METHODS TO INFLUENCE PRECISE AUTOMATED SOUNDING SELECTION VIA SOUNDING ATTRIBUTION & DEPTH AREAS

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SUMMARY

Automated sounding selection for use in nautical charting is an imperfect process. There are many factors that must be considered to create a sounding set which successfully portrays the seafloor, is appropriately spaced for the scale of the product and the depth of water, honors the charted depth contours, and above all honors the shoalest soundings. New methods are being investigated at the Atlantic Hydrographic Branch for segmenting this selection by depth area, attribution of soundings to control selection, and eliminating duplicate soundings chosen on chartable features. The intent of this effort is to improve the consistency and cartographic disposition of the final sounding selection while minimizing manual manipulation. This paper will discuss the process used, nature of the seafloor encountered during these trials, the end results and lessons learned.
Key words: Nautical Chart, Sounding Selection, Chart Interface

INTRODUCTION

More than any other process in nautical cartography, sounding selection is the most subjective and complex, yet, along with the related depth contours, is the most critical aspect of a nautical chart. The final set of charted depths has to guarantee that the bathymetric data; has been interpreted accurately, spacing is chart scale appropriate, highlights hazards, and areas of safe passage, and most importantly will be quickly and easily understood by mariners. Not only do the shoalest soundings over shoals and hazardous areas from a hydrographic survey need to be represented, but so do the deepest to indicate natural navigation channels and potential anchorage areas, as well depict the seafloor character. Soundings are also used to support and identify contours, channels, and charted features. However, current sounding selection algorithms are based on providing an evenly spaced shoal biased network of soundings based on a user defined radius. While this is an efficient method, it has several shortcomings.

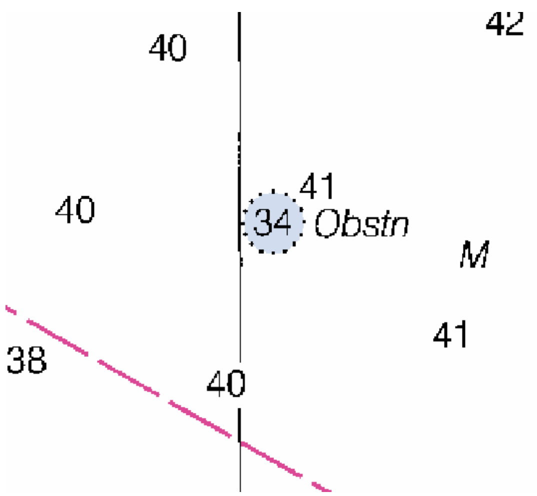


Figure 1

Since many shoalest items in a survey are the non-skin-of-the-earth features (i.e. wrecks, rocks, obstructions) a shoal-biased sounding selection will naturally select these features. This means that there will be two features occupying the same geographic position, the cartographic symbol representing the object and a sounding feature. Topologically this is not allowed; therefore these redundant soundings must be manually removed. But once removed, we would also like to add a supporting sounding near this feature. This supporting sounding is one that helps to provide some information about that feature, specifically how high it rises off the natural seafloor. This can be seen in Figure 1 with the 41 foot sounding immediately next to the 34 foot obstruction which allows the mariner to deduce that this feature rises approximately 7 feet off the seafloor. Ideally, automated cartographically correct sounding selection would ignore the hydrographic survey's features, and select soundings near, but not on these features, which would save a significant amount of time during a survey's compilation to the nautical chart.

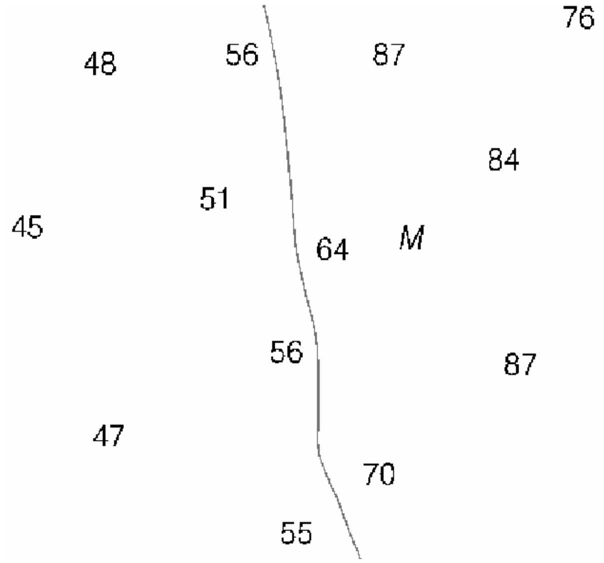
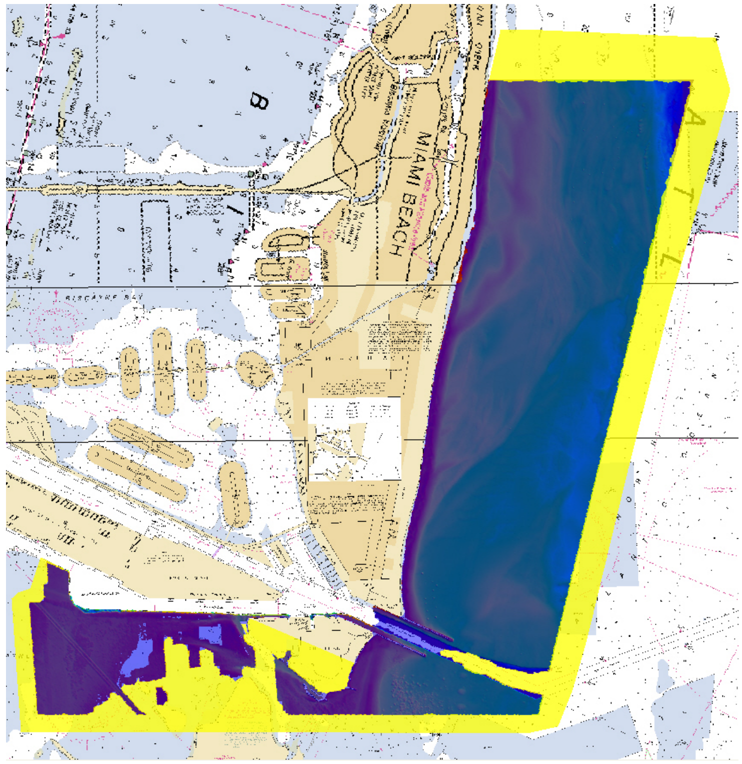


Figure 2

Current automated sounding selection algorithms are also unaware of contours as they work across the survey to choose soundings. Frequently the algorithm will choose soundings with the same depth value as the contour, once again causing two features to occupy the same geographic position. These soundings then have to be manually removed. Like the features, we would also like to provide supporting soundings to the contour which help to identify it to the mariner, for instance, in Figure 2 it is easy to tell that this is a 60 foot contour by the two 56 and one 55 foot sounding on the shoal side of the contour and 64 and 70 foot sounding on the deep side of the contour. Ultimately we would like an algorithm that was cognizant of these contours and treat them appropriately by not placing soundings on top of them, and providing supporting soundings on either side within some user defined cartographic parameters. It should be noted that this paper acknowledges there are cartographic distinctions between the terms "depth contour" and "depth curve", for simplicities sake and to adhere to IHO/S-57 object class definitions, the term "depth contour" will represent both interpretations.

In addition to hazardous feature objects and contours, there are numerous other required components of a nautical chart (chart furniture) that cannot be collocated with a selected sounding and also may require that a sounding be placed either closely or distanced from that object. Again, herein lies the need to be able to intelligently control where soundings will populate and limit the required amount of manual sounding editing. For both RNC and ENC products, some candidates of charted objects that should be acknowledged by an enhanced automatic sounding selection method are; aids to navigation (sounding on buoy block), dredged areas, spoil areas, the bounding areas of navigation channels, pipelines, and directly against shoreline objects among others. There are other instances where being able to control the propagations of soundings could be used to avoid sounding placement that would affect RNC's only such as charted text areas, compass roses, title blocks, scale bars, etcetera.

