CHAPTER 148

AERIAL PHOTOGRAPHIC WATERLINE SURVEY OF AN ESTUARY

by

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Abstract.

The project of a barrage across an estuary in Northern Germany was accompanied by a programme to monitor the hydrologic and morphologic situation. This became necessary in order to avoid dangers resulting from the sensitivity of the shallow wadden area to human interference.
Various methods to record the morphology were tested. The aerial photographic waterline survey proved superior as it supplies a complete and economic record and allows accurate analysis of the topography.
The principle consists in taking aerial photographs at short time intervals between low water and high water, each photo showing a different waterline. The scale chosen was 1:18000, corresponding to a flight altitude of 2700 metres. Rectification of the distorted photos requires reference markers to be distributed over the survey area which measures about 140 km^2. By using simultaneous tide gauge records, contour lines can be constructed from the photographed waterlines.
This morphologic record is supplemented by submarine survey of the estuary. It is expected that details of sediment transport and of tidal prism changes may be revealed. Predicted and actual effects of the barrage will be compared, which might lead to a better understanding of such coasts.

1. The necessity of monitoring morphologic changes.

Aerial photography is certainly not new in coastal engineering. Here we shall have a closer look at the waterline method which differs from the conventional aerial photographic survey in several respects. Since 1965 the Wasser- und Schiffahrtsverwaltung (i.e. Federal Waterways Administration) in Germany applies this method, so that it should be possible now to report on its suitability.

In order to appreciate the need for monitoring an estuary, a brief look at the area concerned might be helpful. (Figure 1). Off the German North Sea Coast spreads an instable and shallow wadden area. Tidal flats, sand banks and channels shift frequently, especially in the funnel-shaped mouths of four major rivers. The tide is semi-diurnal and has a mean range in the order of three metres.

The particulars of the wadden area affect the tidal characteristics, the sediment transport as far as it is related to the tides, as well as energy and direction of waves attacking sea walls and eroding beaches. Thus, changes in the wadden area may result in an increased threat to the shore. Morphologic changes are important for shipping, too, which in this region is confined to a few navigable channels.

Some changes of the local morphology are expected as a result of a barrage built across the Eider estuary and completed in 1973.(Figures 2 and 3). It is about 5 kilometres long and allows to control the discharge of the river. Thus it is hoped to maintain a cross section required for draining the low marshes upriver. In addition, it serves as a flood barrier. Before the planning and hydraulic model tests started, the existing hydrologic and morphologic situation had to be recorded. During constructing changes had to be detected in time in order to allow the prevention of dangerous developments. And now, after completion, the actual effects of this interference with nature will be established and compared with the predictions as supplied by the model tests. Observations will continue until we can be sure that unfavourable changes are no longer likely to occur.

2. Requirements and methods of morphologic monitoring.

Morphologic monitoring is concerned with :

Fig. 1 Location of the Eider estuary.

