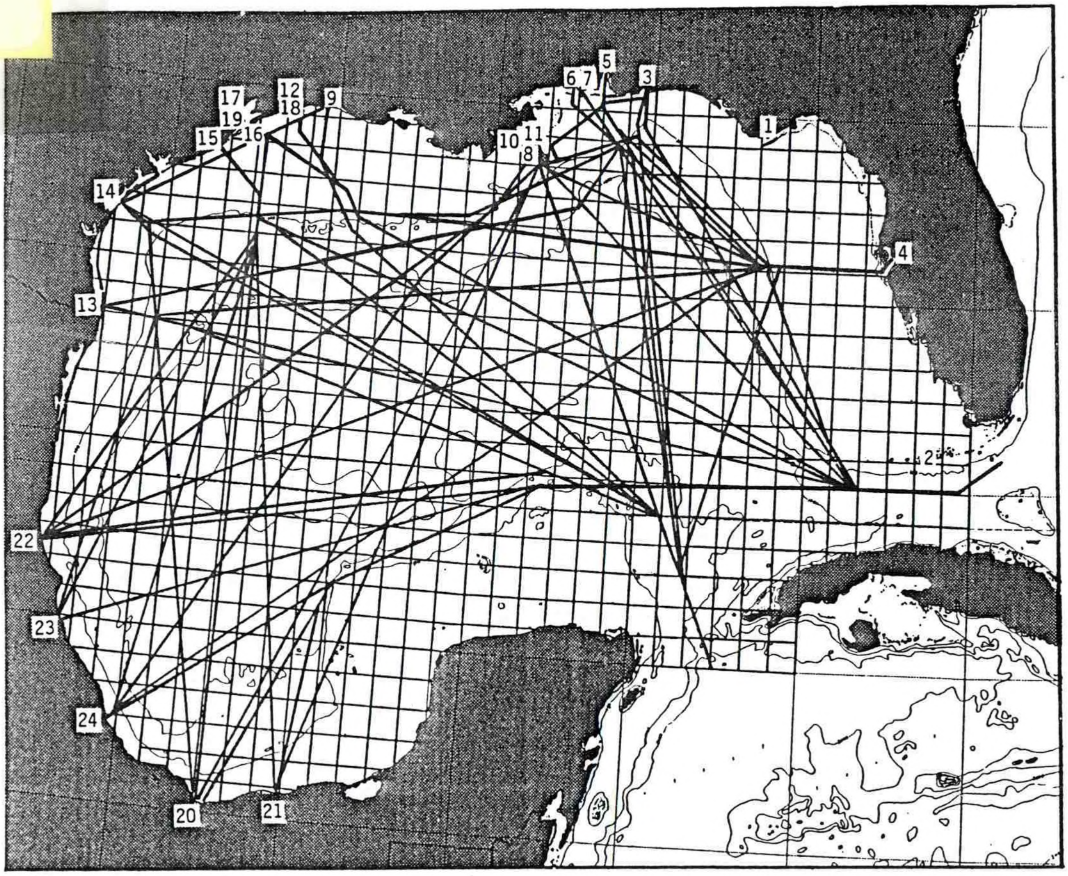

Operational Discharges of Oil from Marine Transportation Sources in the Gulf of Mexico

September 1981

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Services
National Ocean Service
National Oceanic and Atmospheric Administration
Rockville, Maryland 20852

SAB's Mission

The Strategic Assessment Branch is one of four branches of the Ocean Assessments Division, Office of Oceanography and Marine Services, National Oceanic and Atmospheric Administration. The mission of SAB is to conduct comprehensive interdisciplinary assessments of multiple ocean resource uses for the Nation and its major coastal and oceanic regions to determine marine resource development strategies which will result in maximum benefit to the Nation with minimum environmental damage or conflicts among uses. To accomplish this goal, SAB evaluates existing and projected ocean resource demands in terms of levels of use, resource availability, pollution discharges, potential environmental impacts and use conflicts, and maintains comprehensive national inventories of coastal and ocean resources and their existing and proposed uses. SAB develops strategic assessment methods and maintains an operational capability with which to evaluate the environmental and economic effects of national policies and management strategies affecting coastal and ocean resources. This paper briefly describes the development of data for one important source of oil pollution -- discharges from the normal operations of six types of ships in the Gulf of Mexico.

Introduction

This paper describes the first of two phases of a project undertaken by Engineering Computer Optecnomics, Inc. (ECO), Annapolis, Maryland, to develop a data base of oil discharges from ships operating in the Gulf of Mexico for the Office of Resources Coordination and Assessment (ORCA) of the National Oceanic and Atmospheric Administration. Although the National Academy of Sciences (NAS, 1975) has estimated that, on a global basis, over one-third of petroleum inputs to the oceans come from marine transportation sources, no comprehensive estimates have been made to date of the spatial and temporal distribution of oil discharges from these sources for individual waterbodies. This study represents a first attempt at estimating the spatial and temporal pattern of oil discharges from ships over an area as large as the entire Gulf of Mexico.

The development of this data base is an integral part of ORCA's strategic assessment project for the Gulf of Mexico region (ORCA, 1981a). The project was initiated in October 1980 and is the second of a series of five strategic assessments that will cover the entire "coastal zone" of the U.S. (excluding the Great Lakes), extending seaward to the 200-mile limit of the fishery conservation zone. These assessments are described as "strategic" because they are carried out from a comprehensive, long-term and large scale planning perspective intended to complement, not replace, the necessary detailed, site-specific or "tactical" analyses of specific ocean use proposals (ORCA, 1981b).

The Gulf of Mexico strategic assessment project focuses on the entire Gulf, including the coastal and ocean waters of both the U.S. and Mexico. The project is developing data on the distribution of various characteristics of the region including: 1) physical environments; 2) biotic environments; 3) species; 4) economic activities, including their pollutant discharges; and 5) political jurisdictions. These data, in conjunction with analyses performed using pollutant transport models, will be used as a basis for identifying and better understanding some of the relationships between and among economic activities, their pollutant discharges, and living marine resources in the Gulf of Mexico.

