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Physical Coast and Port Characteristics, and Selected Deepwater Port Alternatives

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13. ABSTRACT

This report provides an overall appraisal of deep port needs for the United States by means of identification of the factors critical to U. S. deepwater port decision; development of criteria appropriate to the evaluation of engineering, economic and environmental aspects of deep port needs and policies, analysis of the development options available at this time and the critical issues surrounding each and the identification of critical issues which need further analysis. The study emphasizes port requirements for bulk commodities.

Volume I contains the Summary Report

Volume II contains Commodity Studies and Projections

Volume III contains Physical Coast and Port Characteristics, and Selected Deepwater Port Alternatives

Volume IV contains The Environmental and Ecological Aspects of Deepwater Ports

Volume V contains Transport of Bulk Commodities and Benefit-Cost Relationships

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CONTENTS

ANNEX B. RECONNAISSANCE SURVEY OF U.S. COASTAL AREAS, PORTS AND PORT FACILITIES

CONTENTS

INTRODUCTION

This annex contains reconnaissance surveys of U.S. coastal areas, ports, and port facilities. For this purpose the coast has been subdivided into the following five coastal zones:

1. North Atlantic coast -- Maine through Virginia
2. South Atlantic coast -- North Carolina through Atlantic coast of Flordia
3. Gulf coast -- gulf coast of Florida through Texas
4. South Pacific coast -- California
5. North Pacific coast -- Oregon and Washington.

The primary function of these surveys in relation to the objectives of the U.S. Deepwater Port Study is to provide background data relevant to the selection of deepwater port alternatives for detailed analysis, and for the identification of other possible alternatives including other possible deepwater ports.

The attached subannexes B-1 through B-5 present the following information for each of the five coastal zones:

1. A general description of the physical characteristics of the coastline and of the major harbors and port areas, including water depths, distance

contour lines at depths of 60-, 90-, and 120-feet, and longitudinal cross sections of major channels from the major facilities to a depth of 120 feet.

2. Data on the volumes of imports and exports for 1968 and 1969, and intracoastal receipts and shipments for 1969 and 1970 of the study commodities by individual port, i.e., crude petroleum and petroleum products, iron ore, alumina, bauxite, coal, phosphate rock, and grains and soybeans and soybean meal.

3. Detailed descriptive information on major harbors and channels, including graphic presentation of harbor and port configuration, and the locational characteristics of ports, major bulk commodity handling and storage facilities, channels, and physical constraints such as bridges and tunnels.

ANNEX B-1. RECONNAISSANCE SURVEY OF THE NORTH ATLANTIC COAST

CONTENTS

I. DESCRIPTION OF COAST AND PORT LOCATIONS

The north Atlantic region extends from Maine (Canadian border, near 45° latitude) to Virginia (boundary with North Carolina, near 36° 45' latitude). It is subdivided into the New England and Middle Atlantic coasts. These two coastal regions are depicted in figures 1 and 2.

New England

The coast of New England is, for the most part, exceedingly rugged and uneven, and covered with dense forests. There are long and rocky headlands with deep narrow bays between them. In a direct line, it is a little over 200 miles along the coast of Maine from the New Hampshire boundary to Eastport, but the actual shoreline of Maine, including all the windings and the shores of the islands, is about 2,000 miles long. From Boston southward toward Cape Cod the shores are rocky in places, but along the cape there are long stretches of sandy beach.

The southern shores of New England are irregular. The branches of Narragansett Bay in Rhode Island and the bays and tidal river channels of Connecticut are much like those of Cape Cod.

The entire coastline of Connecticut is protected from the sea by various islands. To the east of the Plum Island and Fishers Island chain is Block Island Sound, which itself is protected from the sea by the southerly fork of Long Island and by Block Island. Thus

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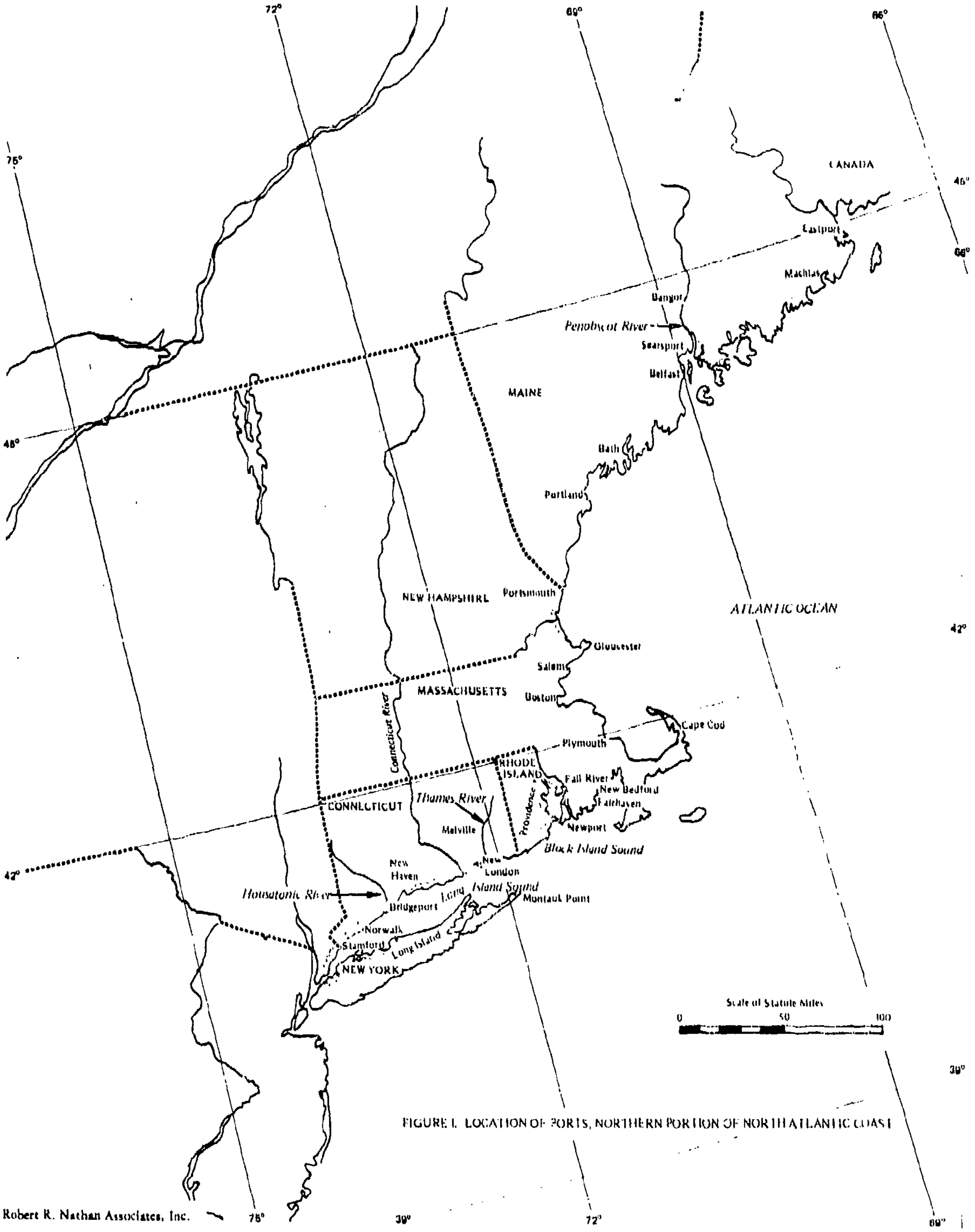

FIGURE I. LOCATION OF PORTS, NORTHERN PORTION OF NORTH ATLANTIC COAST

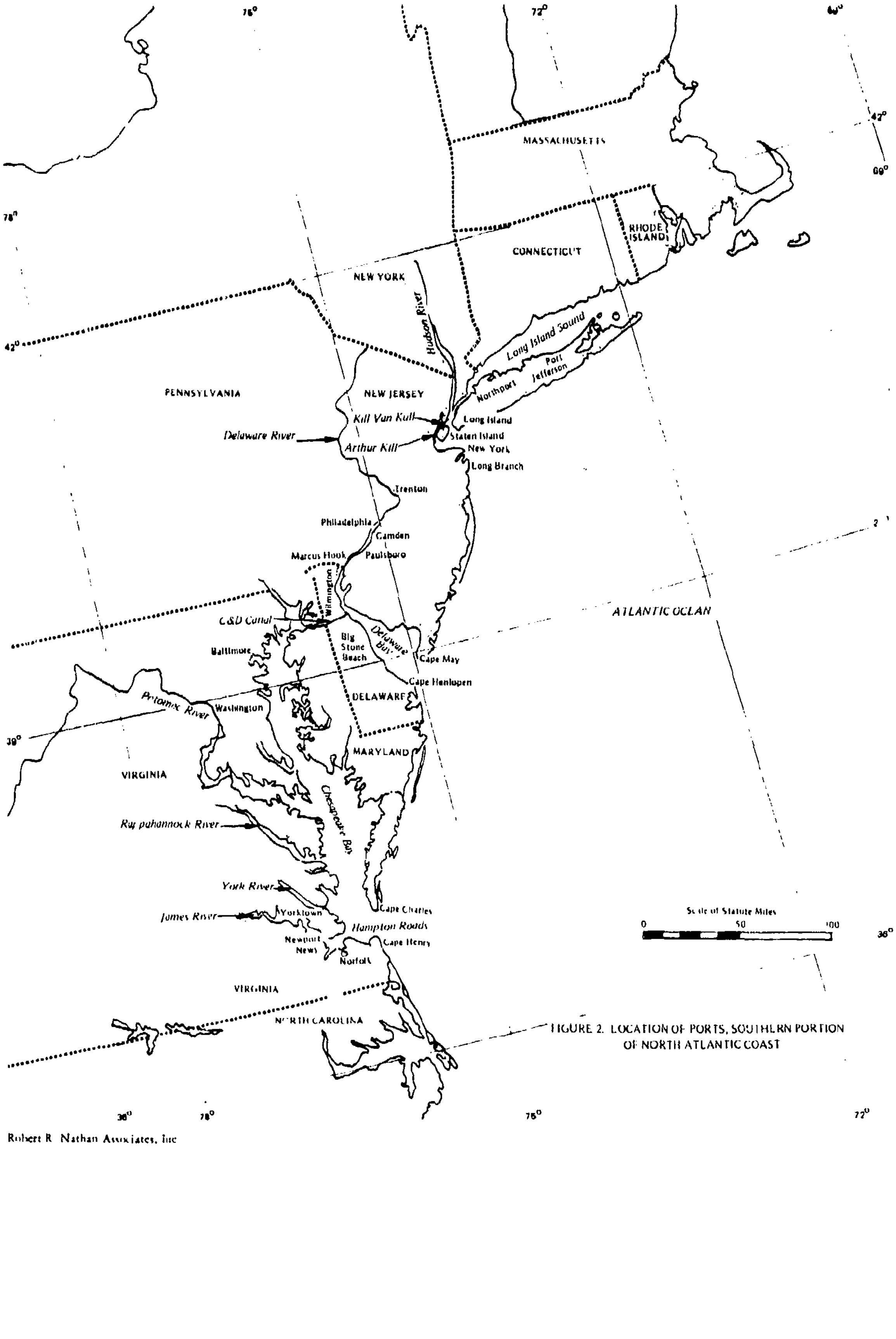

FIGURE 2. LOCATION OF PORTS, SOUTHERN PORTION OF NORTH ATLANTIC COAST

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three-fourths of the coast is protected by Long Island, and one-fourth is protected to a lesser degree by an island chain. These protected waters offer ships smoother navigation than do the waters to the south of Long Island.

The Connecticut coastline's geographic conformation differs from the rest of the Atlantic coastline. It is also unique in that it extends almost east and west, while the bulk of the Atlantic coastline of the United States runs northeasterly and southwesterly.

The principal bulk commodity ports of New England are Portland and Boston. Other ports are Searsport, Maine; Portsmouth, New Hampshire; Fall River, Massachusetts; Providence, Rhode Island; and New London, New Haven, and Bridgeport, Connecticut. Table 1 shows project channel depths for these ports and the number of waterfront facilities present at the time of the latest publication by the Board of Engineers for Rivers and Harbors (BERH).

Figure 3 shows distances from the shoreline (in nautical miles) to water depths of 60, 90, and 120 feet. The distance at each location can be found by drawing a horizontal line to the graph from the location being considered on the map. On the same horizontal line the various distances are found. For example, for a location at the shore in latitude 43°, south of Portsmouth, New Hampshire, 60-, 90-, and 120-foot water depths are found at distances of 2, 4, and 5 nautical miles, respectively, off the coast. The method of graph construction is shown in figure 4. The distance between each shore location was 5 minutes in latitude; hence, 12 locations per latitude were used. The entire coast was turned counterclockwise 37° in order to arrive at a projecting axis which is more or less parallel to the coastline.

It should be noted that (1) the configuration of the coast of Maine is an approximation, since it is impossible to show all indentations on the scale used; (2) the distances to the coasts bordering Cape Cod Bay and Long Island Sound could not be presented because

Table 1. Channel Depths and Waterfront Facilities in Principal New England Ports

Name of port	Project[a/] depth (ft.)	Number of waterfront facilities[b/]		
		Total	oil[c/]	General cargo
Searsport, Maine......	35	5	3	1
Portland, Maine.......	45[d/]/35	54	14	4
Portsmouth, New Hampshire...........	35	22	5	1
Boston, Massachusetts.	40	156	29	17
Fall River, Massachusetts............	35	15	7	1
Providence, Rhode Island..............	35	23	9	2
New London, Connecticut.................	33	36	8	1
New Haven, Connecticut.................	35	40	16	2
Bridgeport, Connecticut.................	35	29	12	--
Total...............		380	103	29

a/ In main channel(s) only, at mean low water.
b/ Piers, wharves and docks described in Port Series publications.
c/ Crude oil and/or petroleum products.
d/ Serving two facilities only.

Source: Searsport, Portland, and Portsmouth -- Board of Engineers for Rivers and Harbors, Port Series 1, 1964; Boston -- Port Series 3, 1967; All others -- Port Series 4, 1964.

12.

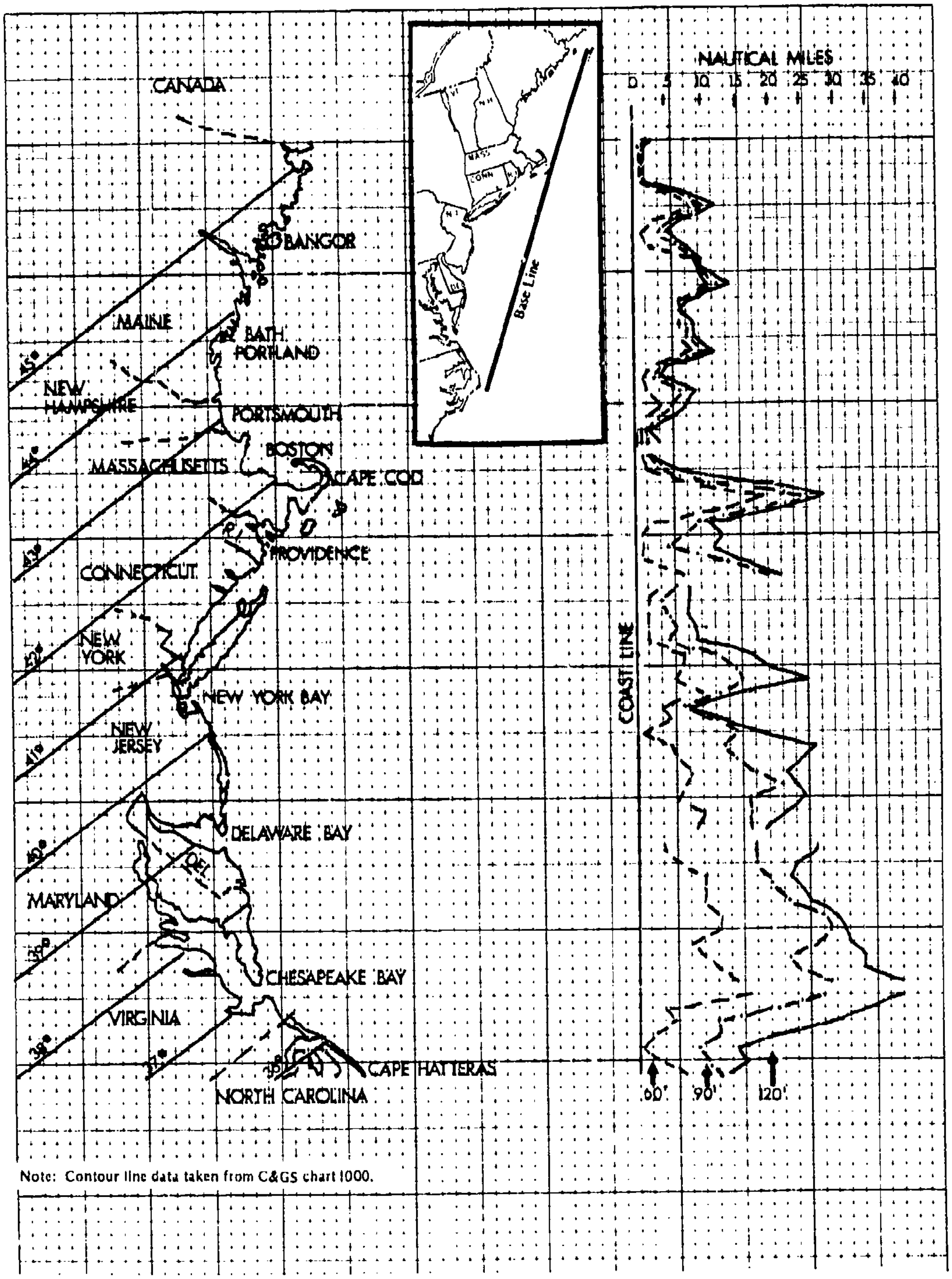

FIGURE 3. DISTANCES BETWEEN COASTLINE AND 60-, 90-, AND 120-FOOT CONTOUR LINES, NORTH ATLANTIC COAST

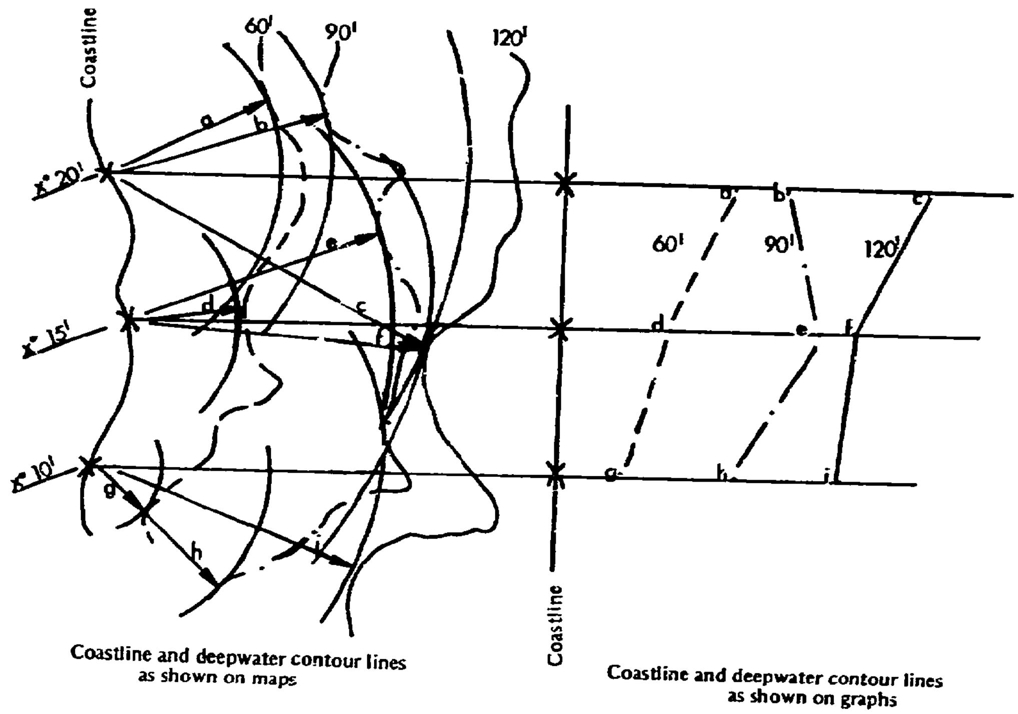

FIGURE 4. METHOD OF GRAPH CONSTRUCTION

they are obstructed in the graph by the Atlantic coastlines of Cape Cod and Long Island; (3) the interruption of the coastline by such bays as Long Island Sound and New York, Delaware, and Chesapeake Bays causes interruption of the schematic coastline; (4) when islands are present off the coast, distances are measured to locations on the Atlantic coasts of these islands and not to the shoreline behind them (as, for example, in the case of the islands surrounding Nantucket Sound); and (5) the graph does not show the distances between the 60-, 90-, and 120-foot contour lines, since the minimum distances to a location on shore are measured on different bearings, as shown in figure 4.

Of primary significance to the study of deepwater ports are the irregularity of the depth contour lines and the comparatively few locations where the 60- and 90-foot depths are found less than 5 miles from shore. This occurs along the New England coast in Maine (near the Canadian border at Eastport, Machias, Bangor, Searsport and Belfast); at Portsmouth and Boston; and at Narragansett Bay (Providence).

Middle Atlantic Coast

The middle Atlantic coast extends from New York through Virginia (see figure 2). Nearly all the land bordering the sea is low and sandy. This coastal border area includes many large cities as well as numerous resorts and beaches.

The principal bulk commodity ports of the middle Atlantic coast are New York, Philadelphia, Paulsboro, Marcus Hook, Baltimore, and Hampton Roads (Norfolk and Newport News). Table 2 shows the channel depths of these ports and the number of waterfront facilities present at the time of the latest surveys by BERH. Table 3 presents a breakdown of all facilities of New York Harbor by main waterway.

Analysis of the depth contour lines in figure 3 shows that the location with the most favorable access to the 60- and 90-foot depths is off the northern coast

Table 2. Channel Depths and Waterfront Facilities in Principal Ports of Central Atlantic Coast

Name of port	Project depth[a/] (ft.)	Number of waterfront facilities[b/]					
		Total	Oil[c/]	Coal	Iron ore[d/]	Grain	General cargo
New York, N.Y., N.J.	45/35	1,160	277	34	0	1	157
Wilmington, Del.[e/]	40	38	13	0	1	--	1
Marcus Hook and Chester, Pa.[f/]	40	31	8	1	--	--	--
Paulsboro, N.J.[g/]	40	13	6	0	--	--	1
Philadelphia, Pa.	40	141	21	8	--	2	30
Gloucester and Camden, N.J.	40	49	12	0	--	--	2
Trenton, N.J.[h/]	40/35	21	10	2	1	--	1
Hampton Roads, Va.[i/]	45/40	235	13	4	0	2	16
Baltimore, Md.	42	227	25	9	1	3	33
Total		1,915	385	58	3	8	241

a/ In main channel(s) only, at mean low water.
b/ Piers, wharves and docks described in Port Series publications.
c/ Crude oil and/or petroleum products.
d/ Berths handling "ores" excluded.
e/ Including Delaware City, Pigeon Point, Edge Moor and Claymont, Del., and Deepwater Point, Oldmans Point and Logan Township, N.J.
f/ Including Eddystone, Darby Creek and Essington, Pa.
g/ Including Thomson Point and Mantua Creek, N.J.
h/ Including Cornwells Heights, Tullytown, and Penn Manor, Pa., and Beverly, Burlington, Roebling, Fieldsboro and Duck Island, N.J.

continued--

Table 2. Channel Depths and Waterfront Facilities in Principal Ports of Central Atlantic Coast continued--

i/ Including Norfolk and Newport News.

Source: New York -- Board of Engineers for Rivers and Harbors, Port Series 5, 1965; Philadelphia, Gloucester and Camden -- Port Series 7, 1967; Hampton Roads -- Port Series 11, 1971 (presently under preparation); Baltimore -- Port Series 10, 1966; all others -- Port Series 8, 1966.

Table 3. Channel Depths and Waterfront Facilities in the Port of New York, N.Y. and N.J.

Name of river or bay	Project depth[a] (ft.)	Number of waterfront facilities			
		Total	Oil	General cargo	
				Deep draft	Total
Hudson River.....	48/45, 40, 30	260	21	38	74
East River[b].....	40, 35, 30, 20	227	57	18	20
Harlem River.....	15	30	4	0	2
Long Island Sound[c].........	15, 12, 10	86	37	0	0
Upper New York Bay........	45-60[d]	136	10	32	40
The Narrows......	50-80[d]	28	2	9	9
Kill Van Kull....	35[e]	66	17	0	0
Newark Bay, Passaic and Hackensack Rivers..........	35[e], 32[e], 30	127	52	12	12
Arthur Kill......	35[e]	110	43	0	0
Raritan and South Rivers....	25	17	6	0	0
Lower New York Bay, Northeast part...........	20, 18	66	27	0	0
Lower New York Bay, Sandy Hook Bay........	35	7	1	0	0
Total............		1,160	277	109	157

a/ At mean low water.
b/ Including Buttermilk Channel and Newtown Creek.
c/ Including Bronx River, Westchester and Eastchester Creeks and Flushing Creek.
d/ Available depths without dredging.
e/ Increased by 2 feet in case of rock.

of New Jersey near Long Branch. Other favorable locations to the 60-foot depth in particular are off the coasts of Long Island, Delaware Bay, and Virginia.

II. FOREIGN AND COASTAL MOVEMENTS, BY PORT, OF THE SIX STUDY COMMODITIES

Table 4 shows U.S. waterborne imports and exports of the study bulk commodities by port for the north Atlantic coastal zone for 1968 and 1969. Table 5 shows similar data on the waterborne coastal trade in these commodities.

In New England, the movement consists almost entirely of receipts from foreign and domestic sources of crude petroleum and petroleum products. However, only one small petroleum refinery is located in New England, and 1968 and 1969 imports of over 21 million tons of crude petroleum, all through Portland, Maine, were in transit to refineries in Canada. All other imports were petroleum products (16.6 million and 19.0 million tons in 1968 and 1969). However, there were substantial receipts of petroleum products from domestic sources (37.5 million tons and 38.7 million tons in 1968 and 1969, respectively). The movement of dry bulk commodities is confined almost entirely to receipts of coal from domestic sources.

It is apparent from the wide distribution of imports and domestic receipts of petroleum products among the ports, and from their relative proportions, that these receipts are essentially oriented to local rather than broad regional requirements. The four leading ports in terms of volume of foreign imports and domestic receipts of petroleum products in 1969 were Boston (18.5 million tons), New Haven (7.8 million tons), Providence (7.7 million tons), and Portland (4.9 million tons).

Table 4. U.S. Waterborne Exports of Domestic and Foreign Merchandise and General Imports of Selected Bulk Commodities, North Atlantic Coast, 1968 and 1969

(In thousands of short tons)

Port/area	Total all study comm.		Exports: Total grains a/		Exports: Coal		Exports: Phosphate rock		Exports: Total		Imports: Crude oil		Imports: Petroleum products b/		Imports: Iron ore		Imports: Bauxite		Imports: Alumina		Imports: Total	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
New England																						
Bangor, Maine	56	100	--	--	--	--	--	--	--	--	--	--	56	100	--	--	--	--	--	--	56	100
Searsport, Maine	606	708	--	--	--	--	--	--	--	--	--	--	593	701	--	--	13	6	--	--	506	707
Belfast, Maine	380	318	--	--	--	--	--	--	--	--	--	--	380	318	--	--	--	--	--	--	380	318
Bath, Maine	112	--	--	--	--	--	--	--	--	--	--	--	112	--	--	--	--	--	--	--	112	--
Portland, Maine c/	22,571	22,177	--	--	--	--	--	--	--	--	21,478	21,060	1,093	1,117	--	--	--	--	--	--	22,571	22,177
Portsmouth, New Hampshire	626	644	--	--	--	--	--	--	--	--	--	--	626	644	--	--	--	--	--	--	626	644
Gloucester, Massachusetts	d/	d/	d/	d/	--	--	--	--	d/	d/	--	--	--	--	--	--	--	--	--	--	--	--
Salem, Massachusetts	524	660	--	--	--	--	--	--	--	--	--	--	524	660	--	--	--	--	--	--	524	660
Boston, Massachusetts	6,864	7,785	d/	d/	--	1	--	--	d/	1	60	4	6,803	7,780	--	--	--	--	--	--	6,863	7,784
Plymouth, Massachusetts	35	385	--	--	--	--	--	--	--	--	--	--	35	385	--	--	--	--	--	--	35	385
New Bedford, Massachusetts	693	429	--	d/	--	--	--	--	--	d/	--	--	693	429	--	--	--	--	--	--	693	429
Fall River, Massachusetts	254	693	--	--	--	--	--	--	--	--	--	150	254	543	--	--	--	--	--	--	254	693
Newport, Rhode Island	15	44	--	--	--	--	--	--	--	--	d/	--	15	44	--	--	--	--	--	--	15	44
Providence, Rhode Island	1,616	1,973	--	d/	--	--	--	--	--	d/	--	--	1,616	1,973	--	--	--	--	--	--	1,616	1,973
Melville, Rhode Island	228	47	--	--	d/	--	--	--	d/	--	35	--	193	47	--	--	--	--	--	--	228	47
New London, Connecticut	550	962	--	--	--	--	--	--	--	--	--	--	550	962	--	--	--	--	--	--	550	962
New Haven, Connecticut	2,331	1,988	--	--	--	--	--	--	--	--	--	--	2,331	1,988	--	--	--	--	--	--	2,331	1,988
Bridgeport, Connecticut	774	1,354	--	--	--	--	--	--	--	--	--	--	774	1,354	--	--	--	--	--	--	774	1,354
Total	38,235	40,267	d/	d/	d/	1	--	--	d/	1	21,573	21,214	16,648	19,045	--	--	13	6	--	--	38,234	40,265
New York																						
New York, New York	42,139	39,884	46	39	7	3	6	3	59	45	10,502	8,747	31,538	31,066	d/	d/	40	27	--	--	42,080	39,840
Albany, New York	742	1,016	266	138	--	--	--	--	266	138	--	--	476	878	--	--	--	--	--	--	476	878
Total	42,881	40,900	312	177	7	3	6	3	325	183	10,502	8,747	32,014	31,944	d/	d/	40	27	--	--	42,556	40,718
Delaware Bay area																						
Philadelphia, Pennsylvania	22,179	23,653	854	363	295	378	1	d/	1,150	741	9,345	9,052	1,123	1,540	10,561	12,295	--	25	--	--	21,029	22,912
Camden, New Jersey	1,471	2,451	--	d/	--	--	2	--	2	d/	54	94	1,394	2,170	21	187	--	--	--	--	1,469	2,451
Paulsboro, New Jersey	11,942	11,085	d/	16	--	6	--	--	d/	22	8,117	7,446	3,825	3,617	d/	--	--	--	--	--	11,942	11,063
Marcus Hook, Pennsylvania	6,326	8,275	--	--	--	--	--	--	--	--	5,797	7,405	529	870	--	--	--	--	--	--	6,326	8,275
Wilmington, Delaware	3,433	4,540	--	--	--	--	--	--	--	--	3,334	4,313	46	167	--	--	53	60	--	--	3,433	4,540
Total	45,351	50,004	854	379	295	384	3	d/	1,152	763	26,647	28,310	6,917	8,364	10,582	12,482	53	85	--	--	44,199	49,241
Chesapeake Bay area																						
Baltimore, Maryland	18,560	19,185	1,090	874	2,442	2,659	19	d/	3,551	3,533	537	488	3,981	4,522	10,374	10,542	117	101	--	--	15,009	15,653
Alexandria, Virginia	d/	--	--	--	d/	--	--	--	d/	--	--	--	--	--	--	--	--	--	--	--	--	--
Washington, D.C.	--	d/	--	d/	--	--	--	--	--	d/	--	--	--	--	--	--	--	--	--	--	--	--
Richmond, Virginia	d/	--	--	--	d/	--	--	--	d/	--	--	--	--	--	--	--	--	--	--	--	--	--
Cape Charles, Virginia	d/	--	--	--	d/	--	--	--	d/	--	--	--	--	--	--	--	--	--	--	--	--	--
Newport News, Virginia	10,209	12,174	3	2	7,523	9,375	--	--	7,525	9,377	2,201	2,341	140	350	342	106	--	--	--	--	2,683	2,797
Norfolk, Virginia	28,808	32,568	2,241	1,549	24,410	27,669	68	--	26,719	29,218	d/	--	2,087	3,347	--	--	3	3	--	--	2,090	3,350
Total	57,577	63,927	3,334	2,425	34,375	39,703	87	d/	37,796	42,128	2,738	2,829	6,208	8,219	10,716	10,648	120	104	--	--	19,782	21,800
Total, north Atlantic coast	184,044	195,098	4,500	2,981	34,677	40,091	96	3	39,273	43,075	61,460	61,106	61,787	67,572	21,298	23,130	226	222	--	--	144,771	152,024

Note: Individual items may not add to totals due to rounding.
a/ Includes food grains (wheat, rice, rye), feed grains (barley, corn, oats, cereals, n.e.c.), and soybeans and mill products.
b/ Includes gasoline, jet fuel and kerosene, distillate fuel oils, and residual fuel oils.
c/ For crude oil, 1968 and 1969, includes inbound in-transit shipment (SA-305-IT).
d/ Less than 500 short tons.

Source: U.S. Department of Commerce, Bureau of the Census, U.S. Waterborne Exports of Domestic and Foreign Merchandise, SA-705; U.S. Waterborne General Imports of Merchandise, SA-305; and U.S. Waterborne General Imports of Inbound In-Transit Merchandise, SA-305-IT, 1968 and 1969.

Table 5. U S. Domestic Waterborne Coastal Receipts and Shipments of Selected Bulk Commodities, North Atlantic Coast, 1969 and 1970

(In thousands of short tons)

Port/area	Total all study commodities				Crude oil				Petroleum products[a]				Dry bulk commodities[b]					
	1969		1970		1969		1970		1969		1970		1969			1970		
	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Commodity	Rect.	Shipt.	Commodity
New England																		
Penobscot River, Maine	926	4	916	11	--	--	--	--	926	4	916	11	--	--	--	--	--	--
Searsport Harbor, Maine	245	18	154	6	--	--	--	--	189	18	154	6	56	--	Coal	--	--	--
Portland Harbor, Maine	3,832	1,030	3,874	933	41	--	--	--	3,791	1,030	3,874	933	--	--	--	--	--	--
Portsmouth Harbor, New Hampshire	824	6	995	54	--	--	--	--	824	6	995	54	--	--	--	--	--	--
Beverly Harbor, Massachusetts	263	--	--	--	--	--	--	--	263	--	--	--	--	--	--	--	--	--
Salem Harbor, Massachusetts	545	15	305	1	--	--	--	--	333	15	305	1	212	--	Coal	--	--	--
Port of Boston, Massachusetts[c]	10,723	1,983	12,267	1,998	--	--	15	--	10,723	1,831	12,252	1,998	--	152	Coal	--	--	--
New Bedford and Fairhaven Harbor, Massachusetts	46	36	45	14	--	--	--	--	46	36	45	14	--	--	--	--	--	--
Fall River Harbor, Massachusetts	2,702	143	1,875	96	--	--	--	--	1,953	143	1,875	96	749	--	Coal	--	--	--
Providence River and Harbor, Rhode Island	5,710	669	5,590	358	305	--	325	--	5,405	669	5,265	358	--	--	--	--	--	--
New London Harbor, Connecticut	299	1,536	697	1,320	--	--	--	--	259	1,536	697	1,320	--	--	--	--	--	--
Thames River, Connecticut	659	d/	504	--	--	--	--	--	223	d/	244	--	436	--	Coal	260	--	Coal
Connecticut River below Hartford, Connecticut	4,236	3	3,700	10	--	--	--	--	4,236	3	3,700	10	--	--	--	--	--	--
New Haven Harbor, Connecticut	5,769	1,025	5,909	1,409	--	--	--	--	5,769	1,025	5,909	1,409	--	--	--	--	--	--
Housatonic River, Connecticut	1,009	--	748	--	--	--	--	--	251	--	312	--	758	--	Coal	436	--	Coal
Bridgeport Harbor, Connecticut	1,512	324	1,350	195	--	--	--	--	1,512	324	1,350	195	--	--	--	--	--	--
Norwalk Harbor, Connecticut	957	--	989	--	--	--	--	--	168	--	208	--	789	--	Coal	781	--	Coal
Stamford Harbor, Connecticut	646	--	594	--	--	--	--	--	601	--	592	--	45	--	Coal	2	--	Coal
Total	40,903	6,792	40,512	6,405	346	--	340	--	37,512	6,640	38,693	6,405	3,045	152		1,479	--	
New York																		
Port of New York, N.Y.[c,e]	21,352	16,888	27,409	13,745	9,453	36	10,002	--	10,377	14,967	16,733	12,262	--	d/	Phos. rock	--	d/	Iron ore
													15	9	Grains[f]	19	9	Grains[f]
													1,507	1,876	Coal	655	1,474	Coal
Hudson River, N.Y.	2,141	956	3,081	579	--	--	--	--	2,141	3	3,077	4	--	947	Coal	--	d/	Iron ore
													--	6	Grains[f]	4	5	Grains[f]
													--	--	--	--	570	Coal
Hempstead Harbor, N.Y.	1,259	--	1,051	6	--	--	--	--	1,259	--	1,051	1	--	--	--	--	5	Coal
Huntington Harbor, N.Y.	116	--	34	--	--	--	--	--	116	--	34	--	--	--	--	--	--	--
Great South Bay, N.Y.	275	--	--	--	--	--	--	--	275	--	--	--	--	--	--	--	--	--
Port Jefferson, N.Y.	1,688	165	2,714	167	--	--	--	--	1,688	165	2,714	167	--	--	--	--	--	--
Total	26,831	18,009	34,289	14,497	9,453	36	10,002	--	15,856	15,135	23,609	12,434	1,522	2,838		678	2,063	
Delaware Bay area																		
Delaware River, Trenton, N.J. to the sea[c]	23,344	4,498	33,650	5,070	18,583	27	26,709	150	5,227	4,471	6,914	4,915	23	--	Phos. rock	16	--	Phos. rock
													--	d/	Grains[f]	--	5	Grains[f]
													11	--	Coal	11	--	Coal
Wilmington Harbor, Delaware	65	--	20	--	--	--	--	--	65	--	20	--	--	--	--	--	--	--
Total	23,909	4,498	33,670	5,070	18,583	27	26,709	150	5,292	4,471	6,934	4,915	34	d/		27	5	
Chesapeake Bay area																		
Baltimore Harbor and Channels, Maryland	2,305	115	4,002	189	49	--	62	--	2,053	62	3,793	109	202	--	Phos. rock	--	--	--
													1	53	Grains[f]	d/	80	Grains[f]
													--	d/	Iron ore	147	--	Phos. rock
Nanticoke River, Del. and Md.	--	5	--	d/	--	--	--	--	--	--	--	--	--	5	Grains[f]	--	d/	Grains[f]
Washington Harbor, D.C.[c]	11	--	--	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--
Potomac River below Wash., D.C.	232	--	263	--	--	--	--	--	232	--	263	--	--	--	--	--	--	--
Hampton Roads, Virginia[c]	1,302	2,586	1,730	706	--	--	35	--	1,249	41	1,609	29	52	--	Phos. rock	86	--	Phos. rock
													1	10	Grains[f]	--	11	Grains[f]
													--	2,535	Coal	--	666	Coal
James River, Virginia[c]	18	--	15	2	--	--	--	--	18	--	15	2	--	--	--	--	--	--
York River, Virginia	386	1,515	641	1,162	248	22	414	--	138	1,493	227	1,162	--	--	--	--	--	--
Total	4,254	4,221	5,651	2,059	297	22	511	--	3,701	1,596	5,907	1,302	256	2,603		233	757	
Total, north Atlantic coast	95,897	33,520	115,122	28,031	28,679	85	37,562	150	62,361	27,842	75,143	25,056	4,857	5,593		2,417	2,825	

a/ Includes 2911, gasoline; 2912, jet fuel; 2913, kerosene; 2914, distillate fuel oil; and 2915, residual fuel oil.
b/ Includes grains; 1011, iron ore and concentrates; 1051, bauxite and other aluminum ores and concentrates; 1121, coal and lignite; and 1471, phosphate rock.
c/ Consolidated report.
d/ Less than 500 short tons.
e/ Excludes Hudson River (lower section), New York.
f/ Includes 0105, rice; 0106, sorghum grains; 0107, wheat; 0111, soybeans; 0102, barley and rye; 0103, corn; 0104, oats; and 2049, grain mill products, n.e.c.

Source: Department of the Army, Corps of Engineers, Waterborne Commerce of the United States, Part I, "Waterways and Harbors, Atlantic Coast," 1969 and 1970.

As shown in table 5, these and other ports also shipped petroleum products in coastal trade (6.4 million tons in 1970), indicating that they do serve to a limited extent as transshipment or distribution points for other nearby ports.

In the New York Harbor area the movement again is composed almost entirely of petroleum receipts from foreign and domestic sources (47.8 million tons of petroleum products and 18.2 million tons of crude petroleum in 1969 of total imports and coastal receipts of 67.5 million tons). Most of the remainder is coastal receipts of coal. There is a substantial volume of shipments in coastal trade of petroleum products, indicating substantial redistribution in the port area of receipts from both foreign and domestic sources. In fact, for 1969, the port of New York is reported to have shipped in coastal trade more petroleum products than it received, indicating that some part of its shipments was imported petroleum products. Reported receipts of petroleum products in coastal trade in other ports in the New York area were probably from the port of New York.

In the Delaware River and Bay area, the bulk commodity movement is similarly dominated by the receipt of petroleum from foreign and domestic sources (in 1969, 46.9 million tons of crude and 13.7 million tons of products). In addition, there are substantial imports of foreign ore (12.3 million tons in 1969). The relatively greater proportion of crude petroleum over petroleum products reflects the importance of the Delaware River and Bay area as a center for petroleum refining.

In the Chesapeake Bay area, the bulk commodity movement is dominated by the export of coal (39.7 million tons in 1969, of which 2.7 million tons was through Baltimore and the balance through Hampton Roads ports), and the import of iron ore into the port of Baltimore (10.5 million tons in 1969). Relatively small petroleum refineries in Baltimore and on the York River in the Lower Chesapeake Bay area account for some receipts of crude petroleum (0.5 million and 3.1 million tons, respectively, in 1969).

The largest movement of grains in the north Atlantic is through the Chesapeake Bay area (2.4 million tons in 1969, of which 1.5 was through Norfolk and 0.9 through Baltimore).

III. MAJOR HARBORS AND CHANNELS

This section reviews the major channels to New York, the Delaware River ports, Baltimore and Hampton Roads. The locational characteristics of these channels are depicted in figures 5 through 9, and longitudinal cross sections are presented in figures 10 and 11. The project dimensions of the major channels are presented in table 6.

The longitudinal cross sections graphically depict the fact that the principal New York channels are naturally shallow throughout most of their entire length and have had to be dredged to their present depths. Further deepening would require dredging throughout most of their lengths.

The situation in the Delaware River and Bay is similar, with the natural depth being less than 40 feet for almost all of its 130-mile length. However, at the lower end of the bay, within a distance of 5 miles to the ocean, depths sharply increase to over 100 feet. This is followed by a sharp decrease to depths of approximately 50 feet, but the surface area of these shallower depths is relatively narrow, and channels for deeper ocean-going vessels can be provided with a relatively limited amount of dredging.

The Chesapeake Bay channels to Baltimore, in contrast to those of the Delaware Bay, are naturally below 50 feet deep for most of their 160-mile length, and are below 75 feet for three-quarters of their length. Baltimore Harbor itself, however, is quite shallow.

26.

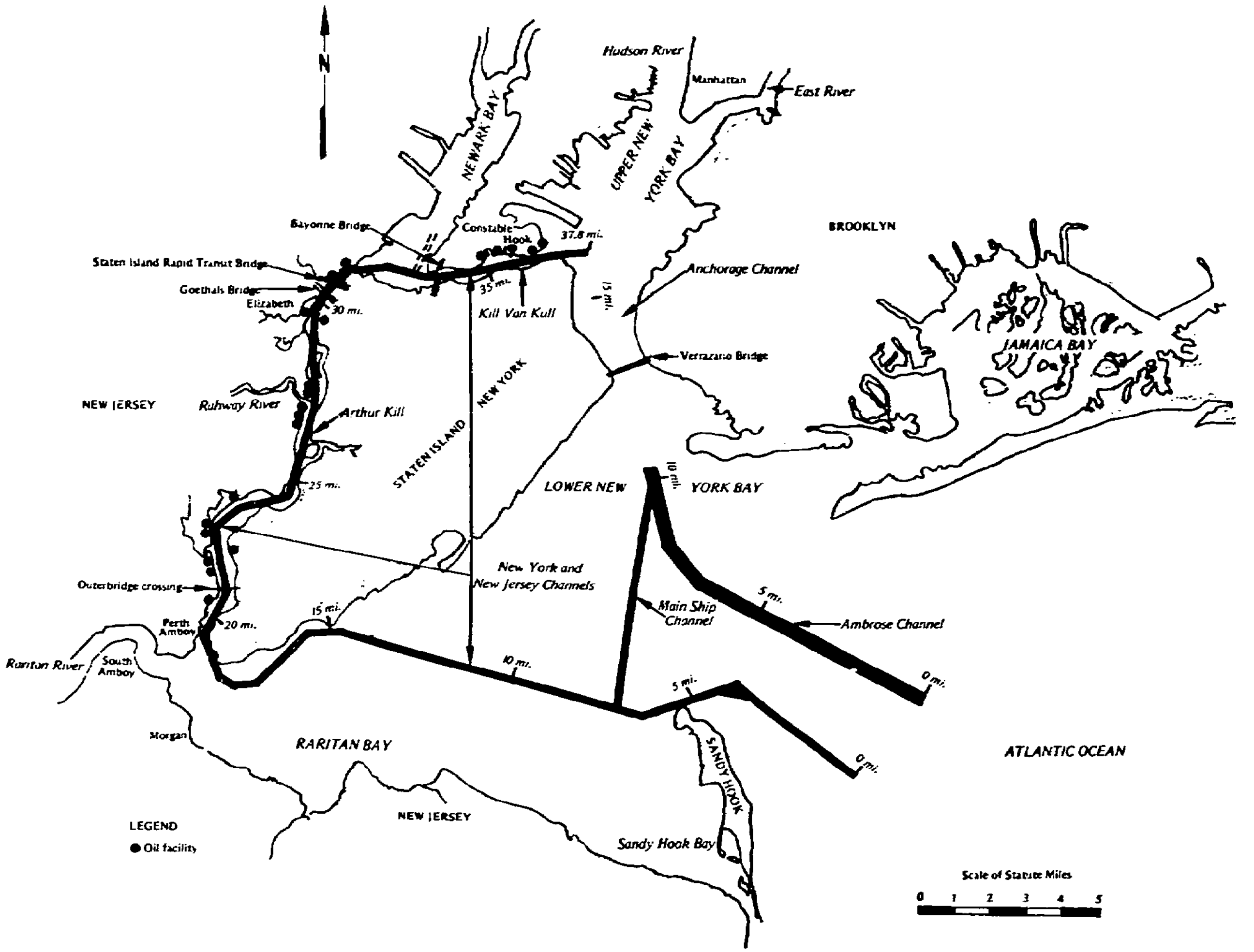

FIGURE 5. CHANNELS AND OIL HANDLING FACILITIES ALONG NEW YORK AND NEW JERSEY CHANNELS

Robert R. Nathan Associates, Inc.

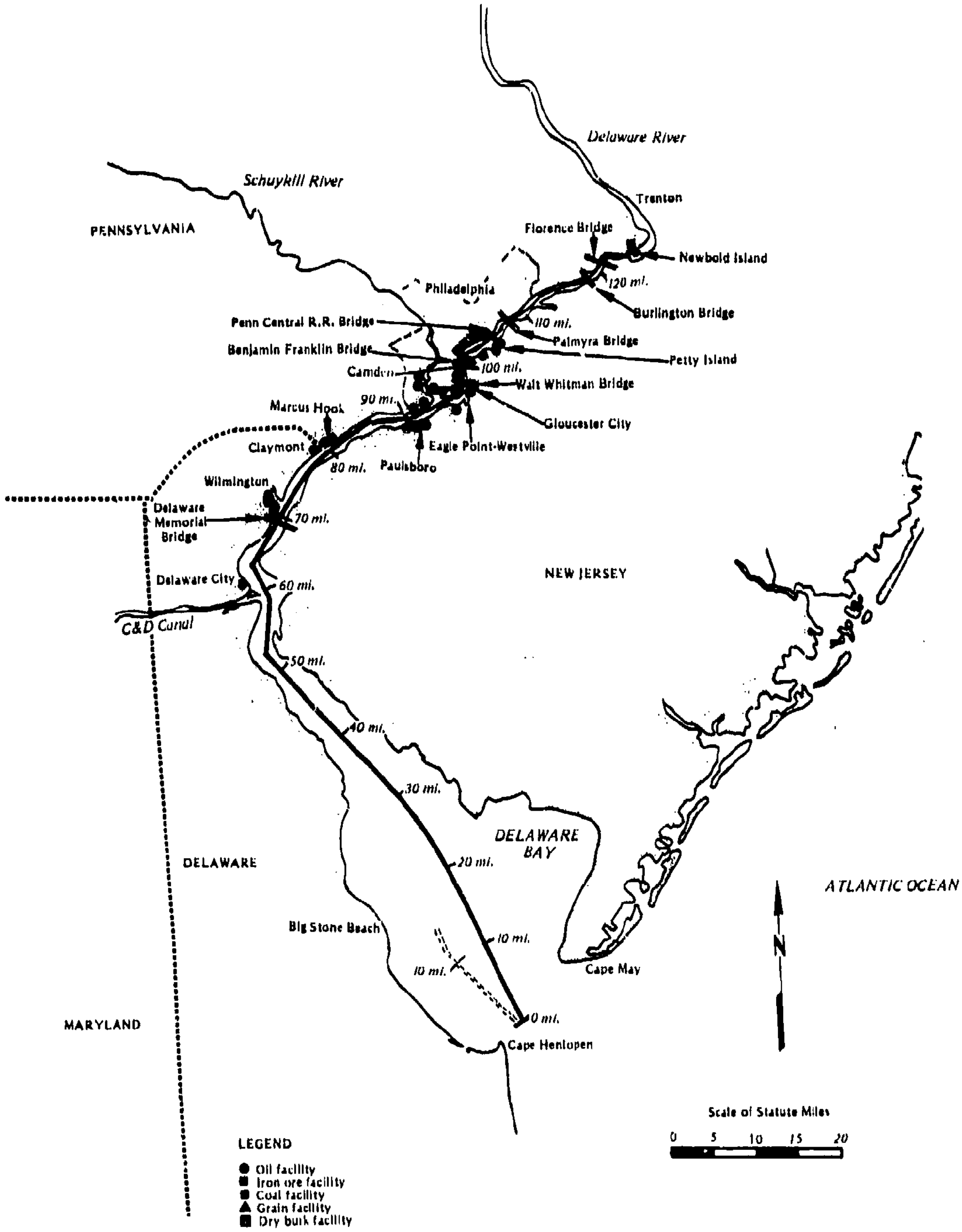

FIGURE 6. CHANNELS AND BULK HANDLING FACILITIES, DELAWARE RIVER HARBORS

Robert R. Nathan Associates, Inc.

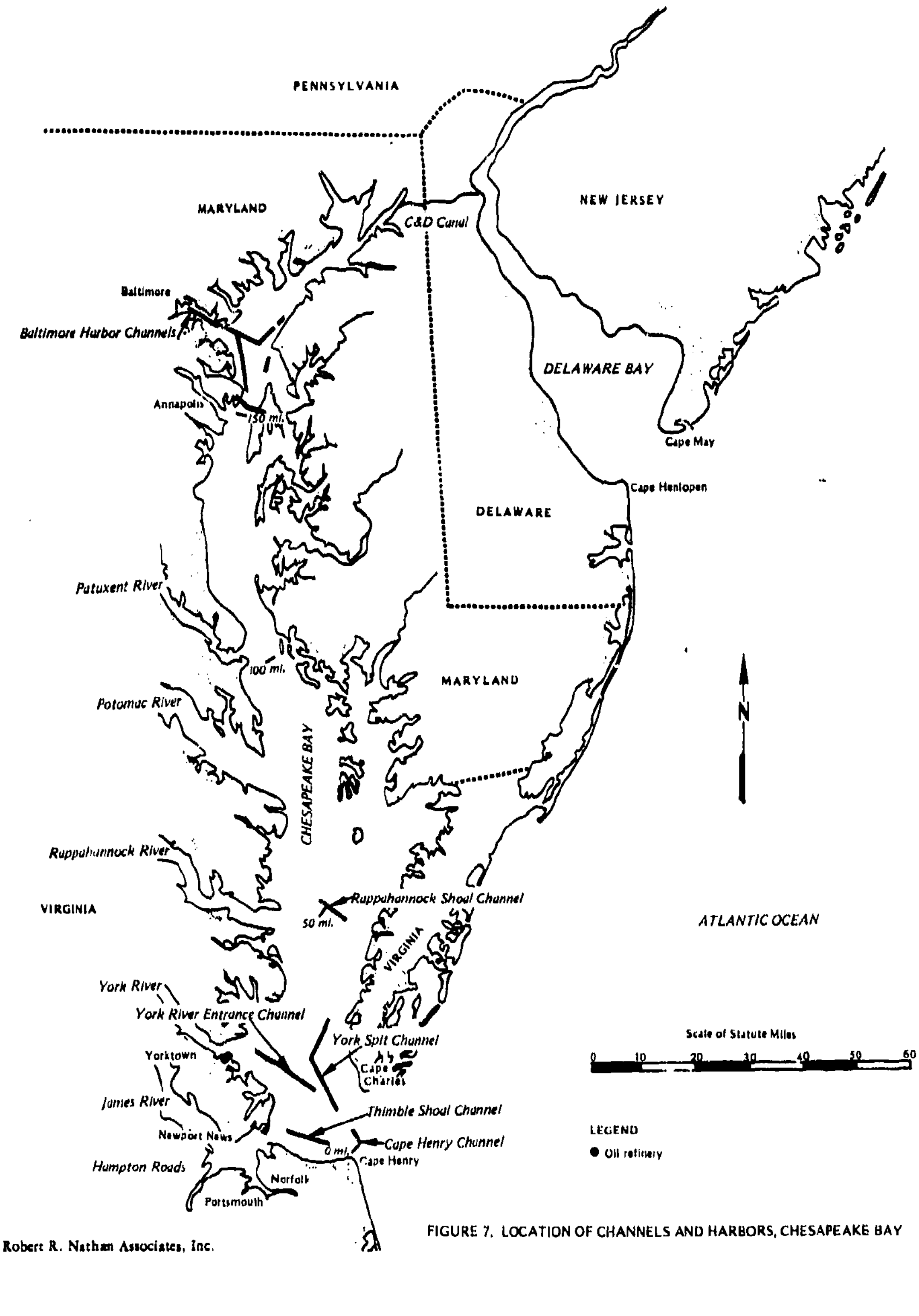

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FIGURE 7. LOCATION OF CHANNELS AND HARBORS, CHESAPEAKE BAY

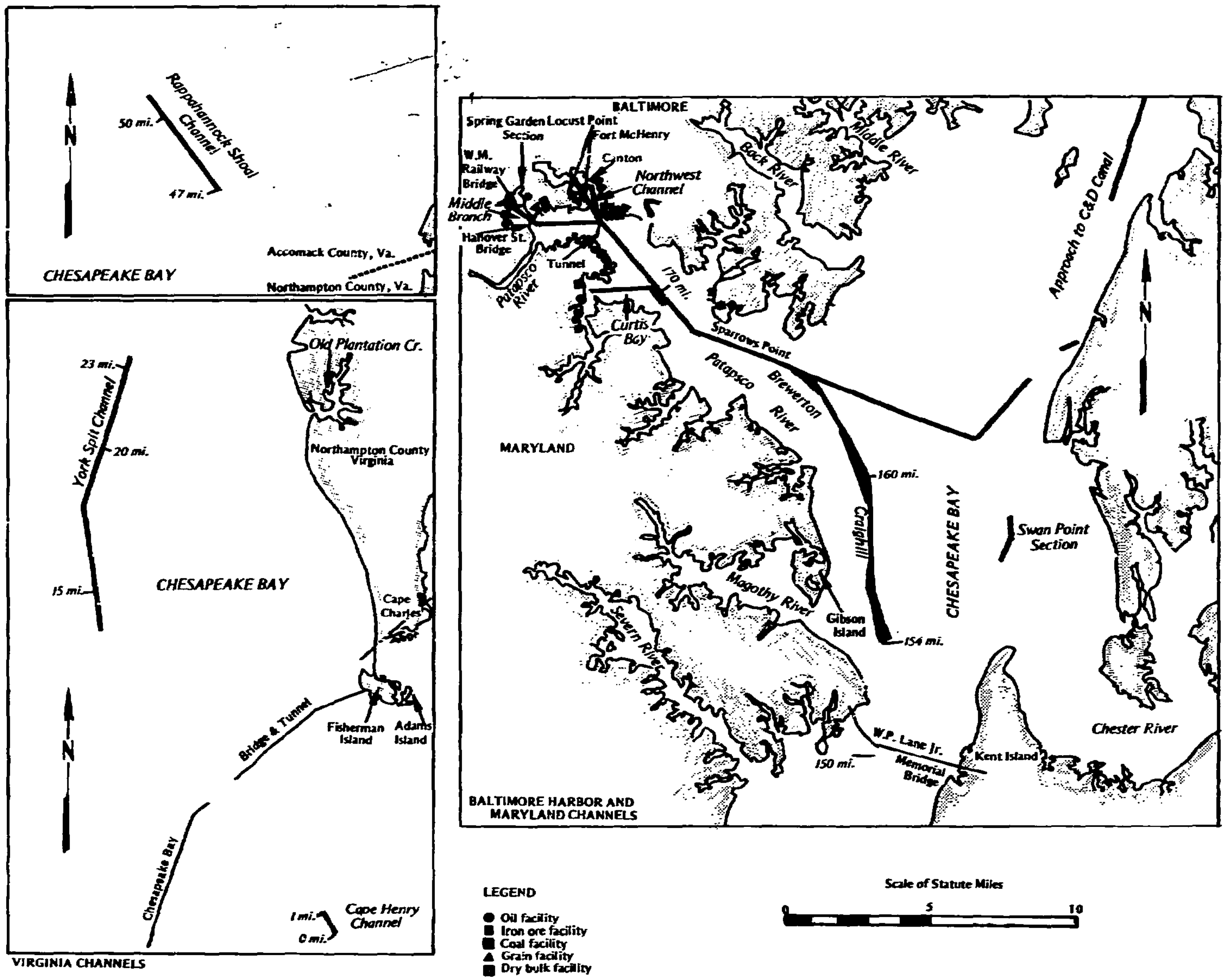
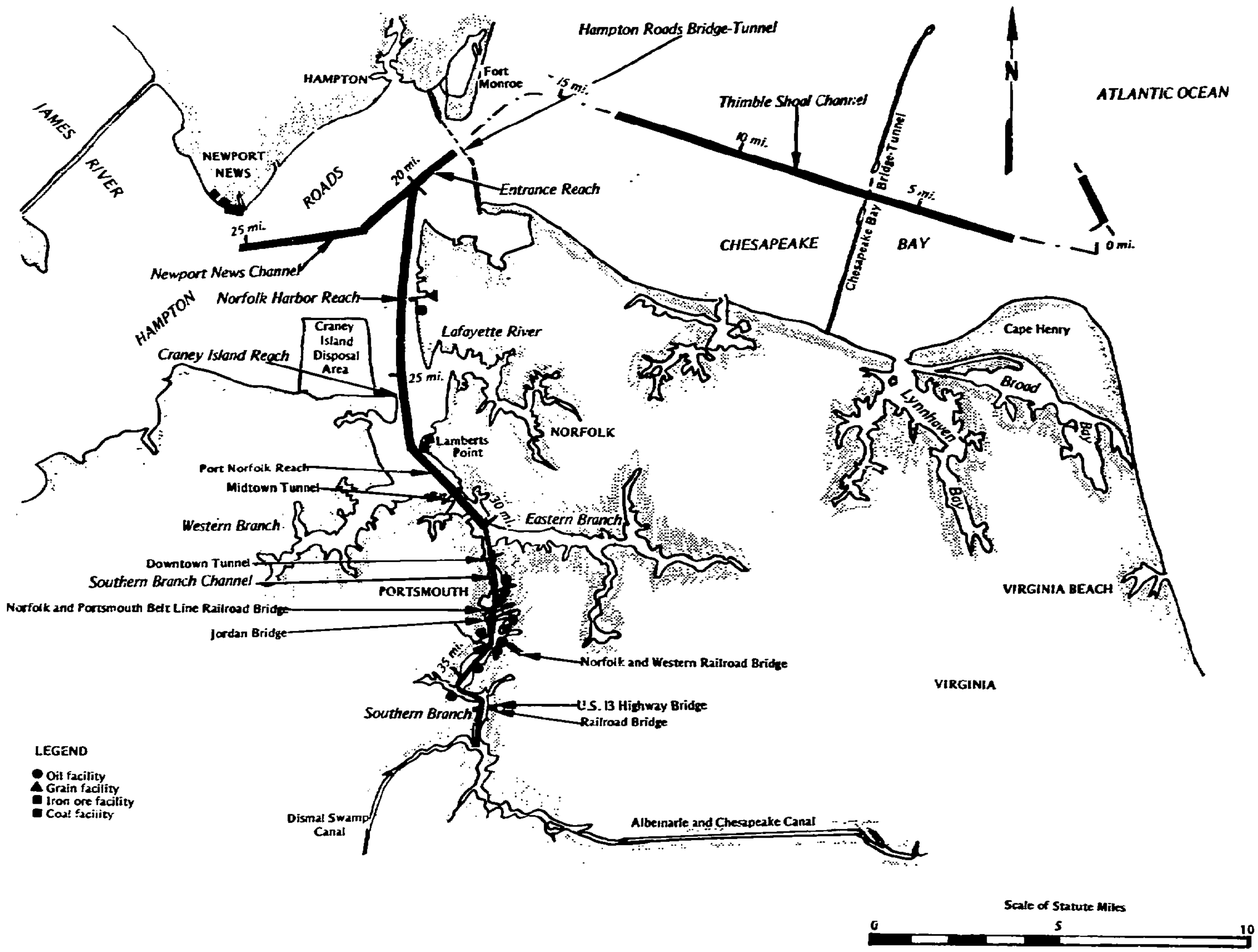


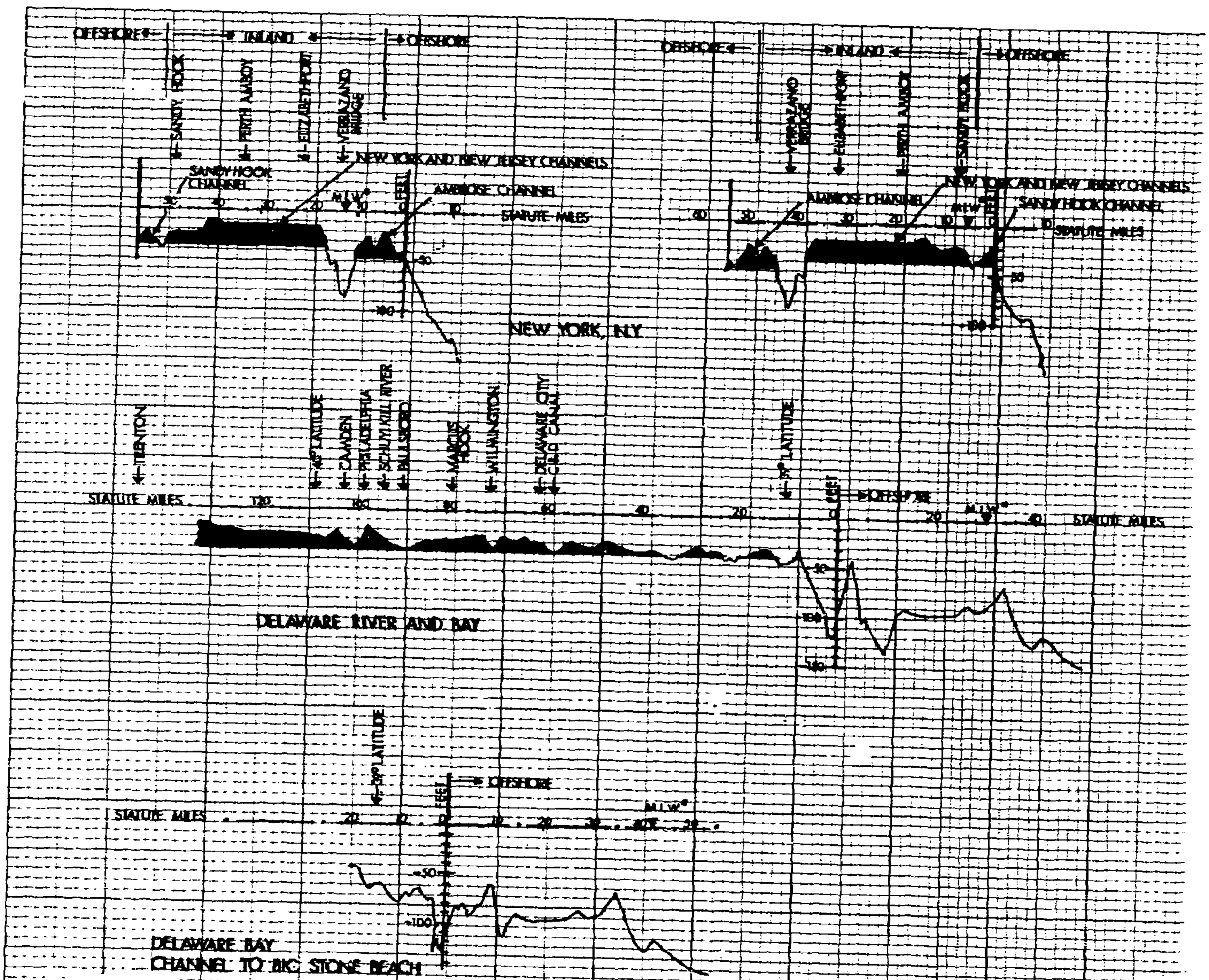
FIGURE 8. CHANNELS AND BULK HANDLING FACILITIES, BALTIMORE HARBOR, MARYLAND, AND VIRGINIA CHANNELS

Robert R. Nathan Associates, Inc.



Robert R. Nathan Associates, Inc.

FIGURE 9. CHANNELS AND BULK HANDLING FACILITIES, HAMPTON ROADS HARBORS



a Mean low water.

Robert R. Nathan Associates, Inc.

FIGURE 10. LONGITUDINAL CROSS SECTIONS OF NEW YORK AND DELAWARE CHANNELS

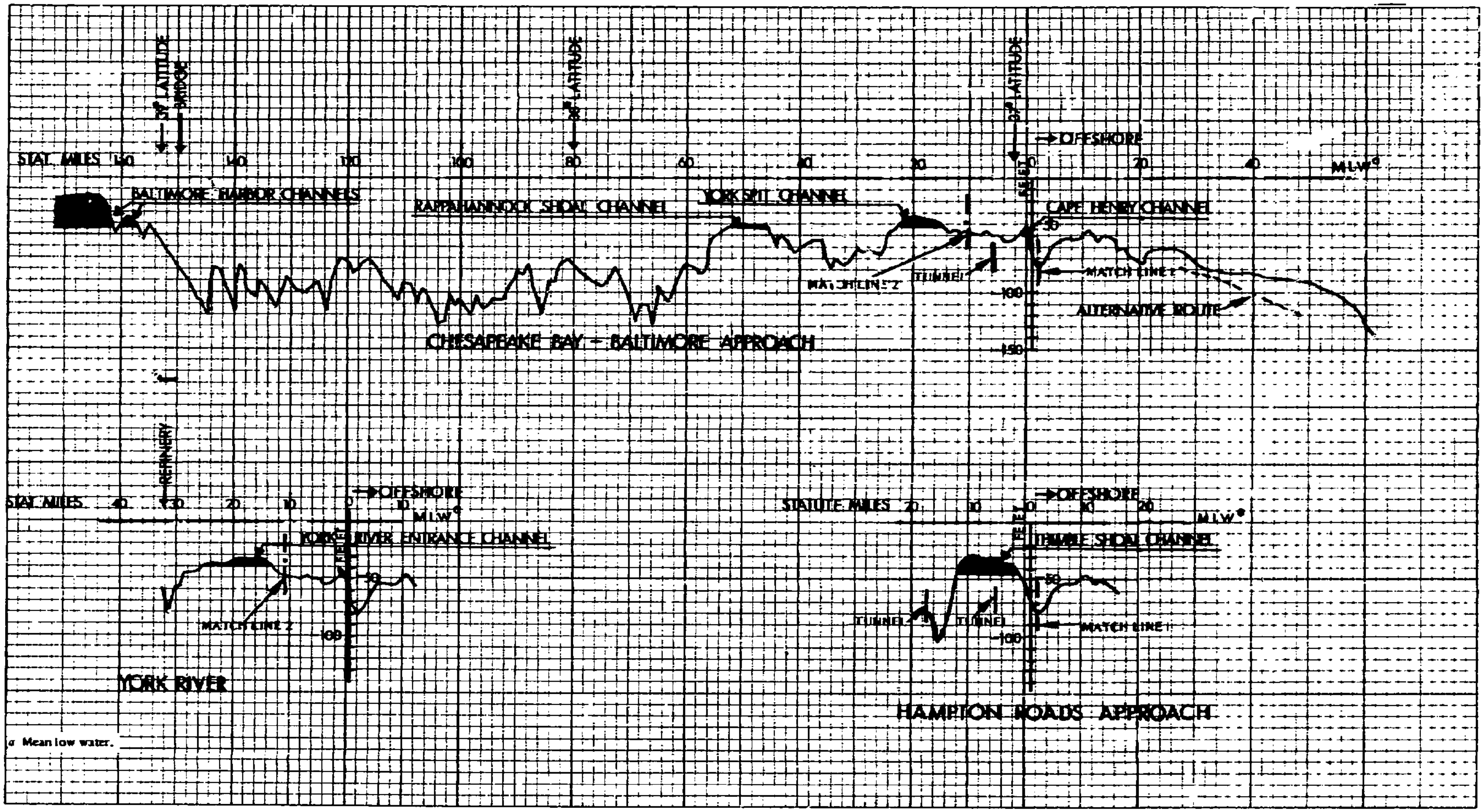


FIGURE II. LONGITUDINAL CROSS SECTIONS OF CHESAPEAKE BAY CHANNELS

Robert R. Nathan Associates, Inc.

Table 6. Project Dimensions of Major Channels on the North Atlantic Coast

Name of channel	Depth (Feet)	Width (Feet)	Length: Naut. miles	Length: Stat. miles	Location[a/]: Stat. miles
New York, N.Y. and N.J.					
Ambrose Channel	45	2,000	8.9	10.2	0.0-10.2
Sandy Hook and Bayside Channel	35	800	6.2	7.1	0.0-7.1
New York and New Jersey					7.1-37.8[c/]
Channels	35[a/]	500[b/]	26.6	30.7	16.2-46.9[d/]
East River Channel	40	1,000	2.1	2.4	20.0-22.4[d/]
	35	550[e/]	12.2	14.1	22.4-36.5[d/]
Delaware Bay and River, Del., N.J. and Pa.					
Philadelphia to sea	40[f/]	800[g/]	83.7	96.5	7.5-104.0
Philadelphia to Trenton	40	400[e/]	20.4	23.5	104.0-127.5
	35	300	4.8	5.5	127.5-133.0
Baltimore, Md.					
Cape Henry Channel	42	1,000	0.9	1.0	0.0-1.0
York Spit Channel	42	1,000	9.0	10.4	13.5-23.9
Rappahannock Channel	42	800	4.6	5.3	46.0-51.3
Baltimore Harbor Channels	42	800	17.3	19.9[h/]	155-175[i/]
York River Entrance Channel[j/]	37	750	9.5	11.0	14.5-25.5
Hampton Roads, Va.					
Thimble Shoal Channel	45	1,000	9.9	11.4	2.[illegible]-13.5
Entrance Reach	45	1,500	1.7	2.0	18.5-20.5
Newport News Channel	45	800	4.2	4.8	20.5-25.3
Norfolk Harbor Reach	45	1,500	3.2	3.7	20.5-24.2
Craney Island Reach	45	800	2.3	2.6	24.2-26.8[k/]
Port Norfolk Reach[l/]	40	750	3.6	4.2	26.8-31.0
Southern Branch Channel	40	450[m/]	3.8	4.4	31.0-35.4
	35	250[n/]	2.7	3.1	35.4-38.5

continued--

Table 6. Project Dimensions of Major Channels on the North Atlantic Coast continued--

a/ 37 feet in rock.
b/ 600 feet through Lower New York and Raritan Bay; 800 feet through Kill Van Kull.
c/ Approach through Sandy Hook and Bayside Channel.
d/ Approach through Ambrose Channel.
e/ Locally wider.
f/ 37 feet deep on east side between mile 96.0 (Eagle Point, N.J.) and mile 104.0 (Allegheny Ave., Phil.).
g/ 1,000 feet wide from deep water in Delaware Bay to Ship John Light; 1,000 to 1,200 feet wide at various bends; 500 feet wide through Horseshoe Bend (approximately mile 95) and 400 feet wide through Philadelphia Harbor.
h/ Not including the three branch channels in Curtis Bay, Middle Branch and Northwest Channel.
i/ Approximate location near Locust Point.
j/ To Yorktown, Virginia.
k/ At Lamberts Point.
l/ Including Town Point Reach.
m/ 375 feet between Belt Line and N&W Railroad Bridges, thence 250 to 500 feet.
n/ Locally wider, up to 500 feet.

The materials dredged in maintaining the Ambrose Channel, the New York and New Jersey Channels, the Sandy Hook Channel, and the southern portion of the East River Channel are disposed of in the Atlantic Ocean. The disposal area for the northern portion of the East River Channel is located in Long Island Sound. In general the disposal areas for the Delaware River are 5 to 10 miles from the dredging site, and are located either on shore or on islands between the river banks. The disposal areas for the channel through Delaware Bay and for all channels in the Chesapeake Bay run parallel to the channels. The disposal area for the channels in Hampton Roads is at Craney Island.

New York Harbor

The Port of New York Authority District, comprised of 17 counties, embraces parts of New Jersey within an approximate 25-mile radius of the Statue of Liberty, a total of 1,500 square miles. It has a frontage of 755 miles measured along the shorelines of its navigable waterways, of which 460 miles are in New York and 295 miles are in New Jersey.