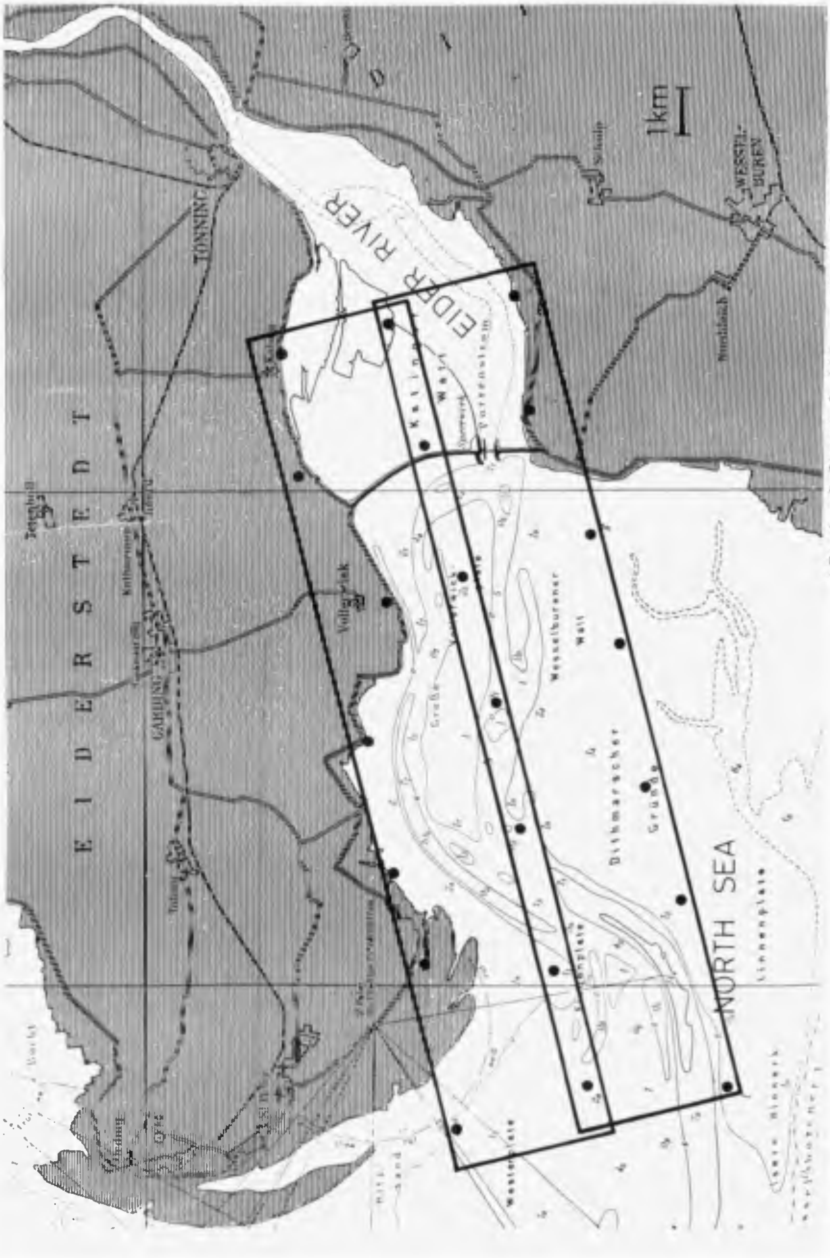


Fig. 2 Location of the survey area and distribution of reference markers.

(Part of Chart D 103, with kind permission of Deutsches Hydrographisches Institut, Hamburg)

