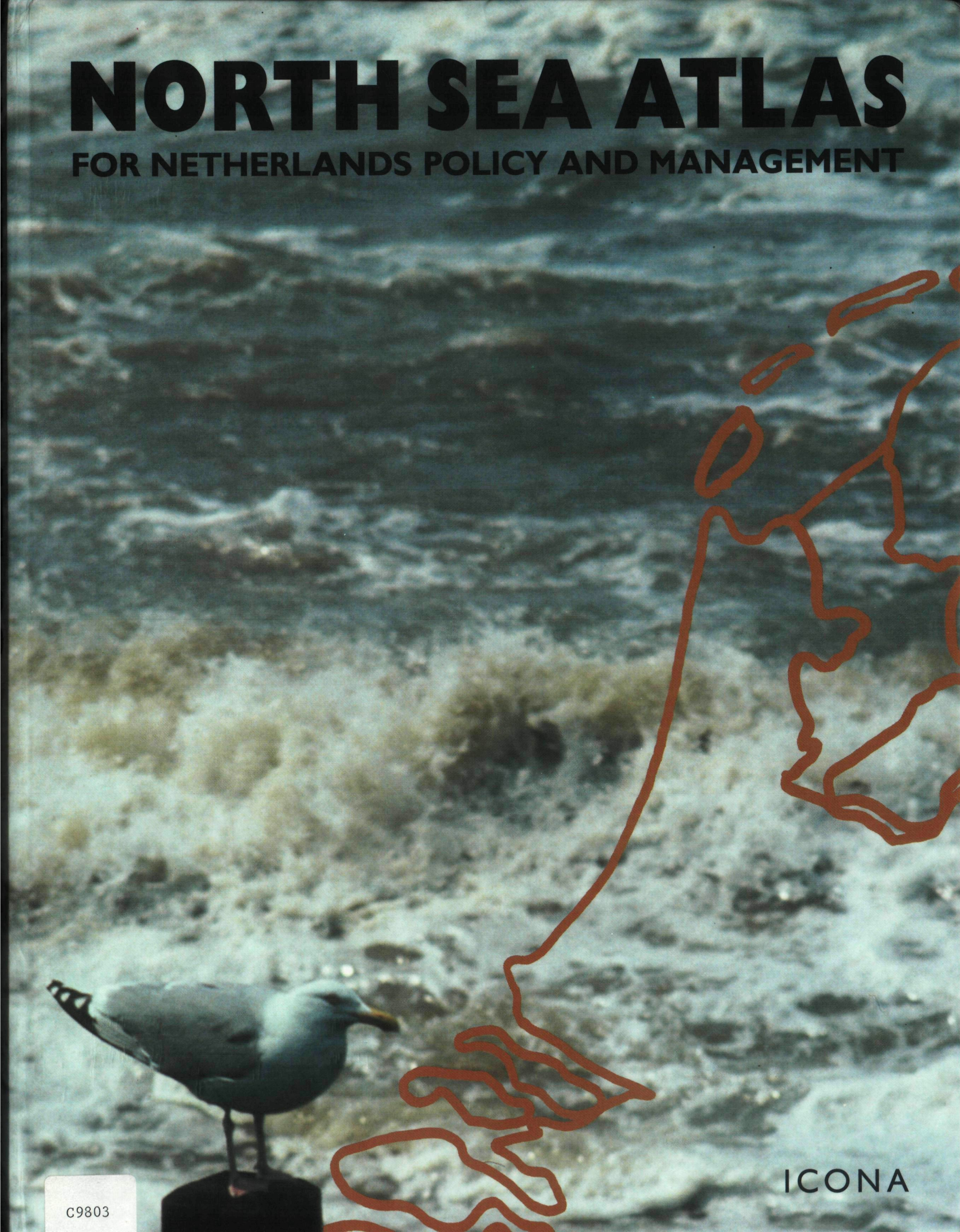
NORTH SEA ATLAS

FOR NETHERLANDS POLICY AND MANAGEMENT



ICONA

NORTH SEA ATLAS

for Netherlands Policy and Management

ICONA

(Interdepartmental Co-ordinating Committee for North Sea Affairs)

Stadsuitgeverij Amsterdam

CIP-GEGEVENS KONINKLIJKE BIBLIOTHEEK, DEN HAAG

North

North Sea atlas for Netherlands policy and management
/ ICONA, (Interdepartmental Co-ordinating Committee for
North Sea Affairs). - Amsterdam : Stadsuitgeverij
Amsterdam. - Ill.
Met bijlage
Vert. van: Noordzee-atlas voor het Nederlands beleid en
beheer. - Amsterdam : ICONA, Interdepartementale
Coördinatiecommissie voor Noordzee-aangelegenheden,
1992. - Met lit. opg.
ISBN 90-5366-047-X geb.
NUGI 501
Trefw.: Noordzee ; Nederland ; atlassen.

ISBN 90-5366-047-X

Foreword

When you open this atlas you will not smell the salty air of the North Sea. Nor will you hear the murmur of the waves or feel the loose North Sea sand under your feet. Nevertheless this atlas is about the North Sea. The atlas forms part of a triptych. The other two parts of the triptych consist of the report "The North Sea ... new possibilities" and the "Discussion Memorandum on North Sea Spatial Policy". These three documents mark the conclusion of a policy exploration of North Sea spatial policy. This policy exploration began by investigating what developments may be expected in the future. We then set down on paper the policies we propose to adopt to control the present and future spatial use of the North Sea. Lastly, the latter were given visual form in the present North Sea Atlas.

We cannot of course claim that, when we have the North Sea Atlas on our bookshelves and have studied the various reports, we will indeed know the vast space of the North Sea: the North Sea cannot be known. It presents itself to us in so many different guises that not even the North Sea Atlas can show them all. Sometimes the North Sea is grey and recalcitrant, threatening those who sail on it or fish it or even live on it. At other times it is green and withdrawn, wholly at the user's command. This North Sea, which is a home to so many animal and plant species, is a valuable heritage that cannot be sufficiently cherished.

The triptych shows how important the North Sea is for us. We would like its treasures to be actively preserved for our children and the following generations. We are doing all we can to make that possible. The North Sea Atlas shows the treasures that we wish to protect and how we protect them. It is an excellent medium for the purpose.

J.R.H. Maij-Weggen
The Netherlands Minister of Transport, Public Works and Water Management
Co-ordinating Minister for North Sea Affairs

Acknowledgements

The "NORTH SEA ATLAS for Netherlands Policy and Management" has been produced on behalf of the Interdepartmental Co-ordinating Committee for North Sea Affairs (ICONA) under the supervision of the ICONA Working Group for North Sea Policy. This publication was financed by: the Ministry of Education and Science; the Tidal Waters Division, ICONA, North Sea Directorate and the Survey Department of the Directorate-General for Public Works and Water Management, Ministry of Transport, Public Works and Water Management; the Directorate-General for Shipping and Maritime Affairs of the Ministry of Transport, Public Works and Water Management; the Nature Conservation, Environmental Protection and Wildlife Management Department and the Fisheries Directorate of the Ministry of Agriculture, Nature Management and Fisheries; the National Physical Planning Agency of the Ministry of Housing, Physical Planning and Environment; the Ministry of Economic Affairs.

The content and arrangement of the atlas are based on the spatial approach of North Sea policy, supplemented with physical, chemical and biological information about the North Sea. The arrangement of the North Sea Atlas is as follows:

- general information about the North Sea, partly as a support to the other maps
- description of the spatial diversity of the North Sea environment, insofar as it is relevant to its spatial use
- spatial use
- environmental effects of spatial use, insofar as these can be depicted spatially
- spatial effect of measures taken to harmonise the uses of the North Sea and to protect the marine environment.

All the maps have been based on the most recent information which could be presented in map form. This information is shown in maps of the North Sea, the Netherlands sector of the Continental Shelf or of the Netherlands coast, depending on the nature of the subject or the information supplied. Each map is accompanied by an explanatory text and a reference to the relevant sources. Maps can be compared among themselves with the loose enclosed overlays. The cartographic material and the commentaries have been supplied by a large number of officials from various departments and members of research institutes (see colophon). The editors have processed this material into the present form and content. The Translation Branch of the Ministry of Foreign Affairs has looked after the translation of the Netherlands version 'Noordzee-atlas voor het Nederlands beleid en beheer' into English. The contributors have checked their texts on a correct translation of technical terms.

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FLORA AND FAUNA

USE OF SPACE

Loose enclosed overlays of the North Sea, the Netherlands sector of the Continental Shelf and the Netherlands coast

General

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Research (map 8 to 11)

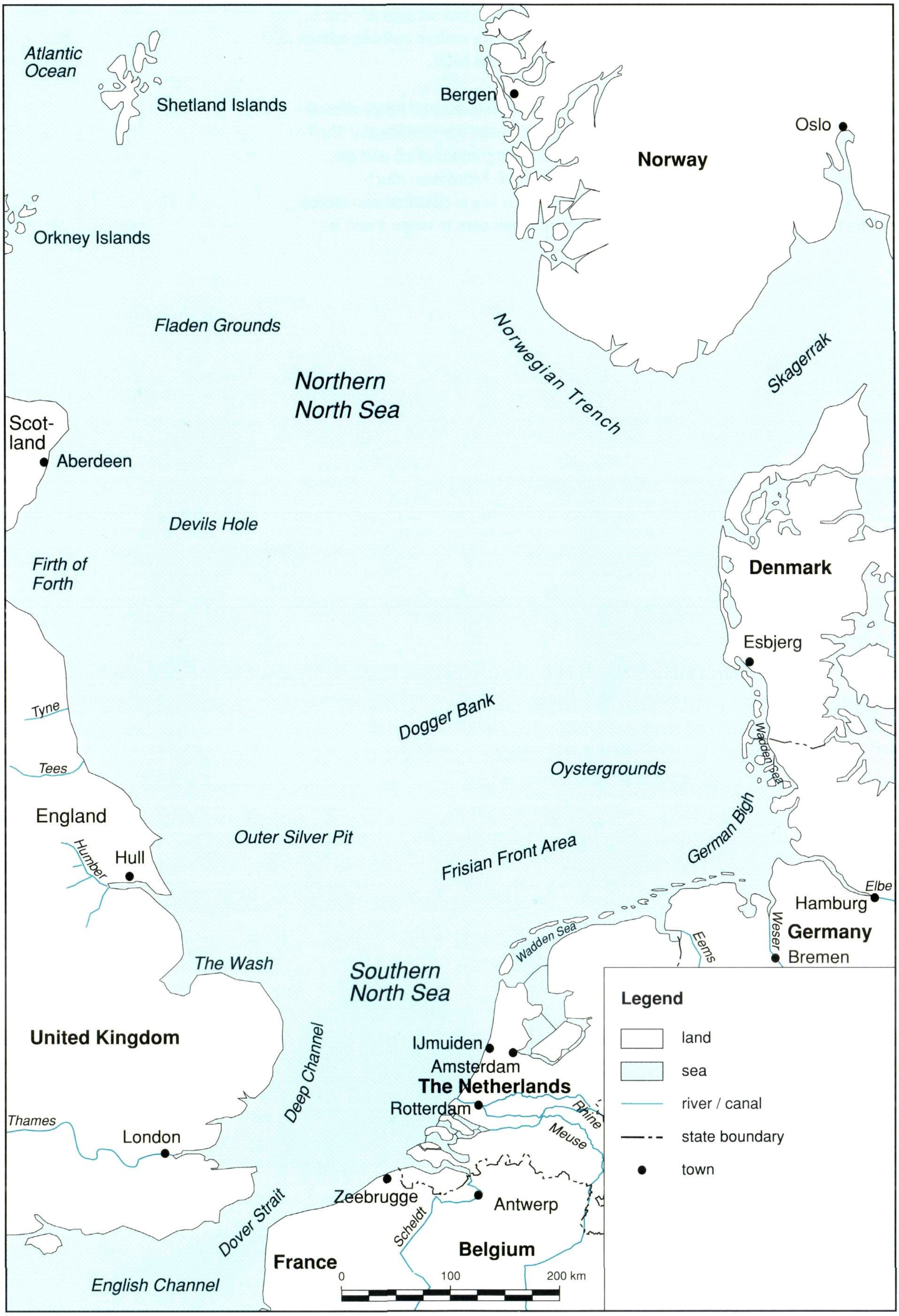
The North Sea

The information contained in the North Sea Atlas is plotted on maps of the North Sea (1), the Netherlands Continental Shelf (2) or the Netherlands coast (3), depending on the nature of the subject. In order to facilitate comparisons between maps, the basic topography is also shown on overlays. The North Sea overlay shows latitudes and longitudes and the ICES quadrants (ICES stands for: International Council for the Exploration of the Sea). ICES quadrants are of particular relevance to the fisheries maps (64 to 67).

The solid land is shown in yellow on the basic topography of the maps. The sea, inland waters and rivers are shown in blue. White is used on the maps to indicate that data about the area in question were lacking or not available. Maps 1 to 3 contain all the topographical names included in the atlas.

The North Sea, in fact, occupies the area between 4° west and 12° east longitude, and between about 49° and 62° north latitude. The whole North Sea, taken from the Strait of Dover to a line from the Shetland Isles to Bergen, has an area of about 572,000 km^2.

