NOTES ON HYDROGRAPHIC ASSISTANCE TO THE SOLUTION OF SEA BOUNDARY PROBLEMS

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Introductory remarks

The present paper does not pretend to be a systematic account of all relevant hydrographic operations; it is merely a collection of personal notes and points relating to sea boundary problems, i.e. those of baseline systems, extension of internal and external territorial waters, fishery limits, continental shelf delimitation, division of the seabed and subsoil on the high seas, and similar problems.

A great many of these notes arise from my experiences during the trilateral negotiations between West Germany, the Netherlands and Denmark resulting from the judgment of the International Court of Justice (20 February 1969) in the North Sea Continental Shelf cases.

From a hydrographic point of view there is a general impression that great importance should be attached to the concise and accurate definition or determination of delimitation lines, areas cut off, etc., in relation to the practical means for accomplishing future precise geodetic and nautical fixing at sea. More specifically, the need for a uniform geodetic or hydrographic approach to the adequate solution of sea boundary problems has arisen. It is felt that if this need is not satisfactorily met there will be general confusion when moving further out to sea (cf. U.N. activity on the Law of the Sea).

Basic material

The complex of Geneva conventions dated 29 April 1958 forms the nucleus of the relevant basic material. These conventions are in particular:

a. The Convention on the Territorial Sea and the Contiguous Zone.
b. The Convention on Fishing and Conservation of the Living Resources of the High Seas.
c. The Convention on the High Seas.
d. The Convention on the Continental Shelf.

National laws and decrees based upon the Geneva conventions, as well as upon existing bi-, tri- and multi-national agreements of analogous substance, constitute the legal part of the written material.

Official charts and maps, professional manuals and directives are the fundamental aids of the hydrographic specialist charged with sea boundary problems.

Professional experience and knowledge

A sound knowledge of the pertinent basic material and professional literature is required. Beyond a thorough understanding of projections and their properties, of chart datums and their references, the hydrographer should more specifically be familiar with the reliability and accuracy of the geodetic or hydrographic data material on which charts and maps of the region in question are based. Furthermore, he should be currently informed regarding the practical possibilities in precise geodetic or nautical fixing.

The principles governing the construction or drawing of baselines as well as the character and the geometry of the various delimitation lines (thalweg, equidistance line, median line, equal-area cut off lines, etc.) should also be well-known to the hydrographer.

The hydrographer often needs technical assistance from his office in the field of geodetic computations or transformations and such cartographic work as the production of graphic outlines, drawings, etc.

PRESENTATION OF SELECTED PROBLEMS. DISCUSSION ON SUGGESTED TECHNIQUES AND PROCEDURES

Baseline systems

Take such expressions as "fringe of islands", "general direction of the coast", "low water line" (reference (a) of Article 3.4). The implicit definitions and the explanations appear sound, but in fact they are insufficient. As regards islands forming a fringe, how big are these to be ? How much should the intermediate distances between them be ? How far may they lie off the coast ? How can an island, a reef, or a shoal be defined when information on tides is lacking ? Of course, some guidance or suggested answers may be found in the literature, but much is left to the hydrographer's imagination, and much is dependent upon the state of his hydrographic knowledge. In the same way, what is actually the general direction of a specific coast, especially in relation to the expression "baselines must not depart to any appreciable extent from the general direction of the coast" ? Is it a question of distances in absolute measurements, or of "chart" distances irrespective of scale ? (See figures 1 and 2).