Photo: Kaack

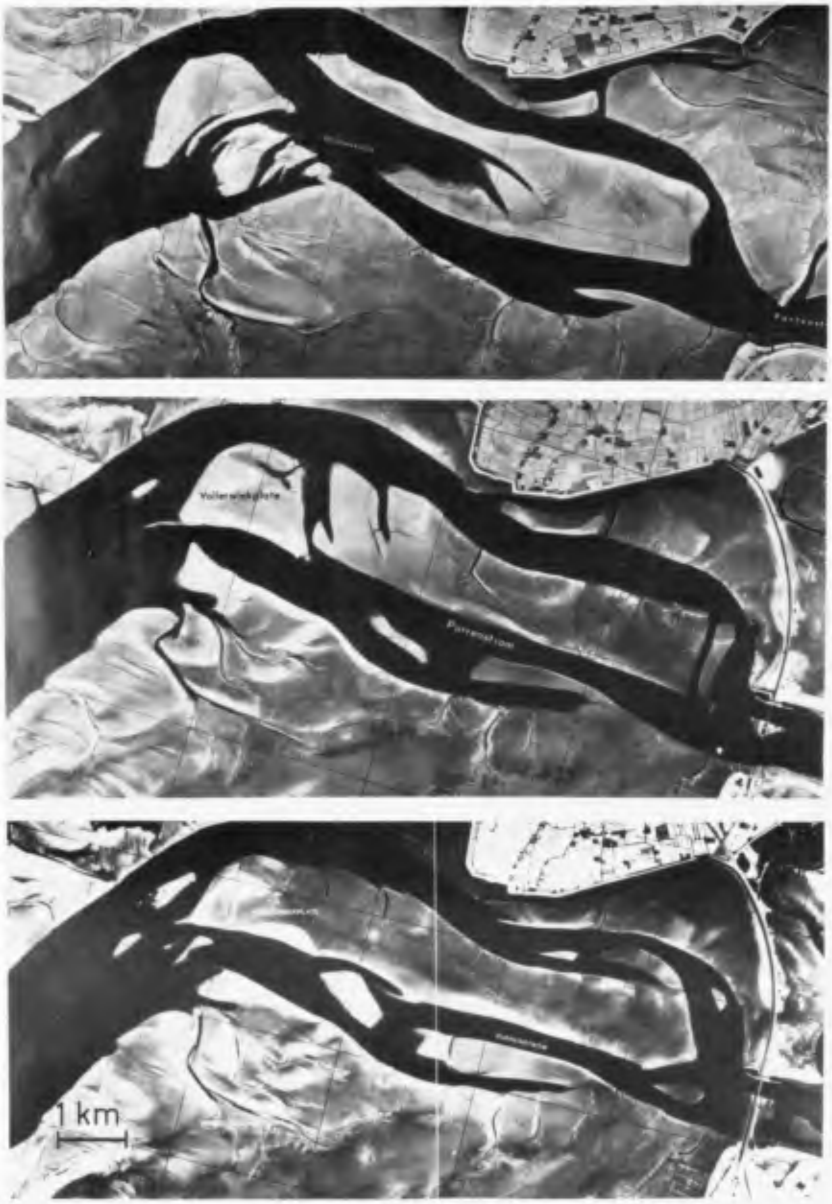
Fig. 3 The Eider flood barrier.

1. location, shape and elevation of those tidal flats lying above a certain level (in this case NN, which is the general reference datum, minus two metres).
2. location, shape and depth of channels.

The first requirement is to detect rapid changes in the wadden area equally rapidly, because of their potentially dangerous consequences. The necessary qualitative information is supplied about every three months by aerial photography at low water. The shape of the waterline is compared with that on earlier photographs to reveal changes. (Figure 4). Secondly, a quantitative record of surface and submarine topography should be obtained economically, and with some reliability. It might be mentioned that the wadden area is extended, but shows small height differences only. The accessibility depends on the tide, and so a boat is required in most cases. It is those particulars which determine the suitability of the various survey methods, mainly:
1. levelling,
2. aerial photography for stereophotogrammetric survey,
3. aerial photographic waterline survey,
for channels: echo-sounding with radio position-fixing.

With levelling, the stations are 100 to 150 metres apart. The rate of progress depends largely on accessibility and thus on the tide. About 0,5 km^2 may be covered per tide, according to Dolezal (1952). The results are fairly accurate, unless the factor t i m e is considered. For in that case it becomes obvious that, with reasonable expense, levelling cannot be accomplished as fast as a tidal flat sometimes shifts or changes its shape. Thus it is hardly ever possible to record the shape of the whole area as at a certain time. Further uncertainty arises from the difficulty to definitely derive shape and position of contour lines from the heights of solitary points. (Figure 5).

Stereophotogrammetric evaluation of aerial photographs does not supply a true topographic record either. Lack of contrast, in addition to an often nearly horizontal surface, almost prevents the successful use of the stereoplanigraph. Furthermore, unfavourable illumination of a wet wadden surface sometimes reverses the grey shades and causes misinterpretation of the relief. These difficulties may be overcome only by flying rather low, or by a considerable amount of additional levelling, both of which make the whole operation too expensive.



Photos: K. Hüpke

Fig. 4 Low water photographs of the Eider estuary in
1966, September (top)
1972, March (middle)
1973, May (bottom).

