ADVENTURES IN INTERACTIVE COMPILATION

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Abstract

Interactive compilation was proven to be a practical tool in the production of Chart 2011 and Chart 2048. The successful completion of these two charts has shown that applying computer-assisted techniques as an integral part of the construction of nautical charts is an effective alternative to traditional chart compilation. The advent of fast colour graphics devices and the increasing availability of digital hydrographic data requires innovative solutions to manage and use these data effectively.

INTRODUCTION

This paper discusses current research into interactive compilation techniques and the implementation of computer-assisted methods in nautical chart compilation, an aspect of chart production relatively untouched by the computer revolution in the Canadian Hydrographic Service (CHS).

Since the late 1960's, computers have had an impact on many cartographic functions, but the main goal of the cartographer remains that of producing charts in the most efficient way possible, with minimum reasonable cost in both production and time, while maintaining a high quality product.

The assistance of computers does not directly translate to instant efficiency in any given process. Detailed testing of theories and techniques must be done to estimate if the ends justify the means. The first experiment in interactive compilation, using contemporary hardware and software, involved the production of Chart 2011, Belleville Harbour. The production of this A2 size chart was done using the CARIS[1] system with the focal point being a Tektronix 4125 colour

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[1] CARIS is an acronym for 'Computer Assisted Resource Information System' and is the name of the cartographic system used in the Canadian Hydrographic Service. CARIS is a product of Universal Systems Limited of Fredericton, New Brunswick, Canada.

graphics terminal.

The need for interactive compilation exists because the outmoded ideal of 'automated cartography' is largely unattainable — the 'traditional' paper chart cannot be produced 'automatically'. Therefore, the mandate of interactive compilation research has not been to invent the means to produce a chart automatically, but rather by 'interactive' methods. To produce a chart 'automatically', the cartographer would simply be required to issue commands that would manipulate data in such a way that no other human interface would be required. We must understand that, invariably, interaction must take place between the cartographer and the computer. The term 'interactive' relates to a reciprocal action between two parties.

Many of the more mundane functions may be reduced or completely eliminated by computer applications. Contouring, sounding selection, and projection changes are just three examples of operations in which computers are being applied. This allows the cartographer to devote more attention to the compilation process: the assembly, evaluation and correlation of the various source data to be used in the construction of the chart, and the presentation of this data in the form of a manuscript. This is done by means of a process of selection and generalization and the preparation of additional non-manuscript data as required.

The purpose of the 'interactive compilation' project is to produce a nautical chart from digital field sheets and to explore the possibilities of compiling data on a colour graphics terminal, paying close attention to the efficiency of such a method of chart production.

SELECTION OF A DATA SET

For several reasons, Chart 2011 was selected as the test bed for the first interactive compilation research project:

1. The chart size, A2, meant that the file would be easier to work with on the graphics terminals due to its small size,

2. The source set consisted of a relatively small and manageable data set of two field sheets,

3. The surveys were of a recent vintage (1984-1985), hence the data was contemporary,

4. In addition to the results generated by interactive compilation research, a new chart could be published upon completion of the project.

The chart was compiled both manually and interactively. This, it was felt, would be the better way to identify gains and losses of the interactive method. The cartographers recorded times required for each process. Although not recorded, there were many discussions pertaining to more intangible things such as the use of colour and changes in stress arising from spending more time at a workstation rather than huddled over a drafting table.

Overall, the interactive method took approximately 20 per cent more time

than the traditional method. Further enhancements of software, recommended as a result of this research, should be beneficial to the chart production process. More importantly, it must be stressed that interactive compilation is in the embryonic stage. To make firm comparisons to well established traditional methods would be iniquitous.

SOURCE DATA PREPARATION

The original digital field sheets contained soundings, notes, a title, and graticules. Although the CHS has been collecting data digitally for many years, the policies and infrastructures to support digital survey files rather than graphic field sheets are just beginning to be put into place. What was considered to be a complete digital data set was not available for this project. In order to mimic a hard copy field sheet, additional data normally shown on a hard copy field sheet were added to the digital file, i.e.:

1. Bottom samples
2. Rocks
3. Dangers
4. Pipelines
5. Shoreline
6. Topographical details.

All the non-digital information was digitized at field sheet scale, regardless of whether or not it would be used at chart scale. It is anticipated that, in the near future, digital field sheets will contain all this data. The digitizing and editing time of this process totalled 38 hours.

