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SWATHE SOUNDING DATA BASE MANAGEMENT

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1. INTRODUCTION

A scheme to manage data bases requires the definition of a number of uses which are, or can be, made of the data either for applications which have already been identified by current usage, or which may become evident at a later date. Data is normally collected for an already known purpose and it may be the intention of managing it to ensure it meets that purpose or to extend its useful life. Although other applications may be secondary, the cost benefit of extending the use beyond the original intention is normally welcomed. It may also be desirable to identify other potential beneficiaries to help to share the financial burden of the initial data collection. The supplementary purpose of management may then become an exercise in identifying the value to a new user. Conversely, for military applications, the desire may be to limit unauthorised use of the data, without the need to conceal real hazards which, if undeclared, could be the indirect cause of environmental damage in the case where a polluting cargo is spilled as a consequence of an otherwise avoidable grounding.

Wide swathe sounding now offers the capability to produce data economically at a high density such that both surface navigation and seabed engineering can be served from one data base.

It is suggested that there are three forms of data base, viz. Raw, Source, and User, which can be seen as equivalent to the present products, the echo trace, fair or smooth sheet, and chart, the chief difference being that the former, stored digitally, allow much easier access to the data bases, although the quantities have increased greatly. Because of this new, potential flexibility, it becomes possible to tailor the user data base either to the needs of the individual user, or to the needs of the occasion. Thus the customer needs only pay for what he gets, and even though he only gets what he needs, he is also assured of the level of safety, and ease of use of the data base.

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2. WHAT WE HAVE NOW

Digital sea bed data is traditionally presented graphically in two forms, one is the fair or smooth sheet, the other is the chart. It is collected in the form of positioned lines of depths. The distinction between the two is that the first, the fair sheet, is intended to show what is, and the latter, the chart, to show what matters, primarily navigationally.

A chart contains many other navigational aids to assist the navigator to compensate for the lack of sufficiently distinguishable 'landmarks'. All the landmarks which are in any way helpful to a navigator are above water, most of them being some considerable distance from the ship's route. Those marks which are closer to the track, such as buoys, have rather imprecise positions relative to the grounding hazards of which they give warning. The consequence is that the sea areas which are safe for navigation, as far as concerns depth, are used in a rather profligate manner because the information from navigational aids is imprecise and the depth data of varying age and quality.

The distinction between fair sheet and chart is significant. On the face of it, there is no room for interpretation in the production of the survey fair sheet, whereas the chart, being a compilation, clearly involves a considerable degree of interpretation. In fact, representation of the seabed features, on a chart, is deliberately grossly inadequate. Only large features are shown, and great pains are taken to err on the safe side by generalising and biasing the data, to encourage shipping to stay as far as possible from grounding hazards so that there is a great deal of distortion and omission for the sake of clarity and safety. This policy is understood by navigators and it is at least possible that awareness that safety margins are built in lulls some people into a greater sense of security than is altogether wise. It also has the somewhat unfortunate effect, on busy routes, of causing a narrowing of the usable sea lanes so that a safety measure against grounding may exacerbate the hazard of collision by enhancing the potential traffic congestion.

Marine navigation is heavily dependent on the existence, and the maintenance, of man-made aids. All of these are above water. Indeed the only one readily available to the navigator which provides below water information, the echo sounder, is of relatively little use, because the reference data, i.e. soundings, are shown so sparingly on the chart that they can barely be cross referred to the echo traces.

Few would argue that the main purpose of the survey fair sheet is to record, as factually as possible, the dimensions of seabed features. Nevertheless, the traditional resulting paper documents suffer from a constraint, which is imposed upon them by their historical evolution and by the inflexibility of the graphic mode of recording.

Surveys are said to be executed on a certain scale. Since the advent of the echo sounder, this has come to mean the proportional size of paper on which the sounding lines appear to lie close enough together to provide a reassuring impression of dense coverage, rather than the minimum size necessary to show all the data collected in the course of the survey, as was the case in the days of the lead line.

The concept of chart scale probably dates from the time when positions of soundings were plotted by means of a station pointer. The land stations on which bearings were taken by sextant had to lie on the same sheet of paper as the area being surveyed, so that graphic resections could be executed rapidly. Hence surveys, some distance offshore, tended to be produced on a smaller scale than those nearer the coast because the station pointer loses precision when its legs are too long, so that it was more convenient and more sensible to reduce the plotting scale. In general, this practice of reduced scales with increasing distance offshore also agreed with the general conception that depths were greater, and therefore less critical, the greater the distance from shore. In reality, it is evident that depths do not necessarily become greater with increasing distance from the shore.

Rather more attention was also paid to those depth areas which corresponded to the mean draughts of ships at the time of surveying, than to greater or lesser depths, but the depth zone which is critical to navigation has widened significantly during the last few decades, which has had the result of making earlier surveys of the areas, now of major interest, look relatively less good, although they can be better than modern surveys in the shoaler regions. In addition, there are now a great many engineering activities offshore at virtually all depths where the utmost attainable precision and detail are needed.

Disregarding for the moment whether or not a survey will have discovered the least depth in the equivalent area of seabed as compared with the capability of a swathe survey, it is evident that there can be measurable variations of depth within the space occupied by one sounding, since even on a large scale survey the area covered by the sounding may be about 50 m^2.

The graphic fair sheet is therefore an edited document, in the sense that the soundings shown are not exactly those recorded in the positions where they are shown, and measurable features are necessarily omitted altogether or distorted. Also the considerable discrepancy of the data density along track and across track would make the retention of such data, derived from an ordinary echo sounding survey, less useful since the survey track directions generally do not correspond to the orientation of navigational routes.

