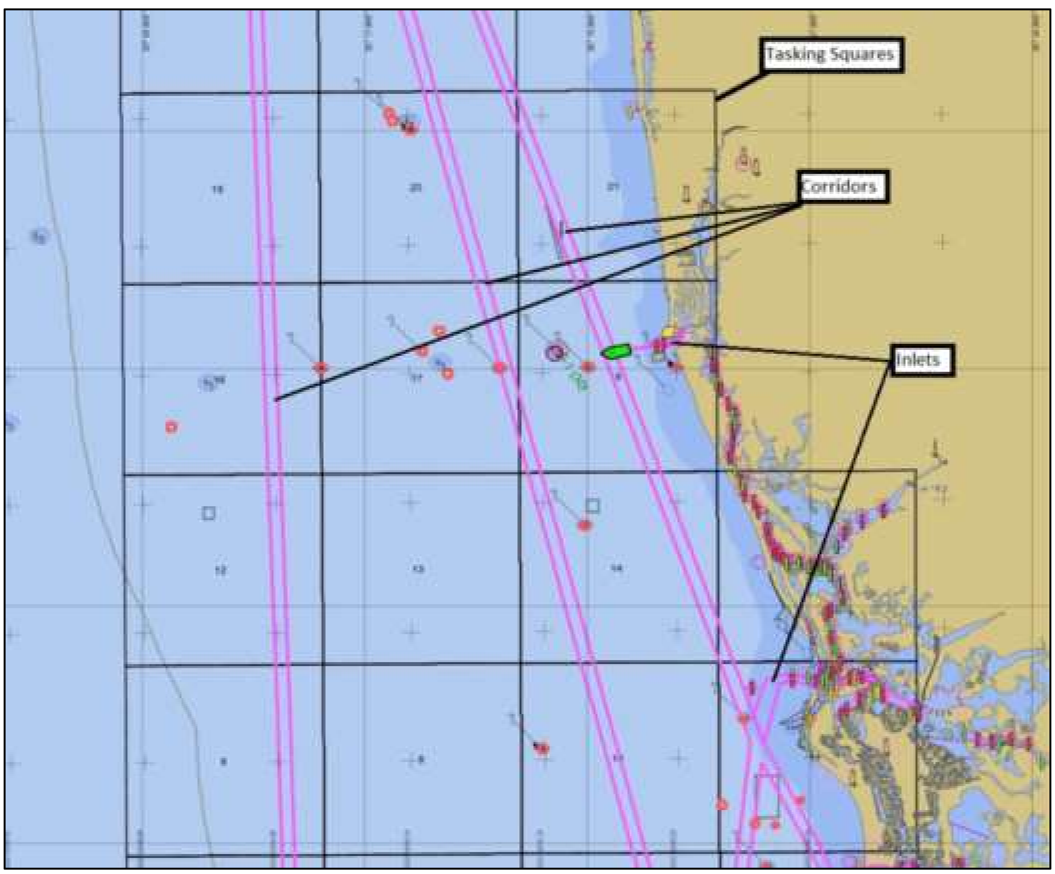

Figure 2. Tasking Squares Overlaid on Project Boundaries for OPR-H358-KR-17.

Real-time QC

During acquisition, eTrac utilized many of the custom displays within QINSy's online environment in order to QC the quality of data in realtime. One such QC display was the SV (Sound Velocity) comparison metric. This tool compares the SV value from the sensor located at the sonar head (streaming at 1hz to QINSy) to the SV value recorded at the surface during the previous full water column velocity cast taken. When the comparison value exceeds 2m/s, a visual alarm is displayed and the hydrographer is notified that a new velocity cast is required per NOAA's Hydrographic Survey Specs and Deliverables (HSSD, 2017).

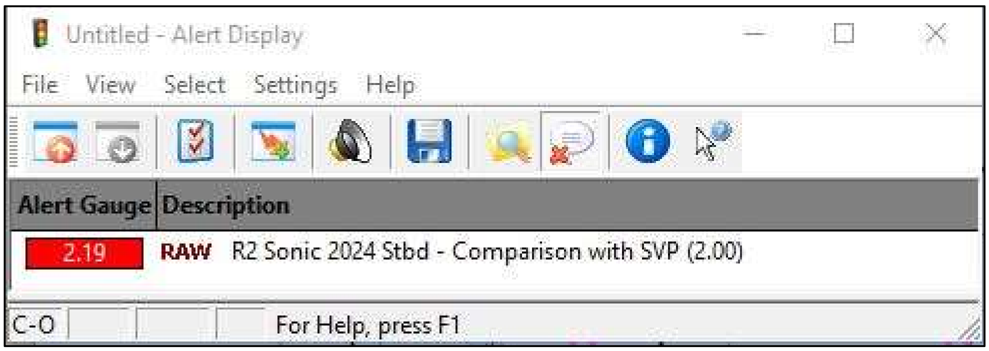

Figure 3. SV Comparison Alarm notifying the operator that a new SV cast is required

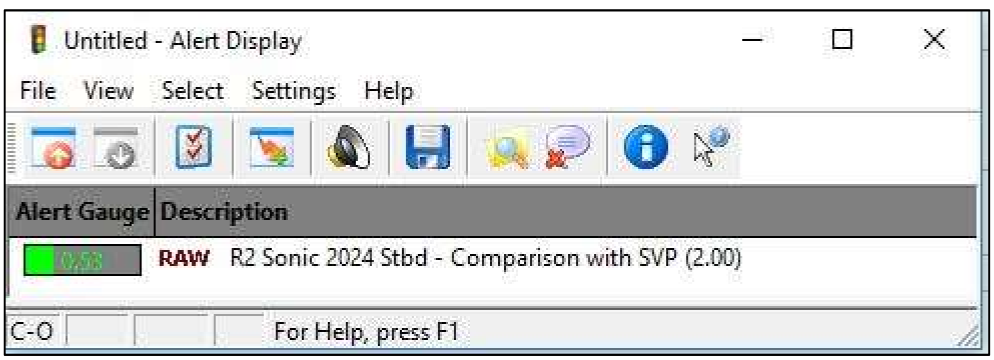

Figure 4. SV Comparison Alarm after updating system with new SV cast.

In addition to displaying the navigation coverage grid colored by depth, eTrac utilizes QINSy's multi-attributed "Sounding Grid" to display 2 sigma (95% confidence level) standard deviations colored on a single gradient color ramp. This view is particularly useful in identifying, in real-time, incorrect vessel biases, refraction artifacts, motion artifacts, and positioning inaccuracies. By leveraging this utility, eTrac is able to identify data deficiencies on the fly, correct for them, and minimize recovers that are traditionally discovered only in post processing.

