MASTER

Contract No. E(04-3)-1175

January 11, 1977

DRAFT REPORT
ENERGY USE IN THE MARINE
TRANSPORTATION INDUSTRY
TASK I - INDUSTRY SUMMARY

1175 8-2

Division of Transportation Energy Conservation
Non-Highway Transport Systems
Energy Research and Development Administration
20 Massachusetts Avenue
Washington, D.C. 20545

BOOZ · ALLEN & HAMILTON Inc.

Management Consultants

4733 BETHESDA AVENUE
BETHESDA, MARYLAND 20014
656-2200
AREA CODE 301

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4733 BETHESDA AVENUE
BETHESDA, MARYLAND 20014
656-2200
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Mr. Richard Alpaugh
Division of Transportation Energy
Conservation
Non-Highway Transport Systems
Energy Research and Development
Administration
20 Massachusetts Avenue, N.W.
Washington, D.C. 20545

Subject: <u>Draft Report Task I - Energy Use in the Marine Transportation Industry - Industry Summary</u>

Dear Dick:

We are pleased to submit our draft Task I report entitled, "Energy Use in the Marine Transportation Industry - Industry Summary." As per your request, we are enclosing 25 copies for your use. Three copies have been forwarded to Ms. E. Romo in ERDA Oakland as required by the contract.

As agreed earlier, the model developed during Task I is being documented in a separate report. If you have any questions concerning this report or the conclusions reached as a result of the analysis please do not hesitate to call Mr. Leo Donovan or myself at (301) 656-2200.

Very truly yours,

BOOZ · ALLEN & HAMILTON Inc.

John G. Blackburn
Project Manager

Approved:

Leo J. Donovan
Research Director

Enclosures

cc: E. Romo

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I. INTRODUCTION AND SUMMARY

I. INTRODUCTION AND SUMMARY

This report covers the first of four tasks of an energy study of ship transportation systems conducted for the Transportation Conservation Division of the Energy Research and Development Administration (ERDA) by Booz, Allen & Hamilton's Transportation Consulting Division. The objective of each of these tasks is as follows:

- Task 1. Develop a Marine Transportation Industry profile in terms of equipment, costs, operating profiles and energy consumption.
- Task 2. Identify the roles of all government and quasi-government agencies that impact energy use in the Marine Transportation Industry.
- Task 3. Identify existing and expected R&D programs that could impact energy use in the Marine Transportation Industry.
- Task 4. Evaluate alternative industry futures in the operational, regulatory and technological areas to determine the overall energy impact of each scenario.

The output of this study is intended to assist ERDA in developing the baseline information needed to formulate R&D programs in the marine transportation sector.

1. OBJECTIVE OF TASK 1

The objective of Task 1 of this study is to identify the various operating or service sectors of the Marine Transportation Industry and determine the numbers and types of vessels, their operating characteristics and energy consumption. This analysis includes all powered waterborne craft, with the exception of those owned or operated by a government organization and fixed offshore production platforms.

2. OUR APPROACH TO TASK 1

The approach used in this research effort consisted of the following four steps:

- Divide the Maritime Transportation Industry into sectors based on vessel types and services
- Determine the vessel population of each sector and identify representative vessels for each sector
- Identify the operating profiles associated with each vessel type
- Simulate operations in order to develop energy use patterns.

Each of these four steps is described in greater detail below.

(1) The Marine Transportation Industry Was Divided Into Seven Sectors

The Maritime industry consists of a diversified fleet of watercraft that can be classified into seven broad operating and service sectors:

- The ocean shipping sector or those U.S. and foreign flag general cargo ships, dry bulk carriers and tankers that participate in the foreign commerce of the United States.
- The Great Lakes sector or those U.S. and Canadian vessels that participate in the U.S. and Canadian Great Lakes trade.
- The coastal shipping sector or those U.S. flag vessels that participate in our coastwise and intercoastal trade.
- The offshore sector consisting of drill rigs and ships, pipe laying barges and workboats that are employed in the discovery and production of offshore oil.
- The inland waterway sector consisting of towing vessels and barges engaged in the

transportation of predominantly bulk products on our inland river systems.

- The fishing and miscellaneous sector. Miscellaneous craft include those special purpose service craft operating predominantly in local harbor areas.

- The pleasure boat sector consisting of small noncommercial craft used exclusively for recreational purposes.

(2) The Population of Each Sector Was Determined and Generic Vessels Were Identified for Each Vessel Type

The populations and physical characteristics of the vessels in the various sectors were assembled from a number of sources including the Maritime Administration, Army Corps of Engineers, Military Sealift Command, U.S. Coast Guard, American Waterways Operators and other trade associations and nongovernment organizations. Estimates of foreign flag vessel populations and physical characteristics were obtained through assembling and correlating data from such sources as the Journal of Commerce, Drewry's Shipping Statistics and Economics, British Petroleum's Statistical Review of the World Oil Industry, Containerization International Yearbook, and the Maritime Administration Statistical Review of the World Merchant Fleet.

Using data available, generic ships, representative of the typical vessel types found in each of the industry sectors were identified. Each industry sector and the generic vessels identified to represent that sector are discussed in greater detail in the following chapters.

(3) Operating Profiles Associated With Each Industry Sector and Vessel Type Were Developed

Defining the operating profiles or duty cycles for generic vessels involved calculating round trip voyage lengths, time spent at sea, time spent in port, and deadweight utilization factors.

Operating profiles for the ocean shipping sector were based on and calculated for all essential trade routes as defined by the Maritime Administration. Where available, empirical data describing weight and space utilization, voyage lengths, etc., were obtained from various U.S. shipping companies. In the absence of such data, operating characteristics were developed based on distances between major ports, itineraries published in the Journal of Commerce, and the operational experience of Booz, Allen's Maritime Group.

For the various domestic shipping sectors, Corps of Engineers data and information supplied by the Maritime Administration, trade associations and operators, were used in compiling operating profiles. These sources provided productivity estimates in ton-miles, average haul distances, typical locking times, and information on the types of commodities carried in the domestic shipping sectors.

(4) Maritime Transportation Operations Were Simulated in Order To Develop Energy Use Patterns

Trading patterns were developed on the basis of commodities movement identified for the year 1974. The year 1974 was selected as it was the latest for which data was available from the Maritime Administration for the ocean shipping sector and the Army Corps of Engineers for the Coastal, Great Lakes and Domestic Inland sectors. The generic vessels developed in the second step were applied to the commodity movement consistent with the operating profiles developed in Step 3. The number of ship cycles required to support this level of trade were calculated and the energy required to support this level of activity was determined. A more detailed explanation of the energy consumption calculations is contained in Appendix A.

3. FINDINGS AND CONCLUSIONS

Our energy consumption analysis of the Marine Transportation Industry has led to five major findings.

(1) The Marine Transportation Industry Consumes 2.95 Quads* Annually

Utilizing the latest annual trade statistics available (1974), it is estimated that the Marine Transportation Industry consumes 2.95 quads annually. Table I-1 provides a summary of the industry's productive activity and energy consumption by industry sector. This energy consumption figure reflects the fuel or energy estimated by Booz, Allen to be required, (regardless of purchase point), by all vessels (regardless of flag) when engaged in the foreign and domestic commerce of the United States.

Table I-1
Productivity and Energy Consumption Summary of the Marine Transportation Industry

Sector	Population	Long Tons of Cargo Moved (Millions)	Energy Consumed (quads)	Percent of Total Energy Consumed
Ocean	4,800	654.9	2.360	80.0
Great Lakes	690	175.3	0.052	1.8
Inland Waterways	2,400	535.8	0.009	3.0
Coastal	1,930	213.0	0.112	4.0
Offshore	620	–	0.064	2.2
Pleasure Craft	7,400,000	–	0.241	8.2
Fishing & Misc.	90,300	–	0.032	0.8
Total	7,500,740	1,579	2.950	100.0

Prior to the Arab oil embargo in 1974, the questions of fuel consumption rates and their reduction were either not addressed by operators or given a very low priority due to the relatively minor

* One quad is equal to 10^{15} Btus.

impact that changes in the rate in fuel consumption had on total transportation costs. Consequently, a shortage of data exists concerning energy consumption in the industry, and until recently, few comprehensive studies have been initiated to determine the industry's energy intensiveness. As a result, our estimates of the energy consumption of the industry carry a degree of uncertainty. The methodology developed to calculate energy consumption required a number of assumptions. The major assumptions are:

- In the ocean shipping sector a specific vessel was dedicated to one trade route, as defined by the Maritime Administration. In reality vessels frequently deviate from these trade routes.

- In all sectors a generic vessel was applied to historical trade flows. The degree to which these generic vessels accurately represent a cross section of each trade and sector is unknown.

- In the Maritime industry vessel capacity is generally measured in deadweight* tons or cubic feet and trade flows are measured in tons. A deadweight utilization factor, based on historical averages was applied to each generic vessel type in order to compensate for variations in both cargo densities and vessel utilization. In reality the amount of a vessel's weight carrying capability actually used varies significantly based on factors such as:

  - Vessel operator
  - Type of cargo carried
  - Industry sector
  - Season of the year
  - Direction of the trade flow
  - Shipping technology used
  - Depth of water at pier side.

* Deadweight—A term describing the weight carrying capacity of a cargo ship, it includes the weight of cargo, crew, stores, and fuel and is measured in long-tons of 2240 pounds.

- In almost all bulk trades and to a lesser degree liner trades the trade flows are not balanced as far as tonnages moving in both directions. In the bulk trades, vessels typically spend half their life in ballast. The extent to which the search for back haul cargos effect operating profiles and energy consumption is unknown.

- The analysis of the recreational boating sector relied on 1973 U.S. Coast Guard data describing populations, sizes and operating patterns. These 1973 operating patterns were applied to 1975 recreational boating population statistics. The extent to which operating profiles identified in 1973 accurately represent those occurring in 1975 is unknown.

- The fishing and miscellaneous, and offshore sectors are so diverse that meaningful operating profiles could not be developed. As a result, the analysis used for these sectors differs from that developed for the other sectors.

These factors effect the calculated marine transportation energy consumption figure of 2.95 quads. It is estimated that the uncertainty associated with our estimate of total industry energy consumption could reach plus or minus 25 percent.

(2) Energy Consumption in the Marine Transportation Sector Represents 15 Percent of the Energy Consumed for Transportation Services

The Energy Research and Development Administration estimates that the nonmaritime transportation services consume 16.55 quads as shown in Table I-2. Adding the 2.95 quads calculated for marine sector yields 19.50 quads used by all transportation modes. The Marine Transportation Industry represents approximately 15 percent of this total.

Table I-2
Energy Consumed for Transportation Services

Sector	Energy Consumed (Quads)	Percent of Total Energy Consumed
Highway	12.91	66
Air	1.92	10
Pipeline	1.15	6
Rail	0.57	3
Marine	2.95	15
Total	19.50	100

Source: Marine consumption represents estimates provided by Booz, Allen & Hamilton. All other estimates are provided by the Energy Research and Development Administration.

(3) The Ocean Shipping Sector Consumes 80 Percent of the Estimated Marine Transportation Energy Requirements

Of the estimated 2.95 quads required to support the Marine Transportation Industry, Table I-3 indicates that the ocean shipping sector accounted for 2.36 quads or 80 percent. Table I-3 provides a distribution of the total ocean shipping sectors energy requirements among the five types of shipping service identified.

(4) A Maximum of 35 Percent of the Energy Required by the Marine Transportation Industry Is Purchased in the U.S.

Table I-4 presents a summary of all the marine fuels purchased in the United States. This total of

Table I-3
Energy Requirements of the
Ocean Shipping Sector

Service Type	Energy Requirements (Quads)	Percent of Total
Liner	0.53	22
Tramp	1.08	46
Dry Bulk	0.33	14
Tankers	0.33	14
Passenger	0.08	4
Total	2.36	100

Table I-4
Reported U.S. Purchases of Marine Fuel, 1974
(Quads)

Trade	Residual	Distillate	Gasoline	Total
Domestic	0.19	0.09	0.09	0.37
Ocean	0.39	0.05		0.44
Total	0.58	0.14	0.09	0.81

Sources: "Bunker Fuel," U.S. Department of Commerce, Bureau of the Census.

"Mineral Industry Survey," U.S. Department of Interior, Bureau of Mines.

"Private and Commercial Nonhighway Use of Gasoline—1974," U.S. Department of Transportation, FHA.

.81 quads represents 35% of the total energy requirements or 2.95 quads presented earlier in Table I-2.

1. Approximately 20 Percent of the Energy Consumed by the Ocean Shipping Sector is Purchased in the United States

Further inspection of Table I-5 shows that 0.37 quads were reported purchased by the domestic sectors and 0.44 quads were reported purchased in the U.S. by the ocean shipping sector. This 0.44 quads represents approximately 20 percent of the ocean shipping sector's estimated energy requirements. Table I-5 displays the percentage of fuel required by the ocean shipping sector by flag of registry and purchase point.

Table I-5
Ocean Shipping Fuel Requirements*

	Point of Purchase			
	United States		Overseas	
Vessels	Quads	Percentage	Quads	Percentage
U.S.	.090	43%	.125	57%
Foreign Flag	.350	16%	1.795	84%
All Vessels	.440	20%	1.920	80%

* Based on "Bunker Fuels" published U.S. Department of Commerce, Bureau of Census.

2. The Present Energy Reporting Systems Account for Approximately 60 Percent of the Estimated Domestic Requirements

The "Mineral Industry Survey" published by the U.S. Department of Interior, Bureau of

Mines, and the "Private and Commercial Non-highway Use of Gasoline - 1974" published by the Federal Highway Administration report fuel representing 0.37 quads as purchased for domestic marine use in 1974. This represents approximately 60 percent of the 0.59 quads estimated for the six domestic shipping sectors as shown in Table I-2. Table I-6 provides a comparison of the fuel reported sold vs. estimated requirements.

Table I-6
Comparison of Fuel Reported Sold for Marine Use vs. Estimated Requirements
(Quads)

Trade	Reported Sold (Quads)[1]	Estimated Requirements (Quads)[2]	Percent to Which Reported Sales Represent Estimated Requirement
Foreign	0.44	2.36	20%
Domestic	0.37	0.59	63%
Total	0.81	2.95	27%

1 From Table I-4.

2 From Table I-1.

The low percentage that is shown for our foreign trade has been previously explained as being caused by foreign purchases. The rationale for the relatively low percentage that domestic purchases represent of domestic requirements is difficult to explain. A partial explanation for the differential may be due to

- The purchase of fuel by fishing and pleasure craft at nearby foreign locations
- The nonreporting of consumption by vessels under charter to the major petroleum production and refining companies in support of offshore drilling and production activities or petroleum product distribution efforts.

4. ORGANIZATION OF THE REPORT

This report is organized into eight chapters. This first chapter is intended to provide an introduction to the overall assignment, a summary of our approach to the problem, and the major findings and conclusions.

The following chapters each address themselves to one of the seven industry sectors identified above. In each chapter the industry sector is described in terms of:

- Population
- Operating profiles
- Energy consumption
- Typical or generic vessels
- Costs
- Cargo movements.

The depth of treatment of each sector varies due to availability of data and its importance as an energy consumer.

II. THE OCEAN SHIPPING SECTOR

II. THE OCEAN SHIPPING SECTOR

The oceangoing merchant fleet is defined as those steel-hulled, self-propelled vessels of over 1,000 gross registered tons capable of operating in the U.S. foreign trade. This chapter provides a comprehensive discussion of the four services provided by the ocean shipping sector.

1. THE OCEAN SHIPPING SECTOR REPRESENTS 5 PERCENT OF THE COMMERCIAL POPULATION AND CONSUMES 80 PERCENT OF THE ENERGY REQUIRED BY THE MARINE TRANSPORTATION INDUSTRY

The U.S. economy generated approximately 655 million long tons of seaborne imports and exports in 1974. Table II-1 indicates that there are nearly 4,800 vessels engaged in this trade. Approximately 7 percent or 340 of these vessels are registered under U.S. flag. Table II-1 summarizes the results of the analysis of the ocean shipping sector by flag of registry.

Table II-1
Ocean Sector by Flag

Flag	Population	Millions of Tons Carried	Billions of Ton-Miles	Btus in Quads	Btus/ Ton-Mile
U.S.	340	45.0	260.1	.215	827
Foreign	4,434	610.0	3,467.4	2.145	619
Total	4,774	655.0	3,727.5	2.360	633

The ocean shipping sector can be subdivided into four major subsectors according to the type of service offered.

- Liner
- Nonliner or tramp
- Dry bulk
- Tanker.

Table II-2 summarizes the results of the analysis of the ocean shipping sector by service and flag of registry. Energy requirements were calculated based on 1974 cargo data. The method used to derive energy consumption is described in Appendix A.

