International Hydrographic Review, Monaco, LXI (1), January 1984

COMPUTER-ASSISTED SOUNDING SELECTION TECHNIQUES

by George MACDONALD(*)

This paper was presented to the 4th International Symposium "HYDRO 82" held at the University of Southampton in December 1982. It is reproduced here with the kind permission of the organisers, The Hydrographic Society.

SUMMARY

Soundings that are acquired and stored in digital form go through three distinct selection processes before they appear on a Canadian nautical chart. On board the survey vessel, many depths are collected each second and filtered by the on-board computer. The sounding which best represents the depth over the second is selected and stored. The filtering process provides a reliable data base from which the hydrographer can later select the most significant soundings to be portrayed at survey scale.

There are a number of techniques that can be used to select soundings for the field sheet. Each method has its advantages and disadvantages. Most schemes use the computer to perform a task that has been done by hand for a number of years, and the final product closely resembles the hand-drawn field sheet. More recently, investigations into the feasibility of contour-style field sheets, which show only the most critical soundings, have been conducted.

Soundings are selected from digital field data and portrayed on the chart. The ease with which field data can be incorporated into the chart production process governs the viability and acceptance of computer-assisted hydrographic and cartographic techniques.

(*) Canadian Hydrographic Service, P.O. Box 5050, Burlington, Ont. L7R 4A6, Canada.

INTRODUCTION

It has been many years since the first digital sounding was recorded on board a survey vessel. Many charts throughout the world bear the results of computer-assisted logging and processing techniques. Still, there is little agreement within the hydrographic community on which methods should be used by the hydrographer and cartographer to select soundings from the abundance of digital data collected each survey season.

There are many good reasons for collecting data in digital form. It saves time and money; it improves accuracy and efficiency; it reduces errors and makes the job easier. Not every system that was ever developed does this, but that was the intention. Some systems are more reliable or more sophisticated than others, so some work better than others. The technique used to select soundings might depend on how reliably the logging and processing equipment performs.

There are other considerations. Is the survey scale large or small; is the bottom rough or smooth; is the survey inshore or offshore; are the depths deep or shallow; are the depths critical; will the data be used for purposes other than navigation ? If all these various factors influence sounding selection, there may not be one method that will suit all the needs of the hydrographer.

There are three stages where soundings are selected from digital data before they appear on a Canadian nautical chart. First, on board the survey vessel, soundings are filtered in real time before the most significant data are recorded. Second, soundings are processed in the field where depths are selected to best represent the bottom at survey scale. Third, the digital data are used to produce a nautical chart.

LOGGING : REAL TIME SOUNDING SELECTION

A computer on board the survey vessel can be a real asset to the hydrographer, because it can monitor the digital depths to ensure that only valid ones are accepted, and because it can select and record the most significant depths from all of those collected each second. There are a number of ways to filter out bad depths. One technique used by the Canadian Hydrographic Service establishes a depth gate around an accepted depth (see figures 1 and 2A). A new depth is compared to the gate limits, and if it falls within the gate, the gate is re-established around the new depth (see figure 2B). Since depth can change abruptly and unpredictably, no depth is discarded unless it is out of gate for a period less than the defined gate length.

If a depth is outside the permanent gate limits (see figure 2C), a temporary gate is established around that depth. When the number of depths through the temporary gate exceeds the gate length (see figures 2E and 2F), the depths are accepted as good depths. If the depth falls within the permanent gate before the number through the temporary gate exceeds the gate length (see figure 2D), the depths that fall inside the temporary gate are discarded. This takes care of

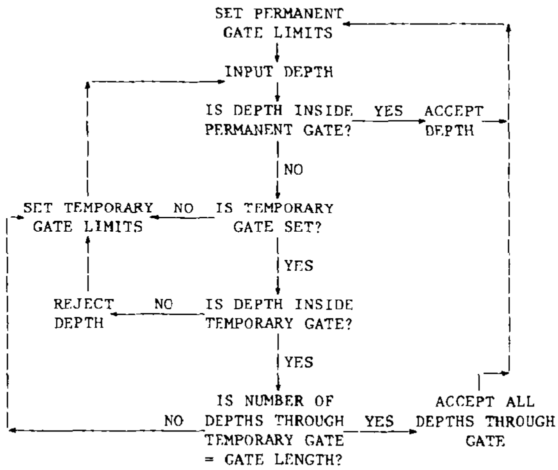


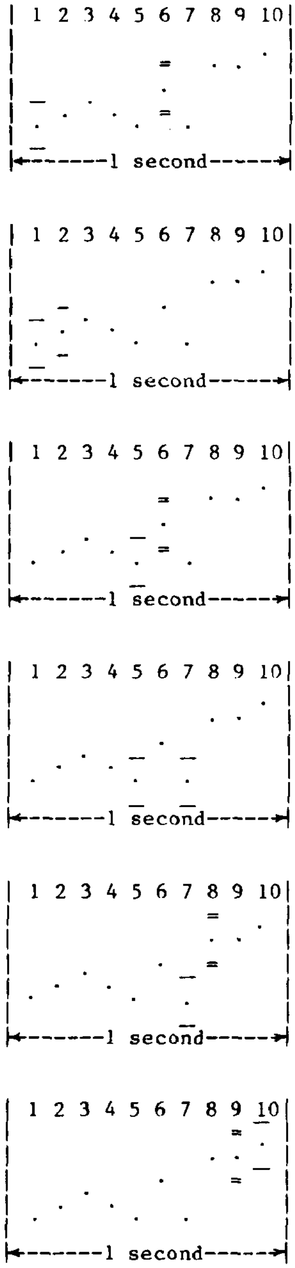
FIG. 1. — Depth gating technique.

conditions where the bottom changes abruptly, such as at the limits of dredged areas or in rough terrain.

