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Final Report

PROBABLE SIZE OF FUTURE GREAT LAKES SHIPS

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FOREWORD

This report has been prepared at the request of the U. S. Army Engineer District, Detroit, Corps of Engineers, as an aid in the determination of proper dimensions for the proposed new lock at Sault Ste. Marie. Specifically, this study is aimed at predicting the probable upper range of dimensions of Great Lakes vessels built within the next 25 years. These forecasts are made on the assumption that ship size will not be limited by the lock itself and that the nominal channel depths will remain at 27 feet.

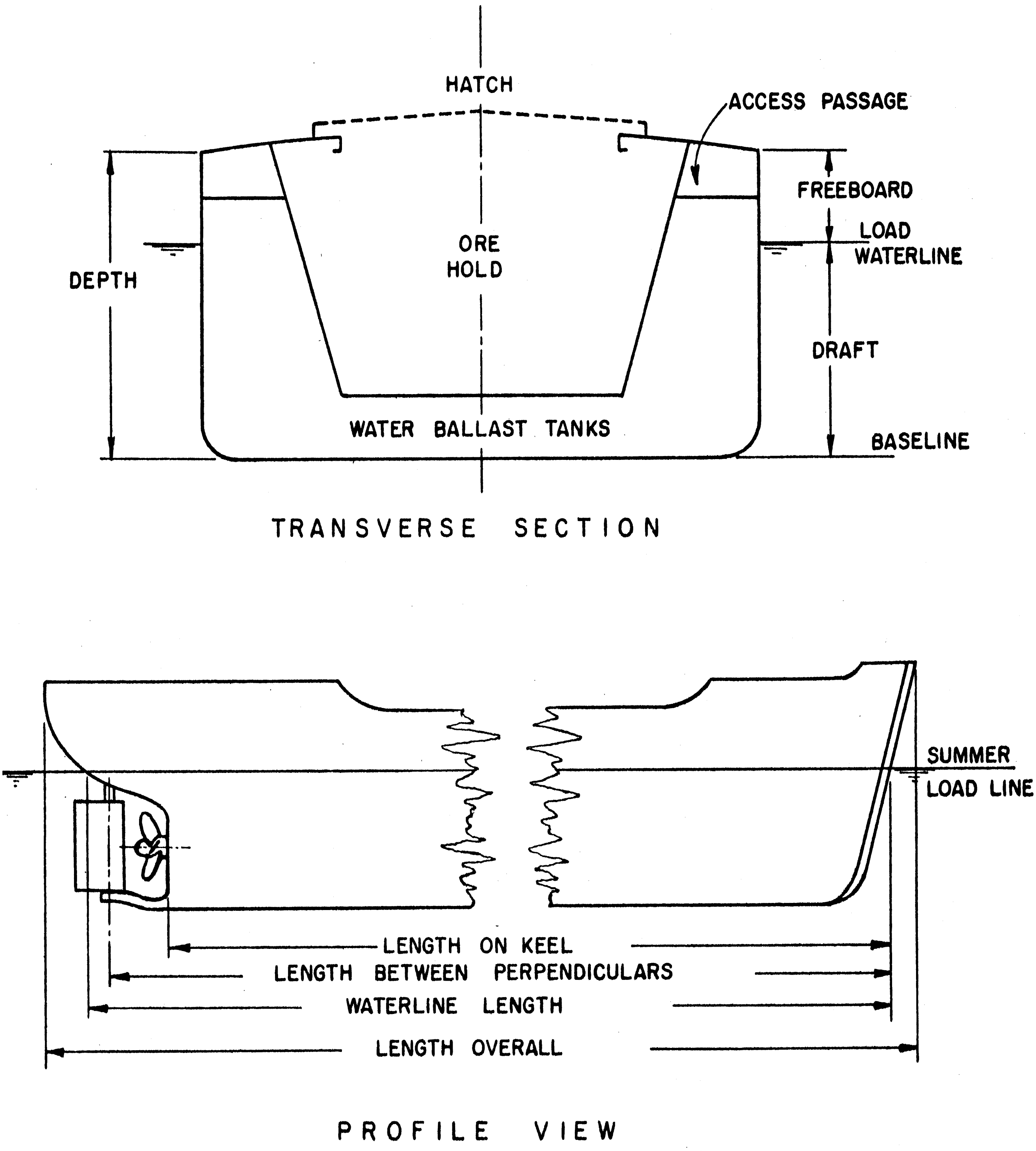

Fig. 1.

