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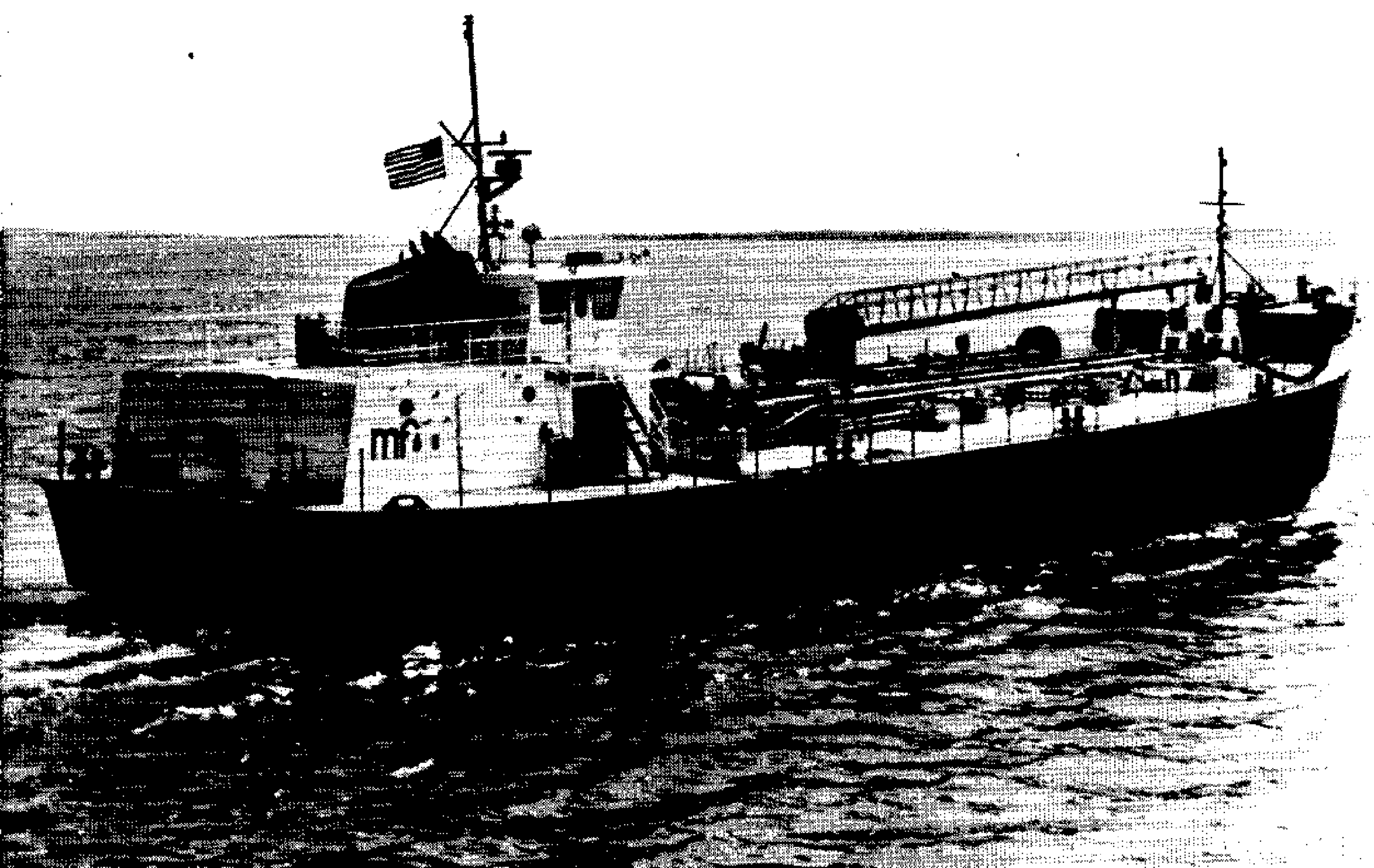
MICHIGAN SEA GRANT PROGRAM

PETROLEUM TRANSPORT ON THE GREAT LAKES

ROBERT M. SCHER



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PETROLEUM TRANSPORT
ON THE
GREAT LAKES

Michigan Sea Grant Report

MICHU-SG-79-213

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November 1979

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INTRODUCTION

It would be difficult to imagine a geographical area in which the balance between economic necessity and environmental protection is more delicate or complex than that of the Great Lakes region. The economy of the region is intimately bound to the lakes: for water supply, recreation and tourism, fisheries, and not least, for transportation of the resources and products of some of the most important industrial centers of the nation. Thus, the use of the lakes has always been characterized by some degree of conflict between competing interests and apparently irreconcilable goals.

Nowhere have the lines of conflict been more sharply drawn than in the transport of hazardous substances, including large shipments of petroleum, on the waters of the Great Lakes. The risks associated with petroleum transport are evident, certainly in a qualitative sense, from recent and bitter experience on the world's oceans.

No technological history of the 20th century would be complete without some mention of the groundings of the Torrey Canyon, the Argo Merchant, and the Amoco Cadiz. While the world's attention has naturally turned to such catastrophic spills, terrible as they are, the resulting focus of public opinion has led to governmental and international action to reduce the probability and severity of spills from large tankers. This, at least, is a positive repercussion of disaster: we can learn from our mistakes or our mischances.

There is another, less hopeful, side effect, however. As attention centers, justifiably enough, on the special problems of massive oil spills and of larger tankers, we tend to forget that there is a tremendous potential for environmental violence even in a "modest" spill of 100,000 gallons or so, literally a drop in the bucket beside the Amoco Cadiz loss of 240,000 tons.

The consequences of a given volume of oil discharge on the Great Lakes can be expected to differ from those in ocean coastal areas, and probably to be more serious and long-lasting, for the following reasons:

1. The total water mass (and biomass) of the Great Lakes is an insignificantly small fraction of the ocean's.

2. The limited extent of the lakes does not permit any sizable discharge to disperse "innocuously" in the open lake; it will almost certainly end up ashore.

3. The absence of tidal water exchange does not permit the lakes to unburden themselves in the same way as the coastal ecosystem. As a result, a healthy ecology cannot readily be restored from adjacent environments.

For these reasons, it is particularly important in the context of the Great Lakes to protect the environment from petroleum discharge.

It is tempting to regard the lakes as an ocean in miniature, complete with its own petroleum trade, tanker fleet, and ports. It would be somewhat misleading to do so, however. Firstly, the ships themselves, though dwarfed in absolute terms by comparison with new generations of ocean tankers, are far larger in relation to their environment. They are never far from land, by ocean standards; they spend a far greater percentage of their working lives in restricted waters, and in heavy traffic. Port calls and cargo handling operations are more frequent. Secondly, the lakes, although specialized, are not closed. Since the opening of the St. Lawrence Seaway, a portion of the Great Lakes petroleum tonnage has been carried in tankers designed and built for general ocean and coastal service. In spite of the size limitation imposed by the Seaway locks, many of these ocean tankers are substantially larger than the specialized intralake vessels presently operating. For this and other reasons, they are generally less suitable for the specialized conditions of the lakes, in terms of maneuvering capabilities and spill-prevention equipment. Thirdly, a large fraction of Great Lakes petroleum tonnage is carried in barges, while the barges themselves are very nearly as large as the self-propelled tankers in the Great Lakes fleet. This is not true of the ocean petroleum trades.

The purpose of this report is to present an introduction to the Great Lakes petroleum trade, its development, its geographic distribution, and the vessels serving it. Forecasts of the future of this trade are presented, subject to the current uncertainties of any projection related to petroleum. Finally, the recent safety record of Great Lakes petroleum transport is assessed, and compared with the larger experience of the world tanker fleet.

WATERBORNE PETROLEUM TRAFFIC ON THE GREAT LAKES: PETROLEUM PRODUCTS

History and Geography

As shown in Fig. 1, waterborne shipments of petroleum products in the Great Lakes trade represent a stable or slightly declining share of the regional energy transport requirement. Apart from a few unusual fluctuations, the total annual tonnage of petroleum products carried by the combined U.S. and Canadian tank fleet on the lakes has been surprisingly constant over the twenty-year period 1958-1977. During that same period, the total population of the six-state region (Illinois, Indiana, Michigan, Ohio, Wisconsin, and Minnesota) increased by about 16%, while total energy consumption in the region increased at a slightly higher rate.

In part, the absence of corresponding growth in the marine shipment of petroleum in the Great Lakes region might be explicable in terms of larger economic forces. For example, the region's relatively modest growth in manufacturing employment with respect to other regions, the long-term migration of industrial concentration from the Great Lakes states into the South and Southwest, and the consequent shift of energy demand from the industrial sector to lighter commercial and residential consumers, might be invoked as a partial explanation (Ref. 1). However, the extent to which this and other demographic trends may have influenced the current pattern of petroleum products distribution on the Great Lakes is beyond the scope of this report.

On the supply side of the equation, it might be supposed that the long-term constancy of the marine tonnage of petroleum products

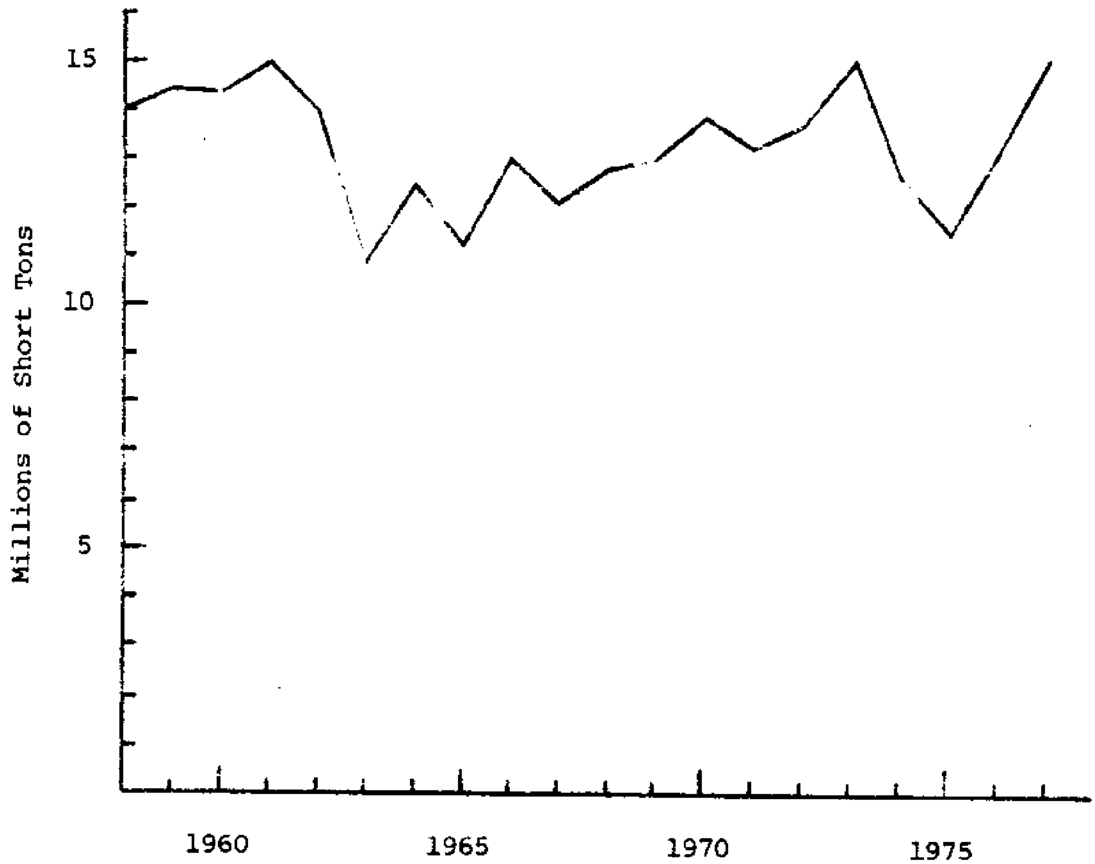

Figure 1. Total U. S. and Canadian shipments and receipts of petroleum products on the Great Lakes, 1958-1977.

Source: Annual Report of the Lake Carriers Association.

reflects a decline in the relative importance of petroleum in the regional energy supply. For the period in question, however, the available data suggests that this has not been the case: the petroleum share of the total energy supply of the region has in fact increased over most of the period. In recent years, shipments of western coal have begun to play a new and significant role in the electric utility sector in the Great Lakes region, and given a favorable policy environment this trend will continue and expand (Ref. 2). Even more topically, recent uncertainties in supplies and prices of petroleum fuels (most notably gasoline and diesel fuel) cast some doubt on the future development of the energy markets. Certainly, any long-term forecasts regarding the relative importance of various grades of fuels in the various consumption sectors would be perilous. However, in view of the present lack of technologically and economically feasible alternatives, and the time necessary to obtain such alternatives, it seems undeniable that petroleum fuels will continue to be essential in some industrial applications, as well as in the majority of transportation uses, for some years.

The single most significant factor that has limited the growth of the marine petroleum trade on the Great Lakes appears to be the geographic structure of the trade itself, and especially the competitive situation of the marine mode with respect to pipeline, rail, and highway movement. The geography of the region is such that the majority of industrial and population centers are directly accessible to the overland modes from most of the regionally important refineries. These major concentrations in the petroleum product market, including centers of heavy industry and electric power generation, are naturally susceptible to product pipeline service, due to the relatively high volume and reasonably consistent demand. Smaller, outlying centers of energy consumption, as well as intermediate nodes in the product distribution network, can often be served by the marine mode, if only in part.

In the regional growth process typical of the early and middle 1950's, many smaller communities remained relatively stable in both population and energy demand, as the larger industrial cities expanded. More recently, a shift of manufacturing employment from larger to smaller communities has effected some decentralization of regional energy demand (Ref. 1). In spite of this apparent reversal of effects, the over-all change in the geography of the petroleum product distribution system has been consistent. Initially, the increased concentration of population and industry encouraged an expansion of the product pipeline system; much of the local distribution to the "new" industrial communities is firmly established as pipeline, rail, or over-the-road tonnage, depending on local demand volume.

The marine mode, in essence, serves as an adjunct to the pipeline network, and as an intermediate segment of the distribution system. In many cases, the competitive position of the marine mode is "sandwiched" between the pipe and the highway. Together with the complete insusceptibility of many inland commodity moves, the structure of the petroleum trade is such that the waterborne share has been characterized by limited growth.

Nevertheless, the marine mode continues to fulfill several important functions:

1. Providing a low-cost alternative for the distribution of

petroleum products from the pipehead to communities, industries, and transshipment nodes whose tonnages are too small to justify pipeline extension (or rail improvement), and too large to be served efficiently over the road.

2. Serving local movements of petroleum products in and around ports and harbors, including bunkering operations.

3. Providing a flexible transport capacity that can augment pipeline flows during periods of high demand.

4. Serving "spot" movements of commodities which, for institutional, scheduling, or geographic reasons, cannot be put into a pipe.

Tables I, II, and III record U.S. shipments and receipts of three broad categories of petroleum products, on the Great Lakes, for the years 1971-1976. Within each commodity, tonnages are disaggregated by type of movement, as follows:

Import/Export:	Including Canadian and overseas movements, of which the latter is a very small portion, for petroleum products.
Coastwise:	Domestic traffic which includes ocean carriage.
Lakewise:	Including all domestic traffic between lake ports, whether or not inland waterways are involved in the movement.
Local:	Movements of freight within a port or harbor, including bunkering.

The data shows the following general trends regarding the movement of petroleum products on the lakes:

1. Total shipments of the lighter refined products (gasoline,

Table I. Total shipments of petroleum products through U. S. ports of the Great Lakes: gasoline, jet fuel, and kerosene. (Short tons.)

	Total	Import Export	Coast	Lake	Local
1971	3344980	6030	988	3071409	266553
1972	2843313	6642	6721	2682889	147061
1973	2765033	15657	19910	2606756	122710
1974	2098279	57	4125	1977362	116735
1975	2044873	157211	7078	1799588	80996
1976	1823130	59084	7018	1740070	16958

Source: Waterborne Commerce of the United States.