The North Sea

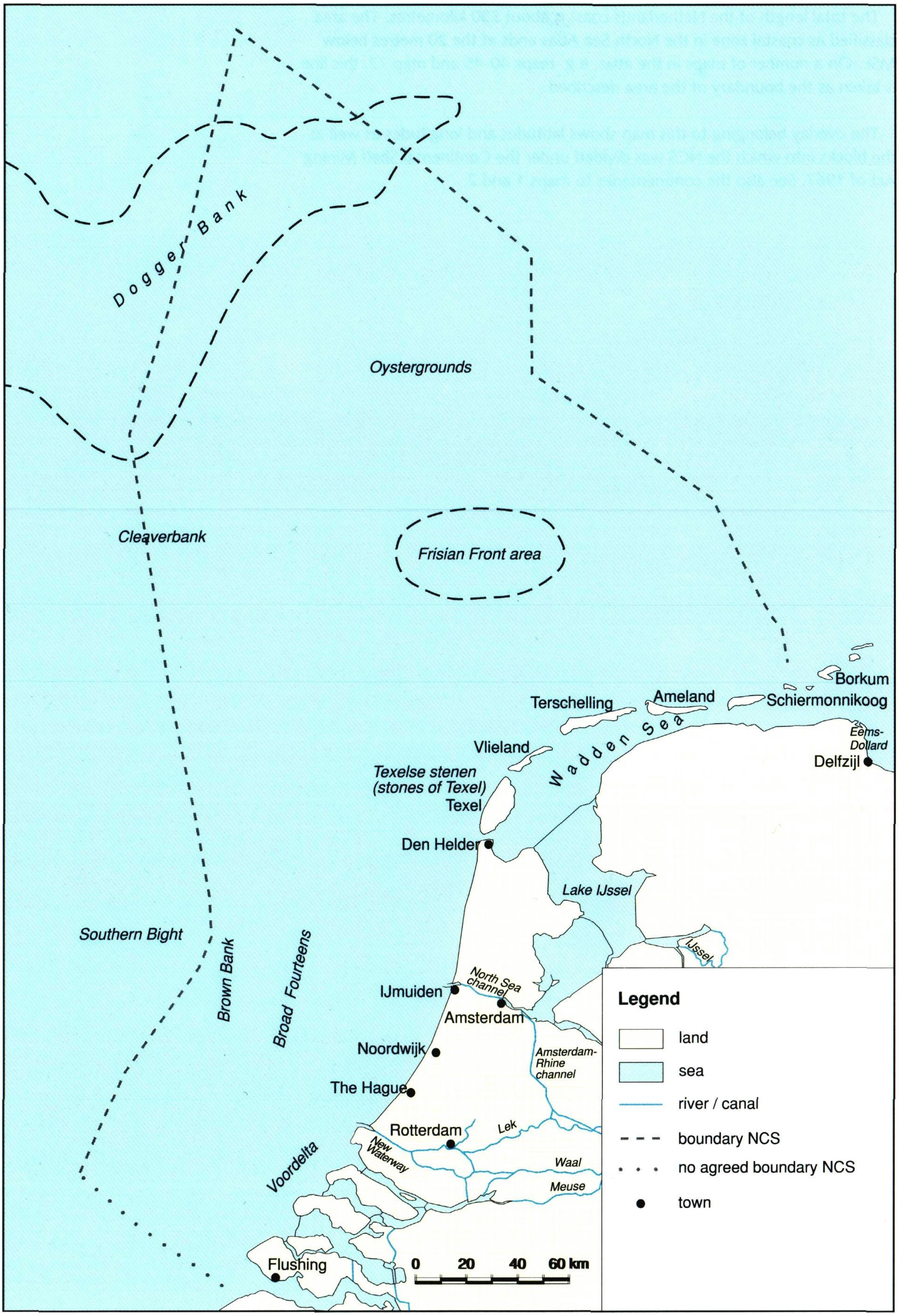


The Netherlands Continental Shelf (NCS)

The Netherlands sector of the Continental Shelf (NCS) has an area of about 57,065 km². By Continental Shelf is generally meant the seabed and the subsoil. Many of the maps, however, show only the limits of the NCS.

The overlay of the topography of the NCS shows latitudes and longitudes as well as the blocks into which the NCS was divided under the Continental Shelf Mining Act of 1967. These blocks are used in the assignment of oil and gas activities and in relation to the extraction of sea sand. Moreover, much information about the geology and use of the North Sea is classified and stored on the basis of this subdivision. See also the commentaries to maps 1 and 3.

The Netherlands Continental Shelf (NCS)



The Netherlands coast

The total length of the Netherlands coast is about 390 kilometres. The area classified as coastal zone in the North Sea Atlas ends at the 20 metres below MSL. On a number of maps in the atlas, e.g. maps 40-45 and map 72, this line is taken as the boundary of the area described.

The overlay belonging to this map shows latitudes and longitudes as well as the blocks into which the NCS was divided under the Continental Shelf Mining Act of 1967. See also the commentaries to maps 1 and 2.

The Netherlands coast

Delimitation of the Continental Shelf

By Continental Shelf is generally meant the seabed and the subsoil, beyond the territorial sea, up to a distance of 200 nautical miles measured from the coast (baseline). International legal rules have been established for the delimitation of the Continental Shelf by the bordering coastal states. They have been mainly laid down in the Convention of Geneva on the Continental Shelf (1958). The UN Convention on the Law of the Sea (1982) also contains rules relating to the Continental Shelf, but this Convention has not yet come into force.

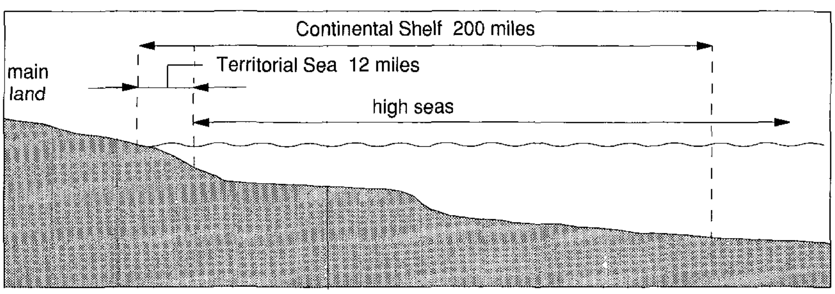
Article 6 of the Continental Shelf Convention states that the delimitation must be effected through an agreement between the states whose Continental Shelf borders on that of the other. If the states concerned cannot reach an agreement, the equidistance line shall be taken as the boundary. This is a line each point of which is equidistant from the coasts of the states concerned. A different formulation has been chosen in the UN Convention on the Law of the Sea (which will supersede the Continental Shelf Convention when it comes into force). It emphasises that the result of the delimitation shall be equitable.

A coastal state enjoys sovereign rights on its Continental Shelf in relation to the exploitation of its natural resources (oil, gas, sand, gravel, sedentary animal species).

Many bilateral delimitation agreements were concluded between the North Sea states in the 1960s and the first half of the 1970s after the conclusion of the Convention of Geneva. The resultant boundaries have been drawn in on the map. The oldest agreement is that between the Netherlands and Germany (1964). The boundary was then only partially defined (over a segment of 26 nautical miles). Further agreement was not possible because of a dispute about the correct delimitation criteria. The Netherlands and Denmark considered that the equidistance line should be applied. Germany pointed out that, because of the convex form of the coast, application of the equidistance rule would result in the German Continental Shelf being completely enclosed by the Netherlands and Danish areas, which would be unequitable. In anticipation of the solution of this dispute the Netherlands and Denmark concluded a delimitation agreement in 1966. The dispute between the three countries was submitted to the International Court of Justice which decided in favour of Germany in 1969. The agreement between the Netherlands and Denmark was withdrawn in 1971 when Germany concluded agreements with the Netherlands and Denmark fixing the boundaries of the Continental Shelf.

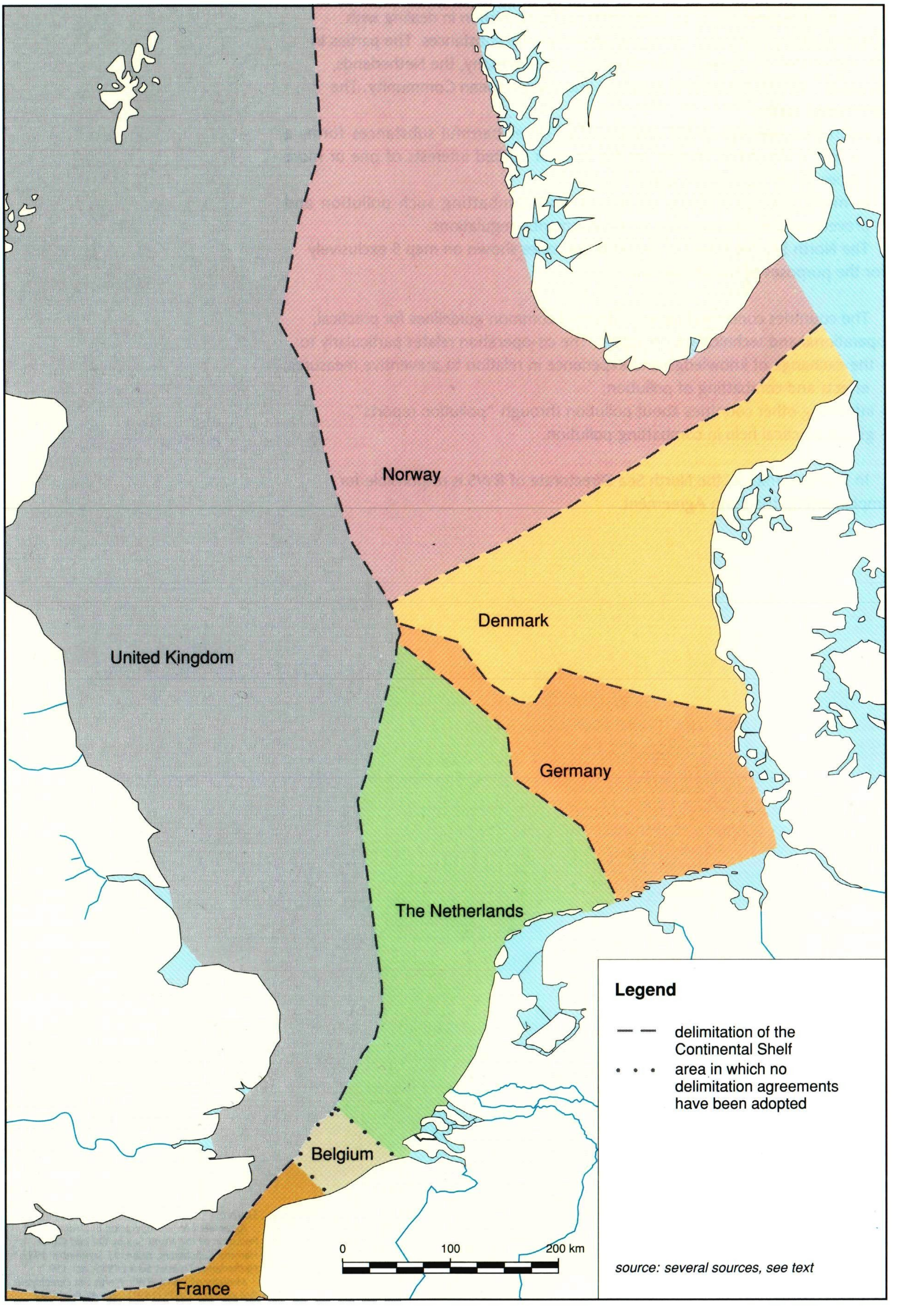
Seventeen delimitation agreements have now been concluded for the partition of the Continental Shelf in the North Sea. The most recent agreements are those between the United Kingdom and Belgium (1991) and between Belgium and France. No agreement has yet been concluded for one Continental Shelf boundary, that between Belgium and the Netherlands.

Maritime zones



Source:
Freestone, D., IJlstra, T. (eds.) (1991). The North Sea: Basic Legal Documents on Regional Environmental Co-operation. p. 215-227 and p. 383-418. Graham and Trotman/Martinus Nijhoff. ISBN 0-7923-0919-7.
Convention on the Continental Shelf, Geneva, 29 April 1958, Netherlands Threaties Series 1959, no. 126.
United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982.

Delimitation of the Continental Shelf



Zones of responsibility under the Bonn Agreement (1983)

The Bonn Agreement is an agreement for co-operation in dealing with pollution of the North Sea by oil and other harmful substances. The parties to the agreement are: Belgium, Denmark, France, Germany, the Netherlands, Norway, Sweden, the United Kingdom and the European Community. The agreement applies:

- whenever pollution of the sea by oil or other harmful substances forms a serious or immediate danger to the coast or related interests of one or more parties to the agreement; and
- to monitoring as a means of tracing and combatting such pollution and preventing the contravention of environmental regulations.

The North Sea has been divided into the zones shown on map 5 exclusively for the purposes of the agreement.

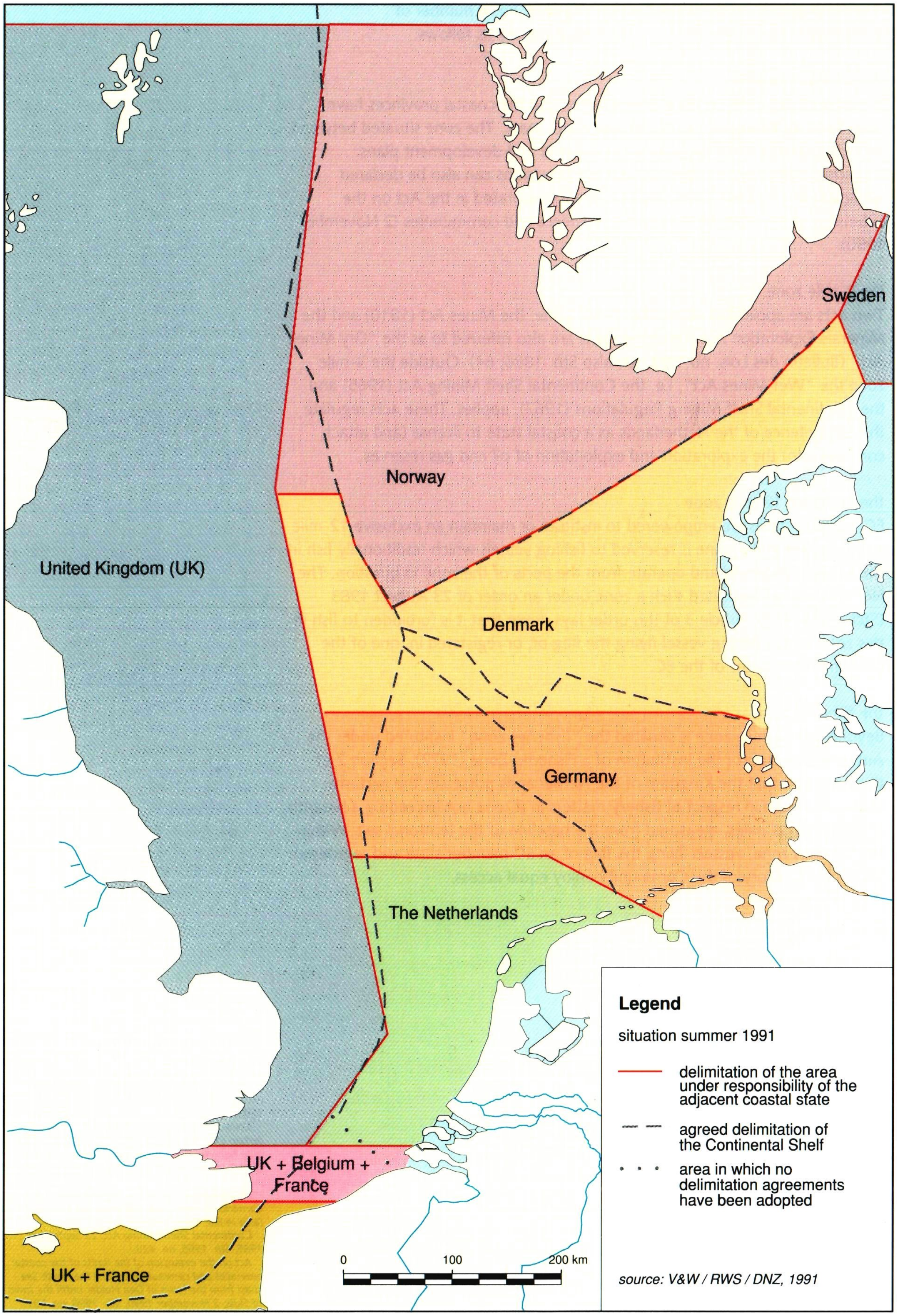
The countries concerned have established common guidelines for practical, operational and technical co-operation. The co-operation relates particularly to:

- the exchange of knowledge and experience in relation to preventive measures, effects and combatting of pollution;
- informing other countries about pollution through "pollution reports";
- giving practical help in combatting pollution.