Table II-2
Ocean Sector by Service*

Vessel Type	Flag	Population	Millions of Tons Carried	Billions of Ton-Miles	Millions of Btus/Tons	Btus/ Ton-Mile	Btus in Quads
Liner	US	270	15.4	117.3	10.6	1,390	.163
	FF	984	36.1	256.4	10.2	1,430	.447
Tramp	US	3	6.4	9.6	3.0	1,990	.019
	FF	2,500	152.6	729.5	7.0	1,450	1.061
Dry Bulk	US	17	2.0	13.1	2.9	442	.006
	FF	500	145.9	1,035.6	2.3	320	.331
Tanker	US	50	21.2	120.1	1.3	228	.027
	FF	450	275.3	1,445.9	1.1	212	.306
Total		4,774	655.0	3,727.5	1.6	590	2.360

* Foreign flag population figures are Booz, Allen estimates.

These four service groups are estimated to have consumed 2.36 quads of energy, 91 percent of which was consumed by foreign flag vessels.

(1) Liner Vessels Represent 26 Percent of the Ocean Shipping Population and Consumed 26 Percent of the Energy Estimated for the Ocean Shipping Sector

Liner vessels operate as common carriers and provide a regularly scheduled service between specified ports. This portion of the ocean shipping sector is characterized by fast ships moving relatively high value cargo. There are a variety of vessel types employed in liner service. This variety in vessel types is a result of the growth of intermodal transportation. The intermodal vessels call on fewer ports and minimize port time due to their more efficient cargo handling techniques and links to other transportation modes. Liner vessels have been classified according to ship type in the following five categories:

- Break-bulk and partial container
- Container
- Roll-on/Roll-off
- Barge carriers
- Passenger.

Table II-3 identifies the generic vessels used for each ship type and the trade routes to which they were applied. The trade routes used in this analysis are those defined by the Maritime Administration as essential to U.S. foreign trade and described in Appendix B. The five largest liner trade routes are illustrated in Figure II-1.

Foreign flag vessels carried approximately 70 percent of the liner tonnage in 1974 and consumed 73 percent of the total energy required for liner service. In terms of energy consumed per long ton of cargo carried, liners were found to be the least efficient vessels in the ocean sector due to their obligation to maintain scheduled service and the high volume to weight ratio of the cargo carried.

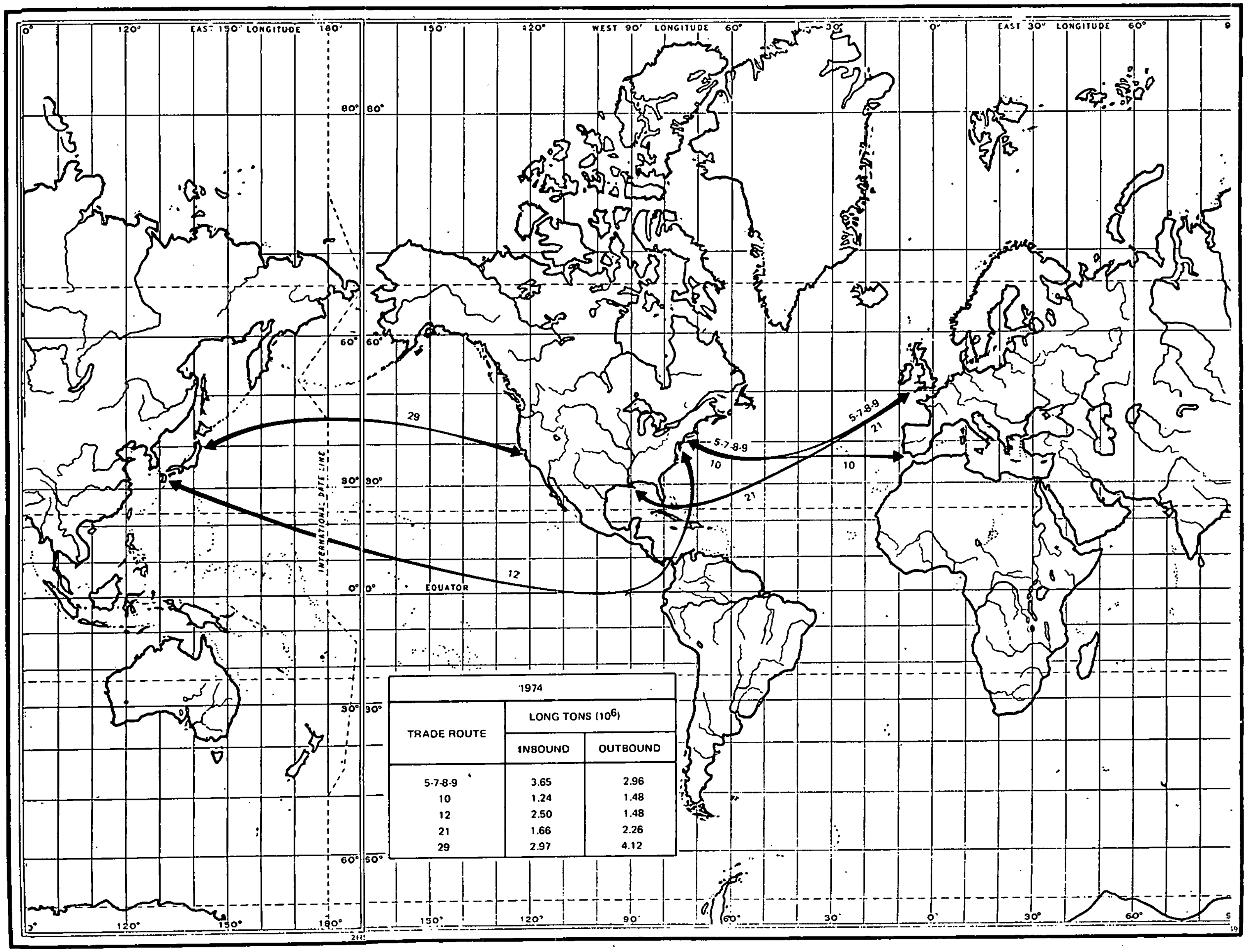
1. <u>Break-Bulk and Partial Container Vessels Accounted for 53 Percent of Liner Cargo Tonnage and 59 Percent of the Total Liner Energy Requirements</u>

Break-bulk and partial container vessels are designed primarily for the carriage of packaged cargoes. These vessels are equipped with cargo booms to facilitate the loading and discharge of cargo. Partial container vessels are generally break-bulk vessels that have been converted so they are able to accommodate a limited number of containers either on the main deck, and often, one or more holds are cellularized to carry containers exclusively. Included in this group are combination cargo-passenger ships, capable of carrying up to 200 passengers, which depend primarily on cargo for their revenues. The typical break-bulk vessel is described in Table II-4.

Table II-3
Generic Liner Vessels and Trade Routes

Vessel Type	Deadweight	Horsepower	Speed (Knots)	% DWT Util.	1	2	4	5 7 8 9	6	10	11	12	13	14	15A	15B	16	17	18	19	20	21	22	23	24	25	26	27	28	29	31
Container	12,000	18,000	16	50%			●																				●	●	●		
	16,500	17,000	20																												
	18,500	18,000	20					●			●						●														
	23,000	28,000	23																			●								●	
Roll On/Roll off	10,000	11,000	24	33%			●																								
	16,500	22,000	22.5							●									●	●	●								●	●	
	18,000	25,000	22.5					●	●																			●			
Barge Carrier	33,000	33,000	22	60%						●									●		●							●	●		
	42,000	38,000	22															●				●	●								
Break Bulk	13,500	14,500	19	40%	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Passenger	20,000 GRT	20,000	20.5				●																	●		●					
	30,000 GRT	26,000	21					●		●	●																				

Trade Routes: columns 1–31 above.



1974		
TRADE ROUTE	LONG TONS (10^6)	
	INBOUND	OUTBOUND
5-7-8-9	3.65	2.96
10	1.24	1.48
12	2.50	1.48
21	1.66	2.26
29	2.97	4.12

FIGURE II-1
The Five Largest Liner Trade Routes

Table II-4
Typical U.S. Break-Bulk Vessel

DWT	HP	Engine	Speed (Knots)	1976 Estimated Construction Cost	1976 Estimated Daily Operating Cost
13,500	14,500	Turbine	19	$30 million	$6,190

Foreign flag break-bulk liners operating in the U.S. foreign trade have similar characteristics except that they are predominantly diesel-powered. Current foreign construction costs are 30 to 50 percent below domestic costs.

The operating profiles of break-bulk vessels differ from other liner vessels in that they typically make more port calls and require longer voyages than the intermodal type vessels. These vessels also spend more time in port because of the relatively slow method of loading and discharging cargo. As a result, their typical voyages are considerably longer than other liner vessel types.

Energy consumption for break-bulk liner vessels was estimated at 0.357 quads in 1974, of which 71 percent was consumed by foreign flag vessels.

2. Containerships Accounted for 29 Percent of Liner Cargo Tonnage and 15 Percent of Total Liner Energy Requirements

Containerships are designed to carry unitized cargo in the form of steel or aluminum "vans" or containers. The standard measure of container capacity is a container 20' x 8' x 8' called the 20 foot equivalent unit (TEU). Fully containerized vessels have a cellular structure allowing the vessel to accommodate only containers. The containerization concept allows for the cargo to be packed and sealed by the shipper, trucked to the ship, loaded aboard and discharged from the ship and trucked directly to the consignee with a minimum handling of the cargo. Containerships rely on quick turnaround to stay viable. The method of cargo handling virtually assures a minimum stay in port and prior to the 1974 oil embargo, new containerships were being built with increasing speed capability for the ocean voyage. One example is the Sea-Land SL-7 class containerships, which is compared to four typical container vessels in Table II-5 below.

Table II-5
Container Vessels

Deadweight	Horsepower	Engine	Speed (Knots)	Estimated 1976 Construction Cost in Millions of Dollars	Estimated 1976 Daily Operating Cost
12,000	8,000	Steam Turbine	16	16.1	$ 8,300
16,500	17,000	Steam Turbine	20	32.2	$ 8,300
18,500	18,000	Steam Turbine	20	43.1	$ 8,900
23,000	28,000	Steam Turbine	23	47.4	$ 7,300
27,000 (SL-7)	120,000	Steam Turbine	33	79.2	$12,000

Container vessels were estimated to have consumed .094 quads of energy in 1974 with foreign flag containerships accounting for 64 percent.

3. Roll-on/Roll-off (Ro/Ro) Vessels Accounted for 12 Percent of Liner Cargo Tonnage and 9 Percent of Total Liner Energy Requirements

Ro/Ro vessels are designed to load and discharge mobile cargo and other unitized cargoes capable of being driven aboard by forklift. Trailers, automobiles, and other self-propelled vehicles comprise the major cargo carried by these vessels. Ro/Ro vessels utilize an extensive internal movement of cargo.

The storage capability of the Ro/Ro ship is less than other liner types due to the unutilized cubic space above and below the wheeled cargo. The characteristics of three typical Ro/Ro vessels is shown below in Table II-6. Ro/Ro vessels are estimated to have required .056 quads of energy in 1974 with Foreign flag Ro/Ro vessels accounting for 79 percent of the total.

Table II-6
Ro/Ro Vessels

Deadweight	Horsepower	Engine	Speed (Knots)	Estimated 1976 Construction Cost (in Millions of Dollars)	Estimated 1976 Daily Operating Cost
10,000	11,000	Steam Turbine	24	$16.1	$8,200
16,500	22,000	Steam Turbine	22.5	$32.2	$7,200
18,000	25,000	Steam Turbine	22.5	$56.7	$6,500

4. Barge Carriers Accounted for 7 Percent of Liner Cargo Tonnage and 3 Percent of Total Liner Energy Requirements

Barge carriers represent a relatively new form of intermodalism in which barges are preloaded, meet the line haul vessel at a specific point, and are hoisted aboard. There are two principal types of barge carriers in operation today; the Sea-Barge and the "lighter aboard ship" or Lash vessel. The Sea-Barge employes an elevator in the stern of the ship for loading and discharging its barges, while the Lash vessel uses a traveling gantry crane to pick up the barges at the stern and carry them over the deck to the holds. Table II-7 compares the two types of barge carriers.

Table II-7
Comparison of U.S. Sea-Barge and
Lash Barge Carriers

Type	Deadweight	Horsepower	Engine	Speed (Knots)	Estimated 1976 Construction Cost in Millions of Dollars	Estimated 1976 Daily Operating Cost
Seabee	38,000	36,000	Steam Turbine	20.0	33	$9,400
Lash	30,000	32,000	Steam Turbine	22.5	28	$9,400

Foreign flag barge carriers serving the U.S. trade typically range from 44,000 to 48,000 deadweight tons and make 19 knots. Considering the physical characteristics of both U.S. and foreign flag barge carriers, the generic vessels shown in Table II-8 were chosen as representative of the type of vessels serving the U.S. trade.

Table II-8
Generic Barge Carriers

Deadweight	Horsepower	Engine	Speed	Deadweight Utilization
33,000	33,000	Steam Turbine or Diesel	22	60%
42,000	38,000		22	60%

The energy consumed by barge carriers in 1974 was estimated to be .017 quads, of which 94 percent was consumed by U.S. flag vessels.

5. Passenger Vessels Represent 7 Percent of the Liner Population and Consumed 3 Percent of the Estimated Liner Energy Requirement

Passenger ships are sleek, fast vessels that can accommodate more than 200 passengers on cruises ranging from short island-hopping trips to transatlantic crossings. Passenger liners in the U.S. foreign trade operate cruises primarily to the Caribbean, Central America, and Europe originating from New York, Florida, and California ports. Florida ports have been the traditional leaders with half the number of passengers embarking there. Recently, however, certain gulf ports have emerged as major ports of embarkation for winter cruises. Most cruises are short, lasting from 7 to 10 days with relatively little port time.

According to several passenger cruiseship associations, it is estimated that approximately 84 foreign ships serve the U.S. cruise trade. Approximately two-thirds of the passenger vessels serving the U.S. cruise trade are powered by steam turbine engines. Table II-9 gives the characteristics of two typical passenger vessels.

Table II-9
Typical Passenger Vessels

Size*	Horsepower	Engine	Speed (Knots)
20,000 GRT	20,000	Steam Turbine	20
30,000 GRT	26,000	Steam Turbine	22.5

* Size is in Gross Registered Tons (GRT), a measure of the internal volume of a vessel in which 100 cubic feet is one ton, excluding spaces exempted from measurement by law.

These foreign flag vessels were estimated to have required 0.08 quads of energy in 1974, 66 percent of which was residual "Bunker C" fuel.

(2) Tramp Vessels Represent 52 Percent of the Ocean Shipping Population and Consumed 46 Percent of the Energy Estimated for the Ocean Shipping Sector

Tramp vessels, in contrast to liner vessels, offer irregular service and are available for hire to a shipper under either a time or voyage charter, to load and discharge specified cargo between such ports as the charter stipulates. In some cases foreign flag operators move their vessels between liner and tramp service. This is particularly true in the ocean service to the Great Lakes. Another perturbation occurs when an operator offers berth service in one direction on a trade route and contract or tramp service in the other direction. A typical tramp vessel is generally of the breakbulk variety but is different in that it is a generally older and slower vessel with a smaller cargo carrying capacity. Because the tramp movements represent a charter market, the world pool of general cargo freighters can be drawn upon. The estimate of 2,500 tramp ships operating in the U.S. foreign trade is represented by the typical tramp vessel described in Table II-10.