Terminology

INTRODUCTION

The economic pressures which have led to ever-increasing efficiencies of Great Lakes bulk carriers are still present today. In fact, the depletion of the high-grade ores on the United States side of Lake Superior coupled with competition from overseas ore developments have magnified these pressures. While there remain tremendous ore reserves around Lake Superior, those within the U.S. are largely of inferior quality and require benefication before shipping. Much of the foreign ore, on the other hand, is of "direct shipping grade." Further, imported ores are carried in extremely large ships, some three times as large as our present maximum-sized Great Lakes carriers. These ocean giants are extremely economical to operate, not only because of their great size, but also because their foreign registry allows low costs in construction and operation.

Throughout the years of development of bulk cargo vessels, the one area of evolution which has made the most obvious and consistent contribution to increased transport efficiency has been that of increased size. It is axiomatic that, within practical limits, the larger the ship, the lower the unit cost of construction and operation. It is for this reason that the midwest steel industry is extremely interested in any development which will allow the use of larger ore carriers on the Great Lakes.

If we assume that the new lock at the Soo will be of ample size, then the problem of predicting future ship dimensions will hinge on one of two points. (1) Since draft is definitely limited, reasonable proportions will set upper limits on the overall dimensions of the ship. (Ships of extreme proportions become uneconomical largely because of excessive structural weight.) On the other hand, it is quite possible that, before such excessive dimensions are reached, the vessel will have already been restricted by (2) availability of shoreside cargo gear and/or shipyard facilities able to handle ships of extreme size.

It seems safe to predict that, once the present lock restrictions are removed, there will be a rapid increase in ore-carriers' beams. A more gradual but nevertheless steady growth in length is also to be expected. Most Great Lakes shipyards would require major revisions before they could handle larger ships, and the companies are understandably reluctant to make the large expenditures involved. However, any real demand by the shipowners will have to be met by any of the major yards that wish to remain competitive. They will perhaps be encouraged in this by the realization that bidding on these larger ships will be confined to yards on the Great Lakes. A temporary plateau of growth will be reached when any further increase would require major alterations to an appreciable number of shoreside cargo-handling installations. The new lock should certainly be made large enough to accommodate those ships which attain the abovementioned "plateau."

Another spurt in growth can be expected when major changes have been made in dock facilities. It is difficult to predict when this will occur, but its possibility should not be overlooked when assigning dimensions to the new lock. Once this development is effected, ship size will be limited only by available channel depths. Draft will be limited and maximum size will be governed by proportions alone.

GENERAL REQUIREMENTS

Before setting out to predict the characteristics of future Great Lakes ships, it is important that we try to establish exactly what we shall be aiming at in their design.

We are not concerned here with the continuing need for relatively small ships capable of servicing existing steel plants located on such confining rivers as the Cuyahoga. Rather, we must look ahead to the extremely large ships of the future which will keep the midwest steel industry competitive. Such ships may be few in number and restricted in ports of call, and yet their importance to the local economy will be great. It is plain that economic pressures will force a continued growth in lake carrier dimensions despite the fact that shore facilities are already frequently extended to their limits. Numerous conferences with ship owners have convinced the writer that cargo-handling facilities, both ashore and on board, can and will be arranged to allow further enlargement of Great Lakes freighters.

Concerning future trade requirements, most authorities feel that the biggest commodity will continue to be iron ore with an ever-increasing percentage of it beneficated before shipment. Much of this beneficated ore will be in the form of pellets which make self-unloading more attractive. There will be a strong demand for extremely large ships to handle this beneficated ore. Such ships will in all probability be designed for this specific commodity alone. In the past, ore carriers have been provided with oversized cargo holds to accommodate an occasional return load of coal or to provide winter grain storage. With the removal of such requirements, the naval architect is free to effect changes in design which will allow present shoreside cargo gear to load and unload deeper and wider ships than are now considered possible. Furthermore, most owners have relaxed their former insistence on the ability of their ships to turn around in certain harbors. They are now convinced that the extra tug fees and awkwardness involved in leaving a berth stern-first are more than paid for by the money-earning advantages of added length.