Table II. Total shipments of petroleum products through U. S. ports of the Great Lakes: distillate fuel oil. (Short tons.)

	Total	Import Export	Coast	Lake	Local
1971	3002239	115754		2391327	494058
1972	3184471	119681		2363678	701112
1973	2654298	50670		2046716	556912
1974	2638660	151817		1758143	728700
1975	2522421	596146		1570178	356097
1976	2731499	633511		1768080	329908

Source: Waterborne Commerce of the United States.

Table III. Total shipments of petroleum products through U. S. ports of the Great Lakes: residual fuel oil. (Short tons.)

	Total	Import Export	Coast	Lake	Local
1971	2627769	535015		1341676	751078
1972	3196379	823912		1583973	788494
1973	3598481	1454287	17025	1448138	679031
1974	3085893	934946		1505571	645376
1975	2877902	734663		1497316	645923
1976	3437606	888235		1753576	795795

Source: Waterborne Commerce of the United States.

jet fuel, and kerosene) have declined by 45% over the six-year period. While the most drastic annual decrease occurred at the time of the '73-'74 "crisis," the decline was already established in prior years, and has continued since. The impact of the 1979 disruptions will be watched with some interest. The most important elements in this steady decrease have been the losses of lakewise and, even more notably, of local tonnage, presumably due to shifts to the land modes rather than to such marked declines in the available market.

2. Total tonnage of distillate fuel oil has remained relatively stable, although showing a slight downward trend. Decreases in lakewise and local domestic traffic have been largely counterbalanced by receipts of Canadian imports.

3. Marine shipments of residual fuel oil have increased, with greater domestic lakewise and import/export tonnages available. Local movements have remained quite steady over the period.

Figure 2 indicates a comparison of the relative magnitudes of the various product categories for the years 1971 and 1976, while Fig.3 shows a similar comparison on the basis of movement type for the same two years. The implication of these figures is that the recent trends are toward the use of the marine mode for somewhat larger consignment sizes, and for somewhat longer trips than in the past. Particularly for local moves of the more highly refined products, the waterborne mode appears to be relinquishing some of its former tonnage to overland systems. Bunkering of merchant ships continues to support the local movement of residual fuels, and to a lesser extent, blends and distillate fuel oils.

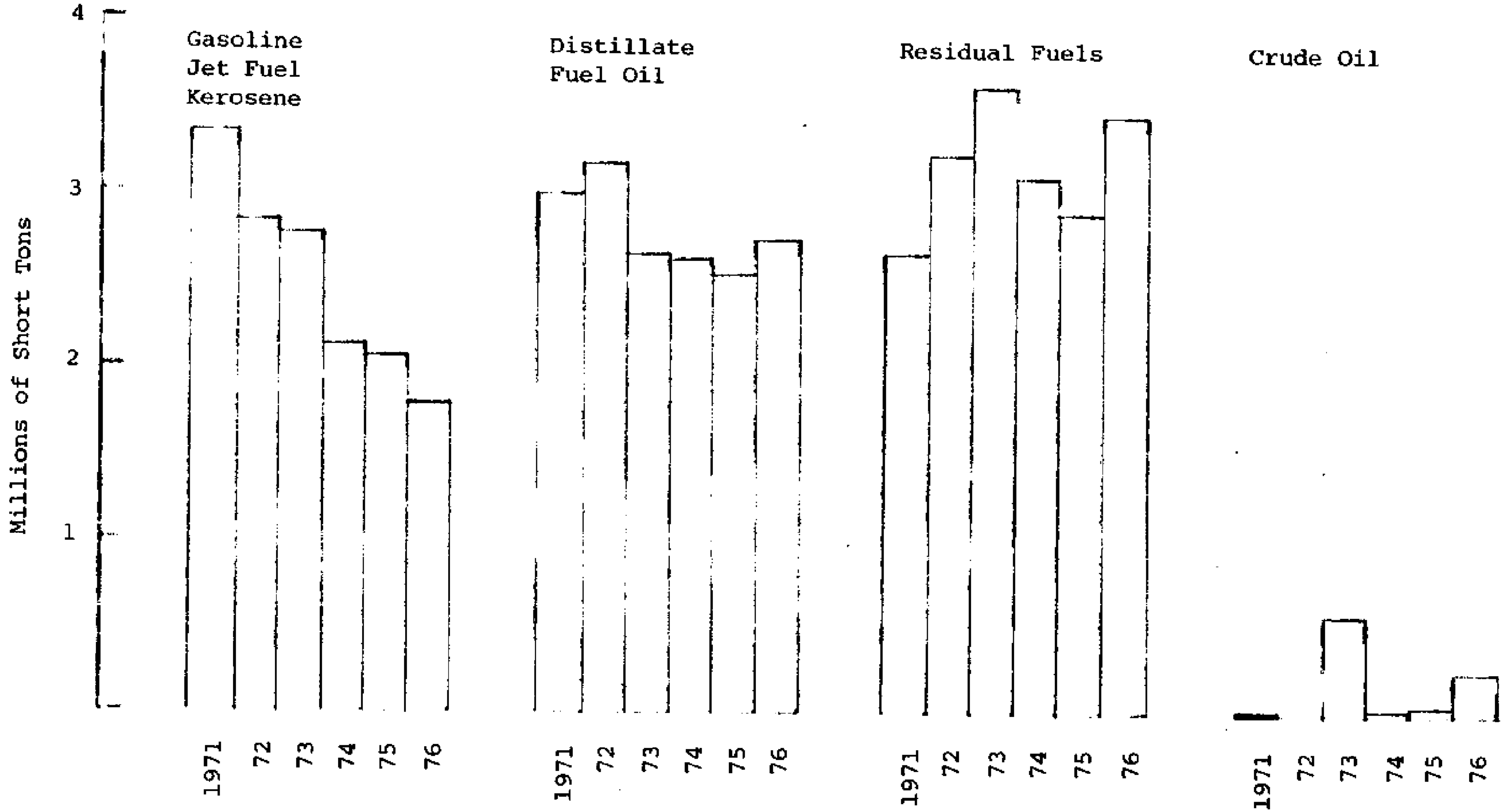

Figure 2. U. S. shipments and receipts of petroleum products and crude oil, 1971-1976.

Source: Waterborne Commerce of the United States.

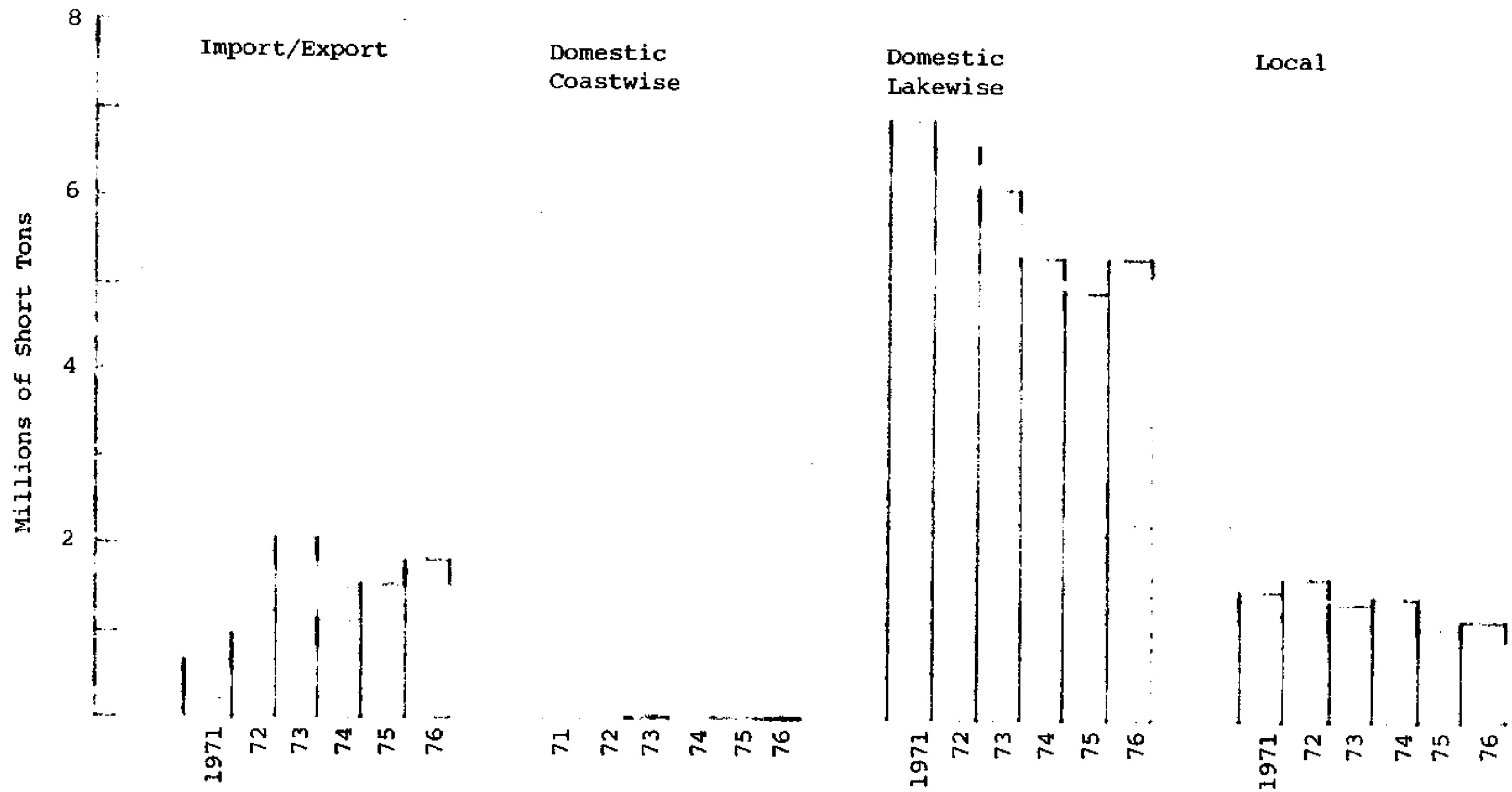

Figure 3. U. S. shipments and receipts of petroleum products and crude oil, by type of move.

Source: Waterborne Commerce of the United States, The geographic distribution of petroleum movements on the Great Lakes, involving shipments and receipts at U.S. ports only, is shown in Tables IV-VI for the year 1976, disaggregated by product category and type of movement, including direction. The largest center of product distribution is Indiana Harbor, Ind., which accounted for a major share of all U.S. petroleum product shipments in 1976: 77% of gasoline and other light products, 72% of distillate fuel oils, and nearly 50% of residual fuels. Other major shipping ports included Chicago, Toledo, and Buffalo. This pattern of distribution is quite typical. The annual tonnages for some of the minor ports are very small: they represent marginal markets for the marine mode.

Certain types of petroleum products, representing a small fraction of the total tonnage, were excluded from further consideration in this study. These products, together with their 1976 total Great Lakes tonnages, were as follows:

Lubricating oils and greases	104,436
Naphtha and other petroleum solvents	10,752
Asphalt, tar, and pitch	276,335
Petroleum coke	135,970
Liquified gases	1,766
Asphalt building materials	658
Miscellaneous products	7,865
Total tonnage	537,782

This excluded tonnage amounted to just over 6% of all products carried in the petroleum trade in 1976.

Table IV. Distribution of petroleum products at U. S. ports of the Great Lakes, 1976.

Gasoline, jet fuel, and kerosene. (Short tons.)

		Overseas		Canadian		Domestic		
	Total	Import	Export	Import	Export	Receipt	Shipment	Local
Duluth-Superior	50495						50495	
Presque Isle, MI	16703					16703		
Bayfield, WI	334					334		
LaPointe, WI	334						334	
Gladstone, MI	117368					117368		
Green Bay, WI	6967					6188	779	
Kewaunee, WI	158					158		
Port Washington, WI	123719					123719		
Milwaukee, WI	244797		94	345		244358		
Port of Chicago	528265			38295		319583	153433	16958
Indiana Harbor	1396478						1396478	
Detroit Harbor, WI	779					779		
Racine, WI	19247					19247		
Sturgeon Bay, WI	16963					16963		
Escanaba, MI	137294					137294		
Traverse City, MI	217967					217967		
Frankfort, MI	158						158	
Grand Haven, MI	60448					60448		
Alpena, MI	8030					8030		
Saginaw River, MI	96461					73431	23030	
Port of Detroit	68489						68489	
Toledo, OH	96893			20350			76543	
Charlevoix, MI	556					556		
Cheboygan, MI	92858					92858		

(Continued)

Table IV. (Continued.)

	Total	Overseas Import	Overseas Export	Canadian Import	Canadian Export	Domestic Receipt	Domestic Shipment	Domestic Local
Harrisville, MI	23030					23030		
Kelly's Island, OH	640					640		
Leland, MI	24					24		
Mackinaw City, MI	68959					68959		
Port Clinton, OH	279					279		
Put-In-Bay, OH	522					522		
Sault Ste Marie, MI	38539					38539		
Beaver Island, MI	556					556		
Sandusky, OH	693					9	684	
Erie, PA	67821					67821		
Port of Buffalo	37674					878	36796	
Ogdensburg, NY	87592					87592		
Sackets Harbor, NY	4317					4317		

Source: Waterborne Commerce of the United States.

Table V. Distribution of petroleum products at U. S. ports of the Great Lakes, 1976.

Distillate fuel oil. (Short tons.)

		Overseas		Canadian		Domestic		
	Total	Import	Export	Import	Export	Receipt	Shipment	Local
Duluth-Superior	189941					149624	35521	4796
Presque Isle, MI	25100					25100		
Bayfield, WI	225					225		
LaPointe, WI	225						225	
Taconite Harbor, MN	10421					10421		
Gladstone, MI	101778					101778		
Green Bay, WI	82530					80115	2415	
Port Washington, WI	35682					35682		
Milwaukee, WI	154828					149484	5344	
Port of Chicago	833832					434405	166515	232192
Indiana Harbor	1322936					7102	1313657	2177
Detroit Harbor, WI	2415					2415		
Racine, WI	25059					25059		
Sheboygan, WI	32850					32850		
Sturgeon Bay, WI	47576					47576		
Escanaba, MI	126219					126219		
Gary, IN	210					210		
Drummond Island, MI	3073					3073		
Traverse City, MI	112169					112169		
Frankfort, MI	11861					11861		
Muskegon, MI	23770					23770		
Grand Haven, MI	33595					33595		
St Joseph, MI	9830					9830		
Alpena, MI	776					776		

(Continued)

Table V. (Continued.)

	Total	Overseas Import	Overseas Export	Canadian Import	Canadian Export	Domestic Receipt	Domestic Shipment	Domestic Local
Saginaw River, MI	44433					29555	14878	
St Clair, MI	5712					5712		
Port of Detroit	792210	2692		628081		7746	61491	92200
Toledo, OH	98693						98593	
Charlevoix, MI	241					241		
Cheboygan, MI	51681					51681		
Kelly's Island OH	640					640		
Leland, OH	85					85		
Mackinaw City, MI	32177					32177		
Port Clinton, OH	90					90		
Port Huron, MI	2738					2738		
Put-In-Bay, OH	365					365		
Beaver Island, MI	241					241		
Sandusky, OH	671					671		
Lorain, OH	109491					109491		
Cleveland, OH	10506					10506		
Erie, PA	33455					33455		
Port of Buffalo	153602					36525	17077	
Ogdensburg,NY	79597					79597		
Sackets Harbor, NY	40322					40322		

Source: Waterborne Commerce of the United States.

Table VI. Distribution of petroleum products at U. S. ports of the Great Lakes, 1976.

Residual fuel oil. (Short tons.)

