SECOND INTERNATIONAL CONFERENCE ON
PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
UNIVERSITY OF ICELAND
DEPARTMENT OF ENGINEERING AND SCIENCE

A SURVEY OF HARBOUR POSSIBILITIES ON THE SOUTH COAST OF ICELAND

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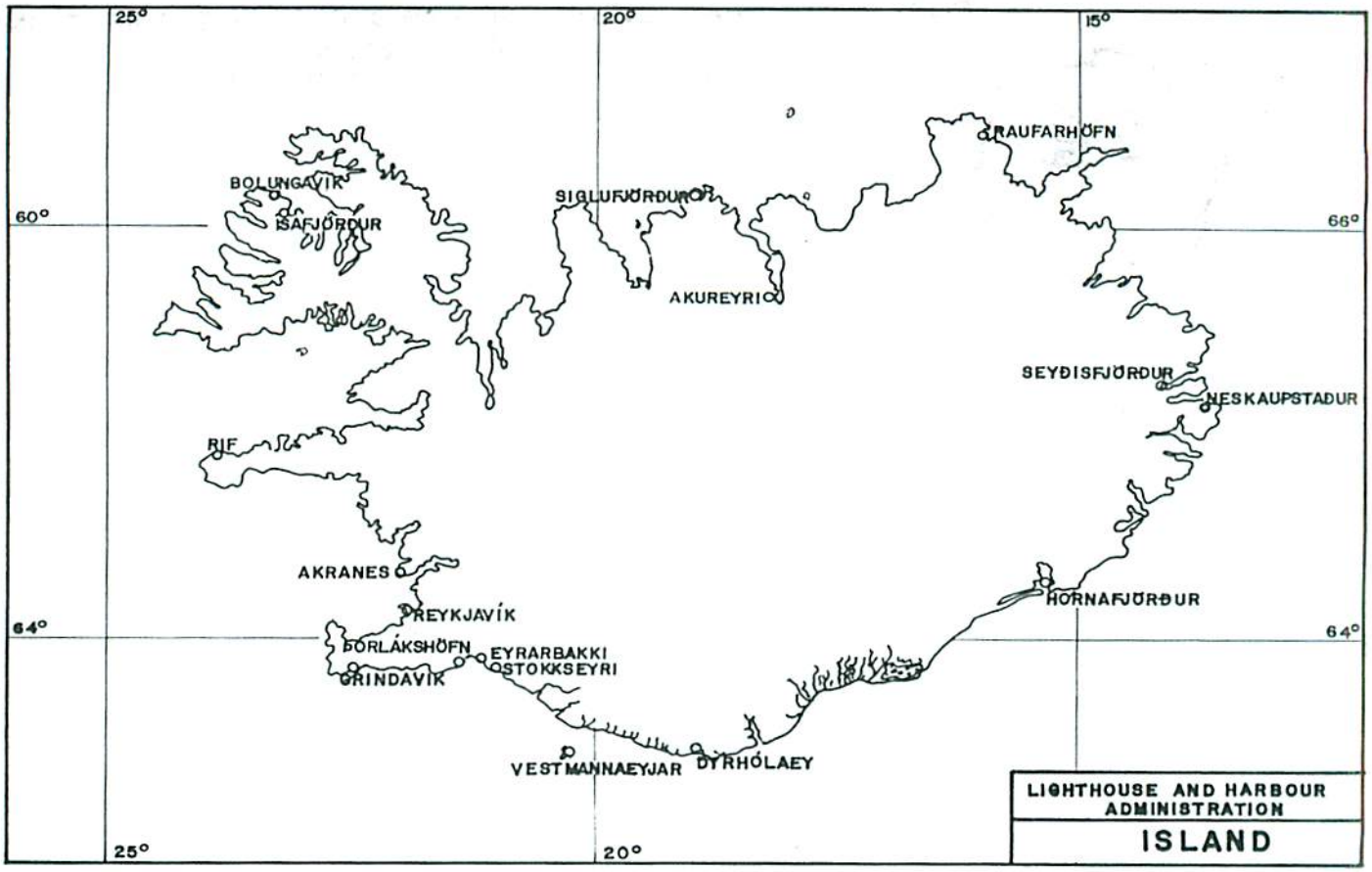
When this paper was written the volcanic eruption in Vestmannaeyjar was still going on and this has to be kept in mind while reading it.

Almost the entire south coast of the country, from Reykjanes to Eystra Horn is harbourless in the sense that nowhere on this coastline is there a harbour navigable for ships and boats in all weathers or safe for them in all conditions. However, the harbours at Grindavík and Höfn in Hornafirði are so good that boats which have entered them may be considered safe in any weather, if their number is not too great.

These two harbours, at the western and eastern extremes of the coastline, will be discussed only briefly here, but common to them both is a difficult entrance. However, some mooring facilities have been provided which make it possible for a small number of boats to be safe there yet neither of them has any cargo ship facilities to speak of, although vessels of limited size, or up to 1000 tons, have entered them and have been serviced there.

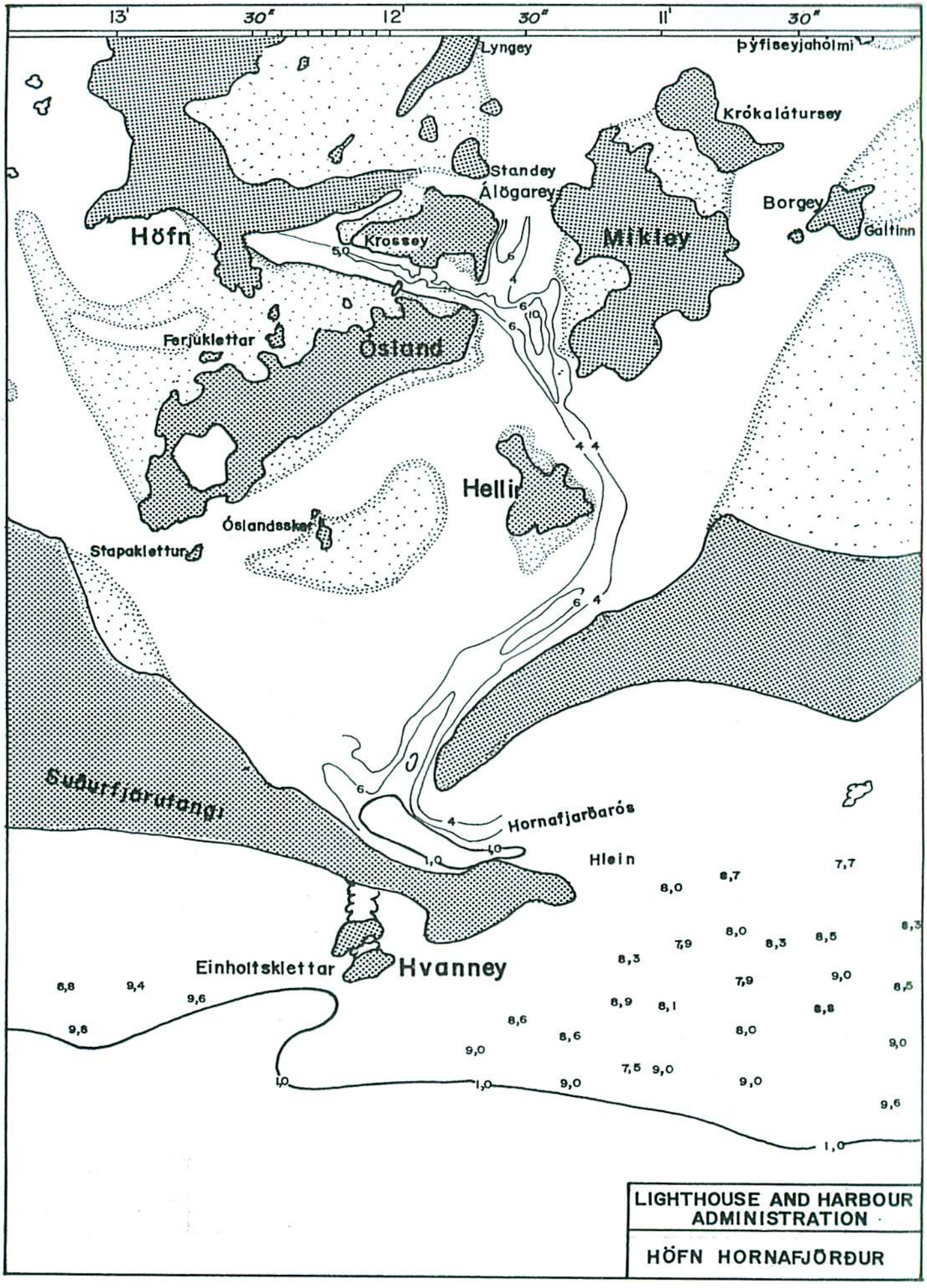
There are regular sailings of cargo ships to Höfn in Hornafirði but not to Grindavík. It is difficult to improve the entrance to Hornafjörður, but expansion possibilities of the inner harbour are almost unlimited.