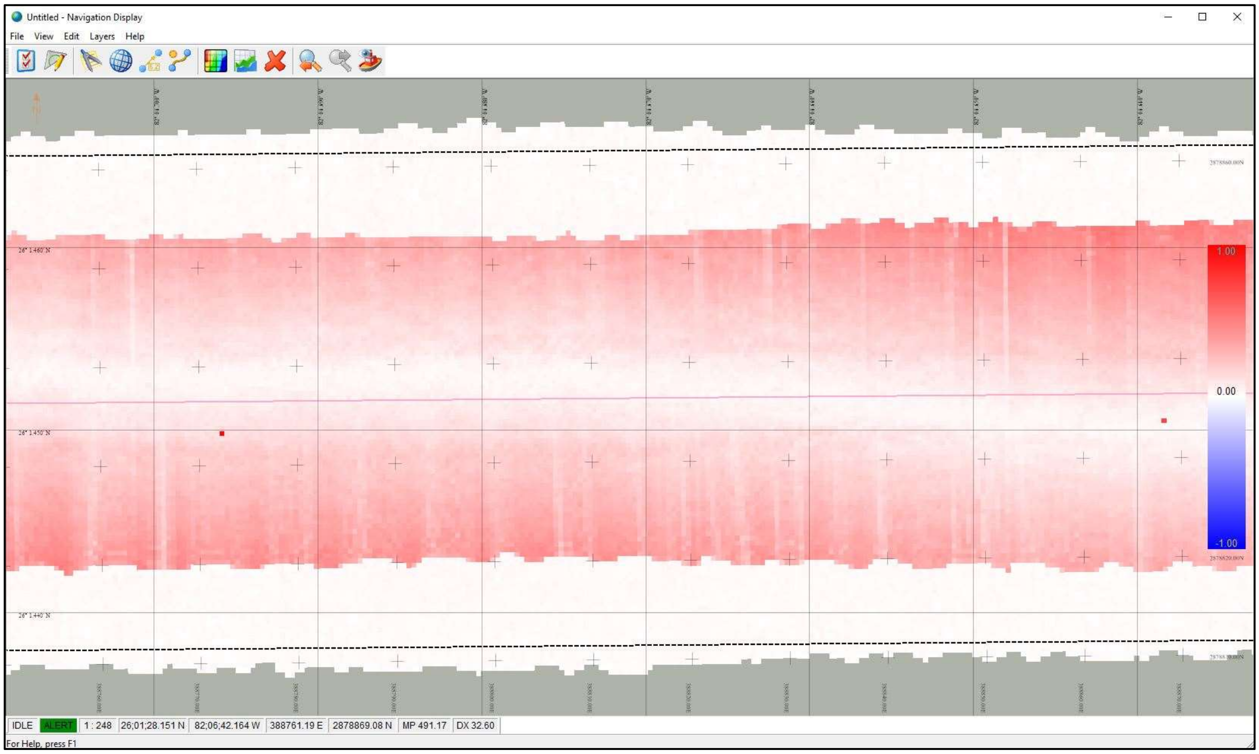

Figure 5. Reciprocal lines colored by standard deviation with roll misalignment of 1 degree.

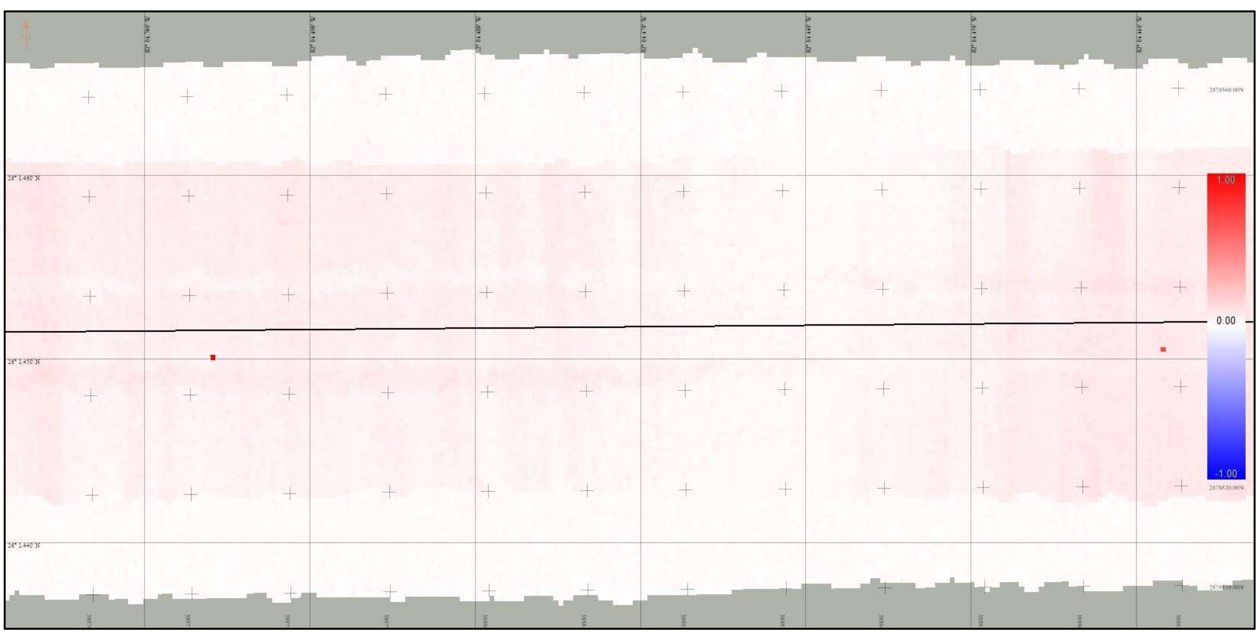

Figure 6. Reciprocal lines colored by standard deviation with roll misalignment corrected.

Geodetics

The Marinestar corrections system was implemented on each vessel for OPR-H358-KR-17. The Marinestar system is a global realtime GNSS broadcast system that delivers corrections from a network of base stations around the world via geo-stationary satellites. The Marinestar corrections system was utilized for both vertical and horizontal positioning.

By implementing the Marinestar corrections system, eTrac was able to obtain elevations referenced to the ITRF08 ellipsoid in real-time within an accuracy of approximately 15 centimeters throughout the entire survey area. Leveraging this advantage, eTrac created a custom separation file between the ITRF08 Ellipsoid and the MLLW navigation datum as defined by NOAA’s published VDatum tool. The custom separation model was configured in each vessels settings database. By configuring this custom separation, field units were able to achieve MLLW, in real-time, on each vessel.

eTrac’s inshore limit line, in most cases, was defined by the 4 meter MLLW contour. Traditionally this contour is verified after tidal post processing in the office and vessels are routinely required to return to a shoreline area to complete coverage that did not meet the 4 meter contour. By utilizing the ERS workflow, Marinestar corrections, and custom separation model, eTrac was able to position the 4 meter contour within 15 centimeter accuracy on every vessel in realtime. By setting an overflow color at the 3.5 meter depth contour, eTrac was able to confidently complete shoreline area developments in real-time without the need to revisit areas due to insufficient coverage.