In the Netherlands, the North Sea Directorate of RWS is responsible for implementing the Bonn Agreement.

Source:
Agreement for Co-operation in Dealing with Pollution of the North Sea by Oil and Other Harmful Substances, Bonn, 13 September 1983, Netherlands Treaties Series 1983, no. 159.
Ministry of V&W, RWS, North Sea Directorate (V&W/RWS/DNZ) (1991): unpublished data.

Zones of responsibility under the Bonn Agreement (1983)



Administrative zones on the NCS

The Netherlands sector of the Continental Shelf has a number of administrative zones. Viewed from the land these are as follows:

- the 1-kilometre limit

The boundaries of the coastal communities and the coastal provinces have been fixed at 1 kilometre from the low water mark. The zone situated between these boundaries must be included in regional and development plans. Municipal and provincial land use control provisions can also be declared applicable to this zone. These matters are incorporated in the Act on the extension of the limits of the coastal provinces and communities (2 November 1990).

- the 3-mile zone

Two acts are applicable within the 3-mile zone: the Mines Act (1810) and the Minerals Exploration Act. These two acts are also referred to as the "Dry Mines Act" (Bulletin des Lois, no. 285, see also Stb. 1886, 64). Outside the 3-mile zone the "Wet Mines Act", i.e. the Continental Shelf Mining Act (1965) and the Continental Shelf Mining Regulations (1967), applies. These acts regulate the competence of the Netherlands as a coastal state to license (and attach conditions to) the exploration and exploitation of oil and gas reserves.

- the exclusive 12-mile zone

EC member states are empowered to institute or maintain an exclusive 12-mile zone. Fishing in this zone is reserved to fishing vessels which traditionally fish in the waters concerned and operate from the ports of the zone in question. The Netherlands has instituted such a zone under an order of 23 August 1983 (Stct. 1983, 165). Article 3 of this order lays down that it is forbidden to fish in this zone with a fishing vessel flying the flag of, or registered in, one of the other member states of the EC.

- the fisheries zone

Beyond the 12-mile zone is situated the "fisheries zone" instituted under the Authorisation Act for the Institution of a Fisheries Zone (1977). Section 2 of this act states that the Kingdom of the Netherlands possesses the exclusive legal jurisdiction in respect of fishery matters in a zone not exceeding a breadth of 200 nautical miles, measured from the baseline of the territorial sea. Within the fisheries zone, vessels flying the flag of an EC member state and registered within the territory of the Community enjoy equal access.

Source:

Decision on the establishment of a 12-mile exclusive fisheries zone, 23 August 1983, Stct. 1983, no. 165.

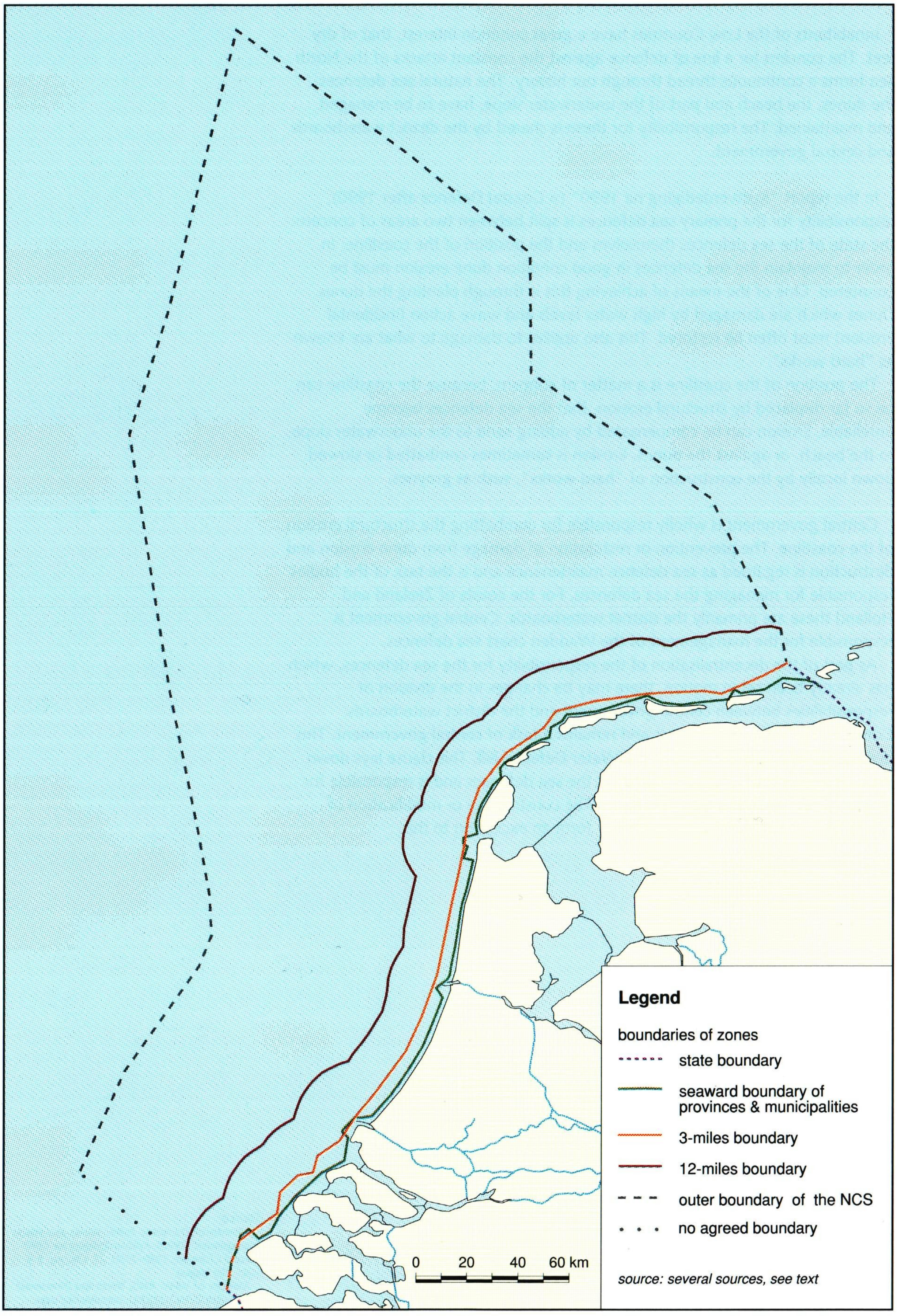
Council Resolution of 3 November 1976 on certain External Aspects of the Creation of a 200-mile Fisheries Zone in the Community with Effect from 1 January 1977, OJEC No C 105, 7.5.1981, p. 1.

Loi concernant les Mines, les Minières et les Carrières, 21 April 1810, Bulletin des Lois no. 285 (also in Stb. 1886, no. 64).

Continental Shelf Mining Act, 23 September 1965, Stb. 1965, no. 428.

Act on the extension of the limits of the coastal provinces and communities along the North Sea coast from the town of Den Helder untill the town of Sluis, 2 November 1990, Stb. 1990, no. 553.

Administrative zones on the NCS



Sea defence management

Inhabitants of the Low Countries have a great common interest, that of dry feet. The concern for a line of defence against the constant attacks of the North Sea forms a continuous thread through our history. The natural sea defences, the dunes, the beach and part of the underwater slope, have to be managed and maintained. The responsibility for these is shared by the district waterboards and central government.

In the report "Kustverdediging na 1990" (= Coastal Defence after 1990), responsibility for the primary sea defences is split between two areas of concern: the state of the sea defences themselves and the position of the coastline. In order to maintain the sea defences in good condition dune erosion must be countered. One of the means of achieving this is through planting the dunes. Dunes which are damaged by high water levels and wave action (incidental erosion) must often be restored. This also applies to damage to what are known as "hard works".

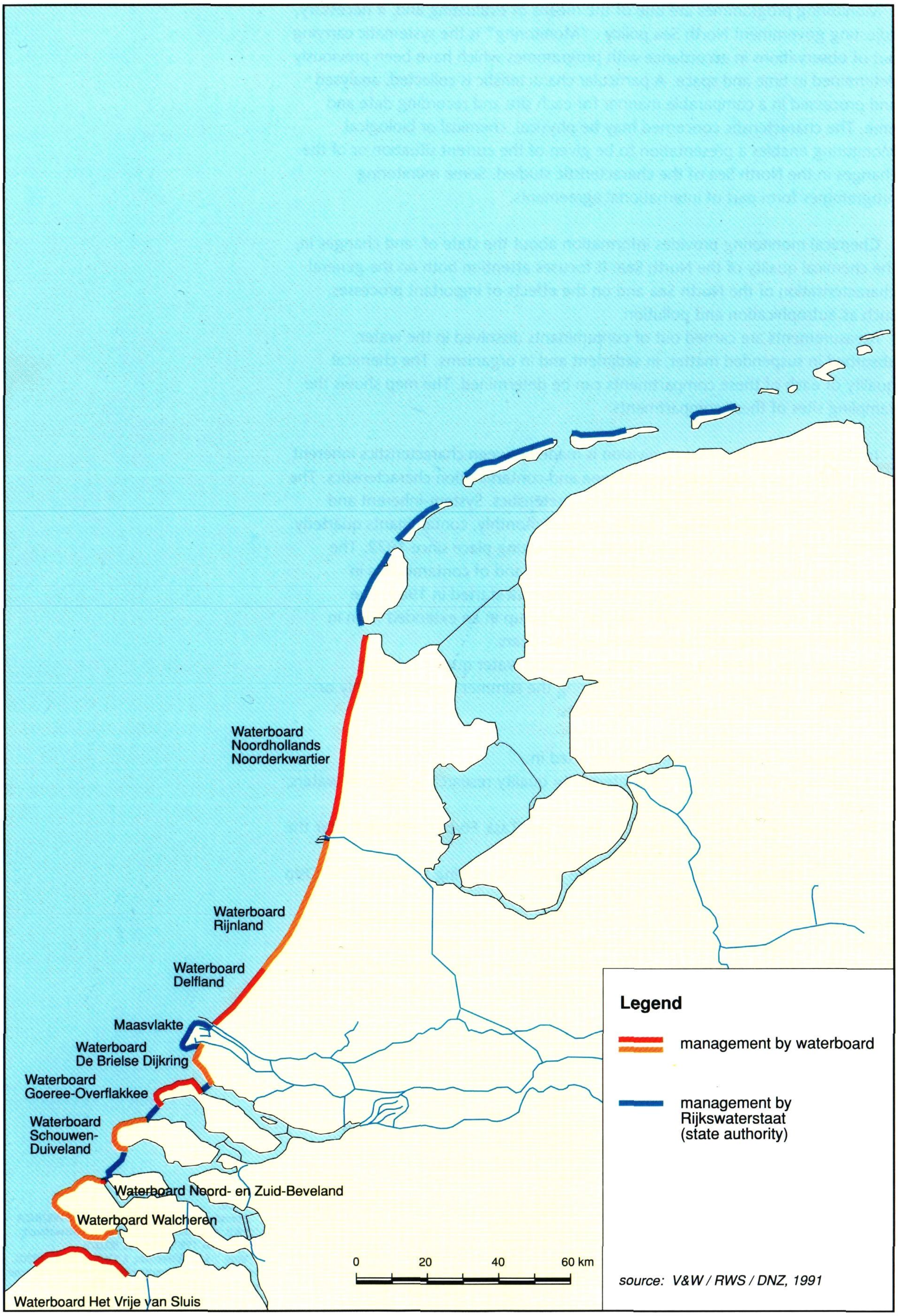
The position of the coastline is a matter of concern, because the coastline can be so far displaced by structural erosion, that the sea defences become unreliable. Erosion can be compensated by adding sand to the underwater slope, to the beach, or against the dunes. Erosion is sometimes combatted or slowed down locally by the construction of "hard works", such as groynes.

Central government is wholly responsible for combatting the structural erosion of the coastline. The prevention or restoration of damage from dune erosion and destruction is regarded as sea defence maintenance and is the task of the bodies responsible for managing the sea defences. For the coasts of Zeeland and Holland these are primarily the district waterboards. Central government is responsible for the management of the Wadden coast sea defences.

As part of the decentralisation of the responsibility for the sea defences, which has already been set in motion, there may be changes in the division of responsibilities between central government and the district waterboards. Combatting structural erosion is and remains a task of central government. This division derives from clause 8 of the Water Defence Bill. This clause lays down that the sea defence manager manages the sea defences and is responsible for all the works needed to maintain them. The construction or modification of works for combatting structural erosion form an exception to this.

Source:
Ministry of Transport, Public Works and Water Management (1990). Kustverdediging na 1990. Second Chamber, 1989-1990, 21 136, no. 5-6. SDU, The Hague.
Ministry of V&W, RWS, North Sea Directorate (V&W/RWS/DNZ) (1991): unpublished data.

Sea defence management



Chemical monitoring

Monitoring programmes are one of the means of evaluating and, if necessary, adjusting government North Sea policy . "Monitoring" is the systematic carrying out of observations in accordance with programmes which have been previously determined in time and space. A particular characteristic is collected, analysed and processed in a comparable manner for each site and recording date and time. The characteristic concerned may be physical, chemical or biological. Monitoring enables a presentation to be given of the current situation or of the changes in the North Sea of the characteristic studied. Some monitoring programmes form part of international agreements.

Chemical monitoring provides information about the state of, and changes in, the chemical quality of the North Sea. It focuses attention both on the general characterisation of the North Sea and on the effects of important processes, such as eutrophication and pollution.

Measurements are carried out of contaminants dissolved in the water, absorbed in suspended matter, in sediment and in organisms. The chemical quality of each of these compartments can be determined. The map shows the sampling sites of these compartments.

In monitoring programmes a division is made between characteristics inherent in the system, eutrophication phenomena and contamination characteristics. The sampling frequency differs by group of characteristics. System-inherent and eutrophication parameters are usually sampled monthly, contaminants quarterly. Monsters of the water compartment has been taking place since 1972. The monitoring of suspended matter started in 1988, and of contaminants in organisms in 1979. The mussel monitoring network started in 1989. The monitoring programme for sediment was started up in an extended form in 1990 and monitoring will take place every two years.

The map also shows the sites where swimming water quality is being investigated by means of monitoring. During the summer season monthly or fortnightly samples are taken at these points.