Table II-10
Typical Tramp Vessel

Size	Horsepower	Engine	Speed (Knots)	Efficiency
8,400 DWT	5,000	Diesel	14	40% DWT Utilization

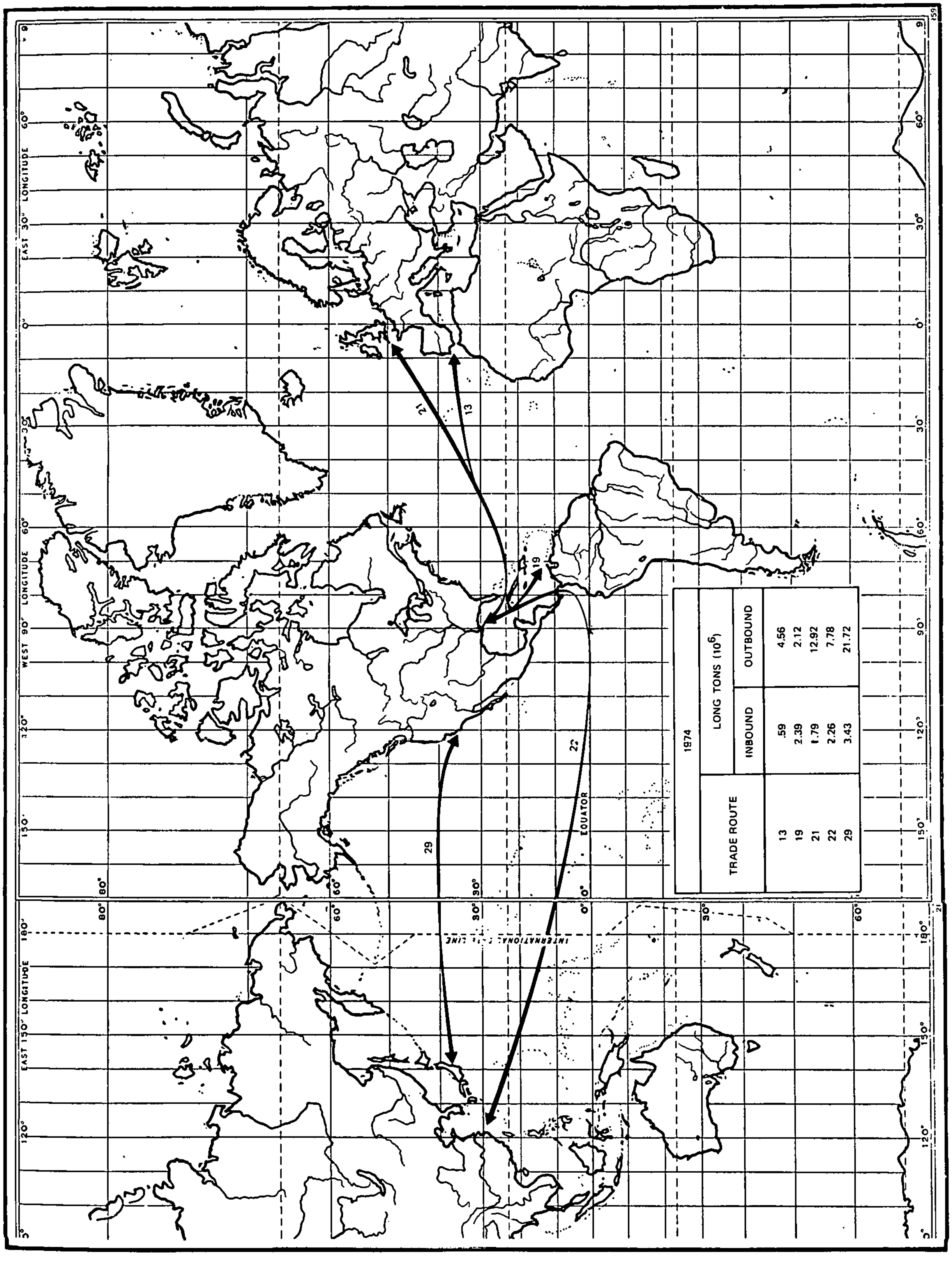
Tramp vessels are the largest energy users in the ocean sector. Of the estimated 1.08 quads of energy required by tramp vessels, 98 percent was consumed by foreign flag vessels. Tramp shipments accounted for approximately 159 million tons of cargo in 1974 (24 percent of all ocean sector cargo tonnage), only 4 percent of this total moved in U.S. flag tramp vessels. Figure II-2 illustrates the five largest non-liner trade routes.

(3) Dry Bulk Carriers Represent 11 Percent of the Ocean Shipping Population and Consumed 14 Percent of the Energy Estimated for the Ocean Shipping Sector

Dry bulk carriers are designed to carry such bulk cargoes as grains and ores. This group also includes ore/bulk/oil (OBO) vessels suited for both the liquid and dry bulk trades. Like tramp vessels, dry bulk carriers are chartered on a time or voyage basis, and are drawn from the world pool. Three typical dry bulk carriers are described in Table II-11 on the following page.

Dry bulk carriers are engaged in importing such commodities as sugars, fertilizers, iron ore, and exporting such commodities as grain, coal, and fertilizers to and from the United States. Dry bulk shipments primarily originate or terminate in east and gulf

FIGURE II-2
The Five Largest Non-Liner Trade Routes



1974		
TRADE ROUTE	LONG TONS (10^6)	
	INBOUND	OUTBOUND
13	.59	4.56
19	2.39	2.12
21	1.79	12.92
22	2.26	7.78
29	3.43	21.72

coast ports. These vessels typically call at one or two ports on each leg of the voyage and rarely spend more than 1 or 2 days in port. The typical operating profile of a dry bulk carrier is loaded in one direction and ballast on the return leg. There is seldom any opportunity for backhaul cargo.

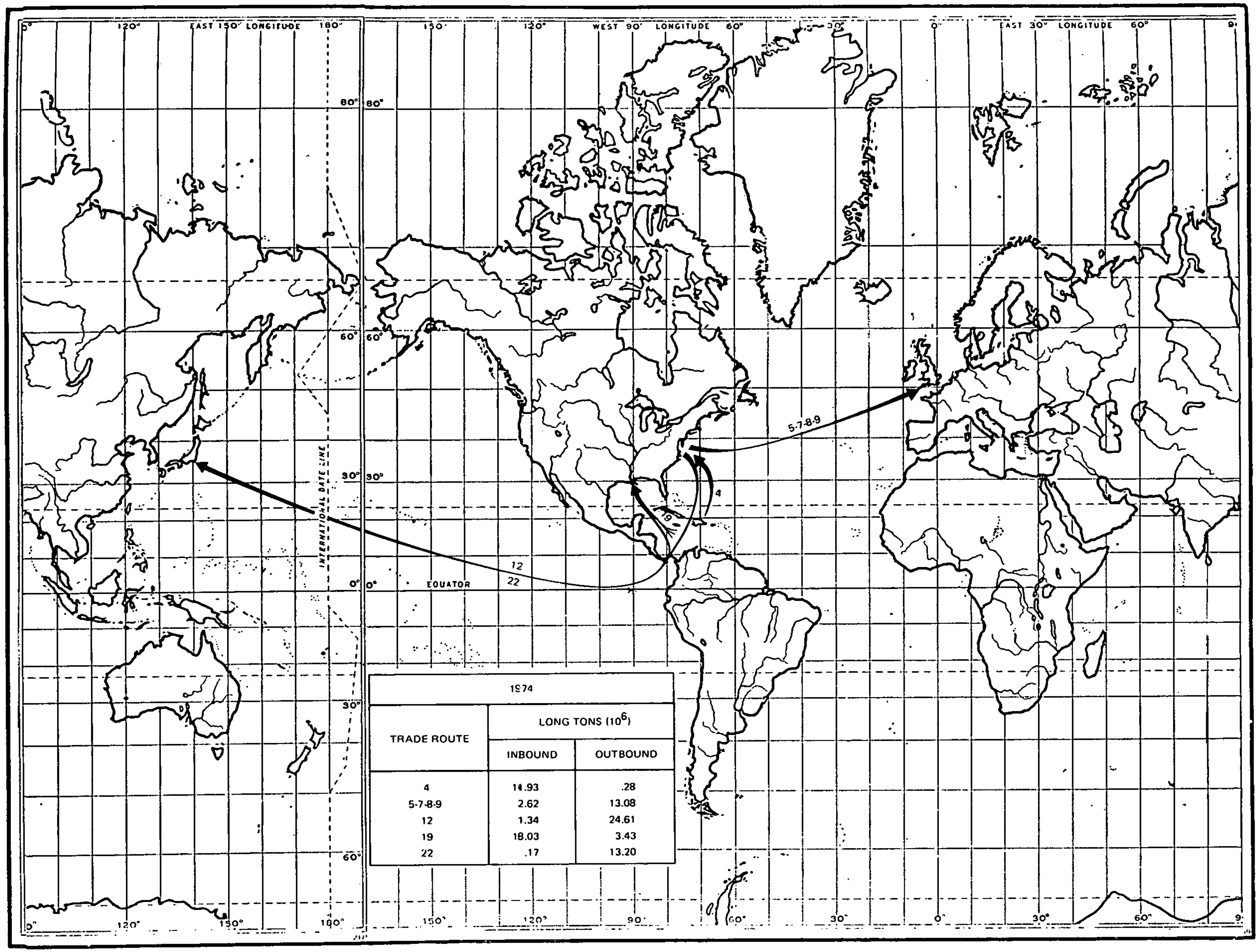
Table II-11
Dry Bulk Carriers

Deadweight	Horsepower	Engine	Speed (Knots)	DWT Utilization
20,000	8,000	Diesel	15	96%
30,000	10,000	Diesel	15	96%
40,000	11,000	Diesel	15	96%

It is estimated that approximately 148 million long tons of cargo moved by dry bulk carrier in 1974, representing 23 percent of all ocean cargo tonnage. The five largest dry bulk trade routes are illustrated in Figure II-3. Approximately .337 quads of energy were required to support the dry bulk trade, of which 98 percent was consumed by foreign flag dry bulk carriers.

(4) Tankers Represent 11 Percent of the Ocean Shipping Population and Consumed 14 Percent of the Energy Estimated for the Ocean Shipping Sector

Tankers are designed for the carriage of liquid bulk cargoes such as crude oil, refined petroleum products, chemicals and edible oils. These vessels are also used to move dry bulk cargoes that can be handled using pumping or suction systems. They have been employed extensively in the U.S. foreign grain trade. Table II-12 provides a representative listing of the tankers involved in the United States foreign trade.



1974		
TRADE ROUTE	LONG TONS (10^6)	
	INBOUND	OUTBOUND
4	11.93	.28
5-7-8-9	2.62	13.08
12	1.34	24.61
19	18.03	3.43
22	.17	13.20

FIGURE II-3
The Five Largest Dry Bulk Trade Routes

Table II-12
Typical Tankers

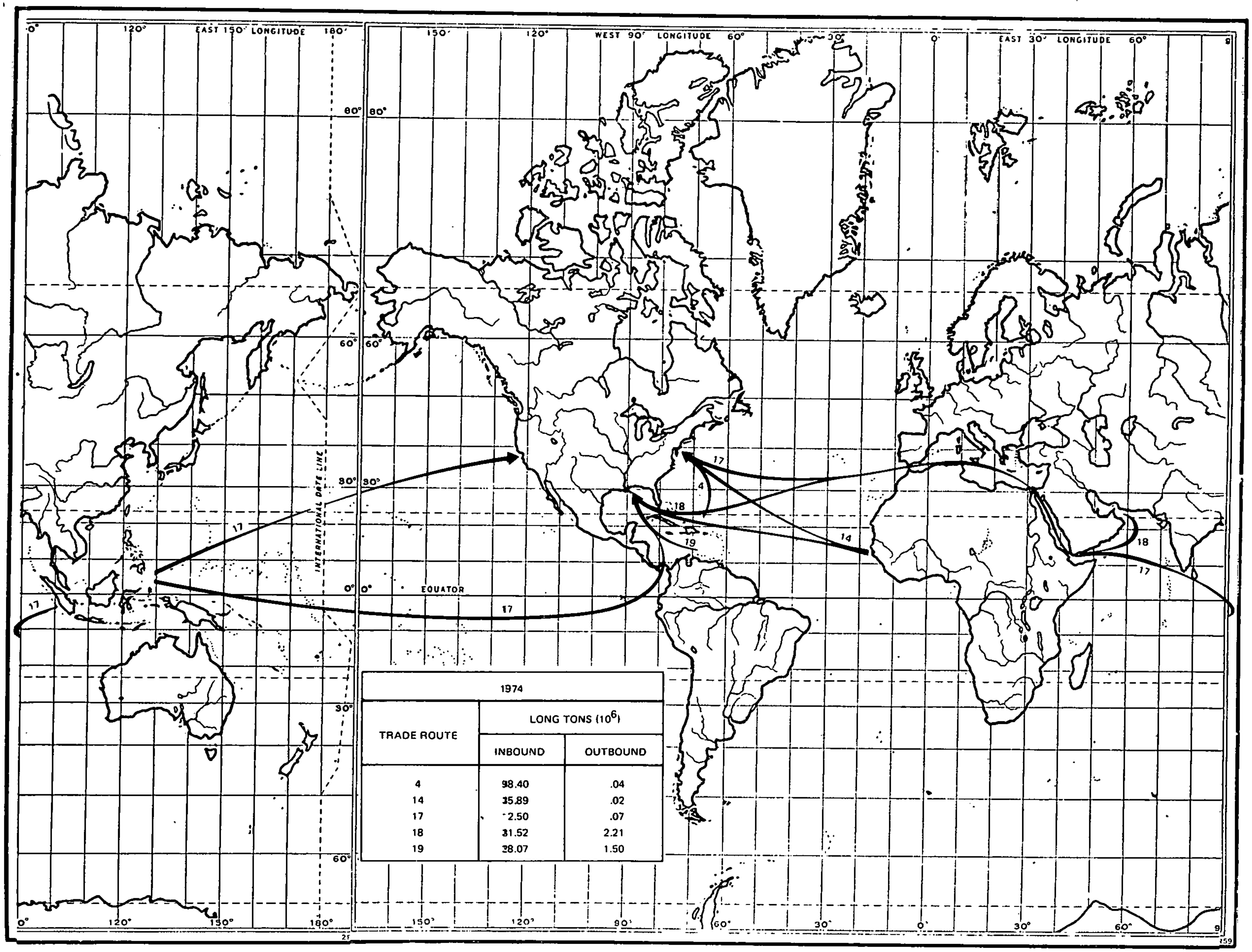
DWT	Horsepower	Engine	Speed (Knots)	Percent DWT Utilization
20,000	7,000	Diesel	14	96
40,000	9,000	Diesel	14	96
65,000	14,000	Diesel	15	96
80,000	16,000	Diesel	15	96
150,000	20,000	Diesel	15	96

Crude petroleum destined for the United States generally originates in South America, Africa, and the Arabian Gulf, while clean petroleum products move primarily from the Caribbean area to the U.S. east coast. Figure II-4 gives an illustration of the five largest tanker trade routes.

As with dry bulk carriers, tankers typically call at only one port on each leg of the voyage, spend a minimum amount of time in port, and carry no backhaul cargo.

Nearly 297 million long tons of cargo were transported by tanker in 1974, representing 45 percent of all ocean shipping cargo tonnage. Tankers proved to be the most efficient users of energy in the ocean sector. It is estimated that .333 quads of energy was required, 92 percent of which was consumed by foreign flag tankers. In terms of energy consumed per long ton of cargo delivered, the tanker is the most energy efficient vessel type in the ocean sector.

A specialized category of tankers is designed for the carriage of liquified natural gas (LNG) and liquified petroleum gas (LPG). There are 24 existing LNG tankers in the world fleet with a capacity of between 1,000 and 125,000 cubic meters of LNG. Although none of these vessels are under U.S. registry, 16 additional LNG tankers are under construction in U.S. shipyards and due to be delivered during 1977 and 1978. The LNG tanker described in Table II-13 is typical of the future United States LNG fleet. These vessels are using "Bunker C" and cargo boil-off as fuel.



1974		
TRADE ROUTE	LONG TONS (10^6)	
	INBOUND	OUTBOUND
4	98.40	.04
14	35.89	.02
17	[illegible]2.50	.07
18	31.52	2.21
19	28.07	1.50

FIGURE II-4
The Five Largest Tanker Trade Routes

Table II-13
U.S. Future LNG Fleet

Deadweight	Horsepower	Engine	Speed (Knots)	Capacity	Estimated 1976 Construction Cost
63,000	43,000	Steam Turbine	20.5	125,000m^3	$125 million

2. ALTHOUGH THE OCEAN SHIPPING SECTOR CONSUMES 80 PERCENT OF THE MARINE TRANSPORTATION ENERGY REQUIREMENT, ONLY 20 PERCENT IS PURCHASED IN THE UNITED STATES

The major portion of bunkering activity by vessels engaged in the U.S. foreign commerce takes place overseas. Table II-14 displays the percentage of fuel required by the ocean shipping sector by flag of registry and purchase point.

Table II-14
Ocean Shipping Fuel Requirements*

Vessels	Point of Purchase			
	United States		Overseas	
	Quads	Percentage	Quads	Percentage
U.S.	.09	43%	.125	57%
Foreign Flag	.34	16%	1.800	84%
All Vessels	.43	20%	1.925	80%

* Based on "Bunker Fuels" published U.S. Department of Commerce, Bureau of Census.

Of the estimated .215 quads of energy required by U.S. vessels in the ocean shipping sector, approximately 43 percent was reported sold in the United States by the U.S. Department of Commerce, Bureau of Census. The Bureau of Census also reported that of the 2.145 quads required by foreign flag vessels approximately 16 percent was sold in the United States.

Bunker fuel sales in the United States to foreign vessels had been declining until the Arab oil embargo, due to lower fuel prices abroad. Since that time, price controls have kept U.S. fuel prices low relative to overseas sources, and bunker fuel sales in the U.S. have been increasing.

III. THE GREAT LAKES SECTOR

III. THE GREAT LAKES SECTOR

The Great Lakes sector of the U.S. merchant fleet has been defined as those vessels operating within the Great Lakes/St. Lawrence Seaway system. The system stretches for more than 2,300 miles from the Atlantic Ocean to mid-America, with a controlling depth of 27 feet. Traditionally, the Great Lakes operating season has been cut short by the winter season, as icing on the lakes has rendered navigation virtually impossible. In recent years, successful attempts have been made in extending the operating season in certain sections from 10 to 12 months. There are 16 locking points and more than 155 miles of channels and canals in the system.