It has been brought forth as a possibility that future technical and economic developments may reverse the present direction of trade on the Lakes. That is, we may find coal and limestone being carried to steel mills on Lake Superior. Such an upheaval would require new loading and unloading plants and this development would thereby hasten the trend towards larger ships.

EXISTING SHORESIDE CARGO GEAR

Reference 1 shows average dimensions of existing ore loading docks (of the hopper type) as well as of Hulett unloaders. These characteristics have long been used as bases for the establishment of upper limits on beam and depth. (The maximum hull depth suitable for present hopper type loading docks is usually taken between 40 and 42 feet. These limits are set by the remaining freeboard when the ship is completely ballasted. By decreasing the ore hold volume, ballast capacity is thereby increased and additional depth becomes feasible. Calculations show that a ship with a 44-foot depth could fit below the loading docks with water level 18 inches above datum and still have 24 inches to spare. Some spare clearance is required to allow for trimming fore and aft.) However, there is a growing feeling that we must reconsider whether these old facilities should continue to tie our hands. New belt-type loading rigs, such as those at Sterling Harbor and Taconite Harbor, have considerably surpassed these old upper limits. Furthermore, it is at least technically possible to raise one or more of the old hopper-type docks so as to accommodate wider and/or deeper ships. Limitations set by the unloading rigs are in a way less inflexible in that their mechanical parts wear out more rapidly than in the case of the relatively simple loading docks, and so replacement or enlargement is not as onerous. Older clam shell rigs can be enlarged without too much difficulty and any future ore docks will probably be serviced by similar gear of great height and outreach. Self-unloaders, of course, solve this part of the problem automatically.

It is possible that future ships may be so large that their cargo capacity will be greater than any single receiving port can readily accommodate. In such cases, it would not be impractical to split the cargo between various ports.

TEMPORARY CARGO-HANDLING EXPEDIENTS

If the owner sees the need for a vessel which is too big for existing shoreside gear, he can adapt the ship to these restrictions by the use of one or more expedients. Several of these are noted below:

(1) If the beam is too large for loading-docks, he can partially load, then turn the ship around and complete loading from the other side.

(2) As an alternative to the above, he can equip his ship with one or more devices for collecting the ore from the chute and spreading it athwartships. This could be quite readily accomplished by means of an endless belt carried on a framework which moves fore and aft on the hatch crane track. At least one such rig has already been fitted on an ocean ship.

(3) Where the beam is too large for unloading-gear, he may again turn the ship around, or:
(4) It is already the practice on at least one ship to let the bulldozers move the outboard few feet of ore over to where the unloaders can reach it. This is reported to be entirely practical and the owner sees no reason why it could not be done on a larger scale.

SHIPYARD FACILITIES

A survey of existing Great Lakes shipways and drydocks indicates the following:

(1) One shipyard has already quoted a price on a 900-foot-by-100-foot vessel and made plans for providing a drydock to handle such a ship.
(2) Another yard claims the ability to build a 1200-foot-by-95-foot vessel.
(3) The largest existing drydock on the Lakes can handle a vessel up to 750 feet long (overall) and 90 feet wide. This is a floating dock and could be readily lengthened by the addition of one or more sections.
(4) Where shipways are too short, a hull can be built in two sections and later joined in drydock.

CHANNEL DEPTHS AND DRAFT

It is commonly agreed that, when the present dredging program is completed, we can expect no further general deepening within the foreseeable future. The 27-foot channel depths now in process of attainment are believed to have reached the maximum practical limit. The allowable draft, based on low water datum will be 25.5 feet. It must be kept in mind, however, that lake levels fluctuate and greater drafts are frequently permissible. Recent figures supplied by the Corps of Engineers indicate that the allowable mid-summer (May 16-September 15) drafts are greater than 25.5 feet 81% of the time, greater than 26.0 feet 58% of the time, greater than 26.5 feet 27% of the time and greater than 27.0 feet 4% of the time. This indicates that future lake carriers should be designed around drafts of at least 26.0 feet. To carry the maximum possible payload throughout the sailing season, it is advisable to provide enough depth so that the maximum probable draft (say 26.0 or 26.5 feet) will be attainable with winter freeboard. In vessels of length over 550 feet, the winter freeboard will be 2.3 to 2.4 feet greater than summer freeboard.