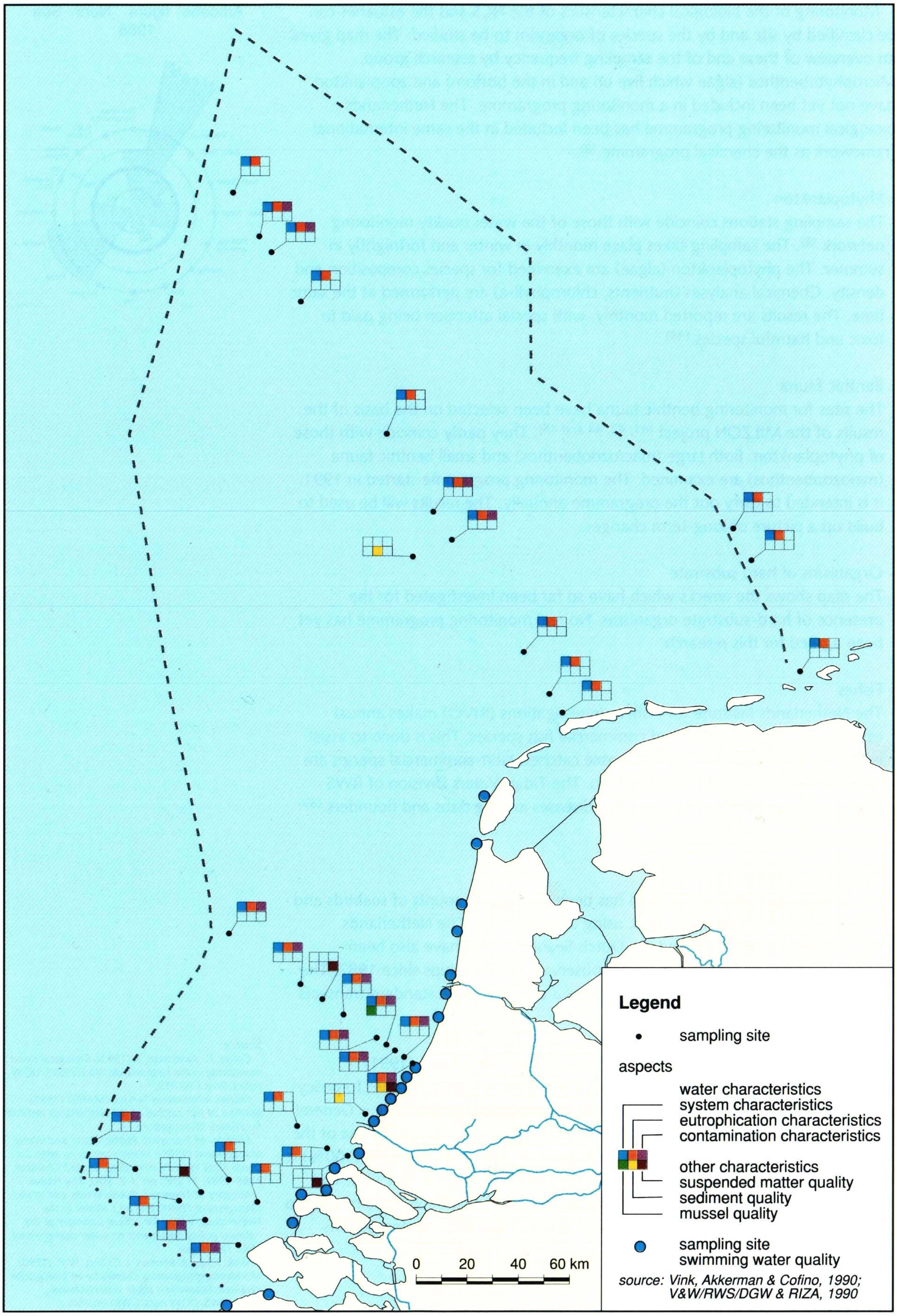
The results of chemical monitoring are used in:

- "Kwaliteitsonderzoek in de rijkswateren"(= quality research in national waters; water quality monitoring network)
- the Monitoring Master Plan of the North Sea Task Force (instituted after the Second North Sea Ministers Conference in 1987)
- the Joint Monitoring Programme of the Joint Monitoring Group of the Oslo and Paris Commissions (since 1979).

The mussel monitoring network and the swimming water quality monitoring network are used only in the water quality survey of the national waters. The monitoring programme concerned is carried out by the directorates of Zeeland, Noord-Holland, Friesland and Groningen, the North Sea Directorate and the Tidal Waters Division of RWS.

Source:
Ministry of V&W, RWS/DGW and RWS/RIZA (1990). Kwaliteitsonderzoek in de rijkswateren; programma 1991. Nota no. 90.079.
Vink, J.S.L., Akkerman, I, Cofino, W.P. (1990). Monitoringsprogramma chemische en biologische kwaliteitskenmerken zoute watersystemen. V&W/RWS/DGW nota GWIO-90.050.

Chemical monitoring



Biological monitoring

Monitoring of the biological characteristics of the NCS and the estuaries can be classified by site and by the species of organism to be studied. The map gives an overview of these and of the sampling frequency by research group. Microphytobenthos (algae which live on and in the bottom) and zooplankton have not yet been included in a monitoring programme. The Netherlands biological monitoring programme has been included in the same international framework as the chemical programme [8].

- Phytoplankton
  The sampling stations coincide with those of the water quality monitoring network [8]. The sampling takes place monthly in winter and fortnightly in summer. The phytoplankton (algae) are examined for species composition and density. Chemical analyses (nutrients, chlorophyll-a) are performed at the same time. The results are reported monthly, with special attention being paid to toxic and harmful species [84].

- Benthic fauna
  The sites for monitoring benthic fauna have been selected on the basis of the results of the MILZON project [41, 43, 44 and 45]. They partly coincide with those of phytoplankton. Both large (macrozoobenthos) and small benthic fauna (meiozoobenthos) are examined. The monitoring programme started in 1991. It is intended to carry out the programme annually. The results will be used to build up a picture of long-term changes.

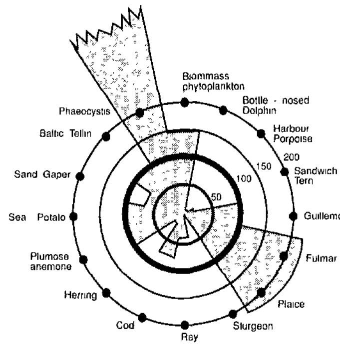
- Organisms of hard substrate
  The map shows the wrecks which have so far been investigated for the presence of hard-substrate organisms. No real monitoring programme has yet been agreed for this research.

- Fishes
  The Netherlands Institute for Fishery Investigations (RIVO) makes annual estimates of the populations of commercial fish species. This is done to assist with the determination of the allowable catches. Non-commercial species are not covered by the systematic research. The Tidal Waters Division of RWS collects data at certain sites about fish diseases among dabs and flounders [89-91].

- Seabirds and mammals
  The Tidal Waters Division of RWS has been conducting counts of seabirds and mammals on the NCS since 1985, using aircraft [49-51]. The Netherlands Institute for Sea Research and the Dutch Seabird Group have also been conducting bird counts and mammal observations from ships since 1987. The aerial counts are now carried out six times a year along the standard transects on the NCS.

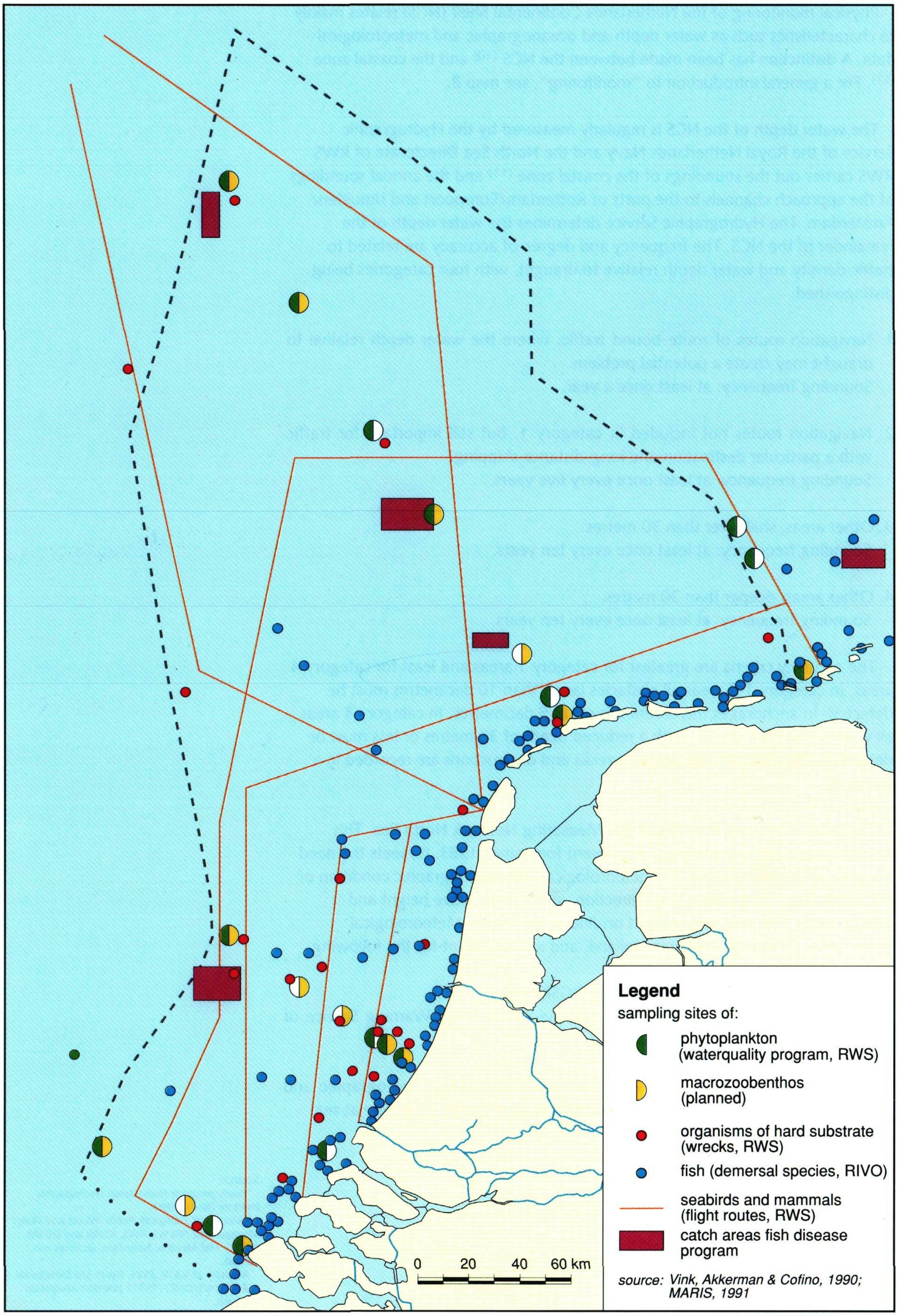
The document "Water in the Netherlands: a time for action" (1991) introduces a method of relating the results of monitoring programmes to policy: the "AMOEBE" (Algemene Methode voor Oecologische Beschrijving = General Ecological Description Method). The "AMOEBE" figure for the North Sea of the situation in 1988 is included here as an illustration. The reference level (100%) is equivalent to a virtually untouched salt-water system (situation in 1930). The relative numbers of various characteristic species are indicated in 1988 relative to 1930. The results show clearly the present disturbance of the water systems.

'Amoebe' figure North Sea 1988



Source:
Colijn, F., Akkerman, I. (1990). Biological trend monitoring in the Netherlands. V&W/RWS/DGW nota GWAO-90.018.
Marine Information Service (MARIS) (1991): position of fish catches of the Netherlands Institute for Fishery Investigations.
Ministry of Transport, Public Works and Water Management (1989). Water voor nu en later, De Derde Nota Waterhuishouding. Second Chamber, 1988-1989, 21 250, no. 1-2. SDU, The Hague. .
Ministry of Transport, Public Works and Water Management (1991, 2nd ed.). Water in the Netherlands: a time for action: summary of the national policy documents on water managemant. SDU, The Hague.
Vink, J.S.L., Akkerman, I, Cofino, W.P. (1990). Monitoringsprogramma chemische en biologische kwaliteitskenmerken zoute watersystemen. V&W/RWS/DGW nota GWIO-90.050.

Biological monitoring



Physical monitoring of the NCS

Physical monitoring of the Netherlands Continental Shelf (NCS) relates mainly to characteristics such as water depth and oceanographic and meteorological data. A distinction has been made between the NCS (10) and the coastal zone (11). For a general introduction to "monitoring", see map 8.

The water depth of the NCS is regularly measured by the Hydrographic Service of the Royal Netherlands Navy and the North Sea Directorate of RWS. RWS carries out the soundings of the coastal zone (11) and the annual soundings of the approach channels to the ports of Rotterdam/Europoort and IJmuiden/ Amsterdam. The Hydrographic Service determines the water depth of the remainder of the NCS. The frequency and degree of accuracy are related to traffic density and water depth relative to draught, with four categories being distinguished:

1. Navigation routes of route-bound traffic, where the water depth relative to draught may create a potential problem.
   Sounding frequency: at least once a year.

2. Navigation routes not included in category 1, but still important for traffic with a particular destination and long-distance shipping.
   Sounding frequency: at least once every five years.