The reverse is the case in Grindavík, where there is limited space for expansion, but the entrance can be improved consider-



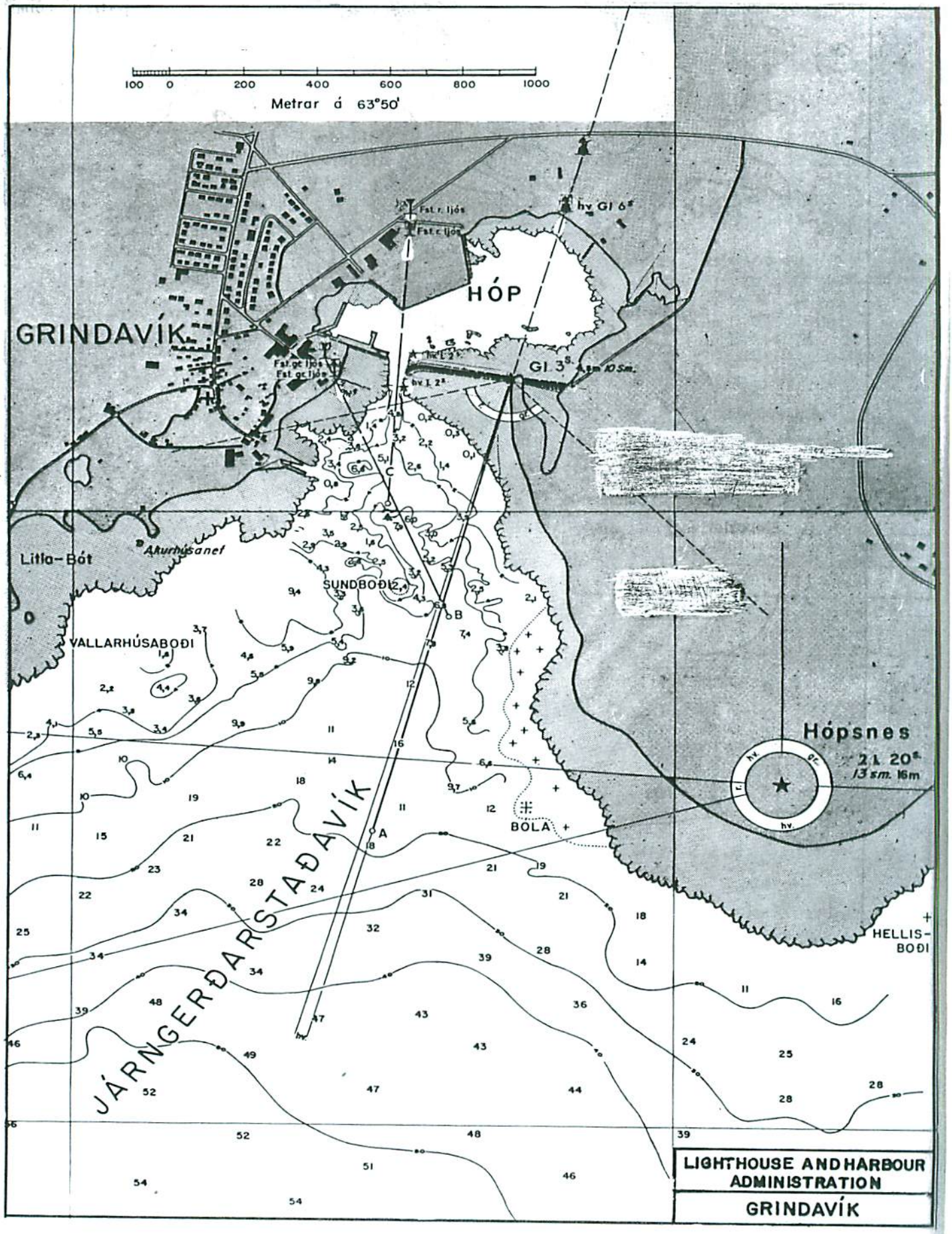
ably. By deepening and widening the entrance channel from the outer harbour more room will be created, so that there will be less danger of accidents when entering and leaving the harbour than at present, and larger ships can be taken in with more safety. A breakwater will most likely decrease movement still further in the harbour and entrance. Due to the shallows in front of the entrance at Járngerðarstaðavík, breaking waves may be expected in winter storms, and in those cases the harbour entrance may be considered impassable.

Almost directly between these two outermost harbours on the south coast are Vestmannaeyjar, which was considered a safe all weather harbour once it had been entered, but it was by no means always passable for ships or fishing boats in heavy seas. Prior to the catastrophe at Heimaey, the facilities for the home fleet of Vestmannaeyjar were satisfactory and there were facilities to service cargo ships which called in there. Compared to most



LIGHTHOUSE AND HARBOUR ADMINISTRATION

HÖFN HORNAFJÖRÐUR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LIGHTHOUSE AND HARBOUR ADMINISTRATION
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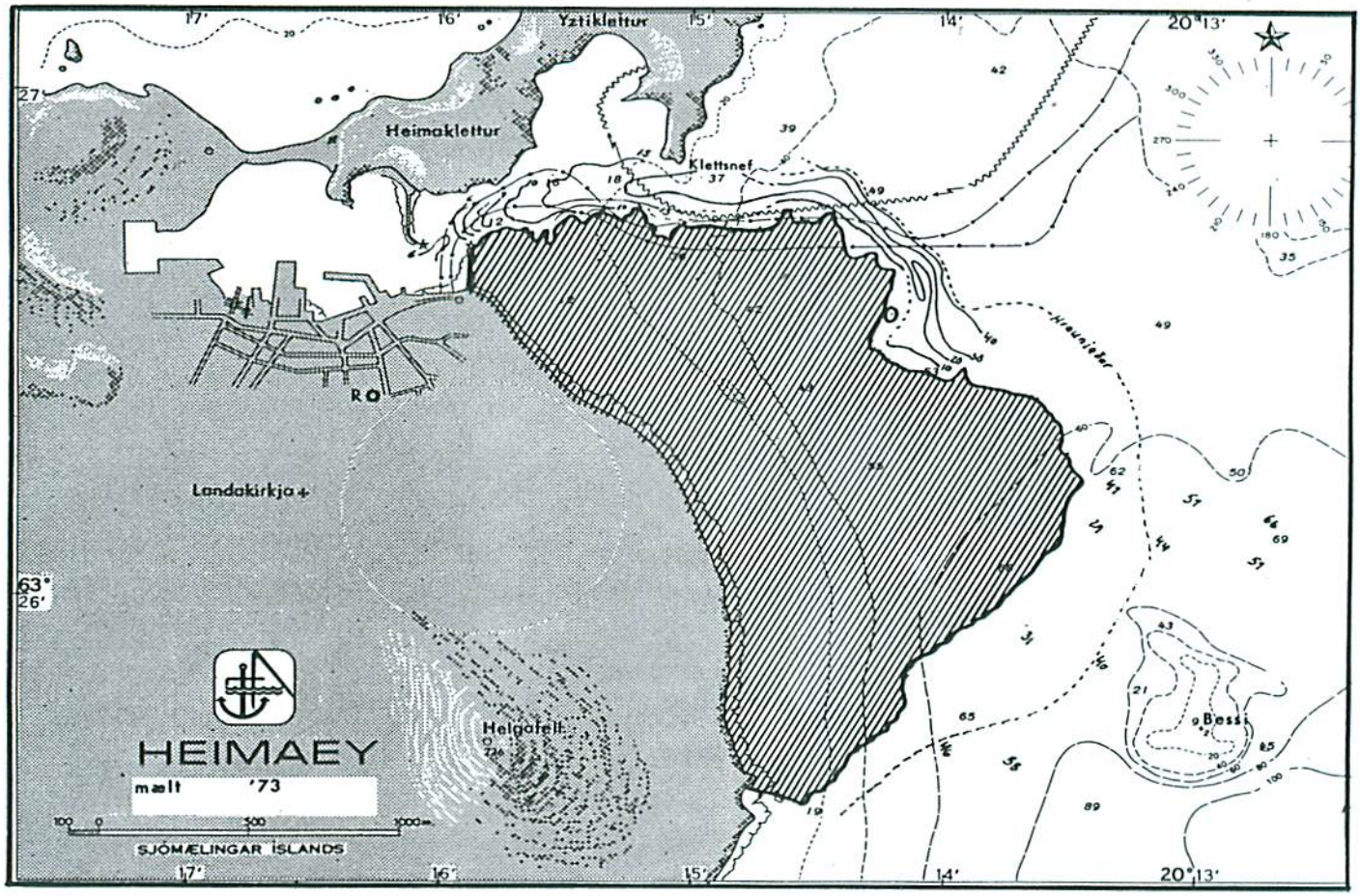
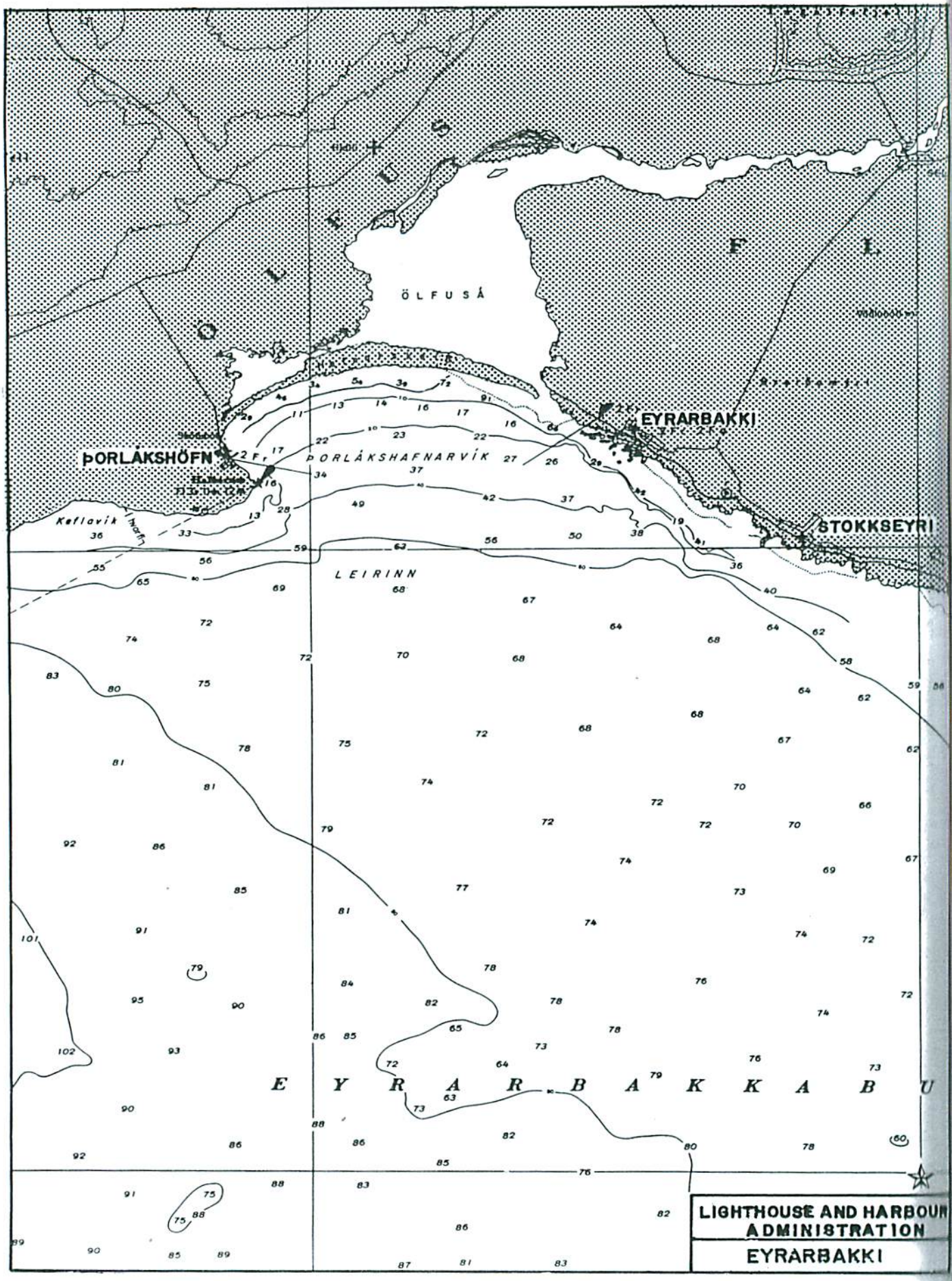


other harbours in the country, it could be considered fairly good and in the class of better harbours.