Large areas in the hinterland are reached by the New York State Barge Canal System, an inland waterway communication between Lakes Erie and Ontario on the west and the Hudson River and Lake Champlain on the east. Points are accessible on the Great Lakes and the St. Lawrence Seaway by way of the Hudson River and the Erie and Oswego Canals, and on the St. Lawrence River via the Hudson River and the Champlain Canal and Lake, the Richelieu River, and the Chambly Canal. Included in the port are areas contiguous to New York City extending westward beyond Newark, New Jersey, northward including the Passaic and Hackensack Rivers, and southward including the Raritan River up to New Brunswick, New Jersey, and South River to Madison, New Jersey. The southern boundary encompasses Sandy Hook and includes the Atlantic Highlands in New Jersey, westward along the southern parts of Sandy Hook Bay and Raritan Bay. To the north, the port extends as far as Tarrytown, New York, on the Hudson River, and includes Port Chester, New York, on Long Island Sound; and to the east it includes Jamaica Bay on

Long Island. Nearly five whole counties in New Jersey are included within the area known as the port of New York. New York Harbor is divided into the Lower Bay (Outer Harbor) and Upper Bay (Inner Harbor) by the Narrows.

Outer Harbor

Lower Bay, Jamaica Bay, Raritan Bay and their entrance channels form the Outer Harbor. The Lower Bay is triangular in shape with the apex extending inland for 12 miles; for a length of about 6 miles the bay is open to the sea. Jamaica Bay is an indentation in the south shore of Long Island. Raritan Bay lies west of Lower Bay between the southern end of Staten Island and the New Jersey shore. Channels in the Outer Harbor are as follows:

Ambrose Channel, providing the principal entrance to New York Harbor, extends from the sea to deep water south of the Narrows. Main Ship, Sandy Hook, and Bayside Channels are located south of Ambrose Channel.

New York and New Jersey Channels extend from deep water northwest of Sandy Hook, through the Lower Bay and Raritan Bay to Perth Amboy, and thence through Arthur Kill, Lower Newark Bay, and Kill Van Kull to deep water in the Upper Bay.

All channels in the Lower Bay are marked with lights, ranges, and buoys; the buoys include the bell, whistling, and lighted types.

Inner Harbor

The Inner Harbor consists of the Upper Bay, Lower Hudson River, East River, Long Island Sound, and tributary waterways. To the east, the tributary waterways are Gowanus Creek, Newtown Creek, Harlem River, Bronx River, Westchester Creek, Flushing Bay and Creek, and East Chester Creek; to the west, the Kill Van Kull, Arthur Kill, Newark Bay, Passaic River, and Hackensack River. The Inner Harbor is connected with the Outer Harbor by the Narrows, a natural channel having a width of about 3,500 feet and depths varying from 45 to 100 feet.

Upper Bay extends southerly from the junction of Hudson and East Rivers opposite the Battery, to the Narrows, a distance of about 5 1/2 miles. Anchorage Channel, a continuation of Ambrose Channel, extends northward from the Narrows to the mouth of the Hudson River at the Battery. Bay Ridge and Red Hook Channels lie along the east shore of the Upper Bay and together with Buttermilk Channel, which lies between Governors Island and the Brooklyn shore, form an easterly channel along the Brooklyn waterfront from the Narrows to deep water in the East River.

Hudson River Channel, which is contiguous to the Weehawken-Edgewater Channel, extends from deep water in the Upper Bay to about 1 mile south of the George Washington Bridge. The largest vessels entering the port of New York berth in the Hudson River; the channels are used also by vessels proceeding north to Albany, New York.

The East River is a tidal strait about 16 miles long and from 600 to 4,000 feet wide. It connects deep water at Governors Island in the Upper Bay with Long Island Sound at Throgs Neck, separating Long Island from the mainland.

Arthur Kill is a narrow body of water separating Staten Island, New York, from New Jersey. To the north it connects with the Kill Van Kull; to the south, with Raritan Bay. On the shores of the Arthur Kill are the cities of Perth Amboy, Carteret and Elizabeth, New Jersey, and Staten Island, New York. Kill Van Kull lies between Staten Island and Bayonne, New Jersey, and is the connecting link between the main harbor channel and Arthur Kill and Newark Bay.

Newark Bay is a tidal estuary about 1 mile wide and 6 miles long, situated west of Upper New York Bay. On the east side of the bay are Bayonne and Jersey City; on the west, Elizabeth and Newark. To the south it connects with the Kill Van Kull and Arthur Kill. The Hackensack and Passaic Rivers both flow south, joining Newark Bay at its northern extremity.

Delaware River Harbors

The Delaware Bay and Delaware River form the boundary between the State of New Jersey on the east and the States of Delaware and Pennsylvania on the west. The bay is an expansion of the lower part of the river, with the dividing line 42 nautical miles above the Delaware Capes. The entrance to the bay is about 10 nautical miles wide between Cape May and Cape Henlopen. The Chesapeake and Delaware Canal extends from the Delaware River at Reedy Point, Delaware, just below Delaware City, to the Elk River, an arm of the Chesapeake Bay, and provides an alternate approach for vessels to these Delaware River ports and a protected route between them and Baltimore, Maryland, and Chesapeake Bay ports.

The bay and river provide the principal artery for waterborne commerce for Trenton, Philadelphia, Camden, Gloucester City, Chester, Marcus Hook, Wilmington, and Delaware City. The head of navigation on the Delaware River is at the Pennsylvania Railroad bridge at Trenton, a distance of 116 nautical miles above the Delaware Capes.

The port of Philadelphia, Pennsylvania, is at the junction of the Delaware and Schuylkill Rivers, about 80 nautical miles above the Delaware Capes. The ports of Camden and Gloucester City, New Jersey, are directly opposite Philadelphia on the New Jersey bank of the Delaware River. The port of Philadelphia includes a 22-mile stretch of waterfront along the Pennsylvania bank of the Delaware River from Poquessing Creek at the upper city limits to the Hog Island wharf of the Gulf Oil Corporation, about 2.1 miles below the mouth of the Schuylkill River; and both banks of the Schuylkill River from its mouth to Spring Garden Street, near Fairmount Dam, a distance of 8.5 miles. The junction of the Chesapeake and Delaware Canal with the Delaware River is 29 nautical miles below the mouth of the Schuylkill

River. The dredged channel through the bay and river commences about 6.5 nautical miles inland from the capes.

The port of Wilmington is on the Christina River at the junction with the Delaware River, about 62 nautical miles above the Delaware Capes.

Hampton Roads Harbor

Hampton Roads Harbor is located at the confluence of three tidal rivers -- the James, the Nansemond, and the Elizabeth. It has an area of 25 square miles and forms the approach to the ports of Newport News, Norfolk, Portsmouth, and Chesapeake.

Ships entering Hampton Roads from the sea follow a course between the capes and across the lower end of Chesapeake Bay via Thimble Shoal Channel, crossing the South Tunnel at the entrance of the Chesapeake Bay into the deep waters of Hampton Roads.

Two deepwater channels extend through Hampton Roads. One channel, 18 miles long, extends southward into Norfolk, Portsmouth, and Chesapeake via the Elizabeth River and its southern branch. The other channel, 4.8 miles long, extends westward to Newport News and thence up the James River.

Baltimore Harbor

Baltimore Harbor is located on the lower Patapsco River near its junction with the west side of Upper Chesapeake Bay. It is 150 nautical miles north of the Chesapeake Capes, which form the entrance from the Atlantic Ocean to the bay.

The bay varies in width from 5 statute miles at Annapolis to 10 and 20 miles at the confluence with the Potomac and York Rivers, respectively. Its maximum depth varies from 35 feet at the confluence with the

York River to 70 to 120 feet between statute miles 58 and 151. Ships entering Baltimore Harbor through the bay follow a course between the capes via Cape Henry Channel and continue, crossing the North Tunnel at the entrance of the Chesapeake Bay, via York Spit and Rappahannock Shoal Channels to the deeper part of the bay.

Vessels also have access to the port from the ocean by way of the Chesapeake and Delaware Canal and the Delaware Bay, a distance of 113 nautical miles. The canal extends from the Delaware River at Reedy Point, Delaware, to Back River, Maryland, thence down Back River to Elk River and the Chesapeake Bay. The Patapsco River enters Chesapeake Bay between North Point and Bodkin Point, about 9.5 miles below Fort McHenry at Baltimore. The river is about 4.0 miles wide at its mouth, between North and Bodkin Points.

The port area of Baltimore includes the navigation part of the Patapsco River below Hanover Street; the Northwest and Middle Branches; Curtis Bay and its tributary, Curtis Creek; and parts of Colgate, Bear, and Jones Creeks. The Northwest Branch, known locally as the Inner Basin, extends about 3.0 miles in a northwesterly direction from Fort McHenry to its head at Calvert Street and varies in width from 1,200 to 3,000 feet. Middle Branch, also known locally as Spring Garden, extends about 1.5 miles in a northwesterly direction from Ferry Bar past Hanover Street to the foot of Eutaw Street, and varies in width from 1,000 to 4,000 feet. Curtis Bay is an estuary, about 2.0 miles long and 0.7 mile wide, that is situated on the southwest side of the Patapsco River, 6.0 miles above the river's mouth.

Important waterfront bulk handling and/or general cargo facilities are located along the Patapsco River at Sparrows and Hawkins Points, Dundalk, Lower Canton, and Port Covington; on the west side of Curtis Bay; and on the Northwest Branch at Lazaretto Point, Upper Canton, and Locust Point.

IV. PHYSICAL OBSTACLES TO CHANNEL ENLARGEMENT

Bridges and Tunnels

All relevant bridges and tunnels crossing the major channels have been listed in table 7.

Bedrock

Bedrock is encountered only in the New York and New Jersey channels. The elevation of the bedrock varies by location, but in the area between mile 24.0 and mile 35.5, rock occurs at the bottom of the channel.

Tides

Table 8 presents the mean tidal range at various major ports.

Table 7. Review of Relevant Bridges and Tunnels in Major North Atlantic Coast Ports

Name	Location	Bay, river or channel	Purpose	Kind	Clearance	
					Horizontal feet	Vertical[a/] feet
	(stat. m.)					
Verrazano Bridge......	13	Narrows, New York	Highway	Suspension	4,000	228
Outerbridge Crossing..	21	Arthur Kill, N.Y., N.J.	Highway	Fixed	635	143
Goethals Bridge.......	30	Arthur Kill, N.Y., N.J.	Highway	Fixed	588	137
Staten Island Rapid Transit Bridge.......	30	Arthur Kill, N.Y., N.J.	Railroad	Vert. lift	500	135
Bayonne Bridge........	34	Kill Van Kull, N.Y., N.J.	Highway	Fixed	1,640	150
Delaware Memorial Br..	70	Delaware River	Highway	Fixed	2,000	188
Walt Whitman Bridge...	98	Delaware River	Highway	Fixed	1,930	150
Benjamin Franklin Br..	101	Delaware River	Highway	Fixed	1,686	135
PCRR Bridge...........	105	Delaware River	Railroad	Vert. lift	500	135
Palmyra Bridge........	108	Delaware River	Highway	Bascule	240	--
Burlington Bridge.....	119	Delaware River	Highway	Vert. lift	500	134
Florence Bridge.......	122	Delaware River	Highway	Fixed	550	135
South Chesapeake Bay Tunnel...............	7	Chesapeake Bay, Thimble Shoal	Highway	--	1,000[b/]	57.5[b/]
North Chesapeake Bay Tunnel...............	7	Chesapeake Bay	Highway	--	1,400[b/]	62.5[b,c/]
Hampton Roads Tunnel..	18	Hampton Roads	Highway	--	3,310[b/]	62.5[b/]
W. Preston Lane Jr. Memorial Bridge......	151	Chesapeake Bay, Annapolis	Highway	Fixed	1,500	187

a/ Above mean high water.
b/ Approximate maximum channel dimensions; depth with respect to mean high water.
c/ This figure might be 2 or 2.5 feet smaller.

Table 8. Tidal Range Under Ordinary Conditions

Location	Mean range[a] (feet)
New York	
Sandy Hook.....................	4.6
Arthur Kill and Kill Van Kull..	4.5
Delaware River	
Philadelphia to Liston Point, Delaware.....................	5.5-6.0
Lewes, Delaware................	4.1
Hampton Roads	
Thimble Shoal..................	2.5
Sewells Point, Norfolk Harbor..	2.5
Baltimore	
Cape Henry.....................	2.8
Fort McHenry...................	1.2

a/ Difference between mean high water and mean low water.

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APPENDIX A. REVIEW OF STUDIES ON CHANNEL DEEPENING AND PORT EXPANSION

1. North Atlantic Regional Water Resources Study, prepared by the North Atlantic Regional Water Resources Study Group, North Atlantic Division, Corps of Engineers, U.S. Army, for the National Atlantic Regional Water Resources Study Coordinating Committee, February 1972. This study contains 22 volumes, of which the following are of particular relevance to the deepwater port study: Appendix B -- Economic Base; Appendix C -- Climate, Meteorology and Hydrology; Appendix D -- Geology and Ground Water; Appendix G -- Land Use and Management; Appendix K -- Navigation; Appendix L -- Water Quality and Pollution; Appendix M -- Recreation; Appendix O -- Fish and Wildlife; Appendix Q -- Sediment and Erosion; Appendix S -- Legal and Institutional Environment; Appendix T -- General Program and Alternatives; and Appendix U -- Coastal and Estuarine Areas.

2. Regional Harbor Analyses, memoranda to Division Engineer, North Atlantic Division. The district offices of New York, Philadelphia, Baltimore, and Norfolk were requested to calculate the cost of deepening their main channels to 60 feet. All costs presented should be considered very rough, indicating the order of magnitude only. The following data were presented:

a. New York. The district office prepared estimates on cost and time for dredging the Ambrose and the New York and New Jersey Channels to a depth of 60 feet. These data are presented in appendix tables 1 through 4. It should be noted that the cost of dredging a portion of the New York and New Jersey Channels (between miles 24.0 and 35.5) beyond 45 feet was so high that no cost estimates were prepared beyond that depth.

Appendix table 1. Dredging Cost and Time of Ambrose and Anchorage Channels
(In millions of dollars and years)

Dredging interval (feet)	Ambrose Channel			Anchorage Channel[a]		
	First cost	Annual maint. cost	Time to deepen	First cost	Annual maint. cost	Time to deepen
45-47............	8	0.43	2.2	1	0.14	0.3
45-49............	12	0.43	3.1	2	0.14	0.7
45-51............	15	0.43	3.9	3	0.14	0.9
45-53............	18	0.44	4.8	4	0.14	1.2
45-55............	22	0.44	5.7	6	0.14	1.5
45-57............	25	0.44	6.6	7	0.14	1.8
45-60............	30	0.44	7.9	8	0.15	2.2

a/ Between Upper New York Bay and Ambrose Channel.

Appendix table 2. Dredging Cost and Time of Sandy Hook and New York and New Jersey Channels (from 35' to 45')

(In millions of dollars and years)

Dredging interval (feet)	Sandy Hook Channel[a]			New York and New Jersey Channels[b]		
	First cost	Annual maint. cost	Time to deepen	First cost	Annual maint. cost	Time to deepen
35-37............	1	0.14	0.3	116	0.69	20
35-39............	1	0.14	0.3	160	0.72	27
35-41............	2	0.14	0.4	199	0.74	34
34-43............	2	0.14	0.5	227	0.76	39
35-45............	2	0.14	0.6	289	0.80	49

a/ From mile 0.0 to mile 7.0.
b/ From mile 7.0 to mile 37.8.

Appendix table 3. Dredging Cost and Time of Sandy Hook and New York and New Jersey Channels (from 35' to 60')

(In millions of dollars and years)

Dredging interval (feet)	Sandy Hook Channel[a]			New York and New Jersey Channels[b]		
	First cost	Annual maint. cost	Time to deepen	First cost	Annual maint. cost	Time to deepen
35-47..........	3	0.14	0.7	101	0.61	21
35-49..........	3	0.14	0.8	108	0.62	23
35-51..........	3	0.14	0.9	120	0.62	25
35-53..........	4	0.14	1.0	137	0.64	28
35-55..........	4	0.14	1.1	148	0.65	30
35-57..........	4	0.14	1.2	164	0.66	33
35-60..........	5	0.14	1.3	180	0.66	36

a/ From mile 0.0 to mile 7.0.
b/ From mile 7.0 to mile 24.0, and from mile 35.5 to mile 37.8.

Appendix table 4. Dredging Cost and Time of New York and New Jersey Channels
(In millions of dollars and years)

Dredging interval (feet)	Mile 7.0-mile 24.0			Mile 24.0-mile 35.5			Mile 35.5-mile 37.8		
	First cost	Annual maint. cost	Time to deepen	First cost	Annual maint. cost	Time to deepen	First cost	Annual maint. cost	Time to deepen
35-37........	31	0.57	8	71	0.11	10	13	0.01	2
35-39........	34	0.57	9	106	0.13	15	19	0.01	3
35-41........	37	0.57	10	135	0.15	20	26	0.02	4
35-43........	40	0.58	10	147	0.16	22	40	0.03	7
35-45........	43	0.58	11	198	0.19	30	48	0.03	8
35-47........	46	0.58	12				55	0.03	9
35-49........	49	0.58	13				59	0.04	10
35-51........	52	0.58	14				68	0.04	11
35-53........	55	0.59	14				82	0.05	14
35-55........	58	0.59	15				90	0.06	15
35-57........	61	0.59	16				103	0.07	17
35-60	66	0.59	17				114	0.07	19

The number of years required to deepen the channels to the projected depths is based on dredging with the Essayons. All costs are based on August 1966 levels.

b. Delaware Bay and River to Philadelphia. No separate study of costs to dredge to 60 feet was undertaken, since dredging to 45 feet was estimated at $386 million and dredging to 50 feet at $713 million.

c. Baltimore. The District Office prepared estimates of first cost and time for deepening of all channels leading to the port of Baltimore by 2-foot increments. It should be noted that for depths in excess of 49 feet, dredging in the Atlantic would be required. Appendix table 5 presents the estimated values of first cost and time. All costs allow for an overdepth of 2 feet. All channel widths would remain the same. It should be noted that for depths greater than 49 feet in the Curtis Bay Channel, relocation of the Harbor Tunnel would be required. The cost of the tunnel was $29 million when built in 1958.

d. Hampton Roads. The south tunnel of the Chesapeake Bay Bridge and Tunnel system will not allow dredging deeper than about 57 feet. Deepening the Thimble Shoal Channel to 55 feet was estimated at $80 to $100 million.

3. New York and New Jersey Channels: Information on Considered Plans of Improvement, Office of the District Engineer, U.S. Army Engineer District, New York, Corps of Engineers, New York, New York, February 17, 1972. The plans consider a one-way deep-draft channel and an offshore common petroleum unloading terminal connected with the existing terminals by pipelines.

The one-way deep-draft channel has varying channel dimensions for the various sections of the channel. The dimensions depend on the physical characteristics of the sections. The main restrictions of these dimensions are caused by the presence of rock, which at certain locations in the Arthur Kill is found at a depth of 30 feet or less, and by the presence of the river banks. The estimated first costs are presented in appendix table 6.

Appendix table 5. Dredging Cost and Time of Baltimore Channels
(In millions of dollars and years)

Baltimore channels	Dredging interval (feet)							
	42-45	42-47	42-49	42-51	42-53	42-55	42-57	42-60
Atlantic Ocean								
First cost..................	--	--	--	0.1	1.6	3.0	4.3	6.4
Time........................	--	--	--	0.1	0.4	0.8	1.0	1.5
Cape Henry								
First cost..................	0.8	1.3	1.8	2.7	3.9	5.1	6.8	9.2
Time........................	0.2	0.3	0.4	0.7	0.9	1.2	1.6	2.2
York Spit								
First cost..................	14.4	23.2	32.2	39.0	51.2	60.1	70.8	85.6
Time........................	3.4	5.4	7.6	9.2	12.1	14.3	16.7	20.0
Rappahannock Shoal								
First cost..................	2.4	3.8	5.3	6.8	8.3	10.0	12.2	15.3
Time........................	0.5	0.8	1.1	1.4	1.7	2.0	2.5	3.2
Main Ship								
First cost..................	18.5	26.0	33.4	41.4	50.0	59.0	68.4	82.6
Time........................	5.2	7.3	9.3	11.5	13.9	16.4	19.1	23.0
Curtis Bay								
First cost..................	1.0	1.5	1.9	2.4	2.9	3.3	3.8	4.4
Time........................	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.3
Middle Branch								
First cost..................	1.7	2.5	3.1	3.9	4.7	5.5	6.2	7.4
Time........................	0.5	0.7	0.8	1.1	1.3	1.5	1.8	2.1
Total								
First cost..................	38.8	58.3	77.7	96.3	122.6	146.0	172.5	210.9
Time........................	10.1	15.1	19.7	24.7	31.1	37.1	43.8	53.3

Appendix Table 6. First Costs of One-Way Deep-Draft Channel

Channel depth (feet)	First costs (mil. dol.)
38	11
40	16
42	21
45	28

For the offshore terminal, sites at or near Seguine Point, Hoffman Island, Gravesend Bay, Stapleton, Red Hook and Constable Hook have been considered. Four pipelines would be required to serve all New York/New Jersey terminals, one line for transporting crude oil, one for residual fuel, one for kerosene and high flash fuel, and the other for diesel and distillate fuel oils. Consideration was given to a dead-end system, as well as to a looped system, for delivery. The pipeline plans include a terminal for surge storage of products; however, no allowance was made for crude oil storage because direct pump-out via pipeline to the respective refineries is contemplated. A total of eight berths would be eventually required. The water depth at the terminal was set at 45 feet. The total first cost of this alternative was estimated at $180 million.

4. Feasibility Report: Delaware River, Philadelphia to the Sea, Offshore Terminal, Department of the Army, Philadelphia District, Corps of Engineers, Philadelphia, Pennsylvania, November 1969. This report considers nine plans of improvement. It studies the variation of depth of the river channel from 40 feet (present depth) to 45 and 50 feet. It also considers an offshore terminal off Big Stone Beach in either 62 or 72 feet of water.

The estimated first costs of the various plans of improvements are as follow:

a. $200 million for the offshore facility, including tank farms and pipelines to the present refineries. (This estimate was made by the Delaware Bay Transportation Company, representing the various oil companies.)

b. $17 million for dredging the 72-foot approach channel to the offshore facility located in an original water depth of 62 feet.

c. $386 million for dredging the river channel from Philadelphia to the sea from 40 to 45 feet.

d. $713 million for dredging the same channel from 40 to 50 feet.

The annual operating and maintenance cost was estimated at $800,000 for the mooring facility, $800,000 for pipelines and tank farm, $210,000 for the annual maintenance of the 72-foot channel to the offshore facility, and $500,000 and $600,000 for annual maintenance cost of the 45- and 50-foot channels, respectively.

5. Long-Range Spoil Disposal Study, U.S. Army Engineer District, Philadelphia, Corps of Engineers, North Atlantic Division, June 1968. This seven-volume study concludes that the availability of disposal areas between Philadelphia and the bay sited either at the banks of the Delaware River or on islands in the river have a total capacity of 110 million cubic yards. Taking into consideration the fact that the annual maintenance dredging of the present 40-foot channel requires a disposal area of 7 million cubic yards, it is apparent that after 1985 no disposal areas at the present locations will be available. The present disposal areas are normally within a range of 5 to 10 miles from the location of dredging. The shortage of sufficient and nearby disposal areas indicates that after 1985 the disposal has to be carried either to the Delaware Bay or to the Atlantic Ocean. This will result in a tremendous increase of transportation distance to approximately 50 miles in the case of disposal in Delaware Bay, or to 100 miles and over in the case of disposal in the Atlantic. The cost involved in this longer transport may easily result in an increase of the dredging costs from the present

$.40 per cubic yard to $1.50 in the case of disposal in the Delaware Bay or $2.50 and over in the case of disposal in the Atlantic. It is unnecessary to say that deeper dredging will augment the amount of annual maintenance dredging and will accelerate the consumption of available nearby disposal areas.

6. Review Report: Baltimore Harbor and Channels, Department of the Army, Baltimore District Corps of Engineers, Baltimore, Maryland, June 1969. This report considers dredging of the present 42-foot channels by 1-foot increments to a maximum of 50 feet. The estimated cost of deepening the Virginia channels (Rappahannock Shoal, York Spit and Cape Henry Channels) and Maryland channels (Main Shipping Channel, Curtis Bay Channel, and Northwest Branch and East Channel) is presented in appendix table 7. Deepening to 50 feet was recommended.

Appendix table 7. Estimated First Cost of Virginia and Maryland Channels to Baltimore Harbor

(In millions of dollars)

Channel	Channel depth (feet)							
	43	44	45	46	47	48	49	50
Federal cost								
Virginia Channels.............	13	17	21	26	31	36	41	47
York Spit....................	10	13	16	20	29	28	33	37
Rappahannock Shoal...........	2	2	3	4	4	5	5	6
Cape Henry...................	1	2	2	2	3	3	3	4
Maryland Channels.............	17	22	26	31	35	40	45	49
Main Shipping Channel........	15	20	23	28	31	36	39	43
Curtis Bay Channel...........	2	2	2	2	3	3	4	4
Northwest Branch, East Channel........................	0	0	1	1	1	1	2	2
Total Federal cost.............	30	39	47	57	66	76	86	96
Total Non-Federal cost.........	1	2	3	3	3	3	3	4
Total project cost.............	31	41	50	60	69	79	90	100

ANNEX B-2. RECONNAISSANCE SURVEY OF THE SOUTH ATLANTIC COAST

CONTENTS

I. DESCRIPTION OF COAST AND PORT LOCATIONS

The south Atlantic coastline from Cape Hatteras, North Carolina, to Key West, Florida, can be divided into the following six distinct areas (figures 1 and 2):

1. From Cape Hatteras, North Carolina, to Cape Romain, South Carolina

2. From Cape Romain, South Carolina, to Jacksonville, Florida

3. From Jacksonville, Florida, to Cape Kennedy, Florida

4. From Cape Kennedy, Florida, to Lake Worth Inlet, Florida

5. From Lake Worth Inlet, Florida, to Miami, Florida

6. From Miami, Florida, to Key West, Florida.

The coastline from Cape Hatteras to Cape Romain is 240 nautical miles long and is characterized by three arc-shaped bays of nearly equal length and depth, named Raleigh Bay, Onsolow Bay, and Long Bay. The depth contour lines are closest to the coastline near Cape Hatteras (approximately 2, 9, and 19 miles respectively for the 60-, 90-, and 120-foot lines) (figure 3). Moving southward, the contour line distances from the coast increase sharply until a point just south of Wilmington, North Carolina, where they reach a maximum of approximately 22, 37, and 55 miles, respectively. From that point to Cape Romain, they decrease to within a range of approximately 12 to 47 miles.

60.

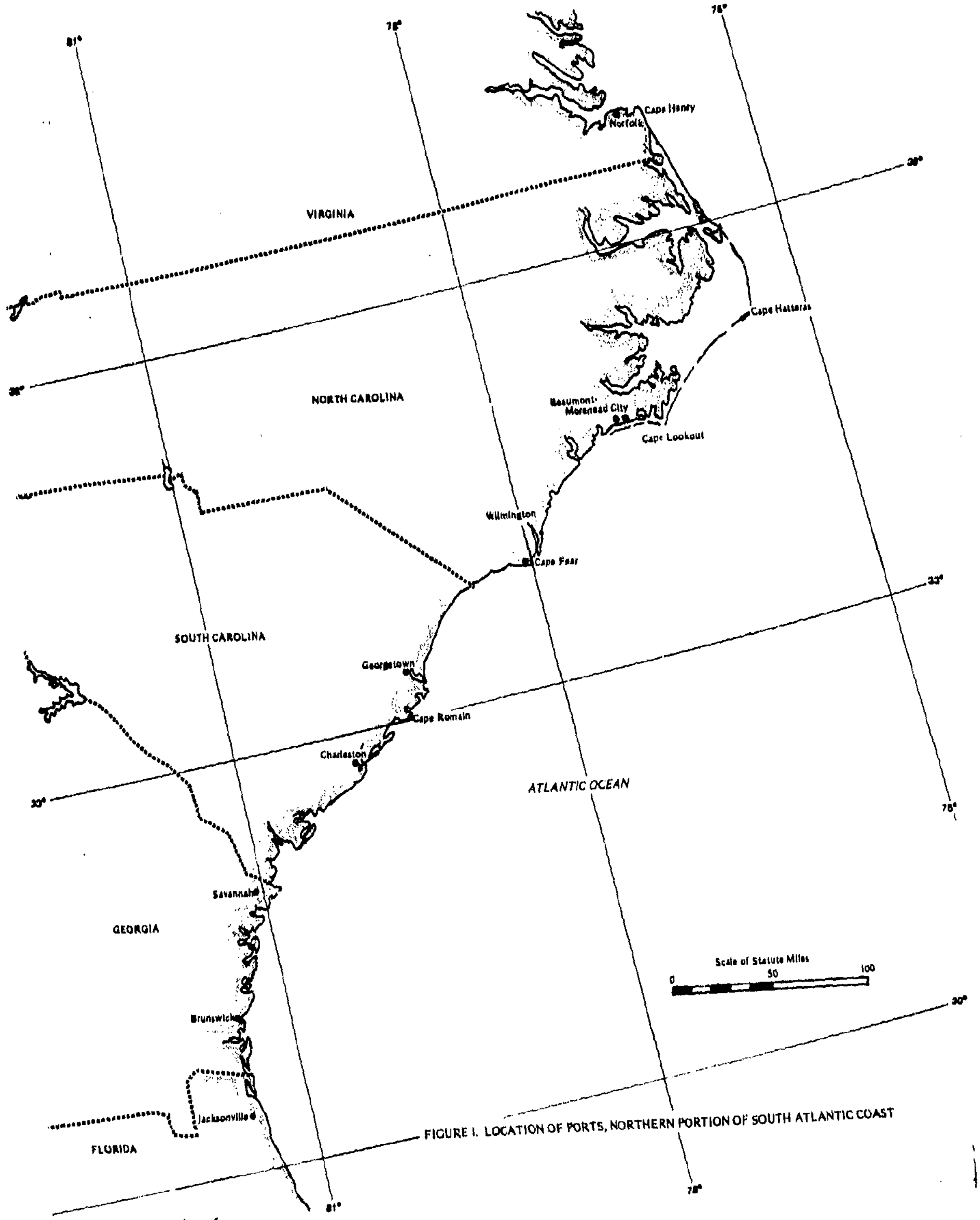

FIGURE I. LOCATION OF PORTS, NORTHERN PORTION OF SOUTH ATLANTIC COAST

Robert R. Nathan Associates, Inc.

FIGURE 2. LOCATION OF PORTS, SOUTHERN SOUTH ATLANTIC COAST

Robert R. Nathan Associates, Inc.

62.

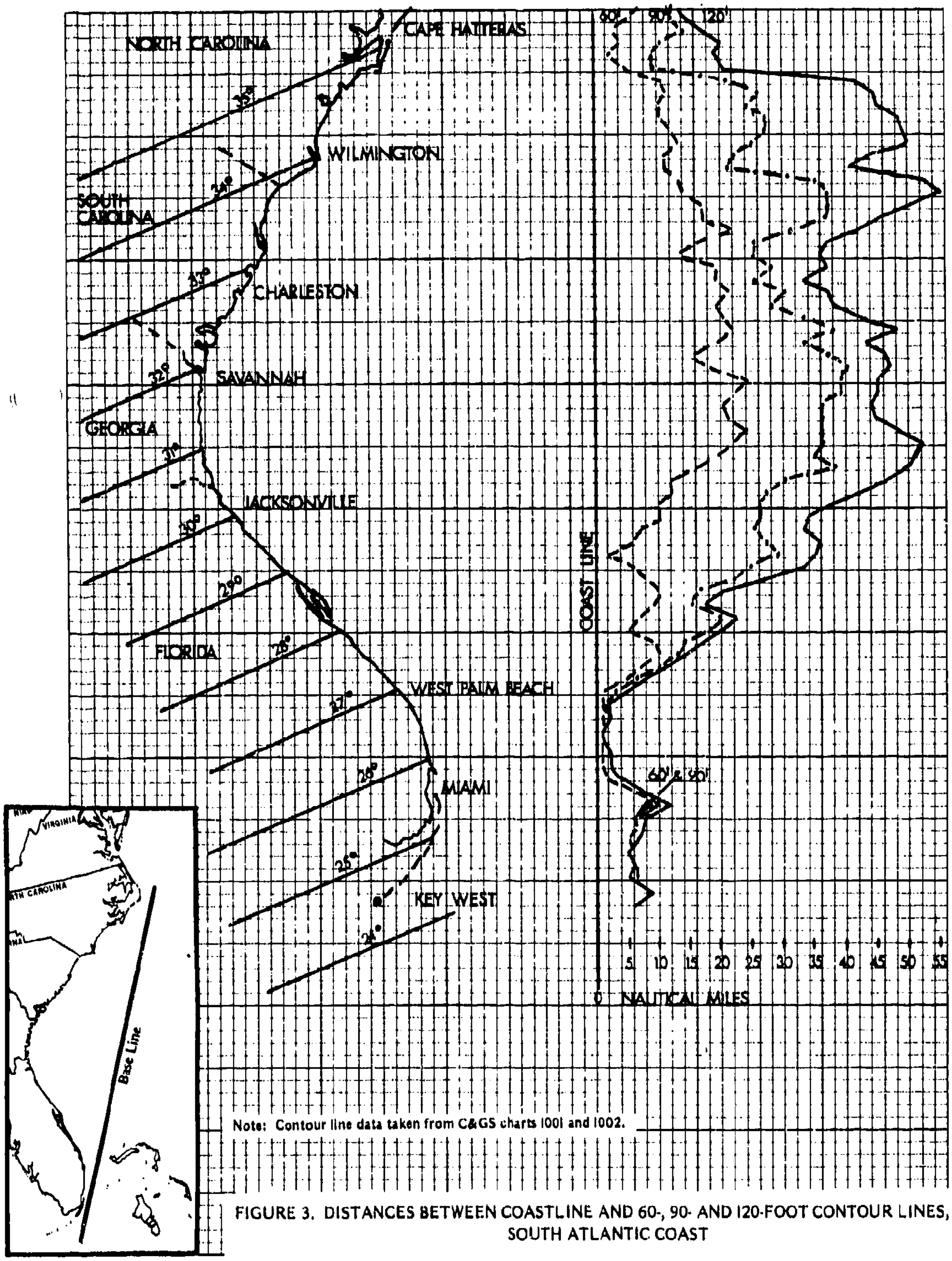

FIGURE 3. DISTANCES BETWEEN COASTLINE AND 60-, 90- AND 120-FOOT CONTOUR LINES, SOUTH ATLANTIC COAST

The coastline from Cape Romain to Jacksonville is 200 nautical miles long and is characterized by numerous islands and sounds.

There is a tendency for the contour lines to increase their distance from the coastline until they reach a point just north of Jacksonville where the distances are roughly the same as they are at Cape Romain.

The coastline from Jacksonville to Cape Kennedy is 125 nautical miles long, and has no offshore islands. From Jacksonville to a point just north of Cape Kennedy the 60-foot depth line moves continuously closer to shore, reaching a distance of approximately 2 miles at one point, and then increasing to approximately 10 miles opposite Cape Kennedy. The 90-foot and 120-foot contour lines decrease their distance to shore in a ragged but continuous pattern, and at Cape Kennedy are both less than 20 miles from the coastline.

The coastline between Cape Kennedy and Lake Worth Inlet is about 100 nautical miles long. It is similar in nature to the area around Cape Kennedy in that there is a lagoon along almost its entire length. From Cape Kennedy to Lake Worth Inlet, all contour lines move sharply closer to shore, reaching a distance of 1 nautical mile or less. From Lake Worth Inlet to Miami, a distance of approximately 60 nautical miles, the contour lines continue to stay very close to shore. The steep decline of the ocean bottom in this area is depicted graphically in figure 4, showing the longitudinal cross section of Port Everglades Channel, located just north of Miami.

The coastline from Miami to Key West is about 130 nautical miles long and is distinguished by its numerous islands, known as the Florida Keys. The depth contour lines move out to over 10 miles and then decline to approximately 5 miles along the keys. To the east and south are the Straits of Florida, running in a west-to-east direction at Key West and in a south-to-north direction at Miami. To the east at a distance of approximately 120 miles is Andros Island, one of the Bahama Islands, and to the south is Cuba, at a distance of

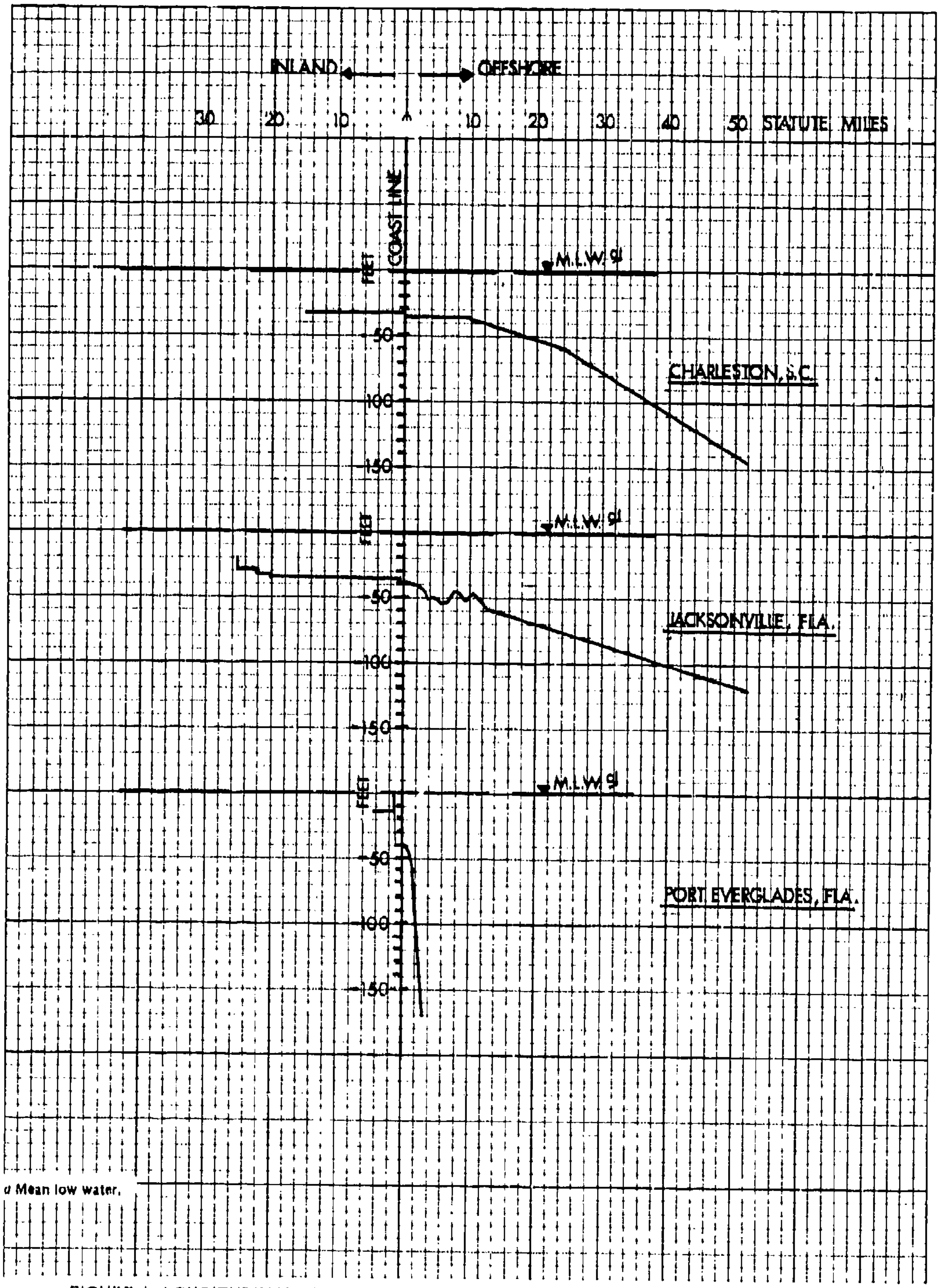

FIGURE 4. LONGITUDINAL CROSS SECTIONS OF MAJOR SOUTH ATLANTIC COAST CHANNELS

Robert R. Nathan Associates, Inc.

approximately 80 miles. Between Cuba and Andros Island, at a distance of approximately 60 to 80 miles from the Florida Keys, is a shoal called Caysal Bank. The part of the Gulf of Mexico between the Florida Keys and the Florida Peninsula is very shallow, less than 60 feet.

From the point of view of relative proximity or ease of access to natural deep water, Port Everglades and the Miami area are most favorably situated, with Jacksonville ranking next, but with much greater limitations. The rest of the south Atlantic coast does not appear to be favorably situated. This is graphically demonstrated in figure 4, which shows longitudinal cross sections of ocean channels for Charleston, Jacksonville, and Port Everglades.

II. FOREIGN AND COASTAL MOVEMENTS, BY PORT, OF THE SIX STUDY COMMODITIES

The movement of bulk commodities at south Atlantic ports is dominated by receipts of petroleum products from both foreign and domestic sources (tables 1 and 2). Foreign imports consist principally of residual fuel oil; domestic receipts are principally motor fuel. Both foreign imports and domestic receipts are scattered among most of the ports on the south Atlantic, but the greatest concentration is in the ports of Charleston, South Carolina, and Jacksonville and Port Everglades, Florida.

In 1969, foreign imports of petroleum products equaled 9.4 million tons, of which 2.2 million tons went to Carolina ports, 0.8 million tons to Savannah, and most of the balance to Jacksonville and Port Everglades (2.7 and 1.7 million tons, respectively). Domestic waterborne receipts of petroleum products in 1970 were 14.2 million tons, of which 4.1 million tons went to Carolina ports, 3.2 million tons to Jacksonville, and 5.3 million tons to Port Everglades.

Because there is only one petroleum refinery[1/] in the entire Atlantic coastal area ranging from North Carolina through Florida, the receipts of crude petroleum are minimal, as are related port requirements. There are no known plans for the development of additional refinery capacity, but it would be reasonable to

1/ It is located at Savannah and has a capacity of 6,900 barrels per day.

Table 1. U.S. Waterborne Exports and General Imports of Selected Bulk Commodities, South Atlantic Coast, 1968 and 1969
(In thousands of short tons)

Port/area	Total all study comm.		Exports								Imports											
			Total grains[a/]		Coal		Phosphate rock		Total		Crude oil		Petroleum products[b/]		Iron ore		Bauxite		Alumina		Total	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Carolinas																						
Beaufort-Morehead City, N.C.	140	362	—	—	—	—	69	258	69	258	53	17	18	87	—	—	—	—	—	—	71	104
Wilmington, N.C.	506	662	—	c/	—	—	3	—	3	c/	—	—	502	662	—	—	—	—	—	—	502	662
Georgetown, S.C.	340	382	—	—	—	—	—	—	—	—	—	—	340	381	—	—	—	—	—	—	340	381
Charleston, S.C.	1,278	1,286	306	180	—	—	c/	—	306	180	—	—	947	1,087	—	—	25	19	—	—	972	1,106
Total	2,264	2,692	306	180	—	—	72	258	378	438	53	17	1,807	2,217	—	—	25	19	—	—	1,885	2,253
Georgia and Florida																						
Savannah, Ga.	680	882	5	6	c/	—	—	—	5	6	7	45	644	797	—	—	24	33	—	—	675	875
Brunswick, Ga.	3	c/	—	c/	—	—	—	—	—	c/	—	—	3	—	—	—	—	—	—	—	3	—
Jacksonville, Fla.	2,713	3,504	10	7	—	—	907	811	917	818	7	—	1,789	2,687	—	—	—	—	—	—	1,796	2,687
Port Canaveral, Fla.	367	658	—	—	—	—	—	4	—	4	—	—	367	654	—	—	—	—	—	—	367	654
Fort Pierce, Fla.	—	c/	—	c/	—	—	—	—	—	c/	—	—	—	—	—	—	—	—	—	—	—	—
West Palm Beach, Fla.	610	477	2	3	—	—	c/	—	2	3	—	—	608	474	—	—	—	—	—	—	608	474
Port Everglades, Fla.	1,700	1,744	—	2	—	—	—	—	—	2	5	—	1,696	1,742	—	—	—	—	—	—	1,701	1,742
Miami, Fla.	[illegible]	823	2	2	—	—	c/	c/	2	2	19	27	942	794	—	—	—	—	—	—	961	821
Total	7,037	8,088	19	20	c/	—	997	815	926	835	38	72	6,049	7,148	—	—	24	33	—	—	6,111	7,253
Total south Atlantic coast	9,301	10,780	325	200	c/	—	979	1,073	1,304	1,273	91	89	7,856	9,365	—	—	49	52	—	—	7,996	9,586

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Note: Individual items may not add to totals due to rounding.
a/ Includes food grains (wheat, rice, rye), feed grains (barley, corn, oats, cereals, n.e.c.), and soybeans and mill products.
b/ Includes gasoline, jet fuel and kerosene, distillate fuel oils, and residual fuel oils.
c/ Less than 500 short tons.

Source: U.S. Department of Commerce, Bureau of the Census, U.S. Waterborne Exports of Domestic and Foreign Merchandise, SA-705, and U.S. Waterborne General Imports of Merchandise, SA-305, 1968 and 1969.

Table 2. U.S. Domestic Waterborne Coastal Receipts and Shipments of Selected Bulk Commodities, South Atlantic Coast, 1969 and 1970

(In thousands of short tons)

Port/area	Total all study comm.				Crude oil				Petroleum[a/] products				Dry bulk commodities[b/]					
	1969		1970		1969		1970		1969		1970		1969			1970		
	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Commodity	Rect.	Shipt.	Commodity
Carolinas																		
Morehead City Harbor, N.C. ...	240	--	146	--	--	--	--	--	240	--	146	--	--	--	--	--	--	--
Port of Wilmington, N.C.	1,453	--	1,772	12	36	--	--	--	1,417	--	1,772	12	--	--	--	--	--	--
Georgetown Harbor, S.C.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Charleston Harbor, S.C.[c/] ...	1,911	44	2,150	39	--	--	--	--	1,911	27	2,150	39	d/	17	Grains[e/]	--	d/	Grains[e/]
Total	3,604	44	4,068	51	36	--	--	--	3,568	27	4,068	51	d/	17		--	d/	--
Georgia and Florida																		
Savannah Harbor, Ga.	1,274	68	1,359	80	165	--	78	--	1,109	68	1,281	80	--	--	--	--	--	--
Brunswick Harbor, Ga.	58	--	--	--	--	--	--	--	58	--	--	--	--	--	--	--	--	--
Fernandina Harbor, Fla.	--	--	--	--	--	--	--	--	--	--	-	--	--	--	--	--	--	--
													2	1	Grains[e/]	3	2	Grains[e/]
Jacksonville Harbor, Fla. ...	3,191	112	3,240	190	--	--	27	--	3,189	23	3,210	51	--	88	Phos. rock	--	137	Phos. rock
Canaveral Harbor, Fla.	182	--	223	--	--	--	--	--	182	--	223	--	--	--	--	--	--	--
Palm Beach Harbor, Fla.	--	--	15	d/	--	--	--	--	--	--	15	d/	--	--	--	--	--	--
Port Everglades Harbor, Fla.	5,375	347	5,386	597	--	280	55	502	5,375	67	5,331	95	--	--	--	--	d/	Grains[e/]
Miami Harbor, Fla.	105	19	64	1	--	--	--	--	105	19	64	1	--	--	--	--	d/	Grains[e/]
Total	10,815	546	10,287	868	165	280	160	502	10,018	177	10,124	227	2	89	--	3	139	--
Total south Atlantic coast.	13,789	590	14,355	919	201	280	160	502	13,586	204	14,192	278	2	106		3	139	

a/ Includes 2911, gasoline; 2912, jet fuel; 2913, kerosene; 2914, distillate fuel oil; 2915, residual fuel oil.
b/ Includes grains; 1011, iron ore and concentrates; 1051, bauxite and other aluminum ores and concentrates; 1121, coal and lignite; and 1471, phosphate rock.
c/ Consolidated report.
d/ Less than 500 short tons.
e/ Includes 0102, barley and rye; 0103, corn; 0104, oats; 0105, rice; 0106, sorghum grains; 0107, wheat; 0111, soybeans; and 2049, grain mill products, n.e.c.

Source: U.S. Department of the Army, Corps of Engineers, Waterborne Commerce of the United States, Part I, "Waterways and Harbors, Atlantic Coast," 1969 and 1970.

assume that, to the extent that such capacity were constructed, it would be designed to meet essentially local and regional markets, and insofar as waterborne commerce is concerned, would chiefly result in the substitution of crude petroleum receipts for petroleum product receipts.

At the present time, a substantial share of the consumption of motor fuels and light fuel oils in the south Atlantic region is supplied by the Plantation and Colonial Pipeline Companies, which move these products from the Texas and Louisiana area to Southeastern and Middle and North Atlantic States (see Annex A-2).

The only dry bulk commodity of any significance moving at south Atlantic ports is phosphate rock, which is exported through Beaufort-Morehead City, North Carolina, and from Jacksonville. However, as stated in Annex A-VII, exports of phosphate rock from these ports are not expected to grow significantly from recent levels, which in 1969 were 258,000 tons from Beaufort-Morehead and 811,000 from Jacksonville.

More recently, a new steel mill has been constructed near Georgetown, South Carolina, and is bringing in foreign iron ore in quantities below a million tons. It is not expected that there will be any significant growth in the size of that operation in the foreseeable future.

Although the volume of petroleum receipts in the four-state area from both domestic and foreign sources can be expected to grow over time, as long as such receipts are limited to local and regional requirements they are not expected to move in vessels requiring deep-draft channel and harbor facilities. This would likewise appear to be true of dry bulk commodities. This judgment is confirmed by the American Association of Port Authorities Committee on Ship Channels and Harbors report of June 1970. This report, the result of a study in which all of the major south Atlantic ports participated, concluded that there was no need for a Federal regional survey to determine the need for and location of a very deep water channel (i.e., in excess of 55 feet) to serve the south Atlantic region. It was reported that all of the ports felt their needs could be met by channel depths in the 45-foot range for all foreseeable vessels.[1]

1/ Ship Channel Capabilities for Merchant Vessels in United States Deepwater Seaports through the Year 2000, South Atlantic and Caribbean, The American Association of Port Authorities, Washington, D.C., June 1970.

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III. MAJOR HARBORS AND CHANNELS

A list of south Atlantic ports and their project depths is given in table 3. Depths in the principal ports range from 35 to 38 feet. Dredging to the authorized depth of 38 feet at Jacksonville Harbor, Florida, from the present 34-foot depth is underway. In addition, a survey review report recommends an entrance channel of 42 feet and a harbor channel of 40 feet at the port of Morehead City, North Carolina.1/

Table 4 gives detailed channel dimensions for the ports of Charleston, Jacksonville, and Port Everglades. Figures 5, 6, and 7 show the locational characteristics of channels and bulk handling facilities in Charleston, Jacksonville and Port Everglades. Port Everglades has the greatest natural advantage for deep port development.

1/ U.S. Army Corps of Engineers, Pamlico River and Morehead City Harbor, Review Report, U.S. Army Engineer District, Wilmington, Corps of Engineers, Wilmington, North Carolina, April 1970.

Table 3. South Atlantic Coast Ports and Project Depths

(In feet)

Harbor project	Project depth
Morehead City Harbor, N.C..........	35
Wilmington Harbor, N.C.............	38
Georgetown Harbor, S.C.............	27
Charleston Harbor, S.C.............	35
Port Royal Harbor, S.C.............	24
Savannah Harbor, Ga................	38
Brunswick Harbor, Ga...............	30
Fernandina Harbor, Fla.............	28
Jacksonville Harbor, Fla...........	38
Canaveral Harbor, Fla..............	37
Fort Pierce Harbor, Fla............	27
Palm Beach Harbor, Fla.............	35
Port Everglades Harbor, Fla........	37
Miami Harbor, Fla..................	38
Key West Harbor, Fla...............	30

Source: Regional Review of Deep-Draft Harbors on the South Atlantic Coast, Board of Engineers for Rivers and Harbors, May 1970.

Table 4. Project Dimensions of Major Channels

Name of channel	Depth	Width	Length		Location[a]
	Feet		Naut. miles	Stat. miles	Stat. miles
Charleston, S.C.					
Fort Sumter Range..........	35	1000[b]	9.0	10.4	(11.3)-(0.9)
Mt. Pleasant Range.........	35	1000[c]-600	1.6	1.8	(0.9)- 0.9
Cooper River Channel.......	35	600-400	11.3	13.0	0.9 -13.9
Jacksonville, Fla.					
Bar Channel................	42[d]	800	2.4	2.8	(2.8)- 0.0
St. John River Channel[e]...	38	400[f]	17.4	20.0	0.0 -20.0
Terminal Channel[g].........	34	600	1.7	2.0	20.0 -22.0
South Jacksonville Channel[h].....................	30	varies	2.5	2.9	22.0 -24.9
Port Everglades, Fla.					
Entrance Channel...........	40	500-300	0.43	0.50	(0.5)- 0.0
Approach Channel...........	37	300	0.46	0.54	0.0 - 0.54
Turning Basin..............	37	1200	0.40	0.46	0.54 - 1.0
North extension of Turning Basin.....................	31	800-500	0.20	0.23	1.1 - 1.3
South extension of Turning Basin.....................	31	1200	0.20	0.23	1.1 - 1.3

a/ Figures in parentheses indicate offshore locations.
b/ Maintained to a width of 800 feet.
c/ Maintained to a width of 800-600 feet.
d/ Locally to 40 feet.
e/ Via Dame Point-Fulton Cutoff.
f/ Locally wider up to 1,200 feet.
g/ To Commodore Point.
h/ To Florida East Coast Railroad Bridge.

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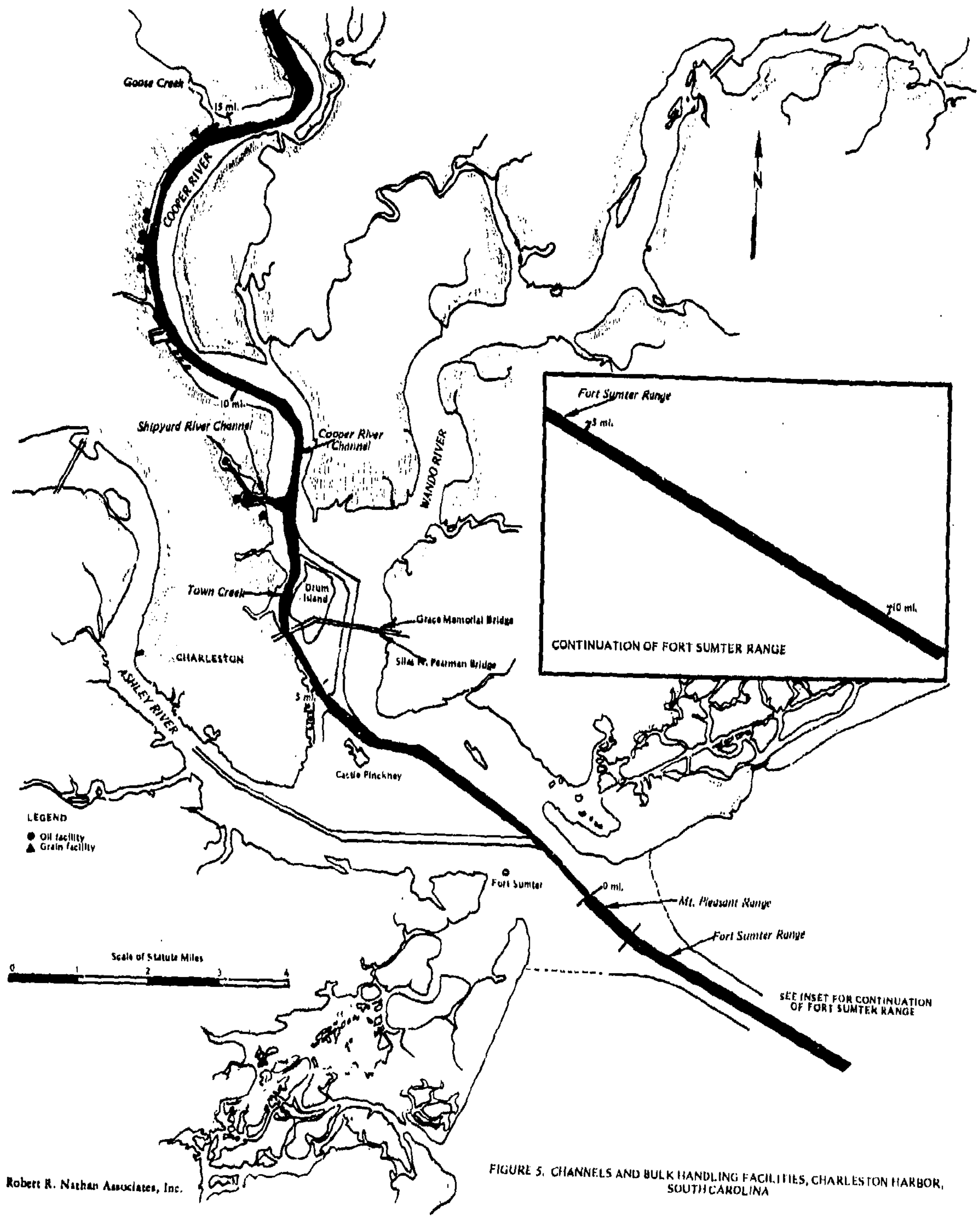

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FIGURE 5. CHANNELS AND BULK HANDLING FACILITIES, CHARLESTON HARBOR, SOUTH CAROLINA

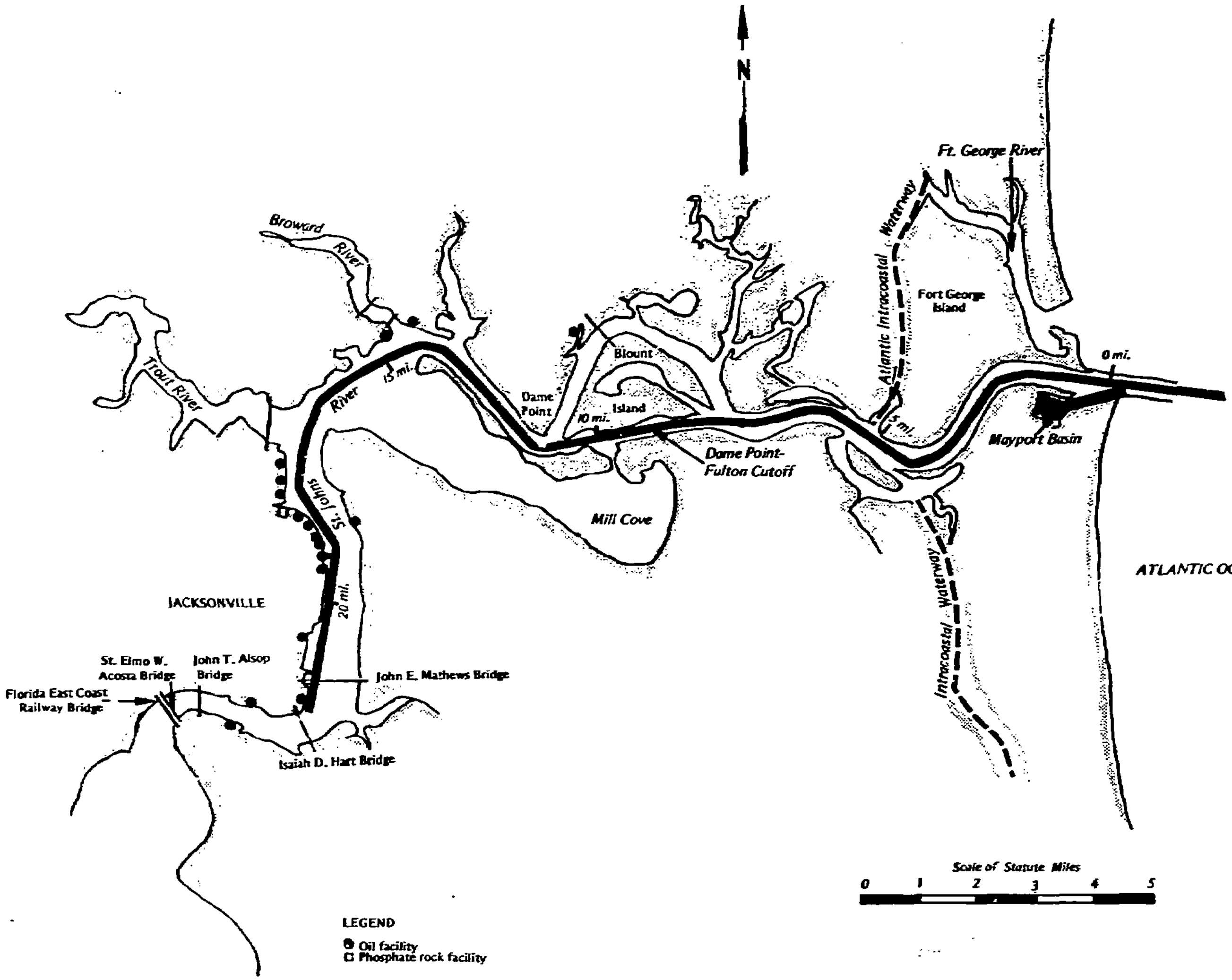

FIGURE 6. CHANNELS AND BULK HANDLING FACILITIES, JACKSONVILLE HARBOR, FLORIDA

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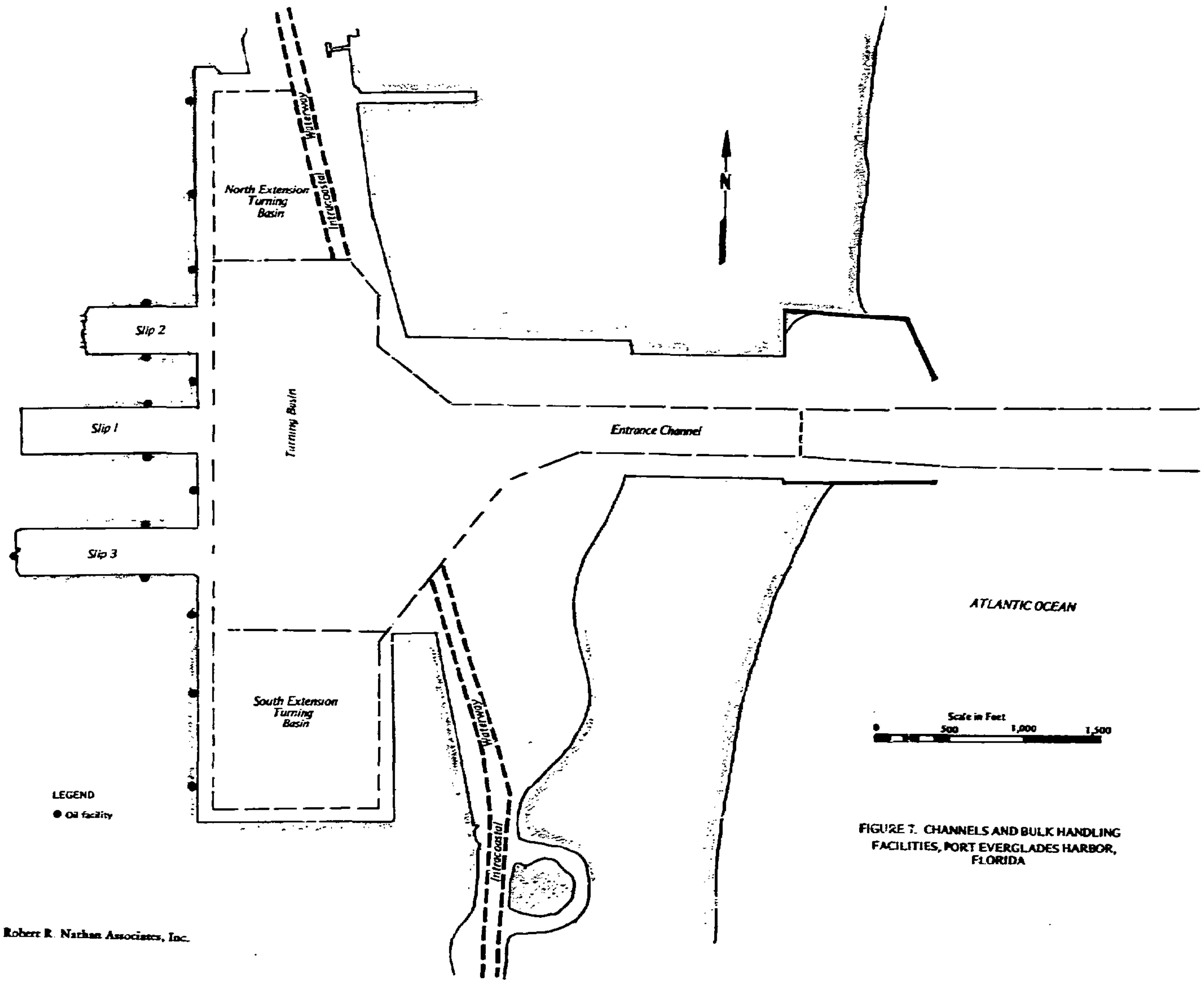

FIGURE 7. CHANNELS AND BULK HANDLING FACILITIES, PORT EVERGLADES HARBOR, FLORIDA

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IV. PHYSICAL OBSTACLES TO CHANNEL ENLARGEMENT

Bridges and Tunnels

Information on bridges and tunnels crossing the main ship channels of Charleston, South Carolina, and Jacksonville, Florida, is provided in table 5. It shows that no bridges or tunnels cross Jacksonville's main channel below mile 21.4; however, a tunnel crossing is under consideration. No bridges or tunnels cross the 1-mile-long channel of Port Everglades.

Information on the existence of rock is available only for the channel of Jacksonville. The information is provided in the Survey-Review Report on Jacksonville Harbor, Florida (1964), based on borings up to a depth of 50 feet. Upstream from mile 4 on various stretches the top of the rock formation is located between about 37 and 45 feet, but at some locations it is at depths of 50 feet and over. The hardness of the rock varies from place to place and is described in the boring logs presented in the Survey-Review Report on Jacksonville Harbor.

Tides

Table 6 presents the mean tidal range of the three main ports.

Strong northeasterly winds raise water levels about 2 feet at Mayport and Jacksonville. Strong southwesterly winds lower water about 1.5 feet at Mayport and 1.1 feet at Jacksonville.

Table 5. Table of Relevant Bridges in South Atlantic Coast Ports

Name	Location	Bay, strait or channel	Purpose	Kind	Clearance	
					Horizontal	Vertical
	(stat. m.)				------- feet	----
Charleston, S.C.						
Silas N. Pearman Bridge...............	6	Town Creek and Cooper River	Highway	Fixed, high-level	1,000	150
Grace Memorial Bridge.	6	Town Creek and Cooper River	Highway	Fixed, high-level	1,000	150
Jacksonville, Fla.						
John E. Mathews Bridge...............	21.4	St. Johns River	Highway	Fixed, high-level		
Terminal Channel.....					705	152
Arlington Channel....					376	86 a/
Isaiah D. Hart Bridge.	22.0	St. Johns River	Highway	Fixed, high-level	960	135 b/
John T. Alsop Bridge..	24.7	St. Johns River	Highway	Vertical lift	350	40 c,d/
St. Elmo W. Acosta Bridge...............	24.86	St. Johns River	Highway	Vertical lift	174	50 c,e/
Florida East Coast Railway Bridge.......	24.9	St. Johns River	Railroad	Bascule	195	5 c/
Seaboard Coast Line Railroad Bridge......	0.1	Trout River	Railroad	Swing	55 f/	1 c/

a/ At center.
b/ 141 feet at center.
c/ Closed position.
d/ 135 feet raised position.
e/ 164 feet raised position.
f/ Left and right openings.

Table 6. Tidal Range Under Ordinary Conditions
(In feet)

Location	Mean range[a]
Charleston, South Carolina..........	5.2
<u>Jacksonville, Florida</u>	
On the bar..........................	5.3
Mayport (mile 3.8)..................	4.5
Fulton (mile 8.3)...................	3.4
Dame Point (mile 11.5)..............	3.0
Jacksonville (mile 19.3)............	2.0
Jacksonville (mile 24.9)............	1.3
<u>Port Everglades, Florida</u>	
At the entrance.....................	2.5
At the terminals....................	2.3

a/ Difference between mean high water and mean low water.

Currents

Tidal currents are strong in St. John's River as far upstream as Jacksonville. Velocities in the channel at the strength of the current are about 2.9 knots near the mouth and about 2.3 knots at Jacksonville. Strong southeasterly winds increase the velocity of the ebbtide and decrease or may interrupt the flood. Crosscurrents of concern to navigators of deep-draft ships occur at three principal points along the main channel below Jacksonville. One is at the downstream end of Dame Point-Fulton Cutoff (mile 7) at its intersection with the old channel around Blount Island, almost opposite St. Johns Bluff. Another is opposite the mouth of Sisters Creek (mile 5) where the Intracoastal Waterway enters the river, and the third is off the end of the north jetty at the river mouth. Difficulty is experienced at the first two points by ships proceeding upstream during strong ebbtides. The strong southerly set of the ebb at those points, first across the bow and then the stern of a ship, makes it difficult to maintain steerageway into the succeeding cut. At the third point, northerly winds cause a strong southerly set on the floodtide.

APPENDIX A. REVIEW OF STUDIES ON CHANNEL DEEPENING AND PORT EXPANSION

1. Port Everglades, Florida Study. A report is in progress studying the deepening of the 37-foot channel at Port Everglades, Florida, to 43 feet. The findings will be available within a few months.

2. Survey-Review Report on Jacksonville Harbor, Florida. U.S. Army Engineer District, Jacksonville, Corps of Engineers, Jacksonville, Florida, 1964. This report studies further dredging of the 34-foot channel to 37 and 38 feet. It deals only with the import of petroleum products because the phosphate rock facility was neither under construction nor in operation at that time. It recommends deepening of the channel up to 38 feet from the ocean to mile 24, as well as widening of various banks of the river channel. The deepening to 38-feet has been authorized to mile 20.0, and deepening of the first 10 miles of dredging is underway.

For further dredging the availability of sufficient disposal areas might become a problem. At this moment the spoil is disposed of parallel to the channel.

The first-cost estimate for dredging from 34 to 38 feet is $8.5 million (Federal) and $326,000 (non-Federal), totaling $8.8 million.

Estimated annual maintenance cost of the 38-foot channel is $57,000 (Federal) and $14,000 (non-Federal), totaling $71,000.

3. <u>Review Report on Pamlico River and Morehead City Harbor, North Carolina.</u> U.S. Army Engineer District, Wilmington, Corps of Engineers, Wilmington, North Carolina, April 24, 1970. The syllabus of this report reads as follows:

> Local interests have requested an investigation of the deepening of Morehead City Harbor, North Carolina, or providing a ship channel in Pamlico River through Pamlico Sound to the Atlantic Ocean through an appropriate inlet for the transportation of commodities in large bulk-carrier ocean vessels.
>
> The District Engineer has studied the feasibility of providing for the improvements desired by local interests. He finds that average annual charges for deepening Morehead City Harbor, including increased annual maintenance costs of $504,000 for the United States, are $646,000; benefits are $1,477,000; and the ratio of benefits to costs is 2.3. He further finds that construction of any ship channel between Pamlico River and the Atlantic Ocean is not economically feasible at this time.
>
> The District Engineer recommends that the existing Morehead City Harbor project be modified to provide for a depth of 40 feet in the east leg of the turning basin through a channel, 400 feet wide, to a cutoff channel, 600 feet wide, and a channel, 42 feet deep and 450 feet wide, through the ocean bar at Beaufort Inlet to deep water in the Atlantic Ocean; ... at an estimated first cost of $2,642,000 to the United States for new work, with an estimated $504,000 for annual maintenance in addition to that now required; subject to certain conditions of local cooperation.

ANNEX B-3. RECONNAISSANCE SURVEY OF THE GULF COAST

CONTENTS

I. DESCRIPTION OF COAST AND PORT FACILITIES

Figures 1, 2, and 3 show the shoreline configuration and port locations for the eastern, central, and western sections of the gulf coast area. They also indicate the principal port and harbor areas for which detailed channel and other relevant port data are presented. These areas are (1) Tampa-St. Petersburg; (2) Mobile; (3) Mississippi River ports; (4) Port Arthur and Beaumont; (5) Houston, Galveston, Texas City, Baytown, and Freeport; (6) Port Lavaca; (7) Corpus Christi; and (8) Brownsville.

Figure 4 presents longitudinal cross sections for eight major gulf channels from the major facilities to a depth of 120 feet. Figures 5 and 6 show similar information for the eastern gulf coast and the central and western gulf coasts, respectively, in the form of distance and depth contour lines at 60-, 90-, and 120-foot depths. Of primary significance in terms of relative natural advantages and disadvantages for deepwater port development is the substantial variation in distance to deep water in the different coastal areas. Along the Florida coast, for example, the distance to the 60-foot line varies from approximately 40 miles in southern Florida to 15 miles at Tampa and to less than 5 miles at Panama City and Pensacola. At Mobile and Gulfport the distance is between 5 and 10 miles, and just south of the Mississippi River Delta it is less than 5 miles.