A base plot, with control points, was mathematically calculated and generated using in-house software and plotters. The conversion values for the North American Datum (NAD) 27 to NAD 83 shift were obtained from the CHS Nautical Geodesy Section. The appropriate corrections were applied to the data, using existing software. The border frame of a chart printed on A2 paper requires an extended frame to include the title, location diagram, hydrograph[*], sailing directions and oblique photograph. To accommodate this aspect, the file was edited interactively using the CARED[**] graphics editor.

The manual compilation required the preparation of a manual mosaic of the field data. Hard copies of the digital field data were photomechanically reduced to chart scale and pasted on a plot of the projection, which was generated on a Kongsberg optical plotter. These hard copies were not generated from the original survey tapes but were obtained from the Data Centre in the Central Region Office of the CHS since they were easily available and had been checked. Plans and additional information from other sources were evaluated and did not require

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(*) Hydrograph is a term used for a graphical description of temporal variations in the water level. Used particularly on charts of the Great Lakes where there is a seasonal and annual variation.

(**) CARED refers to the interactive editing module from the primary graphics component of the CARIS system. It is an acronym for 'Computer Assisted Resources Editor'.

any chart action mainly because of the recent surveys. The time (1 day) and cost (laboratory work) spent to prepare the manual mosaic was not included in the interactive process.

COLOUR BANDING

Data selection and contouring was simplified using a technique called 'colour banding' to display the soundings. This means that different colours were used to draw soundings. The colour assigned to any given sounding was based on its depth. The resulting image appears as bands of colours. Colour banded depth ranges with contrasting colours quickly draw the attention of the cartographer to areas of critical importance. Critical areas often appear as a mix of several colours, indicating very rugged undersea topography. Less critical areas appear very 'even' since they are displayed in a single colour, with an easily identifiable isoline delineating the boundary of the next colour.

A simple example of colour banding used:

1. 0.1 metres to 2.0 metres, red,
2. 2.1 metres to 5.0 metres, yellow,
3. 5.1 metres and deeper in green.

This technique allows the general shape of the bottom to be readily visualized. The depth ranges reflect the chart specifications, and colours selected for compilation are selected at the discretion of the cartographer.

Colour banding is supported in several plotting packages used in the CHS. The implementation of a Versatec electrostatic plotter allowed an extension of the colour banding concept: for each sounding range, the plot program allows the user to specify one of three geometric shapes, a circle, a square, or a triangle, as well as the size and colour of each shape. Using the appropriate combination of colour, shape, and size, this technique resulted in almost continuous colouration of the digital plots. Certain colours, when used for adjacent ranges, tended to create a distinct third colour along the boundary of the two ranges, immediately identifying the location of the contour. This permits the cartographer to thoroughly assess the data set in less time, and to make areas of critical importance more readily apparent.

CONTOURING

Bathymetric contours were drawn directly on the graphics terminal. Although many automatic contouring programs are available, none solve the unique charting problem of generating 'safe' contours. For this reason, the approach taken was to use colour to qualify the data and highlight critical areas. The final interpretation of the data was still left to the cartographer.

A primary advantage of the Tektronix colour graphics terminal is the local

memory. This 'intelligent' terminal permits rapid panning and zooming through the data, allowing the operator to move around quickly in the file. The relatively small size of the local memory in this particular terminal became a problem early in the project; the usefulness of the local memory was limited because not enough data could be stored at one time. By upgrading the memory in this terminal to 2.5 megabytes, the data of the entire field sheet could be drawn on the screen and stored in the local memory.

The best results were obtained by initially drawing the field data at chart scale and subsequently using the local pan, zoom, and view functions to display the information at a magnification best suited to the task at hand. The zoom function allows the user to enlarge an area in order to display the data on the screen and make them legible. The combination of legible soundings and colour banding allowed the cartographer to enter contours in a precise and efficient way. Isolated shoals were easily identified, which allowed the cartographer to select the information so critical to mariners. It was, however, important to keep in mind the reduction factor between the survey scale and the chart scale.

The lack of experience in on-screen contouring resulted in a great deal of additional editing, the most noted problem being the roughness of the generated contours. This was due to working at a high magnification and then reviewing at chart scale, in this case a 6 times reduction: the contours were jagged and required smoothing.

