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Mapping of Tidal Flat Areas by New Methods

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SUMMARY: Mapping of tidal flat areas is characterized by two new methods and by the use of electronic data processing applied in both cases. The new methods are the electronic recording tacheometry and water-line method. In the first case automatic procedures refer to the interpolation of the contours in a network of automatically formed triangles. The second case deals with the digitizing of water-lines and their transformation into contours.

RÉSUMÉ: La production des cartes de veys est caractérisée par deux méthodes nouvelles et par l'emploi du traitement électronique des données dans ces deux cas. Les méthodes nouvelles sont la tachéométrie enregistreuse électronique et la méthode des lignes d'eau. Dans le premier cas le traitement automatique se rapporte à l'interpolation des courbes de niveau dans un réseau triangles établi automatiquement. Le deuxième cas traite la digitalisation des lignes d'eau et leur transformation en courbes de niveau.

ZUSAMMENFASSUNG: Die Herstellung von Wattkarten ist gekennzeichnet durch zwei neue Verfahren und durch den Einsatz der automatischen Datenverarbeitung in beiden Fällen. Die neuen Verfahren sind die Registriertachymetrie und die Wasserlinienmethode. Im ersten Falle bezieht sich die automatische Verarbeitung auf die Interpolation von Höhenlinien in einem automatisch gebildeten Dreiecksnetz. Der zweite Fall umfaßt die Digitalisierung der Wasserlinien und ihre Umformung in Höhenlinien.

1. Preface

Tidal flat areas are continuous sheets of land, usually plain sands, periodically being covered by water due to the influence of the tide. Formerly, their cartographic representation was very neglected: In topographic maps they were only represented by their outlines while in charts beyond that some altimetric information was given. The increasing importance of these areas for environmental development, coastal engineering, traffic, fishery, etc. intensifies the demand for suitable maps at 1 : 5,000 scale and smaller.

The first systematic surveys of wadden areas started around 1930, were based on terrestrial methods (measurements of parallel profiles) or hydrographic processes (plumbing and position-finding from a ship). Nowadays there are two new methods:

— Electronic tacheometry with automatic recording,

— Water-line-method by means of air photographs.

In the evaluation, both methods are especially efficient by the application of electronic data processing.

2. Maps by electronic recording tacheometry

2.1. *Local survey*

The record refers to the following elements of a polar measurement: the electro-optically measured oblique distance, the horizontal and the vertical angle, both recorded from graduated circles. Beyond this, twelve digits allow the input of further information in a coded mode. The theoretical range of the instrument of the type RegElta 14 (Zeiss/FRG) is 2,000 m. In practice, however, maximum distances only of a little more than 1,000 m suffice. Survey work begins at the time of receding water and ends at the time of swelling water.

In relation to the map scale, the demands on the accuracy of position are always met. However, the observance of a standard deviation of ± 0.03 m in altitude at a distance of nearly 1,000 m is somewhat problematic. Such distances need special dispositions in order to obtain a high degree of reliability in the data of terrestrial refraction.

2.2. *Evaluation*

The punch tapes of local survey are submitted to an evaluation, the final result of which is a graphic data output in the form of a planimetric and terrain representation at a given scale. To solve this task, a programming system was developed within the scope of research work entrusted to the chair of topography and cartography of the Technical University Hannover. This system consists of several program modules, each producing an output list during execution. The contents of these lists allow to decide whether and how to modify the input data.

The programming system stands in the programming language "ANSI FORTRAN" and is adapted to the combination of the digital computer Cyber 73 and 76. This large capacity computer installed in the „Regional Computing Center of Lower Saxony" is a very efficient system disposing of large primary and secondary memories and an extensive periphery.

Unfortunately, this center has no precise flat bed plotter. Therefore the graphic output was performed on a drum plotter of the type Calcomp 1036. For this reason, it only has the character of a map compilation, not of an original. The drum plotter can draw within a breadth of 0.60 m, the length being optional. For the drawing, leads of ball-point pens are used, available in three colours. The geometric accuracy of the graphic results does not quite reach the geometric accuracy of precise plotters, however, it can be sufficiently compensated by the choice of larger drawing scales.

The program begins with a formal and logical check of the data followed by a corresponding correction. If required, adjustments of points are performed and finally the coordinates and altitudes of all measured points are calculated and stored. Thereby a digital terrain model of the surveyed area is at disposal.

Tidal flat areas present only a few topographic objects. Thus, the maps scarcely contain a planimetric representation and therefore further considerations will be turned to the terrain representation. Such areas being extremely flat, the interest of map users is not only turned to the contours but also to the representation of all directly measured points needed especially for technical projects. For this, the program offers the following possibilities:

- Automatic drawing of the points with their numbers or
- automatic drawing of the points with their height values.

As required, these representations may appear separately or together with the contour representation.

