" HYPOS "
A SYSTEM FOR PROCESSING HYDROGRAPHIC SURVEY DATA

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ABSTRACT

The Canadian Hydrographic Service finds that modern technology is permitting data to be collected at a faster rate than it can be processed using present methods. In an attempt to overcome this problem, a system call " Hypos " (Hydrographic Position) has been developed. It is hoped that this system will result in a smooth flow of information. " Hypos " is a set of programs that are used to control xy digitizers, digital computers and automatic plotters.

INTRODUCTION

Three years ago, in an endeavour to speed up the introduction of modern technology, the Canadian Hydrographic Service set up several small technical development groups. The authors of this article formed one of these groups. They were given the task of developing a method to process hydrographic data immediately after collection and before it is passed to the cartographers.

One of the first stages of the development involved a study of the methods used by other organizations. Techniques that are used in other countries have been incorporated in the " Hypos " system and the authors are indebted to those who have given them assistance. In particular, they wish to mention the Swedish Hydrographic Office.

At the present time, the methods used to process data in the Canadian Hydrographic Service are mainly manual. For example, depths are read from the echo sounder graphs by means of a plastic scale and positions are generally interpolated on a lattice of plotted position lines. The " Hypos " system resorts mainly to numerical methods that result in the computation of a set of x, y, z co-ordinates that can be plotted automatically.

An initial consideration in the system design was whether the processing equipment should be on board the collecting vessel or located at some central point ashore. The matter is mainly one of economics and it was decided by the writers that in the prototype system the equipment should be located ashore and that data be transmitted to and from the survey location. It should also be remarked that as more data are collected by launch than by ship in this organization it was decided to place the emphasis on the processing of data collected by survey launch. A final, but most important point, is that the hydrographer in the field needs to know how his survey is progressing in a very short period of time. Accordingly, one of the objectives of the system is that the time between collection of the raw data and receipt of the processed data in an understandable and useful form must not exceed one week.

HORIZONTAL POSITION DATA

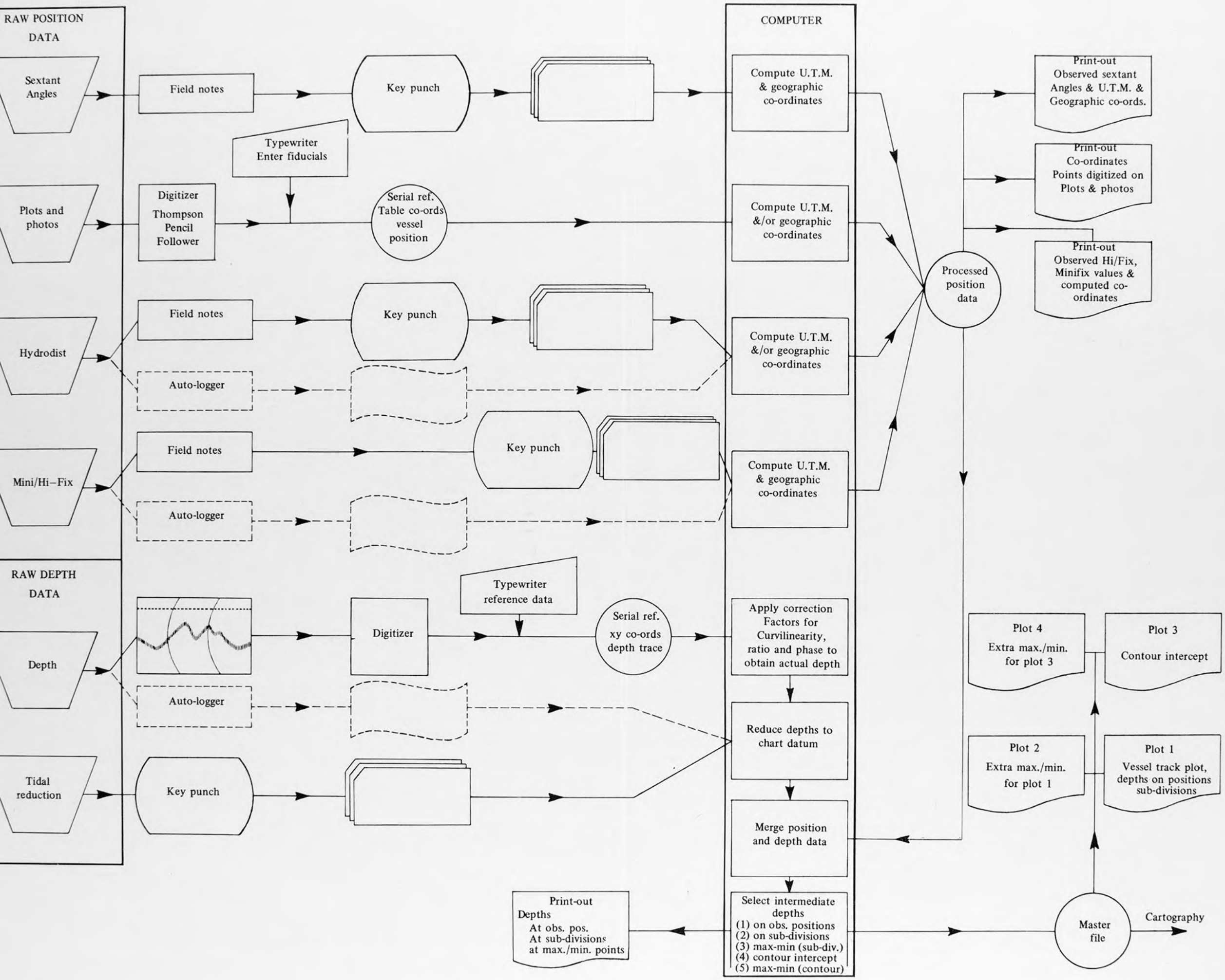
As it can be seen in figure 1, four types of navigational information have been considered. These are : horizontal sextant angles, identification on photographs (see figure 2), Hydrodist and Hi-Fix (Mini-Fix). The objective is to translate each of these inputs into a common form, namely a set of Universal Transverse Mercator co-ordinates referenced by serial numbers. To achieve this objective each input must be presented to the computer in a digestible form. At the present time, the data from all except the photographs are recorded on specially designed forms and are then key-punched on to cards. It is expected that the next step will be the introduction of automatic logging systems and the manual recording and key punching will be by-passed. In the case of the aerial photographs, an xy digitizer, which will be described later, is used to obtain co-ordinates of the vessels' position and co-ordinates of reference marks on the photographs. These points are automatically recorded on magnetic tape.