SOUNDING SELECTION

As mentioned previously, the sounding selection was done manually and interactively for time comparison. The manual sounding selection was compiled through traditional methods comprising the assembly of a mosaic after photomechanical reductions of the field sheets. Both sounding selection and bathymetric contour development were done on a scribe coat portraying the data of the field sheets at chart scale. The generalization of the depth contours was done at the same time as the contouring. This procedure proved to be an advantage over the interactive method mainly because of the additional editing required during the interactive compilation to smooth the original contours.

Once the sounding selection was verified, corrections were done on the scribe coat. The source data was in digital form, therefore the information selected on the compilation document could be identified in the digital file. The original intent was to register the scribe coat on a digitizing table and simply point to the desired soundings. However, the density of the sounding data after photomechanical reduction of the original data to chart scale made it difficult to point at a sounding with the digitizing cursor and be guaranteed that the same sounding would be selected.

The density of sounding data is increasing as survey systems become more sophisticated and digital storage media become cheaper. In order to cope with the huge volumes of sounding data, research into the relevance of 'sounding overplot removal' software for use in chart production has been initiated.

Sounding selection was completed on the graphics terminal without reference to hard copy field sheets. To assist the cartographer in the selection process, the depth data was colour banded according to the contour interval to be shown on the chart. Initially, the size of the displayed soundings was problematic. The program used to change the scale of a digital file did not, unlike a photo-mechanical process, change the size of soundings; when the field sheet was reduced to chart scale, overplotting made the soundings difficult to read, and made it difficult for the cartographer to judge the appropriateness of the spacing. This problem could be avoided with an overplot removal routine. In the production of Chart 2011, it did not represent much of a problem because of the limited number (2) of field sheets used. On a chart consisting of a large number of field sheets (10-15), at a variety of different scales, the situation could be quite unmanageable. Also, this problem has been addressed through the modification of all drawing software in the CARIS system to allow the user to adjust the size of soundings dynamically.

The lack of experience in selecting data on the screen was also a performance factor. The selection of the data was first done on the larger scale field sheet and then at the next largest scale field sheet. Another drawback of the interactive compilation method lies in the size of the graphics screen. The screen is limited to 30 by 37 centimetres in dimensions and does not allow the user to visualize a chart in its entirety at chart scale. The cartographer cannot properly evaluate the information until the file is plotted. In both methods of compiling, the digital information can easily be revised for datum adjustments and conversions from imperial units to metric units, which has proven to be an asset.

The mosaicing of digital field data (amending the scale, projection, etc.) is easily performed via the MOSAIC program. (MOSAIC is a general purpose program used for changing file parameters such as scale, projection, geographic window, concatenating files together based on geographic values, etc.).

Although not originally specified as an objective of the interactive compilation project, all text, including notes, sailing directions, names and titles to be shown on the chart, were added on the digital chart file. The first attempt at entering text was done as a batch process. A command file was created which would run the graphics package in batch and enter text strings at specified x and y positions in the file. This method required a great deal of calculation to position text from a known point and required further interactive editing to adjust the text for right and left justification. Advantages of preparing the title, notes and other textual information in a batch process lies in the fact that the colour graphics terminal may be used by other cartographers at the same time and typographical errors may be corrected by editing the command file and re-submitting it to the batch processor.

The additional editing required on text which has been digitized by a batch process has proven to be as lengthy as entering the data directly on a graphics terminal. This has clearly shown the need for better typesetting capabilities, so critical in the cartographic world. Recommendations arising from this research project were instrumental in providing the catalyst to greatly enhance the text processing capabilities of the CARED interactive graphics editor.

CHART COMPONENTS

Adding standard chart notes (i.e. submarine cables, radar reflectors, etc.) to a digital chart file requires substantial effort over the manual technique because the cartographer is required to type, position, and justify the text. Similar logic applies to diagrams such as the conversion table and hydrograph. Master copies of these were created and made available to all users.

Software generated borders have resulted in significant reductions in time over the days when cartographers had to calculate and draw projections by hand. This procedure could be extended further by automatically generating common chart information. This includes logos, the wordmark[*], copyright note, chart numbers, publication note and so forth. In an attempt to produce a chart by completely digital means, digital renditions of several of these features were generated.

