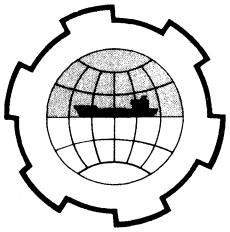
PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY



NATURAL DEPTHS ALONG SHORES IN THE NORTH SEA AND ADJACENT SEAS

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General remarks.

Natural depths in oceans and along shores have become still more important for shipping and for the design of vessels. This is because larger vessels include several advantages for transportation. While ten years ago, a supertanker was of 100.000 DWT, its size has increased to 300.000 DWT in 1971. Cost of transportation generally decreases with increasing size of vessel. The natural occurring depths, however, limits the application of vessels of deeper draft. Tankers of 500.000 - 1 mill. DWT may, however, be realistic in the future at certain ship routes.

The size of bulk and general cargo vessels has also increased. One probably has to accept a practical upper limit for bulk to approximately 150.000 DWT, and to approximately 40.000 DWT for container vessels. Drafts in these cases have to be adjusted to the trade of the vessel. For ships which are not in regular trades, drafts must be suitable for a great number of regions.

Most of the important ports of the world have official navigation depths ranging from 30 ft. to 40 ft. which means that general cargo and smaller special vessels will not experience problems with depths.

In industrialized countries depths in ports have been adjusted to the actual drafts of the vessels in the trade. This has not caused serious problems because the demand for depths has usually been of the order 30 - 40 ft., which corresponds fairly well to the natural

depths occurring at the ports. Obtaining greater depths may, however, involve serious difficulties. The result has often been that off-shore terminals had to be established, as initial depths to be dredged and maintenance cost would become very high. The natural depths in ports therefore limit the size of the vessels.

This does not mean that ship sizes will not continue to increase in the future. The larger ships will still be the most economical, if their use is not limited in choice of trades and ports. The limitations therefore have to be as small as possible. The question is; How can this be accomplished?

The answer is, through optimalization analyses it may be demonstrated that in routes exceeding a certain distance, bigger ships calling at special distribution terminals, will always be the most economical. In other words, one may expect that great changes will be enforced upon the terminal structure in the wake of the ships increasing sizes. The main criteria will be that of obtaining sufficient depths at a relatively low cost.

To review the present depth situation of world ports and evaluate the development during the next decade, we asked approximately four hundred ports questions about their present and planned maximum depths. Fig. 1, 2, 3 and 4 are all based on data from these ports. The figures reproduce the distribution of ports with maximum depths exceeding a certain depth, d .

From figure 1, it may be noted that approximately 19 % of the general cargo terminals have depths above 40 ft. in 1970. The corresponding figures for 1975 and 1980 are 24 % and 28 %, figure 2 and figure 3, respectively. The relatively few general cargo terminals with depths above 40 ft. are located at deep natural or at deep dredged basin- or navigation channels. The diagrams may also indicate that most ports which have the possibility as well as the interest of dredging to 40 ft. depth have already done so. The figures pertaining to tank and bulk terminals seem to indicate the same trend. The fact that only a few new ports seem to plan to develop terminals for drafts above 40 ft. may be interpreted in such a way that generally speaking only special terminals for distribution of bulk loads need drafts above 40 ft. The diagrams also indicate that relatively few bulk-harbours will be able to accomodate vessels of deeper drafts than 60 ft. in 1980.

Figure 5 shows the draft as a function of ship size in ton deadweight (DWT), for tankers and bulk carriers. A ship of 100.000 DWT has a draft of approximately 50 ft. It may be noted that when size increases from about 300.000 DWT to 700.000 DWT, draft is almost constant, that means approximately 80 - 90 ft. From this it may be seen that a depth of approximately 100 ft. is sufficient to serve these ships.

Problems associated with deepening of ports.

Problems of obtaining these depths are most serious on shallow littoral drift shores and in estuaries. Many ports, however, are situated in such regions. Deepening means expansion of navigation channels, and consequently increasing maintenance. The port will then have to establish an upper limit for its "economic depth". Because of the profile of the continental shelf in such regions, the length of the navigation channel may increase considerably for every ft. of deepening of the approach channel.

As mentioned earlier, the demand for depths is greater for bulk and tank terminals. Because of the depths needed, very few, even the most important European ports, seem to be able to establish such depths at terminals through dredging of navigation channels. Future terminals will be located at places having the best natural depths.

Natural depths in the North Sea.

Figure 6 gives an impression of the depth conditions in the North Sea. The map shows the location of the 10, 20 and 100 fathoms depth contours. It may be seen that depth in the North Sea proper - is very limited. Vessels with drafts less than 40 - 50 ft. can move quite freely, however. The super-class of 50 - 70 ft. is more limited in its traffic, especially in the southern part of the North Sea. Because of heavy wave action, up to 15 m, and the instability of the bottom, the underkeel clearance must be adequate. The situation for vessels of deeper drafts is still more difficult.

Along the Norwegian coast, and a part of the west coast of Sweden, however, the 100 fathoms depth contour runs close to the shore, and consequently there are very few depth restrictions.

Natural depths along shores in the North Sea.

The location of depth contours may be used for an evaluation of the possibilities of establishing deep water ports. Let us have a look at the 60' and 120' depth contours: Generally speaking the possibilities of economic deepening are better the closer the depth contours are to the shore.

Figure 7 gives a more detailed view of the location of the 60 and 120 ft. depth contours. The shoreline was rectified, horizontal scale is ten times the vertical scale. Beginning at the northern point of Scotland, one will note that the 60 ft. depth contour is located relatively close to shore southward to Scarborough. Distance from shore varies in the range zero to approximately 8 km, with an average distance of less than 5 km. The most favourable coast is from Aberdeen to Arbroath, at St. Abbs Head and Grangemouth. South of Scarborough the depth conditions vary, but the distance from shore to the 60 ft. depth generally is greater than further north. This is true until Dover. However, there is a channel with depths exceeding 60 ft. off Boston. Besides, it may be seen that the depth conditions off London are the most critical on the east coast of Great Britain.