		Overseas		Canadian		Domestic		
	Total	Import	Export	Import	Export	Receipt	Shipment	Local
Duluth-Superior	8286					8286		
Taconite Harbor, MN	15590					15590		
Green Bay, WI	59375					52725	6650	
Milwaukee, WI	76035					76035		
Port of Chicago	2443739					1629242	479972	334525
Indiana Harbor	1365423					258298	974843	132282
Sheboygan, WI	39606					39606		
Sturgeon Bay, WI	43704					43704		
Gary, IN	9684					9684		
Frankfort, MI	13369					6650	6719	
Ludington, MI	5743					5743		
St Joseph, MI	38361					38361		
Saginaw River, MI	29038				5211		23827	
Port of Detroit	423376			20141	7887	168883	31698	194767
Toledo, OH	447190						426163	21027
Cleveland, OH	221033			25720		187996		7317
Ashtabula, OH	18859	18859						
Erie, PA	7752					7752		
Port of Buffalo	329347					200174	23296	105877
Oswego, NY	767102	5934		761168				
Ogdensburg, NY	15086					15086		

Source: Waterborne Commerce of the United States.

Projections

In spite of uncertainties regarding the continued reliability of supplies of various fuels, a few recent trends may be noted:

1. In comparison with the country as a whole, the Great Lakes region has a well-balanced dependency on the three principal fuels (coal, petroleum, and natural gas) in its total energy consumption. In particular, regional consumption of coal accounts for approximately 35% of the total energy production, as opposed to about 20% for the nation at large. The remainder of the gross regional demand is almost equally divided between petroleum and natural gas supplies. In the long run, coal is expected to account for an increasing fraction of electric power generation, replacing other fuels. However, the importance of oil fuels in transportation and agriculture will continue. In spite of recent congressional interest in synthetic liquid fuels (mainly derived from coal), the possibility of commerical production of such fuels in significant amounts must be considered very slight, at least for the next two decades.

2. The Great Lakes region, and particularly the states of Illinois and Wisconsin, have been in the forefront of nuclear power development. In view of the recent reverses suffered by the nuclear power industry, however, it seems likely that the continued growth of nuclear capacity will be hindered. As a result, some of the planned generating capacity that was originally intended to be nuclear based will necessarily resort to another fuel. However, at present price levels, it is quite probable that the alternative fuel will be coal, barring unforeseen tightening of environmental requirements.

3. The Great Lakes region is, by a substantial margin, a net importer of energy. While coal production and reserves in the region are substantial, much of the resource is environmentally unacceptable for burning in an unblended or unmodified form. By contrast, petroleum production in the region accounts for no more than 1% of the national total, and reserves are of corresponding size. Therefore, the region will continue to depend on outside sources for nearly all of its liquid fuels until synthetic fuels become commercially feasible and economically attractive. This will probably not happen soon.

Because of the basic attachment of the regional electric utilities to coal resources, it seems unlikely that petroleum shipments will increase markedly in the foreseeable future. On the other hand, the dependency of domestic and transportation demand on liquid fuels shows no sign of abating: therefore, it seems equally unlikely that shipments of distillate fuels (and residual fuels for marine and industrial applications) will decrease below a certain ground level without implying serious economic disruptions. Accordingly, present trends show no compelling reason to expect other than modest growth in marine tonnages over the coming two decades.

Before the present round of petroleum uncertainties, the Corps of Engineers Great Lakes Freight Model had produced the following forecasts, (Ref. 3), summarized as projected percent annual tonnage increases for the period 1975-2000:

U.S. Domestic	3.7%
Imports from Canada	3.9%
Exports to Canada	1.3%
Imports from overseas	4.0%

These projections were for the aggregate of all petroleum fuels, for all U.S. ports on the Great Lakes-St. Lawrence Seaway System. During the same period, Canadian domestic waterborne transport and overseas imports were projected to increase at about 5% per year.

Even with an increasing dependence on foreign fuels, imports of the refined products are not expected to amount to more than 7% of total Great Lakes marine tonnage, and even this fraction will not materialize without substantial changes in the operating environment of the St. Lawrence Seaway, including navigational improvements and season extension. Thus, no significant new influx of saltwater tankers is to be expected in the products trade.

From the standpoint of total U.S. Great Lakes port receipts, a rate of increase of 3.7% per year seems excessive in view of a regional population growth rate of about 0.1%, and manufacturing employment growth perhaps lower than that. It may well be that the slow growth of regional industry, coupled with new efforts in energy conservation, will reduce the rate of petroleum traffic growth to substantially less than 3.7%. The geography of the existing products movement, as well as its approximate volume, should remain fairly stable.

As mentioned above, such long-term forecasts of fuel use must be viewed with the greatest suspicion. Recent developments in the petroleum situation make even short-term forecasts of relatively little value. However, in this very uncertainty there is a lesson to be learned. Under conditions of uncertain tonnages and trade routes, the marine mode offers a very tangible advantage: a vessel employed in a given service, or built in anticipation of a certain economic environment, can often be shifted to another service if and when conditions change. Furthermore, a marine transport system allows capital investment in discrete units, along with additional capacity as needed. The same cannot be said of a new pipeline, or even new rail.

WATERBORNE PETROLEUM TRAFFIC ON THE GREAT LAKES: CRUDE OIL

In contrast to the products trade, the movement of crude petroleum on the Great Lakes has been characterized by great fluctuation in annual tonnage, and by geographic shifts from year to year. Table VII shows annual tonnage for U.S. Great Lakes ports from 1971 to 1976, by type of movement, as described previously in connection with petroleum products. The variability of annual flow is evident from the data.

The 1976 geographic distribution of crude-oil shipments and receipts at U.S. ports is shown in Table VIII. Tonnages handled through the Chicago area dominated the 1976 traffic, and the importance of Chicago was evident in most other years of the sample period. However, large shipments to other areas were found in other years. For example, the unusually high crude-oil tonnage of 1973 centered on the Toledo, Ohio area, while much of the 1975 traffic was directed to refineries on the St. Clair River.

This lack of uniformity in both history and geography of the crude-oil traffic reflects the importance of short-term energy demands in the distribution of the crude resource. In general, however, most of the crude oil arriving on the lakes originates as domestic cargo via the Great Rivers through the port of Chicago. By contrast, the anomalous 1973 traffic consisted largely of Canadian imports.

Crude-oil tonnages handled at U.S. ports are relatively small by comparison with petroleum products, and the distribution network is less widespread, reflecting the centralization of the refining industry. Canadian domestic movements show the same general characteristics, although the average annual tonnages are somewhat larger.

Table VII. Total shipments of crude petroleum through U. S. ports of the Great Lakes. (Short tons.)

	Total	Import Export	Coast	Lake	Local
1971	16184	16184			
1972	7355	7355			
1973	573775	564523		9252	
1974	24486	24486			
1975	51708	50475			1233
1976	250316	223919		15826	10571

Source: Waterborne Commerce of the United States.

Table VIII. Distribution of crude petroleum at U. S. ports of the Great Lakes, 1976.

(Short tons.)

		----Overseas----		----Canadian----		----------Domestic----------		
	Total	Import	Export	Import	Export	Receipt	Shipment	Local
Port of Chicago	183145					90613	81967	10571
Indiana Harbor	2702						2702	
Ludington, MI	5615					5616		
Saginaw, MI	13124						13124	
St Clair, MI	102341			102341				
Port of Detroit	76120	68612				7508		
Oswego, NY	52966			52966				

Source: Waterborne Commerce of the United States.

Projections of the future of crude petroleum tonnage are even more dubious than forecasts of petroleum products. A 1977 Corps of Engineers projection used an average annual rate of growth for U.S. imports from Canada of 3.4%, for the period 1975-2000. During the same period, Canadian imports were projected at a 4.9% annual growth rate. These rates are probably high.

THE GREAT LAKES TANKER FLEET

Tankers

While the total annual Great Lakes petroleum tonnage has remained fairly steady over recent years, there has been a drastic reduction in the number of vessels serving this tonnage. Table IX shows the total number of U.S. and Canadian self-propelled tankers involved in the intra-lakes petroleum product movement for the years 1958-1977, as compared with total annual tonnages.

The decrease in the number of tankers serving lakewise petroleum cargoes has been accomplished mainly by an increase in vessel size. Nevertheless, the typical Great Lakes tanker remains extremely small by seagoing standards. Table X presents the size distribution of the existing Great Lakes tanker fleet, excluding barges. The data have been grouped by nationality, and the average age within each cell is indicated. The number of Canadian vessels of the largest size classes shows the influence of the St. Lawrence Seaway on Canadian petroleum movements. It should be noted that many of these tankers are operated on the Seaway at significantly less than their full load deadweight, due to the Seaway draft constraints of 25.5 ft. These vessels are frequently involved in coastal voyages as well as purely interlake movements, and are therefore more typical of oceangoing vessels than of tankers intended specifically for the lakewise trades. Nevertheless, the larger classes are becoming increasingly important in the crude-oil and fuel-oil distribution systems, particularly as import/export tonnage replaces the strictly lakewise and local traffic flows.

Table IX. Number of self-propelled vessels involved in Great Lakes domestic movements of petroleum products, 1958-1977.

	Vessels	Total Great Lakes Petroleum Product Tonnage (Millions of Short Tons)
1958	97	14.0
1959	100	14.4
1960	97	14.3
1961	88	14.9
1962	87	13.9
1963	80	10.8
1964	82	12.4
1965	74	11.2
1966	72	13.0
1967	67	12.1
1968	66	12.8
1969	71	13.1
1970	69	13.9
1971	65	13.3
1972	44	13.8
1973	42	15.1
1974	39	12.7
1975	36	11.5
1976	33	13.2
1977	31	15.1

Source: Annual Report of the Lake Carriers Association.

Table X. Size and age of self-propelled vessels principally serving the Great Lakes petroleum trades.

Deadweight (Long ton)	Number	Avg Year Built	Number	Avg Year Built
	-----American-----		-----Canadian-----	
- 999	7	1955	1	1939
1000 - 1999	2	1955	3	1964
2000 - 3999	2	1944	4	1952
4000 - 5999	1	1963	9	1958
6000 - 7999	2	1952	10	1956
8000 - 9999	4	1953	10	1964
10000 - 14999			5	1969
15000 +			7	1957
Total	18	1953	49	1959
Combined Deadweight	66668		433537	

This gradual change in the character of the petroleum products trade is probably the principal reason for the increase in average vessel size, and the consequent reduction in the number of vessels in the fleet. Increased vessel utilization has also resulted from slightly faster service speeds, more efficient turnaround, and tighter scheduling.

The actual limit on the length and beam of vessels using the St. Lawrence Seaway is 730 x 76 ft, dimensions typical of a large class of lakes freighters. However, such proportions are inefficient for purely oceangoing vessels, and no tanker of these dimensions has been built, on or off the lakes.

Because of the specialized nature of the trades, many of the Great Lakes tankers differ in proportions, power, and equipment from tankers intended for coastal or ocean trades. Apart from size, which has already been mentioned, specialized Great Lakes tankers are marked by the following characteristics:

1. Relatively shallow draft. Typical Great Lakes tankers in the size range of 6000-9000 tons deadweight (dwt) usually draw 22-23 ft. The economic value of shallow draft is dictated by the geography of the service, in which many of the smaller ports involved have not been dredged to the full Great Lakes - St. Lawrence Seaway draft.

2. Relatively low power and service speed. Because of the short voyages, with frequent calls and substantial restricted-speed mileage, less of an economic premium is placed on service speed. Apart from ocean-going vessels serving the St. Lawrence overseas trades, tanker service speeds rarely exceed 12.5 knots.

3. Prevalence of twin-screw arrangements. Of 18 American tankers operated exclusively on the lakes, 8 are twin-screw vessels, while of

of the remainder, 6 were built prior to 1940. Of 49 Canadian tankers, including salt-water vessels serving the St. Lawrence Seaway during 1976, 11 are twin-screw. Significantly, many smaller vessels have adopted the twin-screw arrangement, and the trend in both fleets has been toward this type of power-plant. It should be pointed out that for relatively low-powered vessels of this size, the twin-screw plant offers little or no advantage in propulsive efficiency. Furthermore, with the advent and widespread application of bow and stern thrusters, twin-screw vessels no longer possess marked advantages in low-speed maneuverability. However, the added reliability of the twin-screw propulsion systems offers several key advantages in the field of hazard avoidance and consequent spill prevention. A price is paid for this additional maneuverability and reliability, however; almost without exception, a twin-screw plant costs more to build and operate than a single-screw plant of similar output, while its additional weight incurs a further penalty in cargo capacity.

4. Limited extent and height of superstructures. Many of the Great Lakes tankers are constrained by overhead clearances in the ports and harbors on their routes. The low, compact superstructures that are required give a distinctive appearance to tankers intended for the purely interlake trades. By contrast, the normal superstructure proportions of St. Lawrence Seaway and ocean-going tankers would effectively bar these vessels from many of the smaller terminals.

The vast majority of tankers serving the Great Lakes are motor vessels. Of a total of 67 self-propelled tankers, Canadian and U.S., 59 are diesel powered. Of the remainder, at least half are older vessels fitted with obsolete reciprocating steam engines. At the low horsepowers typical of these small ships, the steam turbine is placed at an insoluble disadvantage, which is further aggravated by the usual choice of twin-screw configuration.

Tank arrangements of Great Lakes oil carriers vary somewhat, even among vessels of similar size and age. The newer vessels, with the exception of bunkering tankers (ships of the smallest classes), have adopted either a single longitudinal bulkhead arrangement with relatively short tanks, or a twin-bulkhead plan. These arrangements have been typical of products carriers since the 1950's. The most recent additions to the U.S. Great Lakes tanker fleets have also incorporated a full double shell over the length of the cargo space.

Advanced vessel-handling equipment has been fitted to a number of small Canadian tankers of between 1200 and 2100 dwt, built between 1963 and 1970. These vessels are twin-screw, of relatively low power, and are equipped with directionally-controlled propellers of the Harbormaster type. For local moves, and bunkering, within the confines of a harbor or waterway, these installations provide exceptional maneuverability, with consequent improvements in both efficiency and safety.

As of this writing, the newest and largest American tanker specifically designed and built for Great Lakes service is the 6700 gross ton Gemini, delivered to Cleveland Tankers in 1978. On over-all dimensions of 419 x 65 x 29 ft depth, with a cargo deadweight of 9710 long tons, she is very little larger than the lakes tanker Amoco Illinois of 1918. Clearly, the increase in tanker size within the Great Lakes fleet is a shift of the average rather than of the extreme. It is interesting to compare this modest growth with trends in the deep-water tanker fleet. When built, the Illinois was about half the size of the largest tankers then sailing; by contrast, Gemini is about one-fiftieth of the size of the world's largest ocean tankers.

Tankbarges

Petroleum barging on the Great Lakes may be divided into two distinct classes. At the smaller end of the size scale, barges have been a traditional harbor appliance, and have carried a great deal of the local petroleum tonnage. These barges have declined in number over the years, however, as local movements have slowly gravitated toward non-waterborne modes.

Above 2000 tons deadweight, however, the Great Lakes tankbarge fleet has grown rapidly, with much of the added tonnage built during the 1960's. Table XI lists the characteristics of the barge fleet as of 1977, grouped by deadweight and nationality. The barge mode, in its modern form, is largely an American innovation. The advantages of barging, in a trade such as the Great Lakes petroleum product movement, can be summarized briefly as follows:

1. Savings in initial costs. By making use of some standardized barge components, and by taking advantage of the relatively high productivity of specialized barge yards, substantial economies in building costs can be realized. In addition, tugs represent a virtually "off-the-shelf" commodity in the marine transport field.

2. Savings in operating costs. Due to the present manning regulations, a tug/barge combination can be operated with a substantially reduced crew versus a ship of roughly comparable deadweight and

Table XI. Size and age of tankbarges principally serving the Great Lakes petroleum trades.

Deadweight (Long ton)	Number	Avg Year Built	Number	Avg Year Built
	-----American-----		-----Canadian-----	
- 999	3	1935		
1000 - 1999	7	1958		
2000 - 3999	6	1957		
4000 - 5999	6	1963		
6000 +	2	1972		
Total	20	1957		
Combined Deadweight	72535			

dimensions. In some cases, savings of 40% in annual crew costs can be realized.

3. Interchangeability of system components. The tug/barge system, because of its ability to separate the cargo-carrying and propelling vessels, can often realize a valuable flexibility in route and schedule. Furthermore, the availability of standard units permits a higher degree of service protection without prohibitive investments in backup equipment.