Once the data are on punched cards or tape a digital computer (CDC 3100 or IBM 360/) is used to compute the rectangular U.T.M. co-ordinates. The co-ordinates with serial reference numbers are then stored on magnetic tape for further processing. At this stage line-printer listings are also produced for reference and quality control purposes (see figure 8). Conversion to geographic co-ordinates is also available on demand.

DEPTH DATA

Before describing the method of processing the depth data it may be useful to describe the versatile Thompson Pencil Follower that is used for several operations in the " Hypos " system (see figure 3). The instrument consists of a flat table (100 cm $\times$ 50 cm), a plastic cursor connected by

HYPOS



RAW POSITION DATA
Sextant Angles
Field notes
Key punch
Typewriter Enter fiducials
Plots and photos
Digitizer Thompson Pencil Follower
Serial ref. Table co-ords vessel position
Hydrodist
Field notes
Key punch
Auto-logger
Mini/Hi–Fix
Field notes
Key punch
Auto-logger
RAW DEPTH DATA
Depth
Digitizer
Typewriter reference data
Serial ref. xy co-ords depth trace
Auto-logger
Tidal reduction
Key punch
COMPUTER
Compute U.T.M. & geographic co-ordinates
Compute U.T.M. &/or geographic co-ordinates
Compute U.T.M. &/or geographic co-ordinates
Compute U.T.M. & geographic co-ordinates
Apply correction Factors for Curvilinearity, ratio and phase to obtain actual depth
Reduce depths to chart datum
Merge position and depth data
Select intermediate depths (1) on obs. positions (2) on sub-divisions (3) max-min (sub-div.) (4) contour intercept (5) max-min (contour)
Processed position data
Print-out Observed sextant Angles & U.T.M. & Geographic co-ords.
Print-out Co-ordinates Points digitized on Plots & photos
Print-out Observed Hi/Fix, Minifix values & computed co-ordinates
Plot 4 Extra max./min. for plot 3
Plot 3 Contour intercept
Plot 2 Extra max./min. for plot 1
Plot 1 Vessel track plot, depths on positions sub-divisions
Print-out Depths At obs. pos. At sub-divisions at max./min. points
Master file
Cartography

Fig. 1.

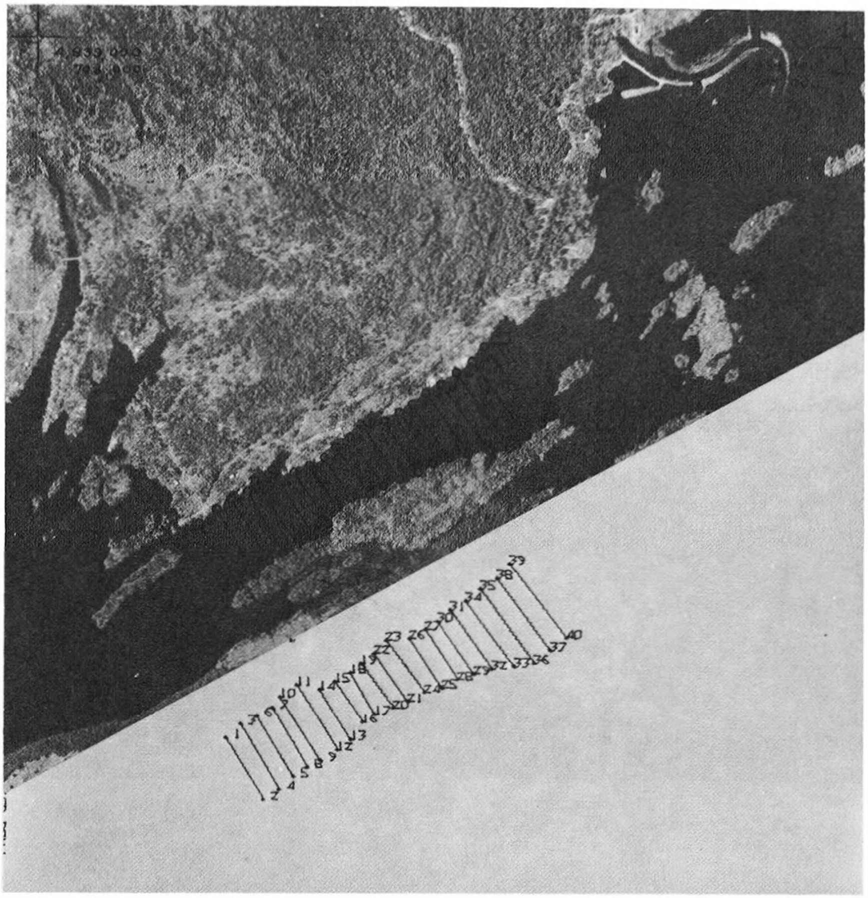


FIG. 2. — Typical aerial photograph with plot offset for comparison.

wires passing around pulleys to two encoders, a box of electronics, a magnetic tape recorder and an electric typewriter. A unique method of electromagnetic coupling enables the operator to have a completely " free floating " cursor. Positions can be digitized in increments of 0.1 mm on both the x and y axis. Recording can be on operator demand, on a time demand or when passing discrete increments on the x axis. The typewriter is used to place reference information in coded form on the output tape.

In designing the " Hypos " system it was decided that initially automatic digital echo sounders would not be included. At the present stage of their development their high cost and unproven reliability limits their use. It is therefore expected to be several years before existing graphical recording sounders will be phased out. As a result it is proposed to process the echo sounder strip charts using the Thompson Pencil Follower. The method is as follows: (see figures 1 and 4). The operator starts by typing in reference data, such as vessel number, date and location. The next step is to digitize the intersection of the zero depth line with the position reference marks. The machine is then switched into either the time demand or the x increment mode and the seabed, as shown on the strip chart, is carefully followed. One sounding line at a time is followed in this manner. The result of these operations is to define the seabed by a set of very closely spaced xy coordinates that is in fact rather similar to the output of a fully digitized echo