Figure 3



Lastly, although counter intuitive, certain charted soundings themselves need to be avoided or taken into account during an automated or semi-automated sounding selection when applying a hydrographic survey to a chart update product. The following offers some insights as to why this is a problem and provides some solutions and methods to be considered. Since the area where a hydrographic survey was conducted has specific bounds, so does the area of application to the nautical chart. Therefore, this region, which we refer to as the "Chart Interface", can be defined as the edge limits of the survey requiring deconfliction with the nautical chart where the charted sounding data has not been disproved or superseded by survey coverage (see Figure 3 in yellow). Typically, the chart interface provides the most challenging and time consuming area of cartographic effort. As in the soundings-on-contours issue, basic sounding selection has no way of being cognizant of the charted data. The algorithm alone cannot determine that a deeper survey sounding should not be placed directly beside a shoaler charted sounding undisproved by the survey, and since the routine will populate soundings out to the very edge of survey area in all directions, many of these edge limit soundings will have these conflicts. When one attempts to manually deconflict these chart interface areas the interdependent evenly distributed sounding spacing created by the automated method is quickly destroyed and the influence of changing a sounding selection can have ramifications on the whole field of soundings for a large radius around the edited area. Current sounding selection methods developed at AHB by E. Owens have incorporated a method to"smarten" the sounding selection in the chart interface area through a semi-automated procedure. This method requires the harvesting of charted soundings from the ENC, giving these chart soundings a unique attribution to distinguish them from survey soundings, then combining them with the survey scale data set that will be used for chart scale sounding selection. Thus, the current sounding selection algorithm's shoal biasing determines whether a survey sounding should be inserted or a charted sounding should be retained in this chart interface area. This semi-automated method of sounding selection utilizing chart interface soundings is demonstrated in Figure 4. Although this method works well in most instances it is by no means automated, and requires diligent manual manipulation in the setup and execution of the procedure.

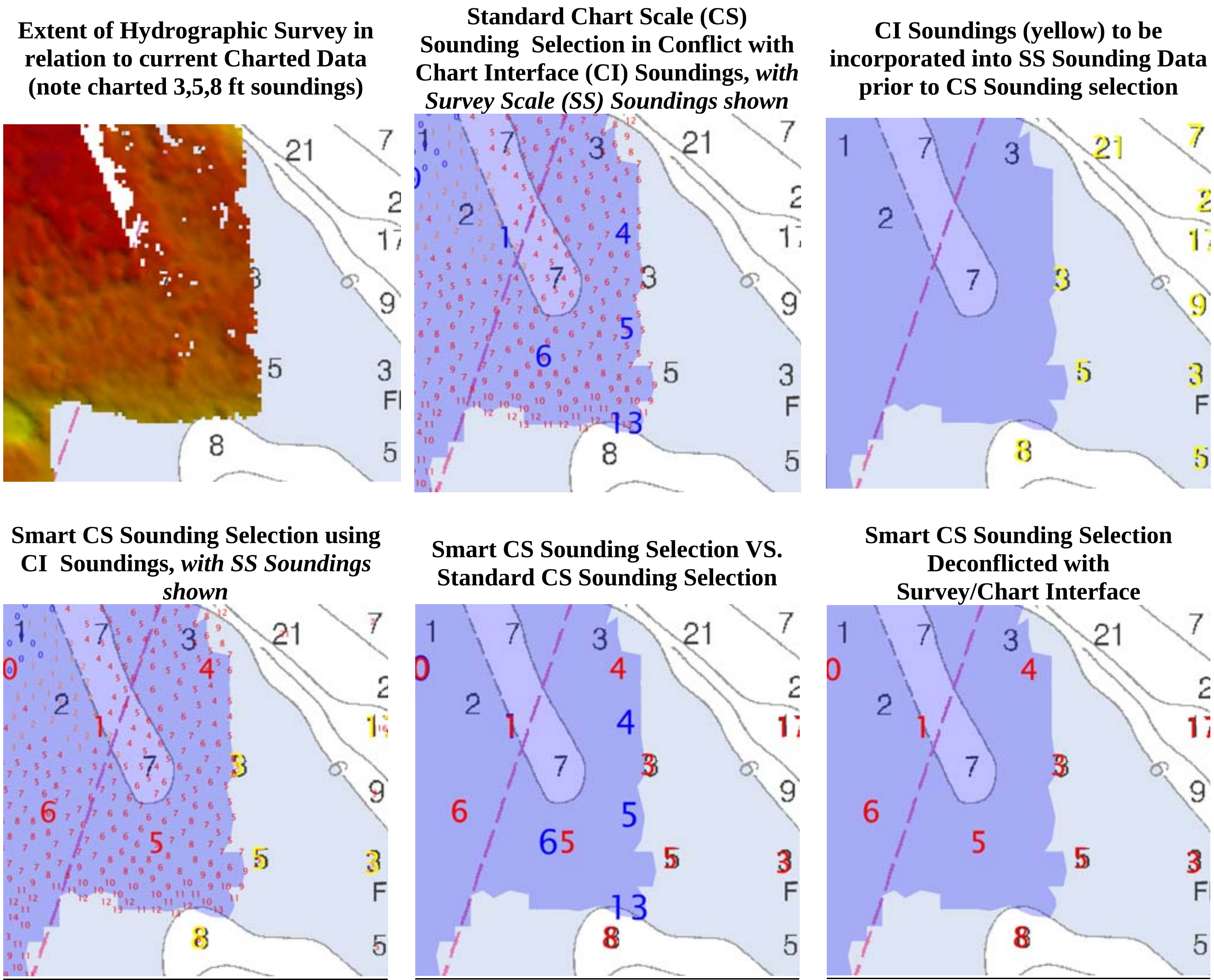


Figure 4 – Semi-automated sounding selection utilizing Chart Interface Soundings

The authors strongly feel that the spatial and hierarchical relationships sounding selection has in regards to survey features, charted contour intervals, and chart interface soundings have to be incorporated into a more efficient, rigorous, and automated routine. Since this perfect algorithm does not yet exist, the authors have attempted to utilize existing tools and tailor their usage to achieve the desired outcome. In this paper we will discuss how we have dealt with each of these problems to arrive at a desirable final sounding selection at the scale of the chart. Methods for achieving this will be discussed along with problems encountered with these methods. In addition, clear recommendations will be enunciated to help guide the development of an improved sounding selection algorithm.

SOUNDINGS

Types of soundings

Commonly, charted soundings are categorized into 5 distinct groups; least depths, critical soundings, deep soundings, fill soundings, and supportive soundings. Both least depths and critical soundings usually represent the shoalest areas relative to surrounding depth areas within a survey. During hydrographic data processing these shoal features should have been attributed as "designated" to highlight their significance. Current automated and semi-automated sounding selection routines are designed, and succeed, in assuring that least depths and critical soundings are captured for chart application. Isolated deep soundings are far less significant than least depths and critical soundings, although, the inclusion of these deep soundings does have navigational importance. However, assuring isolated deep soundings be identified during an automatic sounding selection routine is not of the greatest concern since deeps being discreet are relatively easy to manage manually for inclusion during sounding selection. Fill soundings typically represent areas of little or gradual submarine relief within discreet depth areas with sounding distribution being relatively equal and symmetric. Again, current automated and semi-automated sounding selection routines are designed to manage sounding selection in areas such as these where homogenous distribution of soundings are not disrupted by contour intervals, hazards, and a variety of other features. Lastly, supportive soundings, as the name implies, are used in support of all of the previously mentioned sounding types and can be described as the structural information that makes a chart interpretable to the human eye. Given this variability, current sounding selection algorithms, methods, and procedures are completely lacking in how and when to properly distribute supportive soundings, except by manual manipulation.

