A BATHYMETRIC EVALUATION OF DOUBTFUL HYDROGRAPHIC DATA

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ABSTRACT

The Bathymetrist at the U.S. Naval Oceanographic Office sees much doubtful hydrographic data that are below the depth range affecting safety in navigation. Since some of these data are valid and useful for bathymetric chart construction, the Bathymetrist must attempt to evaluate it. The most successful method of evaluation consists of fitting prominent forms seen in profile, or as soundings on the random lines, to the same forms developed from survey data. Valid random data will present a logical fit to all the surveyed forms; other random data will fit with minor position adjustments; still other data will be rejected as erroneous.

Survey data are not always available for establishing the accurate positions of forms. Random data can be used if a reiterative process of form development and profile fitting is followed. At first, multiple positions or form irregularities are observed because of errors in the random data. The selection of average depths, positions, and forms from these data significantly reduces the multiple positions and form irregularities.

INTRODUCTION

During the construction of a typical bathymetric chart at the U.S. Naval Oceanographic Office, the Bathymetrist encounters much doubtful hydrographic data in addition to those listed in International Hydrographic Bureau Special Publication 20. These additional doubtful data originate in the same manner as those in Special Publication 20, but they represent features below the depths constituting a hazard to navigation. These data are random, or non-survey data, taken by vessels in routine passage between ports. The amount of these additional data is so large that there is little probability that they will all be evaluated by surveys for many years. Much of these data is valid and can be useful in chart construction, and the Bathymetrist must attempt to evaluate it.

Several methods of data evaluation appear to exist, but studies conducted at the U.S. Naval Oceanographic Office show that one method is superior to all others. This method consists of contouring or outlining prominent submarine features or bottom gradient changes from survey data, and then selecting the random data that fit the contoured or outlined forms. In many areas there are no surveys available, and the contours or outlines are established from an analysis of the prominent forms and gradient changes seen in the random data. The analysis is a reiterative process in which the forms and gradient changes are first drawn in positions that represent an average of the varying reported positions. Next, sounding lines are selected that approximately fit the forms and gradient changes. Then, the "average" forms are adjusted for a better fit. The final step consists of once again reviewing the sounding data to select all that can be fitted to either the forms, or a combination of forms and other data at the intersections.

NATURE OF DOUBTFUL HYDROGRAPHIC DATA

The Bathymetrist sees doubtful hydrographic data as adjacent or intersecting sounding lines which do not correlate in depth. When contoured, the doubtful data present forms which are distorted in shape, or foreign to the area in which they are reported. Doubtful data may consist of individual sounding reports or entire sounding lines.

When doubtful hydrographic data are evaluated, one often finds a position or depth error related to the limitations of accuracy of navigation and sonic depth recording. Position accuracy in navigating can be divided into two parts: the accuracy of the periodic fix; and the accuracy of the dead reckoning navigation between fixes. Based on several studies, the average position error in random data is about 8 nautical miles, most of which can be attributed to the difficulty of maintaining accurate course and speed during the period of dead reckoning navigation.

Depth accuracy is limited by the accuracy of the recording device, and the skill of the operator in interpreting and annotating the depth record. The most common depth error is a 3% variation above or below true depth, resulting from variation in depth recorders or their power supplies. The next most common error is the phase error resulting from the failure of the depth recorder operator to know the correct depth multiple in which the recorder is operating. Phase errors are most common in deep water where irregular or steep bottom slopes scatter the acoustic signal and cause poor bottom traces to be recorded.

A particularly troublesome depth error is the reporting of a scattering layer as the ocean floor. These layers may be at shoal depth and when mistaken for true bottom, they appear as hazards to navigation. These errors occur most frequently from the operation of shallow water echo sounders in deep water. Shallow water echo sounders may not record the deep ocean floor under many circumstances, and the chances are additionally reduced if a scattering layer interferes. Depth errors caused by the scattering layer can be difficult to resolve since a considerable area must be surveyed to determine that the "feature" is non-existent and not just positioned incorrectly.

The terms " position " and " depth " error used here denote the measurement that is causing the inaccuracy. Both are observed as depth discrepancies.

Most of the inaccurate doubtful hydrographic data collected in the past 25 years probably results from the above types of errors. The next largest amount results from written errors in recording and plotting data, particularly the transposition and omission of digits.