Gate width and gate length values are variable, and are set by the hydrographer depending on bottom roughness. If the gate is too narrow or too long, bottom detail may be ignored; if it is too wide or too short, bad depths may be accepted. The proper settings are determined from field observations. This method, used since 1977, has proven to be effective in reducing the number of recorded bad depths. It works on the presumption that there will be more good depths than bad, and that a competent hydrographer will be setting gate values and monitoring the results.

In order to record good depths, the computer must first receive good depths, and this factor may depend on a number of variables : type of bottom, depth, weather, vessel speed, type of echo sounder or frequency of transducer. Although the true depth can usually be discerned by eye from the echogram, depth digitizers have not always been able to separate the false echoes from the bottom. This has caused many a hydrographic headache over the years. But a new breed of digitizer is on the market now. It is referred to as the 'smart' digitizer because it has a microprocessor that analyses the depths before they are output to the logger. There is one digitizer, for instance, that fits a fourteen point polynomial to the bottom. The first ten points are acquired data and the leading four are predicted values. A depth gate is established around the eleventh point, and the gate width is set dependent on bottom roughness as determined from the first ten points. A smooth bottom narrows the gate; a rough bottom or steep slope widens it. The hydrographer cannot change the gate parameters directly, but he can control the gate by turning it on or off and by moving it up or down until it is superimposed on real depth data.

This is only one example of what a smart digitizer might do. It results in better depths and it makes the hydrographer's job that much easier later on. The combination of a 'smart' digitizer and an on-board computer to filter depths can eliminate most depth errors.



A: · Depth return
– Permanent gate limit
= Temporary gate limit

B: Establish permanent gate around depth 1.
Depth 2 inside gate.
Re-establish gate around depth 2.

C: Depth 6 outside permanent gate.
Establish temporary gate.

D: Depth 7 inside permanent gate.
Discard depth 6.
Establish permanent gate around depth 7.

E: Depth 8 outside permanent gate.
Establish temporary gate.
Gate length set to 3.

F: Third depth inside temporary gate.
Accept all three depths.
Establish permanent gate around depth 10.
Store depth 10.

FIG. 2 (A-F). — Depth gate example.

The on-board computer can be used to select good depths from the many received each second, but there is some disagreement within the hydrographic community about which depths should be recorded ? If seven depths are acquired each second, in an eight hour working day over 200,000 soundings could be collected. This is a large amount of data to log and later process. Should they all be recorded ? If not, then which ones should be recorded ? The computer can make some sort of intelligent decision on which depths are most significant. They could all be recorded and this may seem, in theory, to be the best solution. But it is not the most practical solution. It takes longer to send seven soundings to the logging medium. It takes more tape to store the soundings and it takes longer to process them. It puts an additional strain on the hydrographer who has to edit all the data. Are seven depths of much value without a position for each one ? A position for each depth would burden the logger, processor and hydrographer even more. A varying number of depths each second would further complicate logging and processing operations.

If recording all the depths presents some problems, maybe three each second could be recorded; the shallow, the deep and the average. But consider how these data will eventually be used. Will the deep or the average ever be needed except in some mathematical exercise ? The shallow must be used. Any error must be on the side of safety. So one depth a second seems a reasonable solution. The shallow is the obvious depth to be recorded (see figure 2F), since it is most important as far as the navigator is concerned, even though the average depth might tend to compensate for heave. If one depth is recorded each second, does it match the recorded position ? Probably not. If the recorded position is the average value for the second, for instance, then the depth and position can be offset by up to half a second. At a speed of 20 knots, this is a little over five metres. It is obvious that there are many things that need to be considered when the on-board computer is programmed to do some real time processing.

There is one other real time option. Depths can be selected on-line for plotting at survey scale. It is a feasible if not practical alternative. Besides burdening the on-board computer, it means a launch installation that is more expensive, requires more electrical power, takes up more space and adds more weight. It means a second pass to correct for sound velocity, tide correction and range calibration. It means editing the data to include critical points that may have been missed during the initial selection stage. Weigh this against the advantage of a real time preliminary plot. Is it worth it ? The use of an on-line micro-processor can go a long way towards making subsequent sounding selection faster and simpler. The use of simple gating techniques and sounding selection schemes in real time is one result of recent technological advances. Care must be taken in current and future efforts, to guard against improper filtering techniques that can hide errors or magnify them, or make bad data out of good.

OFF-LINE PROCESSING : FIELD SHEET SELECTION

In Canada, the field sheet is the document that contains the selected soundings, shoreline, contours, bottom samples and other data collected in the field and plotted at survey scale. It can take many forms and go through many stages, from rough plot to final product, from graphic document to digital tape. Ever since the first digital sounding was recorded on board a survey vessel, the Canadian Hydrographic Service has been involved in writing computer software that will select soundings for the field sheet.

Canadian hydrographers have been displaying soundings on field documents for a century. When soundings were collected by lead line, every sounding could be shown on the field document. It was not until echo sounders were developed that methods had to be devised to select soundings for plotting, from the abundance of recorded data. Whether depths are recorded in analog or digital form, the problem is the same : how to make a selection that represents the true bottom, while ensuring that important depths like shoals are not missed, and also ensuring that the resulting document clearly portrays the bottom. The manual technique is to pick soundings at even intervals, based on survey scale, and to pick significant deeps and shallows as well. A mixture of art and science, brought about by combining the hydrographer's eye, hand, training and intellect, produced acceptable and, by now, well established results. It might appear to be an easy task to emulate this method in a computer program. But it is not.