(NCM Vol. 1 -2011)

The importance of supporting soundings

The importance and succession of selecting supportive soundings is secondary only to that of selecting least depths and critical soundings. Support soundings serve a very important role to the mariner by affording more detailed information about the disposition of hazardous features, the topology of the seafloor, and communicate the value of depth contours. Additionally, these soundings can convey the gradient of the seafloor on surrounding shoals and deeps, as well as, along depth contours all of which aid the mariner in safe and accurate chart interpretation. Additional supportive soundings provide the critical role of depicting the preferred navigation routes between shoals, islands, and other obstructions. The method of selecting supportive sounding is generally done in a manner of succession, choosing depth areas from shoalest to deepest, making appropriate choices around least depth soundings, hazardous features, shoals, and then significant deeps. Inside each depth area supportive soundings are selected around the critical sounding based on what is best suited to show the sloping characteristics and to help define the depth contours. *(NCM Vol. 1 -2011)*

Usage of supporting soundings around features and shoals

Hazardous features, critical soundings, and least depths represent the most important charted information to ensure safe navigation. A mariner would be very perplexed about the size, magnitude, and course to avoid these dangerous chart features if they were represented in the absence of supporting sounding data and depth contours. It is imperative that supportive soundings be selected adjacent to these dangerous features and that the frequency/density thereof increase as a function of the increased degree of slope (seafloor steepness) surrounding the feature. This results in a greatly enhanced representation of seafloor around these features while not creating chart clutter. Furthermore, this increased density of supportive soundings adjacent to a potentially dangerous feature will make the presence of the hazard more apparent.

Usage of supporting soundings on contours

In order to portray the bathymetry of an area so that it is promptly recognized by a mariner both contours and soundings, particularly supportive soundings, need to be shown together and visually associated easily. In areas where the seafloor bathymetry is highly variable a higher density of supportive soundings outside the depth contour of an isolated shoal are used to indicate the slope of the seafloor near the shoal. For areas where the seafloor bathymetry is relatively consistent and the distance between contours is greater the density of supportive soundings is diminished since the need to communicate to the mariner substantial variations in depth is not required. Therefore, it can be concluded that the required number of soundings needed to indicate the detail in areas where the seafloor gradient is steeper must be greater than areas where the seafloor is relatively flat and featureless. Additionally, the relationship between contours and soundings is further complicated by the degree of slope along the area parallel to a contour depth area by general rules that govern the appropriate depth values of soundings that should be used to populate a contour interval because they provide no additional information about the contour. In general, soundings should not appear on a contour line, shoal-side supportive soundings should not be selected at the same sounding interval as the contour value, and deep-side supportive soundings should be greater than one chart unit deeper than the contour value unless other choices aren't available. To accommodate these general rules one surmises that the distance a sounding should be placed adjacent to a contour should be a function of the degree of slope of the seafloor since to provide a sounding not equal to or one unit greater than the contour interval the distance off a contour will be greater over flat areas than over steeply sloping areas. This relationship is illustrated in Figure 5.

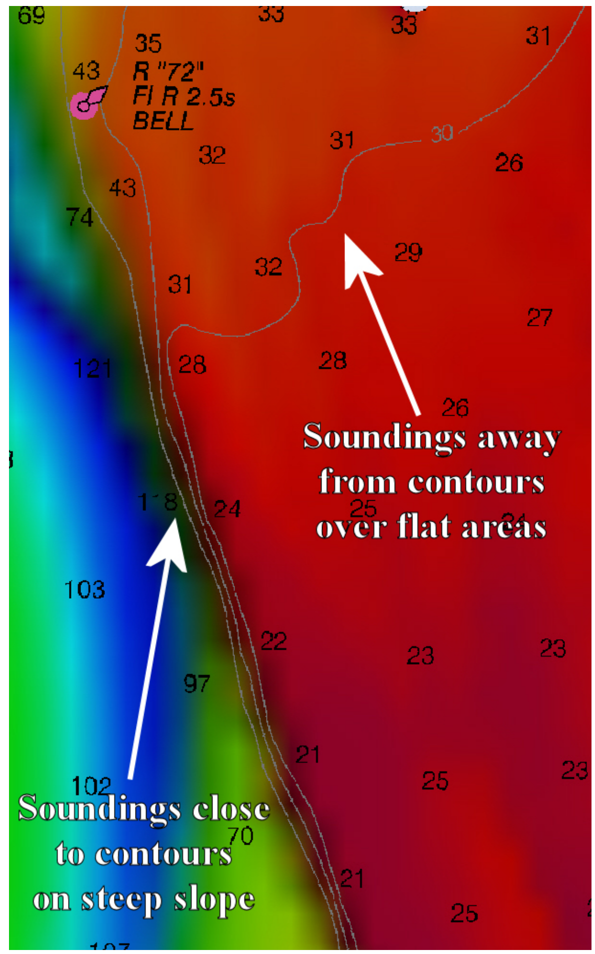


Figure 5

Current AHB sounding selection methods

Current sounding selection methods combine automated sounding selection with manual sounding manipulation to reach a final chart scale sounding representation. As a point of reference, the series of steps to achieve this are as follows:

High resolution source grids of the same or varying resolutions are combined into a single resolution grid that is no less than the resolution of the coarsest source grid. The survey scale soundings are created from the combined surface using a shoal biased selection of either a single defined radius of millimeters (nominally 1mm) at the map scale of the largest scale chart covering the respective area of the survey, or a varying density of survey soundings can be achieved through the use of a "sounding space range file (SSR file)", which varies the distribution by adjusting the millimeter scale as a function of depth range. At this stage, as described in the section above discussing the utilization of chart interface soundings; the soundings from the ENC and chart scale junction survey soundings located in the chart interface are incorporated into the survey scale sounding selection to aid in deconfliction and proper sounding spacing. The survey scale soundings are imported into a *Caris* *. CSAR "point cloud" grid. The chart scale soundings are then selected using a shoal biased radius selection using either a discreet value of distance on the ground or utilizing a SSR file with varying values of distance on the ground as a function of depth range if a varying sounding density is desired. The chart scale soundings are derived directly from the survey scale soundings point cloud grid to preserve continuity between the charted depths, the survey scale soundings, and the original source grids. From this point on all chart scale sounding manipulation is manual, consisting of a wide range of deconfliction with charted features dependent on the varying complexities of the survey.

Failures in current automated sounding selection

As previously described, un-exhaustively, there are numerous complexities in the process of appropriately selecting soundings when creating a nautical chart update product from a hydrographic survey. Somewhat unfairly, the inability of current sounding selection algorithms and tools to traverse this host of issues is seen as a "failure point", when in all fairness the intent to address these convolutions was never intended nor perhaps conceived. Therefore, with the firm conviction that the assault on figuring out how to automate rigorous chart scale sounding selection is obligatory for NOAA's charting program a series of trials were conducted at the Atlantic Hydrographic Branch. The following sections discuss the desired outcomes, the assertions made, the trials and methods along with the results and recommendations.

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Desired sounding selection outcomes

When first attempting to enhance the sounding selection method, a list of desired outcomes was assembled. The following major areas of concern have been discussed in various details thus far:

- Soundings should not propagate on features, contours, and other predetermined objects
- Least depths and critical soundings representing the shoalest "dangerous" areas must be represented
- Supportive soundings on Features
  - be selected adjacent to these dangerous features
  - frequency/density increase as a function of the increased degree of slope
  - always appear adjacent to a dangerous feature to make the presence of the hazard more apparent and provide reference in scale and magnitude
- Supportive soundings on Contours
  - will propagate either side of a contour line
  - should not be selected at the same sounding interval as the contour value on the contour's shallow side or one chart unit above the contour value on the contour's deep side unless other choices aren't available
  - the distance off a contour will be greater over flat areas than over steeply sloping areas
- Supportive soundings in support of navigation safety will propagate to depict the preferred navigation routes between shoals, islands, and other obstructions.
- Soundings have to be deconflicted with the Chart Interface and junction survey soundings
- Isolated deep soundings should be included per chart scale and navigational significance
- Fill sounding distribution in general should be relatively equal and symmetric

<u>Assertions made regarding current cartographic sounding selection tools</u>

As stated previously the current sounding selection tools available and tested at AHB do a very good job in regard to capturing the shoalest soundings and creating a fairly regular matrix of soundings that is controllable with regard to desired density and range of densities. The cartographic procedures at AHB rely on *Caris Bathy DataBASE* tools for all sounding generation and manipulation and virtually all cartographic production. The desired enhanced functionality discussed in this paper, to date, is not present in any commercial software the authors are aware of at this time. However, *Caris* has been providing NOAA expert support to the complexities faced and have been energetically introspective in finding solutions to our needs through newly prescribed procedures and software developments in support of those needs. Therefore, with a good understanding of tools at hand and a variety of desired outcomes the initial assertions regarding enhanced sounding selection were made:

- Seeding a sounding selection destination file with soundings one requires for the final selection <u>does</u> prevent the automated sounding selection routine from populating soundings on or near those soundings.
- To avoid soundings on contours, eliminating a certain depth range equal a contour interval is not a good solution since instances of that depth (isolated shoal sounding = contour interval) would be eliminated and have to rely on QC to have those valid instances included.

