4. ENVIRONMENTAL IMPACT OF THE PROPOSED ACTION.

4.01 The proposed deep draft port would have far reaching social and environmental impacts on the entire project area. The proposed project would provide economic benefits in the region through improvement of marine transportation facilities. In turn, the developmental potential of the already major navigation dependent industrial complex, the employment and income associated with these industries, and, consequently the economic well-being of the inhabitants of the area would be enhanced. The beneficial effects of ocean-going commerce through the port would extend far beyond the local community and would make significant contributions to the economy of the state, region, and nation. The project would, however, have adverse effects on the natural environment. These adverse impacts include the loss of wetland areas, removal of benthic life in the channel and disposal areas, disruption of wildlife habitat, increased turbidity during construction, and other social and environmental impacts.

4.02 Effects on Water Quality. Some temporary water quality effects could be expected to result from construction and maintenance of the project, including increased turbidity and possible resuspension of pollutants. During dredging and disposal activities, increased turbidity would affect an area several hundred feet or more from the source. The significance of this effect depends on dredging time and methods used to control turbidities.

4.03 Adverse effects which could result from increased turbidity, include reduction of light penetration which results in lower photosynthetic activity and a reduction at the base of the aquatic food chain. Other effects which may result from increased turbidity include sedimentation in adjacent wetlands, smothering of some benthic organisms, and death of juvenile fish and shellfish by coating of gill tissues with sediment. The significance of these impacts depends on the length of dredging time and number and size of dredges. Should dredging be continuous in one location for the 2 years of anticipated construction time, the primary production in the immediate vicinity could be affected through a loss of photosysthetic activity.

4.04 Because of the nature of the materials and the lack of pollutants in the material to be dredged, no significant degradation of water quality should occur through resuspension of heavy metals, organohalogens, organosilicones, pesticides, or other constituents. Even if the sediments contain pollutants, little or no data exist to indicate that dredging and disposal of polluted sediments would cause a significant degradation in water quality. After several years of intensive study of this problem, laboratory investigations done in conjunction with the Corps of Engineers' Dredged Material Research Program have shown that most heavy metals in sediments are unavailable to the water column and that zinc, mercury, cadmium, and most other heavy metals are immobile and unavailable biologically. Lee (1976), in studying the results of elutriate testing, found only ammonia and manganese were released in sufficient amounts to become of potential concern with respect to acute lethal toxicity. All other chemicals released were in quantities considerably lower than the acute lethal limits for various forms of aquatic life. Lee concluded that concentrations of these contaminants in the water column would be rapidly diluted below the acute lethal limit and, therefore, present little or no hazard to aquatic life in the water column, either from acute lethal or chronic sublethal effects.

4.05 Other studies on the effects of water quality degradation from dredging have been made in recent years. These studies were generally made in the actual areas being dredged and reflect the naturally occurring influences of chemicals and materials present in bay areas. The results of most of these studies indicate that a portion of the pollutants contained in sediments may be resuspended in the bay waters immediately surrounding the point of disposal and that these pollutants are then rapidly removed from biological accessibility.

4.06 In pilot laboratory studies, Gustafson (1972) discussed the fallacies connected with turbidity and resuspension of sediments by dredging. He showed that suspended clays attract bacteria and remove oils, pesticides, sewage products (except nitrates), and metals from the water and demonstrated the probability that metals adsorbed to clays are not released when clays are resuspended and that organic molecules are not liberated in amounts sufficient to cause ecological concern.

4.07 Because of rapid settlement of dredged materials, volatile solids are of little importance to dredging situations unless they are high enough concentration to have already degraded water quality.

4.08 The Galveston District Corps of Engineers has conducted numerous water quality monitoring programs in conjunction with dredging operations along the Texas coast over the past four years. The results of these programs have invariably shown that the only potentially harmful constituents normally entering the water column during dredging and disposal operations are nitrogen compounds. The Galveston District is not aware of any situation where the resuspension of heavy metals caused by dredging has been reliably demonstrated.

4.09 Every reasonable effort would be made to protect sensitive wetlands from increased turbidity during construction of the project. Wherever practical, cutter suction dredges and land based equipment would be used in inshore areas. These produce less turbidity than other types suitable for inshore use. Further, dredging would be minimized as much as reasonably possible during peak migratory movements. Disposal areas would be diked to reduce turbidity in adjacent waters and effluent from these diked disposal areas would be controlled by wiers.

4.10 For the forgoing reasons, it is believed that the dredging of the inshore portions of the channel and the contained land disposal operations would not have any significant adverse effect on water quality other than localized temporarily high turbidities. Nitrogen compounds released could aid in recovery and growth of vegetation near the channel.

4.11 The following paragraphs (provided primarily by Southwest Research Inc.) are devoted to the forecast of water quality components in the project area. The overall forecasting techniques are general in most cases, as the various components do not lend themselves to specific, quantifiable prediction. The forecast interval was 1980 through 2020. The 1980 forecast year was selected by SWRI as a projected construction date. Furthermore, any increase in pollutants which would otherwise occur as a result of secondary industrial or residential development would be regulated and controlled through adminstrative water pollution control programs. The 1972 Amendments to the Federal Water Pollution Control Act prohibit any discharge of pollutants to a navigable waterway (42 U.S.C. § 301a) unless the discharge is permitted by the Environmental Protection Agency through a National Pollution Discharge Elimination System (NPDES) permit, issued pursuant to 42 U.S.C. § 1342. Under such a permit, the discharge must meet the effluent standards established by the Act. The level of treatment, based upon technological capabilities, is set forth for both industrial sources and sanitary sewage treatment plants in 42 U.S.C. § 1311. If those technology-based effluent limitations are insufficient to protect a given waterway from water pollution, then EPA is authorized under 42 U.S.C. § 1312 to adopt more stringent effluent limitations for those sources which are causing the condition of pollution so as to

> ". . . assure protection of public water supplies, agricultural and industrial uses, and the protection and propagation of a balanced population of shellfish, and wildlife, and allow recreation activities in and on the water..."

Consequently, governmental regulatory programs are expected to preclude any significant water pollution as a result of secondary industrial or residential development which might occur as a result of this project.

4.12 Heavy Metals. The construction and maintenance activities should have little, if any, effect on the heavy metals content of the area's waters. Some sediment containing undesirable metals would be dredged and confined in the various disposal areas utilized.

4.13 If some fraction of heavy metal accumulation in the water and sediment does indeed result from the use of a waterway by vessels, then an increase in heavy metal content of the sediment, in particular, would occur in the new turning basin at Harbor Island.

4.14 It is possible that heavy metals content in the water and sediments offshore could increase due to the flushing effect of tidal exchange at Port Aransas. Levels offshore should not, however, approach inshore levels because of the long distance from the zones of greatest potential heavy metal concentration in the Corpus Christi Inner Harbor and along La Quinta Channel.

4.15 Pesticides. No effect on pesticide concentration is anticipated as a result of the Harbor Island Deepwater Port and its related activities, including population growth and industrial activity. Because of the additional water exchange in the system there may be a slight lessening of pesticide concentrations in the water in the system.

4.16 Suspended Solids. No overall change in the suspended solids is expected, though dredging operations could raise levels for short time periods in the vicinity of activities. No detrimental effect of dredged material disposal on baywide suspended solid contents is expected. A slight increase of suspended solids in the entrance channel, Lydia Ann, Aransas and Corpus Christi Ship Channel to Ingleside could develop due to expected velocity increases engendered by deepening and widening of the ingress-egress area at Port Aransas, but additional suspended particle quantities should pose no environmental hazard. The same mitigation measures used to control turbidity could act to reduce suspended solids levels.

4.17 Transmissivity. No appreciable long lasting transmissivity change should develop. During the construction period, considerable turbidity of a short duration and small spatial extent would be created, but there should be no long-term effects on transmissivity from one-time dredging and disposal. The maintenance dredging operations could produce turbidity (transmissivity) problems, but the activities and effects would be short-term and could probably be mitigated by preventive and controlling actions, such as silt curtains, bottom disposal of dredged materials, and other techniques.

4.18 Mitigation measures used to control turbidity will also act to improve transmissivity.

4.19 Nutrients. A small increase in nutrients delivered by the additional seawater flowing through the system might ensue, but the increase would be insignificant. There would be no increase due to the actual channel deepening and widening.

4.20 If pollution control laws are not enforced, nutrients derived from wastes could be added to the system by the burgeoning population and its concommittant industrial development. Estimates are that by 2030 Corpus Christi Bay nutrient levels could be about 2-1/2 times higher than the 1980 level, but still only reach 40 percent of Galveston Bay's 1980 level (Galveston Bay's 1980 level is viewed as the highest acceptable level for Corpus Christi Bay). Corpus Christi Bay's increase in nutrients, while advancing the bay toward unacceptable quantities will probably result in an increase in productivity in the bay system. However, once optimum levels of nutrients are obtained, additional increases may result in deterioration of aesthetic conditions.

4.21 Temperature. A very small moderation of temperature range could develop due to the additional seawater available for mixing, but the magnitude of the change would be insignificant and would have no measurable effect on the biota.

4.22 Salinity. Salinity would be elevated slightly in the area of Harbor Island as the enlargement of the entrance channel (to 80-foot depth) would allow more Gulf water to enter the inshore system. Based on computer simulations conducted by SWRI, salinity in the Harbor Island area may rise as much as 5 percent from the 1980 base average of 30 ppt to about 31.5 ppt in 2030. Elsewhere in the Bay system very little effect on salinity would be experienced. Because the channels leading from Harbor Island to Corpus Christi Bay, Aransas Bay, and Redfish Bay would not be enlarged concommittantly, the exchange of water between the open Gulf and the inshore bays should be affected minimally. A change of less than 1/2 percent in salinity content might occur in the inshore bays, with the effects increasing as Harbor Island is neared. The reduction in salinity range would be greatest at Harbor Island and lessen away from the area. Effects of lessened salinity range should not be significant.