4. Intermodality. Typical barge proportions permit vessels of nearly 3000 dwt to operate fully loaded at the dredged river draft of 9.5 ft. The movement through the Illinois waterway, connecting the Great Lakes with the Great Rivers, can be significantly more economical with a barge operation.

5. Winter operations. In some situations, the tug/barge combination can be used advantageously under relatively severe ice conditions. Often, the tug can act as an icebreaker, freeing the stuck barge and resuming the tow. Furthermore, where ice conditions warrant, the barge operator can double the assigned horsepower with a second tug. Both of these techniques have been used successfully on the lakes.

6. Barge-swapping capability. Where the availability of short-term cargo makes it desirable, the operator can institute a barge-swapping operation. The utilization of labor and capital (horsepower) can be increased drastically by reducing the towboat's turnaround time to an absolute minimum. In the past, the use of barge-swapping in the petroleum trades has been limited by tonnage constraints, but changes in the geography of the market may make this option more attractive in the future.

With an increased reliance on push-towing, and with technical developments in tug/barge connection, the integrated tow (ITB) has largely overcome the traditional operational problems of the wire-towed barge. These are disadvantages which have occasionally proved particularly costly in terms of damage and loss, with a special significance for petroleum transport:

1. Significant loss of precision in vessel handling and maneuvering.
2. Yaw instability.
3. Vulnerability to parting of the tow rope in heavy weather.

In modern barges, even when unsuitable weather conditions force wire-towing operations, improved skeg designs contribute somewhat to the safe and stable operation of wire tows. However, the penalty of these devices is a higher horsepower requirement, and increased fuel consumption. Improvements in cordage and towing machines have somewhat reduced the dangers of losing the tow.

In the push-towing mode, which is becoming standard barge practice, the powering disadvantage can be reduced to a few percent of annual fuel costs, while maneuvering capabilities are essentially those of a self-propelled vessel. The use of fully integrated tows will certainly increase as obsolete equipment is retired from the tankbarge fleet.

Tank arrangements of Great Lakes tankbarges closely parallel current practice on the self-propelled tankers. The standard configuration, with few exceptions, consists of a single longitudinal bulkhead with relatively short cargo tanks. A few of the newest and largest barges have also adopted double-shell construction.

Possible future developments of tug-barge technology include the concept of multibarge operations in open water, along the lines of present river flotillas (Ref. 4). Although the safe operation of multibarge combinations in relatively unprotected waters will depend on the development of effective and economically feasible linkage devices, not available at present, the advantages of multi-barge systems in the petroleum trade could become significant, particularly for the low-volume routes.

Tanker and Tankbarge Market Share

Over the past several years, the distribution of domestic marine products tonnage on the Great Lakes has undergone a substantial shift from self-propelled tank vessels to tankbarges. The magnitude of this trend during the years 1973-1977 is shown in Table XII.

The economic reasons for this apparent shift of market share into the barge mode are not difficult to find. Barge costs per deadweight ton are substantially less than for tankers, while the standardization of both barge and tug designs in recent years has permitted specialized yards to reduce initial costs even further. Due to Coast Guard manning requirements, tug-barge combinations can usually be operated by a smaller complement than a tanker of similar cargo capacity. Finally, the local availability of replacement tugs (and to an extent, barges) adds to the protection of the service.

Table XII. Self-propelled tanker versus tankbarge in the principal domestic Great Lakes petroleum trades, 1973-1977. (Tonnages in thousands of short tons.)

	---1973---	---1974---	---1975---	---1976---	---1977---
Gasoline, jetfuel, kerosene:					
Self-propelled tankers	2207 (89%)	1565 (87%)	1292 (74%)	1214 (73%)	1161 (70%)
Tankbarges	269 (11%)	239 (13%)	446 (26%)	453 (27%)	504 (30%)
Distillate fuel oil:					
Self-propelled tankers	1481 (76%)	1273 (77%)	894 (58%)	981 (59%)	990 (51%)
Tankbarges	455 (24%)	376 (23%)	641 (42%)	670 (41%)	969 (49%)
Residual fuel oil:					
Self-propelled tankers	252 (18%)	368 (25%)	369 (27%)	464 (28%)	776 (29%)
Tankbarges	1137 (82%)	1087 (75%)	1007 (73%)	1180 (72%)	1870 (71%)
All petroleum fuels:					
Self-propelled tankers	3940 (68%)	3206 (65%)	2555 (55%)	2659 (54%)	2927 (47%)
Tankbarges	1861 (32%)	1702 (35%)	2094 (45%)	2303 (46%)	3343 (53%)

Source: U. S. Department of Commerce, Domestic Waterborne Trade of the United States, 1973-1977.

Traditionally, the operational disadvantages of barges were associated with the wire-tow, namely, additional power requirements and maneuvering difficulties. With the advent of the fully-integrated tow, however, the tug-barge system is rapidly approaching the geometry, appearance, and capability of the conventional self-propelled vessel. In a sense, as the two technologies converge in form and function, it will be interesting to see whether the economic distinctions between them will become increasingly artificial. Elimination of the economic difference will, at that point, depend largely on official recognition of the artificiality of the operating differences, particularly with respect to manning requirements.

POLLUTING INCIDENTS INVOLVING WATERBORNE PETROLEUM TRANSPORTATION

During 1976, the U.S. Coast Guard Ninth District reported 190 incidents of vessel-related petroleum spillage on the Great Lakes and tributary waters, with a total discharge of 440,376 gallons. Of this total volume, approximately 250,000 gallons (or about 75 %) were recovered.

Table XIII summarizes 1976 vessel-related spill statistics by vessel type, with number of incidents, total discharge, and percent recovered. Taken together, tankships and tankbarges were the source of over 98% of the marine-related spill volume, and almost 99% of the unrecovered spillage. It should be pointed out that 1976 was a "bad" year for tanker-related spills. By contrast, in 1977, the corresponding reports show 174 incidents leading to a total released volume of 38,435 gallons, of which 43% was recovered. Tankers and tankbarges were the source of 63% of Great Lakes marine-related spillage for 1977. In terms of spill figures, 1977 was more typical of the decade as a whole.

Regardless of "good" or "bad" years, the most important feature of tanker-related oil pollution is simply that a single incident can produce a more massive release of oil than any other marine source. For example, in 1976, two incidents out of 190, that is, 1% of the occurrences, resulted in 97% of the total spill volume. The vast majority of incidents, on the other hand, produce spills on the order of a few gallons, or tens of gallons. This experience is typical not only of the Great Lakes, but of other regions as well (Ref. 5).

Table XIII. Vessel-related discharge of petroleum on the Great Lakes and connecting waterways, including the St. Lawrence Seaway, 1976.

Source	Number of Incidents	% Total	Volume (Gallon)	% Total	% Recovered
Tankships	37	19.7%	3454	0.8%	79%
Tankbarges	43	22.9%	429303	97.5%	56%
Dry Cargo Vessels	35	18.6%	1587	0.4%	83%
Tugs & Towboats	11	5.9%	1045	0.2%	30%
Fishing Vessels	3	1.6%	26	-	15%
Passenger & Recreational Vessels	29	15.4%	780	0.2%	18%
Public Vessels	13	6.9%	111	-	20%
Unidentified Vessels	17	9.0%	3990	0.9%	83%
Total	188		440296		56%

Source: Polluting Incidents in and around U. S. Waters, CG-487.

Referring back to the base year 1976, Table XIV summarizes spill data by volume released. This table clearly shows the two-fold nature of the problem: a large number of small-volume spills, usually caused by improper cargo-handling procedures and equipment failures, punctuated by a relatively small number of high-volume spills caused by collision, either with another vessel or a fixed obstruction, or stranding.

In the context of the over-all regional oil-spill problem, the marine transportation mode should be compared to other sources of oil discharge. For 1976, non-marine sources were associated with 588 incidents in the Great Lakes region, resulting in a total spill of 273,757 gallons. The marine mode, based on these data, was clearly a substantial contributor to over-all spillage, identified with almost 62% of the regional total spill volume. This figure should be compared with the nationwide marine-transport percentage for 1976: for that year, vessel-related spills accounted for 46% of the total U.S. volume. Tank vessels, including both self-propelled tankers and barges, were again the prime sources, accounting for 97% of the vessel-related spillage, by volume.

In general, the pattern of Great Lakes oil discharge from tank vessels is fairly characteristic of the national situation in terms of the distribution of spill causes and sizes, with one notable exception: Due to the absence of very large tankers on the lakes, the frequency of spills in the million gallon range is curtailed (Ref. 7). There is scant comfort in this, however. Experience has shown that even a relatively "modest" spill of fuel oil in coastal waters can have significant and costly environ-

Table XIV. Vessel-related discharge on the Great Lakes and connecting waterways: cumulative distribution of spill volumes, 1976.

Spill Volume Gallon	Number of Incidents	% Total	Combined Volume	% Total
Less than 10	121	64.4%	553	0.1%
Less than 50	159	84.6%	1759	0.4%
Less than 100	168	89.4%	2560	0.6%
Less than 500	179	95.2%	5356	1.2%
Less than 1000	183	97.3%	8496	1.9%
Less than 5000	186	98.9%	14296	3.2%
Total all spills	188	100.0%	440296	100.0%

Source: Ninth Coast Guard District Spill Reports.

mental effects, both short and long-term. The West Falmouth spill of 1969, described in Ref. 6, involved the release of about 175,000 gallons of Number 2 fuel oil (generally similar to diesel fuel) from a stranded tankbarge. Most of the discharged oil came ashore.

On the Great Lakes system, spills of this magnitude are rare, but two occurred in 1976: one of 300,000 gallons on the St. Lawrence River, of which about 80% was recovered, and another of 125,000 gallons near Cleveland. The larger spill involved Number 6 fuel oil, substantially similar to bunker fuel, and potentially more environmentally damaging than the lighter distillate of the Falmouth incident. Both of these large spills involved tank-barges: the river incident was a grounding, the Cleveland spill was due to impact with a fixed object.

Vessel Risk on the Great Lakes

Recent work on Great Lakes vessel hazards indicates that the loss rate for Great Lakes bulk carriers (including tankers) was significantly lower than for the world tanker fleet (based on data for the years 1950-1976). In Ref. 8, a loss rate due to all causes was placed at 0.0013 per ship·year, with an upper confidence limit (95%) of 0.0022. By comparison, the total loss rate for all ocean tankers was approximated in Ref. 5 as 0.0043, although some national fleets were as high as 0.0075 or as low as 0.0018.

While the data cited in Ref.8 were derived from a fleet consisting largely of dry bulk carriers, it could be argued that the use of these figures is more logical than attempting to draw significant inferences from the far smaller fleet of Great Lakes tankers. In doing so, it should be noted that there have been no losses of Great Lakes tankers since the tanker Cardinal was declared a total loss after being in collision, in 1974. The vessel was not sunk.

It would be logical to suggest that the predominance of twin-screw arrangements and double-shell construction, and even more importantly, efficient watertight subdivision, should combine to make Great Lakes tankers even more secure against some vessel hazards (collision, grounding, machinery or hull structural failure) than the typical Great Lakes bulk carrier. However, the corresponding risk of fire and explosion is far greater for the tankers, although the magnitude of this risk difference is only available for the world fleet at large. Surprisingly, the risks are approximately equal at sea, but the tankers are at approximately twice the risk in port (during cargo handling, tank cleaning, etc.), as listed in Ref. 9.

Needless to say, the loss of a loaded tanker or tankbarge on the lakes or connecting channels would in all probability lead to an environmentally disastrous cargo spill. Depending in great part on the location and weather conditions surrounding the spill, much of the spill volume might be recovered, or it might not.

Even in the less drastic circumstances of a "minor" casualty, the loss of cargo is entirely possible. For Great Lakes bulk carriers, casualty rates (per round trip) for events not leading to vessel loss have been estimated as follows (Ref. 8):

Grounding	0.00319
Contact with ice or fixed object	0.00137
Collision	0.00064
All other damage	0.00046
Total Rate	0.00565

The frequency data show a preponderance of grounding and fixed-object contact, suggesting that detailed improvements in navigation and ship-handling systems, possibly including personnel training, might be effective measures in reducing cargo-spill risk. It should be noted that for a typical lakes vessel making 50 round trips per year, the probability of suffering at least one incidence of a minor casualty, according to the above rates, is about 0.25 in any given year. The figure may be higher for barges than for self-propelled vessels.

SPILL PREVENTION

Two principal avenues are available in attempting to reduce tanker-related oil spill probabilities and severities: changes in operating procedures and in design of the vessels and their subsystems. Many specific alternatives are listed in Refs. 10-13, together with some quantitative assessments of their effectiveness.

With regard to these alternatives, the Great Lakes tanker fleet enjoys substantial advantages over the world fleet at large:

- The fleet is specialized. Vessels are specifically adapted to the conditions and routes of the Great Lakes, and their officers and crews are more familiar with the channels, approaches, and ports on the lakes; trips are usually short, and therefore frequent. This is primarily true of the intralake fleets, of course, but saltwater vessels are required to carry a Great Lakes pilot. Language is not a problem in maneuvering against collision threats.
- Traffic separation and local control are already implemented in key locations on the lakes, notably on the St. Marys River and at Port Huron, and on the approaches to many ports. Upbound and downbound vessel tracks are well separated on the open lakes as well.
- Vessel speeds are low, as a matter of choice.

From the standpoint of design features, many existing Great Lakes tankers already incorporate a number of recommended systems:

- Twin screws and rudders, with consequent improved maneuvering and reliability.
- Double bottoms and double shells. (The relative costs and safety merits of double shell designs have long been controversial. An excellent summary of arguments pro and con may be found in Ref. 10.)
- Relatively modest vessel size. (Great Lakes tankers are likely to remain small, by deep-water standards, over the coming years.)

On the other hand, it must be remembered that in many other ways, the Great Lakes tanker fleet is in a troublesome position:

- The compactness of the trade implies that a vessel must operate for a substantial part of its lifetime in areas of high traffic density, in shoal water, or in port.
- Due to the short trips, cargo handling operations are frequent, and the possibility for minor spills is increased.
- The fleet is relatively aged, although this is less critical in fresh water than in salt.
- The proportion of cargoes carried by barge is high, and increasing from year to year.
- Due to the environmental sensitivity of the lakes, spills of relatively small volume can represent major threats.

The effectiveness of spill prevention measures in a particular tanker fleet is difficult to assess, and it is often misleading to try. As pointed out in Ref. 5, the simplest method of comparison, namely, in terms of volume spilled per unit of cargo carried, is not particularly useful, since it contains no information about the distribution of spill volumes, their locations, and the actual harm done. On the other hand, while such a simplistic measure is of little value in absolute terms, it may be interesting as a means of comparing the experience of two different fleets.

Typically, yearly values of the parameter for the world tanker fleet have averaged in the range 0.015% to 0.020%. Data for spills in U.S. waters show tremendous variation in spill volume from year to year, while the number of incidents is relatively steady by comparison. The obvious reason is that a single incident, such as the Argo Merchant spill of December 1976, can represent a significant part of the total annual cargo loss. Thus, for example, recent U.S. experience varies from a typical value 0.011% for 1975 and 1977, to 0.018% for the "bad" year 1976.

On the Great Lakes, corresponding figures can be summarized as follows:

1975	0.010%
1976	0.013%
1977	0.001%

The over-all three year rate for the lakes is about 0.0077%, versus a value of 0.0133% for U.S. waters as a whole. The relatively low rate of cargo loss on the lakes is due, at least to some degree, to the fleet mix of small, maneuverable vessels, crew familiarity with local waters, and the growing prevalence of twin-screw and double-shell designs, both in self-propelled tankers and barges.

It should be pointed out, however, that there is a substantial difference in spill prevention performance between self-propelled vessels and barges. In 1976, to cite an extreme example, the barge share of domestic petroleum traffic amounted to 46% for all commodities, yet barges accounted for over 99% of total cargo loss. This comparison is scarcely fair, however, since it is unduly biased by two very large spills. Comparable data for 1977 show a barge market share of 53% in the domestic trades, while accounting for 92% of spill volume. Again, as in 1976, the major spills, including two of 10,000 gallons each, and another of 3000 gallons, were from barges. The precise reasons for the seeming vulnerability of tankbarges may lie in several areas: maneuvering and course stability, equipment, and crew training.