- Soundings can only be generated from a grid (chart scale selection uses *CSAR Point Cloud). (NOAA requirements dictate that a survey scale sounding set be provided and that the chart scale sounding set be a subset of that data.) *Caris* survey scale sounding *.hob files although the source of a subsequent chart scale sounding cannot be down sampled directly from the survey scale file (needs to be imported to point cloud).
- Depth Area limits constitutes one of the major sources of automated sounding selection faults.
- The utilization of Chart Interface and junction survey soundings works exceedingly well to “melt” the chart update product into the existing charted data.
- Hydrographic surveys vary immensely and need solutions that will work for all seafloor topologies. It’s hard to determine one-size-fits-all parameters.
- Charting requirements vary depending on scale, user base, and complexity. Tools need to be adaptable.

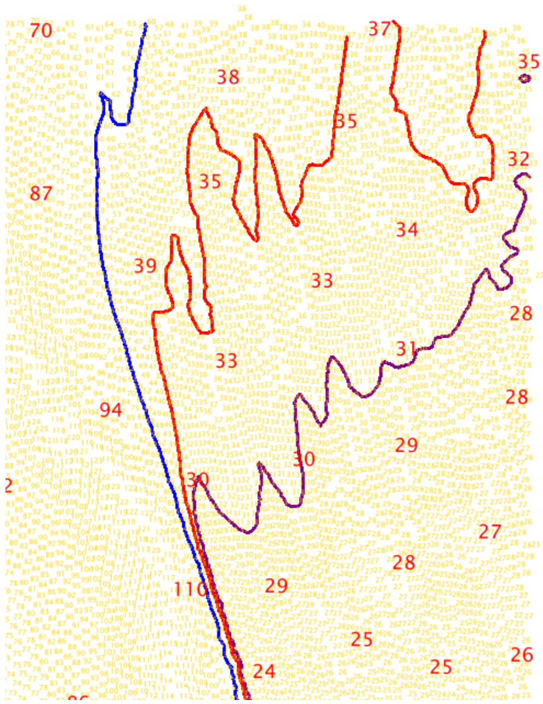

Figure 6

<u>Trials and methods</u>

Given the herculean task of solving the enumerable shortfalls in current sounding selection methods, initial testing was limited to addressing sounding selection on and around contours and features utilizing a hydrographic survey that straddles the naturally formed Chesapeake Bay Channel. As demonstrated in Figure 6, soundings propagate indiscriminately with regard to contours; note the soundings that will have to be manually deleted on or too near the contours. From this behavior it was surmised that the best approach would be to address each depth area (discreet depth range between contour intervals) independently. The idea being that by populating soundings for each depth area separately, with buffers added for supporting soundings on either side of the contour, one could avoid the range of soundings from possible selection that

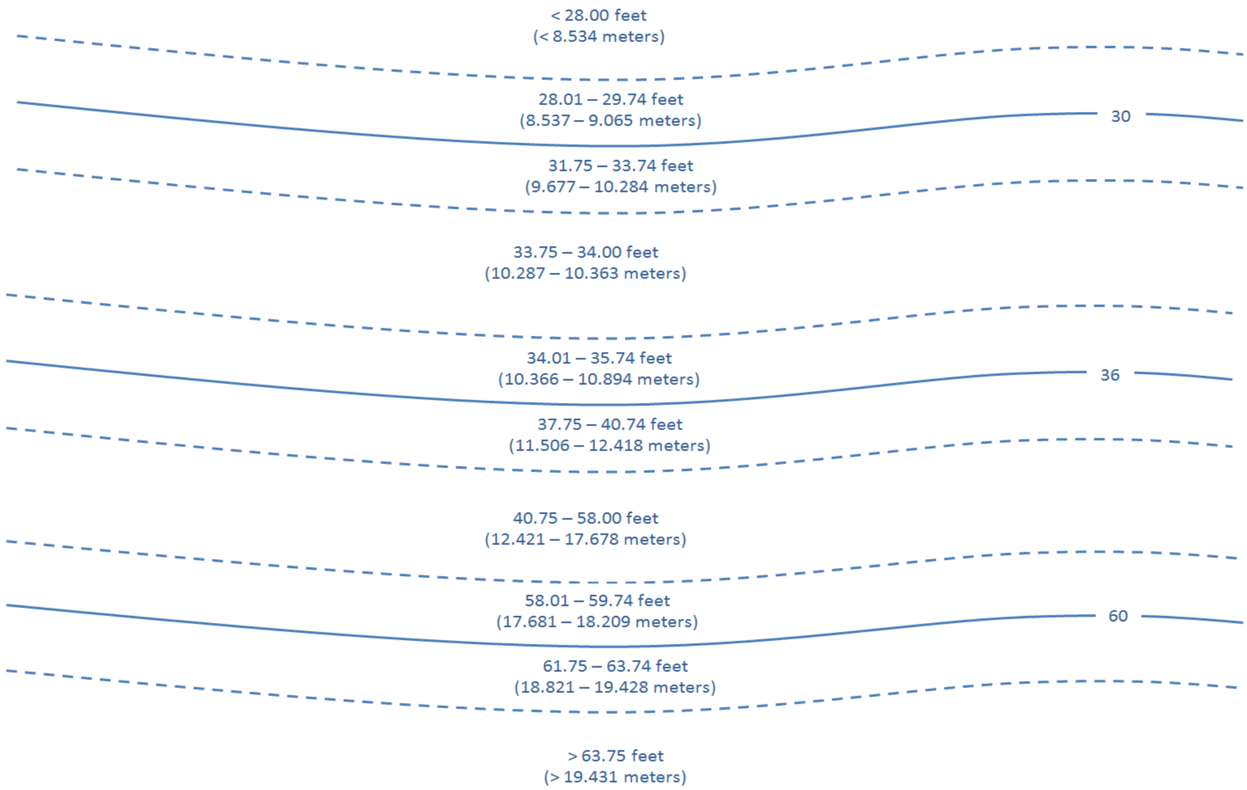

Figure 7: Sketch showing how the buffers for a survey would be laid out by depth, assuming a moderately sloping seafloor.

would fall within these contour buffers. This is demonstrated in Figure 7 where the buffered depth ranges, for instance 58.01 feet to 63.74 feet, would be excluded from the primary sounding selection in order to both protect from populating soundings on the 60 foot contour, and to provide a range within which we can populate supportive soundings. In order for this to work, the supportive soundings for the contours must be selected first and added to the sounding file. In this way, when the field of soundings within the depth area are selected they will choose their spacing based on the already present contour's supporting soundings. While in theory, this method is viable, it breaks down in several ways:

- Shoal soundings and least depths on features falling within the depth band of the buffers are eliminated, which are valid instances of the prohibited sounding interval, as well as, the undesired soundings which may fall on the contour giving a very unwanted side effect.
- The horizontal distance away from a contour cannot be determined strictly by depth, as seen in the right side of Figure 8, because this does not equate to a fixed horizontal distance due to the slope of the seafloor in the vicinity of the contour. Areas of steep slope create buffers too narrow to contain a sounding at scale, while nearly flat seafloors create excessively wide buffers that are cartographically useless. As seen in Figure 8, when the buffer limits from Figure 7 are applied to a topologically diverse seafloor the

distance varies greatly depending on the steepness of slope bracketing the depth area. Notice, to the right of the image, how the black regions (reserved for contours) and the yellow regions (recommended for support soundings) expand greatly over shallow areas and contract immensely over steep slopes. Also note, to the left of the image, that the result along the 60 ft contour worked well.