Estimation of the discharges of oil from ships operating in the Gulf of Mexico has been separated into two phases because of the varied nature of the phenomena that affect them. The two general types of oil discharges are: 1) "operational discharges" which occur routinely and intentionally as the result of normal operating procedures; and 2) "spills" which are the result of accidents. The latter type can be further divided into those which involve relatively small amounts of oil and are the result of, for example, equipment malfunction on board a vessel ("operational spills") and those which result from a major accident involving a vessel casualty, for example, a grounding, collision, ramming, fire, or explosion ("casualty spills"). The first type -- operational discharges -- is the subject of this paper. The data base developed during the first phase of the project is now being used by ECO to develop a Monte Carlo type simulation model to predict the likely location and magnitude of future operational and casualty spills in the Gulf. Additional discussion of this predictive model is included at the end of this paper.

Completion of the first phase has resulted in estimates of operational discharges of oil from six types of ships by 30-by-30 minute "grid cells" of longitude and latitude for the entire Gulf of Mexico for each month in 1979. The Gulf of Mexico has been divided into 611 grid cells, each roughly 30-by-30 nautical miles, for purposes of data organization and analysis (see figure on cover).

Nature of the Problem

Operational discharges of oil from ships are primarily the result of two operations: 1) bilge water pumping; and 2) tank cleaning and ballasting. The second type of operation is by far the most important -- accounting for about 70 percent of operational discharges of oil from ships.

Bilge pumping is the result of oil and water collected in the lower part of a ship's hull from leaking pipes and machinery and from hull valve connections. During transit bilge water must be periodically pumped overboard, either directly or after being pumped into a settling tank to allow the oil to separate from the water. Bilge water can also be discharged at sea through an oil-water separator which can reduce the total oil content of discharged water to less than 50 ppm.

Oil discharges also occur during routine tank cleaning and ballasting operations because some oil (clingage) remains in the cargo tanks, pumps, and pipelines after discharge of the cargo. To clean cargo tanks of product tankers and those of crude oil tankers not equipped with a crude oil washing (COW)1/ system, water is introduced into the tanks through spray nozzles which wash down the tank sides and bottom to:

1) remove cargo residue and sediment to avoid sludge build-up (a routine cleaning operation);

2) remove cargo residue and sediment to avoid contamination of the next cargo (an operation usually confined to product tankers only);

3) provide departure ballast when segregated ballast2/ is not provided;

1/ Crude oil washing systems use the lighter fractions of crude oil located at the top of subsequent cargo tanks to wash down each crude oil cargo tank as it is emptied. No water is introduced into the tank during washing and all tank contents are pumped ashore to the refinery.

2/ Segregated ballast is ballast water kept in ballast tanks which have no connections to the cargo tanks.

4) provide space for clean saltwater ballast; and

5) remove cargo residue and sediment prior to entering a shipyard for repair work (this operation is required only at 18-month to 2-year intervals).

These ballast and tank cleaning water discharges are usually handled in one of four ways:

1) for crude oil tankers on voyages longer than three days duration, tank cleaning water is pumped into a slop tank allowing the oil and water to separate, thereby retaining the oil on board and allowing the next crude oil cargo to be loaded on top (LOT)3/;

2) for product and crude oil tankers on voyages less than four days duration, ballast and tank cleaning water are discharged directly overboard without any effort to separate the oil from water and retain the oil on board;

3) all oil mixtures are retained on the vessel and discharged in port to a reception facility for oily wastes (Note that no ports in the Gulf of Mexico now have such facilities); or

4) oily mixtures are treated on board the vessel to separate the oil from the water.

Under the first and fourth alternatives, water and oily mixtures meeting applicable discharge criteria are then discharged overboard. The remainder is retained on board to mix with the next cargo, if compatible, or be transferred to reception facilities on shore (if they exist) for reuse or disposal.

The main forum for preventing and regulating oil pollution from ships is the United Nations Inter-Governmental Maritime Consultative Organization (IMCO). Although not all nations have ratified the requirements recommended by IMCO, the United States has adopted many of the IMCO recommendations4/. U.S. regulations concerning operational discharges from tank ships that operate in U.S. waters and which are relevant to this analysis include the following: 1) tank ships are prohibited from discharging oil or oily mixture unless the vessel is proceeding en route at a distance of more

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3/ For voyages of less than four days duration, insufficient time exists to allow the oil and water to separate properly.

4/ The 1973 International Convention for the Prevention of Pollution from Ships (MARPOL-73), as amended by the 1978 Tanker Safety and Pollution Prevention Conference (TSPP). In the U.S. these same standards are contained in the Port and Tanker Safety Act of 1978 (P.L. 95-474).

than 50 nautical miles from land, and the rate of discharge does not exceed 60 liters of oil per nautical mile; 2) segregated ballast tanks or crude oil washing (COW) systems are required on older crude oil tankers with a capacity of 40,000 deadweight tons (DWT) or greater; 3) new crude oil tankers require both segregated ballast tanks and COW systems to control operational discharges; and 4) the segregated ballast tanks on new crude oil and product tankers must be "protectively located" to reduce the risk of an oil spill in the event of a grounding or collision.

It is important to emphasize that while oil spills from vessel casualties -- especially the grounding or sinking of tankers -- typically capture the attention of the general public and many policy makers, operational discharges of oil account for the major share of oil inputs to the oceans from marine transportation sources. The preliminary results presented in this paper indicate that, in any given year, routine (i.e., operational) discharges from ships are many times the quantity of oil that enters the waters of the Gulf of Mexico from accidental (i.e., casualty and operational) spills.

Method of Analysis

Three factors conditioned the method of analysis. First, the spatial units of the operational discharge estimates had to be compatible with the spatial units of a surface oil spill trajectory model also being developed for the Gulf 5/. Second, and closely related to the first, estimates of operational discharges had to be made for time periods commensurate with those of the overall assessment, i.e., be representative of conditions in the Gulf of Mexico in the late 1970's and early 1980's for the winter and summer seasons. Third, detailed data on vessel movements in the Gulf were nonexistent. Where and when ships moved within the Gulf had to be determined.