1. WATERBORNE COMMERCE ON THE GREAT LAKES CONSISTS PREDOMINANTLY OF THE MOVEMENT OF DRY BULK COMMODITIES IN THE U.S. DOMESTIC TRADE

Waterborne commerce in the Great Lakes can be divided into the following categories:

- Domestic interlake and intralake movements or trade between U.S. ports within a specific lake or between lakes
- Trans-lakes movements between the United States and Canada
- Overseas foreign movements.

Table III-1 presents the distribution of cargo tonnage among these three Great Lakes service areas.

Table III-1
Great Lakes Trade During 1974

Service	Total Trade in Millions of Long Tons	Percent
Domestic	138.2	75
Trans-Lake	37.7	20
Overseas Foreign	8.1	5
Total	184.0	100%

Source: "Domestic Waterborne Trade of the United States 1967-1974," Maritime Administration, U.S. Dept. of Commerce.

The table indicates that 184 million long tons of waterborne commerce moved during 1974. This represents 12 percent of the total U.S. waterborne commerce during the year.

The domestic trade accounted for 75 percent of total trade on the lakes, as shown in Table III-2. This particular trade is predominantly a bulk trade with bulk commodities representing 75 percent of the domestic trade.

Table III-2
1974 Movement of Bulk Commodities in Great Lakes Domestic Trade

Commodity	In Millions of Long Tons	Percent
Iron Ore and Concentrates	66.4	64
Limestone	29.5	28
Nonmetallic Minerals	1.4	1
Sand, Gravel, Crushed Rock	1.1	1
Wheat	1.0	1
Distillate Fuel Oil	1.6	1
Gasoline	1.4	1
Residual Fuel Oil	1.3	1
Other	2.0	2
Total	104.3	100%

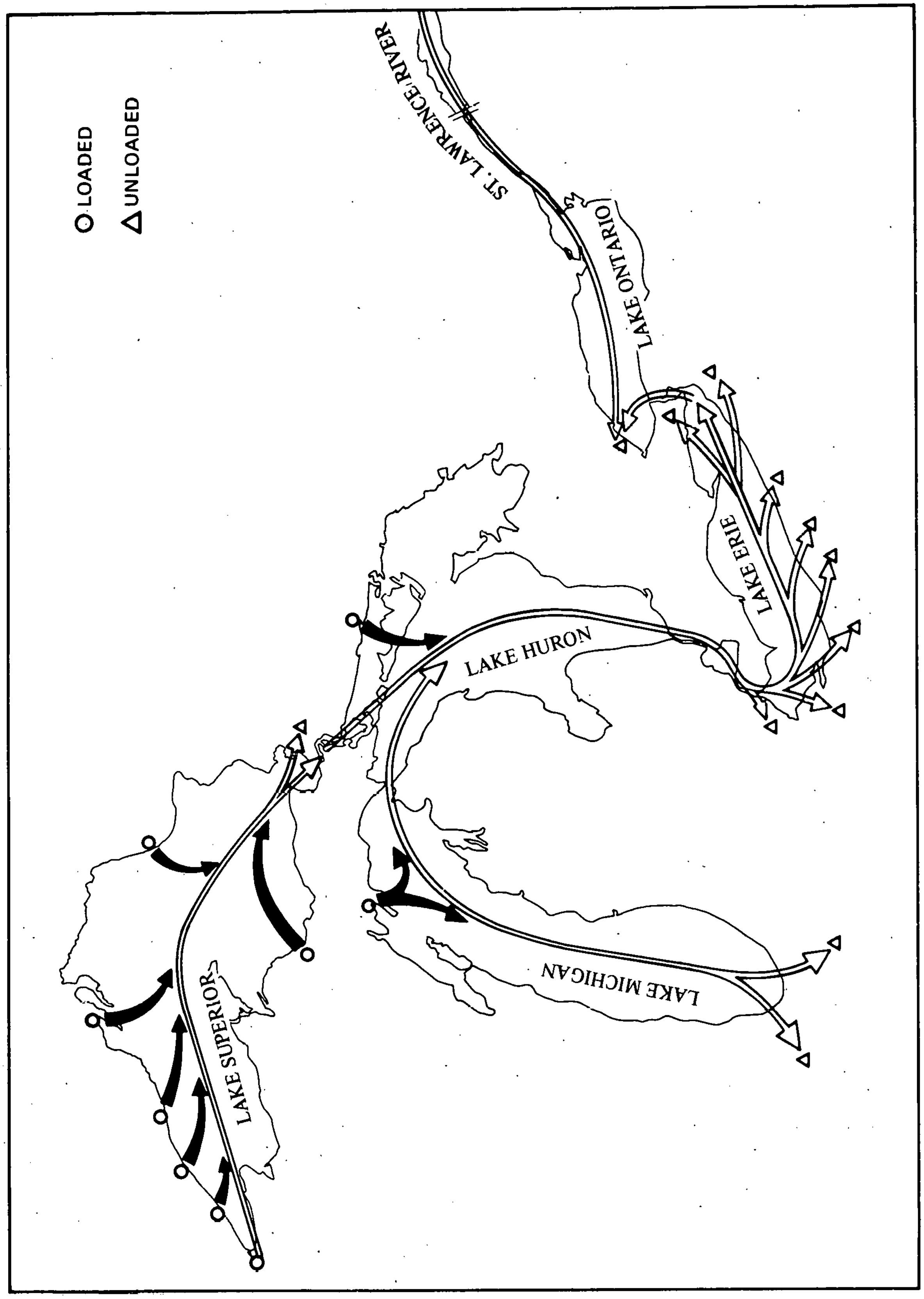
Source: Waterborne Commerce of the United States.

Iron ore is the major moving commodity on the lakes and represents nearly 50 percent of our domestic commerce. Figure III-1 shows the pattern of iron ore movements on the lakes.

2. THE GREAT LAKES IS UNIQUE TO WATERBORNE TRANSPORTATION AS IT PRESENTS A DEEP DRAFT NAVIGATION ALTERNATIVE TO OTHER TRANSPORTATION MODES

Unlike any other U.S. waterway, the Great Lakes provides shippers and consignees with a deep draft all-water alternative to other transportation modes. This is especially important in the overseas trade. As was indicated in Table III-1, over 8 million tons of cargo moved overseas from U.S. Great Lakes ports. The likely alternatives for this cargo is a rail or truck movement to east coast ports and a barge or rail movement to gulf

FIGURE III-1
Iron Ore Movements on the Great Lakes



coast ports. The cargo would then be loaded aboard ship at these ports for the continuation of its routing to Europe, South America or the Far East. The Great Lakes alternative provides all shippers with savings in transportation costs because of the competitive interaction between modes and is more efficient than the overland methods from an energy perspective.

3. <u>THE GREAT LAKES SECTOR REPRESENTED 1 PERCENT OF THE COMMERCIAL VESSEL POPULATION AND CONSUMED APPROXIMATELY 1.8 PERCENT OF THE ENERGY REQUIRED BY THE MARINE TRANSPORTATION INDUSTRY</u>

Table III-3 provides a productivity and energy consumption profile of the Canadian and U.S. Great Lakes fleets.

The fleet accounted for nearly 102 billion ton miles of service in 1974 or approximately 3 percent of that reported for the ocean sector. The fleet consumed 511 Btus for each ton-mile of service provided. By comparison, the ocean sector consumed approximately 20 percent more fuel per ton-mile of service provided.

<u>Table III-3</u>
Production and Energy Consumption Profile of the Great Lakes Fleet

Ship Type	Flag	Population	Millions of Tons Carried	Billions of Ton-Miles	Millions of Btus/ Ton	Btus/ Ton-Mile	Btus (in Quads)
Dry Bulk	U.S.	172	132.80	71.4	0.27	543	.036
	Canada	128	32.10	16.1	0.24	484	.008
Tanker	U.S.	16	4.63	2.5	0.35	652	.002
	Canada	43	0.90	4.5	2.90	587	.003
Tug	U.S.	203	3.89	2.3	0.18	304	.001
	Canada	130	0.99	5.0	1.60	320	.002
Total		692	175.31	101.8	0.30	511	.052

The table indicates that the fleet consists primarily of

- Dry bulk carriers
- Tankers
- Tug boats.

In addition, a limited number of packaged freighters and ferries operate in the lakes. Typical characteristics of these ship types are presented in Table III-4.

The Great Lakes/St. Lawrence Seaway system is a freshwater system. The vessels are not subjected to corrosion caused by the interaction between seawater and the vessel's hull. As a result, many of the vessels in the lakes remain in service far longer than normally encountered in other maritime sectors as evidenced in Figure III-2. Table III-4 presents typical characteristics of the major Great Lakes vessels.

After inspection of Tables III-3 and III-4, the following observations may be made about the principal types of ships in the lakes:

- Dry bulk carriers represent 39 percent of the Great Lakes fleet; carry 94 percent of the tonnage involved in the domestic and Canadian trades and consume 85 percent of the fuel used in the Great Lakes sector. Most of the dry bulk commodities moved are carried on U.S. flag ships. They carried 80 percent of the products and consumed 82 percent of the fuel used by all dry bulk carriers in the lakes.

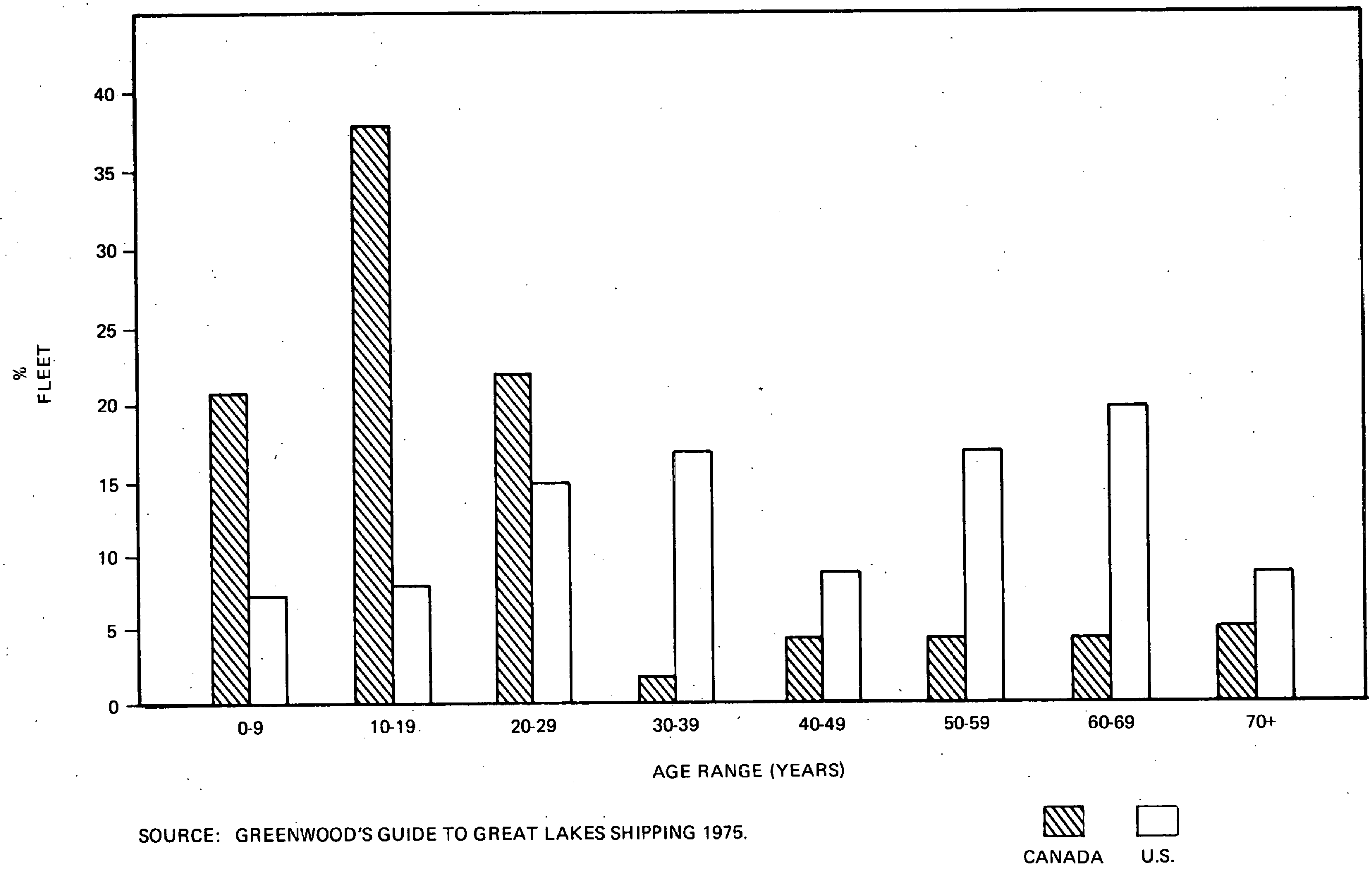
- Tankers represent 8 percent of the number of ships; carry less than 7 percent of the tonnage and consume approximately 10 percent of the fuel. As shown in Table III-4, tankers are considerably smaller than their ocean counterparts.

- Tugs represent 43 percent of the number of ships; are responsible for less than 3 percent of the cargo movements and consume approximately 10 percent of the fuel. The inbalance between the population and productivity of tug

Table III-4
Average Characteristics of Great Lakes Vessels

Characteristic	Flag	Dry Bulk Carriers	Tankers	Tugs	Package Freighters	Car Ferries
Population	U.S.	172	16	203	20	39
	Canada	128	43	130	8	12
# Steam	U.S.	135	4	0	0	7
	Canada	69	6	0	2	0
# Diesel	U.S.	37	12	203	20	32
	Canada	59	37	130	6	12
Deadweight Tons	U.S.	15,000	3,700	–	85	–
	Canada	18,000	7,400	–	6,000	–
Gross Tons	U.S.	8,800	1,740	103	100	1,330
	Canada	12,000	4,700	150	4,300	530
Length in Feet	U.S.	596	259	64	80	160
	Canada	614	377	79	374	112
Breadth in Feet	U.S.	61	42	18	22	38
	Canada	66	53	21	51	33
Draft	U.S.	24	14	Depth 9	7	9
	Canada	25	21	Depth 10	20	8
Horsepower	U.S.	4,000	1,540	900	440	1,780
	Canada	5,000	3,300	1,750	4,300	660
Speed in Miles per Hour		12	12	9	9	9

FIGURE III-2
Age Distribution Comparison of
the Great Lakes Fleet



SOURCE: GREENWOOD'S GUIDE TO GREAT LAKES SHIPPING 1975.

boats is caused by the fact that oftentimes tugs are required to attend overseas vessels during maneuvering and docking and undocking and because of the considerable amount of out of service time experienced by tugs.

- Package ferries represent 4 percent and ferries account for 6 percent of the Great Lakes population.

Compared to oceangoing ships and coastal ports, development of the Great Lakes fleet and ports has been relatively slow. It is likely that, as efforts to extend the seaway season and to promote shipping on the lakes continue, development could occur both in shipping and cargo handling technology in the Great Lakes fleet.

IV. THE COASTAL SHIPPING SECTOR

IV. THE COASTAL SHIPPING SECTOR

The coastal shipping sector of the U.S. merchant fleet was defined as those vessels transporting cargo in the U.S. domestic deep-sea trade, which is protected from foreign competition by the Jones Act. This sector includes the non-contiguous trades with Puerto Rico, Hawaii, and Alaska.

1. THE COASTAL SHIPPING SECTOR IS DOMINATED BY BULK COMMODITY MOVEMENTS

Nearly all of the cargo movements in the domestic deep-sea trade consist of bulk commodities transported by either tanker or barge. In 1974, nearly 213 million long tons of cargo was carried in this trade, 90 percent of which was bulk commodities as shown in Table IV-1.

Table IV-1
Coastal Shipping Commodities

Commodity	Millions of Tons	Billion of Ton-Miles	Percent of Tonnage
Petroleum & Products	162.7	225.0	76%
Other Bulk	27.0	37.3	13%
Other	23.3	32.2	11%
Total	213.0	294.5	100%

Source: "Waterborne Commerce of the United States," Corps of Engineers, U.S. Army.

Movements of non-bulk commodities are handled predominantly by coastwise container feederships and Ro/Ro ships. The coastal fleet was divided into the following three categories:

- Tanker
- Tug/barge
- Other coastal.

The coastal sector has long been the staging ground for the development of unique ship types such as the container ship, the integrated tug/barge and the parcel tanker. After development these ship types are generally deployed in our competitive foreign trades. Table IV-2 presents typical coastal vessels.

Table IV-2
Coastal Ship Types

	Deadweight	Horsepower	Engine	Speed (MPH)
Tanker	40,000	12,000	Steam Turbine	18
Tug	–	2,000	Diesel	9
Other	7,800	6,000	Steam Turbine	15.5

2. APPROXIMATELY 80 PERCENT OF U.S. FLAG TANKERS ARE EMPLOYED IN THE COASTAL SHIPPING SECTOR

Tankers employed in the coastal shipping sector have the same characteristics as those in the ocean shipping sector, and many participate in both trades.