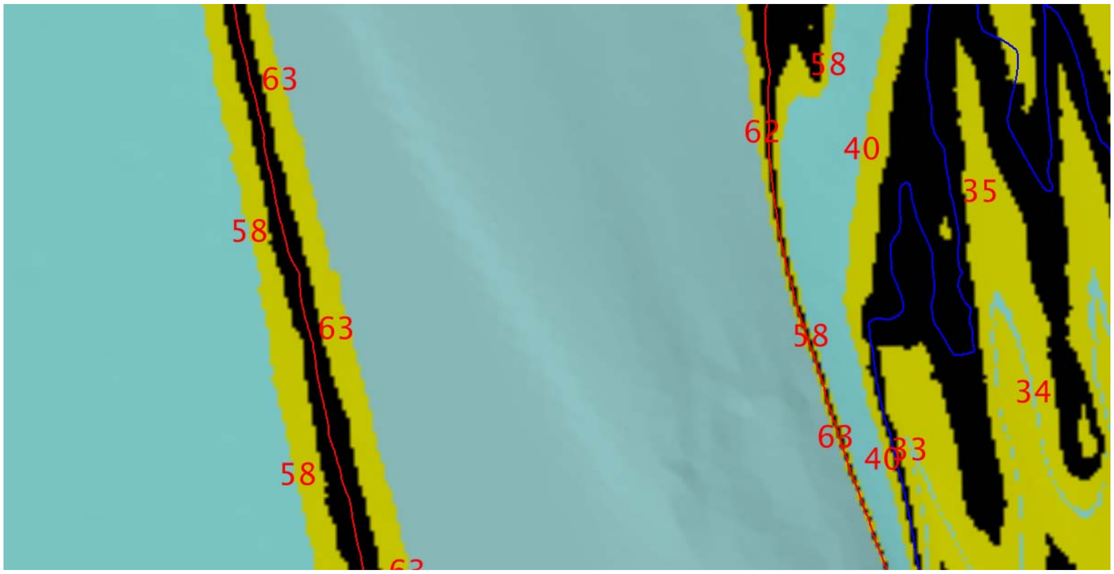

Figure 8

Stage two of this method was the idea, as stated above, of first populating the support soundings along contours and then seeding that file with soundings on the features (as a placeholder for the features, since only soundings, not features, are recognized by the routine). So when the general sounding selection routine was run these soundings would be seen and avoided, then the remaining areas within each depth area and around features would, hopefully, fill in very nicely. The shortcomings of this method were then coupled with another unforeseen and unwanted effect based on the results. From running various variations of this test it became apparent that as the matrix of soundings was spawning across the survey area (origin seemed top right corner) it neither anticipated nor could react to being confronted with the seed soundings. The best explanation that could be divined, by the experimenters, was that the soundings were being generated across the survey area at a prescribed interval and once meeting a seed sounding if the distance from its previous placement was too close, ~less than twice the allowed distance (to put another sounding in-between to fill the void) it just skipped it and moved on. The result was a distribution exhibiting random sounding distances and void areas around some of the seed soundings. These were apparently affected at random due to the random progeny distribution of soundings from an origin. For this reason any attempt to stage the sounding selection in a series of seeding of *.hob files and re-running sounding selection was abandoned.

From the lessons learned, another approach was taken that avoided most of the pitfalls present in the prior methods. Depth alone, as the variable, could not be relied upon to give adequate results over a diverse seafloor and tools are not available to calculate and vary distances from a given value as a function of slope in an automated sounding selection. Therefore, the idea occurred that giving a sounding precedence of selection was already in place within the program, its use just needed to be expanded. An answer lay in "attribution", utilizing the sounding attribution of "designated" preference could be given to virtually any configuration of soundings. Sounding designation is traditionally reserved for assuring hazardous features and shoals maintain their true x,y,z values and that they are favored over simple "accepted" soundings through a prebuilt process which is controlled by certain internal parameters. The idea was to preselect the areas where soundings should be populated and give them a designated attribute. Attribution would also have to be given to those "reserved" areas where other chart features exist and we did not want soundings to propagate. The image from *Caris BDB* seen in Figure 9 shows how the survey scale sounding *.hob file was attributed to segregate the areas as follows for the tests to follow (attribution is S-57 based):

- STATUS=3 (Recommended) – These soundings are where we want to provide support soundings to features and bracketing contour intervals. They will be designated and receive preferential treatment during chart scale sounding selection.
- STATUS=6 (Reserved) – These soundings are where we want to avoid a sounding being populated on features and contours, etc. They will be eliminated from possible selection during chart scale sounding selection
- STATUS= (Undefined) – These soundings are the general soundings remaining. They will be treated without preference except shoal biasing as in traditional sounding selection methods.

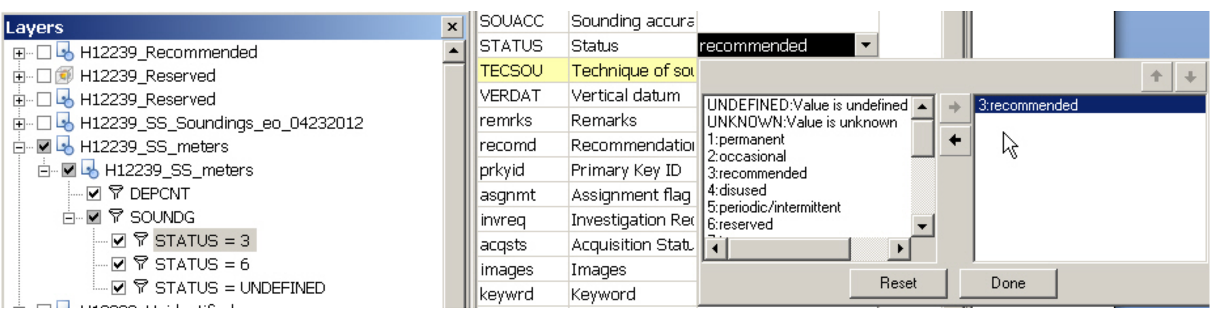

Figure 9

Since an easy method could not be developed during the scope of these tests a modified manual selection method was devised to make the appropriate attribution. The following images under Figure 10 show how the symbolization scale of contours and features was used to systematically and consistently make the appropriate selections for attribution. Of note, the true Chart Scale for this survey is 1:40K. Central contour survey scale STATUS attributes were done as follows by adjusting the contour symbolization scale increasingly larger to make the SS selections wide enough that a sounding would not populate on the contour when depicted at scale on the shallow side and further away on the deep side to allow for contour generalization and populate the deeps further off the contour. Then selection and attribution was made by the lasso select tool.