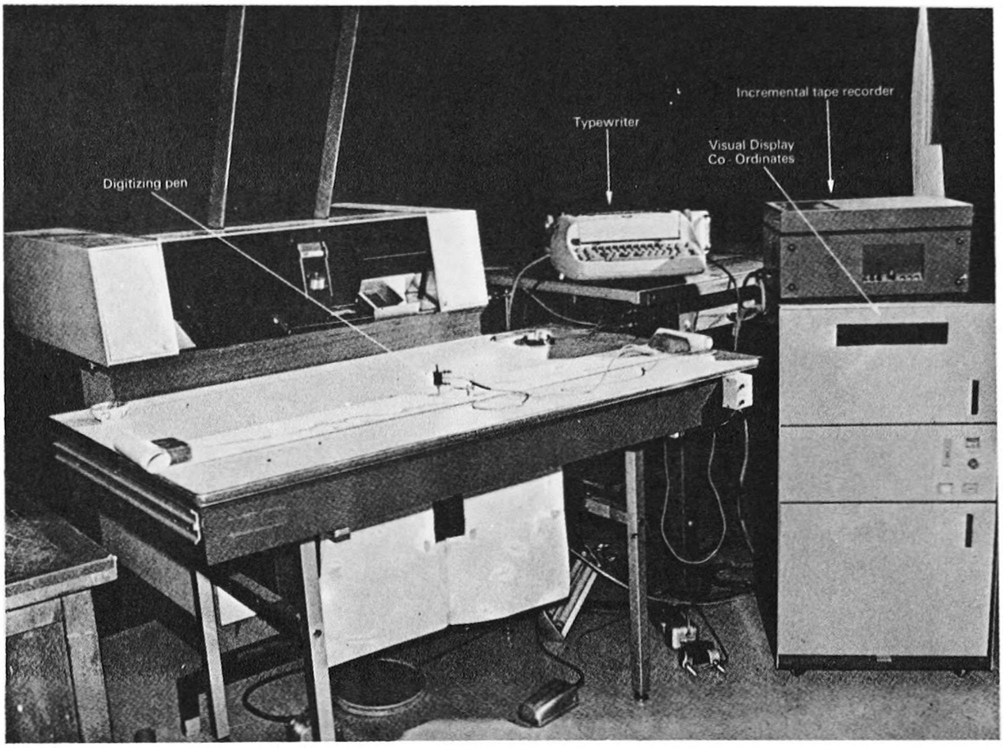


FIG. 3. — Thompson Pencil Follower.

sounder. However, in this system there is the advantage that the operators can analyse the sea bottom themselves and that one operator appears capable of processing as many as ten vessel/day records a day.

The depth data that are now on magnetic tape must undergo a number of operations by the computer. The first of these is to translate the co-ordinates obtained by the digitizer into actual depth units. As the Canadian Hydrographic Service uses a variety of echo sounders, some of which have curvilinear and others rectilinear graphs and all have different sized depth units and phases, it is necessary to compute the depths in feet, fathoms (or metres).

TIDAL AND VELOCITY CORRECTIONS

All depths must be reduced to chart datum and in the cases where fixed speed echo sounders are being used, corrections must be applied for the signal propagation. At this time the tidal corrections are handled quite simply. The reductions are referenced directly to the position serial numbers

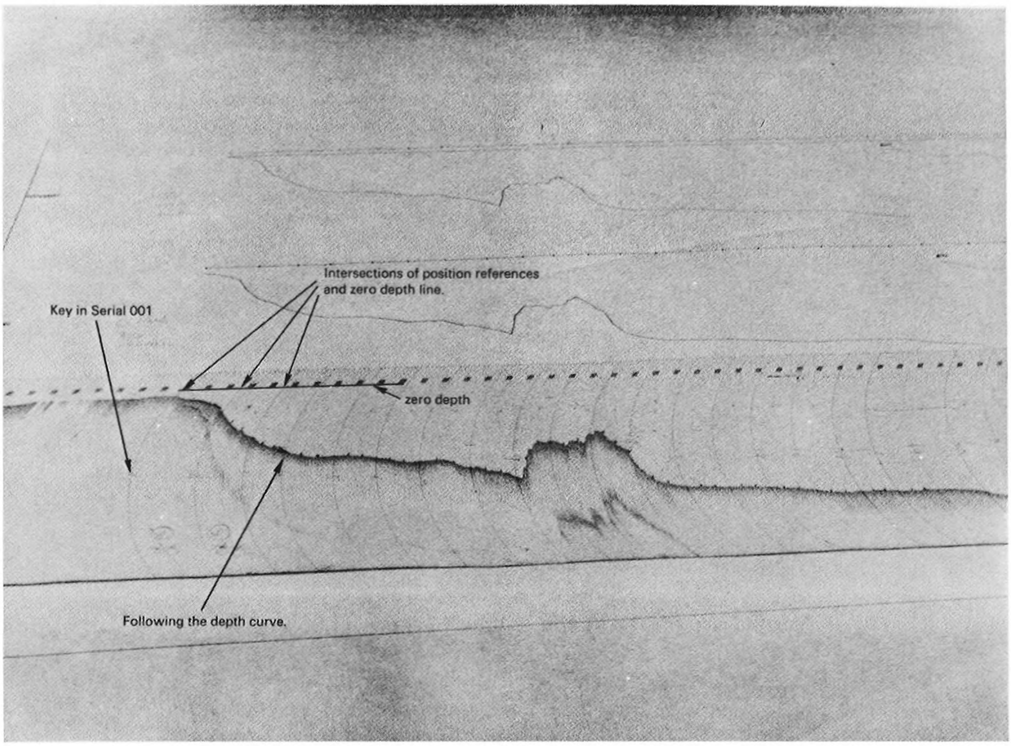


FIG. 4. — Sounding roll digitization.
The two upper fine line curves are " replays " of the digitized values on a Calcomp plotter for quality control checking.

and are key punched on cards that are read by the computer and applied in the program. A more sophisticated method is under development that will use co-tidal information and a time reference. No programming has yet been done for applying propagation corrections as the emphasis has been on variable speed echo sounders used in shallow water.

MERGING POSITION AND DEPTH DATA

Two types of data are now available. These are the navigational positions and the depths reduced to chart datum. Both forms of data have a common serial reference (see figure 5). These two streams of data are then fed into the computer and result in one channel which consists of a large serial set of depths referenced at intervals to a geographical position in the form of UTM co-ordinates.