The approach taken was first to determine the spatial and temporal distribution of vessel movements in the Gulf and then, given that distribution, estimate operational discharges of oil based on the characteristics and operating procedures of different types of vessels and the

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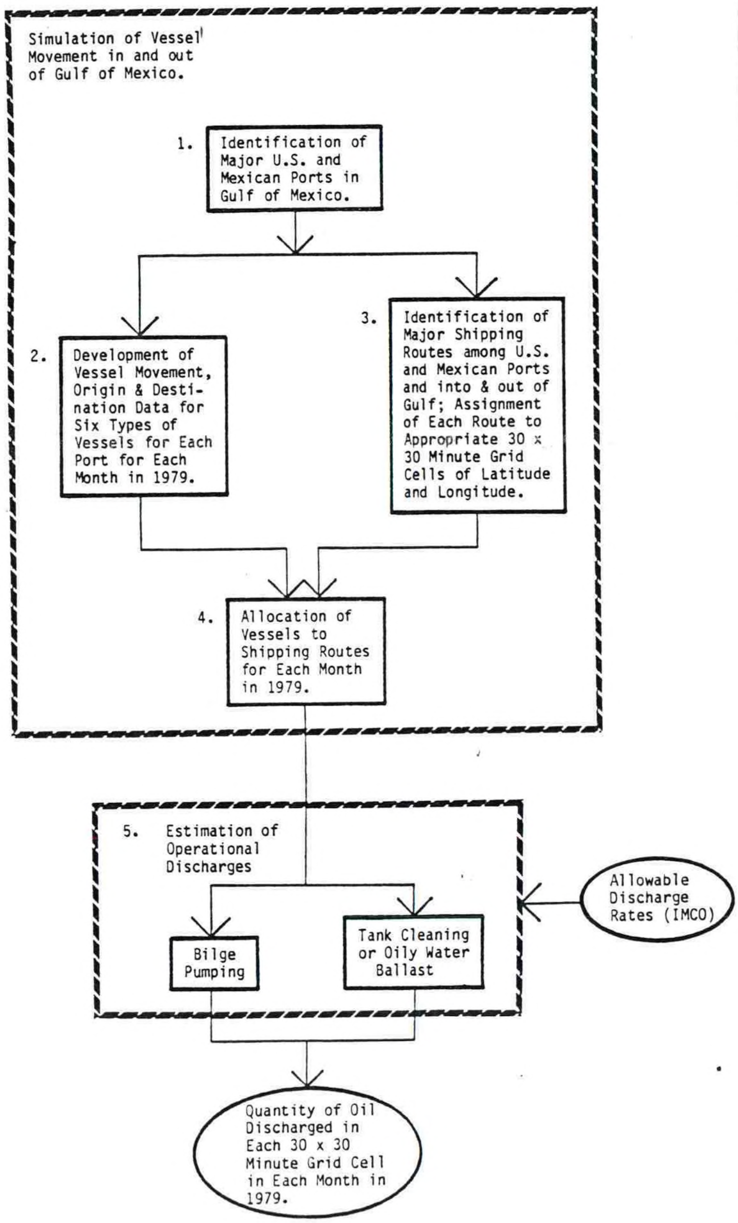
5/ The oil spill trajectory model is being developed by Dr. Peter Grose and his colleagues in the Marine Environmental Assessment Division of the Center for Environment Assessment Services, NOAA. The model is based on average surface currents and wind statistics and distributes oil discharges in each grid cell to adjoining cells based on the frequency distribution of local winds. The model will predict the "steady state" redistribution and degradation of oil on a monthly basis for the entire Gulf.

discharge rates allowed by IMCO. Five steps comprised the approach: 1) identification of major U.S. and Mexican ports in the Gulf; 2) computation and compilation of the number of vessel movements, i.e., the number of ships entering and leaving each port, including their origin and destination; 3) identification of the "major" shipping routes between and among each of these ports, as well as into or out of the Gulf via the Yucatan Channel and the Straits of Florida; 4) assignment of each ship entering or leaving a port to a specific shipping route; and 5) estimation of operational discharges by simulating vessel movement throughout the Gulf. Steps 1-4 represent the method that was devised, given available data, to estimate the spatial and temporal distribution of vessel movements in the Gulf of Mexico. Figure 1 illustrates these steps.

Figure 1. Method for Estimating Operational Discharges of Oil from Ships in the Gulf of Mexico



<u>Identification of Ports</u>: The procedure for selecting ports for analysis was to select ports, starting with the major ones, based on the amount of commercial traffic in and out, until 80 to 90 percent of the total tank ship, dry cargo ship, tank barge, tugboat, fishing vessel, and offshore crew and supply vessel traffic in the Gulf was accounted for in the base year. The latest year for which sufficient data were readily available was 1979. Table 1 lists the ports that were included in the analysis and identifies some of their traffic characteristics.

Table 1. Vessel Traffic Characteristics for Major Ports - 1979

		PORT	MAJOR PORT ACTIVITIES			PORT CALLS					
			Commercial	Fishing	Supply (OCS)	Dry Cargo	Tank Barges	Tank Ships	Tugboats/ Towboats	Fishing Vessels[a]	Offshore Supply Vessels[a]
UNITED STATES	1	Apalachicola, FL		●		-	-	-	-	5,000	-
	2	Key West, FL		●		-	-	-	-	18,000	-
	3	Pensacola, FL	●	●	●	160	-	10	-	11,000	2,000
	4	Tampa, FL	●	●		1,740	310	630	350	33,000	-
	5	Mobile, AL	●	●	●	940	<10	100	<10	18,000	1,000
	6	Biloxi, MS		●	●	-	-	-	-	16,000	4,000
	7	Pascagoula, MS	●			210	140	210	140	-	-
	8	Houma, LA		●	●	-	-	-	-	27,000	66,000
	9	Lake Charles, LA	●	●	●	380	70	200	110	3,000	7,000
	10	Morgan City, LA		●	●	-	-	-	-	10,000	72,000
	11	New Orleans, LA	●	●	●	4,920	70	1,310	150	20,000	85,000
	12	Beaumont, TX	●			290	60	770	160	-	-
	13	Brownsville, TX	●	●		90	<10	40	<10	19,000	-
	14	Corpus Christi, TX	●	●	●	530	70	670	110	23,000	13,000
	15	Freeport, TX	●			200	50	450	90	-	-
	16	Galveston, TX	●	●	●	890	<10	100	20	23,000	7,000
	17	Houston, TX	●	●	●	3,270	50	1,410	150	6,000	32,000
	18	Port Arthur, TX	●	●	●	<10	110	440	140	3,000	2,000
	19	Texas City, TX	●			110	50	1,100	90	-	-
MEXICO	20	Coatzacoalcos (SPM)	●		●	-	-	400	-	-	8,000
	21	Dos Bocas (SPM)	●			-	-	100	-	-	-
	22	Tampico	●	●	●	300	100	200	100	21,000	5,000
	23	Tuxpan	●		●	40	80	60	30	-	5,000
	24	Veracruz	●	●	●	700	120	100	120	12,000	4,000

Abbreviations: OCS, outer continental shelf; SPM, single point mooring facility

a/ Note that values in these columns are approximations only, estimated based upon number of vessels in each port and assumptions regarding average number of trips per week.