4.23 Dissolved Oxygen. No change in the overall average or in the 1980 base conditions should develop in Nueces and Corpus Christi Bays. The 80-foot deep Harbor Island Turning Basin and Entrance Channel would be an area of possible concern. Since the dissolved oxygen content generally decreases slightly with depth, values lower than 1980 contents would be expected in the deepened channels. Within the docking basin dissolved oxygen content could lessen additionally due to the confined nature of the basin. The lowest dissolved oxygen levels probably would be found at the portion of the docking basin farthest from the entrance channel. Due to the large opening in the configuration of the basin and the basin's nearness to the zone of maximum water exchange at Port Aransas, the dissolved oxygen values should stabilize above acceptable limits. It is probable that dissolved oxygen values at the bottom of the Harbor Island Turning Basin would be slightly higher than the 1980 base condition within the Inner Harbor (the 1980 Inner Harbor condition being the worst case condition in the various segments of concern).

4.24 Biological Oxygen Demand. The physical construction and existence of the Harbor Island facility should produce no effect on biological oxygen demand levels. A secondary effect related to the project is the development of industrial and population sectors. This could add organic waste pollutants to the system, particularly if proper safeguards were not initiated. With proper pollution control, however, biological oxygen demand levels should not increase.

4.25 Chemical Oxygen Demand. The construction, modification, and physical nature of the Harbor Island facility and its associated channel developments should not increase chemical oxygen demands. The associated population growth and industrial development could cause chemical oxygen demand values in the system to increase, particularly in La Quinta Channel area and the Inner Harbor, along which most new industry would locate. The 2030 chemical oxygen demand values would not be significantly higher than 1980 values if pollution control law enforcement is continued. The worst case maximum chemical oxygen demand change would be a doubling of 1980 base conditions. This would not constitute a threat to the biota of the bay water, though some localized effects on oxygen availability might be evident.

4.26 pH and Alkalinity. A slight increase in pH and alkalinity due to the influx of additional seawater could occur in the area of the Harbor facilities, but it should be smaller than both seasonal and isolated meteorologically induced fluctuations.

4.27 Oil and Grease. The levels of oil and grease in the Inner Harbor, La Quinta, and Harbor Island areas should be a function of the quantity of ship traffic through the area. Since overall traffic attributable directly to the project (number of vessels) would decline with the proposed project, it is assumed that oil and grease background levels would similarly decline. While land derived oil and grease pollution could grow proportionally with the growth of population, the projected 1980 oil and grease base is so low that it is probable that no adverse conditions would result from increased background levels of oil and grease in the study area.

4.28 Water Exchange. By opening the entrance channel to an 80-foot depth, additional water would be allowed to enter at Aransas Pass. The maximum estimated increase would be 10 percent at Aransas Pass with the water flowing out via Corpus Christi Ship Channel (handles 5.9 percent of increase), Aransas Channel (handles 0.3 percent of increase), and Lydia Ann Channel (handles 3.8 percent of increase).

4.29 Current Velocity. Current velocity should be affected positively in the channels at the confluence near Harbor Island. A 4 percent(± 2 percent) increase in speed is postulated within the entrance channel, but should average only 3 percent(± 1 percent) (Theoretical maximum speed in 1980 is 3.2 knots, should be 3.4 knots at most in 2030). Corpus Christi Ship Channel, Aransas Channel and Lydia Ann Channel should exhibit similar increases of about 5 percent in their maximum velocities and an average change of 3 percent (± 1 percent). These increases are quite small and relatively insignificant.

4.30 The Effects of the Proposed Project on Hurricane Surge. The SW Research Institute studies of surge were performed by utilizing the Bay Wind Surge model, namely the Standard Project Hurricane with a large radius to region of maximum winds and a slow speed of translation of hurricane center. The Standard Project Hurricane (SPH) is a hypothetical hurricane intended to represent the most severe combination of hurricane parameters that is reasonably characteristic of a specified region, excluding extremely rare combinations. It is further assumed that the SPH would approach a given project site from such direction, and at such rate of movement, as to produce the highest hurricane surge hydrograph, considering pertinent hydraulic characteristics of the area. The distance from the hurricane center to the point of maximum wind velocity is called the radius of maximum winds. The slow speed is about 4 knots, and the large radius is about 19 nautical miles. Peak surge varied less than 0.3 feet with the addition of channel modifications and disposal sites in the Southwest Institute simulations.

4.31 A utilization of the Standard Project Hurricane model with a large radius to region of maximum winds but moderate speed of translation (about 11 knots) was made for the project location. An improved channel entrance and a simulated barrier on the coastal islands resulted in the model peak surge of the back bay near Corpus Christi to fall about a half foot and peak surge behind the barrier island to decrease almost one foot.

4.32 A comparison by SWRI of the As-Is versus proposed Project conditions for a slow speed hurricane using numerical models indicate a minimum project influence on peak surge elevations. This is due to the long time period of inflow to the bay thus minimizing the effect of the increased flow area. The surge hydrographs indicate a gradual rise and fall of surge heights. In the back bay, the surge has a faster rate of rise and peaks higher than in the forebay. There is no indication of development of a rapid or steep wave movement out of the Bay. The results of these studies indicate that storm surges which would result from channel enlargement for SPH would have negligable effect on the surrounding bay systems. The following table indicates the expected changes in Surge Elevations (in feet) with and without the project.

	With Project	Without Project
Corpus Christi	16.3	16.6
OSO Bay	15.1	15.5
Port Aransas	11.5	11.5
Ingleside	14.3	14.5
Portland	5.7	5.9

4.33 The project should provide additional protection against storm induced high water in several areas. The stabilized dike on San Jose Island (disposal area B) should help protect the Aransas Pass -Rockport area from storm surge and the broad levee at the west side of area D would help protect Port Aransas from back surge and to confine storm waters to the Corpus Christi Channel.

4.34 Oil Spills. Near-shore and inshore marine oil spills occur from several sources. These include groundings or collisions of ships, loading and unloading accidents at terminals, rupture or leakage of submerged pipelines, and accidents at onshore facilities very near the water. Although accidental oil spills are spectacular events and attract the most public attention, they constitute only about 10 percent of the total amount of oil entering the marine environment. The other 90 percent originates from the normal operation of oil-carrying tankers, other ships, offshore production, refinery operations, and the disposal of oil-waste materials. The following percentages for 1969 sources of direct oil pollution are based on Revelle, et al. (1972):

Tankers	24%
Other Ships	23%
Offshore Production	5%
Refinery Operations	14%
Oil Wastes	25%
Accidental Spills	9%
	100%

Oil spills from loading activities are in general easier to control and clean up than spills from vessel accidents. In addition, application of known technology and good practices can virtually eliminate major loading spills.

4.35 Oil Spill Risks Analysis. A. H. Beyer and L. J. Painter developed a method for determining the potential for oil spills from tankers. The technique provides a worst case estimate since it does not account for continuing improvements in technology, operation procedures, and safety measures. Only cargo spillage from casualties such as ruptured cargo tanks from collisions, structural failures, grounding, etc. are considered. Cargo-transfer related spills are not amenable to this prediction.

4.36 Bayer and Painter (1977) compiled information from the literature on world-wide tanker casualty spills during 1969-1972 (Table 29), and determined that such spills could be expected to occur within 50 miles of land, on an average of once in every 1000 vessel port-calls or about once in every 50 vessel years of operation. The average size of these casualty spills (within 50 miles of land) was 7100 bbl and the average spill rate Was about 87 bpmb (bbl per million bbl) transported. Using this information they developed a technique for spill predicting. Table 29 contains a summary of historical spill parameters for predicting future tanker casualty spills by any of three exposure variables, number of vessel port calls, volume of cargo transported, and number of vessel-years of operation. Using an exposure variable from table 29 the mean spill size, and the spill size distribution must be determined to make future spill projections. The projections include such information as spill recurrence intervals, spill probability and average annual spillage.

4.37 For this project, only volume of cargo transported, and number of vessel-years can be used as exposure variables since the number of Port calls (trade routes) have a great

Table 29. Historical parameters for predicting tanker casualty spills within 50 miles of land

Exposure Variable	Spill Frequency		Spill Size		Generally
	Mean	Basis	Mean (Bbl)	Basis	Suitable for Use When:
Number of Port-Calls	0.92 spills/ 10^3 port-calls	1969-1970 world-wide spills < 50 miles from land and 1969-1972 spills at 7 major U.S. ports	7,100	1969-1972 world-wide spills < 50 miles from land	The tanker fleet, total volume of cargo, and trade routes are known
Volume of Cargo Transported	12 spills/ 10^9 bbl transported	1969-1972 world-wide spills < 50 miles from land	7,100	Same as above	The total volume of cargo is known, but the tanker fleet and trade routes are uncertain.
Number of Vessel-Years	20 spills/ 10^3 vessel-years	1969-1972 world-wide spill < 50 miles from land	7,100	Same as above	The tanker fleet is known, but the total volume of cargo and trade routes are uncertain.

SOURCE: Beyer and Painter, 1977

deal of variability. Using these exposure variables to compare the proposed project with the as is situation the following predictions in spills per year result:

Exposure Variable	Without Project	With Project
Number of vessel-years	10.46 spills/year	2.5-3.0 spills/year
Volume imported	.278 spills/year	3.81 spills/year

4.38 It is important to recognize that the information used in this analysis was derived from international historical statistics and hence does not reflect the higher degree of regulatory control of ship design and operations of U.S. flag carriers. Further, the estimates do not reflect recent pollution control regulations.

4.39 Accidental releases occurring in ship to shore transfers are the second major source of oil pollution from waterborn crude transport. These spills result from human error or from mechanical failure of transfer equipment. U.S. Coast Guard (1971) determined that 0.00007% of the oil handled is spilled. Porricelli et al., (1971) suggested a larger volume of 0.00015% spilled. Using the Porricelli value and an assumed 870,000 bbl per day volume, or 317 x 10^6 bbl annually results in 476 bbl spilled annually by unloading operations. This estimate of terminal spillage is based solely on the volume of crude oil transferred and not upon transfer frequency. Quite obviously, frequency will have a bearing on the general conditions at terminal locations as the number of connects and disconnects and transfer pump starts and stops present opportunities for human error and equipment failure. Thus, it can be argued that the total amount of oil spilled from these operations should be proportional to the number of transfers, rather than to the total volume. It should be noted that larger crude carriers employ larger piping sizes and increased transfer pumping rates. Therefore, although the frequency of terminal spills may decrease with the use of larger vessels the severity will likely increase in proportion. The total net discharge may also increase since total volume unloaded at Harbor Island would increase with the proposed project.