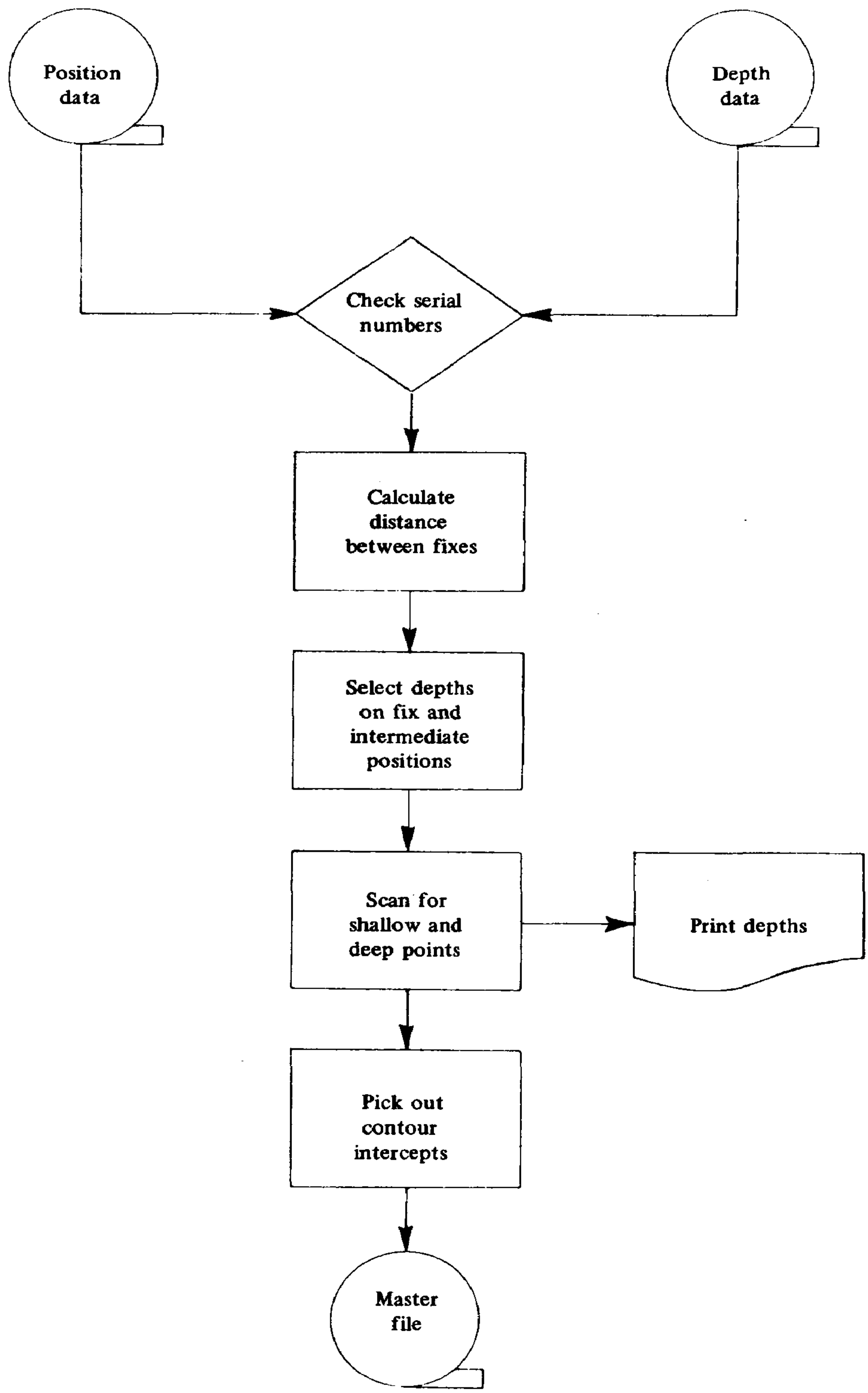
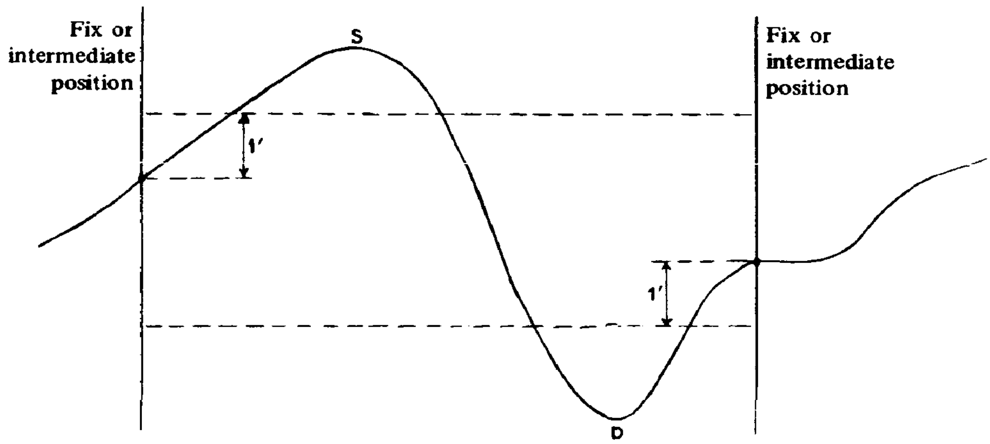
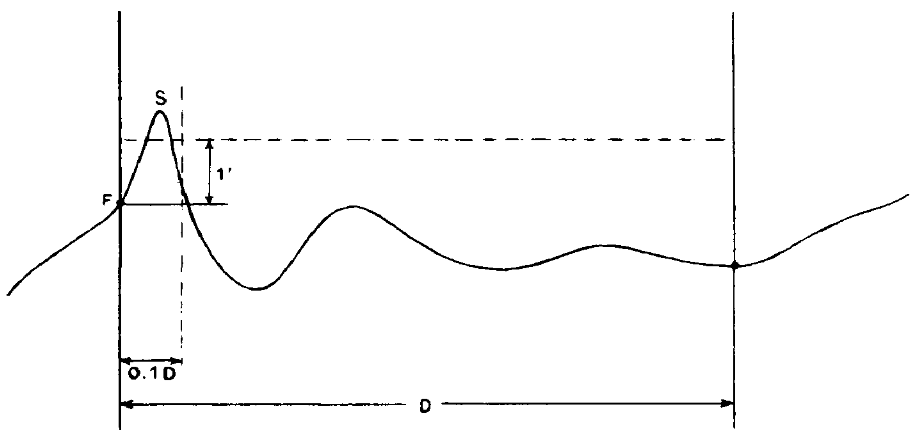


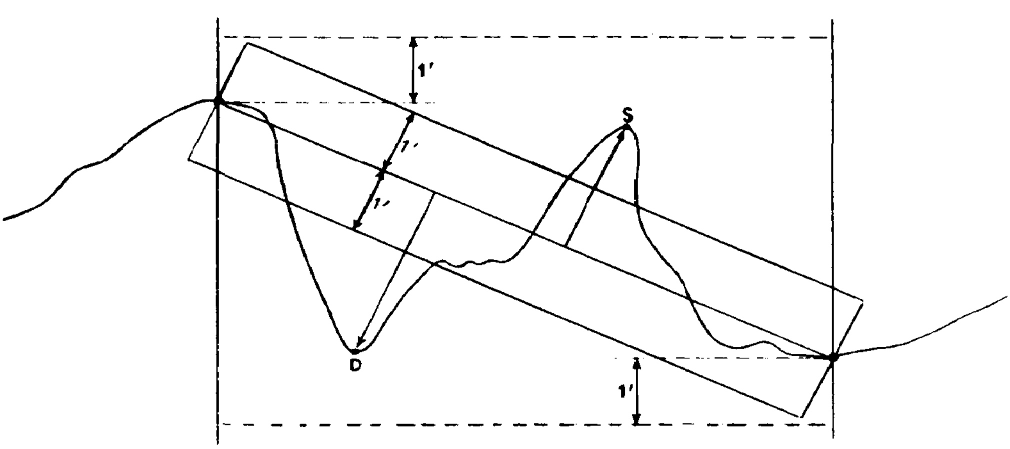
FIG. 5. — Simplified flow diagram of merge process.



