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ISOHALINES IN THE DELTA AREA OF THE RIVERS RHINE, MEUSE AND SCHELDT

CLASSIFICATION OF WATERS IN THE DELTA AREA ACCORDING TO THEIR CHLORINITY AND THE CHANGES IN THESE WATERS CAUSED BY HYDRO-TECHNICAL CONSTRUCTIONS

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I. INTRODUCTION

The Division Delta-Research of the Hydrobiological Institute, Yerseke, studies the changes in flora and fauna in the waters of the Delta area in the South-west of the Netherlands, to be expected as a result of the realisation of the so called "Delta Plan". This plan, carried out by the Department of Roads and Waterways (Rijkswaterstaat), aims at the closure of the three sea-arms Haringvliet, Grevelingen and Eastern Scheldt by means of the construction of dams in the mouths of these estuaries, thus offering better protection to the hinterland and preventing a repetition of the flood-disaster of February 1 and 2, 1953.

The hydrobiological investigations of the above-named institute pertain to the subsequent situations bound to be realized in the course of the

execution of this project, scheduled to need about twenty five years for completion. In the past similar research had been carried out, when the former Zuiderzee had been dammed and changed into the IJsselmeer in 1932. In this case a single bay was cut off from the sea and flushed with river water from the IJssel, a branch of the river Rhine. In the Delta area, however, a number of islands and peninsulas gives the area a complicated structure and for this reason seven dams must be constructed. Each of these dams affects the hydrographical situation in its own way and thus different hydrographical situations will follow one another, some of them of fairly long duration. Aquatic flora and fauna will react to these situations, so in the biological changes to be observed various phases must be distinguished in tune with the successive construction of the various dams.

The present paper describes the course of the isohalines in Delta waters in the past, present and future, in order to create a background for the descriptive biological work of the institute.

II. DESCRIPTION OF THE DELTA AREA AND THE DELTA PLAN

From north to south the coastline shows the following natural or artificial inlets. A description of each of them will be followed by some remarks on the way the Delta Plan will affect – or has already affected – the waterbody involved (map 1).

1. Rotterdamse Waterweg. Entrance to the harbour of Rotterdam, dug in 1868 because the former entrance – the river mentioned below under 2 – was silting up. This entrance will not be closed, its depth is 15 m.
2. Brielse Maas and Brielse Gat. Former mouth of the Waal, a branch of the Rhine, and of the Meuse. The Brielse Maas was closed in 1950 and the Brielse Gat in 1966.
3. Haringvliet. Continuation of Hollands Diep, present mouth of the Nieuwe Merwede, a branch of the river Waal, tributary of the Rhine, dug in 1870, as well as of the Bergse Maas, dug in 1904, in order to direct the water from the Meuse towards the Amer. In the mouth of the Haringvliet, a sandbar rises to a height of 4 m below average sealevel. More inland an artificial island was built in 1957, necessary for the construction of the locks in the future dam closing this rivermouth. This dam will be finished in 1970. When this dam is finished, these locks will serve as an outlet for surplus riverwater.

4. Brouwershavense Gat. This, together with Springers Diep, forms the two gullies in the Grevelingen, to be closed by the primary Grevelingendam in 1971. The secondary Grevelingendam, separating Krammer and Volkerak from the Grevelingen, was constructed in 1964. Another secondary dam at Midden Hellegat will separate Keeten-Krammer-Volkerak from the Hollands Diep and will be finished in 1969.

5. Eastern Scheldt. The former mouth of the river Scheldt. At the moment a sea-arm, as no rivers discharge into it. According to the Delta Plan the Eastern Scheldt will be closed by the biggest and last dam, to be completed in 1978. The side-arm of the Eastern Scheldt, known as Zandkreek, was the first of the inlets closed during the execution of the Delta Plan. In 1960 the dam separating this inlet from the Eastern Scheldt was finished. A second dam severed its connection with the sea – known as Veerse Gat – in 1961. The newly formed lake – still filled with brackish water – received the name Veerse Meer.

6. Western Scheldt. The present mouth of the river Scheldt. In 1867 and 1871 the islands of Zuid Beveland and Walcheren were linked together and to the mainland by a railway, thus separating Western and Eastern Scheldt. The Western Scheldt will not be closed as it forms the entrance to the harbour of Antwerp in Belgium. Continuous silting makes dredging compulsory. The dykes along this estuary will be reinforced.

III. RIVERS

As the Rhine is fed by rain as well as by glaciers its discharges do not fluctuate to the same extent as those of an exclusively rain-fed river. Discharges measured at Lobith – where the river enters the Netherlands – fluctuated in the period 1960–'67 between 800 and 7300 m³/sec, with an average of 2200 m³/sec. According to the Department of Roads and Waterways 40% of this amount of water flowed through the Nieuwe Merwede towards the Hollands Diep.

The Meuse is a true rain-river with strongly fluctuating discharge between a few m³/sec and 2200 m³/sec. There are many barrages in the river, but these are all opened at high discharges. In accordance with the different character of both rivers the ratio Rhinewater: Meusewater shows a good deal of variation. At low discharge the Rhine predominates; high discharges increase the share of the Meuse, as the following figures, measured at Lith, the last barrage in the Meuse, show:

Low discharge of Rhine and Meuse = 20:1 (800 m³/sec Lobith, 15 m³/sec Lith)

Average discharge of both rivers = 2 $\frac{2}{3}$:1 (2200 m³/sec Lobith, 330 m³/sec Lith)

High discharge of both rivers = 1 $\frac{1}{2}$:1 (7300 m³/sec Lobith, 2200 m³/sec Lith)

All values calculated at surface water discharge Willemstad.

Although the Scheldt has the lowest discharge of the three rivers, its influence is so strongly felt in the Western Scheldt at normal discharge, that all transitions from fresh water to sea water are found inside the coastline and this water body may be compared *e.g.*, with the Elbe (CASPER, 1959). The Scheldt is a true rain-river with an average discharge at Antwerp of about 90 m³/sec, fluctuating between a few m³/sec and 5–600 m³/sec. There are barrages in this river as well.

IV. CHLORINITY

For the distribution of the aquatic flora and fauna the chemical composition of the water is of special importance, and notably so its chlorinity, as the chloride ion is a non-metabolic ion. In the present paper the classification known as the "Venice System", proposed at the Symposium of Classification of Brackish Waters in 1958, will be used, because this system was created to describe biological phenomena within salinity gradients. The trajectories distinguished are the following:

Euhalinicum	from 22	till 16.5 ‰ Cl'
Polyhalinicum	from 16.5	till 10 ‰ Cl'
Mesohalinicum	from 10	till 3 ‰ Cl'
to be divided	into α	mesohalinicum 10 till 5,5 ‰ Cl'
	and β	mesohalinicum 5.5 till 3 ‰ Cl'
Oligohalinicum	from 3	till 0.3 ‰ Cl'
Fresh water	lower than	0.3 ‰ Cl'

For a clear hydrological description it will be necessary to use an isohaline of 15 ‰ Cl' and sometimes of 1 ‰ Cl'. During the better part of the year the chlorinity of the Rhine will fluctuate between 0.3 and 0.1 ‰ Cl', the Meuse will usually have chlorinities below 0.1 ‰ Cl'. On the maps, presented here, the isohalines of 0.1 ‰ are also shown.

