CHAPTER 135

EXPERIENCES WITH TIDAL SALINITY MODEL EUROPOORT

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SUMMARY

To guide the works for the new harbour entrance at Rotterdam-Europoort in 1965 a tidal salinity model (scales 1:640 hor., 1:64 vert.) was constructed. The model includes a part of the North Sea and the Rotterdam Waterway Estuary. For its regular adjustment, use could be made of extensive prototype measurements, two-dimensional tidal computations and tidal computations by msans of the DELTAR (analogue, one-dim.). The model has proved to be very valuable for predicting stream patterns for nautical purposes because the shipping (huge crude carriers) had to go on without danger while the works were being carried out. The model has also been used for the solution of harbour problems (design, siltation), for predicting cooling water recirculation, and for advice on salinity intrusion problsms.

1. Introduction

The seaward extension of the Europoort harbour system is being realised on the flats south of the mouth of the Rotterdam Waterway. Knowledge of the hydraulic conditions is of fundamental importance with the creation of complicated constructions in the field of coastal hydraulics. In the area at issue these are not only governed by the tidal movement but also to a considerable rate by density differences. To check the hydraulic aspects of the consequences of ths execution of the works, at the moment two methods are available: one- and two-dimensional mathematical models can be used without taking into account, however, density differences, and use can be made of hydraulic tidal ssa and estuary models reproducing three-dimensional flow and taking density differences into account. A combination of the two methods

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can also be applied, as shown later.

The prssent knowledgs on the physics of density currents is not so far advanced that computational methods can be successfully ussd for such a complicatsd pattern as the Europoort area with the inland tidal area of the Rotterdam Waterway Estuary. On ths other hand, there is sufficient knowledge about model laws for salinity models, so that a real chance of success may be expected. Consequently, at this moment the use of a hydraulic model is preferred in which ths tidal and density currents can be reproduced with a sufficient degree of accuracy. The construction of a hydraulic salinity model may thus be justified, and this has been affirmed by the results of the model tests carried out.

2. Preliminary Studies

In the years 1957-1962 the lay-out of the harbour entrance was investigated in a pilot model (tidal model scales 600/100, also tests not on Froude scals with wavss and mobile bed). Some aspscts wsre chscked in a detail modsl (harbour mouth with flood and ebb conditions, permanent flow, scales 375/125, also salinity aspects). The present model, which was commissioned in 1965 by the Rijkswaterstaat (Department of Traffic and Waterways) in ordsr to guids the works as an operational model, is a tidal salinity model with a fixed bsd.

In the years 1964-1967 an ad-hoc committee on tidal hydraulics (Rijkswaterstaat Services, Port Authority of Rottsrdam, Delft Hydraulics Laboratory) invsstigated future problems related with watsr, salt and sediment movement in the Rotterdam Waterway Estuary, which resulted in rscommendations for research. As a result, a tidal salinity flume was established to guide the above-mentioned Europoort model with respect to the fundamental aspects (a.o. selection of the scales).

To a certain extent data from field studies and computations were available. Since the beginning of this century many field data have been collected from ths Rotterdam Waterway Estuary. There was a substantial amount of know-how about the behaviour of the estuarine system (tide, currents and salinity aspects). For the Rotterdam Waterway Estuary as a part of the Delta system tidal computations had been executed and a great deal of experience was available in this field (including data from a tidal modsl, scales 2400/64 of the Delta area).

In 1965 no detailed information existed about the coastal region of the North Sea. There had been some float measurements for various purposes, amongst others to calibrate the pilot model of the mouth of the Rotterdam Waterway; but no detailed insight had been obtained of the flow distribution along the ooast and the behaviour of the salinity distribution under the influence of the estuaries in the Delta region. The configuration of the sea bottom was well-known by soundings made by the hydrographic service of the Navy and the measuring services of the Rijkswaterstaat.

In 1965, moreover, no advanced computation methods existed for a detailed computation of the flow pattern in the coastal region. An idea of the effect of the new harbour mouth could be ascertained by simply applying the potential theory (obstacle in a parallel flow). This gave some insight into the flow pattern and the limits where the disturbance would be reduced to an acceptable degree. This information was required to estimate the position of the boundaries of the model. The tests in the pilot model also gave some information about this aspect. The stream atlasses available in 1965 showed that at an adequate distance from the coast, the velocities are directed almost parallel to a certain direction. For this reason (and for economic reasons) it was decided to have the western sea boundary parallel to the above direction and to have this limit as a closed model boundary.

3. Set-up of the Model (Fig. 1)

The conditions in the harbour mouth are governed by tidal and density currents. The tidal range is 1.60 m (mean tide), 1.35 m (neap tide) and 1.75 m (spring tide). The fresh water discharge from the Rotterdam Waterway is 1,000 m^3/s (mean value) and ranges roughly from 400 m^3/s to 4,000 m^3/s. The salinity of the North Sea is about 33 ppt. The current at sea runs almost parallel to the coast and during flood the flow is in a northerly direction. High water slack at sea is $3\frac{1}{2}$ hours after high water in the harbour mouth ($3\frac{1}{2}$ hours time lag). For the Europoort harbour there is no time lag and for the Rotterdam Waterway it is $2\frac{1}{2}$ hours.

Consequently the interaction of the currents is very complex, and is complicated even more by the action of strong density currents.

The boundaries of the eea section of the model were choeen on limite where disturbancee due to coastline modificatione are negligibly emall and where, except in eome caeee, the flow ie almoet homogeneous. The boundaries of the river system were choeen in the tidal region but beyond the region of salinity intrusion. There is one temporary non-homogeneous boundary (Haringvliet, before the closure of the eetuary).

The eelection of the scales of the model (1:640 horizontal dimeneion, 1:64 vertical dimeneion, 1:8 horizontal velocity, 1:80 time, 1:1 density) was based on eimilarity according to the Froude law and on coneideratione on diffusion. It ehould be mentioned that in 1965 no sound theoretical basis was available for the selection of the scalee; the tidal flume was not available in time to produce a physical background. Information from literature had to be the determining factor in the final decieion. It can now be said that the choice of the scales 640/64 hae been juetified by experimente with the model and by data from the tidal ealinity flume.

The eelection of the boundary conditions wae a major problem, being a determining factor for an efficient boundary control of the model. Apart from certain exceptione, the system has proved only well-defined if in the case of n boundary conditions in n-1 the flow and in one the water level ie prescribed. The boundary in which the water level ie prescribed was neceesary becauee of inaccuraciee and echematieations in the boundary conditions. This boundary had to be far enough from the problem area, sufficiently wide and without traneveree variation of flow and deneity. In the present model, the northern boundary fulfile these conditions best.