The concept of designing around a draft somewhat greater than actually expected has been shown to be economically sound in ocean-going ore-carriers and tankers.[2,3] There is no reason to doubt that this principle would hold true in the case of vessels plying the Great Lakes.

PROPORTIONS

Figure 2 shows the proportions of about 75 Great Lakes ore-carriers of individual design. It can be seen that there is a well-defined relationship between draft and depth. ("Depth" refers here to hull depth, not channel depth.) This consistency can be explained by the fact that naval architects have always sought minimum freeboard to save steel weight and hence increase payload capacity. Such variation as does exist is largely explained by the influence of length on the allowable freeboard.[4]

Future Great Lakes ore-carrier designs may depart from the minimum freeboard concept and depth should tend to increase faster than draft. As can be seen in Fig. 2, vessels designed for 26.5-foot winter draft should probably incorporate excess freeboard in lengths above 800 feet.

As depth is increased, the problem of fitting the ship beneath the ore dock becomes more acute and when the ultimate depth is attained, the water ballast capacity will of necessity equal the ore capacity.

The relationship of length to depth (L/D ratio) has considerable bearing on hull girder strength and rigidity characteristics. Any designer contemplating a ratio in excess of 21 can expect discouragement from the classification societies and other authorities, who generally favor 18 or 19 as an upper limit. There are no explicit rules on this, however, and at least a few qualified naval architects argue that greater ratios may prove feasible. Strength can be provided by adding steel, and limberness of itself is not necessarily dangerous. It is further argued that since Great Lakes waves have definite length limitations (Reference 5 places this at 350 feet), vessels of greater size should never be poised upon a wave of their own length. Under these circumstances, extra length is not likely to affect the strength requirements of Great Lakes ships in the same manner that it does ocean vessels. The latter must expect sooner or later to meet waves of their own lengths and so undergo the maximum possible bending loads. In this connection it is interesting to note in Fig. 2 that the apparent trend of Great Lakes ships shows the 350-foot vessel having a L/D ratio of 14.0, which is identical with the upper limit of salt water ore-carriers. And to suggest an absolute upper limit on this ratio, a value of 30 is acceptable in tank barges confined to rivers and canals. In short, it seems reasonable to expect that current trends will result in gradually increasing allowable ratios of length to depth, particularly as ships continue to grow in size. A value of 22 might not seem unreasonable for a 900-foot ship.