3. Other areas, shallower than 30 metres.
   Sounding frequency: at least once every ten years.

4. Other areas, deeper than 30 metres.
   Sounding frequency: at least once every ten years.

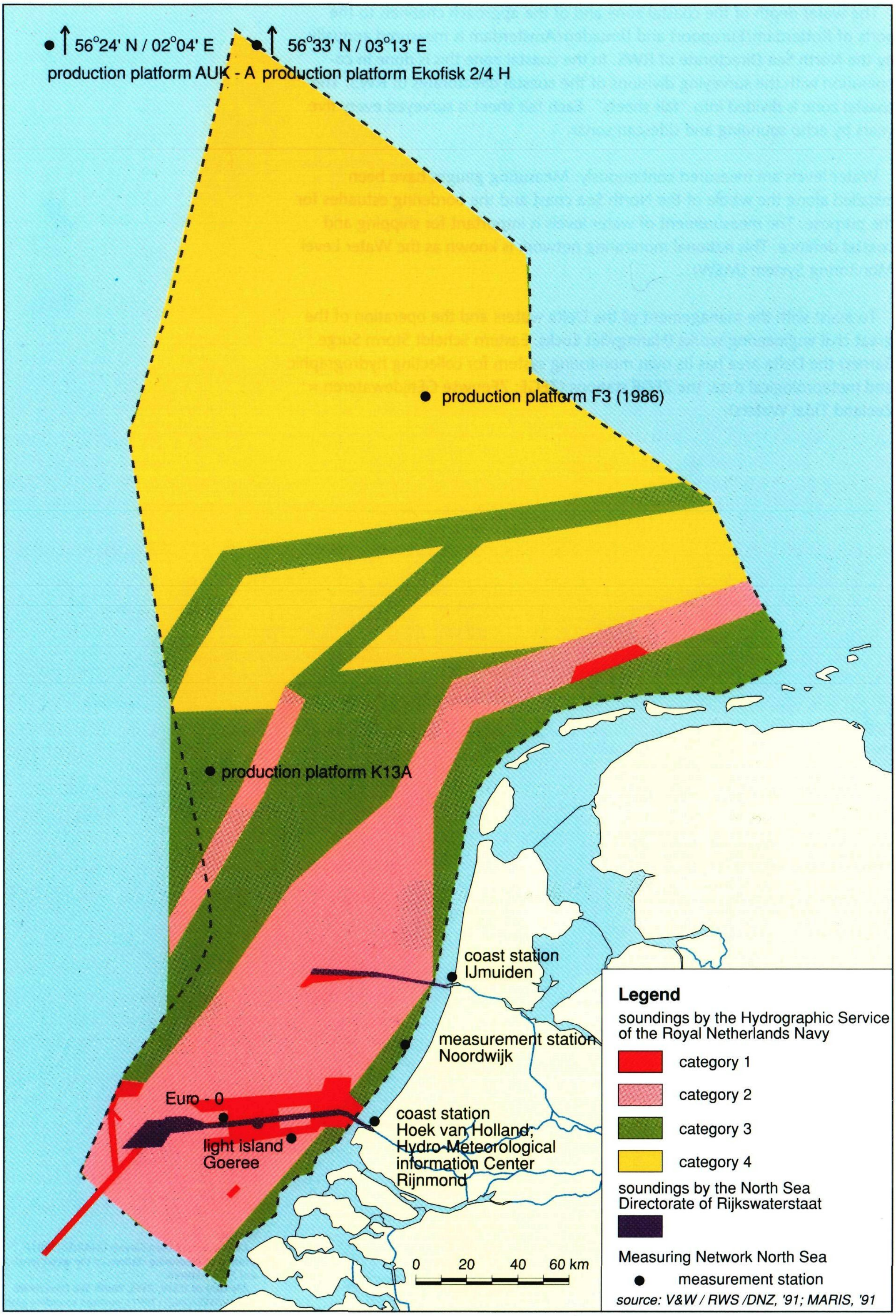
The accuracy criteria are greatest for category 1 areas and least for category 4 areas. In category 1-3 areas all obstacles larger than 10 decimetres must be detected. In anchorages this criterion is set at 5 decimetres. In category 4 areas all wrecks and obstructions with a reduced depth of 30 metres or less must be detected. The data of investigated wrecks and obstructions are recorded in a wreck file.

The map also shows the sites of the Measuring Network North Sea. This network has been functioning in its present form since 1983. It meets the need for basic information about the meteorological and oceanographic condition of the North Sea: wind speed, wind direction, water level, wave height and temperature. The data are received on-line at the Hydro-Meteorological Information Centre at Hoek van Holland, and are important for the following tasks and services:

- assistance to route-bound shipping by DGSM (59);
- storm surge warning by the KNMI and the Storm Surge Warning Service of RWS;
- KNMI weather forecasts;
- management of the NCS by RWS: predicted and actual hydrographic and meteorological data are important constraints on all kinds of activity at sea;
- climatological research.

Source:
Yearly program Netherlands Hydrographic Institute (NHI), 1990.
Ministry of Transport, Public Works and Water Management (V&W), RWS, KNMI and DGSM (1983). Het Meetnet Noordzee; techniek en gebruik.
Ministry of V&W, RWS, North Sea Directorate (V&W/RWS/DNZ) (1991): position navigation channels.

Physical monitoring of the NCS



Physical monitoring of the coastal zone

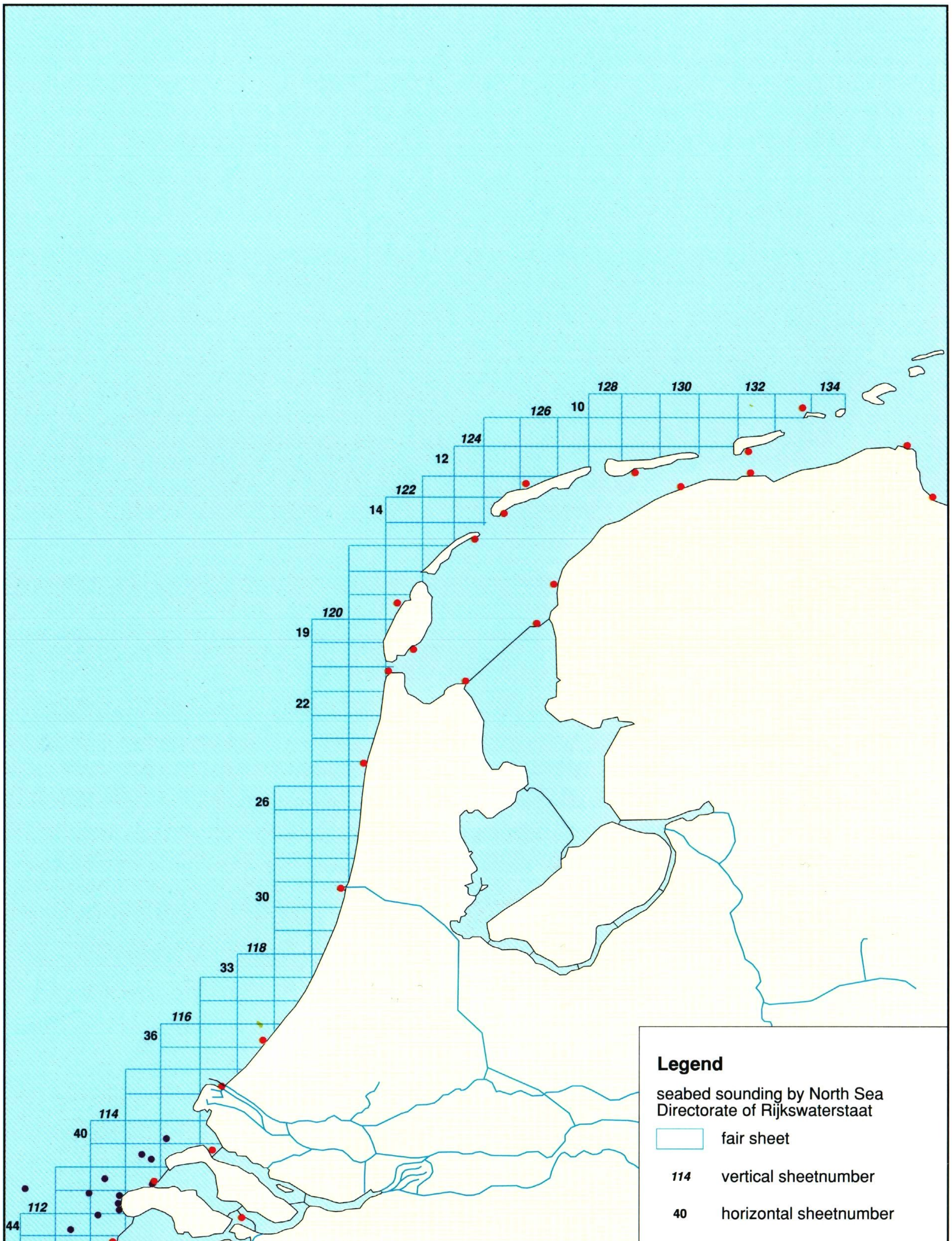
The water depth of the coastal zone and of the approach channels to the ports of Rotterdam/Europoort and IJmuiden/Amsterdam is measured annually by the North Sea Directorate of RWS. In the coastal zone this is done in co-operation with the surveying divisions of the coastal directorates of RWS. The coastal zone is divided into "fair sheets". Each fair sheet is surveyed every five years by echo sounding and sidescan sonar.

Water levels are measured continuously. Measuring gauges have been installed along the whole of the North Sea coast and the bordering estuaries for the purpose. The measurement of water levels is important for shipping and coastal defence. This national monitoring network is known as the Water Level Monitoring System (MSW).

To assist with the management of the Delta waters and the operation of the great civil engineering works (Haringvliet Locks, Eastern Scheldt Storm Surge Barrier) the Delta area has its own monitoring system for collecting hydrographic and meteorological data: the ZEGE stations (ZEGE: ZEeuwse GEtijdewateren = Zeeland Tidal Waters).

Source:
Marine Information Service (MARIS) (1991): position of measuring stations of the water level and ZEGE-stations.
Ministry of V&W, RWS, North Sea Directorate (V&W/RWS/DNZ) (1991): position sounding plots.

Physical monitoring of the coastal zone



Water

Bathymetry

The North Sea is as a result of the subsidence of the earth's crust in the whole of the area concerned. In the south the sedimentation of sand and mud from the land has kept pace with the subsidence; in the north the supply of erosion material was insufficient. This explains why the depth of the North Sea increases from a few tens of metres in the south to over 500 metres in the north. The relief of the North Sea floor is a relic of the ice ages, during which the land ice pushed up, scoured or displaced the sediments.

In the shallow southern part of the North Sea the sandy sediments have been much exposed to more recent forces such as the tides and wave action. In this part of the North Sea the bottom therefore consists mainly of undulating sands and elongated sandbanks like the Norfolk and Flemish Banks [30]. An exception to this is the Deep Channel, which is about 50 metres deep and extends in a north-south direction off the English coast. During the ice ages this area acted as the meltwater discharge of the ice masses to the north.

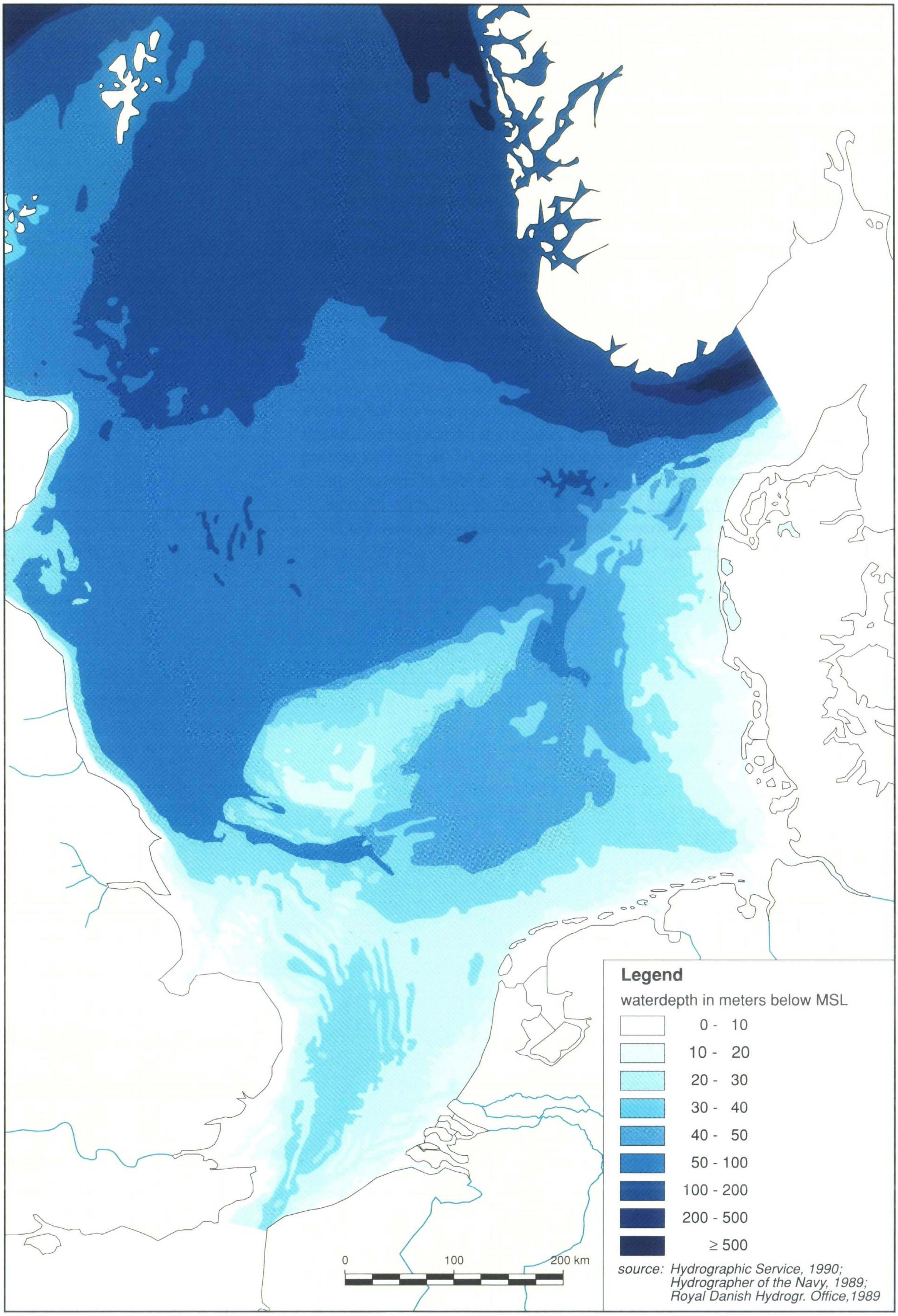
North of around 53° 30' N the water becomes deeper than 30 metres. This transition coincides with lower current velocities, different water masses and a sediment richer in silt.

Still farther north, at about 55° N, lies the Dogger Bank, a shallow zone with an area about half as large as the Netherlands. There are only about 18 metres of water at the shallowest point. During severe storms the waves from the northern North Sea break here.

The Dogger Bank was probably pushed up by land ice. The same ice has elsewhere scoured out deep channels and troughs. The latter include the Silver Pit, a 90-metre deep trough south of the Dogger Bank, and the great trench along the Norwegian coast which is some 700 metres deep in some places. Other depressions are the Fladen Grounds (300 metres) and Devils Hole (260 metres). There are long tunnel valleys in the neighbourhood of these depths. They are 1 to 3 kilometres wide and 100 metres deep. It is assumed that they were formed by meltwater which flowed under high pressure under the land ice.

Source:
Hydrographic Service of the Royal Netherlands Navy (1990). North Sea Southern Sheet, international chart series, 1 750,000, sheet 1014.
Eisma, D., Jansen, J.H F , van Weering, Tj C.E. (1979). Seafloor morphology and recent sediment movement in the North Sea. In: Oele, E., Schüttenhelm, R T E., Wiggers, A.J. (eds.). The Quarternary history of the North Sea, 217-231 Acta Univ. Uppsala, Uppsala.
Hydrographer of the Navy (1989). North Sea Central Sheet, international chart series, 1:750,000, sheet int 1042
Royal Danish Hydrographic Office (1989) North Sea Northern Sheet, international chart series, 1 750,000, sheet int. 1041

Bathymetry


Legend
waterdepth in meters below MSL
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 100
100 - 200
200 - 500
≥ 500
0
100
200 km
source: Hydrographic Service, 1990; Hydrographer of the Navy, 1989; Royal Danish Hydrogr. Office, 1989

Residual currents, water masses and fronts in winter

The water in the North Sea circulates according to a fixed pattern: Atlantic water enters via the English Channel in the south and along the Scottish coast in the north. Outflowing water leaves the North Sea along the Norwegian coast.