From that point there is a sharp increase in the distances to deep water along the Texas coast to a maximum at Beaumont-Port Arthur of 35 miles to the 60-foot depth and 80 miles to the 120-foot depth. From

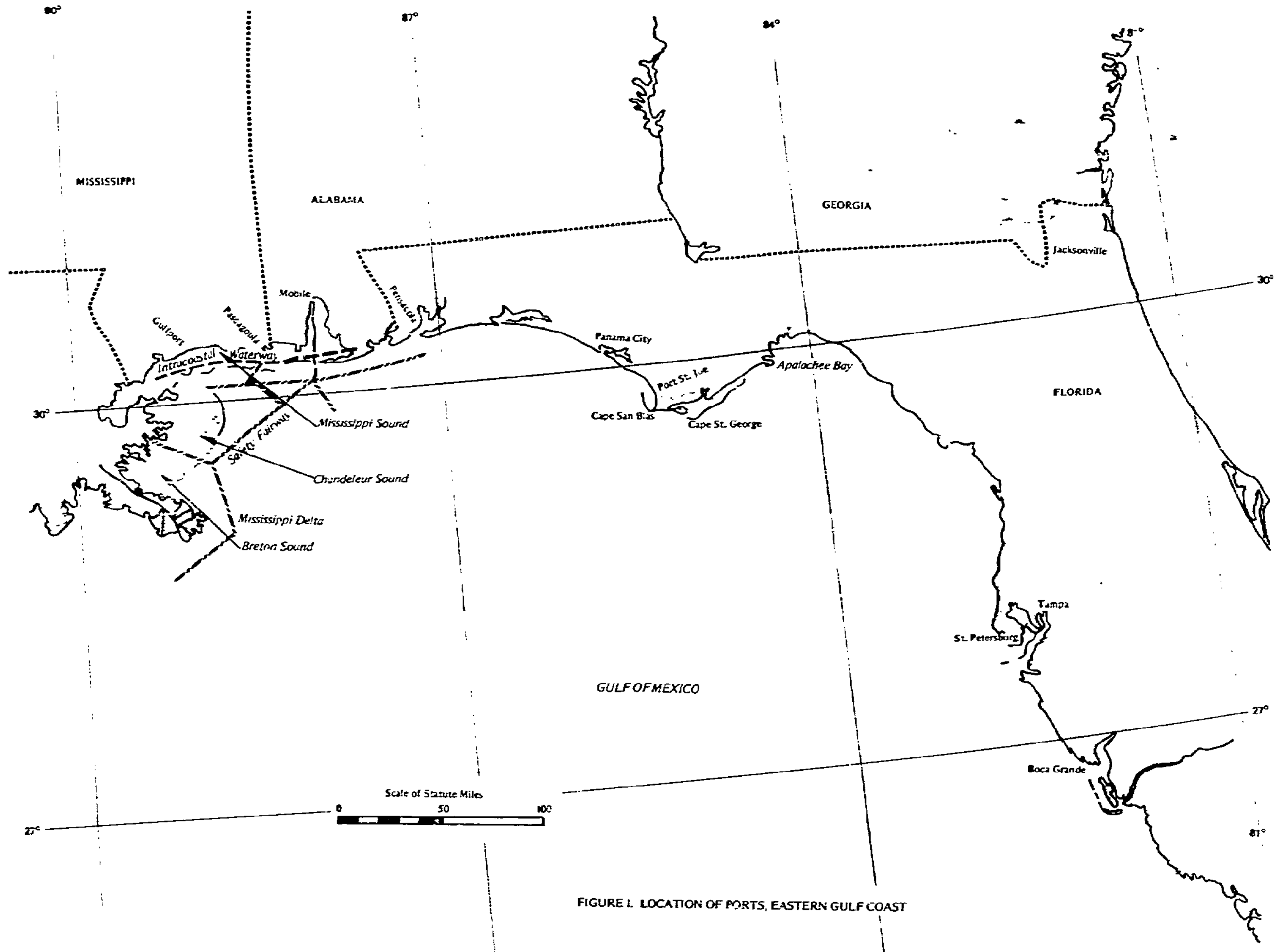

FIGURE I. LOCATION OF PORTS, EASTERN GULF COAST

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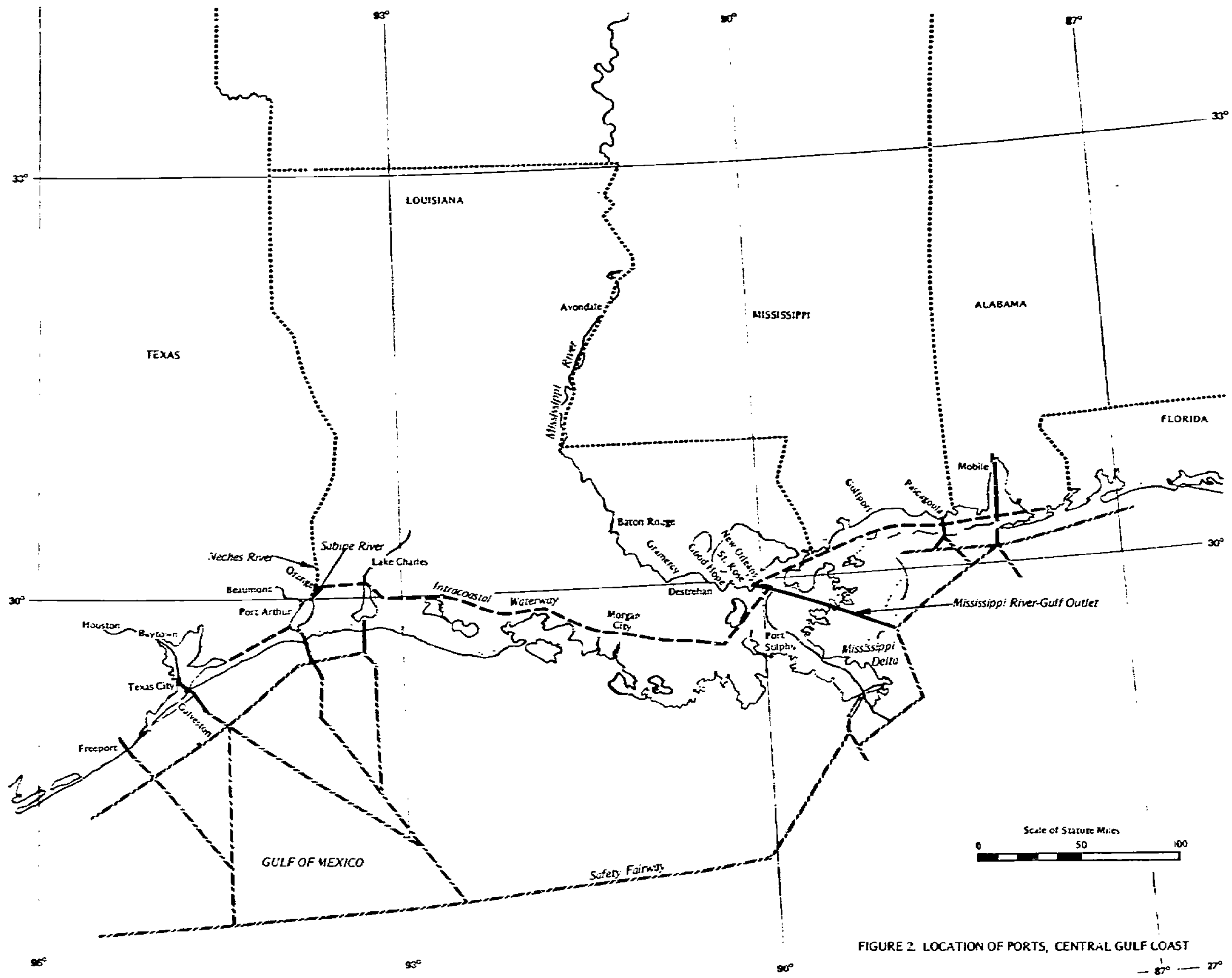

FIGURE 2. LOCATION OF PORTS, CENTRAL GULF COAST

Robert R. Nathan Associates, Inc.

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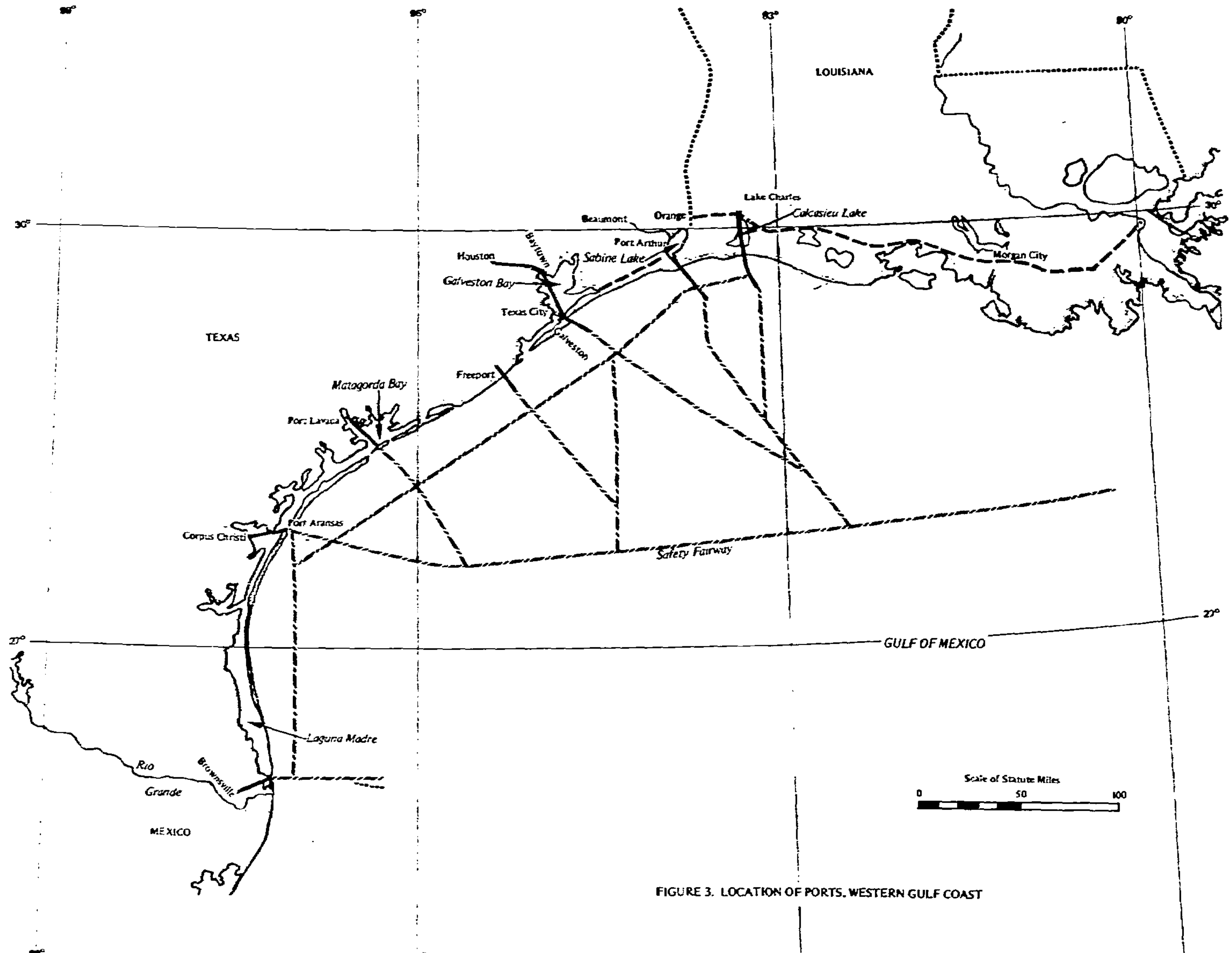

FIGURE 3. LOCATION OF PORTS, WESTERN GULF COAST

Robert R. Nathan Associates, Inc

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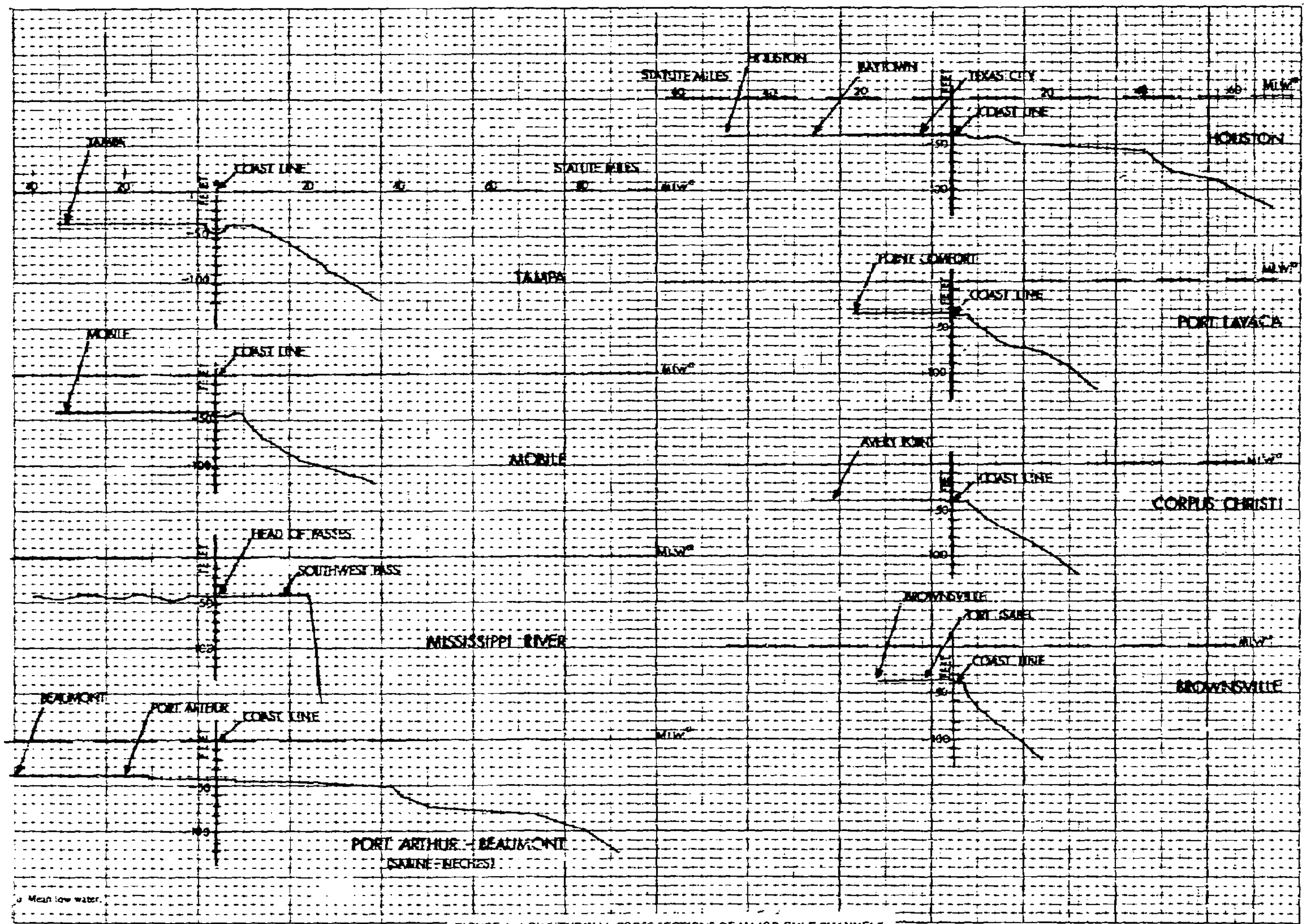

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FIGURE 4. LONGITUDINAL CROSS SECTIONS OF MAJOR GULF CHANNELS

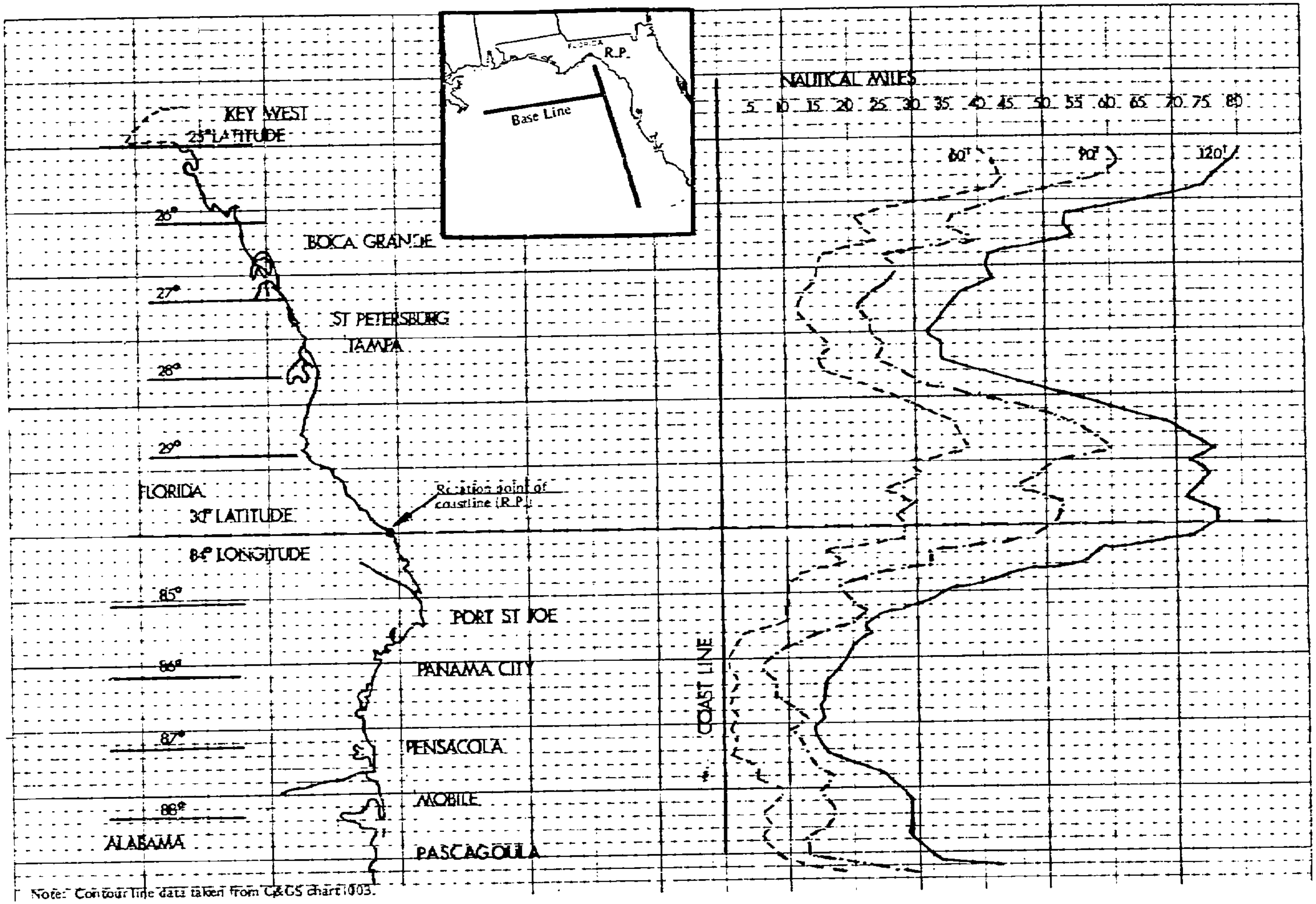

FIGURE 5. DISTANCES BETWEEN COASTLINE AND 60-, 90-, AND 120-FOOT CONTOUR LINES, EASTERN GULF COAST

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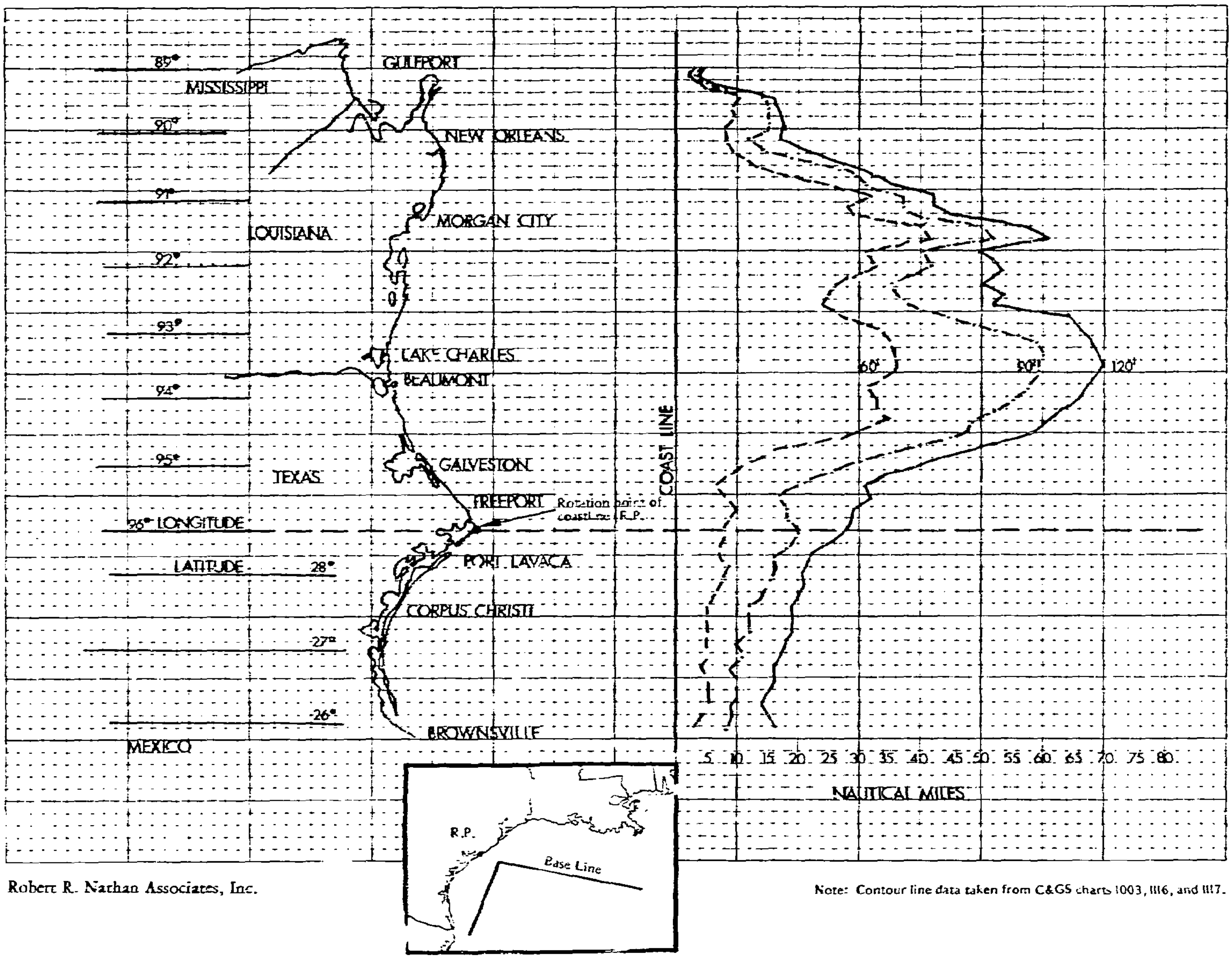

Robert R. Nathan Associates, Inc.

Note: Contour line data taken from C&GS charts 1003, 1116, and 1117.

FIGURE 6. DISTANCES BETWEEN COASTLINE AND 60-, 90-, AND 120-FOOT CONTOUR LINES, WESTERN GULF COAST

Beaumont-Port Arthur southward there is a sharp decrease to approximately 12 miles for the 60-foot depth at Freeport, just south of Galveston-Houston, and further decreases to 5 miles at Corpus Christi and about 3 miles at Brownsville.

II. FOREIGN AND COASTAL MOVEMENTS, BY PORT, OF THE SIX STUDY COMMODITIES

Table 1 shows imports and exports of our study commodities for 1968 and 1969 by individual port. Table 2 shows similar data for coastal waterborne movements in domestic trade for 1969 and 1970. For the gulf coast as a whole, foreign trade movements approximated 69 and 67 million tons in 1968 and 1969, respectively, of which approximately one-half was exports of grains and soybeans and meal. Two-thirds of these grain exports, or approximately 20 million tons, moved through ports on the Mississippi River; most of the balance moved through Texas ports, principally Houston. Exports from grain shipping ports in the eastern gulf (Mobile and Pascagoula) were less than 10 percent of total gulf exports.

Phosphate rock, the only other export commodity of significance, moved entirely through the Florida ports of Boca Grande and Tampa, and most of this movement (92 percent in 1969) was handled by the latter port.

Next to grains, the largest single commodity flow was the import of bauxite, which in 1968 and 1969 approximated 14 and 16 million tons, respectively. This import, however, was much less concentrated by port and port region than were grain exports, and imports in excess of 2 million tons were handled at each of the following ports: Port Lavaca and Corpus Christi, Texas; Gramercy and Baton Rouge, Louisiana; and Mobile, Alabama. As was pointed out in Annex A-4, this bauxite moved directly to processing plants at locations near the port areas.

Table 1. U.S. Waterborne Exports of Domestic and Foreign Merchandise and General Imports of Selected Bulk Commodities, Gulf Coast, 1968 and 1969
(In thousands of short tons)

Port area	Total study area		Exports: Total grains a/		Coal		Phosphate rock		Total		Imports: Crude oil		Pet. products b/		Iron ore		Bauxite		Alumina		Total	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Eastern gulf coast																						
Boca Grande, Fla.	909	1,050	--	--	--	--	712	712	712	712	--	--	196	338	--	--	--	--	--	--	196	338
St. Petersburg, Fla.	361	252	--	--	--	--	--	--	--	--	--	--	361	252	--	--	--	--	--	--	361	252
Tampa, Fla.	9,491	9,419	c/	c/	--	c/	8,804	8,198	8,804	8,198	--	--	687	1,221	--	--	--	--	--	--	687	1,221
Port St. Joe, Fla.	83	106	2	--	--	--	--	--	2	--	41	23	40	83	--	--	--	--	--	--	81	106
Panama City, Fla.	248	251	1	--	--	--	--	--	1	--	164	100	83	151	--	--	--	--	--	--	247	251
Pensacola, Fla.	1	3	1	3	--	--	--	--	1	3	--	--	--	--	--	--	--	--	--	--	--	--
Mobile, Ala.	8,693	8,266	1,244	991	2	1	--	--	1,246	992	54	26	233	359	4,413	4,576	2,748	2,314	--	--	7,448	7,275
Pascagoula, Miss.	1,942	1,200	1,942	1,200	--	--	--	--	1,942	1,200	--	--	--	--	--	--	--	--	--	--	--	--
Gulfport, Miss.	3	14	c/	14	c/	c/	3	--	3	14	--	--	--	--	--	--	--	--	--	--	--	--
Total	21,731	20,56[illegible]	3,190	2,20[illegible]	2	1	9,519	8,910	12,711	11,119	259	149	1,600	2,404	4,413	4,576	2,748	2,314	--	--	9,020	9,443
Central gulf coast																						
Port [illegible], La.	c/	--	c/	--	--	--	--	--	c/	--	--	--	--	--	--	--	--	--	--	--	--	--
New Orleans, La.	9,579	9,261	8,770	7,630	31	82	12	7	8,813	7,719	126	--	439	812	18	103	28	554	156	73	767	1,542
St. Rose, La.	359	383	359	383	--	--	--	--	359	383	--	--	--	--	--	--	--	--	--	--	--	--
Destrehan, La.	6,563	6,797	6,563	6,797	--	--	--	--	6,563	6,797	--	--	--	--	--	--	--	--	--	--	--	--
Good Hope, La.	84	60	--	15	--	--	--	--	--	15	--	--	84	45	--	--	--	--	--	--	84	45
Gramercy, La.	2,282	3,634	--	1,428	--	--	--	--	--	1,428	--	--	--	--	--	--	2,282	2,206	--	--	2,282	2,206
Baton Rouge, La.	8,273	8,079	3,664	3,202	--	--	--	--	3,664	3,202	--	127	2	--	707	407	3,900	4,342	--	--	4,609	4,876
Avondale, La.	2	--	2	--	--	--	--	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--
Morgan City, La.	1	c/	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Lake Charles, La.	574	596	574	595	--	--	--	--	574	595	--	--	--	1	--	--	--	--	--	--	--	1
Total	27,717	28,810	19,933	20,0[illegible]	31	82	12	7	19,976	20,139	126	127	525	858	725	510	6,210	7,102	156	73	7,742	8,670
Western gulf coast																						
Orange, Texas	91	50	91	50	--	--	--	--	91	50	--	--	--	--	--	--	--	--	--	--	--	--
Port Arthur, Texas	396	415	229	90	--	c/	--	--	229	90	c/	78	167	246	--	--	--	--	--	--	167	324
Beaumont, Texas	1,287	717	1,283	717	--	--	--	--	1,283	717	--	--	4	--	--	--	--	--	--	--	4	--
Galveston, Texas	740	646	740	646	--	c/	--	--	740	646	--	--	--	--	--	--	c/	--	--	--	c/	--
Houston, Texas	8,615	5,625	[illegible]	3,992	4	2	3	c/	6,853	3,994	6	12	842	852	889	753	27	14	--	--	1,764	1,631
Freeport, Texas	1	--	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--
Port Lavaca, Texas	2,623	3,090	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2,623	3,090	--	--	2,623	3,090
Corpus Christi, Tex.	3,798	4,870	1,327	1,360	--	--	--	--	1,327	1,360	80	55	--	39	--	--	2,391	3,416	--	--	2,471	3,510
Brownsville, Texas	1,975	2,155	193	307	--	--	--	--	193	307	1,713	1,847	69	--	--	--	--	--	--	--	1,782	1,847
Total	19,526	17,568	10,710	7,162	4	[illegible]	3	c/	10,717	7,164	1,799	1,992	1,082	1,137	889	753	5,041	6,520	--	--	8,811	10,402
Total gulf coast	68,974	66,938	33,833	29,420	37	8[illegible]	9,534	8,917	43,404	38,422	2,184	2,268	3,207	4,399	6,027	5,839	13,999	15,936	156	73	25,573	28,515

Note: Individual items may not add to total due to rounding.
a/ Includes food grains (wheat, rice, rye), feed grains (barley, corn, oats, cereals, n.e.c.), and soybeans and mill products.
b/ Includes gasoline, jet fuel and kerosene, distillate fuel oils, and residual fuel oils.
c/ Less than 500 short tons.

Source: U.S. Department of Commerce, Bureau of the Census, U.S. Waterborne Exports of Domestic and Foreign Merchandise, SA-705, and U.S. Waterborne General Imports of Merchandise, SA-305, 1968 and 1969.

Table 2. U.S. Domestic Waterborne Coastal Receipts and Shipments of Selected Bulk Commodities, Gulf Coast, 1969 and 1970
(In thousands of short tons)

Port area	Total, all study comm.				Crude oil				Petroleum[a/] products				Dry bulk commodities[b/]					
	1969		1970		1969		1970		1969		1970		1969			1970		
	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Commodity	Rect.	Shipt.	Commodity
Eastern Gulf coast																		
Charlotte Harbor, Fla.	19	1,339	126	628	--	--	--	--	19	--	126	--	--	1,339	Phos. rock	--	628	Phos. rock
St. Petersburg Harbor, Fla.	--	--	22	--	--	--	--	--	--	--	22	--	--	--	--	--	--	--
													92	1	Grains[c/]	148	--	Grains[c/]
													2,270	--	Coal	2,654	--	Coal
Tampa Harbor, Fla.	8,039	3,332	8,333	4,320	--	--	--	--	5,677	6	5,518	29	--	3,125	Phos. rock	--	4,291	Phos. rock
Port St. Joe, Fla.	142	--	232	26	--	--	--	--	142	--	232	26	--	--	--	--	--	--
Panama City Harbor, Fla.	29	--	22	--	--	--	--	--	29	--	22	--	--	--	--	--	--	--
Pensacola Harbor, Fla.	1	--	4	--	--	--	--	--	1	--	4	--	--	--	--	--	--	--
													--	266	Grains[c/]	d/	253	Grains[c/]
													--	d/	Coal	--	d/	Coal
Mobile Harbor, Ala.[e/]	[illegible]	1,907	[illegible]	1,590	--	1,635	--	1,287	14	6	10	50	29	d/	Phos. rock	11	--	Phos. rock
Pascagoula Harbor, Miss.[e/]	382	2,061	324	1,997	--	--	27	--	161	2,061	--	1,997	221	--	Phos. rock	29	--	Phos. rock
Biloxi Harbor, Miss.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gulfport Harbor, Miss.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total	8,655	8,439	9,071	8,561	--	1,635	27	1,287	6,043	2,073	5,934	2,102	2,612	4,791	--	3,110	5,172	
Central Gulf coast																		
													--	3	Grains[c/]	--	35	Grains[c/]
Mississippi River, Baton Rouge, La., to but not including New Orleans, La.	1,916	11,173	2,0[illegible]	11,227	--	2,353	54	2,478	126	8,814	210	8,714	1,790	--	Phos. rk.	2,056	--	Phos. rock
													--	80	Grains[c/]	d/	115	Grains[c/]
													--	d/	Al. ores	--	3,705	Coal
													1,229	--	Phos. rock			
Mississippi River, New Orleans, La., to mouth of Passes	1,24[illegible]	2[illegible],633	1,[illegible]37	24,22[illegible]	--	16,163	--	18,991	14	1,305	102	1,412	--	3,085	Coal	1,235	--	Phos. rock
Calcasieu River and Pass, La. Lake Charles, La.	--	1,208	14	2,672	--	326	--	839	--	1,855	14	1,995	--	27	Grains[c/]	--	38	Grains[c/]
Total	3,15[illegible]	34,311	3,671	38,322	--	18,842	54	22,308	140	11,974	326	12,121	3,019	3,195		3,291	3,893	
Western Gulf coast																		
Sabine-Neches Waterway, Tex. Beaumont, Orange, Port Arthur, and Sabine Pass Harbor, Tex.	5,[illegible]97	20,058	3,72[illegible]	22,392	4,056	5,083	2,894	6,333	1,031	14,970	836	16,053	--	--	--	--	d/	Grains[c/]
Houston Ship Channel, Tex.	947	14,614	1,23[illegible]	17,431	67	302	95	2,066	95	14,291	171	15,394	785	--	Phos. rock	969	--	Phos. rock
Texas City Channel, Tex.	73	3,221	d/	3,767	43	253	--	286	30	2,967	d/	3,481	d/	21	Grains[c/]	d/	21	Grains[c/]
Galveston Channel, Tex.	--	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Freeport Harbor, Tex.	--	502	--	485	--	--	--	--	--	502	--	485	--	2	Grains[c/]	--	--	--
Matagorda Ship Channel, Tex.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Corpus Christi Ship Channel, Tex.	[illegible]	14,9[illegible]	[illegible]	16,554	--	6,214	--	6,655	51	8,741	59	9,893	--	--	--	--	--	--
Brazos Island Harbor, Tex. Brownsville and Port Isabel, Tex.	--	1,543	77	1,365	--	1,465	--	1,365	--	78	77	--	--	--	--			
Total	6,1[illegible]	74,694	5,792	62,044	4,166	13,322	2,979	16,705	1,207	41,549	1,143	45,318	785	23	--	969	21	--
Total Gulf coast	17,972	97,404	17,833	108,927	4,166	33,799	3,060	40,300	7,390	55,596	7,403	59,541	6,416	8,099		7,370	9,086	

a/ Includes 2911, gasoline; 291[illegible], jet fuel; 2913, kerosene; 2914, distillate fuel oil; 2915, residual fuel oil.
b/ Includes grains, iron ore and concentrates, coal and lignite, phosphate rock, and bauxite and other aluminum ores.
c/ Includes [illegible], barley and [illegible]; [illegible], corn; 0104, oats; 0105, rice; 0106, sorghum grains; 0107, wheat; 0111, soybeans; 2049, grain mill products, n.e.c.
d/ Less than 500 short tons.
e/ Consolidated report.

Source: U.S. Department of the Army, Corps of Engineers, Waterborne Commerce of the United States, Part II, "Waterways and Harbors, Gulf Coast, Mississippi River System and Antilles," 1969 and 1970.

Two-thirds of iron ore imports of approximately 6 million tons went to the port of Mobile, while crude oil imports of just over 2 million tons went almost entirely to Brownsville, Texas. Imports of petroleum products of 3.2 million and 4.4 million tons in 1968 and 1969, respectively, were scattered among a large number of ports throughout the gulf area.

Coastal movements of study commodities consisted predominantly of crude petroleum and petroleum products (10.5 million tons of receipts and 99.8 million tons of shipments in 1970). These commodities were shipped principally from the ports of New Orleans, Beaumont-Port Arthur, Galveston-Houston, and Corpus Christi. There were shipments of 3.7 million tons of coal from New Orleans (mainly to Tampa) and 4.3 million tons of phosphate from Tampa (mainly to New Orleans, Baton Rouge, and Houston). Shipments of phosphate from Charlotte Harbor (the port of Boca Grande), Florida, declined from 1.4 to 0.6 million tons from 1969 to 1970.

To recapitulate, domestic and foreign bulk commodity movements in excess of 1 million tons in 1970 in the order of their importance by major port were as follows:

Tampa	Phosphate rock shipments and petroleum and coal receipts
Mobile	Grain shipments and receipts of iron ore and bauxite
New Orleans and other Mississippi River ports	Shipments of petroleum products, grain, and coal; and receipts of bauxite
Beaumont-Port Arthur	Shipments of petroleum and grain
Galveston-Houston	Shipments of petroleum and grain
Port Lavaca	Shipments of petroleum and receipts of bauxite
Corpus Christi	Shipments of petroleum and grain and receipts of bauxite.

III. MAJOR HARBORS AND CHANNELS

Table 3 gives depths, widths, and lengths of various channels in the major gulf coast harbors and waterways as identified by the Corps of Engineers. The alignment of these channels is shown in figures 7 through 16.

In general, depths of 40 feet prevail with the principal exception of Tampa (34 feet), Beaumont (36 feet), Freeport (36 feet), and Brownsville (36 feet). However, Corpus Christi and Freeport have authorized depths of 47 feet and 45 feet, respectively, for entrance and harbor channels.

Table 3. Project Dimensions of Major Channels

Name of channel	Depth	Width	Length		Location[a]
	Feet		Naut. miles	Stat. miles	Stat. miles
Tampa, Florida					
Egmont Bar Channel..........	36	600	3.9	4.5	(7.2)-(2.7)
Mullet Key Channel..........	34	500	2.9	3.3	2.1 - 5.4
Tampa Bay Channel...........	34	400	13.6	15.7	5.4 -21.1
Gadsden Point Channel[b].....	34	400	3.1	3.6	21.1 -24.7
Hillsborough Bay Channel[c]..	34	400	6.6	7.6	24.7 -32.3
Port Sutton Channel.........	34[d]	280[d]	1.5	1.8	32.3 -34.1
Sparkman and Ybor Channel[e].	34	400[f]	3.1	3.6	32.3 -35.9
Port Tampa Channels[g].......	34	400	7.7	8.9	21.1 -30.0
Mobile, Alabama					
Entrance Channel............	42	600	1.4	1.6	(4.9)-(3.3)
Main Ship Channel...........	40	400	25.2	29.0	1.5 -30.5
Mobile River Channel........	40	500-775[f]	4.1	4.7	30.5 -35.2
Theodore Ship Channel.......	40	400-300[f]	6.3	7.3	18.2 -25.5
Mississippi River					
South Pass..................	30	450	11.4	13.1	(13.1)- 0.0
Southwest Pass..............	40	800	17.5	20.1	(20.1)- 0.0
Head of passes to New Orleans....................	40	1,000	75.2	86.7	0.0 -86.7
Port of New Orleans.........	40	500	14.9	17.2	86.7-103.9
	35	1,500			
New Orleans to Baton Rouge..	40	500	112.4	129.6	103.9-223.5
Mississippi River-Gulf Outlet....................	36	500	65.3	75.4	0.0 -75.4

continued--

Table 3. Project Dimensions of Major Channels continued--

Name of channel	Depth	Width	Length		Location[a]
	Feet		Naut. miles	Stat. miles	Stat. miles
Sabine Lake, Texas					
Sabine Bank Channel........	42	800	12.8	14.7	(18.1) - (3.4)
Sea Bar Channel............	40	800	3.0	3.4	(3.4) - 0.0
Sabine Pass Jetty Channel..	40	800-500	3.5	4.1	0.0 - 4.1
Sabine Pass Channel........	40	500[f]	4.8	5.6	4.1 - 9.7
Port Arthur Canal..........	40	500	5.5	6.2	9.7 - 15.9
Taylors Bayou Channel......	36	200-250	1.7	2.0	15.7 - 17.7
Sabine-Neches Canal to mouth of Neches River.....	36	400	10.1	11.2	15.9 - 27.1
Mouth Neches River to mouth Sabine River........	30	200	3.9	4.5	27.1 - 31.6
Neches River Channel to Beaumont..................	36	350[f]	16.6	18.3	27.1 - 45.4
Sabine River Channel.......	30	200	8.1	9.3	31.6 - 40.9
Galveston Bay, Texas					
Entrance Channel...........	42	800	4.2	4.9	(9.3) - (4.4)
Outer Bar Channel..........	42	800	1.4	1.6	(4.4) - (2.8)
Inner Bar Channel..........	40	800	2.4	2.8	(2.8) - 0.0
Bolivar Roads Channel......	40	800[f]	0.8	1.0	0.0 - 1.0
Texas City Channel.........	40	400[f]	5.9	6.8	1.0 - 7.8
Houston Ship Channel:					
Bolivar Roads to Carpenter Bayou................	40	400	31.1	35.8	1.0 - 36.8
Carpenter Bayou to Sims Bayou....................	40	400-300[f]	10.6	12.2	36.8 - 49.0
Sims Bayou to Houston Turning Basin............	36	300[f]	3.3	3.8	49.0 - 52.8

continued--

Table 3. Project Dimensions of Major Channels continued--

Name of channel	Depth (Feet)	Width (Feet)	Length Naut. miles	Length Stat. miles	Location[a] Stat. miles
Freeport, Texas					
Outer Bar Channel............	47[h]	400[i]	2.9	3.3	(3.3) - 0.0
Jetty Channel................	45[j]	400[k]	0.8	0.9	0.0 - 0.9
Inland Channel...............	45[j]	350-375[k]	2.3	2.7	0.9 - 3.6
Matagorda Bay, Texas					
Sea Bar and Jetty Channel....	38	300	2.7	3.1	(3.1) - 0.0
Matagorda Ship Channel.......	36	300-200	10.8	12.4	0.0 -12.4
Lavaca Bay Channel (from light 48 to 76)............	36	200	7.4	8.5	12.4 -20.9
Point Comfort Harbor Channel.	36	200[f]	1.1	1.2	20.9 -22.1
Corpus Christi Bay					
Outer Bar Channel............	47[l]	700	6.0	7.2	(6.8) - 0.4
Jetty Channel................	47-45[l]	700-600	1.5	1.7	0.4 - 2.1
Port Aransas-Corpus Christi Waterway:					
Bay section.................	45[m]	400	18.5	21.3	2.1 -23.4
Inland section to Avery Point.....................	45[m]	400	1.5	1.7	23.4 -25.1
From Avery Point to end.....	45[m]	400-300[f]	5.6	6.5	25.1 -31.6
La Quinta Channel............	45[n]	300[f]	5.0	5.8	11.5 -17.3
Brownsville, Texas					
Entrance Channel.............	38	300	1.9	2.2	(2.2) - 0.0
Laguna Madre Channel.........	36	200	2.2	2.5	0.0 - 2.5
Brownsville Ship Channel.....	36	200[f]	12.4	14.3	2.5 -16.8
Port Isabel Channel..........	36	200[f]	2.1	2.4	4.0 - 6.4

continued--

Table 3. Project Dimensions of Major Channels continued--

a/ Figures in parentheses indicate offshore miles.
b/ Cuts A through F.
c/ Cuts A and C.
d/ Authorized dimensions are 30'x150'; however, local interests dredged it to the listed dimensions in 1965.
e/ Including Hillsborough Bay Channel, cut D, and Ybor Turning Basin.
f/ Locally wider at turning basin(s).
g/ Tampa Bay Channel cuts G, J, J-2, K, Port Tampa Turning Basin and Channel.
h/ Present depth, 38 feet.
i/ Present width, 300 feet.
j/ Present depth, 36 feet.
k/ Present width, 200 feet.
l/ Present depth, 42 feet.
m/ Present depth, 40 feet.
n/ Present depth, 36 feet.

Source: Tampa -- C&GS 1257, March 6, 1971.
Mobile -- C&GS 1266, September 19, 1970.
Mississippi River -- AAPA. Ship Channel Capacity Study, June 1970.
Sabine Lake, Texas -- C&GS 1279, March 27, 1971 and C&GS 517 and C&GS 533.
Galveston Bay, Texas -- C&GS 1282, April 10, 1971 and C&GS 519.
Freeport, Texas -- Report on Freeport Harbor, C&GS 1284.
Matagorda Bay, Texas -- C&GS 1284.
Corpus Christi Bay -- AAPA. Ship Channel Capacity Study, June 1970.
Brownsville, Texas -- C&GS 1218.

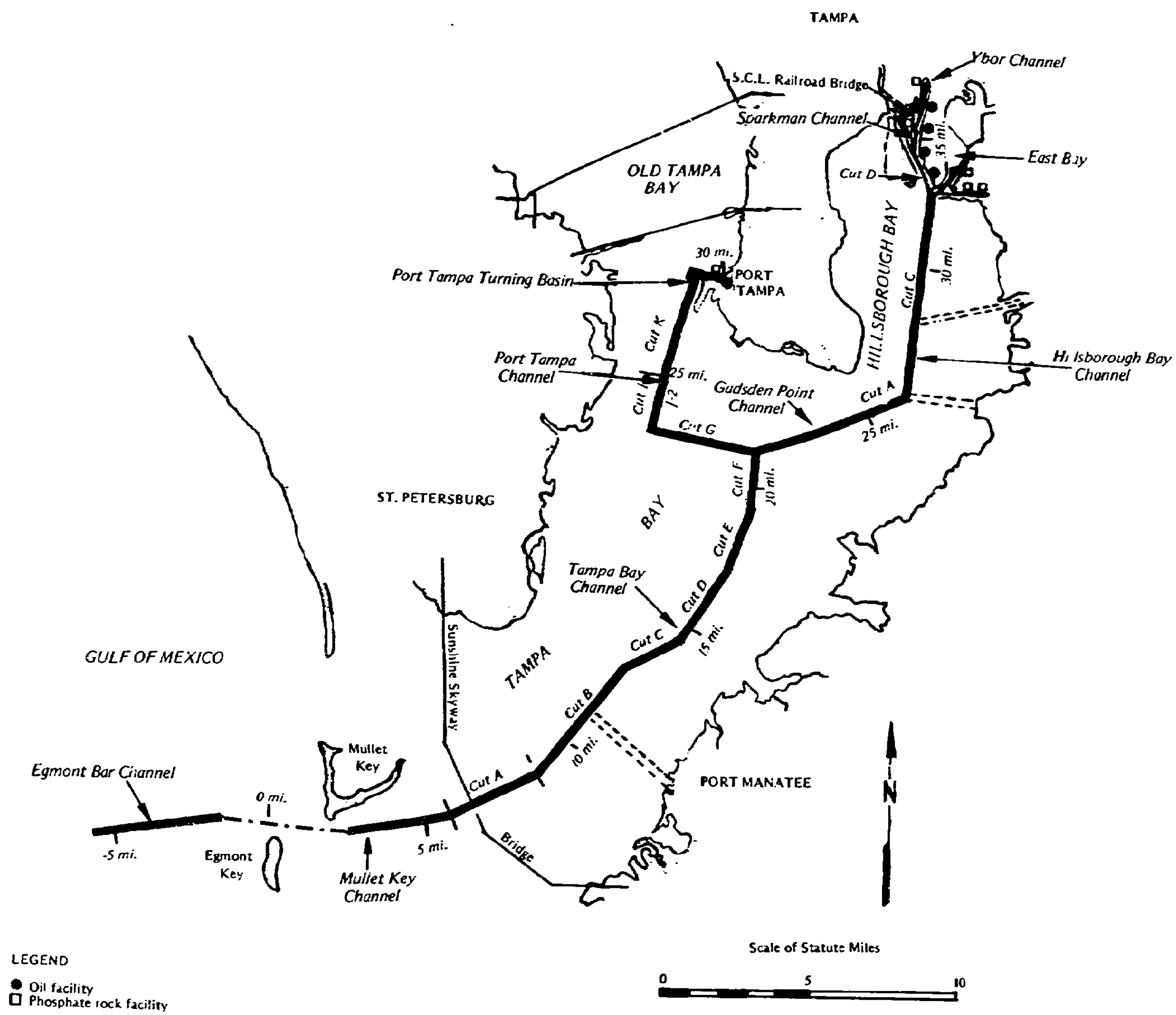

FIGURE 7. CHANNELS AND BULK HANDLING FACILITIES, TAMPA HARBOR, FLORIDA

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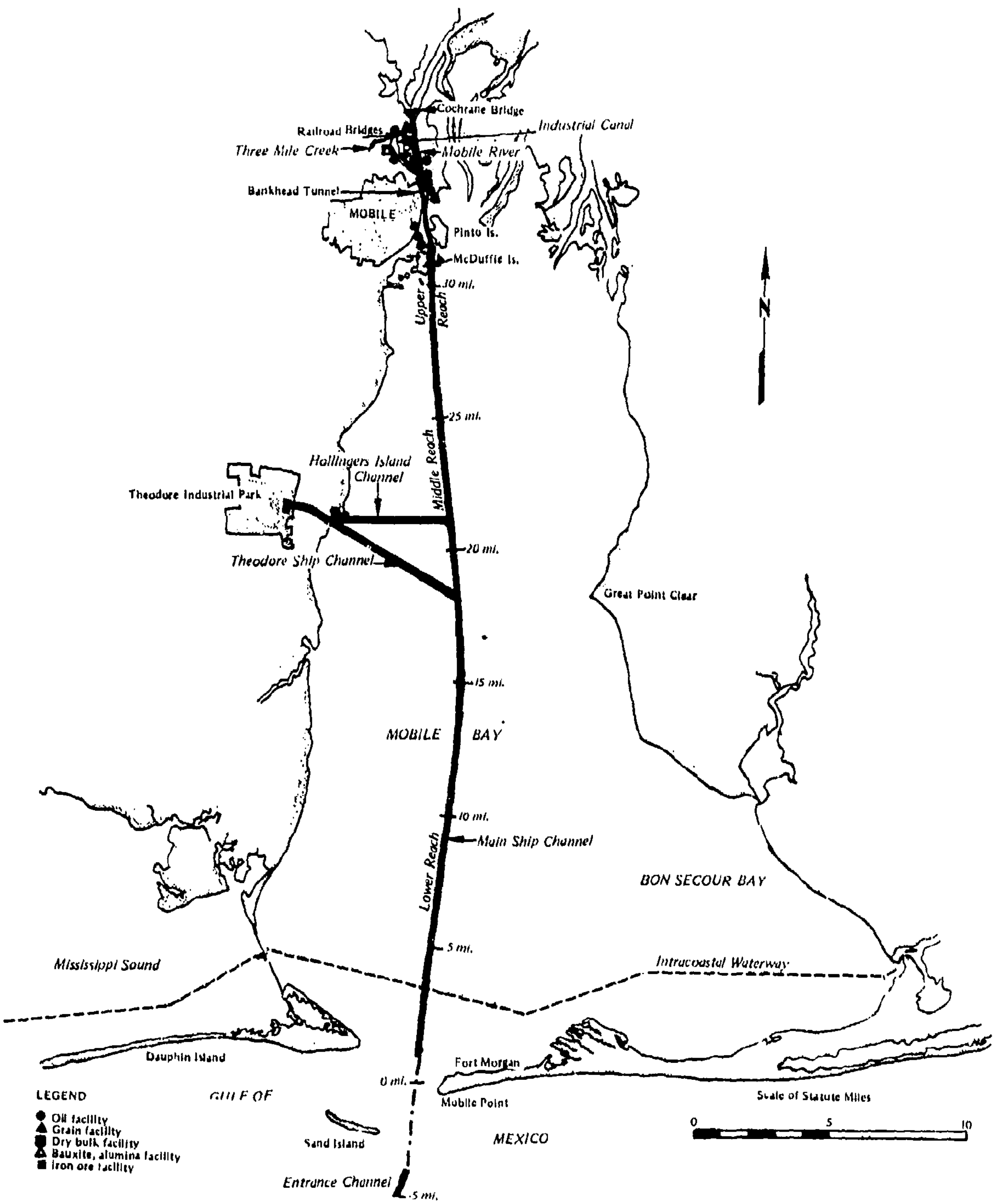

FIGURE 8. CHANNELS AND BULK HANDLING FACILITIES, MOBILE HARBOR, ALABAMA

Robert R. Nathan Associates, Inc.

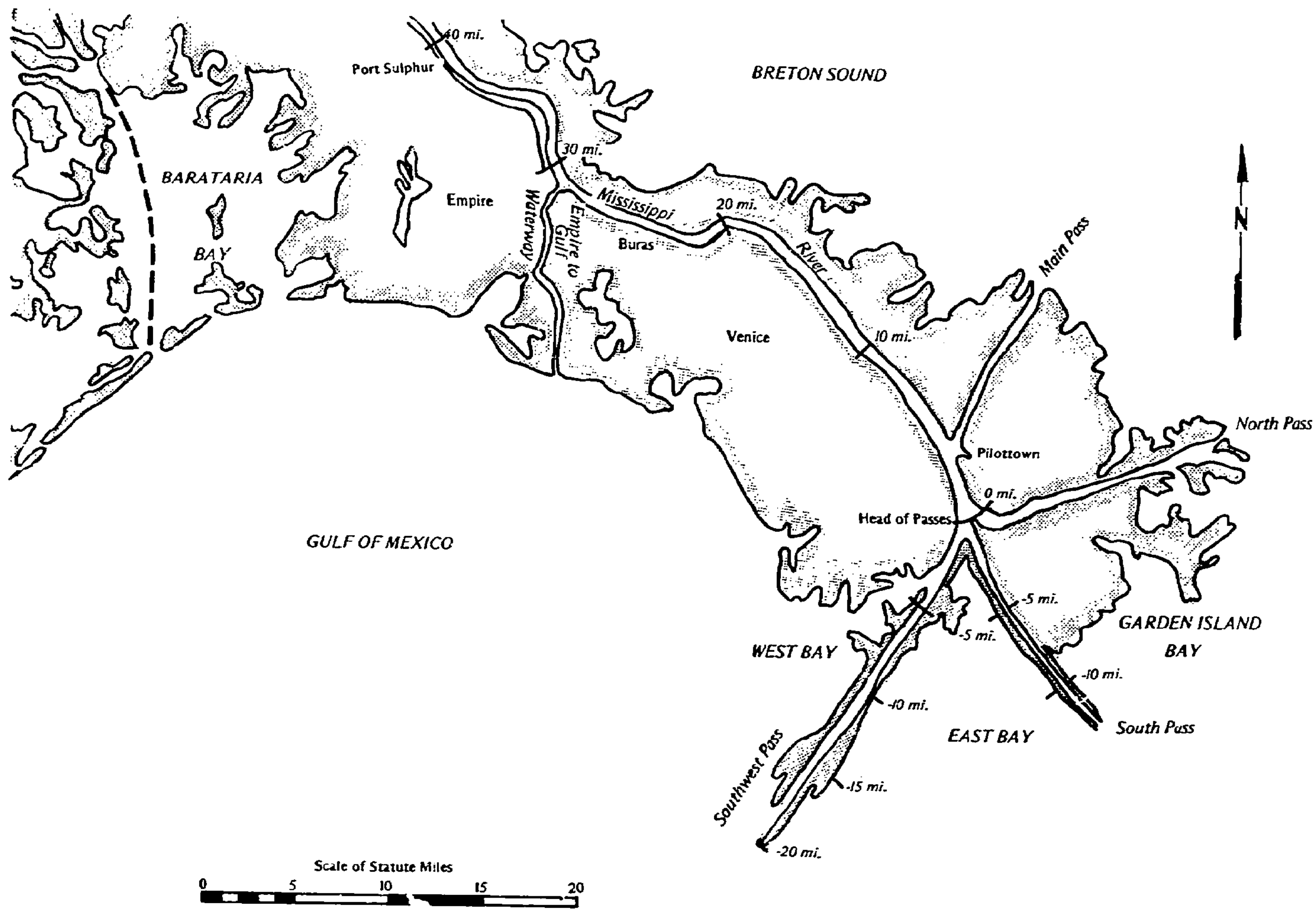

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FIGURE 9. MISSISSIPPI RIVER DELTA PASSES, LOUISIANA

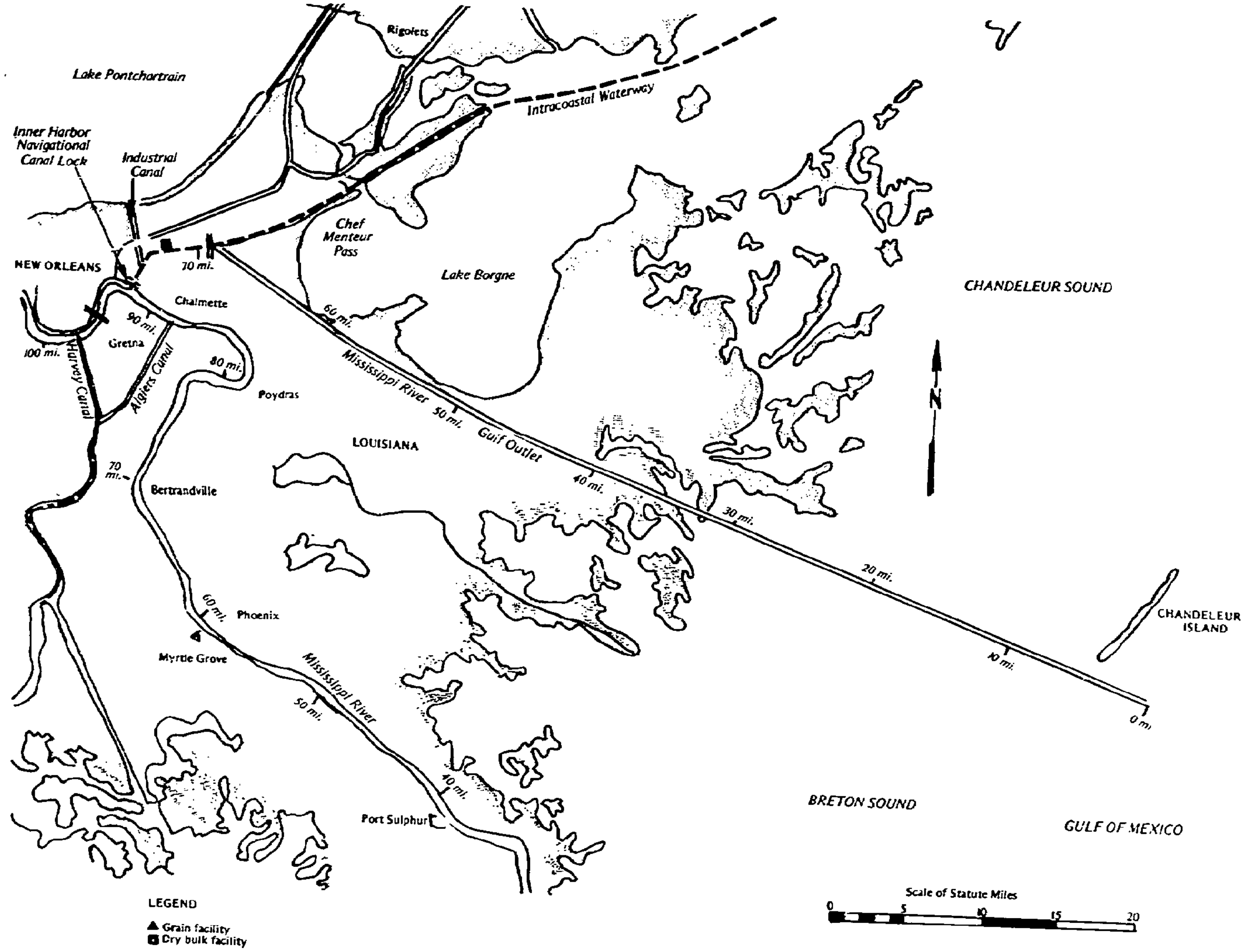

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FIGURE 10. MISSISSIPPI RIVER DELTA, NEW ORLEANS AND VICINITY

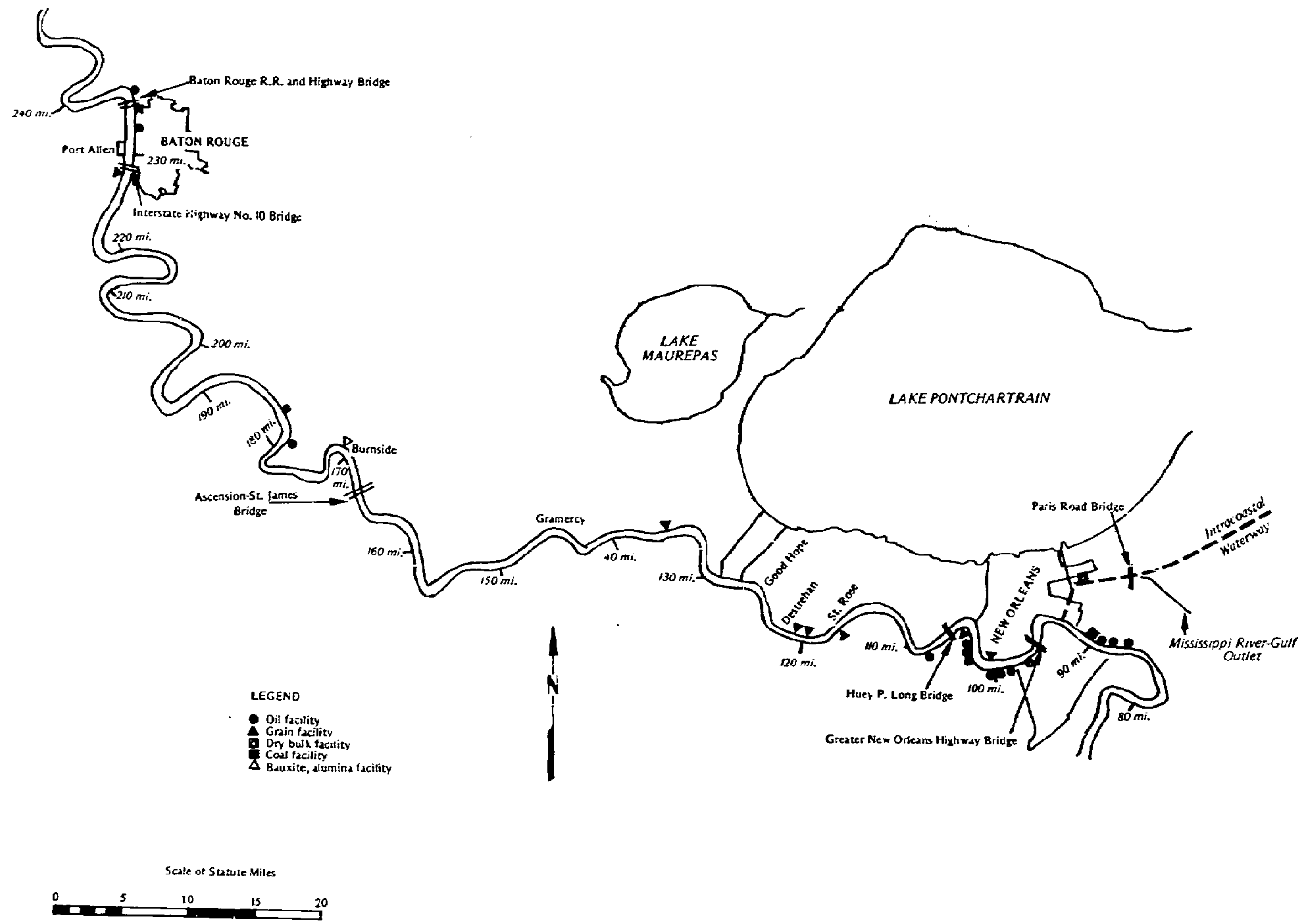

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FIGURE 11. BULK HANDLING FACILITIES, MISSISSIPPI RIVER FROM NEW ORLEANS TO BATON ROUGE, LOUISIANA

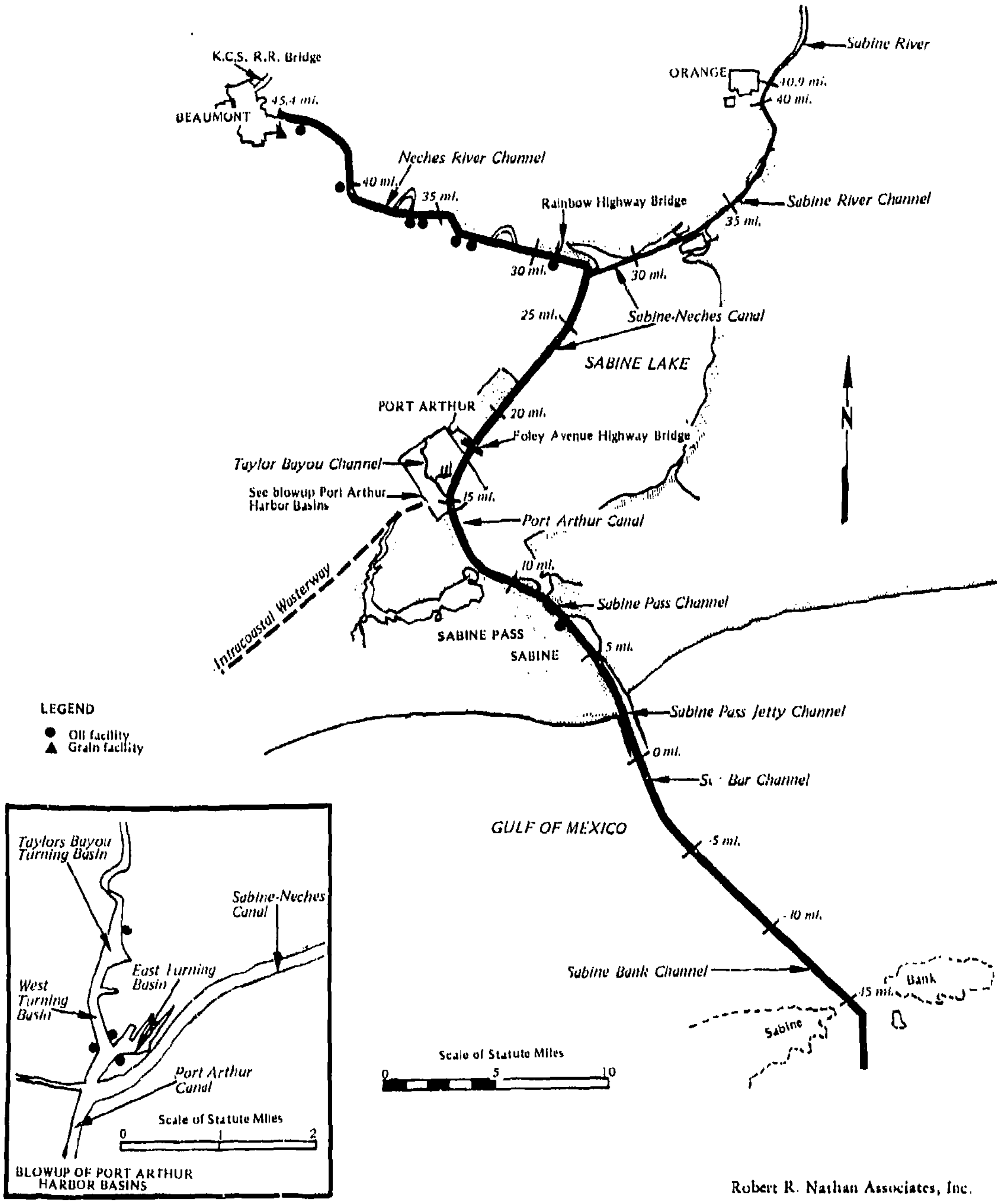

FIGURE 12. CHANNELS AND BULK HANDLING FACILITIES, PORT ARTHUR, BEAUMONT, AND ORANGE HARBORS, TEXAS

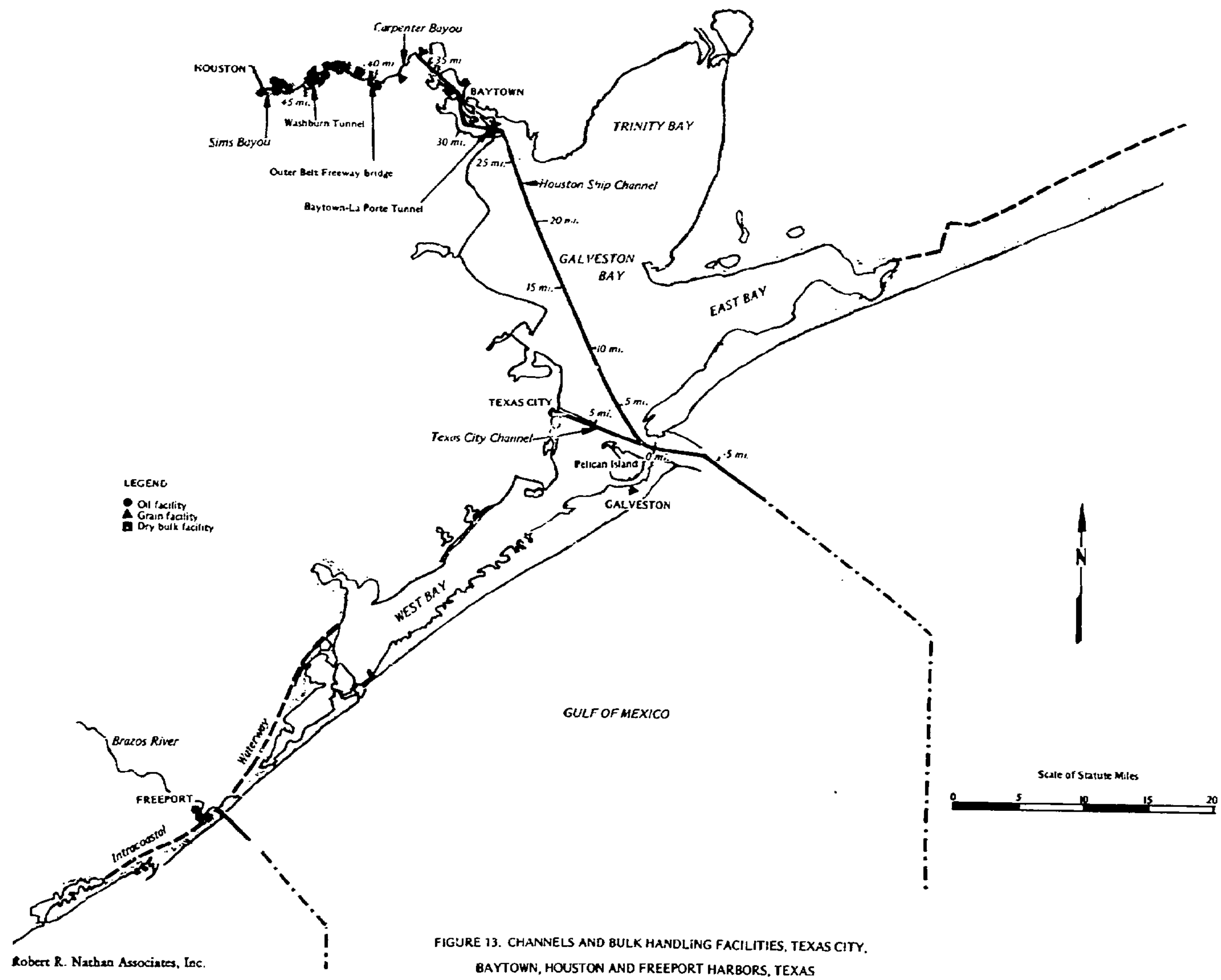

FIGURE 13. CHANNELS AND BULK HANDLING FACILITIES, TEXAS CITY, BAYTOWN, HOUSTON AND FREEPORT HARBORS, TEXAS

Robert R. Nathan Associates, Inc.

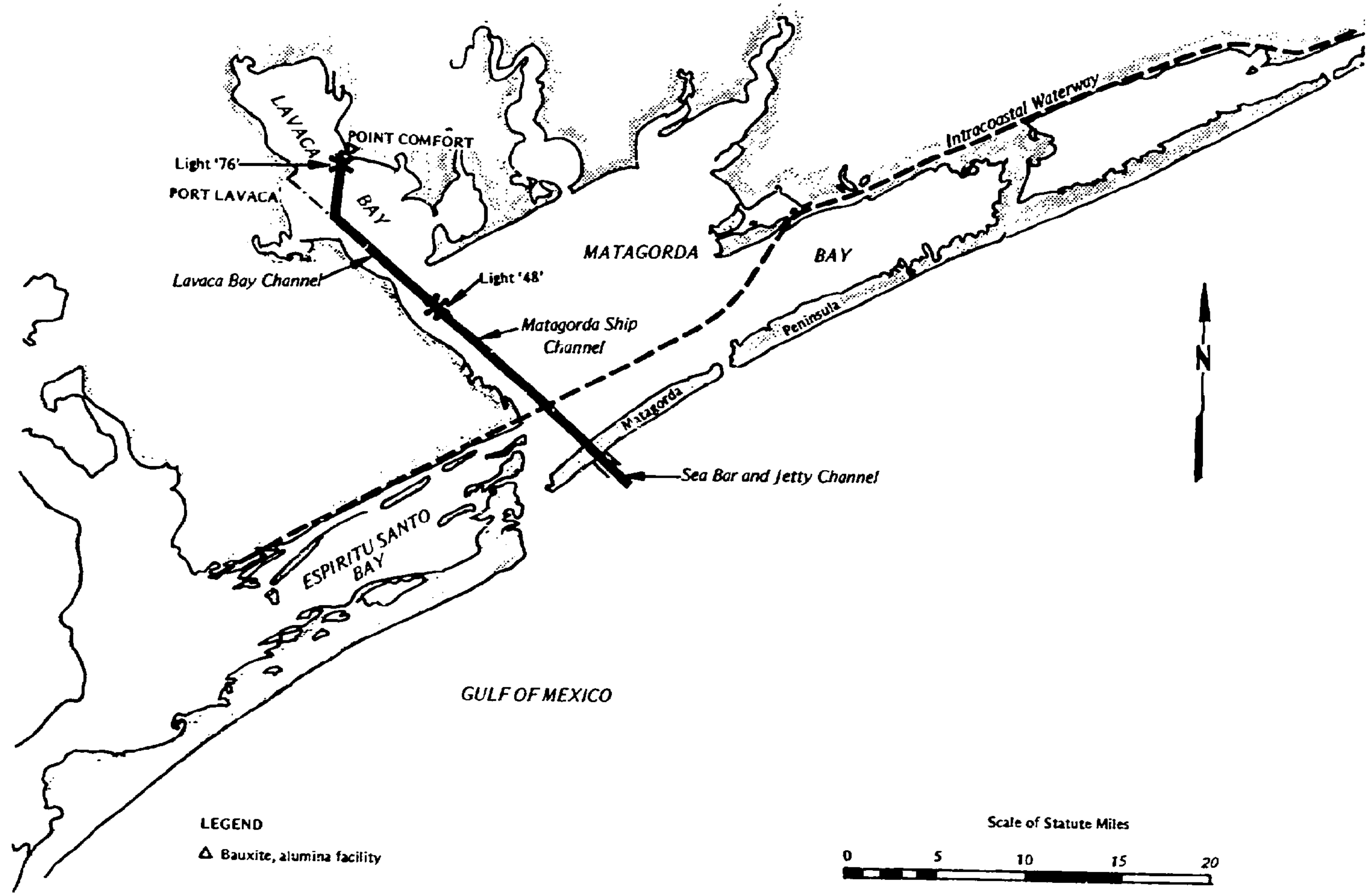

FIGURE 14. CHANNELS AND BULK HANDLING FACILITIES, PORT LAVACA HARBOR, TEXAS

Robert R. Nathan Associates, Inc.