VALIDATION

The most serious problem anticipated in interactive compilation is the checking of the information. Cartographers do not work with hard copy documents. Although the cartographers could easily supply the quality control officers with a plot of the final compilation (which in fact is already at the drafting stage), the checkers would not be supplied with a hard copy mosaic or reduction of the field sheets. Photomechanical reductions or copies of the overplot removal files would be required for checking purposes. Today, field data is being collected in astronomical numbers with the acoustic sweep surveys. To process all this data, hydrographers must use overplot removal routines to reduce the amount of data to be portrayed, and remain legible, on a hard copy at field sheet scale. Cartographers need a similar method to display the data at chart scale from digital field data. The second phase of interactive compilation research involved producing Chart 2048 (Port Credit Harbour), including preliminary testing and evaluation of an overplot removal package. The objective was to achieve a sounding selection by running the file through the software package with different variables. The resultant file was submitted to Quality Control for checking.

CHANGING TECHNOLOGY

With the implementation of an electrostatic plotter, the impact on chart production methodologies is again under scrutiny. When used in conjunction with software for converting normal line and point data to topological data, this plotter

(*) Wordmark is a Canadian term used to describe a symbol that incorporates part of the Canadian flag and the name of the Government Department.

allows files to be drawn with colour filled areas. Even when plotting only linework, the plotter gives the user the capability of generating colour plots in a matter of minutes, rather than pen or film plots in hours.

In present day chart production, a digital file must be split according to final colour before generating final negatives. Peel coats must also be generated and manually peeled. Electrostatic technology is being evaluated as an alternative to this process since plots can be generated, not only on paper, but also on positive and negative film. While creating colour filled areas for a digital chart file, the cartographer is actually preparing colour separation files. At the present time, quality of the negative film plots from the electrostatic plotter does not meet with standards for printing or reproduction quality. If a quality negative film was available for reproduction work (contact), cartographers could generate negatives from the electrostatic plotter by building the required topology for a specific file. Contemporary topological software allows relatively easy conversion of data from so-called 'spaghetti' linework into structure data. The production of tint negatives on the electrostatic plotter would eliminate the need to produce peel coats. Cartographers could also verify the tinting of the chart directly on the screen as well as on a plotted paper copy. The future looks promising, but further testing is still required to fully evaluate time and quality factors.

OVERPLOT REMOVAL ROUTINE

Overplot removal software was used on the second chart that was compiled interactively. This was the Port Credit Harbour chart, which consisted of three non-digital field sheets of recent vintage and no additional hydrographic data. The digitizing and editing of the three field sheets took an average of 40 hours per field sheet. The checking of the field sheet data, after digitizing, totalled some 20 hours per field sheet. Each field sheet was reduced to chart scale (1:5,000) through the MOSAIC program prior to running overplot removal. Concatenation of all digital field data was done after a preliminary overplot removal run in order to reduce the size of the digital file.

There are several command qualifiers available to the user for controlling the behaviour of the overplot removal algorithm. The Port Credit chart underwent more than one iteration of this process simply to find out how the program responded to a variety of parameters.

The first attempt dealt with the size qualified. Using this qualifier, the cartographer decides on the variables to obtain a spacing between soundings by specifying the size of an imaginary box or circle to be drawn around soundings. This variable is referred to as the 'constant term' and is entered as a size in millimetres. A size of 5 mm was selected since that would be large enough to include any double digit sounding.

The package also allows the user to specify a 'linear term' to force an increase in the spacing between soundings as depth increases. The spacing of the soundings is based on the following calculations:

spacing = (depth × linear term) + constant term.

After looking at different sounding selections, a linear term of 1 mm was found to produce the best results. Therefore, the spacing between soundings of 1 metre would be 5 mm (i.e. (1 × 1) + 5 = 5). The spacing between soundings of 10 metres would be 15 mm.

From the results of this run, it was found that overplot removal is not only useful for reducing the number of soundings in the field data set to a readable level at chart scale, but is also a mechanism of automatic sounding selection. The overplot removal package generated a selection that closely resembled a manual sounding selection. Two major points were noted:

1. In areas along complex shoreline such as wharves or narrow passages, the overplot removal routine did not recognize the line data and eliminated too many soundings. Cartographers would normally indicate depths along all faces of wharves for the security of the mariner, but the overplot removal routine produced only one sounding, if any, depending on the surrounding depths and the values of the variables within the size qualifier.