Considering the future mammoth tankers, demanding depths greater than 100 ft., it is of interest to look at the location of the 120 ft. depth contour. It proves that Great Britain actually has relatively satisfactory depths, especially along the coast north of Scarborough, where, in great ranges, this contour is no more than 10 km from the shore. South of the Humber Estuary, however, the depths are very shallow, and the 120 ft. depth contour is located far from the coast.

On the coast of the European continent, particularly off Belgium, Holland and Germany, the 120' depth contour is quite out of reach from the coast, while the 60' contour generally follows the shore, although not very close to it. On an average the distance is 10 km. Along the coast of Belgium, the shortest distance between shore and the 60 ft. depth contour is 10 km. Off Holland, this distance is minimum 4 km and averagely 7 km. Off the German coast the distance is 10 km. Near Bremerhaven the distance, however, is greater than 50 km.

Approaching the Danish border the 60' contour turns seaward. The

heavy littoral drift Danish North Sea coast has many shoal areas. The distance from the shore to the 60' contour is approximately 30 km. north of Esbjerg. Further north distance decreases, and from Ringkjøbing Fjord and north it is approximately 3 km. The 120' contour is located at great distance from the shore.

At Hirtshals, on the Skager Rack, the distance is about 10 km. but it decreases to 3 km. at the Skaw, the northernmost tip of Jylland, where the 60' contour comes close to shore.

Natural depths on the west coast of Sweden are relatively satisfactory on the coast from Helsingborg to Øresund, and up to Norway, where the 120' contour is situated about 7 km. from the shore.

In the sound south of Helsingborg depths are shallow, navigation depth at Copenhagen being 36 ft. for tanker terminal.

Figure 8 gives a general view of the depth conditions along shores in the North Sea, except Norway. The upper part of the figure shows in percent the part of shore when distance to the 60 ft. depth contour is greater than x . To summarize: The depth conditions are satisfactory in England and the west coast of Sweden, and least satisfactory in the German Bay. The lower part of the figure shows the corresponding distribution of the distance to the 120 ft. depth contour. The same general conclusions may be drawn from this figure.

Depths in ports on the North Sea Coast.

If we look at the depths in the ports on the North Sea coast, figure 9 shows the number of ports with maximum depths in the depth range indicated. Present and planned depths in 1975 and 1980 are indicated for three groups of cargo, tank bulk and general. The major part of the present tank terminals have depths in the range 30 - 50 ft. In 1980 the number of terminals in the depth range 35 - 45 ft. has decreased, and the number in the range 80 - 90 ft. have increased. The same tendency is also evident for bulk terminals. For general cargo terminals, there is an evident decrease in the number of ports in the 30 - 35 ft. range, and an increase in the 40 - 50 ft. range. Tank and bulk terminals with depths exceeding 70 ft. seem to be located in sheltered waters with sufficient natural depths. They can often appear as piers and off-shore buoys. The uniform distribution of general cargo terminals with depths less than 50 ft., indicates a high utilization of the economically available depth poten-

sial in the present ports.

Figure 10 shows the most important ports on the North Sea coast with depths exceeding 40 ft. - as of to-day.

Most of these ports have planned further dredging during the next decade. Evidently there are a score of ports with depths exceeding 40 ft. Among those only about 7 have depths exceeding 50 ft. The size of future vessels therefore will have to be adjusted to the actual depths in these ports. This problem has become acute in connection with the planned future oil-transportation from wells in the North Sea.

Depth conditions along the Norwegian coast.

Because of the special character of the Norwegian coast, it will be dealt with separately. Norway is fortunate in having great natural depths along its coasts. The 120 ft. depth contour runs close to the shores, in bays and fjords.

Norway's rocky and indented coast offers a great number of fjords and sheltered areas with many natural harbours. Although many of the fjords are wide, they are well protected against wave action. Figure 11 shows cross sections of various parts of Hardangerfjord. The steep mountains and the great depths are obvious.

The drawback with many of the Norwegian fjords is that their location is often far from the general land transportation system. Further, they are faced with great limitations with respect to land area available.

Figure 12 discusses the relation between Norwegian fjords, the main land transportation system and the most important towns on the coast. The depths are generally in the range 100 to 300 m., 300 to 1.000 ft. all are well protected against wave action and the navigation conditions are good.

Concluding remarks.

Compared with the natural depth conditions in the rest of western Europe, Norway obviously has a great depth potential. Though Norway is located in the periphery of mainland Europe, an alteration of the European terminal structure may imply the utilization of Norway's depth potential.