The bottom roughness of the model was brought to ecale by blocks (various sizes, for the greater part cubee with an edge of 0.05 m). In the river system it proved to be unneceseary to uee mixing devices (e.g., air bubble screens) in order to bring mixing to scale. It eeems that the compensating effect of the exaggerated wall roughnees in the highly dietorted channele is important. Though the sea part of the model ie quite large, it proved to be unneceeeary to have devicee for simulating Coriolis force. The effect of the Coriolis acceleration ie implicit in the boundary conditions as they were obtained from prototype data. For the internal area, two-dimensional tidal computations were executed with and without Coriolis acceleration, which have shown that there is no important difference in the tidal movement. It is obvious that the boundary conditions determine the phenomenon in the internal area to such an extent that no additional mechanism is necessary. A complicated problem could thus be avoided, for no experience existed about the effect of Coriolis devices (e.g., tops) in non-homogeneous flow, as in the internal area of the model.

A hall (3,000 m^2) was built for the model with its technical equipment and with facilities to make brine. The model was constructed on a concrete slab 1.25 m above the hall floor to provide space for reservoirs and other facilities. The sea part of the model consists of pre-stressed concrete plates following the bottom of the sea, while the other part of the model, including the problem area near the harbour mouth, was moulded in a sand bed. The water circulation system for the sea boundaries consists of a reservoir of 1,500 m^3 (below the model) and a closed canal to the boundaries, and in the system there are 3 pumps with a total capacity of 1.5 m^3/s. For the river boundaries there is a small reservoir with a pumping system to realise the tidal discharge and the fresh-water input; the most southern estuary branch (Haringvliet) has a reservoir (labyrinth) in which a two-phase system can be maintained so that a non-homogeneous boundary condition more or less can be realised. For the model the total use of salt is 1 ton (mean) and 4 tons (extreme) per hour.

The control of the model could not be realised as strictly as suggested earlier in this survey. The flow in the model is controlled (by means of a system with gates) at 12 points along the sea boundaries and at 3 points on the river boundaries. On the sea side gates are used with overflow, and on the river side with underflow. When calibrating the model, the gates are controlled in such a way that the currents on the boundaries are in accordance with prototype conditions. Once the movement of the gates is known, only the movement is reproduced (boundary control without feed back). Naturally the system in the final stage is very stable and the currents are very well reproduced, but it is very time-consuming to find the good calibration. This led to a switch-over to volumetric discharge control, a principle which is now being adopted for the river boundaries. Density is controlled by injecting brine in the water circulation system of the sea boundaries, with samples being continuously extracted from the system and measured by means of a specific weight meter (gravitrol).

In the model the overall stream pattern is recorded by photographing floats (5 m, 10 m and 15 m lengths on prototype scale). To measure forces and moments (due to currents) along a certain shipping route (e.g., in the harbour entrance) a towed plate is used. The plate is towed into and out of the harbour, while the speed can be controlled and an angle with the route introduced. For tanker problems a plate of 300x15 m is used, and for coaster problems a plate of 100x5 m (prototype dimensions). For detailed measurements of the flow field, micro-propellers are used (in combination with a vane), and for measurements of the density distribution use is made of conductivity probes (in combination with a temperature meter). The tide is measured by water-level followers (vibrating needle principle). For the compilation and evaluation of the results a data-processing system (pencil follower, computer, plotter) has been available, but in 1972 a computer system is being introduced to take over the total data-processing, the checking of the model and in the near future also the boundary control of the model.

4. Boundary Conditions (Figs. 2 and 3)

To realise the tidal movement in the hydraulic model, the necesray tidal conditions must be given on the boundaries of the model: for instance, the vertical tide on the boundaries on the sea side together with the vertical tide on the inland boundaries. To obtain the salinity distribution, the river boundaries should be supplied with fresh water and the sea boundaries with salt water with a constant and homogeneously distributed salinity, except in some cases of non-homogeneous flow. These boundary conditions, together with the bottom configuration and data on flow resistance, provide sufficient information to realise the non-homogeneous tidal movement. The velocities could also be given, perpendicular to the sea boundaries of the model, provided at least one or more vertical tides were given at the same time for the involved tidal area, whereas on the inland boundaries the currents may be given, too. Generally, this boundary condition is more strict than the vertical tide. The outline just given holds for a mathematical and a hydraulic model, although for the hydraulic model discussed in the preceding paragraph an extremely strict system of boundary conditions has to be used because of the reproduction of the salinity situation.

The next problem was to decide how the conditions on the sea boundaries and the inland boundaries could be obtained, together with sufficient information on the internal area. For this purpose, on June 15, 1966, extensive sea measurements were carried out by the measuring services of the Rijkswaterstaat, including detailed measurements of flow, density and silt distribution along rows corresponding with the boundaries of the model and in the internal area; water levels were measured at stations along the coast and at a few points in the sea and at regular distances along the Rotterdam Waterway Estuary. The sea measurements were so extensive,however, that it was impossible to carry out simultaneously flow and density measurements in the river system, so the river flow data had to be simulated by computation.

As the model could not be extended outside the tidal region, boundary conditions were required on boundaries inside. These data were computed starting from the data (at the river mouth) of the sea measurements of June, 1966, as boundary conditions. Computations were made by means of the DELTAR, which is an electrical analogon used by the Delta Division of the Rijkswaterstaat and simulating the tidal movement in the northern part of the Delta area (schematised to a system of tidal channels with a one-dimensional character) (Ref. 1). The DELTAR was essential during the operation of the model, particularly for the supply of data when conditions had changed, e.g., after the closure of the Haringvliet Estuary.

At the time of the sea measurements of June 15, 1966, the northern part of the Delta plan was not yet completed. As these works would already be finished at the time of completion of the Europoort Works, it was necessary to close the Haringvliet Estuary in the model for the realisation of the actual situation to be expected. By this, however, not only was the tidal movement in the adjacent sea area influenced, but at a more important rate the water movement in the inland tidal area. In consequence of this enclosure, a way had to be found to adapt the boundary conditions to the new artificially-created circumstances. Due to the cutting-off of a volume of 550.10^6 m^3/tide (average value), it was to be expected that in particular the velocities at the southern tidal boundary would be changed.