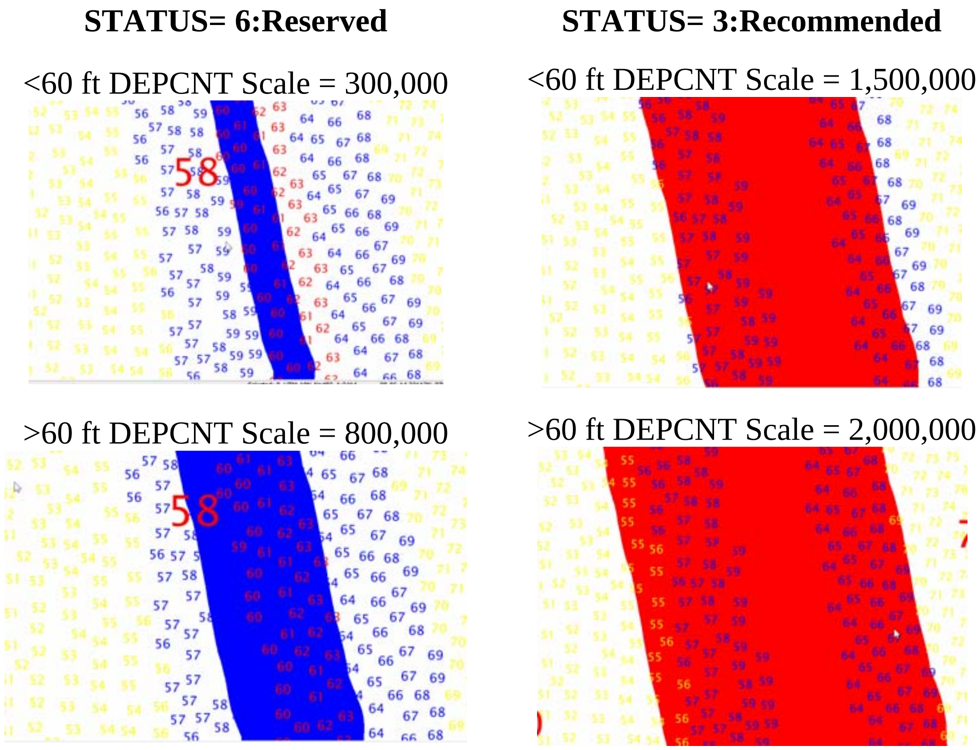

Figure 10

The result of the manual selection and attribution are shown by the colored STATUS attribute in Figure 11. Note that only the central 60 ft contour bounds were attributed for this trial.

RED - STATUS= 6:Reserved
BLUE- STATUS= 3:Recommended
YELLOW- STATUS= Undefined

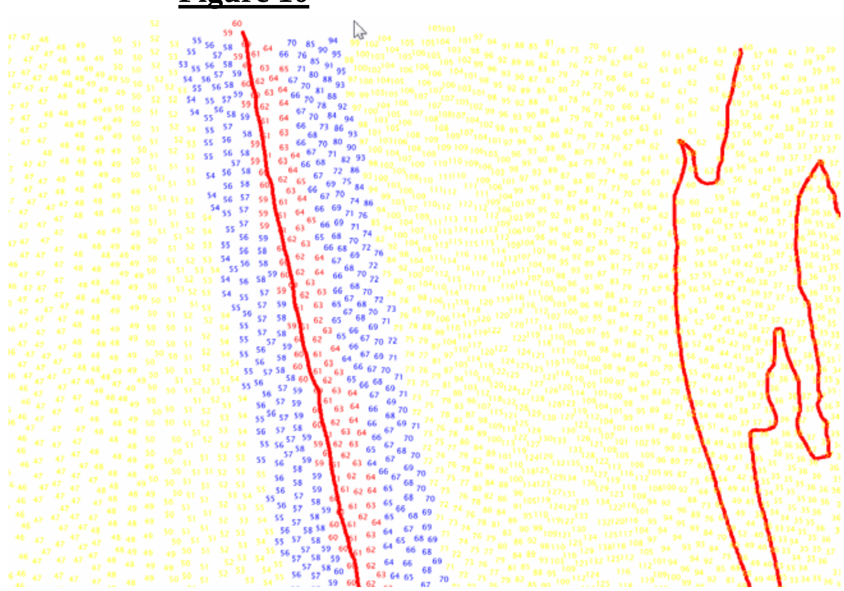

Figure 11

Similarly, the survey scale STATUS attributes for three dangerous obstruction features was completed as in Figure 12 by adjusting the OBSTRN symbolization scale increasingly larger to make the sounding selections and attribution wide enough that a sounding would not populate on the feature, but a supporting sounding would populate adjacent to the feature. The selection made by circle select tool.

(Standard for chart scale is 1.5 x Chart Scale {40K} = 60K shown in Black)

STATUS= 6:Reserved	**STATUS= 3:Recommended**
OBSTRN Symbol Scale (Presentation= INIT1) = 100,000	OBSTRN Symbol Scale (Presentation= INIT1) = 200,000
Post attributing	Post attributing