The current employment of the U.S. flag tanker fleet is shown in Table IV-3.

Movement of tankers in and out of the coastal shipping sector is dictated by market demand. For example, many tankers are employed in the grain trade on spot charters and later returned to domestic petroleum service. With the coming of the winter season, some of the U.S. tankers employed in foreign trade are diverted to domestic service to move winter fuel oil requirements.

Table IV-3
Current Employment of U.S. Tankers

Area of Employment	# Vessels	Deadweight Capacity In Thousands of Long Tons
Foreign Trade		
Nearby Foreign	15	501
Overseas Foreign	37	1948
Foreign to Foreign	4	980
Domestic Trade		
Coastwise	96	2968
Intercoastal	16	472
Noncontiguous	22	706
M.S.C.	23	692
Inactive	23	1266
Laid-Up	18	754
Total	254	10,287

Source: "Merchant Marine Data Sheet," Maritime Administration 1 September 1976.

3. THE COASTAL SHIPPING SECTOR REPRESENTS 2 PERCENT OF THE NON-RECREATIONAL POPULATION AND CONSUMES 4 PERCENT OF THE ENERGY REQUIRED BY THE MARINE TRANSPORTATION INDUSTRY

The coastal shipping sector carried nearly 213 million long tons of waterborne commerce and over 316 billion ton-miles of activity in 1974. It is estimated that 2,000 vessels are engaged in this trade. The coastal shipping sector is estimated to have consumed .12 quads of energy in 1974. Table IV-4 summarizes the results of the analysis of the coastal sector by vessel type. A detailed explanation of the method used to derive energy consumption is given in Appendix A.

Table IV-4
Coastal Sector By Vessel Type

Vessel	Population	Tons Carried (Millions)	Ton-Miles (Billions)	Btus/ Ton (Millions)	Btus/ Ton-Mile	Btus in Quads
Tug/Barge	1,561	53.0	73.0	0.38	278	.020
Tanker	173	144.0	199.8	0.49	355	.071
Other	200	16.0	21.7	1.32	941	.021
Total	1,934	213.0	294.5	0.53	380	.112

(1) Tankers Account for Approximately 70 Percent of Cargo Movements and 66 Percent of the Energy Required by the Coastal Shipping Sector

Domestic deep-sea tankers are mainly engaged in carrying clean petroleum products and chemicals between East, West and Gulf Coast ports.

Tankers spend a minimum amount of time in port, typically one day, and carry no backhaul cargo. Tankers were the heaviest users of energy in the coastal shipping sector, consuming approximately .079 quads of energy or 66 percent of the sector's port requirements. Tankers have the second best energy efficiency in the coastal sector due to their large size and high deadweight utilization.

(2) Tug/Barge Operations Accounted for 23 Percent of Cargo Movements and 17 Percent of the Energy Required by the Coastal Shipping Sector

These vessels are primarily engaged in transporting oil and dry bulk commodities along the Atlantic and Gulf Coasts, into the Caribbean, and along the Pacific Coast to Alaska and Hawaii; some vessels service the offshore oil industry.

In ocean barge movements, propulsion is provided by tugboats either pulling barges with a towline or pushing them. The nearly 1,600 ocean tugboats range from 100 feet to over 150 feet in length and develop from 1,500 to over 9,000 horsepower. The typical tugboat is 125 feet in length and is powered by a 1,500 to 3,200 horsepower diesel engine.

Some typical ocean barges and types of cargo are shown in Table IV-5.

Table IV-5
Typical Ocean Barges

Size Range	Commodities Carried
7,500-12,000 DWT	Fuels
12,000-20,000 DWT	Lumber products, cement, petroleum

Source: American Waterway Operations, Inc.

Tug/barge operations were the lowest energy consumers in the coastal shipping sector, requiring only 278 Btus per ton-mile and .38 million Btus per ton of cargo carried. These vessels are very efficient in carrying large volumes of bulk commodities over long distances.

(3) Other Vessels in the Coastal Shipping Sector Accounted for 7 Percent of Cargo Movements and 17 Percent of the Energy Required

Container feederships and Ro/Ro vessels are the primary non-bulk vessels operating in the coastal shipping sector. A typical coastal freighter is described in Table IV-6.

Table IV-6
Typical Coastal Freighter

Deadweight	Horsepower	Engine	Speed (MPH)
7,800	6,000	Steam Turbine	15.5

Container feederships are engaged in intercoastal and limited non-contiguous movements. These vessels provide a service which distributes and consolidates containers at a major port for a larger line haul vessel. Containerships and Ro/Ro vessels are engaged in carrying semi-finished and finished goods in the Puerto Rican, Hawaiian, and Alaskan trades. These intermodal vessels typically require quick turnaround for profitable and reliable operations to remain viable, therefore port time is minimized.

In the next chapter the offshore sector is discussed.

V. THE OFFSHORE SECTOR

V. THE OFFSHORE SECTOR

The offshore sector consists of those craft engaged in the discovery and recovery of oil from offshore areas. This sector is the most recent and fastest changing of the seven industry sectors.

1. THE PRESENT LEVEL OF ACTIVITY IN THE OFFSHORE SECTOR IS EXPECTED TO DOUBLE BY 1980

The offshore oil industry originated in the 1950's in the shallow waters of the U.S. Gulf Coast. Initial drilling was from barges. As the search for oil moved into deeper waters and away from the coastal areas, jack-up rigs and semisubmersibles were developed and used.

During the 1969-1972 period drilling activity declined off the U.S. Coast due to the almost complete cessation of leasing of offshore acreage due to environmental concerns. A federal leasing program has accelerated and since 1972, 9.4 million acres have been offered for lease and 4.6 million have been accepted. It is anticipated that approximately 5 million acres will be leased annually through 1980. This indicated that the number of rigs in service off the coasts of the United States may be double those in service today. Table V-1 provides rig employment during 1976 and compares it with employment during 1974 and 1975.

The level of activity of offshore rigs is probably the single most important factor or parameter that determines the energy requirement of this sector. The energy consumption estimates developed in the following sections, are based on the level of rig activity.

Table V-1
Number of Offshore Oil Rigs Employed
Off the U.S. Coast 1974 to 1976

State	1974	1975	1976 (annualized)
Alaska	2.8	2.9	3.2
California	2.2	3.3	3.4
Louisiana	114.2	132.1	134.7
Texas	21.3	21.0	32.2
Florida	–	1.9	–
New Jersey	–	–	.4
Massachusetts	–	–	.4
Total Offshore Rig Years of 356-Day Years	140.5	161.2	174.3

Source: Hughes Tool Company.

2. THE OFFSHORE SECTOR CONSISTS PRIMARILY OF FOUR HIGHLY SPECIALIZED VESSEL TYPES

The offshore segment consists of the following types of specialized vessels:

- Exploration or survey craft
- Drilling rigs
- Service craft
- Construction and pipelaying.

Each of these vessel types is discussed below.

(1) Exploration or Survey Craft

The offshore oil exploration fleet for the U.S. consists of approximately 30 vessels classified as geophysical or survey vessels. The typical vessel is 125' in length with 1,000 HP installed, develops from 10 to 12 knots and is diesel-powered.

(2) Drilling Rigs

Offshore drilling rigs fall into the four major categories shown in Table V-2. Fuel consumption of these rigs averages 50 bbl's/day for the submersible, jack-up and moored drillships. The larger, dynamically positioned rigs average 100 bbl's/day due to their position keeping propulsion requirements.

Submersible, jack-up and moored drillships typically operate in the shallow water close to shore while the semisubmersible dynamically positioned rigs operate in deeper water.

(3) Service Craft

The offshore service industry is the largest part of the offshore sector in terms of numbers of units. It consists of those firms operating the specialized types of service craft necessary to supply the various drilling rigs and construction and pipelaying barges with men and material. The estimated size of the offshore fleet, by type of craft is given in Table V-3. The offshore service craft population of 757 vessels indicated in Table V-3 represents those vessels actively employed in this sector as of 1976. This population figure differs from the 621 service craft population in Table V-4, which represents a calculated vessel requirement for 1976 based on duty cycle assumptions explained in Appendix A. By far the most prevelant types of craft fall into four categories:

- Crew Boats. These are aluminum hulled, diesel-powered, high speed craft that transport men and a minimal amount of equipment to offshore rigs. As exploration has moved farther offshore, transportation of crews by helicopter is becoming more accepted.

Table V-2
World Rig Population By Type

Type	In Operation	Under Construction	Total No.	%	Max Operating Water Depth	Average* Fuel Usage	Average Constr. Costs (Millions)
Submersible	23	0	23	5	80'	50 bbl/day	–
Drillships & Barges	71	30	101	22	20,000'	50 bbl/day 100 bbl/day	Moored - $30 Dynamically - Positioned $50
Jack-Up's	135	57	192	43	600'	100 bbl/day	$27 million
Semisubmersibles	75	52	127	30	6,000'	100 bbl/day (Diesel Oil)	$45 million

* Ocean Drilling and Exploration Company.

Source: Ocean Industry, Sept. 1975.

Table V-3
U.S. Offshore Service Fleet
Typical Characteristics

	Number	Length in Feet	Horsepower	Speed (knots)
Crewboats	160	90	1,800	25
Crew/Utility	5	90	1,000	15
Crew/Supply	12	100	2,000	25
Tugs	238	100	4,000	14
Tug/Supply	165	190	3,300	15
Supply	112	170	3,300	13
Supply/Utility	12	100	1,000	10
Utility	23	100	1,500	12
Geophysical	30	125	1,000	10
Total	757			

Source: Ocean Industry, June 1976.

Note: Figures are Booz, Allen estimates based on a partial listing of the world service fleet.

- Tugs. These are steel hulled and diesel-powered units that are used for towing rigs and barges, anchor handling and stand-by emergency duty.

- Tug/Supply. These are steel hulled, diesel-powered vessels with large open deck area aft for cargo. In addition to providing towing service, similar to tugs, they transport supplies to various offshore activities.

- Supply Boats. These are steel hulled, diesel-powered units with large ocean deck area aft for cargo, designed specifically for carriage of drilling supplies to the offshore rigs.

Industry sources estimate that approximately 70 percent of the offshore service fleet is engaged in support of exploratory drilling and the remaining 30 percent is engaged in support of production, offshore construction and pipelaying.

(4) Construction and Pipelaying and Production Vessels

Construction of production platforms, production drilling and pipelaying follow the location of a proven oil field. Construction of production platforms is accomplished from work barges that are kept supplied by the offshore service fleet. Production platforms are generally permanently mounted on the ocean floor and production drilling is then undertaken from the fixed platform.

Pipelaying activities are generally conducted from nonself-propelled barges and are also supported by the service fleet.

3. THE EXPLORATORY DRILLING RIGS ACCOUNT FOR 70 PERCENT OF THE TOTAL SUPPLY CRAFT ACTIVITY

Drilling rigs and the supply craft needed to support their activity account for approximately 70 percent of the total activity in the offshore sector. Supply craft typically operate less than 16 hours per day in order to avoid U.S. Coast Guard requirements for additional crew members. Industry sources confirm this figure stating that a 50 percent utilization level for a supply boat is considered excellent. Much of the typical operating day for tugs and supply boat support craft is spent at very low power levels, either loading, unloading, or standing-by. Equivalent full power operating hours were estimated between 4 and 6 hours per day for support craft.

Earlier in this chapter it was estimated that drilling activity during 1976 required the equivalent of 174 rig-years. Industry estimates indicate that each rig requires the dedication of 2.5 supply boats. This figure is expected to rise to 3 boats per rig as exploratory drilling activity moves further offshore and supply lines lengthen. Based on these assumptions, the present active offshore fleet requirements are estimated to be 621 boats, split between the four major service types as shown in Table V-4.

Table V-4
U.S. Offshore Fleet Requirements
1976 and High 1985 Estimates

Vessel Type	% of Existing Fleet	1976 Share of 621 Boat Requirement	1985 Share of Maximum 1,491 Boat Requirement*
Crew	24	149	358
Tug	35	217	522
Tug/Supply	24	149	358
Supply	17	105	253

* Based on expected doubling of offshore drilling and and 3 boat/rig service requirement.

4. THE OFFSHORE SECTOR CONSUMES .064 QUADS OR 2 PERCENT OF THE ESTIMATED ENERGY REQUIREMENTS OF THE MARINE TRANSPORTATION INDUSTRY

The offshore sector's energy requirements were calculated based on the following assumptions:

- 174 annual rig-years activity
- 621 service craft requirements based on 2.5 boats per rig, distributed as shown in Table V-4

and representing 70 percent of the energy consumption of the service industry

- An average operating day equivalent to 5 full power hours

- Boat sizes and rig consumption figures based on Table V-2 and V-3

- Exploratory and construction energy requirements were estimated to be minimal.

These assumptions lead to a calculated energy consumption, shown in Table V-5, for the offshore oil exploitation sector of .064 quads. Of this total, .027 quads were estimated to be required by drilling rigs and .036 quads were attributed to service craft. Energy consumption by production platforms was not included in this analysis. The energy consumption of the survey sector and in pipelaying and construction was estimated to be minimal by industry sources when compared to that required by the supply craft and drilling rigs.

Table V-5
Estimated Annual Energy Consumption Within the Offshore Sector

Subsector	Estimated Energy Consumption (Quads)
Drilling Rigs	.027
Supply Craft Supporting Drilling Rigs	.026
Supply Craft Supporting Production and Pipelaying Activities	.010
Total	.064

VI. THE INLAND WATERWAYS SECTOR

VI. THE INLAND WATERWAYS SECTOR

The inland waterways segment of the U.S. Merchant Marine refers to those vessels operating between ports in the United States where the movement takes place entirely in rivers, canals, ports, channels, and other inland waters. Vessels operating within the U.S. Great Lakes system were discussed previously. Figure VI-1 provides a graphic illustration of the geographic boundaries of the U.S. inland waterway system.

1. THE U.S. INLAND SHIPPING SECTOR HAS DEVELOPED A UNIQUE METHOD OF MOVING WATERBORNE CARGO

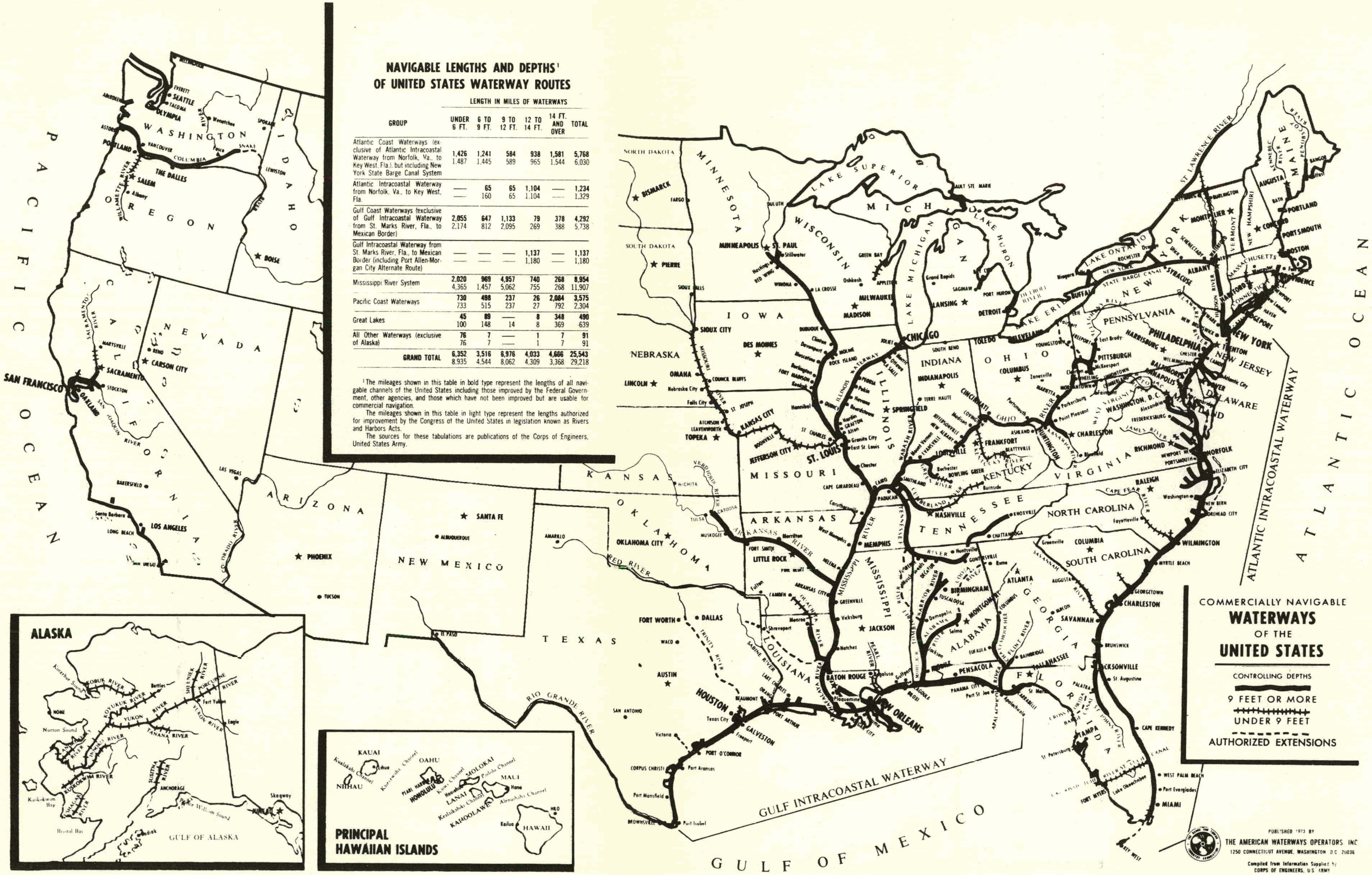
Most of the vessels operating upon the U.S. inland waterway system fall into the following categories:

- Towboats
- Tugboats
- Barges.