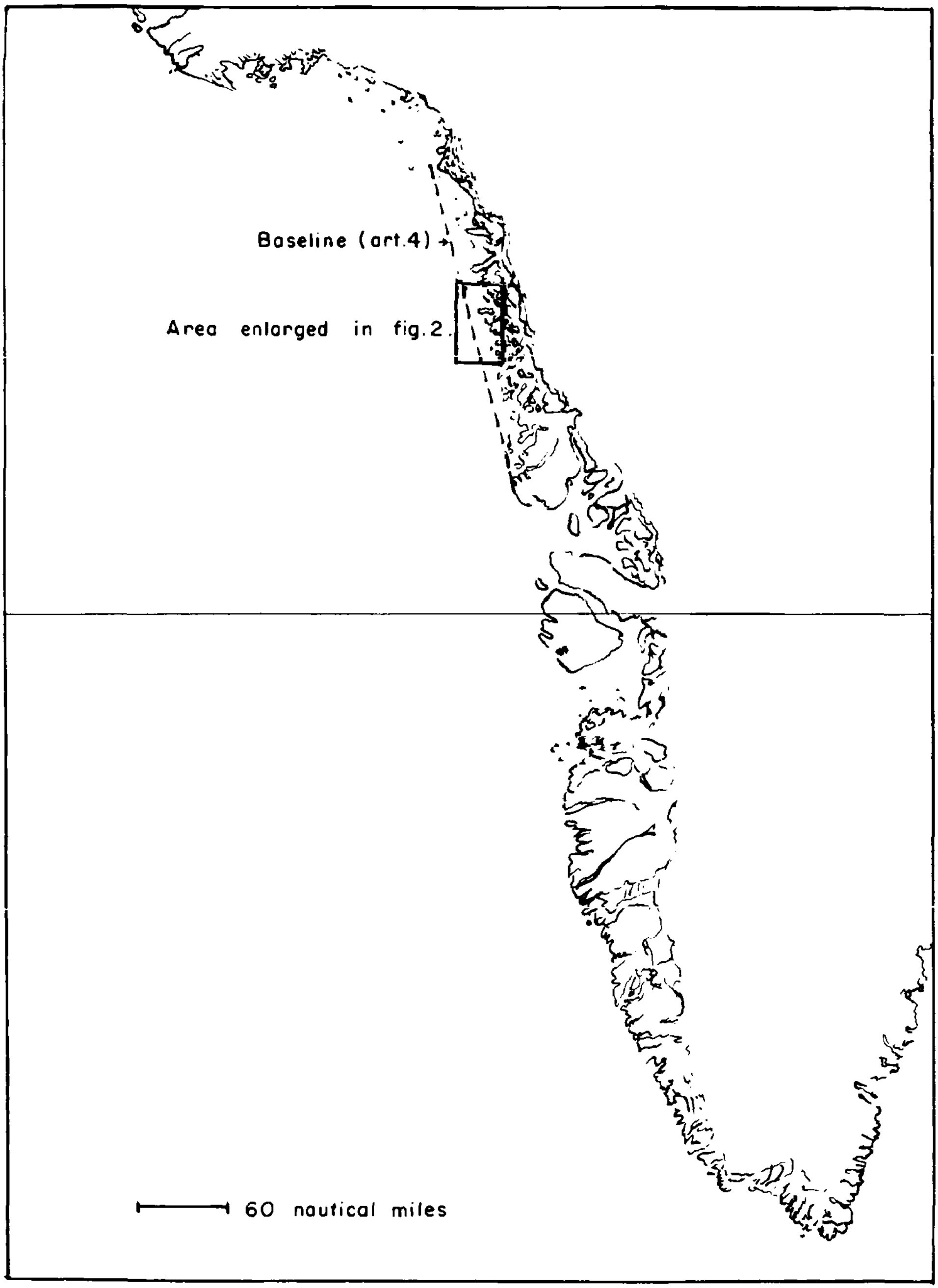

FIG. 1. — The west coast of Greenland.

As regards the low water line, it is generally accepted that in most cases the topographical coastline is not identical with the chart datum coastline. But are we sure that it is equally well-known and appreciated that the low water line does not always correspond to chart datum level which, depending on the circumstances, could be mean sea level, mean lower water level, mean low water springs level, lowest low water level, etc. Another point : does the wording "low water line" as used in the Convention refer only to the astronomical tide, or is the meteorological tide also allowed to play a part in certain regions ?