While the eruption at Heimaey continues it is difficult to foresee the future of Vestmannaeyjar harbour, but at the present the harbour has improved a great deal both as regards movement and entrance, and if it turns out, as everybody hopes, that the eruption is drawing to a close, then the harbour will have improved to a great extent, due to the lava flow from Heimaey towards Bjarnarey. However, extensive repairs have to be made on the harbour, its depth has decreased by approx. 1.0 m and there is reason to believe that the entire harbour area will have to be planned again with a view to the fullest utility if new fish processing and freezing factories are to be built and new facilities for shipbuilding and repairs are provided.

So far, three harbours, if they deserve that name, have not been mentioned, i.e. Þorlákshöfn, Eyrarbakki and Stokkseyri. In the


ÖLFUSÁ
EYRARBAKKI
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ÞORLÁKSHAFNARVÍK
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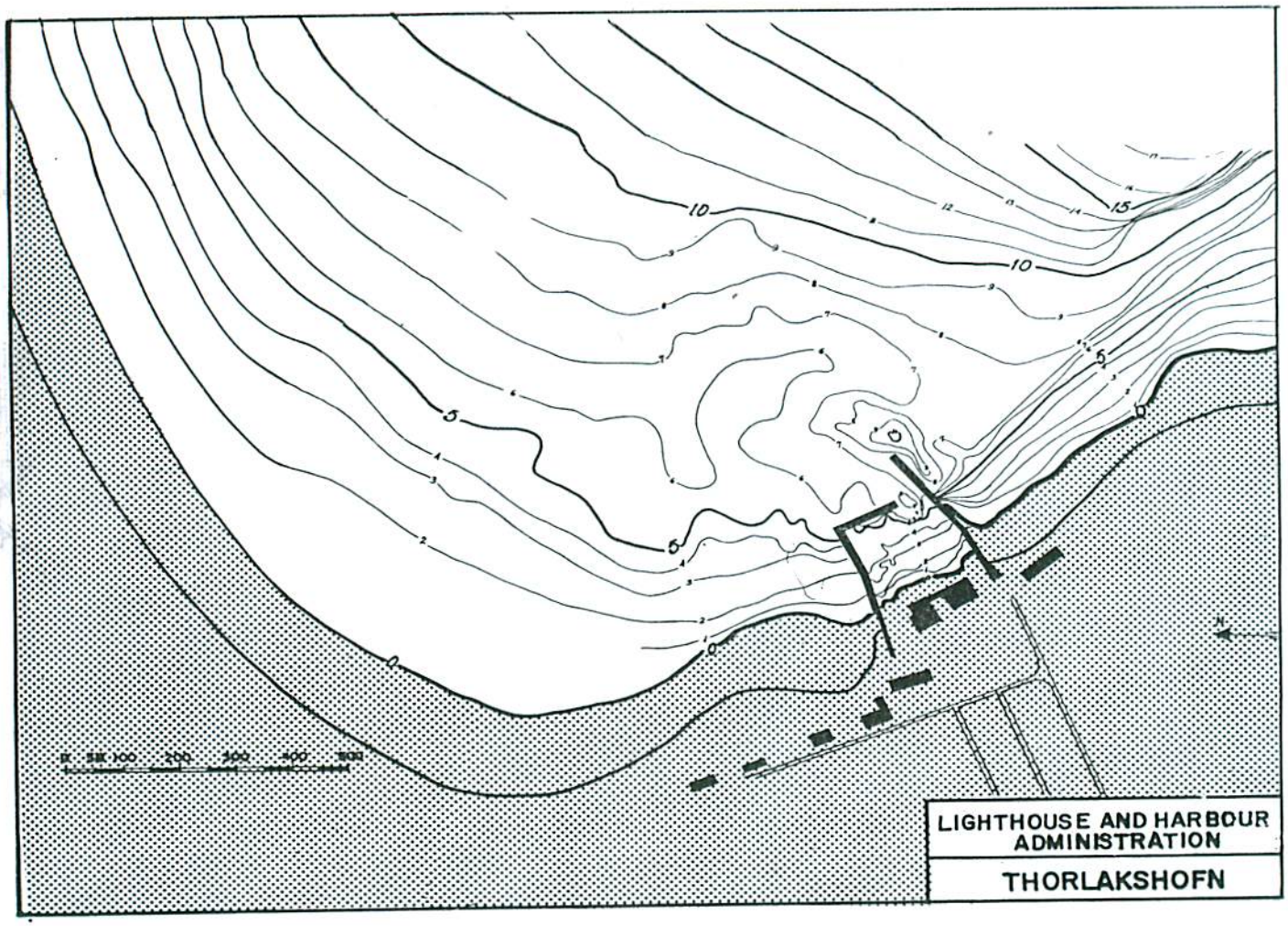
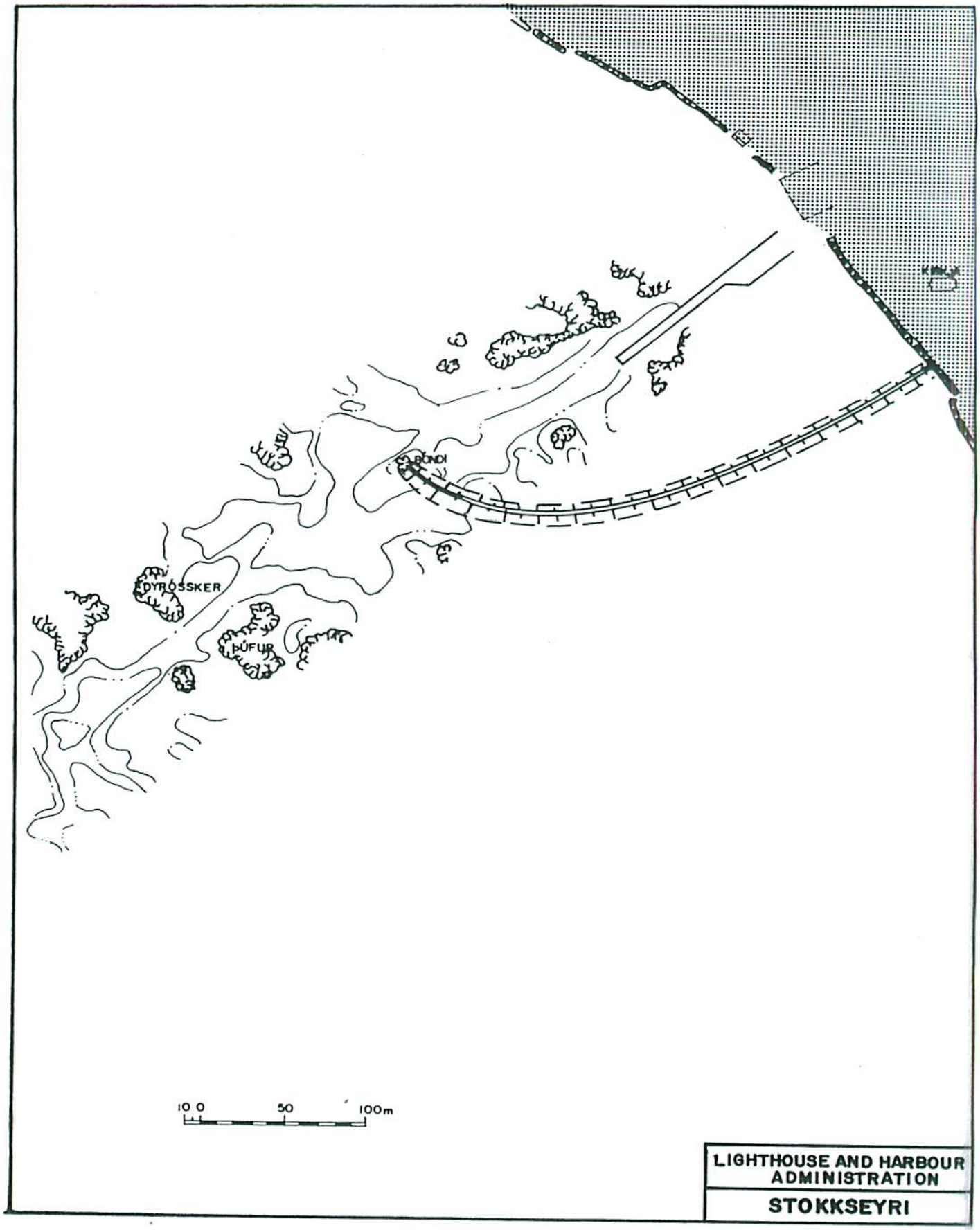
LIGHTHOUSE AND HARBOUR ADMINISTRATION
EYRARBAKKI