EFFECT OF DATA ERRORS

Depth errors are noted only in flat areas where a position error has no effect. A typical 3% depth error, with a range of 6%, results in the contouring of non-existent ridges and troughs on bathymetric charts. On a nautical chart, one also finds the 6% range of depth in the individual soundings in areas known to be flat. This results from the habit of selecting depths from unrelated sources to fill in blank spaces on the chart. The Bathymetrist, charting the deep ocean depths, must correct these depth errors since they present non-existent features often 100 to 300 fathoms in relief.

Position errors are best noted over moderate to steeply sloping bottoms where the average position error of 8 nautical miles may cause a depth error of up to 1 500 fathoms. If such an error occurs perpendicular to the slope, a large spur or valley is produced depending on the direction of error. If the error occurs parallel to the slope, a large ridge or trough is formed depending on whether the error is down or up slope.

When position errors occur in crossing a canyon, small ridge, or hill, the individual feature may appear to be several features clustered in the same area. Small seamounts are also easily mistaken for multiple features; however, on the larger seamounts the position errors will appear only as elongations, irregularities, or multiple peaks.

Dangers to navigation in the doubtful hydrographic data commonly result from position errors which report continental or island shelf depths in adjacent deep waters. With the advent of deep diving submarines, one might also count as hazards the erroneous reporting of adjacent deep water depths on the shelves.

EVALUATING DOUBTFUL HYDROGRAPHIC DATA WITH SURVEY DATA

One might expect that the errors in random data are most easily studied and corrected by comparing depths on intersecting random and survey sounding lines. This procedure does not work because one does not know whether the discrepancies observed in the random sounding line are the result of a position error, a depth error, or both. The magnitude of error cannot be judged by comparing depths at the intersection either, since a simple adjustment of the random line to match the survey depth does not guarantee that the depths matched are related. For example, one might adjust a random line so that a 100-fathom random line depth would now correlate with a 100-fathom survey line depth. The true correlation might have been to match 50-fathom depths.

The better method consists of matching forms seen in the random data, to the same forms seen in the survey data. The first step in this procedure is to have, or put, all of the prominent forms known from the survey data on a transparent work sheet. The second step is to "one by one" place each random sounding line beneath the survey data in the reported position. If the random data are valid, the depths at each feature will be seen to match, or appear as a logical correlation to, the survey data. Ideally, the submarine features in an area are of differing sizes and located in random positions so that no random line would fit perfectly in two separate locations. Thus the accuracy of random data is established by the ability or failure of its features to fit the survey features.

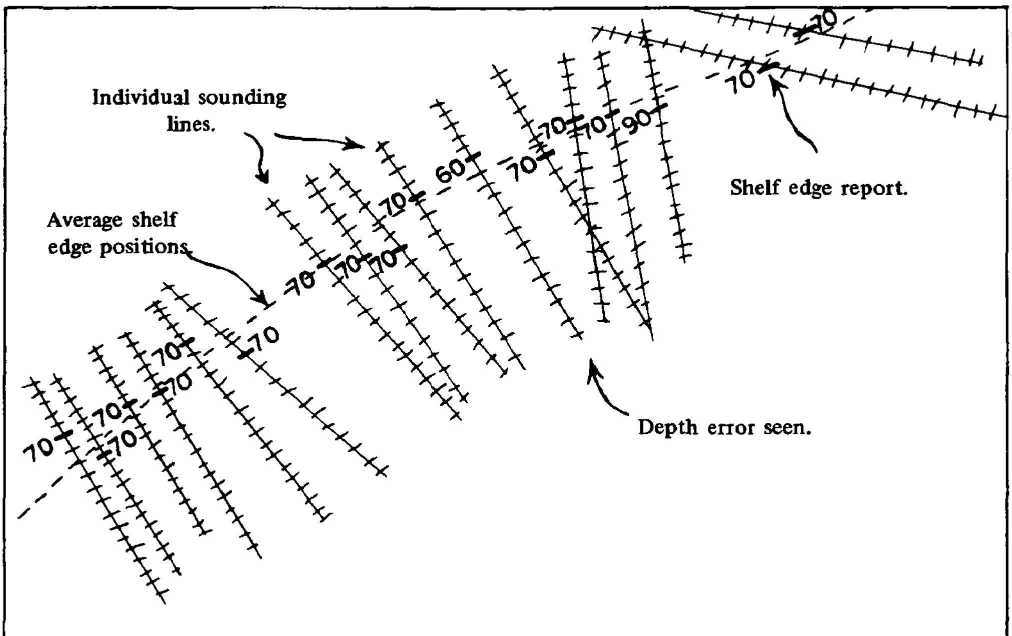
EVALUATING WITHOUT SURVEY DATA

The preceding evaluation assumed that survey data were always available as the standard for determining the accuracy of the random data. The Bathymetrist seldom has sufficient survey data but the evaluation can be conducted as before by first establishing the necessary forms from the random data.