4.40 Oil Spill Movement Analysis. As part of the environmental assessment, SWRI (1977) used a non-computerized approach in predicting oil spill movements and computerized approach in predicting oil spill movements and the following discussion outlines the results of that approach.

4.41 Investigations were conducted to evaluate the non-computerized techniques available for oil slick movement and their predictive capabilities. Sources which had investigated the spread of oil on a water surface, the direction and speed of oil on a water surface, the direction and speed of movement, and the maximum attainable size were comprised of three principal investigating teams: Fay and Hoult (1971), Fannelop and Waldman (1971), and Wang and Tayfun (1973). Thus, combining the slick size and spreading formulas developed by Fay and Hoult (1971), and Fannelop and Waldman (1971) with the slick movement and direction formula developed by Wang and Tayfun (1973) an estimate of the overall slick movement processes was made. The formula developed by Wang and Tayfun (1973) is based on an overall slick movement composed of 56% of the water current speed and 3% of the wind speed in a direction to the right of the wind (due to the Coriolis effect).

4.42 Applicability of the Approach. The investigation of the applicability of the non-computerized approach addressed both inshore and offshore considerations. Therefore, a somewhat modified approach to the offshore oil spill movement predictions was required. The influence of water current drift was neglected and wind drift was assumed to be the prime influence. This is a reasonable approach for the offshore Texas area since the majority of water movements in the Gulf are thought to be induced by the prevailing wind patterns. Under this assumption, the movement of an oil slick from an offshore spill site was investigated under the following conditions:

> The oil spill was considered as a single point release of 10,000,000 gallons.
>
> One release point was considered, this being the proposed SPM location in the vicinity of coordinate 27° 33'N, 96° 53'W, approximately 7 nautical miles offshore.
>
> The oil slick movement was evaluated for four different wind directions which (with other forces) would tend to move the slick towards land areas. These directions are N, NE, E, SE. A continuous velocity of 25 knots was used for a

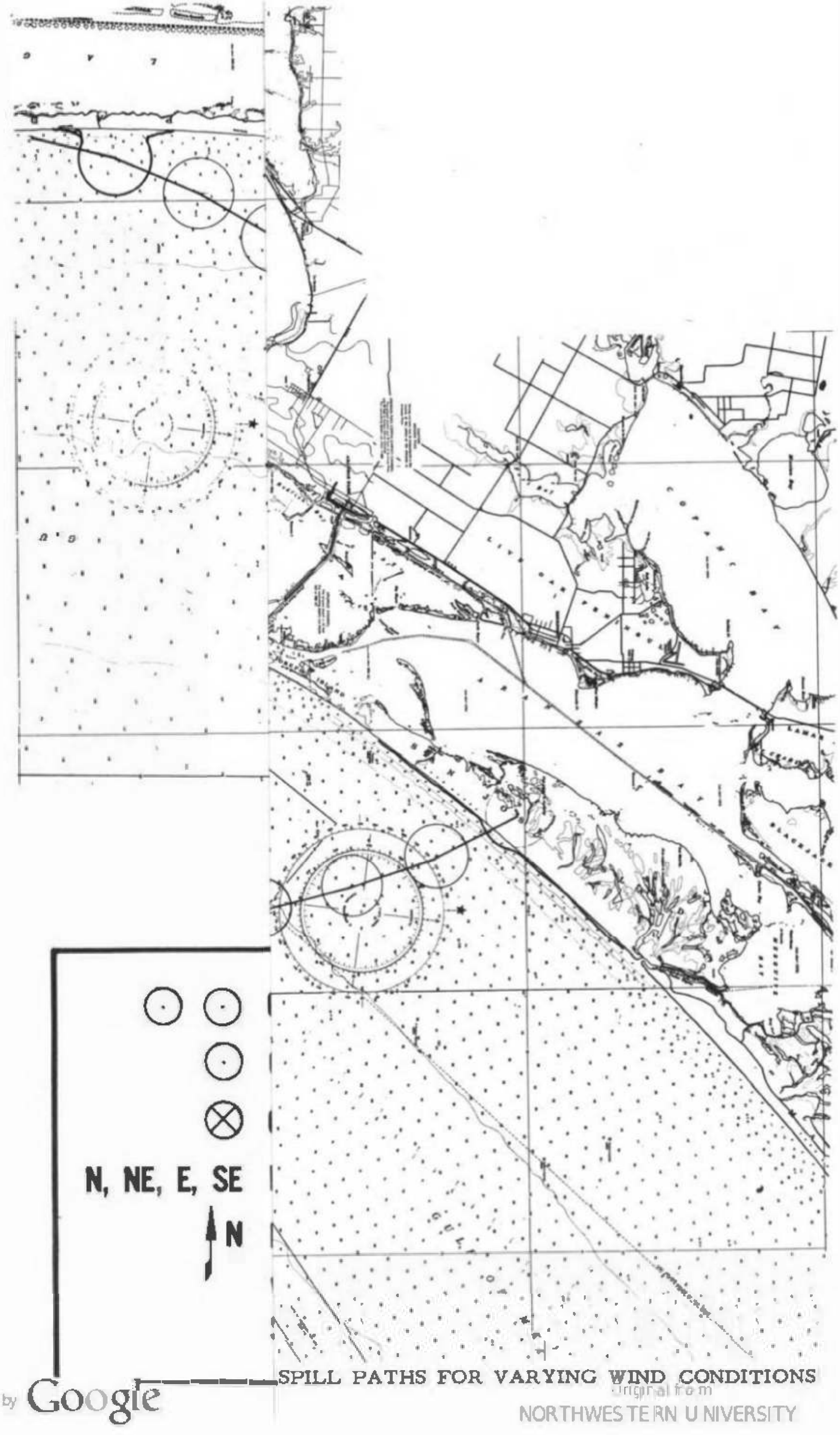
period until that time at which the oil slick reached shore.

The oil slick movement trajectory was computed for every four hour time increment from start of spill until land fall occurred.

Under the above stated conditions, the following parameters were estimated: trajectory for each given wind direction, time for the oil slick to reach shore, size of each oil slick at any given time increment, point at which the oil slick will first reach shore, and area of inundation by the oil slick for each given condition.

4.43 The results for the predicted oil spill movement in the offshore area are shown in Figure 33. Several observations can be made for each of the spill paths depicted. A summary of these observations is presented in Table 30. It appears that an oil spill occurring at the offshore location could reach land in as little as 22 hours. This condition exists with an East wind. The potential areas of inundation, except for that portion of Padre Island below Baffin Bay, are in most cases prime recreational areas for South Texas inhabitants.

4.44 Next the applicability of the oil spill movement predictive approach was investigated for the inshore area. The necessary inputs relating to water current speed and direction were generated by the Texas Water Development Board°s (TWDB) tidal hydrodynamic computer model. The complete oil slick drift rate formula developed by Wang and Tayfun (1973) were used. The oil slick drift and spreading was evaluated for two different spill locations in and around the Harbor Island area. The locations were chosen to analyze the implications of the effect of tidal variances and to recognize the potential effects of oil spreading into Redfish, Corpus Christi, and Aransas Bays. These sites will not be accessible to a VLCC; however, the problem was purposefully approached in this manner to adequately evaluate the effects of oil spills on all three of the major bay areas mentioned. The analytical techniques do not lend themselves to use in channels or constricted areas. Therefore, oil coming through channels was treated as coming from a psuedo-source where the channel opens to the bay. This approach covered the environmentally significant areas both adjacent to and removed from the proposed Harbor Island



SPILL PATHS FOR VARYING WIND CONDITIONS

TABLE 30

SUMMARY OF OFFSHORE OIL SPILL MOVEMENT OBSERVATIONS

Spill Wind Condition	Approximate Time to Reach Shore	Estimated Maximum Spill Diameter	Point of Oil Spill Shore Contact
North	44 hours	2.5 nautical miles	Padre Island shoreline several miles below Baffin Bay.
Northeast	26 hours	2.0 nautical miles	Padre Island shoreline seven miles south of John F. Kennedy Causeway
East	22 hours	2.0 nautical miles	Mustang Island shoreline in line with Shamrock Cove
Southeast	34 hours	2.25 nautical miles	San Jose Island shoreline three miles north of Mud Island.

SOURCE: SWRI, 1977

VLCC off-loading terminal. For the inshore deep water port at Harbor Island, the movement of an oil slick was investigated under the following conditions:

The spills consisted of single releases of approximately 1,000,000 gallons.

Release points were located at the following locations:

.. In the Corpus Christi-Aransas Pass Channel, near the vicinity of Point of Mustang.

.. In Lydia Ann Channel near the vicinity of Lydia Ann Island.

Water current velocities determined by the Texas Water Development Board's hydrodynamic model were used in estimating the oil slick movement.

The oil slick movement was estimated for a release at the start of an incoming tide and at the start of an outgoing tide and for the four most probable wind conditions over any given year, N, NE, E, and SE, at a continuous velocity of 25 knots. The simulation produced data points at four hour increments from the start of the spill until the time the oil slick was assumed beached or moved to the offshore area.

4.45 By conducting the oil slick movement analysis under the above stated conditions the parameters estimated included trajectory for each given wind condition and tidal prism, approximate time for the oil slick to reach any ecological and economically important areas, and areas inundated by the oil slick for each given condtion.