2. In open flat areas, the soundings selection was quite acceptable. The output selection of data is evenly spaced for soundings of the same value and gradually increases as the depths increase.

Isolated shoals near contours of the same value are not necessarily selected, especially if the value is equal to the contour value. Although most of the isolated contour lines on field sheet 8222 would be joined to the main contour after generalization at chart scale, the cartographers' attention was retained by two areas, circled and numbered 1 and 2 on Appendix A. In the first situation, a sounding with a 4.5 metre value was left out; in the second situation, a 5 metre value sounding was suppressed. In both examples, the increasing size of the box around the soundings is probably the cause of the suppression of the sounding value.

The second attempt at overplot removal was done using the table qualifier. A table was created by specifying the different sizes of the boxes to be drawn around the soundings and increasing the size as the value of the soundings increased. The results were disappointing; the selected data are shown in Appendix B. The most interesting aspect lies in the area circled No. 1 where the 4.5 metre sounding that was left out on the previous run had now been selected and a 4.8 metre sounding, circled No. 2, was now suppressed when it had been retained previously. In the flat or regular bottom area, the sounding selection was sparser and is considered visually acceptable.

Since the attempts at generating automatic sounding selections from the original field data set were not acceptable, the approach was modified. The results of the first two runs did not allow the cartographer to revise the selection easily by displaying the suppressed soundings plotted one on top of the other and selecting new data; a preliminary overplot removal pass was made, to obtain as many soundings as possible without overplots at chart scale. The spacing between soundings increased with the depth as specified in the table qualifier. Although no soundings were overplotted, there is room to have more soundings available to the cartographer for selection purposes.

In the next attempt, the size qualifier was used to define only the size of the box around the soundings. Once again, it was noticed that in some areas additional data could have been shown. Using the default value for the size qualifier resulted in some soundings being overplotted. Although suitable for selection purposes, the values of the soundings in some areas were quite ambiguous.

Following the previous runs, it was concluded that the ideal overplot removal should have a size value equal to 2.25 mm to display as many soundings as possible without having any overplots that may display some confusing information on the screen. The three field sheets required to produce Chart 2048 were then processed through the MOSAIC program to bring all data to chart scale, and then overplot removed with a size qualifier of 2.25 mm, for the preliminary sounding overplot run. The resulting three files were then concatenated.

Finally, to prepare a sounding selection on Chart 2048, overplot removal was run using the size qualifier and specifying a linear term of one and a constant term of seven. The intent was to use as many soundings as possible for the final sounding selection that would be retained from the overplot removal run and modify the selection where deemed necessary. As expected, the selection near the shoreline and wharves required some modifications but, moving into deeper water, the generated selection was retained. Appendix C is a copy of the final sounding selection submitted to the Quality Control officer for checking.

The time spent on sounding selection for Chart 2048 totalled 8 hours, including the processing and additional editing to include soundings in critical areas such as along wharf faces. This is in comparison to 12 hours spent on Chart 2011, both digitally and manually. In neither case was the ability to adjust the drawing size of soundings used.

Overplot removal should be used to reduce the amount of soundings required to do a sounding selection from an original data set. The cartographer then has the option of re-submitting the output file to a second overplot removal run, keeping in mind that the output selection will require some changes in areas close to shore or proceed with a selection from the first overplot removal run by pointing at the soundings to be retained for selection purposes. An early estimate of time savings when using overplot removal is in the order of 15 to 25 per cent of a manual selection, including the transfer of the selected information to the digital chart file. These savings should increase as cartographers become better acquainted with the output of the software package and as more system experience is acquired. The program cannot output a satisfactory final sounding selection, but is a valuable tool for thinning out source data.