If the method that hydrographers have been using for years is acceptable, then why bother trying to copy it with a computer ? Every engineer or programmer involved with hydrography will quote the usual reasons. They will tell the hydrographer how easy it is to utilize the computer, and how it will improve accuracy and productivity while reducing expenses and manpower. These are good arguments and, as it turns out, valid ones.

There are a number of algorithms that can be used to decide which soundings to plot. A simple method might base the decision on the distance between selected points : keeping in mind survey scale and number size, is there room to plot another depth (see figure 3) ? This would produce a neat sheet, but obviously the deeps and shallows that would interest the chart user could be overlooked.

Since the important depths are shallows and deeps, a technique was developed by the Canadian Hydrographic Service to select these and other points that would be the least number required to define the bottom profile within some set of specified tolerances (figure 4). These are : the allowable difference in depth between two consecutive soundings, which determines whether the depth is a significant shallow or deep and : the maximum allowable separation of a recorded depth from the straight line joining two selected depths. The tolerances are variable and input by the hydrographer. They will vary depending on sea state at the time of logging, bottom roughness, and the intended use for the data. For instance, the tolerances might be large on reconnaissance or small scale surveys, and might tighten up on large scale or special purpose surveys.

On the first pass, the program selects all the maximum and minimum points in the original data (see figure 5). The selected points are reduced further on a second pass, to those points required to define a set of straight line segments that satisfy the specified tolerance. To do this, a straight line joins the first and third

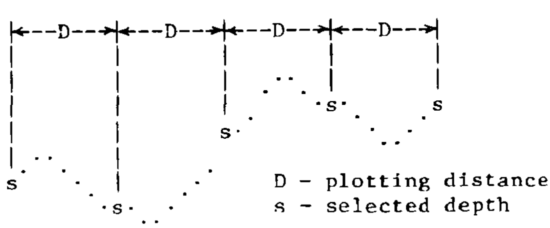


FIG. 3. — Simple depth selection.

points (see figure 6) and the second point is tested to see if it falls within specified limits. If it does, points 1 and 4 are joined (see figure 7), and points 2 and 3 are tested. The procedure continues until one or more points fail the test (see figure 8). The line that represents the bottom within the defined tolerances is the preceding test line (see figure 7). The test line origin is redefined as the last point on the previous test line (point 4 in this case) and the procedure continues until all the points in the data set have been tested (see figure 9). A third pass checks all the data points (not just the selected minimum and maximum points) and adds those that fall outside the specified limits (see figure 10) to the final data set. In this example point 4a is added to the final selected data set.

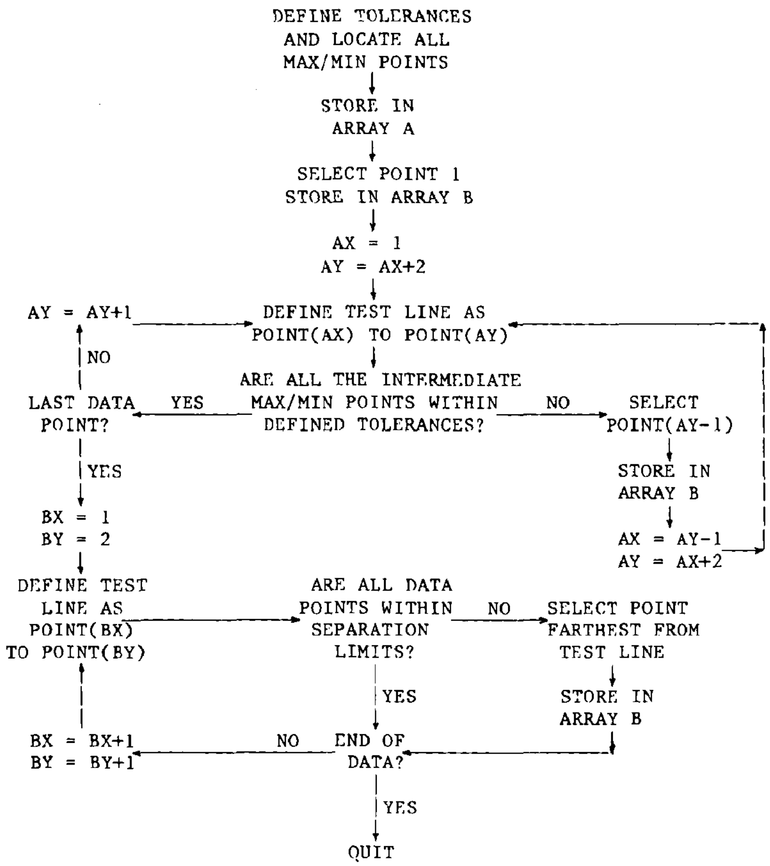


FIG. 4. — Depth selection to define profile within specified tolerances.

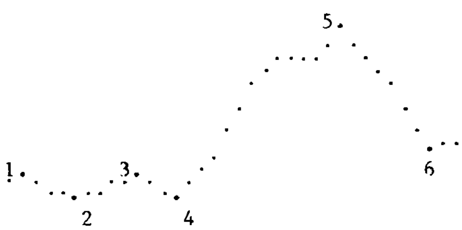


FIG. 5. — Selected max./min. points.

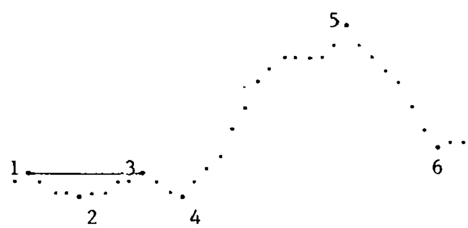


FIG. 6. — First test line.

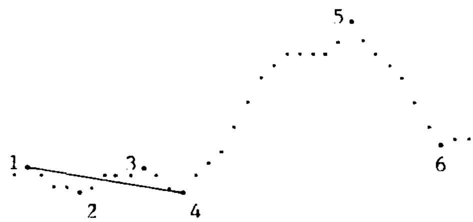


FIG. 7. — Second test line.