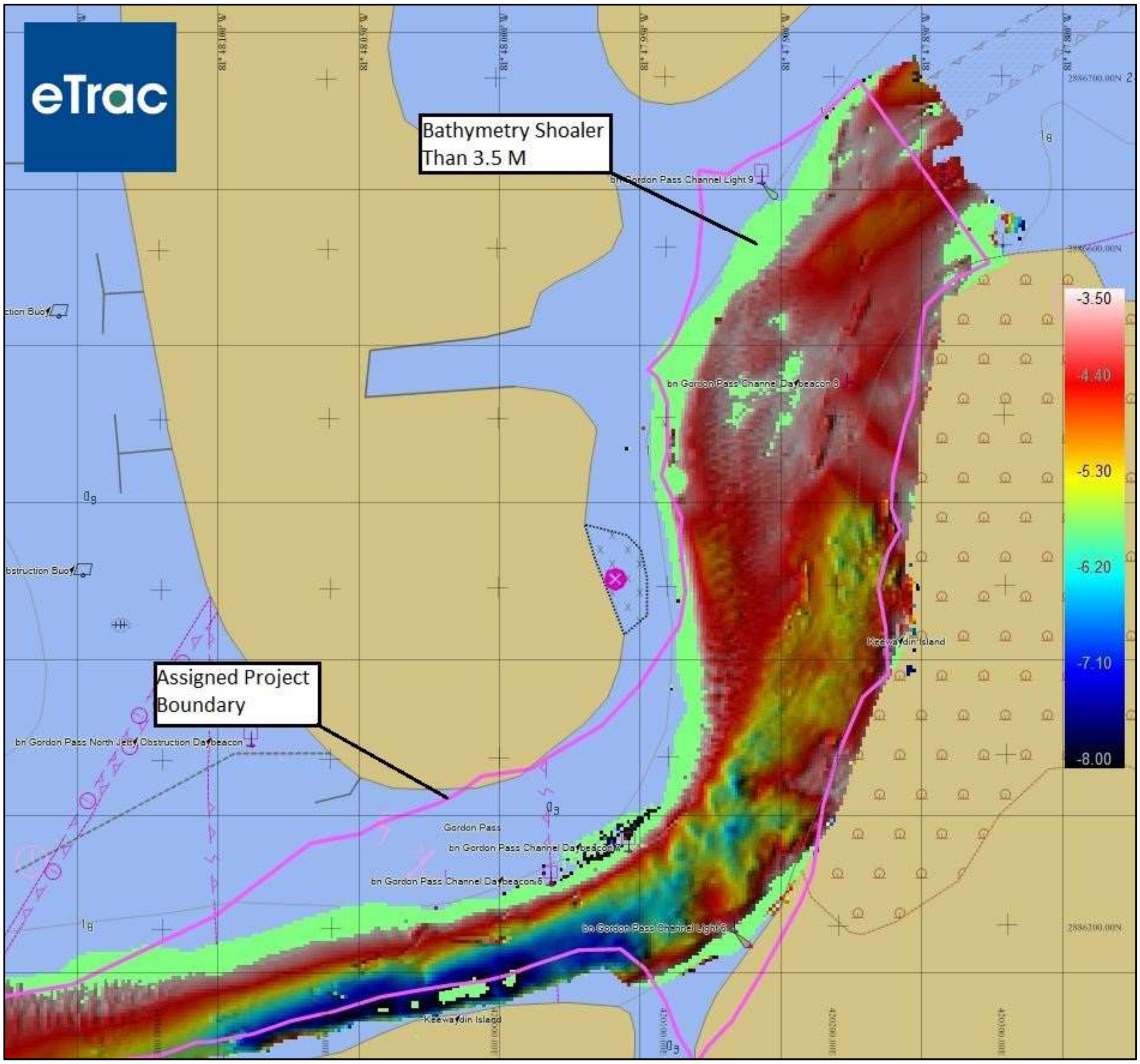

Figure 7.Gordon Pass, Naples FL. Colored by depth with depths shoaler than 3.5m colored in solid light green. With knowledge of the MLLW in-shore coverage in real-time, efficiency in acquisition was maximized.

Processing

Qimera was utilized during this project purely for evaluation purposes, and was not used in this project for the processing of the data and ensuing creation of products for submission to NOAA. However, future projects may consider using Qimera as the processing solution for the NOAA workflow, as Qimera v1.6 will have full S57 functionality in 2018. In the meantime, this project provided excellent opportunity to test Qimera, and eTrac personnel are partners in the development and evaluation of the new tools.

With three vessels, each operating dual-head multibeam echosounders, the data from this project provided a good test for Qimera to operate under a heavy data-throughput requirement. Additionally, the high number of feature investigations was good opportunity to test the S57 functionality that is new with Qimera v1.6. Such an evaluation is quite timely, as nautical charting workflows are in need of better solutions. NOAA reported in 2015 about recurring data quality issues, specifically, those related to vessel files, anomalous data in grids, errors in S-57 files, and the proper application of correctors (Gonsalves, 2015). Such issues have promulgated in-house NOAA software development, such as QC Tools (Wilson, Masetti, and Calder, 2016), a collaboration with the Center for Coastal and Ocean Mapping and Joint Hydrographic Center (CCOM/JHC), as an attempt to mitigate the ongoing data quality issues.

As described in the section to follow, the very philosophy of Qimera, as an intuitive software built to eliminate human error from the workflow, has resulted in a platform which by its very nature effectively circumvents the numerous errors that have for so long persisted in the NOAA workflow. Note that such errors are likely quite common in any hydrographic office, and QPS, with important consultation from eTrac, continues to develop workflows to accomplish the most advanced processing, but in the simplest way possible.

The design philosophy of Qimera is based on four pillars (Beaudoin and Doucet, 2017), which will be discussed individually with regards to how each pillar benefits the nautical charting workflow, with data from Project OPR-H358-KR-17 utilized as a case study. As described below in a step-by-step fashion, the design pillars of Qimera are inherent through the process of importing data, adjusting post-processing parameters and correctors, and finally, conducting the necessary re-processing.

Importing data into Qimera

As longtime users of QINSy, eTrac is particularly primed to reap considerable benefit from the QPS nautical charting workflow, as there is great advantage in the QINSY-to-Qimera integration. While it is not necessary to link these two, i.e. Qimera is perfectly modular and can interface with most any acquisition platform and incoming raw sonar data format, the first Qimera design pillar of deep and intelligent data extraction achieves as much value as possible within data as collected by QINSy. Angular and linear offsets are retrieved automatically and a vessel file is created upon import, with any changes in the configuration captured as well. Other “rich” file formats (such as Kongsberg .all) are handled in a similar manner, to thus remove opportunity for human error in the vessel file transcription. Additionally, Qimera extracts sound speed profiles from those raw sonar formats that maintain such information, which again removes opportunity for human error during the sound speed import.

Importing DB files from Project OPR-H358-KR-17 as acquired by QINSy automatically creates the vessel file as shown below in Figures 8 and 9, and the user is not required to manually enter in offsets, nor must they make a “zero” vessel file to guard against the unintentional reapplication of offsets. Thus, errors resulting from manual data entry are eliminated, as is any chance of undesired double-application. Additionally, the sound speed casts contained within the DB files are available automatically in sound speed editor for various post-processing strategies.