Random data tend to report submarine features in multiple positions because of the data errors previously described. On moderately large features, the general position is quite evident but peak depths are reported in multiple locations and the feature margin is blurred. If sufficiently large amounts of data are available, the peak depths are seen to concentrate in one limited area and one can determine that there is one best, or perhaps average position. If one then studies profile forms on one or more sounding lines of favorable orientation, which correlate with the average position, a relatively clear feature form is also established.

On relatively small features, a number of peaks may be reported in a small area for a single feature. If sufficiently large amounts of data are available, it can be observed that all lines report only one feature, thus establishing the probability of only one existing in that area. Again, the least depth, or depths, are seen to be concentrated in one area and an average position can be selected.

On simple linear gradient changes, such as a shelf edge, the change may be seen to occur at multiple irregular locations along the trend of the shelf edge. Since the shelf edge is normally straight, one can select an average position once again (figure 1).

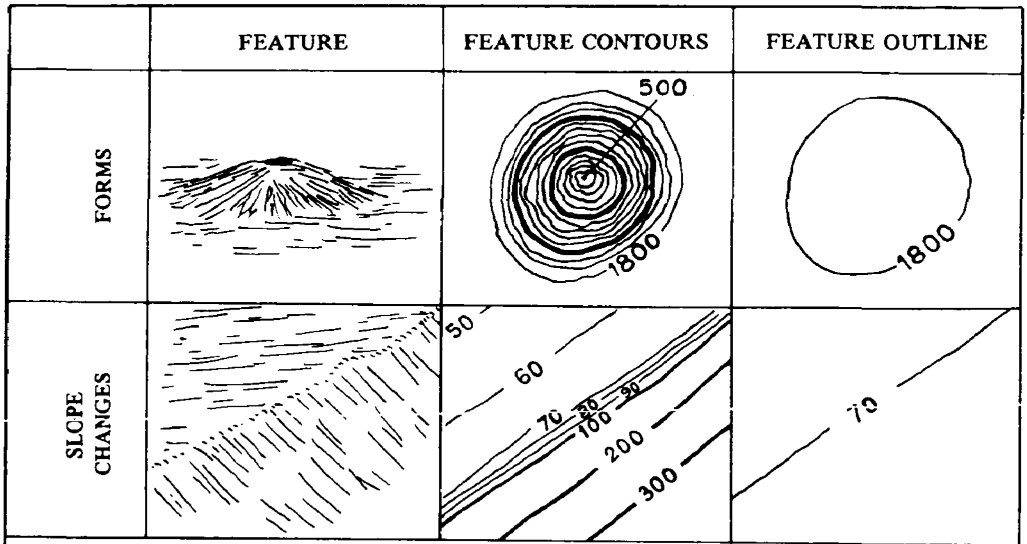


When a slope change, such as the shelf edge, is known to be relatively straight and smooth position and depth errors are observed as apparent irregularities. The correct position can be determined as an average.

FIG. 1

Submarine canyons, ridge and trough axes and escarpments can be similarly studied and found to be distorted and disjointed by the errors in typical random data. In each instance, if sufficient data are available, some sensible and average form can be determined.

Average positions are most easily established by placing the feature forms on a work sheet. Some error will exist in the average positions determined because some features will be analyzed from less abundant, or poorer, data. Thus it is not convenient to fully contour the features, since some will be repositioned subsequently. Instead, they can be outlined on a transparent work-sheet with a minimum of soundings and contours (figure 2).