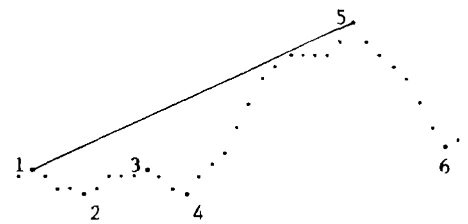


FIG. 8. — Points fail test.

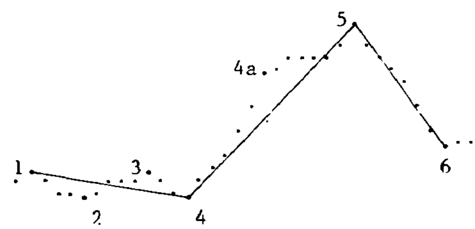


FIG. 9. — Selected points (pass 2).

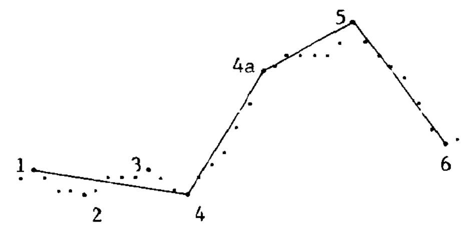


FIG. 10. — Final selection.

Although the selected soundings closely represent the bottom within the specified tolerances they still present some problems. If the terrain is complicated all the selected points cannot be plotted, so a program to select plottable depths is still required. In flat areas only a few points are selected, leaving gaps in the plotted survey information. Whether the points that fall within the defined tolerances are shallower or deeper than the test line is not considered. For the program to work well, sounding data must be clean; heave and pitch, as well as bad data, can cause problems. For these reasons, this particular method is used very little in Canada.

Neither of the methods just described is satisfactory on its own, but by combining some of their features the hydrographer might be able to develop an algorithm that would suit his needs. If he selected critical shallows and deeps, but also checked the distance between selected points to see if there was room to plot them, and, if not, then make sure the shallowest gets selected, he would be getting closer to his requirement. The method used most by the Canadian Hydrographic Service was developed in 1969 (see figure 11). The same number of points are selected from each record, including the shallowest depth in the record, and the deepest depths preceding and following the shallow (see figure 12). The distance between two selected shallows is checked to see if there is room at survey scale to plot soundings. If not, the shallowest is saved, depths are selected from the next data record and the distance between shallows is again compared. The process continues until a shallow depth is selected for plotting. Once two shallows have been selected, the deeps between the shallows are checked to see if there is room for the deepest one to be plotted. To make a good sounding selection using this technique, the record length has to match survey scale and launch speed, so that one sounding will be picked from each record. This can easily be done during processing, by dividing each record into the required number of sub-records. This method works well but has some flaws. For instance, if two shoals show up in the same record (see figure 13), only the shallowest will be picked. Both could be important, so verification of the selected points by comparing them to the echogram is an important processing step.

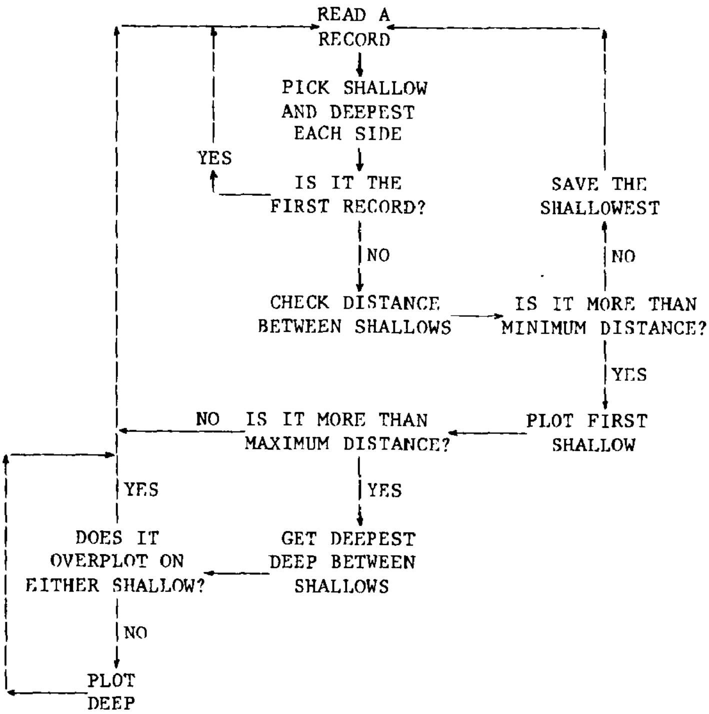


FIG. 11. — Combined depth selection technique.

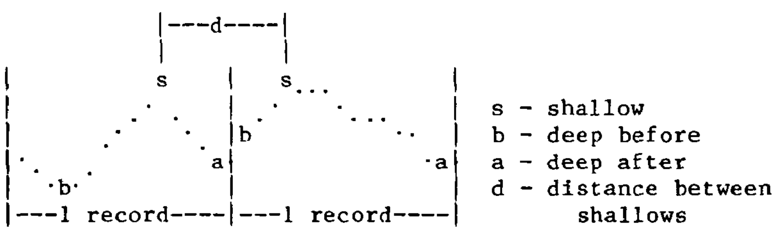


FIG. 12. — Selected points.