On the whole, the safety record of Great Lakes tankers and tankbarges has been better than U.S. experience at large. However, the nature of the lakes environment, where even very modest spill volumes can represent substantial damage, allows little room for self-congratulation.

CONCLUSIONS

Development and Geography of the Petroleum Traffic

1. The Great Lakes petroleum products trade is a mature trade, and annual tonnage has been remarkably constant from year to year since the late 1950's.

2. While the steady tonnage in fact indicates a slowly declining market share of all petroleum moves in the region, the present climate of uncertainty in petroleum supplies may favor investment in the marine mode as opposed to pipeline and rail systems.

3. Year-old projections of future growth in the marine trade, forecasting annual growth rates in the neighborhood of 3% to 4%, are probably too high, based on recent energy trends.

4. The distribution of products is highly diffuse, with a few central shipping ports serving the needs of more numerous receiving ports. The chief distributing ports in the U.S. are Indiana Harbor, Chicago, Milwaukee, Detroit, Oswego, Toledo, and Buffalo. In Canada, tanker activity is centered on refineries in Sarnia and Thunder Bay, Ontario, and the St. Lawrence River ports of Montreal, Quebec City, and Sept Isles, P.Q. The geographic pattern is stable.

5. By contrast, the Great Lakes traffic in crude oil is highly variable from year to year, both in volume and geographic distribution. Fluctuations in the trade make projections of future trends questionable, at best.

The Existing Fleet

1. While the number of tankers serving the intralake trade has steadily declined over the years, the "growth" of ships in the fleet has been a growth of the average size, rather than an increase in maximum vessel size. In this, the Great Lakes experience has been unlike that of the world tanker fleet as a whole.

2. Specially designed lakes tankers of recent years have favored twin-screw machinery and double-shell construction, resulting in improved maneuverability and resistance to casualty-related cargo loss.

3. As a rule, vessel speeds are quite low.

4. In the domestic petroleum trades, the market share of the barge industry has grown rapidly over the past few years, and is now over 50% of Great Lakes products moved.

5. Ocean-going tankers operating up the St. Lawrence Seaway are generally larger than the intralake tankers. They are predominantly single-screw vessels, built to ocean standards, and they frequently operate at reduced draft, adding to the possibility of maneuvering problems.

Spill Prevention Experience

1. Recently published data suggest that Great Lakes vessels are subject to somewhat lower levels of risk of loss than the world fleet in general (Refs. 8 and 9), in spite of a significantly older fleet.

2. Risks of minor casualties (grounding or collision not leading to vessel loss) are approximately equal to world risk. In itself, this reflects the particularly confined and specialized nature of Great Lakes service.

3. The rate of cargo loss, expressed in terms of total spill volume per volume of cargo carried, is significantly lower on the Great Lakes than in U.S. coastal waters in general, including data for both tankships and tankbarges.

4. Tankbarges, however, account for a disproportionate share of total cargo spillage.

5. Distributions of spill volumes are similar to general experience: a very large number of low-volume spills accompanied by a handful of major discharges. On the Great Lakes, however, the limited size of tank vessels results in a skewing of the major spills to a smaller volume, in the range of 10,000-300,000 gallons.

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12. J. L. E. Jens, "IMCO's Activities with Particular Reference to the Impact on Ship Design," Proceedings of the 2nd West European Conference on Marine Technology, Safety at Sea, May 1977.

13. W. D. Snider, D. F. Sheehan, and E. K. Johnson, "An Overview of Current and Proposed Tank Vessel Safety and Pollution Prevention Measures," Society of Naval Architects and Marine Engineers, Spring Meeting/STAR Symposium, April 1979.

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A computer-aided search of the available literature related to petroleum transport on the Great Lakes, with its attendant environmental impact, was made using the facilities of the National Transportation Information Service (NTIS). The resulting output is included here.

Water Resources Research Program: Transport and Dispersion of Oil-Refinery Wastes in the Coastal Waters of Southwestern Lake Michigan (Experimental Design: Sinking-Plume Condition)

Argonne National Lab., Ill.*Energy Research and Development Administration. (0448000)
AUTHOR: McCown, D. L.; Harrison, W.; Orvosh, W.
D225511 Fld: 13B, 68D GRAI7712
Jul 76 51p
Contract: W-31-109-ENG-38, EPA-INA-D6-E681
Monitor: 18

Abstract: The field phase of the experimental design was implemented on February 14-16, 1976, and consisted of (1) tagging 170 l of simulated refinery waste with 1.4 kg of a 50-percent acid solution of dysprosium acetate and spreading the tagged waste on the water surface at the entrance to the Indiana Harbor Canal (IHC), (2) tagging 3600 m exp 3 of water at the IHC mouth with 13.6 kg of samarium complexed with DTPA, (3) sampling the surface and subsurface waters of the lake downflow for 10 km using three boats with submersible pumping systems, and (4) sampling raw-water from the shore and Dunne Crib intakes at Chicago's South Water Filtration Plant (SWFP). The laboratory portion of the experimental design involved neutron activation analysis of the samples after evaporation of the water phase. Reactors and low-energy, photon spectrometers at Argonne and Ames, Iowa were used for sample irradiation and counting. Results indicate that the methodology, with appropriate changes, can be used successfully to study the transport and dispersion of simulated refinery waste injected into the IHC's sinking plume. Deficiencies in the original experimental design are discussed, and recommendations are given for their remedy. More-frequent sampling at the SWFP, and the use of an underway water-sampling system that will permit sampling coverage farther offshore, are the principal improvements required for the 1976/1977, full-scale, sinking-plume study. (ERA citation 02:015792)

Descriptors: *Hydrocarbons, *Petroleum refineries, *Water pollution, Activation analysis, Coastal waters, Diffusion, Dysprosium, Environmental effects, Environmental transport, Lake michigan, Measuring methods, Neutrons, Petroleum, Plumes, Samarium, Tracer techniques, Waste disposal, Waste management

Identifiers: ERDA/020900, ERDA/520200, ERDA/020800, Neutron activation analysis, Marking, *Oil pollution, NTISERDA

ANL/WR-76-4 NTIS Prices: PC A04/MF A01

Acoustic Estimates of Fish Density and Scattering Function

Wisconsin Univ., Madison.**Gulf Oil Corp., New Orleans, La.*National Oceanic and Atmospheric Administration, Rockville, Md. Office of Sea Grant. (380 100)
AUTHOR: Peterson, Miles L.; Clay, Clarence S.; Brandt, Stephen B.
D1652H1 Fld: 6C, 17A, 63A, 98F, 86M GRAI7708
28 May 76 8p
Rept No: WIS-SG-76-367
Monitor: NOAA-76122806
Prepared in cooperation with Gulf Oil Corp., New Orleans, La.
Pub. in Jnl. of Acoustical Society of America, v60 n3 p618-622 Sep 76.

Abstract: The amplitude of a sonar echo from a fish depends upon the species and size of the fish, acoustic wavelength, aspect, position of the fish in the sonar beam, range and backscattering cross section. The problem is simplified to a single species and size of fish, vertically downward echo sounding, single aspect, and nonoverlapping echoes. After removal of attenuation due to range and absorption two random functions remain. The position of the fish in the sonar beam is random and the scattering cross section for each trial is random. It is assumed that the fish have a uniform density and the probability density function (PDF) for insonification and reception are calculated. It is assumed that the PDF of the envelope of the echo has a Rayleigh PDF. Assuming two PDF's are independent, the PDF of the echo envelopes depends upon the beamwidth of the sonar and the mean backscattering cross section. The fit of the PDF's are used to estimate the backscattering cross section and fish density. This calibrates the echo-integration processing system.

Descriptors: *Fishes, *Echo sounding, *Acoustic detection, Sonar, Backscattering, Signal processing, Biomass, Size, Abundance, Lake Michigan

Identifiers: Reprints, Alosa pseudoharengus, Sea Grant program, NTISCOMNOA

PB-263 513/4ST NTIS Price: PC A02

Report on Pollution of Lake Erie and Its Tributaries. Part I: Lake Erie

Public Health Service, Washington, D. C. Div. of Water Supply and Pollution Control
D1485D1 Fld: 13B d7604
Jul 65 56p
Monitor: 18
See also Part 2, PB-260 274 and report dated Aug 65, PB-229 712.

Abstract: Two years of studies are summarized in this report on pollution of Lake Erie and its tributaries. Quality characteristics of the waters as they currently exist are considered. Effects of waste discharges on water uses are evaluated and principal problems and needed corrections are summarized. Part 1 of the report concerns the main body of Lake Erie.

Descriptors: *Water pollution, *Water quality, Lake Erie, Lakes, Waste disposal, Industrial wastes, Sewage disposal, Oil pollution, Sediments, Nutrients, Eutrophication

Identifiers: NTISEPAO

PB-260 273/8ST NTIS Prices: PC A04/MF A01

Report of the Symposium on Prevention of Marine Pollution From Ships Held in Acapulco, Mexico 22-31 March 1976

Inter-Governmental Maritime Consultative Organization London (England) (409234)
D0131K1 Fld: 13B, 8J, 68D, 47A, 85G GRAI7701
Apr 76 1437p
Monitor: USCG-WEP-1-77

Abstract: ;Contents: General Review of the 1973 Convention, National and Regional Arrangements; Construction, Equipment and Operation of Chemical Tankers; Segregated Ballast Tankers; Oily-Water Separators and Oil Monitoring and Control Equipment; Operation of Oil Tankers; Reception Facilities in Ports; Sewage and Garbage from Ships; Contingency Planning; Measures for Control, Detection and Data Collection; and Methods for Dealing with Spillages.

Descriptors: *Water pollution, *Pollution abatement, *Symposia, *Oil pollution, Ship design, Shipboard sewage treatment systems, Hazardous materials transportation, International relations, Monitoring, Oil spills, Separators, Ballast tanks, Ocean waste disposal, Ocean environments, Information systems, Accidents, Tankers, Harbors, Waste disposal, Chemicals, Great Lakes, Remote detectors, Labeled substances

AD-A031 581/2ST NTIS Prices: PC A99/MF A01

Research and Demonstration Programs to Achieve Water Quality Goals: What the Federal Government Needs to Do. (Report to the Congress)

Comptroller General of the United States, Washington, D.C.
C7595D2 Fld: 13B, 68D, 70E, 70F GRAI7624
16 Jan 74 449p
Rept No: B-166506-740116
Monitor: 18

Abstract: To comply with Federal requirements of the Federal Water Pollution Control Act Amendments of 1972 the General Accounting Office undertook an extensive study of water pollution problems and Federal water pollution research, development, pilot, and demonstration (R&D) programs to determine whether Federal R&D programs were producing the results necessary to help clean up the Nation's waterways. It sought answers to the following questions: What has been accomplished. What needs to be done to achieve national water pollution control goals.

Descriptors: *Water pollution abatement, *Federal assistance programs, *Project planning, *Research projects, Great Lakes, Oil pollution, Law enforcement, Industrial wastes, Agricultural wastes, Municipalities, Sewage, Thermal pollution, Rivers, Streams, Water quality management, Recommendations, Information systems, Surveys

Identifiers: Demonstration projects, *Federal Water Pollution Control Act Amendments of 1972, NTISEPAO, NTISGAO

PB-257 317/8ST NTIS Prices: PC A19/MF A01

Proceedings of the International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterway (4th)

Coast Guard Washington D C Office of Research and Development (408731)
C6445L4 Fld: 15E, 13L, 68D*, 99B*, 85D*, 47A GRAI7612
Oct 75 619p
Rept No: USCG-D-24-76
Monitor: 18
Includes 24 pages of film negatives.

Abstract: This volume contains the papers, list of authors and list of registrants for the Fourth International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterways. The Symposium was held 26 - 30 October 1975 in Jacksonville, Florida. The Fourth International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterways was held in Jacksonville, Florida, October 26-30, 1975 under the auspices of the U.S Coast Guard, with the scientific assistance of the National Academy of Sciences-National Research Council Committee on Hazardous Materials. Approximately three-hundred people from 14 countries registered and attended the four days of plenary sessions.

Descriptors: *Water traffic, *Hazardous materials transportation, *Safety, *Symposia, Marine transportation, Inland waterways, Hazards, Cargo, Materials handling, Toxicity, Explosions, Fire hazards, Disasters, Flammability, Water pollution, Oil spills, Shipping containers, Risk analysis, Emergencies, Tankers, Coastal regions, Great Lakes, Information systems

Identifiers: *Hazardous materials transportation, Hazardous materials spills, Contingency planning, Chemical industry, *Transportation safety, NTISDODXA, NTISDODCG, NTISDOTCG

AD-A023 505/1ST NTIS Prices: PC E08/MF A01

Water Pollution Investigation: Calumet Area of Lake Michigan. Volume II. (Appendices)

IIT Research Inst., Chicago, Ill.*Environmental Protection Agency, Chicago, Ill. Region V. (175 350)

Final rept.
AUTHOR: Snow, Richard H.
C4392F3 Fld: 13B, 68D GRAI7509
Oct 74 240p
Contract: EPA-68-01-1576
Monitor: EPA/905/9-74-011-B
See also Volume 1, PB-239 376.

Abstract: An investigation of the Calumet area of Lake Michigan was conducted. The objective was to determine trends in water quality, to determine effluent loads entering the Lake, and to predict reductions in effluents needed to achieve Lake water quality standards. The report describes the status of industrial and municipal effluent sources. Effluent data were compiled from NPDES permit applications and operating reports. These were checked by a field sampling program. Water quality data were compiled from several sources. Field measurements were made in the Indiana Harbor Canal (IHC) and at 16 Lake stations. The report contains chapters assessing the impact of each of the more important pollutants, and gives recommendations for reduction of some effluent loads. Appendices are included on the biological impact of pollutants on the Calumet area of Lake Michigan.

Descriptors: *Water pollution, *Lake Michigan, Water quality, Industrial wastes, Sewage, Overflows, Combined sewers, Sampling, Chlorides, Sulfates, Water analysis, Bacteria, Phenols, Inorganic nitrates, Oil pollution, Inorganic phosphates

Identifiers: *Water quality data, NTISEPAG

PB-239 377/5ST NTIS Prices: PC A11/MF A01

Water Pollution Investigation: Calumet Area of Lake Michigan. Volume I

IIT Research Inst., Chicago, Ill.*Environmental Protection Agency, Chicago, Ill. Region V. (175 350)

Final rept.
AUTHOR: Snow, Richard H.
C4392F2 Fld: 13B, 68D GRAI7509
Oct 74 325p
Contract: EPA-68-01-1576
Monitor: EPA/905/3-74-011-A
See also Volume 2, PB-239 377.

Abstract: An investigation of the Calumet area of Lake Michigan was conducted. The objective was to determine trends in water quality, to determine effluent loads entering the Lake, and to predict reductions in effluents needed to achieve Lake water quality standards. The report describes the status of industrial and municipal effluent sources. Effluent data were compiled from NPDES permit applications and operating reports. These were checked by a field sampling program. Water quality data were compiled from several sources. Field measurements were made in the Indiana Harbor Canal (IHC) and at 16 Lake stations. The report contains chapters assessing the impact of each of the more important pollutants, and gives recommendations for reduction of some effluent loads. Appendices are included on the biological impact of pollutants on the Calumet area of Lake Michigan.

Descriptors: *Water pollution, *Lake Michigan, Water quality, Industrial wastes, Sewage, Overflows, Combined sewers, Sampling, Chlorides, Sulfates, Water analysis, Bacteria, Phenols, Inorganic nitrates, Oil pollution, Inorganic phosphates

Identifiers: *Water quality data, NTISEPAG

PB-239 376/7ST NTIS Prices: PC A14/MF A01

Regional Oil and Hazardous Substances Pollution Contingency Plan. Region V Inland

Environmental Protection Agency, Chicago, Ill. Region V.
C4043H1 Fld: 13B, 13J, 68D GRAI7504
Feb 74 147p
Monitor: 18

Abstract: This Regional Contingency Plan of Region Five (Inland) has been prepared within the framework of the National Oil and Hazardous Substances Pollution Contingency Plan and provides a mechanism for coordinating response to a spill of oil or other hazardous substances in the Region

and integrated response by Departments and Agencies of the Federal Government to protect the environment from the damaging effects of pollution discharges. It promotes the coordination and direction of Federal and State response systems and encourages the development of local government and private capabilities to handle such discharges in the event of a marine disaster.