Chlorinity determinations were carried out according to Knudsen's method with Standard Seawater and with the Mohr titration, when

chlorinity did not exceed 4‰ Cl'. In an estuary the position of an isohaline depends on river discharge, on meteorological conditions and tidal effects (see below). For this reason it is most desirable to depict the position of an isohaline at normal weather conditions and average river discharge. After consultation with authorities of the Department of Roads and Waterways, average river discharge in the Hollands Diep at Willemstad was chosen as a standard. This discharge is composed of two components, *viz.*, 40% of the discharge of the Rhine at Lobith, two days previously, increased by 100% of the discharge of the Meuse at Lith, measured one day previously. As the average discharge of the Rhine at Lobith amounts to 2200 m³/sec, the Rhine-fraction at Willemstad amounts to 880 m³/sec. Taking 330 m³/sec for the average discharge of the Meuse (Rijkswaterstaat, 1964) we arrive at a value of 1210 m³/sec for an average discharge at Willemstad. As data on actual discharge of both rivers are measured daily and as these data were kindly placed at my disposal by the Department, it was possible to calculate the discharge at Willemstad on any day. Only data gathered during days when weather conditions were not unusual and the discharge did not deviate too much from the average were used to locate the isohalines to be described below. The discharges of the Dordtse Kil and the Spui, two small branches of the Rhine, fluctuate greatly owing to wind-action. Their combined total discharge amounts to a maximum of about 10% of the discharge of the Rhine, normally it is about 6%. For these reasons both are left out of consideration here.

It is obvious that isohalines do also shift with the tidal movements, being situated more inland at high tide and more seaward at low tide. In the maps the positions at mid tide are shown. For the various parts of the area, relevant in this respect, chlorinities were measured during entire tidal periods of 13 hours. It is intended to deal with these investigations in a later paper. These studies enabled us to locate the limits of tidal fluctuation of the isohalines involved, and correct our field-data so as to represent chlorinity at mid tide, either at average, low, or high discharge.

V. LOCATING THE ISOHALINE AFTER ACTUAL MEASUREMENTS

As an example of the way in which the correct place of the isohalines were determined, we will now describe the procedure which enabled us to draw the 10‰ Cl' isohaline at average river discharge at the moment of mid tide in the Krammer, as indicated in figure 1. Two series of salinity measurements form the base of our procedure:

1. a series of measurements carried out at 6 fixed stations where water samples were taken every half hour throughout more than an entire tidal period (15 hrs.) and,
2. a series of measurements of 5 water samples taken in the area during a day (22-8-'66) when the actual river discharge at Willemstad of $1190 \text{ m}^3/\text{sec}$ did not differ materially from the average value of $1210 \text{ m}^3/\text{sec}$, calculated as the standard.

The first series of measurements, carried out on 6-7-'66 when the river-discharge at Willemstad amounted to $1500 \text{ m}^3/\text{sec}$, occupied the stations indicated in figure 1 by dots and gives evidence on the shift of the isohalines with time during a tidal cycle. The second series enables us to correct our data to standard discharge. The stations sampled during this series are indicated by crosses and the actual chlorinities are given in the legenda together with the tidal phase in which the samples were taken. As a result of the data collected on 6-7-'66 (first series) three isohalines could be drawn - dotted lines in figure 1 - indicating the place of the 10‰ isohaline at low tide, mid tide, and high tide, respectively, and showing the amplitude of the displacement of this isohaline during a tidal cycle. The fact that these measurements were carried out at a discharge somewhat higher than standard, does not materially alter the magnitude of the amplitude, as witnessed by measurements on other days when the river discharge was four times normal and the tidal amplitude was found to remain nearly the same.

During the measurements of 22-8-'66 a value of approximately 10‰ Cl' was found at station d, three hours after high tide at Willemstad. As a value of 12.22‰ Cl' had been found at station c, the place of the 10‰ Cl' isohaline is determined by interpolation as indicated by the drawn line AB.

Now a correction must be applied for the fact that the line AB was not crossed at mid tide but at some other time. Station c was sampled 2 hours after high tide at Willemstad and station d 3 hours after high tide, so the line AB was reached about $2\frac{3}{4}$ hours after high tide. As in this estuarine area the duration of the ebb - during which period the measurements were taken - is 7 hours, the chosen standard time of mid tide is $3\frac{1}{2}$ hours after high tide at Willemstad. For this reason the line AB must be shifted seawards over a distance of a tidal shift of $\frac{3}{4}$ hour. In doing so we must account for the fact that around half tide the current ran at maximum velocity. In this way the position indicated by the line CD was determined.

The above procedure has been used in every case.

In addition to the above mentioned influence of tidal movement, other influences also act upon the pattern of isohalines. These influences, listed below, were dealt with in the construction of the maps.

- a. Tide period of 14 days with spring-tide and neap-tide.
- b. Diurnal inequality.
- c. Difference in tidal phase, *e.g.*, high tide will reach Flushing one hour earlier than Hook of Holland and low tide $2\frac{1}{2}$ hours earlier.
- d. Difference in tidal height, Flushing nearly 4 m, Hook of Holland 1.75 m.
- e. Variation in resistance of the tidal inlets.
- f. Effect of the Coriolis force.
- g. Residual current along the coast from S.W. to N.E.

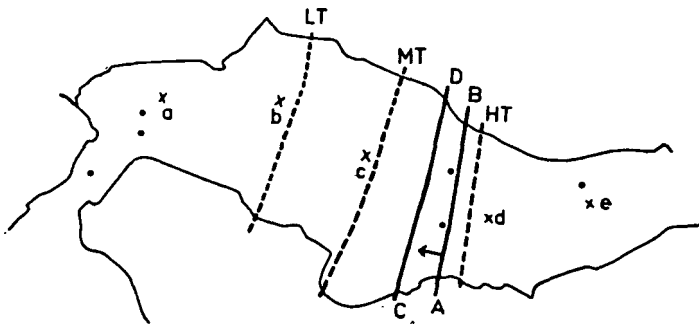


Fig. 1. Tracing the 10‰ Cl' isohaline in the Krammer. Example of locating the 10‰ isohaline at average discharge, from actual measurements at 6 stations during a complete tidal cycle at slightly higher discharge than average, combined with 5 measurements at different stations taken during a one-day period with approximately average discharge.

----- isohaline 10‰ Cl', 6-7-'66, 1500 m³/sec discharge Willemstad.
 ——— isohaline 10‰ Cl', 22-8-'66, 1190 m³/sec discharge Willemstad.
 calculated average standard = 1210 m³/sec discharge Willemstad.