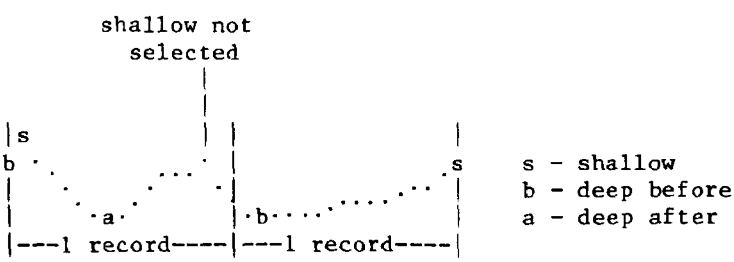


FIG. 13. — Shallow depth not selected.

The program has been recently modified so that real deeps and shoals, independent of record length, are selected. Every other data point is regarded as a filler, and these are selected as necessary to complete the picture. The new program resolves all the flaws in the original algorithm, and the true bottom is more closely represented by the selected soundings. Deep channels, for instance, which could be missed due to the extreme shoal bias in the old routine, will be selected by the new routine without jeopardizing the critical shoal selection.

Ever since the first sounding appeared on a field sheet, it has been a discrete number representing the depth in the area covered by the figure. Each depth acquired by lead line or sounding machine was a discrete sounding. Although methods of collecting hydrographic data changed with the advent of the echo sounder, and new data selection techniques were developed, the method of representing the survey results as a number of discrete data points did not change. Even when computers were introduced, the hydrographer continued to select data and plot them following all the traditional concepts. Taking into consideration survey scale and size of digit, he shows as many depths as possible without plotting one on top of the next, and if some depths cannot be plotted he ensures that the shallow is kept at all costs. This has certain advantages, since a shoal bias protects the navigator, since it is easier for a programmer to copy an established technique than to develop a new one, and since it is easier to get a conventional looking product accepted. But I think it was a mistake to simply try and duplicate the manual method that has been refined over the years. The advent of the computer can lead to better ways of using and depicting depth information.

Chart and field sheet design and content are being influenced by the technology available to collect, process and display information. Color plots can be used to great advantage. Soundings can be plotted in colored bands according to depth. It makes a great checking tool and contouring aid, and has been used with great success on recent surveys in Canada.

The hydrographer could go a step further and modify the whole selection philosophy. Chart production has adopted the contour-style format for all new charts. Fewer soundings and more contours are being used to depict the shape of the bottom on the chart. Field sheet production, in the meantime, has remained virtually unchanged. Is it not time to consider contour-format field sheets ?

There would be a number of advantages to this. The field sheet data would be directly useable at the chart compilation stage. The accuracy and clarity of the field sheet would improve. Compare a sheet of contours (see figure 14) to a sheet full of numbers (see figure 15). Which one shows what the bottom looks like at a glance ? The contours of course. The move in recent years to the contour chart is evidence that a contour can portray the bottom more clearly, more efficiently and more effectively than a large number of soundings.

Over the years many experts have taken traditional field sheet data and attempted to contour them using a computer, some with more success than others. There are two basic approaches to contouring digital data. The most widely accepted contouring packages grid the depths, using rectangles or triangles, and interpolate the contour intercepts. The interpolated points are joined by a smooth line (see figure 16). A well written program can certainly interpolate as good as a hydrographer, and the programs produce pretty good results. But by themselves,

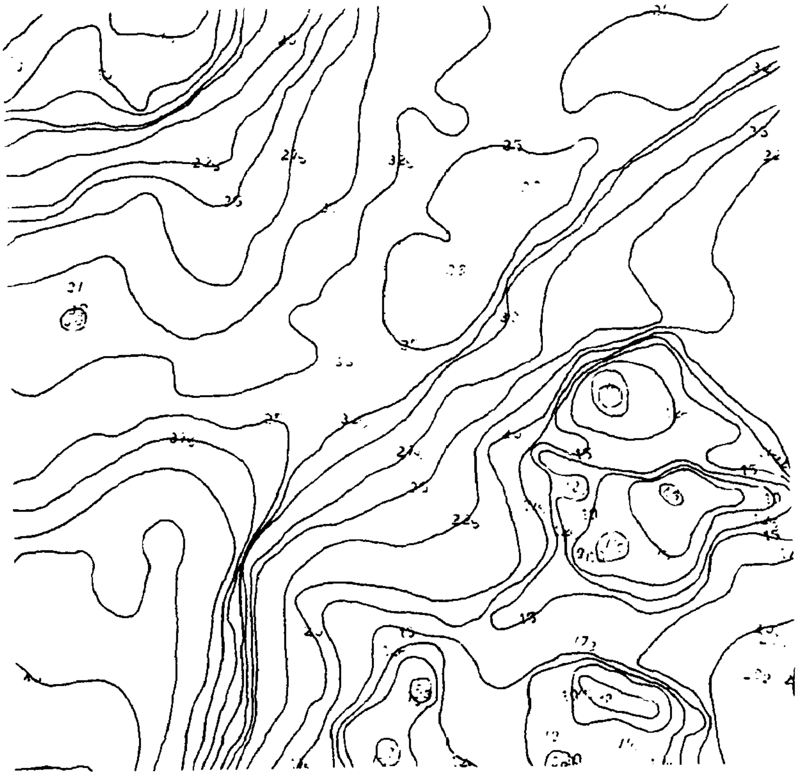


FIG. 14. — Contour format field sheet. Scale 1/30 000.