4.46 The results of inshore area investigations are presented in a series of spill path illustrations. Figures 34 and 35 provide information on the potential movement of an oil spill occurring near Lydia Ann Island at incoming and outgoing tides, respectively. Both figures show the almost immediate contact of the spill with surrounding natural land forms or other obstructions. It appears saltwater marshes and grass flats are the areas potentially affected by the movement of the oil spill. The estimation of spill spread is hindered by the immediate beaching of the spill. The spill configuration will be greatly modified by its contact

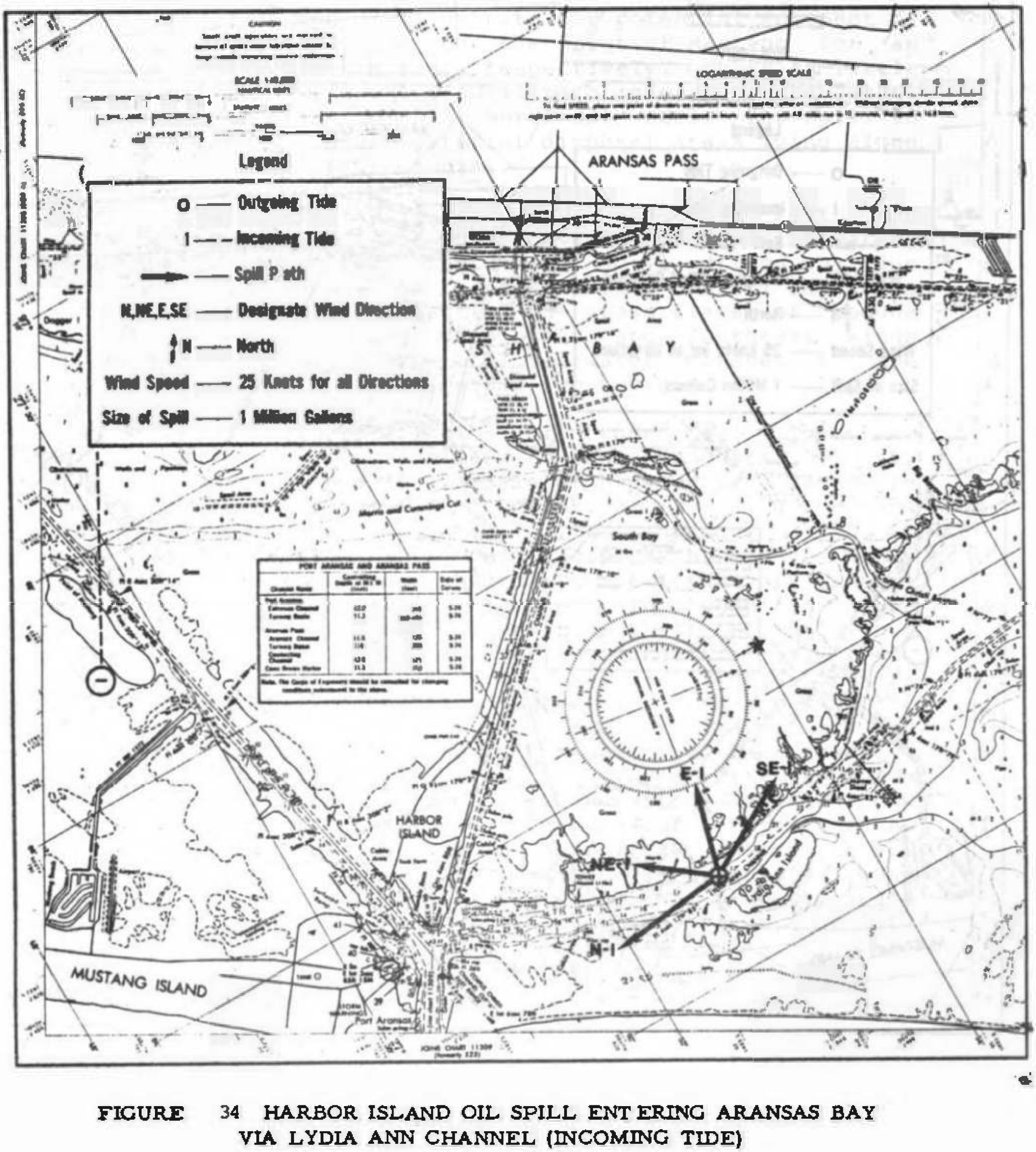


FIGURE 34 HARBOR ISLAND OIL SPILL ENTERING ARANSAS BAY VIA LYDIA ANN CHANNEL (INCOMING TIDE)

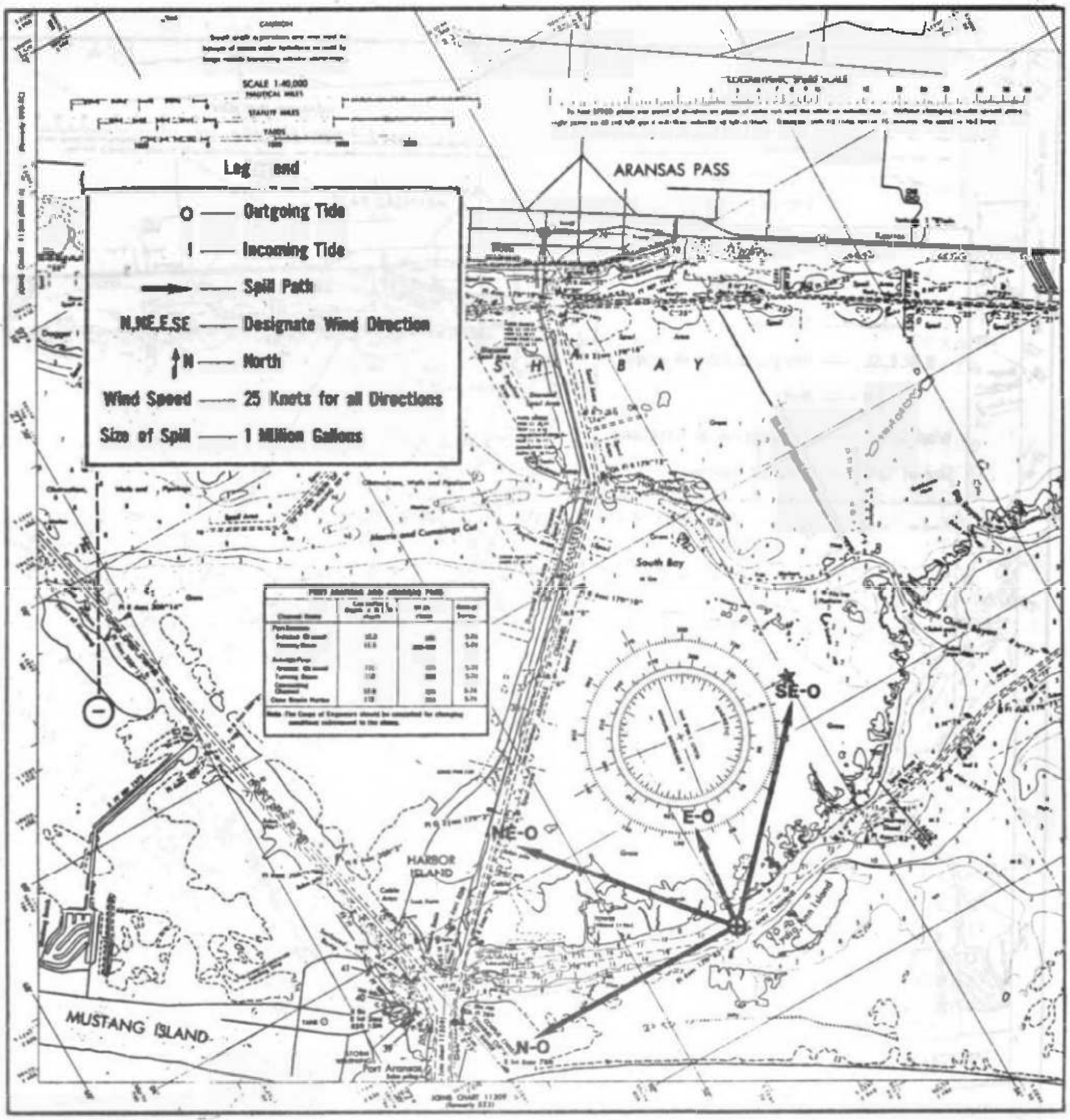


FIGURE 35 HARBOR ISLAND OIL SPILL ENTERING ARANSAS BAY VIA LYDIA ANN CHANNEL (OUTGOING TIDE)

with the natural land forms near Lydia Ann Island. Similar results are obtained whether the spill is released at the start of an incoming or outgoing tide.

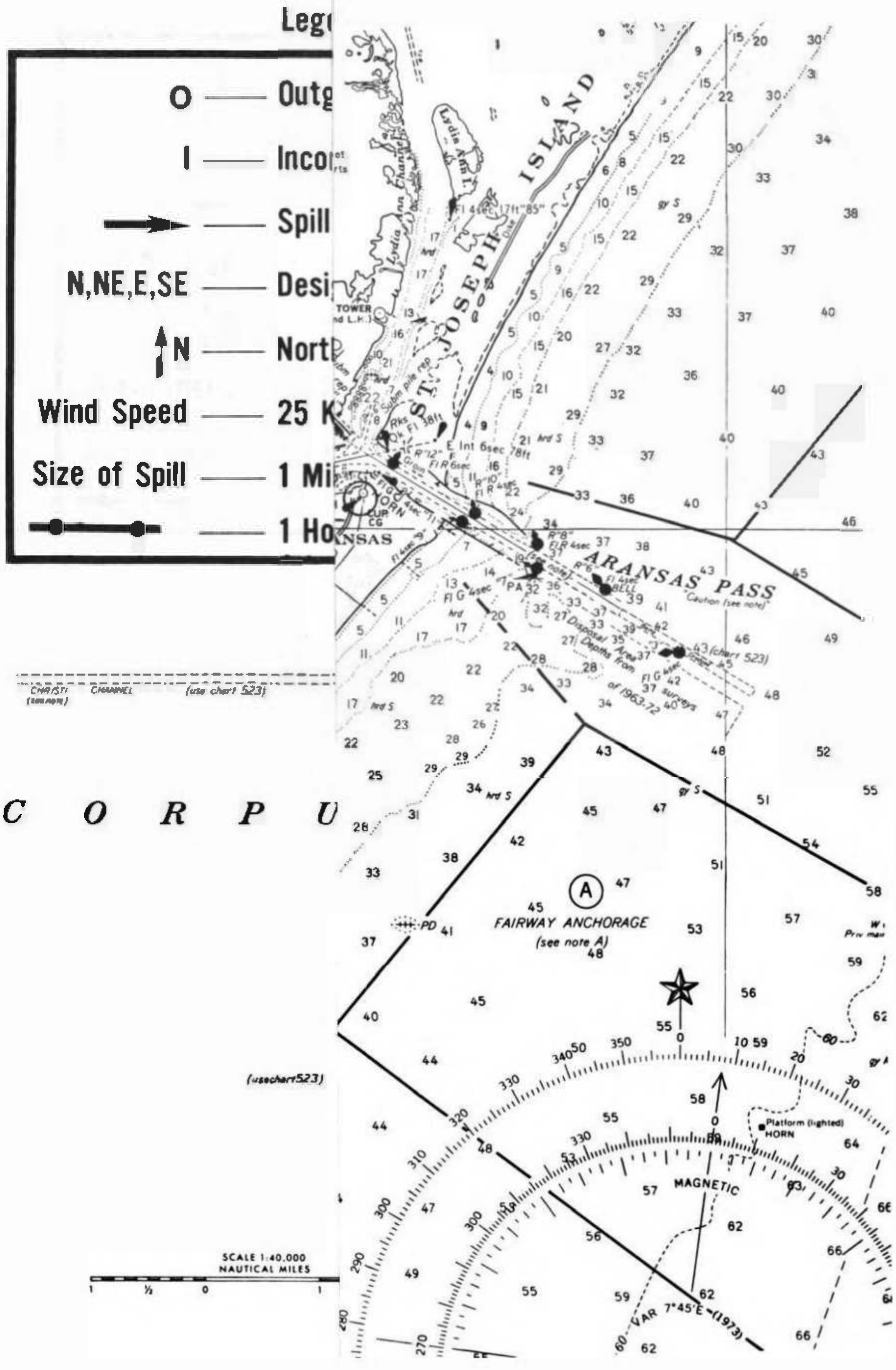
4.47 Figures 36 and 37 illustrate the potential movement of an oil spill taking place near the Point of Mustang for an incoming and outgoing tide, respectively. There is little difference in the predicted spill path in each of the cases. Winds from the North and Northeast cause the spill to contact existing dredged material disposal areas lying along the Corpus Christi Ship Channel.