There is overwhelming evidence that the fundamental conception of hydrographic surveying was that sounding lines run at right angles to the contours stood the best chance of discovering, and delineating, dangerous seabed features. The assumption was that channels generally had relatively smooth bases and sides.

3. WHAT WE CAN DO

The principal aim of swathe sounding is to achieve, as far as possible, the same data density ratio without loss of quality, cross track as along track, in order to remove the main limitation of line sampling, so characteristic of the use of the echo sounder when surveying. The most conspicuous difference between echo sounding and swathe sounding is the highly increased data rates of the latter. It is consequently important that, because the number of sensors needed to generate soundings has increased appreciably, the monitoring and recording of their efficient performance be continuous during the course of a survey. However, it may well be that the greatest benefit to be derived from swathe sounding, as a means of collecting data, lies in the ability to obtain overlapping strips of depth data which permit quality control, resulting from continuous cross checking.

Over the decades, as the draughts of ships increased, critical depth zones have gradually become deeper, from down to 3 fathoms a century ago, to 40 metres today. The result is that the increasing draughts of vessels effectively presented surveyors with new, and different, physical environments where it was no longer valid to assume that dangerous seabed features could be delineated adequately by existing surveying methods. Consequently, when evidence began to accumulate that the bases of channels or routes were not smooth, and that larger scale surveys still did not delineate them with the desired degree of resolution, safety of shipping could only be assured by recommending proportionately generous underkeel allowances. This highlights a conflict between the desire for caution and the need for economy of effort.

In the course of the last decade, the cost of cautious generosity has begun to be assessed, and is bringing into perspective the importance of objective quality assessment of hydrographic surveys.

The discussion of swathe sounding data base management is therefore not confined to the ability to obtain much more data, but of necessity includes consideration of the accuracies which are desirable or attainable and verifiable, of the uses which are, or can be, made of depth measurement data bases, the limitations of their quality and of the contributory measurements which convert depth measurements into soundings, as well as other environmental properties of the seabed, which users of the data find relevant.

It may well be possible to devise a data base which is all embracing, but it could end up by being too cumbersome to be accessed. To do so would be to perpetuate the present state of data accessibility, where fair sheets are seldom analysed critically, or even historically, because it is, in practice, too time-consuming, and thus uneconomic. If prodigious quantities of data are produced in the course of many decades, and hardly any of it is examined critically, it is then probable that the recipients of the data have a low regard for it. Indeed there are those who complain about the cost of charts even though they are subsidised products and must frequently avert environmental disasters.

We can make use of the opportunity, grown out of necessity, to construct data bases so that they reflect the maximum amount of information which can be managed by the users. Planners and analysers can cope with multidimensional bases, but navigators will benefit from a version which permits rapid access, preferably in an easily interpreted image form. The latter can be shorn of all information not instantly usable. Expressing this in land terms, it is useful to see the condition of the road ahead, but it is also helpful to interpret what conditions face the other traffic around. Continuing the analogy, one does not need the geographical coordinates of a telephone booth in order to find it. It is sufficient for the user to know that it exists and that it is located in a particular square. For those unfamiliar with the appearance of such an object, an image library can assist with one or more suitable sample presentations.

4. THE DESIRABLE DATA

It has already been argued that the positions of the areas of the seabed which were deemed to need to be surveyed most critically, have, in the course of time, altered so that the sea areas which are now of economic importance have tended to lie in relatively unsurveyed territory. Yet, by and large, the type of seabed features, which eventually are found there, are often not fundamentally different from those encountered in the more familiar shoaler areas surveyed previously in some detail, although their dimensions may be different.