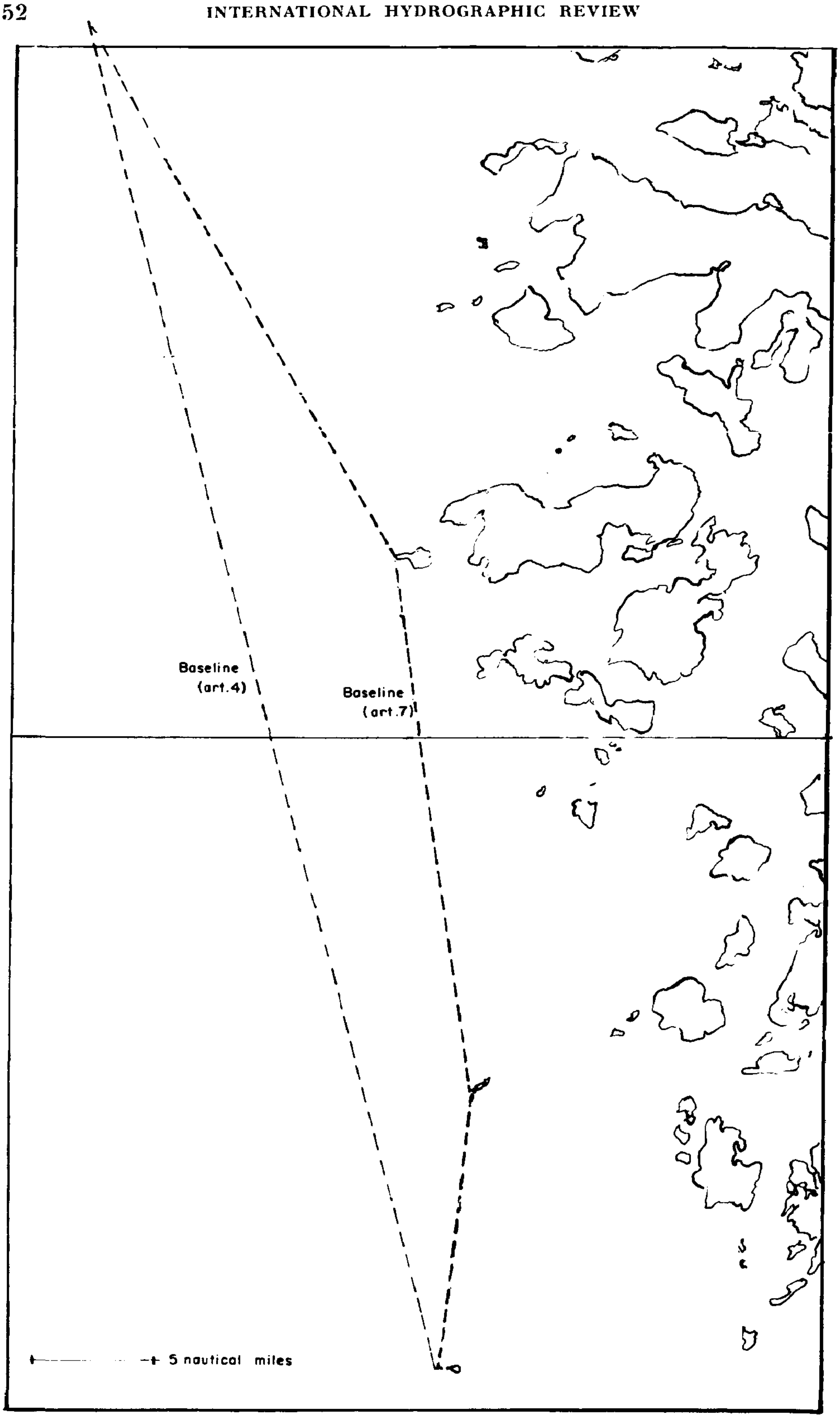

FIG. 2. Detail of figure 1.

The above examples drawn at random from the international rules give some indication of the nature of the problems with which the hydrographer is faced when asked to outline baseline systems. Of course, when the coastal facade is steep, the influence of the above indicated factors, apart from their effect on doubtful islands or reefs, is only of minor importance, but the case of a foreland or a cape with a high tidal range and a slight littoral gradient, the actual position of the baselines, baseline points, or low water line may influence not only the extent of the internal and external territorial waters, but also — and this is perhaps more important — the position of a lateral equidistance line between adjacent states. Figure 3 outlines situations which severely affect the course of lateral equidistance lines. It goes without saying that any possibility of interpretation as to the actual position of the low water mark may equally cause deviations in the general direction of the line.