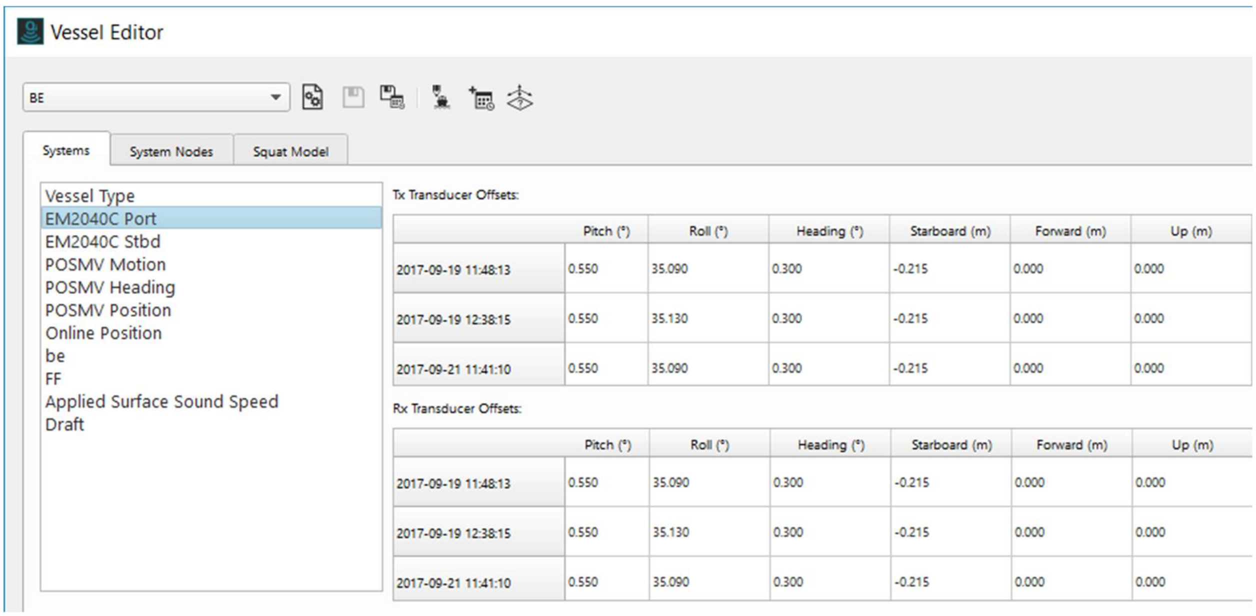

Figure 8. From the raw sonar data import into Qimera, linear and angular offsets are populated into an auto-generated vessel file, thus eliminating human error in their manual transcription.

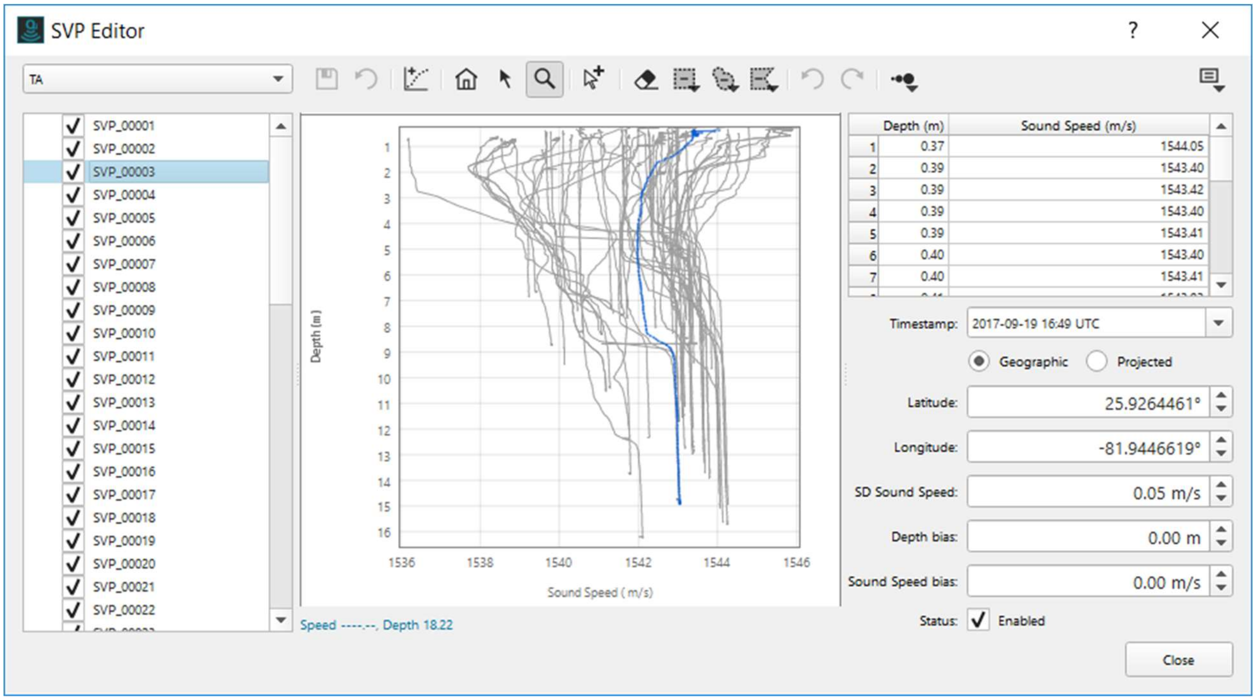

Figure 9. All sound speed casts contained in the raw data are available in SVP Editor. The auto-extraction eliminates error involved in the import of this data that is otherwise necessary.

Adjusting Post-processing Parameters and Applying Correctors

After importing the DB files from QINSy, all the sound speed profiles are available automatically, with positions and timestamps, thus a new sound speed strategy may be readily applied. In this case, nearest in distance within four hours was preferred over the real-time application. Additionally, Applanix Smoothed Best Estimates of Trajectory (SBET) were generated and applied in post-processing for improved horizontal and vertical accuracy over the real-time solution, with the VDatum Separation Model also included in the vertical referencing to achieve MLLW.

Immediately after completing such actions, the user is asked if she would like to reprocess the affected files. If answering yes, all necessary re-processing will ensue automatically and the lines will be up-to-date. This functionality is the second design pillar of Qimera, a guided workflow that prompts users to the next logical step after specific actions are performed. This approach further minimizes opportunities for human error, and does so in an unobtrusive manner. It is particularly useful for the NOAA workflow, or any hydrographic agency or similarly large organization where inexperienced processors maybe quite common. Such cues to the user about appropriate actions can avoid critical errors and save considerable time and effort in nautical charting workflows.