(A) Search for major shallow or deep points.



(B) Situation where depth on fix would be replaced by depth of shallow point.



(C) Where there are no major shallow or deep points a search is made for minor shallow or deep points.

FIG. 6. — Depth selection.

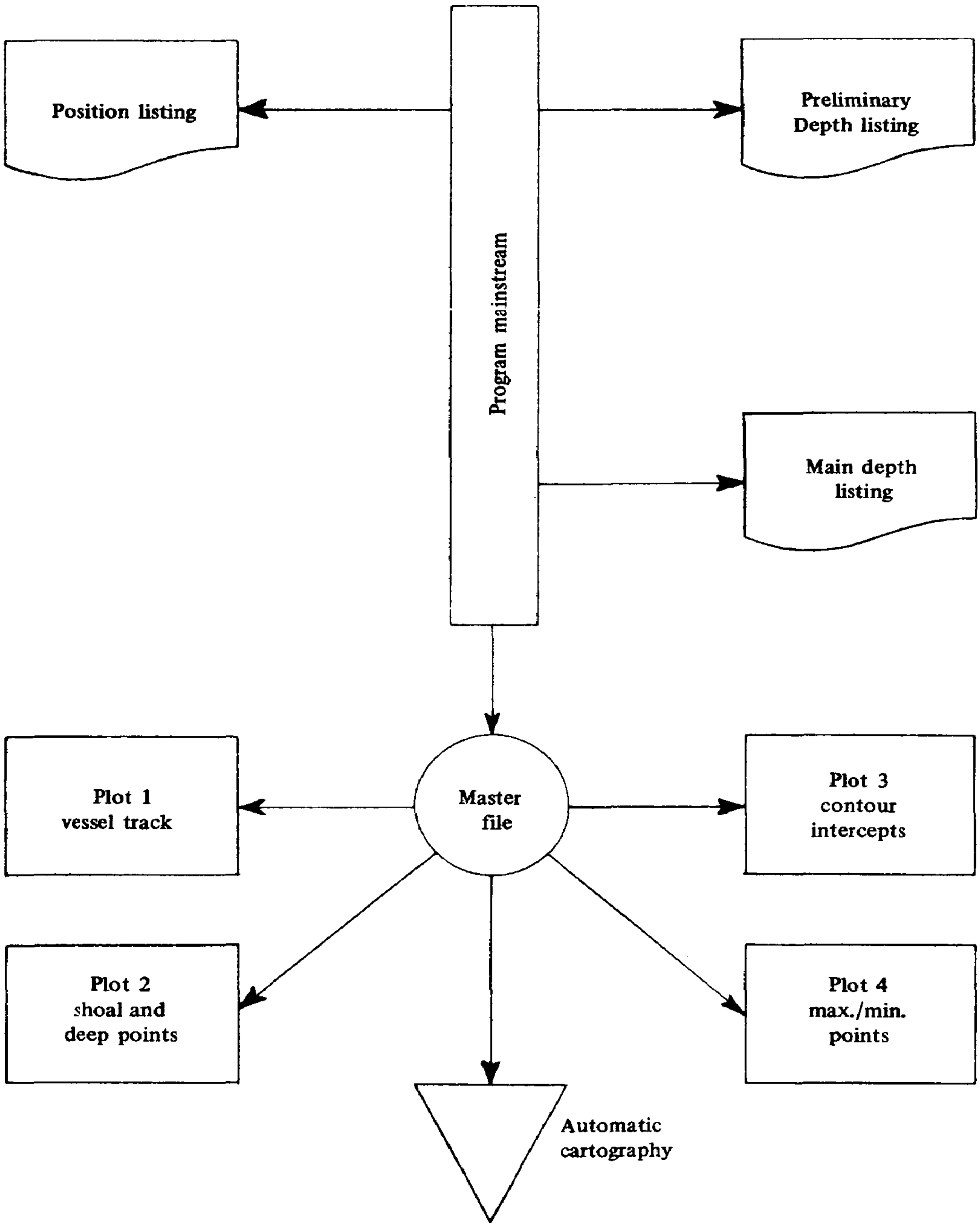


FIG. 7. — Types of output information.

SELECTION OF DEPTHS

The method of digitization of echo soundings provides a large number of depths that must be refined into usable information. At present, the accepted method in the Canadian Hydrographic Service is to show soundings on the Field or Smooth Sheet approximately 0.2 inches (5 mm) apart. These are supplemented by significant shallow and deep depths between the regular grid. The " Hypos " system tries to fulfill this requirement and in addition selects depths at points where the vessel track passed pre-selected depth contours (see figure 5).

The method of selecting the regularly spaced depths is as follows. Using the position information, the distance between two known points at the desired plot scale is computed. These distances divided by the sounding interval (usually 0.2 inch) determine the number of intermediate points required. The location of these intermediate depth points can then be interpolated between known positions using the x values which have been obtained previously on the Pencil Follower.

In order to determine the logic for locating shallow and deep depth points the methods used by skilled hydrographers were studied carefully. This logic is shown diagrammatically in figure 6. In actual practice it has been found that this logic is more demanding than that used by a hydrographer and results in a greater number of points. As in the case of the regularly spaced depths, the positions of the shallow and deep points are interpolated linearly between the points of known position.

Finally, the contour intercepts are located by feeding the desired depth contours into the computer program and then scanning each available depths in turn. As each one is located it can be assigned a geographic position in a similar manner to the two previous types of selection.

The result of these various selections is a master file (see figure 7) which contains positions and depths of all the selected points.