- stations of measurements complete tidal cycle, 6-7-'66, 1500 m³/sec.
- x stations a – e of station measurements, 22-8-'66, 1190 m³/sec.
- AB isohaline of 10‰ Cl' at 1210 m³/sec discharge at Willemstad, derived from value of 9.63‰ Cl' found at station d, 3 hrs. after high tide at Willemstad.
- CD correct place of 10‰ Cl' isohaline 1210 m³/sec discharge at Willemstad, shifted seawards from AB to account for the difference in tidal phase of $\frac{3}{4}$ hour.

a	=	14.93‰	1 hr.	after high tide Willemstad
b	=	14.89‰	$1\frac{1}{2}$ hrs.	after high tide Willemstad
c	=	12.22‰	2 hrs.	after high tide Willemstad
d	=	9.63‰	3 hrs.	after high tide Willemstad
e	=	6.74‰	$3\frac{1}{2}$ hrs.	after high tide Willemstad
H.T.	=		$3\frac{1}{2}$ hrs.	after high tide Willemstad

It will be clear that owing to inertia of their water masses the various sea arms will only react to fluctuations in river discharge after a few days.

The isohalines on the maps are based on about 5000 chlorinity titrations of samples gathered during about 80 field-trips, carried out between 1960 and 1967, and on data kindly furnished by the Department of Roads and Waterways.

VI. SALINITY GRADIENTS IN THE PAST, PRESENT AND FUTURE

In the following chapter we will deal with the salinity gradients in the various waterbodies, as they are depicted on the maps, showing the situation in four subsequent situations:

- a.* the initial situation (maps 2, 3 and 4);
- b.* the situation after the completion of the secondary dam through the Grevelingen (maps 5, 6 and 7);
- c.* the situation after completion of the dam through the Volkerak and the functioning of the locks in the Haringvliet (map 8);
- d.* the ultimate situation after total completion of all dams and flushing of the entire area with water from the rivers (map 9).

The description of the situations *c* and *d*, must be seen as a prognosis.

SITUATION *a*

The initial situation is shown on map 2, based on average discharge of the rivers Rhine, Meuse and Scheldt at mid tide, at the surface. Isohalines near the bottom will be slightly differently located, as the heavier sea water will move downward and penetrate further inland along the bottom. At a chlorinity of 16.5–15‰ and 10‰ Cl' there will hardly be any difference between salinity at the surface and at the deeper layers and the same holds for the chlorinities of 3–0.3‰ and 0.1‰ Cl'. A different situation is found at a chlorinity of 5.5‰. Here the isohaline in the Volkerak is shifted 10 km to the east in deep water but in the Haringvliet only 1 km, owing to the presence of the sandbar mentioned above.

In 1961 DEN HARTOG published a map of the Delta area showing the distribution of the littoral and benthic flora and fauna according to the classification of brackish waters known as the "Venice System". His map is primarily based on biological data (DEN HARTOG, 1961). In an earlier paper (DEN HARTOG, 1959) he points out that the Western Scheldt near Flushing, the Brouwershavense Gat, and the western part of the Grevelingen, are characterized biologically by a very rich flora and fauna and chemically by very slight fluctuations in salinity. For

these reasons he wants to incorporate this area in the euhalinicum and he uses the new name "Scaldian District" for these regions. However, if the Venice System is strictly adhered to, this area should be part of the polyhalinicum. In the maps published by DEN HARTOG (1963, 1966 a, b) the originally biological border-lines are replaced by chemical ones, but, in doing so, he leaves his Scaldian District in the euhalinicum. In two publications DEN HARTOG (1966a, 1966b) has drawn the isohaline of 1.8‰ Cl' at the same place as originally he drew the 3‰ Cl' isohaline.

As it is our aim in the present paper to draw the isohalines on chemical evidence alone and to disregard – for the time being – all biological data, and as we wish to emphasize the difference between normal, low and high river discharge and to average the displacement caused by the tides, our isohalines will be found at localities differing from those given by DEN HARTOG in the above mentioned papers.

EISMA (1965) published a small map of isohalines based on data available in our institute at that time. As these data had not yet been corrected for average river discharge, his map is slightly different from those published in the present paper, for instance with regards to the Eastern Scheldt. The eastern basin of this water body does belong to the euhalinicum according to our own measurements and also according to the average value of 20 years: 16.83‰ Cl' (KORRINGA, 1941).

Map 3 shows the situation at low discharge, according to our measurements of November 1962. Discharge at Willemstad amounted to about a third of its normal value: 450 m³/sec. The isohalines are shifted to the land side (*cf.* ZONNEVELD, 1960).

Map 4 shows the situation at high discharge of *circ.* 4000 m³/sec – about four times normal – as was found in the beginning of February 1961. The isohalines are seen to move towards the sea and the 10‰ Cl' isohaline now runs through Grevelingen, Keeten and Krabbekreek.

SITUATION *b*, AFTER COMPLETION OF THE DAM THROUGH THE GREVELINGEN

This situation is depicted in map 5. The dam through the Grevelingen altered the flow of riverwater in the entire area. The ebb-volume in the Zype increased. As a result the river water influx now extends far into the Eastern Scheldt and the eastern end of this sea-arm now belongs to the polyhalinicum (*cf.* BAKKER, 1967). On the map the isohaline of 10‰ Cl' is seen to run 5 km more to the West than on map 2, compare RIJKSWATERSTAAT, 1966.

In the initial situation a certain heterogeneity could be found in the Midden Hellegat, owing to the flood-surplus. North of the little island of Tiengemeten salinities were usually lower than on the south side.

After the construction of the Grevelingendam this heterogeneity is hardly ever found. At the moment a process of diffusion between salt and fresh water mainly dictates the pattern of isohalines in the Keeten-Krammer-Volkerak region. This results in an ebb-surplus during periods of high river discharge and a flood-surplus when river discharge is lower than average¹.

A smaller amount of saline water now enters the Haringvliet from the Midden Hellegat than formerly. Consequently the fresh water influence in the Haringvliet increased and – compared with the situation earlier – the area of the meso- and polyhalinicum in the mouth of the Haringvliet is enlarged. This change was facilitated by the concomittant erosion of the gully between the island of Voorne and the artificial island, built in the Haringvliet for the construction of the locks in the dam.

The construction of the dam through the Grevelingen coincided with heavy fluctuations in the river discharge. The summer of 1964 was very dry and discharges during July and August were far below average. Values of about a third of the normal discharge were reached. As a result all isohalines shifted inland to a marked extent (map 6).

At mid tide the borderline of 0.3‰ Cl' was found at the western end of the Biesbosch, the 3‰ isohaline at 3 km West of Moerdijk, the 10‰ isohaline occurred where usually the 3‰ isohaline is to be found, *viz.*, West of Willemstad, and the 16.5‰ isohaline changed places with the 10‰ isohaline, in front of the mouth of Krammer and Haringvliet. South of Goeree in the Grevelingen basin, a small stretch of the polyhalinicum was observed, owing to an influx of fresh water from the Haringvliet around the island of Goeree. A comparison with map 3 will show a shift of the 10‰ isohaline towards Willemstad. In the estuary of the Scheldt a decrease in the area of brackish- and fresh water occurred as well².