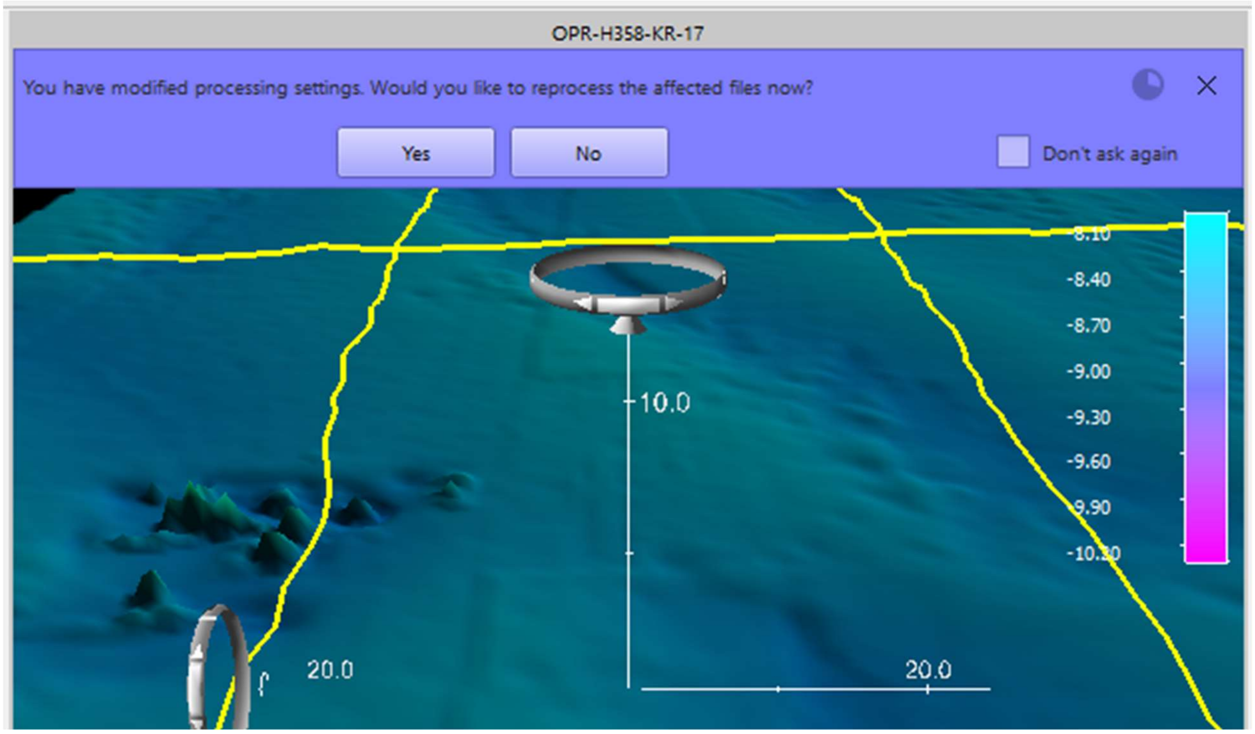

Figure 10. The guided workflow in Qimera, triggered automatically by Qimera, suggests to the user an optimal course of action after making changes. The user may defer this until later, if desired, but is reminded that processing is pending.

Re-processing

For any action performed in Qimera, the third design pillar, processing state configuration, automatically identifies which files are affected, and the necessary re-processing that is required to bring those files back "up-to-date". In other processing software, it is the responsibility of the user to know which re-processing steps are necessary, the correct order they must be applied, and which lines are affected. In Qimera, this responsibility is removed, thus the quite common errors associated with re-application of correctors are eliminated entirely.

For Project OPR-H358-KR-17, after setting the new sound speed strategy and loading the SBETs and VDatum model, the user is alerted that the re-processing is required. If the re-processing is delayed, the necessary actions are held "in queue", and at any time the user may then query the affected lines to learn exactly what re-processing is needed. In this case, the sound speed strategy and vertical referencing were both adjusted, and as such, those particular processing "flags" are set in Qimera, as shown below in Figure 11, which is a demonstration of Qimera's change tracking, effectively removing that responsibility from the user.

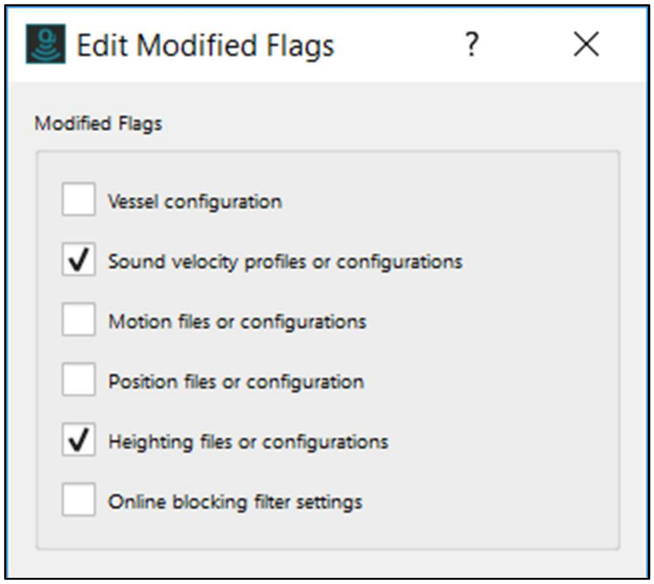

Figure 11. After making adjustments to the sound speed strategy and vertical referencing, those particular processing flags are "set", and whenever the user desires the necessary re-processing will be performed with a single click. The quite common errors traditionally associated with the proper order and application of re-processing steps is avoided entirely.

Data Cleaning

Data cleaning is facilitated by the Dynamic Workflow in Qimera, which is the fourth design pillar. It allows for instant validation of results, accomplished through the tight coupling of point cloud files (QPD) with the QPS Dynamic Surface, which allows for fast update to the gridded bathymetry and therefore immediate validation. In this manner, issues are rapidly identified and subsequently mitigated, rather than lingering until further along in the nautical charting workflow, wherein the further the issues propagate, the more problematic they become.

An example of the dynamic workflow in action is shown below in Figure 12. Grid fliers were identified during 3D viewing along one of the Dynamic Surfaces that encompasses Project OPR-H358-KR-17. A quick selection window reveals that point cloud that confirms the presence of noise that birthed the grid fliers. Their subsequent removal, from both point cloud and gridded bathymetry, in an extremely rapid manner, is facilitated by the dynamic workflow.