Accordingly, the provision of some sort of technical criteria would be useful in order to avoid future criticism and confusion.

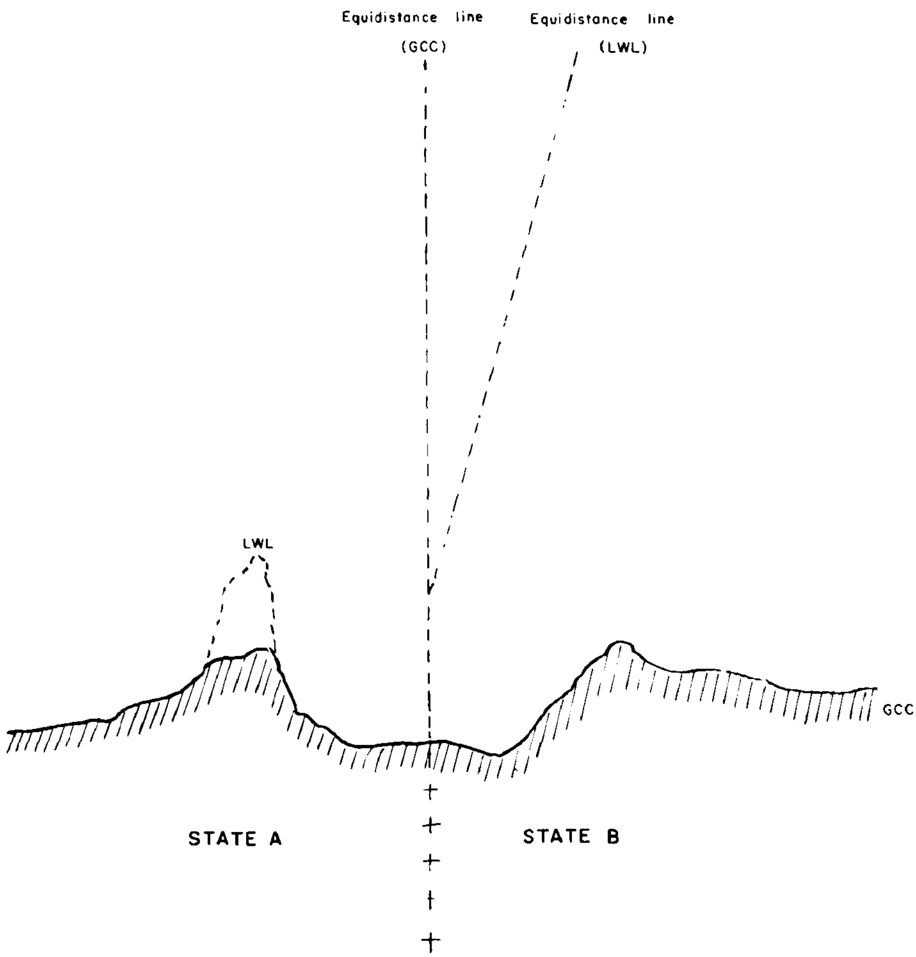

Fig. 3. — Sketch illustrating the discrepancy between lateral equidistance lines referred to the geodetic coastal contour (G.C.C.) and to the low water line (L.W.L.). To simplify L.W.L. only departs from G.C.C. at the conspicuous point of State A.

Construction or calculation of the median and the equidistance line

According to reference (d) of Article 6 the median or the equidistance line on certain occasions may serve as the continental shelf delimitation line between opposite or adjacent states. As regards geometry there is no difference between the two lines — both of them are multi-legged perpendicular bisector lines referred to the Earth as an ellipsoid of revolution.

A detailed description of the practical construction of the median or the equidistance line with a pair of compasses or by the protractor method has been given by R.H. KENNEDY (1958) (*).

The advantages of such a procedure are obvious: it is simple, easily done and fairly accurate when constructed on a true distance and angle chart (e.g. Lambert's conformal conical projection). Due to distortion the accuracy on the ordinary nautical chart (Mercator projection) will only be accceptable for cases of small distance at moderate latitudes.