4.48 The North wind spill could reach the grass flats and saltwater marshes of the Shamrock and Mustang Island areas in a little over four hours. A spill driven by the Northeast wind heads for the open Corpus Christi Bay areas with the potential of contacting the grass flats of Laguna Madre. Spills occuring with East and Southeast winds approach the grass flats and saltwater marshes of the Redfish Bay area in approximately two hours.

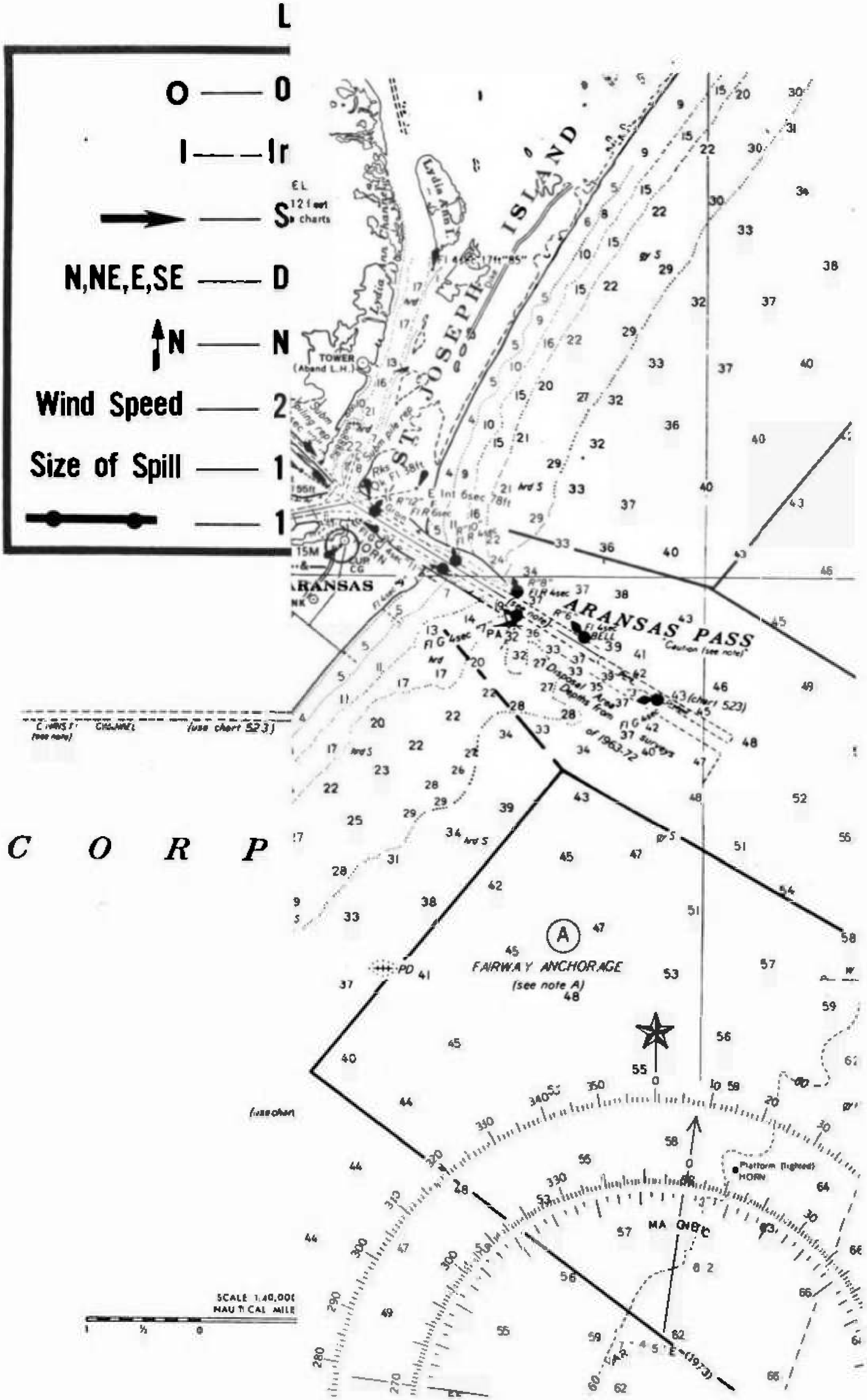
4.49 General Characteristics of Crude Oil. The term petroleum (crude) is applied to the deposits of oily material, usually composed largely of hydrocarbons found in the upper strata of the earth's crust.

4.50 Crude petroleum is a very complex substance whose physical appearance and chemical composition vary widely, depending on its course. Variations are found in crude petroleum not only from different parts of the world, but also from different fields in the same area. Thus, crude may appear as a yellowish-brown mobile liquid, a black viscous semisolid, or anything between. Corresponding to this variation in appearance is a similar range in physical/chemical properties, such as specific gravity, boiling point, volatility, etc. This variability is caused by the different proportions of the various hydrocarbons contained in the crude, the occurrence of nonhydrocarbons (e.g., sulfur, nitrogen, vanadium, etc.), and the amount of dissolved gas in the oil. These characteristics are important not only in terms of the type of processing to which the crude will be subjected and the number and quality of the products obtained, but also in terms of the commodity's impact on the environment (U.S. Army Corps of Engineers, 1972).

4.51 Table 31 presents data on the primary hydrocarbon fractions of a characteristic Mideast crude, with physical



.NG OIL SPILL (OUTGOING TIDE)



ING PHENOMENA

TABLE 31

CHARACTERISTIC MID-EAST CRUDE FRACTIONS

	Light Gasolines	Naphtha	Kerosene and Gas Oil Distillate	Distillate	Residuum	Cumulative Overall Composition
Viscosity, S.U.S. @ 100°F	35	35	36.8	85	250	
Tbp range, °F	122-208	210-399	401-620	622-797	800†	
Gravity, Sp. G.	0.700	0.785	0.850	0.890	0.965	Vol %
Sulfur, wt %	0.07	.18	0.97	2.3	3.2	
Paraffins	8.2	11.3	12.4	6.1		38.0
Ring Cycloparaffins	1.6	4.1	3.5	3.9		13.1
Alkyl benzenes	0.2	3.7	1.4	0.6		5.9
Indans		0.1	0.7	0.2		1.0
Dinaphthenebenzenes			0.4	0.2		0.6
Naphthalenes			0.3	0.1		0.4
Acenaphthenes – Acenaphthylenes			0.5	0.7		1.2
Anthracenes, Phenanthrenes			0.2	0.7		0.9
Pyrenes, Chrysenes				0.4		0.4
Benzothiophenes, Naphthobenzothiophenes			0.9	2.5		3.4
Yield, vol % of total crude	10.0	19.2	20.7	15.4	34.7	
Yield, vol %, cumulative	10.0	29.2	49.9	65.3	100.0	65.3

Source: Martin, et al., *Proc. of 6th World Petroleum Congress*, 1963.

properties and chemical constituents listed for each. The composition data are that given by Martin (1963) of a 29 API gravity Iranian crude from the Darius Field.

4.52 Table 32 presents data on the chemical and physical properties of a characteristic Mideast crude.

4.53 Phases of Oil. The fate of oil spilled on the sea surface is determined by a number of physical, chemical, and biological factors. Part of the oil evaporates into the atmosphere, part dissolves in the water column, part may be emulsified and become suspended in the water column, and part may precipitate and sink to the bottom. The oil on the surface, in addition to that which is emulsified or precipitated, is subject to degradation. Thus, the five major mechanisms by which oil may be removed from the surface of the sea are evaporation, solution, emulsification, precipitation, and degradation (James et al. 1972).

4.54 Evaporation. Crude, being a complex mixture, will evaporate initially by loss of the lower boiling ends, such as gasoline and naphtha fractions, and later, of successively higher boiling fractions. The evaporative process which occurs is a complex function of film thickness, wave action, wind, temperature, type of oil, etc. In general, the fractions which evaporate early in the life of a slick are the most toxic (James et al. 1972). The important role of evaporation in removing oil from the surface of the sea was demonstrated in a study conducted during the "Torrey Canyon" spill. The study (Smith, 1968) indicated that 25 percent of the oil, by volume, was lost in the first few days.