The inflow is caused by the predominantly westerly wind, which pushes the Atlantic water towards the North Sea, and by the tidal wave. The ebb tides do not completely neutralise the water movement of the flood tides. A counter-clockwise residual current remains in the North Sea basin. When the wind blows for a long time, not from a westerly, but from a northerly or easterly direction, the circulation pattern may be temporarily reversed. Averaged over the whole year, the residual current along the Netherlands coast amounts to a few centimetres per second. The North Sea water travels a distance of about 1500 kilometres per year. It is refreshed every one to two years.

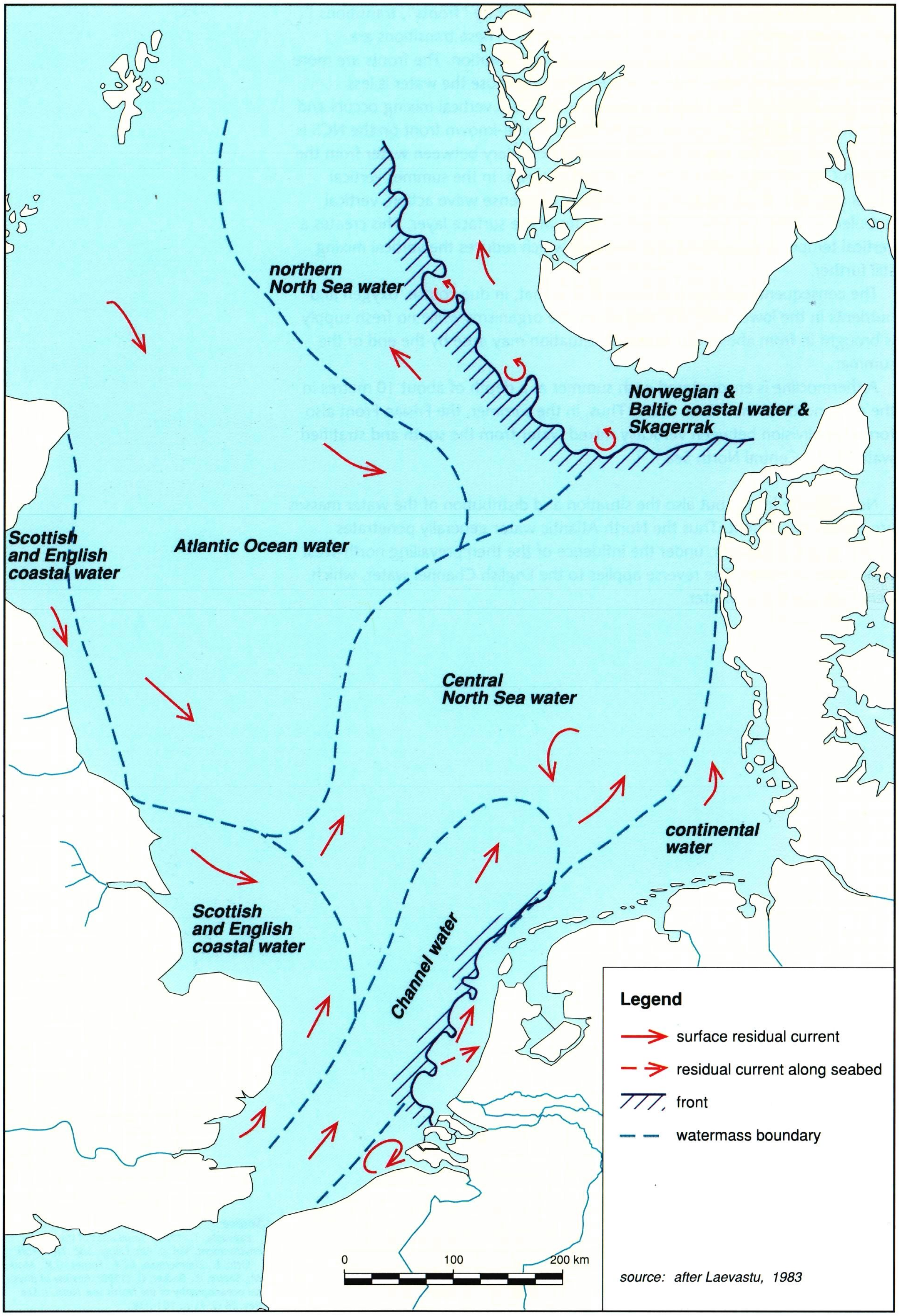
North Sea water consists of different water masses which meet and partly mix. Besides the Atlantic water just referred to, water from the Baltic Sea also flows into the North Sea, entering via the Skagerrak. Closer to the coasts of the United Kingdom and the continent the seawater has a high concentration of river water which is relatively light and spreads slowly from the rivers over the salt seawater. As a reaction to this movement more saline seawater is transported coastwards along the bottom. Because of its slow seaward spread and the generally strong residual current along the coast, the river water with its load of contaminants lingers along the coast for a long time. Contaminants consequently become concentrated in a zone a few dozen kilometres wide along the coast. For an explanation of fronts, see map 14.

Source:

Laevastu, T (1983). Serial atlas of the marine environment. Vol 4. Am Geogr Soc., New York.

Otto, L., Zimmerman, J T F , Furnes, G.K., Mork, M., Saetre, R., Becker, G. (1990). Review of physical oceanography of the North Sea Neth J. Sea Res. 26 (2-4), p. 161-238.

Residual currents, water masses and fronts in winter



Residual currents, water masses and fronts in summer

Water masses are often separated from each other by "fronts", transitions within a relatively short distance (a few kilometres). These transitions are measurable in salinity, temperature, nutrients and pollution. The fronts are more clearly marked in summer than in winter. This is because the water is less strongly agitated by the wind in summer, so that less vertical mixing occurs and the horizontal gradients remain longer intact. A well-known front on the NCS is the Frisian Front. The Frisian Front forms the boundary between water from the English Channel and water from the Atlantic Ocean. In the summer vertical fronts may also occur. As a result of the lack of intense wave action, vertical turbulence is low and solar heat accumulates in the surface layer. This creates a vertical temperature gradient (thermocline) which reduces the vertical mixing still further.

The consequence of this stratification (15) is that, in due course, oxygen and nutrients in the lower layer are used up by the organisms while no fresh supply is brought in from above. An anaerobic situation may arise by the end of the summer.

A thermocline is encountered each summer at a depth of about 10 metres in the area, north of the Frisian Front. Thus, in the summer, the Frisian Front also forms the division between vertically mixed water from the south and stratified water in the Central North Sea (15).

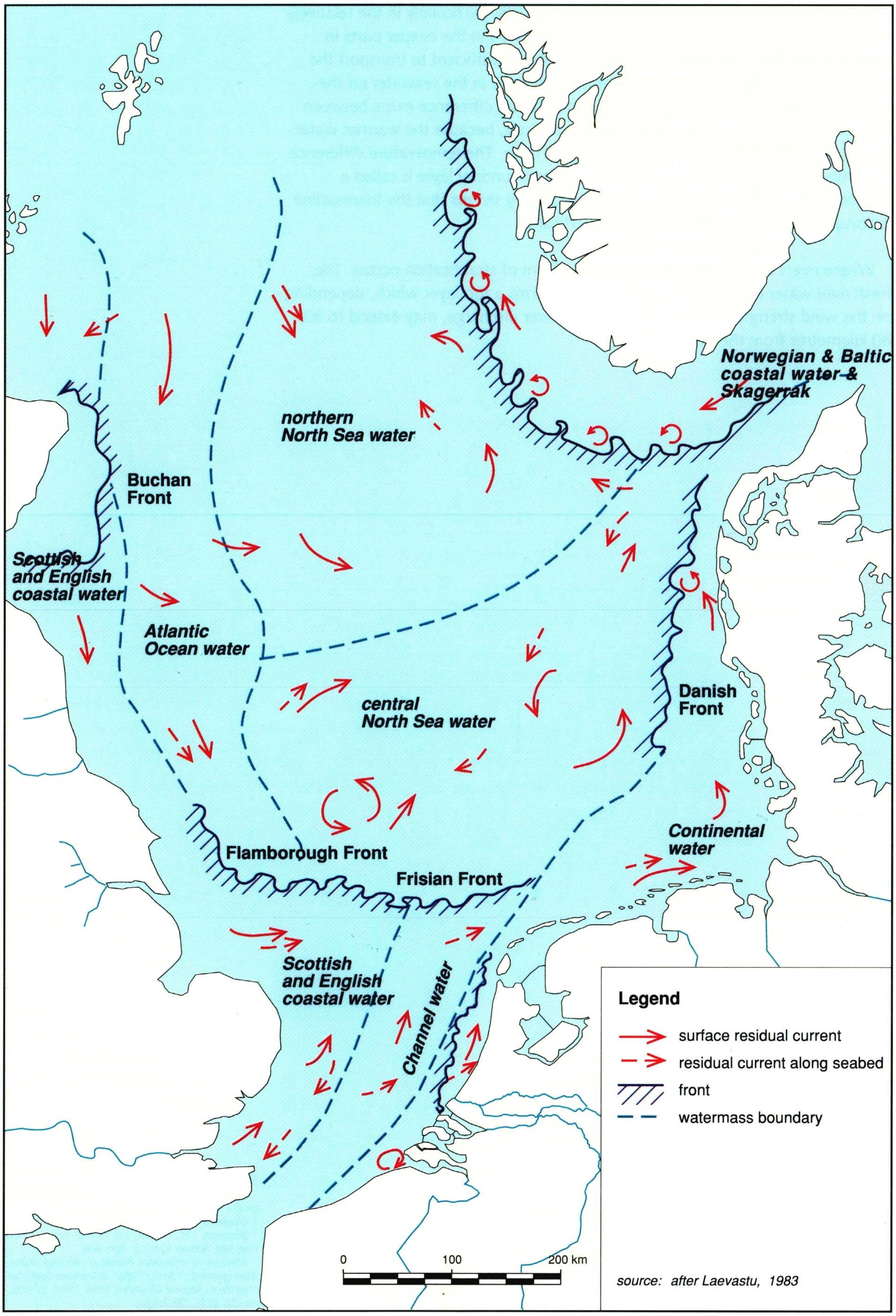
Not only the fronts, but also the situation and distribution of the water masses are season-dependent. Thus the North Atlantic water generally penetrates farther south in summer, under the influence of the then prevailing north-west wind, than in winter. The reverse applies to the English Channel water, which penetrates farther in winter.

Source

Laevastu, T (1983) Serial atlas of the marine environment Vol 4 Am Geogr Soc, New York

Otto, L, Zimmerman, J T F, Furnes, G K, Mork, M, Saetre, R, Becker, G. (1990) Review of physical oceanography of the North Sea. Neth J Sea Res 26 (2-4), p 161-238

Residual currents, water masses and fronts in summer



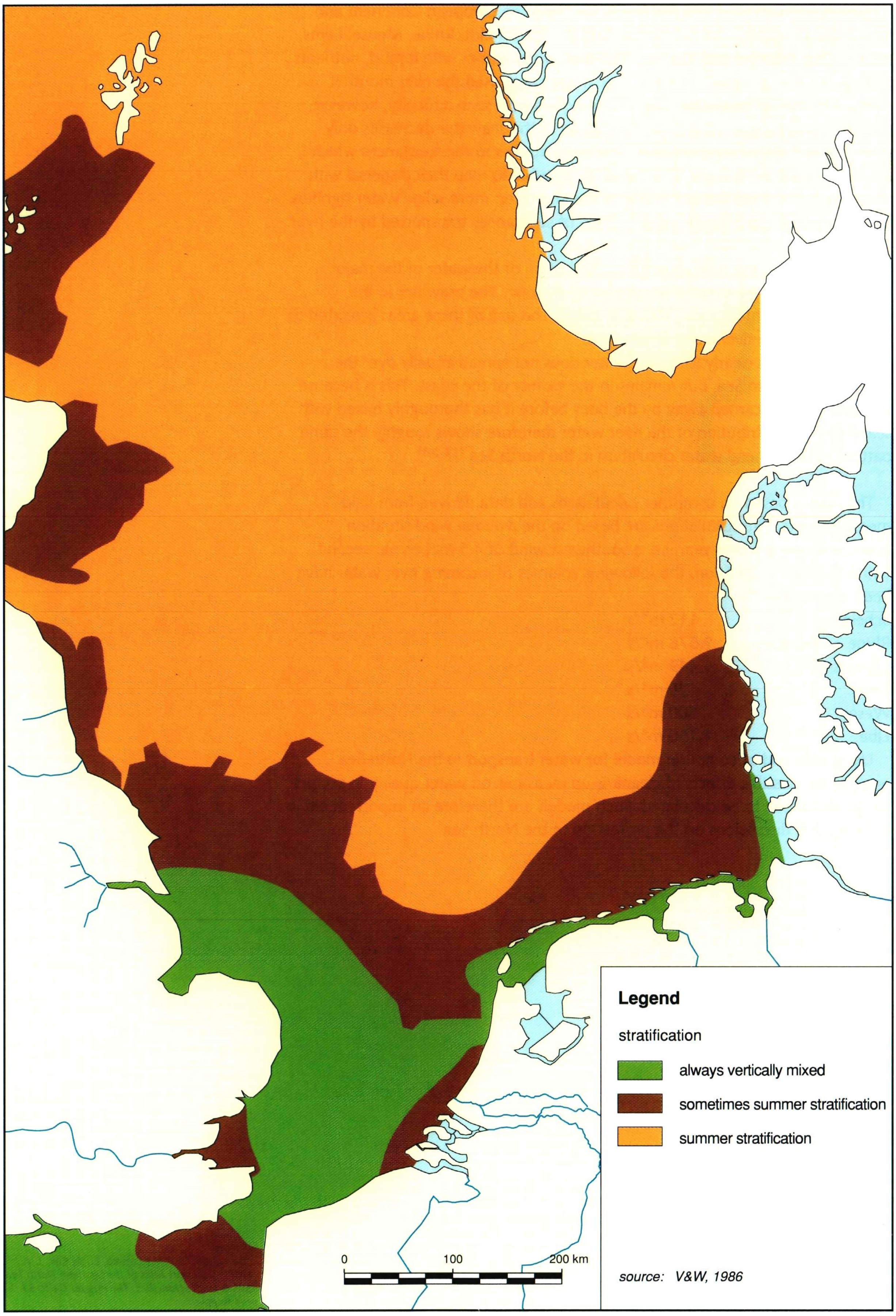
Stratification

The water in the North Sea is generally well mixed, particularly in the relatively shallow areas with strong tides. A stratification occurs in the deeper parts in summer. The action of waves and currents is then insufficient to transport the solar heat, which causes a small temperature increase in the seawater on the surface, to greater depths. As soon as a temperature difference exists between different water layers, mixing is made more difficult, because the warmer water continues to float on top of the colder bottom layer. The temperature difference can amount to a couple of degrees Celsius. The boundary layer is called a thermocline. In autumn the sea is so churned up by storms that the thermocline is disrupted, and the water mixes again vertically.