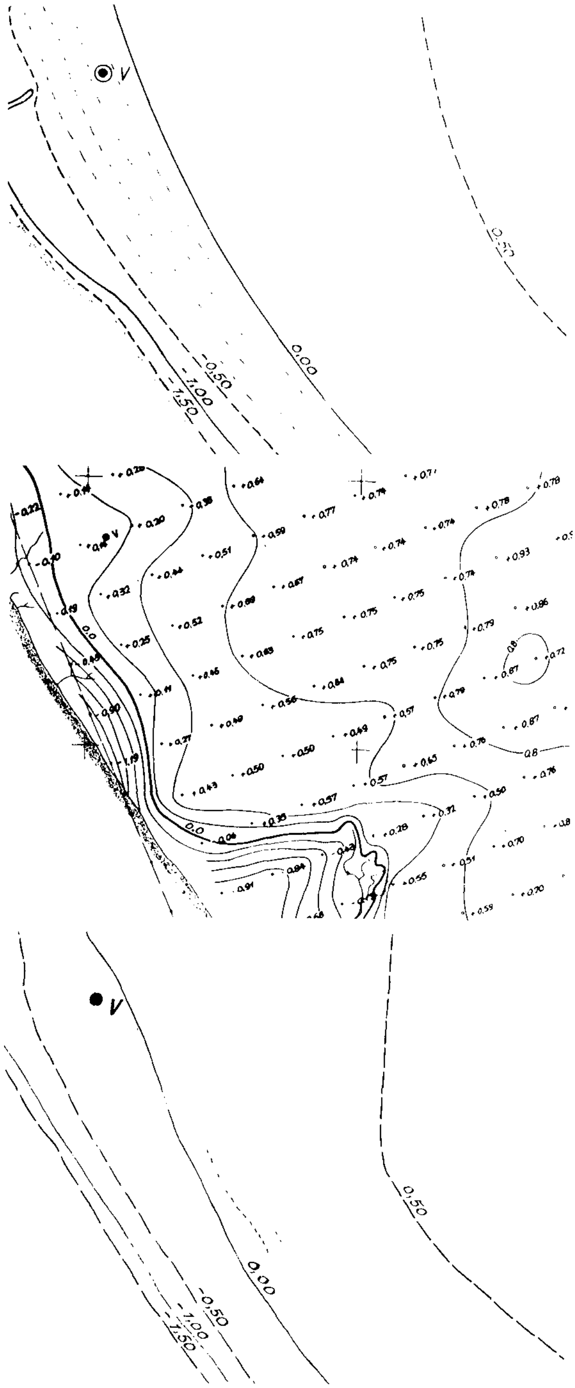


Fig. 5 Contour lines of the same area, constructed from data provided by
levelling (top)
aerial photo, stereophotogrammetric survey (middle)
aerial photographic waterline survey (bottom).

3. Aerial photographic waterline survey.

Because of these drawbacks we looked for a method allowing to record the topography completely and instantaneously, and yielding reliable contour lines. The publication "Mapping the low water line of the Mississippi Delta" by William Shofnos and Bennett Jones in 1960 encouraged us to do some experiments. They led to the waterline method as it is used now for surveying the Eider estuary every second year.

The principle is straight forward. Beginning at low water, aerial photographs from the survey area are taken at short time intervals until the flood tide has covered the tidal flats. Each series of photos shows a different waterline. (Figure 6). With the help of tide gauge records horizontal contour lines can be derived from the waterlines.

The survey area measures about 21 by 6,5 km. (Figure 2). Figure 2 shows also the location of the reference points. At least three, preferably four of them should be visible on each single photograph in order to enable rectification of the distorted photos. Accordingly, their maximum distance depends on size, scale, and degree of overlapping of the pictures. In the present case, distances vary between 1,7 and 3,2 km, according to the suitability of the locations. The coordinates are determined conventionally. On the photographs the reference points should allow to be identified clearly, both against the light background of a sandy surface and against darker mud. Unfortunately, only very few sufficiently conspicuous natural points are available, so that a number of artificial markers has to be set out. Their design was chosen with easy identification and handling in mind. (Figure 7). A shape of three white discs in triangular arrangement on steel tubes stuck into the ground proved suitable, i.e. reasonably portable, robust and cheap. Erecting and surveying the twenty-odd markers takes about two weeks.