Note that some of the ports included are not necessarily "commercial" ports from the view point of value of waterborne commerce, but are important fishing ports or supply ports for OCS oil and gas operations or both: e.g., Apalachicola and Key West in Florida; Biloxi, Mississippi; and Houma, Louisiana.

Development of Origin and Destination Data: For each port two types of data were developed for the six categories of ships shown in Table 1 for each month in 1979: 1) the number of ships in each category entering and leaving the port; and 2) the origin and destination of each of these ships. For tank ships two additional types of data were also developed: 1) the load condition of each tank ship, i.e., was it carrying crude or product and its ballast condition; and 2) the size of each ship, by deadweight tons grouped into five size intervals.

Four sources of information were used to develop the data for U.S. ports: 1) the Maritime Administration's (MARAD) Vessel Movement Monthly Master Data File (U.S. Department of Commerce, 1979); 2) the Army Corps of Engineer's waterborne commerce statistics (U.S. Department of the Army, Army Corps of Engineers, 1978); 3) the U.S. Coast Guard's Documented Vessel File (U.S. Coast Guard, 1979); and 4) experienced personnel in local port authorities, the Corps of Engineers and the Department of Commerce. No single source provided all the requisite information for a given port. Information from each source had to be combined and synthesized to develop a complete data set for each one. For example, the MARAD Data File contains vessel traffic data for vessels engaged in foreign trade, i.e., vessels whose voyages originate from or terminate in foreign ports. It contains no traffic data for vessels engaged solely in domestic trade, i.e., U.S. port to U.S. port. The MARAD Data File does, however, contain vessel traffic data for foreign trade vessels which call on a series of U.S. ports as part of their foreign trade voyage, and thus contains some information on vessel movements from one U.S. port to another. Consequently, to account for vessels engaged solely in domestic trade the Corps of Engineer's waterborne commerce statistics had to be utilized in conjunction with the other sources mentioned. The U.S. Coast Guard's Documented Vessel Data File was particularly important for developing data on fishing and supply vessels.

Three sources of information were used to develop information on Mexican ports: 1) a market survey of Mexican ports, harbors, and shipyards (U.S. Department of State, 1976); 2) a Mexican report on port facilities (National Port Commission of Mexico, 1976); and 3) knowledgeable petroleum industry representatives. As was the case with U.S. ports, no one source provided all of the information necessary to generate the requisite data. Extrapolations had to be made for each port based on information on the vessel types, sizes, and numbers utilizing each port contained in the market survey report and information on berthing and ship handling contained in the Mexican report on port facilities. Petroleum industry personnel were particularly helpful in developing information on the oil loading facilities at Dos Bocas and Coatzacoalcos. Overall, the data developed for Mexican ports is less certain than that developed for U.S. ports where considerable effort has been routinely invested in collecting port statistics. Nevertheless, the data which has been developed for Mexican ports represent the best available and are adequate for the purposes of this analysis.

Identification of Shipping Routes and Vessel Assignments: Vessel origin and destination data derived for each port were used to identify the combinations of major ports between which shipping routes had to be defined. The routes were defined using a variety of sources and plotted on standard navigational charts. The most important source of information was operating personnel in major oil companies, independent oil companies, cargo shipping companies, and offshore supply and fishing vessel operations, who had considerable experience in the Gulf of Mexico. These individuals were able to provide detailed information on the routes which ships actually take between ports. This was especially important because once a ship leaves a port or terminal area there are no regulations which govern its movement. Two publications were also particularly useful, Essential U.S. Foreign Trade Routes (U.S. Department of Commerce, Maritime Administration, 1975) and "Vessel Traffic Study of the Florida Straits" (U.S. Coast Guard, 1976). Each vessel in each port in each month in 1979 was then assigned to a shipping route based on the origin and destination data.