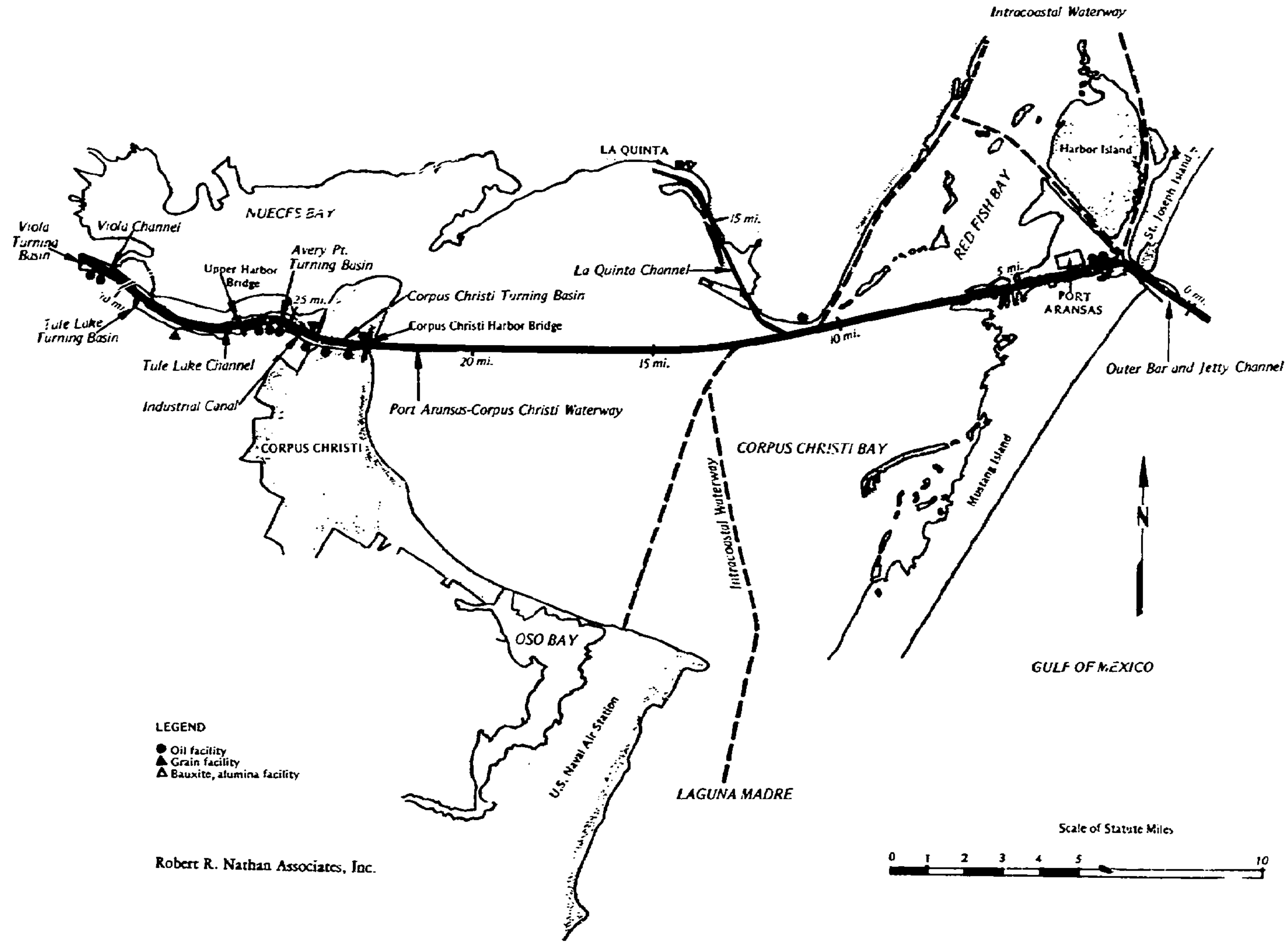

FIGURE 15. CHANNELS AND BULK HANDLING FACILITIES, PORT ARANSAS AND CORPUS CHRISTI HARBORS, TEXAS

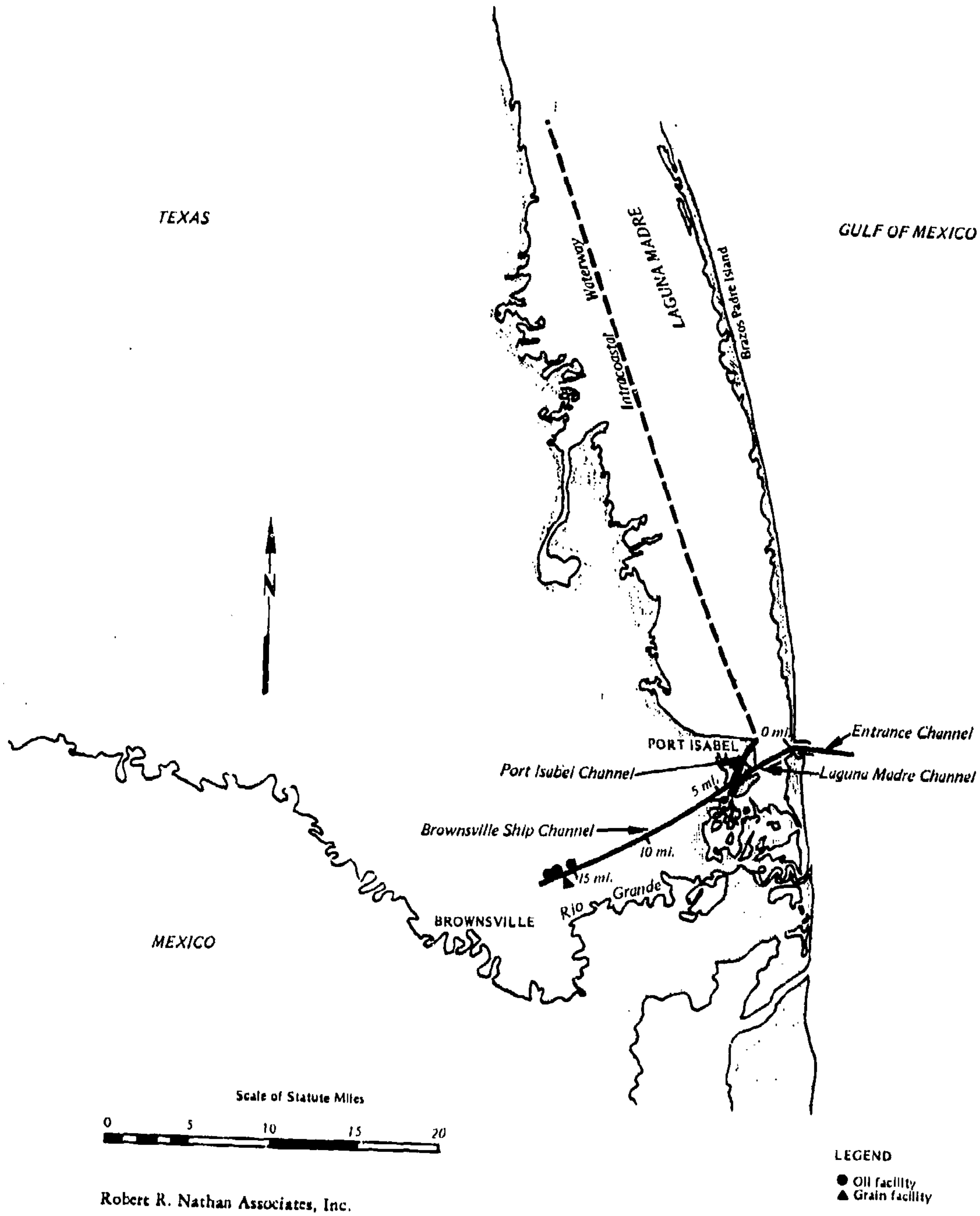

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FIGURE 16. CHANNELS AND BULK HANDLING FACILITIES, BROWNSVILLE HARBOR

IV. TERMINAL FACILITIES

The locations of individual relevant bulk handling facilities in each major port are shown in figures 7 through 16. Detailed descriptive information on these facilities and related storage facilities appear in the appropriate volume of the port series published by the U.S. Army Corps of Engineers.

V. PHYSICAL OBSTACLES TO CHANNEL ENLARGEMENT

Bridges and Tunnels

Table 4 presents detailed information on each bridge and tunnel affecting channels in major gulf ports. The relationship between port traffic in study commodities and the location of the bridge or tunnel by port follows.

Tampa

The Sunshine Skyway Bridge influences all traffic. However, the bridge to Seddon Island does not influence the movement of study commodities at all, although it could restrict port expansions for petroleum products in that area.

Mobile

The Bankhead Tunnel could influence movements to and from all dry bulk facilities and most petroleum facilities. Further channel deepening over this tunnel is unacceptable since the present cover is 5 feet or less.

The projected twin-tube tunnel is planned 540 feet to the south of the Bankhead Tunnel and could replace the latter if the Mobile River Channel is deepened to 50 feet. Dredging beyond this depth is unacceptable in view of the projected depth and cover of this tunnel.

Table 4. Review of Relevant Bridges and Tunnels in Major Gulf Ports

Name	Location	Bay, river or channel	Purpose for which used	Kind	Navigation opening: Horizontal clearance	Navigation opening: Vertical[a] clearance
	(stat. m.)				------- feet	-------
Sunshine Skyway Br....	7	Tampa Bay, Fla.	U.S. Hwy. 19	Fixed	800	151[b]-140[c]
Br. to Seddon Is.....	37	Garrison Chan., Tampa	S.C.L. Railroad	Bascule	110	5[d]
Bankhead Tunnel[e].....	33	Mobile River, Ala.	U.S. Hwy. 9 & I-10	--		46[b]-42[f]
Planned Twin Tube Tun.	33	Mobile River, Ala.	I-10	--		57[b]-50[g]
Cochrane Br..........	36	Mobile River, Ala.	U.S. Hwy. 31,90,98	Vert. lift	300	135[h]
L & N Railroad........	36	Three Mile Creek, Mobile	Railroad	Swing	56	10[d]
Terminal Railroad.....	36	Three Mile Creek, Mobile	Railroad	Swing	53	4[d]
Greater New Orleans Hwy. Br............	96	Miss. River, New Orleans	Expressway	Fixed	1,400	170[i]-150[j]
Huey P. Long Br.......	106	Miss. River, Jeff. Parish, La.	U.S. Hwy. 90 & RR. N.O.P.B.	Fixed	750	153[i]-133[j]
Ascension-St. James Bridge..............	167	Miss. River, St. James Parish, La.	Hwy.	Fixed	750	168[i]-133[j]
Baton Rouge Hwy. Br...	229	Miss. River, B. Rouge	I-10	Fixed	500	172[i]-128[j]
Baton Rouge Railroad & Hwy. Br...........	234	Miss. River, B. Rouge	U.S. Hwy. 190 & RR. K.C.S.L.	Fixed	748	110[i]-65[j]
Paris Rd. Hwy. Br.....	69	Intracoastal WW/M.R.-G.O.	State Hwy. 47			
Foley Avenue Br.......	18	Sabine-Neches Can.,Tex.	Highway	Fixed	664	138
Rainbow Br............	29	Neches River, Tex.	State Hwy. 87	Fixed	600	172
Kansas City Southern Railroad Br.........	47	Neches River, Tex.	K.C.S. RR.	Vert. lift	200	145[h]
Bay Town Tunnel.......	28	Houston Ship Ch., Tex.	Hwy.	--		
Outer Belt Freeway Br.	40	Houston Ship Ch., Tex.	Hwy.	Fixed		
Washburn Tunnel, Pasadena............	44	Houston Ship Ch., Tex.	Hwy.	--		
Corpus Christi Harbor Br..................	23	Corpus Christi Ship Channel, Tex.	U.S. Hwy. 181	Fixed	300-400	138-116
Upper Harbor Br.......	26	Tule Lake Ch., C.C.	Hwy. and RR.	Vert. lift	300	138

a/ At mean high water.
b/ At the center.
c/ At the side fenders.
d/ In closed position.
e/ The twin tunnel is planned 540 feet to the south.
f/ At west edge of channel.
g/ At the edges.
h/ In raised position.
i/ Average low water plane.
j/ 1927 high water.

The Cochrane Bridge does not influence the movements of ocean vessels carrying study commodities. However, it could restrict port expansions to the north.

The L&N and Terminal Railroad Bridges influence all movements to the Industrial Canal (Alabama State Docks Bulk Material Wharf).

New Orleans, Burnside, and Baton Rouge

Five bridges (Greater New Orleans Highway Bridge, Huey P. Long Bridge, Ascension-St. James Bridge, Baton Rouge Highway Bridge, and Baton Rouge Railroad and Highway Bridge) cross the Mississippi River between New Orleans and Baton Rouge. The vertical clearances of the first four bridges differ only slightly. The Baton Rouge Railroad and Highway Bridge is situated to the north of Baton Rouge and only influences traffic to and from one petroleum facility.

The Paris Highway Bridge crosses the traffic moving through the Mississippi River-Gulf Outlet to and from the port of New Orleans bulk facility.

Beaumont

Three bridges (the Foley Avenue Bridge, Rainbow Bridge and Kansas City Southern Railroad Bridge) cross the ship channel to Beaumont. Although the latter bridge at Beaumont does not presently affect the traffic movements of study commodities, it might influence planned port expansions to the north.

Houston

Two tunnels (the Bay Town Tunnel and Washburn Tunnel, Pasadena) cross the Houston Ship Channel, and one bridge, the Outer Belt Freeway Bridge, is presently under construction. The further bridges or tunnels are located above the mouth of the channel, the less they will influence the traffic.

Corpus Christi

The Corpus Christi Harbor Bridge influences traffic to all facilities except four oil facilities and the Reynolds Metals dry bulk facility. The Upper Harbor Bridge influences traffic to two oil terminals and one grain terminal.

Other Ports

There are no bridges across the navigation channels to Theodore Industrial Park, Pascagoula, Port Arthur, Galveston, Texas City, Freeport, Point Comfort, Port Aransas, La Quinta, and Brownsville. However, a bridge across the Bolivar Roads between Galveston and the Bolivar Peninsula is under consideration.

Pipelines and Cables

Numerous pipelines and cables cross the navigation channels. Deepening the channels would require deepening or re-laying many of these, the costs of which would be borne by the various owners.

Levees

The distance between levees could become a confinement for channel widening. This might be a constraint for the Mississippi River-Gulf Outlet if widening is required beyond 750 feet, although its banks are not occupied by industry and the channel lies in easily dredged earth. This could also be the case for the ship channel to Beaumont, which is very narrow in the upper part (approximately 500 to 600 feet wide).

Natural Obstacles

Some hard rock has been encountered during dredging of the navigation channels or in executing core borings in the channels of Tampa. Here limestone was found, ranging in textural composition from soft and amorphous to very hard and crystalline. The fracture pattern is irregular. No rock was found in Mobile, New Orleans, Port Arthur and Beaumont, Texas City, Galveston, Freeport and Corpus Christi.

The Floridan aquifer is the source of all large ground-water supplies in the Tampa Bay area. The limestone forms the principal artesian aquifer.

Tides

Table 5 lists the mean range[1/] of the tides in all major gulf ports. From this tabulation, it is obvious that the tidal variation is insignificant from the standpoint of providing additional water depth in the channels.

1/ Mean range is the difference between mean high water and mean low water.

Table 5. Tidal Range Under Ordinary Conditions
(In feet)

Location	Mean range
Tampa Bay	
Entrance to Tampa Harbor...........	1.3
Port Tampa.......................	1.5
Tampa............................	1.8
Mobile Bay	
Lower end........................	1.2
Upper end........................	1.5
Mississippi River	
Gulf.............................	1.1
New Orleans......................	0.7
Baton Rouge......................	--
Sabine Lake	
Sabine Pass......................	1.5
Port Arthur......................	1.0
Beaumont, Orange.................	0.5
Galveston Bay	
Outer bar........................	1.6
Galveston Harbor.................	1.3
Texas City.......................	1.3
Baytown..........................	1.0
Houston..........................	0.1
Freeport.........................	1.5[a/] - 1.8[b/]
Corpus Christi Bay	
Aransas Pass.....................	1.1[a/] - 1.7[b/]
Corpus Christi...................	1.0
Brownsville	
Brazos Santiago..................	1.4

a/ Corps of Engineers.
b/ Coast and Geodetic Survey.

APPENDIX A. REVIEW OF STUDIES ON CHANNEL DEEPENING AND PORT EXPANSION

1. Port Sutton and Tampa Harbor, Florida, House Document No. 91-150, 91st Congress, 1st Session, September 3, 1969. This document recommends that the maintenance costs of the approximately 5,000-foot-long channel between Hillsborough Bay Channel and Port Sutton would be borne by the Federal Government. This channel was dredged from 30 to 34 feet by local interests. The first cost would be $9,000, of which $7,000 represents aids to navigation and $2,000, financing the land cost; estimated average annual cost is $9,800. The last figure is based on a 50-year economic life and an interest rate of 3 1/4 percent, resulting in $400, and in addition an annual maintenance cost for dredging of $9,400.

The U.S. Department of Interior, Fish and Wildlife Service has no stated objections to the proposed maintenance work.

2. Survey-Review Report on Tampa Harbor, Florida, U.S. Army Engineer District, Jacksonville, Corps of Engineers, Jacksonville, Florida, September 5, 1969. This report considers deepening of the present main and branch channels to 38-, 40-, 42-, and 44-foot water depths. It also considers the following alternative locations of port development:

a. Offshore berth (in excess of 8 to 10 miles offshore)

b. Port Manatee, which is located about 20 miles closer to the bay entrance

c. Port Boca Grande, whose entrance to Charlotte Harbor is about 60 miles south of the Tampa Bay entrance and about 95 miles closer to the Atlantic shipping lanes than the phosphate terminals at Tampa

d. Intraharbor alternatives. The report concludes that deepening the existing channels is economically more attractive than any of the aforementioned alternatives.

The report recommends that all main channels should be deepened 8 feet and widened 100 feet, whereas channels of secondary importance should be deepened only 4 to 6 feet.

The present project was completed in 1965 at a Federal cost of $22.4 million of new work and $5.4 million of maintenance. In addition, $2.8 million was spent on new work from public works funds, emergency relief funds, and contributed funds. The average annual maintenance cost in the period 1963-68 was $282,000.

The Big Bend, about 7 miles south of Port Sutton, a new terminal and industrial park, is now under development by the Tampa Electric Company and other private interests. New phosphate handling terminals were recently built between Port Sutton and East Bay at a cost of approximately $30 million. These new terminal developments provide a greater centralization of terminals than has existed heretofore. Nearly 80 percent of deep-draft cargo tonnage will be concentrated in the areas adjacent to Hooker Point, East Bay, and Port Sutton. Present investment in marine terminals and industries at Tampa is estimated to total in excess of $250 million. New installations now in progress or recently completed will represent an additional investment of more than $350 million.

In this report, an under-keel clearance of 4 feet allowing for vessel squat, wind and wave action has been used. However, although the existing project depth is 34 feet and the draft of the vessel should not be in excess of 30 feet, vessels ranging in a fully loaded draft between 40 and 48 feet are already calling. Paragraph 48 states that "there is no basis to expect that tankers in excess of 48,000 DWT would be used for petroleum deliveries to Tampa, since the economy of this class of tankers is sufficiently attractive to warrant their use of these movements."

The estimated first cost to deepen the channels to indicated depths is approximately $71 million. The estimated annual maintenance cost would be $200,000 in addition to amounts presently required.

First cost is based on an average dredging cost per cubic yard of $.80 for the main channels, $1.00 for Hillsborough Bay Cut D Channel, $1.70 for Sparkman Channel, $2.30 for Ybor Channel, and $.90 for Port Tampa Channel and Basin. The estimated annual dredging costs for the above-mentioned channels are $192,000 for the main channels and $2,000 for each of the remaining channels. Of the total cost involved, 99.4 percent is Federal and 0.6 percent is non-Federal cost.

3. Tampa Harbor, Florida, House Document No. 91-401, 91st Congress, 2d Session, October 12, 1970. This House Document includes comments of the Board of Engineers for Rivers and Harbors, of the Office of Management and Budget, and of the Department of Natural Resources of the State of Florida on report no. 2 above.

The Office of Management and Budget notes that the recommended project includes 5 feet of additional depth for "safety and ease of navigation." It states that it has no basis for objecting to such clearance, noting that 3 feet is presently provided for the existing channel depths, with a minimum reporting of vessel damage. The office states that it understands that the 5-foot clearance is mainly a value judgment based on minimum engineering and economic analysis and notes that the additional 2 feet will increase the project cost an estimated $30 million. The office states that the Corps of Engineers should determine more accurately the necessary requirements for navigational clearance before funds of this magnitude are expended.

The comments of state and Federal agencies pertaining to dredging, spoil placement, pollution control, protection and improvement of marine and fresh water fish and wildlife resources, and other ecological considerations relating to modifications of Tampa Harbor are contained in Appendix D of the project report. Those comments with which the Department of Natural Resources of the State of Florida is in agreement are not unfavorable to the project.

The Corps of Engineers, therefore, has the obligation, with respect to further port improvements of Tampa Harbor, to

a. Justify the additional $30 million required for the additional 2 feet of under-keel clearance of vessels

b. Execute an environmental study showing the impact of former spoil areas on the environment.

In addition the Corps of Engineers was requested to present data on an offshore location more detailed than presented in report no. 2. Funds have not yet been appropriated to commence work on it.

The Board of Engineers for Rivers and Harbors notes that "the recommended project depth has been formulated with an allowance for the design vessel of 4 feet at mean high water to take care of vessel trim, squat, and clearance under the keel. This allows about 3 feet at mean low water. The Board believes that an allowance of at least 5 feet at mean low water is necessary for the safety and ease of navigation. Consequently, the Board concludes that a depth of 46 feet should be provided across Egmont Bar; channels 44 feet deep should be provided in the main channels in lieu of 42 feet; channels 42 feet deep should be provided in Hillsborough Cut D, Sparkman, and Port Tampa Channels; and a channel 40 feet deep should be provided in Ybor Channel. The total estimated first cost of this plan is $102,800,000, of which $101,920,000 is the Federal cost, including $860,000 for navigation aids." The total cost figure of $102.8 million was later re-estimated at $112 million. The estimated construction time is 10 years.

Two dredgers would execute the works, with a small dredge preceding a larger dredge. The small one would build up a containment dike parallel to the channel. A 30-inch dredge with a 1-mile-long floating pipeline would follow the small one and construct the channel, dumping the dredged material behind the dikes. The estimated capacity of the 30-inch dredge is 1 million cubic yards per month, resulting in a cost of $.55 per cubic yard. The estimate was supervised by a Dutch dredging expert. The material dredged would be clay, sand, shells and limestone.

Dredging cost at Port Manatee was estimated at $.20 per cubic yard. Dredging cost at Port Sutton was estimated at $.50 per cubic yard, including removal of some limestone.

4. Mobile Harbor, Alabama (Theodore Ship Channel), House Document No. 91-335, 91st Congress, 2d Session, May 6, 1970. The plan recommended in this document provides for an access channel 40 feet deep, 400 feet wide, and 5.3 miles long from the Mobile Ship Channel to the western shore of Mobile Bay, and a 40-foot-deep and 300-foot-wide land-cut channel 1.9 miles long to Theodore Industrial Park, with anchorage and turning basins. Some consideration was given to an alternative plan which would provide for an access channel the same as recommended but extending only to a turning basin near the shoreline, where port facilities would be constructed on land created by material dredged from the channel. This alternative would not include the recommended land-cut channel to the industrial park.

Both the recommended and alternative projects' total estimated costs are about the same, with the Federal share of the cost substantially greater in the recommended plan. The land-cut channel portion of the recommended plan, which maximizes net benefits, would eliminate double handling and transfer of commodities to and from a big iron plant at the industrial park.

In view of the dependency of this portion of the project upon commerce from a single industry, the Bureau of the Budget suggests that further consideration should be given to the alternative plan during preconstruction planning of the project, if authorized.

The comments of the Department of the Interior include additional recommendations with respect to the impact of this project on the environment. The additional recommendations include:

a. Development of a model of Mobile Harbor enabling the study of the impacts of the project on fresh-water flows and existing tidal current patterns of the harbor

b. The location of spoil sites as feasible on upland areas not valuable as nursery areas for fish and wildlife

c. Compilation of a comprehensive plan of waste water collections, treatment, and disposal to be developed prior to construction.

The Department of Health, Education and Welfare comments that the detrimental effect of the proposed project on the shellfish harvesting industry is expected to be minimal.

The first cost of the project was estimated at $9,164,000, of which $7.9 million is Federal cost and $1.3 million is non-Federal cost. The estimated annual operation and maintenance cost is $252,000, of which $10,000 is a non-Federal cost. The total cost to the Coast Guard for new installations would be $300,000, and an annual maintenance cost of $12,000 would be incurred in addition to the above-mentioned figures.

Work on the latest modification of Mobile Harbor was completed in July 1965. As of June 30, 1968, total cost for the existing and prior projects was $32,139,000, of which $14,489,000 was for new work and $17,650,000 for maintenance. Maintenance during the last 5 years averaged $605,000 annually. During a portion of this period, the channel was maintained only to a depth of 36 feet. Maintenance of the 40 foot project averaged about $810,000 annually.

The State Docks Department has planned the construction of a modern public bulk material handling facility in the industrial park. The new plant reportedly will have an initial unloading capacity of 2,000 tons per hour. It will serve the iron ore reduction plant now under construction and will supplement the existing bulk handling plant on Mobile River in importing and distributing iron ore to steel mills located principally at Birmingham and Gadsden. Private terminals will be constructed by the Alabama Refining Company for the handling of inbound crude oil and outbound products, and by McWayne Cast Iron Company for unloading oyster shell and coal and for loading pig iron. The prospective commerce of this industrial plant is mainly iron ore and secondary crude oil, pig iron, and petroleum products.

The two alternative plans considered in this document deal with four different water depths: 38, 40, 42, and 45 feet.

5. Review of Reports on Sabine-Neches Waterway, Texas, U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas, March 1962, Revised May 18, 1962. This report requests deepening of the former 36-foot channels to Port Arthur and Beaumont and the existing 30-foot Sabine River Channel to Orange to a depth of 40 feet. The 4-foot deepening of the channels serving Port Arthur and Beaumont was authorized, but the 10-foot deepening of the channel to Orange has not yet been authorized. The activities of the harbor of Orange are primarily related to chemical and shipbuilding industries, with some shipments of agricultural products.

The unit cost used for dredging ranges from $0.14 to $0.35 per cubic yard, based on 1962 levels. No borings or soil data are presented.

6. Review of Reports on Galveston Harbor and Channel, Texas (Galveston Channel 40-foot project), U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas, April 10, 1970. This report recommends deepening of the existing 36-foot channel by 4 feet. The estimated first cost is $1,600,000. The length of the 36-foot channel is 20,700 feet, or 4.1 statute miles. The results of 19 borings to a depth of 50 feet are presented. The unit cost used for dredging is $0.35.

7. Review of Reports on Texas City Channel, Texas (Industrial Canal), U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas, February 18, 1970. This report deals with the industrial barge canal which is located southwest of the Texas City Channel Turning Basin. The Federal project provides for a canal 16 feet deep, 125 feet wide, and 1.6 miles long (between mile 7.5 and mile 9.2). In the past, local interests dredged this canal to a depth of 34 feet, a width of 200 feet, and a length of 9,908 feet (1.9 miles). This report recommends the channel dimensions to be 40 feet deep and 250 to 350 feet wide.

In addition to the deepening and widening of the Industrial Canal, the report also recommends widening of the Texas City Channel (figure 13) Turning Basin from 1,000 to 1,200 feet, and widening of the Texas City Channel from 400 to 600 feet from mile 0.0 to mile 1.8 and to 500 feet from mile 1.8 to mile 6.7.

The estimated first cost to the United States of all recommended new work, exclusive of navigation aids, is $1,625,000, excluding $60,000 that has already been expended for surveys and studies. The estimated increase in annual maintenance cost is $37,300, exclusive of navigation aids.

The report considers three plans. Plan I provides a depth of 34 feet and a width of 200 to 250 feet; Plan II, a depth of 40 feet and a width of 250 to 350 feet; and Plan III, a depth of 40 feet and a width of 300 to 400 feet, allowing two-way traffic.

8. Review of Reports on Freeport Harbor, Texas (45-foot project), U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas, April 28, 1970. In general this report recommends deepening of the existing channel by 9 feet, and widening by 100 to 200 feet. This means that an entrance channel 47 feet deep and 400 feet wide is recommended, and the jetty and Brazos Port Channel are recommended to be 45 feet deep and 400 feet wide. Also, widening and deepening of turning basins is recommended. The estimated first cost to the United States of all recommended new work, exclusive of navigation aids, is $13,545,000, exclusive of $140,000 expended for surveys and studies. The estimated increase in the annual maintenance and operation costs is $192,400, exclusive of navigation aids.

There are no bridges across the various channels of the Federal navigation project.

The total cost of the existing project to June 30, 1969, was $11,202,335. The maintenance cost of the channels during the period 1965-69 averaged $450,000.

9. Review of Reports on Port Aransas-Corpus Christi Waterway, Texas (45-foot project), U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas, April 4, 1968. This document requests 5-foot deepening of the channel to Corpus Christi, 9-foot deepening of the La Quinta Channel, and some widening and extending of other channels.

The estimated total project costs, exclusive of navigation aids, is $20,682,000, of which approximately 80 percent is Federal cost. The annual maintenance is estimated to increase by $150,800.

The total cost of constructing the existing project to June 30, 1967, was $26,136,646. The total maintenance cost of the existing project to June 30, 1967, was $25,008,587. Annual maintenance cost for the project currently is estimated at $1,100,000 (April 1968), exclusive of jetty maintenance cost.

The report anticipates that petroleum and petroleum products will continue to be the principal commodities moved over the waterway in the future years. Furthermore, it expects the volume of grain to increase to over 5 million tons per annum (1975). Also, bauxite imports and movement of chemicals are anticipated in the future trade.

In lieu of future deepening the report considers lighterage of vessels as well as offshore structures.

With respect to these alternatives it observed the following:

> The alternatives considered to some degree, at least, included lightering, a pipeline system to other Texas petroleum ports, a common loading terminal about 6-1/2 miles offshore in the Gulf of Mexico near Aransas Pass, and a common loading terminal just inshore from Aransas Pass near Harbor Island. The common loading terminals would include necessary pumping facilities and pipeline connections to the existing refineries at Corpus Christi and to the crude oil shipping terminals at Ingleside and Harbor Island. The inshore common loading terminal would include a large amount of storage facilities at Harbor Island.
>
> Other than lightering, no true alternate to waterway improvements was found, since the prospective commerce in grain, ores, and chemicals is not adaptable to movement through common loading and terminal facilities. Lightering as an alternate was not investigated in detail, since it is known that this is a costly operation and there are many practical disadvantages to handling a variety of products in this manner. The construction of pipelines to other Texas ports was not investigated in detail as an alternate, since extensive changes in marketing relationships would be required and a cursory examination

indicated prohibitive cost levels. The offshore and inshore common loading terminals were investigated in some detail. Between these two, it was found that the inshore terminal at Harbor Island, with channel improvement from the gulf to this point, would be less costly and much more practicable from a service standpoint. This facility was found, however, to have estimated first costs approximately twice as large as the estimated first costs for channel improvements and estimated annual charges over 3 times greater. In addition to the unfavorable cost comparison, the facility would satisfy only a portion of the petroleum commerce needs, and the requirements of prospective commerce in grain, ores, and chemicals would remain unsatisfied.

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ANNEX B-4. RECONNAISSANCE SURVEY OF THE SOUTH PACIFIC COAST

CONTENTS

I. DESCRIPTION OF COAST AND PORT LOCATIONS

Most of the California coast is mountainous, particularly along the central and northern sections. Although the coast is characterized by much irregularity, the only large bay and river system is at San Francisco. There are a number of smaller bays, but of these only San Diego is both a naturally enclosed harbor and a well-developed port.

There are only three developed general port areas of economic significance on the coast of California: San Diego, the twin ports of Los Angeles and Long Beach, and the ports in the San Francisco Bay area. The location of these port areas and of other less important ports on the coast are shown in figures 1, 2, and 3.

The port of San Diego is situated on San Diego Bay about 96 miles southeast of Los Angeles and 10 miles north of the border between the United States and Mexico. The bay is about 15 miles long and from 1/4 to 2 1/2 miles wide.

The ports of Los Angeles and Long Beach are situated on San Pedro Bay, about 23 miles from downtown Los Angeles and 1 mile from downtown Long Beach.

The San Francisco Bay area is about 423 miles north of Los Angeles. The bay area, entered through the Golden Gate, consists of several bodies of water, including San Francisco Bay, San Pablo Bay, Carquinez Strait, Suisun Bay, and the Sacramento and San Joaquin Rivers. As shown in figure 3, a number of individual ports are located along these several bodies of water.

FIGURE I. LOCATION OF PORTS, SOUTHERN AND CENTRAL CALIFORNIA

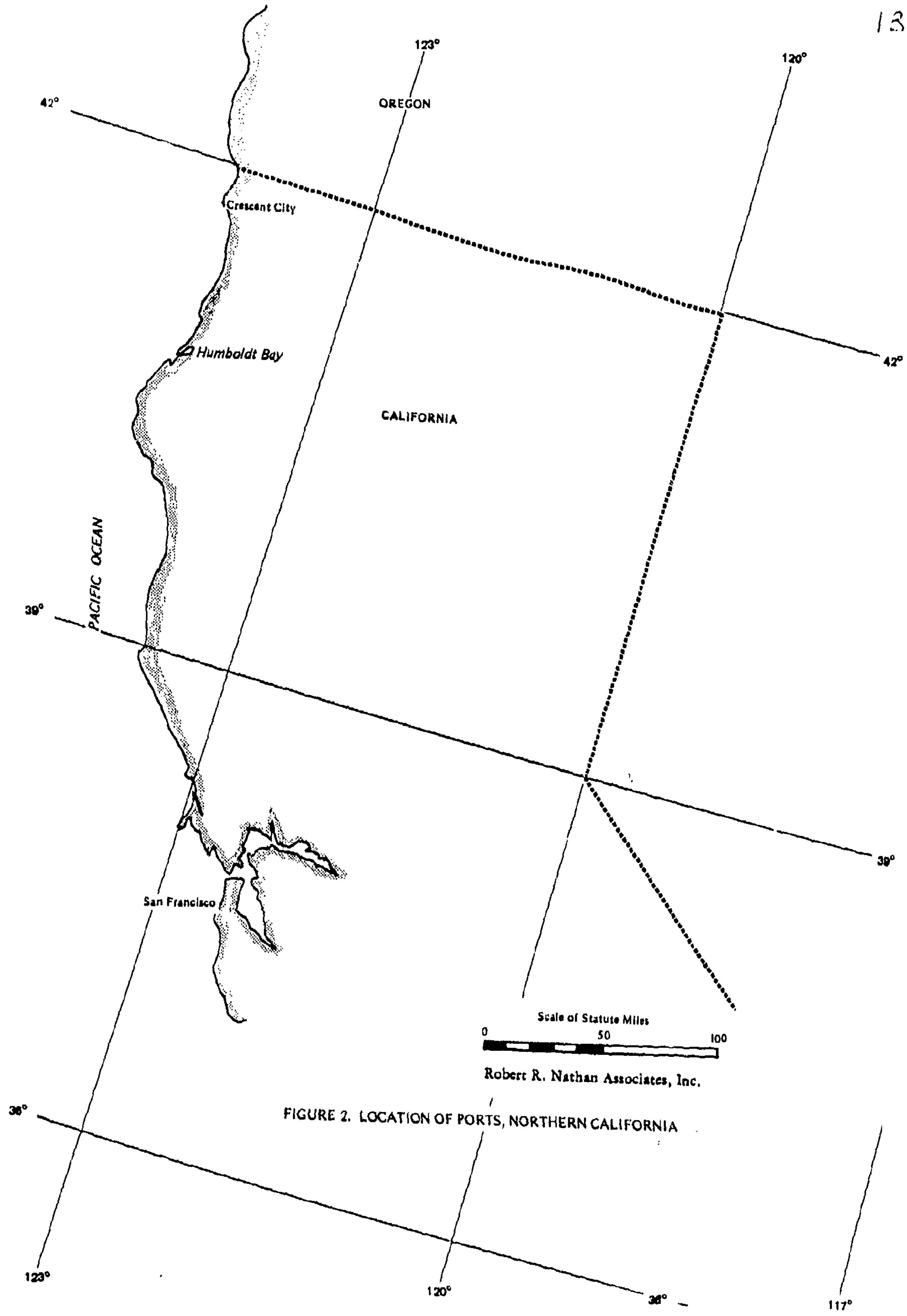


FIGURE 2. LOCATION OF PORTS, NORTHERN CALIFORNIA

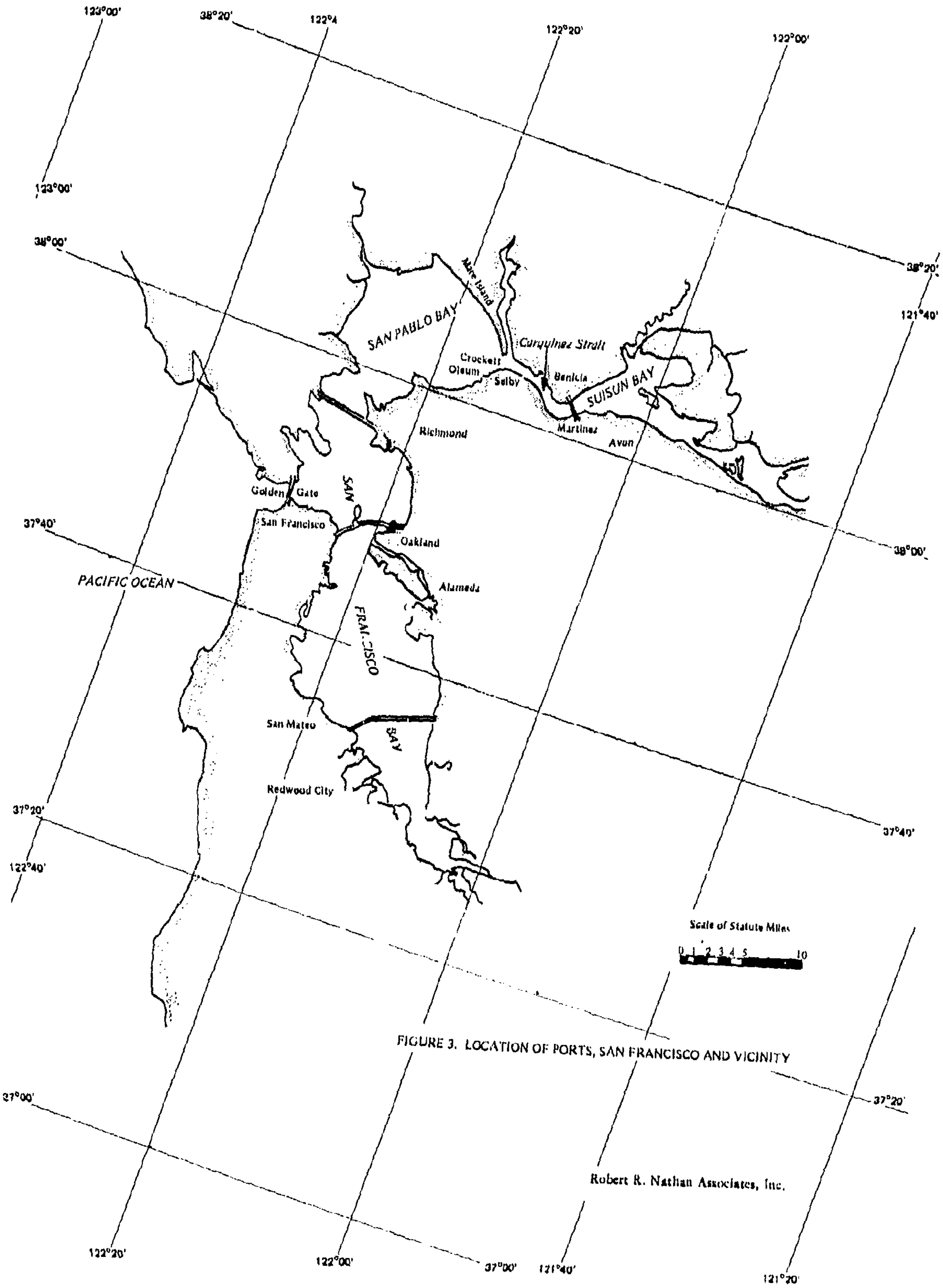


FIGURE 3. LOCATION OF PORTS, SAN FRANCISCO AND VICINITY

Robert R. Nathan Associates, Inc.

Figure 4 shows that in general the 60-, 90-, and 120-foot depth contour lines are very close to the shore. At many stretches they are only 1 or 2 miles off the coast, and are never more than 5 miles distant except at the latitude of San Francisco Bay. Here a semicircular bar creates the only shallow spot in the entire offshore area, and the 60-, 90-, and 120-foot contour lines are respectively 3, 5 1/2, and 8 miles off the coast. At Hueneme and Moss Landing, submarine canyons exist in the offshore area, resulting in deep water close to the shore.

142.

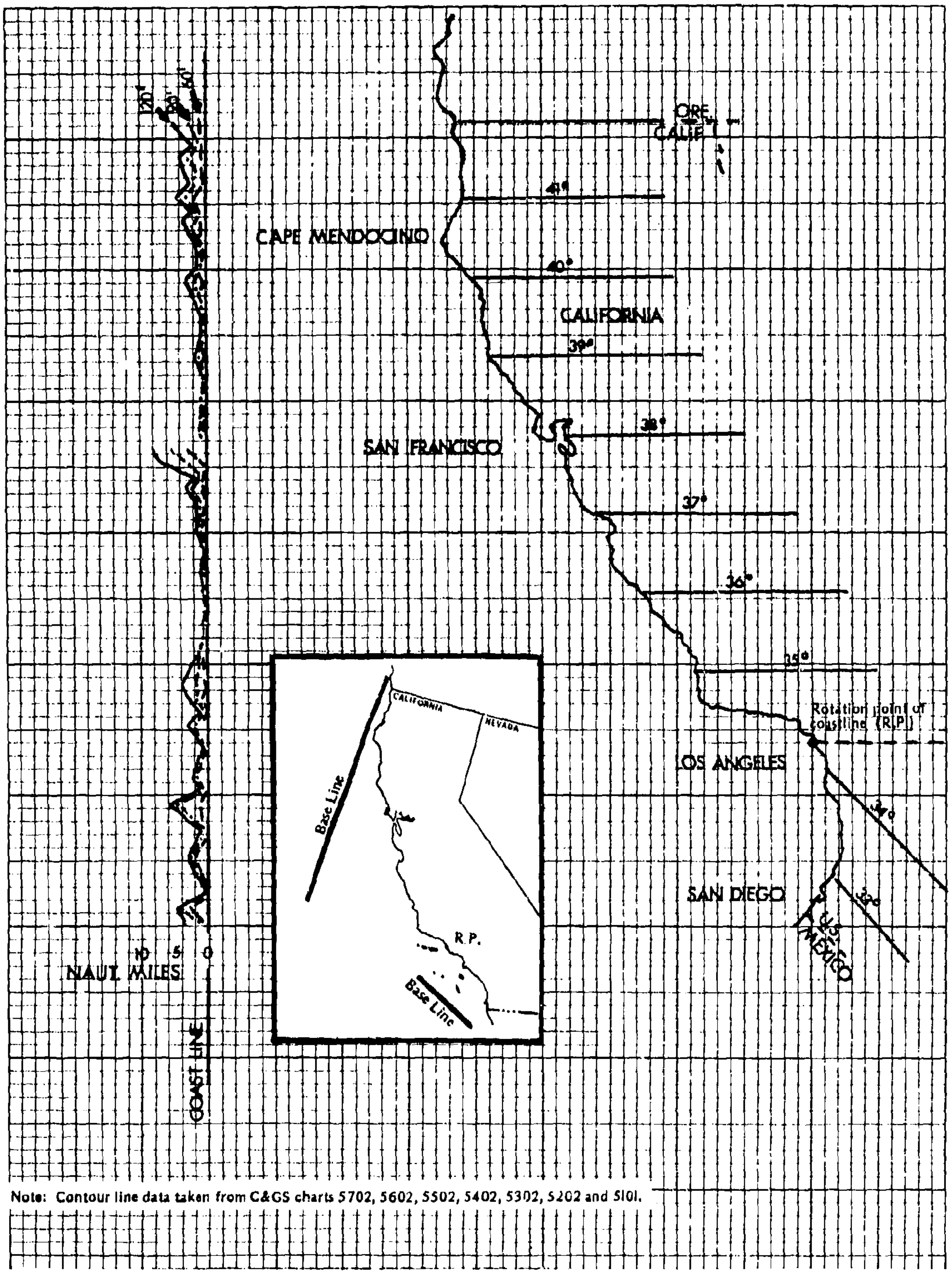


FIGURE 4. DISTANCES BETWEEN COASTLINE AND 60-, 90-, AND 120-FOOT CONTOUR LINES, SOUTH PACIFIC COAST

II. FOREIGN AND COASTAL MOVEMENTS, BY PORT, OF THE SIX STUDY COMMODITIES

Table 1 shows the foreign import and export movements of our deepwater port study bulk commodities through ports on the south Pacific coast for 1968 and 1969. Table 2 shows similar data for coastal movements for 1969 and 1970. Total foreign exports of study commodities were 0.8 million tons in 1968 and 1.1 million tons in 1969, of which over 90 percent was grain that moved principally through Long Beach and Sacramento. Total imports of commodities in 1969 were 10.3 million tons, of which 82 percent was crude oil and 17 percent was petroleum products, moving mainly through Los Angeles, Long Beach, and the San Francisco Bay ports. Other than grain, the largest dry bulk movement was about 100,000 tons of coal exports through Los Angeles and Long Beach in 1969.1/

Coastal movements of study bulk commodities are over 99 percent crude petroleum and petroleum products, with the volume of both receipts and shipments being substantial. Most of these movements are believed to be intracoastal, but some originate or are destined for other coastal areas, including the gulf coast, Alaska, and Hawaii. In 1970 total receipts and shipments of crude petroleum were 18.4 and 1.5 million tons, respectively, and of petroleum products, 6.8 and 13.7 million tons, respectively. Consistent with the concentration of both refinery capacity and market demand in the San Francisco and Los Angeles areas, the bulk of both foreign

1/ There were also exports of 3 million tons of iron ore through Los Angeles and Long Beach.

Table 1. U.S. Waterborne Exports of Domestic and Foreign Merchandise and General Imports of Selected Bulk Commodities, South Pacific Coast (California), 1968 and 1969

(In thousands of short tons)

Port/area	Total all study comm.		Exports: Total grains a/		Exports: Coal		Exports: Phosphate rock		Exports: Total		Imports: Crude oil		Imports: Pet. products b/		Imports: Iron ore		Imports: Bauxite		Imports: Alumina		Imports: Total	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Southern California																						
San Diego..........	28	45	9	8	--	--	--	--	9	8	19	--	--	37	--	--	--	--	--	--	19	37
Long Beach..........	1,529	2,647	70	369	8	48	c/	--	78	417	981	1,774	465	457	--	--	6	--	--	--	1,452	2,231
Los Angeles.........	2,852	3,369	13	9	c/	46	3	c/	16	55	2,096	2,431	707	882	33	--	--	--	--	--	2,836	3,313
El Segundo..........	699	634	--	--	--	--	--	--	--	--	699	617	--	17	--	--	--	--	--	--	699	634
Total..............	5,108	6,695	92	386	8	94	3	c/	103	480	3,795	4,822	1,172	1,393	33	--	6	--	--	--	5,006	6,215
Northern California																						
Monterey............	c/	--	c/	--	--	--	--	--	c/	--	--	--	--	--	--	--	--	--	--	--	--	--
Redwood City........	108	85	--	--	--	--	--	--	--	--	--	--	108	85	--	--	--	--	--	--	108	85
San Francisco.......	44	689	42	15	--	1	c/	--	42	16	c/	667	c/	6	c/	--	2	--	--	--	2	673
Alameda.............	2	1	1	c/	--	--	c/	c/	1	c/	c/	1	--	--	--	--	--	--	--	--	c/	1
Oakland.............	2	3	2	3	--	--	c/	c/	2	3	c/	--	--	--	--	--	--	--	--	--	c/	--
Sacramento..........	540	455	540	455	--	--	--	--	540	455	--	--	--	--	--	--	--	--	--	--	--	--
San Pablo Bay.......	1,261	839	--	--	--	--	--	--	--	--	1,261	833	--	6	--	--	--	--	--	--	1,261	839
Martinez............	1,085	812	--	--	--	--	--	--	--	--	836	560	250	252	--	--	--	--	--	--	1,086	812
Crockett............	20	--	--	--	--	--	--	--	--	--	20	--	--	--	--	--	--	--	--	--	20	--
Suisun Bay..........	--	80	--	--	--	--	--	--	--	--	--	80	--	--	--	--	--	--	--	--	--	80
Selby...............	--	35	--	--	--	--	--	--	--	--	--	35	--	--	--	--	--	--	--	--	--	35
Carquinez Strait....	69	178	--	--	--	--	--	--	--	--	26	178	43	--	--	--	--	--	--	--	69	178
Richmond............	1,044	1,332	3	c/	--	--	--	--	3	c/	984	1,227	43	74	--	--	14	31	--	--	1,041	1,332
Stockton............	117	111	117	111	--	--	--	--	117	111	--	--	--	--	--	--	--	--	--	--	--	--
Eureka..............	--	54	--	--	--	--	--	--	--	--	--	54	--	--	--	--	--	--	--	--	--	54
Total..............	4,292	4,674	705	584	--	1	c/	c/	705	585	3,127	3,535	444	423	c/	--	16	31	--	--	3,587	4,089
Total south Pacific coast............	9,400	11,369	797	970	8	95	3	c/	808	1,065	6,922	8,457	1,616	1,816	33	--	22	31	--	--	8,593	10,304

Note: Individual items may not add to totals due to rounding.
a/ Includes food grains (wheat, rice, rye), feed grains (barley, corn, oats, cereals, n.e.c.), and soybeans and mill products.
b/ Includes gasoline, jet fuel and kerosene, distillate fuel oils, and residual fuel oils.
c/ Less than 500 short tons.

Source: U.S. Department of Commerce, Bureau of the Census, U.S. Waterborne Exports of Domestic and Foreign Merchandise, SA-705, and U.S. Waterborne General Imports of Merchandise, SA-305, 1968 and 1969.

Table 2. U.S. Domestic Waterborne Coastal Receipts and Shipments of Selected Bulk Commodities, South Pacific Coast (California), 1969 and 1970
(In thousands of short tons)

Port area	Total, all study comm.				Crude oil				Petroleum[a/] products				Dry bulk commodities[b/]					
	1969		1970		1969		1970		1969		1970		1969			1970		
	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Commodity	Rect.	Shipt.	Commod
Southern California																		
San Diego Harbor.....	504	--	621	5	--	--	--	--	504	--	621	5	--	--	--	--	--	--
Long Beach Harbor....	4,047	3,204	4,745	2,947	3,623	952	4,310	1,170	393	2,252	395	1,776	20 11	-- --	Grains[c/] Phos. rock	-- 40	-- 1	-- Grains[c/]
Los Angeles Harbor...	4,527	4,973	4,857	5,099	2,505	120	2,433	240	2,022	4,853	2,424	4,859	d/	d/	Grains[c/]	--	d/	Grains[c/]
Total...............	9,078	8,177	10,223	8,051	6,128	1,072	6,743	1,410	2,919	7,105	3,440	6,640	31	d/	--	40	1	--
Northern California																		
Suisun Bay Channel...	925	475	685	421	864	--	618	--	61	475	67	421	--	--	--	--	--	--
Sacramento River[e/]...	--	127	--	122	-	--	--	--	--	6	--	--	--	121	Grains[c/]	--	122	Grains[c/]
San Joaquin River[e/]..	226	--	201	9	--	--	--	--	111	--	64	9	115	--	Phos. rock	137	--	Phos. rock
San Francisco Harbor.	--	55	--	4	--	--	--	--	--	54	--	4	--	1	Grains[c/]	--	--	--
Redwood City Harbor..	41	9	11	--	--	--	--	--	41	9	11	--	--	--	--	--	--	--
Oakland Harbor.......	145	263	39	258	--	--	--	--	145	213	39	196	d/	50	Grains[c/]	d/	62	Grains[c/]
Richmond Harbor......	7,333	3,111	6,138	2,588	4,416	73	4,330	21	2,917	3,038	1,808	2,567	--	--	--	--	--	--
San Pablo Bay........	1,628	1,449	1,680	1,820	1,441	--	1,399	--	187	1,449	281	1,820	--	--	--	--	--	--
Carquinez Strait.....	4,686	1,313	5,895	2,067	4,161	--	5,348	26	525	1,313	547	2,041	--	--	--	--	--	--
Humboldt Harbor......	296	--	298	d/	--	--	--	--	296	--	298	d/	--	--	--	--	--	--
Crescent City Harbor.	219	--	250	--	--	--	--	--	219	--	250	--	--	--	--	--	--	--
Total...............	15,499	6,802	15,197	7,289	10,882	73	11,695	47	4,502	6,557	3,365	7,058	115	172	--	137	184	--
Total south Pacific coast...............	24,577	14,979	25,420	15,340	17,010	1,145	18,438	1,457	7,421	13,662	6,805	13,698	146	172	--	177	185	--

a/ Includes 2911, gasoline; 2912, jet fuel; 2913, kerosene; 2914, distillate fuel oil; 2915, residual fuel oil.
b/ Includes grains; 1011, iron ore and concentrates; 1051, bauxite and other aluminum ores and concentrates; 1121, coal and lignite; and 1471, phosphate rock.
c/ Includes 0102, barley and rye; 0103, corn; 0104, oats; 0105, rice; 0106, sorghum grains; 0107, wheat; 0111, soybeans; 2049, grain mill products, n.e.c.
d/ Less than 500 short tons.
e/ Consolidated report.

Source: U.S. Department of the Army, Corps of Engineers, Waterborne Commerce of the United States, Part IV, "Waterways and Harbors, Pacific Coast, Alaska and Hawaii," 1969 and 1970.

trade and coastal petroleum movements are to and from the ports in the San Francisco Bay area and Long Beach and Los Angeles.

The comparatively small volume of coal and iron ore exports through Los Angeles and Long Beach are destined to Japan. According to information provided by the U.S. supplying company, shipments of both commodities are expected to terminate in the next several years.

In addition to the traffic flows at ports which are shown in table 2, the Corps of Engineers reports a movement of 11.6 million tons of petroleum and petroleum products in 1970 at lesser ports, as shown in table 3. These data could not be incorporated in table 2 because they do not distinguish between foreign and domestic trade or between receipts and shipments. However, it is believed that all these movements are coastal except for the import of some foreign crude petroleum at El Segundo, a refinery location (see table 1).

Table 3. Waterborne Traffic in Crude Petroleum and Major Petroleum Products at Lesser South Pacific Coast Ports

(In thousands of short tons)

Port	Crude petroleum	Petroleum products
Carpenteria.........	492.2	128.1
El Segundo..........	2,028.4	958.3
Estero Bay..........	3,634.1	165.6
San Luis Obispo.....	899.2	573.0
Ventura Harbor......	2,770.0	13.0
Total.............	9,803.9	1,838.0

Source: U.S. Department of the Army, Corps of Engineers, Waterborne Commerce of the United States, Part IV, "Waterways and Harbors, Pacific Coast, Alaska and Hawaii," 1970.

III. MAJOR HARBORS AND CHANNELS

Only the channels leading to the crude oil and petroleum handling berths of the four major ports or port areas will be reviewed. These ports or port areas are Long Beach, Los Angeles, Richmond, and San Pablo Bay/Carquinez Strait.

Table 4 shows the project dimensions of the major channels being considered. In both Long Beach and Los Angeles, local interests have dredged entrance and main channels to considerably greater than authorized project depths. Authorized depths for the Long Beach Channel, the entrance channel, and the Inner Harbor turning basin are all 35 feet, whereas actual depths are 62 feet, 55 feet, and 50 feet, respectively. In Los Angeles, the actual depth of both the entrance channel and turning basin is 47 feet, whereas the authorized depth is 40 feet in each instance. On the other hand, several of the main channels leading to the port of Richmond in the San Francisco Bay area are below the authorized depths.

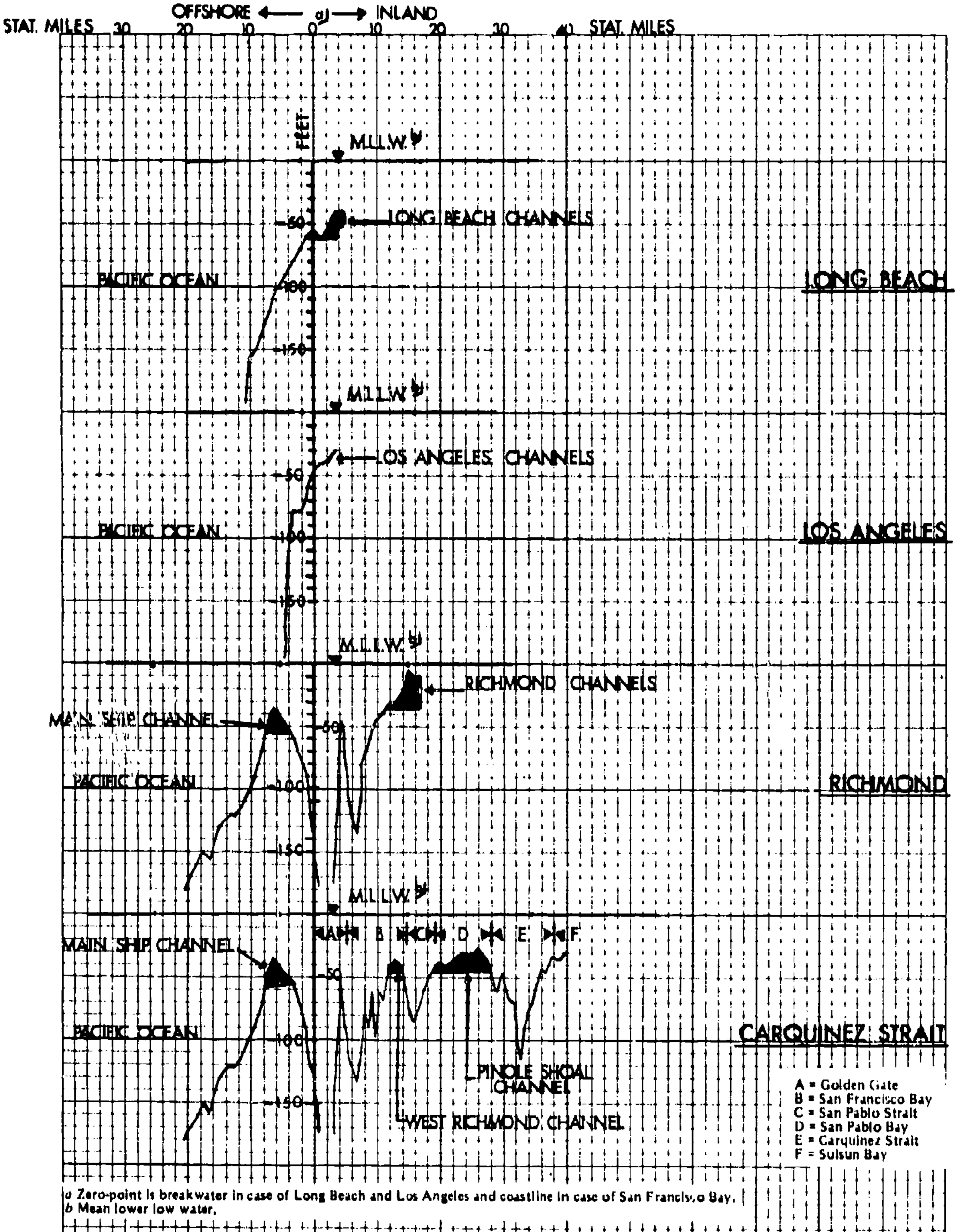
Figure 5 presents longitudinal cross sections of the navigation channels leading to the four major harbors on the south Pacific coast. They graphically depict the steep decline in the channel depths offshore, with the exception of the shallow bar off the Golden Gate entrance.

Figure 6 presents the alignment of the channels to the harbors of Long Beach and Los Angeles. Figure 7 presents the alignment of the channels leading to the harbor of Richmond and those along the banks of San

Table 4. Project Dimensions of Major Channels, South Pacific Coast Ports

Name of channel	Depth	Width	Length		Location
	Feet		Naut. miles	Stat. miles	Stat. miles
Long Beach					
Long Beach Channel	35[a]	700	2.2	2.5	0.0-2.5
Long Beach Entrance Channel	35[a]	300-500	1.1	1.3	2.5-3.8
Turning Basin Inner Harbor	35[b]	1,100	0.3	0.3	3.8-4.1
Cerritos Channel	35[c]	400	1.1	1.3	4.1-5.4
Los Angeles					
Los Angeles Entrance Channel	40[d]	1,000	0.9	1.0	0.0-1.0
Los Angeles Turning Basin	40[e]	1,500	0.6	0.7	1.0-1.7
Los Angeles Main Channel	35	1,000	2.1	2.4	1.0-3.4
San Francisco Bay					
Main Ship Channel	55[f]	2,000	2.1	2.4	(6.6)-(4.2)[g]
Richmond Channels:					
Southampton Shoal	35	600	1.9	2.2	11.6-13.8
Long Wharf Manufacturing Area	45[h]	600-2,500	0.6	0.7	13.8-14.5
Inner Harbor Entrance	35	600	1.4	1.6	14.5-16.1
Inner Harbor Channel	35	500-1,150	2.0	2.3	16.1-18.4
Santa Fe Channel	30	200	0.3	0.4	18.4-18.8
West Richmond Channel	45[i]	600	2.2	2.5	12.5-15.0
Pinole Shoal Channel	45[h]	600	9.7	11.1	19.0-30.1

a/ Dredged to 62 feet by local interests.
b/ Dredged to 55 feet by local interests.
c/ Dredged to 50 feet by local interests.
d/ Middle section dredged to 47 feet (width 500 feet) by local interests.
e/ Dredged to 47 feet by local interests.
f/ Presently 50 feet deep.
g/ Figures in parentheses indicate offshore locations.
h/ Presently 35 feet deep.
i/ Present natural depth is 36 feet.



a Zero-point is breakwater in case of Long Beach and Los Angeles and coastline in case of San Francisco Bay.
b Mean lower low water.

FIGURE 5. LONGITUDINAL CROSS SECTIONS OF MAJOR SOUTH PACIFIC COAST CHANNELS

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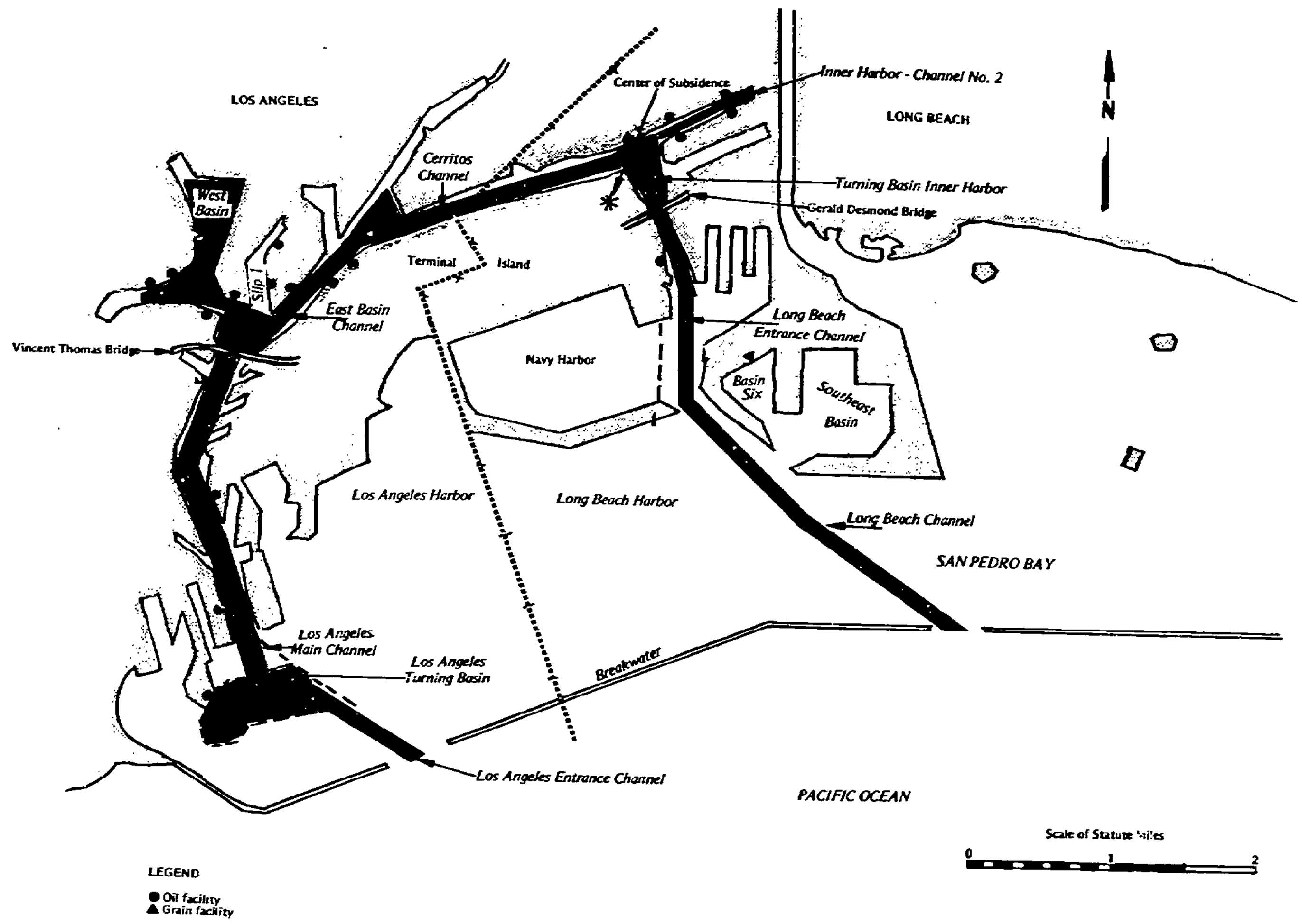

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FIGURE 6. CHANNELS AND BULK HANDLING FACILITIES, LONG BEACH AND LOS ANGELES HARBORS, CALIFORNIA

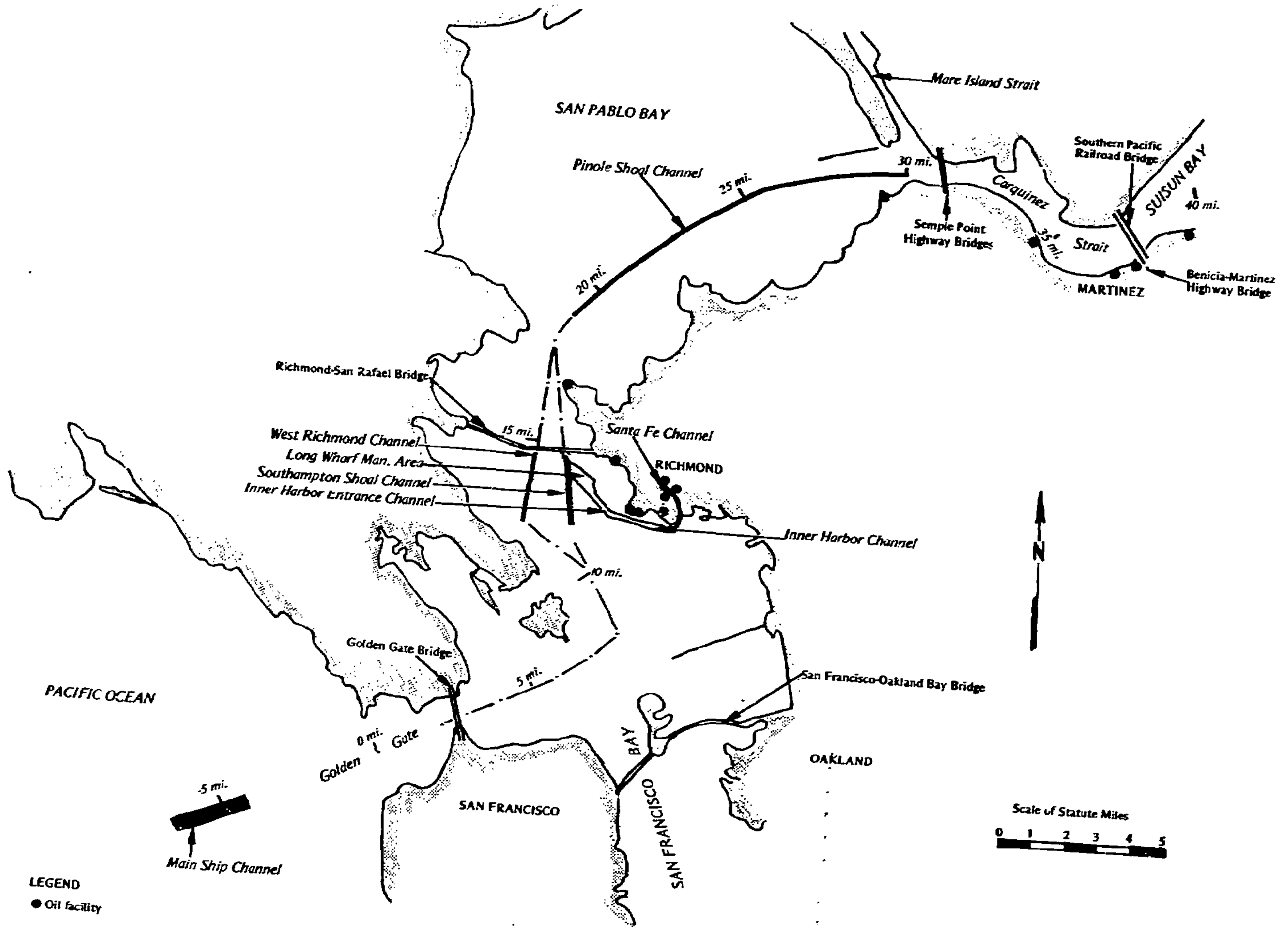

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FIGURE 7. CHANNELS AND BULK HANDLING FACILITIES RICHMOND, SAN PABLO BAY, CARQUINEZ STRAIT AND SUISUN BAY, CALIFORNIA

Pablo Bay (Oleum), Carquinez Strait (Port Costa and Martinez), and Suisun Bay (Avon).

These figures also show the location of petroleum and grain handling facilities.

The following description of the main characteristics of the ports of Los Angeles, Long Beach, San Francisco Bay, Richmond, and San Pablo Bay, Carquinez and Mare Island Straits are from the U.S. Army Corps of Engineers publications, Port Series Part II, No. 28 (Revised 1967), No. 30 (Revised 1962), and No. 31 (Revised 1962).

Los Angeles

Los Angeles Harbor is entirely man-made and is composed of an Outer and an Inner Harbor. The Outer Harbor shoreline consists mainly of two districts, San Pedro and Terminal Island; the Wilmington District borders entirely on the Inner Harbor. Protected water in the Outer Harbor is afforded by two Federal breakwaters with a 2,200-foot-wide entrance. San Pedro Breakwater extends about 0.9 mile in a southeasterly direction from the eastern side of Point Fermin, then turns northeastward for another 0.9 mile to Los Angeles Harbor Light. Middle Breakwater is detached and extends northeastward for 2.1 miles from the Los Angeles entrance, then extends eastward for 1 mile to the Long Beach entrance, which has a width of 1,800 feet.

Long Beach Breakwater, a continuation of the detached breakwater, extends eastward 2.2 miles from the Long Beach entrance.

The Inner Harbor has a total water area of about 1,000 acres and consists of a series of channels and a turning basin, approximately 1,600 feet in diameter, located opposite Smith's Island. From the turning basin, a channel extends to West Basin, the entrance to Northwest and Southwest Slips. North of the turning basin between Mormon and Terminal Islands, the East Basin Channel provides the approach to Slip No. 5 and East Basin. Cerritos Channel extends easterly from East Basin Channel and connects the Inner Harbors of Los Angeles and Long Beach.

Most of the cargo handling and service facilities are concentrated in the Inner Harbor, which is about 3 3/4 miles from the breakwater entrance.

Long Beach

Long Beach Harbor is on the eastern part of San Pedro Bay. The distance between the entrances to Long Beach and Los Angeles Harbors is about 4 miles. Natural protection for San Pedro Bay is provided by the highlands of San Pedro Hills and the island of Santa Catalina, which is about 25 miles distant.

Long Beach Harbor is made up of the Inner, Middle, and Outer Harbors. Cerritos Channel, two dead-end channels, and a turning basin comprise the Inner Harbor. The Middle Harbor area consists of East and West Basins, separated by the Inner Harbor entrance channel and enclosed by a solid-fill mole and the outer extension of Pier A. The distance from the detached breakwater (Long Beach Harbor entrance) to the Inner Harbor turning basin is approximately 4 miles. The Outer Harbor consists of those harbor areas south of the Naval Base Mole and Pier A Extension. Pier F, Pier G, Pier Y, Pier J, and Pier A Extension enclose Basin Six and Southeast Basin. The 700-foot entrance (500-foot channel width) to the Southeast Basin is approximately 1 3/4 miles from the Long Beach Breakwater entrance.

San Francisco

San Francisco is located on the northern portion of a peninsula which separates the southern part of San Francisco Bay from the Pacific Ocean; the city covers the width of the peninsula. The principal waterfront facilities of the port extend from Black Point on the north side around to India Basin on the east side of the peninsula, a distance of nearly 6 1/2 miles. The bay is more properly described as a series of connecting bays and harbors, of which South San Francisco Bay, San Francisco Bay proper, and San Pablo Bay are the largest bodies of water. The entire bay system has an area of about 450 square miles, varying from deep water to tidal flats, with a shoreline of more than 200 miles.

San Francisco Bay proper is of generally deep water with depths up to 216 feet. Entrance to the bay from the Pacific Ocean is through a strait known as the "Golden Gate"; it varies in width from 1 to 3 miles and has maximum depths of almost 400 feet.

Outside the entrance to San Francisco Bay, a semicircular bar extends from a point about 1/2 nautical mile west of Point Bonita to a point approximately 3/4 nautical mile off shore, 3 nautical miles south of Point Lobos. The extreme seaward point of the bar lies about 5 miles south-southwest of Point Bonita. Except for the dredged portion of the Main Ship Channel, depths over the bar range from 31 to 36 feet near the southern end to the shallowest area near the northern end, known as Four Fathom Bank (Potatopatch Shoal), where depths of less than 24 feet exist.

The Golden Gate can be entered through one of 3 channels -- Bonita Channel, parallel to the coast north of Point Bonita; the Main Ship Channel, which crosses the bar from a southwest direction; and the South Channel, parallel to the coast south of Point Lobos. The controlling depths are 39, 49, and 34 feet, respectively. The Main Ship Channel, under improvement by the Federal Government, is the one most frequently used.