By about 1968 the two-dimensional computations had developed so far that the measured 1966-situation could be modified. In connection with the developments along the Dutch coast as a result of the execution of the Delta plan, two-dimensional tidal computations were carried out for a rectangular sea area covering the coastal area of the North Sea, including the Delta region and ranging about 40 kms seaward (the Europoort area is within this rectangle). The dimensions of the computation molecules of the system were 1,600 m x 1,600 m (Ref. 2). In order to introduce the necessary vertical tidal boundary conditions to solve the tidal problem, measurements at sea were made on June 27, 1967, in which the vertical tides were measured along the above-mentioned rectangle. In the internal area of the rectangle, velocity measurements were also made for verification of the results of the two-dimensional computation.
The boundary conditions along the sides of the rectangle were assumed to be invariable. This means that the influence of the enclosure of the Haringvliet a priori was thought to be no longer noticeable on the vertical tides along the sea boundaries of the mathematical model. Consequently, by closing the Haringvliet and so putting the velocities there at zero, the changes of the velocities along the sea boundaries of the hydraulic model could be computed for the tide on the day of the sea measurements (June 27, 1967).
From the results of computation it appeared that water transportation through the southern part of the western sea boundary increased, while in the coastal region part of the southern sea boundary there was a considerable decrease. Along the northern sea boundary hardly any changes could be noticed. The vertical tide in the mouth of the Rotterdam Waterway, too, hardly changed after the enclosure of the Haringvliet.
The difficulty was now to translate the changes due to the enclosure of the Haringvliet, known from computation, into velocity changes on the model boundaries, corresponding with the tide on which the

model had been calibrated (June 15, 1966). This was done by expressing the changes of the normal velocities at the model boundaries in percentages, and by presuming that in similar phases these percentages would also apply to the changes of the velocities measured on June 15, 1966, thus adapting conditions along the sea boundaries to the new situation.

The realisation of the northern part of the Delta plan is changing considerably the inland boundary conditions which had originally existed. Of course, this was to be expected, as the tide used to penetrate into the northern part of the Delta area from three sides, viz., the mouth of the Rotterdam Waterway, the mouth of the Haringvliet and the inland connection with the southern part of the Delta area (Volkerak). If the entrances - Haringvliet and Volkerak - are left out, the tide in the northern part of the Delta area will be damped out considerably.

As already mentioned, the vertical tide in the mouth of the Rotterdam Waterway had hardly been changed by the enclosure of the Haringvliet. Consequently it could be introduced in the DELTAR as a tidal boundary condition and the tide of June 15, 1966, could thus be simulated for the completed northern part of the Delta area. The currents measured in the DELTAR at the already-mentioned inland boundaries of the hydraulic model were introduced in the model. Currents and water levels measured in the DELTAR along the Rotterdam Waterway Estuary could also be measured later in the hydraulic model. The current in the mouth of the Rotterdam Waterway as a function of time, proved to be in good agreement with the corresponding measuring results of the DELTAR.

5. Experimental Studies

5.1. Operational studies Europoort (Figs. 4, 5 and 6)

The main purposes of the model is research to support the works for the new harbour entrance at Rotterdam-Europoort (Ref. 3). The investigations were commissioned by the Rijkswaterstaat, Harbour Entrances Department.

The main aspects are:

(a) Operational research in connection with the making of a new entrance to the Europoort harbours and closing the temporary one.

(b) Additional rssearch for an optimum design of the combined harbour entrance to the Europoort basins and the Rotterdam Waterway.
(c) Operational research on the stages of exscution of the Northern and the Southern breakwaters.

(a) Operational research has been carried out for the rsalisation of a new sntrance to the Europoort harbours and for the closurs of ths tsmporary one. In four stages ranging from February 1970 up to April 1972 the planning for the exscution of ths works was tested and a number of alternative solutions wers examined. The opening of the new entrance was started by dredging from the inland side. A barrier, which was part of the old Southern breakwater was temporarily left, but in the final stages the breakwater was cut through. A gradual change occurred in the stream pattsrn in the harbour and in the temporary entrance. Howsver, as the least change could creats difficulties, because manoeuvring with big oil tankers in ths temporary sntrance was alrsady critical, the opening of the new entrancs had to be done vsry carefully. A jet stream into ths harbour would be dangerous for ths manoeuvring of the tankers in ths basin. It was known from DELTAR computations that above a critical size the connection between the new entrance and ths temporary one would operate as a shunt to the Rotterdam Watsrway. As a conssquence the stream pattern in the tsmporary entrance and in the harbour basin would change considerably, during ths flood period as well as the ebb period. This could bs dangerous for ths shipping, especially as manosuvrability is a big problem when ths speed is reduced considerably on sntering the harbour basin. The conclusions from DELTAR computations have been confirmed by the results from the modsl.
In the model stream patterns have been photographed for floats of various lsngths. For the junction of the temporary entrance with the Rottsrdam Waterway and for the main shipping routes in ths harbours, forces perpendicular to the routss have been computed bassd on velocity data from photographs.

(b) Additional ressarch is being done for an optimum design of the combined entrancs to the Europoort harbours and the Rotterdam Waterway. The works startsd from the south with a sand dam which joins up with the Southern breakwater through a transit structure. One problem

to be solved was the best length of this structure to guide the currents along the coast. To find an answer, stream patterns were photographed. The optimum length of the Northern breakwater had provisionnally been estimated from tests in the pilot model. This problem, which has important economic aspects, was also governed by other aspects apart from the hydraulic criteria (manoeuvring length, wind and waves, morphological problems, etc.). In the model the length was varied from 2,150 m to 2,950 m, measured from the old breakwater. This proved that the stream pattern was not very sensitive. Although a length of 2,550 m showed optimum with respect to the stream pattern, the design length of 2,750 m was maintained because of other aspects.
A big extension of the beach north of the Northern breakwater is in execution; the design was checked by photographing stream patterns in the model and found satisfactory.
The temporary entrance to the Europoort harbours will not be closed completely but an entrance for small shipping will be left and in this connection various alternatives have been tested by photographing stream patterns and by local velocity measurements.

(c) Operational research on the various stages of the execution of the Northern and the Southern breakwater has been carried out. Eight stages have been tested for the period April 1971 upto June 1974. For overall data stream patterns have been photographed. In the main shipping route, starting in the 66' approach gully and ending in the harbour, forces and moments have been measured by means of the towed plate and local velocity measurements were made at various locations where current concentrations were feared, for instance, at the end of dams. It proved that, starting from a very smooth stream pattern (April 1971), as the works proceed the stream pattern will gradually become less favourable (more concentrated between the dams), although in the final situation there will again be a slight improvement (smoother stream pattern). This is most important information for shipping.

Control measurements are regularly executed in prototype to check the results of the model. Though comparing the results is sometimes cumbersome because of different tidal conditions and fresh water flow, it has been shown that there is a good correspondence between information from the model and that from nature. Extensive control measurements are those during closing the temporary entrance (an opening for small shipping was left) and regular measurements at sea in the approach route to the harbour mouth.

5.2. Other investigations

At the rsquest of the Electricity Board of Rotterdam research has been carried out on the dispersion of the cooling watsr of a huge electrical plant (in 1990 6,500 MW) to be situated in the new harbour area. The cooling water (250 m^3/s in 1990 and a temperature jump of 8^o C) can be taken from the harbour and released directly into the sea or in the opposite way. Four alternatives have been tested in the model.

The dispersion was photographed with fluorescine for a tracer and the concentration was measursd with rhodamine B. Density differences were simulated by adding fresh water to the salt water from the intake; a few tests were done with warm water, primarily to test thermovision techniques.