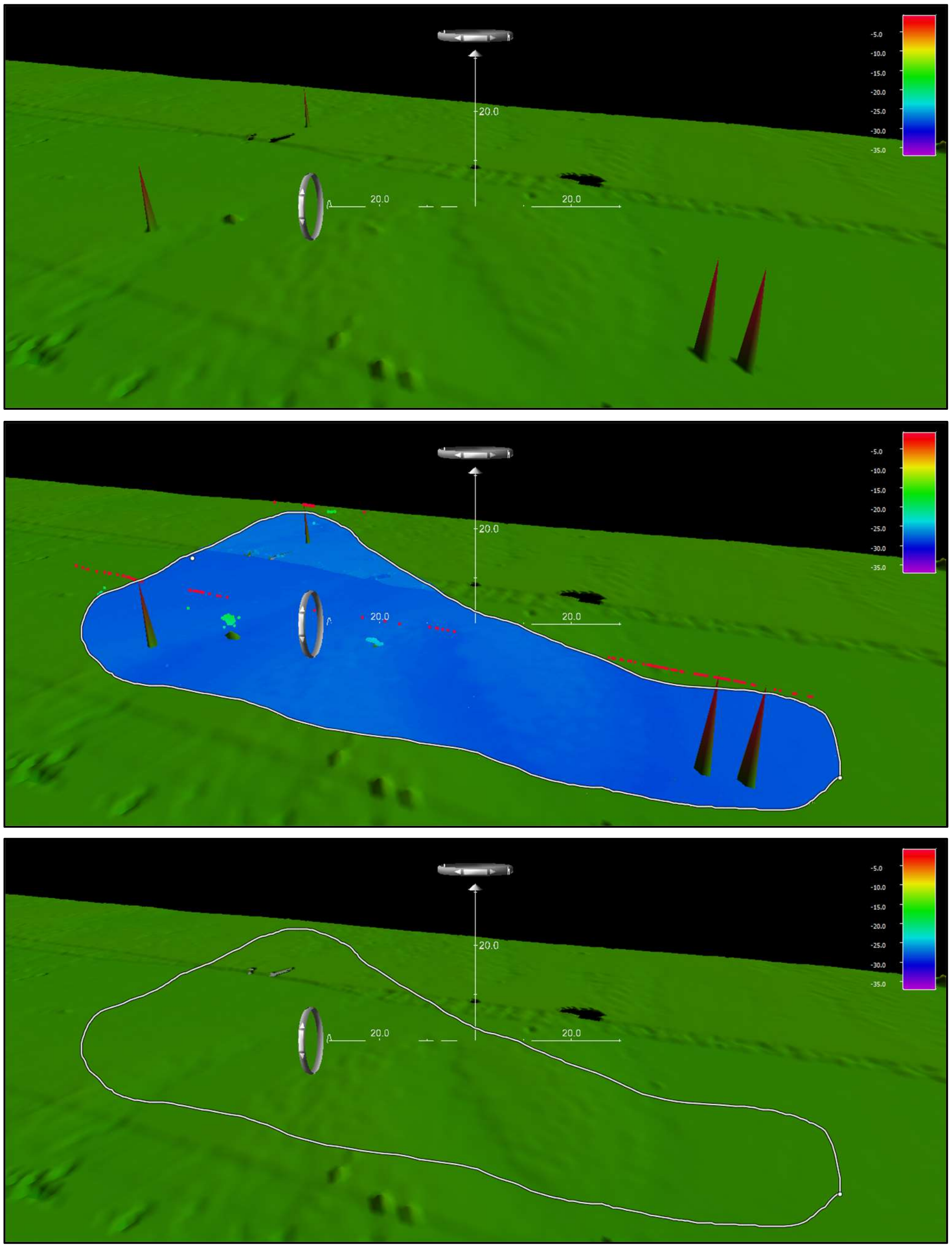

Figure 12. Grid fliers found along a Dynamic Surface (top), a quick selection drawn to encompass them with Slice Editor enabled reveals spurious soundings to be the cause (middle), and after the noise is removed in Slice Editor (with a 1-click filter), the point cloud and grid are both automatically updated (bottom).

Data cleaning is facilitated by QPS Surface Spline Filters, which are automated data cleaning routines, designed to remove noise that resides too far from a Dynamic Surface based on customized tolerance levels, correlating to IHO S-44 standards for vertical error tolerance. Furthermore, the application of the filters have great flexibility in Qimera - they may be applied within a user-defined selection, or to an entire line, or set of lines, or even to an entire survey. In this case, nautical charting work by nature has high scrutiny in sounding rejections as to absolutely ensure valid soundings are not rejected, as to always uphold safety of navigation. Thus, the preference may be toward applying such filters only in user-defined selections, in a step-by-step basis as one advances along a line as to ensure no valid soundings are rejected. An additional level of granularity is available in that the level of tolerance for the filters can be set to be more aggressive *under* the surface, wherein only the deep soundings are rejected, and more conservative *above* the surface, wherein there is more scrutiny in the cleaning.

Traditionally, rejected data step-by-step along a line requires very manually intensive work by the user to "clean" the data. While these methods remain necessary and are offered in Qimera, the Spline Filters are very effective in accelerating this process—generally all spurious soundings may be removed in a single click. Because the user has eyes on the data while working in this step-by-step fashion, they can advance quite rapidly, while being more exclusive in those areas of shoal points or features, to visually confirm that the soundings rejected via Spline Filter are indeed spurious in those areas. Meanwhile, the bulk of the survey is cleaned with a single click along each step, greatly facilitating and speeding up this process. The added benefit to this approach is the lack of grid fliers—because the point cloud data has been fully cleaned, the user may have much greater confidence that the gridded solution is free of anomalous grid data fliers, effectively circumvented one of NOAA's most prominent data quality issues.

Figure 13, shown below, a snapshot from Project OPR-H358-KR-17, demonstrates the value of the Spline Filters in terms of rapid data cleaning, while also allowing for visual confirmation from the user on all soundings rejected.

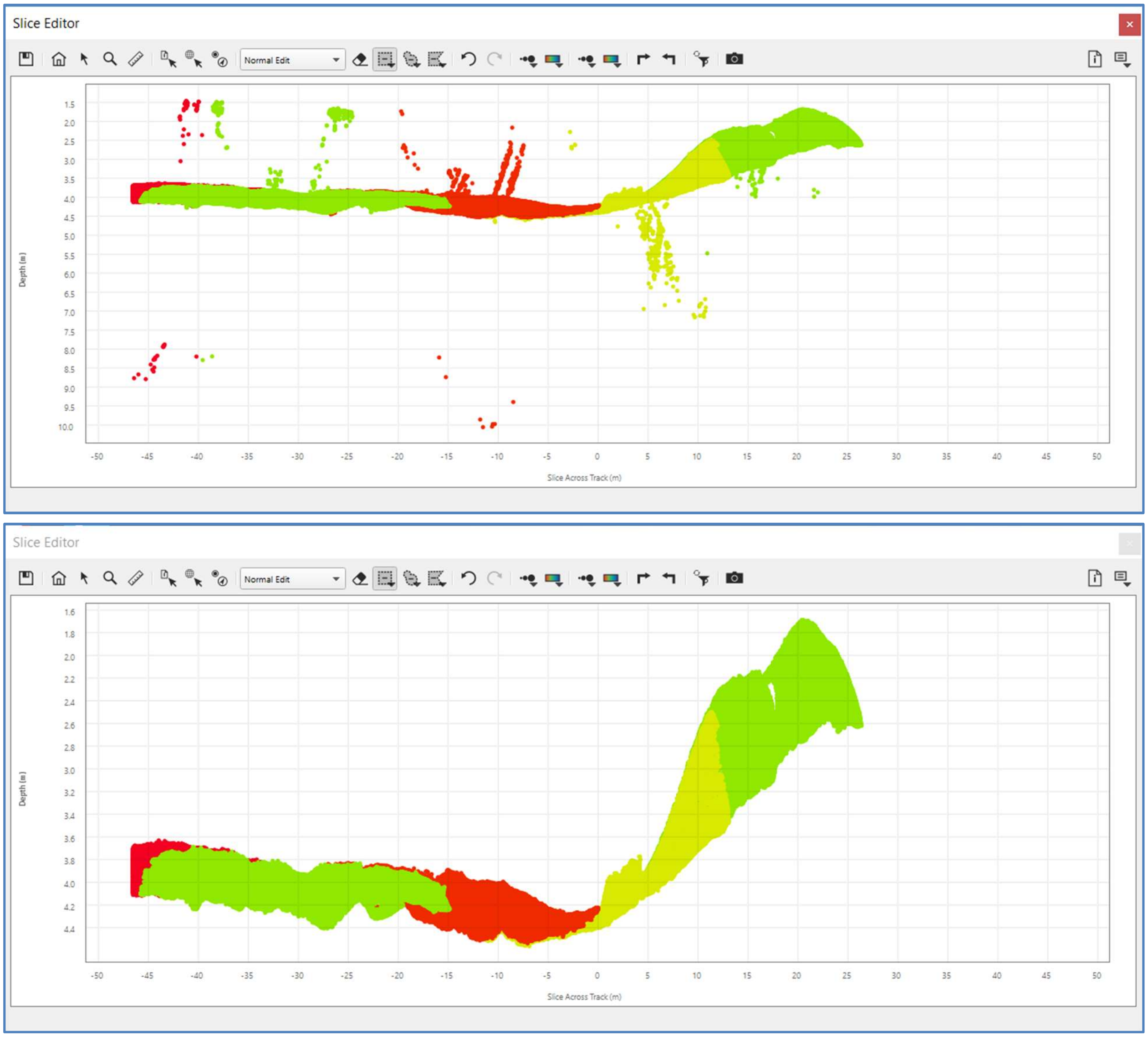

Figure 13. A demonstration of the Qimera Spline Filter as performed in the 2D Slice Editor, both before (top) and after (bottom) a considerable amount of noise is rejected with a single click. This functionality offers great time savings, while also it allows for visual confirmation from the user on all soundings rejected, important for nautical charting work.