In January 1967, on the other hand, a period of very heavy river discharge took place, which at Willemstad amounted to 4836 m³/sec. This situation will be found on map 7. The borderline of 0.3‰ Cl' lies in the Volkerak at Galatese Haven, 3‰ Cl' will be found near Zype and the 10‰ isohaline West of Zierikzee. In the Haringvliet the 0.3‰ isohaline is situated 2 km East of the artificial island, and the 3‰ Cl' border 5 km West of it, the 10‰ Cl' border runs from Goeree beyond the Rotterdamse Waterweg over the sandbar.

¹ For this reason phytoplankton from the Eastern Scheldt can be transported into the Haringvliet, via Keeten-Krammer-Volkerak. A publication on this phenomenon is in progress.

² For the construction of this map data were kindly furnished by the State Institute for Purification of Sewage (RIZA, Voorburg)

In the Scheldt estuary similar heavy discharges were measured towards the end of December 1966, when the 0.3‰ isohaline shifted towards the Belgian border and the 3‰ isohaline towards Hansweert; the 10‰ isohaline was found 3 km East of Flushing. It is always difficult to locate the borderline between polyhalinicum and the marine zone, but in this case this line must have shifted far out of the coast. The shape of this borderline is strongly dependent on the winds blowing at that time, because a layer of less saline water of about 2 meters, lies on top of the seawater and such a thin layer will be very susceptible to wind action¹.

A comparison between maps 2 and 5 shows that, owing to the presence of the Grevelingendam a strong influx of fresh water from the Keeten shifts the position of the 16.5‰ isohaline in the Eastern Scheldt towards the sea and the greater, eastern part of the Eastern Scheldt is transformed into a polyhaline area by the new influence of river discharge. In the Grevelingen the difference with the normal situation – map 2 – is caused by the fact that now the inflow of freshwater does not come from an eastern direction but now only from the North-West, as water of lower salinity flows around the island of Goeree. How this effect changes the general pattern of isohalines is clearly shown on the map.

It follows from a comparison of maps 5, 6 and 7 that the typical feature of this phase in the execution of the "Delta Plan" is the fact that more riverwater is able to penetrate into the southern parts of the area because its flow to the sea via the Grevelingen is blocked. Formerly influence of fresh water in the Eastern Scheldt was only noticeable during periods of extremely heavy river discharge.

SITUATION c, AFTER COMPLETION OF THE DAM THROUGH THE VOLKERAK AND THE DAM – WITH LOCKS – THROUGH THE HARINGVLIET (prognosis)

The whole pattern of isohalines will be drastically changed when the dam through the Volkerak will be finished in 1969, because river water can no longer flow through Keeten and Krammer-Volkerak. Under the influence of the tides the sea will turn the whole southern part quickly into an entirely marine area. Some river water may enter through the locks and via the small rivers Dintel and Steenbergse Vliet, but in view of the large volume of the sea-arms this influence is almost negligible. During a short period of some months after the closure of the Volkerak until 1970, the Haringvliet will still be open and the estuarine character

¹ In this area some measurements on changes in salinity in the course of a tidal period were carried out in collaboration with the Sections for Hydrometry of the Department of Roads and Waterways at Hellevoetsluis and Zierikzee.

of the Haringvliet-Hollands Diep will be preserved, although the tidal volume will be smaller, as no water can enter via the Volkerak. But in 1970 the dam through the Haringvliet will be ready and the locks will operate. It is intended to manipulate them in such a way that more river-water will flow through Spui, Dordtse Kil and Beneden Merwede in the direction of the Rotterdamse Waterweg. It may be possible that the situation shown on map 8 will be slightly changed and the isohalines slightly shifted towards the east, because more sea-water can enter, as the gully, in front of the new harbours of Rotterdam, will be dredged to a greater depth to facilitate the entrance of larger vessels. As the salinity gradient in the Rotterdamse Waterweg will be shifted towards the sea, the surrounding polders and the Waterworks of the city of Rotterdam will profit from the better quality of the less saline water. The isohalines in the mouth of the Haringvliet were drawn in accordance with an experiment carried out by the Department of Roads and Waterways in a hydrological model and published by RIJKSWATERSTAAT (1966). During this phase the marine area shows its greatest extent.

ULTIMATE SITUATION *d* (prognosis)

The situation after completion of the dams in the Brouwershavense Gat and in the mouth of the Eastern Scheldt is shown on map 9. When the Eastern Scheldt will be closed in 1978 all basins can be flushed with riverwater and this process is expected to be finished in 1983. The Veerse Meer will also lose its intermediate salinity of today and become totally fresh. The isohalines in the mouth of the Haringvliet are not expected to change, because here river flow will remain the same. It is virtually impossible to predict what will happen in the Western Scheldt, because it is insufficiently known at present what exactly the future of this estuary will be and how industry and new harbours will affect this area. The closed Eastern Scheldt, than named Zeeuwse Meer, also has many future possibilities.

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SUMMARY

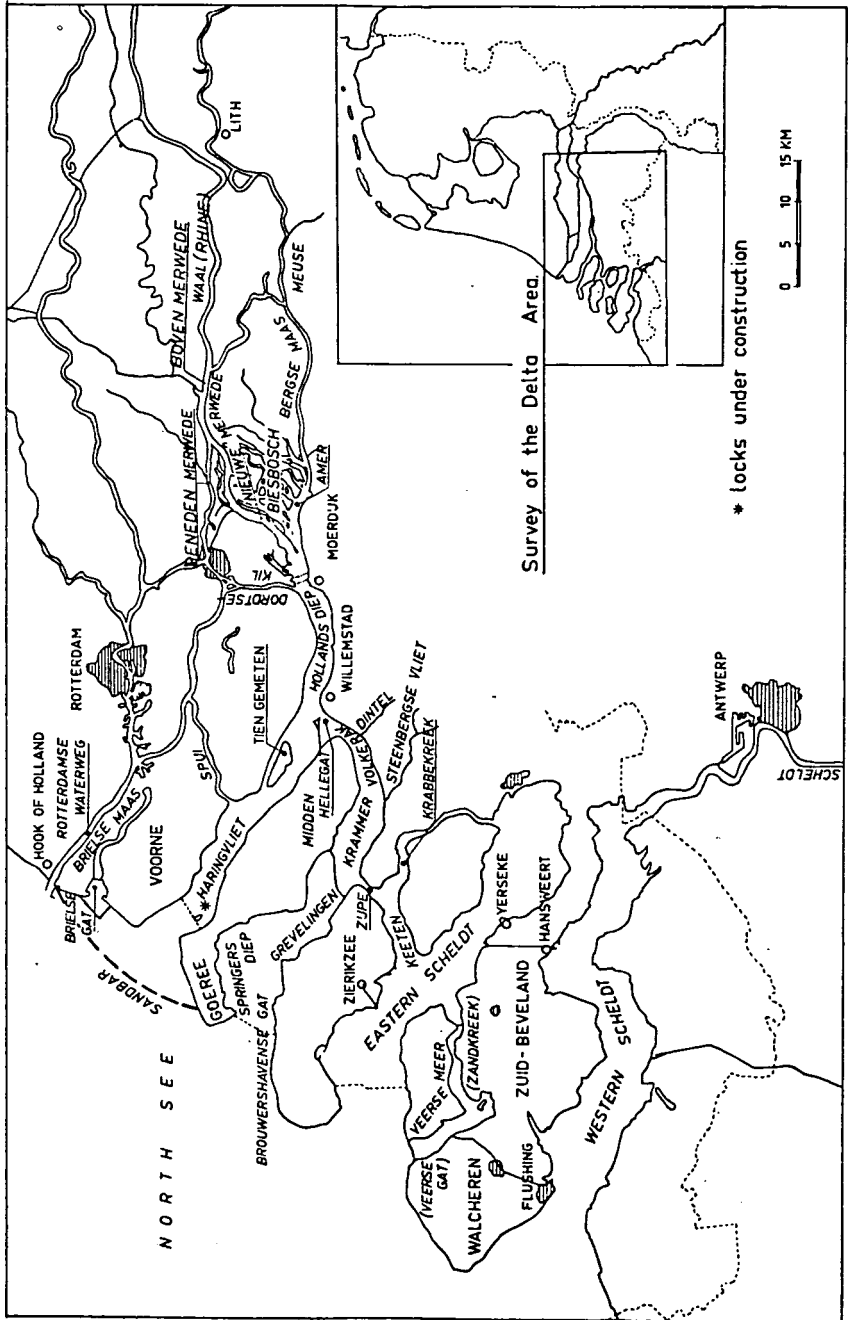
A description is given of the location of the isohalines in the Delta area of the rivers Rhine, Meuse and Scheldt in the South-west of the Netherlands, during the subsequent phases of the realisation of the Delta Plan. This Plan aims at the closure of most of the estuaries and sea-arms in the area.