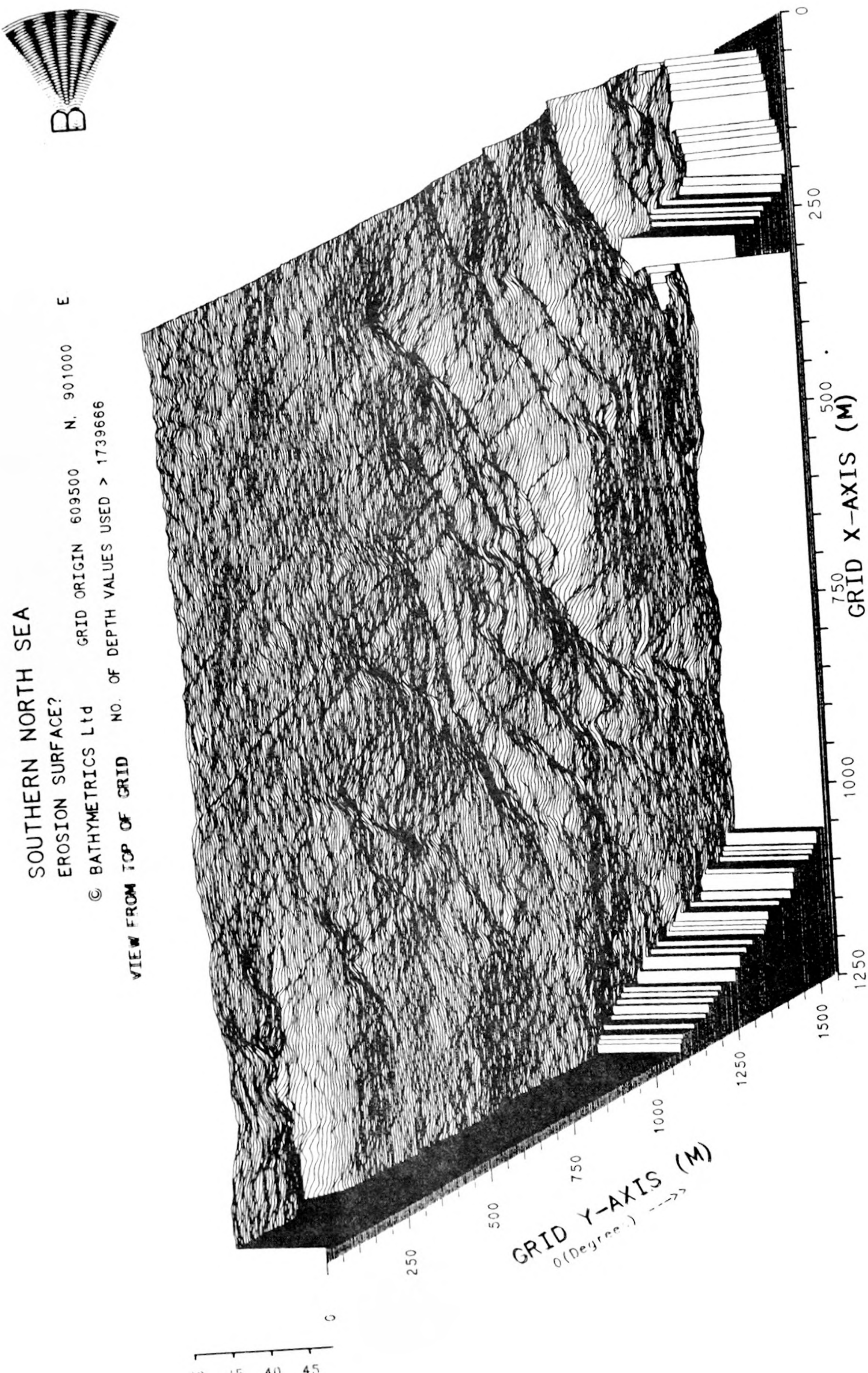
In terms of the current usage of depth data, there would appear to be three major interests:

1. Safety of navigation;
2. Seabed engineering operations;
3. Environmental monitoring.

In the first case, it has been generally assumed that only the dangerous high spots which puncture the critical depth zones need to be retained and promulgated. Experience has shown that the useful life of depth data can exceed a century, so that navigation planning decisions are made on the basis of data of an earlier age, probably because the resources of the world's hydrographic community are nowhere near adequate to meet today's, let alone tomorrow's, needs. If the problem is one of depth instability, it can then take as much as a decade to come to a conclusion. This sort of time scale is unattractive to port developers dependent on a safe transit through an area and the temptation to cut corners to shorten the gestation periods for major developments cannot be ignored.

Modern surface navigation can extend to depths close to 100 m, e.g. when exploration platforms are moved. Subsurface navigation extends some considerable depth beyond that. Of course, where the sea is deep enough, it is reasonable not to demand the same accuracy of depth measurement if it is only to be used by surface navigation.

If depth data could be presented in such a way that navigators could make fuller use of it in the process of navigation, it would provide them with a data base which is independent of signals transmitted from an outside source, such as is generally the case with positioning systems. Such independent control would be welcomed but, to be practical, it would need to be rapidly accessible and visually unambiguous. The responsibility of the compiler of the data base would be great because increased reliance would be placed on such data. Therefore, the quality would need to be assured to a clearly declared level. This is not so much a case of needing data of the highest possible quality, something which is always desirable, but a matter of knowing, and being able to promulgate in sufficient detail, the tolerances of the measurements.


SOUTHERN NORTH SEA
EROSION SURFACE?
© BATHYMETRICS Ltd
GRID ORIGIN 609500 N. 901000 E
VIEW FROM TOP OF GRID
NO. OF DEPTH VALUES USED > 1739666
GRID X-AXIS (M)
0
250
500
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1000
1250
GRID Y-AXIS (M)
250
500
750
1000
1250
1500

Fig. 1.

When the navigational desiderata are spelled out in this form, it becomes evident that they should differ little from those which would be helpful in seabed engineering operations. A major difference remains in the initial compilation of data bases for these two purposes. The product aimed at navigation always errs on the side of perceived safety. A sounding is usually the locally shoalest reading, reduced to a tidal datum which ensures no negative corrections need be made to estimate the depth at the time passage is made. Although this practice is soundly based on the well proven human predilection to commit an error if this is possible, it is nevertheless a practice which may hamper the fuller use of the data in the long term. A distinction can be made between the form in which the data is presented to the user and the form in which it is stored. It remains to be defined what is the necessary adequacy of the data, because the accuracy, however great, of a sample set of depths which, because of the way it is distributed over the area, does not define the surface to the degree of detail which must be identified for any desired use, may remain unsatisfactory.

5. GUIDING PRINCIPLES FOR DATA BASE CONSTRUCTION

The test questions which are sometimes asked when discussing depth measuring instrumentation are:

1. Will it show a lost container?
2. Will an object the size of an oil barrel show? or
3. Will it find a mast?

None of these are natural features, but all are hazardous to shipping, and none are at all easily found by existing seabed mapping methods.