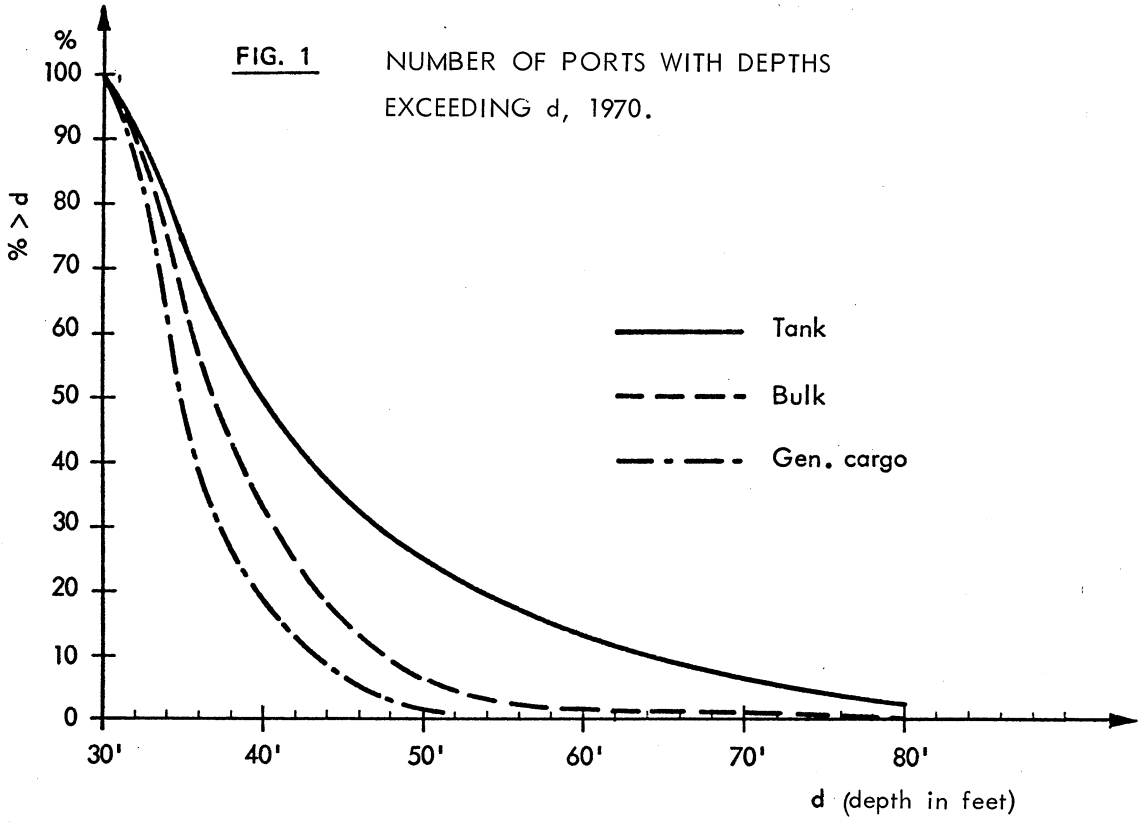


FIG. 1 NUMBER OF PORTS WITH DEPTHS EXCEEDING d, 1970.

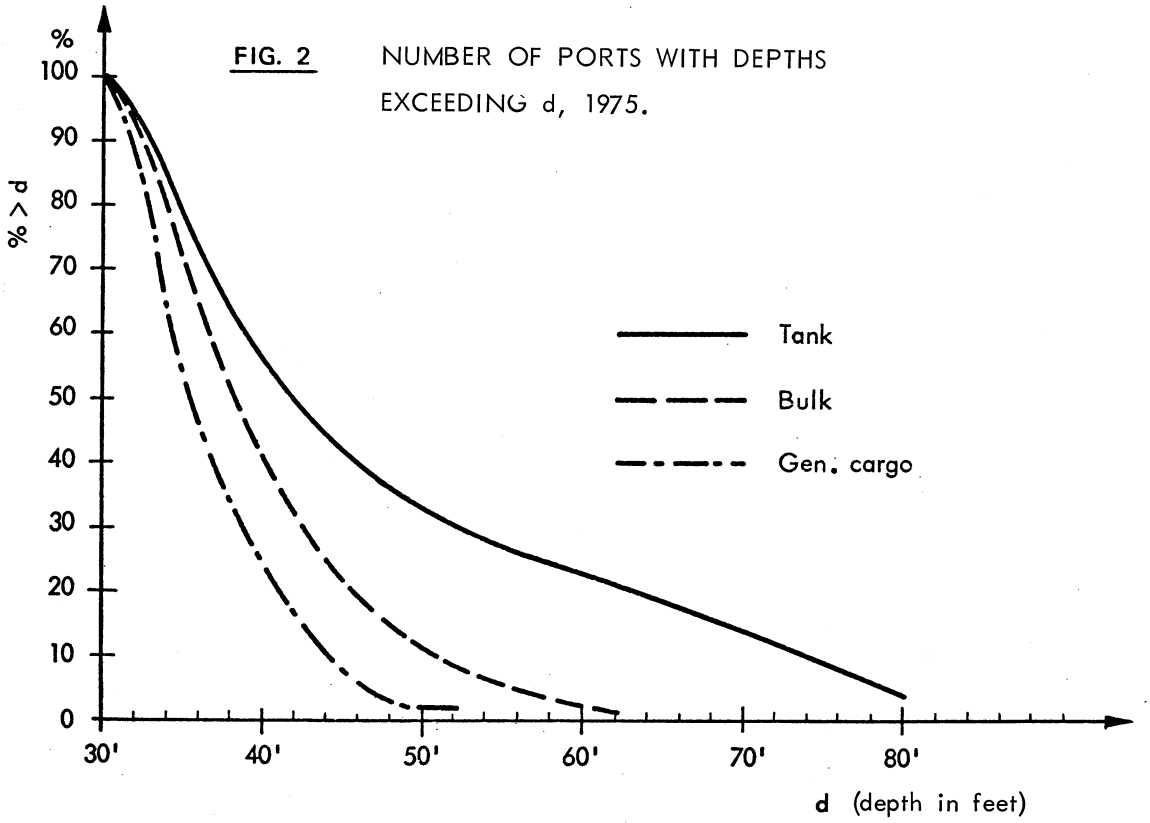


FIG. 2 NUMBER OF PORTS WITH DEPTHS EXCEEDING d, 1975.