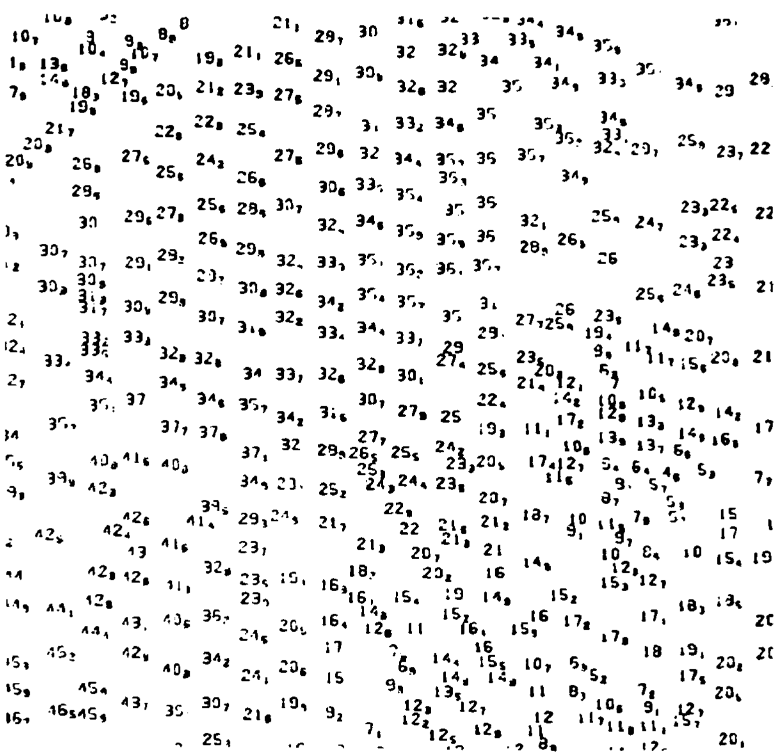


FIG. 15. — Conventional field sheet depths. Scale 1/30 000.

the contours are not a lot of use unless they can be added to the field sheet or can supplement the field sheet to make the cartographer's life a little easier later on.

The gridding programs have many variables that make some better than others, such as the techniques used to join the intercepts (splines or polynomials), or how much line smoothing is employed. But, without exception, they all estimate where the contour lies. As the hydrographer runs his survey lines, collecting positions and depths as he goes, he measures and records the exact position of the contour intercepts. A more accurate approach to contouring digital hydrographic data would be to develop a selection routine that would pick the contour intercepts, and critical deeps and shallows, from the recorded data. The exact positions of these points have been recorded during the sounding operation, so no interpolation is necessary. Since more contours than depths can be shown on a field sheet, and since there is only room for so many soundings, no matter how complex the bathymetry might be, contours can show bottom topography without losing clarity, in areas where the bottom profile is steep or complicated. Once the contour intercepts are joined, the resulting contour field sheet, complete with critical deeps and shallows, would be the first step towards a completely digital field document.

Both of these approaches are viable, and further testing of both techniques will indicate which method is the most practical. For instance, the first method, contouring the selected data using some sort of gridding technique, may have less absolute accuracy, but the second method, selecting contour intercepts and critical depths from recorded data, may take a lot longer and be a less practical field tool.

OFF-LINE PROCESSING : CHART SELECTION

It seems that everyone these days is digitizing data. Hydrographers have been doing it for a number of years, and it is getting easier all the time. If recording digital data is easy, using the digital data properly is not. There are many methods of selecting soundings for the field sheet from digital data. Each has its advantages and disadvantages. But if this digital field sheet information cannot be used directly by the chart compiler, collecting the data in digital form is really an academic exercise.

The cartographer has trouble using digital field sheet data when they are in the traditional format (a large collection of discrete depths). When the data are plotted at chart scale they are often impossible to read because of the overplot (see figure 17). If the plot size of the number is reduced to eliminate overplot, the data are very difficult to read. The shape of the bottom, and hence the location of dangers and other features, is not obvious because of the lack of contours. All the data required to compile the chart may not be in digital format. To overcome these problems, the cartographer has developed a production scheme that requires the chart to be compiled manually, and then digitized on a table, before a computer can be used interactively to draw or edit the information. This method does not make use of the digital field document. There has been some some work done in the area of sounding selection for chart compilation from the digital field sheet. An internal Canadian Hydrographic Service report on the manual technique for 'The

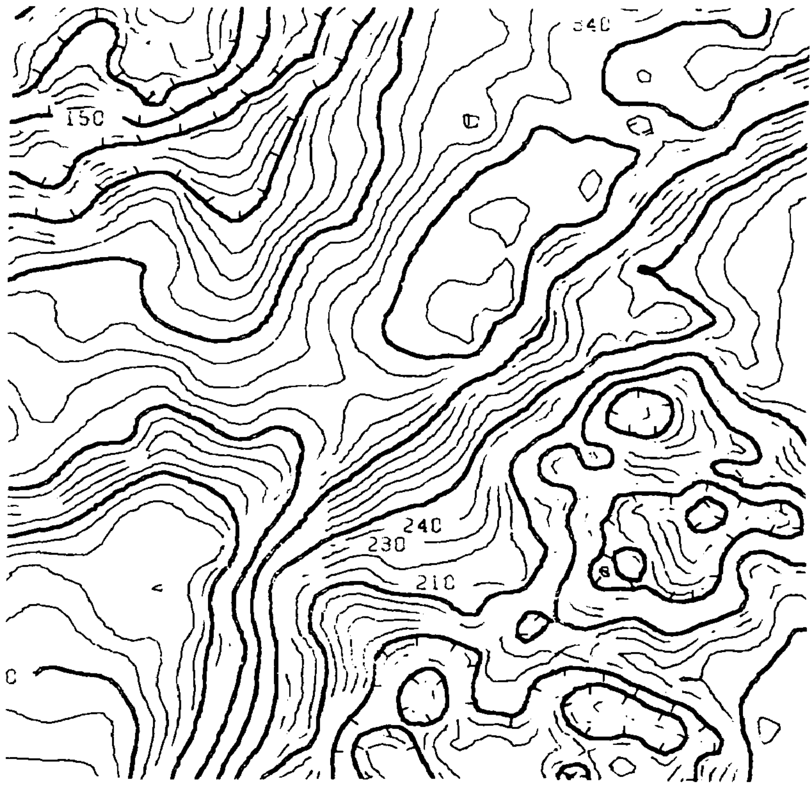


FIG. 16. — Output from computer contour package. Scale 1/30 000.