A major problem was the expected change in metsorological conditions (fog), which would be unfavourable for the quality of the harbour entrance. It turned out that this problsm was imaginary for about one kilometer from the outlet the warm water disappeared, and tests showed that a three-layer system had been established: from the bottom to the surface cold salt water, warm salt water, cold fresh water. The recirculation of cooling water to the intake proved to be unimportant, as even the most unfavourable alternative.

On assignment by the Port Authority of Rotterdam designs have been tested for a container harbour connected to the Rotterdam Waterway. The harbour lies in the estuarine region, and the flow conditions in the harbour mouth are governed by the tide and density differences. For overall data stream patterns have been photographed, and the nautical aspects have been analysed on the basis of forces computed along certain shipping routes. To analyse the morphological aspects the velocity distributions in various cross-sections have been measured and from velocity data in the harbour mouth the exchange flow (primarily due to density differences) has been computed, on the basis of which and of the expected silt coneentration a prognosis of the siltation has been made. The effect of the harbour on the salinity intrusion has also been analysed.

At the request of the Rijkswaterstaat, Rotterdam Waterway Authority, the consequences of connecting a canal (depth 6 m, width 150 m, length 25 km) to the estuarine system havs been analysed. The canal is a part of the harbour system which leads from the inland side into the Europoort harbour area; it is connected by a sluice to the Old Meuse, a branch of the Rotterdam Waterway. Because of the ever-increasing shipping, particularly push tows, it is necessary either to build more sluices or to create an open connection. The latter solution has been investigated in the model. The criterion is the response at the salinity situation, although the steam pattern in the junction is also important for nautical reasons. By examining both situations (closed and open canal) in the same model experiment, maximum accuracy ($\pm$ 0.3 ppt in concentration difference and $\pm \frac{1}{2}$ km in intrusion length) could be achieved. Alternative configurations of the junction were analysed on the basis of photographs of stream patterns. Particularly interesting is the phenomenon in the mouth of the canal: because of the high tidal velocities and the small density differences, there is no dispersion due to critical flow conditions. The canal thus serves the function of a fresh water barrier.

6. Discussion of the Results

6.1. Analysis of the shipping problem (Fig. 7)

In the model the currents have been recorded as a function of place and time. But with these data alone the preparation of an advice on the navigability of a harbour entrance is a difficult task. The relation between navigability and currents (e.g., in a harbour entrance) is not well-known and the problem therefore involves the integration of the knowledge and experiencs of a number of disciplines Fortunately there exists a substantial know-how in various disciplines and information is available with respect to many aspects, a.o.:

1. Plots of tankers entering a harbour entrance, including the

recording of positions as function of time, drift angles and rudder angles; comments and interviews with pilots are simultaneously collected.

2. Experiences with sense perception-physiological research regarding the factor "man" in the system, e.g., from tests with ship simulators.
3. Response of model ships to certain types of currents in typical situations (e.g., influence of berths and bottom).
4. Measurements in prototype of the currents in the same situations as mentioned under 1 and/or simulations of the currents in a model.
5. Forces and moments on model ships towed along fixed routes with tests in a ship model basin, in addition to the information under 3. For purposes under 6, also tests with a towed plate have been done (Ref. 4).
6. Currents in a tidal salinity model. As this type of model is highly distorted, tests with model ships are not possible, therefore tests are made with a towed plate. In situations where this is not possible (e.g., in curved shipping routes), data are computed from stream patterns.

Much work is being done in this field, for a great deal by Rijkswaterstaat:

- Data are collected from existing situations to try and analyse the relation between current patterns and criticisms of the pilots. The effect of new situations is smoothed by instructing the pilots beforehand through stream atlasses about new situations, predicted from stream patterns measured in the tidal salinity model.
- On the initiative of Rijkswaterstaat a Nautical Committee has been formed on which the various disciplines and pilot organisations are represented. This committee co-ordinates the activities in the various fields and watches the nautical aspects with respect to the works in execution.

The lack of good criteria is obvious. Judgment of data for routes where there has been hardly any shipping or model data rising above limits known from the past, involves the danger that there are no criteria which indicate that the situation is inadmissible. Besides, the factor "man" is hard to judge; it has proved in some cases that situations which initially were found difficult, did not create problems after some experience. In general, however, it is not necessary to judge the model data in an abeolute way as just described. A great part of the work consiets of comparison of mutual situations or comparison of situations with a reference situation. Nevertheless, not only forces and moments, but also gradients of these functions might have repercussions for shipping. There is an obvious lack of know-how to judge this; yet this problem can also be solved, in most cases by referring to known situations. The data on, for example, forces and gradients are tabulated as a function of place and time and are compared with similar data from a reference situation. Some well-eelected codes help to visualise the relative improvement or worsening, so that a final judgment can be made (in co-operation with the Nautical Committee).

6.2. Analysis of various problems (Fig. 8)

The analysis of dispersion due to density differences as with salinity intrusion problems, is based on intrusion lengths and longitudinal and vertical salinity distributions. When the model reproduces the tide (water level, flow) in an accurate way, the convective transports (in one-dimensional terms) are reproduced correctly. The reproduction of the dispersive transports can be checked by comparing these transports in model and prototype, and these data can be directly computed if the spatial distribution in a cross-section of horizontal velocity and concentration is known. The model has been scaled on a correct overall reproduction of horizontal dispersion; local diffusion aepects cannot be analysed in the model.

In the case of dispersion problems with no or very small density differences,a field in which the dispersion of cooling water from an electrical plant has been investigated, the success of the studies depends on whether the horizontal distribution of the effluent is the predominant phenomenon. As the model has been scaled on a correct reproduction of the horizontal dispersion (in longitudinal and in transverse directions), realistic results can be expected.

For siltation problems in a harbour a tidal salinity model is essential if the exchange due to density currents is predominant (there is also an exchange in connection with the tidal prism and the effect of vortices in the mouth). The exchange flow can be computed from velocity data in the harbour mouth. When the silt concentration is known, the siltation can be predicted, if the longitudinal salinity distribution in the river is also known, by applying the formulas for the exchange flow in the sluice problem for this case (with the appropriate empirical coefficient).

For siltation problems in a river the model gives only little information. The predominance of the time mean value of the flow at the bottom is a criterion for siltation (no predominance means siltation), but for the Rotterdam Waterway it does not seem to be important. Sedimentation and erosion can hardly be predicted from the model. The velocity fields in a model with appropriate scales for a correct reproduction of salinity dispersion have some significance. For an overall impression a "bottom" velocity (1-2 m above the bottom) is generally used as a rough indication of changes in morphological conditions.