PLOTS AND OTHER OUTPUTS

The most useful form in which data can be displayed to the hydrographer is a two dimensional plot. From the advent of hydrography up to the present day the results of a survey have been shown on a carefully drawn plot. This plot is used by the hydrographer in the field to assess his progress and by the cartographer in the office to compile into the nautical chart. It appears that although the latter process may change, no substitute for the former exists at present. Therefore, the writers consider the production of plots an essential part of the system. A deviation from previous methods has been made in the number of plots made and the fact that the data in a

FIX CO-ORDINATES FROM SEXTANT ANGLE CONVERSION PAGE 12

ROLL	SERIAL	LEFT REF	DEG	MIN	MID REF	DEG	MIN	RIGHT REF	NORTHING	EASTING
80	122	1 BLLT	31	15	5 DEL	22	20	14 PRLT	4868668.426	280808.124
80	123	1 BLLT	36	20	5 DEL	23	34	14 PRLT	4869282.884	280826.300
80	124	1 BLLT	41	33	5 DEL	24	29	14 PRLT	4869760.960	280834.820
80	125	1 BLLT	48	12	5 DEL	25	10	14 PRLT	4870232.457	280822.366
80	126	1 BLLT	69	9	5 DEL	25	25	14 PRLT	4871142.994	280768.099
80	127	1 BLLT	63	50	5 DEL	25	32	14 PRLT	4870966.158	280781.487
80	128	1 BLLT	78	12	5 DEL	25	8	14 PRLT	4871390.447	280754.198
80	129	1 BLLT	95	58	5 DEL	24	20	14 PRLT	4871757.600	280740.445
					*****					
80	130	1 BLLT	110	6	5 DEL	22	25	14 PRLT	4871985.141	280647.425
80	131	1 BLLT	91	20	5 DEL	23	24	14 PRLT	4871688.302	280644.888
80	132	1 BLLT	75	59	5 DEL	24	0	14 PRLT	4871371.681	280643.350
80	133	1 BLLT	61	46	5 DEL	24	18	14 PRLT	4870955.928	280644.476
80	134	1 BLLT	53	12	5 DEL	24	10	14 PRLT	4870606.957	280636.638
80	135	1 BLLT	48	0	5 DEL	24	0	14 PRLT	4870327.989	280640.439
80	136	1 BLLT	42	50	5 DEL	23	38	14 PRLT	4869985.710	280639.459
80	137	1 BLLT	37	38	5 DEL	23	3	14 PRLT	4869540.706	280642.125
80	138	1 BLLT	34	33	5 DEL	22	32	14 PRLT	4869217.013	280637.102
80	139	1 BLLT	32	0	5 DEL	22	0	14 PRLT	4868903.225	280629.496
80	140	1 BLLT	29	30	5 DEL	21	23	14 PRLT	4868540.156	280622.878
80	141	1 BLLT	27	50	5 DEL	20	54	14 PRLT	4868264.639	280613.515
***** BAD GEOMETRY ON ABOVE FIX.RECOMPUTED VALUES ARE-									4868263.283	280618.883 ***
					*****					
80	142	1 BLLT	27	10	5 DEL	20	29	14 PRLT	4868229.173	280510.283
***** BAD GEOMETRY ON ABOVE FIX.RECOMPUTED VALUES ARE-									4868227.418	280515.842 ***
80	143	1 BLLT	29	8	5 DEL	20	58	14 PRLT	4868588.691	280495.454
80	144	1 BLLT	31	15	5 DEL	21	22	14 PRLT	4868931.604	280473.102
80	145	1 BLLT	33	34	5 DEL	21	44	14 PRLT	4869247.798	280460.944
80	146	1 BLLT	37	46	5 DEL	22	12	14 PRLT	4869714.604	280446.968
80	147	1 BLLT	43	12	5 DEL	22	24	14 PRLT	4870191.029	280417.861
80	148	1 BLLT	49	42	5 DEL	22	23	14 PRLT	4870605.804	280401.685
80	149	1 BLLT	60	6	5 DEL	22	3	14 PRLT	4871059.496	280392.755
80	150	1 BLLT	73	5	5 DEL	21	11	14 PRLT	4871440.161	280369.297
					*****					
80	151	1 BLLT	71	30	5 DEL	20	17	14 PRLT	4871467.496	280279.667
80	152	1 BLLT	60	17	5 DEL	20	57	14 PRLT	4871161.786	280279.785
80	153	1 BLLT	51	15	5 DEL	21	19	14 PRLT	4870808.510	280271.659
80	154	1 BLLT	45	8	5 DEL	21	22	14 PRLT	4870484.999	280256.178
80	155	1 BLLT	40	30	5 DEL	21	18	14 PRLT	4870160.771	280246.277
80	156	1 BLLT	37	6	5 DEL	21	10	14 PRLT	4869859.066	280243.129
80	157	1 BLLT	33	38	5 DEL	20	54	14 PRLT	4869480.437	280241.605
80	158	1 BLLT	32	0	5 DEL	20	45	14 PRLT	4869260.075	280251.022
					*****					

FIG. 8.

numerical form has been stored on magnetic tape for experiments in automated cartography and for posterity. In addition, various tabulations of the depth data are available as line-printer listings for quality control and reference purposes (see figures 8 and 9).

At this time all plots are produced on a drum type incremental plotter. The type available has a rather large (0.1 inch) step size and results in some work of a crude appearance. Consequently, these plots do not replace the smooth sheet but assist in its preparation. During the next year a new flatbed plotter with a smaller step size (.001 inch) will be available and will result in more accurate and more aesthetically appealing work. All plots are on the UTM projection and are superimposed with a 10 cm rectangular grid.

```
                                  D-MAC SOUNDING CONVERSION PROGRAM DRTM
ERIAL   80                 CARDINAL PRESQU,LLE SEPT 7, 1967
YPE SOUNDER 36A0       TIDAL REDUCTION=  -3 FT                                  PAGE    20
  FIX    SOUNDING
  NO.     ON FIX
                              69    73
  114     70    70    67    67    73    76
                   70

  115     78    81    81    83    84

                              79
  116     85    86    85    85

                   80
  117     79    79    83    80
                        83
             70
  118     74    69    69    67

             65               76
  119     65    69    71    74    78
                        75

  120     78
                                                 ************
                       TIDAL REDUCTION=  -3 FT
                              71 -
  121     M     67    67    71
                   68-,  71  *  77 -
                   73
  122     76    73    76    72    69    68    69
                              72    70
                        76
  123     70    74    75    80    85

  124     85    87    88    88    86
                              88
  125     86    85    84    81    81    81    78    78    78
                        84                81

  126     78    75

  127     74    72    70    70    69

                              57
  128     67    64    60    59
             67    63    60

  129     51
                                                 ************
```

Fig. 9.

This relatively small grid minimizes any plotting errors that develop during the drawing.