The situation previous to the building of the dams is shown at average, low and high river discharge (maps 2, 3 and 4). In maps 5, 6, 7 the situation of the present moment, after the construction of the secondary dam through the Grevelingen, is shown at the same discharges. In map 8 a prognosis is given of the course of the various isohalines after the closure of the mouth of the Haringvliet and the construction of the secondary dam through the Midden Hellegat and map 9 visualizes the ultimate situation in the area, when the last dam – closing the Eastern Scheldt – is completed and the whole area has been flushed with river water from Rhine and Meuse.

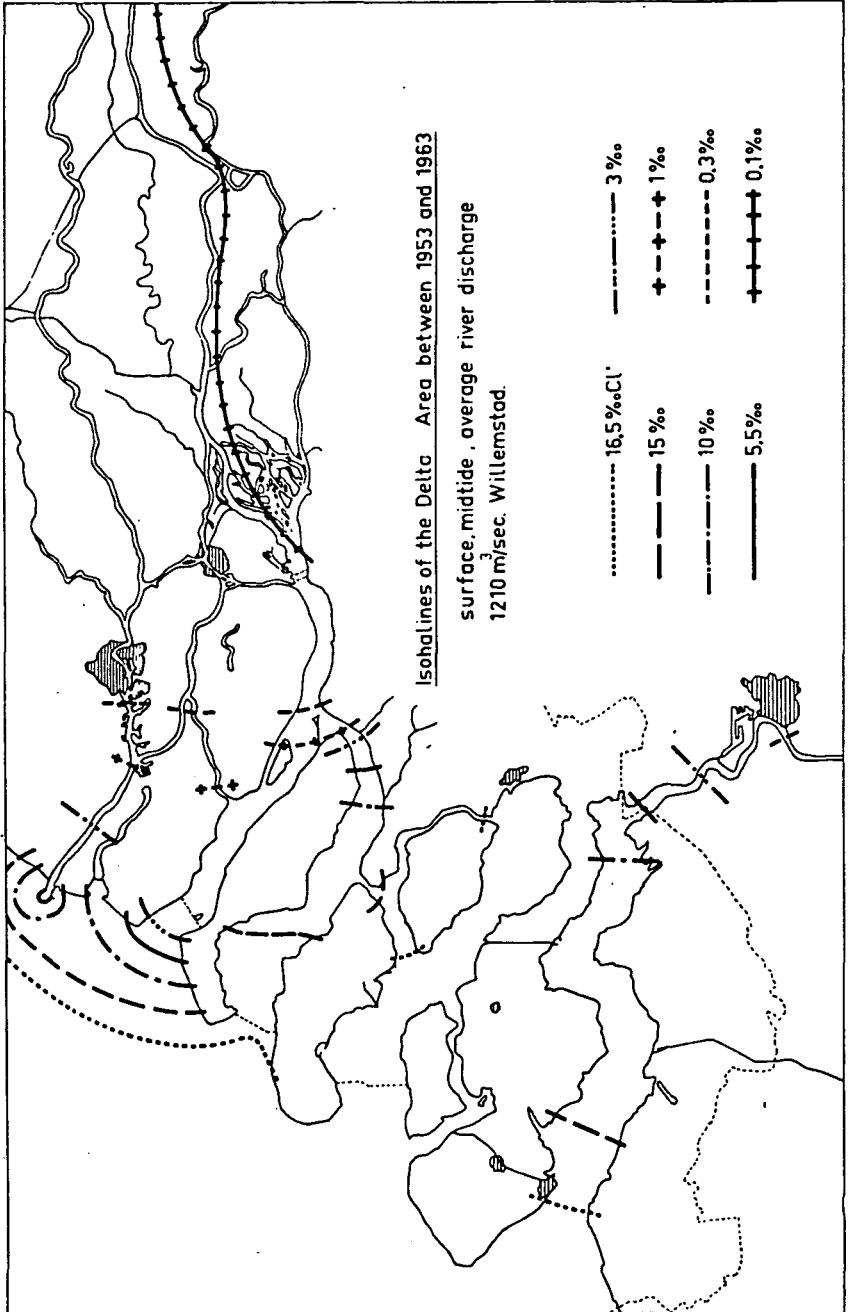
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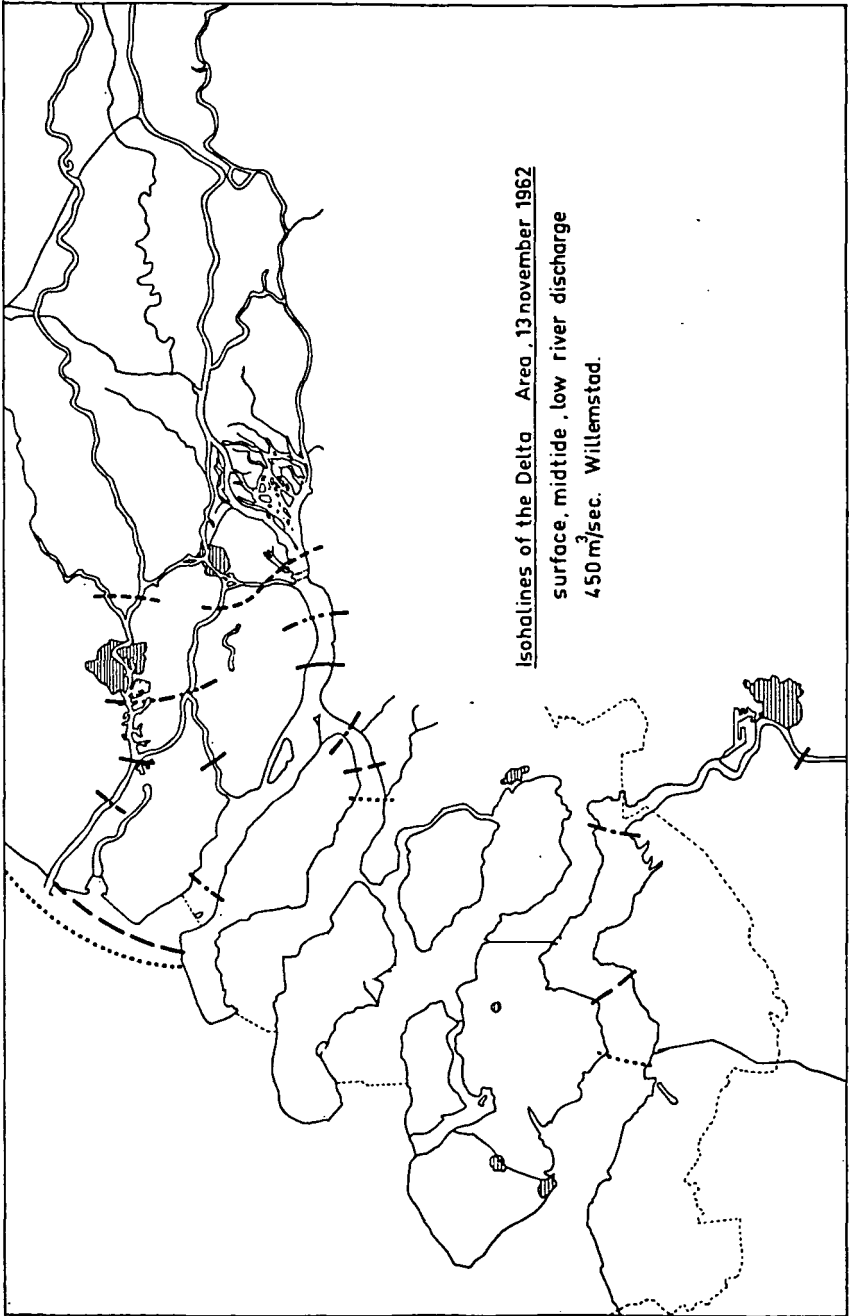
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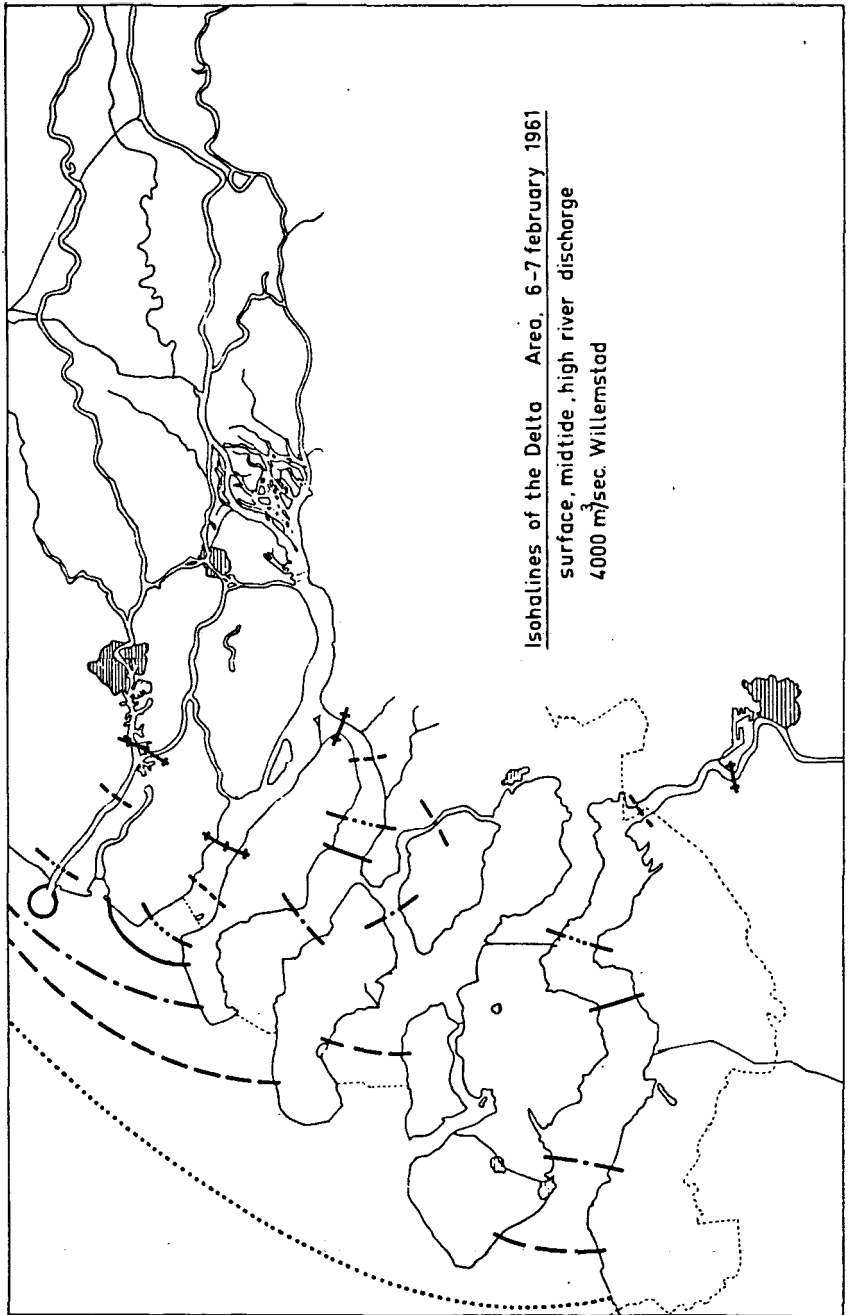
Map 1.