With the aid of a special subroutine program a triangle net is formed by the measured points, a method well known in classical tacheometry. Here the remarkable thing is that the third point of a triangle is found in relation to two given points by a method of automatic seeking whereby special geometric conditions are to be observed. The two points of the first triangle are automatically sought near the center of mass or are especially selected. Within the triangle net thus formed, a linear interpolation of the altitude values is made along the triangle sides to obtain the crossing points with the contours. The contours themselves result from a linkage of the corresponding crossing points by a polynomial of 5^{th} degree. With the available storage capacity, the program is able to process at one stroke 5,000 points at most and to calculate up to 100 contours. The program ends with the plotting instructions for the drum plotter.

The polynomial of 5^{th} degree for interpolation is used in a parameter mode separately for x and y. The curve is uniquely determined by 6 successive points, but only the section between point 2 and 3 is utilized.

In the course of the curve, difficulties may arise when several interpolated points are closely packed in the area of a common triangle point. To avoid unfounded salients or the like, the program is able to comprise two or more points to one single point when their distances among one another are smaller than a given value. The more this value increases, the more the course of the contours gets a generalizing effect.

With regard to a correct representation of the contours, the automatic processes of map compilation have their critical points there where the contours show a more strongly curved course. To guarantee a true automatic evaluation, there is a general rule: In these areas, the density of measured points must be increased. By that, the schematic formation of triangles does not neglect the areas of more strongly curved contours. The higher density of points leads to the development of more triangles. This in turn, leads to more points of interpolation, and thus, finally, to a more accurate course of the contour. Corresponding tests have substantiated the rightness of this demand.

3. Maps by water-line method

3.1. Principle of the method

The method starts out from air photographs taken at regular intervals of time e. g. every 10 minutes, and showing one water-line each. The water-line, for the most part well perceptible, is the boundary between the water surface and the tidal flat area still being dry. But these water-lines are only approximate and only in small sections identical with contours of a certain altitude. Therefore they must be transformed into exact contours of a round altitude value assigned to the cartographic representation by the choice of the equidistance.

3.2. *Local work*

As the water-lines have a sufficiently constant altitude, a single-photograph measurement without planimetric error is possible. However, the air photographs must be rectified. The elements of the exterior orientation not being sufficiently known, controlpoints for rectification are necessary. They are marked by signals above the high water level and fixed in their planimetric and altitude positions.

Hitherto, the necessary transfer of altitude values to the water-lines was predominantly carried out by means of especially installed water-gauges proportionately distributed over the whole area. However, such work being expensive, tests were recently made with altitude controlpoints being determined in unsignalized form before or after the taking of air photographs. Within the scope of such tests, a special case is the digitizing of water-line points which are at a later time located in the locality with the help of the computer Eltac (Zeiss/FRG) and then are determined according to their altitudes.

3.3. *Photographic flight*

The air photographs were taken at an approximate scale of 1 : 20,000 on infrared film material with a camera RMK A 15/23 (Zeiss/FRG). This corresponds to a flight altitude of nearly 3,000 m. The square dimension of the area is allowed to be only of such size that the aeroplane may fly over the area in successive turns every 10 minutes at the latest. Thus with a photo scale of 1 : 20,000 and a flight speed of 280 km/h, the maximum dimensions of the area are nearly 100 km^2. The flight begins at the time of low water and ends at the time, when the area is totally covered by water. With a normal tide, there are nearly 20 successions of overflying.

3.4. *Evaluation*

Of the original negatives of the air photographs, enlargements on film are produced at a scale of nearly 1 : 10,000. On these positives the water-lines are digitized, on every photograph one water-line. The digitizing is performed in a line following mode by means of a digitizer with light table of the type Aristo/Bendix. Owing to the large longitudinal overlap, all enlargements of one series related to a partial area always contain the same controlpoints for rectification. The digitizing of these points – three or four points per photo – and the data of the internal orientation of the camera allow to calculate a spatial resection with the aid of a suitable program and to rectify the photos numerically.

The further evaluation is based on the following work:

- The height differences between adjacent water-lines are deduced from the tidal curves recorded by the water-gauges.
- With the aid of the altitude controlpoints well distributed over the whole area, these relative values may be transformed into absolute altitude values.

- Then, within the connection line between two points of adjacent water-lines thus determined, the crosspoints of contours are deduced by linear interpolation. The chosen equidistance is 0.1 m and 0.2 m respectively at scales of 1 : 5,000 and 1 : 10,000. Near water courses, larger equidistances are used as well. The form of the contour itself between two crosspoints results from a weighted mean value of the respective sections of the two adjacent water-lines. Thereby the typical forms of the water-lines are preserved.

The topographical problems of contours in extremely flat areas are well known. In general, the contours represent chiefly the large forms and less frequently those small structures typical of tidal flat areas. For this reason it is intended to combine at a later date the contour representation with a rectified air photograph taken at the time of low water level. The result is a photo map showing in addition to the geometric information of the contours a sufficient number of image-like representations of the numerous small forms of the tidal flat area.