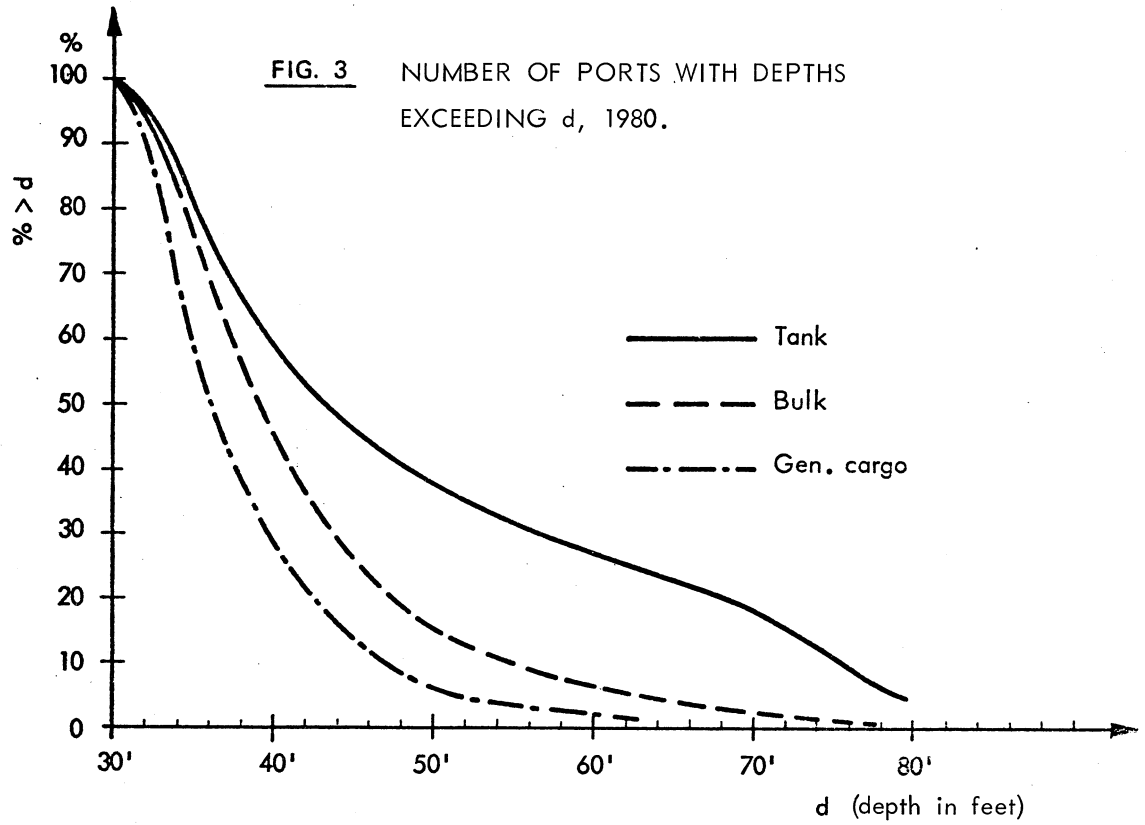


FIG. 3 NUMBER OF PORTS WITH DEPTHS EXCEEDING d, 1980.

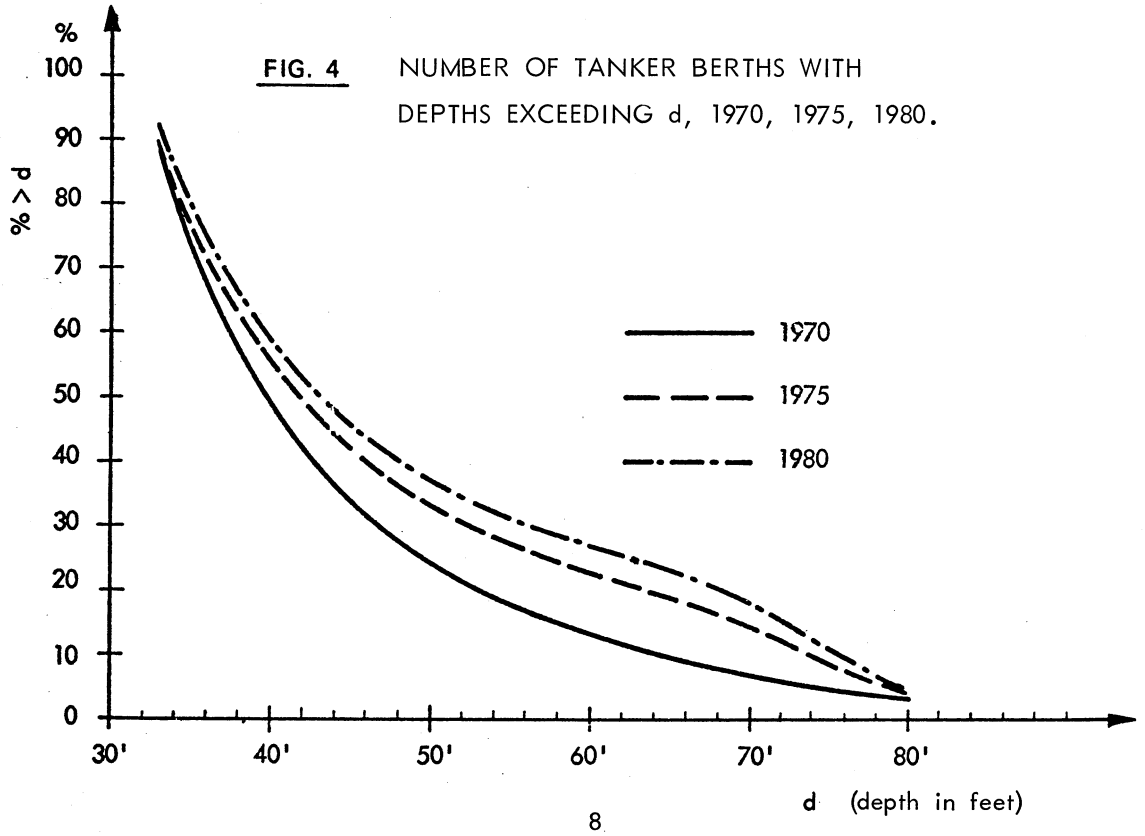
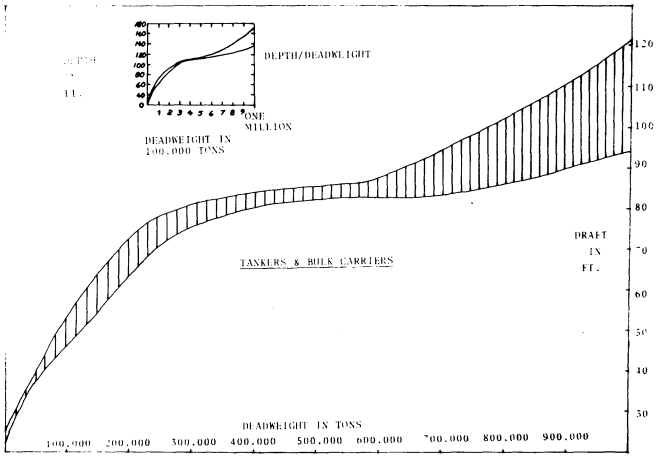
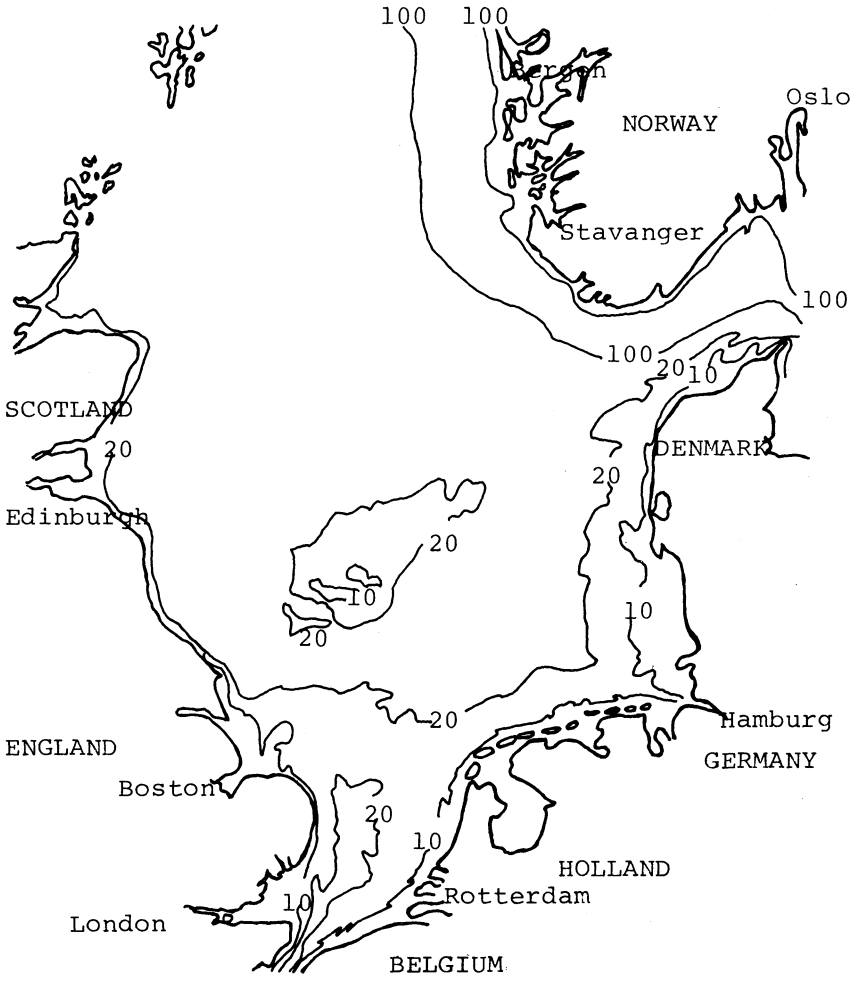