With a view to an exact automatic calculation of the median or the equidistance line a few introductory remarks should be made. The individual leg of the line is no simple geodetic curve, i.e. it is neither a loxodrome (straight line on the Mercator chart) nor a great circle arc (shortest line between two points on the sphere) nor an ellipsoidal geodesic (shortest line between two points on the ellipsoid of revolution, which is the mathematical reference surface for charts and maps).

With a view to the practical applications of the delimination line the question of a reasonable simplification of its mathematical stringency should be examined. Where the final legs of the delimitation line are less than, say, 100 km great circle arc representation could be used without any appreciable error. In cases of greater distances — for example on the high seas — geodesics are perhaps to be preferred.

How should the problem of basic automatic calculation of the median or the equidistance line be attacked ? Primarily, the low water line that closes the lines of bays, and the baselines which together form the rectified coastline of the respective states must be digitized in the Universal Transverse Mercator grid system (UTM — metre coordinate system) or in a similar universal grid system. The discretional choice of coastal points (see figure 4) could for instance be based on a preliminary plot, as proposed by KENNEDY (1958). Charts on Lambert's conformal conical projection or another true distance and angle projection and at an adequate scale should be preferred to the Mercator projection chart. One should be careful that all prominent points, continental-shelf governing islands, and other appropriate zones of the coast are sufficiently covered; concave zones of the coastline representation that are definitely irrelevant could of course be omitted. All the coordinated points for both State A and State B must necessarily refer to the same UTM coordinate system.

From a geodetic or a hydrograhic point of view the mere calculation of distances along geodesics is a simple operation which could be carried out

(*) R.H. KENNEDY : Brief remarks on median lines and lines of equidistance and the methods used in their construction. Presented at the Geneva Conference on the Law of the Sea, 2 April 1958.

with practically infinite accuracy. The computer strategy aiming at an exact automatic definition of the median or the equidistance line is, however, somewhat involved.

The following line of thought is suggested (cf. figure 4).