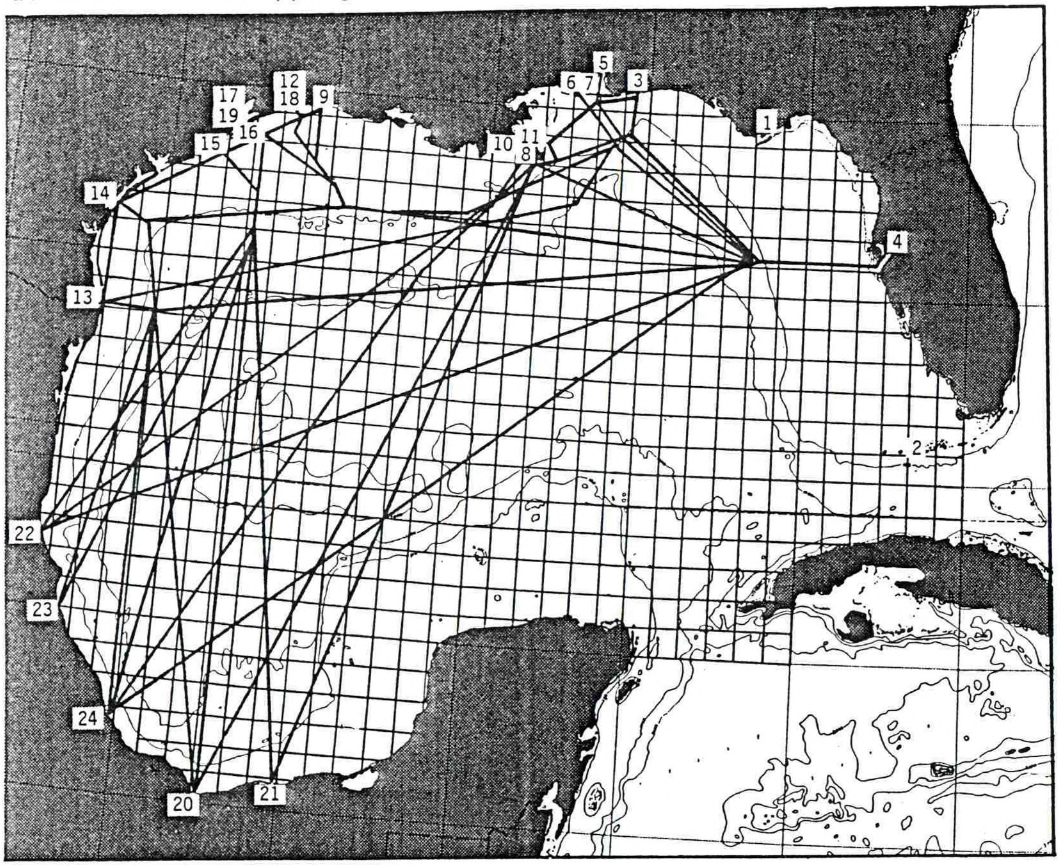
Shipping routes were then transcribed from the navigational charts on to the standard base map of the Gulf of Mexico Strategic Assessment Project (a Lambert conformal conic projection, scale = 1:2,000,000), on which a 30 x 30 minute longitude and latitude grid was overlayed. The cells of this grid represent the spatial units of the oil trajectory model. Each shipping route was defined as a sequence of 30-minute grid cells. Thus, as the movement of each ship is simulated along an appropriate shipping route, the oil it discharges can be assigned to specific grid cells. When all vessel movements are simulated along all shipping routes for a given time period, the total quantity of oil discharged into each grid cell by vessels passing through it can be determined. This is the basic structure which was used to distribute operational discharges of oil across the Gulf. Figure 2 illustrates the shipping routes that have been defined for the Gulf, as well as the 30-minute grids.

Estimation of Operational Discharges: Comprehensive data on operational discharges of oil from vessels is sparse and incomplete. However, given knowledge of the shipboard operations which result in these discharges and information on the types of ships of concern, estimates can be made based on some simple assumptions. Different estimation procedures were used for tank cleaning and ballasting operations than for bilge pumping.

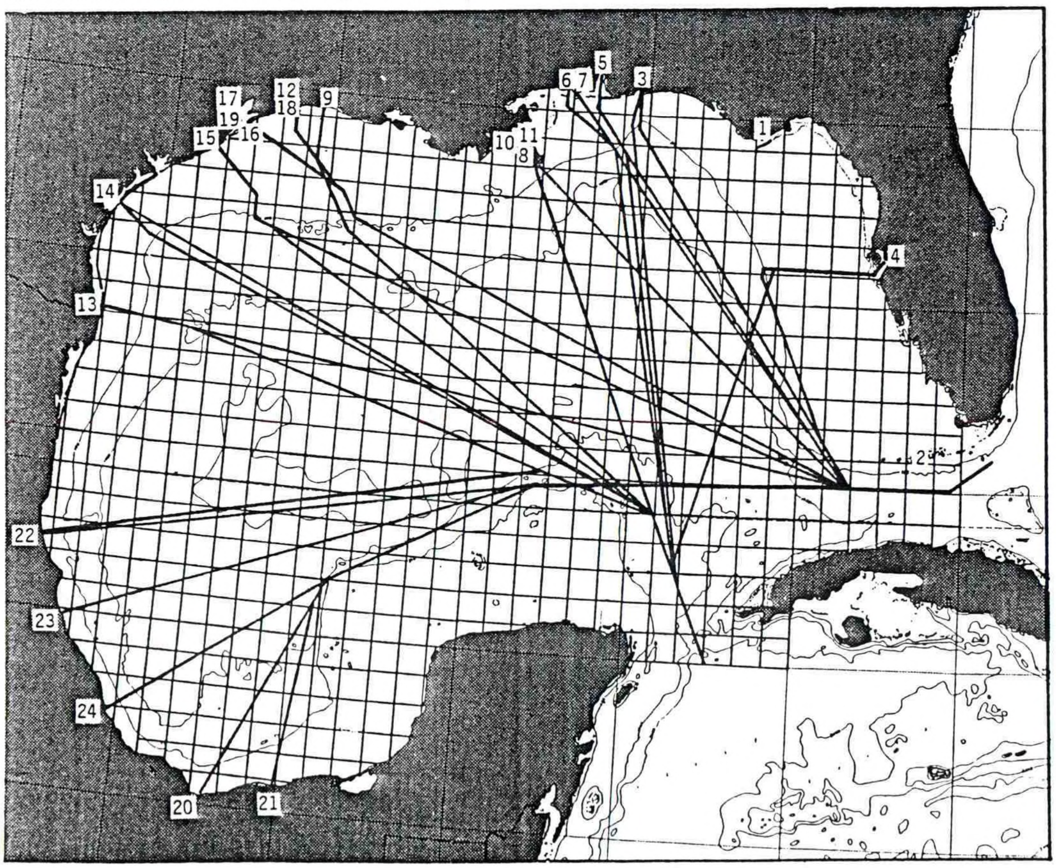
Tank cleaning water and oily ballast water discharges were estimated by assuming that tank ship operators would not exceed the limitations permissible under the IMCO regulations. The regulations stipulate that a tank ship cannot discharge a quantity of tank cleaning water and oily ballast that is more than 1/15,000 of its deadweight, and that these discharges are permitted only beyond 50 miles from land. Consequently, when vessel movements were simulated, tank ships were permitted to discharge tank cleaning water or oily ballast only after they were 50 miles from port. Once a tank ship began discharging it was assumed that either operation -- tank cleaning or discharging ballast -- would generally take about 24 hours

Figure 2. Major Shipping Routes in the Gulf of Mexico

a. Intra-Gulf Shipping Routes



b. Inter-Gulf Shipping Routes



a/ See Table 1 for Port Names

to complete, except in the case of large crude oil tankers. Assuming an average speed of 15 knots, the discharge was distributed along the assigned shipping route and hence into the appropriate grid cells. At no time was a tanker permitted to discharge more than the IMCO limit on rate of discharge -- 60 liters per mile. In a limited number of cases, trips between ports occurred either totally within the 50-mile limit or where insufficient time existed to allow proper tank settling and decanting. In these cases no discharges were permitted for the trip.