Richmond

Richmond Harbor, California, is situated near the northern extremity of San Francisco Bay, on its eastern shore about 10 miles north of Oakland. The port area includes an Outer Harbor approximately 5 miles in length between Point San Pablo and Point Richmond, and an Inner Harbor extending from Point Richmond to and around Point Potrero, and thence to the inner end of Santa Fe Channel at Cutting Boulevard, Richmond, a distance of 3.75 miles. The Outer Harbor faces natural deep water in San Francisco Bay; the Inner Harbor has been dredged from deep water in San Francisco Bay through shallow flats and marshlands. The shore and channel between Point Richmond and Point Potrero are protected by a 10,000-foot training wall extending in a westerly direction from its anchorage on Brooks Island opposite Santa Fe Channel.

Ports on San Pablo Bay and Carquinez and Mare Island Straits

San Pablo Bay connects with the northern extremity of San Francisco Bay at a narrowing between Point San Pedro and Point San Pablo. On the east it connects with Carquinez Strait, and through this connection Suisun Bay and the Sacramento and San Joaquin Rivers are joined with the San Francisco Bay system. Mare Island Strait extends northwesterly from Carquinez Strait from a point near the confluence of the latter with San Pablo Bay. Mare Island Strait is in reality the estuary of the Napa River, a comparatively small stream draining the Napa Valley of the Coast Range Mountains.

The northern part of San Pablo Bay consists of low marshes intersected by numerous sloughs with a large area of shoal water and mudflats that bares at extreme low tides. The southern part is bolder, except for the area between Point San Pablo and Pinole Point, which is low and marshy for about 3 miles. Carquinez Strait is about 6 nautical miles in length; it extends in an easterly direction and connects San Pablo Bay and Suisun Bay. For the first 3.5 miles it is a little less than 1/2 mile in width, then expands to a width of about 1 mile. It is deep throughout, with the exception of a small stretch of flats on the northern shore. Suisun Bay is a broad, shallow body of water with marshy shores and contains numerous marshy islands. Many of these islands have been reclaimed and a number are under cultivation. The Sacramento and San Joaquin Rivers enter Suisun Bay at Collinsville at the eastern end.

The Federal navigation project for a deepwater channel from San Francisco Bay to Stockton, California (John F. Baldwin and Stockton Ship Channels), authorized by the 1965 River and Harbor Act, provides for the deepening of the Richmond Long Wharf maneuvering area to 45 feet and construction of a connecting channel, the West Richmond Channel, 45 feet deep, 600 feet wide and approximately 2.5 miles long through the west navigation opening of the Richmond-San Rafael Bridge. The overall project plan is contained in House Document 208, 89th Congress, 1st Session. Further actions, however, depend on the findings of the so-called "San Francisco Bay Area In-Depth Study," which was authorized pursuant to a resolution adopted by the Committee on Public Works, House of Representatives, on 19 October 1967 (Navigation-Docket No. 1635).

IV. MAJOR TERMINAL FACILITIES

Long Beach

Oil Handling Facilities

Eight wharfs are used for receiving or shipping petroleum products. Six of these handle imports of crude oil for three companies.

Grain Elevators

The city of Long Beach, Harbor Department, owns a waterside grain elevator on the Basin Six side of Pier A. This elevator, operated by Koppel Bulk Terminal Company, consists of 49 concrete silos and 23 interstices with a total capacity of 1,810,000 bushels. The elevator is equipped to receive and ship grain via rail cars, trucks, and vessels. The combined loading rate of the spouts is 43,000 bushels of grain per hour.

Los Angeles

Oil Handling Facilities

Twenty-six waterfront facilities are equipped to handle petroleum products. Six of the oil companies operating waterfront facilities have pipeline connections between storage tanks at their waterfront locations and their inland refineries in the Los Angeles area.

Grain Elevators

The Los Angeles Harbor Grain Terminal owns and operates a waterside bulk grain handling and storage facility (located at the north side of East Basin Channel). This facility has 13 steel silos with a total storage capacity of 410,000 bushels and is equipped to receive and ship grain and other bulk feed products -- primarily alfalfa pellets -- via rail cars, trucks, and vessels.

Richmond

Thirteen oil handling facilities at the port are equipped to received and/or ship petroleum products by water; three are located in the Outer Harbor, three at Point Richmond, and seven in the Inner Harbor.

San Pablo Bay and Carquinez Strait

Ten waterfront oil handling facilities are equipped to receive and/or ship petroleum products.

Other Ports

Oil Handling Facilities

In addition to the facilities mentioned above, there are oil handling and storage facilities in the port of Oakland-Alameda, most of which are located at the Outer Harbor.

Ten offshore petroleum terminals are in operation in the vicinity of Los Angeles and in the central coastal area between Los Angeles and San Francisco. Table 5 lists the location and water depth of these facilities.

Table 5. Location and Water Depth of Offshore Petroleum Terminals

Location	Water depth (feet)
Encia................	40
Huntington Beach.....	50
El Segundo...........	58
Ventura..............	42
Carpenteria..........	60
Ellwood..............	60
Capitan..............	32
Gaviota..............	36
Estero Bay...........	36
San Luis Obispo......	32

Grain Elevators

Two grain elevators are located on the Oakland waterfront; each is operated in conjunction with adjacent grain milling and processing plants. The storage capacities of the two plants are 1,125,000 and 525,000 bushels of grain.

Table 6 summarizes petroleum and grain storage at all major south Pacific coast ports.

Table 6. Summary of Storage Capacities, South Pacific Coast Ports

(In millions)

Port	Crude oil and pet. products (bbl.)	Grain (bu.)
Long Beach...........	3.0	1.81
Los Angeles..........	10.0	--
Richmond.............	20.1	--
San Pablo Bay, Carquinez Strait, and Suisun Bay......	17.8[a]	--
Oakland-Alameda......	1.0	1.65
Total...............	51.9[a]	3.46

a/ Excludes tank farms at Martinez and Avon.

V. PHYSICAL OBSTACLES TO CHANNEL ENLARGEMENT

Bridges

Bridges which might be obstacles to harbor expansion are listed in table 7 by port or port area. The table also provides detailed information on each bridge.

Tides

Table 8 presents the mean tidal range of the various ports.

Table 7. Review of Relevant Bridges in Major South Pacific Coast Ports

Name	Location	Bay, strait or channel	Purpose	Kind	Clearance	
					Horizontal	Vertical[a]
	(stat. m.)				----- feet -----	
Gerald Desmond Bridge...	4	Inner Harbor Entrance Channel, Long Beach	Highway	Fixed	526	155[b]
Vincent Thomas Bridge...	4	Main Channel, Los Angeles	Highway	Fixed	1,150	185[b]-165[c]
Golden Gate Bridge......	3	Golden Gate, San Francisco	Highway (U.S. 101)	Fixed	4,028	232[b]-214[d]
Richmond-San Rafael Bridge.................	15	San Francisco-San Pablo Bay	Highway	Fixed Fixed	1,000[e] 970[f]	185[e] 135[f]
Sample Point Bridge (downstream)...........	31	Carquinez Strait	Highway	Fixed	1,030	134[g]-147[h]
Sample Point Bridge (upstream).............	31	Carquinez Strait	Highway	Fixed	1,000	135[g]-146[h]
Benicia-Martinez Bridge.	38	Carquinez Strait	Highway	Fixed	400	135
Southern Pacific Railroad Bridge...........	38	Suisun Bay	Railroad	Vert. lift	291	135[i]

a/ At mean higher high water.
b/ At the center.
c/ At the sides.
d/ At the north tower, and 211 feet at the south tower.
e/ West opening in the main channel.
f/ East opening in the Richmond Outer Harbor.
g/ South span.
h/ North span.
i/ In raised position.

Table 8. Tidal Range Under Ordinary Conditions

Location	Mean range[a/] (feet)
San Pedro Bay	
Long Beach/Los Angeles Harbor......	3.8
San Francisco Bay	
Fort Point.........................	5.7
San Francisco Airport..............	7.2
Oakland Pier.......................	6.0
Richmond...........................	5.8
Stockton...........................	3.5

a/ Difference between mean higher high water and mean lower low water.

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APPENDIX A. REVIEW OF STUDIES ON CHANNEL DEEPENING AND PORT EXPANSION

1. Comprehensive Framework Study, California Region, Appendix XVII, Navigation, prepared by California Region Framework Study Committee for Pacific Southwest Inter-Agency Committee, Water Resources Council, June 1971. The purpose of this appendix is to survey the future needs for navigation facilities, both commercial and recreational, in the California region.

Estimates of future requirements for commercial navigation facilities were based upon projected quantities and types of waterborne commerce likely to move through the region's ports and waterways to the year 2000.

2. Wave Statistics for Seven Deep Water Stations Along the California Coast, prepared by National Marine Consultants, Santa Barbara, December 1960. It presents the average annual sea and swell rises for seven different locations.

3. San Diego Harbor, California, House Document No. 365, 90th Congress, 2d Session, July 23, 1968. This document recommends widening of the entrance channel in the bends and deepening of the channel in the Central Bay to 40 feet from mile 7.0 to mile 8.84 and to 35 feet from mile 8.84 to mile 12.0. The total project first cost amounts to $11 million.

4. Los Angeles-Long Beach Harbors, Interim Review Report, U.S. Army Engineer District, Los Angeles,

Corps of Engineers, Los Angeles, California, June 1971. This report recommends channel improvements as shown in appendix table 1, compared with the existing project and current actual channel dimensions.

5. Vertical Movement in Long Beach Harbor District, Civil Engineering Division, Port of Long Beach, Long Beach, California, October 1970. The paper deals with the phenomenon of subsidence in the harbor area of Port Long Beach. It shows that during the period 1928-70 a maximum subsidence of 29 feet was measured at a location indicated on figure 6 of this annex.

6. Latest Permit for Current Dredging in Long Beach Harbor, issued to Board of Harbor Commissioners, Port of Long Beach, by U.S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, California, October 22, 1969. Application was granted for a permit to construct dikes for the expansion of Piers G and J and to dredge 8,300,000 cubic yards of material in Long Beach Harbor.

7. Survey of Deepwater Harbor Program, South Pacific Division, letter from Division Engineer, South Pacific, to Chief of Engineers, 12 October 1967. This letter summarizes the findings of the district offices with respect to data and information on physical problems associated with further deepening of harbors for 11 projects within the division. Eight of the 11 projects are within the San Francisco Bay system, and to a large degree controlling depths are interrelated. The three other projects are Humboldt Harbor and Bay, Los Angeles-Long Beach Harbors and San Diego Harbor.

8. San Francisco Bay, California: Disposal of Dredge Spoil, Supplement I to Appendix V, Sedimentation and Shoaling and Model Tests to Report of Survey on San Francisco Bay and Tributaries, California, U.S. Army Corps of Engineers, Committee on Tidal Hydraulics, December 1965. This study shows that the current average quantity of maintenance dredging performed annually by all interests amounts to about 11.0 million cubic yards inside the bay, and 1.2 million cubic yards at the Bar

Appendix Table 1. Summary of Channel Dimensions, Los Angeles and Long Beach Harbor

(In feet)

Channel	Existing Federal project		Recommended Federal project[a]			Current[b]	
	Depth	Width	Depth	Width	Length	Depth	Width
Long Beach							
Long Beach Channel.....	35	700	62[c]	700[c]	14,000[c]	62	700
Entrance Channel.......	35	300-500	62	300-500	7,000	62	300-500
Turning Basin Inner Harbor................	35	1,100	55	1,100	1,600	55	1,100
Cerritos Channel.......	35	400	50	400	6,000	50	400
Los Angeles							
Los Angeles Entrance Channel...............	40	1,000	80	1,000	6,000	47	500
Los Angeles Turning Basin.................	40	1,500	80	1,500	3,500	47	1,500
Los Angeles Main Channel...............	35	1,000	45	1,000	12,500	d/	d/
Turning Basin Inner Harbor................	35	e/	45	1,600	1,650	d/	d/
East Basin and Cerritos Channel..............	35	e/	45	400-650	e/	d/	d/
West and East Basin....	35	e/	45	e/	e/	d/	d/

a/ Dimensions recommended in interim report.
b/ Due to dredging by local interests.
c/ Not shown in report.
d/ Same dimensions as existing project.
e/ Varying.

Channel. Major improvements of the primary navigation channels from San Francisco Bar to the Port of Stockton, now under consideration, may increase the average annual maintenance quantities considerably. About 87 percent of the material removed from the navigation facilities is deposited overboard, i.e., into the water of the various bays without confining structures. The study also gives consideration to disposal behind banks.

The current unit cost of maintaining the channels, slips and docks in the bay system is $.25. If the material removed from the Oakland project was hauled out to sea, the unit cost would increase by $.30.

9. Dredge Disposal Study for San Francisco Bay and Estuary, Preliminary Report on Main Ship Channel (San Francisco Bar), U.S. Army Engineer District, San Francisco, Corps of Engineers, San Francisco, California, June 1971. This report studies the adverse effects resulting from dredging and disposal operations prior to and concurrent with initital construction activities on the bar, and how to eliminate these effects. The study programs included sampling, testing and analyzing the physical, biological and chemical properties of the Main Ship Channel and disposal site on the bar prior to, during and after dredging operations. This report sets forth results of the study programs to date and outlines future studies to accumulate necessary data to determine proper dredging and disposal procedures.

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ANNEX B-5. RECONNAISSANCE SURVEY OF THE NORTH PACIFIC COAST

I. DESCRIPTION OF COAST AND PORT LOCATIONS

The coast of Oregon and Washington is interrupted at Astoria by a large river, the Columbia, and at Cape Flattery by a large bay system, the Strait of Juan de Fuca. Smaller bays located along the coast are Grays Harbor and Willapa Bay in Washington, and Coos Bay, Nehalem Bay, Tillamook Bay, and a number of others in Oregon (figure 1).

Figure 2 shows that in general the 60-, 90-, and 120-foot contour lines are very close to the shore. At many stretches south of the mouth of the Columbia River the distance is only 1 or 2 miles, whereas north of the mouth the distance varies between 3 and 7 miles up to Cape Flattery, where the 120-foot line is 1 mile off shore.

The ports of the Pacific Northwest can generally be grouped into the following geographical segments: ports on the Columbia River and its tributaries, ocean bay ports, and ports in Puget Sound and adjacent water entered via the Strait of Juan de Fuca. The Columbia River, one of the great North American rivers, is the navigable approach to river ports between its mouth and the head of ocean shipping navigation at Portland. Vancouver, Washington, on the Columbia River, and Portland, Oregon, are respectively about 106 and 110 miles from the Pacific; the latter port is situated on the Willamette River about 9 miles above its junction with the Columbia. Navigation by river craft is conducted for a considerable distance up the Columbia above Vancouver and for a comparatively limited distance up the Willamette above Portland. Figure 3 shows longitudinal cross sections of the Columbia and Willamette River channels.

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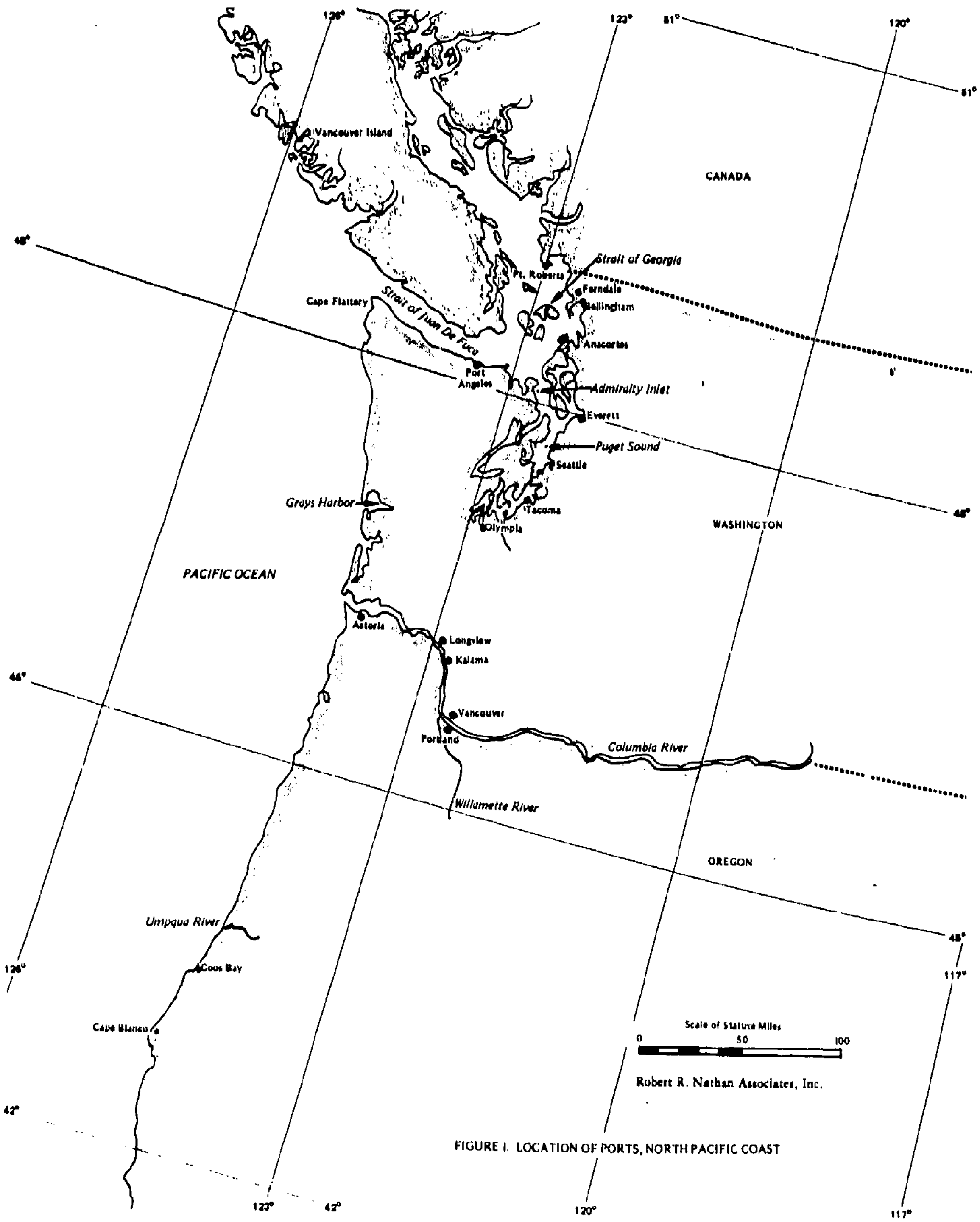
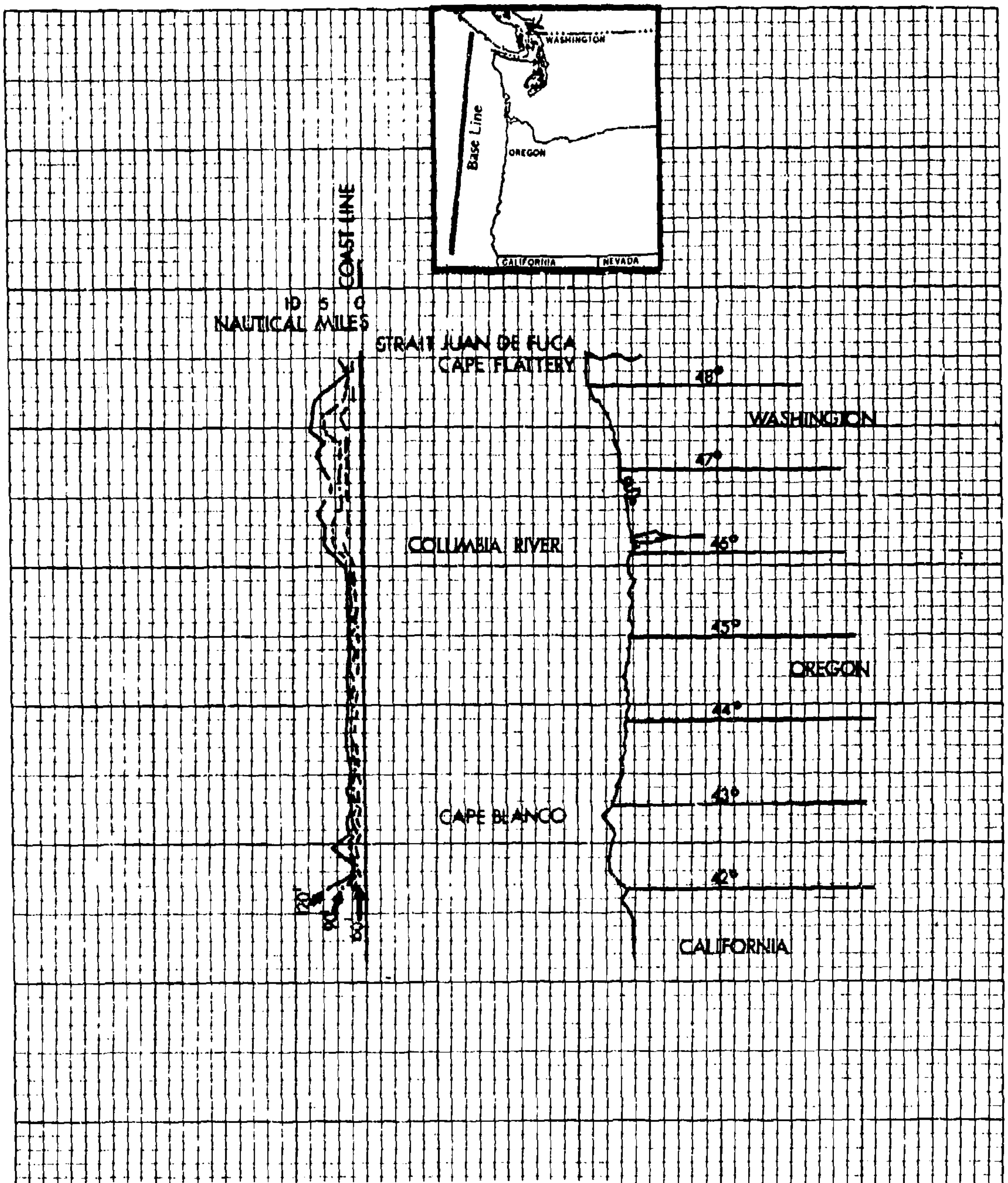


FIGURE I. LOCATION OF PORTS, NORTH PACIFIC COAST



Note: Contour line data taken from C&GS charts 6102, 6002, 590 ' 5802 and 5702.

FIGURE 2. DISTANCES BETWEEN COASTLINE AND 60-, 90-, AND 120-FOOT CONTOUR LINES, NORTH PACIFIC COAST

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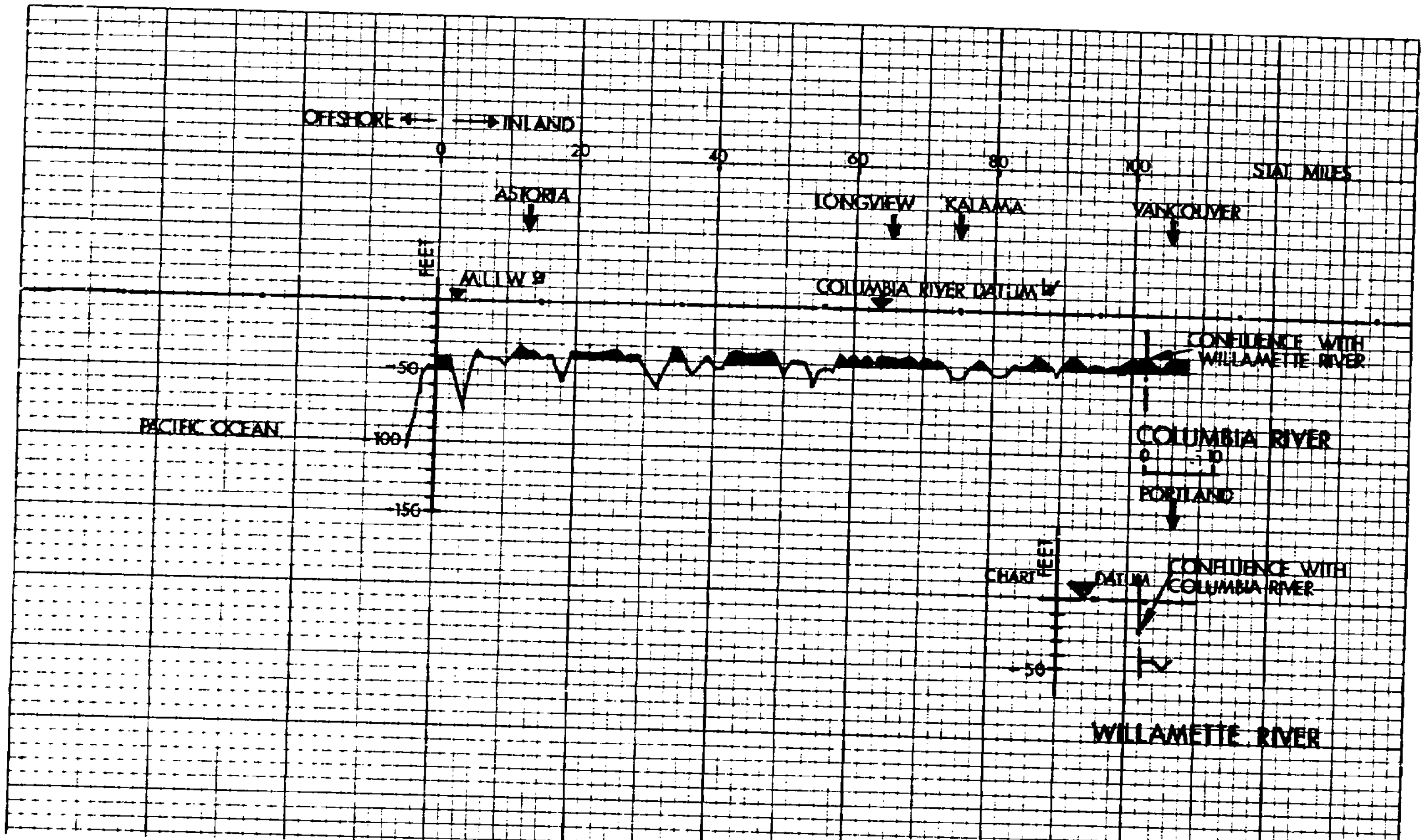

a From Columbia River mouth to Harrington Point (mile 24).
b Upstream from Harrington Point.

FIGURE 3. LONGITUDINAL CROSS SECTION OF COLUMBIA RIVER CHANNELS

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The entrance to the Strait of Juan de Fuca is 683 nautical miles north of San Francisco, California. This strait is the connecting channel between the ocean and Admiralty Inlet extending southward to Puget Sound, and to passages extending northward to the inland waters of British Columbia and southeastern Alaska. The Strait of Juan de Fuca separates the southern shore of Vancouver Island, Canada, and the northern coast of the State of Washington. Throughout the length of Puget Sound, there are numerous channels around islands, and inlets branching from the sound in all directions, particularly near its southern end.

The Strait of Juan de Fuca is approximately 80 nautical miles long and over 8 miles wide with depths in excess of 120 feet. For Admiralty Inlet these dimensions are respectively 20 and 2 miles, and for Puget Sound, 40 and 1.5 miles. Port Angeles is located on the south side of the Strait of Juan de Fuca; the ports of Seattle and Tacoma, on the east side of Puget Sound; the port of Everett, on the east side of Possession Sound, a bay north of Puget Sound; and the ports of Anacortes and Bellingham, on the east side of Rosario Strait. The locations of these ports in relation to the mouth of the Strait of Juan de Fuca are given in table 1.

Table 1. Distance of Northwest Washington Ports from the Mouth of the Strait of Juan de Fuca

Port	Distance (statute miles)
Port Angeles.............	70
Everett..................	130
Seattle..................	140
Tacoma...................	165
Anacortes................	107
Bellingham...............	125

The ocean bay ports of Coos Bay, Willapa River and Grays Harbor are of local significance only.

II. FOREIGN AND COASTAL MOVEMENTS, BY PORT, OF THE SIX STUDY COMMODITIES

Table 2 shows waterborne exports and imports of our six study bulk commodities by port for 1968 and 1969, and table 3 shows comparable data for domestic waterborne coastal receipts and shipments for 1969 and 1970. Movement of the export commodities in foreign trade is limited to grains, which in both years approximated 6 million tons. Virtually all of these exports (5.4 million tons) moved through the Columbia River ports, with the balance moving principally through Tacoma and Seattle.

Of the import commodities, only alumina was of quantitative significance, accounting in 1969 for 1.8 million of a total of 2.5 million tons of imports of study bulk commodities. Imports in 1969 increased 700,000 tons over 1968.

Coastal movements in domestic trade were principally petroleum products, which in 1970 accounted for 5.9 million tons out of a total of 6.6 million tons of receipts and for 1.5 million out of a total of 2.3 million tons of shipments. Almost all of the balance was crude petroleum.

Approximately half of the domestic waterborne receipts of petroleum products were received at Portland, Oregon, and about one-quarter at Seattle, Washington.

Table 2. U.S. Waterborne Exports of Domestic and Foreign Merchandise and General Imports of Selected Bulk Commodities, North Pacific Coast, 1968 and 1969

(In thousands of short tons)

Port/area	Total all study comm.		Exports: Total grains a/		Exports: Coal		Exports: Phosphate rock		Exports: Total		Imports: Crude oil		Imports: Pet. b/ products		Imports: Iron ore		Imports: Bauxite		Imports: Alumina		Imports: Total	
	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969	1968	1969
Columbia River area																						
Portland, Oregon....	2,695	2,598	2,596	2,310	--	--	--	--	2,596	2,310	--	--	20	17	--	141	8	15	71	115	99	288
Astoria, Oregon.....	55	26	55	26	--	--	--	--	55	26	--	--	--	--	--	--	--	--	--	--	--	--
Longview, Wash......	1,209	1,116	1,166	1,070	--	--	--	--	1,166	1,070	--	--	--	--	--	--	--	--	43	46	43	46
Kalama, Wash........	579	507	579	507	--	--	--	--	579	507	--	--	--	--	--	--	--	--	--	--	--	--
Vancouver, Wash.....	817	1,192	508	700	--	--	--	--	508	700	--	--	--	--	--	--	17	13	292	479	309	492
Total.............	5,355	5,439	4,904	4,613	--	--	--	--	4,904	4,613	--	--	20	17	--	141	25	28	406	640	451	826
Northwest Washington																						
Port Angeles........	--	1	--	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--
Tacoma..............	1,094	1,232	291	304	--	--	--	--	291	304	353	371	65	20	--	4	--	--	385	533	803	928
Seattle.....	911	1,012	772	862	--	--	--	--	772	862	--	--	139	150	--	--	--	--	--	--	139	150
Everett.............	1	24	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	24	--	24
Bellingham..........	288	564	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	288	564	288	564
Total.............	2,294	2,833	1,064	1,167	--	--	--	--	1,064	1,167	353	371	204	170	--	4	--	--	673	1,121	1,230	1,666
Total, north Pacific coast..............	7,649	8,272	5,968	5,780	--	--	--	--	5,968	5,780	353	371	224	187	--	145	25	28	1,079	1,761	1,681	2,492

Note: Individual items may not add to totals due to rounding.
a/ Includes food grains (wheat, rice, rye), feed grains (barley, corn, oats, cereals, n.e.c.), and soybeans and mill products.
b/ Includes gasoline, jet fuel and kerosene, distillate fuel oils, and residual fuel oils.
c/ Less than 500 short tons.

Source: U.S. Department of Commerce, Bureau of the Census, U.S. Waterborne Exports of Domestic and Foreign Merchandise, SA-705, and U.S. Waterborne General Imports of Merchandise, SA-305, 1968 and 1969.

Table 3. U.S. Domestic Waterborne Coastal Receipts and Shipments of Selected Bulk Commodities, North Pacific Coast, 1969 and 1970
(In thousands of short tons)

Port/area	Total, all study comm.				Crude oil				Petroleum[a/] products				Dry bulk commodities[b/]					
	1969		1970		1969		1970		1969		1970		1969			1970		
	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Rect.	Shipt.	Commodity	Rect.	Shipt.	Commodity
Columbia River area[c/]																		
Astoria, Oregon... ...	20	--	21	--	--	--	--	--	20	--	21	--	--	--	--	--	--	--
Longview, Wash........	197	--	173	36	--	--	--	--	197	--	173	--	--	--	--	--	20	Grains[d/]
Kalama, Wash..........	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
St. Helens, Oregon....	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vancouver, Wash.......	15	--	21	--	--	--	--	--	15	--	21	--	--	--	--	--	--	--
Portland, Oregon......	3,706	171	3,637	146	353	--	305	--	3,343	127	3,332	126	--	44	Grains[d/]	--	20	Grains[d/]
Total.................	3,938	171	3,852	182	363	--	305	--	3,575	127	3,547	126	--	44	--	--	56[e/]	--
Ocean Bay ports																		
Willapa River and Harbor and Naselle River, Wash..........	f/	--	7	--	--	--	--	--	f/	--	7	--	--	--	--	--	--	--
Grays Harbor and Chehalis River, Wash.	183	--	188	--	--	--	--	--	183	--	188	--	--	--	--	--	--	--
Coos Bay, Oregon......	253	5	260	--	--	--	--	--	253	5	260	--	--	--	--	--	--	--
Total.................	436	5	455	--	--	--	--	--	436	5	455	--	--	--	--	--	--	--
Northwest Washington																		
Port Angeles Harbor...	110	--	128	--	--	--	--	--	110	--	128	--	--	--	--	--	--	--
Port Townsend Harbor..	20	--	24	--	--	--	--	--	20	--	24	--	--	--	--	--	--	--
Port Gamble Harbor....	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Olympia Harbor........	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tacoma Harbor.........	325	26	381	57	287	--	258	--	38	26	123	57	f/	--	Iron ore	--	--	--
													f/	1	Grains[d/]	--	1	Grains[d/]
Seattle Harbor........	2,044	165	1,448	105	21	--	--	--	2,023	164	1,448	104	--	f/	Coal	--	f/	Coal
Everett Harbor and Snohomish River......	9	--	--	--	--	--	--	--	9	--	--	--	--	--	--	--	--	--
Anacortes Harbor......	219	1,675	352	1,985	--	417	142	759	219	1,258	210	1,226	--	--	--	--	--	--
Bellingham Bay and Harbor................	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Total.................	2,727	1,866	2,333	2,147	308	417	400	759	2,419	1,448	1,933	1,387	f/	1	--	--	1	--
Total north Pacific coast.................	7,101	2,042	6,640	2,329	671	417	705	759	6,430	1,580	5,935	1,513	f/	45	--	--	57	--

a/ Includes 2911, gasoline; 2912, jet fuel; 2913, kerosene; 2914, distillate fuel oil; and 2915, residual fuel oil.
b/ Includes grains; 1011, iron ore and concentrates; 1051, bauxite and other aluminum ores and concentrates; 1121, coal and lignite; and 1471, phosphate rock.
c/ Excludes ports of Bradford, Wauna, Beaver, Painier, and Prescott.
d/ Includes 0102, barley and rye; 0103, corn; 0104, oats; 0105, rice; 0106, sorghum grains; 0107, wheat; 0111, soybeans; and 2049, grain mill products, n.e.c.
e/ Includes 16,000 tons of aluminum ores shipped from Longview, Washington.
f/ Less than 500 short tons.

Source: U.S. Department of the Army, Corps of Engineers, Waterborne Commerce of the United States, Part IV, "Waterways and Harbors, Pacific Coast, Alaska and Hawaii," 1969 and 1970.

III. MAJOR PORTS AND CHANNELS

Only the channels leading to the crude oil and/or petroleum products and grain terminals of the six major ports will be reviewed. These ports are Portland, Longview, Kalama, Vancouver, Tacoma, and Seattle.

1. Portland, Oregon. This port is located on the right bank of the Willamette River, about 8 nautical miles from the confluence with the Columbia River and about 97 nautical miles from the Pacific Ocean (figure 4). The port is located about 6 statute miles to the northwest of the business center.

2. Longview, Washington. Located on the right bank of the Columbia River, this port is situated about 58 nautical miles from the Pacific Ocean, just westward of the mouth of the Cowlitz River (figure 4).

3. Kalama, Washington. This port is also located on the right bank of the Columbia River. Its distance to the mouth of the river is about 66 nautical miles (figure 4).

4. Vancouver, Washington. This is another port located on the right bank of the Columbia River. It is situated about 92 nautical miles from the Pacific Ocean, and is at the upstream limit of the Federal Project for the Columbia and Lower Willamette Rivers below Vancouver and Portland, Oregon. The main channel of the river passes between Vancouver and Hayden Island, a midriver island opposite the port (figure 4).

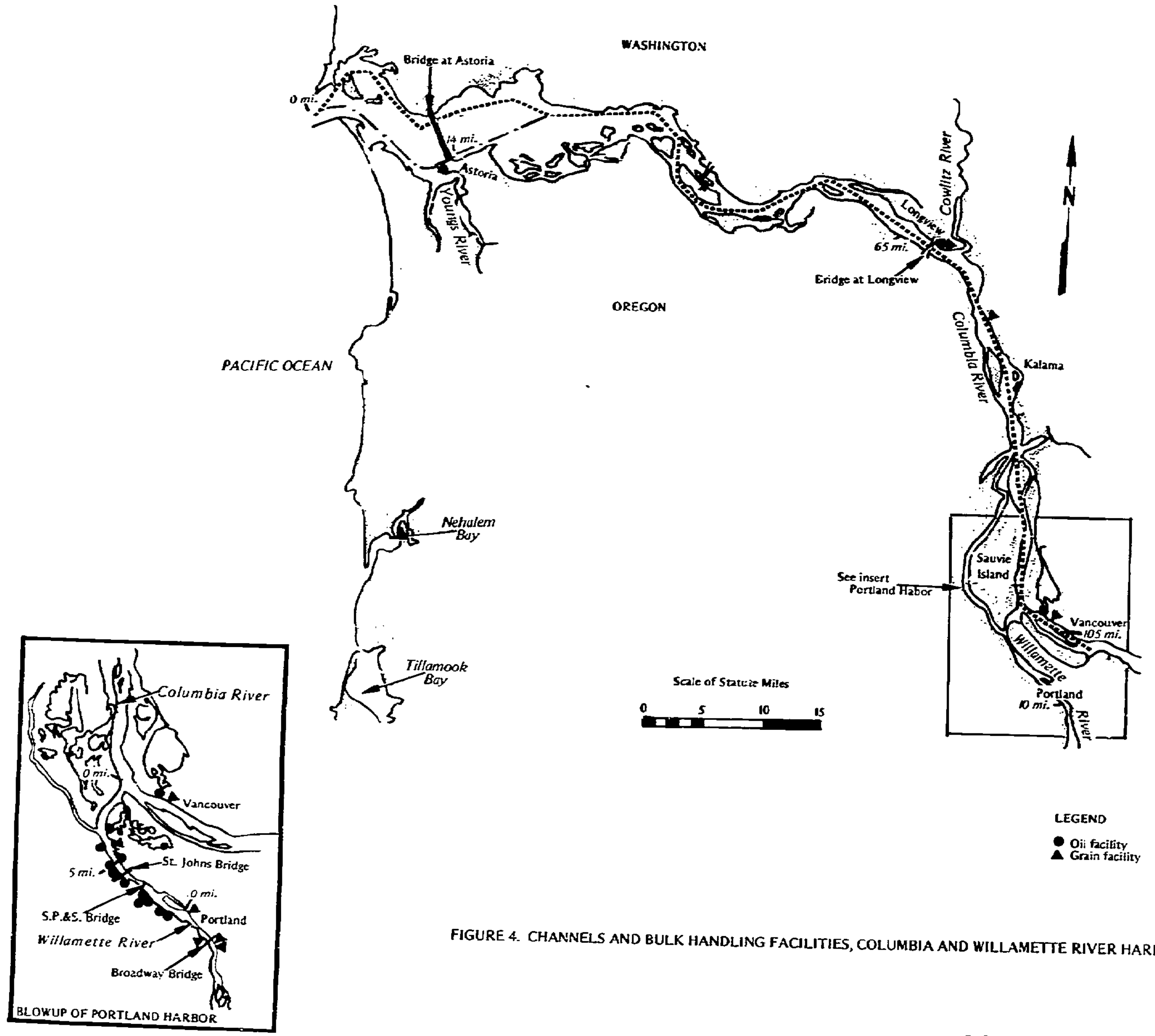

FIGURE 4. CHANNELS AND BULK HANDLING FACILITIES, COLUMBIA AND WILLAMETTE RIVER HARBORS

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5. Tacoma, Washington. Tacoma Harbor is at the head of Commencement Bay, a southeasterly arm of Puget Sound. Tacoma is 25 nautical miles south of Seattle, Washington, and 143 nautical miles from the Pacific Ocean. The port district includes the entire area of Commencement Bay. From the ocean to the port, vessels traverse the Strait of Juan de Fuca, Admiralty Inlet, and Puget Sound. These waters are wide and deep.

Commencement Bay is bordered by hills on the southwest and northeast and by extensive tidal flats on the Puyallup River entrance between Point Brown and Point Defiance. It has an average width of 2 miles and a length of approximately 2.5 miles from Point Brown to the head of the bay. Most of the land bordering the bay is within the Tacoma city limits. The waters in Commencement Bay range in depth from 570 feet at the entrance to 100 feet at the head where they shoal abruptly to tidal flats. Eight waterways have been dredged in the tidal flats and the spoil used to fill adjacent land (figures 5 and 6).

6. Seattle, Washington. Seattle Harbor is at Elliott Bay, an easterly arm of Puget Sound, located near the middle of the sound. Seattle is 25 nautical miles north of Tacoma, Washington, and 125 nautical miles from the Pacific Ocean. From the ocean to the port, vessels traverse the Strait of Juan de Fuca, Admiralty Inlet, and Puget Sound. These waters are wide and deep.

Elliott Bay is bordered by hills and by extensive tidal flats on the Duwamish River Delta on the southeast. The bay is about 6 miles wide at the entrance between West Point and Alki Point, has an average width of 2 miles, and a length of approximately 6 and 3 miles respectively from West Point and Smith Cove to the head of the bay. All land bordering the bay is within the Seattle city limits. The waters in Elliott Bay range in depth from 600 feet and over at the entrance to 70 feet at the head, where they shoal abruptly to tidal flats. Three waterways have been dredged in the tidal flats (figures 5 and 7).

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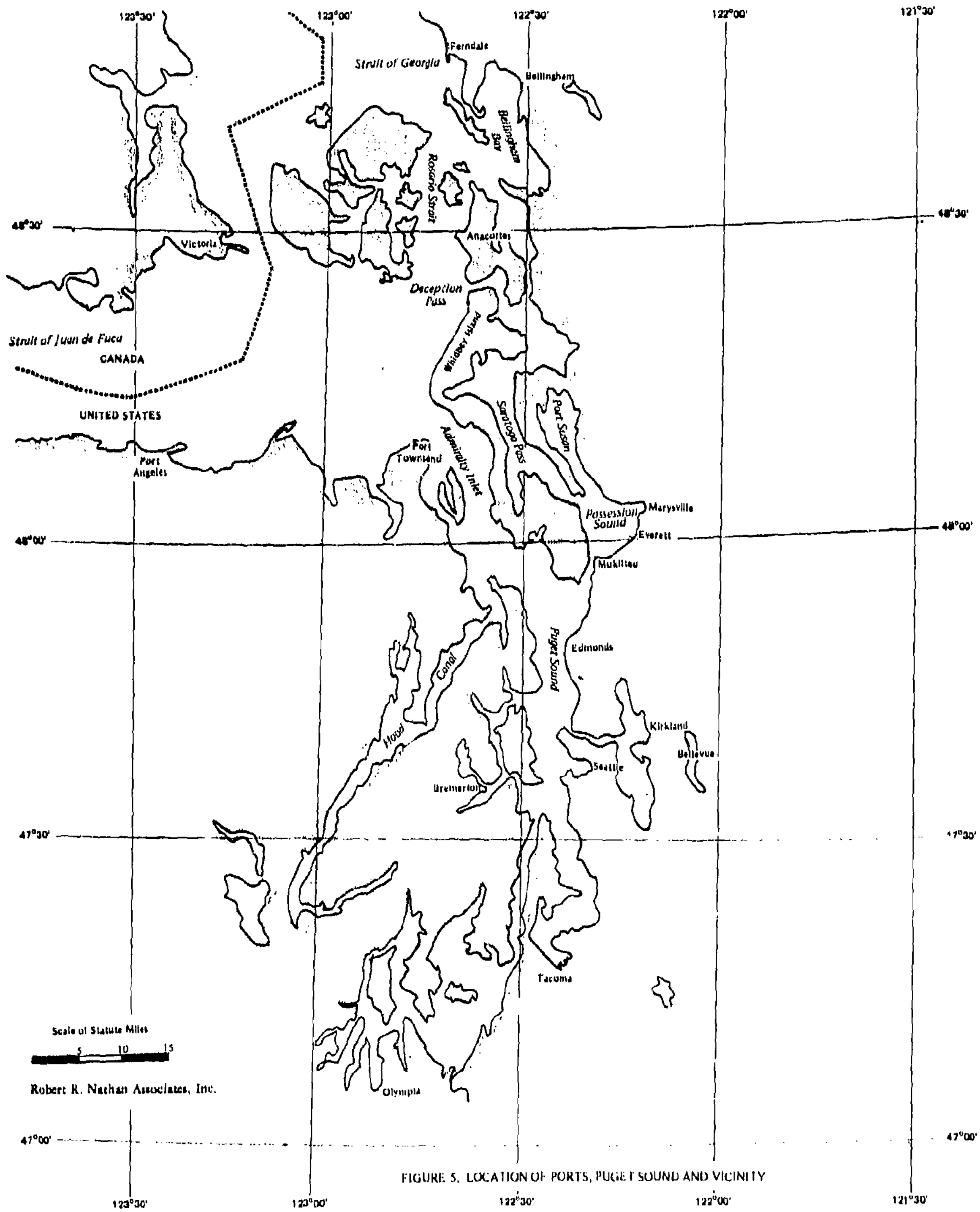

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FIGURE 5. LOCATION OF PORTS, PUGET SOUND AND VICINITY

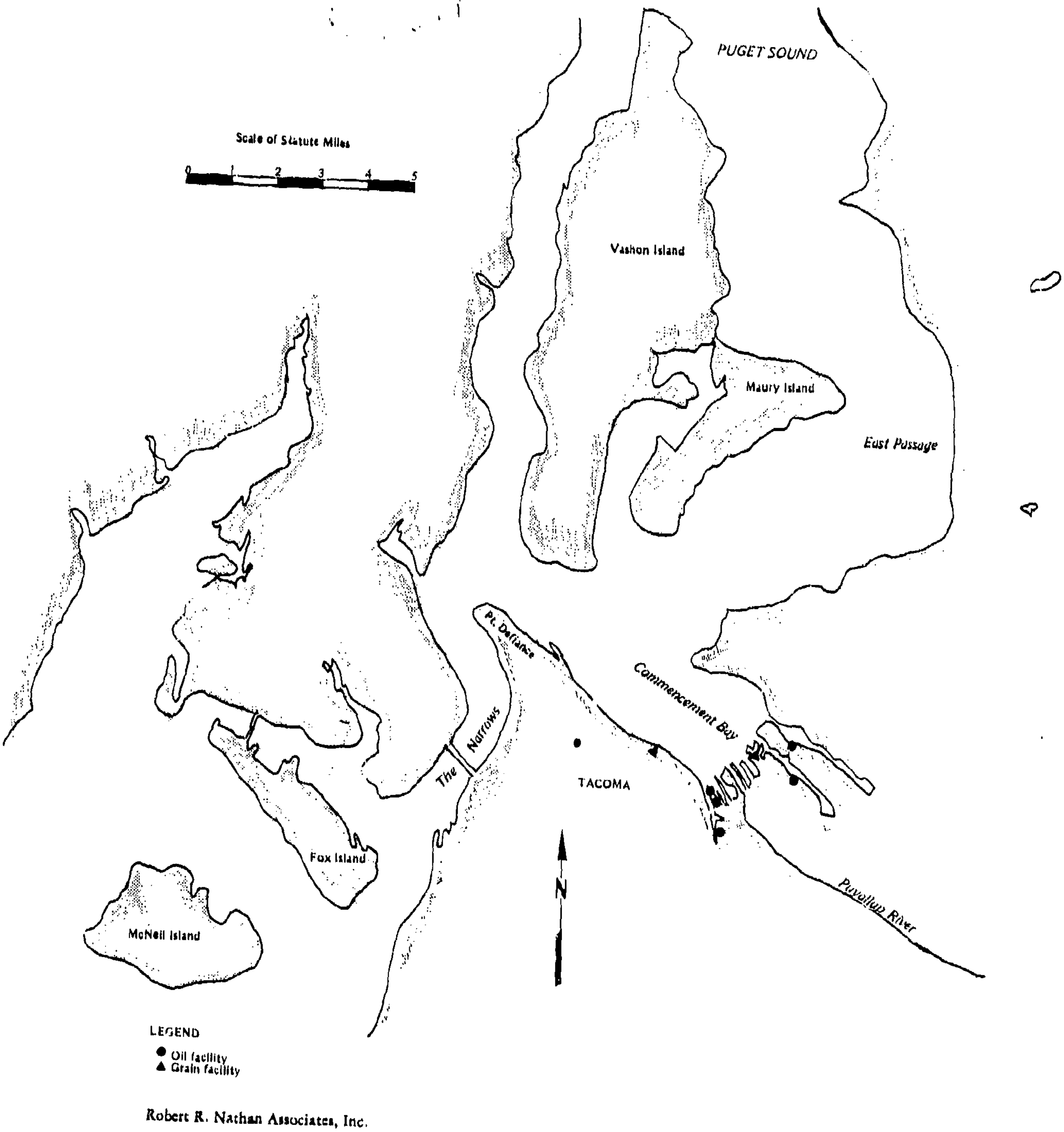

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FIGURE 6. LOCATION OF BULK HANDLING FACILITIES, TACOMA HARBOR, WASHINGTON

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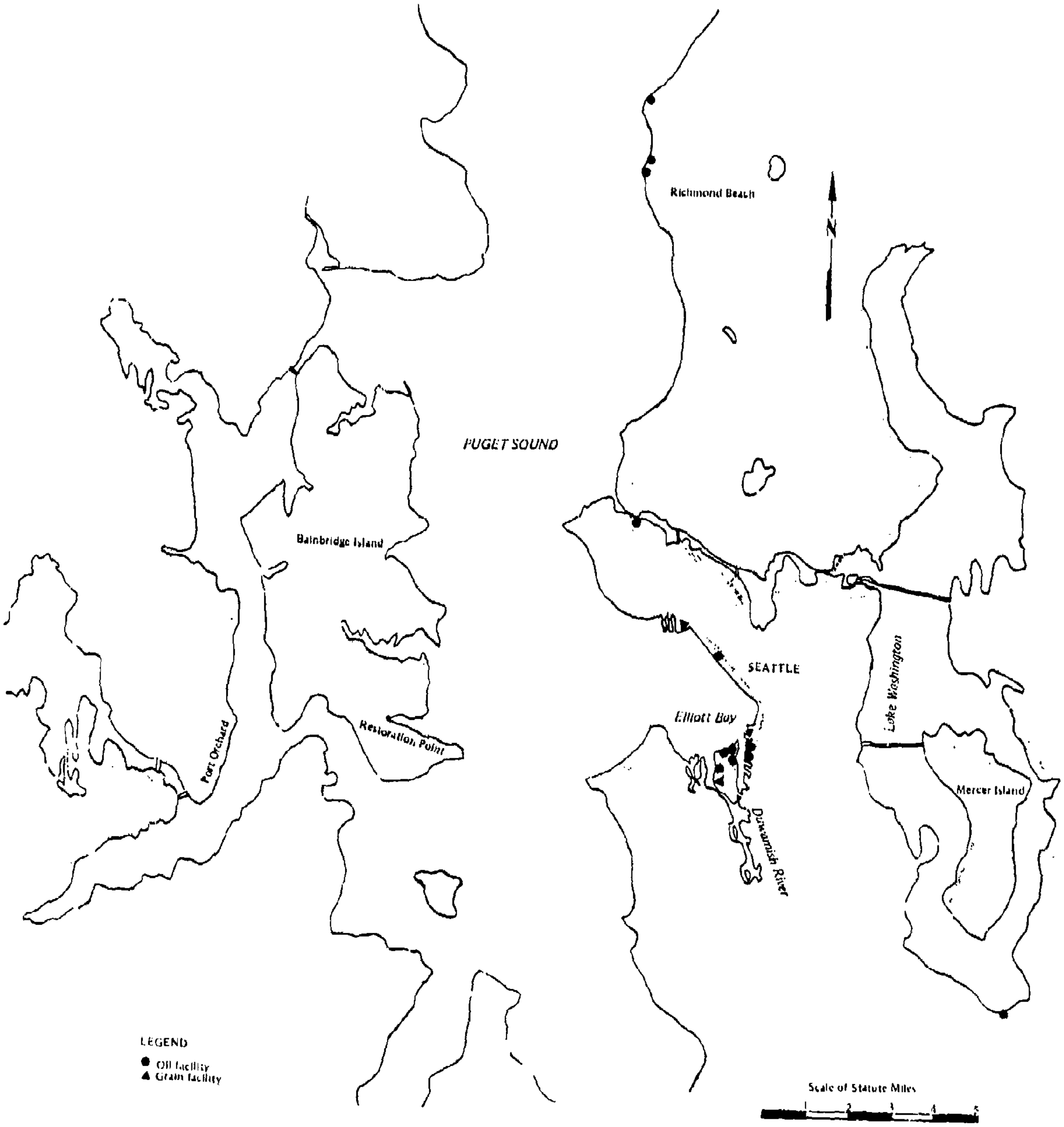

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FIGURE 7. LOCATION OF BULK HANDLING FA LITIES, SEATTLE ARBOR, WASHINGTON

The present status of the navigation channels to the Columbia River ports is given in table 4.

Table 4. Project Dimensions of Major Channels, North Pacific Coast

Name of channel	Depth	Width	Length	Location
	--- ft. ---		- stat. miles ---	
Columbia River, Ore. and Wash.				
Ocean Bar Channel..	48	2,640	1.5	(1.5)a/-9.0
River Channels b/...	40	600 c/	102.5	3.0-105.5
Willamette River, Ore.				
River Channel......	40	600 d/	11.6 e/	101.5-113.1

a/ Figures in parentheses indicate offshore locations.
b/ Composed of a great number of bar channels of varying lengths.
c/ Turning basin at Longview 1,200 feet wide and turning basins at Vancouver 800 feet wide.
d/ Locally 1,900 feet wide.
e/ From mouth to Broadway Bridge.

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IV. TERMINAL FACILITIES

Information on terminal and storage facilities for petroleum and petroleum products, grain, and bauxite at the six major ports and port areas is summarized here. The sources of these data are the relevant port series of the Corps of Engineers, all of which date back to the 1962-65 period.

The locations of grain and petroleum handling facilities in the major port areas are shown in figures 4, 6, and 7. There are five grain handling facilities at ports on the Columbia and Willamette Rivers, with storage capacity for 21.5 million bushels of grain. Three petroleum facilities are located at Longview and Vancouver, with storage capacity of approximately 0.5 million barrels.

At Tacoma, Washington, five oil handling facilities have a combined storage capacity of 2.4 million barrels, and two grain elevators have a combined storage capacity of approximately 5 million bushels.

In Seattle, 11 oil handling facilities with a combined storage capacity of more than 5 million barrels are owned by petroleum refiners and distributors. There are also two grain handling facilities with a combined storage capacity of 0.3 million bushels.

There is a refining capacity of approximately 265,000 barrels per day at three locations in northwest Washington (Ferndale, Anacortes, and Tacoma). In addition, a large refinery is being constructed near Ferndale by the Atlantic-Richfield Company.

In the Pacific Northwest, there is an aluminum reduction capacity of approximately 1.5 million tons, about a third of which is located along the Columbia River, with the balance in Northwest Washington. Imports of alumina are for consumption by these plants.

APPENDIX A. REVIEW OF STUDIES ON CHANNEL DEEPENING AND PORT EXPANSION

Coos Bay, Oregon, House Document No. 91-151, 91st Congress, 1st Session, September 3, 1969. This document recommends that the present channel system, 40 feet deep at mean lower low water across the outer bar and gradually reducing to 30 feet in the bay, be modified to 45- and 35-foot depths respectively at an estimated first cost of $9,100,000.

ANNEX C. DESIGN CRITERIA, ENGINEERING REQUIREMENTS, AND COST ESTIMATES OF DEEPWATER PORT ALTERNATIVES SELECTED FOR DETAILED ANALYSIS

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CONTENTS

I. INTRODUCTION

This annex deals with the locational, engineering, and direct economic cost characteristics of the specific deepwater port alternatives that were selected for detailed analysis.

The commodities and the port and coastal areas for which deepwater ports needed to be considered in detail were determined on the basis of the volumes of present and projected flows between U. S. and foreign coastal zones of the commodities studied in Annex A, and evaluation of economic, institutional, and technical factors expected to have an influence on the size and capacity characteristics of vessels to be employed in the ocean transport of these commodities (Annexes E and F).

An understanding of the purposes and limitations of the selection of these alternatives and of the design and cost estimates is essential. The prime purpose of the selection was to provide a basis for a preliminary economic and environmental evaluation of specific and concrete deepwater port alternatives having capacity, locational, and engineering characteristics realistically related to the indicated requirements. Therefore, the development of the design criteria and the determination of the engineering requirements of specific alternatives in this annex are undertaken with the prime objective of providing a basis for the development of order-of-magnitude estimates of first costs and operation and maintenance costs essential to economic benefit-cost analysis.

The selection was the result of a screening process which, in addition to the commodity flow data, took into account such factors as indicated vessel draft requirements; locations of bulk commodity production and consumption; coastal water depth characteristics; different concepts of berths, transshipment and storage locations; and present or past proposals for deepwater port developments.

It was considered essential to the purposes of the study to demonstrate the environmental and economic characteristics of different locational and conceptual approaches to the provision of deepwater port facilities. Thus, on the Atlantic coast, for example, we study crude petroleum ports at locations in New York Harbor and Delaware Bay that are capable of supplying local as well as regional needs, with fixed berths and pipeline connections to refineries; monobuoys off the coast of northern New Jersey to supply regional needs, with pipeline links to refineries; and fixed berths connected to an artificial island in the Atlantic Ocean off the Delaware Capes, with barge links to refineries. We also consider the supply of crude petroleum products to the east coast from refineries on the gulf coast, supplied with imported crude petroleum delivered through deepwater ports at different locations and employing different concepts. Thus a range of possible alternative solutions with varying engineering, geographic, economic, and environmental characteristics is evaluated.

The number of alternatives selected was limited arbitrarily by the time and resources available. Hence, not all alternatives meriting consideration were included. On the whole, the list of alternatives, in terms of locational and conceptual characteristics, would appear to include all or most of those suggested by existing refinery location patterns, by water depth conditions in the port and coastal areas, and by the state of the art of port design. But it does not, for example, include the alternative of wholly new refinery centers where naturally deep water is more accessible. Examples of such areas are the State of Maine and the Eastern Shore of Maryland off Chesapeake Bay, where naturally deep water is available, but where access by deep-draft vessels is obstructed by stretches of shallower water and by the tunnel structures of the Chesapeake Bay Bridge and Tunnel. The exclusion of these and other possible alternatives does not imply that they may not have both environmental and economic merit equal or superior to some of the alternatives studied.

On the other hand, the alternative of deepening channels to existing east coast refinery centers to accommodate 70-foot draft vessels, as in the selected alternatives, was excluded. Studies made by the Corps of Engineers indicated that the economic costs, as well as the environmental problems and impacts, of such deepening would be so much higher than those of other possible deepwater port alternatives as to rule it out for further study.

In addition, one must understand the tentative character of the estimates of first costs and operation and maintenance costs of the deepwater port alternatives studied. First costs were estimated for the major project components included in the engineering design on the basis of best available information, mainly from secondary sources, as were costs of operation and maintenance. The results should be regarded as order-of-magnitude estimates which serve the need of broad comparative evaluation of the benefits and costs of the alternatives studied. Although they should be useful in determining the direction of further, more detailed studies, they would not satisfy the requirements of a feasibility study.

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II. GENERAL CONSIDERATIONS IN THE SELECTION OF ALTERNATIVES

Introduction

The objective of the analysis in this annex is to determine the main technical components of various deepwater port alternatives, to present their physical requirements, and to establish a reasonably firm basis for estimating the first and the annual operating and maintenance costs of these alternatives.

The engineering aspects of this detailed analysis will deal with the selection of sites and with the determination of the number of berths; the dimensions of various maneuvering areas; the quantities -- if any -- to be dredged for these areas; the length of breakwaters and the volumes of sand fill required for island construction; the storage capacities and land acreages; the lengths and sizes of pipelines; the capacity of booster pumps; and the lengths of conveyor belts and trestles.

Port Areas

In a study of this nature, a limited number of port areas can be considered. The selection of port areas was based on a combination of the port area's nearness to the existing waterfront facilities, its nearness to existing or projected refinery centers in the case of crude oil, and the characteristics of the deepwater contour lines in general.

The following port areas will be considered for this detailed analysis:

East coast:

Area 1. New York
Area 2. Delaware Bay
Area 3. Chesapeake Bay

Gulf coast:

Area 4. Mississippi Delta
Area 5. Texas

West coast:

Area 6. Los Angeles-Long Beach
Area 7. San Francisco
Area 8. Ferndale-Bellingham, Washington.

The numbering of the alternatives will be based on the numbering of these port areas. For example, the first, second and third alternatives in the New York area (area 1) will be numbered 1-1, 1-2, and 1-3, respectively.

Sites and Water Depths

The selection of sites will mainly be based on the characteristics of the deepwater contour lines in the considered port area. Therefore, it is not possible to select a specific site without determining in advance the required water depth. Even given a particular site and water depth, various alternatives are possible. For instance, the cost of more or less dredging can be weighed against the cost of shorter or longer pipelines or trestles, and the cost of a breakwater and artificial island in shallower or deeper water can be weighed against the cost of longer or shorter trestles or submarine pipelines, etc. The close relationship between site and water depth makes it impossible to separate one from the other.

The selection of sites and water depths will also be based on present and past proposals for deepwater port developments in the considered port areas. Such developments are or were proposed or are under serious consideration off Long Branch, New Jersey; in and off the Delaware Bay; at Hampton Roads; in the Mississippi Delta; off Texas; and at Los Angeles-Long Beach and off Moss Landing, California.

Berths

Various types of crude oil berths exist. However, fixed berths are most commonly used for inland harbors, whereas single buoy moorings are used at various offshore locations. Fixed berths have been the only type of berth for dry bulk handling until recently. Now some monobuoys are in operation, handling iron ore in slurry form. Other types of crude oil berths are the conventional buoy moorings and single pile moorings. A description of these different types of berths is presented below.

Fixed Berths

Fixed berths can be one-sided sea islands (marginal berths) or double-sided sea islands (island piers). Island piers can be considered only if sufficient maneuvering space at either side of the pier is available.

A fixed berth consists of the following basic components:

1. A central unloading platform which would carry the required unloading arms, piping, and metering.

2. Breasting dolphins, spaced at such distances to allow berthing of tankers in the applicable tanker range and capable of absorbing the breasting energy at the assumed approach velocity of the maximum specified vessel. Two secondary dolphins would be required when the range in the length of the tankers served includes smaller tankers that could not otherwise be supported on their parallel sides.

3. Four mooring dolphins located along the longitudinal axis of the sea island. If tankers with a

large range of lengths are to be served, two more mooring dolphins would be required. The mooring and breasting dolphins are normally interconnected by catwalks to provide easy access by personnel handling the mooring lines.

A typical layout of a double-sided sea island is depicted in figure 1.

Berthing and deberthing would generally be effected with the aid of tugs. For a maximum-size vessel of 300,000 d.w.t., the total bollard pull of the tugs should be approximately 90 tons. A 2,000-horsepower tug with Kort-nozzles propelling arrangement has a bollard pull of about 28 tons. The minimum number of tugs required would therefore be three 2,000-horsepower tugs.

Fixed berthing structures do not consist of standard manufactured components.

A helicopter landing deck could be located on one of the outer mooring dolphins protruding over the side. It should be supported by cantilevered steel truss construction so as not to interfere with the mooring lines. A helicopter deck is required for the evacuation of injured personnel or for use during other emergencies.

If the sea island is not connected by trestle to the shore or to an offshore storage area, a launch landing for personnel would be required at one of the outer mooring dolphins.

The adequacy of a fixed structure solution depends on the average weather, sea, and current conditions in the area under consideration. Waves higher than 6 feet and winds with a velocity of 24 knots and over, will suspend berthing and deberthing operations, whereas currents not parallel to the axis of the berth will increase the difficulty of these maneuvers. Wind speeds in excess of 37 knots will suspend unloading operations because of the forces on the unloading equipment.

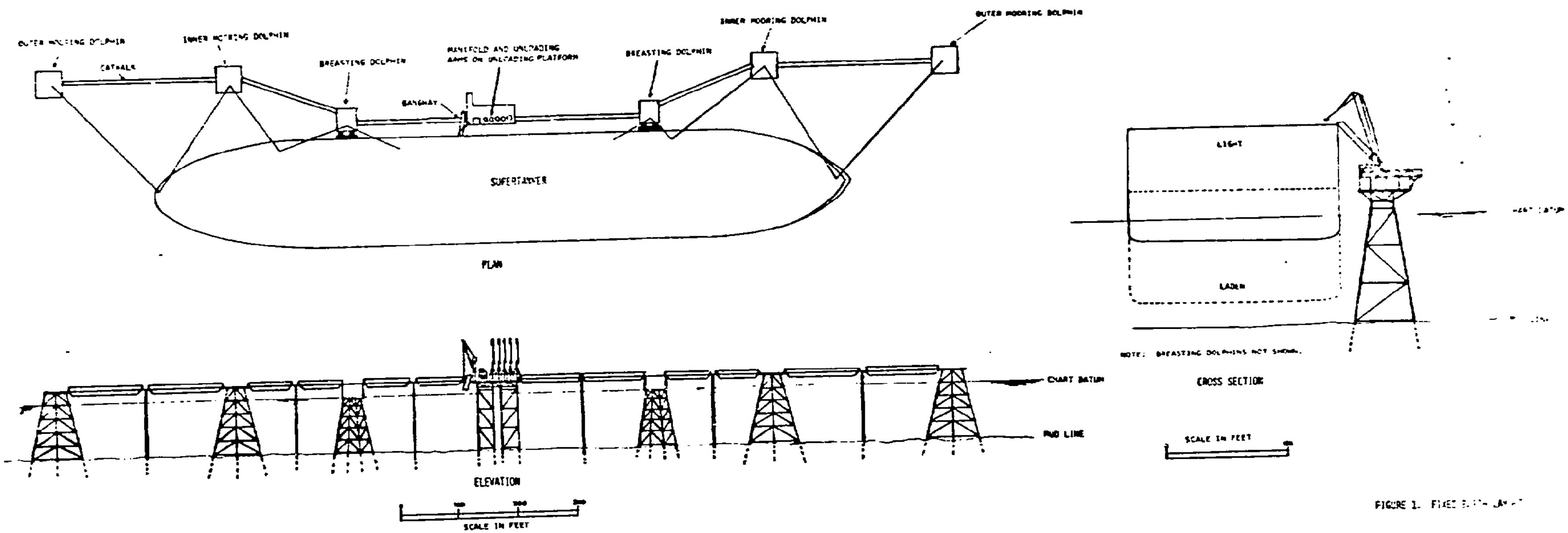

FIGURE 1. FIXED BERTH LAYOUT

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No attempt will be made in this study to evaluate the above-mentioned conditions for the various deepwater ports selected for detailed analysis. When fixed berths are considered, it will be assumed that the weather, sea, and current conditions are such that this type of berth is feasible without the construction of breakwaters.

Single Buoy Moorings

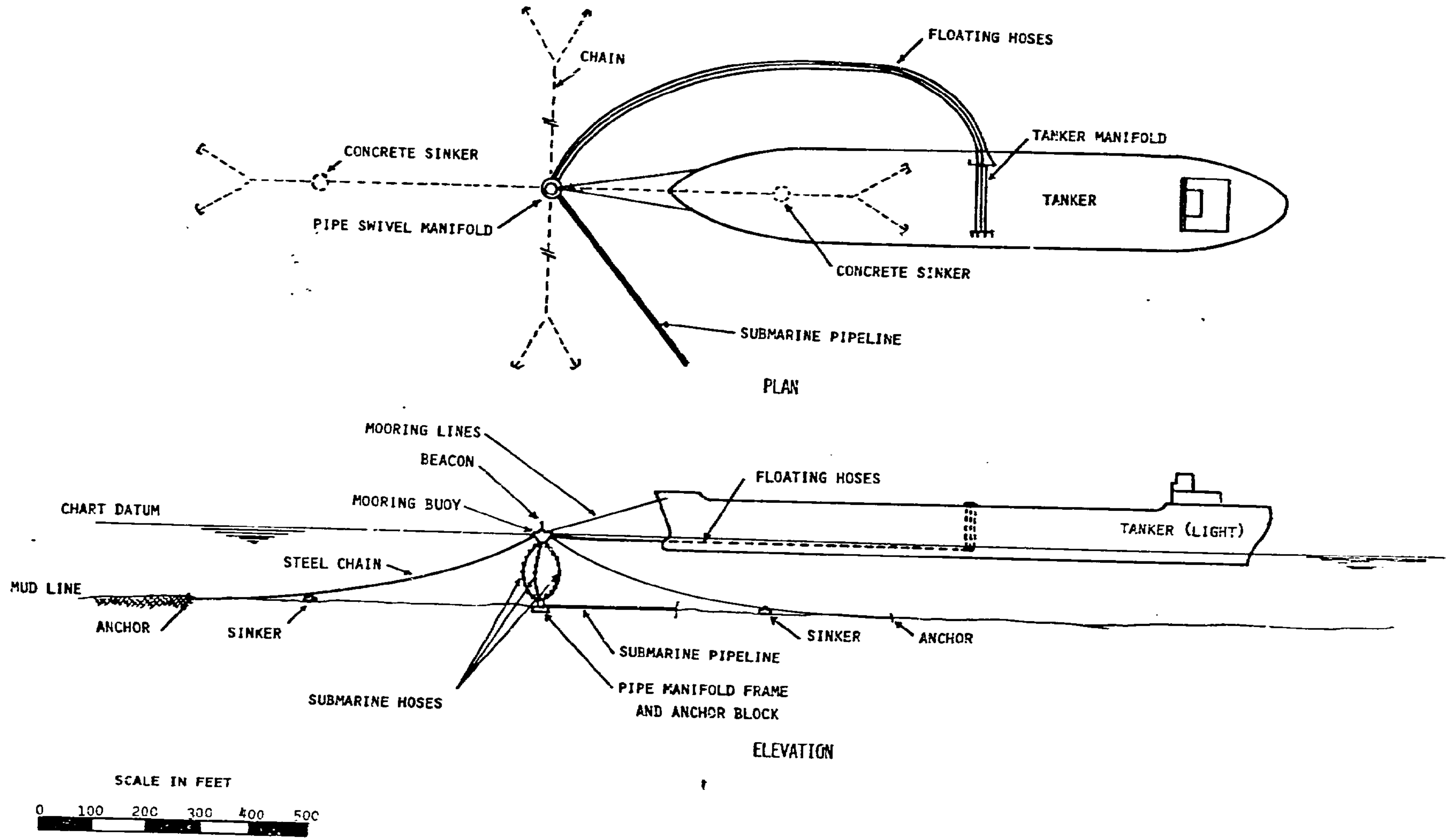
Single buoy moorings (SBM's), also referred to as monobuoys, consist of a buoy mooring designed to resist the loads from tankers attached to it with bow mooring lines. Tankers will always be aligned with the resultant of current, wind, and wave forces. Therefore, a minimum of force caused by these elements is transmitted to the mooring. The buoy is generally kept in position with chains that are anchored to piles.

The oil is transferred from the midship tanker manifold to the buoy through floating hoses. When not in operation, these hoses are normally allowed to swing free on the water surface. However, newly designed hoses are able to sink to the sea bottom when out of use to reduce the damage caused by adverse wave conditions. When tankers are moored, the hoses are pulled alongside the tanker by a launch which remains in attendance during oil transfer. Raising of the hoses to the tanker's manifold is generally done by the ship's gear.

The hoses are connected to a swivel on the buoy, which allows the hoses to rotate 360 degrees. The oil is transferred from the buoy to the submarine line by submarine hoses. Buoyancy chambers keep these hoses in a lazy S-curve, which allows movement of the buoy.

SBM's with accessories may be purchased as standard manufactured equipment. A typical single buoy mooring installation is depicted in figure 2.

SBM installations have been in operation at various locations throughout the world. Experience with



Robert R. Nathan Associates, Inc.

FIGURE 2. MONOBUOY LAYOUT

this type of installation has generally been satisfactory. At some locations, however, adverse sea and weather conditions, as well as improper operating practices, have caused considerable downtime, high maintenance costs, and occasional spills.

An experienced disadvantage of SBM's is that a tanker has a tendency to creep towards the buoy during periods of calm weather and slack tide. This could lead to damage as the bulbous bow of modern tankers could foul the buoy mooring chains or submarine hoses. Therefore, a launch of sufficient power should remain by the tanker to keep it at a satisfactory distance from the buoy.

Floating hose strings are susceptible to damage by vessels, particularly at night, and to damage by waves in adverse sea conditions when they will cause the hoses to override. Sticking of the turntable and subsequent wrapping of the hoses around the buoy can also cause damage. The submarine hoses can be damaged due to shifting of the buoy in adverse sea conditions.

In spite of these difficulties, SBM's find growing application. New developments exist in the construction of buoys and the fabrication of marine hoses. In particular, the development of the integral hose is believed to be a substantial improvement. SBM's are particularly suitable for locations where rotary tidal stream patterns exist or where sudden changes in wind direction are characteristic.

In principle, tankers can moor at SBM's without tug assistance. To berth safely at SBM's a 4,000-foot radius is required. However, at various locations where SBM's have been installed, the aid of high-power launches or low-power tugs are operationally necessary or desirable to reduce the berthing and deberthing times of large tankers.

For the maintenance of submarine hoses and anchor chains, a craft equipped with suitable lifting gear and diving equipment will be required. Regular inspection, maintenance and repairs of buoy, hoses, chains and anchors is required for a successful operation. The hoses must be replaced regularly. Drydocking of the buoy might be required every 3 to 5 years, depending upon site. Downtime can be at least 1 day per month. Drydocking of the buoy might take 1 month.

Conventional Buoy Mooring

A conventional buoy mooring (CBM) is a facility at which tankers are moored to a number of buoys, generally in one heading only. Unloading of the tankers takes place through hoses which are connected to the submarine line. These hoses rest on the sea bottom when not in use. Hose marker buoys are attached to the submarine hose strings to enable the hoses to be found and lifted from the sea bottom. A CBM installation consists of standard manufactured equipment.

Tidal streams of a rotary nature would create major maneuvering difficulties during berthing and deberthing operations. Because of the great flexibility of mooring lines and anchor chains, it is doubtful if this type of mooring can successfully be applied when the tanker size is 100,000 d.w.t. and over.