past some harbour structures have been built in all these places, especially at Þorlákshöfn where there are facilities to service cargo ships of the size which normally sail to this country, these however, can only use it under good weather conditions. In Þorlákshöfn there is also a small-craft harbour which is fairly safe for a small number of boats, approx. 15 boats of the size which fish from there at present. The whole harbour has been built since the second world war, and most of it was built after 1962, when a contract was taken out for the extension of the main breakwater and creation of the small-craft harbour. When the decision about this project was taken it was based on the assumption that boats using Þorlákshöfn would normally be 15 - 50 BRT in size and the size of the harbour was decided with this in view, besides, money was scarce and the increases in the size and number of boats sailing from fishing harbours on the south coast could not be foreseen at the time.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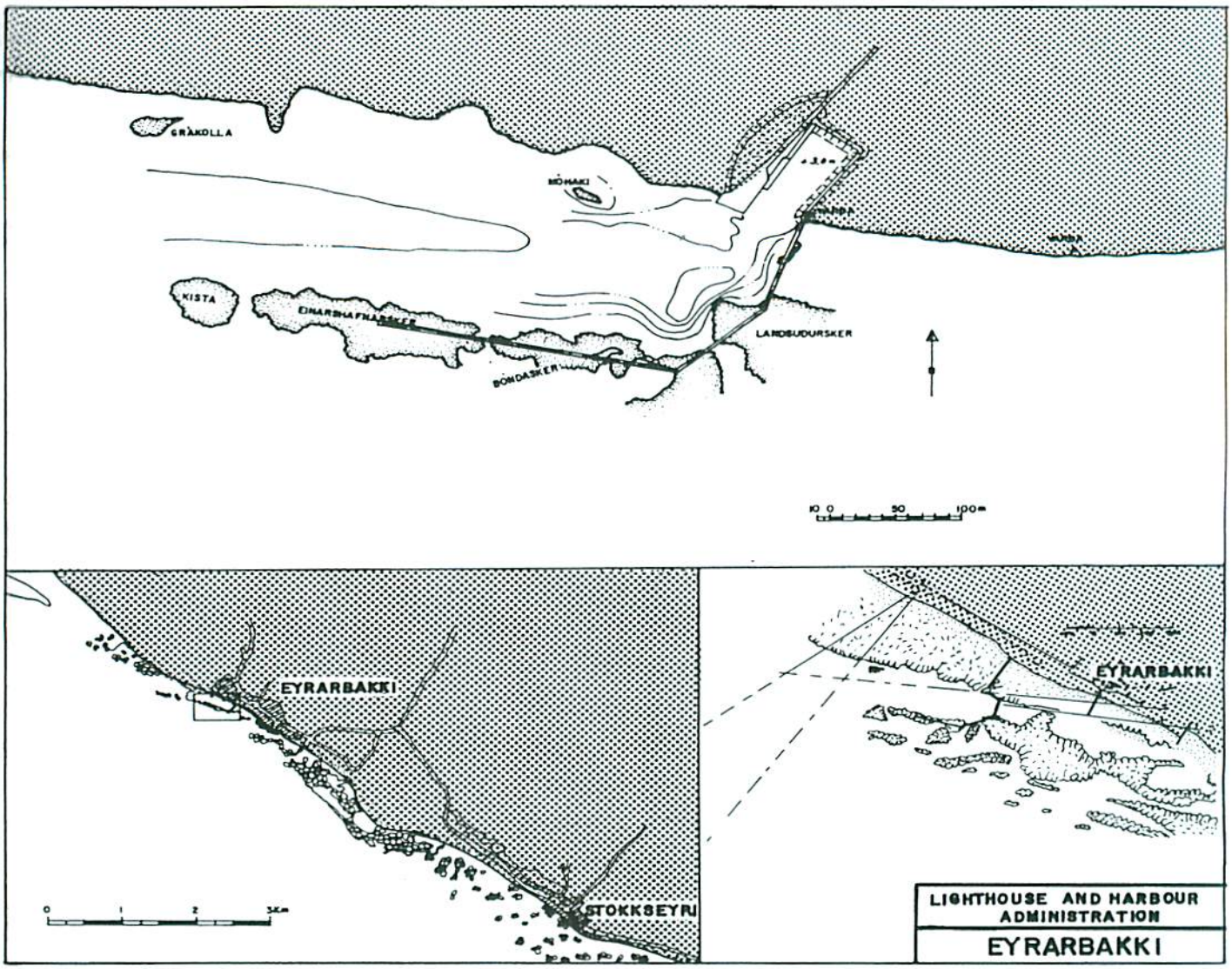
LIGHTHOUSE AND HARBOUR ADMINISTRATION
STOKKSEYRI



Conditions at Stokkseyri and Eyrarbakki are similar, i.e. the edge of a lava flow is a few hundred meters from the coast and a few channels from this edge up to the coast, but the main lava flow is a little below low tide. Close to the shore there are a few lagoons and bays in the lava. In those, boats could be moored in lee of the off-shore breakers. However, boats were by no means save in these lagoons, and in both places, breakwaters have been built outside the lagoons along with primitive jetties from the coast, extending out to the depth where the boats float at low tide. In both places rock blasting has been carried out to increase the depth at the jetties, and at Stokkseyri there are a few submerged reefs in the entrance to the harbour area. In both cases the harbour entrances are unsafe and difficult and completely impassable in heavy weather.

About 10 boats have fished from each harbour during the past few years and a small number of other boats landed their catch there during the past winter fishing season. The boats from these places, however often have to go to Þorlákshöfn for landing their catch when the entrance to their home harbour was unsafe in bad weather or when there was danger that they would miss a trip if they got hemmed in by bad weather.

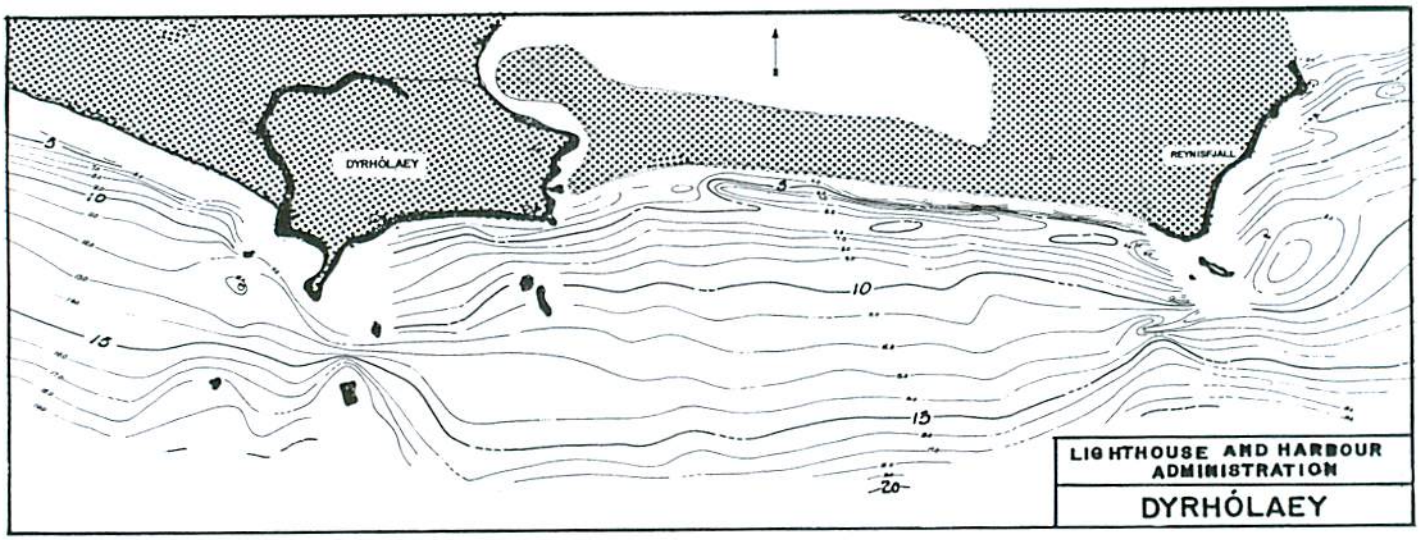
It can be said, then, that the south coast, which adjoins our richest fishing grounds is not very well endowed with harbours. Therefore it is easy to understand that improvements have been sought for a long time.

A basic rule in harbour building in Iceland has been that the various communities have built their own harbours with financial aid from the government, and in later years the communities have also been given government help in obtaining loans to finance their share in the total cost of the construction. Thus, the initiative has come from the communities themselves and therefore the demands for harbour constructions have been limited to the local needs of regions and communities. Therefore it was an unprecedented move when the counties of Árnessýsla and Rangárvallasýsla in a joint venture bought land at Þorlákshöfn and decided to construct a harbour there.

The Icelandic administrative system is organized in such a way that the financial resources of the counties are severely limited, and it turned out that the counties handed the ownership over to the government, of the harbour structures and a strip of coast, with the proviso that in exchange the government would relieve the counties of considerable debts.

The community of Mýrdalur and later the whole of the county of Vestur-Skaftafellssýsla have repeatedly made requests for studies with a view to harbour construction, and have pointed at Dyrhólaey as a likely location, but there fishing operations have been carried out for centuries, and off the coast there are good fishing grounds. Initial investigation has shown that harbour construction there would be very difficult. It has always been the opinion of the engineers who have carried out these studies

on behalf of the Lighthouse Administration and later the Harbour Authority that this was a very large and unique project, which would have to be tackled differently from other harbour constructions. On the other hand, local opinion maintains that with relatively small resources compared to normal harbour construction in Iceland it would be possible to initiate construction on a small scale and the project could be enlarged by degrees until a good harbour had been made. This has not been the opinion of the Icelandic Harbour Authority, but let us now examine conditions at Dyrhólaey a little more closely.



In 1958 a fairly extensive soundings was made of the area a little west of Dyrhólaey all the way east of Vík in Mýrdal. These soundings were the first stage in the study of a harbour site at Dyrhólaey carried out by the Harbour Authority, but Althing had passed a resolution to that effect.

The main factors in harbour construction on the south coast apply equally to Dyrhólaey and other possible locations. Therefore I will examine these factors with reference to Dyrhólaey and mention them less when considering other possible locations on the south coast. A preliminary report on basic studies in connection with harbour construction at Dyrhólaey, made by the Harbour Authority, is now available. The report was submitted to the Ministry of Communications last year and was prepared by

Harbour Authority engineers. The report was chiefly prepared by Daníel Gestsson, Chief engineer, who supervised the work, and Magnús Ólafsson, Divisional engineer, who prepared text and diagrams. Final engineering examination theses of Jónas Elíasson, 1963 and Pálmi Jónsson 1969 were used for reference. Dr. Per Bruun, Professor of harbour construction in Norway and Torben Sörensen, Director of The Danish Hydroulic Institute in Copenhagen, also contributed suggestions and advice.