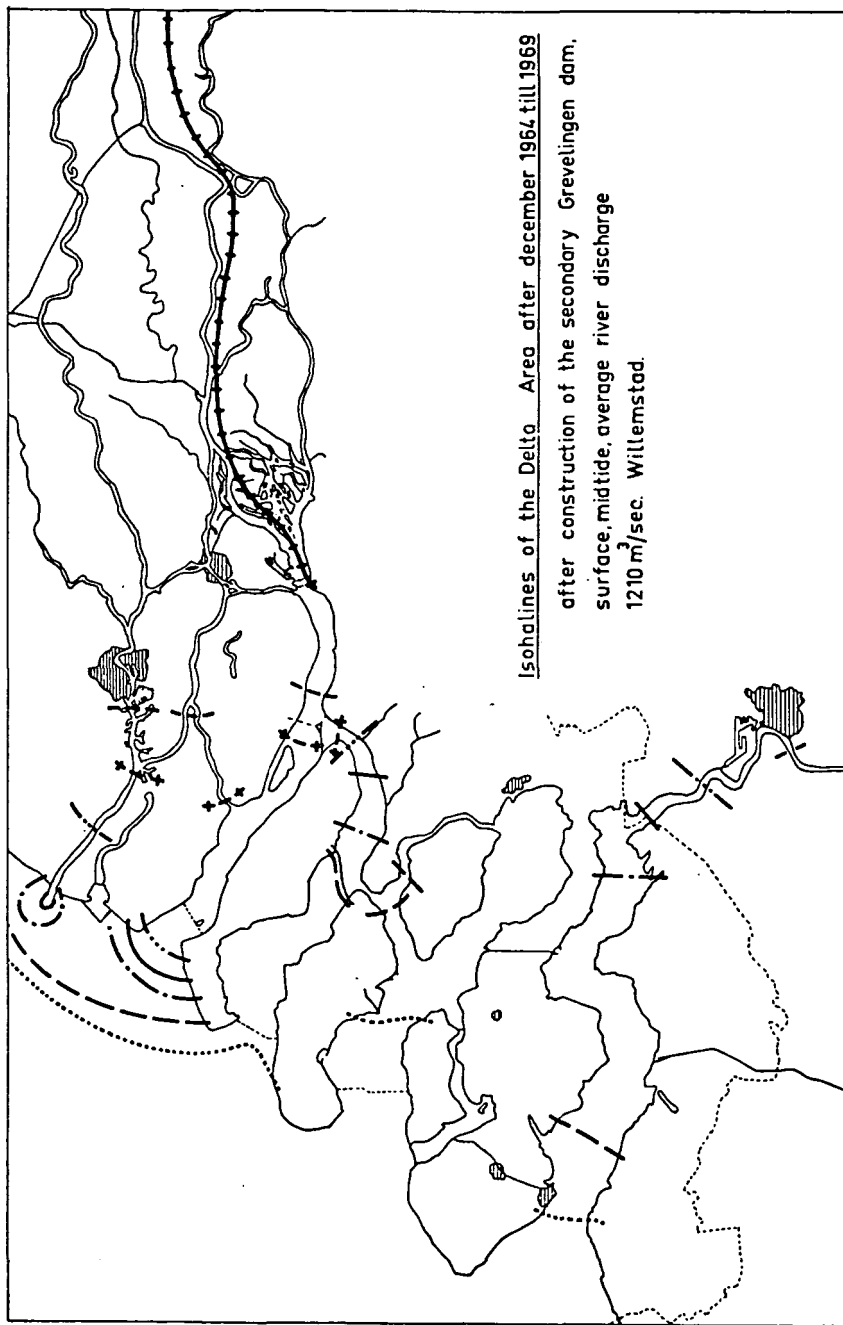
Map 2.



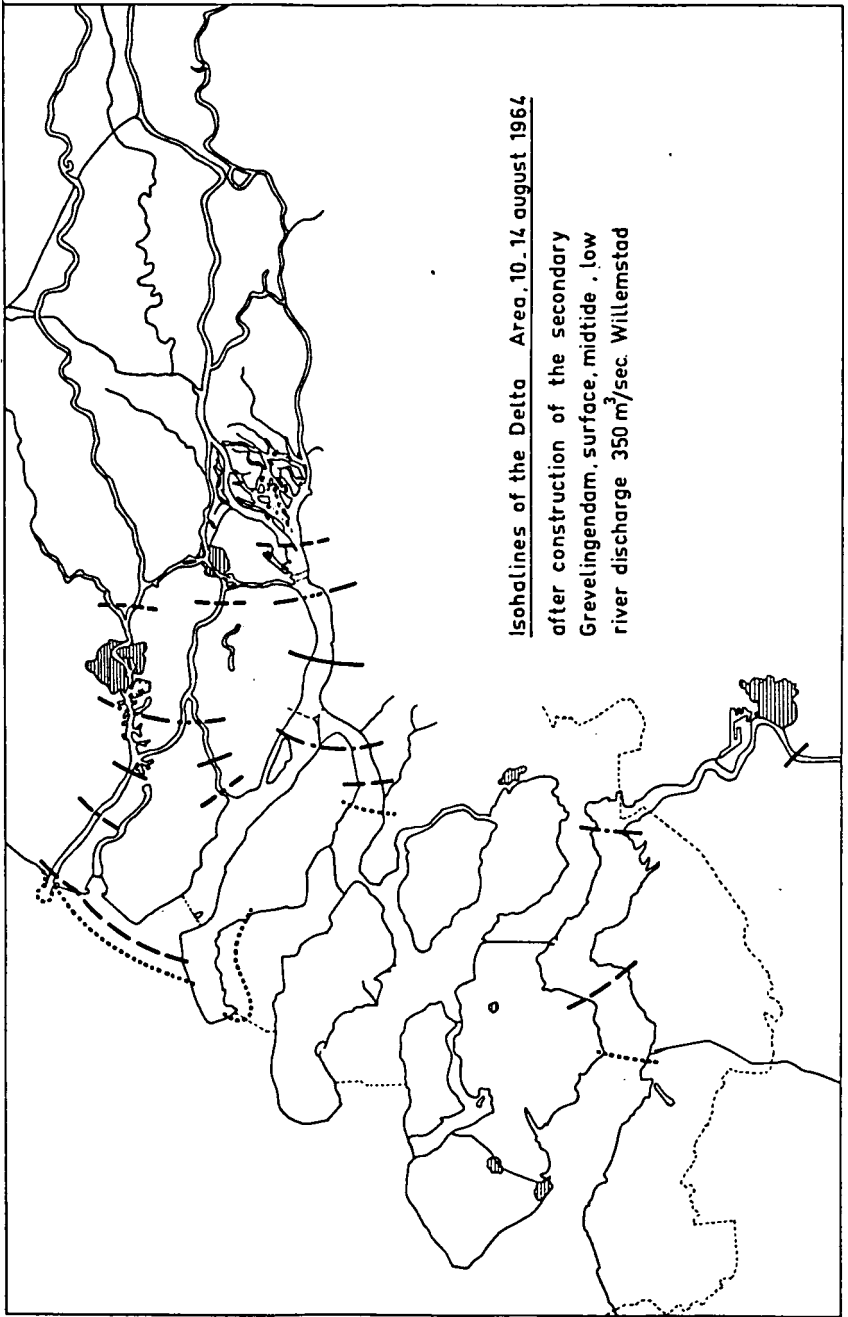
Map 3, for explanation see map 2.