For the evaluation later on the sea level heights at the time of photographing will be required. The density of the stations should be such that accuracy does not suffer from the assumption of a linear sea level slope between two adjacent tide gauges. Therefore, the five permanent gauges are augmented by five to six provisional portable ones, also self-recording. The coordinates are established by conventional survey. To transfer the reference datum to a gauge turned out to be a good

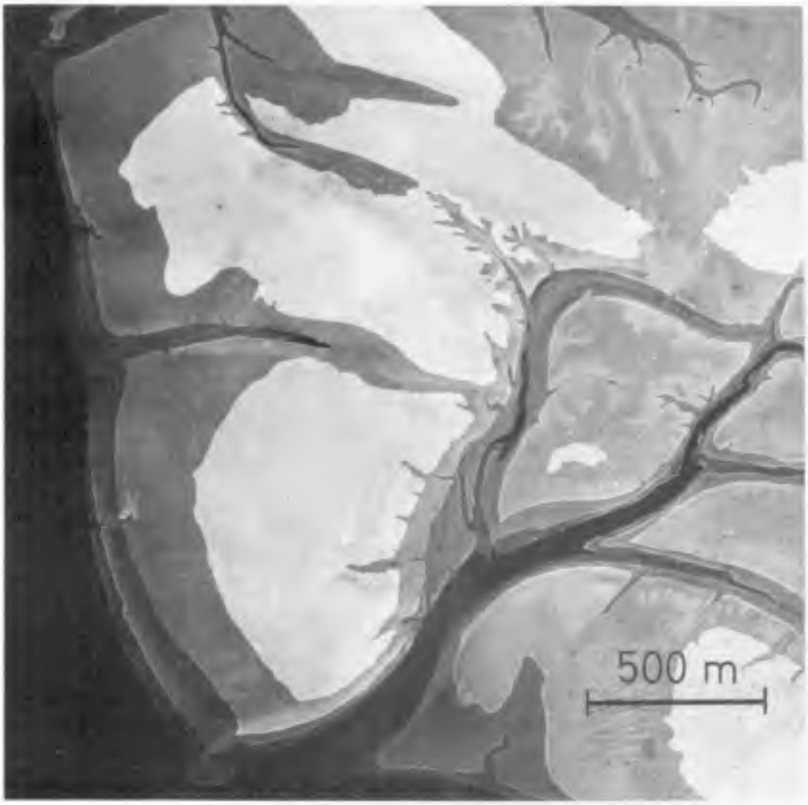


Photo: N.Rüpke

Fig. 6 The waterline, photographed at 45-min-intervals.