Technical characteristics of these vessel types are presented in the following section.

(1) Towboats Have Given Rise to the Concept of "Push-Towing", Which Is Unique to the United States

The towboat is a virtually flat-bottomed vessel which serves as the power unit for "push-towing" barges, in waterways that are protected or relatively calm in their natural state. Figure VI-2 presents an illustration of a typical towboat. Barges are lashed together by cables and ropes to form a single unit for push-towing. The towboat pushing from the rear of the tow is capable of handling a greater number of barges under better control than in the "pull-towing" method. These diesel powered vessels are capable of pushing barges carrying as much as 50,000 tons of cargo. The use of multiple rudders allows maximum control in forward, backing, and flanking movements; all necessary to navigate the winding channels of the inland rivers and canals.



NAVIGABLE LENGTHS AND DEPTHS[1] OF UNITED STATES WATERWAY ROUTES

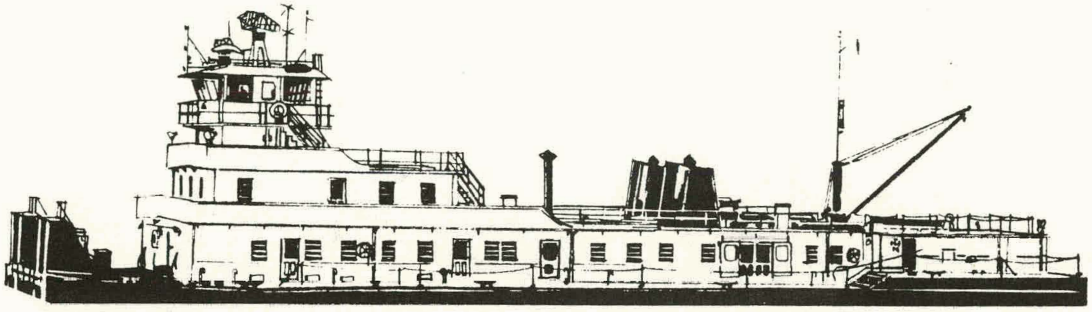
GROUP	LENGTH IN MILES OF WATERWAYS					
	UNDER 6 FT.	6 TO 9 FT.	9 TO 12 FT.	12 TO 14 FT.	14 FT. AND OVER	TOTAL
Atlantic Coast Waterways (exclusive of Atlantic Intracoastal Waterway from Norfolk, Va., to Key West, Fla.), but including New York State Barge Canal System	**1,426** 1,487	**1,241** 1,445	**584** 589	**938** 965	**1,581** 1,544	**5,768** 6,030
Atlantic Intracoastal Waterway from Norfolk, Va., to Key West, Fla.	— —	**65** 160	**65** 65	**1,104** 1,104	— —	**1,234** 1,329
Gulf Coast Waterways (exclusive of Gulf Intracoastal Waterway from St. Marks River, Fla., to Mexican Border)	**2,055** 2,174	**647** 812	**1,133** 2,095	**79** 269	**378** 388	**4,292** 5,738
Gulf Intracoastal Waterway from St. Marks River, Fla., to Mexican Border (including Port Allen-Morgan City Alternate Route)	— —	— —	— —	**1,137** 1,180	— —	**1,137** 1,180
Mississippi River System	**2,020** 4,365	**969** 1,457	**4,957** 5,062	**740** 755	**268** 268	**8,954** 11,907
Pacific Coast Waterways	**730** 733	**498** 515	**237** 237	**26** 27	**2,084** 792	**3,575** 2,304
Great Lakes	**45** 100	**89** 148	— 14	**8** 8	**348** 369	**490** 639
All Other Waterways (exclusive of Alaska)	**76** 76	**7** 7	— —	**1** 1	**7** 7	**91** 91
GRAND TOTAL	**6,352** 8,935	**3,516** 4,544	**6,976** 8,062	**4,033** 4,309	**4,666** 3,368	**25,543** 29,218

[1] The mileages shown in this table in bold type represent the lengths of all navigable channels of the United States including those improved by the Federal Government, other agencies, and those which have not been improved but are usable for commercial navigation.

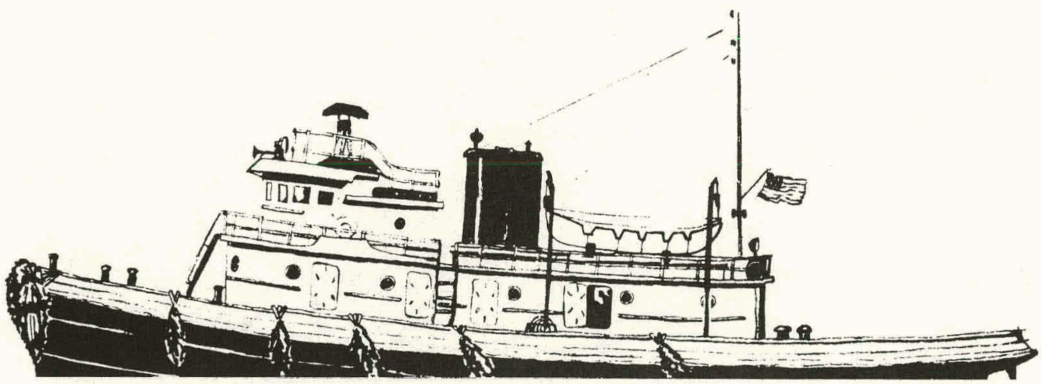
The mileages shown in this table in light type represent the lengths authorized for improvement by the Congress of the United States in legislation known as Rivers and Harbors Acts.

The sources for these tabulations are publications of the Corps of Engineers, United States Army.

FIGURE VI-2
Typical Inland Waterway Vessels



Towboat



Tugboat

The character and conditions of the waterway, locking conditions, the size of the tow, and the horsepower of the towboat all influence load characteristics and productivity. Some towboats are being rigged for both push and pull-towing by the addition of an after towing bitt. Towboats are unsuited for ocean towing because of their flat bottom and conventional (nontight) doors and windows. Table VI-1 presents the characteristics of some common towboats.

Table VI-1
Towboats

Length (ft)	Breadth (ft)	Draft (ft)	Horsepower Range
117	30	7.6	1,000–2,000
142	34	8	2,000–4,000
160	40	8.6	4,000–6,000

Source: "Big Load Afloat," American Waterways Operators, 1973.

(2) Tugboats Provide "Pull-Towing" in Areas of the Inland Waterway System Where Towboats are Unsuited

Tugs are designed for pull-towing under conditions where wind, wave, and tidal actions would normally break up a tow of barges rigidly lashed together. Figure VI-2 presents an illustration of a typical tugboat. In portions of the inland waterway system, particularly the Atlantic and Gulf Intracoastal Waterway, a tug pulls barges behind on a hawser. The pull-towing method essentially provides propulsion power, with very little guidance or control. These vessels have shaped hulls and are fitted with sealed portholes and watertight doors. Although tugboats are suited for a myriad of jobs, such as assisting oceangoing vessels in docking and undocking, and salvage work; they are commonly used to tow barges along the inland waterways. Table VI-2 presents the characteristics of some common tugboats.

Table VI-2
Tugboats

Length (ft)	Breadth (ft)	Draft (ft)	Horsepower Range
65-80 90	21-23 24	8 10-11	350-650 800-1,200

Source: "Big Load Afloat," American Waterways Operators, 1973.

(3) Barges Provide Low-Cost Commodity Shipping on the U.S. Inland Waterways

Barges are nonself-propelled, steel-hulled, shallow draft vessels designed for operation as single units or as part of an integrated tow. Integrated tows, having an underwater shape almost equivalent of a single vessel, provide the most efficient method of barge movement. Barges are designed to carry various types of cargo and are generally of the following types:

- Hopper barges
- Tank barges
- Deck barges.

Hopper barges are double-skinned, open-topped boxes, with the inner shell forming a cargo hold. They can be equipped with or without hatches.

Tank barges are used to transport bulk liquid commodities. This variety of barges are single-skinned vessels with collision bulkheads, double-skinned vessels, and those fitted with independent cylindrical tanks to carry pressurized cargoes.

Deck barges are designed to carry cargo that can be tied down and does not require protection from the elements. These barges have a simple box hull with a well supported deck. Many of these vessels are employed by the construction industry as work platforms and for moving equipment and supplies. They are also commonly used as railcar ferries.

2. INLAND CARGO MOVEMENTS ARE DOMINATED BY BULK COMMODITIES

Traffic on the inland waterway system is characterized by large loads of semi-finished and bulk commodities as shown in Table VI-3. In 1974, inland waterway traffic amounted to over 500 million long tons, or approximately 16 percent of the U.S. domestic waterborne commerce.

Table VI-3
Inland Waterway Commodities 1974

Commodity	Long Tons (10^6)
Petroleum and Products	193
Coal and Coke	108
Iron Ore, Iron, Steel	14
Sand, Gravel, Stone	66
Grains	23
Logs, Lumber	22
Chemicals	33
Shells	16
All Other	61
Total	536

Sources: Waterborne Commerce of the United States, 1974. U.S. Army Corps of Engineers.

The operating profile for the inland waterways sector of the Maritime industry was developed using information obtained from the Maritime Administration, American Waterways Operators Association, and individual operators. It was found that barges are generally committed to one trade, eliminating the need to clean multiple tows if more than one type of cargo is carried. Smaller sized boats are frequently used for movements above St. Louis in the Mississippi River System and average 15 barges per tow. South of St. Louis the waterways allow larger boats to accommodate up to 30-50 barges in a tow. The boats operate at full power virtually all of the time. High speed oil tows move at 13 to 14 miles per hour and dry bulk tows move at 7 to 9 miles per hour. In many of the dry bulk trades, boats deliver loaded barges and pick up empty ones, avoiding port delays. Normal loading/unloading time in the petroleum trade averages about 12 hours.

3. THE INLAND WATERWAYS SECTOR REPRESENTS 2 PERCENT OF THE NON-RECREATIONAL POPULATION AND CONSUMED 3 PERCENT OF THE ENERGY REQUIRED BY THE MARINE TRANSPORTATION INDUSTRY

In 1974 there were over 2,400 tug/towboats operating on the U.S. inland waterways according to Army Corps of Engineer's data shown in Table VI-4. The total number of towing vessels differs from the U.S. Coast Guard's estimate. The towing vessels listed by the Corps of Engineers reflect Army figures built up from data voluntarily supplied by operators and is not inclusive due to some non responses. U.S.C.G. data shown in Appendix D includes all vessels registered with a service of towing and include some vessels that are uneconomical and very old.

Table VI-4

Number of Towing Vessels and Barges of the United States Operated For the Transportation of Freight as of January 1, 1975[1].

Types of Vessels	Mississippi River System and the Gulf Intracoastal Waterway
SELF-PROPELLED	
Towboats and Tugs	
Number of Vessels	2,404
Horsepower	3,226,545
NON-SELF-PROPELLED	
Dry Cargo Barges and Scows	
Number of Vessels	17,345
Cargo Capacity (net tons)	21,031,652
Tank Barges	
Number of Vessels	2,903
Cargo Capacity (net tons)	6,117,768
Total Non-Self-Propelled	
Number of Vessels	20,248
Cargo Capacity (net tons)	27,149,420

1 From Corps of Engineers, U.S. Army.

Source: 1974 Inland Waterborne Commerce Statistics, American Waterway Operators, Inc.

The inland waterways sector of the Maritime industry is estimated to have consumed .089 quads of energy in 1974. The inland waterways sector is the most efficient sector of the Marine Transportation Industry in terms of Btus consumed per ton of cargo moved. Table VI-5 summarizes the results of the analysis of the inland waterways sector of the Marine Transportation Industry.

Table VI-5
Inland Waterways Sector Summary

Vessel	Population	Millions of Tons Carried	Billions of Ton-Miles	Millions of Btus/Ton	Btus/Ton-Mile	Btus in Quads
Tug/Towboat	2,404	535.8	185.0	.16	481	.089

This efficiency is due to the fact that inland waterways transportation is primarily the movement of large volumes of bulk commodities. The energy estimates for the inland waterways sector were based on the use of an average or "generic" towboat, shown in Table VI-6, and the amount of cargo capable of being towed by that generic vessel.

Table VI-6
Generic Towing Vessel

	Horsepower	Speed (mph)
Tug/Towboat	1,350	7.2

A more detailed explanation of the means in which energy consumption estimates were developed is provided in Appendix A.

VII. FISHING AND MISCELLANEOUS SECTOR

VII. FISHING AND MISCELLANEOUS SECTOR

The U.S. commercial fishing fleet can be characterized as fragmented and dominated by single family one boat operations. According to the National Marine Fisheries Service, the U.S. fishing fleet consists of over 15,000 vessels with capacities in excess of 5 net tons and more than 72,000 boats with capacities less than 5 net tons. The U.S. Coast Guard listing of fishing craft shown in Appendix D includes approximately 22,000 craft. Many fishing craft are registered with municipal or state agencies, and most small craft are not required to register at all. In 1973, the U.S. fishing fleet landed a catch of nearly 5 billion pounds of seafood, and consumed approximately .022 quads of energy. Table VII-1 presents the distribution of fishing craft among the major fisheries of the United States.

Table VII-1
Major Fisheries of the United States*

Fishery	Vessels	Boats	Total Craft
Pacific Salmon Purse Seine	1,019	1,411	2,430
Gill Net	1,340	8,507	9,847
Troll Lines	2,978	5,450	8,428
Pacific Tuna Purse Seine	1,444	2	1,446
Lines	1,937	228	2,165
All Menhaden Districts:			
Purse Seine	118	217	335
All Crab Pot Districts	1,531	4,349	5,880
All Oyster Dredges	693	579	1,272
All Shrimp Districts:			
Otter Trawl	5,243	6,060	11,303
All Fish Otter Trawl	1,181	160	1,341
Total	17,484	26,963	44,447

* Some fishing vessels operate in more than one fishery and may be double counted.

Source: "Fishery Statistics of the United States," National Marine Fisheries Service, Department of Commerce, 1973.

1. PHYSICAL CHARACTERISTICS AND OPERATING PATTERNS OF FISHING CRAFT VARY GREATLY WITH THE METHOD OF FISHING AND TYPE OF GEAR USED

Fish landed each year in the United States are caught using a variety of fishing gear including nets, lines and traps. The major types of vessels and the manner in which they operate are discussed in the following sections.*

(1) Seiners Accounted For More Than 50 Percent of All Landings in 1973

These vessels seek out a school of fish and encircle them with their net using one or two small boats or skiffs. The nets are then pulled in until the fish are sufficiently concentrated in the nets to allow brailing or pumping aboard. Most of the fuel consumption of this type of vessel takes place in transit to and from the fishing grounds.

(2) Trawlers and Dredges Are Probably the Most Fuel Intensive of All Fishing Craft

Trawling and dredging vessels will spend up to 20 days a month at sea. During this operational period these vessels are underway and under power 90 percent of the time and are actually engaged in trawling about 60 percent of the time. This method of fishing requires that the vessel remain underway while hauling a huge net or dredge through the water to capture the fish. Although such vessels are engaged in catching numerous species of fish, they may be best known for their service in the shrimp and menhaden fisheries (trawlers) and the shellfish industry (dredges).

(3) Vessels Utilizing Long Lines and Nets Will Often Operate at Sea for Extended Periods

This type of vessel utilizes sets of nets or bouyed lines and hooks strung together, (which may

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* Operating patterns for the major types of fishing were obtained through information from actual operators, trade associations, the National Marine Fisheries Service, the Food and Agricultural Organization of the United Nations, and various fishing publications.

extend for 50 to 75 miles) to land its catch. Sets are cast into the sea when a school of fish is spotted and hauled back in to secure the catch. The vessels cruise at low speeds when setting and hauling nets, making one catch a complete day's work. Because these vessels are often at sea for extended periods (sometimes up to 3 or 4 months), they must be seaworthy and capable of operating the engines continually without frequent overhaul.