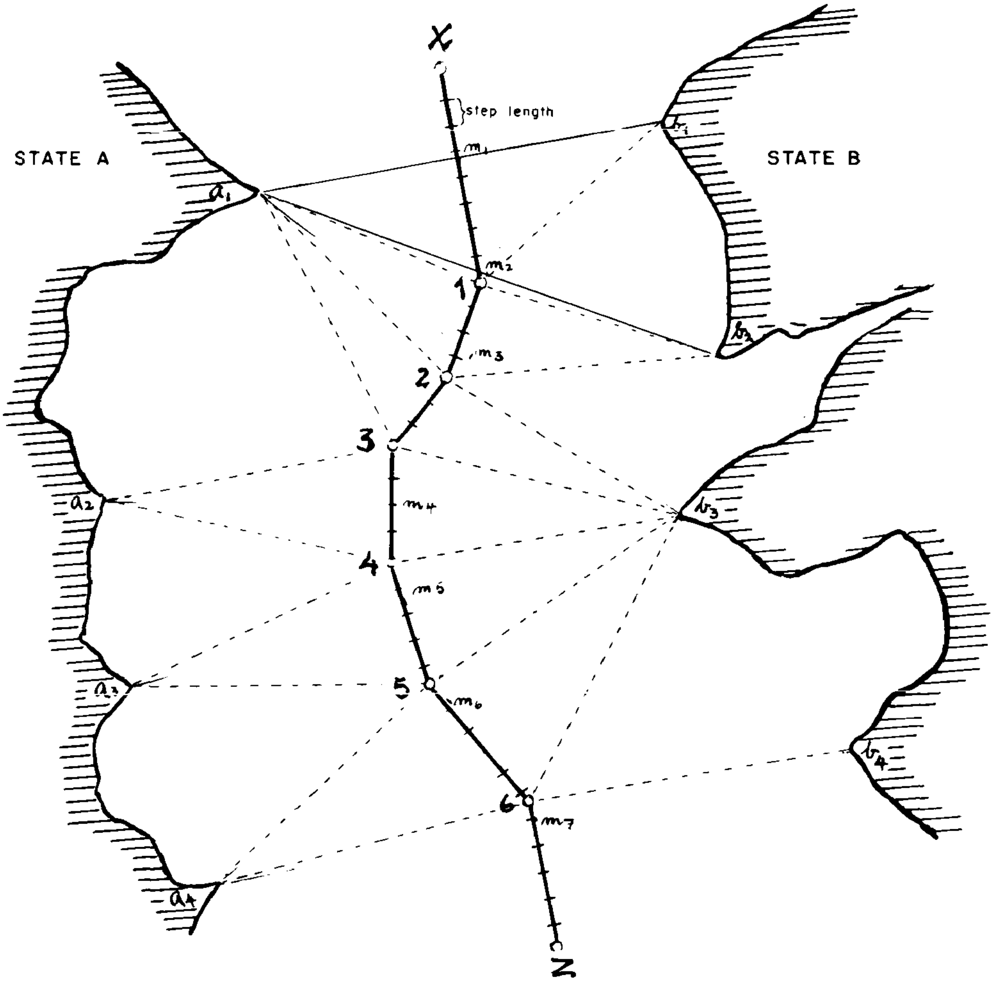

FIG. 4. — Illustration of the construction of an equidistance line between opposite states. To simplify, baselines are not drawn, and only one point at each conspicuous foreland is considered.

Input : digitized coastlines marked A or B.

First, the geodetic distance and azimuth of line a_1b_1 is computed. Then the midpoint m_1 of a_1b_1 is determined. Steps of a chosen length along the perpendicular bisector line relative to a_1b_1 are introduced, and corresponding preliminary points are calculated beginning at position X. By an iterative procedure the exact position of the discretional points on the bisector line are then determined. The distance from each of the final discretional points to the remaining coastal points is tested; when the distance to a new point on one or the other side becomes less than the distance to the original points a_1, b_1 a normal halving procedure is started up to encircle the exact position of the tri-point in relation to a_1, b_1, b_2. Then either point a_1, or b_1, is disregarded, according to whether a_1 or b_1 is situated on the side of the new point. In the case of figure 4 it is b_1 which is disregarded. Slightly modified, the step procedure is then regenerated on the new bisector line (a_1, b_2) and so on until a final position Z is reached.

Output : coordinates (UTM or geographic) of the sequence of the median or the equidistance points. The coastal points used are listed in numerical order.

When the coastlines are rather complex (many islands, indentations, capes, etc.) the equidistance line will accordingly be short-legged and ondulated. In such cases the parties may often tend to reach a settlement by replacing the mathematically stringent line by a series of relatively long loxodromes, great circle arcs or geodesics between true equidistance points, and drawn in such a way that areas of equal size or of equal economic potential on either side of the true equidistance line are cut off.

A combination of iterative electronic computer calculations and accurate plotting has been used in a few cases in connection with the division of the North Sea continental shelf. The procedure, however, is rather involved, and is not very satisfactory from a general point of view.

Measurement or calculation of areas

The hydrographer will often be faced with problems involving measurement or calculation of areas of various shapes and sizes. When only a rough estimate is required, the Mercator projection chart at a suitable scale may be used. In this case the most accurate way is to divide up the area in question into latitudinal slices, and for each slice to use the relevant square unit (see International Geographical Union : Geographic Conversion Tables, 1961). The measurement could be completed by subsequently adding the areas of the plane triangles or trapezia. A planimeter might also be used, of course, when only a moderately accurate result is desired. Depending on the size and shape of the figure encircled by the planimeter, a relatively high accuracy may be obtained. An estimate of the standard error is established by repetition of the manual process.

An exact calculation of a surface area at sea can generally be made if the boundary lines are well defined geometric curves, i.e. if all the boundary lines are loxodromes, great circle arcs, or geodesics. Of course, the dimensions of the Earth (the excentricity and the ellipsoidal major axis) enter into the calculations if the result is required in km^2 or square nautical miles.