At this point it is relevant to state the basic requirements a harbour has to fulfil, and at the same time, to examine in some detail for what purpose the harbour will be used and the types of ships using it. The resolutions leading to investigation on the harbour site at Dyrhólaey took these factors into account only to a small extent, and in the report mentioned above we had to set out likely requirements for the harbour construction. The chief requirement is that it should be basically a fishing harbour, accommodating a fleet of the size comparable to that of Vestmannaeyjar, i.e. approx. 100 vessels, 30 - 250 BRT in size. Furthermore the harbour would accommodate cargo ships to serve the needs of the surrounding rural areas and the community which inevitably would form around the harbour with a likely population of 5000. Also, the requirement included that the harbour would be passable in all weathers, that is to say, there were only a few days a year when it was impossible to enter or leave the harbour area, and sand and gravel transportation were reduced to a minimum, so that maintenance costs would not be excessive.

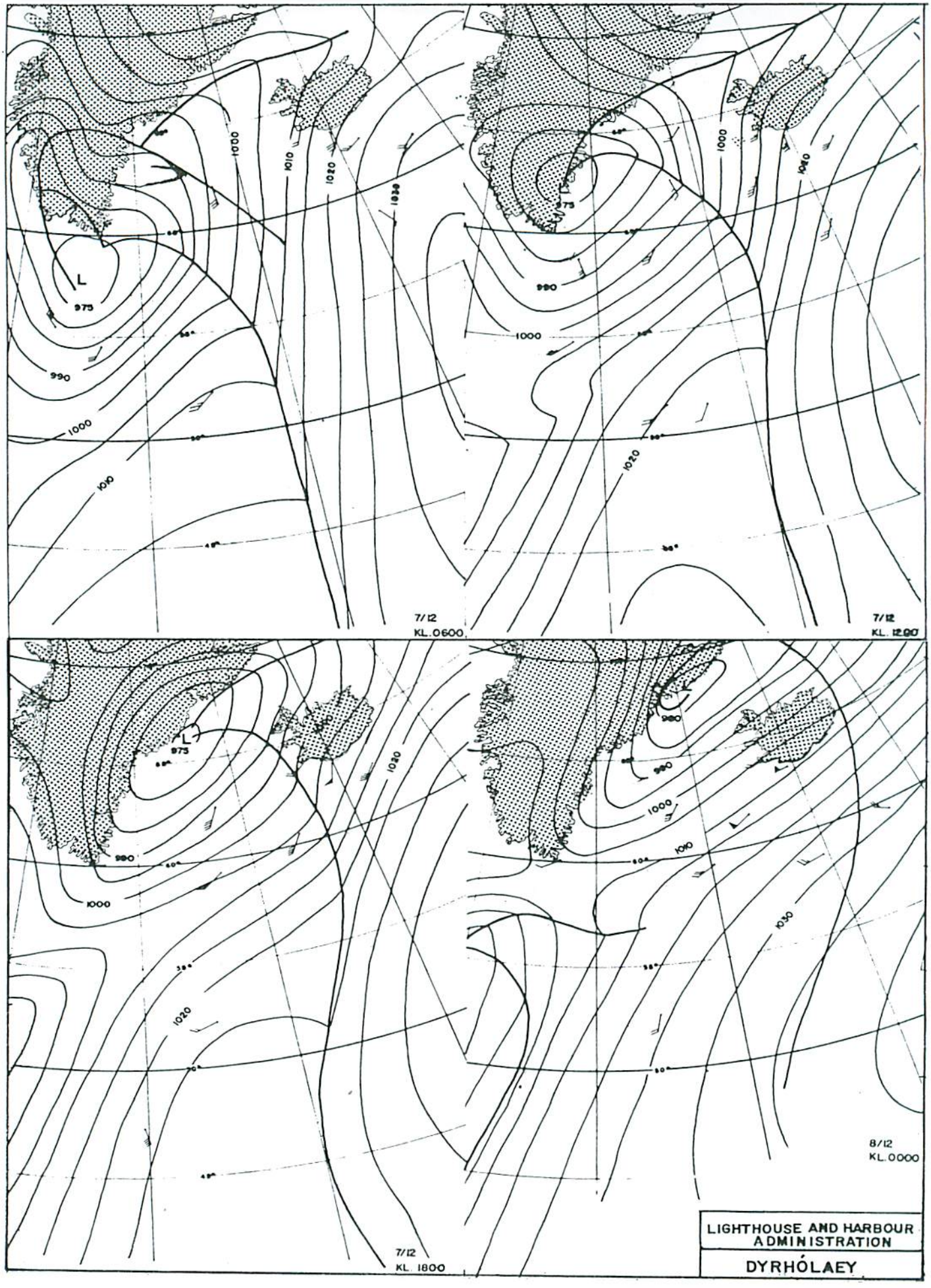
It soon became apparent that the last condition mentioned i.e. that the harbour would be passable fairly often and there was minimal sand transportation into the harbour area, would be the chief determining factors in the cost of the construction. Inner harbour structures turned out to be only a quarter of the total cost, and it appeared to be fairly easy to plan the harbour area with a wiew to keeping extensions of new wharfs easy to carry out and relatively inexpensive.

The National Energy Authority, at the instigation of the Harbour Authority, carried out research which revealed that on both

sides of the island, loose materials, gravel and/or sand extend out to the depth of 20 - 30 m so that construction of docks by sand pumping is fairly easy, and the material created by this could be used for land filling and elevating purposes around the harbour, but at present the land is rather too low for construction purposes.

The most critical element of the forces of nature in harbour construction on the south coast of Iceland is of course the waves that break on the coast, and the movement they create in loose materials and the forces they exert on the harbour structures. It is a well known fact that in few places on earth other than Iceland is the weather more changeable or heavy. The island lies in the path of low pressure systems travelling between two continents, and if we take a closer look at winds and the movement of low pressure system, it is clearly evident that gigantic waves can be expected on the south coast. Research has shown that there is a relatively simple relation between wave height and wind speed and the time the wind blows in a certain direction across the sea surface, and at the same time over what distance the wind has had a chance to blow with this certain speed and direction.

It has been known for a long time that all or almost all major low pressure systems which cause fairly high winds are deep, move fast and come from the south - west on their way north. In the sout-east section of a system the wind follows the pressure lines and blows in the moving direction of the system. If the low pressure system travels with approximately the same speed as the wave groups, i.e. half the speed of the wave crest, the same pressure system may transfer energy to the wave movement over a large area or all the way south from Newfoundland or further away, and therefore waves which accompany such weather can become very high and long. We simply do not know how large the waves can become at the south coast, but during wave measurements at Dyrhóla-ey in autumn 1971, which lasted only for 2 months a significal wave was measured over 8.0 m, but a significal wave is the average size of the highest one third of waves during the measurement period. Here measurements were taken for 15 min. every 3 hrs. so it is by no means certain that the highest waves were measured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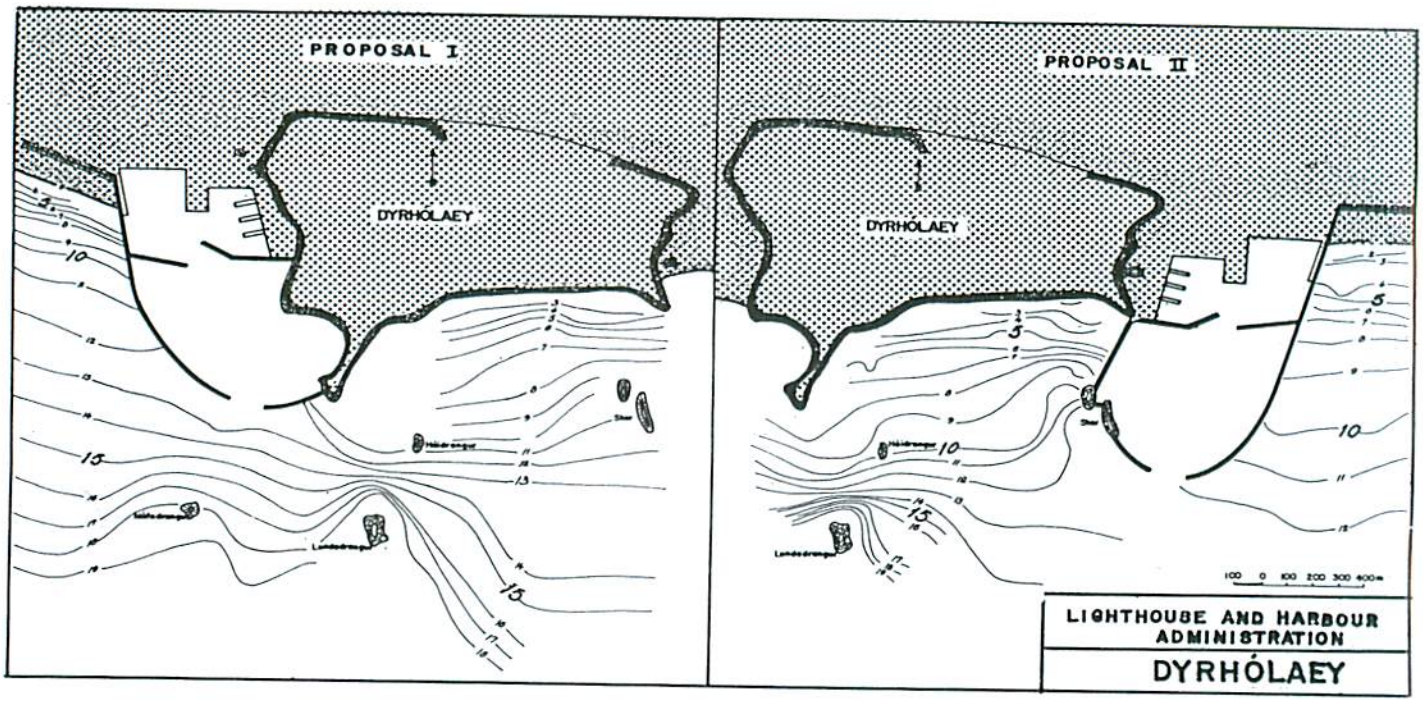
LIGHTHOUSE AND HARBOUR ADMINISTRATION
DYRHÓLAEY

but it is likely that the largest wave was almost 15 m. At the time no major storm occurred so that much larger waves can be expected. Recent research and wave forecasts made by L. Draper concluded that in the Faroe Islands, 30 - 35 m high design wave should be allowed for.