FIG. 4 NUMBER OF TANKER BERTHS WITH DEPTHS EXCEEDING d, 1970, 1975, 1980.

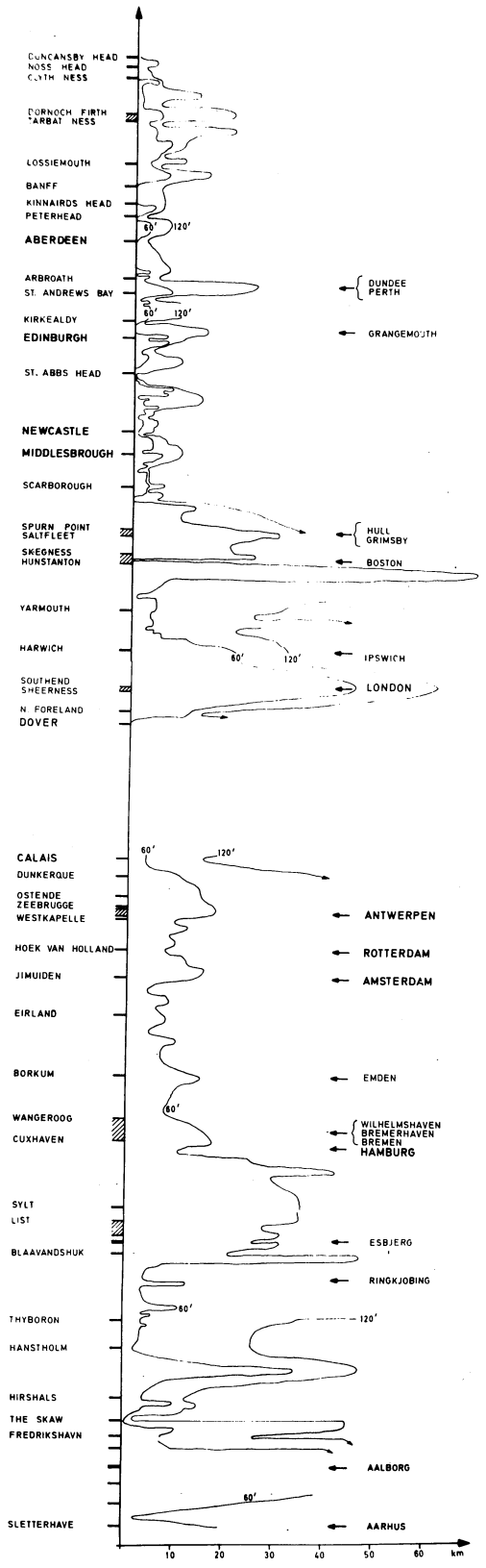


Draft as a function of ship size.

FIG. 5.