Descriptors: *Oils, *Hazardous materials, *Water pollution, *Marine transportation, Regional planning, Government policies, State government, Federal government, Local government, Personnel, Cost estimates, Accidents, Regulations, Great Lakes

Identifiers: *Hazardous materials transportation, Oil spills, Water pollution abatement, *Oil pollution, NTISEPAG

PB-237 540/0ST NTIS Prices: PC A07/MF A01

Characteristics of the Areas in which Fast Current Oil Control is Needed

Coast Guard Washington D C Office of Research and Development (408731)

Final rept.
AUTHOR: Hammer, W. F.; Koburger, C. W.; Jensen, D. S.
C3844B2 Fld: 13B, 8C, 68D*, 47C, 47B GRAI7501
Nov 73 102p
Rept No: USCG-D-103-74
Monitor: 18

Abstract: Present oil spill control measures are effective only in currents up to between 0.8 and 1.0 knot, depending on the characteristics of the oil and ocean conditions. The Atlantic, Pacific and Gulf Coasts, the Inland Area, and the Great Lakes were examined. Forty-four high risk areas were located, determined on the basis of a composite of oil concentration and spill frequency. These included inland rivers (12 of them); open rivers (13); bays (5); channels (5); harbors (4); canals (3); and intracoastal waterways (2). There specific environmental characteristics -- current, tide, water and air temperature, wave heights, and wind -- are identified, discussed, and analyzed.

Descriptors: *Oil spills, *Ocean currents, Air water interactions, Control systems, Oil pollution, Concentration(Composition), Tidal currents, Wind, Environmental protection, Atmospheric temperature, Ocean waves, Atlantic Ocean, Pacific Ocean, Coastal regions, Inland waterways, Great Lakes, Rivers

Identifiers: Oil pollution control, Intracoastal waterways, NTISDODCG, NTISDOT

AD/A-000 452/3ST NTIS Prices: PC A06/MF A01

Joint Canada-United States Marine Pollution Contingency Plan for Spills of Oil and Other Noxious Substances

Coast Guard Washington D C (086450)
C3314J2 Fld: 13B, 68D, 92E GRAI7420
20 Jun 74 56p
Monitor: 18

Abstract: The Joint Canada-United States Marine Pollution Contingency Plan for Spills of Oil and Other Noxious Substances covers specific geographic areas where there may be a significant threat to the waters and coastal areas of both parties. The purpose of the Plan is to provide for coordinated and integrated response to pollution incidents by federal, state, provincial and regional plans of both parties. The Plan provides for pre-designated on-scene commanders and Deputy On-Scene Commanders who will coordinate the response activities to control a spill and for joint response teams to provide advice and assistance. It establishes alerting and notification procedures, command structure, post-clean-up requirements and arrangements for assuming the responsibility for the cost of operations.

Descriptors: *Oil spills, *United States, *Canada, *International relations, *Water pollution, Great Lakes, Information, Policies

Identifiers: Oil pollution, *Contingency plans, National borders, Public information, NTISDODCG

AD-782 895/7 NTIS Prices: PC E03/MF A01

Sources of Oil and Water In Bilges of Great Lakes Ships

Michigan Univ., Ann Arbor. Dept. of Naval Architecture and Marine Engineering. (401 188)

Environmental protection technology series
AUTHOR: Woodward, John B.
C3221G1 Fld: 13B, 13J, 68D, 47A GRAI7418
Jul 74 43p
Contract: EPA-R-802475
Project: EPA-ROAP-21BBU-03
Monitor: EPA-670/2-74-054

Abstract: Sources of bilge water and of oil in bilge water were surveyed aboard five ships of the Cleveland Cliffs Iron Company. The ships included two powered by steam turbines, one by a uniflow steam engine, one by a conventional reciprocating steam engine, and one by a diesel engine. It is found that many sources of bilge water are clean sources. Although no accurate estimate of the water thus contributed to the bilges can be offered, it is concluded that diverting these sources from the bilges could ease the task of separating, storing, and disposing of oil wastes. Several samples of water were taken from each ship, and analyzed for total, fixed and volatile non-filterable residue, color, pH, turbidity, total organic carbon, and oil and grease concentration.

Descriptors: *Tanker ships, *Oil pollution, Great Lakes, Reviews, Sources, Lubricating oils.

Identifiers: *Bilge water, NTISEPAERC

PB-233 846/5 NTIS Prices: PC A03/MF A01

Infrared, Radar, and Optical Applications of ERTS Data

Environmental Research Inst. of Michigan, Ann Arbor. Infrared and Optics Div.

Bimonthly rept. no. 8, 1 Jan-28 Feb 74
AUTHOR: Plocyn, F. C.; Thomson, F. J.; Bryan, M. Leonard; Sattinger, I.; Malila, W. A.
C3011D3 Fld: 93B GRAI7415
26 Mar 74 36p
Rept No: ERIM-193300-4-L
Contract: NAS5-21783
Monitor: NASA-CR-136902
Original contains color imagery. Original photography may be purchased from the EROS Data Center, 10th and Dakota Ave., Sioux Falls, S.D. 57198.

Colorado, Earth atmosphere, Lake Erie, Lake ice, Recreation, Land use, Lake Ontario, International field year for Great Lakes, Water quality, Oil slicks, Water pollution, Earth resources program, Infrared photography, Radar imagery, Optical data processing

Identifiers: NTISNASA

E74-10497 NTIS Prices: PC E03/MF A01

Joint Federal-State OF Michigan Conference on Pollution of Navigable Waters of the Detroit River, Lake Erie, and their Tributaries within the State of Michigan. Session (1st) Held at Detroit, Michigan on 27 March 1962. Volume I

Public Health Service, Washington, D.C. Div. of Water Supply and Pollution Control.
C2822C3 Fld: 13B, 68D GRAI7412
27 Mar 62 207p
Monitor: 18

Abstract: The report is on the conference on pollution of navigable waters of the Detroit River and Lake Erie and their tributaries for the state of Michigan for 1962. Included in the report are statements, recommendations, and discussions on: Municipal water supplies; recreational use of water resources; industrial wastes; characteristics of wastes; bacteriological examination of stream samples; and related information.

Descriptors: *Stream pollution, *Detroit River, *Lake Erie, *Meetings, Michigan, Industrial wastes, Coliform bacteria, Sewage, Suspended solids, Oil pollution, Bacteriology

Identifiers: Water quality data, EPAN

PB-231 340/1 NTIS Prices: PC E08/MF A01

Potential Oil Pollution Incidents from Oil and Gas Well Activities in Lake Erie - Their Prevention and Control

International Lake Erie Water Pollution Board.
C2791C1 Fld: 13B GRAI7412
Sep 69 165p
Monitor: 18

Abstract: The report determines the adequacy of drilling operations, clean up methods, and contingency plans to confine, remove, and prevent oil pollution on Lake Erie.

Descriptors: *Water pollution, *Oils, *Lake Erie, Offshore drilling

Identifiers: *Oil pollution, EPAO

PB-230 091/1 NTIS Prices: PC E07/MF A01

Use of ERTS-1 Data: Summary Report of Work on Ten Tasks

Environmental Research Inst. of Michigan, Ann Arbor. Infrared and Optics Div.

Progress rept. 1 Jul-31 Dec 73
AUTHOR: Thomson, Frederick J.; Polcyn, F. C.; Bryan, M. Leonard; Sattinger, I. J.; Malila, W. A.
C2464C3 Fld: 8B, 93A GRAI7408
25 Jan 74 80p
Rept No: ERIM-193300-37-P
Contract: NAS5-21783
Monitor: NASA-CR-136771
Original contains color imagery. Original photography may be purchased from the EROS Data Center, 10th and Dakota Ave., Sioux Falls, S.D. 57198.

Abstract: The author has identified the following significant results. Depth mapping's for a portion of Lake Michigan and at the Little Banama Bank test site have been verified by use of navigation charts and on--site visits. A thinteen category recognition map of Yellowstone Park has been prepared. Model calculation of atmospheric effects for various altitudes have been prepared. Radar, SLAR, and ERTS-1 data for flooded areas of Monroe County, Michigan are being studied. Water bodies can be reliably recognized and mapped using maximum likelihood processing of ERTS-1 digital data. Wetland mapping has been accomplished by slicing of single band and/or ratio processing of two bands for a single observation date. Both analog and digital processing have been used to map the Lake Ontario basin using ERTS-1 data. Operating characteristic curves were developed for the proportion estimation algorithm to determine its performance in the measurement of surface water area. The signal in band MSS-5 was related to sediment content of waters by modelling approach and by relating surface measurements of water to processed ERTS data. Radiance anomalies in ERTS-1 data could be associated with the presence of oil on water in San Francisco Bay, but the anomalies were of the same order as those caused by variations in sediment concentration and tidal flushing.

Resources management, Environmental quality, Yellowstone National Park(ID-MT-WY), Colorado, Great Lakes(North America), New York, San Francisco Bay(CA), Wyoming, Earth resources program, Water depth, Photomapping, Earth atmosphere, Land use , Recreation, Floods, Image enhancement, Water quality, Oil slicks, Pollution, Iron compounds

Identifiers: NASA

E74-10301 NTIS Prices: PC E03/MF A01

Evaluation of ERTS Data for Certain Oceanographic Uses

National Environmental Satellite Service, Washington, D.C.

Bimonthly rept. Nov-Dec 73
AUTHOR: Strong, Alan E.
C2463L3 Fld: 08H, 93A GRAI7408
Dec 73 3p
Contract: NASA Order S-70246-AG
Monitor: NASA-CR-136673

Abstract: The author has identified the following significant results. Upwelling along the eastern shore of Lake Michigan was occurring during the 3 and 21 August 1973 visits by ERTS-1. The NOAA-2 VHRR thermal-IR data are being digitized for comparison. Early indications are that these upwellings induced a calcium carbonate precipitate to form in the surface waters. It is most pronounced in the MSS-4 channel. On the lake bottom this jell-like sediment is known as marl and adds to the eutrophication of the lake. This phenomenon may help to explain the varve-like nature of bottom cores that have been observed in the Great Lakes.

Upwelling water, Great Lakes(North America), Water circulation , Water pollution, Earth resources, Oil slicks, Eutrophication , Calcium carbonates

Identifiers: NASA

E74-10287 NTIS Prices: PC A02/MF A01

Evaluation of ERTS Data for Certain Oceanographic Uses

National Environmental Satellite Service, Washington, D.C.

Semiannual rept. no. 3, May-Oct 73
AUTHOR: Strong, Alan E.
C2105D4 Fld: 8J, 93A GRAI7403
Oct 73 8p
Contract: NASA Order S-70246-AG
Monitor: NASA-CR-136005

Abstract: The author has identified the following significant results. (1) Sunglint effects over water can be expected in ERTS-1 images whenever solar elevations exceed 55 deg. (2) Upwellings were viewed coincidently by ERTS-1 and NOAA-2 in Lake Michigan on two occasions during August 1973. (3) A large oil slick was identified 100 km off the Maryland coast in the Atlantic Ocean. Volume of the oil was estimated to be at least 200,000 liters (50,000 gallons). (4) ERTS-1 observations of turbidity patterns in Lake St. Clair provide circulation information that correlates well with physical model studies made 10 years ago. (5) Good correlation has been established between ERTS-1 water color densities and NOAA-2 thermal infrared surface temperature measurements. Initial comparisons have been made in Lake Erie during March 1973.

Oceanography, Great Lakes(North America), Algae, Water temperature, Turbidity, Upwelling water, Oil slicks, Sunlight

Identifiers: NASA

E74-10093 NTIS Prices: PC A02/MF A01

Multidisciplinary Investigations Utilizing ERTS-1 Data

Environmental Research Inst. of Michigan, Ann Arbor. Infrared and Optics Div.

Bimonthly rept. no. 6, 1 Jul-31 Aug 73
AUTHOR: Thomson, Frederick J.; Polcyn, F. C.; Leonard Bryan, M.; Sattinger, I.; Malila, W. A.
C1883E3 Fld: 93B GRAI7324
19 Sep 73 101p
Rept No: ERIM-193300-24-L
Contract: NAS5-21783
Monitor: NASA-CR-135622
Original contains imagery. Original photography may be purchased from the EROS Data Center, 10th and Dakota Ave., Sioux Falls, S. D. 57198. ERTS.

Water depth, Yellowstone National Park(ID-MT-WY), Colorado, Lake ice, Land use, Recreation, Water quality, Iron compounds, Mapping, Oil slicks, Water pollution, Earth resources program, Image enhancement, International field year for Great Lakes, Atmospheric physics

Identifiers: NASA

E73-11119 NTIS Prices: PC E04/MF A01

ERIM Progress Report on Use of ERTS-1 Data: Summary Report of Work on Ten Tasks

Environmental Research Inst. of Michigan, Ann Arbor. (407 903)

Progress rept. 1 Jan-30 Jun 73
AUTHOR: Thomson, F. J.
C156113 Fld: 05B, 48C, 93A GRAI7320
Jul 73 141p
Rept No: ERIM197300-16-P
Contract: NAS5-21783
Monitor: NASA-CR-133556
Original contains color imagery. Original photography may be purchased from the EROS Data Center, 10th and Dakota Ave., Sioux Falls, S.D. 57198. ERTS.

Abstract: The author has identified the following significant results. Several of the tasks have produced significant results which are summarized: (1) Absolute water depth can be calculated from a ratio of signals from bands MSS-4 and MSS-5. (2) A 13 category terrain feature classification map of Yellowstone National Park has been produced using supervised pattern recognition techniques. (3) ERTS-1 data has been shown to provide a detection and monitoring capability for a number of water quality problems associated with off-shore ocean dumping sites and inland lakes. (4) A corrected ratio of bands MSS-5 and MSS-7 signals has been formed. (5) A concise format has been devised for storing the ratio signatures of geologic rock and mineral materials determined from laboratory reflectance spectra. (6) Results of work in information extraction demonstrate: signal variability exists among ERTS-1 detectors in any one spectral band that will impact users doing quantitative analysis on successive ERTS-1 images; a newly developed computer-aided procedure for correlating ERTS-1 pixels to ground features; the strong influence of atmospheric effects in ERTS-1 data; and area estimation accuracies are better using the ERIM proportion estimation algorithm than for conventional recognition techniques.

Earth Resources, Environmental quality, Multispectral band scanners, Earth resources program, Water depth, Yellowstone National Park(ID-MT-WY), Colorado, Land use, Recreation, Great Lakes(North America), Water quality, Iron compounds, Mapping, Wyoming, Oil slicks, Water pollution

Identifiers: NASA

E73-10899 NTIS Prices: PC E06/MF A01

Research Prospectus for Marine Pollution Control in the Great Lakes

Kearney (A. T.) and Co., Inc., Chicago, Ill. (390 410)

C084281 Fld: 13B, 13J, 68D*, 60G, 86L GRAI7312
Aug 72 209p
Contract: C-2-36268
Monitor: MA-RD-900-73-009
Prepared in cooperation with Cleveland-Cliffs Iron, Co., Cleveland, Ohio.

Abstract: The prospectus reviews and summarizes the present status of the marine pollution problems on the Great Lakes and their relation to the merchant ships operating thereon, including municipal laws, state laws, and EPA implementation of the Water Quality Act of 1970 and other Federal legislation, and Canadian legislation. The prospectus recommends research in certain areas and outlines the projects needed for soliciting requests for proposals.