The first plot is a vessel track plot which shows the vessels' location at observed positions and shows the track between positions as a fine line. This plot is useful for sorting out erroneous position data and shows gaps in the sounding pattern. The next plot (see figure 10) is similar but in addition shows the location of regular intermediate depth points by short cross lines and draws the depths themselves at the observed positions. Supplementing this plot is a plot showing all the deep and shallow points (see figure 11). It unfortunately suffers from overprinting problems which can be prevented in the future by further programming. Yet another plot is one which shows

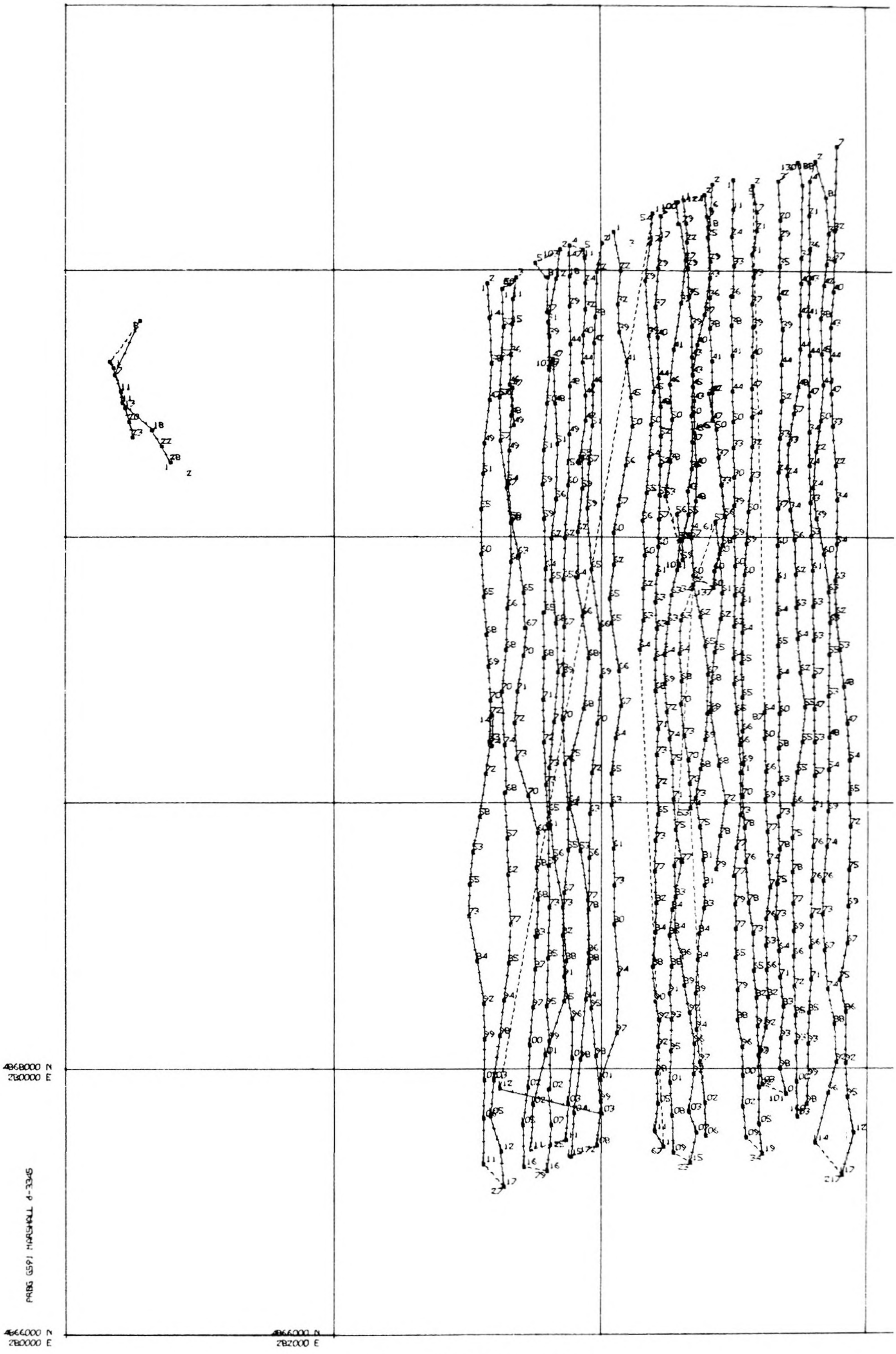


FIG. 10. — Plot of vessel track.