Supposing a seabed mapping system did exist which could satisfactorily delineate all of the above objects once they had been found. The data density would have to be decimetric, if not on occasion centimetric. Clearly not all of the seabed will ever need to be shown in that amount of detail. By far the greater part of the seabed consists of natural features and it would appear to make sense to consider their dimensions as the basic guide to the desired data density. Having said this much it should immediately be added that information about the prevailing dimensions of typical existing features remains somewhat scanty, but it is still possible to find agreement on the broad principles on which data bases could be built.

5.1 Taken over a large area, the orientations of natural features are random. Although there is frequently a distinct tendency for them to be linear and to adopt locally preferred orientations, several such linearities with different orientations can be superimposed one upon another. There is thus a need to have, as near as possible, the same data density in all directions. The most convenient form of data so distributed is on a grid in which x and y measure the same. It is also the most economical way of storing data (see Fig. 1).

5.2 Because, underwater, what is not measured, and recorded, is not known, the data base ideally should not contain interpolated values, unless this is explicitly declared and explained, because interpolation is interpretation and involves making assumptions. Therefore the grid, or matrix, should not have any dimensions which are smaller than the spacing of the collected data.

5.3 A hydrographic swathe survey consists of many bands of depths which overlap. Merging these into a one surface presentation is largely limited by the positioning accuracy. When merging, depths over a seabed feature seen on one swathe have to be combined with similar detail from the overlapping swathe. This has to be done on the basis of positioning data, and the error values of the latter determine the smallest size of feature which can be positively identified in the area of overlap.

5.4 The depth values of the surface matrix are affected by the reproducibility of the tidal datum, and by the spread of values used to determine each matrix depth.

In swathe sounding many measurements may be obtained from one depth area, and some of these will have come from different swathes. These measurements are not strictly independent and can define only one depth.

Not only is the matrix size largely determined by positioning, but also, as far as the data base construction is concerned, it controls the maximum resolution of the depth measuring device from which we can benefit, and of the digital surface which can be generated without prior theoretical assumptions as to the complexity of the surface.

6. THE RAW DATA BASE

In regard to the BATHYSCAN, the raw data gathered while surveying comprises all records of attitude sensor outputs and positioning. This data package is the equivalent of the analogue/digital echo trace, and the positioning log book, or equivalent. It is the most detailed set of data capable of being generated by the instrumentation and techniques used at the time and is uncorrected for instrumental, software, or environmentally induced errors. Storage devices are already available with capacities equivalent to about 70 hours, or 3 days, continuous observation, which makes physical storage of this density of data reasonably manageable. The spatial coverage contained on such a tape or disc equates roughly to a 5 × 5 km area allowing for generous overlaps, inter-lines, etc.

The Raw Data Base contains depth uncorrected for tidal datum as well as the tidal record, and the positioning data. As the tidal information improves over the years, or becomes available in more precise form for the area of interest, it is possible to retro reduce the soundings and improve the value of the historical record where this may be vital for major coastal or offshore engineering works. There have been instances where the physical evolution of an area was seriously misread through inattention to, and inability to correct, the tidal datum assumptions made many decades earlier. There have been a number of instances where recourse to earlier survey data was vital. Weighing the cost of remedying years of neglect of a port, which was being revived, and charging it to the legally responsible authority was, on one recorded occasion, effected by the need to re-establish an old tidal datum in terms of a new one.

It is suggested that the navigationally safe, and sensible, practice of reducing soundings to a Lowest Astronomical Tide, or similar low water related datum, should be replaced by Mean Sea Level and that the time tagged tidal corrections applied should be stored as raw data. The reasons for this are several. One is that there is evidence that the tidal information, used some distance offshore, does not provide the means of determining reproducible depths to the desired levels of accuracy. Since both phase and amplitude values affect it, these alterations cannot be easily applied. It is a common practice for surveyors to examine shoal water areas around high, rather than low, water so that, where the datum is erroneous, it is so to a larger degree in the shoal water. One of the purposes of the use of L.A.T., to ensure maximum safety, may thereby be nullified. Further, the assumption in applying tidal reduction is that datum lies proportionately at the same distance below a low water at the site as at the Standard Port. This assumption is unproven and cannot normally be checked locally. It is in any case more appropriate to one type of user, the navigator, rather than another, the site engineer, and is therefore not a necessary attribute of a common source data base [1].

Where soundings are needed in order to depict a detailed local shape, the best results can be had by examination of the finest possible matrix within individual swathes because it is likely that the consistency of a positioning system over a brief period of time is sufficiently good for this purpose, even when absolute positioning is not good enough for swathe merging. It can be a worthwhile exercise, in survey post processing, to carry out such an analysis where the positioning system is suspect in absolute terms. However, this can be time-consuming though it is also highly rewarding when done. It has already been instrumental in detecting such basic errors as incorrect layback determination, abeam offset miscalculations and tidal datum errors. By their very nature, such detective work is the proper function of the originating authority and the means to do so needs to be part of a Raw Data Base rather than of the post processed data base which can be promulgated.

The value of retaining such a Raw Data Base lies in the fact that it enables the survey, or any part of it, to be completely reprocessed at any time, at a much lesser cost than of a re-survey, although this is something which would normally only be done by the originator authority. In view of the apparently increasing reports of litigation, consequent on accidents, sometimes decades after the survey was carried out, it is likely to be important to be able to establish whether the survey was carried out, without negligence, in the context of the capability of the instrumentation used, or available, at the time. It may even be necessary to provide evidence that the survey, and the post survey processing, procedures adopted were properly carried out. This data base is therefore an important document of archival value.