Discharges of oil due to bilge pumping were estimated by approximating the average quantity of oil typically contained in the bilge water of each of the vessel types included in the analysis. These "coefficients" were then applied to each vessel when its movement between ports was simulated. The average amount of bilge water discharged per vessel type was estimated based on a variety of bilge sizes, engine sizes and types, and machinery age and leakage rates. The quantity of oil contained in a bilge water discharge of a given size was estimated by applying the bilge water contamination limit established by IMCO -- 100 ppm -- to the volume discharged. Table 2 shows the quantity of oil estimated to be discharged with each bilge pumping for each vessel type.

TABLE 2. Estimated Oil Content in Bilge Water Discharges for Vessels Operating in the Gulf of Mexico

Vessel Type	Gallons of Oil per Bilge Water Discharge
Tank Ship	1.8
Dry Cargo Vessels	1.8
Tugboats/Towboats	0.6
Fishing Vessels	0.6
Offshore Crew and Supply Vessels	0.6

It was further assumed that each vessel pumped its bilges once during each trip and that these discharges were made only beyond the 50-mile limit. During the vessel movement simulation, a random number generator was used to determine into which grid cell outside the 50-mile limit, along a shipping route, a vessel discharged its bilge water.

Results

Following the procedures outlined above, estimates of the amount of oil discharged into the Gulf of Mexico due to normal marine transportation operations were made for each month in 1979. Figures 3, 4, and 5 illustrate some of these results. They show, respectively, the distribution of operational discharges of oil aggregated for all of 1979 (annual), the winter season of 1979, and the summer season of 1979. Several patterns are apparent, including the regularity of discharges along certain well travelled shipping routes. High discharges in these areas are due to a relatively constant and high volume of oil discharged from tank cleaning and ballasting operations, for example, in the northern Gulf between Houston and New Orleans where heavy tanker traffic exists. Oil discharges from bilge pumping contributed relatively little to the overall distribution of discharges, despite the high frequency of these operations. In every month, almost every grid cell outside the 50-mile limit received some amount of oil discharge from normal vessel operations.

The significance of these preliminary results can be implied by comparing the total amount of oil discharged from normal vessel operations to the quantity of oil reported to be spilled by ships in the Coast Guard's Pollution Incident Reporting System -- PIRS (U.S. Coast Guard, 1981). In 1979 PIRS reported about 40,000 gallons of oil spilled 12 nautical miles or more from shore. In 1980 PIRS reports about 300,000 gallons spilled, compared to about 2.5 million gallons from normal vessel operations (i.e., outside the 50-mile limit), based on 1979 traffic patterns. Based on these preliminary results, oil discharges from normal vessel operations appear to far outweigh discharges from operational and casualty spills in the Gulf.

However, the actual significance of oil discharges in the Gulf, both from normal vessel operations and operational and casualty spills cannot be assessed until the transport, transformation, and decomposition of these discharges are accounted for, and the potential biological effects of the resulting temporal and spatial distribution of oil throughout the Gulf determined. The latter is impossible to determine at this time. It must also be recognized that the nature of the likely effects of oil discharges from normal vessel operations on marine resources may be quite different over time than those from spills, further compounding this assessment problem, i.e., the distinction of the difference between the cumulative effects of chronic discharges over a very large area versus the acute effects of one or more spills within a much smaller area.

Nevertheless, the shear magnitude of oil discharges from normal vessel operations raises questions regarding current priorities and approaches to the control of oil pollution from marine transportation sources.

Figure 3. Distribution of Operational Discharges of Oil from Vessels in the Gulf of Mexico - 1979 (Annual)