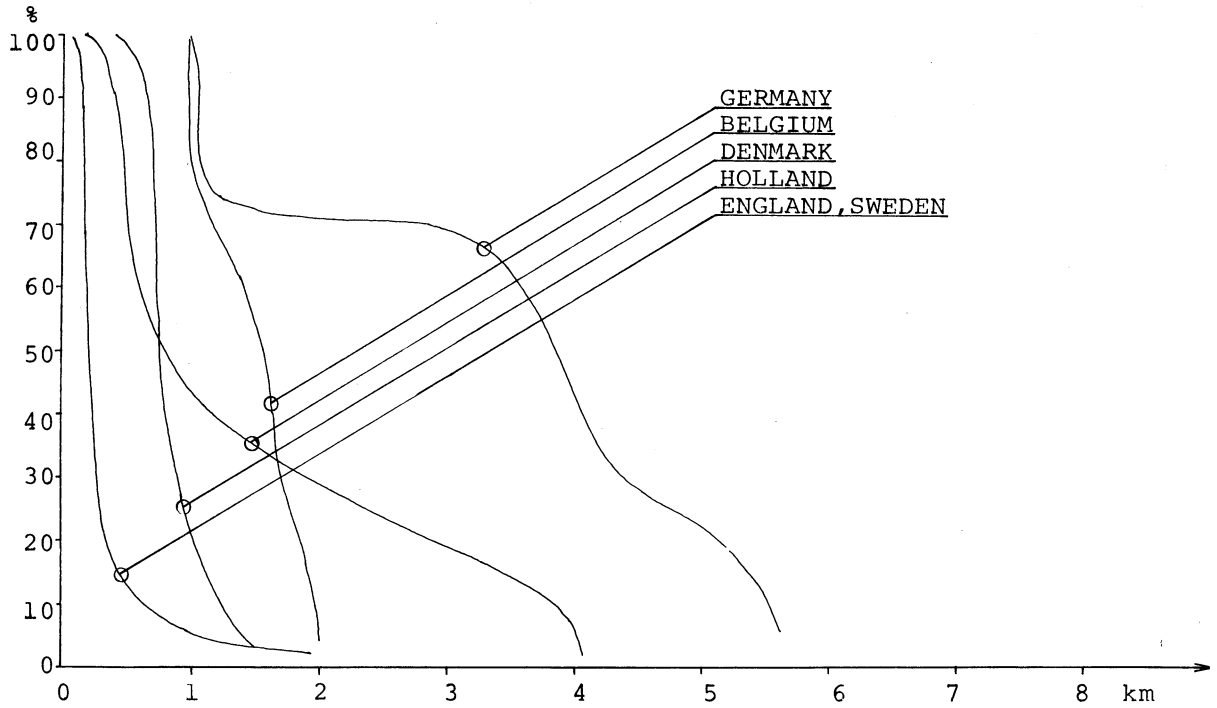


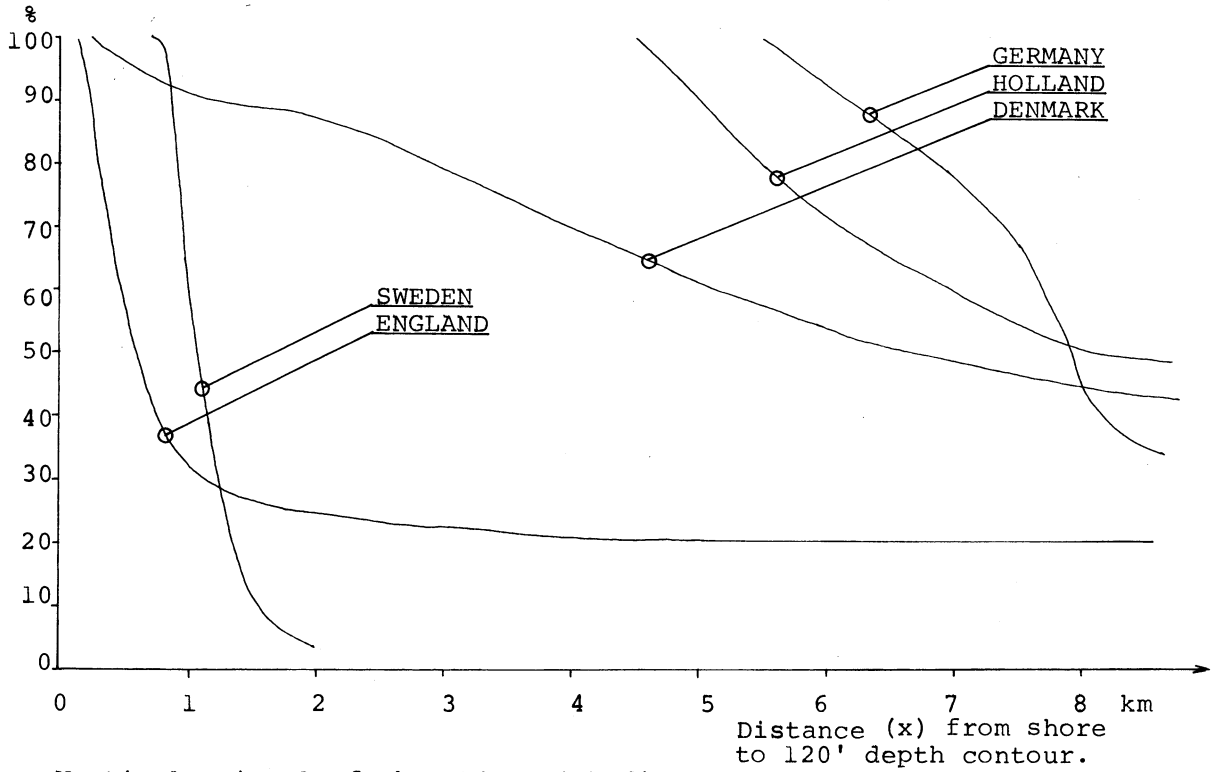
DEPTH CONDITIONS IN THE NORTH SEA
10 - 20 - 100 FATHOMS DEPTH CONTOURS
FIG. 6.