Descriptors: (*Great Lakes, *Water pollution), (*Ships, *Waste disposal), Cargo ships, Law(Jurisprudence), Legislation, Oils, Sewage, Noise, Hazardous materials, Garbage, Exhaust gases, Equipment, Naval architecture, Harbor facilities, Research projects, Recommendations

Identifiers: *Water pollution abatement, *Water pollution control, Oil pollution control, MA

COM-73-10677 NTIS Prices: PC A10/MF A01

Processing and Analysis of ERTS-1 Remotely Sensed Data

Michigan Univ., Ann Arbor. Environmental Research Inst.

Bimonthly rept. 1 Jan-28 Feb 73
AUTHOR: Thomson, Frederick J.
C0771J2 Fld: 05B, 93A GRAI7311
15 Mar 73 53p
Rept No: 193300-6-L
Contract: NAS5-21783
Monitor: NASA-CR-131053
Original contains imagery. Original photography may be purchased from the EROS Data Center, 10th and Dakota Ave., Sioux Falls, S.D. 57198.

Abstract: Research progress on the processing, analysis, and management of ERTS-1 data is reported. Subject areas covered are: (1) water depth measurement in Little Bahama Bank; (2) terrain classification mapping of Yellowstone National Park, Wyoming; (3) atmospheric effects on ERTS-1 data; (4) lake ice surveillance in Michigan; (5) application of dielectric constant measurements to radar imagery interpretation; (6) recreational land use in Michigan; (7) IFYGL data on Lake Ontario and its drainage basin; (8) advanced information extraction techniques; (9) water quality monitoring in New York Bight and Tampa Bay areas; (10) oil pollution detection in Gulf of Mexico and waters off Salem, Massachusetts and Oakland, California; and (11) mapping iron ore deposits in Wind River Range, Wyoming. For individual titles, see E73-10388 through E73-10397.

Imagery, Data processing, Data management, Earth resources program, Water depth, Mapping, Yellowstone National Park(Id-Mt-Wy), Earth atmosphere, Lake ice, Radar imagery, Dielectric properties, Land use, International Field Year for Great Lakes, Image enhancement, Information retrieval, Water quality, Oil slicks, Water pollution, Iron ores, Mineral exploration, Wind River Range(Wy)

Identifiers: NASA

E73-10387 NTIS Prices: PC E02/MF A01

U.S. Foreign Trade Bunker Fuels. Oil and Coal Laden in the United States on Vessels Engaged in Foreign Trade. November 1972-October 1973

Bureau of the Census, Washington, D.C. (069 350)

Monthly repts.
C0563J2 Fld: 5C, 96C, 86I, 87E GRAI7308
1973 12 issues
Rept No: FT-810-72-11--FT-810-73-10
Monitor: 18

Paper copy available from Bureau of the Census, Washington, D.C. 20233, $1.00/year, $0.10/copy.

Abstract: The report presents statistics on total value and total quantity of oil and coal of both domestic and foreign origin laden on vessels of United States and foreign registry engaged in foreign trade and on Canadian vessels passing from the one U.S. port to another in the trade on the Great Lakes, and quantity of customs districts lading. Data in this report are not included in U.S. export statistics.

Descriptors: (*International trade, *Fuels), (*Fuels, Water transportation), Bunker oils, Coal, Canada, Great Lakes, Puerto Rico

Identifiers: Customs districts

COM-73-70008 NTIS Prices: PC-CENSUS

Chicago Coastal Region Multi-Agency Oil and Hazardous Materials Pollution Contingency Plan

Coast Guard District (9th) Cleveland Ohio (407867)
C0524A4 Fld: 13B, 68D GRAI7308
31 Dec 72 317p
Monitor: 18
Includes Change 3.

Abstract: The plan represents an agreement among concerned Departments and agencies of the Federal Government, state and local governments, and private groups for a pattern of coordinated and integrated response to pollution spills. It establishes a regional response team and provides guidelines for the establishment of sub-regional contingency plans and response teams. The plan provides for appropriate preventive and preparedness measures and systems for discovering and reporting the existence of a pollution spill; measures to restrict the further spread of the pollutant; adequate protection; to assure the public health and welfare; techniques to cleanup and dispose of the collected pollutants; a scientific response to spills as appropriate; strike forces of trained personnel and adequate equipment to respond to polluting spills; and actions to recover cleanup costs and to effect enforcement of existing Federal statutes and regulations issued thereunder. The geographic area covered by this plan is the Chicago Coastal Region.

Descriptors: (*Water pollution, *Accidents), Management planning, Law, Response, Oils, Hazards, Classification, Cleaning, New York, Pennsylvania, Minnesota, Michigan, Indiana, Ohio, Illinois, Wisconsin, Great Lakes

Identifiers: *Oil pollution control, Water pollution control, Water pollution detection, *Hazardous materials, *Contingency plans, Government policies

AD-756 233 NTIS Prices: PC A14/MF A01

Oswego Steam Station, Unit 5, Niagara Mohawk Power Corporation, New York

Army Engineer District, Buffalo, N.Y.

Final environmental impact statement.
A389302 Fld: 13B, 68 GRAI7208
17 Feb 72 220p
Monitor: ELR-1968
Supersedes report dated 15 Nov 71, PB-204 155-D.

Abstract: The construction of a fifth oil-fueled electric generating unit with intake and discharge structures, together with other appurtenances is proposed. The following environment impacts are anticipated: Occupation of approximately ten acres of land, discharge of quantities of heat, air-borne emissions, liquid effluents and sound energy, and the receipt and consumption of approximately 9 million barrels of fuel oil per year. All impacts listed above are to some degree environmentally adverse except the receipt of fuel oil. The receipt and handling of the fuel oil are potentially adverse. (Author)

Descriptors: (*Environmental surveys, *Electric power plants), (*New York, Environmental surveys), Thermal power plants, Steam electric power generation, Heat, Water pollution, Air pollution, Combustion products, Fuel oil, Fueling systems, Noise(Sound), Great Lakes

Identifiers: *Oswego Generating Station, *Oswego(New York), Oil pollution, Thermal pollution, Lake Ontario, *Environmental impact statements

PB-204 155-F NTIS Prices: PC A10/MF A01

Oswego Steam Station, Unit 5, Niagara Mohawk Power Corporation, New York

Army Engineer District, Buffalo, N.Y.

Draft environmental impact statement.
A3263E1 Fld: 13B, 68 GRAI7201
15 Nov 71 195p

Abstract: The statement concerns the construction of a fifth oil-fueled electric generating unit with intake and discharge structures, together with other appurtenances at the Oswego Steam station in Oswego, New York on Lake Ontario. The project will include the occupation of approximately ten acres of land, discharge of quantities of heat, air-borne emissions, liquid effluents and sound energy, and the receipt and consumption of approximately 9 million barrels of fuel oil per year. All impacts listed above are to some degree environmentally adverse except the receipt of fuel oil. The receipt and handling of the fuel oil are potentially adverse.

Descriptors: (*Environmental surveys, *Electric power plants), (*New York, Environmental surveys), Thermal power plants, Steam electric power generation, Heat, Water pollution, Air pollution, Combustion products, Fuel oil, Fueling systems, Noise(Sound), Great Lakes

Identifiers: *Oswego Generating Station, *Oswego(New York), Oil pollution, Thermal pollution, Lake Ontario

PB-204 155-D NTIS Prices: PC A09

PARTICLE SIZE DISTRIBUTION OF CHLORINE AND BROMINE IN MID-CONTENT AEROSOLS FROM THE GREAT LAKES BASIN

Michigan Univ., Ann Arbor. Dept. of Meteorology and Oceanography. (228 715)
AUTHOR: Loucks, Ronald H.; Winchester, John W.
A11B2G3 Fld: 13B, 4A, 68A, 55E NSA2420
Aug 69 181p
Contract: AT(11-1)-1705

Descriptors: (*Chlorine, *Air pollution), (*Bromine, Air pollution), (*Atmospheric physics, *Halogens), (*Combustion products, Halogens), Aerosols, Cloud physics, Gasoline, Coal, Fuel oil, Sampling, Great Lakes

COO-1705-5 NTIS Prices: HC A09/MF A01

Report of the Symposium on Prevention of Marine Pollution From Ships Held in Acapulco, Mexico 22-31 March 1976

Inter-Governmental Maritime Consultative Organization London (England) (409234)
D0131K1 Fld: 13B, 8J, 68D, 47A, 85G GRAI7701
Apr 76 1437p
Monitor: USCG-WEP-1-77

Abstract: ;Contents: General Review of the 1973 Convention, National and Regional Arrangements; Construction, Equipment and Operation of Chemical Tankers; Segregated Ballast Tankers; Oily-Water Separators and Oil Monitoring and Control Equipment; Operation of Oil Tankers; Reception Facilities in Ports; Sewage and Garbage from Ships; Contingency Planning; Measures for Control, Detection and Data Collection; and Methods for Dealing with Spillages.

Descriptors: *Water pollution, *Pollution abatement, *Symposia, *Oil pollution, Ship design, Shipboard sewage treatment systems, Hazardous materials transportation, International relations, Monitoring, Oil spills, Separators, Ballast tanks, Ocean waste disposal, Ocean environments, Information systems, Accidents, Tankers, Harbors, Waste disposal, Chemicals, Great Lakes, Remote detectors, Labeled substances

Identifiers: Reviews, *Ships, NTISDODXA, NTISDOTCG

AD-A031 581/2ST NTIS Prices: PC A99/MF A01

Proceedings of the International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterway (4th)

Coast Guard Washington D C Office of Research and Development (408731)
C6445L4 Fld: 15E, 13L, 68D*, 99B*, 85D*, 47A GRAI7612
Oct 75 619p
Rept No: USCG-D-24-76
Monitor: 18
Includes 24 pages of film negatives.

Abstract: This volume contains the papers, list of authors and list of registrants for the fourth International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterways. The Symposium was held 26 - 30 October 1975 in Jacksonville, Florida. The Fourth International Symposium on Transport of Hazardous Cargoes by Sea and Inland Waterways was held in Jacksonville, Florida, October 26-30, 1975 under the auspices of the U.S Coast Guard, with the scientific assistance of the National Academy of Sciences-National Research Council Committee on Hazardous Materials. Approximately three-hundred people from 14 countries registered and attended the four days of plenary sessions.

Descriptors: *Water traffic, *Hazardous materials transportation, *Safety, *Symposia, Marine transportation, Inland waterways, Hazards, Cargo, Materials handling, Toxicity, Explosions, Fire hazards, Disasters, Flammability, Water pollution, Oil spills, Shipping containers, Risk analysis, Emergencies, Tankers, Coastal regions, Great Lakes, Information systems

Identifiers: *Hazardous materials transportation, Hazardous materials spills, Contingency planning, Chemical industry, *Transportation safety, NTISDODXA, NTISDODCG, NTISDOTCG

AD-A023 505/1ST NTIS Prices: PC E08/MF A01

Lake Erie Offshore Drilling

New York State Senate, Albany. Committee on Corporations, Authorities, and Public Utilities.
D3073F3 Fld: 21D, 81, 97K, 48A GRAI7719
17 Feb 76 36p
Monitor: 18
Microfiche copies only.

Abstract: ;Contents: History; Natural gas potential in the New York portion of Lake Erie; New York state dependence on natural gas; Economic impact; Impact on employment; Cost of alternative fuels; Fiscal impact; The natural gas market; Environmental considerations; Safety equipment; Scenery pollution; Hazards to navigation.

Descriptors: *Offshore drilling, *Natural gas, *Lake Erie, Offshore operations, History, Economic impact, Market research , Environmental impacts, Safety, New York

Identifiers: NTISSLLCM

PB-268 613/7ST NTIS Price: MF A01

Workshop on Energy Resources and Electric Power Generation for High School Science Teachers. Final Report

Ohio State Univ., Columbus. (4898000)
AUTHOR: Glower, D. D.
C6314G2 Fld: 10A, 05I, 97A ERA0102
Sep 75 512p
Contract: E(11-1)-2449
Monitor: 18

Abstract: Science teachers spent 15 days learning about and preparing classroom material on applied and philosophical energy-associated problem areas. The available energy resources and the available energy applicable in the short-run and long-run time period were analyzed with regard to location and magnitude of resource. For example, the conversion systems to transform uranium from the ore to electric power were discussed in detail and tours to power sites reinforced the lecture and laboratory instruction. Similarly, coal and other fossil-fueled systems were discussed, and mining and drilling sites were visited. The workshop was designed to allow approximately 5 days concentration on nuclear energy systems, 5 days on fossil energy systems, and 5 days during which the material could be pulled together by the teacher into a format that would be applicable to the particular teacher's classroom. Those teachers who were department heads prepared material for use by their staff. The nuclear sessions were held at The Ohio State University's Lake Erie Laboratory, since this facilitated work with the lake as a heat sink and since the David Besse Nuclear Power Plant was close by. The last 10 days of the workshop were held in southeastern Ohio in the coal-mining region. The 15-day time period appeared to be approximately the correct length of time to complete the workshop goals, since most teachers left the workshop with material that will have a significant impact on their classroom work during the coming year.

Descriptors: (*Energy sources, *Education), (*Power generation , Education), (*Electric power, Education), (*Energy supplies, Education), Availability, Coal mining, Conversion, Drilling, Fossil fuels, Heat sinks, Lake erie, Nuclear fuels, Nuclear power plants, Uranium ores

Identifiers: ERDA/293800, ERDA/296500, ERDA/200100, NTISERDA

COO-2449-1 NTIS Prices: PC A22/MF A01

Behavior of Plutonium and Other Long-Lived Radionuclides in Lake Michigan. II. Patterns of Deposition in the Sediments

Argonne National Lab., Ill. (0448000)
AUTHOR: Edgington, D. N.; Robbins, J. A.
C5693J1 Fld: 8H, 68F, 68D NSA3210
1975 18p
Rept No: SM-198/40
Contract: W-31-109-eng-38
Monitor: 18

Abstract: At present eight operating nuclear power reactors are situated along the shores of Lake Michigan. Since their releases of radioactivity have been much less than that entering the lake from stratospheric fallout, exp 239 exp 240 Pu and exp 137 Cs from the latter source have been measured in order to attempt to predict the depositional patterns of long-lived radionuclides in the lake. Ninety-seven percent of the exp 239 exp 240 Pu and ninety-five percent of the exp 137 Cs that has entered the lake by wet and dry deposition of atmospheric fallout now reside in the sediments. The vertical distribution of exp 137 Cs has been measured in 60 sediment cores, and exp 239 exp 240 Pu in 14 cores taken from all over the lake. The sampling locations were chosen to be representative of the various types of sedimentation, i.e., areas with high sedimentation associated with river inputs, offshore locations where organic-rich, very finegrained material is settling out, and areas of low sedimentation where erosion may be occurring. Results of the studies are discussed.

Descriptors: (*Plutonium 239, *Sedimentation), (*Plutonium 240, Sedimentation), (*Cesium 137, Sedimentation), (*Lake michigan, *Radioactivity), Diffusion, Drill cores, Fallout deposits, Radionuclide migration, Sampling, Sediments, Time dependence

Identifiers: NTISERDA

CONF-750662-1 NTIS Prices: PC A02/MF A01

Potential Oil Pollution Incidents from Oil and Gas Well Activities in Lake Erie - Their Prevention and Control

International Lake Erie Water Pollution Board.
C2791C1 Fld: 13B GRAI7412
Sep 69 165p
Monitor: 18

Abstract: The report determines the adequacy of drilling operations, clean up methods, and contingency plans to confine, remove, and prevent oil pollution on Lake Erie.

Descriptors: *Water pollution, *Oils, *Lake Erie, Offshore drilling

Identifiers: *Oil pollution, EPAO

PB-230 091/1 NTIS Prices: PC E07/MF A01

Geologic Cross Sections Derived from Seismic Profiles and Sediment Cores from Southern Lake Michigan

Wisconsin Univ., Madison. Dept. of Geology and Geophysics. (404 560)
AUTHOR: Meyer, Robert P.; Lineback, J. A.; Gross, D. L.
C0402G2 Fld: 8G, 64F, 86M GRAI7306
1972 47p
Rept No: WIS-SG-72-328, Contrib-286
Monitor: NOAA-72121206
Report on Sea Grant Program. Report on Studies of Lake Michigan Bottom Sediments, Number 9.
Pub. in Environmental Geology Notes, n54 43p Aug 72.