7. References

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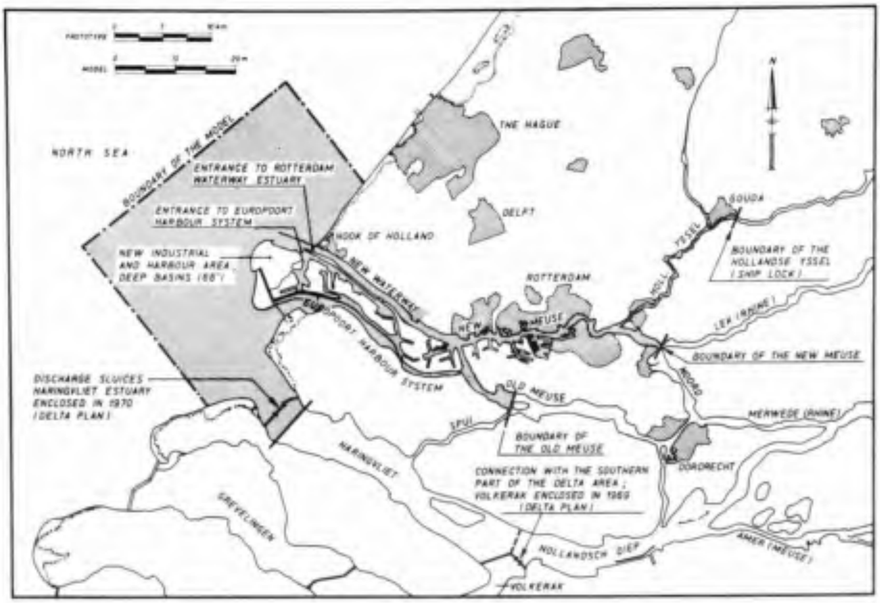