It may be necessary to indicate the average form and position of many features to **determine the most accurate positions of all. This is facilitated by showing the average form and position by feature outline. Ridges are shown as an elongation of the seamount form shown above. Troughs are shown identically, using a deep sounding.**

Fig. 2

Outlines of features are developed from each set of random data. If the sounding data are accurately positioned, only one form and position would be developed for each feature. Since errors are usually present, multiple positions will be indicated. The multiple forms are shown in a stylized manner in figure 3. Normally, one does not know the form of the features being outlined, and the outlines are partial.

In viewing the multiple positions of the features, the Bathymetrist should get some feeling for an average location for each. This average location is then drawn, either on the original work sheet, or a new one. With a series of average positions established, one then reviews each set of data to locate that which fits the outlined forms. Some data will not fit because of positioning errors in the data. Other data will not fit completely because the average positions selected are not all accurate. In a typical situation, the sounding line will fit four or five features and fail to fit one or two others. The average positions of these one or two features are changed to obtain a fit.

When a high degree of correlation is obtained between the features outlined in the average positions and the random data, those sounding lines which fit best are plotted for contouring (figure 4). When contouring, one usually sees small features not outlined in the previous step. The sounding data can be reviewed once again to select data which also fits the small features. The plotting of data also allows correlations to be made at inter-

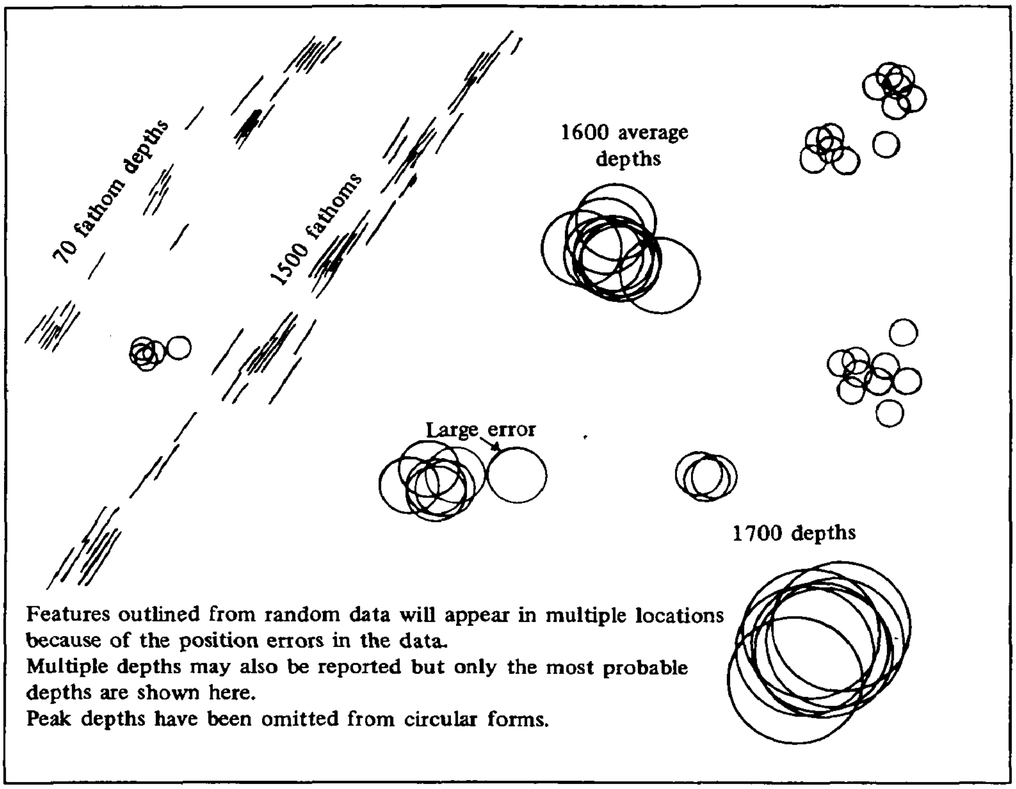


FIG. 3

sections. Minor depth descrepancies at the intersections can be resolved in the contouring process. Larger depth descrepancies indicate depth (rather than position) errors in the data. These can be partially resolved as explained in the section on depth evaluation.

Features positioned in the manner described have been checked on two occasions by survey vessels. There was an apparent positioning accuracy of two nautical miles or better. This reduction in error is primarily the result of detecting and eliminating poor data rather than any significant adjustment of other data, since a certain percentage of the random data is usually found to be accurate to within two nautical miles.