Where rivers enter the North Sea another form of stratification occurs. The fresh river water is lighter than seawater and forms a top layer which, depending on the wind strength and the volume of the river discharge, may extend to 30-80 kilometres from the river mouth.

Source:
Pingree, R.D., Griffiths, D.K (1978). Tidal fronts on the shelf seas around the British Isles J. Geophys. Res, 83, p. 4615-4622.
Simpson, J H., Hunter, J.R. (1974). Fronts in the Irish Sea. Nature 1250, p. 404-406
Ministry of Transport, Public Works and Water Management (V&W) (1986). Waterkwaliteitsplan Noordzee Second Chamber, 1986-1987, 17 408, no. 22. SDU, The Hague.

Stratification



Dispersal of river water in the North Sea

Numerous rivers flow into the North Sea from the European Continent and the United Kingdom. The most important are the Scheldt, Rhine, Meuse, Eems, Weser, Elbe, Humber and Thames. The river water carries with it mud, nutrients and contaminants. Once the fresh river water has passed the river mouth it mixes with the salt seawater. The mixing occurs with such difficulty, however, that the concentration of original river water in the seawater decreases only gradually and over a long distance. The same applies to the substances which are transported by the river. It is therefore possible to map their dispersal with reference to the fresh water fraction of the seawater: more saline water signifies less river water and a lower concentration of substances transported by the river.

The accompanying map shows the distribution of the water of the major continental rivers on a time scale of about one year. The seawater in the coloured areas contains over 1 % river water. The size of these areas is related to the volume of the river water discharged.

The map shows clearly that river water does not spread equally over the whole of the North Sea, but remains in the vicinity of the coast. This is because the river water is carried away by the tides before it has thoroughly mixed with seawater. The distribution of the river water therefore shows roughly the same pattern as the general water circulation in the North Sea [13, 14].

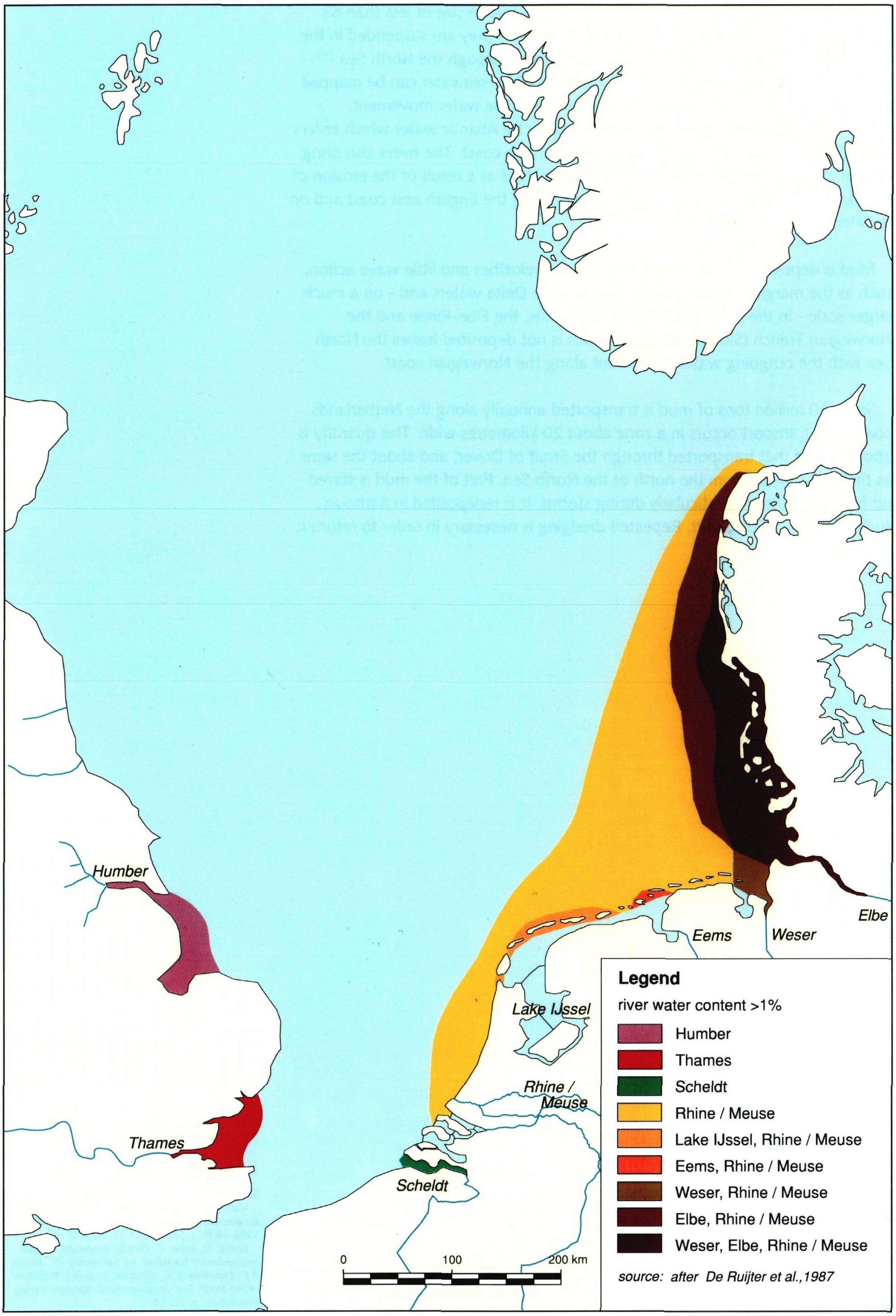
The map is based on computer calculations and data derived from field measurements. The calculations are based on the average wind situation measured over a whole year; i.e. a southwest wind of 4.5 metres per second (wind force 3). In addition, the following volumes of incoming river water have been assumed:

Scheldt:	112 m^3/s
Rhine + Meuse:	2,578 m^3/s
Lake IJssel:	449 m^3/s
Eems:	120 m^3/s
Weser:	500 m^3/s
Elbe:	1,150 m^3/s

Using this kind of computer model for water transport in the North Sea enables the possible effects of cleaning-up measures on water quality in sectors of the North Sea to be calculated. Such models are therefore an important aid in international discussions on the protection of the North Sea.

Source:
De Ruijter, W.P.M., Postma, L., de Kok, J.M. (1987). Transport Atlas of the Southern North Sea. RWS & Delft Hydraulics, The Hague/ Delft, 33 pp.+ floppy.

Dispersal of river water in the North Sea



Mud transport and deposition

"Mud" is the collective name for particles with a grain size of less than 63 micrometres (µm). Because of their small dimensions they are suspended in the water and move with the general water circulation through the North Sea [13, 14]. The quantity of suspended matter transported by seawater can be mapped by multiplying the concentration by the volume of the water movement.

The mud in the North Sea is brought in mainly by Atlantic water which enters through the English Channel and along the Scottish coast. The rivers also bring in mud. Mud is released in the North Sea basin itself as a result of the erosion of clay banks or coasts. Examples can be found along the English east coast and on the Flemish Banks off Belgium.

Mud is deposited at places with low current velocities and little wave action, such as the margins of the Wadden Sea and the Delta waters and - on a much larger scale - in the Silver Pit, the Oystergrounds, the Elbe-Rinne and the Norwegian Trench (Skagerrak). Mud which is not deposited leaves the North Sea with the outgoing water movement along the Norwegian coast.

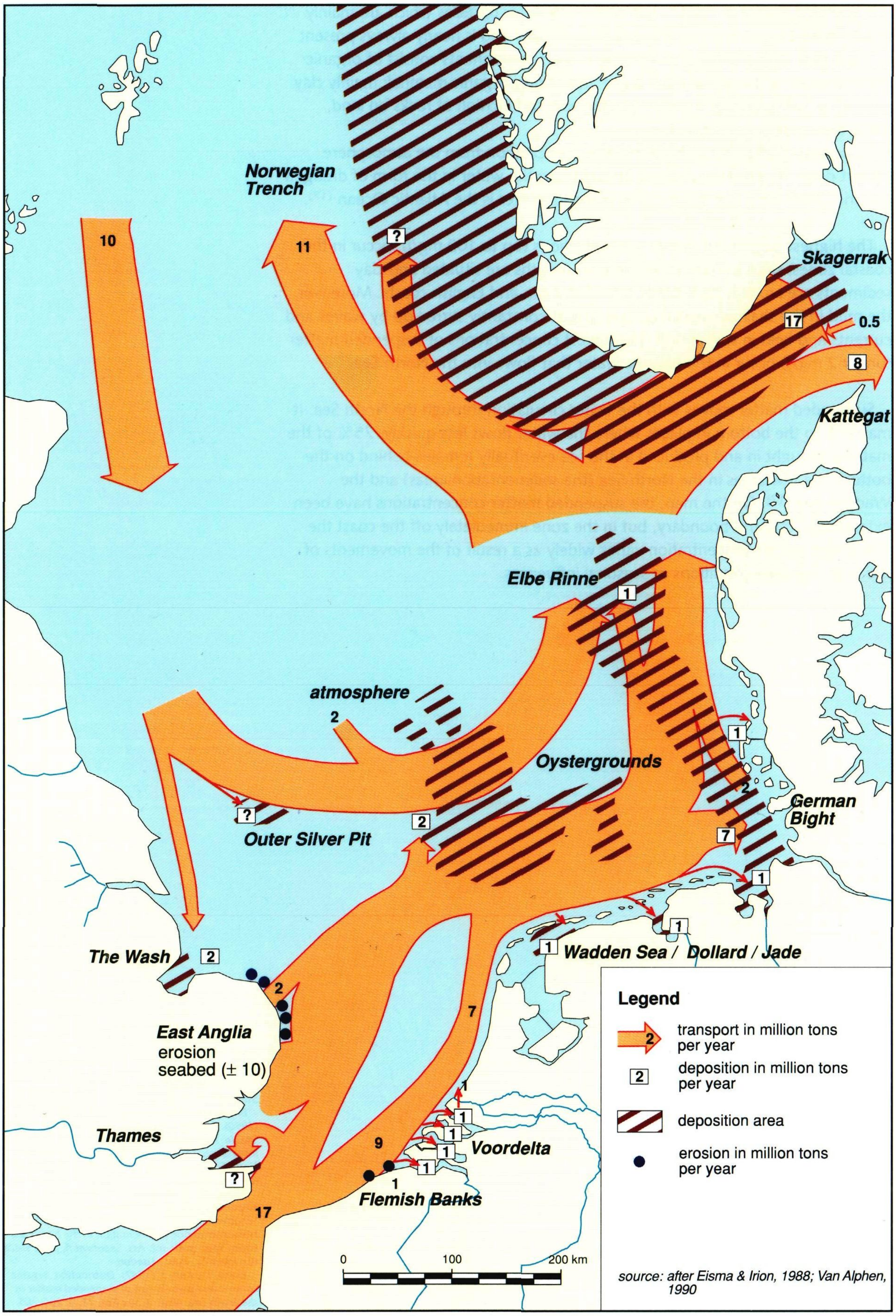
Some 10 million tons of mud is transported annually along the Netherlands coast. The transport occurs in a zone about 20 kilometres wide. This quantity is about half of that transported through the Strait of Dover, and about the same as that transported from the north of the North Sea. Part of the mud is stirred up from the bottom, particularly during storms. It is redeposited in harbours, such as those of Europoort. Repeated dredging is necessary in order to return it to the sea.

Source:

Van Alphen, J.S.L.J. (1990). A mud balance for Belgian-Dutch coastal waters between 1969 and 1986. Neth. J. Sea Res. 25 (1/2), p. 19-30.

Eisma, D., Irion, G. (1988). Suspended matter and sediment transport. In: Salomons, W., Bayne, B.L., Duursma, E.K., Förstner, U. (eds.). Pollution of the North Sea, an assessment. Springer Verlag, Heidelberg, p. 20-35.

Mud transport and deposition



Suspended matter

Suspended matter or mud is a collective name for particles which are mainly smaller than 63 µm. The material sinks very slowly and is nearly always present in suspension in the water column. The various components consist of organic material, such as living and dead algae and of non-organic material: mainly clay particles which originate from the breakdown and erosion of rocks on land, along the coast or on the seabed.

Suspended matter is also brought in as precipitation from the atmosphere (desert dust). A certain quantity is brought into the water in the form of dredged material. Another major source of suspended matter is the Atlantic Ocean [17].

The highest suspended matter concentrations (up to 100 mg/l), occur in the coastal zones, since that is where the river mouths are situated and clay sediments are eroded, particularly off the Belgian and English coasts. Moreover, the mud in the shallow coastal zone is almost constantly stirred up by waves and currents and held in suspension. The lowest concentrations of suspended matter (under 2 mg/l) occur in the Atlantic water that flows into the North Sea.

Suspended matter moves with the water circulation through the North Sea. It may sink to the bottom in places where the water flows less quickly. 75% of the material brought in and produced in the sea eventually remains behind on the bottom in a few areas in the North Sea (the sedimentation areas) and the Wadden Sea [17]. On the map, the suspended matter concentrations have been extended to the land boundary, but in the zone immediately off the coast the suspended matter concentration varies widely as a result of the movements of the tides, weather conditions or seasonal influences.