(4) Vessels Utilizing Pots and Traps Are Unique to the Crab and Lobster Fisheries

Pot and trap vessels usually operate approximately 8 hours a day setting, checking, and resetting their gear. The engines run continually and the vessels make way when working the gear.

2. MISCELLANEOUS SERVICE CRAFT ACCOUNT FOR APPROXIMATELY 0.3 PERCENT OF THE COMMERCIAL MARINE TRANSPORTATION INDUSTRY POPULATION

According to the U.S. Coast Guard listing in Appendix D, there are 297 miscellaneous or harbor service craft. This classification includes such craft as fireboats, ice breakers, pilot boats, police and patrol boats. Miscellaneous service craft were judged to be insignificant in determining energy consumption because these vessels are small in size and see limited duty in local harbor areas.

3. IT IS ESTIMATED THAT FISHING AND MISCELLANEOUS SERVICE CRAFT CONSUMES APPROXIMATELY 1 PERCENT OF THE ENERGY REQUIRED BY THE MARINE TRANSPORTATION INDUSTRY

The U.S. commercial fishing is estimated to have consumed approximately .033 quads of energy. Energy consumption for this sector was estimated subjectively by allocating the remaining portion of domestic fuel oil sales in the United States to marine vessels to the commercial fishing fleet. Lack of sufficient data on which to construct operating profiles on the industry precluded a more detailed analysis of fuel consumption.

VIII. RECREATIONAL BOATS

VIII. RECREATIONAL BOATS

This sector consists of those small craft used exclusively for recreational purposes. The U.S. Coast Guard estimated that there were over 9 million recreational boats owned by Americans in 1975. Of these, more than 7 million were motor-powered boats.

1. THE DISTRIBUTION OF BOAT TYPES IS NOT HOMOGENEOUS THROUGHOUT THE UNITED STATES

Recreational boating statistics were subdivided into the following types of motorized boats:

- Canoe
- Houseboat
- Inboard
- Inboard/outboard
- Outboard
- Rowboat/jonboat
- Sailboat
- Other.

The latest comprehensive recreational boating survey performed by the U.S. Coast Guard in 1973, identifies power boats by type and region of the country as shown in Table VIII-1. The age of the average recreational boat in the

Table VIII-1
Recreational Power Boats by Type and Region, 1973

Type	New England	Middle Atlantic	Gulf Coast	East Central	Great Lakes	Midwest/ Mountains	West Coast	Total
Canoe (Motor)	16,651	12,732	4,272	-0-	22,911	419	-0-	56,985
Houseboat	6,882	7,910	10,960	3,710	7,765	1,415	-0-	38,552
Inboard	94,014	107,547	79,240	27,542	120,731	26,414	105,321	560,817
Inboard/Outboard	45,213	77,256	97,717	24,332	118,485	37,124	127,190	527,317
Outboard	546,315	655,903	997,150	354,316	1,098,017	362,433	405,872	4,420,006
Rowboat/Jonboat	47,812	74,066	63,320	18,508	101,725	32,159	43,071	380,661
Sailboat (Aux)	20,185	15,052	4,124	-0-	4,652	2,652	38,318	84,983
Other	60,565	41,824	114,528	59,306	95,288	60,529	26,582	458,622
Total 1973	837,637	999,290	1,371,319	487,714	1,569,484	523,145	746,354	6,527,943
Total 1975								7,303,286

Source: National Boating Survey, U.S. Coast Guard, 1973.

U.S. is 7.6 years. The national boating survey by the U.S. Coast Guard in 1973 showed that 58.3 percent of the boats are under 16 feet in length and 37.8 percent are between 16 and 25 feet in length. Aluminum and fiberglass are the most common hull materials for recreational boats, making up 33.5 percent and 40.3 percent of the boating population, respectively. The horsepower distribution of recreational boats is presented in Table VIII-2.

Table VIII-2
Horsepower Distribution of
Motor-Powered Recreational Boats

	Horsepower Range			
	<11	11-20	21-35	36-100
Percentage of Recreational Boat Population	31%	9%	12%	31%

Source: U.S. Coast Guard Boating Survey, 1973.

2. PLEASURE BOATS ARE ESTIMATED TO HAVE CONSUMED APPROXIMATELY 7 PERCENT OF THE ENERGY REQUIRED BY THE MARINE TRANSPORTATION INDUSTRY

As shown in Table VIII-3 the average recreational boat consumed 1.46 gallons of fuel per hour of use during 1973.

Table VIII-3
Recreational Boating Exposure and Consumption, 1973

Type	Boat-Hours	Passenger-Hours	Fuel (Gallons)	Gallons Fuel/ Boat-Hour	Gallons Fuel/ Passenger-Hour
Canoe (with Motor)	10,521,958	28,497,775	5,055,717	.48	.18
Houseboat	8,979,244	36,918,388	9,850,733	1.10	.27
Inboard	143,910,487	515,578,254	361,426,930	2.51	.70
Inboard/Outboard	87,597,223	318,295,732	203,824,362	2.33	.64
Outboard	614,174,260	1,719,439,174	811,733,849	1.32	.47
Rowboat/Jonboat (Motor)	34,561,211	84,561,968	26,310,465	.76	.31
Sailboat (Aux)	16,121,041	57,206,703	3,285,897	.20	.06
Other	125,769,890	386,941,283	102,212,382	.81	.26
Total	1,041,635,314	3,147,439,277	1,523,700,335	1.46	.48

Source: National Boating Survey, U.S. Coast Guard, 1973.

Boats with inboard motors have the highest average amount of boating hours and consumed more fuel per boating-hour than any other type. Boats with outboard motors had the highest total number of boating and passenger hours, but ranked third behind inboard and inboard/outboard powered boats in terms of gallons of fuel consumed per boating-hour.

In order to estimate annual consumption it is necessary to determine the annual operating cycle of recreational boats. Table VIII-4 presents the results presented in the National Boating Survey and indicates that the average recreational boat was operated for 186.2 hours during 1973.

Table VIII-4
Average Exposure By Type, 1973

Type	Boating-Hours/Yr
Canoe	184.6
Houseboat	232.9
Inboard	256.6
Inboard/Outboard	166.1
Outboard	139.0
Rowboat/Jonboat	90.8
Sailboat	189.7
Other	229.8
Total	186.2

Source: National Boating Survey, U.S. Coast Guard, 1973.

A review of these two tables indicates that the average recreational boat consumed 271.8 gallons of fuel per year during 1973.

This indicates that the 6.5 million boat population estimated in Table VIII-1 for 1973, consumed approximately 1.8 billion gallons or .220 quads of energy in that year. After adjusting this estimate to reflect the results of the latest survey, it is estimated that recreational boats consumed 2.0 billion gallons or .241 quads of energy during 1975.

APPENDIX A

MARINE FUEL CONSUMPTION CALCULATIONS

APPENDIX A

MARINE FUEL CONSUMPTION CALCULATIONS

Calculations for determining fuel consumption in the Maritime industry differed in level of detail between foreign and domestic cargo movements. The ocean shipping sector calculations were broken down according to service, ship type and flag of registry; while the various domestic sectors were calculated only for each vessel type.

In all cases, calculations were intended to relate energy consumption to the amount of cargo tonnage moved by each industry sector. Trade statistics for the year 1974 were used. These figures were the latest available from government sources.

1. OCEAN SHIPPING SECTOR

Generic vessels were chosen for each ship type in the sector which represent typical ships in the trade. Table A-1 shows the generic vessels, their operational characteristics, deadweight utilization and the trade routes to which they were applied. Figure A-1 presents an operational diagram for commercial vessels. Energy consumption calculations consisted of the following steps:

- The level of trade on each trade route was allocated among the various ship types shown in Table A-1.
- The number of voyages required to move this tonnage on the heavy leg of each trade route was then determined for each ship type by dividing the amount of cargo by the deadweight of the vessel taking into account a deadweight utilization factor.

$$\text{No. Voyages (NV)} = \frac{\text{(tonnage on heavy leg)}}{\text{(vessel DWT)(deadweight utilization)}}$$

- At-sea consumption was determined by first calculating hours (T) spent at sea using the speed of the generic vessel and voyage length. The specific fuel consumption (SFC) rate (.37 lb/shp-hr for diesel and .47 lb/shp-hr for steam) was then multiplied by the horsepower (HP) of the generic vessel, hours at sea, and the number of voyages and divided

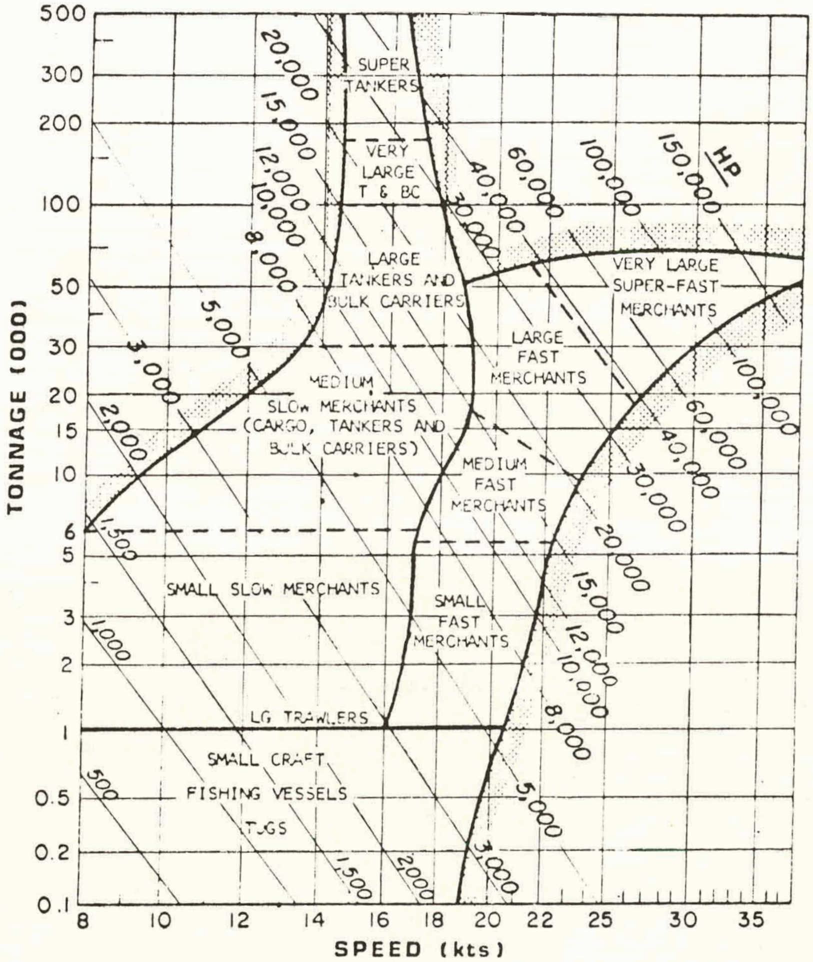
Table A-1
Generic Vessels Physical Description and Applications

Trade Routes

Vessel Type	Deadweight	Horsepower	(Knots) Speed	% Dwt Util.	1	2	4	5 7 8 9	6	10	11	12	13	14	15A	15B	16	17	18	19	20	21	22	23	24	25	26	27	28	29	31
Container	12,000	8,000	16				●																								
	16,500	17,000	20	50%																							●	●	●		
	18,500	18,000	20			●		●			●						●														
	23,000	28,000	23																			●								●	
Roll On-Roll Off	10,000	11,000	24				●																								
	16,500	22,000	22.5	33%						●									●	●	●								●	●	
	18,000	25,000	22.5					●	●																			●			
Barge Carrier	33,000	33,000	22	60%						●									●		●							●	●		
	42,000	38,000	22															●				●	●								
Break-Bulk	13,500	14,500	19	40%	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Tramp	8,400	5,000	14	40%	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Dry Bulk	20,000	8,000	15							●				●	●	●			●	●	●			●	●	●		●			●
	30,000	10,000	15	96%	●	●							●										●				●		●	●	
	40,000	11,000	15				●	●	●		●	●					●	●				●									
Tanker	20,000	7,000	14		●						●	●			●	●	●				●	●	●				●				
	40,000	9,000	14				●		●											●					●					●	●
	65,000	14,000	15	96%		●		●		●			●											●		●		●			
	80,000	16,000	15											●				●	●												
	150,000	20,000	15																										●		
Passenger	20,000 Grt	20,000	20.5				●																	●		●					
	30,000 Grt	26,000	21					●	●	●	●																				

Great Lakes Vessels				
Dry Bulk	15,000	4,000	11	96%
Tanker	4,000	1,500	11	96%
Tug		900	8	
Inland Waterways				
Tug/Towboat		1,350	6.5	
Coastal				
Tug		2,000	8	
Tanker	40,000	12,000	16	96%
Other	7,800	6,000	15.5	50%

FIGURE A-1
Operating Diagram For Major Ship Types



Source: "Trends In Merchant Shipping," Donald Ross, Tetratech Report to Naval Undersea Center.

by 2,240 (pounds per long tons) to get at-sea fuel consumption in long tons.

Fuel Consumption (FCS) = (SFC)(HP)(T)(NV)/(2,240)

- Port consumption was calculated using formulae for general cargo vessels and bulk commodity carriers obtained from various sources.*

  - General cargo vessels (long tons/day) = (.000678)(DWT)

  - Tankers and bulk carriers (long tons/day) = $\frac{(SFC)(HP)(24)(.364)}{2,240}$

The fuel consumption figures were totalled by trade route, ship type, fuel type, and flag before being converted to Btus using the conversion factors in Appendix C.

2. GREAT LAKES SECTOR

The generic vessels chosen for the Great Lakes sector are shown in Table A-1. Energy consumption calculation consisted of the following steps:

- The total ton-miles for both the self-propelled and towing sectors was then divided by the ton-miles per average trip to obtain the average number of trips.

- Using a speed of 9 miles per hour for towing vessels and 12 miles per hour for self-propelled vessels and the average haul distances, the number of steaming hours was calculated:

  - Number of steaming hours per voyage (towing) = 136

  - Number of steaming hours per voyage (self-propelled) = 106.

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* General cargo vessel port consumption is from "General Cargo Ship Economics and Design," Benford. Tanker and dry bulk carrier port consumption is from Maritime Administration report on Tanker Preliminary Design.

- The specific fuel consumption rate of .37 lb/shp-hr for diesel and .47 lb/shp-hr for steam was then multiplied by the average horsepower, "steaming" hours per voyage, and number of trips and divided by 2,240 lb/long ton to obtain the steaming time fuel consumption.
- Port consumption for self-propelled vessels was calculated in the same manner used for the ocean shipping sector. Port consumption for towing vessels was assumed to be negligible due to the operating patterns discussed in Chapter VI.

3. COASTAL SHIPPING SECTOR

The generic vessels chosen for the coastal shipping sector are shown in Table A-1. Energy consumption was calculated using the same method described in the Great Lakes sector. Vessel characteristics for coastal tankers and tugboats were based on numerical averages of the U.S. tanker fleet and the coastal towing fleet. A converted C-2 containership was chosen to represent all other coastal shipping vessels.

4. OFFSHORE SECTOR

The generic vessels chosen for the offshore sector are shown in Table A-2.

Table A-2
Generic Offshore Vessels

Vessel Type	Population	Horsepower	Full Power Operating Hours Per Day
Crewboat	149	1,800	5
Tug	217	4,000	5
Tug/Supply	149	3,300	5
Supply	105	3,300	5

Energy consumption for the offshore sector was calculated based on the following assumptions:

- 174 annual rig-years of activity.
- 620 service craft requirement (all diesel-powered).

- Average operating day equivalent to 5 full power hours.
- Exploratory and construction energy requirements were estimated to be minimal.
- Rig consumption is estimated to be 75 barrels per day.
- Drilling rigs are assumed to operate 365 days per year.

These assumptions lead to a calculated energy consumption for rigs arrived at by multiplying the number of rigs (NR), by the operating days per year (OD), and rig fuel consumption per day (BBL).

$$RC = NR \times OD \times BBL$$

Service craft fuel consumption was arrived at by multiplying the number of boats (NB), full power operating hours per day (OH), operating days per year (OD), horsepower (HP), and specific fuel consumption (SFC). This total was divided by 2,240 (pounds per long ton) to get tons of fuel consumed in one year.

$$SCR = [(NB \times OH \times OD \times HP \times SFC) \div 2{,}240]$$

5. INLAND WATERWAYS SECTOR

The generic vessel chosen for the inland waterways sector, shown in Table A-3, represents a numerical average of towing vessels listed by the Army Corps of Engineers.

Table A-3
Generic Towing Vessel

Horsepower	Speed
1,350	7.2 mph

Energy consumption was calculated using the same method described in the Great Lakes sector.