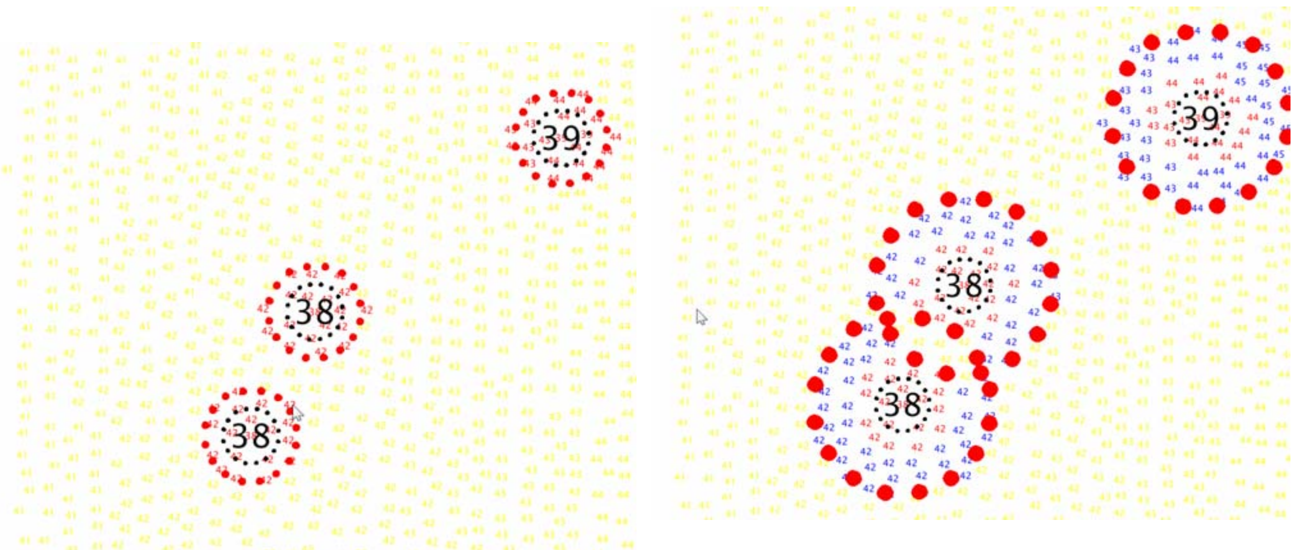

Figure 12

Reserved (faux Rejected) **Recommended (Designated)** **Undefined (Accepted)**

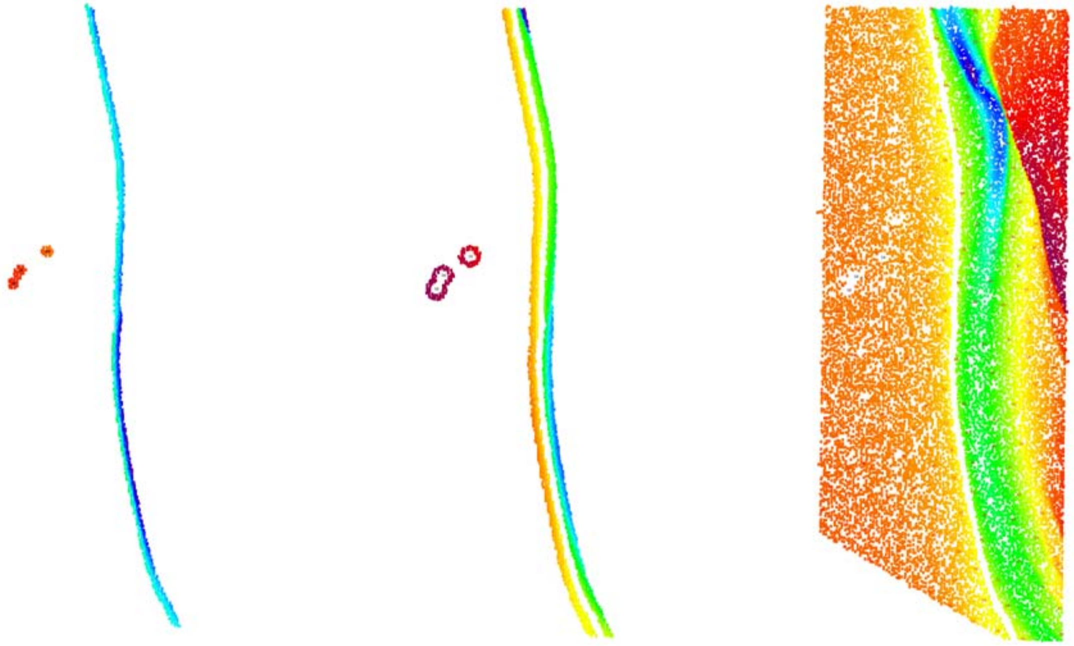

Figure 13

At this stage it is important to note that the S-57 attribution assigned to the survey scale soundings will not translate directly to the *.CSAR point cloud grid during export of the *hob file. This had to be accomplished using *Caris BDB Subset Editor*, however, the previous step of segregating the soundings by STATUS attribute was necessary to create separate point cloud grids for designation and omission during selection. As seen in Figure 13, three point cloud grids representing the aforementioned classes of attribution were made. As seen in Figure 14 the recommended soundings point cloud was designated in subset editor then "joined" to the unidentified sounding point cloud, as in Figure 15. The reserved point cloud was just omitted from the union since attribution was not available, only rejecting the gridded data.

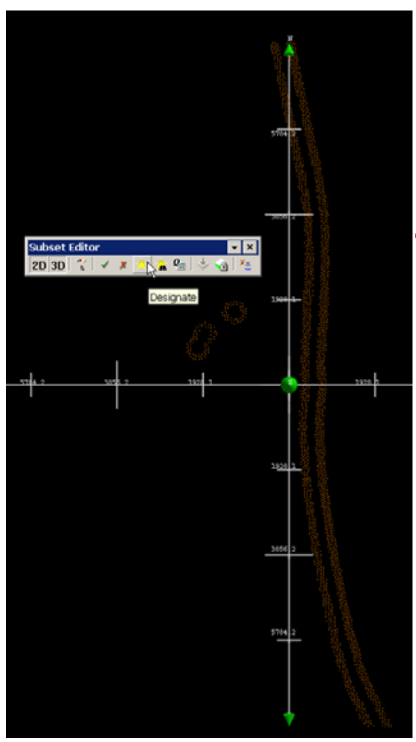

Figure 14

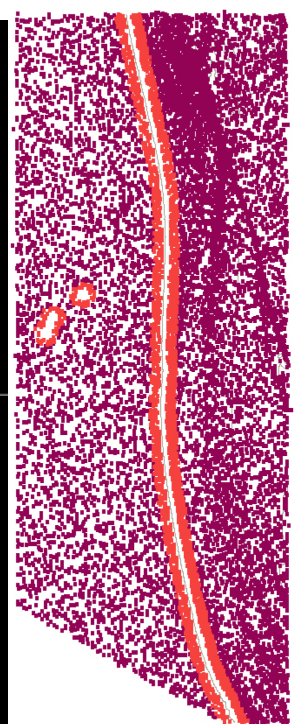

Figure 15

H12239_CS_SSR_40K.txt

0	3.6576	280
3.65761	5.4864	300
5.48641	9.1441	380
9.14411	10.973	450
10.9731	18.288	580
18.2881	54.864	610

Figure 16

Results and recommendations

After the grids were joined, a typical automated sounding selection was run on the resultant point cloud using a shoal biased radius selection and with a Sounding Space Range (SSR) file with varying prescribed meters on the ground entries for different depth ranges as seen in Figure 16. The chart scale depth file product created was quite good as illustrated in Figure 17. The distribution of soundings (red) on either side of the contour were near ideal based on what ranges were designated and which were omitted.

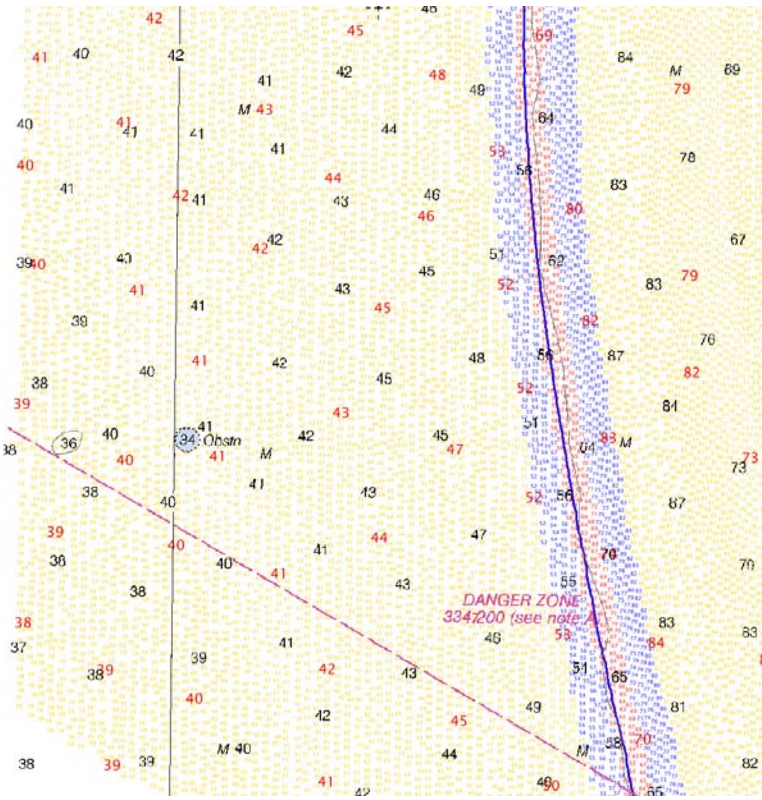

Figure 17

The distribution of fill soundings interacting with the contour supporting soundings was also near ideal. The "wonkiness" that had occurred during the staged sounding selection when the file had been seeded prior to general sounding selection was not present. Moving on to examine the test regions around the three obstructions was also very encouraging. As displayed in Figure 18, the representative support soundings adjacent to the obstruction features are in a good configuration. Additionally the soundings populated around the obstructions and associated supportive soundings are located at the anticipated distances prescribed in the SSR file. The distribution of soundings achieved in both these instances was completely a result of this semi-automated

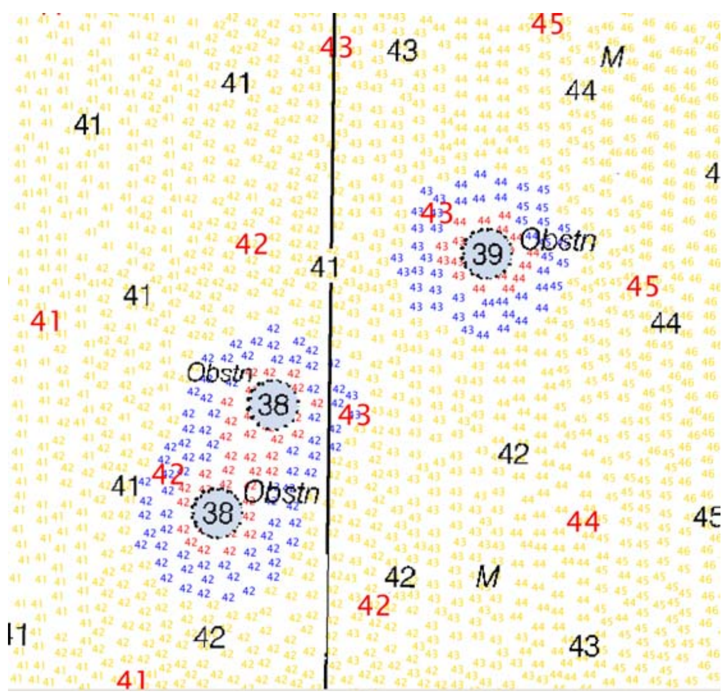

Figure 18

method and the results require no further editing, thus not disturbing the "house-of-cards" sounding matrix. Notice in the full distribution example of Figure 19 that the entirety of the manipulated area that the results were consistent and correct. The necessity to expand the tests for this type of manual "stage setting" for a single sounding selection is not necessary since the results are very controllable. However, let's examine the shortfalls:

- An automatic way to make the appropriate selections for attribution will have to be developed. The time spent manually selecting in this manner may be "a wash" when compared to the time it would have taken to manually edit the selections for complex areas. That stated, the pursuit of an automated selection that could replace this semi-automated method would be fantastic.
- Chart scale should give a good indication of the general parameters to use, but the complicating factor of slope is still a looming problem. This method will populate soundings nicely along, or around, whatever feature one requires. However, remembering from earlier discussions, the distance a support sounding should be placed too and away from a hazard, shoal, contour, etcetera is slope dependent. The steeper the slope the shorter the distance and for the flatter the topology the more distant one will require the soundings to occur. For this particular problem the authors have contemplated that an answer may lie in the co-opting of current OpenGL calculations used in determining slope for sun illumination technologies and the like. Those calculations could perhaps be translated into defined distance attribution tools for application at various scales and solving the problems presented by the variability in seafloor topology.