Of the remaining proportions, the only one of any particular significance

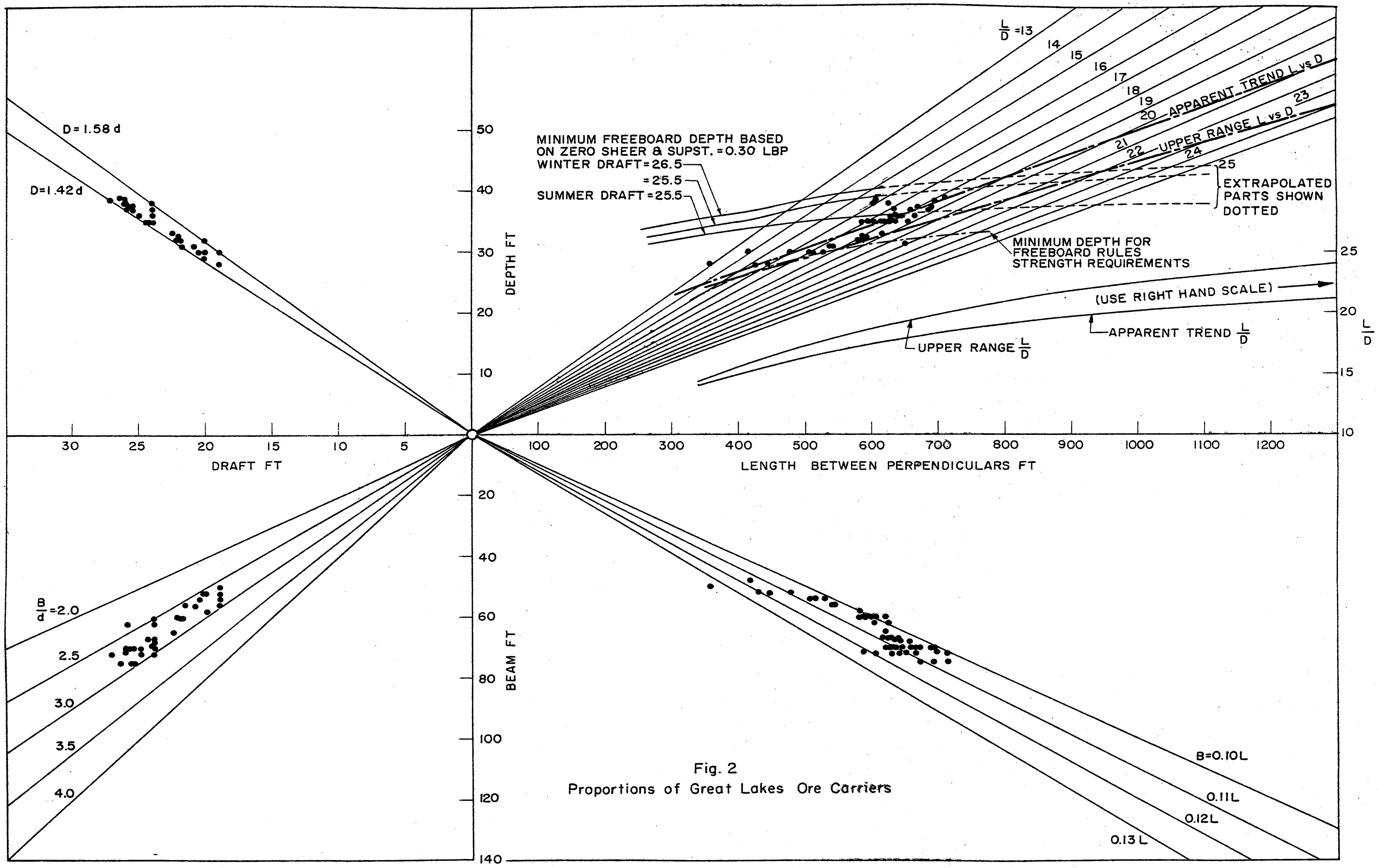

Fig. 2
Proportions of Great Lakes Ore Carriers

is the relationship of beam to draft. For purposes of making the ship comfortable in waves, this ratio should probably not exceed 2 or 2.5. However, the relative infrequency of heavy weather on the Lakes combined with the economic advantages of greater beam make higher ratios attractive. Further, if ore-carriers of the future are designed to carry ore alone, their holds can be arranged so as to raise the center of gravity. This will so reduce the excess stability that undesirable rolling characteristics may be appreciably diminished.

CONCLUSIONS AND RECOMMENDATIONS

Once the present Soo Lock restrictions are removed, and one or more shipyards take the initiative to provide enlarged facilities, it is predicted that ore-carrier size will steadily increase to the following dimensions:

Length between perpendiculars, feet	970
Beam, feet	100
Depth, feet	44

A ship of such proportions could be handled by existing waterfront cargo gear with moderate assistance from athwartship cargo spreaders in loading, and bulldozers in unloading. Careful attention to ballasting arrangements would be required and a midship deep tank might be called for to fit such a vessel under the shoreside gear. It is the writer's recommendation that the above figures be considered as minimum in establishing the size of the new lock.

As regards upper limits, these would, in the final analysis, be set by the draft limitation about as follows:

Length between perpendiculars, feet	1070
Beam, feet	130
Depth, feet	48

Such dimensions would presuppose considerable investment in new cargo-handling gear as well as in shipways and drydocks. It is unfortunate that time does not permit a complete economic study of this problem. The above figures are based on the writer's judgment as to the maximum practical (hence most economical) proportions governed by channel depth limitations.

A vessel of this size would displace between 80,000 and 90,000 long tons and would be as large as could be considered acceptable for single-screw propulsion.

It is recommended that the above figures be considered maximum in establishing the size of the new lock.

Finally, it is recommended that the more confining bends in the various channels be straightened out by dredging as required to provide safe negotiation by vessels of the size noted above.

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