To further facilitate this method of rapid data cleaning, the Slice Editor employed by Qimera offers functionality to set the path of advancement for the selection window per user drawn line, or simply to a particular line heading. Thus, the selection window moves along a custom path, employing the Spline Filter at each step, as demonstrated in Figure 14 below.

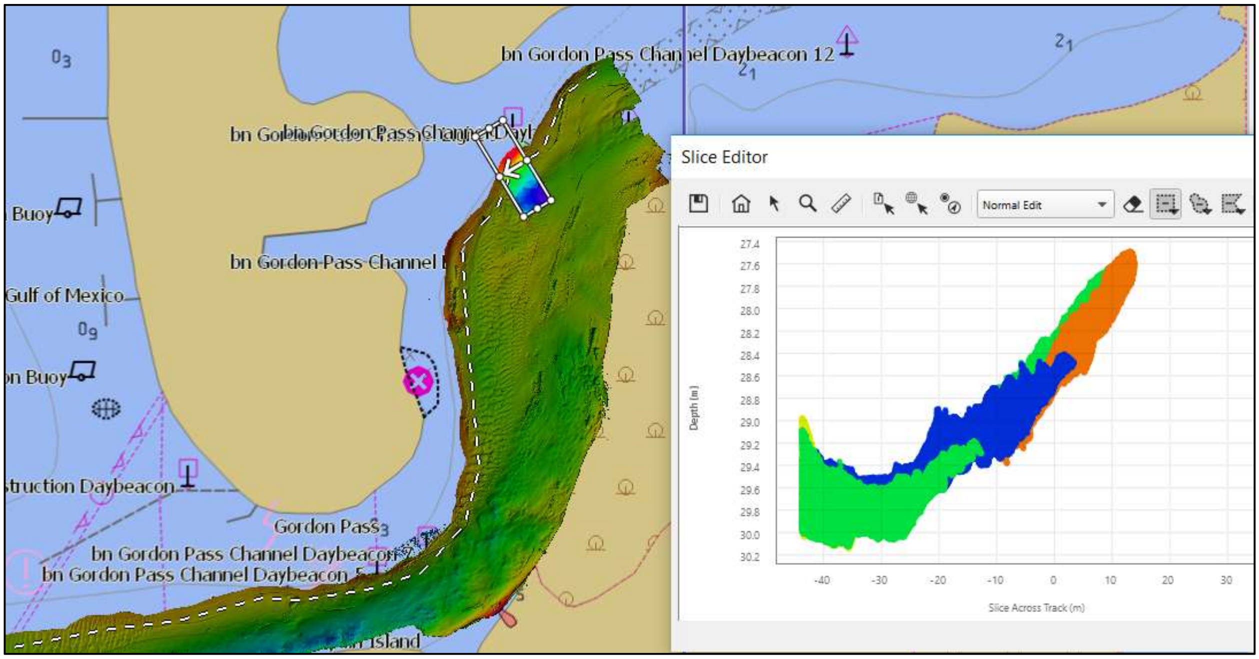

Figure 14. The Slice Editor in Qimera offers the functionality to advance along a user-specified path, or to the heading of a particular line.

S-57 Feature Management

Incorporating S-57 feature management represented opportunity to instill the Qimera ease of use and efficiency into what is traditionally an extremely manual, tedious, and error prone workflow. S-57 workflows require strict attribution, and one such attribute is the value of sounding (VALSOU), intended as the least depth for wrecks, rocks, and obstructions. The VALSOU attribute represents a linkage to the corresponding bathymetry, which is often broken due to either human error, or processing that occurs after feature management actions, therefore breaking these linkages. The agreement with S-57 feature VALSOU attributes and the corresponding bathymetry is one of the most common sources of error in nautical charting workflows, particularly in those hydrographic surveys that encompass hundreds of features, which is not at all uncommon. Although this is a considerable data quality issue, and a significant source of time expenditure, there previously were no attempts made by software manufacturers to maintain a linkage between S-57 features and the corresponding bathymetry. Thus, it is with this particular issue in mind that QPS designed the S-57 functionality.

Supported are two workflows, one that maintains the traditional methodology of deriving a feature from a particular least-depth sounding that is wished to represent a feature. This remains the preferred method for dangers to navigation. A wreck, rock, or obstruction is created directly from a reliable, least-depth sounding, and ensures linkage between feature and sounding. Setting a custom hypothesis for the associated CUBE grid (Calder and Mayer, 2003) completes a three-way agreement between feature, sounding, and grid. Ensuing processing will ensure the update and maintain the agreement, thus circumventing the numerous and persistent errors that traditionally have plagued this workflow. This process to establish and maintain the three-way agreement is shown in Figure 15 with an obstruction from Project OPR-H358-KR-17.

An alternative method of establishing features directly from a grid node is also supported in Qimera. This is not a traditional workflow, but nevertheless, a strong case can be made that the supporting depth for a feature should be taken from the statistical best estimate represented in the corresponding grid node, rather than from a single sounding within the cell, which is but a single data point and not representative nor benefitting from the weight of statistics or gridding algorithm. Both workflows are supported in Qimera, the first one to satisfy the traditional workflow, or simply to ensure safety of navigation, and the second one in-line with more modern methodology.