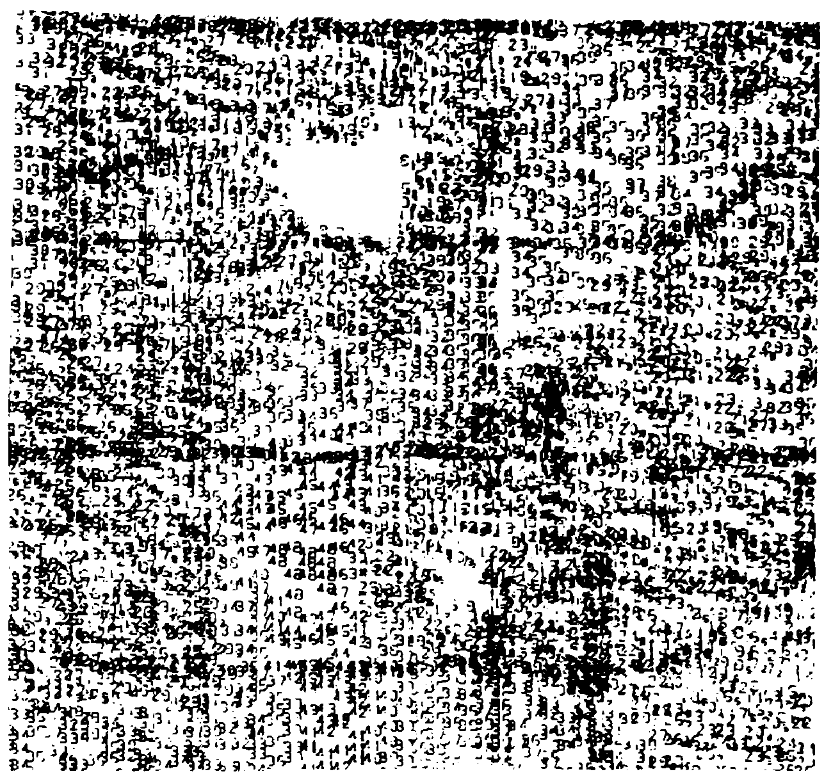


FIG. 17. — Field sheet reduced to chart scale causes overplot.

Selection of Soundings for Nautical Charts' was published in 1972. It contains 83 pages : 11 pages are devoted to basic selection techniques; 72 pages discuss exceptions to the basic formula.

Sounding selection for the chart is a complicated and controversial subject, and it has proven difficult to define, let alone copy, the manual technique. The computer can handle the routine selection but the cartographer has to handle the special cases. Since contours and navigation channels are hard to include in the computer selection algorithm, neither feature is necessarily supported by selected soundings.

A few years ago the Canadian Hydrographic Service began producing charts in contour format. The bathymetry is represented using fewer discrete soundings and more contour information. The selection criteria for charts has been modified to reflect this change. How is the cartographer making use of the digital field sheet ? Because of the new chart format, the digital field sheet is extremely difficult to use in its present form, that is, a collection of discrete depths. It is possible to remove overplot and plot the remaining soundings at chart scale, but it cannot be done without sacrificing the detail and accuracy of contours that are derived from the result. If, on the other hand, the field data are in contour format, they can be reduced to chart scale with no loss of detail or accuracy, and can be easily and directly used by the cartographer.

There is no reason for the hydrographer to collect and process digital data if they cannot be used by the cartographer in the chart production process. Contours and soundings must be selected from the available survey data to define and highlight navigation hazards, to show draft limits for safe navigation, and to portray the general bottom features. To do this, the contours and soundings can be divided into three groups : critical, significant and representative.

Critical soundings show the minimum depth on shoals or submerged obstructions, in the navigable portion of a channel or passage, in the approaches to and alongside a wharf, and along the recommended track of the useable portion of a range. The critical contours are those that define the shape of the bottom in areas where soundings are critical. Significant depths indicate an unexpected change in depth, or show the deepest or shallowest depth inside a closed contour. Where two depths cannot be shown, the shallowest is the most significant. Significant contours are those that are always shown on hydrographic charts, those that indicate an unexpected anomaly, and those from which significant soundings may be derived. Representative contours give an indication of how regular or irregular the bottom is. Representative depths for the chart can be derived from field sheet contours.

All of this information is clearly shown on a contour-style field sheet, and the cartographer can easily incorporate these data, in digital or graphical form, into the final product (see figure 18). In light of the advantages a contour-style field sheet would provide to the chart compiler, the hydrographer must assess the accuracy, quality, usefulness and acceptance of computer-assisted contouring techniques for the field. Techniques to select and portray contour information at the field processing and chart compilation stages are being pursued in earnest.