The North Sea Coast:
The distance from shore to the 60 ft. and 120 ft. depth contours.

FIG. 7



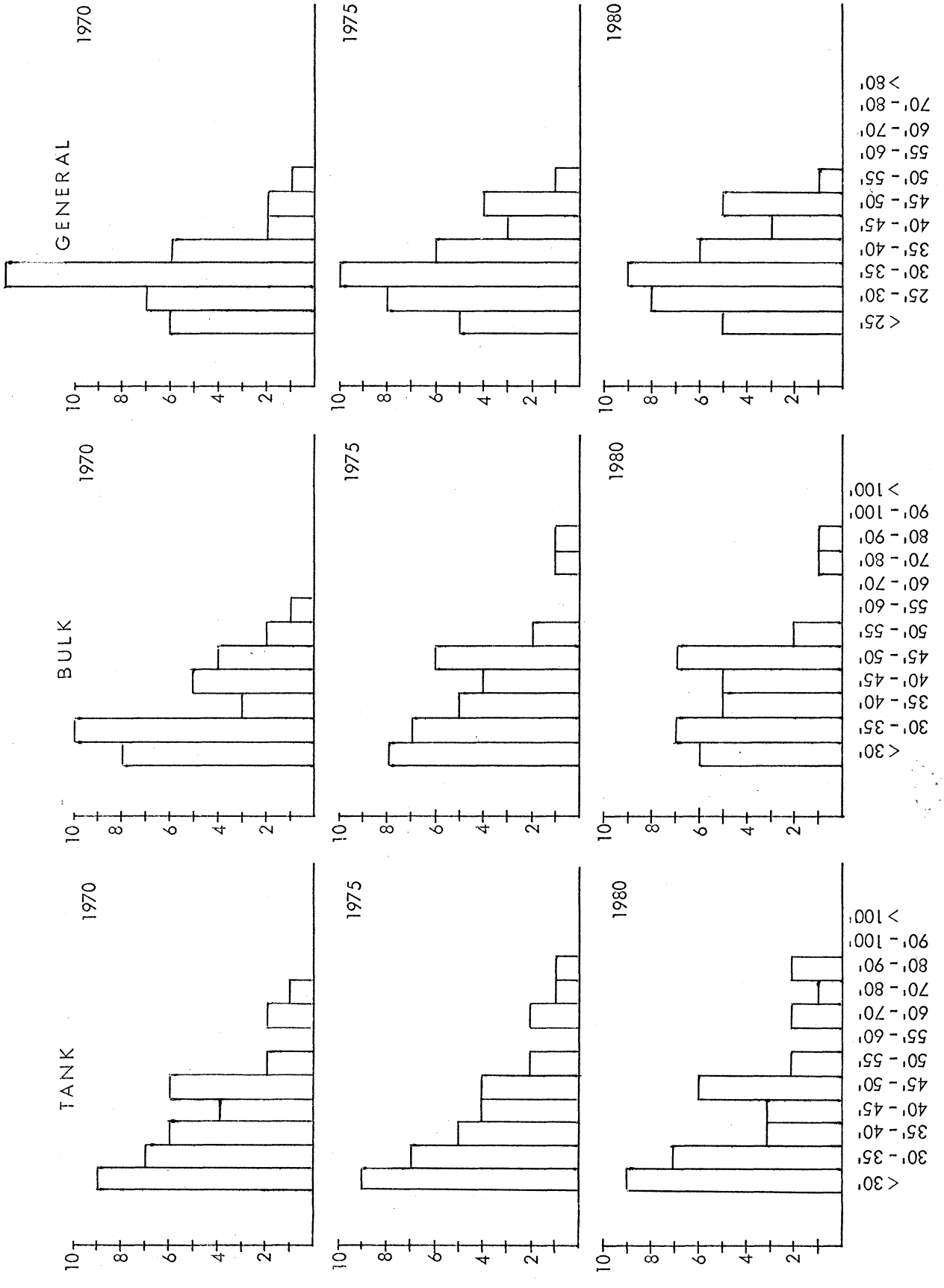


Vertical axis: % of shoreline with distance to the 60' (120') depth contour ≧ x.

GENERAL VIEW OF THE DEPTH CONDITIONS ALONG SHORES IN THE NORTH SEA.
(EXCEPT NORWAY)
FIG. 8.

depths in various depth ranges.