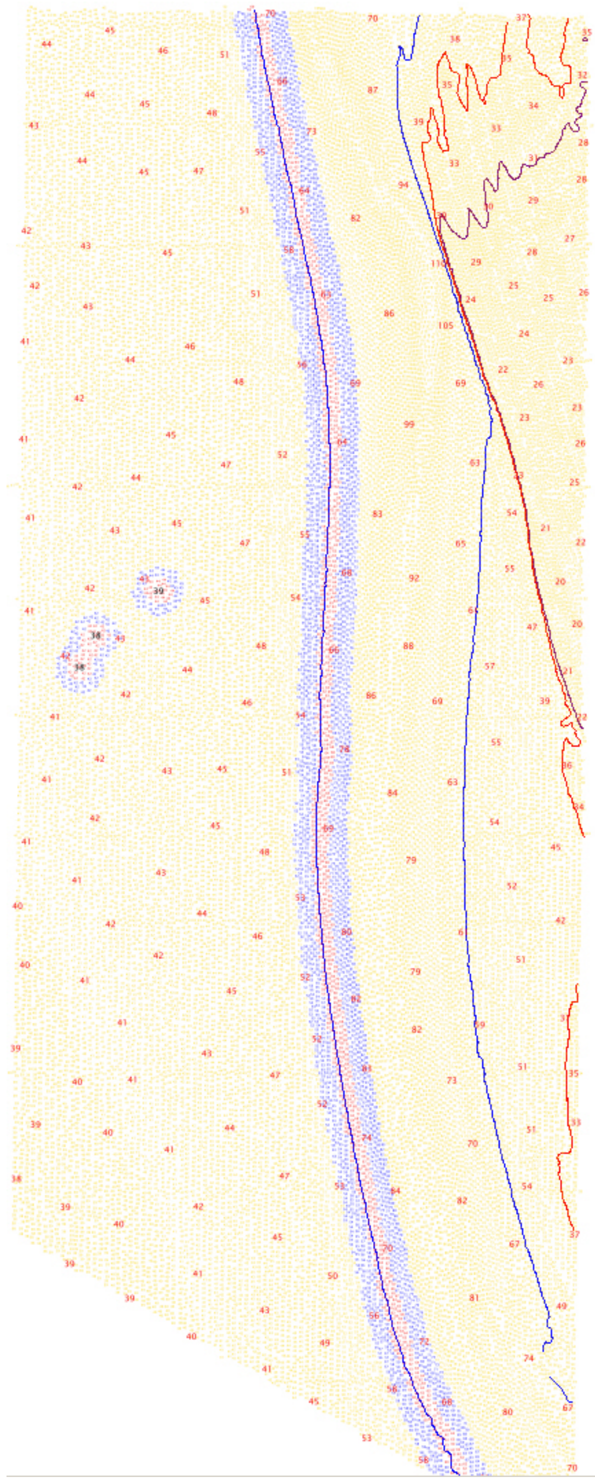

Figure 19

– The area along the contours where soundings were attributed as “reserved”, thus not candidates for sounding selection, was very successful for this expressed purpose. However, this method causes concern with respect to the possibility of omitting critical soundings on shoals or features. Any time data is dismissed without full consideration, the risk is run that a critical piece of data will be lost. In this instance, a data point along the contour line could be much shoaler than its neighbors, but since it does not breach the upper limit of the depth area its presence is not obvious. It is important that these reserved soundings do have the opportunity to be considered as a chart scale sounding, for this reason. What was not tried in this demonstration but should be considered is testing the behavior of what were the “reserved” soundings if they were simply left in with no special attribution. Hopefully, the designated soundings would be preferred, but if a more significant shoal sounding was found in the contour region it would be selected and the contour would just have to be generalized to accommodate that. The other option is that technical developments to improve these processes will “open up” the variety of attribute choices available with a scheme of hierarchical structure of significance.
– The results indicate that given just the advantages of designating soundings in particular areas and, for now, omitting certain areas from sounding selection many of the other complexities faced during chart compilation could be greatly enhanced. By additional manipulation of files to disallow or encourage soundings being selected on other chart furniture (ATON’s, dredged areas, spoil areas, bracketing navigation channels, pipelines, shoreline, compass roses, title blocks, scale bars, etcetera), coupled with chart interface deconfliction, the requirements for post automated sounding selection would be massively reduced and improve the spatial sounding relationships in the final product.

Conclusions

The field of developing improvements to current automated sounding selection in support of chart scale products is wide open. Current sounding selection algorithms and automated methods stop at the survey scale representation which is free from the complexities of coalescing the sounding data with competing objects within the confines of chart scale. As stated, sounding selection is one of the most critical aspects of a nautical chart, yet current processes still rely on manual manipulation by cartographers of widely varying levels of experience and interpretive understanding of guidelines. The reliance on quality review of these products to maintain consistency and correctness of chart products is overly relied upon and often results in far more rework than should be appropriate. This current paradigm consistently adds overhead in the way of additional time, cost, and personnel, delaying getting these essential products into the hands of mariners.

Future work at AHB will continue to refine the processes of automation and improvement of sounding selection and related processes. However, for rigorous and less convoluted methods to eclipse current paths, targeted advancements in the algorithms and supporting software must be invested in and brought to fruition. In the current state, the related technological advancements made in hydrography, given solid efforts for improvement, make many of the industry standard cartographic methods such as chart scale sounding selection appear archaic.

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BIOGRAPHICAL NOTES

Edward A. Owens

Edward Owens is a Physical Scientist for the Atlantic Hydrographic Branch of NOAA's Office of Coast Survey in the United States where he is the Cartographic Team Leader. He has a bachelor's degree in Science and 15 years hydrographic and cartographic experience. He is an experienced Lead Hydrographer and surveyed in Alaskan, Gulf of Mexico, and North Atlantic coastal waters from the Caribbean to Newfoundland. He is also an active team member in the NOAA Biogeography Branch's effort to conduct benthic habitat mapping of Puerto Rico and the U.S. Virgin Islands. Edward is a naturalized citizen to the United States; he was born in Wimbledon, England to Irish and British parents and moved abroad to the US at a young age.

CDR Richard Brennan

CDR Rick Brennan was born in Corpus Christi, Texas and earned a B.S. degree in Civil Engineering from the Citadel in Charleston, South Carolina. CDR Brennan started his NOAA career in 1992 aboard NOAA Ship *Rude*. Since then he has served nine out of his eighteen years of service in the field conducting hydrographic surveys. He earned a M.S. in Ocean Engineering from the University of New Hampshire in 2005 where he specialized in Ocean Mapping at the Center for Coast and Ocean Mapping and NOAA's Joint Hydrographic Center. Additionally, CDR Brennan served as the final Commanding Officer of NOAA Ship *Rude*, and upon her decommissioning served as Executive Officer aboard the NOAA Ship *Fairweather*. More recently, he served as the Chief of the Atlantic Hydrographic Branch in Norfolk, Virginia and is currently serving as Commanding Officer aboard the NOAA Ship *Rainier*.

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