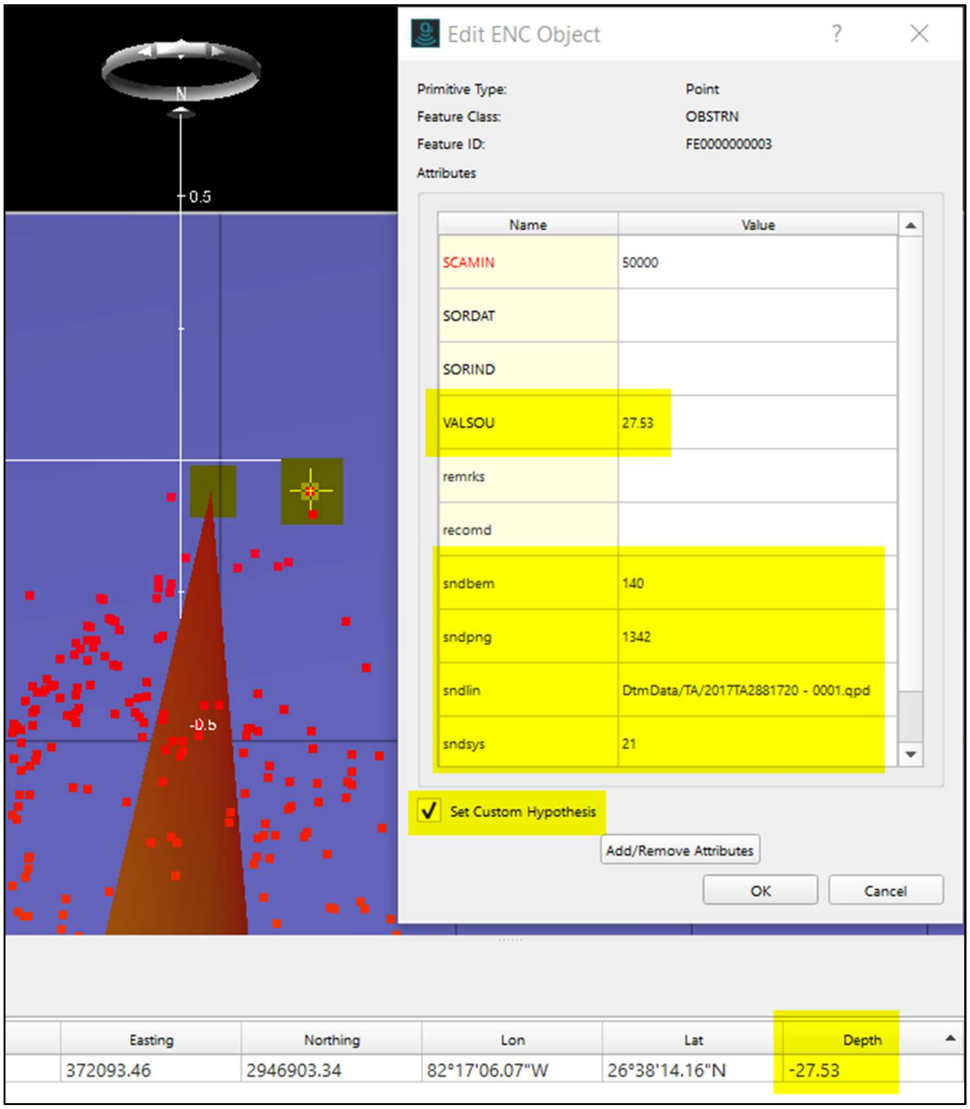

Figure 15. A demonstration of the three-way agreement between soundings, grid, and features as accomplished in Qimera. First, a reliable least-depth sounding is found atop a feature in 3D Editor. The depth is 27.53 m, as shown in the sounding attributes. The sounding is used to create and ENC point object, in this case, an obstruction (OBSTRN), and value of sounding (VALSOU) is automatically populated as 27.53, with the unique attributes "sndbem", "sndpng", "sndlin", and "sndsys" that link this feature to the beam, ping, line, and system from which the sounding originated. Finally, note the check box, "Set Custom Hypothesis", which ensures the CUBE grid depth is also 27.53, thus completing the three-way agreement. This three-way agreement will remain through any ensuing processing in Qimera.

Features created from soundings or grids then appear in the scene. The ENC Editor dock allows for additional editing of attributes, setting custom filters for organizing and displaying. NOAA customized attributes are available for use. Point, line and area features are easily created, and imported to other feature layers rapidly, as either a copy and paste or a cut and paste. Figure 16 below shows a feature management scene from Project OPR-H358-KR-17.

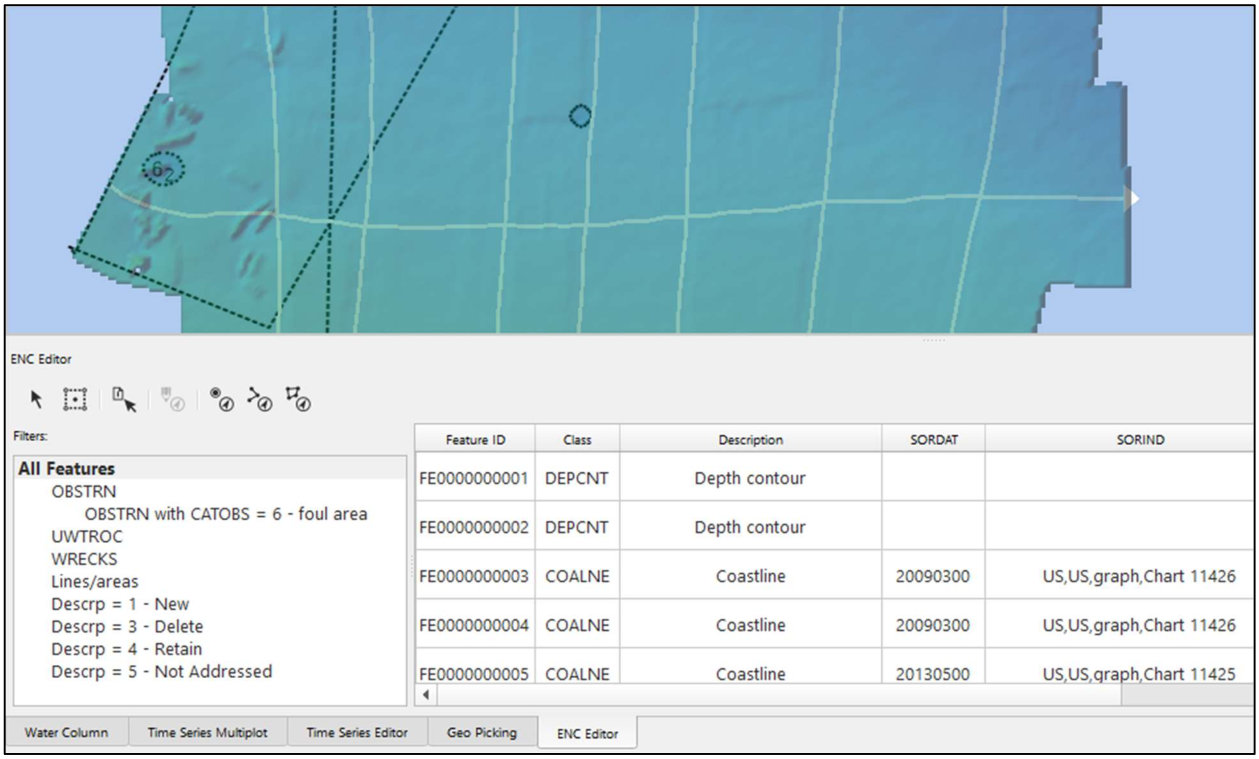

Figure 16. A Composite Source File (which contains all assigned features for a NOAA project) was imported into a working layer, parsed into numerous sub-layers to assist in the organization and proper feature management. With hundreds of assigned features as part of the project, the organization is critical, and the linkage to the bathymetry ensures update of all features with any ensuing bathymetric processing.

Summary and Conclusions

Longtime users of QINSy, eTrac very effectively utilized the real-time functionality in their acquisition software for online QA/QC and ensuring coverage requirements met. Leveraging these capabilities ensures issues are identified right away, rather than in post-processing where they are more problematic. The flexibility of the geodetic setup to achieve MLLW in real-time improves efficiency in operations by ensuring coverage requirements met, while unnecessary data collection is avoided.

Field data acquisition was ongoing during this evaluation, so the processing conducted in Qimera was but a subset of the total Project OPR-H358-KR-17 area. Still, 1535 lines from the project were processed in Qimera, representing 351 GB of raw sonar data, and 126 assigned wrecks, rocks, and obstructions were managed per NOAA specifications. The majority of these were disprovals, while those found in the data were marked as new features, with depths and locations set to update as changes in Qimera dictated.

The advantages of the Qimera workflow are clear, particularly for eTrac who leverages the integration with QINSy, for the most rapid import and rich data extraction in Qimera. Automated re-processing ensures proper actions taken. Surveyors can engage in feature management immediately, trusting that parity with the bathymetry will be maintained. This alleviates the previous habit of waiting until final processing has occurred before engaging in the final processing, and also the ancillary documentation on-the-side that was necessary to track the features, because they couldn't yet be entered into the software. These actions are rendered unnecessary in Qimera's feature management, thus improving efficiency.

Future development steps for Qimera may include continued methods of grid and feature quality control and validation, which serves as a means for a user to know definitively when their survey has met all requirements for accuracy and completeness. Additionally, support to variable resolution gridding is a potential development item, to be considered as customer requirements dictate. Observations and feedback from eTrac as the 2018 field season progresses will be very valuable to guide the development of new and existing tools in Qimera.

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