From these weather charts it can also be seen that if a low pressure system moves from the south-west at great speed, large waves from the south-east are not likely, but in winds from the south-east, large waves may be expected when the swell from the south-west combines with the waves raised by the high south-east winds, blowing almost directly across the south-westerly direction. Possibly this is the reason why fishermen complain more of the south-east waves than the relatively regular south-west swell. On the other hand, it may be expected that in south-west winds, forces exerted on the coast will be greater, since low air pressure follows the systems resulting in a high mean sea level, and also, the waves press the water on the shore, so to speak.

It is a well known fact that a wave breaks when it reaches the shore, and when the slope of the sea bottom is not too steep it has been possible to determine fairly exactly the relation between wave height and sea depth when the wave breaks. This ratio is about 0.8, so that at the depth of 10.0 m a wave 8.0 m in height will break. The breaking occurs when the wave crests travel faster than the main body of the wave due to resistance of the bottom to the movement of the water. By this a great deal of air is often entrapped and is released later with a kind of explosion during which forces become very great. A wave breaking on a ship can cause grave damage, so that it is normally not considered advisable that a ship sails through breakers, but tries to steer clear of them or avoid them in other ways.

Keeping the ratio of 0.8 in mind it was determined to set the depth of the harbour entrance at not less than 12 m at low tide or 15 - 16 m at high tide. This should ensure that waves smaller than 10 - 12 m would not break in the harbour entrance and when the waves outside the harbour are smaller entry and exit of the harbour should be possible.



Visual observations of sea conditions made at Stórhöfði and Loftsalir show that a harbour at Dyrhólaey should be clear for entry all but 6 days a year. These calculations are very inaccurate since visual observations are undependable and furthermore, other factors such as winds and limited visibility can also prevent sailings.

Sand transportation along the coast is another reason for setting the harbour entrance so deep. When a wave falls diagonally on a shore it exerts a certain force on the shore and when it breaks it throws up vast amounts of sand particles and other loose meterial. This current is called the wave current. These currents, along with the prevailing sea currents transport the thrown-up materials in one main direction. These forces decrease with increased depth and the grain size of the meterials which remain in the water becomes smaller so that at some depth only fine sand and clay is being transported. The main transport of sand and gravel, however, takes place in the areas where the wave breaks and the turbulence is greatest.

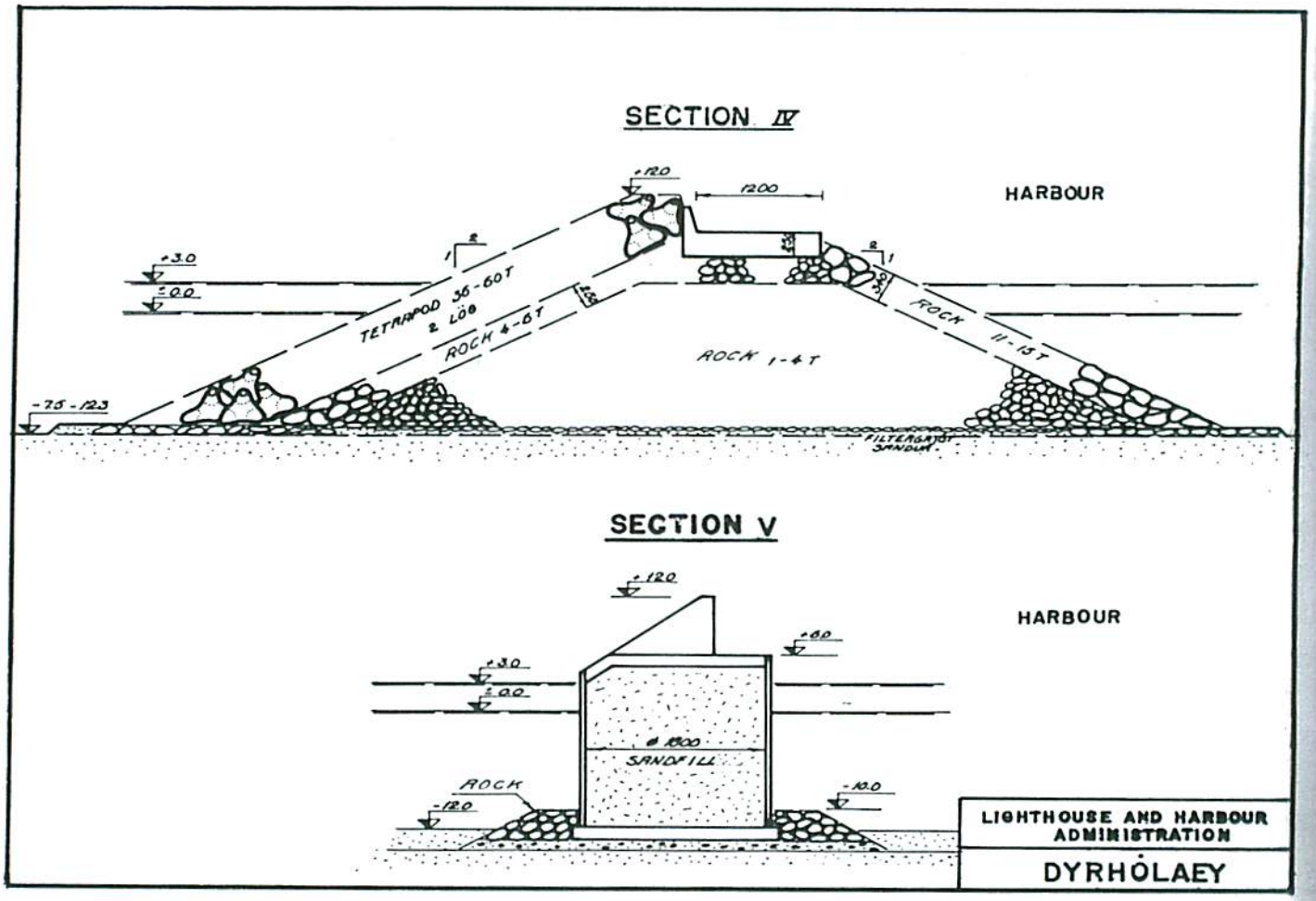
Placing the harbour entrance outside the main breaking area, ensures that relatively low amounts of heavy materials are in the sea that necessarily has to flow across the harbour entrance

and in the sea which must flow into the harbour itself. The water inside the breakwaters should be so calm that stirred up materials would settle rapidly. If the harbour entrance is in the breaking area, the danger of sand being carried into the outer harbour itself, which would make it more shallow or even close it completely, is increased many times.

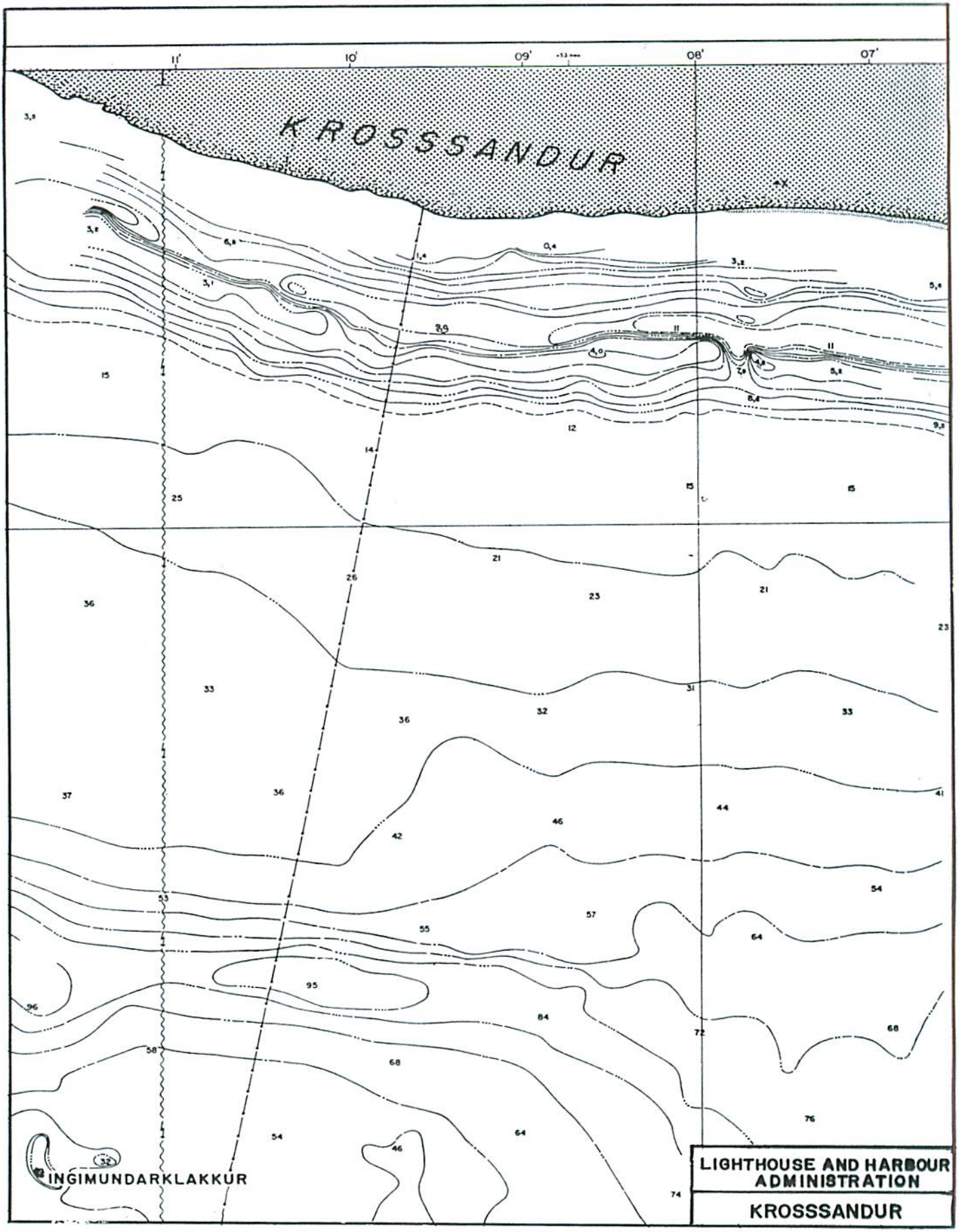
Comparatively little is known about basic sand transportation along the south coast, and exact measurements of such transportation are very difficult. However, it is known that the glacial rivers which enter the sea in this area carry with them great amounts of loose materials. It is estimated that Þjórsá carries about 3 million tons of materials in the water along with a great deal of bottom transport. Markarfljót, Jökulsá on Sólheimasandur, Klifandi and other rivers also carry vast amounts of loose materials. Professor Trausti Einarsson, in an investigation into sand transportation on the south coast, made a few years ago, concluded that the coast, from the mouth of Þjórsá river east to Dyrhólaey has not changed for a long period, perhaps up to 2500 years. According to this, all material carried by the rivers has been ground at the coast and been carried by currents into deeper waters, i.e. out on the continental shelf or over its edge. To make such grinding of materials on the coast possible, movement of the particles back and forth along it must be very great. It has become evident at Dyrhólaey, both east and west of the island that the coast is in considerable movement back and forth. This is explained by the fact that when the prevailing waves are from the west, it throws sand and gravel up on the west side of the island and the coast retires on the east side. Conversely, in easterly winds, the east side of the island fills up and the west coast retires. These movements can be tens or even hundreds of meters in a few weeks in a direction across the coast, so that even though the main coast is almost or completely unchanged, certain small changes occur during the years due to wind, waves and transport of materials with the rivers. Therefore it is to be expected that with the building of a harbour structure on the coast it will seek a new balance.