Single Pile Moorings

The principle of single pile moorings is the same as that of a monobuoy. This mooring has the same advantages as the monobuoys in that tankers are aligned with the resultant of the forces of currents, waves and wind, and that operations can be effected without the aid of tugs. In addition, single pile moorings endeavor to eliminate the major disadvantages of the monobuoys (i.e., the vulnerability of the hoses and the maintenance of the system) by replacing the flexible elements by solid or truss structures. The buoy and submarine hoses are replaced by a pile or truss-type of tower, firmly fixed to the sea bottom, and the floating hoses are replaced by a floating boom, hinged where appropriate to reduce the forces due to currents and waves. However, these forces are considerably higher than they are for monobuoys, and hydraulic model tests will be required to determine these forces. The construction and installation costs of these moorings are 2 to 5 times higher than those of monobuoys. The design and maintenance of the hinges are the critical elements of this type of mooring.

Single pile moorings do not consist of standard manufactured elements. Several consulting engineering firms have patented designs.

Because of the nature of this study and the characteristics of the various types of berths, the following sections will evaluate only two types of berths: fixed berths or monobuoys for crude oil ports, and fixed berths only for dry bulk ports. Each crude oil alternative will consider one type of berth only.

Storage

In principle, the storage area could be located on shore or off shore. If both cases are equally feasible, both options will be developed. However, to limit the number of alternatives, only one case -- storage located either on shore or off shore on an artificial island -- will be evaluated if preliminary investigations indicate that one case might be preferred over the other for technical, economical and/or environmental reasons.

If the berthing facilities would be located at a great distance from the shore, or if onshore storage is not feasible, offshore storage might be considered. The storage can be on an artificial island, in submarine tanks or in floating pontoons. An artificial island might be attractive if shallow areas exist near the berthing area and if the soil characteristics are suitable for this type of construction. Submarine storage might be considered if there are no shallow areas near the berthing facilities and if the feasibility of floating vessels is doubtful because of extreme weather and sea conditions at the site. Floating storage can be considered only when weather and sea conditions are rather moderate and when sufficient water depth is available for the maneuvering of the tankers. In all three cases it is possible to move the tankers directly to the storage or to moor them at some distance from the storage to fixed berths, monobuoys, conventional buoy moorings or single pile moorings.

Transshipment

In principle, all crude oil alternatives can be evaluated with pipelines as well as with transshipment barges as the links between deepwater ports and refinery areas. However, for each alternative a choice will be made between the two. Pipelines will be selected where the storage is assumed to be on shore and the refinery areas are relatively near, and barges will be selected where the storage is assumed to be off shore and the refinery areas are relatively distant. For the regional alternatives of the east and gulf coasts, both systems will be evaluated; however, for the regional alternatives of the west coast, pipelines alone will be considered to avoid transshipment by barge in the traffic-congested areas of San Francisco.

All dry bulk alternatives will consider only transshipment by barges, except where direct loading is anticipated.

Summary of Alternatives Selected

The selected alternatives will vary by commodity, site, location of storage (off shore on an artificial island or on shore), vessel size or vessel draft. Where appropriate, existing proposals for deepwater port developments will be included in the alternatives. For the alternatives dealing with crude oil, the type of berth (fixed or monobuoy) and the type of transshipment (pipeline or barge) will also vary. For some alternatives, subalternatives will be established in which the deadweight tonnage for a given draft, or the draft for a given deadweight tonnage, will be varied. Also different throughputs of the deepwater port will be considered in some subalternatives.

Table 1 presents a summary of the crude oil deepwater port alternatives selected for detailed analysis.

A total of 26 alternatives will be evaluated, of which eight are on the north Atlantic coast, nine on the gulf coast, and nine on the Pacific coast. The total number of alternatives and subalternatives is 67, of which 32 are on the north Atlantic coast, 24 on the gulf coast, and 11 on the Pacific coast. Thirteen deepwater port sites will be evaluated, of which two are located in the New York area, two in the Delaware area, one in the Mississippi Delta, two in Texas, one at Los Angeles, three at San Francisco, and one near Ferndale-Bellingham, Washington. Eleven different storage locations will be considered, of which seven are on shore and four are on an artificial island. Of the 26 alternatives, 21 will consider fixed berths and five will consider monobuoys. Four alternatives will consider transshipment by barge only, 16 will consider transshipment by pipelines only, and six will consider transshipment partly by pipeline and partly by barge. A total of seven different design vessels will be considered; two will be considered on the north Atlantic coast; four will be considered on the gulf coast, and five will be considered on the Pacific coast.

Table 2 presents a summary of the dry bulk deepwater port alternatives selected for detailed analysis. A total of seven alternatives will be evaluated, of which three are on the north Atlantic coast and four are on the gulf coast. The total number of subalternatives is 17, of which six are on the north Atlantic coast and 11 are on the gulf coast. Four deepwater port sites will be evaluated, of which one is located in the Lower Delaware Bay, one at Hampton Roads, Virginia, one in the Mississippi Delta, and one at Freeport, Texas. Four different storage locations will be considered, of which two are on shore and two are on an artificial island. One alternative will consider direct loading and all other alternatives will hypothesize transshipment by barge. Four different design coal carriers, two different design iron coal carriers, and three different design grain carriers will be considered.

Table 3 presents a summary of deepwater port alternatives handling crude oil as well as dry bulk.

The following sections present a detailed description, by coast and commodity, of the various factors

Table 1. Summary of Crude Oil Deepwater Port Alternatives Selected for Detailed Analysis

Code no.a/	Alt.		Port area	Location or site	Refinery areas served	Storage location		Type of berth		Type of transshipt		Water depthb/ (ft.)			Design vessel		Annual throughput (mil. l. tons/year)	
	No.	Sub.				Art. island	On-shore	Fixed	Mono-buoy	Pipe-line	Barge	At M.L.W.	Tidal rise	At M.H.W.	Draft (ft.)	Size (d.w.t.)	1980	2000
0010..	1-1	A	N.Y., N.Y.	Lower N.Y. Bay	Arthur Kill	X		X		X		70-77	4	74-81	70	300,000	30	35
0020..	1-1	B				X		X		X		70-77	4	74-81	70	300,000	35	70
0030..	1-1	C				X		X		X		70-77	4	74-81	70	400,000	30	35
0040..	1-1	D				X		X		X		70-77	4	74-81	70	400,000	35	70
0050..	1-2	A	N.Y., N.Y.	Lower N.Y. Bay	Arthur Kill & Delaware R.	X		X		X		70-77	4	74-81	70	300,000	100	150
0060..	1-2	B				X		X		X		70-77	4	74-81	70	300,000	150	300
0070..	1-2	C				X		X		X		70-77	4	74-81	70	400,000	100	150
0080..	1-2	D				X		X		X		70-77	4	74-81	70	400,000	150	300
0090..	1-3	A	N.Y., N.Y.	Long Branch	Arthur Kill & Delaware R.		X		X	X		77	4	81	70	300,000	100	150
0100	1-3	B					X		X	X		77	4	81	70	300,000	150	300
0110..	1-3	C					X		X	X		77	4	81	70	400,000	100	150
0120..	1-3	D					X		X	X		77	4	81	70	400,000	150	300
0130..	2-1	A	Delaware Bay	Big Stone Be.	Delaware R.		X	X		X		73-80	4	77-84	70	300,000	70	115
0140..	2-1	B					X	X		X		73-80	4	77-84	70	300,000	115	230
0150..	2-1	C					X	X		X		73-80	4	77-84	70	400,000	70	115
0160..	2-1	D					X	X		X		73-80	4	77-84	70	400,000	115	230
0170..	2-2	A	Delaware Bay	Big Stone Be.	Delaware R.	X		X		X		73-80	4	77-84	70	300,000	70	115
0180..	2-2	B				X		X		X		73-80	4	77-84	70	300,000	115	230
0190..	2-2	C				X		X		X		73-80	4	77-84	70	400,000	70	115
0200..	2-2	D				X		X		X		73-80	4	77-84	70	400,000	115	230
0210..	2-3	A	Delaware Bay	Big Stone Be.	Delaware R. & Arthur Kill		X	X		X		73-80	4	77-84	70	300,000	100	150
0220..	2-3	B					X	X		X		73-80	4	77-84	70	300,000	150	300
0230..	2-3	C					X	X		X		73-80	4	77-84	70	400,000	100	150
0240..	2-3	D					X	X		X		73-80	4	77-84	70	400,000	150	300
0250..	2-4	A	Delaware Bay	Big Stone Be.	Delaware R. & Arthur Kill	X		X		X		73-80	4	77-84	70	300,000	100	150
0260..	2-4	B				X		X		X		73-80	4	77-84	70	300,000	150	300
0270..	2-4	C				X		X		X		73-80	4	77-84	70	400,000	100	150
0280..	2-4	D				X		X		X		73-80	4	77-84	70	400,000	150	300
0290..	2-5	A	Delaware Bay	Off Delaware Capes	Delware R. & Arthur Kill	X		X			X	77-80	4	81-84	70	300,000	100	150
0300..	2-5	B				X		X			X	77-80	4	81-84	70	300,000	150	300
0310..	2-5	C				X		X			X	77-80	4	81-84	70	400,000	100	150
0320..	2-5	D				X					X	77-80	4	81-84	70	400,000	150	300
0330..	4-1	A	Miss. R. Delta	Garden Is. Bay	Gulf Coastc/	X					X	63-66	d/	--	55	200,000	100	450
0340..	4-1	B				X					X	63-66	--	--	55	200,000	150	600
0350..	4-2	A	Miss. R. Delta	Garden Is. Bay	Gulf Coastc/	X					X	81-84	d/	--	70	300,000	100	450
0360..	4-2	B				X		X			X	81-84	--	--	70	300,000	150	600
0370..	4-2	C				X		X			X	81-84	--	--	70	400,000	100	450
0380..	4-2	D				X		X			X	81-84	--	--	70	400,000	150	600
0390..	4-3	A	Miss. R. Delta	Garden Is. Bay	Gulf Coastc/	X		X			X	109-114	d/	--	95	500,000	100	450
0400..	4-3	B				X		X			X	109-114	--	--	95	500,000	150	600
0410..	5-1	A	Texas	Freeport	Gulf Coastc/		X		X	X	X	63	d/	--	55	200,000	100	450
0420..	5-1	B					X		X	X	X	63	--	--	55	200,000	150	600

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continued--

Table 1. Summary of Crude Oil Deepwater Port Alternatives Selected for Detailed Analysis continued--

Code no.a/	Alt.		Port area	Location or site	Refinery areas served	Storage location		Type of berth		Type of transshipt		Water depthb/ (ft.)			Design vessel		Annual throughput (mil. l. tons/year)	
	No.	Sub.				Art. island	On-shore	Fixed	Mono-buoy	Pipe-line	Barge	At M.L.W.	Tidal rise	At M.H.W.	Draft (ft.)	Size (d.w.t.)	1980	2000
0430..	5-2	A	Texas	Freeport	Gulf Coastc/		x		x	x	x	81	d/	--	70	300,000	100	450
0440..	5-2	B					x		x	x	x	81	--	--	70	300,000	150	600
0450..	5-2	C					x		x	x	x	81	--	--	70	400,000	100	450
0460..	5-2	D					x		x	x	x	81	--	--	70	400,000	150	600
0470..	5-3	A	Texas	Freeport	Gulf Coastc/		x		x	x	x	109	d/	--	95	500,000	100	450
0480..	5-3	B					x		x	x	x	109	--	--	95	500,000	150	600
0490..	5-4	A	Texas	Freeport	Gulf Coastc/		x	x		x	x	58-66	d/	--	55	200,000	100	450
0500..	5-4	B					x	x		x	x	58-66	--	--	55	200,000	150	600
0510..	5-5	A	Texas	Freeport	Gulf Coastc/		x	x		x	x	74-84	d/	--	70	300,000	100	450
0520..	5-5	B					x	x		x	x	74-84	--	--	70	300,000	150	600
0530..	5-5	C					x	x		x	x	74-84	--	--	70	400,000	100	450
0540..	5-5	D					x	x		x	x	74-84	--	--	70	400,000	150	600
0550..	5-6	A	Texas	Freeport	Gulf Coastc/		x	x		x	x	100-114	d/	--	95	500,000	100	450
0560..	5-6	B					x	x		x	x	100-114	--	--	95	500,000	150	600
0570..	6-1	A	Los Angeles-Long Beach	San Pedro Baye/	Los Angeles-Long Beach		x	x		x		74-81	d/	--	70	300,000	23	111
0580..	6-1	B					x	x		x		74-81	--	--	70	400,000	23	111
0590..	6-2	A	Los Angeles-Long Beach	San Pedro Baye/	L.A.-Long Beach, S.F.f/		x	x		x		74-81	c/	--	70	300,000	43	171
0600..	6-2	B					x	x		x		74-81	--	--	70	400,000	43	171
0610..	7-1	-	San Fran.	Richmond	Richmond-Avon		x	x		x		48-53	5	53-58	50	157,000	15	60
0620..	7-2	-	San Fran.	Richmond-Avon	Richmond-Avon		x	x		x		48-53	5	53-58	50	157,000	15	60
0630..	7-3	-	San Fran.	Richmond	Richmond-Avon		x	x		x		57-62	5	62-67	58.5	250,000	15	60
0640..	7-4	-	San Fran.	Richmond-Avon	Richmond-Avon		x	x		x		57-62	5	62-67	58.5	250,000	15	60
0650..	7-5	-	San Fran.	Monterey Bayg/	Richmond-Avon		x		x	x		95	d/	--	83	400,000	15	60
0660..	8-1	-	Bellingham-Ferndale	Strait of Georgia	San Franciscof/		x	x		x		91	d/	--	83	400,000	15	60
0670..	8-2	-	Bellingham-Ferndale	Strait of Georgia	San Francisco,f/ L.A.-L. Beach		x	x		x		91	d/	--	83	400,000	43	171

a/ Code numbers shown for each alternative are those used in the computer computation of benefits and costs (Annex F).
b/ Excluding overdepth.
c/ Gulf coast refineries are located at Houston-Baytown, Beaumont-Port Arthur, Lake Charles, Baton Rouge, New Orleans, Corpus Christi and Pascagoula.
d/ The tidal rise is not taken into account; therefore, the water depth at M.L.W. is the governing minimum water depth.
e/ For subalternative A, Los Angeles Harbor.
f/ For subalternative A, San Francisco refineries are located in the Richmond-Avon area.
g/ Moss Landing.

Table 2. Summary of Crude Oil Deepwater Port Alternatives Selected for Detailed Analysis

Code no.a/	Alt. No.	Alt. Sub.	Alt. As-sump.b/	Port area	Location or site	Links to existing ports	Storage: Location: Art. Is.	Storage: Location: On-shore	Storage: Coal area b/: 100 %	Storage: Coal area b/: 25 %	Ld./unld.: Trans-shpt. barge	Ld./unld.: Di-rect	Water depth b/ (ft.): At M.L.W.	Water depth (ft.): Tidal rise	Water depth (ft.): At M.H.W.	Design vessel: Draft (ft.)	Design vessel: Size (d.w.t.)	Commodity and annual throughput (mil. l tons/yr.): Coal 1980	Coal 2000	I on ore 1980	I on ore 2000	Grain 1980	Grain 2000
0680..	2-6	A	1			Hampton Roads	X		X		X		71-78	4	75-82	65	250,000	45.4	43.7				
0690..	2-6	A	2	Delaware	Big Stone Be.	and	X			X	X		71-78	4	75-82	65	250,000	45.4	43.7				
0700..	2-6	B	1	Bay		Baltimore	X		X		X		63-70	4	67-74	58.5	250,000	11.5	6.4				
0710..	2-6	B	2				X			X	X		63-70	4	67-74	58.5	250,000	11.5	6.4				
0720..	2-7	A	1			Hampton Roads,	X		X		X		71-78	4	75-82	65	250,000	45.4	43.7	12.5	17.1		
0730..	2-7	A	2	Delaware	Big Stone Be.	Baltimore,	X			X	X		71-78	4	75-82	65	250,000	45.4	43.7	12.5	17.1		
0740..	2-7	B	1	Bay		Philadelphia-	X		X		X		63-70	4	67-74	58.5	250,000	11.5	6.4	12.5	17.1		
0750..	2-7	B	2			Trenton	X			X	X		63-70	4	67-74	58.5	250,000	11.5	6.4	12.5	17.1		
0760..	3-1	A	-	Chesapeake	Hampton Rds.	Norfolk and		X				X	55-60	2.5	57.5-62.5	52	128,000	46.1	46.6				
0770..	3-1	B	-	Bay		Newport News		X				X	55-60	2.5	57.5-62.5	52	179,000	46.1	46.6				
0780..	4-4	A	-	Miss. R.	Garden Is.	Miss. River,	X				X		75-78	c/	—	65	250,000					32.8	58.9
0790..	4-4	B	-	Delta	Bay	Texas & La.	X				X		67-70	—	—	58.5	250,000					18.0	23.6
0800..	4-4	C	-			coast ports	X				X		58-60	—	—	50	120,000					18.0	23.6
0810..	4-5	A	-	Miss. R.	Garden Is.	Mobile, Houston,	X				X		75-78	c/	—	65	250,000			7.6	10.4		
0820..	4-5	B	-	Delta	Bay	Baton Rouge	X				X		67-70	—	—	58.5	250,000			7.6	10.4		
0830..	4-6	A	-			Same as	X				X		75-78	c/	—	65	250,000			7.6	10.4	32.8	58.9
0840..	4-6	B	-	Miss. R.	Garden Is.	alternative	X				X		67-70	—	—	58.5	250,000			7.6	10.4	18.0	[illegible]
0850..	4-6	C	-	Delta	Bay	4-4	X				X		58-60	—	—	50	120,000					[illegible]	[illegible]
						and							75-78			65	250,000			7.6	10.[illegible]		
0860..	4-6	D	-			4-5	X				X		58-60	—	—	50	120,000					18.0	[illegible]
													67-70			58.5	250,000			7.6	10.4		
0870..	5-7	A	-	Texas	Freeport	Texas ports		X			X		75/67	c/	—	65/58.5	250,000					18.0	23.6
0870..	5-7	B	-					X			X		58	—	—	50	120,000					18.0	23.6

a/ Code numbers shown for each alternative are those used in the computer computation of benefits and costs.
b/ For an explanation of the two assumptions, refere to chapter VI.
c/ The tidal rise is not taken into account; therefore, the water depth at M.L.W. is the governing minimum water depth.

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Table 3. Summary of Deepwater Port Alternatives Handling Crude Oil As Well As Dry Bulk

Alternative number	Port area	Location or site	Commodities				Combination of alternatives
			Crude oil	Coal	Iron ore	Grain	
2-8..........	Delaware Bay	Big Stone Beach	X	X			2-1 & 2-6
2-9..........			X	X	X		2-1 & 2-7
2-10..........			X	X			2-2 & 2-6
2-11..........			X	X	X		2-2 & 2-7
2-12..........			X	X			2-3 & 2-6
2-13..........			X	X	X		2-3 & 2-7
2-14..........			X	X			2-4 & 2-6
2-15..........			X	X	X		2-4 & 2-7
4-7..........	Mississippi River Delta	Garden Island Bay	X			X	4-1 & 4-4
4-8..........			X		X		4-1 & 4-5
4-9..........			X		X	X	4-1 & 4-6
4-10..........			X			X	4-2 & 4-4
4-11..........			X		X		4-2 & 4-5
4-12..........			X		X	X	4-2 & 4-6
4-13..........			X			X	4-3 & 4-4
4-14..........			X		X		4-3 & 4-5
4-15..........			X		X	X	4-3 & 4-6
5-8..........	Texas	Freeport	X			X	5-4 & 5-7
5-9..........			X			X	5-5 & 5-7
5-10..........			X			X	5-6 & 5-7

evaluated in the selection of the sites, storage locations, vessel sizes or vessel drafts, throughputs, and types of berth and transshipment in the case of crude oil.

Crude Oil

East Coast

The two major oil refinery areas on the east coast are located along the Arthur Kill and Delaware River. Because these two areas are only about 100 miles apart, alternatives will be considered whereby each area is served by an individual deepwater port (local ports) and whereby both areas are served by one port (regional ports).

Sites

Area 1 -- New York. Depending on the water depth considered, various sites for a deepwater port that would be protected against heavy wave attack exist in the New York area. For depths in the 40- to 60-foot range, several potential sites exist in the vicinity of Staten Island or Sandy Hook. The berths would be located in the Upper New York Bay, the Narrows, or the Anchorage, Ambrose or Sandy Hook Channels. The intermediate storage could be located on Staten Island or at Bayonne near the deepwater area, or could be located nearer the refineries. For depths in excess of 60 feet, the dredging quantities would increase rapidly for sites near Bayonne or Staten Island. Many potential sites for depths up to 100 feet exist in Long Island Sound. However, tank farm location and pipeline routing would present many environmental and land-use difficulties.

The site on Romer Shoal (alternatives 1-1 and 1-2) was selected for the following reasons:

1. A more seaward location would provide less shelter for vessels entering the turning basin area, and in addition would result in a more expensive island because of greater water depth and more exposure to waves during construction.

2. A more landward location would result in greater dredging volumes and the possibility of more interference with all other traffic.

3. Because preliminary investigations showed that an intermediate tank farm on Staten Island most likely would be environmentally difficult to realize, and because an offshore island would not pose this issue, only an offshore island will be considered.

4. The submarine pipeline to the refinery areas could follow an existing pipeline route through Raritan Bay between Morgan, near South Amboy, New Jersey, and Rockaway Point on Long Island, so that no pipeline would cross Staten Island.

The site off Long Branch (alternative 1-3) was selected because an actual proposal deals with this particular location. The 80-foot contour line is located only 6 miles off shore at this location.

Area 2 -- Delaware Bay. Depending on the water depth considered, various sites for a deepwater port that would be protected against heavy wave attack are available in the Lower Delaware Bay area. However, the characteristics of the sites are more or less similar. The site near Big Stone Beach, Delaware (alternatives 2-1 through 2-4), was selected because it deals with an actual proposal, and because it is located near a naturally deep area. For depths in excess of 80 feet, this area is 3.5 miles long and is over ½ mile wide for a length of 2 miles. Also, a naturally deep site located about 10 miles off the Delaware Capes (alternative 2-5) was selected because it would have different environmental characteristics than the site inside the bay. At this particular site, water depths in excess of 100 feet are located close to water depths in the 40-foot range, and this site therefore is attractive for an offshore island.

Location of Storage

For each site, two locations for intermediate storage could be considered: one on shore and one off shore on an artificial island. Preliminary environmental analyses showed that onshore storage on Staten Island or near the refineries along the Arthur Kill would raise many environmental objections, and it was therefore not considered feasible. Consequently, the alternatives dealing with the site in Lower New York Bay will consider offshore storage only. The site at Long Branch will deal only with onshore storage because the actual proposal deals with onshore storage, and an offshore storage island would be similar to that of alternative 2-5, located off the Delaware Capes. The alternatives dealing with the Lower Delaware Bay will evaluate onshore as well as offshore storage.

Vessel Sizes and Vessel Drafts

To limit the number of subalternatives on the east coast, and to enable proper comparison between alternatives, only one vessel draft will be considered for all eight alternatives. To keep the dredging quantities below 100 million cubic yards, to have a draft between 40 and 100 feet, and to be in the same range of draft and vessel size as presented in the proposals for deepwater ports at Big Stone Beach and Long Branch, a vessel draft of 70 feet was selected. This is the draft of a tanker in the 300,000 to 400,000 d.w.t. range.

Type of Berths

In principle, fixed berths can be considered only at locations where the forces on the berth structures, and the movements of the tanker with respect to the berth, are limited. Therefore, naturally or artificially protected areas are required for this type of berth if continuous operations are anticipated. However, it is possible to locate this type of berth in unprotected waters and to accept the unavoidable port closures during inclement weather, if periods of such weather are limited.

Monobuoys, because of their design concept of exposing a tanker to the elements as little as possible, are a logical structural type of berth for use at exposed locations. However, since monobuoys operate without tugs, sufficient maneuvering area for the tankers is required.

Considering these principles, fixed berths could be considered at the selected sites in the Lower New York Bay and Lower Delaware Bay; and monobuoys, at the selected sites off Long Branch, off the Delaware Capes and in the Lower Delaware Bay. Therefore, for the site in the Lower New York Bay, fixed berths were selected; and for the site off Long Branch, monobuoys are considered. Since an actual proposal considers monobuoys off Long Branch, this is an additional reason to evaluate them at this site. For the site off the Delaware Capes, fixed berths without breakwater protection were selected to evaluate the difference with the site off Long Branch. For the site in the Lower Delaware Bay, fixed berths were selected to stay in line with the actual proposal.

Types of Transshipment

Although transshipment by pipeline as well as by barge is feasible in principle for all eight alternatives, only one type of transshipment per alternative will be considered. Since locating deepwater port sites close to refinery areas and onshore storage would limit the length of pipelines, pipelines are selected for the two sites in the New York area and for the site near Big Stone Beach. For the deepwater ports off Long Branch and off Big Stone Beach, selection of pipelines is in accordance with the actual proposals at these sites. Because of its offshore location, and also to demonstrate the difference between the barge and pipeline concept, barges were selected for the site off the Delaware Capes (alternative 2-5).

Throughputs

The explanation for the selection of throughputs at deepwater ports appears in Annex F.

Gulf Coast

The two major oil refinery areas on the gulf coast are located in the Houston-Baytown area and the Beaumont-Port Arthur area, with a total 1970 refining capacity of 2,713,000 barrels per day. Five other refinery areas exist in this area. In sequence of decreasing capacity, these refineries are located near New Orleans, Baton Rouge, Corpus Christi, Lake Charles, and Pascagoula. Their 1970 refinery capacities range from 540,000 to 270,000 barrels per day; their total 1970 capacity was 1,884,000 barrels per day. These data indicate that about 60 percent of the 1970 refining capacity is located in the first two areas, and about 40 percent is located in the latter five areas.

Since the distance between the center of the Houston-Beaumont area and the center of the New Orleans-Baton Rouge area is about 270 miles, consideration should be given to deepwater ports serving each area individually (local ports) as well as serving both areas (regional ports). However, as will subsequently be explained, it was considered necessary to evaluate ports with different water depths in this region. Therefore, to keep the number of alternatives manageable, local ports will not be evaluated in this region, especially since regional ports deal with the same type of issues as local ports.

Sites

Area 4 -- Mississippi Delta. In this area the deepwater and shallow water contour lines are closest in Garden Island Bay, which is located east of the South Pass of the Mississippi River. The distance between the 35-foot and the 70-foot and 120-foot contour lines is about 1 and 2 miles, respectively. The site selected in this area deals with an actual proposal for constructing an artificial island. For further evaluation, it has been assumed that the subsoil conditions and the siltation characteristics are such that island and berth construction are technically feasible.

Area 5 -- Texas. The 60-foot contour line near Freeport, Texas, is located at a distance of about 8 miles from the shoreline. To the northeast, the distance increases rapidly to a maximum of about 40 miles off Port Arthur; to the southwest, the distance remains more or less constant at 8 miles for approximately 80 miles, and then decreases gradually to about 6 miles off Corpus Christi. Because Freeport is located only about 50 miles south of Houston, it offers the most attractive site on the Texas coast for depths of about 60 feet.

The 90-foot contour line near Freeport is located at a distance of about 20 miles from the shore. To the northeast, the distance increases rapidly to a maximum of about 65 miles off Port Arthur; to the southwest, the distance increases to about 23 miles over a length of 30 miles, and thereafter decreases gradually to about 15 miles off Corpus Christi. Therefore, for depths of about 90 feet, a site near Corpus Christi could be somewhat more attractive than a site near Freeport.

The 120-foot contour line near Freeport is located at a distance of about 40 miles from the shore. To the northeast, the distance increases rapidly to a maximum of about 90 miles off Port Arthur; to the southwest, the distance decreases to about 20 miles off Corpus Christi and to about 15 miles off Brownsville. Therefore, a site near Corpus Christi is most favorable for depths of about 120 miles.

It should be noted, however, that in many cases the distances given apply only to individual restricted locations on the respective contour lines. These locations are of interest when dredged channels are being considered. However, they do not necessarily apply to the larger areas that would be required for the installation of a series of monobuoys.

Since the basic characteristics of the coast do not change between Freeport and Corpus Christi, and since this detailed analysis can deal only with a limited number of basic alternatives, it was decided that a site near Freeport would be selected. Freeport was specifically selected because of its closeness to the Houston area for all different water depths to be considered, even though for water depths in the 90- to 120-foot range, a location more to the southwest of Freeport has the advantage of being located closer to these depths.

Location of Storage

Because the actual proposal for a deepwater port in area 4 deals with an offshore island, and because the onshore soil conditions near this site most probably are technically unsuitable for onshore storage, only offshore storage will be considered. It has been assumed that the soil conditions at or in the vicinity of the selected offshore site would permit the construction of an artificial island. Ample good areas for onshore storage exist at Freeport), and moreover, the distance between shallow and deepwater contour lines is very great. For these reasons, and to consider a different type of storage location in area 4 than in area 5, onshore storage near Freeport will be considered.

Vessel Sizes and Vessel Drafts

Given the great differences in distance between the shore and the contour lines in the 60- to 120-foot range, it was considered necessary to evaluate three different vessel drafts. Vessel drafts of 55, 70, and 95 feet were selected. The corresponding vessel sizes are 200,000 d.w.t., 300,000 to 400,000 d.w.t., and 500,000 d.w.t., respectively.

Type of Berths

Considering the contour lines near Freeport with respect to configuration and distance to the shore, monobuoys are a feasible solution for an offshore deepwater port, and will therefore be evaluated for area 5. For dredged channels and basins, fixed berths were selected to restrict the required inland maneuvering space.

In area 4, a great number of monobuoys might present layout problems, whereas fixed berths, due to their confined layout, would result in short pipelines between berths and island. Therefore, fixed berths were selected for area 4. Without further evaluation, it has been assumed for this analysis that no breakwater to provide for calm or calmer water at the berths would be required.

Types of Transshipment

For all nine alternatives, transshipment by pipeline as well as by barge to each refinery area is feasible in principle. However, to limit the number of alternatives, only one type of transshipment per refinery area will be considered for each alternative. Because of the desirability of evaluating both types of transshipment for each refinery area, it is logical to select pipelines in the case of onshore storage and nearness of major refinery areas (as is the case in area 5), and to select barges in the case of offshore storage and greater distances to the major refinery areas (as is the case in area 4). Since the projected volumes for Pascagoula and Corpus Christi are small in comparison to those projected for the major areas and, moreover, because in some cases the distances between deep water and refinery are relatively great, barge movements to these two refinery areas will be hypothesized under all alternatives.

Throughputs

The explanation for the selection of the throughputs at deepwater ports appears in Annex F.

West Coast

The two major refinery areas on the west coast are located in the Los Angeles-Long Beach area and in the San Francisco area. The refineries in Washington and Oregon presently have small refining capacities. The distance between the Los Angeles-Long Beach and the San Francisco refinery areas is about 400 miles, and the distance between the San Francisco and the Ferndale, Washington, refinery areas is about 950 miles. Further deepening of the San Francisco Harbor Channels poses environmental difficulties. Since the dredging amounts in the case of deepening the Los Angeles-Long Beach channels are comparatively small, and since in the case of Ferndale no dredging would be required, regional ports at Los Angeles-Long Beach and at Ferndale will also be evaluated.

Sites

Area 6 -- Los Angeles-Long Beach. Because the channels to the petroleum facilities in the Los Angeles and Long Beach Harbors are separate channels, deepening of both channels should therefore be evaluated. However, because the basic concept of deepening each harbor would be the same, because of the desirability of limiting the number of alternatives, and because both ports would be able to handle the projected imports of the area, deepening of only one port will be considered. The major petroleum facilities at Los Angeles are located closer to deep water than those of Long Beach. However, the present channel of Long Beach is considerably deeper than that of Los Angeles. This study will evaluate deepening of the channel to Los Angeles only; this selection is an arbitrary one.

Area 7 -- San Francisco. The existing major crude oil handling facilities in this area are located between Richmond and Avon. Considering the presence of deep water in the San Francisco Bay, a site for a common deepwater port terminal near Richmond's Long Wharf facility was selected and will be evaluated in alternatives 7-1 and 7-3. Also, dredging to all existing major crude oil handling facilities will be considered (alternatives 7-2 and 7-4), which will allow a continuation of present operational practices. Since deep water in Monterey Bay exists close to shore near Moss Landing, and since a deepwater port is or was under consideration at this location, this site will also be evaluated (alternative 7-5).

Area 8 -- Ferndale-Bellingham. Since sufficient deep water exists close to all major existing crude oil handling facilities in Washington, no alternatives will be considered that evaluate imports for local use. For evaluating deepwater ports which would serve San Francisco or the combined San Francisco and Los Angeles-Long Beach area, a site near Ferndale was selected, because a large area near Ferndale is designated for industrial use.

Location of Storage

Since onshore land for crude oil storage would be available at each of the selected sites, only onshore storage will be evaluated in all alternatives.

Vessel Size or Vessel Draft

For each area the maximum vessel size to be considered was arbitrarily set at 400,000 d.w.t. For dredged channels in the Los Angeles area (alternatives 6-1 and 6-2), the draft was limited to 70 feet, and for areas where natural deep water exists (alternatives 7-5, 8-1 and 8-2), the draft was maximized at 83 feet. For dredged channels in the San Francisco area, the channel depth was arbitrarily set at 50 feet (alternatives 7-1 and 7-2) and 60 feet (alternatives 7-3 and 7-4).

Type of Berths

Because of the confining nature of dredged channels, fixed berths will be considered in alternatives 6-1, 6-2, and 7-1 through 7-4. Monobuoys will be considered for alternative 7-5 because of this alternative's exposed site. Although monobuoys might be feasible in the Ferndale area, in certain areas the water depth at buoy and anchors might be in excess of 120 feet; therefore, fixed berths were selected for alternatives 8-1 and 8-2.

Type of Transshipment

Pipelines as well as barges are feasible types of transshipment. However, because all storage is anticipated to be located on shore, because the channels of San Francisco are congested, and because visual problems from fog exist in this area, pipelines alone will be considered for detailed evaluation in this study.

Throughput

The explanation for the selection of throughputs at deepwater ports appears in Annex F.

Dry Bulk

As is detailed in Annex F of this report, of all the dry bulk commodities considered in this study, only the export of coal and certain grains to particular overseas areas and the import of iron ore from particular overseas areas might have potential for economic movements in very large carriers. Only a few of these potential developments will be evaluated in detail in the seven selected alternatives.

East Coast

Only certain coal exports from Hampton Roads and Baltimore and certain iron ore imports to Baltimore and the Philadelphia-Trenton area will be considered.

Sites

Area 2 -- Delaware Bay. The two sites considered for crude oil transfer facilities in alternatives 2-1 through 2-5 could also be evaluated for the transfer of coal and iron ore. To limit the number of alternatives, only the more protected site selected for alternatives 2-1 through 2-4 in the Lower Delaware Bay will be considered. Two alternatives will be evaluated: alternative 2-6 will consider an offshore island for the transfer of coal, and alternative 2-7 will consider an offshore island for the transfer of coal and iron ore. To limit the number of alternatives, an island handling only iron ore will not be considered, because it is anticipated that such an island might be economically less favorable than the two selected.

Area 3 -- Hampton Roads. In addition to alternatives evaluating transshipment, alternatives should also be considered which deal with deepening of the channels to existing facilities. Only deepening of the channels to Hampton Roads for coal exports (alternative 3-1), will be considered in this Annex. Deepening of the channels to Trenton and to Baltimore for the movement of iron ore alone and other commodities is the subject of recent studies by the Baltimore and Philadelphia offices of the Corps of Engineers.

Location of Storage

For alternatives 2-6 and 2-7, artificial islands will be considered because they could be constructed on a shoal located close to deep water. Since the distance between the coast and the deepwater area is about 6.5 miles, the cost of trestles and conveyor belts would make onshore storage economically unfeasible. However, for coal exports a deepwater port without storage might be worth consideration, in which case the cost of a large island could be offset by the employment of one or two additional transshipment vessels. In that case, close coordination would be required between the loading operations of the transshipment vessels at Hampton Roads and the loading operations of the supercarriers at the deepwater port. With proper planning the additional loading time of the supercarriers might be less than half a day. This alternative will not be evaluated further in this analysis.

A shore-connected island located off Hampton Roads on Willoughby Bank has also had preliminary consideration. For this alternative, the railroad cars could be unloaded directly after arrival at the shunting yard of the Norfolk and Western Railway. If feasible, this would provide the Norfolk and Western Railway an advantage over the Chesapeake and Ohio Railway, which does not own railroad lines in the vicinity of the site. However, connecting the Norfolk and Western Railway's shunting yard with the artificial island would require traversing the residential area located between shunting yard and island, which raises major questions of economic and environmental feasibility. Therefore, this alternative will not be evaluated further in this analysis.

Vessel Size or Vessel Draft

The maximum size of coal and iron ore carriers was arbitrarily set at 250,000 d.w.t. for alternatives 2-6 and 2-7. The corresponding draft would be 65 feet if no depth constraints were presented, or 58.5 feet if depth constraints exist and the wide beam concept is applied in vessel design.

Throughputs

The explanation for the selection of throughputs at deepwater ports appears in Annex F.

Gulf Coast

Only certain grain exports originating from the Mississippi River and the Louisiana and Texas coasts and certain iron ore imports destined for Mobile, Houston, and Baton Rouge, will be considered.

Sites

Area 4 -- Mississippi Delta. The site in Garden Island Bay considered for oil transfer facilities in alternatives 4-1 through 4-3 could also be evaluated for the transfer of grain and iron ore. However, without further evaluation it is anticipated that the iron ore unloading operations would require a breakwater to provide calm water at the berth, and that the grain loading operations would take place without a protecting breakwater.

Area 5 -- Texas. The site near Freeport considered for the crude oil transfer facilities in alternatives 5-4 through 5-6 could also be evaluated for the transfer of grain and iron ore. However, of these two, it is anticipated that grain operations alone might be economically feasible if executed in combination with the oil operations. This possibility will be evaluated in alternative 5-7.

Location of Storage

The same type of storage location will be considered as was considered for the crude oil alternatives; therefore, alternatives 4-4 through 4-6 will consider an artificial island, and alternative 5-7 will consider onshore storage.

Vessel Sizes and Vessel Drafts

Iron ore carriers of 250,000 d.w.t. will be hypothesized, drawing 65 or 58.5 feet. For both areas, grain carriers will be assumed to be 250,000 d.w.t., drawing 65 or 58.5 feet, and 120,000 d.w.t., drawing 50 feet.

Throughputs

The explanation for the selection of throughputs at deepwater ports appears in Annex F.

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III. DESIGN CRITERIA FOR CRUDE PETROLEUM PORTS

Channels and Maneuvering Areas

The dimensions of channels and maneuvering areas will be evaluated in relation to vessel dimensions and the estimated force of currents and waves to which the vessel will be exposed.

The dimensions of the supertankers selected for the various alternatives are established in Annex E and are reviewed in table 4.

Table 4. Supertanker Dimensions
(In feet)

Dimensions	Symbol	Deadweight tons (1,000)						
		157	200	250	300	400		500
Length.	L	980	1,050	1,095	1,100	1,262	1,160	1,195
Beam...	B	164	173	190	192	220	200	208
Draft..	D	50	55	58.5	70	70	83	95

Before a tanker can dock at a fixed-berth terminal complex, it must proceed normally via ocean channel, inland entrance channel(s) and turning basin to the berthing area. The dimensions of these four navigable areas will be related to the appropriate tanker dimensions, depending on hypothesized general wave and current conditions.

Special detailed studies would be required to determine the need for extra width or depth by location, and to analyze trade-offs between the additional dredging cost or additional construction cost in case facilities are constructed in deeper water and the increased port closure time. Table 5 presents the established relations between the dimensions of the vessel and those of channels and maneuvering areas.

Width

In recent hydraulic model studies a safe channel width of three times the beam of the vessel was experienced for one-way traffic channels without crosscurrents. Crosscurrents and/or beam waves will bring the vessel in an oblique position with respect to its travel direction. The stronger the crosscurrents or beam waves and the lower the travel speed of the vessel, the larger will be the angle between the vessel's axis and its travel direction. For example, a 1,200-foot-long vessel sailing at 6 knots and subject to a 1-knot crosscurrent would require an extra channel width of

$$\frac{1}{6} \times 1{,}200 = 200 \text{ feet,}$$

which approximately equals the beam of the vessel. Therefore, for certain ocean channels an extra width of 1.0B would be required. For inland channels a width of 3.5B will be applied, allowing for differences in water pressures on the sides of the hull.

Depth

The underhull clearance has to allow for trim, squat, pitch, roll, and countercurrents, in addition to allowing a safety margin because of the unevenness of channel bottoms. Ocean channels might require 15 to 20 percent of the draft of the vessel, depending on the state of the sea. A value of 10 percent would be acceptable for inland channels due to reduced wave actions.

For turning basins and berthing areas, where wave actions are negligible and the speed of the vessel is almost zero, 5 percent is considered sufficient.

Table 5. Design Dimensions of One-Way Channels and Maneuvering Areas

Description of location	Length	Width	Depth	Radius
Channels				
Over 10 miles offshore....	--	5B	1.2D	--
Less than 10 miles off-shore and less than width between capes inland.....	--	4B	1.15D	--
Protected, limited wave and current actions......	--	3.5B	1.1D	--
Turning Basins				
Unprotected against wave and current actions and over 10 miles offshore:				
Turning basin between two channels............	--	--	1.2D	2L
Turning basin in connection with berthing areas	a/	2L	1.2D	--
Protected, very limited wave and current actions:				
Turning basin between two channels............	--	--	1.1D	1.5L
Turning basin in connection with berthing areas	a/	1.5L	1.1D	--
Berthing Areas[b/]				
Unprotected against wave and current actions and over 10 miles offshore...	1.5L	5B[c/]	1.15D	--
Protected, very limited wave and current actions.	1.5L	3B[c/]	1.05D	--
Maneuvering Areas[d/]				
Unprotected against wave and current actions......	--	--	1.15D	4000[e/]

a/ Depending on the number of berths.
b/ At fixed berths.
c/ For one berth. For two or more berths, see table 6.
d/ At monobuoys.
e/ In feet.

Length

The radius of the turning basin was selected at 1.5 to 2.0 times the ship's length, which is a generally applied and accepted value. The radius of the maneuvering areas of monobuoys was established at 4,000 feet. This dimension depends mainly on the maneuverability of the individual tanker. Maneuverability is determined by speed, length, screw(s), rudder(s) and loading condition of the vessel. At berthing areas with parallel island piers the total width required is presented in table 6.

Table 6. Widths of Berthing Areas of Island Piers
(In multiples of beam [B] of vessel)

Number of berths	Berthing area	
	Unprotected against wave and current actions and over 10 miles offshore	Protected, very limited wave and current actions
1......	5B	3B
2......	11B	7B
3......	12B	8B
4......	18B	12B
5......	19B	13B
6......	25B	17B
7......	26B	18B
8......	32B	22B
9......	33B	23B
10.....	39B	27B
11.....	40B	28B
12.....	46B	32B
13.....	47B	33B
14.....	53B	37B

Supertanker Berths

Introduction

The arrival of ocean-going tankers at terminal facilities cannot be precisely scheduled, for various reasons. First, a vessel may leave the port of lading after its scheduled departure time because inclement weather or the unavailability of a facility necessitated the ship's waiting for a berth, or because the shortage of a stored commodity resulted in loading at a slow rate. Second, the influence of winds, waves and currents may cause vessels to sail faster or slower than their maximum speeds. (Vessels in ballast are influenced mainly by winds; laden vessels are influenced mainly by waves and currents.) A variation of 1 or 2 knots in a maximum speed of 14 to 17 knots would result in an acceleration or deceleration of 6 to 14 percent. On a 30-day voyage this variation could result in a ship's arriving about 2 to 4 days off schedule. This would theoretically mean a period of 4 to 8 days in which the vessel might arrive.

However, the average occurrences of winds, waves, and currents on the various portions of a route are known by season and can be included in the calculations of the voyage time. Deviations from the average always occur and, therefore, off-schedule arrival is a normal phenomenon. When taking the arrival of all vessels at a terminal facility into account, it is obvious that this phenomenon of early or late arrivals will create a pattern that rather closely fits that of a random distribution.

Berth Occupancy Factors

The selection of the number of berths required for a particular alternative will be based on Mettam's ship queuing theory. This theory establishes the relation between berth occupancy and the ratio of average queuing time to the average berth service time for various numbers of berths. This relation is graphically shown in figure 3. The broken lines present the case

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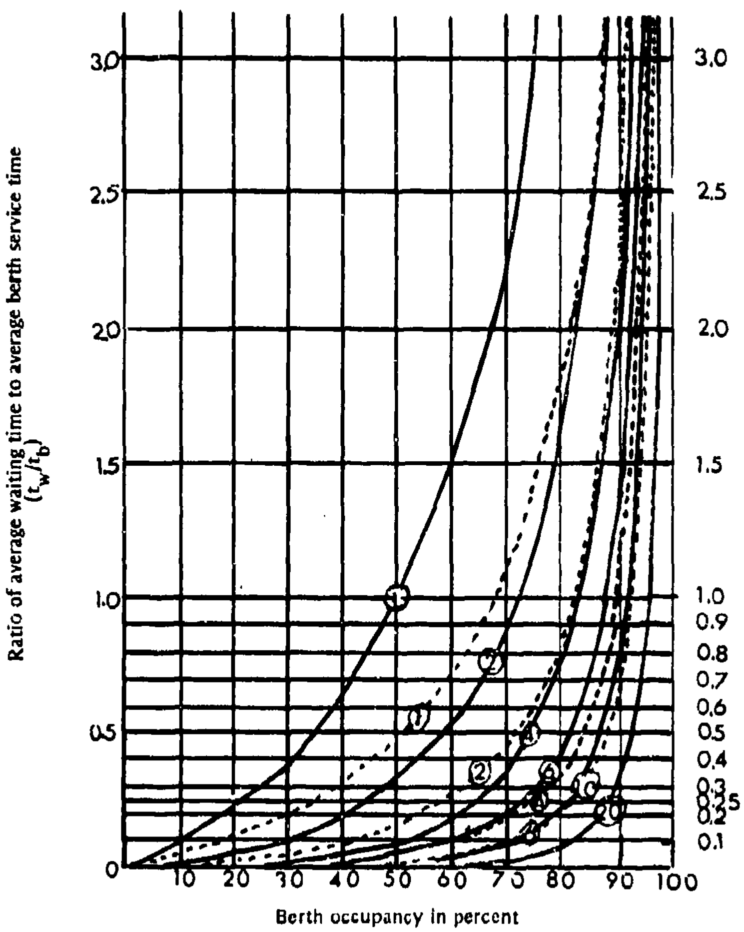


Source: J.D. Mettam, Forecasting Delays to Ships in Port, The Dock and Harbour Authority, London, England, April 1967.

FIGURE 3. QUEUING ANALYSIS WAITING TIMES FOR SHIPS IN PORT

of uniform service times, whereas the full lines present the case of varying service time (the variation is exponential).

The permissible value of the ratio of queuing time to berth service time should be evaluated separately for each case. An increase in the number of berths will reduce the average waiting time of all vessels, and the additional investment cost should be weighed against the value of this reduced waiting time. In many studies the permissible value is set at 0.25, which is an arbitrary figure. It should be noted that Mettam's graphs do not include queuing caused by inclement weather or an overflow or shortage of storage. It is not possible by means of simple hand calculations to adjust the graphs to reflect these factors. In this study the permissible ratio of waiting time to berth service time will arbitrarily be set at 0.20 for all coastal areas. (The actual value of the ratio of waiting to berth service time will be higher than the permissible value because inclement weather is not taken into consideration in the graph.) The sensitivity of this ratio will be demonstrated in the following paragraphs.

Table 7 presents the permissible berth occupancy factors for a given number of berths when the ratio of average waiting time to average berth service time (t_w/t_b) equals .20 and .40 for both varying and uniform service times. From this table several conclusions are apparent. First, for a constant value t_w/t_b, the difference in the permissible berth occupancy factor for uniform or varying service times decreases in absolute value as well as in percentage. For example, if t_w/t_b = .20 and n (number of berths) = 2, the difference in the permissible berth occupancy factor is .15 or 38 percent, whereas for n=4 the difference is .10 or 16 percent. When t_w/t_b = 0.40, these figures are .14 (or 29 percent) and .10 (or 15 percent), respectively. Second, the difference in permissible berth occupancy factor for a varying number of berths decreases rapidly when t_w/t_b = .20 and .40.

Table 7. Permissible Berth Occupancy Factors

Number of berths (n)	Berth occupancy factor					
	t_w/t_b = 0.20			t_w/t_b = 0.40		
	Varying[a]	Uniform[a]	Unif./var.[a]	Varying[a]	Uniform[a]	Unif./var.[a]
1........	.18	.30	1.67	.25	.39	1.56
2........	.40	.55	1.38	.49	.63	1.29
3........	.53[b]	.65[b]	1.22[b]	.60[b]	.72[b]	1.20[b]
4........	.62	.72	1.16	.68	.78	1.15
5........	.67[b]	.76[b]	1.14[b]	.73[b]	.82[b]	1.13[b]
6........	.70	.79	1.13	.76	.84	1.11
8........	.75[b]	.84[b]	1.11[b]	.80[b]	.88[b]	1.10[b]
10.......	.79	.87[b]	1.10[b]	.83	.91[b]	1.09[b]
15.......	.84[b]	.91[b]	1.08[b]	.88[b]	.94[b]	1.07[b]
20.......	.88	.93[b]	1.06[b]	.91	.96[b]	1.05[b]

a/ Berth service time.
b/ Estimated by interpolation or extrapolation.

For n=2 the difference in absolute value is .09 for varying and .08 for uniform service times, or 22 and 15 percent, whereas for n=4 these figures are .06 and .06, or 10 and 8 percent, respectively. The above-mentioned examples demonstrate that for an increasing number of berths the differences between permissible berth occupancy factors diminish in cases of varying and uniform service times as well as for different t_w/t_b values. Because most of the deepwater port alternatives will require more than four berths, establishing the actual acceptable value of t_w/t_b for three berths and less is not a critical issue. The relatively low sensitivity of this ratio for four or more berths allows us to establish one value of the permissible berth occupancy factor for each number of berths. The mean values have been calculated using the formula

$$b = b_u - 0.25(b_u - b_v)$$

where

b = berth occupancy factor (b.o.f.),
b_u = b.o.f. for uniform service times
b_v = b.o.f. for varying service times

In the above formula, 0.25 is an arbitrary number reflecting the expectation that deviation from the factor for uniform service times will be relatively small. The results of these calculations are given in table 8.

High berth occupancy factors seem very attractive, because they yield high utilization of the berth facilities. However, as the rate of utilization rises, the ability to quickly absorb traffic congestions after spells of port closure lessens. In general, where b= berth occupancy factor and n=days of port closure, an average spell of queuing of $\frac{b \times n}{1 - b}$ days will result from a period of port closure. If b = .9 or .75 and n = 4 days, a queuing spell of 36 and 12 days, respectively, will result. In other words, reducing the berth occupancy factor from .9 to .75 (or 16.7 percent) will reduce the queuing spell by 24 days (or 67 percent). For each site the optimum ratio of an additional berth facility to reduced queuing times of all vessels per year should be determined. This optimization process will

Table 8. Theoretically Permissible Mean Berth Occupancy Factors

Number of berths	Berth occupancy factor
1	.27
2	.51
3	.62
4	.70
5	.74
6	.77
7	.80
8	.82
9	.84
10	.85
15	.89
20	.92
30	.93

not be undertaken in this study; however, in the following calculations, an arbitrary maximum berth occupancy factor of .75 will be used. Table 9 presents the established practicably permissible mean berth occupancy factors.

Table 9. Practicably Permissible Mean Berth Occupancy Factors

Number of berths	Berth occupancy factor
1	.27
2	.51
3	.62
4	.70
5	.74
6 and over	.75

Berth Occupancy Times

The average unloading time of a tanker depends on its installed pumping capacity. For tankers of 326,000 d.w.t. and less, unloading rates were assumed to equal the maximum pumping capacity for each class of tanker as listed in the 1971 edition of The Tanker Register, published by H. Clarkson and Company, Ltd., London. Because no pumping data were available for tankers of 350,000 d.w.t. and over, a maximum of 100,000 barrels per hour was assumed. Table 10 gives the relationship between tanker size and pumping time.

Table 10. Relationship of Tanker Size to Unloading Time

Tanker size (d.w.t.)	Pumping rate	Ship's pump discharge pressure	Unloading time at maximum pumping rate
	(b.p.h.)	(p.s.i.g.)	(hours)
157,000....	75,000	150	15
200,000....	80,000	150	18
250,000....	85,000	150	21
300,000....	90,000	150	23
400,000....	100,000	150	28
500,000....	100,000	150	35

Table 11 gives assumed total berth occupancy times, broken down into unloading, berthing, clearance, and deberthing times.

In general, the maneuvering time of vessels to and from a fixed berth will be longer than that to and from a monobuoy. This is because the terminal will be located nearer to the shore or may even be inland, and, moreover, vessels may have to wait for tug assistance or high tide to approach terminals.

Table 11. Berth Occupancy Times[a]
(In hours)

Item	Fixed structure berth						Monobuoy			
	Vessel size (1,000 tons)									
	157	200	250	300	400	500	200	300	400	500
Berthing[b] .	4	4	4	4	4	4	3	3	3	3
Clearance[c] .	2	2	2	2	2	2	2	2	2	2
Unloading[d] .	15	18	21	23	28	35	18	23	28	35
Deberthing[e]	3	3	3	3	3	3	2	2	2	2
Total	24	27	30	32	37	44	25	30	35	42

a/ Excluding delays for inclement weather, berth occupancy and overflow or shortage of storage.
b/ Including maneuvering and mooring.
c/ Customs and health clearance.
d/ Average value.
e/ Including maneuvering.

The calculated berth occupancy time of a fixed berth is 2 hours more than that of a monobuoy.

Throughputs

Table 12 gives the number of vessel callings per year and corresponding annual throughput capacities for a berth occupancy factor of 1.0. For these calculations a year is considered to consist of 350 working days, excluding all local and Federal holidays. The maintenance of a pier can normally be done during periods of absence of tankers. Because regular maintenance is not time-sensitive and can therefore be executed without interfering with tanker discharge operations, 350 days are theoretically available. Maintenance of a monobuoy normally requires 1 day a month, whereas dry-docking of the buoy, which is required once every 3 years, will take about 1 month.

Table 12. Vessel Callings and Throughputs per Vessel Size at a Berth Occupancy Factor of 1.0

Vessel size (1,000 long tons)	Number of vessel callings per year			Annual throughput (million long tons)
	Pier	Monobuoy	Average	
157...........	350	n.a.	350	55
200...........	311	320	315	63
250...........	280	n.a.	280	70
300...........	262	267	265	80
400...........	227	229	228	91
500...........	191	191	191	96

n.a. = not applicable.

Assuming that half of the monthly maintenance of a buoy can be done when no tanker is available for discharge, the number of working days per year will be reduced by 6/1 + 30/3 = 16 days. Thus, the available number of working days is 334. Since at a berth occupancy factor of 1.0 the difference between the number of vessel callings per year at a pier or monobuoy is only 3 percent or less, an average number is established for both cases (table 12). The average number of vessels times the vessel sizes results in the annual throughputs when the berth occupancy factor equals 1.0.

Taking into account the practicably permissible mean berth occupancy factors established in table 9 and the number of berths available, the maximum permissible annual throughputs can be determined for different numbers of berths. Because this deepwater port analysis establishes the maximum annual throughput for 200,000, 300,000, 400,000, and 500,000 d.w.t. tankers at 600 million tons per annum (m.t.a.), only throughputs up to 600 m.t.a. have been calculated, and the results are given in table 13. For 157,000 and 250,000 d.w.t. vessels the maximum throughput is approximately 60 m.t.a.

Table 13. Annual Throughput Volumes for Varying Vessel Sizes and Numbers of Berths

(In millions of long tons)

Number of berths	Vessel size (1,000 d.w.t.)					
	157	200	250	300	400	500
1............	15	17	19	22	25	26
2............	56	64	71	82	93	98
3............		117		149	169	179
4............		176		224	255	269
5............		233		296	337	355
6............		283		360	409	432
7............		331		420	478	504
8............		378		480	546	576
9............		425		540	614	648
10...........		473		600		
11...........		520				
12...........		567				
13...........		614				

Pipelines Between Berths and Intermediate Storage

Pipelines

The number and size of the pipelines linking supertanker berths and intermediate storage are determined mainly by the viscosity of the oil, the unloading rate of the tankers, and the length of the pipelines.

Van Houten Associates, Inc.,1/ advised selection of the following crude oil characteristics:

Gravity = 32° API (sp. gr. = .8654)
Viscosity = 80 SSU at 60° F.
Design flowing temperature = 60° F. (average)
Pour point: 40° F. or lower

1/ Van Houten Associates Inc., Consulting Engineers, 420 Lexington Avenue, New York, New York.

These characteristics are representative of approximately 95 percent of Middle East crudes and do not require heater stations. Problem crudes, such as those found in Lybia or Nigeria, with pour points much higher than 40° F. (and some exceed 100° F.) are not suitable for transportation through cold submarine pipelines because the oil will solidify in the pipeline when the flow stops. Although research and development is proceeding on systems to handle these problem crudes, they are excluded from the design of the pipelines.

The unloading rates were assumed to equal the maximum pumping capacities listed for each class of tankers in The Tanker Register. Table 14 presents the selected unloading rates for the various classes of supertankers.

Table 14. Unloading Rates

Tanker size (1,000 d.w.t.a/)	Unloading rates per hour	
	Barrels	Long tons
157	75,000	10,350
200	80,000	11,000
250	85,000	11,650
300	90,000	12,300
400	100,000	13,700
500	100,000	13,700

a/ In long tons.

Recommended submarine pipeline sizes have been limited to 48 inches. At present this is the largest diameter submarine pipeline capable of being installed by lay-barges.

It must be noted, however, that in cases where terminals are more than 10 miles offshore, the use of 54-inch- or 60-inch-diameter pipelines would greatly reduce pumping horsepower. These sizes may well be worthy of future consideration as the state of the art improves and lay-barges become available to handle these very large submarine pipelines.

It is assumed that all berths will be served by individual pipelines to segregate the different crudes. However, consideration might be given to common submarine pipelines serving multiple berths, especially for facilities of four or more berths. An optimization study should also consider a reduction of unloading rates, comparing the reduction of capital cost of pipelines, pumps, and drivers to an increase in port time of unloading tankers. Since the above-mentioned optional possibilities have not been evaluated in this study, the selection of pipe sizes and required horsepowers should be regarded as very preliminary and should be considered as only one solution to a many-faceted and complex problem.

Horsepower

The required horsepower of drivers depends on the pressure differential between the ship's manifold and the oil level in the storage tank.

The total differential pressure of the piping system between ship's manifold and storage tanks is composed of four main components:

1. p_1 = pressure loss due to friction in unloading arms or hoses and meters.
2. p_2 = pressure loss due to friction in the pipeline between berth and tank farm.
3. p_3 = pressure loss due to friction in manifolds of tank farm.
4. p_4 = pressure loss or gain due to difference in elevation of ship's manifold and oil level in storage tanks.

The pressure loss p_1 can be set at about 15 p.s.i. for fixed terminals utilizing metal unloading arms and at about 70 p.s.i. for single-point moorings utilizing hoses and swivel. Both values are averages of values experienced by Van Houten Associates, Inc.

The pressure loss p_2 can be calculated using Darcy's equation, which expresses the pressure drop per mile as

$$p = \frac{34.87 \times f \times B^2 \times s}{D^5}$$

where

p = pressure drop, p.s.i./mile
f = friction factor
B = barrels/hour
s = specific gravity of oil
d = internal pipe diameter in inches

The friction factor, f, is a function of the Reynolds number, R. The relation is presented in figure 4. The Reynolds number is expressed:

$$R = \frac{2{,}214\ B}{Dv}$$

where

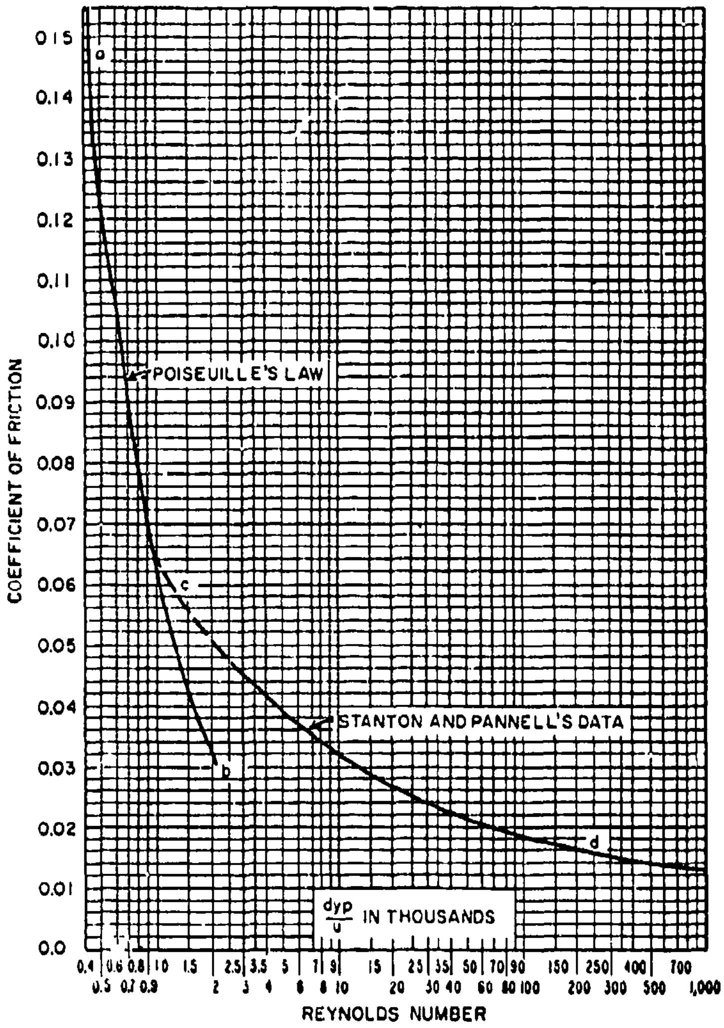
R = Reynolds number, dimensionless
B = barrels/hour
D = internal pipe diameter, inches
v = kinematic viscosity, centistokes

The following data apply for all cases:

Outside diameter = 48 inches with an assumed average wall thickness of 1.0 inch (conservative)
D = 46 inches
v = 14.5 centistokes (corresponds with 80 SSU)
s = .8654

The unloading rate varies by vessel size, and may equal 75,000, 80,000, 85,000, 90,000, or 100,000 barrels per hour.

Applying these data to the formulas results in values of differential pressures per mile as presented in table 15.



Source: Harold Sill Bell (ed.), Petroleum Transportation Handbook (New York: McGraw-Hill Book Company, Inc., 1963), p. 1-14.

FIGURE 4. RELATION BETWEEN REYNOLDS NUMBER (R) AND FRICTION COEFFICIENT (F)

Table 15. Differential Pressures per Mile

Unloading rate (barrels/hour)	Reynolds number (R)	Friction coefficient (f)	Differential pressure (p)
	(1,000)	(0.01)	(p.s.i./mile)
75,000..........	248	1.54	12.7
80,000..........	266	1.52	14.1
85,000..........	280	1.50	15.9
90,000..........	298	1.49	17.4
100,000........	330	1.47	21.2

The pressure loss p_3 in the manifolds of the tank farm does not exceed 5 p.s.i. and will therefore be disregarded.

The pressure loss or gain p_4 due to the difference in the elevation of the ship's manifold and the oil level in the storage tank can be expressed by

$$p_4 = (E_s - E_t) \frac{s}{2.31}$$

where

p_4 = pressure loss ($E_s < E_t$) or gain ($E_s > E_t$) in p.s.i.
E_s = average elevation of ship's manifold in feet
E_t = average elevation of oil level in tank in feet
s = specific gravity of oil

The elevation of the ship's manifold varies with the unloading conditions of the ship and the stage of the tide. The distance between the ship's manifold and water level can be a minimum of 20 feet for a fully loaded vessel and a maximum of 70 feet for an unloaded vessel, depending on ballast conditions and the draft of vessel. An average elevation of +45 feet will be assumed, which does not include an allowance for an average tidal rise of several feet.

The average elevation of the tank farm will be assumed at +30 feet. Assuming a useful tank height of 50 feet, the average elevation of the oil level in the tanks is +55 feet. The total loss of pressure is 10 feet of oil, or less than 4 p.s.i. This value is insignificant compared with the total pressure differentials, and therefore will be disregarded. From the foregoing, we have:

1. p_1 = 15 p.s.i. (fixed berth with metal loading arms) or 70 p.s.i. (monobuoy with hoses)
2. P_2 = 12.7 p.s.i./mile (75,000 bbl./hr.)
   14.1 p.s.i./mile (80,000 bbl./hr.)
   15.9 p.s.i./mile (85,000 bbl./hr.)
   17.4 p.s.i./mile (90,000 bbl./hr.)
   21.2 p.s.i./mile (100,000 bbl./hr.)
3. p_3 = negligible
4. p_4 = negligible

The assumed pressure at the ship's manifold is 150 p.s.i.

The horsepower requirements can be expressed by the formula

$$H = \frac{P\ B}{2{,}450 \times E}$$

where

H = brake horsepower
P = total differential pressure, p.s.i.
B = barrels (42 U.S. gallons) per hour
E = pump efficiency, decimal fraction; the selected value is .78.

For P = 1 p.s.i. the formula will read

$$h = \frac{B}{2{,}450 \times E}$$

This will produce the following required horsepowers:

1. When B = 75,000 bbl./hr., h = 39 b.hp./p.s.i.
2. When B = 80,000 bbl./hr., h = 42 b.hp./p.s.i.

3. When B = 85,000 bbl./hr., h = 44 b.hp./p.s.i.
4. When B = 90,000 bbl./hr., h = 47 b.hp./p.s.i.
5. When B =100,000 bbl./hr., h = 52 b.hp./p.s.i.

Intermediate Storage

Introduction

The link between intermediate storage and refineries will be a pipeline system, transshipment vessels, or both. The capacity of pipelines and transshipment vessels is based on a steady flow of crude oil from the intermediate storage to the refinery tank farms.

The amount of intermediate storage required will depend on the schedule of arrivals and the average cargo load of the ocean-going tankers on the one hand and the ratio between average and maximum capacity of the pipelines or transshipment vessels on the other. In other words, the intermediate storage is the buffer between an irregular inflow and a more steady outflow; its objective is to provide, in general, sufficient storage capacity for unloading vessels so that unloading can take place at the maximum anticipated rate.

The greater the ratio between average and maximum transshipment capacity, the smaller the intermediate storage can be. This might be called the flexibility of the link. The optimal point of trade-off between tank storage capacity and pipeline capacity is found at the point where, taking into account capital recovery and operating costs, the savings in pipelines attributable to the last (marginal) unit increase in tank storage capacity is equal to the cost of that last (marginal) unit of storage capacity. Since it is outside the scope of this project to deal with optimizations within an alternative, the amount of intermediate storage will be calculated on the basis of the rules developed in the subsequent paragraphs.

In principle, the flexibility of a system of pipelines is different from that of transshipment vessels. The capacity of pipelines can be increased 50 percent over their capacity at optimum cost with a consequent increase in operating cost of approximately 15 percent. An increase in capacity of transshipment vessels will normally result in an increase of investment cost of the same ratio as the capacity increase, since the purchase of more vessels will be required.

The operation of pipelines is independent of weather conditions; however, inclement weather influences the operation of transshipment vessels. When transshipment vessels serve refineries at varying distances from the port, their rate of emptying intermediate storage varies with whether they serve only refineries nearest or further away from the port, if the characteristics of the crude oil and the availability of storage at the receiving refineries permit this. Pipelines do not have this type of flexibility. Because both systems have one advantage and one disadvantage compared with each other, this difference will be considered negligible in the determination of storage requirements.

Derivation of Formula

The amount of intermediate storage will be defined as the difference between inflow and outflow during a certain period. The length of the period will depend on the duration of spells of inclement weather and the effect of the randomness of tanker arrivals. There are few terminals where the storage at or near the terminal is used only as intermediate storage; in most places it is integrated in the long-term refinery storage. However, a pure example of intermediate storage is found in Bantry Bay, Ireland. Here the storage capacity is provided by 12 tanks, each having a capacity of 600,000 barrels. The total capacity is 7.2 million barrels or about 1 million long tons. There is one berth for a very large crude carrier (VLCC) of a maximum size of 326,000 d.w.t. Thus the storage capacity is equivalent to about three times the vessel size.

The inflow of crude oil during 1 week of full berth occupancy can be expressed by

$$I_{1w} = \frac{168}{t} n\ d$$

where

I_{1w} = inflow in millions of long tons, during 1 week of full berth occupancy
168 = number of hours per week
n = number of berths
d = average size tanker in million long tons
t = average total berth occupancy time in hours per vessel

The outflow during 1 week of pumping at maximum rate can be expressed by

$O_{1w} = 0.02T$

where

O_{1w} = maximum 1 week outflow in millions of long tons
0.02 = number weeks/52 weeks
T = maximum annual throughput capacity of pipeline(s) or transshipment vessels in long tons. This maximum is higher than the actual annual throughput in order to get seasonally higher throughputs. An arbitrary factor of 1.2 will be applied, hence T = 1.2A, where A is the annual throughput in million long tons.

The required intermediate storage (S_{1w}) for 1 week of full berth occupancy is $S_{1w} = I_{1w} - O_{1w}$.

The amount of storage (S) is proportional to the number of weeks of full berth occupancy. Additional storage will be required since all tanks will generally not be empty at the beginning of the period of full berth occupancy. However, after a long spell of inclement weather the amount of oil left in storage will be very small. For this amount an arbitrary figure of 10 percent of total storage capacity is selected. Even more additional storage capacity will be required, since not all tanks will be fully loaded because the oil will be segregated by origin and owner. If only tanks with individual capacities of 600,000 barrels (equivalent to 82,000 long tons1/ are used, 200,000,

1/ One long ton equals 7.3 barrels.

300,000, 400,000 and 500,000 d.w.t. tankers will require 2.44, 3.66, 4.88, and 6.10 tanks, respectively. This obviously would result in a requirement for three, four, five, and seven tanks, respectively. This means that the storage volume required is 3 ÷ 2.44 = 1.23, 4 ÷ 3.66 = 1.09, 5 ÷ 4.88 = 1.02 and 7 ÷ 6.10 = 1.15 times larger than that theoretically calculated. Because 600,000-barrel tanks are too unfavorable in size if tankers primarily in the 200,000 d.w.t. range are expected to call, a smaller size tank of 500,000 barrels will be assumed. One 500,000-barrel tank is able to contain 68,500 long tons; therefore, one 200,000 d.w.t. tanker will require 2.92 tanks, or three tanks with an average reserve capacity of 3 ÷ 2.92 = 1.03. Given the above ratios of 1.03, 1.09, 1.02, and 1.15, the average ratio of required overcapacity is 1.0725. In addition, since it is assumed that only 10 percent of the tank farm's total capacity of oil will remain in storage after a long period of inclement weather, this factor must be taken into consideration in the calculation of required overcapacity. The average ratio of overcapacity and the amount of capacity still in use after inclement weather combines to produce a total required overcapacity of 1.0725 x 1.10 = 1.18, or 1.2.

The total amount of storage required is then:

$$S = 1.2\left(\frac{168}{t} n\, d - 0.024A\right)w,$$

where

w = number of weeks of full berth occupancy

Table 16 presents the storage volumes required according to the above formula if 1 week of full berth occupancy is experienced. For fixed berths and monobuoys, an average berth occupancy time of 26, 31, 36, and 43 hours has been applied for 200,000, 300,000, 400,000, and 500,000 d.w.t. vessels, respectively. For 157,000 and 250,000 d.w.t. vessels, the average berth occupancy time is respectively 24 and 30 hours.

Table 16. Storage Volumes for One Week of Full Berth Occupancy

(In millions of long tons)

Number of berths	Vessel size (1,000 d.w.t.)					
	157	200	250	300	400	500
1................	0.89	1.06	1.13	1.32	1.53	1.59
2................	1.03	1.25	1.32	1.54	1.80	1.86
3................		1.29		1.56	1.85	1.87
4................		1.13		1.35	1.61	1.62
5................		1.05		1.23	1.49	1.49
6................		1.16		1.34	1.66	1.62
7................		1.32		1.56	1.91	1.90
8................		1.52		1.79	2.19	2.16
9................		1.71		2.01	2.47	2.43
10...............		1.89		2.22		
11...............		2.08		2.45		
12...............		2.28				
13...............		2.47				

Spells of port closure will vary by site and type of berth facility and might be caused by hurricanes, swells, or fog. In this study no differentiation will be made with respect to site or type of structure. An average major spell of inclement weather of 5 days will be considered applicable for all cases. In case of an average berth occupancy factor b (b ÷ 1-b) x 5 days will be required to eliminate the queue initiated by the 5-day port closure. For one, two, three, four, five, and six berths and over, 0.26 0.74, 1.16, 1.66, 2.04, and 2.14 weeks of queue elimination will be required if the permissible mean berth occupancy factors of table 9 are applied for b. The amount of storage required will be set at a minimum of 1 week of full berth occupancy for one and two berths, and at 1.16, 1.66, 2.04 and 2.14 weeks of full berth occupancy for three, four, five, and six berths and over. The result is presented in table 17.

Table 17. Crude Oil Storage Capacities
(In millions of long tons)

Number of berths	Vessel size (1,000 d.w.t.)					
	157	200	250	300	400	500
1	0.89	1.06	1.13	1.32	1.53	1.59
2	1.03	1.25	1.32	1.54	1.80	1.86
3		1.50		1.81	2.15	2.17
4		1.88		2.24	2.67	2.69
5		2.14		2.51	3.04	3.04
6		2.48		2.87	3.55	3.47
7		2.82		3.34	4.09	4.07
8		3.25		3.83	4.69	4.62
9		3.66		4.30	5.29	5.20
10		4.04		4.75		
11		4.45		5.24		
12		4.87				
13		5.29				

Bantry Bay presently has 1.0 million tons of storage available. For $d = .32$, $t = 33$ (table 11), $n = 1$, $T = 23$ (table 13) and $S = 1.0$, this results in $w = .844$. It should be noted that in this case the present annual throughput is about 15 million tons, only one shipping route is used, the number of vessels is limited and constant, and the outflow is by transshipment vessels only.

Storage Area

One million long tons of crude oil can be stored in approximately twelve 600,000-barrel tanks. Each tank has a diameter of about 260 feet and requires a diked area of about 430 x 430 = 185,000 square feet. Since 1 acre is equivalent to 43,560 square feet, the 12 tanks require an area of about 50 acres.