4.55 Solution. The amount of the various fractions of crude that go into solution is important in assessing impacts because oil in solution is in direct contact with the marine organisms in the water column and because the low boiling aromatic fractions, which are the most soluble and volatile, also appear to be the most toxic (James et al. 1972). The equilibrium solubilities of a few of the more toxic (acute cellular) species in each type of major chemical class are listed below:

TABLE 32

CHARACTERISTIC MID-EAST CRUDE
CHEMICAL AND PHYSICAL PROPERTIES

Gravity[6]	0.8654
Viscosity[6], S.U.S. @ 100°F	57.0
Pour Point[6], °F	–5.0
Surface Tension[6], Dyne cm^{-1}	24.0
Sulfur[6], wt %	2.24
C_4 + lighter, Vol %	2.0
Carbon Residue[12], wt %	10.9
Ash[12], wt	0.04
Water[12] wt %	nil
Nickel[12], ppm	93.0
Vanadium[12], ppm	129.0
Nitrogen[12], wt %	0.58
Metalloporphyrin[7], ppm	152.0
Porphyrin metals[7] as Vanadium, ppm	14.0
Asphlatenes[5], wt %	1.6

Temperature Boiling End Point of Product[6]

°F	Volume% of Crude Cumulative
150	6.6
200	10.7
250	15.6
300	21.2
350	24.3
400	29.1
450	33.9
500	38.4
550	43.0
600	47.8
650	53.2

Source: *Oil and Gas Journal*, April 1963.

Species	Solubility (ppm)	Species	Solubility (ppm)
hexane	140	phenol	82,000
heptane	50	pyridine	indefinite
nonane	10	aniline	36,000
benezene	820		
toluene	470		
naphthalene	300		

4.56 Clearly, the paraffins are the least soluble. The aromatic hydrocarbons have moderate solubility, and the functional derivatives have high solubilities.

4.57 Emulsification. Sea conditions, the type of oil, and weather are the major factors in determining the amount of emulsification (James et al., 1968). A turbulent, choppy sea causes a much higher degree of emulsification than a calm or rolling sea (Murray, 1970).

4.58 Berridge et al. (1968) points out that some crude oil emulsifies readily at sea, forming rigid stable water-in-oil emulsions which can contain up to 80 percent water, having a film thickness of 1mm. Such emulsions are stiff, yellowish-brown in color, and since the Torrey Canyon incident have become widely known as "chocolate mousse". The formation of an emulsion slows down the tendency of a slick to spread, and emulsified oil below the surface may move in a different direction than the slick because of subsurface currents.

4.59 Precipitation. Nelson-Smith (1970) has shown that the phenomenon of sinking may occur by two mechanisms; concentration of residue after prolonged periods of exposure and by suspended matter.

4.60 Concentration of residue results in a higher mean molecular weight, thus causing the specific gravity to increase. Fresh crude has a density of 0.855, but through evaporation of the lower boiling fractions up to gas oil distillate the specific gravity quickly increases to 0.934. Upon further exposure, possibly 20 to 50 days, the residue may have a specific gravity of 1.03, resulting in sinking.

4.61 Where there are large quantities of suspended matter, it may be incorporated into the oil, increasing its tendency to break up and sink. However, increasing salinity reduces the rate of sedimentation. Removal methods for crude have been tried by spreading powder or fine granular solid of high true density over the oil patch to mix with the oil, adhere to it, and sink it. Normally, it was found that after several months under water, the sunken mass was still mobile and could be released by agitation.

4.62 In general, little oil is deposited on the bottom of the sea unless the sea is rough and silt particles are present (James et al. 1972). In the Chevron spill, samples of soil taken directly beneath the platform from which the spill occurred never contained concentrations of oil higher than a few parts per million (Mackin, 1972).

4.63 Degradation. Microbiological degradation is the ultimateate of all oil left in the sea, but such degradation entails a severe oxygen requirement and a supply of other nutrients, such as nitrogen and phosphorus, for the degrading bacteria.

4.64 Little is known about the rate of such degradation, but it is known that no single microbial species will completely degrade any crude oil. Bacteria are highly specific, and several species are probably necessary to decompose the numerous types of hydrocarbons in crude oil. During decomposition, intermediate products are formed, and different species of bacteria and other microorganisms may also be required to attack the decomposition products (Zobile, 1969). The oxygen requirement of microbial oil decomposition is large, and oxidation would be slow in areas where previous pollution had depleted the oxygen content. Even when oxidation proceeds rapidly, depletion of the water°s oxygen content by the active microorganisms may have harmful secondary ecological effects. Unfortunately, the most readily attacked fraction of crude oil - the normal paraffins - is the least toxic. The more toxic aromatic hydrocarbons - especially the carcinogenic polynuclear aromatics - are not degraded rapidly under natural conditions in seawater.

4.65 J. W. Smith (1968) observed the fate of oil lying on the sea bed, and found that the natural biological degradation of oil in the sea, especially when the oxygen content is high, is much more rapid than was at first believed. Based upon rates at which marine bacteria have been ovserved to oxidize various types of mineral oils under controlled laboratory conditions, and upon information of the abundance of bacteria in the sea, oil might be oxidized in the sea at rates as high as 100-960 mg/m^3 per day, or 36-350 g/m^3 per year. These figures are estimations, but nevertheless, do indicate that microbiological degradation is a highly important factor in weathering.

4.66 However, it should also be noted that oil is poor in nutrients and large populations of bacteria acclimated to the oil are required to effectively degrade the material. These populations would not be available for large spills.

4.67 Physical Impacts of an Oil Spill. For the Corpus Christi area, offshore spills under common wind conditions could result in inundation of extensive areas of the barrier island beaches. Oil reaching the beaches would make them uninhabitable for most living things and would destroy their appeal for human use. If the amount of oil is not too great the impacts would be temporary and the beach would recover in a short time. Biological and chemical breakdown of the oil combined with wave action can be very effective. The recovery of the biota would take a much longer time.

4.68 If the oil reached the beaches in quantity, the sands could become saturated with oil and recovery would be slow. The beach may appear cosmetically clean in several weeks and yet remain oil saturated below the surface. As the oil ages, asphalt compounds are left which can leach into the water or surface on the beach for months. The subsurface biohabitat may not recover for years. It has also been reported (Marx, 1971) that oil tends to make beach sand "quick" and can accelerate sand loss. Beach oriented recreation is of great economic importance in the project area and even temporary pollution of the beaches would therefore have great adverse impact.

4.69 For inshore spills, the areas affected would depend on the wind conditions and the point of spill. Due to the presence of cargo transfer activities and the maneuvering of vessels in confined areas, the area of highest oil spill risk is the Harbor Island area with its adjacent channel approaches (this includes the Corpus Christi Ship Channel to Ingleside). Because of the confined nature of the docking basin and relatively low exchange of water with the bay system, oil spills in this location should be more easily controlled through confinement and cleanup actions than in an unconfined area. Additionally, the basin would be closed off by a floating oil fence barrier when unloading operations are taking place and individual oil fences would be placed around each vessel. In the channels of the Harbor Island area, however, moderate currents and tidal exchanges between the bays and the Gulf occur. Spills in this area have the potential for emerging into the three adjacent bays: Corpus Christi, Redfish, and Aransas. However, vessel time in these limited reaches is small and the VLCC's would be under full tug control while in these areas. Heavily used recreational beaches in the city of Corpus Christi and the Rockport vicinity are points of concern regarding inshore oil spills. Another major concern is the productive breeding and nursery areas of Aransas and Redfish Bays. Oil spills which contact public recreational beaches are the most noticeable and offensive to the public.

4.70 Biological Impacts of Oil Spills. The ultimate impact of oil on the biota of a region depends not only on the effect of oil on individual organisms, but also on the changes that would occur in species, populations, communities, and ecosystems as a result of effects on individuals. Unfortunately, one of the least understood and most difficult aspects of the problem to deal with is the effect on the higher levels of biological organization. A literature review by Moore et. al.,(1973) has provided some clarification of effects of oil on individual organisms.

4.71 The effects of oil (from any source) on individual organisms may be categorized as: immediate (acute) lethal toxicity; sub-lethal disruption of cellular level processes, causing disruption of behavioral patterns (death may follow, but not immediately and usually indirectly, if at all); lethal and sub-lethal effects of coating organisms with oil, which does not interfere with cellular activities, but which mechanically interferes with organism activities such as respiration, feeding, and locomotion; incorporation of hydrocarbons in organism tissue, which may cause tainting, and/or accumulation of high boiling-point polycyclic aromatic hydrocarbons in the food chain; alterations in habitats caused by deposition of oil on substrates such as rocks, sand, and mud. Different types of compounds in oil are responsible for causing these various effects. The lower-boiling (b.p. 250°F), high-solubility, aromatic compounds are the primary cause of immediate toxicity, behavorial disruption, and tainting. Coating and habitat alteration result from the tarry residue components.

4.72 Due to weathering processes the particular individual response listed above which can be expected in any particular case is highly dependent upon the time elapsed since the spill occurred. The lower-boiling, high-solubility components of an oil slick can be expected to be lost in the first three days following the spill release. The acute toxic and other effects associated with these materials would be most significant immediately after the spill occurs. If the slick is thick or oil combines with sediment and silts, however, even these volatile components can persist.

4.73 In addition to dependence on oil composition, the effects of spilled oil also varies due to the different biological sensitivities of various types of organisms. For example, gastropods are apparently much less subject to acute toxicity than crustaceans. Also, sessile organisms, such as mussels, are highly subject to effects of coating, whereas fish are not because of their mobility.

4.74 Another source of confusion in assessing the biological effects of oil is the lack of dependable experimental and field observation on the toxicity and other effects of oil on marine organisms. It is difficult to evaluate the toxicity of this complex mixture. A variety of techniques have been tried. In some experiments, oil is floated on the water in the test container. The concentration is derived from the quantity of oil and the total quantity of water; this is clearly not the concentration to which the organism has been exposed. In other experiments, extracts of oil with hot water or with various solvents are added to the test jar, without identification of the oil fraction being tested. In still other cases, care has been taken to produce a fine emulsion of oil in sea water more representative of the actual concentration to which the test organism is exposed. Considering the differences in the meaning of "concentration" in these tests, and the variation in sensitivity of the test organisms, it is not surprising that the ranges of toxicity that can be found in the literature vary by several orders of magnitude.