FIG. 1a PLAN OF THE MODEL AREA

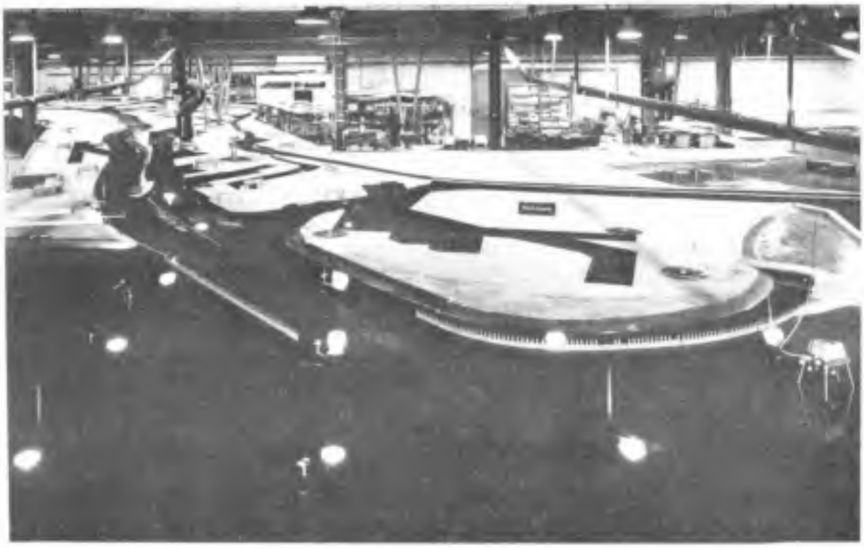


FIG. 1b VIEW OF THE MODEL

FIG. 1 GENERAL INFORMATION

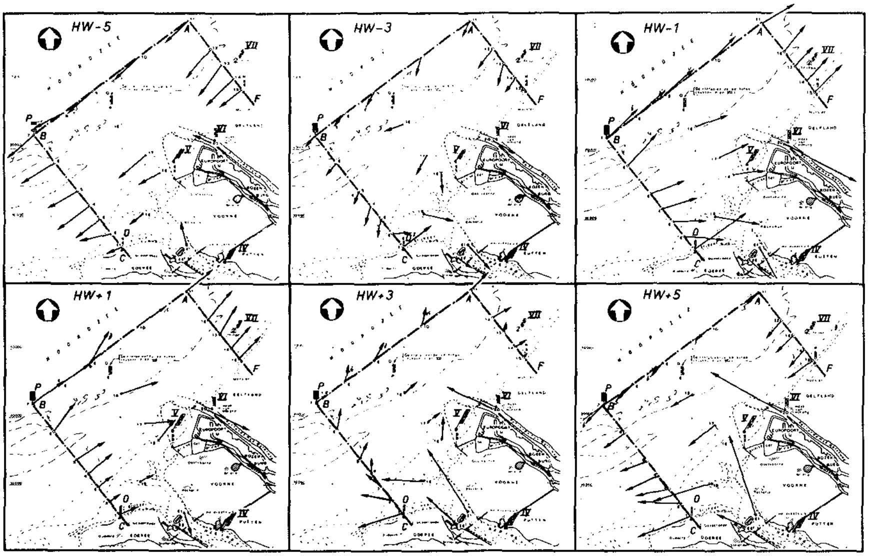


FIG. 2a VELOCITY DISTRIBUTION

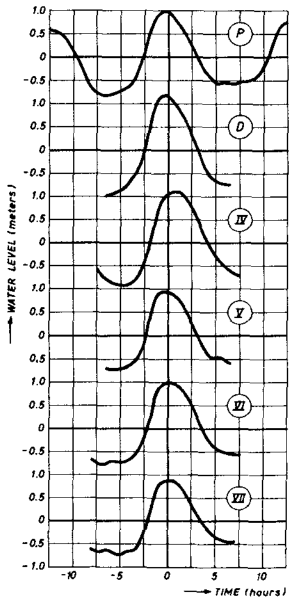


FIG. 2b DATA ON WATERLEVELS

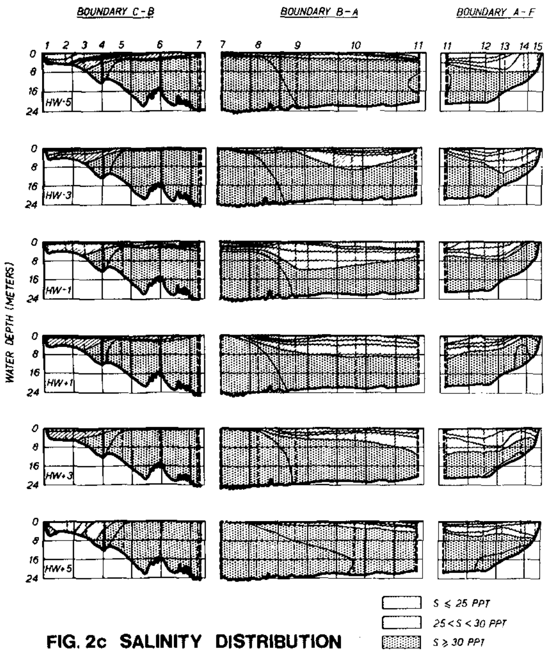


FIG. 2c SALINITY DISTRIBUTION

FIG. 2 PROTOTYPE SEA MEASUREMENT OF 15 JUNE 1966

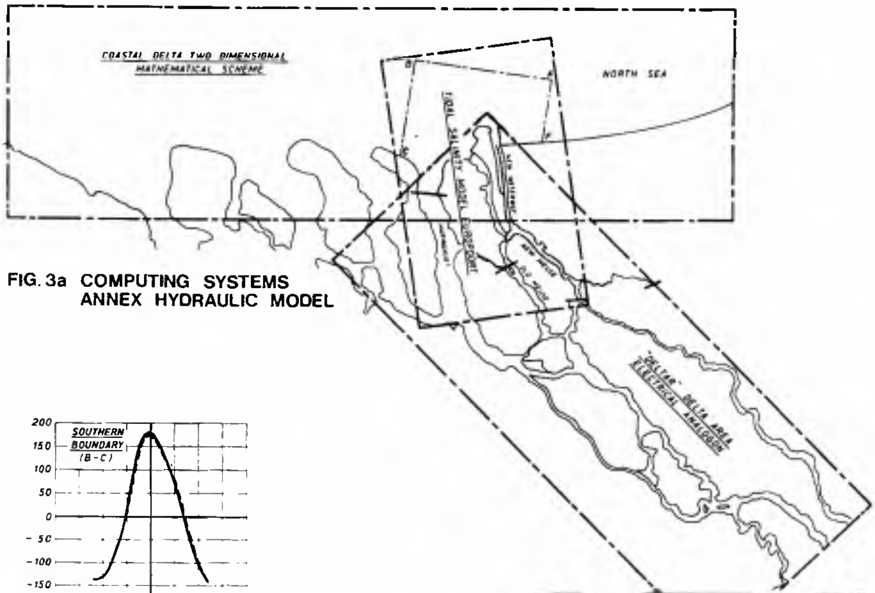
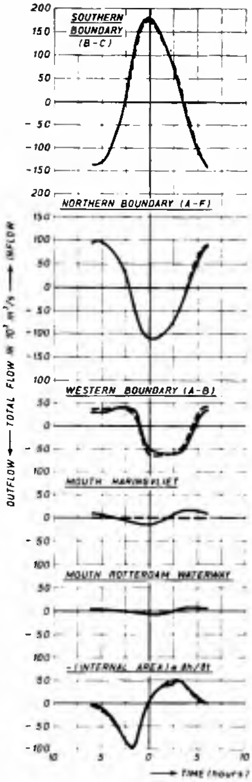


FIG. 3a COMPUTING SYSTEMS
ANNEX HYDRAULIC MODEL

FIG. 3b VIEW OF THE "DELTAR"