CONCLUSION

Research to date has shown that interactive compilation is a viable approach to cartographic production.
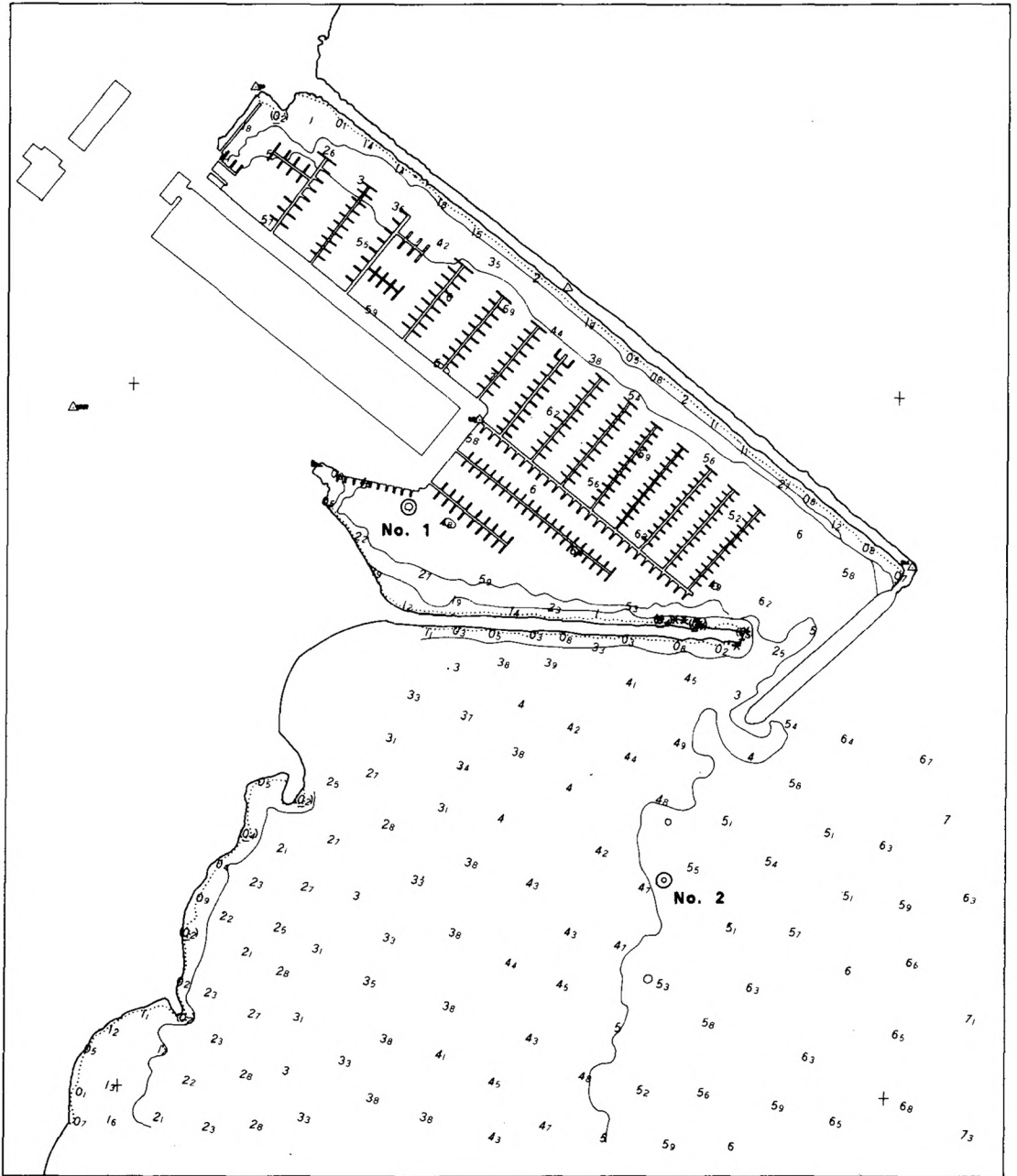
This is made possible, to a large degree, by contemporary hardware, such as workstations oriented around high performance colour graphics terminals and plotters. At the same time, this research has proven that developments in software are keeping pace with the ever-increasing amount of field data being captured. Sounding overplot removal provides for rapid evaluation and reduction of large data sets. Colour banding and adjustable-size soundings provide the cartographer with the ability to more quickly interpret the data set, both as area information and as a basis for interactive contouring, sounding selection, and line generalization.