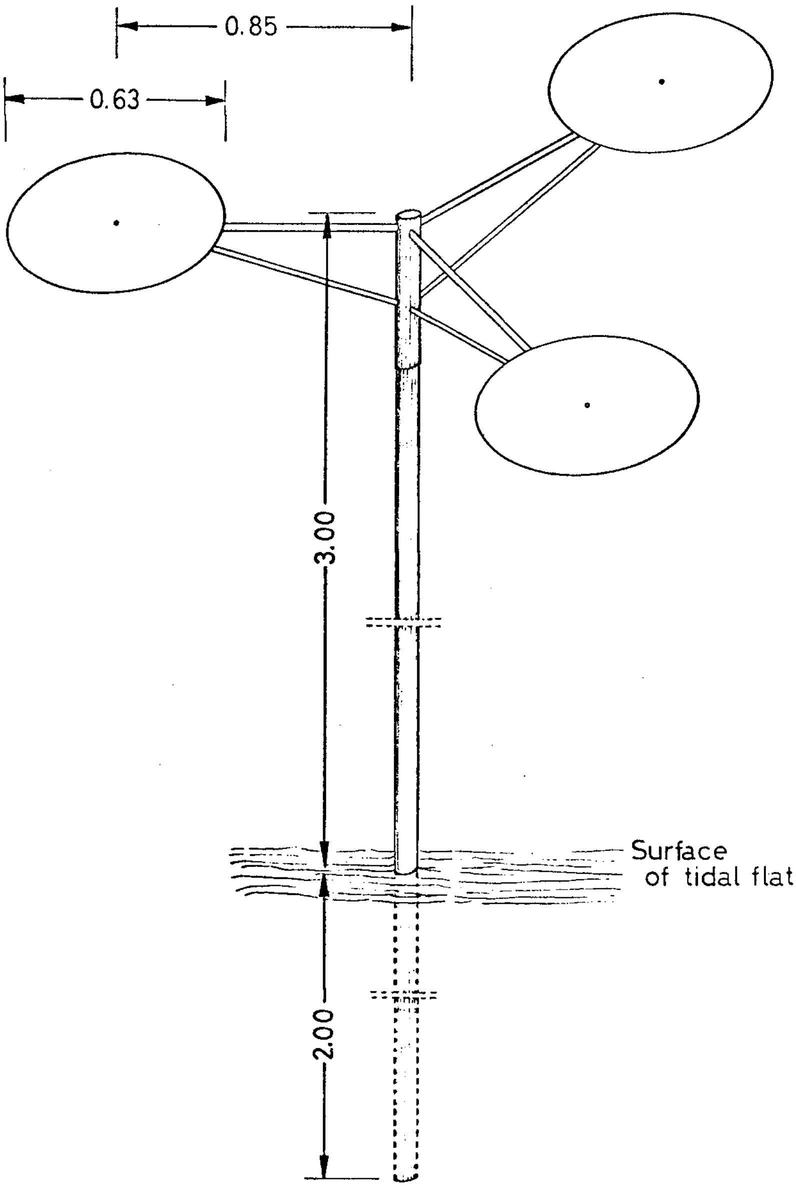


Fig. 7 A reference marker

opportunity to measure the heights on the way for additional checks.

The quality of the photographs depends also on the types of film and camera. Infrared film is used, because even thin layers of water are shown completely black, and cloud shadows and slight haze are suppressed. Very accurate exposure and developing are essential, however. The pictures are taken with an automatic serial camera with Pleogon objective and a focal distance of 15 cm. The negatives measure 23 cm square.

To choose the scale usually means to accept a compromise between accuracy and economy. Experiments have shown that at a flight height equivalent to a scale 1 : 20 000 the quality of the photos is already affected by an omnipresent layer of slight haze, even if infrared film is used. At the other end of the range a scale of 1 : 6 000 supplies excellent pictures. Here, however, the expense for more reference markers and evaluation of a great number of photographs makes scales as large as that less economic. We ended up with 1 : 18 000. Then the resolution of the film allows good enlargements to the working scale 1 : 10 000. Longitudinal overlapping varies between 60 and 80%, laterally the pictures taken along two flight stripes overlap by about 20%.

The flight date can be fixed in advance only provisionally. Sometimes it requires a bit of patience to wait for the day with favourable conditions. Because of the length of daylight the months from April to September are more suitable in this latitude. The entry of low water and the position of the sun determine the start of photographing. A complete flight programme takes up to four hours, so that sunshine and a clear sky should last as long, because of their importance for the quality of the photos. If there is too much wind, flights are better postponed, as even small waves reduce the distinctness of the waterline. Direct communication between field crew (three men on a shallow-draught survey launch) and aircraft crew are of great value. Immediately before the flight, the field crew checks the reference markers and the tide gauges. Via VHF telephone the tide gauge clocks are then compared with the camera clock.

Evaluation consists mainly in rectifying the photos and constructing contour lines. After the flight, the contractor who made the photos submits contact copies on which we try to identify the reference points. Then the contractor rectifies the distorted photos, using the coordinates of the points, and supplies selected enlargements on special sheets insensitive to variations of humidity and temperature.