4.75 Studies of the toxicity of oil have been reviewed by Clark (1971). Mironov (1971) carried out toxicity studies by comparable techniques using a variety of marine organisms. In testing 11 species of phytoplankton, he found that cell division was delayed or inhibited by concentrations of crude oil (unspecified type) ranging from 0.01 to 1000 ppm. He also showed that some copepods were sensitive to a 1 ppm suspension of fresh or weathered crude oil and of diesel oil. Freegarde et al. (1970), found the larvae of Balanus balanoides and adult Xalanus copepods maintained in a suspension of crude oil ingest, without apparent harm, droplets of oil that later appear in the feces. Mironov (1967) found 100 percent mortality of developing flounder spawn at concentrations of three types of oil ranging from 1 to 100 ppm and increased abnormality of development at longer periods of time in concentrations as low as 0.01 ppm. In contrast, other experimenters have found that concentrations of several percent are necessary to kill adult fish within a few days (Chipman and Galtsoff, 1949; Griffith, 1970).

4.76 Finely dispersed droplets may be ingested by filter-feeding organisms and thus become an integral part of the marine food chain. Some of the oil may pass through the gut in the feces of these organisms, but Blumer et al., (1970), have shown that it can pass through the gut wall and be incorporated in the organism's lipid pool. Dissolved within the fatty tissues of the organisms, even relatively unstable hydrocarbons are preserved. They are protected there from bacterial attack and can be transferred from food organism to predators and possibly to man.

4.77 Should an oil spill occur near shore, or an oil slick be brought to the intertidal zone and beach, extensive mortality of marine organisms would occur. When the Tampico Maru ran aground off Baja, California, in 1957, about 60,000 barrels of spilled diesel fuel caused widespread death among lobsters, abalones, sea urchins, starfish, mussels, clams, and hosts of smaller forms (North, 1967).

4.78 In West Falmouth, Massachusetts, a relatively small oil spill occurred within a few miles of the Woods Hole Oceanographic Institution in September 1969; since then, biologists and chemists of the Institution have studied the effects of introducing fuel oil into the coastal waters. Studies of the biological and chemical effects of this spill were continued after the event (Hampson and Sanders, 1969; Blumer, 1969; Blumer et al., 1970; Blumer and Sass, 1972). Immediately after the accident, massive destruction of a wide range of fish, shellfish, worms, crabs, other crustaceans and invertebrates occurred in the region. Bottom-living fish and lobsters were killed and washed ashore. Dredge samples taken in 10 feet of water soon after the spill showed that 95 percent of the animals collected were dead and the other 5 percent were moribund. Much of the evidence of this immediate toxicity disappeared within a few days, either because of breaking up of the soft parts of the organisms or because the organisms were buried in the sediments or dispersed by water currents. Careful chemical and biological analyses reveal, however, that not only has the damaged area been slow to recover but the extent of the damage has been expanding. A year and a half after the spill, identifiable fractions of the source oil were found in organisms that still survived on the perimeter of the area.

4.79 In the crude oil spills from the wreck of the tanker Torrey Canyon and the Santa Barbara oil-well blowout, oil reached the beaches in significant amounts at varying times after release. The oil may thus have been diluted and modified by evaporation or sinking before it reached the beach. In the Santa Barbara spill, many birds died and entire plant and animal communities in the intertidal zone were killed by a layer of encrusting oil, often 1 or 2 centimeters thick (Holmes, 1967). However, in the case of the Torrey Canyon, the deleterious effects have been attributed more to the detergents and dispersants used to control the oil than to the oil itself (Smith, 1968).

4.80 The catastrophic ecological effects of the oil spills of the Tampico Maru (Baja, California) and the Florida (West Falmouth) appear to be more severe than those reported from other oil spills such as the Torrey Canyon (Salty Islands) and the Santa Barbara (California) blowout. The Tampico Maru and the Florida accidents both released refined oils (in one case, diesel oil; in the other, No. 2 fuel oil) and both occurred closer to shore than either the Torrey Canyon or the Santa Barbara accidents, which released crude oil. The differences in the character of the oil and the proximity to shore may account for the more dramatic effects of the first two accidents, but it is clear that any release of oil in the marine environment carries a threat of destruction.

4.81 Planktonic algae are killed throughout the water column by oil but oil's toxicity is reduced rapidly with time. Due to its short reproductive cycle, phytoplankton of an open water area may recover quickly as the oil dissipates. However, if an oil slick is thick enough to obstruct light penetration, photosynthesis will be reduced and the combined effect of increased oxygen demand and reduced oxygen production will increase the mortality of all living things in the area. The decaying of dead organisms will then increase the oxygen demand and produce a snowball effect capable of removing all available oxygen from the water column. If such conditions occur in the bay areas of the project the biota of the bay could be killed.

4.82 With the possible exception of a major spill associated with hurricane winds, the adverse effect on vascular plants would be confined to wetland communities. Most wetland plants have shown a relatively high tolerance for crude oil. However, sufficient oil to heavily coat the vegetation would kill the plant parts above ground and continued exposure would kill the roots. If the root structure survives, as has generally been the case in past oil spills, the plants would recover. However, during the period that the vegetative parts of the plants are absent, the marsh would be more exposed to erosion by wave action and may be reduced in area by the time the plant cover has reestablished. The temporary loss of food and shelter provided by the marsh plants, especially during spring and early summer, would have much greater impact on marsh - dependent species such as commercial shrimp than on the plants themselves.

4.83 If they become coated with oil, the marsh dwelling mammals would die of exposure, but generally the greatest adverse impact on them would be the disruption of their cover and food supply.

4.84 Petroleum would also present a hazard to avian forms. Not only would some of these forms be affected by the immediate presence of oil, but also they may feed upon marine life which has ingested and stored oil. The diving birds which spend most of their life at sea would be most prone to death from oil pollution, but any bird that would feed from the sea or settle on it would be vulnerable. In oil-matted plumage, air is replaced by water, causing loss of both insulation and buoyancy, and oil ingested during preening could have toxic effects.

4.85 Hartung and Hunt (1966) fed oils directly to birds by stomach tube and later analyzed, through autopsies, the pathological and physiological effects. The lethal dose for three types of oil ranged from 1 ml to 4 ml per kilogram (ml/kg) when the birds were kept outdoors under environmental stress. The experimenters concluded that a duck could typically acquire a coating of 7 grams of oil and would be expected to preen approximately 50 percent of the polluting oil from its feathers within the first few days. Enough of this could easily be ingested to meet the lethal dosage of 1 to 4 ml/kg. Thus, birds that would not die immediately from exposure to cold or by drowning as a result of oil pollution, succumb later from the effects of ingestion. The vulnerability to these lethal results is considerably increased by their inability to recognize oil as a threat. Birds appear to make little or no effort to avoid oil slicks.

4.86 The disruption of feeding due to loss of food or its unavailability would result in rapid starvation for birds unless other feeding areas were readily available. The high metabolic rate of birds requires frequent feeding. The brown pelican which nests in the immediate project area, for example, would starve in about three days if deprived of food. Oil intrusion into the marsh during nesting season would be lethal to nestling birds for all of the above reasons.

4.87 Adult finfishes in open waters would generally avoid oil concentrations. However, they may ingest oil contained in copepods or other food organisms, and this oil could be incorporated into their body tissue. The larvae of fishes are much less tolerant.

4.88 Since most fishes of the area are estuarine dependent during part of their life and many are marsh dependent, it is reasonable to conclude that oil entering the estuary and especially the marsh area would be very destructive. The secondary effects would extend back out to the outer edge of the continental shelf causing a reduction in fishes available to the sport and commercial fisherman.

4.89 Oils sink because of increased specific gravity with weathering and the accretion of heavy debris or sand into the oil. Sinking of oil has also been experimentally achieved by scattering talc or chalk on the oil, causing it to agglutinate into globules of density greater than sea water. Sunken oil tends to kill bottom fauna before even the motile bottom dwellers have time to move away. Little is known about the rate of degradation of oil in bottom sediments, but it is known that some fractions will persist for over a year (Blumer, 1969).

4.90 Shellfish are among the most sensitive marine organisms to oil pollution, especially in their larval and juvenile stages. Oil intrusion into the estuaries and marshes during spring and summer months could cause extensive mortality. Adults that survive may become tainted with the flavor of oil and become unmarketable.

4.91 Those crustaceans such as shrimp and crabs that are motile enough to avoid oil in toxic quantities may be so disoriented by the aromatic constituents of oil as to have their behavior altered to a lethal degree. Most of them depend on chemoreceptors to find food, mates, and habitat. These sensors detect indicator substances in quantities as small as a few molecules and this detection is obscured by oil.

4.92 Zooplanton would be affected by exposure to oil in a similar manner to the phytoplankton and would be killed by the resultant drop in dissolved oxygen. In the open sea this loss may be replaced in a short period by rapid reproduction and by immigration from surrounding areas. In the estuaries, the population of zooplankters would require much longer to reestablish resulting in a more significant loss to the food web. Reductions in this base could reduce production in important commercial and sports fish and shellfish.

4.93 Fire and Explosion Hazards. Since crude oil and petroelum products are combustible by their very nature, proper precautions are always mandatory to prevent fires or explosions with resulting loss of facilities and possible human life. Over many years, extensive work and long experience have made it possible to develop adequate safeguards to prevent disastrous incidents of this type.

4.94 The operation of tankers carrying combustible-liquid cargoes has been plagued by a comparatively large number of explosions which have resulted in the total or near-total loss of the ship involved and, in some cases, loss of life. Ever since December, 1969 when three very large crude carriers (VLCC) exploded at sea within a period of twenty days, the menance of cargo-tank explosions has been the subject of numerous research efforts by governments, universities, oil industry, and shipowner associations, as well as individual firms and fleet operators. The three tankers involved in the December, 1969 explosions were all over 200,000 tons dwt, and included the Marpessa (Shell Tankers BV), the Mactra (Shell Tankers UK), and the Kona Heakon VII (Norwegian).

4.95 From these studies have emerged some fundamental facts which are now universally accepted. The principal suspected, and only clearly identified cause of most explosions in cargo tanks (other than those due to collisions and/or other obvious causes), is the spark ignition of fuel-air mixtures due to the high electrostatic charge densities generated by the washing jets used on the tanks. The most probable electrostatic spark-generating mechanism is known as the "water slug" theory. This theory postulates that dimensionally large "water slugs" created by the washing machine can receive induced electrostatic charge in high electrostatic field areas of the tank. The presence of the field is due to the existence of electric charges in the cloud of droplets stripped from the washing jet. The energy of the spark created between the water slug near its impact with the tank structure, has been proven to be sufficient to ignite a proper mixture of air and hydrocarbon gases (Van Weerd and Laar, 1973).