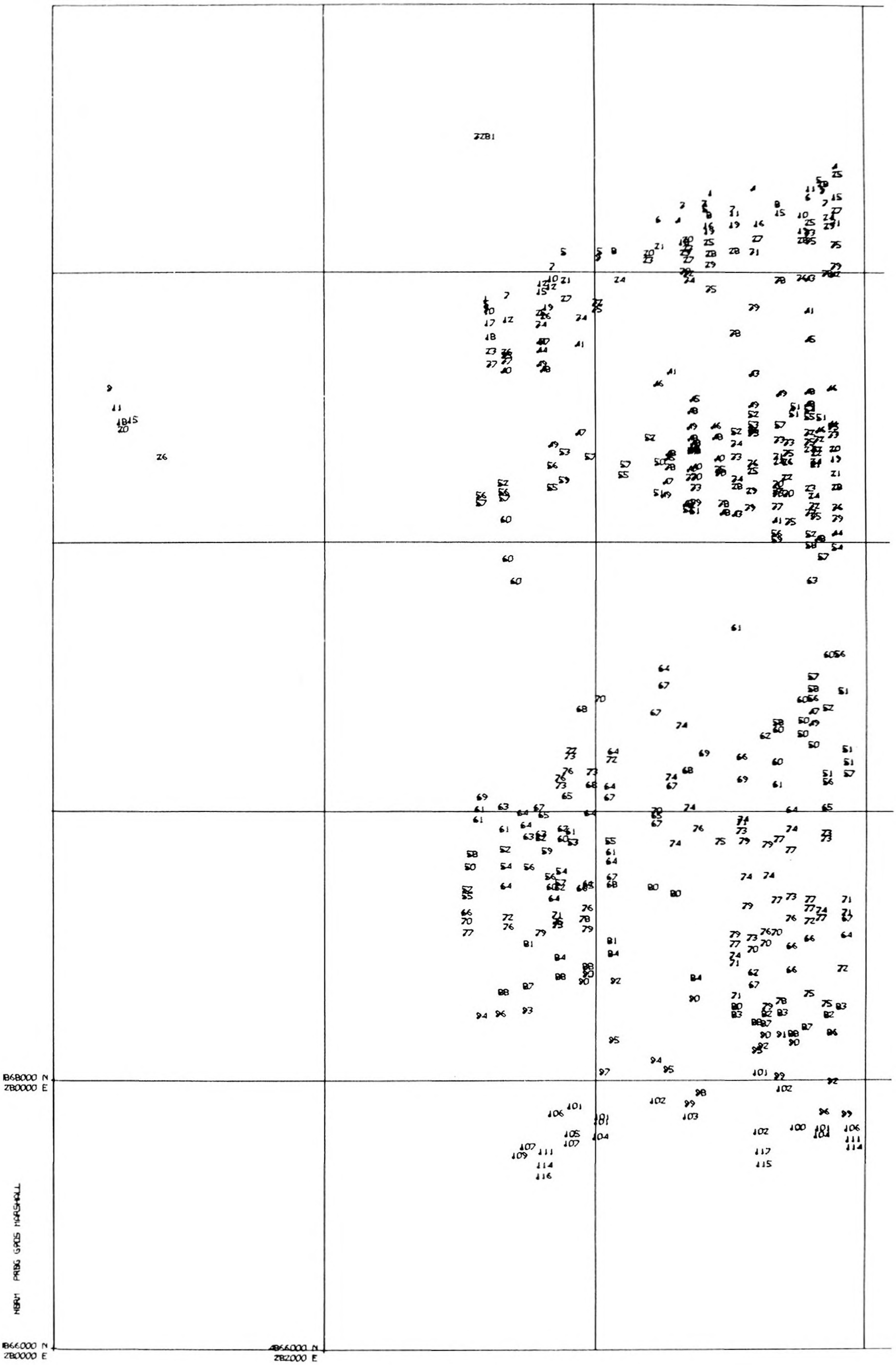


FIG. 11. — Plot of shoal and deep points.

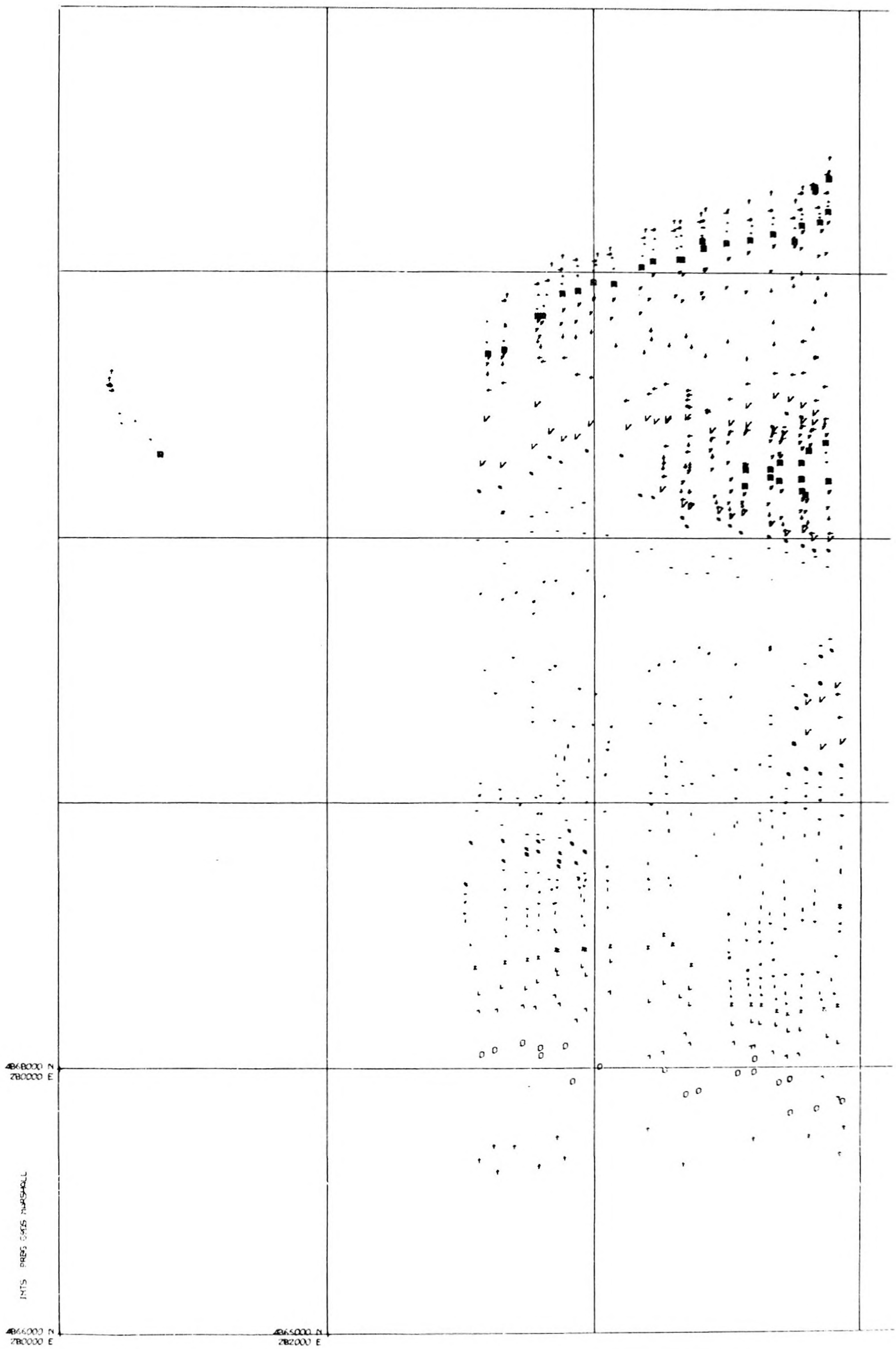


FIG. 12. — Plot of contour intercepts.

the contour intercepts by a series of symbols (see figure 12). These various plots are used in the following manner: The plot of deep and shallow points is used in conjunction with the contour intercept plot to quickly draw contours of the bottom topography by hand. It appears that this type of display can give the hydrographer in the field a clear picture of the features of the seabed, in particular the shoal areas. The plot of shallow and deep points can also be used with the plot of depths at observed positions and with a list of all soundings (see figure 9) to help in the hand preparation of the Smooth or Field Sheet. The automatically prepared plots are placed underneath the plastic smooth sheet and aid in the hand inking of soundings on this sheet.

Some experiments have been made to automatically compute and draw the depth contours. Although the resulting contour lines are rather angular and may be displeasing to the eye of the cartographer they do in fact clearly show the bottom features. Other experiments have been made to draw all soundings on one sheet. Provided the vessel has covered the area regularly, as in an electronic survey, the depth figures can be clearly shown. However, if the survey lines run close together overprinting occurs with the present coarse plotter. Using the new plotter and more detailed programming it will be possible to produce acceptable plots that show all depths and hopefully it will then be possible to automatically produce the final smooth sheet itself.

In conclusion it may be said that the " Hypos " system provides a fairly gentle way for an organization to enter the " automation era ". The only major capital expense is the Pencil Follower. General purpose computers and small plotters are available nowadays in most large cities on a rental basis. Although most hydrographers will prefer to process their data at the survey location it should be pointed out that not only will this involve the high cost of purchasing several small computers but that at present programming small computers is generally more difficult than programming the larger machines.