The next step is the construction of the contour lines. (Figure 8). Provisional contour lines are obtained from the photographed waterlines together with the lines of equal sea level heights as derived from the tide gauge records. Of course both must refer to the same time. However, a lateral downward slope of the sea level in the immediate vicinity of the waterline has not yet been taken into account. As it varies spatially and temporally, recording and analysing would be too expensive for the purpose dealt with here. Instead, a few additional profiles are levelled to establish the final location of the contour lines, the shapes of which are already known. These profiles are about four kilometres apart, with stations every 20-50 metres. This survey immediately after the flight takes about a week.

4. Survey of channels.

The assessment of the morphologic situation requires the knowledge of the submarine topography as well. For this purpose the underwater forms are surveyed by recording echo-sounder while the launch navigates along the hyperbolae of a radio position-fixing system. The results of this survey, too, are transferred onto the working maps mentioned earlier.

5. Result and further work.

Finally, proper charts in the scale 1 : 25 000 are prepared on the basis of the working maps. They supplement existing but less accurate charts of the adjacent coastline and will perhaps replace them in due course. (Figure 9).

With these new charts it should be possible to monitor sediment transfer and changes of the tidal prism more accurately and over long periods. In the case of the Eider barrage, the predicted and actual effects can be compared. If it were possible then to more closely relate hydrologic and geologic data to the morphologic history of this type of coast, the nature of their interdependence might become clearer.

Reference:

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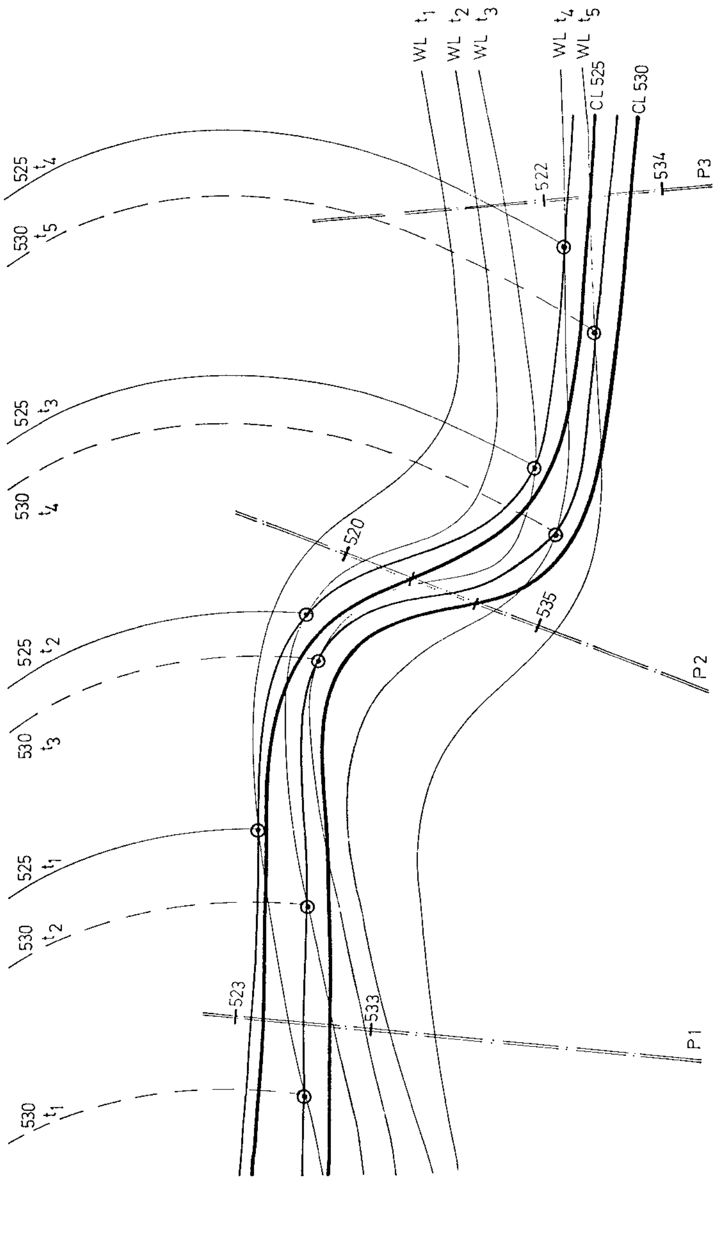

WL Waterline
CL Contour line
P Levelled profile

Fig. 5 Construction of contour lines from sea level heights at different times t_n, waterlines at different times t_n, and additional levelled profiles.