Details of the delimitation line

For the reasons indicated above there should be a common agreement among coastal nations in a specific area to adopt uniform geometry for the delimitation lines. Due to the spherical shape of the Earth, the ellipsoidal geodesic between two points is strictly speaking the correct curve (the shortest line on the ellipsoid of revolution). However, the departure of the geodesic from the corresponding great circle arc and the loxodrome is negligible when it is only a question of short distances at moderate latitudes. From the point of view of mathematics the great circle arc is easy to handle; if distances have to be expressed in metres or in nautical miles the mean radius of the Earth corresponding to the area in question must of course be introduced.

Whereas the loxodrome is presented as a straight line on a Mercator projection chart, on the elliptic Earth it is a complicated line of double curvature. As the Mercator projection chart has long been utilized universally for nautical charts, by tradition the loxodrome has up to now also been used to represent the shortest line between two points at sea, although it is a very poor representation when distances exceed a few nautical miles. In future calculations perhaps the geodesic or the great circle arc should always be chosen, except when all the legs of the delimitation line are short.

Very often it is useful to have details about the dividing lines, in the form, for instance, of a sequence of coordinates for the intermediate points. Table I is a list of sub-points on the great circle arc between :

A { 55°45′54″.00 N / 03°22′13″.00 E } and B { 55°20′00″.00 N / 04°20′00″.00 E }

TABLE I

Computer output : List of great circle sub-points, and distance (D) between points A and B.

A :	55 45 54.00	03 22 13.00		55 33 07.57	03 51 00.00	D : 77 236.66 m
	55 45 33.34	03 23 00.00		55 32 40.67	03 52 00.00	
	55 45 06.95	03 24 00.00		55 32 13.76	03 53 00.00	
	55 44 40.54	03 25 00.00		55 31 46.82	03 54 00.00	
	55 44 14.11	03 26 00.00		55 31 19.87	03 55 00.00	
	55 43 47.67	03 27 00.00		55 30 52.89	03 56 00.00	
	55 43 21.21	03 28 00.00		55 30.25.90	03 57 00.00	
	55 42 54.73	03 29 00.00		55 29 58.89	03 58 00.00	
	55 42 28.23	03 30 00.00		55 29 31.86	03 59 00.00	
	55 42 01.71	03 31 00.00		55 29 04.82	04 00 00.00	
	55 41 35.18	03 32 00.00		55 28 37.75	04 01 00.00	
	55 41 08.63	03 33 00.00		55 28 10.67	04 02 00.00	
	55 40 42.06	03 34 00.00		55 27 43.57	04 03 00.00	
	55 40 15.47	03 35 00.00		55 27 16.45	04 04 00.00	
	55 39 48.86	03 36 00.00		55 26 49.31	04 05 00.00	
	55 39 22.24	03 37 00.00		55 26 22.15	04 06 00.00	
	55 38 55.59	03 38 00.00		55 25 54:98	04 07 00.00	
	55 38 28.93	03 39 00.00		55 25 27.78	04 08 00.00	
	55 38 02.25	03 40 00.00		55 25 00.57	04 09 00.00	
	55 37 35.55	03 41 00.00		55 24 33.34	04 10 00.00	
	55 37 08.84	03 42 00.00		55 24 06.09	04 11 00.00	
	55 36 42.10	03 43 00.00		55 23 38.82	04 12 00.00	
	55 36 15.35	03 44 00.00		55 23 11.53	04 13 00.00	
	55 35 48.58	03 45 00.00		55 22 44.22	04 14 00.00	
	55 35 21.79	03 46 00.00		55 22 16.90	04 15 00.00	
	55 34 54.98	03 47 00.00		55 21 49.55	04 16 00.00	
	55 34 28.16	03 48 00.00		55 21 22.19	04 17 00.00	
	55 34 01.32	03 49 00.00		55 20 54.81	04 18 00.00	
	55 33 34.45	03 50 00.00		55 20 27.41	04 19 00.00	
			B :	55 19 59.99	04 20 00.00	

The list has been calculated by electronic computers and gives the geographical latitude to the nearest hundredth of a second of arc for every full minute of geographical latitude. It should be observed that the steps are longitudinal, and not true distance steps, and this is due to the major influence of the general direction of this particular leg. The number on the right is the distance to the nearest hundredth of a metre along the great circle arc (1 minute of arc latitude being equal to 1852 metres). If required, sub-intermediate points up to the same accuracy can be calculated by linear interpolation.