4.96 The turbulence created by the washing machine jet(s) is the principal cause of the nearly homogeneous electrostatic charge density that appears inside of a tank being washed by any method, including washing machines. The level of charge density normally reaches a value of 107 and 108 Coulombs/m^3. Its polarity may be either positive or negative and, frequently, experiences a complete reversal during the washing cycle. No parameter effectively controlling the level and/or polarity of the charge built-up has been clearly identified, including washing water temperature, pressure, presence of additives, detergents or oil mixtures, tank size or shape, conditions of the tank surface, etc.

4.97 This knowledge, as well as a large volumn of interesting data generated by the many researchers in this field since 1969, has lessened the continuing danger of cargo-tank explosions.

4.98 Rapid and uncontrolled combustion (i.e., an explosion) is only possible when three elements are present aboard a tanker. These elements are fuel, ignition, and oxygen. Remove any one of these and explosion cannot occur. In tankers, fuel will always be present in the form of cargo, and despite every care in choice of materials and equipment, it is impossible to eliminate all sources of ignition. Such sources include static electricity, radio transmission, impact sparking, electrical faults, friction, spontaneous combustion, and irresponsible human actions. Thus, there remains only the third factor -oxygen. To support combustion, a hydrocarbon/air mixture must have a content of at least 12 percent of oxygen by volume. Atmospheric air contains 21 percent, which makes it highly dangerous in tankers. But, if the air is replaced by an inert gas containing less than the critical 12 percent of oxygen, there can be no combustion.

4.99 The foremost justification for installing an inert gas system aboard a tanker will always be that of safety. All owners, now having to pay $50-75 million for a 250,000 ton dwt vessel, have to seriously consider the financial risk involved in operating a tanker with a flammable atmosphere within its tanks. An initial investment in the order of $500,000 to $750,000 for an inert gas system is obviously a reasonable step to protect this large capital investment and the lives of the men who operate that investment.

4.100 Fire Protection Concept. Fire protection services for the Harbor Island deepwater port facility would be provided by the existing Refinery Terminal Fire Company (RTFC) and the described facilities and concept are based on the recommendations of the (RTFC). The facilities would conform to the National Fire Protection Association (NFPA) Code and to the regulations of the U.S. Coast Guard and would provide protection to onshore tankage and to VLCC's at the docks.

4.101 Applicable Facilities. The fire protection concept proposed for this project is based upon the services and facility necessary for a deepwater port for VLCC's, of which a typical tanker vessel would transport 2-1/2 million barrels of crude oil. The applicable surge tankage which would be served would be approximately 15 million barrels in tanks up to about 600 to 700 thousand barrels in capacity which would be up to 300 feet in diameter and 60 feet tall. A basic parameter in designing fire-protection facilities is the area of the petroleum surface in tanks when conflagration must be controlled. The largest Exxon tanks presently on Harbor Island hold 153,000 barrels, and are 140 feet in diameter by 60 feet high. Fina has 80,000 barrel tanks on Harbor Island, measuring 120' x 42'. However, four refineries around the Corpus Christi Inner Harbor presently use 30,000 barrel storage tanks (216' x 46'), and one refiner has tanks containing 500,000 barrels (281 x 48'). These tanks have floating roofs and are equipped with foam chambers. (RFTC) has the technology and is equipped to control fires in these tanks.

4.102 Foam System. Based upon the installation of NFPA-approved foam chambers on each tank, the NFPA recommends 0.1 gpm/ft2 of surface, or 7000 gpm to control a fire in tanks of this diameter. Additional pumping capacity would be required for ground foam lines and cooling of adjacent exposed facilities. To meet these needs it is planned to provide facilities and equipment capable of producing 10,000 gpm of foam solution. This equipment would be backed up by the additional equipment of the RTFC in the Corpus Christi area.

4.103 Fire Water System. Salt water fire mains would provide 12,000 gpm of seawater at 150 psi to suitably located hydrants. When not in fire use, the lines would be purged and filled with freshwater. This would be supplemented by sea water wells fed by gravity conduits from which pumper trucks could draw a water supply. Prepiped turrets would be provided at each dock through which foam could be directed to reach the length of the VLCC's.

4.104 Mobile Units. Six mobile units are planned to protect the Harbor Island terminal; it is assumed that they would be housed in a building in the Aransas Pass-Ingleside area. They would be accessible at all times to the RTFC driver-operators and the RTFC-trained firefighters. The RTFC would provide regular maintenance for these units and each unit would be operated weekly to assure capability of immediate response. It is planned that the Harbor Island mobile units would be identical to units now operated by the RTFC in the Corpus Christi area and that they would include the special design features incorporated in these units. The six units would include four 1000 gpm foam pumpers carrying 1000 gallons of foam concentrate and two 5000-gallon foam concentrate tank trucks with 3000-gpm proportioners which mix a concentrate with water to produce foam.

4.105 Back-up Equipment. The fire equipment and personnel of the RTFC in Corpus Christi would also be available to support Harbor Island - including foam pumpers and tank trucks. Further, the tug boat available to the RTFC which is equipped as a fire boat would also be available to fight any fires which might occur aboard vessels at Harbor Island.

4.106 Air Quality. Air quality in the project area would be affected by construction and operation activities and industrial development which would result from project implementation. During construction, air emissions, primarily nitrogen oxides, carbon monoxide, and hydrocarbons, would be generated temporarily from the operation of heavy construction equipment, trucks, dredges, and process machinery. In addition, dust from the movement of machinery over the exposed soil surface temporarily would increase the level of particulates.

4.107 Sources of air emissions resulting from operation of the project would include evaporation from storage tanks, evaporation from transfer of crude oil and fuel, combustion products from process machinery and marine vessels, and accidental small spills and leakage.

4.108 Hydrocarbon emissions are of particular environmental concern because they combine photochemically in the atmosphere with nitrogen oxides to form photochemical smog.

4.109 Although not part of the proposed project, the participants in the project contemplate construction of additional surge tanks, as a result of the project, to contain hydrocarbon. The participants plan to locate these surge tanks on the south side of the docking basin on Harbor Island. This location is in Nueces County which has been designated as a non-attainment area by EPA for photochemical oxidants emission. The surge tanks will incorporate the lowest achievable emission rate (LAER) but are still expected as a group to emit in excess of 100 tons per year of hydrocarbon into the atmosphere. The surge tanks, if required by current EPA regulation, could be located on the mainland, in Aransas County, along the pipeline leading from the docking basin to the receiving refineries. Aransas County has been designated as an attainment area by EPA for photochemical oxidants.

4.110 Secondary industrial development in the three county area which may result from the proposed project would affect air quality. A "worst case" assessment of the effects of secondary industrial development upon sulphur dioxide and particulate matter levels was prepared by Southwest Research Institute (SWRI 1977). In general SWRI concluded that projected industrial growth would not produce excessive sulphur dioxide emissions based on current standards. Particulate from "worst case" secondary industrial development emissions could exceed current standards from 1980 onward.

4.111 However, the implementation of the provisions of the Clean Air Act Amendments of 1977 (Public Law 95-95) will insure that no significant adverse air quality impacts will result from primary or secondary industrial development. In areas where the national ambient air quality standards for particular pollutants are not now being attained or are exceeded in the future, the implementation of the offset policy under Section 129 of the Amendments will insure that there will not be an increase in total emissions of any non-attainment pollutant despite additional emissions of that same pollutant from major new facilities, which demonstrate attainment of the ambient air quality standards by either 1982 or 1987. In those areas where the standards for particular pollutants are being attained, Part C of the amendments provides for control of emission from new facilities so as to prevent significant deterioration of air quality, including the violation of any national ambient standard.

4.112 Effects on Odors. The disposal of materials on land may result in the release of objectionable odors formed by the decomposition of vegetation and the organic materials from the channel bottom. The odors would be in the form of hydrogen sulfide. This temporary localized air quality effect should be eliminated by natural processes within two or three months. Concentrations of the gases evolved are not expected to be sufficiently high to present a health problem or to damage property. If necessary, odors could be controlled in the leveed disposal area by chemically treating with a proprietary product containing essential oils and deodorized kerosene. The product manufacturer advises that all the essential oils are on the GRAS (Generally Regarded as Safe) list of chemicals approved by the U.D. Department of Agriculture for use. If needed, the mixture of essential oils and deodorized kerosene in a 1 to 4 ratio could be applied over the area at a rate of 0.5 gallons per acre. The frequency of application could vary from once every 2 days to once every 10 days depending on the severity of the problem.

4.113 Industrial growth in the area as a result of the deep draft channel may increase odors in the area. Although EPA has no established standards governing odor, it is an area of concern. Most modern refineries are relatively odor-free, although even best available control technology will allow some hydrogen sulfide (H_2S) emissions from the stacks. Studies have shown the H_2S may be detected in the one to 1000 range. Similar low concentrations could result from other sulfur compounds as well. If incineration is the last step of control, these gases could be almost completely destroyed. Whether incineration would be used as the final step depends on the type of gas scrubbing the particular refinery would employ for sulfur removal.

4.114 Noise Effects. Predicting the exact impact of various sounds on populous areas presents a difficult problem. While the prediction of sound propagation and attenuation mechanisms has at least reached usable form, the response of people to sound has been unpredictable to date except in very specific situations or in large statistical averages. This non-predictability of subjective response is attributable to the fact that below the point where sound is physically injurous to the auditory apparatus the net psychological pre-conditioning of the subject becomes the controlling factor in the hearer's response.

4.115 With this in mind, it is important to realize that any established annoyance criteria can only serve as an approximate guide in predicting annoyance in a different situation. It is possible that even if the noise source produces lower sound pressure levels than the ambient or background noise levels, it may still produce annoyance because of unpleasant frequency components.

4.116 Many different pieces of construction equipment will be used during various stages of construction activity (e.g., excavation, concrete work, tank erection, and others). Since each piece of equipment generates its own characteristic sound, the effect of construction on the neighboring communities will be different during the different construction periods. Table 33 shows approximate noise levels of typical day to day activities, while Table 34 lists noise levels which should result from the different types of construction equipment to be used. In general, most construction activities, except for dredging activities, will be restricted to day time operations. The noise from dredges is observable in this area where the only other noise is produced by commercial and pleasure boats.