7. THE SOURCE DATA BASE

Each gridded depth measurement has a number of attributes. The depth value itself derives from the spread of values, where more than one is used to obtain it. It follows that the population density of each grid bin provides a confidence measure, because the weight of confirmatory data defines its worth. The spread of values may be a reflection of the roughness of the seabed within the depth area, or it may represent the limitation of resolution of the swathe sounder instrument and processing software combined.

Even though data storage is already compact, and likely to become more so, there may, nevertheless, eventually have to be a time limit on the retention of raw data, however regrettable this may be. This is a political decision and the danger is that premature destruction of such data may not protect against allegations of negligence. In any case, the data base to be retained for communication between charting authorities, and therefore its volume, can be reduced significantly if it is possible to retain, with the matrix of depth data, the qualifiers. The latter are essentially the measurement tolerances interpreted in the light of contemporaneous knowledge and ability to measure, while the matrix of depth data, so qualified, is the then best achieved interpretation.

An example will illustrate:

In order to depict a surface by means of swathe sounding, the adjacent swathes need to be joined together. The degree of accuracy of this operation depends on the relative positioning accuracy of adjacent data sets. In the case of BATHYSCAN swathes, it is usually recommended that these should be run with a reasonably generous overlap because it permits quality control during the post processing stage in increments of small unit areas, these being multiples of grid units or even single grid units. The optimisation of the grid unit size is at the discretion of the surveying authority, but its minimum size should be based on the quality of the positioning and attitude sensor resolution capacity. Common sense suggests that, when using a positioning system which cannot reliably be depended upon to better than ± 2 m, merging depth data into grid bins smaller than 5 m will corrupt rather than enhance the value of the contributions from the different swathes. This will show in the misclosure tables, or diagrams, which are generated during post processing or at the pre survey calibration stage (see Table 1).

A misclosure table is the product of one of the post processing stages. The example illustrated compares the mean depths of the same grid platelets derived from overlapping swathes of a BATHYSCAN survey. The platelets measure about 60 m × 80 m and form part of a check on possible small tidal datum gradient errors. The dimensions of the platelets are governed by the need to have 1 minute's worth of data and this in turn is chosen to eliminate the effect of surface waves on the measured flight level of the tow fish when deploying close to the surface. The sizes of the areas are also sufficiently large to reduce the effects of normal positional misclosure to an acceptable level. In consequence, the average misclosure corrected for flying depth can be seen as a local datum plane error, whereas the error about the average is the composite survey error. The

Table 1

Misclosures between overlapping swathes in increments of 300 pings

DYNAMIC SYNOPSIS:

Mean ping No.	Average flying depth	No. of misclosure samples	Misclosure corrected for fish depth	Error about av. corrected misclosure
152	4.0	421	−0.04	0.05
452	4.0	465	−0.05	0.04
752	4.0	444	0.20	0.29
1052	4.1	425	−0.13	−0.04
1352	4.1	416	−0.07	0.02
1652	4.1	392	−0.04	0.04
1952	4.1	409	−0.09	−0.00
2252	4.1	459	−0.06	0.03
2552	4.1	506	−0.06	0.03
2852	4.1	445	−0.03	0.06
3152	4.1	509	−0.51	−0.42
3452	4.1	520	−0.02	0.07
3752	4.1	462	−0.08	0.01
4052	4.1	670	−0.23	−0.14
4352	4.1	717	−0.45	−0.36
4652	4.1	665	−0.24	−0.15
4952	4.1	706	−0.06	0.03
5252	4.1	726	−0.09	0.00
5552	4.1	651	0.01	0.10
5852	4.1	611	0.06	0.15
6152	4.1	598	0.17	0.26
6452	4.1	328	0.07	0.16
AVERAGE:			−0.09	

latter combines position, attitude sensor and interferometer errors and, although these can be separated theoretically, once the swathes are merged those are the values which collectively establish the worth of the survey. Reducing the size of these residual misclosures is the task of the surveyor. Large localised misclosures can often be traced to the malfunction of one or other component measurement. Most frequently this is due to positioning, but occasionally a pronounced course correction is seen to have produced a heave period beyond the sensitivity of the accelerometer.

Whereas the misclosure table, produced in the dynamic synopsis, provides a record of the quality of misclosure, a much more sensitive test will have been carried out at the calibration stage of the survey (see Fig. 2). Overlapping swathe segments are compared at each grid unit increment, in this case every 5 m, or approximately every 2 seconds down track. At this frequency, the misclosure is more noisy due to position and heading errors in an area where there are also small features.