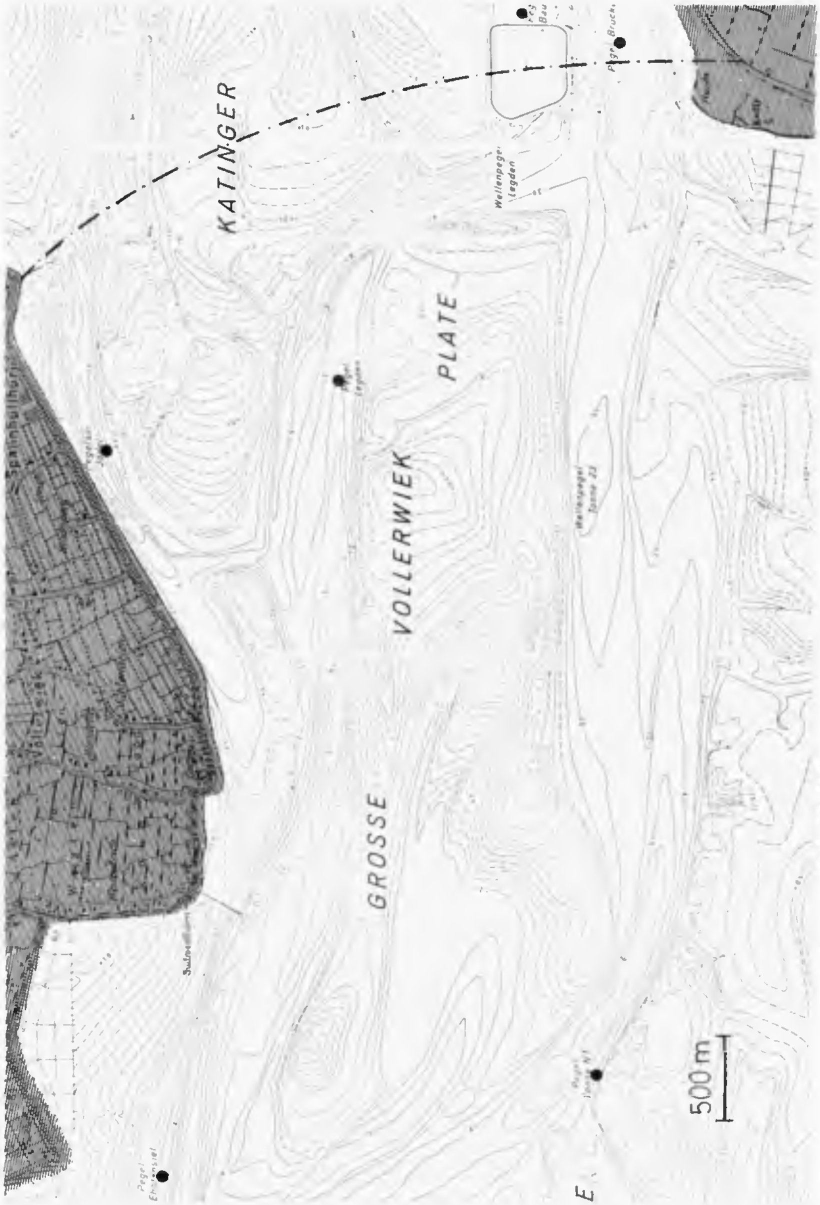

Fig. 9 Part of the final chart of the Eider estuary as in July 1968.
Black dots indicate positions of tide gauges.