In addition to crude oil storage, a general service area is required for the bunker fuel tanks, oil separation tanks and equipment, power generator with diesel fuel tanks, water tanks, booster station, operation and control center, and personnel and customs quarters. This area is estimated at 10 to 30 acres, depending on the number of berths, the number of oil companies involved, and the assumed requirements for bunker fuel and oil separation tanks.

Pipelines Between Intermediate Storage and Refineries

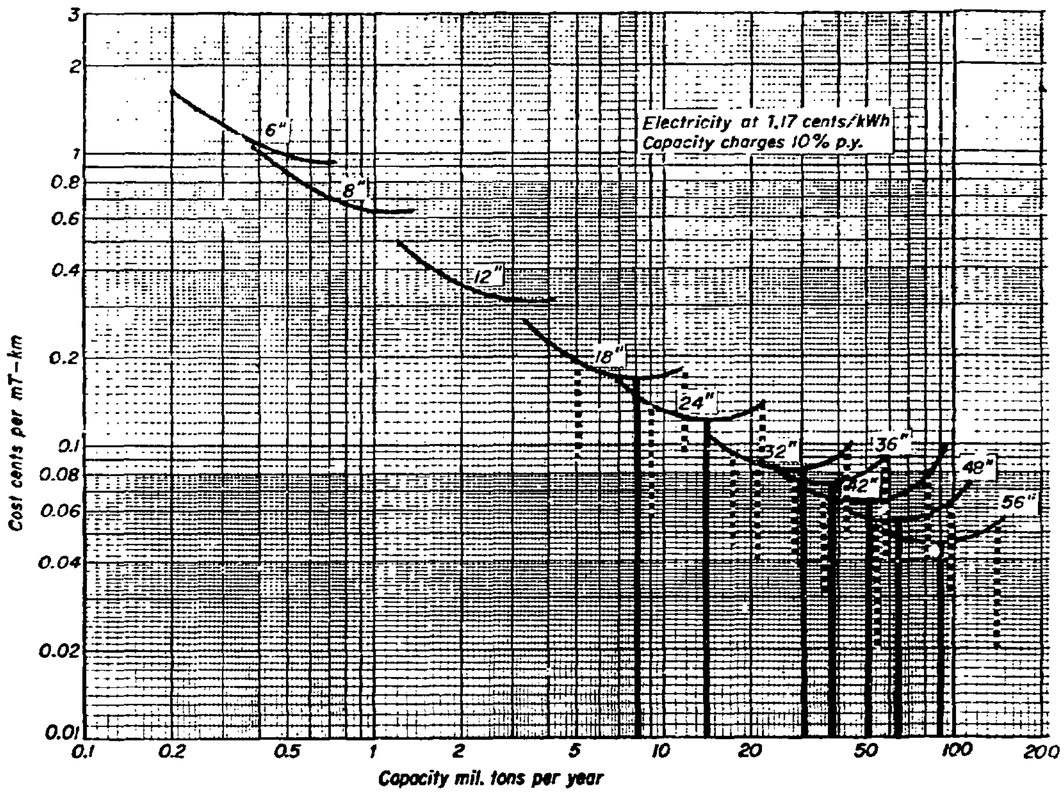
Pipelines

The number and size of the pipelines and the number and horsepower of the booster pumps between intermediate storage and the various refinery tank farms is determined mainly by the annual flow, the viscosity of the oil, and the length of the pipelines. The relation between pipe diameter and annual capacity in long tons was determined by using figure 11-a of Michael Hubbard's publication, The Economics of Transporting Oil To and Within Europe (London: MacLaren and Sons, Ltd., 1967). Hubbard assigned a specific gravity of 0.869 and a viscosity of 20 centistokes to the crude oil.

Figure 5 is based on Hubbard's figure 11-a, and ranges the pipe sizes from 6 to 56 inches. Extrapolations for 48- and 56-inch lines and interpolations for 36-inch lines were made using the factors:

$$\left(\frac{48}{42}\right)^2 = 1.3, \left(\frac{56}{42}\right)^2 = 1.8 \text{ and } \left(\frac{36}{42}\right)^2 = .7$$

respectively, in relation to the capacity of a 42-inch line. To construct the loops of the three curves that were added to Hubbard's figure (the curves for 36-, 48-, and 56-inch lines), two auxiliary points per curve were determined. For this purpose, throughputs at a 15 percent higher operating cost level were selected. The three added curves were drawn tangential to the extension of the envelop of the other curves, since the envelop should be a continuous curve. The solid lines in figure 5 represent optimum capacities; the dotted lines, capacities at a 15 percent increase in operating cost.



Source: Reproduced, with changes, from Michael Hubbard, The Economics of Transporting Oil To and Within Europe (London: McLaren & Sons Ltd., 1967), p. 55.

FIGURE 5. TOTAL COST OF PIPELINES BY DIAMETER AND CAPACITY

Table 18 presents the annual throughput capacities at the lowest (optimum) and the 15 percent higher cost levels given in figure 5. Although the curves in figure 5 are based on average European cost criteria which do not apply in this study, the table itself is valuable, in that it demonstrates the flexibility in throughput capacity of a pipeline system. It shows clearly that by increasing or decreasing the optimum throughput capacity of a pipeline by about 50 percent, the transportation cost would increase only 15 percent under the assumed European conditions.

Table 18. Annual Throughput Capacity

(In millions of long tons)

Diameter of pipeline (inches)	Annual capacity		
	Lower range[a]	Optimum	Higher range[a]
18................	5	8	12
24................	9	14	21
32................	17	29	42
36................	21[b]	37[b]	56[b]
42................	27	50	80
48................	35[b]	65[b]	100[b]
56................	50[b]	90[b]	140[b]

a/ Total cost 15 percent higher than in optimum case under the conditions of figure 5.
b/ Derived by extrapolation or interpolation.

It should also be noted that as the pipe size increases, the cost decreases, since the loops in figure 5 representing the larger pipe sizes are at successively lower levels. This means that scale economies apply. For example, according to this figure, it is less expensive for throughputs in excess of 7 million tons to use a 24-inch rather than an 18-inch line, even when an 18-inch line has its optimum at 8 million tons. However, it should be noted that use of a larger pipe is less expensive only under special circumstances and depends on the pipe sizes that are being compared. For instance, we have just noted that a 24-inch line is less expensive than an 18-inch line; however, in a comparison of 18- and 32-inch lines, the 18-inch is cheaper for throughputs less than 11 million tons.

From the curves in figure 5 it is also evident that the optimum of a certain pipe size is not clearly defined, since the curves are rather flat near their horizontal tangents.

Even though the cost scale of figure 5 does not represent the costs applicable to this study, the general operating cost trend with respect to throughput volumes will still apply. However, under the cost conditions of this study, the various curves might be flatter or steeper, and this graph will therefore be used only for the selection of line sizes.

Horsepower

The horsepower required to boost the oil through the pipelines between the intermediate tank farm and the refinery tank farms can be calculated using the same formulas and basic values established for pipelines from supertanker berths to intermediate tank farms.

Transshipment Berths

For those alternatives on the Atlantic and gulf coasts involving transshipment, the size of all transshipment barges was established at 40,000 d.w.t. (Annex E).

To obtain a flexible transshipment operation, all berths would require at least 40 feet of water depth. The assumed berth occupancy time of transshipment barges at the deepwater port is presented in table 19.

Table 19. Berth Occupancy Time of Transshipment Barges

(In hours)

Item	Time
Maneuvering, berthing and mooring..........	1
Loading....................................	4
Deberthing and maneuvering.................	1
Total......................................	6

With an assumed berth occupancy factor of 1.0 and a total number of 350 working days per year, the number of barge callings per year would be (24 ÷ 6) x 350 = 1,400. Its corresponding annual throughput capacity would be 1,400 x 40,000 = 56 million tons per year. The type of transshipment berth is assumed to be fixed.

Since the same permissible berth occupancy factors apply as in the case of supertanker berths, the maximum annual throughput can be related with the number of transshipment berths. Table 20 presents these throughputs for a number of berths varying from one to 15. The maximum throughput considered in any alternative is 600 m.t.a.

Application of Design Criteria

Each alternative or subalternative will be defined by a given annual throughput and vessel size. The sequence and procedure in determining the number, dimensions or capacities of the main construction items follows:

1. Number of supertanker berths -- determined by the use of table 13, which relates vessel size, annual throughput, and number of berths.

Table 20. Annual Throughput Volumes
(In millions of long tons per year)

Number of berths	Permissible berth occupancy factor	Throughput
1................	.27	15
2................	.51	56
3................	.62	104
4................	.70	157
5................	.74	207
6................	.75	252
7................	.75	294
8................	.75	336
9................	.75	378
10................	.75	420
11................	.75	462
12................	.75	504
13................	.75	546
14................	.75	588
15................	.75	630

2. Channel and maneuvering area dimensions -- determined by the use of tables 5 and 6, which relate vessel dimensions, number of berths, and channel and maneuvering area dimensions. This will result in the amount to be dredged, or in the site selection of the deepwater port when no dredging is the objective.

3. Pipelines between supertanker berths and intermediate storage or refineries -- determined by selecting 48-inch pipes for all lines, one line per berth, and determining the necessity for and capacity of the booster pumps by calculating the pressure differentials as described in a preceding section. The lengths of the pipelines are determined by the selected locations of the deepwater port, intermediate tank farms and assumed pipeline routes.

4. Crude oil storage capacity of the intermediate tank farm -- determined by the use of table 17, which relates number of berths, vessel size, and storage capacity.

5. Pipelines between intermediate tank farm and refineries -- determined by (a) selecting pipe size(s) using figure 5 and table 18, which relates pipe size and throughput capacities, and (b) calculating the capacity of the booster pumps by applying the formula given in a preceding section. The lengths of the pipeline systems are determined by the selected locations of the intermediate tank farms, the assumed pipeline routes, and the locations of the refineries. To facilitate the calculations and to present the results systematically, all basic computations of R, f, p, h, and H have been executed for a range of throughputs and pipe diameters. The results are presented in table 21.

It should be noted that the design throughput is 20 percent higher than the annual throughput to provide more pipeline flexibility in case of seasonality in the flow. The average wall thickness was assumed at 1.0 inch, which is a conservative assumption.

An example of the calculations of R, f, p, h, and H, the results of which are contained in table 21, follows:

Annual throughput (A) = 100 million long tons.
Outside pipe diameter (O) = 48 inches

Design throughput (B) = $\frac{100 \times 10^6 \times 7.3}{365 \times 24} \times 1.2$
$= 100 \times 10^3$ barrels/hours

Inside diameter (D) = 48-2 = 46 inches

Reynolds number (R) = $\frac{2{,}214 \times 100 \times 10^3}{46 \times 14.5}$
$= 330 \times 10^3$

Friction coefficient (f) = Figure 4 = 1.47×10^{-2}

Pressure drop per mile (p) =
$\frac{34.87 \times 1.47 \times 10^8 \times 0.8654}{46^5} = 21.22$ p.s.i.

Horsepower per p.s.i. (h) = $\frac{100{,}000}{2{,}450 \times 0.78}$
= 52.32 b.hp.

Horsepower per mile (H) = 21.22 x 52.32
= 1,125.93 b.hp.

6. Number of transshipment berths -- determined by the use of table 20, which relates annual throughput and number of berths.

Table 21. Calculations of Basic Characteristics of Horsepower Requirements Per Mile

Outside diameter (O)	Annual through-put (A)	Inside diameter (D)	Design through-put (B)	Reynolds number (R)	Friction coeffi-cient (f)	Pressure loss (p)	Horse-power/ p.s.i. (h)	Horse-power/ mile (H)
(inches)	(mill. tons)	(inches)	(1,000 bbl./h.)	(1,000)	(.01)	(p.s.i./ mile)	-----b.hp.	----
24	10	22	10	69	2.00	11.71	5.23	61.24
24	15	22	15	104	1.80	23.71	7.85	186.12
32	10	30	10	51	2.11	2.62	5.23	13.70
32	20	30	20	102	1.82	9.04	10.47	94.65
32	30	30	30	153	1.67	18.66	15.70	292.96
32	40	30	40	204	1.59	31.59	20.93	661.18
32	45	30	45	230	1.56	39.23	23.55	923.87
36	20	34	20	90	1.86	4.94	10.47	51.72
36	25	34	25	112	1.78	7.39	13.08	96.66
36	30	34	30	135	1.72	10.28	15.70	161.40
42	15	40	15	58	2.05	1.36	7.85	10.68
42	20	40	20	77	1.95	2.30	10.47	24.08
42	25	40	25	96	1.82	3.35	13.08	43.82
42	30	40	30	115	1.78	4.72	15.70	74.10
42	35	40	35	134	1.72	6.21	18.32	113.77
42	40	40	40	153	1.67	7.87	20.93	164.72
42	45	40	45	172	1.63	9.72	23.55	228.91
42	50	40	50	192	1.60	11.78	26.16	308.16

continued--

Table 21. Calculations of Basic Characteristics of Horsepower Requirements Per Mile continued--

Outside diameter (O)	Annual through-put (A)	Inside diameter (D)	Design through-put (B)	Reynolds number (R)	Friction coefficient (f)	Pressure loss (p)	Horse-power/ p.s.i. (h)	Horse-power/ mile (H)
(inches)	(mill. tons)	(inches)	(1,000 bbl./h.)	(1,000)	(.01)	(p.s.i./ mile)	-----b.hp.	----
42	55	40	55	211	1.57	13.99	28.78	402.63
42	60	40	60	230	1.56	16.54	31.40	519.36
42	65	40	65	249	1.54	19.16	34.01	651.63
42	70	40	70	268	1.52	21.95	36.64	804.30
48	20	46	20	67	2.01	1.18	10.47	12.31
48	30	46	30	100	1.83	2.41	15.70	37.84
48	35	46	35	116	1.80	3.23	18.32	59.17
48	40	46	40	133	1.72	4.03	20.94	84.42
48	50	46	50	165	1.65	6.04	26.16	158.00
48	60	46	60	198	1.60	8.44	31.40	265.02
48	65	46	65	215	1.57	9.72	34.02	330.67
48	70	46	70	232	1.55	11.13	36.64	407.80
48	75	46	75	248	1.54	12.68	39.24	497.56
48	80	46	80	266	1.52	14.14	41.87	597.12
48	85	46	85	280	1.50	15.87	44.47	705.77
48	90	46	90	298	1.49	17.39	47.10	833.26
48	100	46	100	330	1.47	21.22	52.32	1,125.93
56	45	54	45	127	1.74	2.32	23.55	54.62
56	50	54	50	141	1.70	2.79	26.16	72.99

continued--

Table 21. Calculations of Basic Characteristics of Horsepower Requirements Per Mile continued--

Outside diameter (O)	Annual through-put (A)	Inside diameter (D)	Design through-put (B)	Reynolds number (R)	Friction coeffi-cient (f)	Pressure loss (p)	Horse-power/ p.s.i. (h)	Horse-power/ mile (H)
(inches)	(mill. tons)	(inches)	(1,000 bbl./h.)	(1,000)	(.01)	(p.s.i./ mile)	-----b.hp.	----
56	55	54	55	155	1.67	3.32	28.78	95.55
56	60	54	60	169	1.63	3.86	31.40	121.10
56	65	54	65	183	1.61	4.47	34.01	152.02
56	70	54	70	198	1.60	5.15	36.64	188.70
56	75	54	75	212	1.57	5.80	39.25	227.56
56	80	54	80	226	1.56	6.56	41.86	274.60
56	85	54	85	240	1.55	7.36	44.48	327.37
56	90	54	90	254	1.54	8.20	47.09	386.14
56	95	54	95	268	1.52	9.02	49.70	448.29
56	100	54	100	283	1.50	9.86	52.33	515.97
56	105	54	105	296	1.49	10.80	54.94	593.35
56	110	54	110	310	1.48	11.77	57.55	677.36
56	115	54	115	325	1.47	12.77	60.18	768.50
56	120	54	120	338	1.47	13.91	62.78	873.27
56	125	54	125	353	1.46	14.99	65.40	980.35
56	130	54	130	367	1.45	16.10	68.02	1,095.12

7. Pipelines from intermediate tank farm to transshipment berths -- determined by selecting 48-inch pipes for all lines, one line per berth, and calculating the capacity of the booster pumps using table 21. The loading rate was established at 10,000 long tons, or 73,000 barrels, per hour.

IV. ENGINEERING REQUIREMENTS FOR CRUDE PETROLEUM PORTS

New York Area

Three alternatives, numbered 1-1, 1-2, and 1-3, are considered in the New York area. The locations of the deepwater ports in this area and the pipeline routes to the refineries are shown in figures 6 through 8. Detailed layouts are presented in figures 9 through 11.

Sites

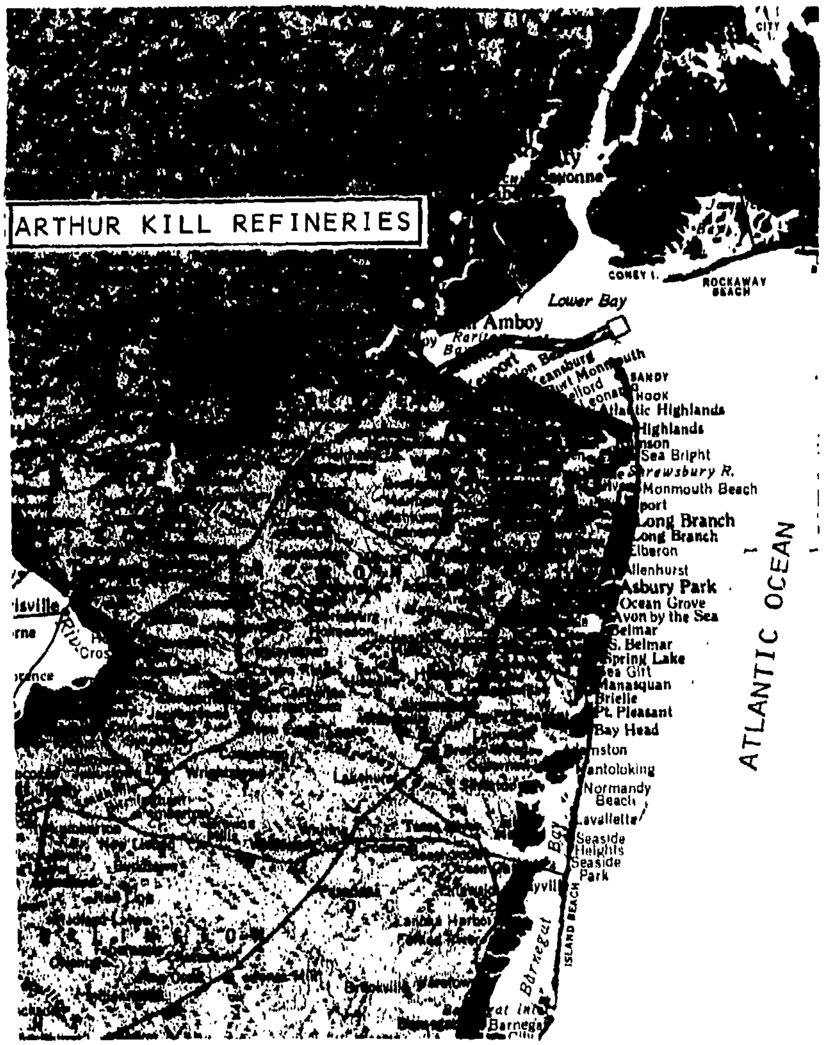
Alternatives 1-1 and 1-2 consider deepwater ports in the Lower New York Bay, whereas alternative 1-3 considers a deepwater port off Long Branch, New Jersey, in the Atlantic Ocean.

Service Areas

Alternative 1-1 serves the refineries along the Arthur Kill; alternatives 1-2 and 1-3 serve the refineries along the Arthur Kill, as well as those along the Delaware River. Intermediate tank farms and refinery tank farms are connected by pipelines.

Throughputs

Alternative 1-1 considers two sets of throughputs. The lower throughput is set at 30 million tons per annum (m.t.a.) in 1980 and 35 m.t.a. by 2000. The higher throughput is set at 35 m.t.a. in 1980 and



LEGEND
ARTIFICIAL ISLAND
O REFINERY
PIPELINE

FIGURE 6. LOCATION OF DEEPWATER PORT AND ASSUMED PIPELINE ROUTE OF ALTERNATIVE I-I

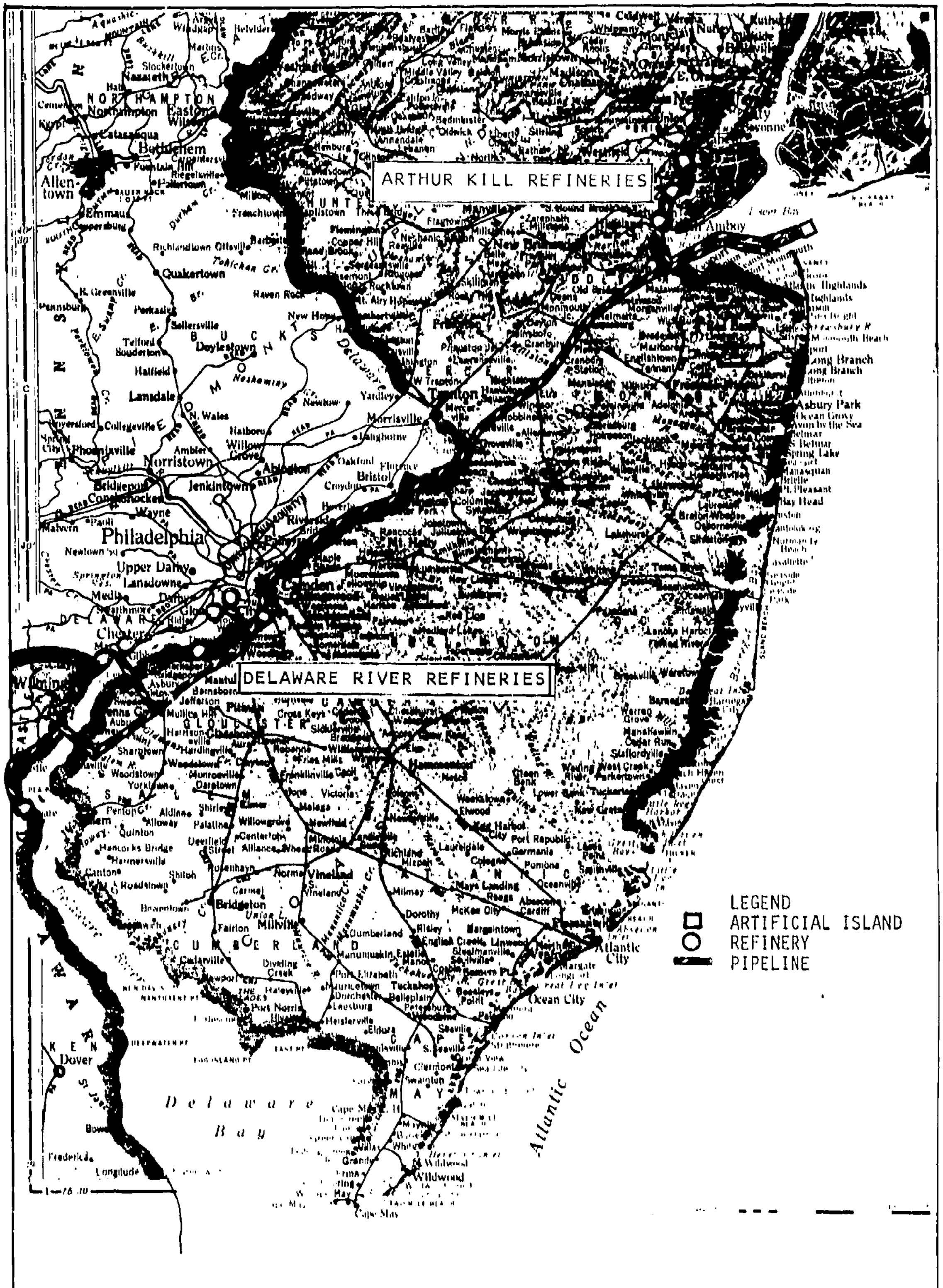


FIGURE 7. LOCATION OF DEEPWATER PORT AND ASSUMED PIPELINE ROUTE OF ALTERNATIVE I-2

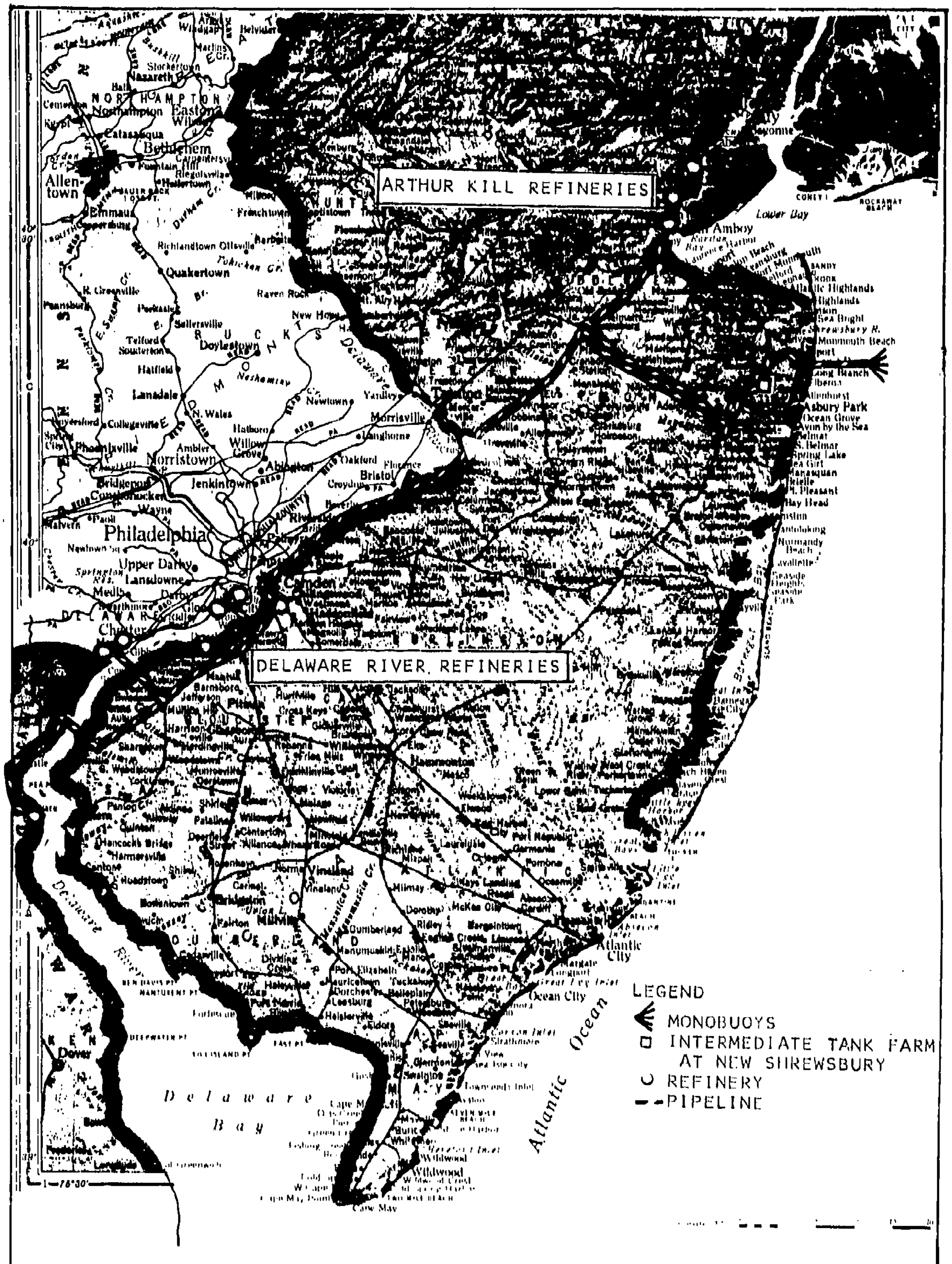


FIGURE 8. LOCATION OF DEEPWATER PORT AND ASSUMED PIPELINE ROUTE OF ALTERNATIVE I-3

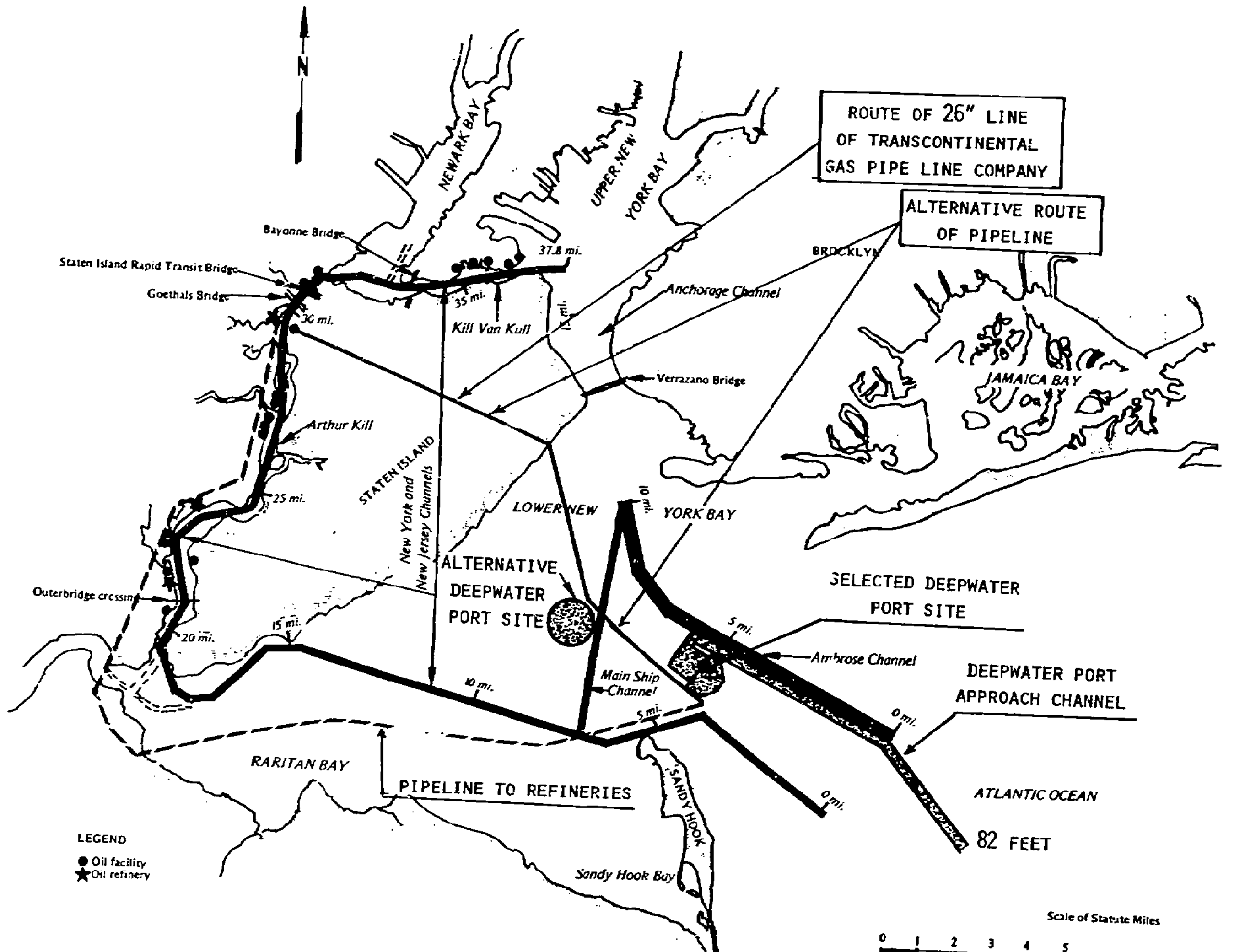


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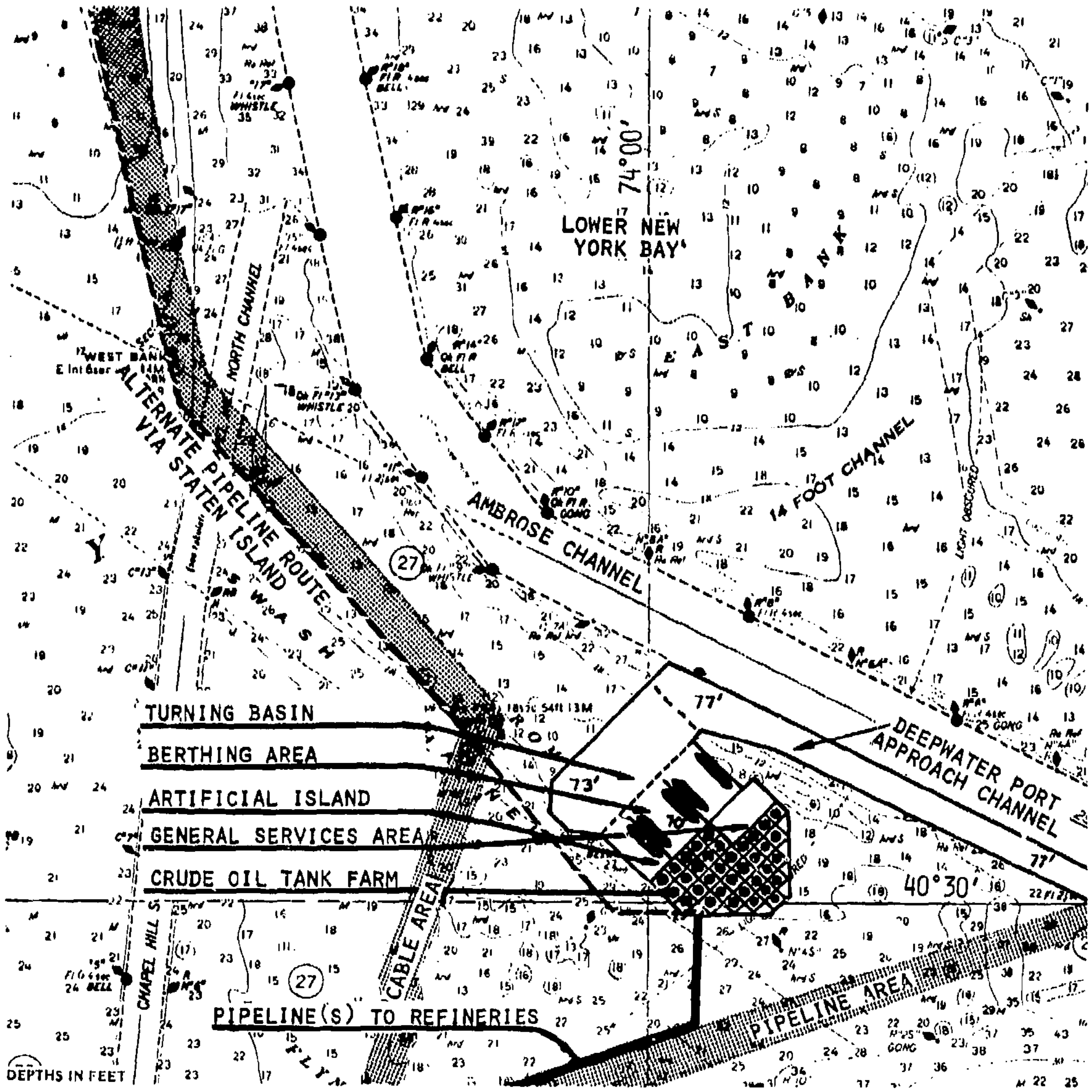
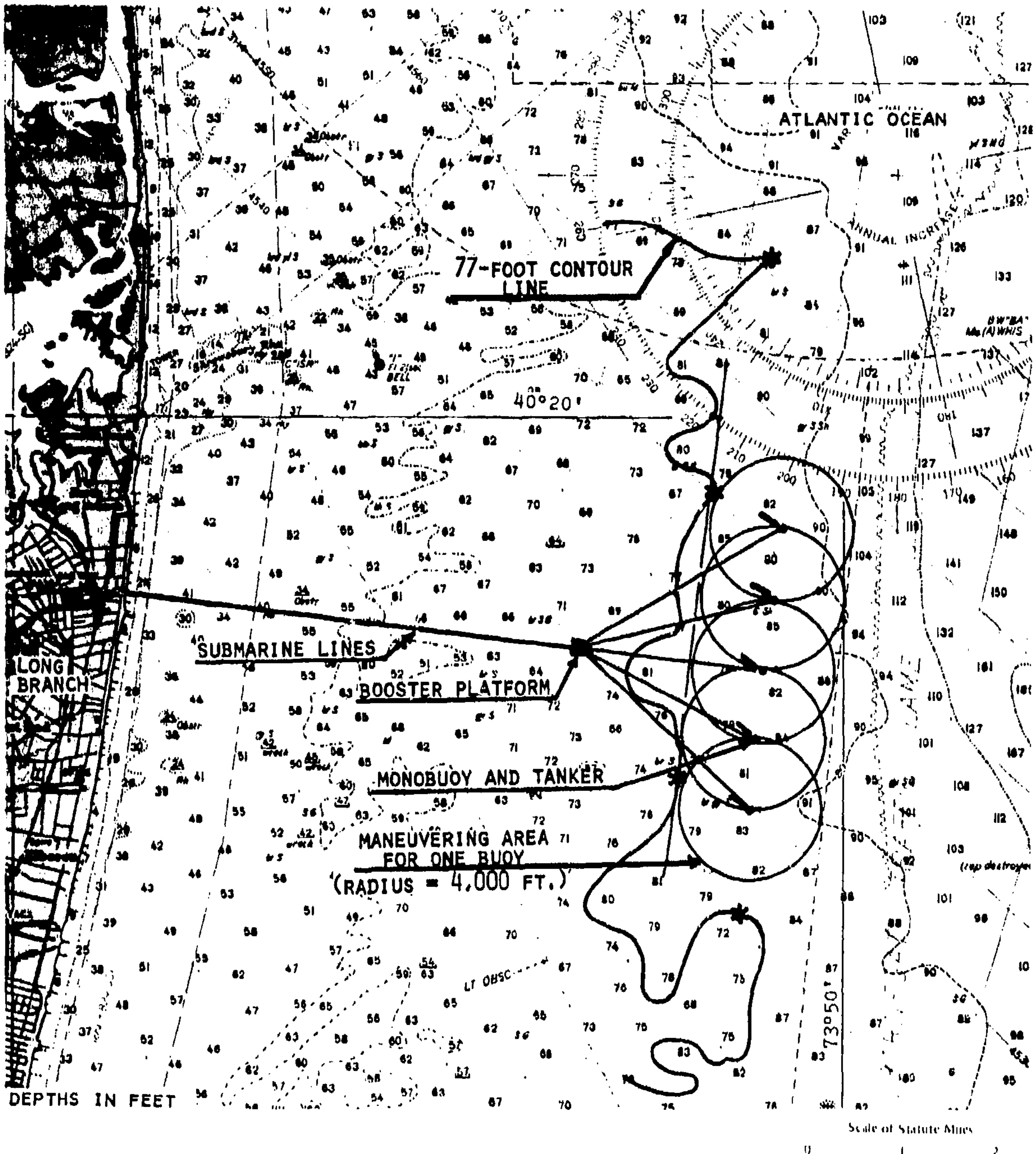
FIGURE 9. DETAILED LAYOUT OF ALTERNATIVE I-I



Note: Ultimate layout for subalternatives B and D of alternative I-2.

Scale of Statute Miles
0 1

FIGURE 10. DETAILED LAYOUT OF DEEPWATER PORT OF ALTERNATIVES I-1 AND I-2



Note: Ultimate layout for subalternatives B and D.
✱ Beacon

FIGURE II. DETAILED LAYOUT OF MONOBUOYS AND SUBMARINE LINES OF ALTERNATIVE I-3

70 m.t.a. by 2000. Alternatives 1-2 and 1-3 also consider two sets of throughputs. The lower throughput is set at 100 m.t.a. in 1980 (30 m.t.a. to the Arthur Kill area and 70 m.t.a. to the Delaware River area) and 150 m.t.a. by 2000 (35 m.t.a. to the Arthur Kill area and 115 m.t.a. to the Delaware River area). The higher throughput is set at 150 m.t.a. in 1980 (35 m.t.a. to Arthur Kill area and 115 m.t.a. to the Delaware River area) and 300 m.t.a. by 2000 (70 m.t.a. to the Arthur Kill area and 230 m.t.a. to the Delaware River area).

Type of Berths

Alternatives 1-1 and 1-2 consider fixed berths, whereas alternative 1-3 considers monobuoys.

Site of Tanks

Alternatives 1-1 and 1-2 consider an offshore tank farm, whereas alternative 1-3 considers an onshore tank farm.

Vessel Sizes

Each alternative considers 300,000 and 400,000 d.w.t. tankers, and it is assumed that all tankers using the deepwater port will be of these maximum sizes. The assumed dimensions of these tankers are given in table 22.

Table 22. Assumed Dimensions of 300,000 and 400,000 Deadweight Ton Tankers

Dimension	300,000 d.w.t.	400,000 d.w.t.
	feet	
Length...........	1,100	1,262
Beam.............	192	220
Draft............	70	70

Dredging

Alternatives 1-1 and 1-2 require dredged channels, turning basins, and berthing areas. The artificial island will be constructed of dredged material. Alternative 1-3 does not require dredging. All submarine and onshore pipelines are expected to be buried.

Water Depths

In all alternatives the depths of channels, maneuvering areas, etc., is such that all maximum-size tankers will need to wait for high tide to approach the facilities. In other words, in alternatives 1-1 and 1-2, the dredged depths are minimum, and in alternative 1-3 the monobuoys are located as close to shore as possible. Calculations of trade-offs between deeper dredging (alternatives 1-1 and 1-2) or longer submarine lines (alternative 1-3) on the one hand and limited or no waiting time for high water by the supertankers on the other hand are necessary to determine the optimum solution. These calculations have not been made.

Because mean high water (MHW) at Sandy Hook is 4.6 feet above mean low water (MLW), a value of 4.0 feet for average tidal rise has been selected.

Construction Program

The time phasing of the various construction items for the period prior to 1980 is given in table 23 for alternatives 1-1 and 1-2, and in table 24 for alternative 1-3. The entire phasing was simplified to facilitate calculations. The total cost of each item will be distributed equally over the pertinent years.

Alternative 1-1

Criteria

1. Site of deepwater port: Lower New York Bay.
2. Service area: Refineries along Arthur Kill.
3. Type of berths: Fixed.

Table 23. Construction Program of Alternatives 1-1 and 1-2

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Breakwater of island....	X	X			
Dredging...............			X	X	X
Land fill and slope protection of island...			X		
Supertanker berths					
Alternative 1-1........					X
Alternative 1-2........				X	X
Pipelines to island.....					X
Tank farm..............				X	X
Pipeline to Arthur Kill refineries............					X
Pipeline to Delaware River refineries					
Onland section........				X	X
Offshore section......					X

Table 24. Construction Program of Alternative 1-3

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Tank farm..............				X	X
Pipelines to refineries.				X	X
Supertanker berths......					X
Pipelines to tank farm..					X

4. Site of tanks: Offshore artificial island.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 25.

Table 25. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A..............	300,000	30	35
B..............	300,000	35	70
C..............	400,000	30	35
D..............	400,000	35	70

7. Type of transshipment: Pipelines only.

Requirements

Supertanker berths. Two berths will be required for all subalternatives by 1980; no additional berths will be required from 1980 to 2000.

Dredging quantities. All quantities will include an overdepth of 4 feet. In determining the channel depth, 4 feet of tide will be taken into account.

1. Ocean Channel, parallel Ambrose Channel
   a. Length = 9 miles
   b. Depth = 81 feet-4 feet (tide) + 4 feet (overdepth) = 81 feet
   c. Average present bottom depth per mile in feet:

Side	Mile								
	1	2	3	4	5	6	7	8	9
South...	75	58	52	44	48	20	21	27	29
North...	75	58	52	45	45	45	45	45	45

d. Approximate average depth
   (1) South side = 41 feet
   (2) North side = 50 feet
e. Approximate average depth, 45 feet; average dredging depth, 36 feet
f. Width at bottom
   (1) Subalternatives A and B = 770 feet
   (2) Subalternatives C and D = 880 feet
g. Quantities to be dredged
   (1) Subalternatives A and B = $\frac{9 \times 5,280}{27} \times 36 \times (770 + 3 \times 36) = 55.6 \times 10^6$ cubic yards
   (2) Subalternatives C and D = $\frac{9 \times 5,280}{27} \times 36 \times (880 + 3 \times 36) = 62.6 \times 10^6$ cubic yards.

2. Turning basin
   a. Length = 3,000 feet
   b. Width
      (1) Subalternatives A and B = 1,650 feet
      (2) Subalternatives C and D = 1,900 feet
   c. Depth = 77 feet-4 feet + 4 feet = 77 feet
   d. Average present bottom depth = 15 feet
   e. Average dredging depth = 62 feet
   f. Quantities to be dredged
      (1) Subalternatives A and B = $\frac{3,000}{27} \times 1,650 \times 62 = 11.4 \times 10^6$ cubic yards
      (2) Subalternatives C and D = $\frac{3,000}{27} \times 1,900 \times 62 = 13.1 \times 10^6$ cubic yards

3. Berthing area
   a. Subalternatives A and B
      (1) Length = 1,650 feet
      (2) Width = 7 x 192 = 1,345 feet

(3) Depth = 74 feet -4 feet + 4 feet = 74 feet
(4) Average bottom depth = 10 feet
(5) Average dredging depth = 64 feet
(6) Quantity = $\frac{1,650}{27}$ x 1,345 x 64 = 5.3 x 10^6 cubic yards

b. Subalternatives C and D
(1) Length = 1,900 feet
(2) Width = 7 x 220 feet = 1,540 feet
(3) Average dredging depth = 64 feet
(4) Quantity = $\frac{1,900}{27}$ x 1,540 x 64 = 6.9 x 10^6 cubic yards

4. Total quantity to be dredged
a. Subalternatives A and B
(1) Ocean channel = 55.6 x 10^6 cubic yards
(2) Turning basin and berthing area = 16.7 x 10^6 cubic yards

b. Subalternatives C and D
(1) Ocean channel = 62.6 x 10^6 cubic yards
(2) Turning basin and berthing area = 20.0 x 10^6 cubic yards

Pipelines from supertanker berths to intermediate tank farm. One 48-inch line per berth would be required. Each line would be about 800 feet on trestle and 3,000 feet on island. No booster pumps would be required.

Artificial island. The following crude oil storage capacities would be required on the island: for subalternatives A and B, 1.54 x 10^6 long tons; and for subalternatives C and D, 1.80 x 10^6 long tons.

For general services, an area of 15 acres was estimated. The total acreage requirement for the island would be: subalternatives A and B, 1.54 x 50 + 15 = about 90 acres; and subalternatives C and D, 1.80 x 50 + 15 = 105 acres.

The assumed average water depth at the island is 15 feet, and the assumed required terrain elevation is + 20 feet. The land fill requirements would be: subalternatives A and B, $(90 \div 27) \times 43{,}560 \times 35 = 5.1 \times 10^6$ cubic yards; and subalternatives C and D, $(105 \div 27) \times 43{,}560 \times 35 = 5.9 \times 10^6$ cubic yards.

For all subalternatives, the breakwater would be about 1 mile long, and the slope protection at the land side of the island would be about 0.5 mile long.

Pipeline to refineries along Arthur Kill. One 48-inch pipeline would be sufficient during the period from 1980 to 2000. The total length of the pipeline system was estimated at 29 miles, about 15 miles of which would be off shore through the Raritan Bay in or parallel to an existing pipeline area. The inland section would have two major river crossings, one about 3,000 feet long (Raritan River) and one about 750 feet long (Rahway River). Figures 6, 9, and 10 show the location of the deepwater port and the assumed pipeline route to the major refineries.

Booster pumps with the following approximate horsepowers would be required: subalternatives A and C would require 29 x 37.84 = 1,100 b.hp. by 1980, and 29 x 59.17 = 1,720 b.hp. by 2000. It is assumed that 1,800 b.hp. (35 m.t.a.) would be installed by 1980.

Subalternatives B and D would require 29 x 59.17 = 1,720 b.hp. by 1980, and 29 x 407.80 = 12,000 b.hp. by 2000. The following installations would be made: before 1980, 3,000 b.hp. (42.5 m.t.a.); in 1983, 3,000 b.hp. (54 m.t.a.); and in 1990, 6,000 b.hp. (70 m.t.a).

The maximum throughput in millions of long tons per year of each system is indicated in parentheses.

Alternative 1-2

Criteria

1. Site of deepwater port: Lower New York Bay
2. Service area: Refineries along Arthur Kill and Delaware River.
3. Type of berths: Fixed.
4. Site of tanks: Offshore artificial island.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 26. The projected flows are given in table 27.

Table 26. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A................	300,000	100	150
B................	300,000	150	300
C................	400,000	100	150
D................	400,000	150	300

Table 27. Projected Flow
(In millions of tons/year)

Subalternative	Arthur Kill		Delaware River	
	1980	2000	1980	2000
A and C............	30	35	70	115
B and D............	35	70	115	230

7. Type of transshipment: Pipelines only.

Requirements

Supertanker berths. Subalternatives A and C will require three berths by 1980, and no additional berths during the period from 1980 to 2000. Subalternative B will require four berths by 1980 and five berths by 1990 (the additional berth will be installed in 1989). Subalternative D would require four berths by 1980 and five berths by 1994 (the additional berth will be installed in 1993).

Dredging quantities. All quantities will include an overdepth of 4 feet. In determining the channel depth 4 feet of tide will be taken into account.

1. Ocean channel. The dimensions will be the same as those required in alternative 1-1. Subalternatives A and B will require 55.6 x 10^6 cubic yards; subalternatives C and D, 62.6 x 10^6 cubic yards.

2. Turning basin. The following dimensions would be required:

a. Length
   (1) Subalternatives A and C = 3,600 feet
   (2) Subalternatives B and D = 4,200 feet
b. Width
   (1) Subalternatives A and B = 1,650 feet
   (2) Subalternatives C and D = 1,900 feet
c. Depth = 77 feet-4 feet + 4 feet = 77 feet
d. Average present bottom depth = 12 feet
e. Average dredging depth = 65 feet
f. Quantities to be dredged
   (1) Subalternative A = $\frac{3,600}{27}$ x 1,650 x 65 = 14.5 x 10^6 cubic yards.
   (2) Subalternative B = $\frac{4,200}{27}$ x 1,650 x 65 = 16.6 x 10^6 cubic yards.
   (3) Subalternative C = $\frac{3,600}{27}$ x 1,900 x 65 = 16.4 x 10^6 cubic yards.
   (4) Subalternative D = $\frac{4,200}{27}$ x 1,900 x 65 = 19.1 x 10^6 cubic yards.

3. Berthing area. The following dimensions would be required:

a. Length

(1) Subalternatives A and B = 1,650 feet

(2) Subalternatives C and D = 1,900 feet

b. Width

(1) Subalternative A = 8 x 192 = 1,535 feet

(2) Subalternative B = 13 x 192 = 2,495 feet

(3) Subalternative C = 8 x 220 = 1,760 feet

(4) Subalternative D = 13 x 220 = 2,860 feet

c. Assumed average dredging depth = 60 feet

d. Quantities to be dredged

(1) Subalternative A = $\frac{1,650}{27}$ x 1,535 x 60 = 5.6 x 10^6 cubic yards

(2) Subalternative B = $\frac{1,650}{27}$ x 2,495 x 60 = 9.1 x 10^6 cubic yards

(3) Subalternative C = $\frac{1,900}{27}$ x 1,760 x 60 = 7.4 x 10^6 cubic yards

(4) Subalternative D = $\frac{1,900}{27}$ x 2,860 x 60 = 12.1 x 10^6 cubic yards

4. Total dredging quantities:

a. Ocean channel

(1) Subalternatives A and B = 55.6 x 10^6 cubic yards

(2) Subalternatives C and D = 62.6 x 10^6 cubic yards

b. Turning basin and berthing area

(1) Subalternative A = 20.1 x 10^6 cubic yards

(2) Subalternative B = 25.7 x 10^6 cubic yards

(3) Subalternative C = 23.8 x 10^6 cubic yards

(4) Subalternative D = 31.2 x 10^6 cubic yards

<u>Pipelines from supertanker berth to intermediate tank farm</u>. One 48-inch line per berth would be required. Each line would be about 800 feet on a trestle and 4,000 feet on the island. No booster pumps would be required.

<u>Artificial island</u>. The following crude oil storage capacities would be required: subalternative A, 1.81×10^6 long tons in 1980; subalternative B, 2.24×10^6 long tons in 1980, and 2.51×10^6 long tons in 1990 (additional storage for 0.27×10^6 long tons to be installed in 1989); subalternative C, 2.15×10^6 long tons in 1980; and subalternative D, 2.67×10^6 long tons in 1980, and 3.04×10^6 long tons in 1994 (additional storage for 0.37×10^6 long tons to be installed in 1993).

For general services an area of 20 acres was estimated. The total acreage requirement for the island would be: subalternative A, 1.81 x 50 + 20, or approximately 110 acres; subalternative B, 2.51 x 50 + 20, or approximately 145 acres; subalternative C, 2.15 x 50 + 20, or approximately 130 acres; and subalternative D, 3.04 x 50 + 20, or approximately 170 acres.

Assuming the elevation of the island is + 20 feet and the present water depth is -15 feet, the land fill volumes required for subalternatives A, B, C, and D would be 6.2, 8.2, 7.3, and 9.6 million cubic yards respectively. The breakwaters for these subalternatives would be about 1.1, 1.3, 1.2, and 1.5 miles long, respectively, and the slope protection at the land side of the island would be about 0.8 miles long.

<u>Pipelines from island to refineries</u>. Two separate pipeline systems have been selected, one serving the refineries along the Arthur Kill and one serving the refineries along the Delaware River. Figures 7 and 10 show the location and layout of the deepwater port, and the assumed pipeline routes to the refineries.

1. Pipeline to refineries along Arthur Kill. The requirements for a pipeline would be the same as those of alternative I-1. The total length of the pipeline system is estimated at 29 miles, about 15 miles of which would be off shore through the Raritan Bay in or parallel to an existing pipeline area. The inland section would have two major river crossings, one about 3,000 feet long (Raritan River) and one about 750 feet long (Rahway River).

Booster pumps with the following approximate horsepowers would be required: subalternatives A and C would require 29 x 37.94 = 1,100 b.hp. in 1980, and 29 x 59.17 = 1,720 b.hp. in 2000. It is assumed that 1,800 b.hp. would be installed before 1980. Subalternatives B and D would require 29 x 59.17 = 1,720 b.hp. in 1980, and 29 x 407.80 = 12,000 b.hp. in 2000. The following installations would be made: 3,000 b.hp. (42.5 m.t.a.) before 1980; 3,000 b.hp. (54 m.t.a.) in 1983; and 6,000 b.hp. (70 m.t.a.) in 1990. The maximum throughput in million long tons per year of each system is indicated in parentheses.

2. Pipelines to refineries along Delaware River. The total pipeline system, including branch lines, would be approximately 110 miles long. About 15 miles would be off shore through the Raritan Bay, in or parallel to an existing pipeline area and to the pipeline to the Arthur Kill area. The onshore section is assumed to run parallel to the Penn Central Railroad line to Jamesburg, a distance of 12 miles; continuing to Burlington and Camden, a distance of 46 miles; and from there to Delaware City, a distance of 47 miles. The latter section has branch lines to Philadelphia, Paulsboro, and Marcus Hook totaling 13 miles. The main line would cross the Delaware River at Deepwater Point and would also cross 10 smaller rivers or creeks. The Delaware River crossing would be about 5,500 feet long; each of the other 10 crossings would not exceed 500 feet. Two branch lines, one to Philadelphia and one to Marcus Hook, would also cross the Delaware River. Each of these crossings would be about 5,500 feet long.

For subalternatives A and C, one 56-inch line would be required. For the offshore section, two 48-inch lines will be assumed for construction reasons. The horsepower requirement for the two 48-inch lines will be considered the same as for one 56-inch line. The size of the branch lines was set at 48 inches.

The required horsepower in 1980 equals 140 x 188.7, or 26,400 b.hp.; and in 2000, 140 x 768.5, or 108,000 b.hp. The following installations would be made: 54,000 b.hp. (90 m.t.a.) before 1980, and 54,000 b.hp. (115 m.t.a.) in 1988. The maximum throughput of each system in millions of long tons per year is indicated in parentheses.

Subalternatives B and D would require two 56-inch lines. For the offshore section, three 48-inch lines will be assumed for construction reasons. The size of the branch lines was set at 48 inches. The horsepower required for three 48-inch lines will be considered the same as for two 56-inch lines. In 2000, the same horsepower capacities per line would be required as in subalternatives A and C. Eventually, the total horsepower installation of subalternatives B and D would be double that of subalternatives A and C. Although the second group of pumps could be installed in 1991 or 1992, to keep the installation program identical with that of subalternatives A and C, 1988 will be used.

Alternative 1-3

Criteria

1. Site of deepwater port: In the Atlantic Ocean off Long Branch, New Jersey.
2. Service area: Refineries along Arthur Kill and Delaware River.
3. Type of berth: Monobuoys.
4. Site of tanks: Onshore at New Shrewsbury.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 28. The projected flows are given in table 29.

Table 28. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A................	300,000	100	150
B................	300,000	150	300
C................	400,000	100	150
D................	400,000	150	300

Table 29. Projected Flow

(In millions of tons/year)

Subalternative	Arthur Kill		Delaware River	
	1980	2000	1980	2000
A and C............	30	35	70	115
B and D............	35	70	115	230

7. Type of transshipment: Pipelines only.

Requirements

Supertanker berths. The number of berths would be the same as that required in alternative 1-2: subalternatives A and C would require three monobuoys by 1980, with no additional buoys needed in the period from 1980 to 2000. Subalternative B would require four monobuoys by 1980 and five monobuoys by 1990 (the one additional buoy being installed in 1989). Subalternative D would require four monobuoys by 1980 and five monobuoys by 1994 (the one additional buoy being installed in 1993).

Dredging quantities. No dredging is required.

Water depth of maneuvering area. The minimum depth requirement is 81 feet -4 feet = 77 feet.

Pipelines to intermediate tank farm. One 48-inch pipeline per berth would be required. Each line is about 16.5 miles long, of which 7.5 miles would be off shore and 9 miles would be on land. The offshore lines would run from the buoys to a booster pump station, located at a maximum distance of 2.5 miles from the southernmost and northernmost buoys. The available pressure remaining at the booster station would, in subalternatives A and B, be 150 -70 -2.5 x 17.4, or 36 p.s.i.; and in subalternatives C and D, 150 -70 -2.5 x 21.2, or 27 p.s.i. The remaining pressure would exceed the minimum of 25 p.s.i.

From the booster station to the tank farm would remain a 14-mile length of pipeline, of which about 5 miles would be offshore and 9 miles would be on land. The power requirement per line would be, for subalternatives A and B, 14 x 47 x 17.4 = 11,500 b.hp.; and for subalternatives C and D, 14 x 52 x 21.2 = 15,500 b.hp.

Intermediate tank farm at New Shrewsbury. The requirements for crude oil storage would be the same as for alternative 1-2. Subalternative A would require 1.81 x 10^6 long tons by 1980. Subalternative B would require 2.24 x 10^6 long tons by 1980 and 2.51 x 10^6 long tons by 1990 (the 0.27 x 10^6 additional long tons being installed in 1989). Subalternative C would require 2.15 x 10^6 long tons by 1980. Subalternative D would require 2.67 x 10^6 long tons by 1980 and 3.04 x 10^6 long tons by 1994 (the 0.37 x 10^6 additional long tons being installed in 1993).

Assuming that one bunker line will be used between the tank farm and booster station, and that the number of bunker lines between the booster station and monobuoys will equal the number of monobuoys, the number of bunker fuel tanks can be minimal. Also, it has been assumed that no oil separation facilities will be installed. Therefore, the general service area has been assumed not to exceed 10 acres.

The required acreage would be: for subalternative A, 1.81 x 50 + 10 = about 100 acres; for subalternative B, 2.51 x 50 + 10 = about 135 acres; for subalternative C, 2.15 x 50 + 10 = about 120 acres; and for subalternative D, 3.04 x 50 + 10 = about 160 acres.

Pipelines to refineries. Two separate pipeline systems will be assumed, one to the refineries along the Arthur Kill and one to the refineries along the Delaware River. Figures 8 and 11 show the location and layout of the deepwater port and the assumed pipeline routes to the refineries.

1. Pipeline to Arthur Kill refineries. The pipeline is assumed to follow a southwesterly route to Farmingdale, and then a northwesterly route to Jamesburg. After Jamesburg, the pipeline would follow a northwesterly route along the Penn Central Railroad line via South Amboy to the refineries. Alternative routes are possible.

The approximate mileage of the various sections of the pipeline would be as follows: New Shrewsbury tank farm to Jamesburg, 25 miles; Jamesburg to South Amboy, 13 miles; South Amboy to Humble Refinery, Elizabeth, 12 miles. The total length of the trunk line would be 50 miles. The length of the branch lines is insignificant.

For subalternatives A and C, one 48-inch line would be required, with about 50 x 37.84 = 1,900 b.hp. in 1980 and 50 x 59.17 = 2,960 b.hp. in 2000. It is assumed that 3,000 b.hp. would be installed before 1980.

For subalternatives B and D, one 48-inch line would be required, with about 50 x 59.17 = 2,960 b.hp.

in 1980 and 50 x 407.80 = 20,400 b.hp. in 2000. It is assumed that 10,200 b.hp. will be installed before 1980 and another 10,200 b.hp. in 1988.

2. Pipeline to the Delaware River refineries. The pipeline is assumed to follow the same route to Jamesburg as the pipeline to the Arthur Kill area. After Jamesburg, the pipeline would follow the same southwesterly route to Delaware City as that of alternative 1-2. The same river crossings would be required. Various alternative routes are possible for the pipeline system between the New Shrewsbury tank farm and the Delaware River area.

The approximate mileage of the various sections of the pipeline would be as follows: New Shrewsbury tank farm to Jamesburg, 25 miles; Jamesburg to Gloucester City, 50 miles; Gloucester City to Deepwater Point, 28 miles; and Deepwater Point to Delaware City, 15 miles. The total length of the trunk line would equal 118 miles; the branch lines to Philadelphia, Paulsboro, and Marcus Hook would total 13 miles.

For subalternatives A and C, one 56-inch line would be required, with 118 x 188.7 = 22,300 b.hp. in 1980 and 118 x 768.5 = 90,700 b.hp. in 2000. It is assumed that 45,500 b.hp. would be installed before 1980 and another 45,500 b.hp. would be installed in 1988. The branch lines would be 48 inches.

For subalternatives B and D, two 56-inch lines would be required, with 118 x 107.12 = 12,640 b.hp. per line in 1980 and 118 x 768.50 = 90,700 b.hp. per line in 2000. It is assumed that 45,500 b.hp. per line would be installed before 1980 and another 45,500 b.hp. per line would be installed in 1988. The branch lines would be 48 inches.

Delaware Area

Five alternatives, numbered 2-1 through 2-5, are considered in the Delaware area. Alternatives

2-1 through 2-4 are considered in combination with a coal and with a coal and iron ore handling terminal.

The locations of the deepwater ports in this area, the pipeline routes to the refineries, and detailed layouts of berths, tank farms, and submarine lines are shown in figures 12 through 22.

Sites

Two sites are considered, one in the Delaware Bay about 10 miles southeast of Big Stone Beach (alternatives 2-1 through 2-4) and one in the Atlantic Ocean about 10 miles east of the Delaware Capes (alternative 2-5).

Service Areas

Alternatives 2-1 and 2-2 serve the refineries along the Delaware River, whereas alternatives 2-3, 2-4, and 2-5 serve the refineries along the Delaware River and the Arthur Kill, New Jersey. In alternatives 2-1 through 2-4, the connection between the intermediate tank farms and the refinery tank farms is assumed to be by pipelines only. In alternative 2-5, this connection is by transshipment vessels only.

Throughputs

Alternatives 2-1 and 2-2 consider two sets of throughputs. The lower throughput is set at 70 million tons per annum (m.t.a.) in 1980 and 115 m.t.a. by 2000. The higher throughput is set at 115 m.t.a. in 1980 and 230 m.t.a. by 2000.

Alternatives 2-3, 2-4, and 2-5 also consider two sets of throughputs. The lower throughput is set at 100 m.t.a. in 1980 (70 m.t.a. to the Delaware River area and 30 m.t.a. to the Arthur Kill area) and 150 m.t.a. by 2000 (115 m.t.a. to Delaware River Area and 35 m.t.a. to Arthur Kill area). The higher throughput

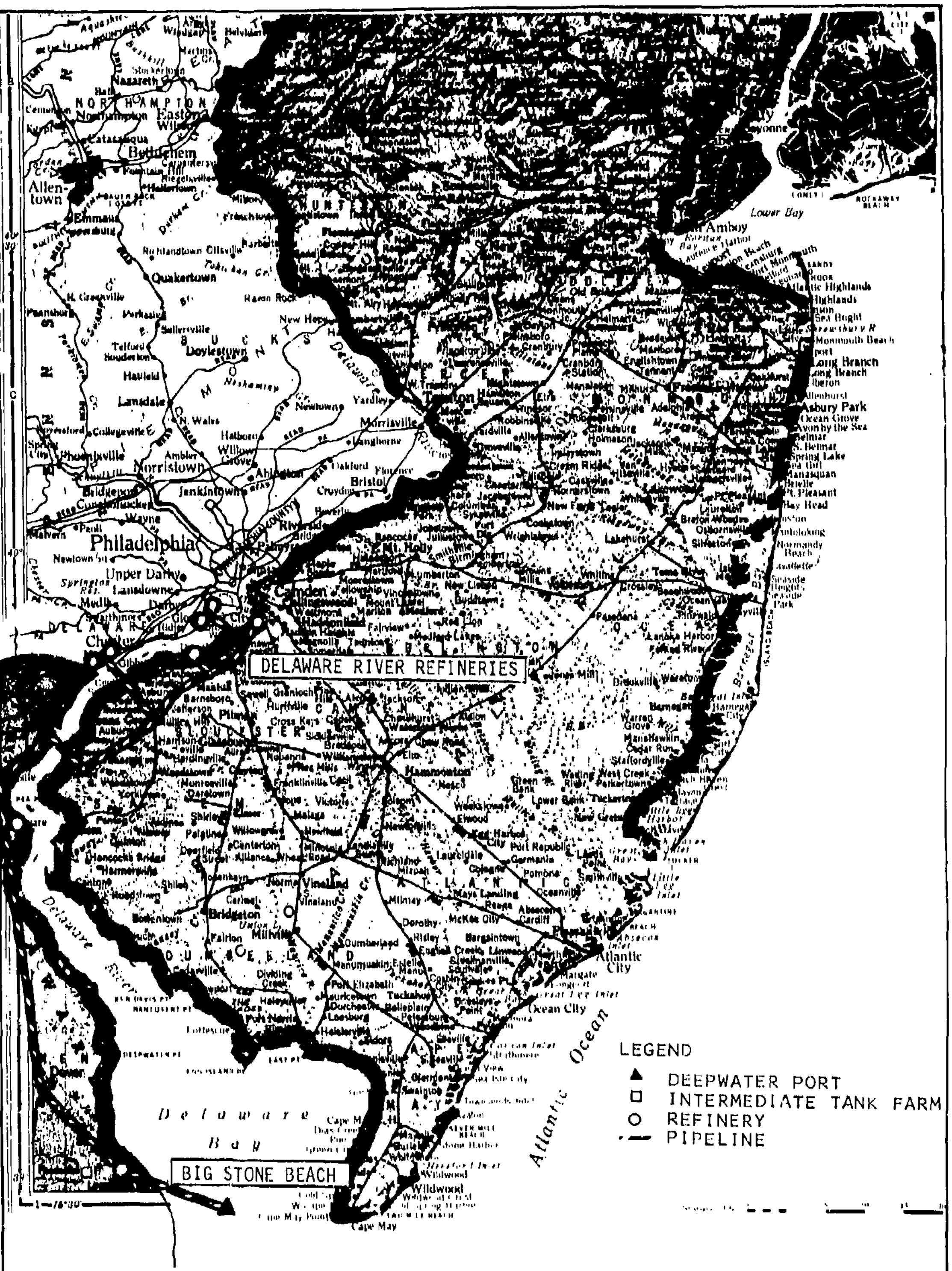


FIGURE 12. LOCATION OF DEEPWATER PORT AND INTERMEDIATE TANK FARM, AND ASSUMED PIPELINE ROUTE OF ALTERNATIVE 2-I

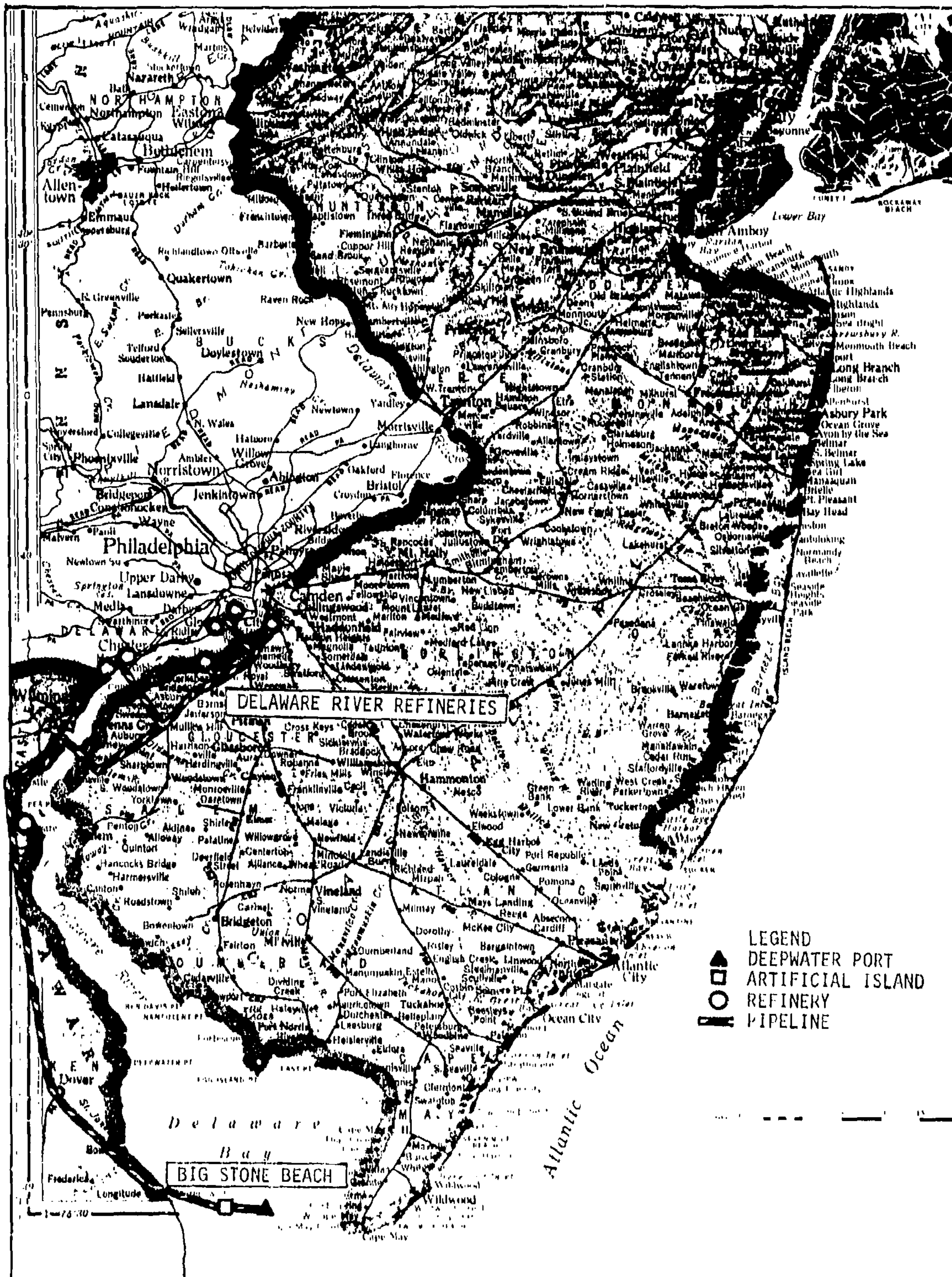


FIGURE 13. LOCATION OF DEEPWATER PORT AND INTERMEDIATE TANK FARM, AND ASSUMED PIPELINE ROUTE OF ALTERNATIVE 2.2

306

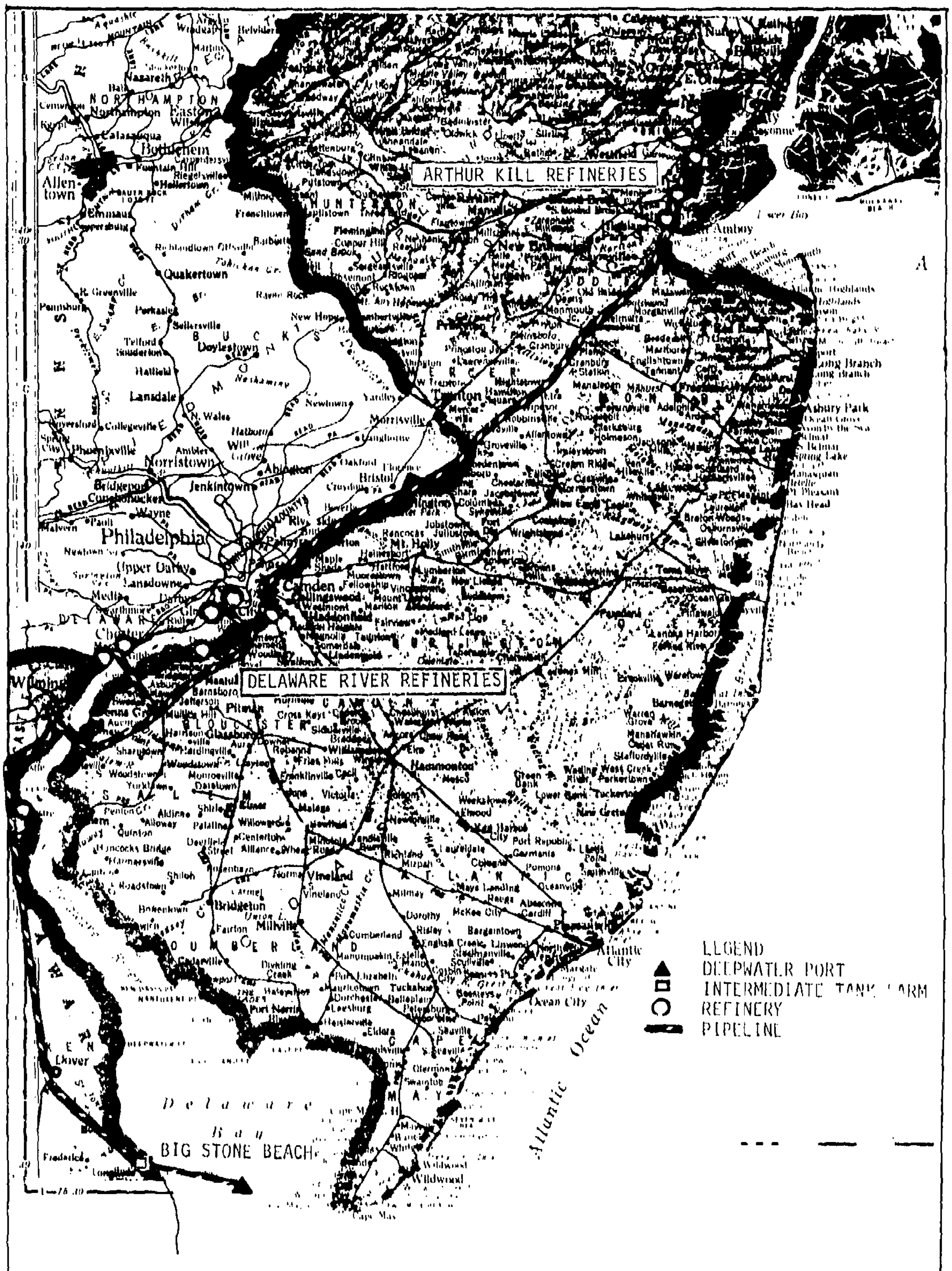


FIGURE 14. LOCATION OF DEEPWATER PORT AND INTERMEDIATE TANK FARM, AND ASSUMED PIPELINE ROUTE OF ALTERNATIVE 2-3

307

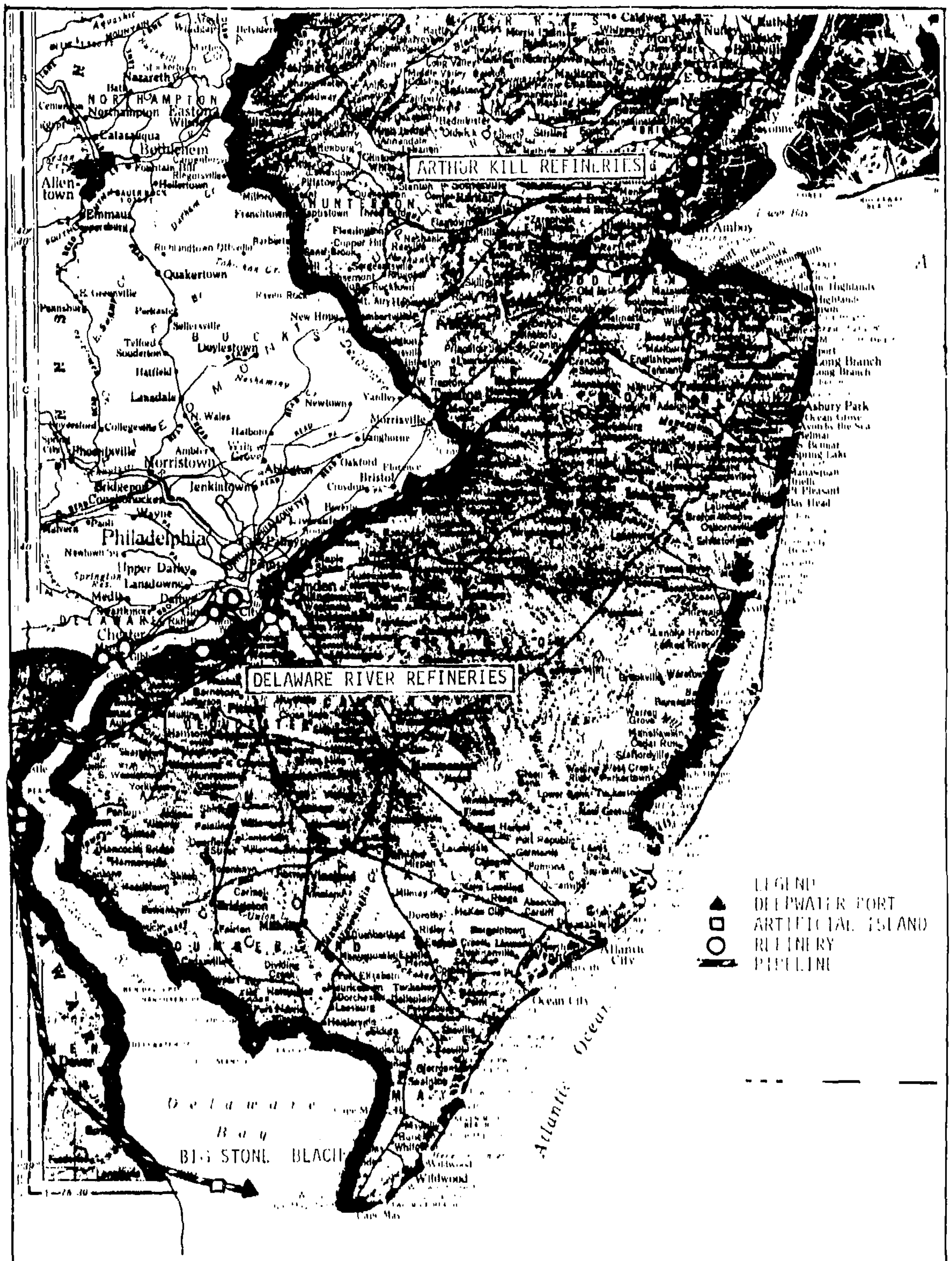
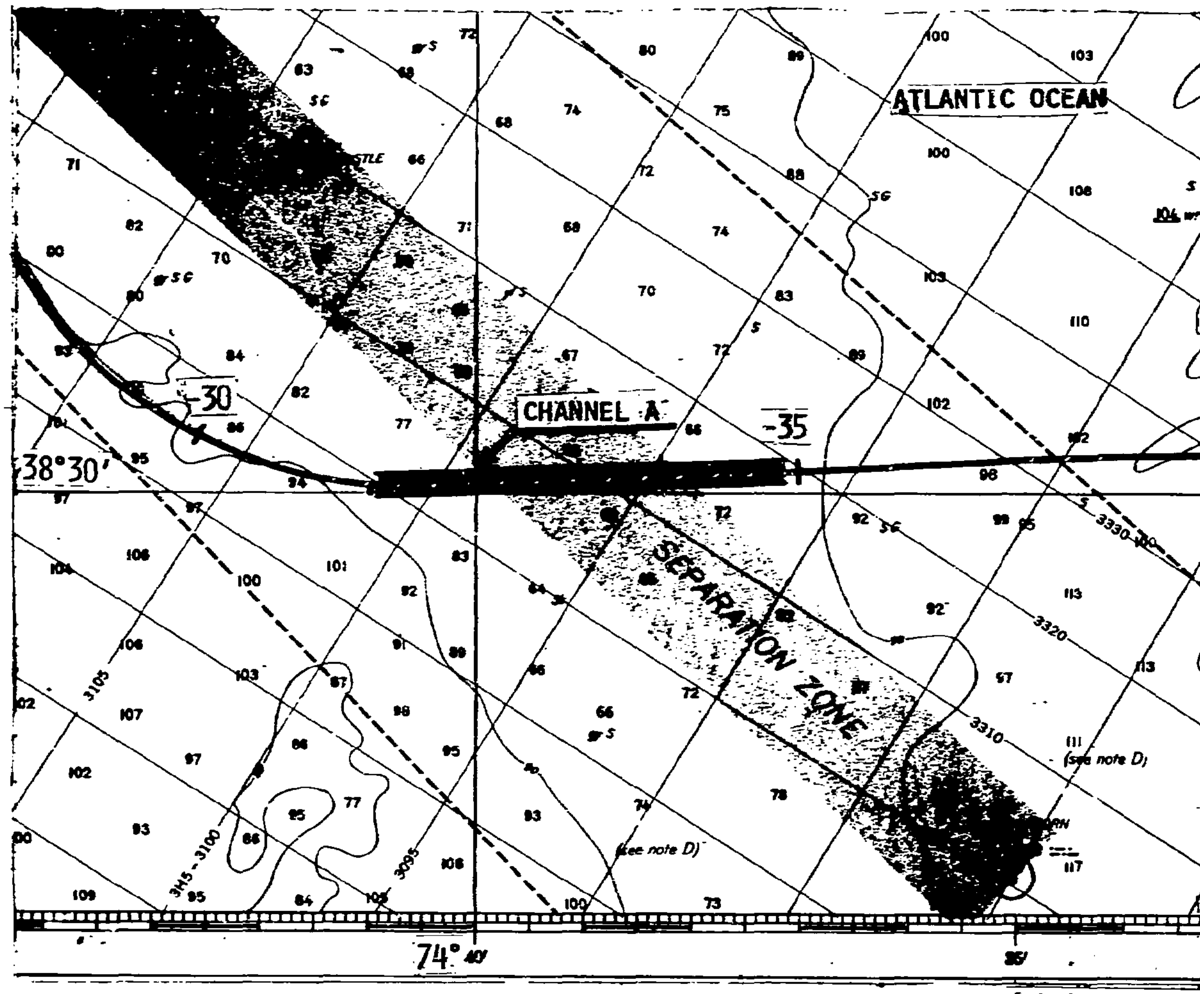


FIGURE 15. LOCATION OF DEEPWATER PORT AND INTERMEDIATE [illegible] FARM AND ASSUMED PIPELINE ROUTE OF ALTERNATIVE [illegible]



Note: Depths are in feet.