6. FISHING AND MISCELLANEOUS SECTOR

Lack of sufficient data precluded a detailed calculation of energy consumption for the fishing and miscellaneous sector. After calculating fuel consumption for all domestic sectors, an energy consumption figure was obtained for the fishing and miscellaneous sector by subtracting the calculated figures from reported fuel sales for domestic marine use. Reported fuel sales were obtained from Department of Commerce, Department of Transportation and Department of Interior publications. Table A-4 describes the steps involved in estimating energy consumption in the fishing and miscellaneous sector.

Table A-4
Energy Consumption Estimate of Fishing and Miscellaneous Sector

Total Distillate Fuel	Btus in Quads
A. Sales to Domestic Vessels	.180
Calculated Distillate Fuel Consumption:	
Great Lakes	.007
Coastal	.020
Inland	.089
B. Total	.119
Difference (A-B)	.064
Assume 50% of Reported Sales to Recreational Boating	.032
Estimated Fishing and Miscellaneous Consumption	.032

Energy consumption of the offshore sector was not included in this analysis since the majority of offshore service craft are chartered by oil companies which supply these vessels with fuel but do not report it as being sold. As a result, fuel consumption by the offshore sector is not included in the government fuel sales statistics.

7. PLEASURE BOAT SECTOR

Energy consumption for the Pleasure Boat sector was estimated by the U.S. Coast Guard in 1973 through a comprehensive nationwide boating survey. Data obtained through the 1973 survey included average boating hours per year per boat and gallons of fuel consumed per boating hour. Based on the results of the 1973 survey, fuel consumption was calculated using the 1975 U.S. Coast Guard estimate of the number of motorized pleasure boats, and divided between gasoline (48%) and diesel powered boats (52%).

APPENDIX B

ESSENTIAL TRADE ROUTES

APPENDIX B

ESSENTIAL TRADE ROUTES

The trade routes used in this study are those deemed by the U.S. Congress to be "...essential for maintaining the flow of foreign commerce of the United States..." The essential trade routes are described below in Table B-1 as defined by the Maritime Administration in its publication, "Essential United States Foreign Trade Routes."

Table B-1
Essential Trade Routes

Trade Route No.	Description
1	U.S. Atlantic/East Coast South America. Between U.S. Atlantic ports (Maine-Atlantic Coast Florida to but not including Key West) and ports in Brazil, Paraguay, Uruguay, and Argentina.
2	U.S. Atlantic/West Coast South America. Between U.S. Atlantic ports (Maine-Atlantic Coast Florida to but not including Key West) and ports in Pacific Coast Colombia, Equador, Peru, and Chile.
4	U.S. Atlantic/Caribbean. Between U.S. Atlantic ports (Maine-Atlantic Coast Florida to but not including Key West and ports in the Gulf of Mexico and Caribbean Sea (Mexico-French Guiana, inclusive), all islands of the Caribbean and West Indies (except Puerto Rico), the Bahama Islands, and Bermuda.
5-7-8-9	U.S. North Atlantic/Western Europe. Between U.S. North Atlantic ports (Maine-Virginia, inclusive) and ports in the United Kingdom, Republic of Ireland, and Continental Europe (Germany south of Denmark to northern border of Portugal).
6	U.S. North Atlantic/Scandinavia and Baltic. Between U.S. North Atlantic ports (Maine-Virginia, inclusive) and ports in Scandinavian and Baltic countries and the intermediate islands of Iceland, Greenland, and Newfoundland.

Trade Route No.	Description
10	U.S. North Atlantic/Mediterranean. Between U.S. North Atlantic ports (Maine-Virginia, inclusive) and ports in Portugal, Spain south of Portugal, Atlantic Morocco, and the Mediterranean Sea (including the Adriatic Sea, Aegean Sea, Black Sea, and other seas which are arms of the Mediterranean).
11	U.S. South Atlantic/Western Europe. Between U.S. South Atlantic ports (North Carolina-Atlantic Coast Florida to but not including Key West) and ports in the United Kingdom, Republic of Ireland, and Continental Europe north of Portugal.
12	U.S. Atlantic/Far East. Between U.S. Atlantic ports (Maine-Atlantic Coast Florida to but not including Key West) and ports in Japan, Taiwan, Philippines, and the Continent of Asia from the Union of Soviet Socialist Republics to Thailand, inclusive.
13	U.S. South Atlantic and Gulf/Mediterranean. Between U.S. South Atlantic and Gulf ports (North Carolina-Texas, inclusive) and ports in Portugal, Spain south of Portugal, Atlantic Morocco, and the Mediterranean Sea (including the Adriatic Sea, Aegean Sea, Black Sea, and other seas which are arms of the Mediterranean).
14	U.S. Atlantic and Gulf/West Africa. Between U.S. Atlantic and Gulf ports (Maine-Texas, inclusive) and ports on the West Coast of Africa from the southern border of Morocco to the southern border of Angola, including Madeira, Canary, Cape Verde, and other islands adjacent to the West African Coast.
15-A	U.S. Atlantic/South and East Africa. Between U.S. Atlantic ports (Maine-Atlantic Coast Florida to but not including Key West) and ports in South and East Africa from the southern border of Angola to Cape Guardafui in the Somali Republic, including the Islands of Ascension and St. Helena in the South Atlantic, the Malagasy Republic, and adjacent islands in the Indian Ocean not east of 60° East Longitude.

Trade Route No.	Description
15-B	U.S. Gulf/South and East Africa. Between U.S. Gulf ports (Key West-Texas, inclusive) and ports in South and East Africa from the southern border of Angola to Cape Guardafui in the Somali Republic, including the Islands of Ascension and St. Helena in the South Atlantic, the Malagasy Republic, and adjacent islands in the Indian Ocean not east of 60° East Longitude.
16	U.S. Atlantic and Gulf/Australia and New Zealand. Between U.S. Atlantic and Gulf ports (Maine-Texas, inclusive) and ports in Australia, New Zealand, New Guinea, and South Sea Islands within the general area.
17	U.S. Atlantic, Gulf, and Pacific/Indonesia, Malaysia, and Singapore. Between U.S. Atlantic, Gulf, and Pacific Coast ports and ports in Indonesia, Malaysia (Malaya, Sarawak, and Sabah), Singapore, and Brunei.
18	U.S. Atlantic and Gulf/India, Persian Gulf, and Red Sea. Between U.S. Atlantic and Gulf ports (Maine-Texas, inclusive) and ports in Southwest Asia from Suez to Burma, inclusive, and Africa on the Red Sea and Gulf of Aden.
19	U.S. Gulf/Caribbean. Between U.S. Gulf ports (Key West-Texas, inclusive) and ports in the Gulf of Mexico and Caribbean Sea (Mexico-French Guiana, inclusive) and all islands of the Caribbean and West Indies (except Puerto Rico).
20	U.S. Gulf/East Coast South America. Between U.S. Gulf ports (Key West-Texas, inclusive) and ports in Brazil, Paraguay, Uruguay, and Argentina.
21	U.S. Gulf/Western Europe. Between U.S. Gulf ports (Key West-Texas, inclusive) and ports in the United Kingdom, Republic of Ireland, and Continental Europe north of Portugal.

Trade Route No.	Description
22	U.S. Gulf/Far East. Between U.S. Gulf ports (Key West-Texas, inclusive) and ports in Japan, Taiwan, Philippines, and the Continent of Asia from the Union of Soviet Socialist Republics to Thailand, inclusive.
23	U.S. Pacific/Caribbean. Between U.S. Pacific ports (Washington-California, inclusive) and ports in the Gulf of Mexico and Caribbean Sea (Mexico-French Guiana, inclusive) and all islands of the Caribbean and West Indies (except Puerto Rico).
24	U.S. Pacific/East Coast South America. Between U.S. Pacific ports (Washington-California, inclusive) and ports in Brazil, Paraguay, Uruguay, and Argentina.
25	U.S. Pacific/West Coasts Mexico, Central and South America. Between U.S. Pacific ports (Washington-California, inclusive) and Pacific Coast ports of Mexico, Central America, Panama, Panama Canal Zone, and South America.
26	U.S. Pacific/Western Europe. Between U.S. Pacific ports (Washington-California, inclusive) and ports in the United Kingdom, Republic of Ireland, and Continental Europe north of Portugal.
27	U.S. Pacific/Australia and New Zealand. Between U.S. Pacific ports (Washington-California, inclusive, and Hawaii) and ports in Australia, New Zealand, New Guinea, and South Sea Islands within the general area.
28	U.S. Pacific/India, Persian Gulf, and Red Sea. Between U.S. Pacific ports (Washington-California, inclusive) and ports in Southwest Asia from Suez to Burma, inclusive, and Africa on the Red Sea and Gulf of Aden.
29	U.S. Pacific/Far East. Between U.S. Pacific ports (Washington-California, inclusive, Alaska, Hawaii, and U.S. islands lying between the United States and the Far East) and ports in Japan, Taiwan, Philippines, the Continent of Asia from

Trade Route No.	Description
	the Union of Soviet Socialist Republics to Thailand, inclusive, and other Pacific islands lying between the United States and the Continent of Asia as heretofore described.
31	<u>U.S. Gulf West Coast South America.</u> Between U.S. Gulf ports (Key West-Texas, inclusive) and ports in Pacific Coast Colombia, Ecuador, Peru, and Chile.

APPENDIX C

CONVERSION FACTORS

APPENDIX C

CONVERSION FACTORS

The conversion factors used in the study are listed in Tables C-1 and C-2.

Table C-1
Energy Content of Fuel Types

Fuel Type	Btus/Long Ton of Fuel
Diesel	43.142×10^6
Residual	41.451×10^6
Gasoline	44.887×10^6
Coal	26.2×10^6

Table C-2
Conversion Factors

To Convert	
Pounds to long tons	Divide by 2240
Gallons to barrels	Divide by 42
Barrels to long tons	Multiply by .134

APPENDIX D

MERCHANT VESSELS OF THE UNITED STATES

APPENDIX D

MERCHANT VESSELS OF THE UNITED STATES

Each year the United States Coast Guard publishes "Merchant Vessels of the United States (Including Yachts)," which lists and describes American merchant vessels and yachts having uncanceled documents. The 1976 computer tapes of this publication were obtained from the U.S. Coast Guard and proved to be a valuable data source for identifying and categorizing the U.S. merchant fleet. Table D-1 through D-7 summarize the various groups of vessels contained in the U.S. Coast Guard publication.

Table D-1

1. CARGO VESSELS

HORSEPOWER	0 TO 50	51 TO 100	101 TO 500	501 TO 1000	1001 TO 5000	5001 TO 10000	10001 TO 20000	20001 TO OVER
NUMBER OF SHIPS	64.	123.	668.	68.	256.	429.	242.	111.
AVERAGE GRT	732.	25.	125.	972.	5644.	10597.	17454.	25184.
AVERAGE NRT	482.	17.	83.	623.	4052.	7028.	11770.	18243.
AVERAGE HP	25.	82.	234.	709.	2506.	7243.	15434.	27597.
AVERAGE LENGTH	69.6	45.1	60.4	136.5	421.4	515.8	597.1	689.6
AVERAGE BEAM	17.6	13.5	16.7	29.8	52.6	68.6	83.7	96.0
AVERAGE DEPTH	5.8	5.2	6.1	10.2	25.3	35.5	40.6	46.0

TOTAL READ 1961

NUMBER OF SHIPS 1961

Table D-2

1. TOWING VESSELS

HORSEPOWER	0 TO 50	51 TO 100	101 TO 500	501 TO 1000	1001 TO 5000	5001 TO 10000	10001 TO 20000	20001 TO OVER
NUMBER OF SHIPS	34.	157.	2841.	1498.	1689.	105.	8.	0.
AVERAGE GRT	23.	17.	34.	99.	266.	659.	1097.	0.
AVERAGE NRT	11.	12.	22.	62.	163.	437.	745.	0.
AVERAGE HP	30.	85.	284.	756.	2091.	6422.	11405.	0.
AVERAGE LENGTH	40.0	41.4	46.9	64.8	99.1	146.3	152.1	0.0
AVERAGE BEAM	12.5	12.1	15.0	21.0	28.5	43.4	56.7	0.0
AVERAGE DEPTH	4.1	4.6	5.6	7.9	10.2	11.2	18.9	0.0

TOTAL READ 6332.

NUMBER OF SHIPS 6332

Table D-3

1. OIL EXPLOITATION VESSELS

HORSEPOWER	0 TO 50	51 TO 100	101 TO 500	501 TO 1000	1001 TO 5000	5001 TO 10000	10001 TO 20000	20001 TO OVER
NUMBER OF SHIPS	4.	20.	998.	433.	602.	20.	1.	0.
AVERAGE GRT	65.	15.	29.	86.	240.	593.	8300.	0.
AVERAGE NRT	64.	12.	20.	57.	161.	381.	7534.	0.
AVERAGE HP	0.	82.	286.	725.	1733.	6467.	12750.	0.
AVERAGE LENGTH	64.0	39.7	41.5	70.6	118.9	186.0	255.1	0.0
AVERAGE BEAM	33.3	13.4	14.9	20.9	29.3	41.4	191.1	0.0
AVERAGE DEPTH	6.6	3.5	5.2	7.6	10.3	16.9	24.3	0.0

TOTAL READ 2078

NUMBER OF SHIPS 2078

Table D-4

1. FISHING VESSELS

HORSEPOWER	0 TO 50	51 TO 100	101 TO 500	501 TO 1000	1001 TO 5000	5001 TO 10000	10001 TO 20000	20001 TO OVER
NUMBER OF SHIPS	695.	3402.	17424.	677.	237.	2.	0.	0.
AVERAGE GRT	12.	15.	36.	161.	634.	1438.	0.	0.
AVERAGE NET	9.	10.	24.	101.	360.	818.	0.	0.
AVERAGE HP	35.	82.	215.	679.	2100.	5875.	0.	0.
AVERAGE LENGTH	36.0	36.8	46.0	83.7	154.8	224.1	0.0	0.0
AVERAGE BEAM	11.1	11.7	14.5	21.8	32.1	43.2	0.0	0.0
AVERAGE DEPTH	4.4	4.7	6.0	9.5	13.3	20.2	0.0	0.0

TOTAL READ 22437

NUMBER OF SHIPS 22437

Table D-5

1. MISC SERVICE CRAFTS

HORSEPOWER	0 TO 50	51 TO 100	101 TO 500	501 TO 1000	1001 TO 5000	5001 TO 10000	10001 TO 20000	20001 TO OVER
NUMBER OF SHIPS	5.	11.	168.	85.	28.	0.	0.	0.
AVERAGE GRT	27.	13.	28.	55.	366.	0.	0.	0.
AVERAGE NRT	25.	10.	20.	35.	234.	0.	0.	0.
AVERAGE HP	28.	89.	271.	667.	1600.	0.	0.	0.
AVERAGE LENGTH	41.0	36.0	44.4	51.9	108.1	0.0	0.0	0.0
AVERAGE BEAM	13.4	12.1	13.8	15.2	25.0	0.0	0.0	0.0
AVERAGE DEPTH	6.0	3.9	5.6	6.8	11.3	0.0	0.0	0.0

TOTAL READ 297

NUMBER OF SHIPS 297

Table D-6

1. PASSENGER VESSELS + FERRYS

HORSEPOWER	0 TO 50	51 TO 100	101 TO 500	501 TO 1000	1001 TO 5000	5001 TO 10000	10001 TO 20000	20001 TO OVER
NUMBER OF SHIPS	315.	474.	4912.	952.	215.	17.	8.	0.
AVERAGE GRT	135.	17.	21.	53.	469.	3311.	11146.	0.
AVERAGE NRT	74.	13.	16.	37.	292.	1558.	6030.	0.
AVERAGE HP	31.	82.	268.	652.	1680.	7098.	17188.	0.
AVERAGE LENGTH	40.3	40.0	41.0	52.4	124.0	362.1	499.6	0.0
AVERAGE BEAM	13.3	12.6	13.2	16.8	36.9	70.2	78.8	0.0
AVERAGE DEPTH	5.3	4.9	5.1	6.4	9.7	20.2	30.3	0.0

TOTAL READ 6893

NUMBER OF SHIPS 6893

Table D-7

1. PLEASURE VESSELS

HORSEPOWER	0 TO 50	51 TO 100	101 TO 500	501 TO 1000	1001 TO 5000	5001 TO 10000	10001 TO 20000	20001 TO OVER
NUMBER OF SHIPS	12767.	2323.	17042.	6130.	235.	1.	0.	0.
AVERAGE GRT	11.	18.	23.	32.	95.	31.	0.	0.
AVERAGE NRT	10.	16.	17.	25.	70.	24.	0.	0.
AVERAGE HP	29.	76.	312.	625.	1262.	9600.	0.	0.
AVERAGE LENGTH	33.6	40.2	37.7	44.8	71.5	48.0	0.0	0.0
AVERAGE BEAM	10.5	12.2	12.1	14.0	18.0	13.0	0.0	0.0
AVERAGE DEPTH	6.4	6.4	5.4	6.8	8.7	7.4	0.0	0.0

TOTAL READ 38498

NUMBER OF SHIPS 38498

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