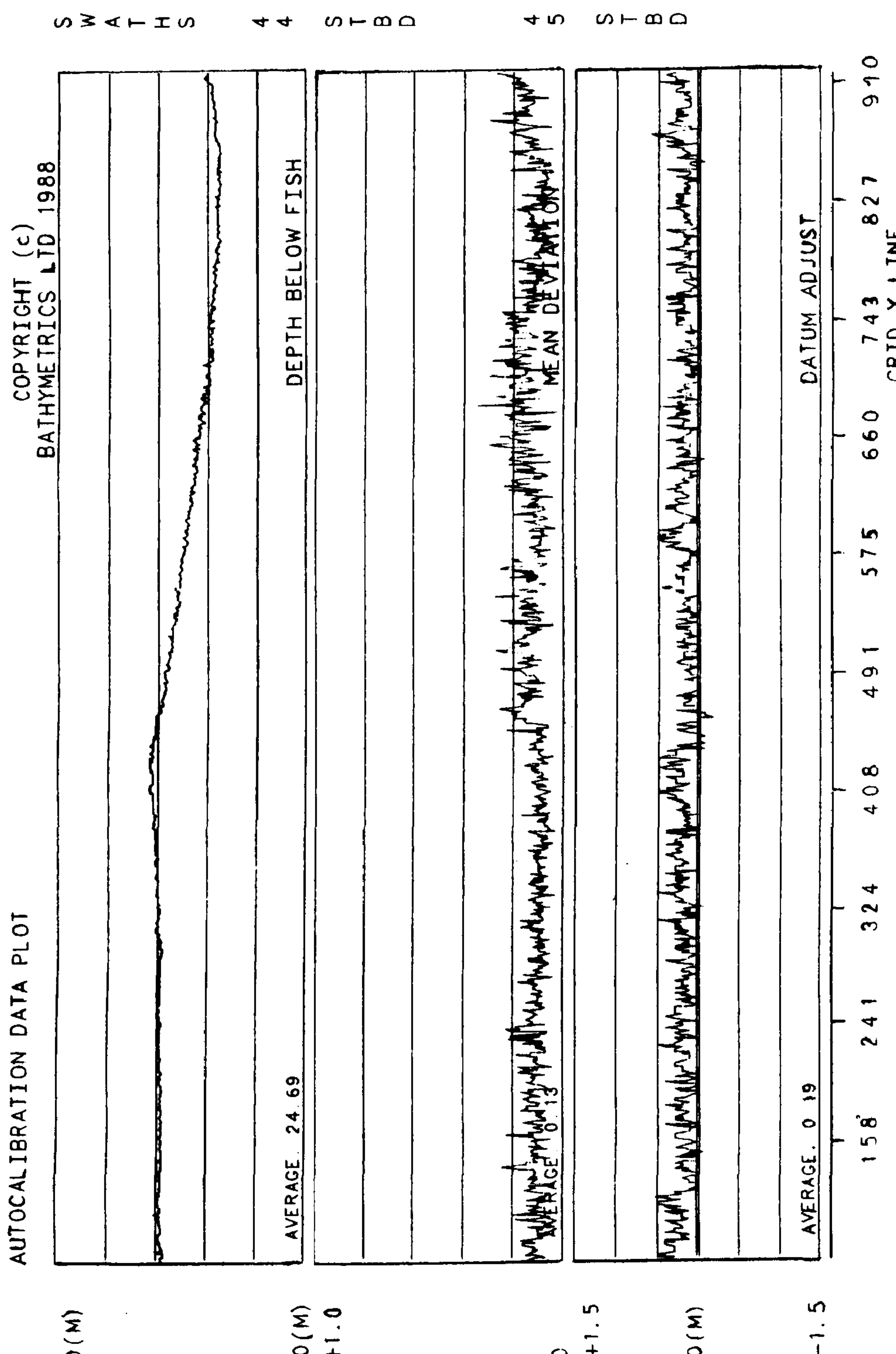

FIG. 2. — The calibration plot shows: (a) the gridded depth profile, (b) the deviation of the depth misclosures in grid increments, (c) the tidal datum adjustment required to optimise the depth disclosure.

Because in this instance field data was used in an area which was far from smooth, it is conspicuous that, after a datum adjustment has been applied, the mean deviation trace clearly shows there are relatively larger misclosure errors caused by positioning on the slope of the seabed, as compared with the level area, and also at the foot of the slope where the depth profile shows small sandwaves. Misclosure in the latter area may also be due to limitations in the heading resolution.

The pertinent consideration is whether the size of the misclosure error matters for the intended use of the data. Suppose there is interest in capturing the shape, amplitude and orientation of features which have 'wavelengths' of about 20 m or more, with amplitudes of 0.5 m, a data spacing of 5 m should be sufficient to delineate them adequately, whereas a coarser grid would be liable to alias the features so that, regardless of a possibly highly accurate set of depth measurements, the survey accuracy could then not exceed 0.5 m. The accuracy of the survey is as dependent on the complexity of the seabed surface as it is on the precision with which individual measurements can be made. To put it more simply, where you measure matters as much as how you measure.

Assuming a depth matrix, having a mesh size of 5 m, is adequate as a replicable representation of the surface, this information can be stored on one side of currently available removable random access discs. The coverage achieved would be more than 150 km^2 per side, or 225 km^2 per disc, so that the entire North Sea could be contained in less than 20 discs on a scale equivalent, in the terms of current conventions, to 1:1000, were the data to be available to that density. Suffice it to say that there is a potential data compression from Raw to Source Data Base of 85M bytes in the former case to 40K bytes per km^2 if only depths are retained.

It is most desirable that a summary of the results of the pre survey calibration and of the dynamic synopsis tables, after position and datum corrections, should also be retained, together with a statement of the matrix unit adopted, to form essential parts of the source data base 'legend'.

The reliability of any sounding, and hence the degree of confidence one has, is greatly enhanced by the number of repeat measurements which have been made to confirm its value within a verifiable tolerance. In swathe sounding, this is best expressed by the population density of individual grid bins. Although the differences between the depth measurements within each bin may be due to small scale bedforms, so long as we have to depend on absolute positioning they are best considered as samples of the same depth area which cannot be discriminated, one from another, as independent depths. Therefore, regarding the significance of soundings as depth values, the number of measurements in each bin is a useful qualifier, the residual misclosure value indicates the reliability, and a measure of the positioning error ellipse will give meaning to the size of the swathe misclosures.