Intermediate points on the loxodrome or on the geodesic could be calculated in the same way.

Notes especially concerning the judgment of the International Court of Justice in the North Sea Continental Shelf cases

Although the judgment (20 February 1969) concerns a specific case, some of the indicated principles and factors in the field of geophysics and hydrography have a general character. The following is a quotation from the relevant part of the judgment.

"101. For these reasons,

THE COURT,

by eleven votes to six,

finds that, in each case,

(A) the use of the equidistance method of delimitation not being obligatory as between the Parties; and

(B) there being no other single method of delimitation the use of which is in all circumstances obligatory;

(C) the principles and rules of international law applicable to the delimitation as between the Parties of the areas of the continental shelf in the North Sea which appertain to each of them beyond the partial boundary determined by the agreements of 1 December 1964 and 9 June 1965, respectively, are as follows :

(1) delimitation is to be effected by agreement in accordance with equitable principles, and taking account of all the relevant circumstances, in such a way as to leave as much as possible to each Party all those parts of the continental shelf that constitute a natural prolongation of its land territory into and under the sea, without encroachment on the natural prolongation of the land territory of the other;

(2) if, in the application of the preceding sub-paragraph, the delimitation leaves to the Parties areas that overlap, these are to be divided between them in agreed proportions or, failing agreement, equally, unless they decide on a régime of joint jurisdiction, user, or exploitation for the zones of overlap or any part of them;

(D) in the course of the negotiations, the factors to be taken into account are to include :

(1) the general configuration of the coasts of the Parties, as well as the presence of any special or unusual features;

(2) so far as known or readily ascertainable, the physical and geological structure, and natural resources, of the continental shelf areas involved;

(3) the element of a reasonable degree of proportionality, which a delimitation carried out in accordance with equitable principle ought to bring about between the extent of the continental shelf areas appertaining to the coastal State and the length of its coast measured in the general direction of the coastline, account being taken for this purpose of the effects, actual or prospective, of any other continental shelf delimitations between adjacent States in the same region."

Paragraph C (1) reads "... natural prolongation of its land territory into and under the sea ...". Up to this point it is only a question of the continuation of land masses into the sea from a geographical rather than from a geophysical point of view. According to paragraph D (2), however, both the geophysical and the geological structure as well as the natural resources should be evaluated and taken into account as relevant factors. Very often the geographical and the geophysical aspects are in conflict, and thus some sort of compromise must be reached.

Paragraph C (2) deals with the division of overlapping areas. It goes without saying in this connection that the hydrographer will be charged with making a series of area calculations paying due regard to the estimated value and character of the region concerned. The wording of paragraph D (2) should be taken in its widest sense. Not only is the sea floor bathymetry and its general morphological features of great importance, but also an evaluation of the known natural resources (minerals, oil, gas, bottom fauna and flora, etc.) on the seabed and in the subsoil forms a significant element. An estimate of potential possibilities in the field of ocean and coastal engineering, aquiculture, etc. could also be incorporated in the negotiations between the contracting parties. Although the hydrographer himself may have an insufficient knowledge of the various scientific fields, he may be asked to collect, coordinate and present information of this kind. Often it might prove useful to produce charts or maps showing quality assessments for the areas in question.

As regards paragraph D (1), the hydrographer, in particular, should be aware of the presence of any conspicuous foreland or cape which might have an excessive influence on a purely geometric delimitation line. The size and situation of any off-lying island should also be carefully investigated to see whether it should have its own shelf or simply be linked to normal territorial waters.

Paragraph D (3) confronts the hydrographer with area calculations which vary in proportion to the lengths of coastline, and he must pay due regard to the actual or possible effects that adjoining shelf delimitation lines could have on his own work.

Generally speaking, we could perhaps say that the hydrographer should be able to give some concrete answers to each of the points indicated above, although it would be up to the expert in international law to propose to what extent the various principles and factors should be applied in order to meet the requirement of equity.