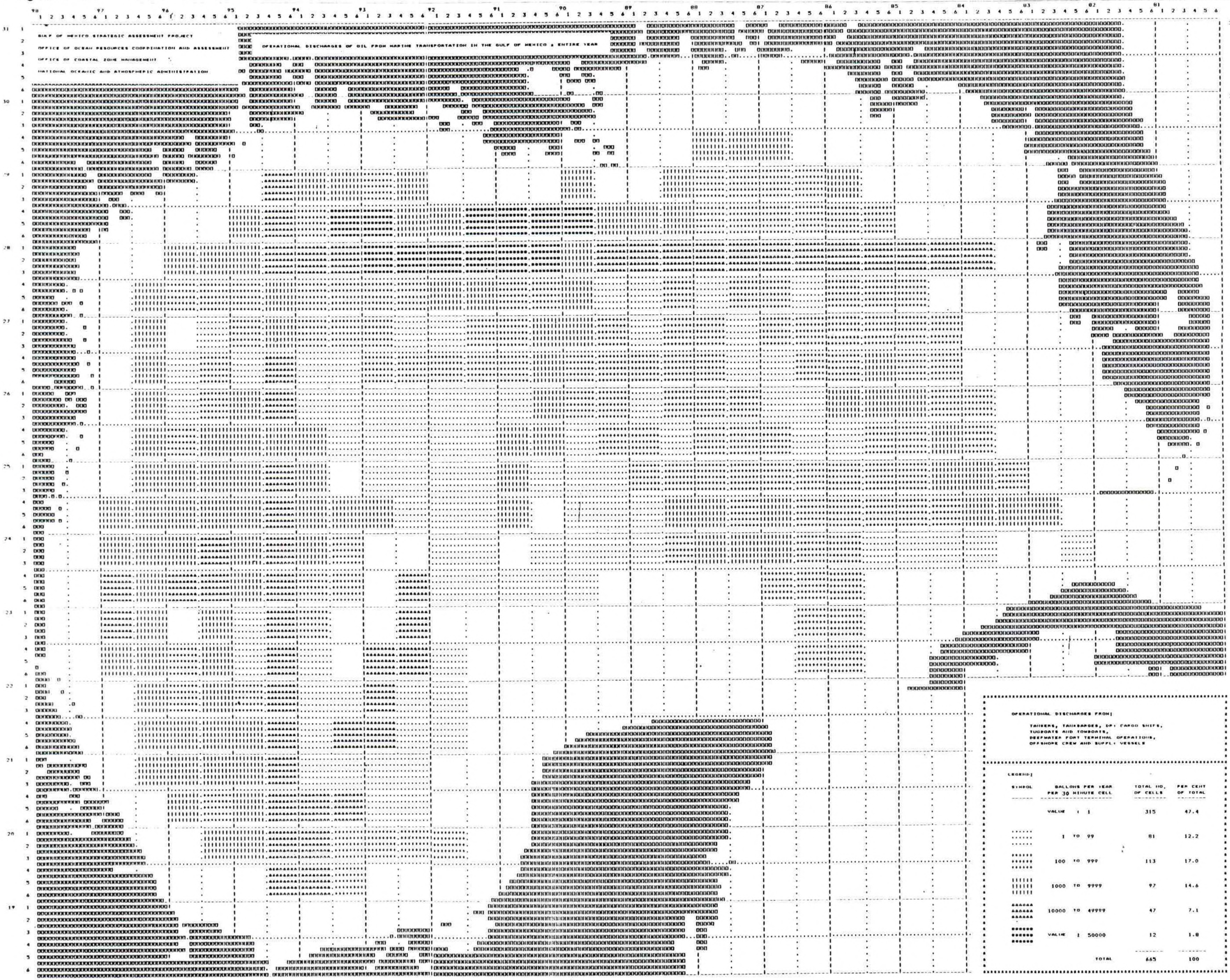


Figure 4. Distribution of Operational Discharges of Oil from Vessels in the Gulf of Mexico - Winter Season 1979

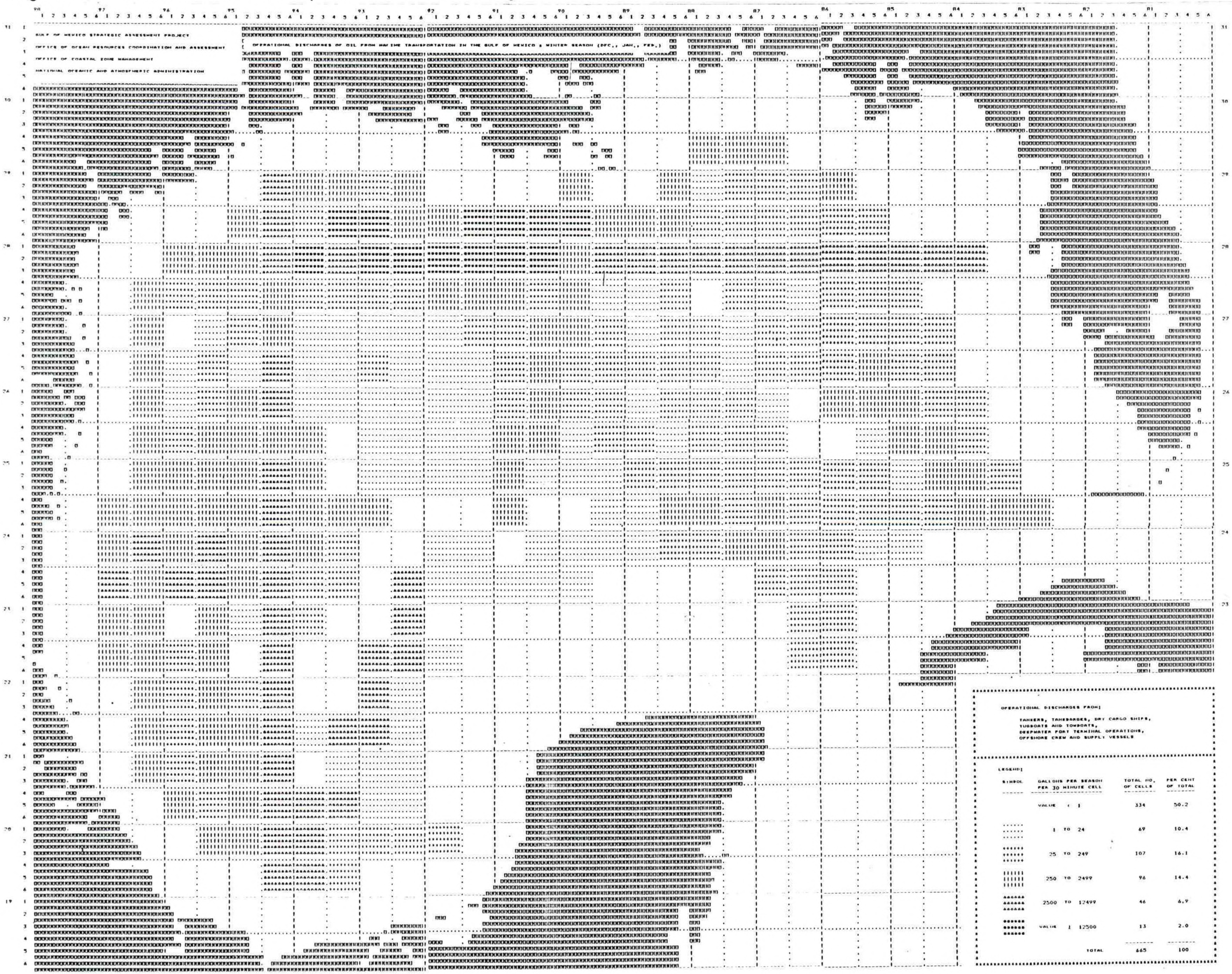
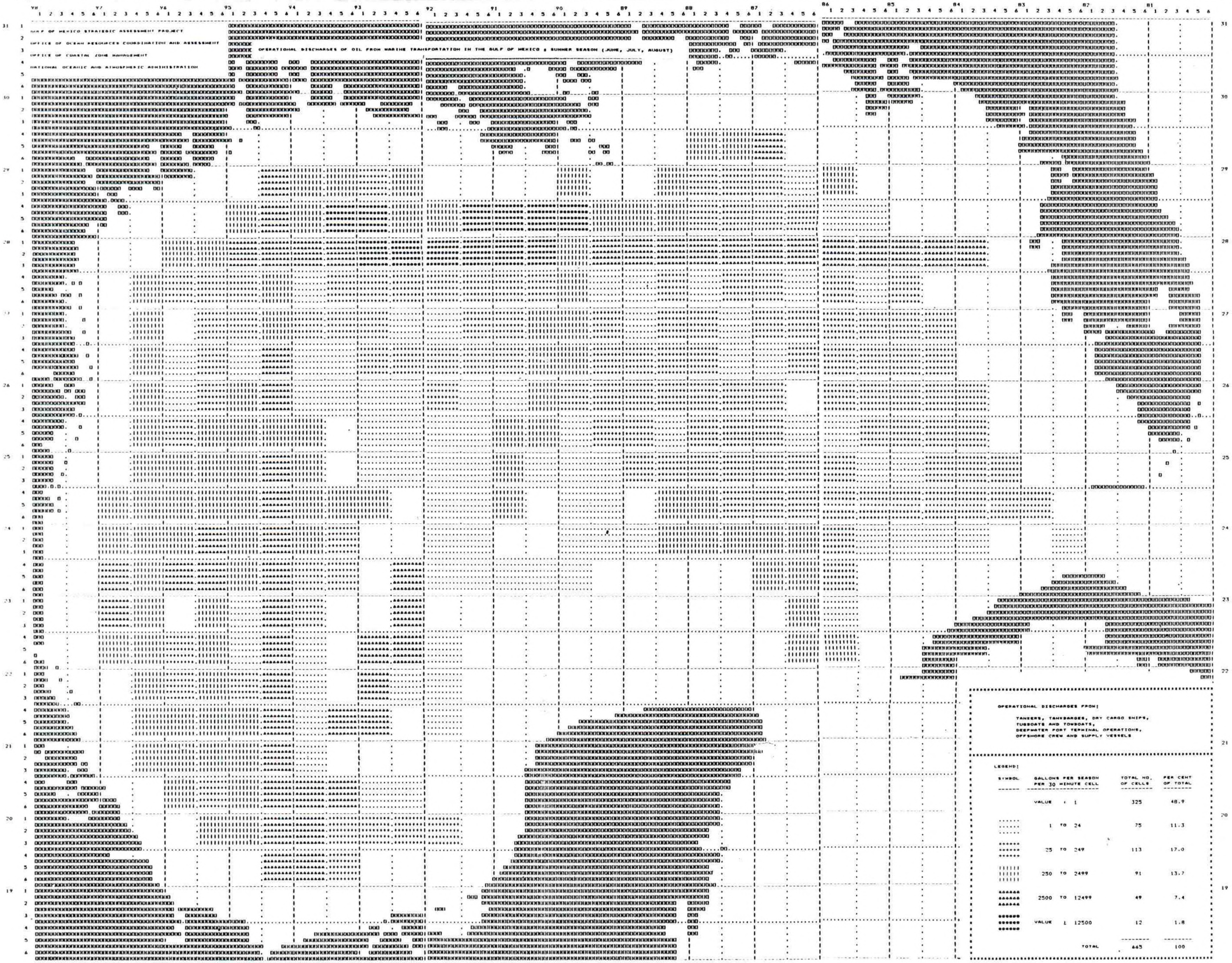