Finally, there is a whole new charting concept emerging that will make digital field sheet and chart data not just desirable, but essential. The 'electronic chart' will

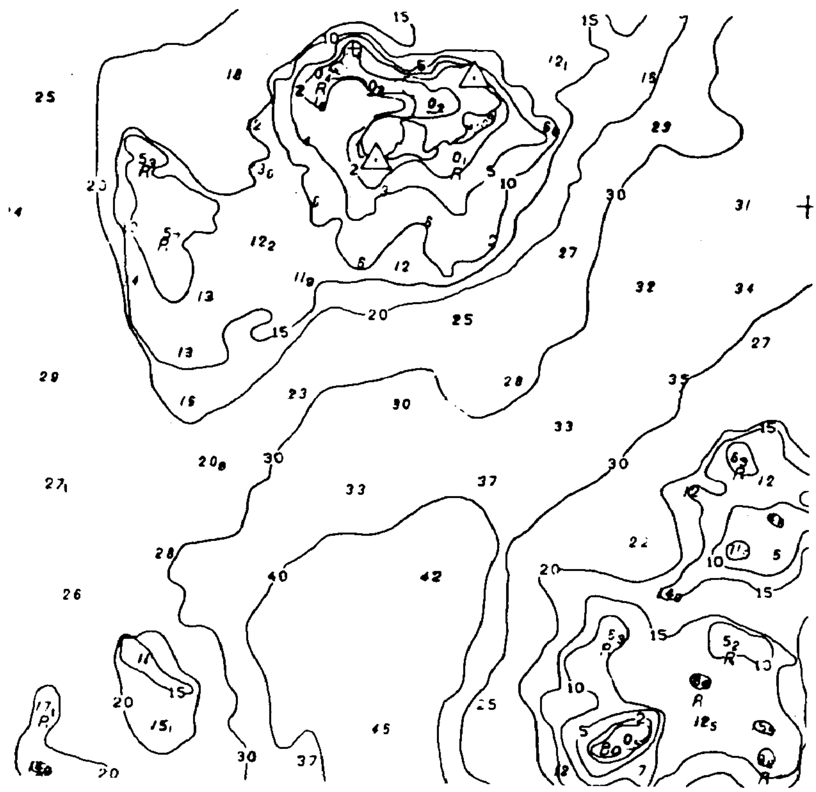


FIG. 18. — Chart compiled from contour field sheet. Scale 1/50 000.

consist of a computer and a high resolution display system, and its use is intended to improve navigation, to allow easy interfacing of radio or satellite navigation aids, to allow easy integration of other navigation information such as ice conditions and tide and current predictions, and to improve chart corrections. This type of revolution can only happen once all the digital data selection problems are solved, and a standard and acceptable mode of data presentation is developed.

CONCLUSION

I once suggested, in an article I wrote, that if a statistician was given the job of selecting soundings for a field sheet, he might average a number of depths, and when there was room to plot a sounding, he would plot the average. This was a facetious and uncalled-for remark, aimed tongue in cheek at a statistician friend of mine. What he would really like to do is to smooth the depths until they look acceptable, and select his depths from the smoothed data using one of the techniques I have described. Either approach could be dangerous. The best place for quality control is at the source, and a computer on board the survey vessel makes an excellent data monitor. But whether smoothed data or real data get recorded is a fundamental question that still needs to be answered. A hydrographer would ideally like to keep all the data, but recording them all is impractical. On-board computers can not only filter the data to eliminate bad depths, but can also make an intelligent decision on which depth to record each second.

Field sheet sounding selection routines are as varied as the type of vessel used to collect the data in the first place. Simple selection routines might prove satisfactory in deep and flat areas, but generally do not meet hydrographic requirements. The technique used most by the Canadian Hydrographic Service over the years tries to copy the manual method of picking a depth every half centimetre at survey scale, paying particular attention to shallows and deeps, plotting the shallow at all costs. While it has proven to be a successful field technique, the cartographer has not been able to use this digital information directly in the chart production process. New chart formats indicate that contours portray the bottom more clearly, more efficiently and more effectively than a chart full of numbers. The hydrographer should take advantage of these benefits by producing contour-format field sheets as the first step towards bridging the gap between digital field sheet and chart. It requires work on both sides : by the hydrographer to select more meaningful and useful data; by the cartographer to develop methods of efficiently using the digital hydrographic product in the cartographic process.

The selection of chart data from the conventional digital field sheet is difficult if not impossible. With the advent of the contour-style chart, a computer program to imitate the manual selection techniques is no longer necessary. The hydrographer, while attempting to solve the current problems involved in representing depths on a field sheet, should not forget the challenge of representing the total field sheet in digital form. Only then will the hydrographer and cartographer be able to make full use of the computer-assisted facilities at their disposal.

BIBLIOGRAPHY

Canadian Hydrographic Service (1972) : *The selection of soundings for nautical charts* (revised). Internal Project Report, Ottawa, January.

CASEY, M. (1980) : The field sheet as an inefficient medium, *Lighthouse*, Journal of the Canadian Hydrographers' Association, Edition No. 22, November.

CZARTORYSKI, J. (1982) : *Field sheet contouring*. Canadian Hydrographic Service, Internal Report.

DOEKES, C., BRYANT, R. & MACDONALD, G. (1976) : *Automated selection of bathymetric data to accurately represent bottom topography*. Proceedings of the 15th Annual Canadian Hydrographic Conference, Ottawa.

MACDONALD, G. (1980) : Sounding selection from a digital data base, *Lighthouse*, Journal of the Canadian Hydrographers' Association, Edition No. 22, November.

MACDONALD, G. (1981) : The use of microprocessors for track control and data verification on hydrographic surveys in Canada, *Intern. Hydrogr. Review*, LVIII (1), January.

MACDONALD, G. (1982) : From a cresting wave to a cresting technology, *Intern. Hydrog. Review*, LIX (2), July.

MEYER, E.A. (1981) : 'Smart' digitizer proven in Arctic, *Lighthouse*, Journal of the Canadian Hydrographers' Association, Edition No. 24, November.

ORAAS, S.R. (1975) : Automated sounding selection, *Intern. Hydrogr. Review*, LII (2), July.

TINNEY, B.L., CASEY, M. & EIDSFORTH, B. (1982) : *Contour style field sheet.* Proceedings of the Canadian Hydrographic Workshops, Quebec, February.