Abstract: High-resolution seismic profiles and cores of bottom sediments have been used in the construction of geologic cross sections of southern Lake Michigan. Major stratigraphic units of the Pleistocene and the surface of the underlying Paleozoic bedrock can readily be distinguished. Cross sections across the central part of the southern lake basin show that the Lake Michigan Formation is thick in the deep central part of the basin and in a band along the eastern shore. Cross sections in the extreme southern part of the lake indicate the Lake Michigan Formation thins southward. They also show that the formation is thick along the eastern shore but absent in the southwestern corner of the lake. Cross sections in the northern part of southern Lake Michigan (near Milwaukee, Wisconsin) cross the Mid-lake High. They show high relief on the bedrock surface, differentiate a thick glacial till, and indicate that in this area the Lake Michigan Formation is confined to low spots on the lake floor. (Author)

Descriptors: (*Geologic surveys, *Lake Michigan), Sedimentology, Stratigraphy, Seismic prospecting, Drill core analysis, Statistical data

Identifiers: Sea Grant program

COM-73-10153 NTIS Prices: Reprint

LATE-GLACIAL AND POSTGLACIAL SEDIMENTATION IN THE DEEP BASINS OF LAKE SUPERIOR, U.S.A

Michigan Univ., Ann Arbor. Dept. of Geology and Mineralogy.
(400 850)
AUTHOR: Farrand, William R.
576281 Fld: 8G USGRDR6908
1967 20p
Grant: NSF-GA-622
Presented at the International Symposium on Paleolimnology, Tihany, Hungary, 28-31 Aug 67.

Abstract: The study is based on some 100 cores--11 long cores taken by means of a shipboard rotary drilling rig and 90 shorter cores taken by means of a normal piston corer-- all from water depths of 150 to 350 meters. The long cores penetrated 15 to 200 meters of unconsolidated sediments and reached bedrock in 4 locations. The sediment sequence is, from bottom to top, (a) red till and outwash sand, (b) red lacustrine clay, upper part varved, (c) gray varved clay and (d) gray and brown massive clays. Although this sequence appears to date simply from Late-Wisconsin and postglacial time, our subbottom soundings suggest that pre-Wisconsin Pleistocene sediments may be present locally in some deep troughs. (Author)

Descriptors: (*Geologic age determination, Great Lakes), (*Sedimentation, Great Lakes), Stratigraphy, Paleontology, Deposits, Glaciers, Drilling, Thickness, Deep water, Echo ranging, Depth finding, Seismic waves, Chemical properties, Sand, Clay, Silt

Identifiers: Lake Superior

PB-182 480 CFSTI Prices: PC A02/MF A01

APPENDIX: GREAT LAKES TANKER AND TANKBARGE DATABASE, 1979

The following data were obtained from a variety of sources. In many cases, minor discrepancies between sources were rectified. The vessels listed were in service either on the Great Lakes (exclusively) at the end of 1978, or had delivered or received cargoes on the Great Lakes - St. Lawrence Seaway System during the year.

The principal sources of the data were as follows:

American Bureau of Shipping Record

Lloyd's Register of Shipping

U.S. Army Corps of Engineers Transportation Lines on the Great Lakes System

The Tanker Register

Great Lakes Red Book

Annual Report of the Lake Carriers' Association

All relevant codes for the data are included in the listing that follows.

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***** GREAT LAKES AND ST. LAWRENCE SEAWAY TANKER DATABASE *****
***** AS OF JANUARY 1979 *****
***** RESTRICTED TO WELLAND CANAL DIMENSIONS *****

NAME	T	N	YEAR	ENG	DWT	LENGTH	BEAM	DEPTH	DRAFT	GRT	SHP	SPD
***** ALLIED BUNKERING SERVICE, DIVISION OF ASHLAND OIL, INC., BUFFALO, NY *****												
L.G. LADUCA II	1	1	1966	1 T	900	125.60	32.20	14.30	.	402	700	
***** ANCO TANKER SERVICE, STOCKHOLM SWEDEN *****												
ANCO DUCHESS	1	3	1968	1	17630	525.33	68.29	38.75	30.00	11102	9000	16.0
ANCO DUKE	1	3	1968	1	17630	525.33	68.29	38.75	30.00	11102	9000	16.0
***** AMOCO OIL COMPANY, WHITING, IN *****												
AMOCO ILLINOIS	1	1	1918	3	8500	420.00	55.00	25.50	22.92	5429	2400	13.3
AMOCO INDIANA	1	1	1937	3	8613	453.33	55.00	25.50	21.17	5443	2500	14.0
AMOCO WISCONSIN	1	1	1930	3	7100	350.00	53.42	24.50	21.88	4432	2400	13.8
AMOCO A-51	2	1	1964		1965	255.00	50.00	12.50	10.00	2267		
AMOCO A-52	2	1	1964		1965	250.00	50.00	12.50	10.00	2254		
AMOCO A-53	2	1	1965		1965	253.00	50.00	14.00	10.00	2482		
AMOCO A-54	2	1	1964		1965	253.00	50.00	14.00	10.00	2482		
AMOCO A-55	2	1	1968		2232	270.00	50.00	14.00	9.00	2356		
AMOCO A-56	2	1	1968		2232	270.00	50.00	14.00	9.00	2360		
***** ATLANTIC-RICHFIELD OIL CO., HARTFORD, IL *****												
FUEL OIL	1	1	1964	1 T	750	146.00	30.00	12.25	.	386	450	
GARY	1	1	1931	1E	1160	155.00	34.00	12.00	10.15	608	375	
GREAT LAKES	1	1	1963	1 T	4520	330.00	50.00	22.00	16.88	2813	3200	
***** BIGANE VESSEL FUELING CO., CHICAGO, IL *****												
JOS. F. BIGANE	1	1	1973	1	565	127.33	40.00	14.00	13.00	493	400	
***** BRANCH LINES LTD., SOREL, PQ *****												
ARSENE SIMARD	1	2	1972	1	8200	400.08	60.50	28.00	22.42	5844	4390	14.0
ARTHUR SIMARD	1	2	1973	1	9033	400.08	60.50	28.00	22.50	5918	4450	14.0
CEDARBRANCH	1	2	1951	1	4000	284.42	43.50	20.00	.	2439	1600	
EDOUARD SIMARD	1	2	1961	1	7200	388.00	52.00	28.00	22.45	5104	4000	13.5
JOS. SIMARD	1	2	1964	1	7153	388.00	53.58	28.08	22.43	5102	5040	13.5
LEON SIMARD	1	2	1974	1	9033	400.00	60.00	28.00	.	5890	4389	
LUDGER SIMARD	1	2	1970	1	7336	388.00	53.67	28.00	22.75	5114	4900	14.0
MAPLEBRANCH	1	2	1958	1	6553	352.00	52.17	27.33	22.69	4491	3200	12.0
WILLOWBRANCH	1	2	1950	1	4041	251.00	43.50	20.00	.	2445	1600	
***** CLEVELAND TANKERS INC., CLEVELAND, OH *****												
GEMINI	1	1	1978	1 T	9710	419.00	65.00	29.00	22.50	6700	5000	12.0
JUPITER	1	1	1976	1 T	8700	352.00	60.00	25.00	19.50	4500		
PHOENIX	2	1	1969		6372	341.00	54.00	22.00	17.87	3275		
SATURN	1	1	1974	1 1	7150	374.29	54.50	25.00	19.34	3904	3000	
***** HANNAH INLAND WATERWAYS CORP., LEMONT, IL *****												
HANNAH 2001	2	1	1951		2800	240.00	52.42	12.00	8.51	1368		
HANNAH 2002	2	1	1951		2800	240.00	52.42	12.00	8.51	1368		
HANNAH 2003	2	1	1951		2800	240.00	52.42	12.00	8.51	1368		
HANNAH 2004	2	1	1951		2800	240.00	52.42	12.00	8.51	1368		

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HANNAH 2903	2 1 1962		4203	264.00	52.42	12.50	10.13	1702			
HANNAH 3101	2 1 1962		4968	264.00	52.60	18.00	13.80	1878			
HANNAH 3102	2 1 1962		4968	264.00	52.60	18.00	13.80	1878			
HANNAH 3601	2 1 1972		5793	290.00	60.00	20.80	15.04	2369			
HANNAH 5101	2 1 1975		8200	340.00	60.00	22.50	18.31	3356			
***** HALL CORPORATION, MONTREAL, PC *****											
GULF CANADA	1 2 1952	2	15425	520.00	68.33	35.08	26.81	10900	5175	12.8	
GULF GATINEAU	1 2 1976	1	9950	432.00	60.00	28.00	.	6350			
GULF MACKENZIE	1 2 1976	1	9950	432.00	60.00	28.00	.	6350			
BAFFIN TRANSPORT	1 2 1955	1	16358	500.00	69.50	38.00	.	10701	5500		
CHEMICAL TRANSPORT	1 2 1969	1 T	8290	370.00	55.33	27.50	21.81	4981	3332	12.5	
DOAN TRANSPORT	1 2 1972	1	10560	359.25	62.33	34.46	.	6285	6000	15.0	
FROBISHER TRANSPORT	1 2 1962	1	11000	426.50	59.08	30.50	.	5650	9400		
HUDSON TRANSPORT	1 2 1962	1 T	7280	335.92	46.00	31.00	.	4076	3200		
INDUSTRIAL TRANSPORT	1 2 1969	1 T	8250	370.00	55.33	27.50	21.81	4982	3332	12.5	
JAMES TRANSPORT	1 2 1967	1 T	7460	350.00	55.16	27.50	21.00	4700	5000	13.0	
SEA TRANSPORT	1 2 1966	1	5381	339.00	47.50	26.92	.	3884	4620		
UNGAVA TRANSPORT	1 2 1959	1	8500	375.00	55.50	28.50	.	5115			
***** IMPERIAL OIL LTD., TORONTO, ON *****											
IMPERIAL ACADIA	1 2 1967	1	10310	412.92	60.15	31.02	25.54	7068	5326	13.5	
IMPERIAL BEDFORD	1 2 1969	1	13980	459.92	70.17	33.25	26.56	9500	6410	13.5	
IMPERIAL COLLINGWOOD	1 2 1948	3U	4016	318.75	43.33	18.15	16.56	2620	1200		
IMPERIAL DARTMOUTH	1 2 1970	1 T	2045	200.00	40.00	16.00	13.25	1192	750		
IMPERIAL LACHINE	1 2 1963	1 T	1243	168.25	36.00	14.00	.	734	750		
IMPERIAL QUEBEC	1 2 1957	1	6462	351.92	52.00	27.08	22.56	4680	2560	11.0	
IMPERIAL ST. CLAIR	1 2 1974	1	12507	415.00	74.00	32.00	.	7964	6500		
IMPERIAL SARNIA	1 2 1948	2	6724	385.00	53.10	26.00	21.43	4947	2900		
IMPERIAL VERDUN	1 2 1963	1 T	1243	168.25	36.00	14.00	.	734	750		
***** JOHNSTONE SHIPPING LTD., TORONTO, ON *****											
CONGAR	1 2 1946	1	5307	336.00	48.00	26.75	.	3734	2500		
***** KENT LINE, ST JOHN, NB *****											
AIME GAUDREAU	1 2 1964	1	2660	310.76	41.00	21.00	.	1903	2880		
HI060	1 2 1964	2	32413	649.00	75.42	48.00	37.18	21372	13750	15.0	
HI070	1 2 1966	2	30360	649.00	75.25	48.00	35.98	21200	17500	15.5	
IRVING GLEN	1 2 1956	1	19936	547.92	70.54	40.00	30.91	13184	8750	14.5	
IRVING MARIGOLD	1 2 1972	1 1	4772	276.46	58.00	19.17	15.25	2427	1980		
IRVING OURS POLAIRE	1 2 1964	1	7500	365.00	52.08	28.00	22.58	4944	4200	14.0	
IRVINGSTREAM	1 2 1952	1	23555	561.58	75.25	42.50	32.89	15185	8100	15.0	
***** LIQUID CARRIERS CORP., NEW YORK, NY *****											
ATLANTIC	2 1 1951		1973	235.00	42.00	15.00	11.99	1038			
HURON	2 1 1959		1600	237.58	43.42	14.83	11.57	1123			
***** MARINE FUELING DIVISION, REISS OIL CO., CLEVELAND, OH *****											
MARINE FUEL OIL	1 1 1960	1 1	575	116.75	31.50	11.50	.	296	440		
MARINE FUEL II	1 1 1926	1	175	100.00	19.10	9.00	.	120	140		
WILLIAM H. BENNETT	1 1 1950	1	240	95.00	26.00	9.08	7.80				
REISS MARINE	1 1 1978	1 T	1190	145.66	39.17	14.50	10.80	569	1300	10.0	
K-10	2 1 1949		38	35.60	20.40	4.00	3.00	26			
MARINE FUELER	2 1 1923		750	144.00	27.00	11.50	9.28	357			
MO-643	2 1 1940		1200	195.00	35.00	10.00	8.35	664			

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MOBIL NEW YORK	1	1	1934	1		2840	289.00	40.00	18.00	14.00	1546		
***** NATOMAS CANADA LTD., MONTREAL, PQ *****													
WINOC	1	2	1930	1	T	2350	253.00	43.59	19.92	.	1877	1000	
***** SHELL CANADIAN TANKERS LTD., TORONTO, ON *****													
NORTHERN SHELL	1	2	1954	1		19750	538.17	73.17	38.25	30.77	12608	8500	14.3
ARCTIC TRADER	1	2	1958	1		4361	295.00	24.51	20.08	.	2701	2000	
BAYSHELL	1	2	1967	1	T	1809	199.00	40.00	14.33	11.66	1072	1000	
EASTERN SHELL	1	2	1962	1	T	5853	335.25	46.00	24.50	.	4009	3200	
FUEL MARKETER	1	2	1944	1	T	3580	251.50	43.83	20.00	.	2404	1000	
LAKESHELL	1	2	1969	1		8560	375.00	60.75	29.75	23.28	5275	4000	13.1
***** TEXACO CANADA LTD., MONTREAL, PQ *****													
TEXACO BRAVE	1	2	1977	1		9000							
TEXACO CHIEF	1	2	1969	1		6885	365.75	55.17	26.50	21.50	5038	4000	13.0
TEXACO WARRIOR	1	2	1970	1		5013	305.75	47.00	24.00	21.33	3295	2900	
***** ASHLAND OIL CO., DETROIT, MI *****													
FUELOIL	2	1	1934			540	152.75	23.94	10.46	8.33	298		
***** GAMBLE SHIPYARDS, PORT DOVER, ON *****													
HUSKY 120	1	2	1939	1		350	130.00	20.00	8.50	.	222	330	
***** ANDERSON TRANSIT CO., WASHINGTON ISLAND, WI *****													
GRIFFIN	1	1	1946	1			65.25	26.25	12.50				
***** DET DANSK* FRANSKE, COPENHAGEN, DENMARK *****													
IRLAND	1	3	1964	1		1990	261.33	41.17	17.08				
***** PARCEL TANKER SERVICE, CSLC, NORWAY *****													
STOLT CROWN	1	3	1970	1		18130	509.33	71.50	40.00	31.06	11235	9800	15.0
STOLT CONDOR	1	3	1958	1		20815	557.75	71.79	40.00	31.06	12649	9000	15.5
STOLT SYDNESS	1	3	1971	1		18200	520.25	71.50	40.00	31.06	11065	9800	15.0

NOTES:

T=VESSEL TYPE: 1=TANKSHIP, 2=TANKBARGE.
N=NATIONALITY: 1=U.S., 2=CANADIAN, 3=OTHER.
ENG=MACHINERY TYPE: 1=DIESEL, 2=STEAM TURBINE, 3=STEAM RECIPROCATING
E=ELECTRIC DRIVE , U=SKINNER UNIFLOW
T=TWIN SCREW.

ALL DIMENSIONS IN FEET. DEADWEIGHT: LONG TONS (2240 LB).