Figure 5. Distribution of Operational Discharges of Oil from Vessels in the Gulf of Mexico - Summer Season 1979



Future Analyses

Two future analyses related to operational discharges are planned. The first will entail entering the discharge estimates for each grid cell in each month into a surface oil spill trajectory model to approximate their redistribution around the Gulf taking into account the effects of surface currents, winds, and weathering and degradation losses. The resulting spatial and temporal patterns of surface oil will then be compared with spatial and temporal patterns of important living marine resources and their life history (ORCA, 1981c). This analysis will provide an indication of which living marine resources located in space and time may be potentially at risk due to operational discharges of oil from marine transportation sources.

The second will be to assess the relative contribution of operational discharges of oil from marine transportation sources in relation to oil entering the Gulf from all other sources -- land-based point and nonpoint sources, OCS oil and gas operations, river inflows, and natural seeps. This analysis will utilize the comprehensive pollutant discharge inventory being developed for the overall Gulf of Mexico Strategic Assessment (ORCA, 1981d). Its objective will be to determine the relative importance and location of major sources of hydrocarbon concentrations in areas of the Gulf of Mexico important to living marine resources. The surface oil spill trajectory model will be used in this analysis, as well as a "standard" advective/dispersive pollutant transport model that has been developed for the winter and summer seasons in the Gulf (ORCA, 1980).

The second phase of ORCA and ECO's assessment of oil discharges from ships operating in the Gulf will analyze operational and casualty types of spills, i.e., the probabilistic component of oil discharges from ships. The objective of this analysis will be to identify those areas which have the highest probability of experiencing these events and the likely magnitudes of the discharges that may be expected within them. The analysis will utilize the port and shipping route data previously developed for estimating operational discharges. Vessel movement will be simulated exactly as in the analysis of operational discharges, i.e., each vessel in each port in each month will be moved along appropriate shipping routes. However, whether or not a vessel has an operational or casualty spill on any given trip will be determined using a random number generator calibrated to statistical distributions that represent the probability of that vessel type having either type of spill event. The size of the spill will also be determined in a similar manner. If, on a given trip, a vessel is indicated to have an operational or casualty spill, its location along the shipping route will be determined in the same manner as the location of bilge pumping discharges were located, i.e., randomly as described above. When all vessel movement in a given year has been simulated, the entire process will be repeated over and over again until it reveals areas within the Gulf, i.e, one or more grid cells, in which occurences of operational and/or casualty types of spills are relatively frequent.

Although work has only just begun on this phase, plans are to use the overall methodology (phases 1 and 2) to assess the probable effects of future changes in production, transportation, and handling of oil in the Gulf of Mexico. At least two development scenarios will be analyzed: 1) an increase in operations at the Louisiana Offshore Oil Port (LOOP) to full capacity; and 2) an increase in the production and export of Mexican oil from the Bay of Campeche.

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