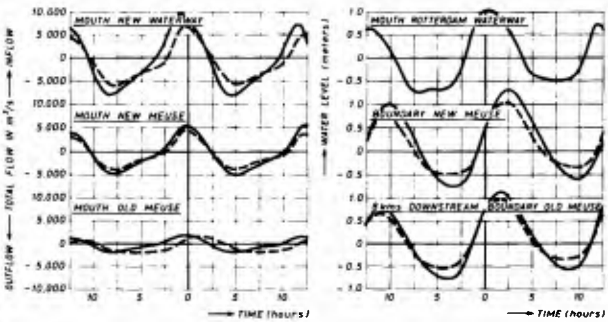


FIG. 3c DATA OF THE SEA AREA

FIG. 3d DATA OF THE RIVER SYSTEM

FIG. 3 COLLECTING DATA ON BOUNDARY CONDITIONS

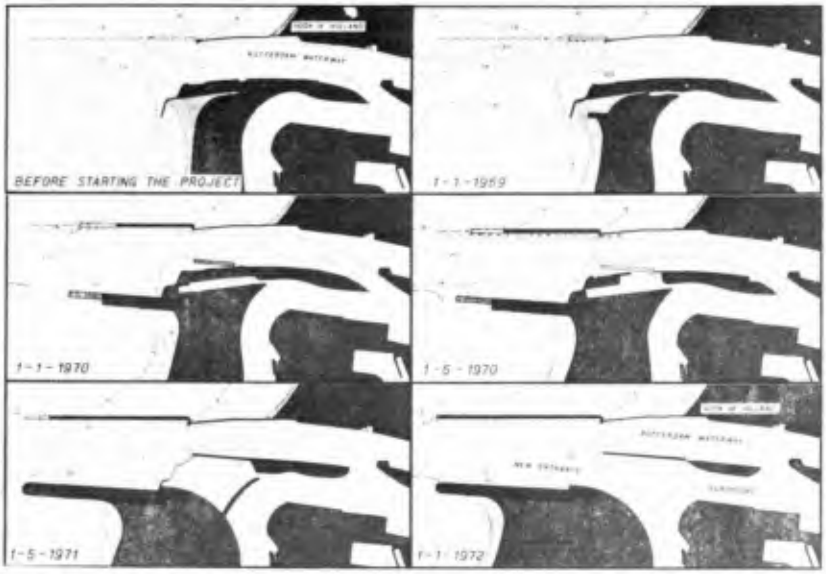


FIG. 4a STAGES OF EXECUTING THE NEW ENTRANCE EUROPOORT

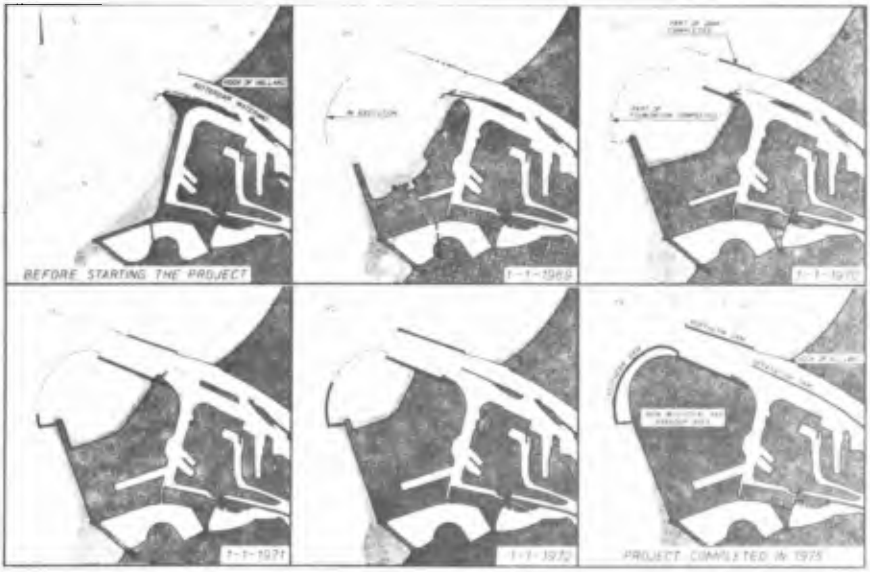


FIG. 4b STAGES OF EXECUTING THE TOTAL PLAN OF THE NEW HARBOUR MOUTH

FIG.4 BUILDING STAGES NEW HARBOUR MOUTH ROTTERDAM-EUROPOORT

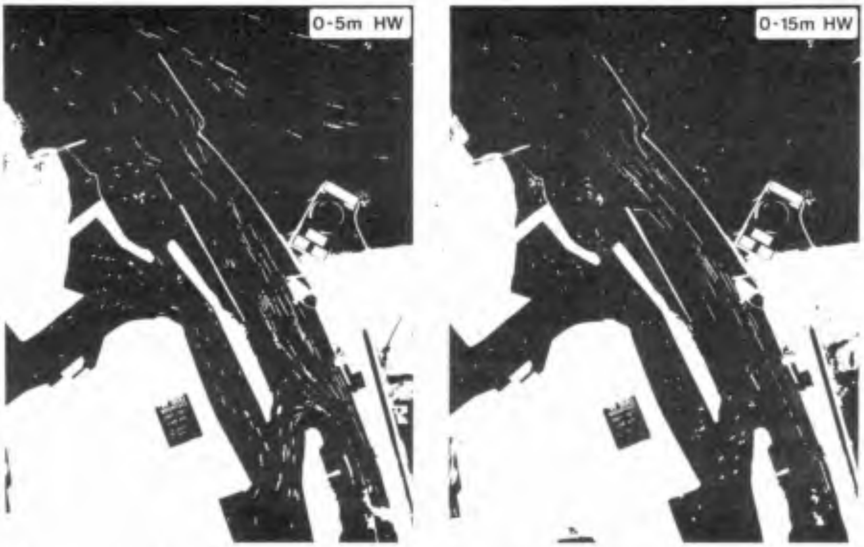


FIG. 5a FLOW PATTERN - BEFORE MAKING NEW ENTRANCE

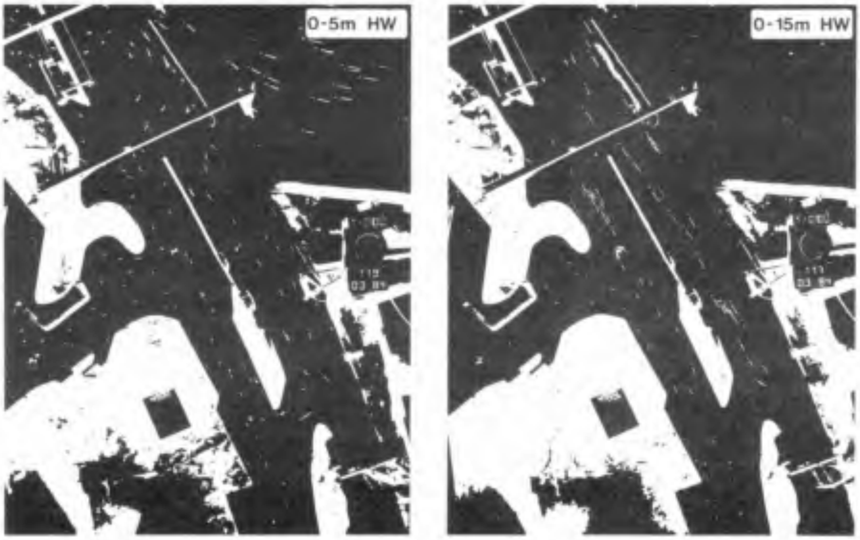


FIG. 5b FLOW PATTERN - AFTER REALISATION NEW ENTRANCE
(THE TIDAL VELOCITIES HAVE CHANGED TOO, BY THE ENCLOSURE OF THE HARINGVLIET)