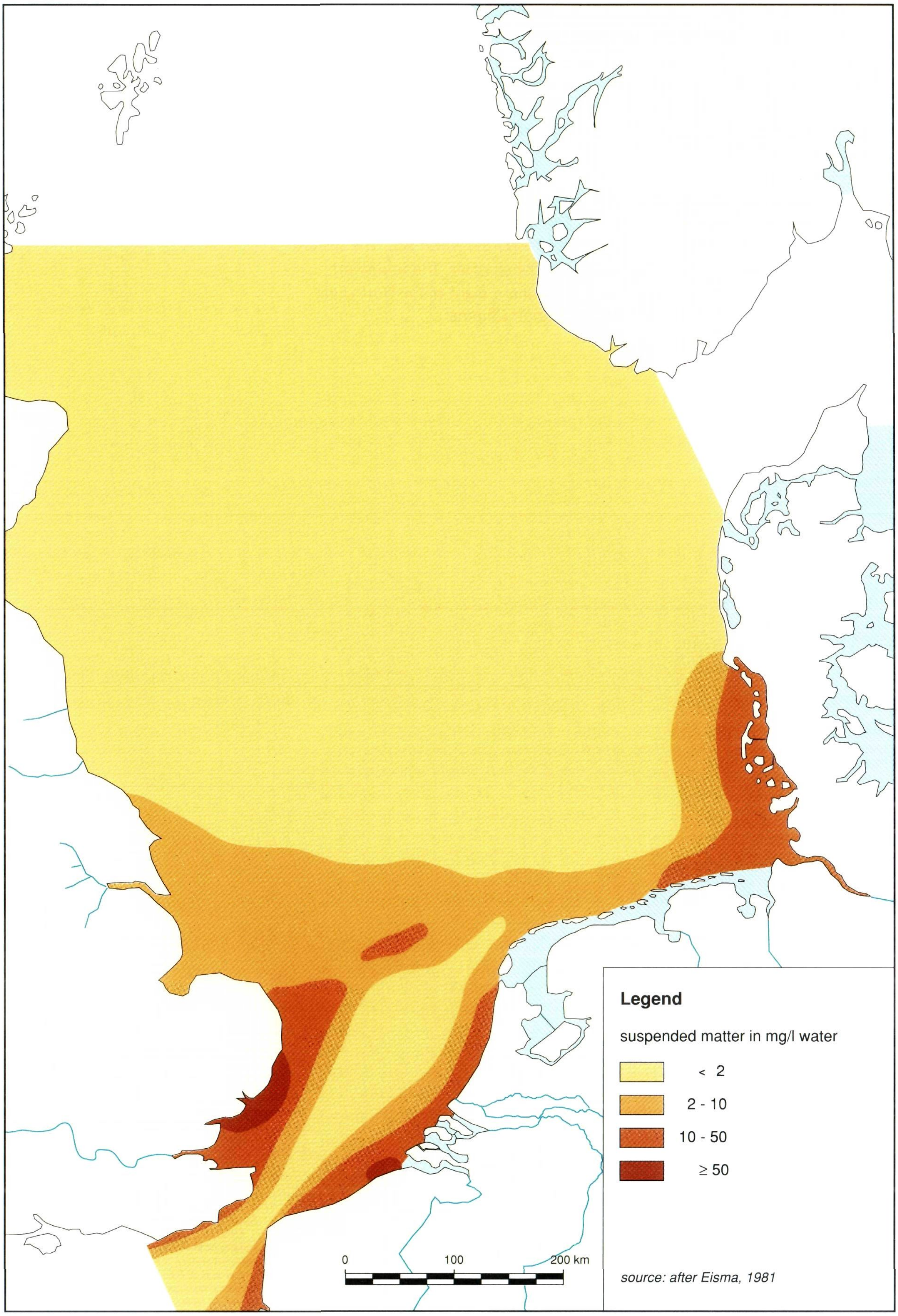
Source:

Brockmann, U.H , Laane, R.W P M , Postma, H (1990) Cycling of nutrient elements in the North Sea In Part 2 of the Proceedings of the International Symposium on the Ecology of the North Sea 18-22, May 1988. Neth J Sea Res 26 (2-4), p 239-264.

Eisma, D (1981) Supply and deposition of suspended matter in the North Sea In Nio, S D , Schuttenhelm, R T E , van Weering, Tj C.E (eds) Holocene marine sedimentation in the North Sea basin Spec publ int Ass Sediment 5, p. 415-428. Blackwell Sc Publ , London

Eisma, D , Kalf, J (1987). Distribution, organic content and particle size of suspended matter in the North Sea Neth J Sea Res. 21, p 265-285.

Suspended matter



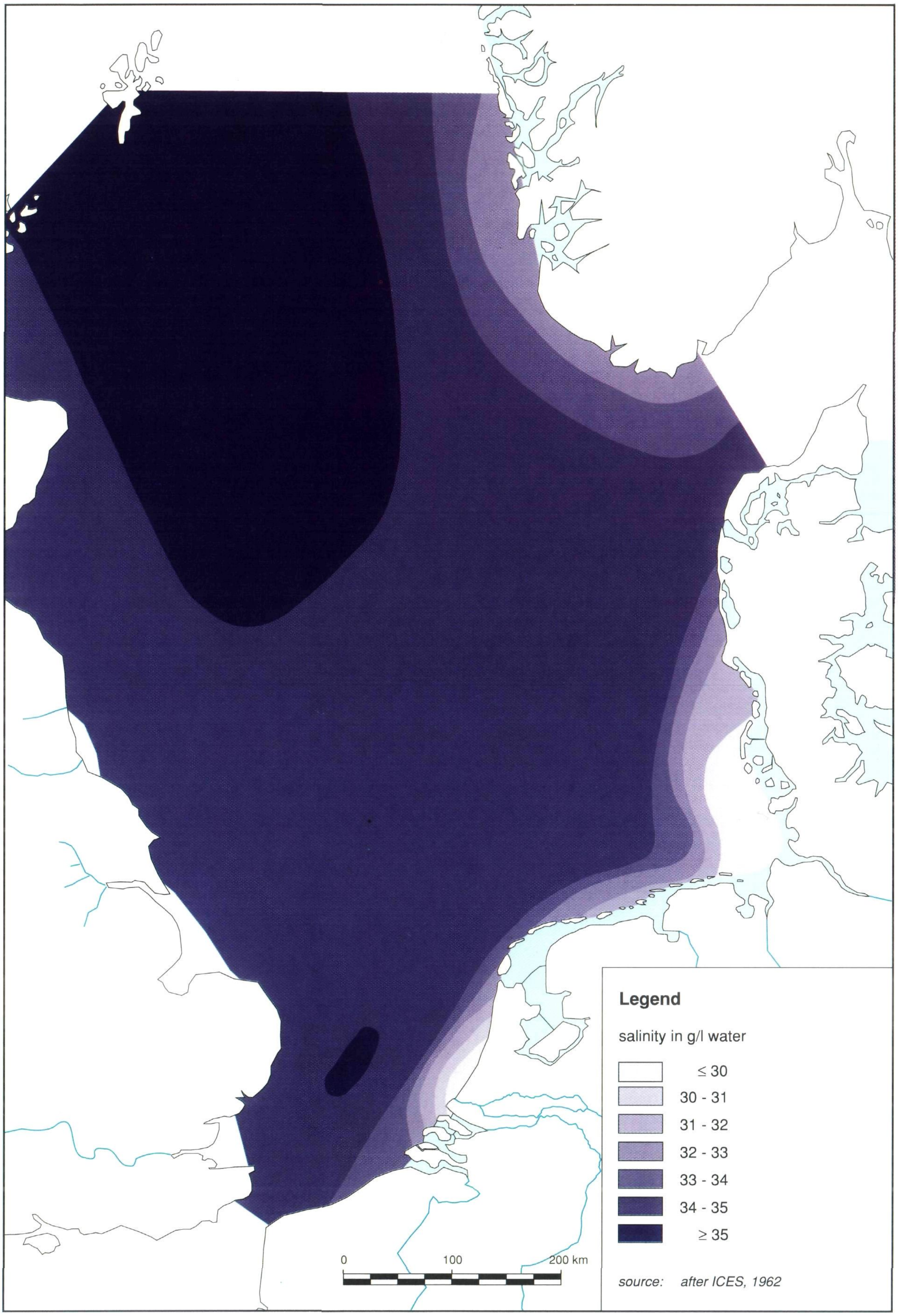
Salinity in winter

The water of the North Sea is not everywhere equally saline. In the Atlantic water, which enters the North Sea through the English Channel and along the Scottish coast in the north, one litre of seawater contains on average about 35 g of salt. Along the coasts of the Netherlands, Germany, Denmark and Norway, as a result of the outflow of fresh river water, the salinity is lower, sometimes only 25 g/l. The map gives a picture of the average winter salinity of the North Sea during the period 1905-1953.

The net water movement in the North Sea is greatly affected by the climatic conditions in the different seasons [13, 14]. This is also reflected in the pattern of salinities. In winter more North Atlantic water enters the North Sea. The salinity of the central North Sea is then higher than in the summer. The southwest winds in winter have a similar effect on the Southern Bight of the North Sea, where more Atlantic water flows in via the English Channel.

Source:
ICES (1962). Mean monthly temperature and salinity of the surface layer of the North Sea and adjacent waters. ICES, Charlottelund.
Laane, R.W.P.M., Leewis, R.J., Colijn, F., van Berge Henegouwen, A., Hisgen, R., (1990). De zee, de zee de Noordzee. SDU, The Hague.

Salinity in winter



Salinity in summer

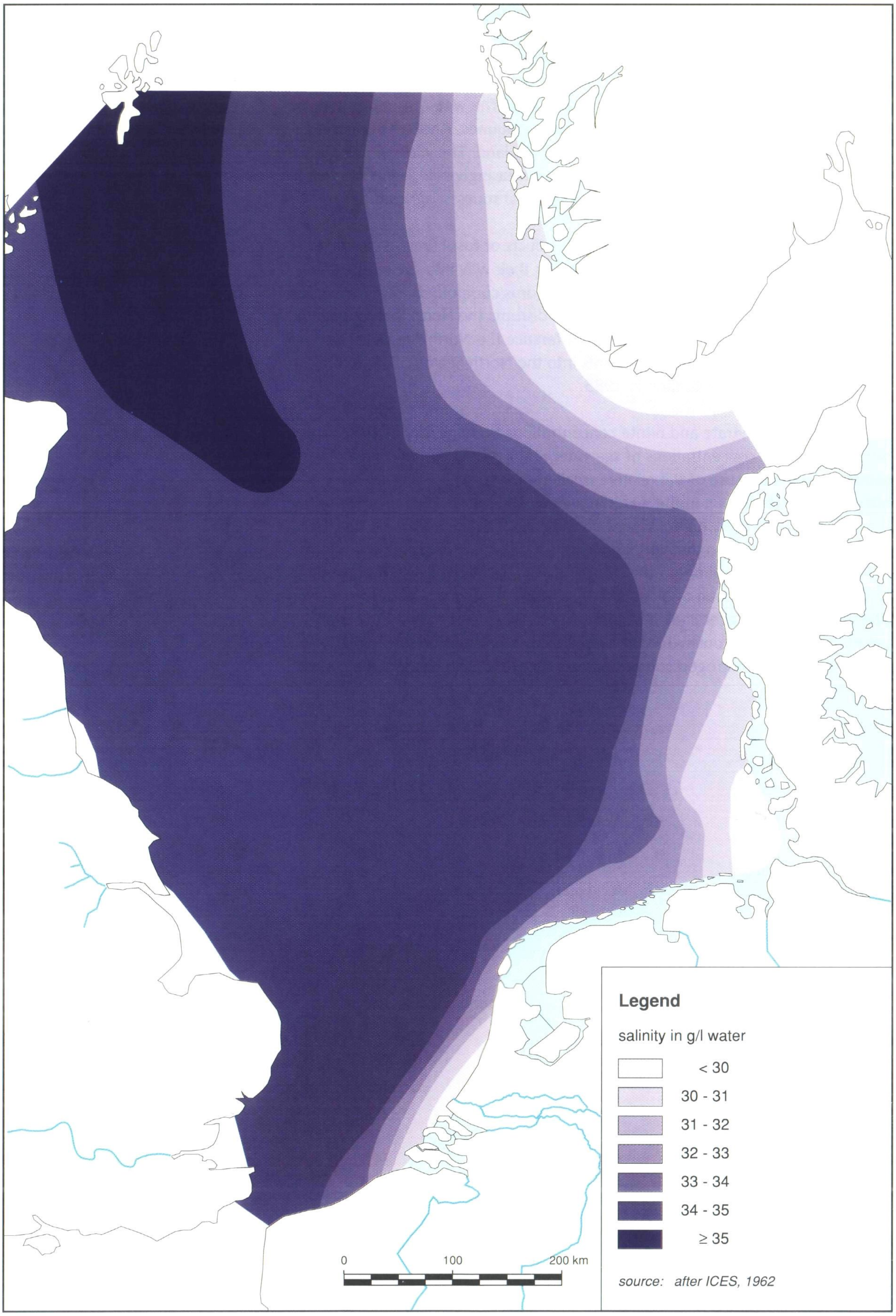
The average salinity in the North Sea is affected by the seasons. The summer values on the map are averages of measurements over the period 1905-1953. The seasonal difference in the Skagerrak is striking [19]. It arises because most of the inland waters in the countries around the Skagerrak freeze in winter, so that little fresh water enters the sea.

Source:

ICES (1962). Mean monthly temperature and salinity of the surface layer of the North Sea and adjecent waters. ICES. Charlottelund

Laane, R.W.P.M., Leewis, R.J., Colijn, F., van Berge Henegouwen, A., Hisgen, R., (1990). De zee, de zee de Noordzee. SDU, The Hague.

Salinity in summer



Nitrate and nitrite concentration in winter

Nitrate and nitrite are chemical compounds of nitrogen (N) with oxygen (O). Together with compounds of phosphorus (P), they are important nutrients for the phytoplankton (algae) in the water, so that they form the basis of all marine life.

Nitrogen compounds occur naturally in seawater. The water from the Atlantic Ocean, in particular, brings in many nitrogen compounds. Another permanent and natural source is the water discharge from the land. The water flowing into the sea from the rivers, however, has become increasingly charged in the course of time with nitrogen compounds from non-natural sources: agricultural fertilisers and sewage discharges.

Nitrogen compounds in the combustion products of fossil fuels in cars and industrial processes are also increasingly finding their way into the sea via the atmosphere. An excess of nitrogen and phosphorus compounds in the seawater causes eutrophication (overmanuring), which disrupts the North Sea ecosystem. During the Second North Sea Ministers Conference the North Sea states decided to aim at reducing the inflow of nutrients into the North Sea by 50% before 1995, starting from the situation in 1985.

The map shows nitrate and nitrite concentrations in the winter of 1987. The nitrate and nitrite concentrations of seawater are higher in winter than in summer. This is because of the relative small number of algae, so that more nitrate and nitrite remain in the water in winter. The transport of river water to the sea causes relatively higher values on the coasts. In the north, nitrate-rich Atlantic water flows into the North Sea.

The nitrate concentration on the Dogger Bank is relatively low. This is related to the primary production of biomass [27], which is relatively high here in winter. The sea over the Dogger Bank is shallow and clear, so that the sunlight even penetrates to the phytoplankton in the bottom water layer. The biological processes, in which nitrogen compounds are absorbed, can continue here even in winter.

Source:

Brockmann, U.H., Laane, R.W.P.M., Postma, H. (1990). Cycling of nutrient elements in the North Sea. Neth. J of Sea Res , 26 (2-4), p. 239-264.

Brockmann & Kattner (in press). In: Estuarine Coastal Shelf Science.

Laane, R.W.P.M., Leewis, R.J., Colijn, F., van Berge Henegouwen, A., Hisgen, R., (1990). De zee, de zee de Noordzee. SDU, The Hague.

Peeters, J.C.H. (V&W/RWS/DGW) (1991): oral information.