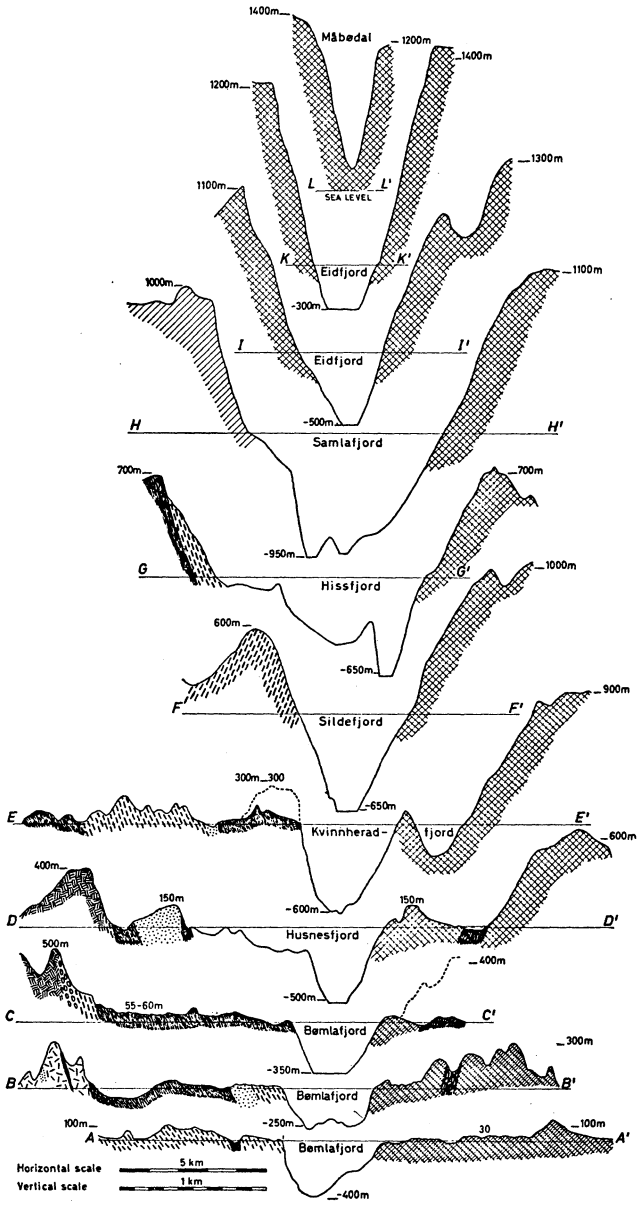
FIG. 9



England:	London	:	49'
(North Sea Coast)	River Tees	:	45'6"
Denmark:	Fredricia	:	49'
(The Catte Gat)	Gulfhavn	:	47'
Belgium:	Antwerp	:	51'
	Zeebrugge	:	43'
	Gent	:	44'4"
France:	Dunkerque	:	55'
Holland:	Amsterdam	:	45'
	Rotterdam	:	62'
	Ijmuiden	:	48'
Western Germany:	Hamburg	:	42'6"
	Wilhelmshafen	:	49'
	Bremerhaven	:	46'
Sweden:	Gothenburg	:	63'
	Nynäshavn	:	69' (Baltic)
Norway:	Narvik	:	46' (Nothern Norway)
	Slagentangen	:	69'
	Stavanger	:	54'
	Kristiansand	:	40'
	Aalesund	:	42'

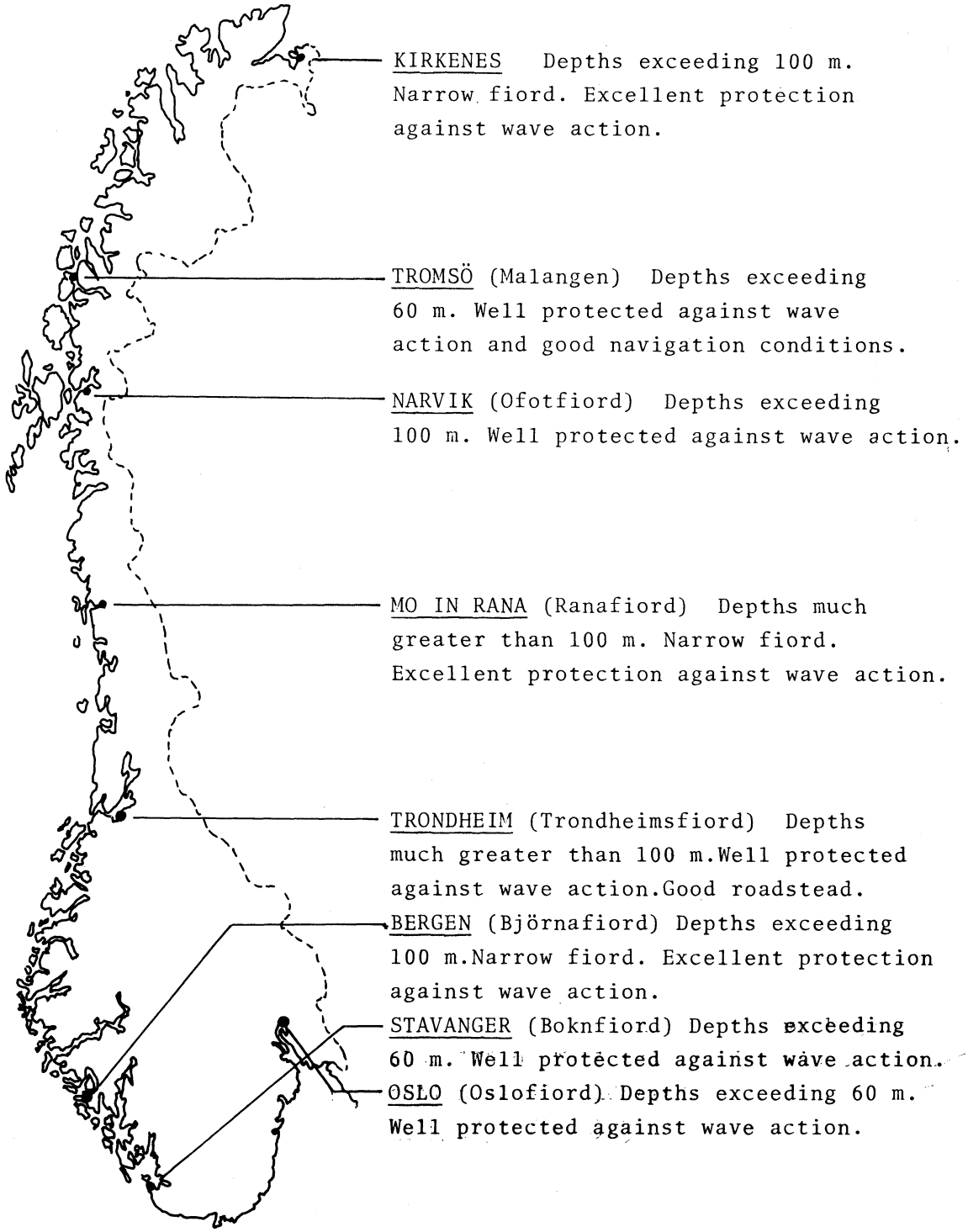
PORTS ON THE NORTH SEA COAST WITH DEPTHS EXCEEDING 40 FT.

FIG. 10



Transverse sections across various parts of Hardangerfjord.

FIG. 11



DEPTH CONDITIONS IN FIORDS NEAR THE MAIN LAND TRANSPORTATION SYSTEM IN NORWAY.

FIG. 12