If for example a structure would reach far out from Dyrhólaey it can hardly be expected that the coast west of the harbour would

extent outwards but keep the same direction. In consequence the coast east of the island would most likely retire as it would not receive sufficient materials which it seems to get in the present state of equilibrium.



The balance on a coastline such as the south coast, involving such vast amounts of material transportation as we know exist there is very delicate, and the results of disturbing such a balance would have to be studied very carefully. In addition to the effects of waves on the shape of a harbour structures, that is to say that the size of waves determines the depth at which a navigable harbour entrance has to be made, and also the effects of waves on sand transportation as mentioned above the basic dimensions of individual parts of the structures will depend upon the ocean waves and the effects they exert on the structural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KROSSSANDUR
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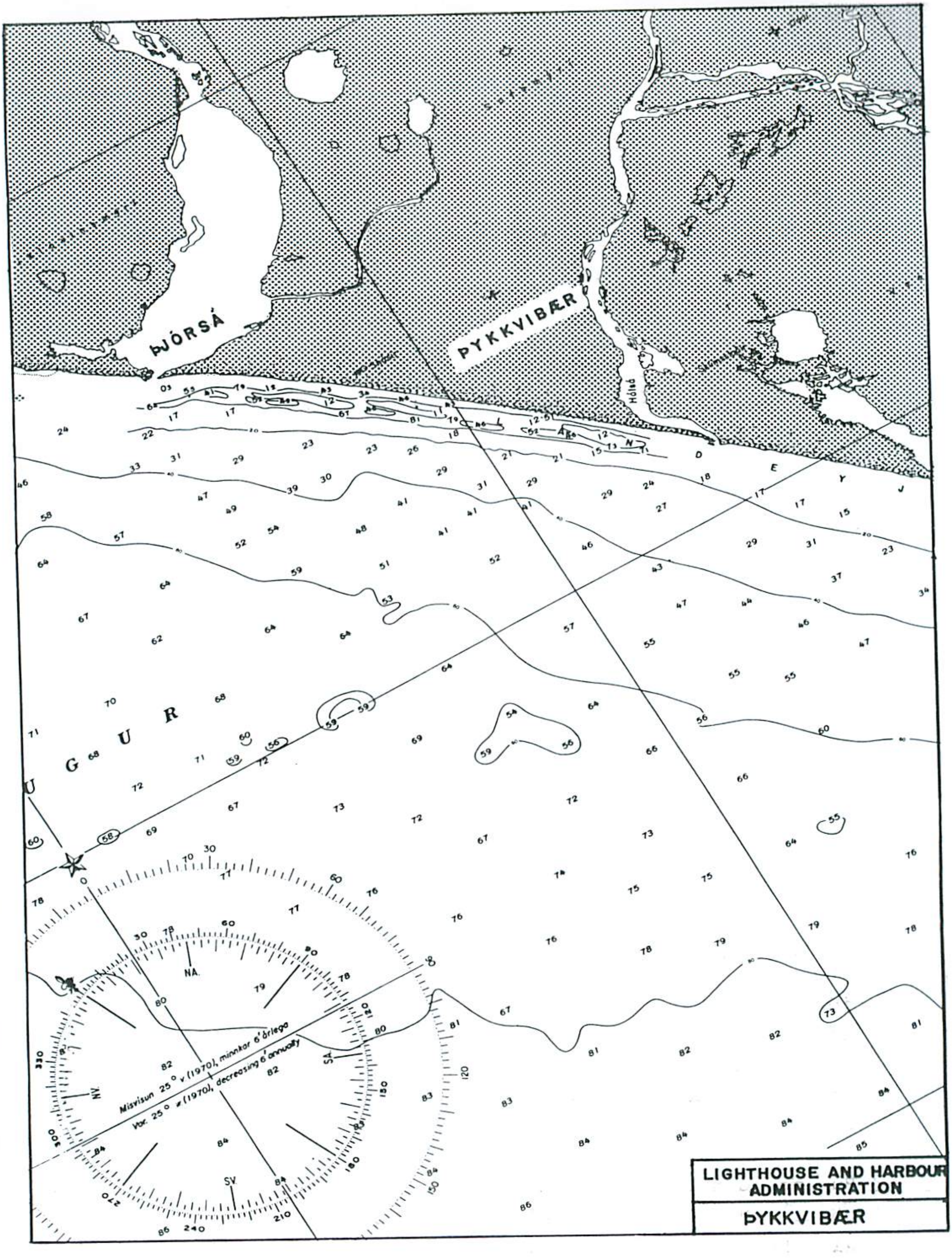
LIGHTHOUSE AND HARBOUR ADMINISTRATION
KROSSSANDUR

parts. Shown here are cross sections of an outer breakwater probably needed at Dyrhólaey. The outermost layer of the breakwaters would be of concrete blocks "Tetrapod", which will have to weigh up to 60 tons each. The size of the blocks would then decrease closer to the shore but the outermost section would consist of concrete caissons.

Cost estimates for a harbour at Dyrhólaey are understandably by no means accurate but the figure arrived at more than 2 thousand million krónur at 1972 prices, is in my opinion accurate enough to be a factor in deciding wether to build a harbour at Dyrhólaey or not.

When preparing this report, no attempt was made to arrive necessarily at the cheapest and best solution of the problems of constructing a harbour at Dyrhólaey, but only to find a probable solution which would facilitate cost estimates and point out the problems which would have to be dealt with in more detail, but which, however could form a basis for making decisions about pursuing the matter further. The next move must then be an investigation into the overall economic importance of Dyrhólaey.

If we then consider other likely locations for harbours on the south coast and begin from the east, then the location directly across from Vestmannaeyjar and close to the freshwater pumping station to Vestmannaeyjar, Krosssandur, affords certain possibilities and advantages. If Vestmannaeyjar remain uninhabitable, then this location would be the nearest possible to the destroyed community. Here the curve of the coastline is such that sand transportation is likely to be less serious than in most other locations, or possibly that due to shelter from the islands sand transportation would be from both directions, but this has not been studied. Furthermore, the fact that large rivers are not very close, not very extensive material transportation from land would lead one to expect that material transportation is minimal here. Soundings show that the distance out to 12 m depth is considerably greater than at Dyrhólaey, and if a comparable harbour is to be built then the breakwaters would have to be longer and consequently more expensive. The cost of the inner harbour would be about the same.