Experience has shown that bin densities in excess of 12, where the bin size is 5 m, do not greatly increase the reliability of the resulting sounding, although many more are normally available. It may well be that, for depth measuring purposes, the surveyor could carry out the survey at speeds exceeding the 6 knots hitherto used, so that the bin counts do not get needlessly great. However, the relative bedform shape resolution would then be coarser and there are many circumstances where he may wish to retain the shape detection facility which has become familiar from the use of sidescan sonar and depends on the data density, which remains available in the swathe sounder. Also, although some bin counts can be high, there are many circumstances where data is lost. The most obvious of these is where shadow occurs, something which is occasionally inevitable when sounding obliquely and at high angles, but there are others too, e.g. where dense fish shoals temporarily obscure, or where the underneath of the wake of a passing ship proves the stronger signal. There are instances where the temporary loss of positioning data causes a swathe segment to be lost. It is very useful to have the maximum data density for the eventual delineation of a wreck. In such a circumstance, it is very helpful to be able to zoom when the finest practical temporary grid size is needed as a two pass post processing procedure. It is then possible still to retain an adequate bin count in the smaller grid squares. It may also be profitable to use a more refined, and more time-consuming, swathe merging technique than absolute positions permits.

A Source Data Base should therefore be equipped with a minimum of three qualifiers, making the matrix four dimensional if stored at full density, equivalent to about 50 km^2 per storage unit. The qualifiers are: depth tolerance, depth density, position tolerance. However, it may be felt unnecessary to store all these values in as much detail as a 5 m depth matrix. An alternative would be to introduce a simple code, on a coarser matrix overlay, denoting the percentage exceedance over threshold accuracy values.

We should not lose sight of how the data may be used. Suppose we need to store metric data, e.g. a lost container. In order to delineate it as an identifiable object, a metric grid would be required and such detail would exist in the swathe Raw Data Base. It would be immensely wasteful to supply the user with a data density which would produce positions and depths of many points on it. The object has an identifiable shape, available as a reference image if necessary, but shown as inhabiting a particular grid bin of the depth matrix. It would appear logical that even if the purpose is to be able to remove the obstacle, it should be sufficient to be able to approach to within positional accuracy in order to find it again.

If economies of storage as described are applied, it would not demand too much additional storage to include information refinements, at present quite impossible, even if it were available, such as a record of the stability or otherwise of certain areas. This kind of data, which is so rarely available, becomes a by-product of a data base system organised as a grid, where repeat surveys are obtained. It permits the scale of effort and the required survey frequency to be monitored. These are all confidence building qualifiers which are likely to be more meaningful than age or the scale of the survey graphic.

There is at times also a need, or a desire, to restrict access to information because the origin authority having invested in the data wishes the potential user to pay an appropriate fee for access to it, or simply for defence security reasons. This may have to be achieved by compiling an alternative Source, the composition of which depends on which aspect of the data is to remain undeclared, though without, in the process, risking environmental damage through not identifying the existence of certain hazards.

Since surveys may have a life of decades if not centuries, it is quite possible that reworked Source Data Bases can be produced at a later date, e.g. as it becomes possible to hindcast improved tidal information. Repeated surveys of an area may identify unsuspected systematic errors in an earlier survey leading to more accurate forecasts of expected bed levels to be incorporated in a User Base enabling a channel to be used more fully and safely.

8. THE USER DATA BASE

It would not be surprising if navigational users of seabed data were tempted to complain that a chart contains a lot of information they cannot use, or do not need, while at the same time they could do with a larger scale chart along the route being followed. Alternatively, an oil company wishing to erect a platform or lay a pipeline, almost invariably has to resurvey, even in supposedly well surveyed waters, because of lack of detailed information in limited areas of direct interest. The dredging operator could programme the deployment of his vessels much more tightly if he had detailed depth data.

Supposing the user is a navigator, he is not likely to need any qualifiers, which give additional information about depth, or positioning accuracies, outside his ship's draught area and is probably also less interested in having a high density depth matrix outside the draught area. The value of charted data outside this area is more that of a map, i.e. a more generalised description of the area which may nevertheless assist in understanding the behaviour of other traffic, much as road users like to be able to anticipate others' reactions.

Extracting the data actually desired by a particular user, or user group, from a Source Data Base, and providing it in an easily accessible form, is a reasonably simple and inexpensive operation. It is possible to provide the navigational customer with tailor made and detailed data sets covering sizable specific areas.

In producing a User Data Base we must also cater for 'landmarks', i.e. seabed features which should be visible on the echo sounder record and are important, though often too small to be adequately delineated even by the Source matrix. Although to depict something like a wreck fully would require a very fine mesh, the navigator will be quite satisfied if its existence is posted into the relevant grid bin with an annotated depth because he would not wish to approach it as close as that anyway. Navigational aids can be treated in a similar manner as bin annotations. Information and detail which is important, but cannot be adequately delineated by the User matrix, can be treated in the same way as qualifiers are in the Source Data Base. For navigational purposes a code, attached to the grid square containing it, denoting 'wreck', or an object on the bottom, or a floating marker, i.e. buoy, will suffice. If shape detail of features or objects which occur infrequently, is demanded, the code can form part of a driver matrix which is an indirect address device to a sub file containing details of size, shape and orientation.