DEPTH EVALUATION

Depth variations in random data can also be reduced by an averaging process. The amount of depth variation between data sets is determined in flat areas where the effect of the position error is not a factor. Data with obvious large errors, such as phase errors, are eliminated first. The remaining data are studied to determine average depth. The data are then reviewed to select those sounding lines which approximately match the

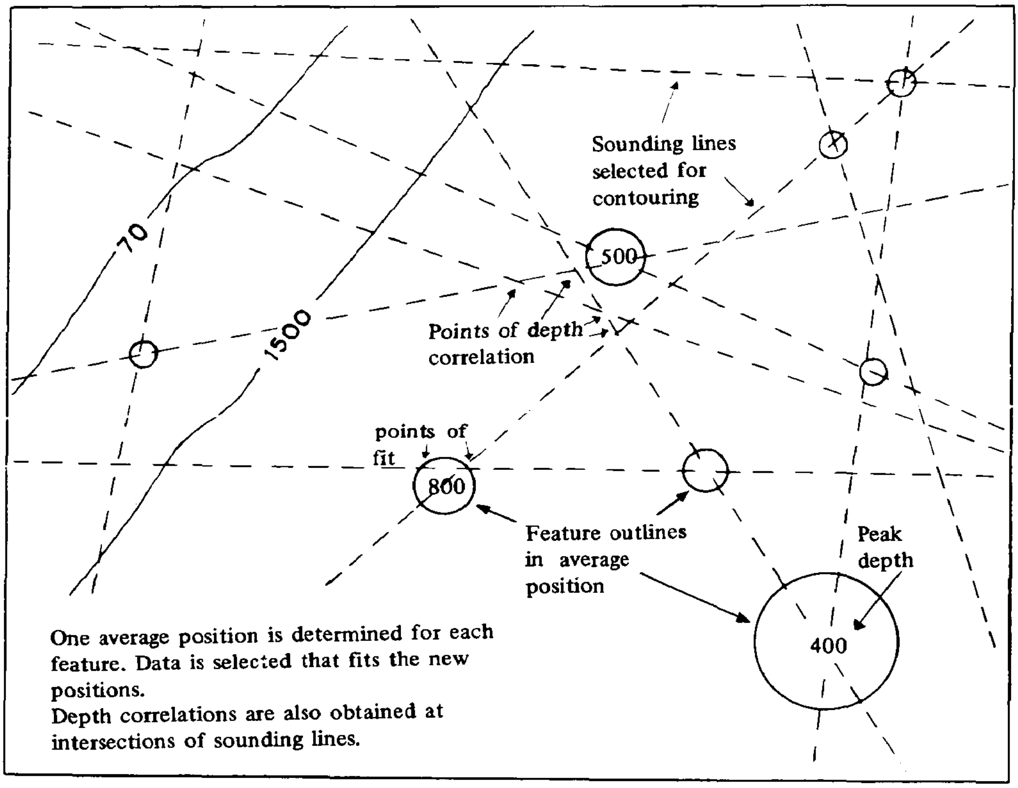


FIG. 4

average depths. It is unlikely that many sounding lines will be found that correlate exactly with the average depths. The problem is relieved somewhat by making depth corrections to various lines to permit them to match the others.

The average depths determined in this manner seldom match the depths determined by survey vessels. This probably results because the echo sounders aboard various ships have not been kept calibrated to a standard. On occasion, the Bathymetrist might suspect that some of the variations are the result of seasonal variations in the water characteristics.

CONCLUSIONS

A procedure has been developed at the U.S. Naval Oceanographic Office for evaluating that portion of doubtful hydrographic data that is below the depth considered as of concern to navigation. These doubtful data are of the same general origin as those listed as dangerous to navigation in the International Hydrographic Bureau Special Publication 20. A major premise in the evaluating procedure is that soundings do not exist alone in abstract form, but represent some part of a submarine feature. Thus, one does not evaluate by matching number to number, but by matching form to form. This greatly increases the possibility of evaluating the doubtful data because the form obviously covers more area and offers more opportunity for correlation than does the number. The correlation of form to form requires a knowledge and confidence that certain submarine features present a consistent and predictable geometry. The precision of correlation lies in finding some unique characteristic of the geometry, such as a sharp gradient change, that presents some minimum ambiguity in correlation.