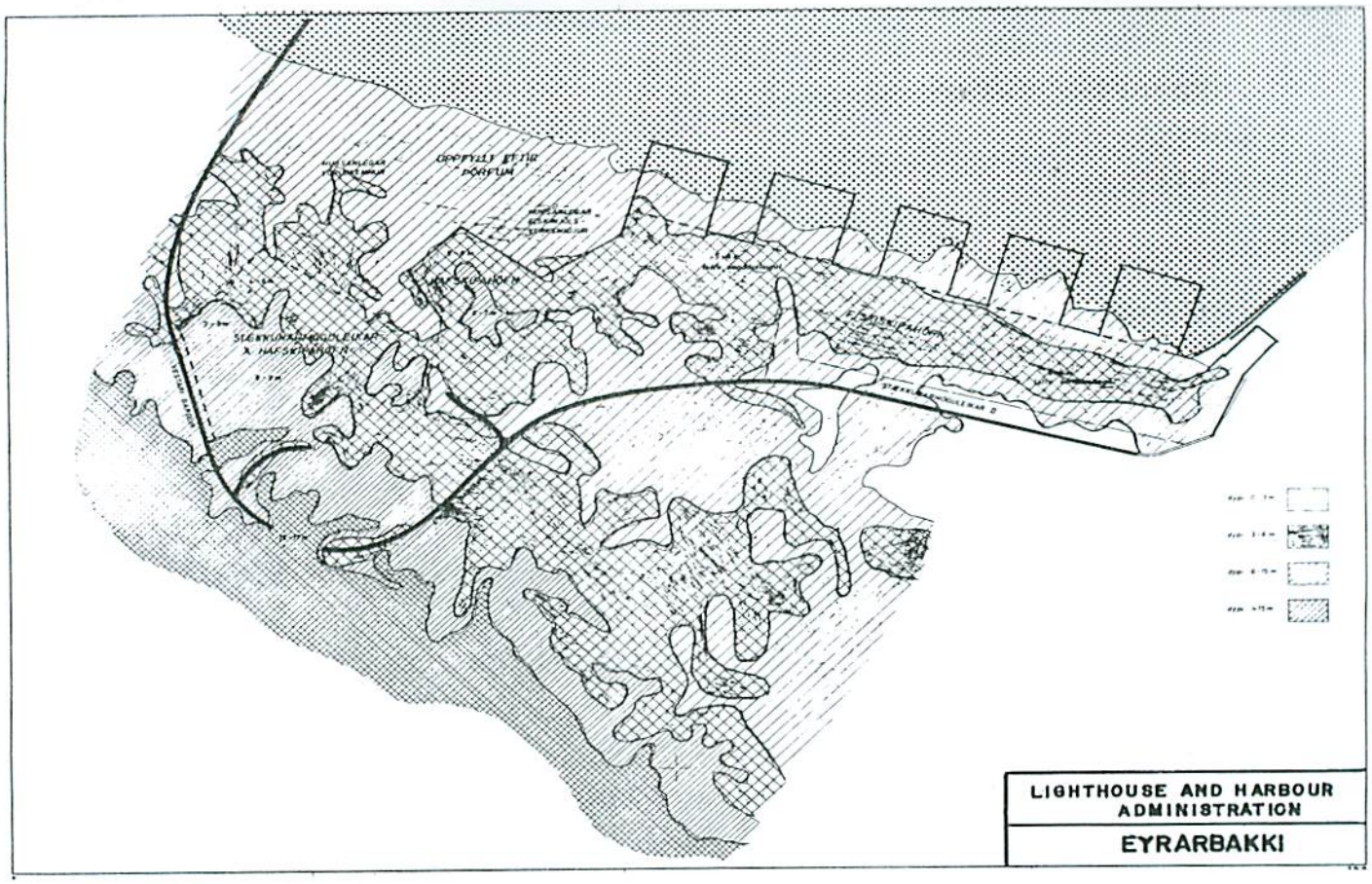

ÞJÓRSÁ
ÞYKKVIBÆR
Misvisun 25° v (1970), minnkar 6' árlega
Var. 25° w (1970), decreasing 6' annually
LIGHTHOUSE AND HARBOUR ADMINISTRATION
ÞYKKVIBÆR

Harbours at Þykkvabær and at the mouth of Þjórsá river have been suggested. At Þykkvabær, soundings show that the distance out to the depth of 12 m is even greater than at Krosssandur, and from that I cannot see that Þykkvabær has any advantages over Landeyjarsandur and Dyrhólaey. The same can be said about the mouth of Þjórsá river. There, distance out to the depth of 12 m is similar to Krosssandur, and there is also a great amount of material transportation in Þjórsá river which inevitably increases maintenance operations very extensively in a harbour close to a river mouth. It seems impossible to me to navigate the river mouth, and I cannot see any gain of having the river flow through the harbour itself, since it is known that waves become steeper when they meet a strong current, and entering such a harbour would become more difficult than if the river did not flow through it.

Common to all the locations mentioned above is the fact that here we would be dealing with harbour construction on a sandy coast with a great deal of material transportation. The cost is likely to be similar, that is, it would have to be counted in equally many thousand million krónur, but no cost estimates exist for these constructions. Therefore I assume that other factors than the actual cost of the construction would govern the choice of location, if these mentioned last were to be preferred to Dyrhólaey.

Next we come to the area of Stokkseyri, Eyrarbakki and Þorlákshöfn, where some harbour structures already exist. Until recently, it has not been possible for us who carry out harbour construction in Iceland to think in greater sums of money than millions of krónur. In the last few years this has changed so that we have been able to operate in the region of tens of million krónur in the construction of individual structures. For this reason our ideas have been restricted when considering possibilities for harbours and therefore our foresight has not been as great as it should have been. Consequently, due to limited funds, we have often considered the building of a harbour impossible in locations where harbours and often good ones, can be built.

But to do this, structures had to be large, accommodating many boats and ships, to remain on the same cost level as harbours elsewhere in the country. This applies especially to places where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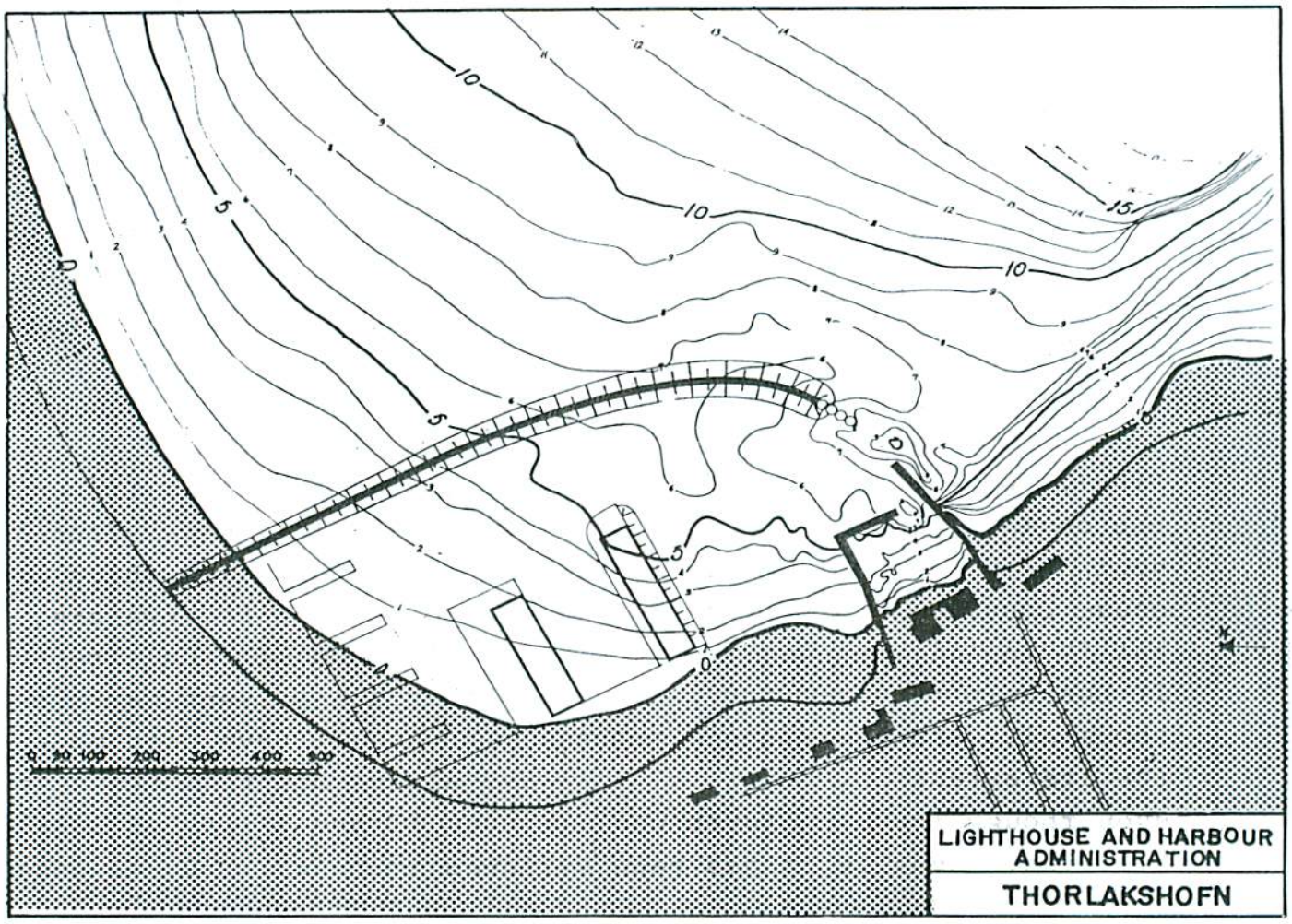
EYRARBAKKI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LIGHTHOUSE AND HARBOUR ADMINISTRATION
THORLAKSHOFN

expensive outer structures are necessary or extensive dredging has to be carried out to obtain reasonably good harbour conditions. From this viewpoint it has been maintained with some right that harbour construction in the true sense of the word was out of the question in Eyrarbakki and Stokkseyri and very difficult in Þorlákshöfn.

By getting away from these restrictions giving up thinking always how to improve each location on a small scale for as little money as possible and instead setting the problem up in this way: How can we get a good harbour, regardless of cost; this way, harbour conditions in many places will necessarily improve.

However, even if we start thinking in hundreds of million krónur, I believe it to be impossible to turn Stokkseyri into a good harbour similar in size and quality, with the same entrance and shelter conditions as the harbour at Dyrhólaey would provide.

At Eyrarbakki, on the other hand there is the possibility to construct a harbour for approx. 100 boats and eventually a few cargo ships, however, the cost would be immense. Benedikt Bogason has put forward an idea to this effect. The main difficulties with harbour construction at Eyrarbakki are that the harbour entrance would face all winds from the sea and since all dredging has to be carried out by blasting in lava, extension possibilities must be considered rather limited. No cost estimate is in existence but it is clear that both breakwaters must be built simultaneously to minimize the danger of sand transportation into the harbour area from Ölfusá.

Finally we have reached Þorlákshöfn. This location is the only one on the south coast offering some shelter from waves from the south west. Unfortunately the bay has a sandy bottom which could cause considerable problems in the foundation of breakwaters, but it facilitates construction of jetties and mooring structures. It has been realized for a long time that the present harbour is too small, and therefore a number of proposals have been made for its extension, but total cost has always had to be kept low even though the structures would hinder future extension possibilities. Usually it has been believed that 100 - 200 or possibly

300 million krónur could be provided for the operations. It seems to me that for this amount facilities for boats could be improved considerably, but cargo vessel facilities would remain more or less the same.

In connection with the harbour problems of Vestmannaeyjar, a larger harbour was being considered. The proposal shown here, however, only outlines a possibility of accommodating approx. 100 boats and two or more cargo vessels which would be safe in all wethers. The proposal has the disadvantage that entry through the harbour entrance is somewhat limited in rough seas from the south-east, when waves occasionally break in or close to the entrance. The depth is only 7 - 8 m at low tide spring. By constructing breakwaters outside the existing harbour, this drawback would be almost eliminated, but the total construction would be considerably more costly since breakwaters would be much longer, built in deeper water and would have to withstand larger waves. In both cases, as shown here, and with larger breakwaters, extension possibilities are almost unlimited on the coast to the north. No cost estimates have been made but a rough estimate seems to indicate that inner structures and dredging could cost 300 - 500 million and a breakwater about 300 million krónur. Construction could begin next year if a decision on commencing operations was made immidiately.