It has been suggested that the Source Data Base should be constructed to a Mean Sea Level tidal datum but, for navigational purposes, it may remain desirable to provide a low water datum in the User Data Base. Tidal information is already available in some sea areas on a matrix, so that instead of having slightly different L.A.T., or similar datum, for the areas of adjacent surveys, these corrections can be supplied on the same basis across surveys of different date. Because the Source Data Base is not affected, this information can be updated whenever it is necessary, thus retaining the safety measure which is an important ingredient of the paper chart.

Collecting data costs money. Whether it is done by a government agency or a commercial concern, there is always a need to justify this expenditure or to recoup the investment. Governments may also have security reasons for limiting access to the data bases, but they are acutely aware that there are potent reasons for declaring the presence of environmental hazards. It would not seem beyond the wit of man to compile User Data Bases which provide safe Bases with an accuracy qualifier appropriate to the User, although not necessarily fully representative of the Source qualifiers for the area.

The commercial approach could be more flexible. The royalty dues on copies of the User Base could be calculated as maximum for an optimum Source Base resolution, decreasing for a modified value of the latter. It may then be possible for data collected commercially to be 'sold' on a royalty basis to the charting agencies, the level of responsibility and accountability being unambiguously identified to reside with the originating authority. This type of data manipulation is a relatively trivial exercise. It depends mainly on appropriate accounting formulae being agreed by the principal Source Base producers, distributors and users.

The navigator would now be in possession of sufficient depth data to match a sample of it to the record being produced on passage by his echo sounder, or alternative sounding equipment, bringing him close to having a bedform tracking facility, capable of yielding, where sufficient topographic texture exists, independent shipborne location information. To achieve the density of data, making this possible, the User Base has been slimmed down to his usable depth zone, and the tolerances used in its construction affect the acuity of the location facility. Elsewhere the User Base has a coarser matrix unit or is derived from a filtered surface.

Two types of 'qualifiers' have been mentioned. The first is no more than supplementary information relating to the first dimension of the depth matrix. Thus a depth D can have a D_t = depth tolerance, based on a B_n = bin population density of n values, and a P_r = positional resolution. In the second case, the numerical value, stored in the appropriate matrix location, is the address, i.e. the file number where the relevant information is located. It is equivalent in some ways to the instructions at present found on the chart, e.g. 'See note 1', or 'For further information consult the Coastal Pilot'. The chief difference is that there can be a default display, i.e. the message *will* appear on the screen unless it is cancelled deliberately. When and where, in the course of using the data, this appears, is a matter which needs to be discussed with the User community.

9. WHAT ABOUT THE PAPER CHART ?

Paper based navigational charts have always presented production problems in the economic sense. It is impractical to have large editions resulting in an unfavourable ratio between setting up printing and the duration of production runs, because of the need to maintain them fully and safely corrected. They can only contain a limited amount of information, because they serve as navigational tools on which insertions have to be made which do not become obscured by a mass of detail. When a User Data Base becomes available, it will not be possible at one and the same time to display great detail and the entire route. Therefore, routeing charts remain necessary and, because the detailed updating is applied to the User Base, the paper chart can show more of the permanent, or at any rate long term, information with more elaboration at acceptable production costs. Effectively, what is being advocated is larger scale equivalents of the International Chart Series.

10. CONCLUSION

An agreed procedure for the construction of qualified data bases, made possible by the use of swathe sounder data, will lead to better controlled survey records, the product of which will be used more fully, if selectively, while allowing levels of confidentiality of existence, origin or even authorship of data to be maintained where necessary. Because the use can be fine tuned, the cost benefit of each stage of the production of data bases can be identified. This can only benefit international data communication and, in the process, enhance the protection of the environment, where interfacing with complementary data bases becomes practical, and increase safety for the many users.

No mention has yet been made of the facility which already exists to present structured data bases visually so that they are more easily interpreted through the use of graphics, whether on screen or as hard copy. It does not seem an unattainable ambition to imbue the underwater scenery with some of the richness of information about so much of our environment on land, which all of us sighted people experience every day of our waking lives.

The seabed is reputed to be composed of features with varied timescales of persistence which makes recording their shapes an operation having a limited duration of usefulness, unless the discovery of such timescales is the purpose of the survey. It is therefore not merely the technical capability of presenting any degree of fine detail, but the practicability of collecting it economically and accessing the resulting data, which has to be considered. Practicability has to be seen in the light of cost, time, and skill levels which may be required, and value for money depends on the level of the technical need to know, or the perceived future need to know. If the features are significant, but have a short persistence, it may be less useful to have a measure of their shapes than of their mode of behaviour and a representative indication of their dimensions. The measurement of short persistence features requires a rapid capability to record detail accurately, over a usefully large area. Therefore, efficiency of coverage, at a predetermined level of accuracy, is in such a case to be preferred over a system potentially capable of showing more detail, but over a timescale which may exceed the persistence period of the features being surveyed. There is also little value in producing a chart depiction of bedforms which will have changed by the time the latter has been compiled and brought into use. The depths shown have to have practical value, not merely historical interest, as is sometimes the case now when only a pilot can use the results of a survey in the light of his extensive, and subjective, local experience.

Although knowledge of short persistence periodicity is useful in deciding on the instrumentation necessary to acquire the data, and the level of bathymetric detail it is worth while recording, an efficient data base must also take account of long persistence and permanent features. It can be critical to have as objective a measure as possible of the quality of the historical data. Sea areas may begin to be used in ways never contemplated at the time the survey was carried out, and it could be highly desirable to review such data from time to time so that suitable cautions may be issued to users, or timely decisions made about the need to re-survey, the better to meet the altered usage of the area.

Reference

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