When these techniques are coupled with software which performs geographic transformations such as scale and projection changes, concatenation and windowing, the potential of interactive compilation emerges. Additionally, when reproduction quality film is available, electrostatic plotting technology should allow the use of structured data (i.e. areas) as a mechanism for creating colour files. This will completely eliminate the need for manual peeling. The interactive compilation process can be made more complete by improved text management techniques, and by creating stronger links to nomenclature and navigation aids databases.
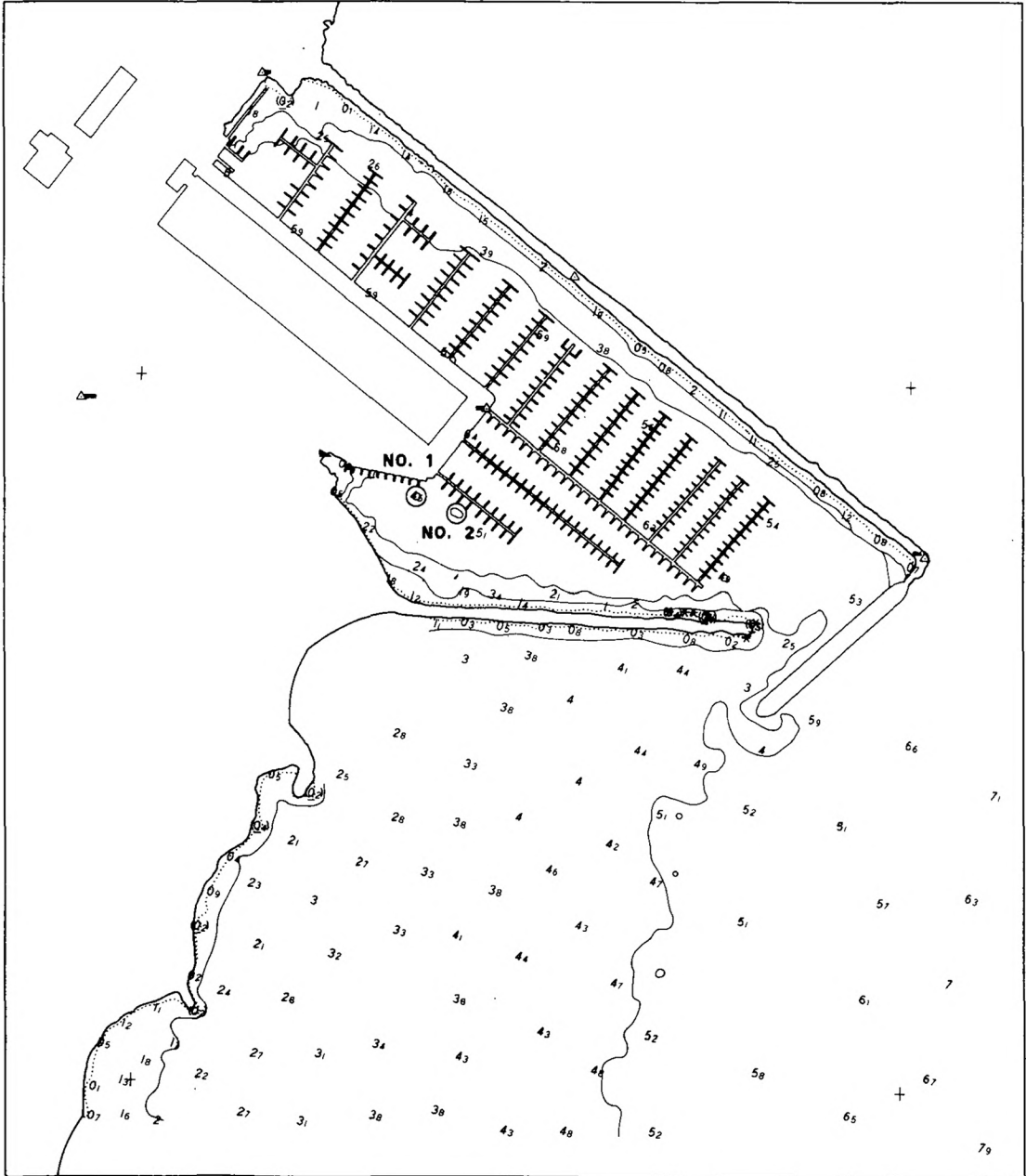
Finally, the digital field sheet must contain, as a minimum, the same information currently supplied by hydrographers on hardcopy field documents.

(See Appendices A, B and C on the following pages)

APPENDIX A

APPENDIX B

APPENDIX C