FIG. 5 INVESTIGATIONS NEW ENTRANCE EUROPOORT

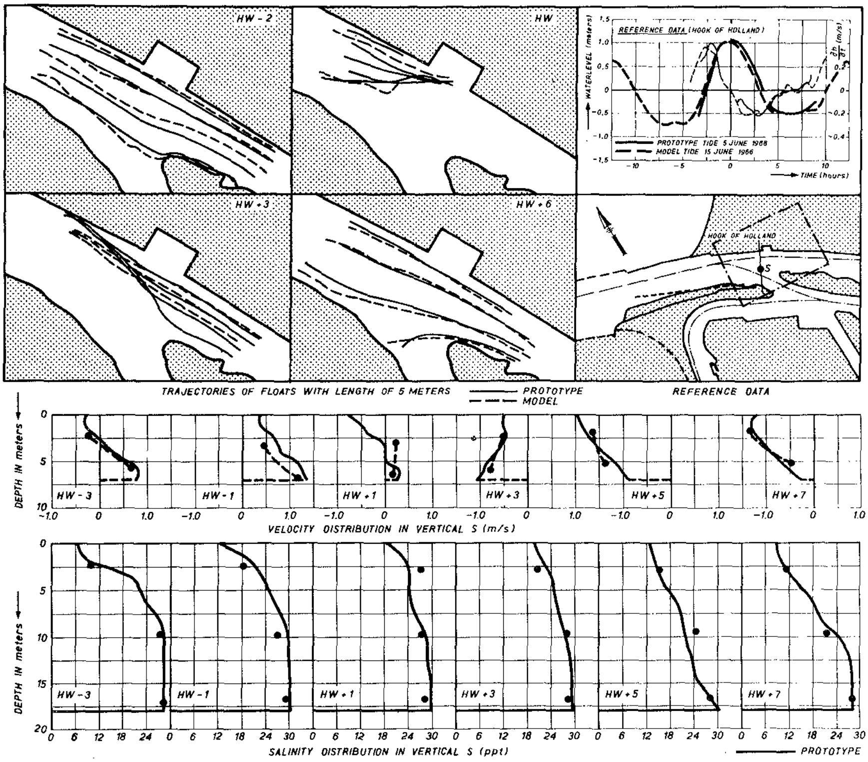


FIG. 6a MEASUREMENTS NEAR THE TEMPORARY ENTRANCE EUROPOORT

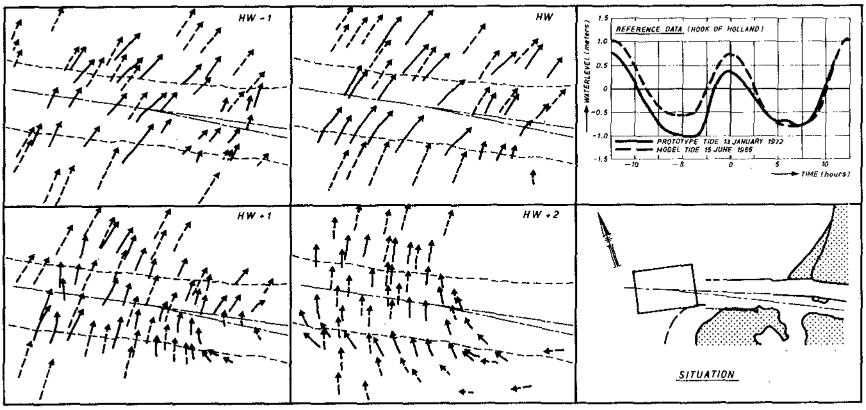


FIG. 6b MEASUREMENTS AT SEA IN THE APPROACH ROUTE

PROTOTYPE
MODEL

FIG. 6 VERIFICATION MODEL DATA BY MEASUREMENTS IN PROTOTYPE

FIG.7a SET-UP WITH TOWED PLATE

FIG.7b TYPICAL STREAMPATTERN

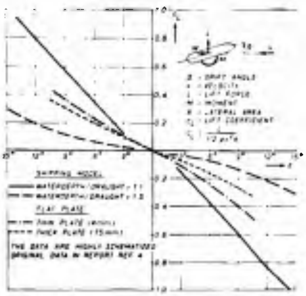


FIG.7c TESTS IN TOWING TANK

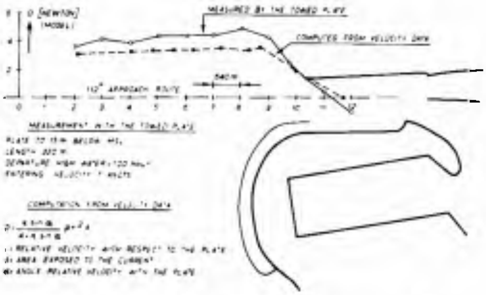


FIG.7d COMPARISON OF MEASURED AND COMPUTED FORCES

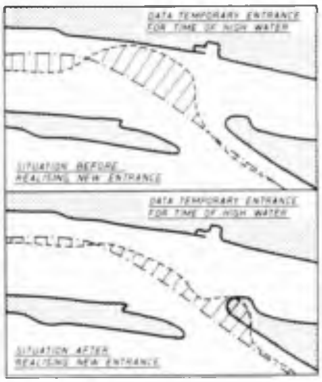


FIG. 7e FORCES IN TEMPORARY ENTRANCE (COMPUTED FROM VELOCITY DATA)

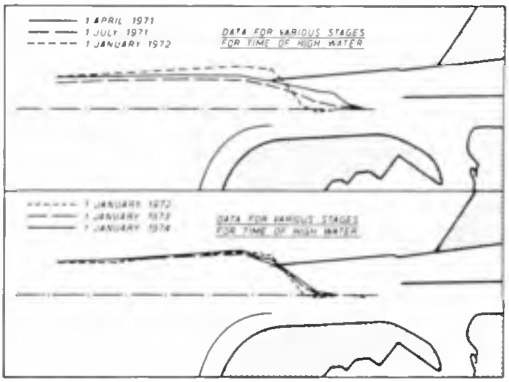


FIG.7f FORCES IN THE HARBOUR ENTRANCE (MEASURED WITH THE TOWED PLATE)

FIG.7 HANDLING THE SHIPPING PROBLEM (SAFE SHIPPING)

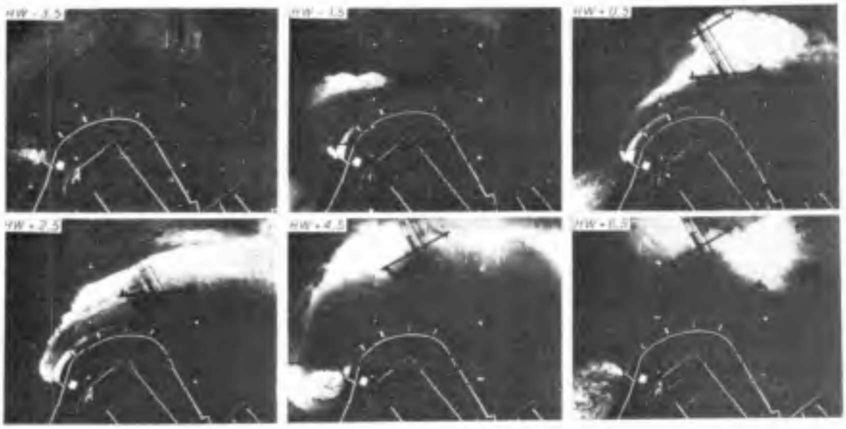


FIG. 8a RELEASE OF COOLING WATER

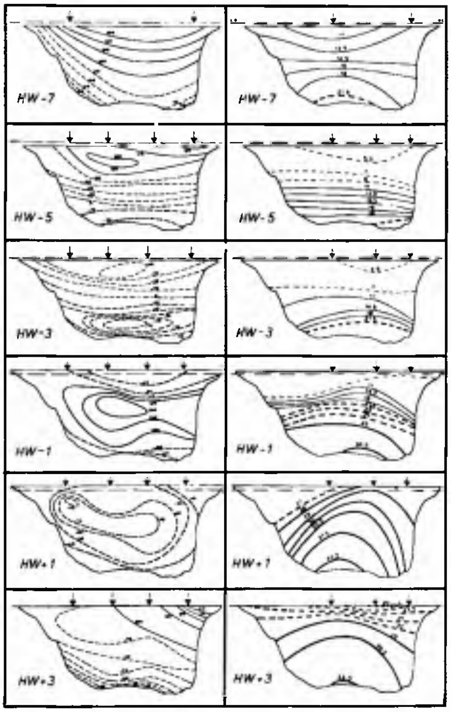


FIG. 8b VELOCITY AND SALINITY DISTRIBUTION
(DATA 21 JUNE 1956 MOUTH ROTTERDAM WATERWAY)

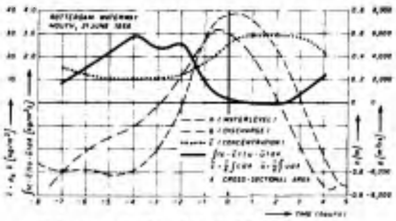


FIG. 8c DATA ON DISPERSION

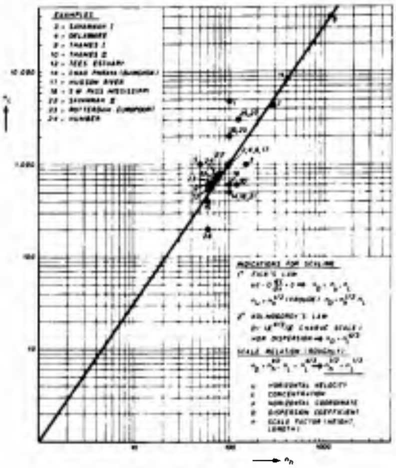


FIG. 8d MODELING OF DISPERSION

FIG. 8 HANDLING DISPERSION PROBLEMS