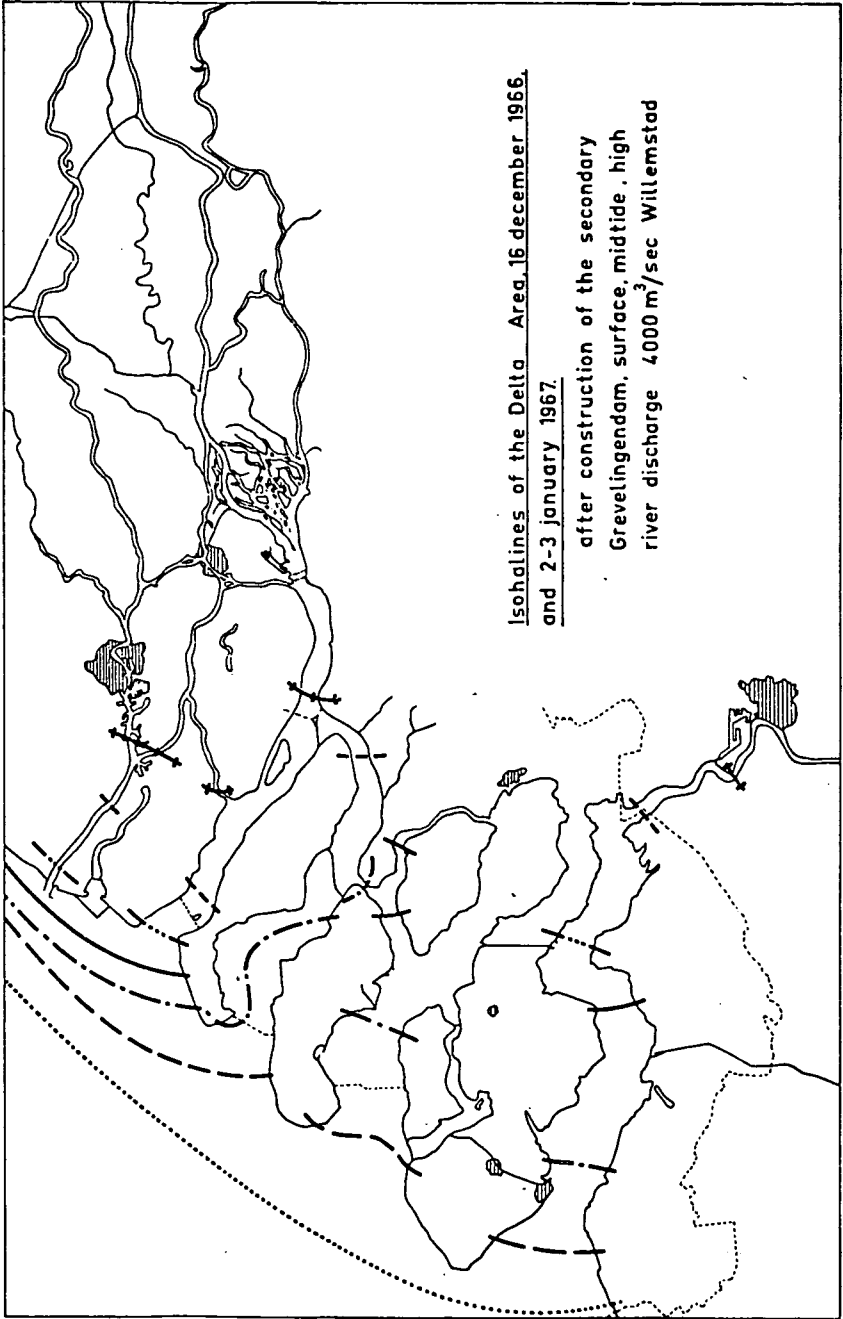
Map 4, for explanation see map 2.



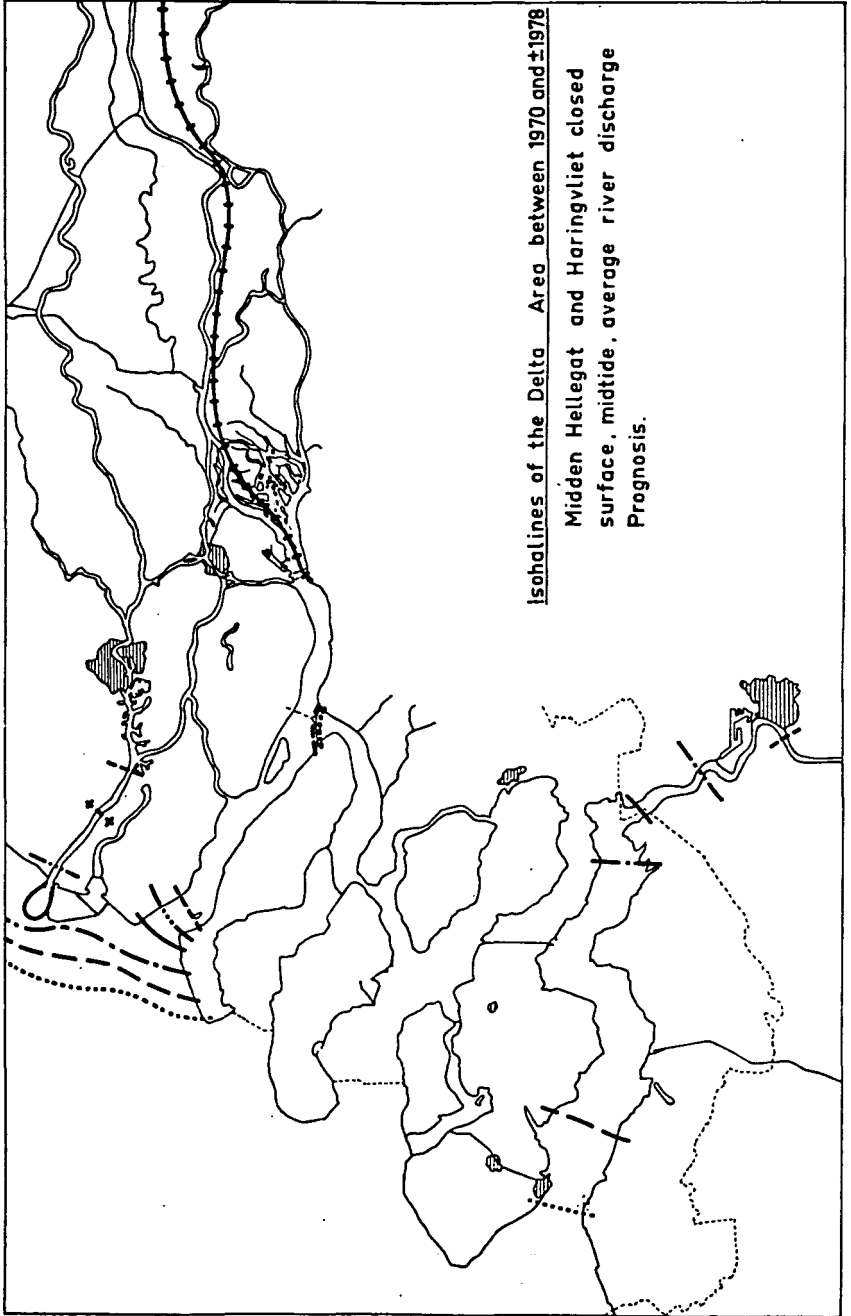
Map 5, for explanation see map 2.



Map 6, for explanation see map 2.



Map 7, for explanation see map 2.



Map 8, for explanation see map 2.



Map 9, for explanation see map 2.