Scale of Statute Miles
0 1 2

FIGURE 16. LOCATION AND ORIENTATION OF CHANNEL A OF ALTERNATIVES 2-1 THROUGH 2-5

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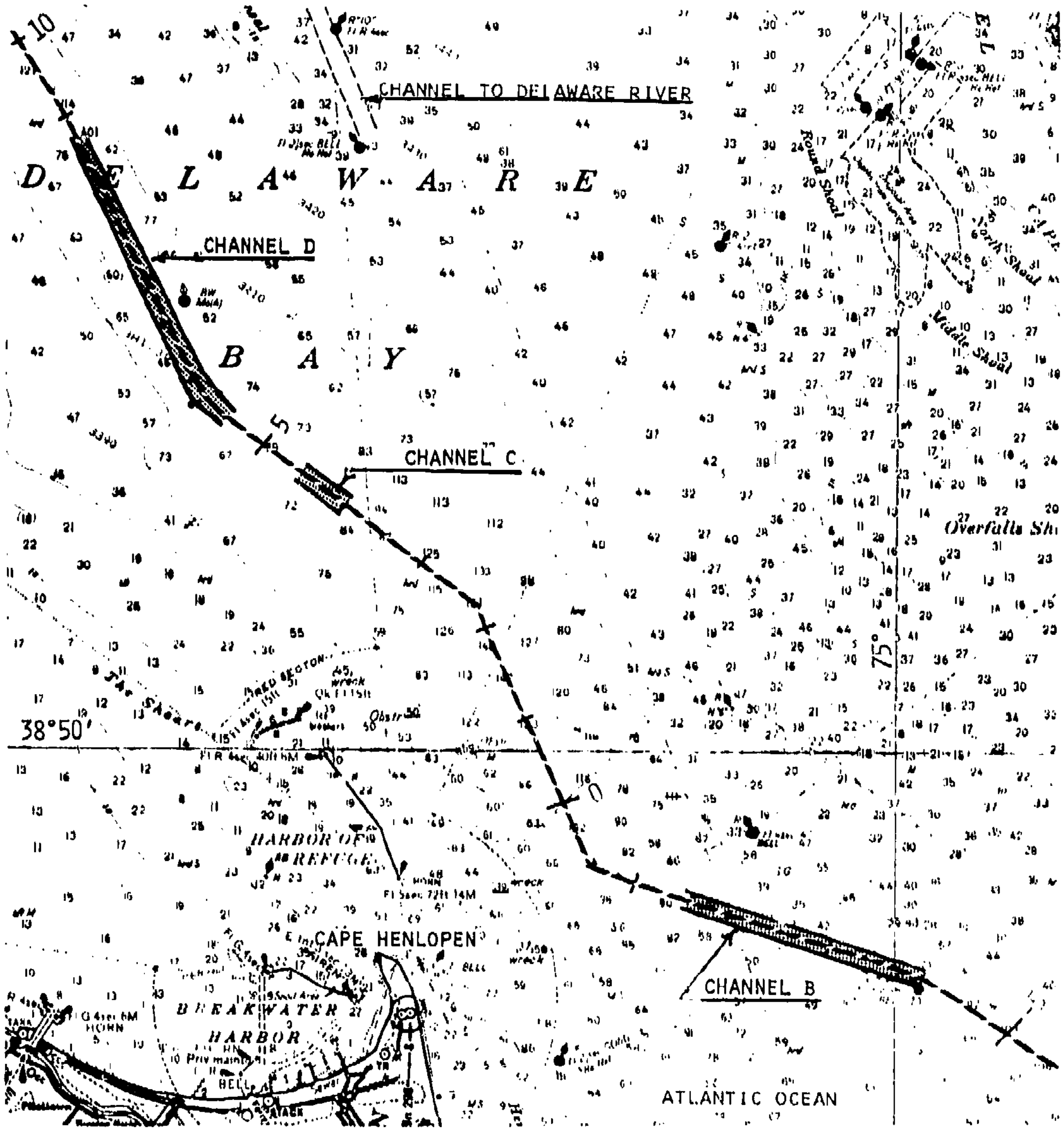

Note: Depths are in feet.

Scale of Statute Miles

FIGURE 17 LOCATION AND ORIENTATION OF CHANNEL B, CHANNEL C AND CHANNEL D OF ALTERNATIVES 21 THROUGH 24

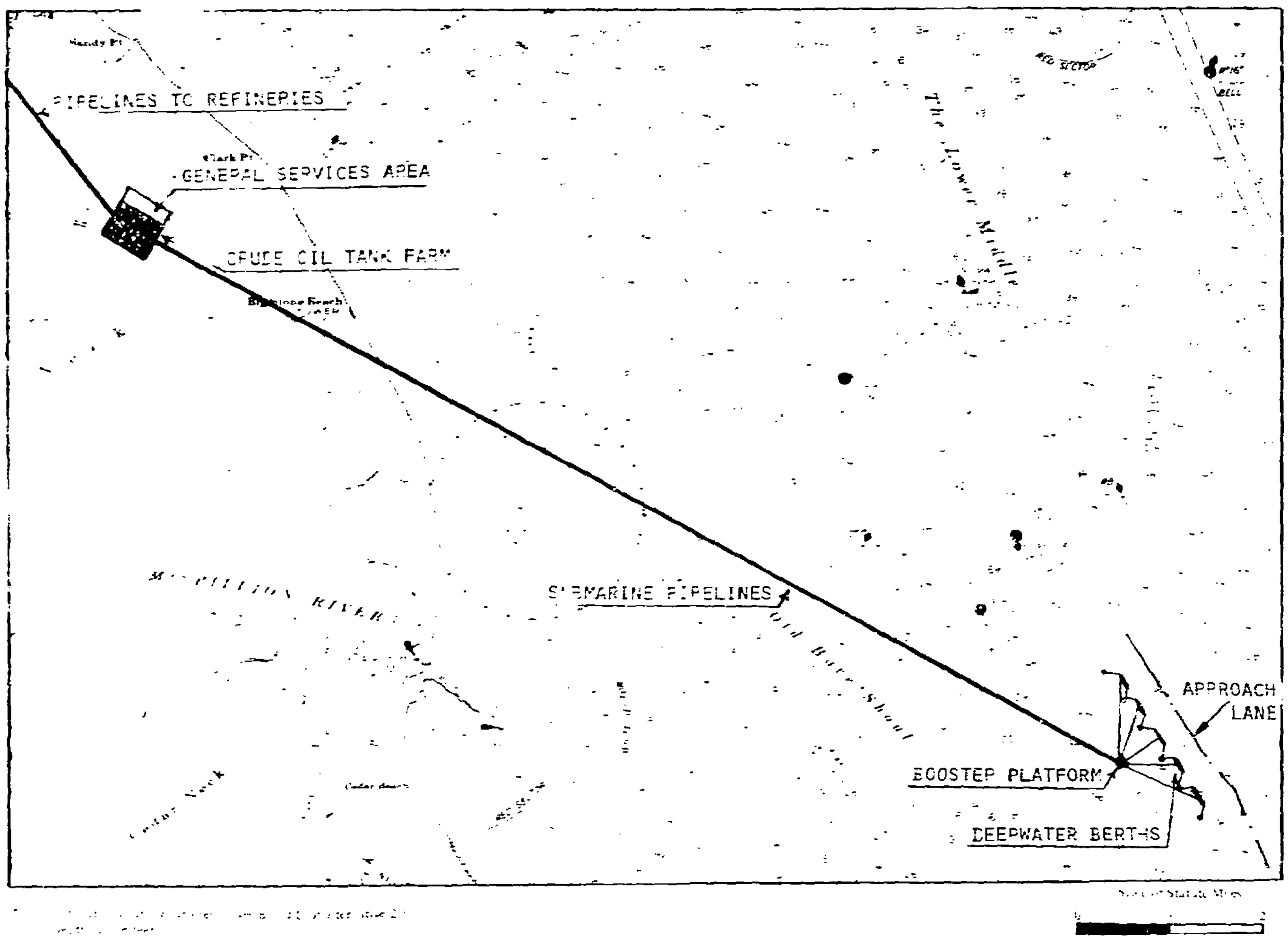

FIGURE . DETAILED LAYOUT OF DEEPWATER BERTHS, SUBMARINE LINES AND INTERMEDIATE TANK FARM OF ALTERNATIVES 2- AND 2-3

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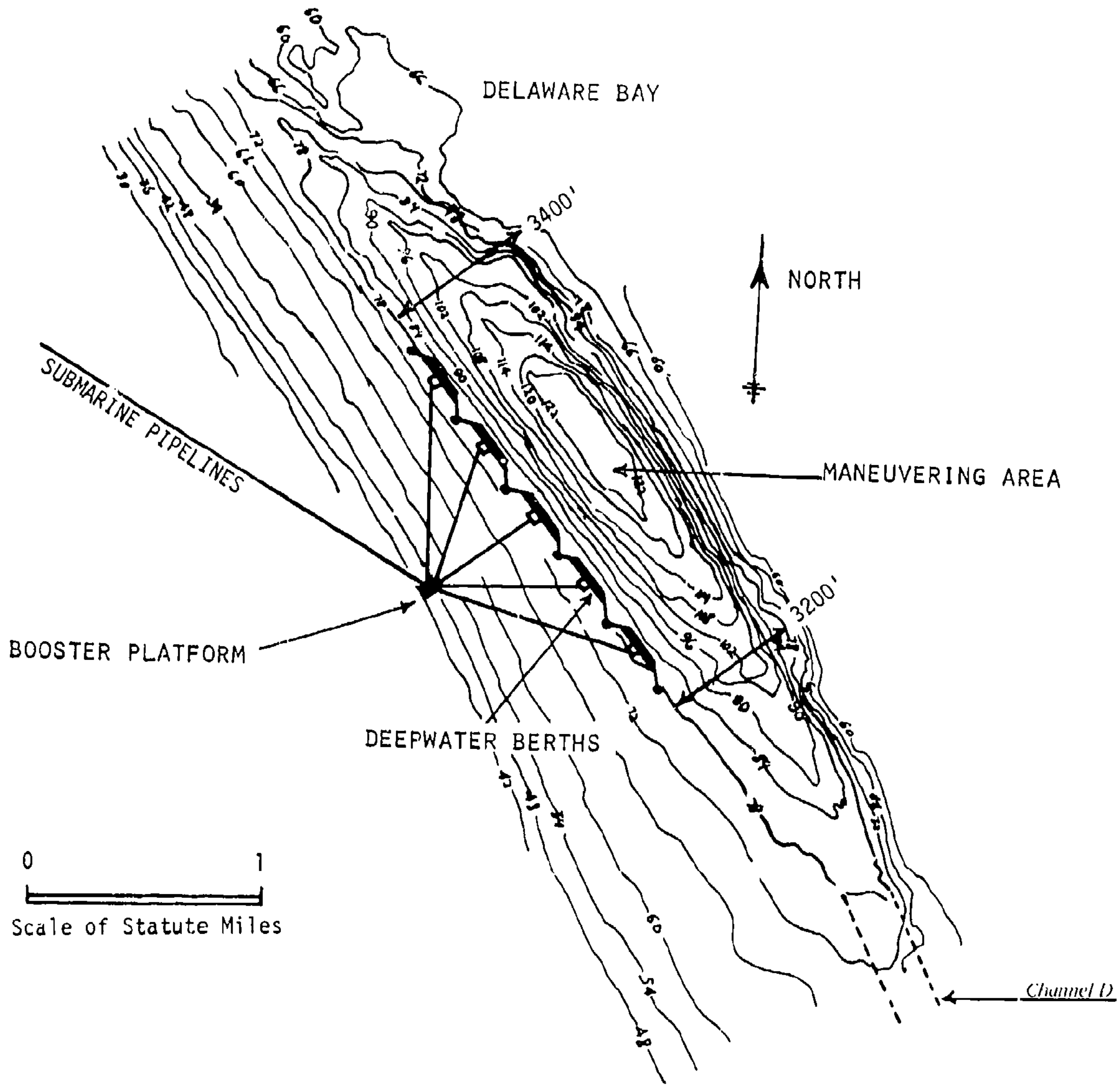
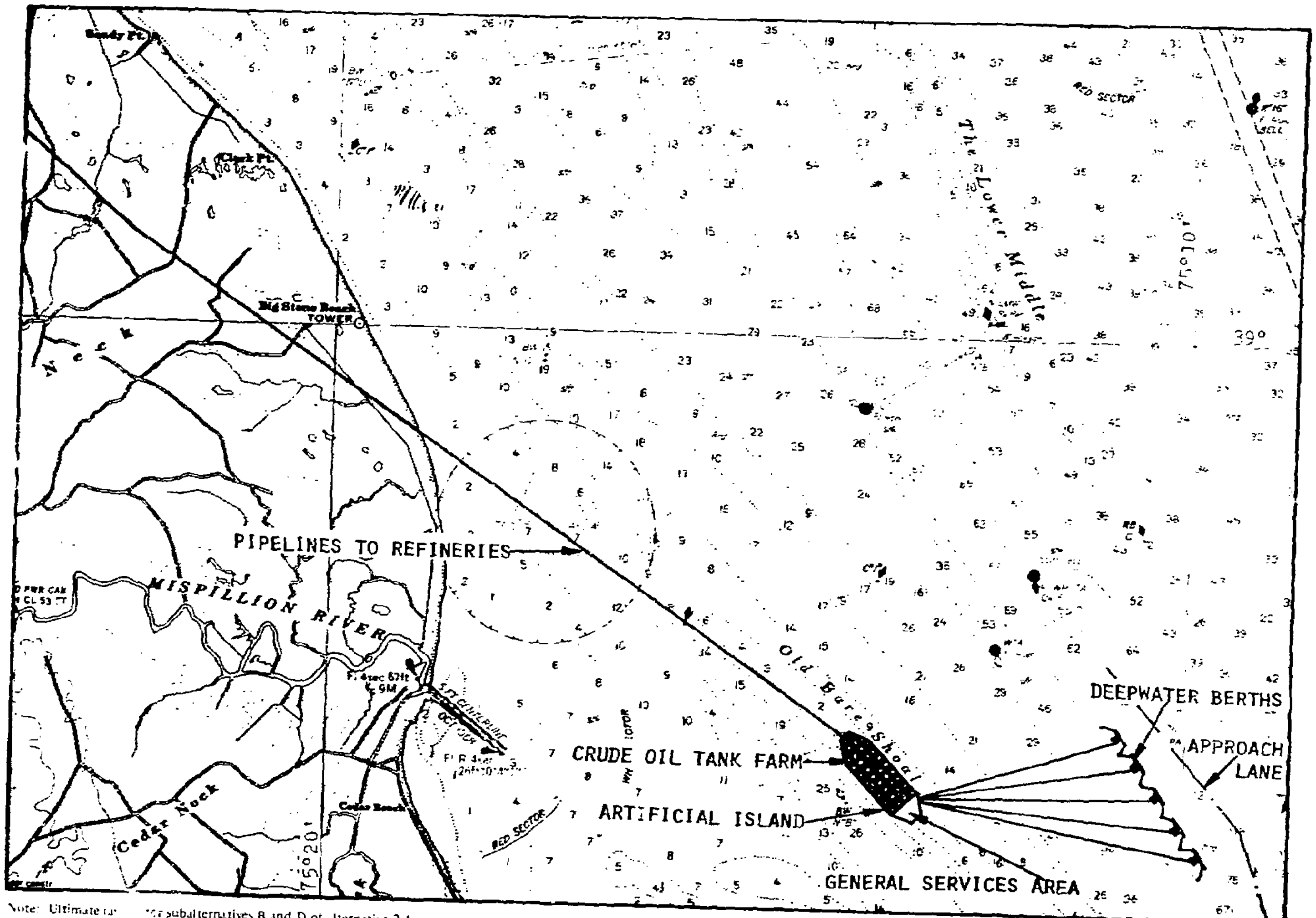


Note: Ultimate layout for subalternatives B and D of alternative 2-3.
Depths are in feet.

FIGURE 19. DETAILED LAYOUT OF MANEUVERING AREA AT THE DEEPWATER BERTHS OF ALTERNATIVES 2-I AND 2-3



Note: Ultimate [illegible] for subalternatives B and D of alternative 2-4.
Depths are in feet.

Scale of Statute Miles

FIGURE 20. DETAILED LAYOUT OF DEEPWATER BERTHS, SUBMARINE LINES AND ARTIFICIAL ISLAND OF ALTERNATIVES 2-2 AND 2-4

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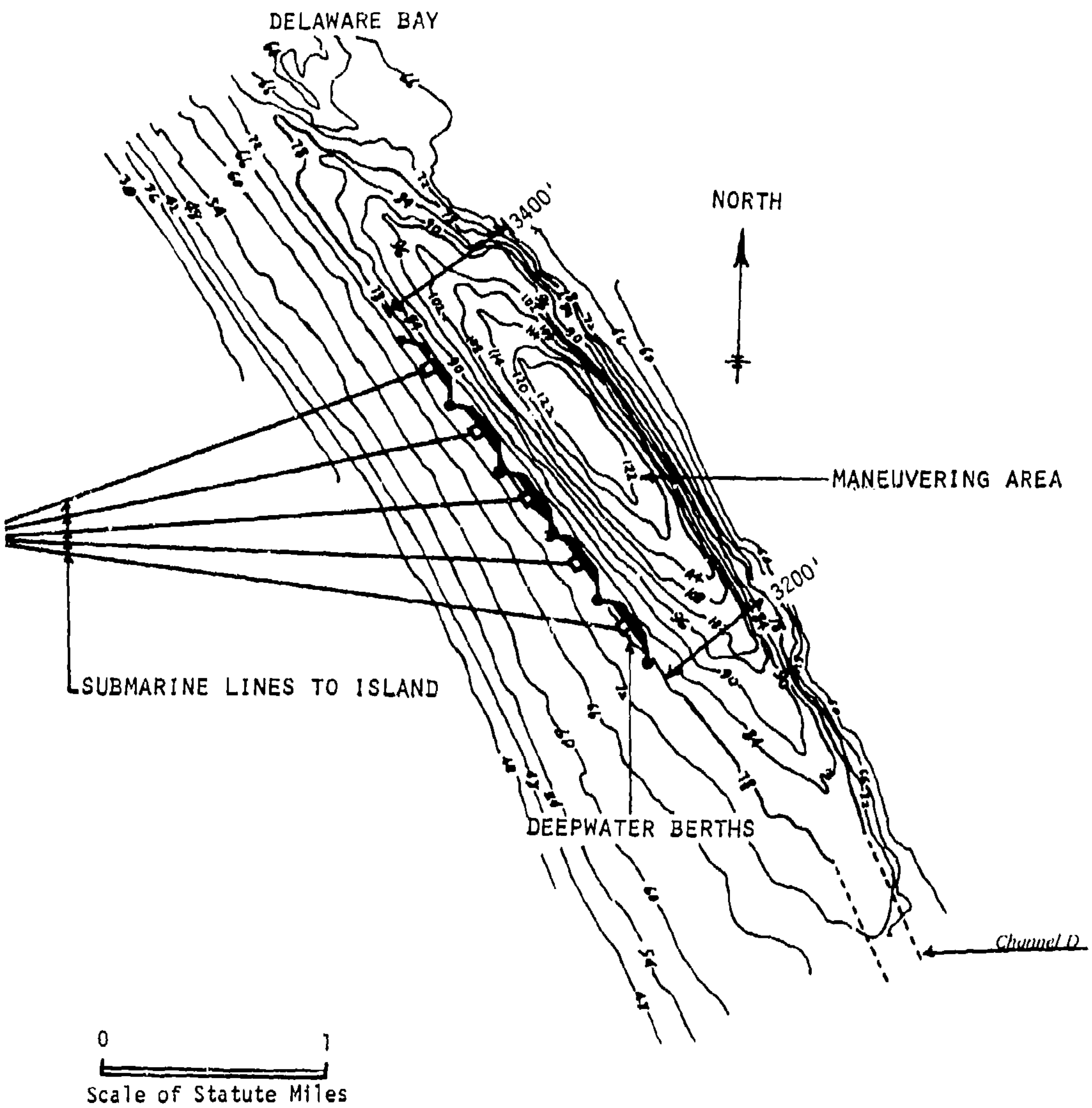
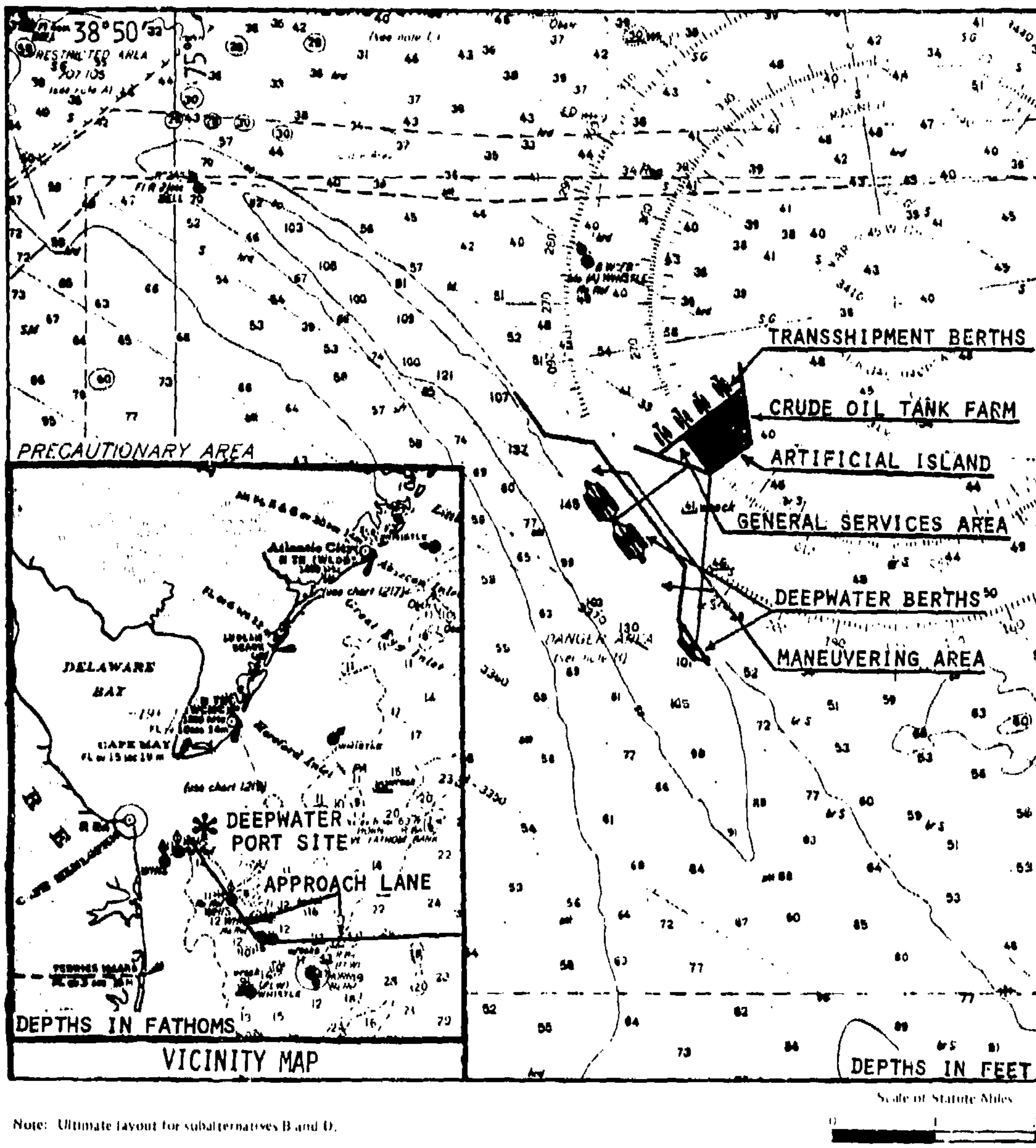


Note: Ultimate layout for subalternatives B and D of alternative 2-4.
Depths are in feet.

FIGURE 21. DETAILED LAYOUT OF MANEUVERING AREA AT THE DEEPWATER BERTHS OF ALTERNATIVES 2-2 AND 2-4



Note: Ultimate layout for subalternatives B and D.

FIGURE 22 LOCATION, ORIENTATION AND DETAILED LAYOUT OF BERTHS, PIPELINES AND ARTIFICIAL ISLAND OF ALTERNATIVE 2-S is set at 150 m.t.a. by 1980 (115 m.t.a. to Delaware River area and 35 m.t.a. to Arthur Kill area) and 300 m.t.a. by 2000 (230 m.t.a. to the Delaware River area and 70 m.t.a. to the Arthur Kill area).

Type of Berths

All alternatives consider fixed berths only.

Site of Tanks

Alternatives 2-1 and 2-3 consider an onshore tank farm, whereas alternatives 2-2, 2-4, and 2-5 consider offshore tank farms on an artificial island.

Vessel Sizes

Each alternative considers 300,000 and 400,000 d.w.t. tankers, and it is assumed that all tankers using the deepwater port will be of these maximum sizes. The assumed dimensions of these tankers are given in table 30.

Table 30. Assumed Dimensions of 300,000 and 400,000 Deadweight Ton Tankers

Dimension	300,000 d.w.t.	400,000 d.w.t.
	feet	
Length..............	1,050	1,100
Beam................	173	192
Draft...............	70	70

Dredging

Alternatives 2-1 through 2-4 require dredged channels, whereas alternative 2-5 requires only a dredged channel and dredged berthing areas. The artificial islands of alternatives 2-2, 2-4, and 2-5 will be constructed of dredged material. All submarine and onshore pipelines will be buried.

Water Depths

In alternatives 2-1 through 2-4, the depths of channels, maneuvering areas, etc., are such that all maximum-size tankers have to wait for high tide to approach the facilities. In other words, in these alternatives, the dredged depths are minimal.

Since MHW at Cape Henlopen, Delaware, is 4.1 feet above MLW, a value of 4 feet for average tidal rise will be applied.

Because alternative 2-5 requires some dredging of the berthing area only, it has been assumed that in this case fully loaded tankers would be able to berth during all stages of tide.

Construction Program

The time phasing of the various construction items for the period prior to 1980 is given in table 31 for alternatives 2-1 through 2-4, and in table 32 for alternative 2-5. The entire phasing was simplified to facilitate calculations. The total cost of each item is distributed equally over the pertinent years.

Alternative 2-1

Criteria

1. Site of deepwater port: In the Delaware Bay about 10 miles southeast of Big Stone Beach, Delaware.
2. Service area: Refineries along Delaware River.
3. Type of berths: Fixed.
4. Site of tanks: Onshore about 2.5 miles northwest of Big Stone Beach, Delaware.

Table 31. Construction Program of Alternatives 2-1 through 2-4

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Breakwater of island (Alternatives 2-2, 2-4)....	X	X			
Land fill and slope protection of island (Alternatives 2-2, 2-4)...			X		
Tank farm..................				X	X
Supertanker berths..........				X	X
Submarine lines.............					X
Pipelines to refineries.....				X	X
Dredging of channels........				X	X

Table 32. Construction Program of Alternative 2-5

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Breakwater of island........		X	X		
Land fill and slope protection of island.......			X		
Tank farm..................				X	X
Pipelines to and from berths....................					X
Dredging....................			X		

5. Draft of tankers: 70 feet fully loaded.

6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 33.

7. Type of transshipment: Pipelines only.

Table 33. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A................	300,000	70	115
B................	300,000	115	230
C................	400,000	70	115
D................	400,000	115	230

Requirements

Supertanker berths. Subalternative A would require two berths by 1980 and three berths by 1986 (the one additional berth being constructed in 1985). Subalternative B would require three berths by 1980 and four berths by 1986 (the one additional berth being constructed in 1985). Subalternative C would require two berths by 1980 and three berths by 1990 (the one additional berth being constructed in 1989). Subalternative D would require three berths by 1980 and four berths by 1990 (the one additional berth being constructed in 1989).

Dredging quantities. All quantities will include an overdepth of 5 feet.

1. Ocean channels. Two stretches would require dredging, one (Channel A) located between miles 35.1 and 31.7 and one (Channel B) located between miles 4.2 and 1.5 off the entrance between the Delaware Capes.

Channel A would be oriented nearly east-west and would be located near latitude 38° 30' at an average distance of about 22 miles off the coast. Because of the orientation and the distances from shore, the required width is set at 1,000 feet and the required depth at 1.2 x 70 = 84 feet. The following dimensions would be required:

a. Length = 35.1 -31.7 = 3.4 miles
b. Depth = 84 feet + 4 feet = 88 feet (no tide will be taken into account because of the distance of the deepwater site from the channel)
c. Average bottom depth per mile = 69, 64, and 80 feet
d. Average present depth = 71 feet
e. Average dredging depth = 17 feet
f. Width at bottom = 1,000 feet
g. Quantities to be dredged for all subalternatives = $\frac{3.4 \times 5,280}{27} \times 17 \times (1,000 + 3 \times 17)$ = 11.9×10^6 cubic yards

Channel B would be oriented nearly west-northwest and would be located about 4 miles west of Cape Henlopen, Delaware. The following dimensions would be required:

a. Length = 4.2 -1.5 = 2.7 miles
b. Depth = 81 feet -4 feet + 4 feet = 81 feet
c. Average bottom depth per mile = 69, 40, and 61 feet
d. Average present depth = 57 feet
e. Average dredging depth = 24 feet
f. Width at bottom = 900 feet (because of anticipated unfavorable orientation of channel with respect to currents and waves)
g. Quantities to be dredged for all subalternatives = $\frac{2.7 \times 5,280}{27} \times 24 \times (900 + 3 \times 24)$ = 12.3×10^6 cubic yards

2. Delaware Bay channels. Two stretches would require dredging, one (Channel C) located between miles 4.0 and 4.4 and one (Channel D) located between miles 5.5 and 8.8 off the entrance between the Delaware Capes.

Channel C would be oriented nearly northwest and would be located about 5 miles north of Cape Henlopen. The following dimensions would be required:

a. Length = 4.4 -4.0 = 0.4 miles
b. Required depth = 81 feet (close to entrance) -4 feet = 77 feet
c. Present depth = 76 feet
d. Dredging quantity = negligible

Channel D would be oriented nearly north-northwest and would be located 6 miles north-northwest of Cape Henlopen. The following dimensions would be required:

a. Length = 8.8 -5.5 = 3.3 miles
b. Required depth = 77 feet -4 feet = 73 feet, or, including overdepth, 73 feet + 4 feet = 77 feet
c. Present depth per mile = 67, 68, and 69 feet
d. Average channel depth = 68 feet
e. Average dredging depth = 9 feet
f. Width = depends on current conditions; a conservative width of 900 feet for all subalternatives is selected
g. Dredging quantity for all subalternatives = $\frac{3.3 \times 5{,}280}{27} \times 9 \times (900 + 3 \times 9) = 5.4 \times 10^6$ cubic yards

3. Turning basin and berthing areas. Because sufficient depth and width is present at the selected site of berths (approximately 10 miles southeast of Big Stone Beach), no dredging would be required for turning basins and berthing areas. An alternative site located 5 miles northwest of the selected site could have been chosen, thus reducing the distance to Big Stone Beach, and consequently the length of the pipelines, by approximately 5 miles. However, in this case a substantial amount of dredging would be required since the water depth at the alternative site is between 60 and 65 feet. The alternative site has an additional advantage in that two-sided island berths could be utilized instead of the marginal berths.

The total quantity to be dredged =

$11.9 + 12.3 + 0 + 5.4 = 29.6 \times 10^6$ cubic yards.

Pipelines from berths to intermediate tank farm. One 48-inch crude line would be required per berth. Each line would run underwater to a booster station located about 2,000 feet from the center berth. From the booster station all crude lines to the intermediate tank farm would run parallel for a distance of about 12 miles, of which 9.5 miles would be underwater.

The booster station would be located not more than 1 mile from the northernmost and southernmost berths, so that a pressure in excess of 25 p.s.i. would be available at the booster pumps.

The total pressure requirements per line would be: for subalternatives A and B, 15 (fixed berths) + $(12 + 1) \times 17.4 - 150 = 91.2$ p.s.i.; and for subalternatives C and D, $15 + 13 \times 21.2 - 150 = 140.6$ p.s.i.

The required horsepower per line would be: for subalternatives A and B, $47 \times 91.2 = 4{,}300$ b.hp.; and for subalternatives C and D, $52 \times 140.6 = 7{,}300$ b.hp.

Intermediate tank farm (onshore). The required crude oil storage capacities would be as follows: Subalternative A would require 1.54×10^6 long tons by 1980 and 1.81×10^6 long tons by 1986 (the additional 0.27×10^6 long tons being installed in 1985). Subalternative B would require 1.81×10^6 long tons by 1980 and 2.24×10^6 long tons by 1986 (the additional 0.43 $\times 10^6$ long tons being installed in 1985). Subalternative C would require 1.80×10^6 long tons by 1980 and 2.15×10^6 long tons by 1990 (the additional 0.35×10^6 long tons being installed in 1989). Subalternative D would require 2.15×10^6 long tons by 1980 and 2.67×10^6 long tons by 1990 (the additional 0.52×10^6 long tons being installed in 1989).

It is assumed that all bunkering would take place directly through special bunker berths. These could be located parallel to the deepwater berths at a distance of approximately 1/2 mile to the southwest. It is anticipated that oil separation tanks and equipment would be present and that an extra berth would be constructed northeast of the tank farm. The general service area has been estimated at 10 acres.

The required acreage would be as follows: for subalternative A, 1.81 x 50 + 10 = about 100 acres; for subalternative B, 2.24 x 50 + 10 = about 125 acres; for subalternative C, 2.15 x 50 + 10 = about 120 acres, and for subalternative D, 2.67 x 50 + 10 = about 145 acres.

Pipelines from tank farm at Big Stone Beach to refineries along Delaware River. The total pipeline system would be approximately 95 miles long. The distance from the tank farm to the refineries at Delaware City would be about 35 miles. From there the line would follow the same 47-mile route via Deepwater Point to Gloucester City as in alternatives 1-2 and 1-3, with branch lines (13 miles long) to Marcus Hook, Paulsboro, and Philadelphia. The total length of the section from Delaware City to Gloucester City, including the branch lines, would be about 60 miles. There would be four major water crossings: one 1,000-foot-long crossing at the Chesapeake and Delaware Canal and three 5,500-foot-long crossings at the Delaware River (at Deepwater Point, New Jersey, and Marcus Hook and Philadelphia, Pennsylvania).

Subalternatives A and C would require one 62-mile-long, 56-inch line for the entire 20-year period from 1980 to 2000. It is assumed that all branch lines and the 20-mile-long trunk line between Swedesboro and Gloucester City would be 48 inches. Subalternatives B and D would require two 62-mile-long, 56-inch lines for the period from 1980 to 2000. The 13-mile-long branch lines and the 20-mile-long trunk line between Swedesboro and Gloucester City are each assumed to consist of two 48-inch lines.

Subalternatives A and C would require approximately 95 x 188.7 = about 18,000 b.hp. in 1980 and 95 x 768.5 = about 73,000 b.hp. in 2000. It is assumed that 36,500 b.hp. would be installed in 1980; in 1990 another 36,500 b.hp. would be required. Subalternatives B and D would have the same horsepower requirements per line as determined for subalternatives A and C. The total requirement would always be twice that of subalternatives A and C.

Figure 12 shows the location of the deepwater port and the intermediate tank farm, and the assumed pipeline route to the refineries. Figures 16 and 17 depict the location and orientation of the channels. A detailed layout of the deepwater port is shown in figures 18 and 19.

Alternative 2-2

Criteria

1. Site of deepwater port: In Delaware Bay about 10 miles southeast of Big Stone Beach.
2. Service area: Refineries along Delaware River.
3. Type of berths: Fixed.
4. Site of tanks: Offshore artificial island.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 34.

Table 34. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A.............	300,000	70	115
B.............	300,000	115	230
C.............	400,000	70	115
D.............	400,000	115	230

7. Type of transshipment: Pipelines only.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternative 2-1. Subalternative A would require two berths by 1980 and three berths by 1986 (the one additional berth being constructed in 1985). Subalternative B would require three berths by 1980 and four berths by 1986 (the one additional berth being constructed in 1985). Subalternative C would require two berths by 1980 and three berths by 1990 (the one additional berth being constructed in 1989). Subalternative D would require three berths by 1980 and four berths by 1990 (the one additional berth being constructed in 1989).

Dredging quantities. The quantities to be dredged would be the same as those for alternative 2-1; the total quantity would equal 29.6×10^6 cubic yards.

Pipelines from berth to intermediate tank farm. One 48-inch crude line would be required per berth. Each line would run underwater to an artificial island where the intermediate tank farm for crude oil and the general service area would be located. It is assumed the island would be located on Old Bare Shoal at an average distance of approximately 3 miles to the west of the berths.

No booster stations would be required between berths and island since the pressure loss would not exceed $150 - 25 = 125$ p.s.i. Assuming a discharge rate of 100,000 barrels per hour, the maximum pressure loss would be approximately $15 + 4 \times 21.2 = 100$ p.s.i.

Artificial island. The crude oil storage capacity required would be the same as that of alternative 2-1. Subalternative A would require 1.54×10^6 long tons by 1980 and 1.81×10^6 long tons by 1986 (the additional 0.27×10^6 long tons being installed in 1985). Subalternative B would require 1.81×10^6 long tons by 1980 and 2.24×10^6 long tons by 1986 (the additional

0.43 x 10^6 long tons being installed in 1985. Subalternative C would require 1.80 x 10^6 long tons by 1980 and 2.15 x 10^6 long tons by 1990 (the additional 0.35 x 10^6 long tons being installed in 1989). Subalternative D would require 2.15 x 10^6 long tons by 1980 and 2.67 x 10^6 long tons by 1990 (the additional 0.52 x 10^6 long tons being installed in 1989).

It is anticipated that the general service area would provide for oil separation tanks and equipment, bunker fuel tanks, etc. The required acreage was estimated at 20 acres. The total required acreage would be: for subalternative A, 1.81 x 50 + 20 = about 110 acres; for subalternative B, 2.24 x 50 + 20 = about 135 acres; for subalternative C, 2.15 x 50 + 20 = about 130 acres; and for subalternative D, 2.67 x 50 + 20 = about 155 acres.

Assuming the elevation of the island at +20 feet and the present water depth at -2 feet, the land fill volumes required would be 3.9, 4.8, 4.6, and 5.5 million cubic yards for subalternatives A, B, C, and D, respectively. The breakwater would be 1 mile long for all subalternatives; the average length of the slope protection would be about 1.5 miles.

Pipelines from island to refineries along Delaware River. The total pipeline system would be about 10 miles longer than that of alternative 2-1. (These 10 miles equal the distance between the tank farm at Big Stone Beach for alternative 2-1 and the tank farm on the artificial island for alternative 2-2.) The total pipeline system would be approximately 105 miles long. The distance to the refineries at Delaware City would be about 45 miles. From there on the line would follow the same 47-mile route via Deepwater Point to Gloucester City as alternative 1-2, 1-3, and 2-1, with branch lines 13 miles long to Marcus Hook, Paulsboro, and Philadelphia. The total length of the section from Delaware City to Gloucester City, including branch lines, would be about 60 miles. There would be four major water crossings: one 1,000-foot-long crossing at the

Chesapeake and Delaware Canal, and three 5,500-foot-long crossings at the Delaware River (at Deepwater Point, New Jersey, and Marcus Hook and Philadelphia, Pennsylvania).

Subalternatives A and C would require one 62-mile-long, 56-inch line for the entire 20-year period from 1980 to 2000. It is assumed that all branch lines and the 20-mile-long trunk line between Swedesboro and Gloucester City would be 48 inches. Because 56-inch lines cannot be installed by laying-barges, it is assumed that the 6-mile-long section between the island and the shore would consist of two 48-inch lines.

Subalternatives B and D would require two 62-mile-long, 56-inch lines for the period from 1980 to 2000. It is assumed that all branch lines and the 20-mile-long trunk line between Swedesboro and Gloucester City would consist of two 48-inch lines. Because 56-inch lines cannot be installed by laying-barges, it is assumed that the 6-mile-long section between the island and the shore would consist of three 48-inch lines.

Subalternatives A and C would require approximately 105 x 188.7 = about 19,800 b.hp. in 1980 and 105 x 768.5 = about 80,700 b.hp. in 2000. It is assumed that 40,000 b.hp. would be installed in 1980; in 1990 another 40,000 b.hp. would be required.

Subalternatives B and D would have the same horsepower requirements per line as those for subalternatives A and C. The total requirement would always be twice that of subalternatives A and C.

Figure 13 presents the location of the deepwater port and the artificial island, and the assumed pipeline route to the refineries.

Figures 16 and 17 depict the location and orientation of the channels. A detailed layout of the deepwater port is presented in figures 20 and 21.

Alternative 2-3

Criteria

1. Site of deepwater port: In Delaware Bay, 10 miles southeast of Big Stone Beach, Delaware.
2. Service area: Refineries along Delaware River and Arthur Kill.
3. Type of berths: Fixed.
4. Site of tanks: Onshore, north of Big Stone Beach, Delaware.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives and the size of the vessels they will serve are given in table 35. The projected flows are given in table 36.

Table 35. Throughputs and Size of Vessels Served by Alternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A.............	300,000	100	150
B.............	300,000	150	300
C.............	400,000	100	150
D.............	400,000	150	300

Table 36. Projected Flow
(In millions of tons/year)

Subalternative	Delaware River		Arthur Kill	
	1980	2000	1980	2000
A and C.......	70	115	30	35
B and D.......	115	230	35	70

7. Type of transshipment: Pipeline only.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternatives 1-2 and 1-3. Subalternatives A and C would require three berths by 1980, with no additional berths needed in the period from 1980 to 2000. Subalternative B would require four berths by 1980 and five berths by 1990 (the one additional berth being constructed in 1989). Subalternative D would require four berths by 1980 and five berths by 1994 (the one additional berth being constructed in 1993).

Dredging quantity. The quantities to be dredged would be the same as those for alternatives 2-1 and 2-2; the total quantity would equal 29.6 x 10^6 cubic yards.

Pipelines from berths to intermediate tank farm. The routing would be the same as those for alternative 2-1. One 48-inch line per berth would be required. Each line would run underwater to a booster station located about 2,000 feet from the center berth. From the booster station all lines to the intermediate tank farm would run parallel for a distance of about 12 miles, of which 9.5 miles would be underwater.

The booster station required would be the same as that for alternative 2-1. The required horsepowers per line would be: for subalternatives A and B, 4,300 b.hp.; and for subalternatives C and D, 7,300 b.hp.

Intermediate tank farm (onshore). The crude oil storage capacity required would be the same as that for alternatives 1-2 and 1-3. Subalternative A would require 1.81 x 10^6 long tons by 1980. Subalternative B would require 2.24 x 10^6 long tons by 1980 and 2.51 x 10^6 long tons by 1990 (the additional 0.27 x 10^6 long tons being installed in 1989). Subalternative C would require 2.15 x 10^6 long tons by 1980. Subalternative D would require 2.67 x 10^6 long tons by 1980 and 3.04 x 10^6 long tons by 1994 (the additional 0.37 x 10^6 long tons being installed in 1993).

The general service area required would be the same as that for alternative 2-1 (about 10 acres). The total required acreage would be: for subalternative A, 1.81 x 50 + 10 = about 100 acres; for subalternative B, 2.51 x 50 + 10 = about 135 acres; for subalternative C, 2.15 x 50 + 10 = about 120 acres; and for subalternative D, 3.04 x 50 + 10 = about 160 acres.

Pipelines from tank farm at Big Stone Beach to refineries along Delaware River and Arthur Kill. The total pipeline system would be approximately 166 miles long. The first section of the route would be the same as that for alternative 2-1. After Gloucester City the system would continue via Jamesburg to the Arthur Kill area. There would be five major water crossings: one 1,000-foot-long crossing at the Chesapeake and Delaware Canal, three 5,500-foot-long crossings at the Delaware River, and one 3,500-foot-long crossing at the Raritan River.

Subalternatives A and C in 1980 would require two 56-inch lines between the Big Stone Beach tank farm and Gloucester City (a total length of 82 miles per line); one 48-inch line between Gloucester City and Woodbridge, New Jersey (a total length of about 59 miles); and one 36-inch line between Woodbridge and Elizabeth, New Jersey (a total length of 12 miles). In addition, one 36-inch line would be required for the branch lines to the refineries along the Delaware River (a total length of about 13 miles).

Subalternatives B and D in 1980 would require two 56-inch lines between the Big Stone Beach tank farm and Gloucester City (a total length of 82 miles per line); one 48-inch line between Gloucester City and Woodbridge, New Jersey (a total length of about 59 miles); and one 36-inch line between Woodbridge and Elizabeth, New Jersey (a total length of 12 miles). In addition, one 36-inch line would be required for the branch lines to the refineries along the Delaware River (a total length of about 13 miles). In 1989, an additional 82-mile-long, 56-inch line would be required between the Big Stone Beach tank farm and Gloucester City, and additional 36-inch branch lines with a total length of 10 miles would be needed between the trunk line and refineries at Marcus Hook and Philadelphia.

The horsepower requirement for subalternatives A and C in 1980 would be approximately 95 x 72.99 = 7,000 b.hp. per line between the Big Stone Beach tank farm and Gloucester City, and 71 x 37.84 = 2,700 b.hp. between Gloucester City and Elizabeth, New Jersey. In 2000 the horsepower requirement would be approximately 95 x 227.65 = 22,000 b.hp. per line between the tank farm and Gloucester City, and 71 x 59.17 = 4,200 b.hp. between Gloucester City and Elizabeth.

It is assumed that 11,000 b.hp. per 56-inch line would be installed in 1980 on the section between the Big Stone Beach tank farm and Gloucester City, and in 1986 another 11,000 b.hp. per 56-inch line would be installed on the same section. In 1980 4,200 b.hp. would be required for the pipeline from Gloucester City to the Arthur Kill area.

The horsepower requirement for subalternatives B and D in 1980 would be approximately 95 x 277.65 = 22,000 b.hp. per line on the section between Big Stone Beach and Gloucester City and 71 x 59.17 = 4,200 b.hp. on the section between Gloucester City and Elizabeth, New Jersey. In 1990 the horsepower requirement for these two sections would be approximately 95 x 768.50 = 73,000 b.hp. per line and 71 x 175 = 12,400 b.hp., respectively. In 2000 the horsepower requirement for the section between Big Stone Beach and Gloucester City would be 146,000 b.hp. for the first two lines combined and 95 x 188.70 = 18,000 b.hp. for the third line. The requirement between Gloucester City and Elizabeth would be 71 x 407.80 = 29,000 b.hp.

It is assumed that 37,000 b.hp. per 56-inch line would be installed by 1980 for the section between Big Stone Beach and Gloucester City, and that in 1983 another 37,000 b.hp. per 56-inch line would be installed on the same section. In 1988, 18,000 b.hp. would be installed for the third 56-inch line between Big Stone Beach and Gloucester City. On the 48-inch line between Gloucester City and Elizabeth, 14,500 b.hp. would be installed before 1980; an additional 14,500 b.hp. would be required in 1990.

Figure 14 shows the location of the deepwater port and the intermediate tank farm and the assumed pipeline route to the refineries.

Figures 16 and 17 depict the location and orientation of the channels. A detailed layout of the deepwater port is presented in figures 18 and 19.

Alternative 2-4

Criteria

1. Site of deepwater port: In Delaware Bay 10 miles southeast of Big Stone Beach, Delaware.
2. Service area: Refineries along Delaware River and Arthur Kill.
3. Type of berths: Fixed.
4. Site of tanks: Offshore artificial island.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 37. The projected flows are given in table 38.
7. Type of transshipment: Pipeline only.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternatives 1-2, 1-3, and 2-3. Subalternatives A and C would require three berths by 1980, with no additional berths needed in the period from 1980 to 2000. Subalternative B would require four berths by 1980 and five berths by 1990 (the one additional berth being constructed in 1989). Subalternative D would require four berths by

Table 37. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A.............	300,000	100	150
B.............	300,000	150	300
C.............	400,000	100	150
D.............	400,000	150	300

Table 38. Projected Flow
(In millions of tons/year)

Subalternative	Delaware River		Arthur Kill	
	1980	2000	1980	2000
A and C.......	70	115	30	35
B and D.......	115	230	35	70

1980 and five berths by 1994 (the one additional berth being constructed in 1993).

Dredging quantities. The quantities to be dredged would be the same as those for alternatives 2-1, 2-2, and 2-3; the total quantity would equal 29.6 x 10^6 cubic yards.

Pipelines from berths to intermediate tank farm. One 48-inch line would be required per berth. Each line would run underwater to an artificial island where the intermediate tank farm for crude oil and the general service area would be located. It is assumed the island would be located on Old Bare Shoal at an average distance of approximately 3 miles to the west of the berths.

No booster stations would be required between berths and island since the pressure loss would not exceed 150 -25 = 125 p.s.i. For a discharge rate of 100,000 barrels per hour, the maximum pressure loss would be approximately 15 + 4 x 21.2 = 100 p.s.i.

Artificial island. The crude oil storage capacities required would be the same as those for alternatives 1-2, 1-3, and 2-3. Subalternative A would require 1.81 x 10^6 long tons by 1980. Subalternative B would require 2.24 x 10^6 long tons by 1980 and 2.51 x 10^6 long tons by 1990 (the additional 0.27 x 10^6 long tons being installed in 1989). Subalternative C would require 2.15 x 10^6 long tons by 1980. Subalternative D would require 2.67 x 10^6 long tons by 1980 and 3.04 x 10^6 long tons by 1994 (the additional 0.37 x 10^6 long tons being installed in 1993).

It is anticipated that the general service area would provide for oil separation tanks and equipment, bunker fuel tanks, etc. The required acreage was estimated at 20 acres. The required total acreage would be: for subalternative A, 1.81 x 50 + 20 = about 110 acres; for subalternative B, 2.51 x 50 + 20 = about 145 acres; for subalternative C, 2.15 x 50 + 20 = about 130 acres; and for subalternative D, 3.04 x 50 + 20 = about 170 acres.

Assuming the elevation of the island at +20 feet and the present water depth at -2 feet, the land fill volumes required would be 3.9, 5.1, 4.6, and 6.0 million cubic yards for subalternatives A, B, C, and D, respectively. The breakwater would be about 1 mile long for all subalternatives; the slope protection at the land side of the island would have an average length of about 1.5 miles.

Pipelines from tank farm on island to refineries along Delaware River and Arthur Kill. The total pipeline system would be approximately 176 miles long. The first section of the route would be the same as that for alternative 2-3. After Gloucester City, the system would continue via Jamesburg to the Arthur Kill area. There would be five major water crossings: one 1,000-foot-long crossing at the Chesapeake and Delaware Canal, three 5,500-foot-long crossings at the Delaware River, and one 3,500-foot-long crossing at the Raritan River.

In 1980 subalternatives A and C would require two 56-inch lines between the tank farm on the island and Gloucester City (a total length 92 miles per line); one 48-inch line between Gloucester City and Woodbridge, New Jersey (a total length of about 59 miles); and one 36-inch line between Woodbridge and Elizabeth, New Jersey (a total length of 12 miles). In addition, 13-mile-long, 36-inch branch lines to the refineries along the Delaware River would be required. Because 56-inch lines cannot be installed by laying-barges, it is assumed that the 6-mile long section between the island and the shore would consist of three 48-inch lines.

In 1980 subalternatives B and D would require two 92-mile-long, 56-inch lines between the tank farm on the island and Gloucester City; one 59-mile-long, 48-inch line between Gloucester City and Woodbridge, New Jersey; and one 12-mile-long, 36-inch line between Woodbridge and Elizabeth, New Jersey. In addition, 13-mile-long, 36-inch branch lines to the refineries along the Delaware River would be required. In 1989 an additional 92-mile-long, 56-inch line would be required between the island and Gloucester City, and additional 36-inch branch lines with a total length of 10 miles would be needed between the trunk lines and the refineries at Marcus Hook and Philadelphia. Because 56-inch lines cannot be installed by laying-barges, it is assumed that the 6-mile long section between the island and the shore would consist of three 48-inch lines in 1980 and four 48-inch lines by 1989.

In 1980 the total horsepower requirement for subalternatives A and C would be approximately 105 x 72.99 = 7,700 b.hp. per 56-inch line on the section between the island and Gloucester City, and 71 x 37.84 = 2,700 b.hp. between Gloucester City and Elizabeth, New Jersey. In 2000 the total horsepower requirement for those two sections would be approximately 105 x 227.65 = 24,000 b.hp. per line and 71 x 59.17 = 4,200 b.hp., respectively. It is assumed that 12,000 b.hp. per 56-inch line would be installed in 1980. In 1986 another 12,000 b.hp. per 56-inch line would be required. Before 1980, 4,200 b.hp. would be installed on the line from Gloucester City to the Arthur Kill area.

In 1980 the horsepower requirement for subalternatives B and D would be approximately 105 x 227.65 = 24,000 b.hp. per 56-inch line on the section between the island and Gloucester City, and 71 x 59.17 = 4,200 b.hp. on the section between Gloucester City and Elizabeth, New Jersey. In 1990, the horsepower requirement for those two sections would be approximately 105 x 768.50 = 80,000 b.hp. per line and 71 x 175 = 12,400 b.hp., respectively. In 2000, the horsepower requirement for the section between the island and Gloucester City would be 160,000 b.hp. for the first two 56-inch lines combined and 105 x 188.70 = 20,000 b.hp. for the third 56-inch line; and for the section between Gloucester City and Elizabeth, 71 x 407.80 = 29,000 b.hp.

It is assumed that 40,000 b.hp. per 56-inch line would be installed in 1980, and another 40,000 b.hp. per 56-inch line would be installed in 1983. In 1990, 20,000 b.hp. would be required for the third 56-inch line. Before 1980 14,500 b.hp. would be installed on the 48-inch line between Gloucester City and Elizabeth; an additional 14,500 b.hp. would be required by 1990.

Figure 15 shows the location of the deepwater port and the artificial island, and the assumed pipeline route to the refineries.

Figures 16 and 17 depict the location and orientation of the channels. A detailed layout of the deepwater port is shown in figures 20 and 21.

Alternative 2-5

Criteria

1. Site of deepwater port: In the Atlantic Ocean about 10 miles east of Delaware Capes.
2. Service area: Refineries along Delaware River and Arthur Kill.
3. Type of berths: Fixed.
4. Site of tanks: Offshore artificial island.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives and the size of the vessels they will serve, are given in table 39. The projected flows are given in table 40.
7. Type of transshipment: Transshipment vessels only.

Table 39. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A.............	300,000	100	150
B.............	300,000	150	300
C.............	400,000	100	150
D.............	400,000	150	300

Table 40. Projected Flow

(In millions of tons/year)

Subalternative	Delaware River		Arthur Kill	
	1980	2000	1980	2000
A and C........	70	115	30	35
B and D........	115	230	35	70

Requirements

Supertanker berths. The number of berths required would be the same as that for alternatives 1-2, 1-3, 2-3, and 2-4. Subalternatives A and C would require three berths by 1980, with no additional berths needed in the period from 1980 to 2000. Subalternative B would require four berths by 1980 and five berths by 1990 (the one additional berth being constructed in 1989). Subalternative D would require four berths by 1980 and five berths by 1994 (the one additional berth being constructed in 1993).

Dredging quantities. The dredging that would be required, and the resulting dredging quantities, are as follows:

1. Ocean channel. Dredging of Channel A only would be required; the total quantity would equal 11.9×10^6 cubic yards.

2. Turning basins and berthing areas for super-tankers. The siting of the berths was done so that all berth structures would be in 81 feet of water after dredging, and the useful part of the dredged material would have a volume equal to the amount of material required for the construction of the artificial island.

a. Turning basins
   (1) Required depth = 84 feet
   (2) Assumed average present depth = 55 feet
   (3) Average dredging depth = 84 feet + 4 feet -55 feet = 33 feet
   (4) Approximate area
      (a) Subalternatives A and B = $2 \times 1{,}800 \times 2{,}200 = 7.9 \times 10^6$ square feet
      (b) Subalternatives C and D = $2 \times 1{,}800 \times 2{,}500 = 9.0 \times 10^6$ square feet
   (5) Total dredging amount
      (a) Subalternatives A and B = $33 \div 27 \times 7.9 \times 10^6 = 9.7 \times 10^6$ cubic yards
      (b) Subalternatives C and D = $33 \div 27 \times 9.0 \times 10^6 = 11.0 \times 10^6$ cubic yards

b. Berthing areas
   (1) Required depth = 81 feet
   (2) Assumed average present depth = 55 feet
   (3) Average dredging depth = 81 feet + 4 feet -55 feet = 30 feet
   (4) Approximate area
      (a) Subalternative A (3 berths) = $1{,}800 \times 1{,}650 + 600 \times 1{,}650 = 4.0 \times 10^6$ square feet
      (b) Subalternative B (4 berths) = $2 \times 1{,}800 \times 1{,}650 = 5.9 \times 10^6$ square feet
      (c) Subalternative C (3 berths) = $1{,}800 \times 1{,}900 + 600 \times 1{,}900 = 4.6 \times 10^6$ square feet
      (d) Subalternative D (4 berths) = $2 \times 1{,}800 \times 1{,}900 = 6.8 \times 10^6$ square feet

c. Total dredging amount
   (1) Subalternative A = $9.7 + 30 \div 27 \times 4.0 = 14.1 \times 10^6$ cubic yards.

(2) Subalternative B = 9.7 + 30 ÷ 27 x 5.9
= 16.2×10^6 cubic yards

(3) Subalternative C = 11.0 + 30 ÷ 27 x 4.6
= 16.1×10^6 cubic yards

(4) Subalternative D = 11.0 + 30 ÷ 27 x 6.8
= 18.6×10^6 cubic yards

Subalternatives B and D would require the construction of a fifth berth in 1989 and 1993, respectively. No dredging would be required if this berth is constructed completely separate from the other four berths, as is shown in figure 22.

Pipelines from berths to intermediate tank farm. One 48-inch line would be required per berth. Each line would run underwater to the artificial island where the intermediate tank farm for crude oil and the general service area would be located. It is assumed the island would be located immediately east of a 100-foot-deep natural channel leading to the Delaware Bay entrance near Cape Henlopen, at a distance of approximately 10 miles from the shore. No booster stations would be required between the berths and island since the average distance would be about 1 mile.

Artificial island. The crude oil storage capacities required would be the same as those for alternatives 1-2, 1-3, 2-3, and 2-4. Subalternative A would require 1.81×10^6 long tons by 1980. Subalternative B would require 2.24×10^6 long tons by 1980 and 2.51×10^6 long tons by 1990 (the additional 0.27×10^6 long tons being installed in 1989). Subalternative C would require 2.15×10^6 long tons by 1980. Subalternative D would require 2.67×10^6 long tons by 1980 and 3.04×10^6 long tons by 1994 (the additional 0.37×10^6 long tons being installed in 1993).

It is anticipated that the general service area would provide for oil separation tanks and equipment, bunker fuel tanks, etc. The required acreage was estimated at 20 acres. The required total acreage would be: for subalternative A, 1.81 x 50 + 20 = about 110 acres; for subalternative B, 2.51 x 50 + 20 = about 145 acres; for subalternative C, 2.15 x 50 + 20 = about 130 acres; and for subalternative D, 3.04 x 50 + 20 = about 170 acres.

Assuming the elevation of the island at +20 feet and the present water depth at -45 feet, the total required height would be 65 feet. The total area requirement would vary by subalternative; the total land fill requirements (assuming 43,560 square feet = 1 acre) would be: subalternative A, $(110 \div 27) \times 43,560 \times 65 = 11.5 \times 10^6$ cubic yards; subalternative B, $(145 \div 27) \times 43,560 \times 65 = 15.2 \times 10^6$ cubic yards; subalternative C, $(130 \div 27) \times 43,560 \times 65 = 12.3 \times 10^6$ cubic yards; and subalternative D, $(170 \div 27) \times 43,560 \times 65 = 17.8 \times 10^6$ cubic yards.

The length of the breakwater would be about 1.4, 1.8, 1.5, and 2.0 miles for subalternatives A, B, C, and D, respectively. The length of the slope protection on the land side of the island for each subalternative would be about 0.7, 0.9, 0.8, and 1.0 mile, respectively.

Transshipment berths. The transshipment barges serving the Arthur Kill and the Delaware River area are assumed to be in the 40,000 d.w.t. range.

According to table 20 this would require, for subalternatives A and C, four berths by 1980, with no additional berths needed in the period from 1980 to 2000; and for subalternatives B and D, five berths by 1980 and one additional berth in each of the years 1985, 1991, and 1997.

Pipelines from tank farm to transshipment berths. One 48-inch line per berth would be required. Each line would be about 3,800 feet long, of which 3,000 feet would be on land and 800 feet on trestle.

The pressure loss per line would be 15 p.s.i. at the berth and 12 p.s.i. per mile of 48-inch line for a throughput of 10,000 tons (or 73,000 barrels) per hour. The average oil level in the tanks is assumed at 20 + 50 ÷ 2 = +45 feet, whereas the average elevation of the tanker's manifold would also be at about +45 feet. Assuming a horsepower requirement of 38 b.hp. per p.s.i., then the requirement per line would be (15 + 0.8 x 12) x 38 = 935 b.hp. The total requirements would be: for subalternatives A and C, 4 x 935 = about 4,000 b.hp. in 1980; and for subalternatives B and D, 5 x 935 = about 5,000 b.hp. initially and 8,000 b.hp. ultimately by 2000.

Location, orientation, and detailed layout of berths, pipelines, and artificial island are presented on figure 22.

Location and orientation of Channel A is depicted on figure 16.

Mississippi Delta Area

Three oil alternatives, numbered 4-1, 4-2, and 4-3, are considered in the Mississippi Delta area of the gulf coast. They differ from each other in the water depth at the supertanker berths. The depths are 63, 81 and 109 feet, respectively, for alternatives 4-1, 4-2, and 4-3.

The location, orientation, and layouts of the berths and the artificial island are shown in figures 23, 24, and 25. The presentation of berths and islands is schematic.

Sites

All alternatives are sited in Garden Island Bay, which is located to the east of the South Pass of the Mississippi River.

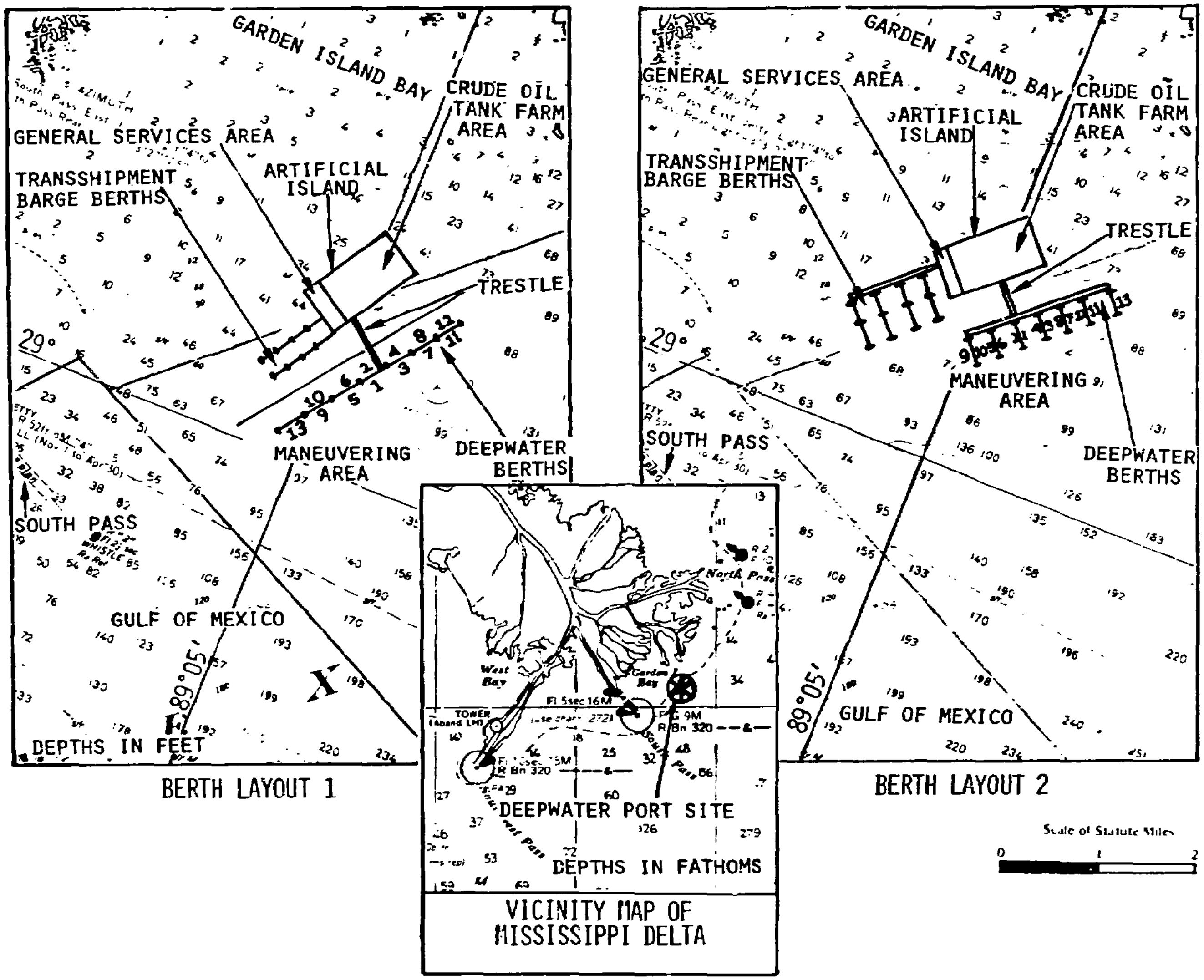


FIGURE 23. LOCATION, ORIENTATION AND LAYOUTS OF BERTHS AND ARTIFICIAL ISLAND OF ALTERNATIVE 4-I

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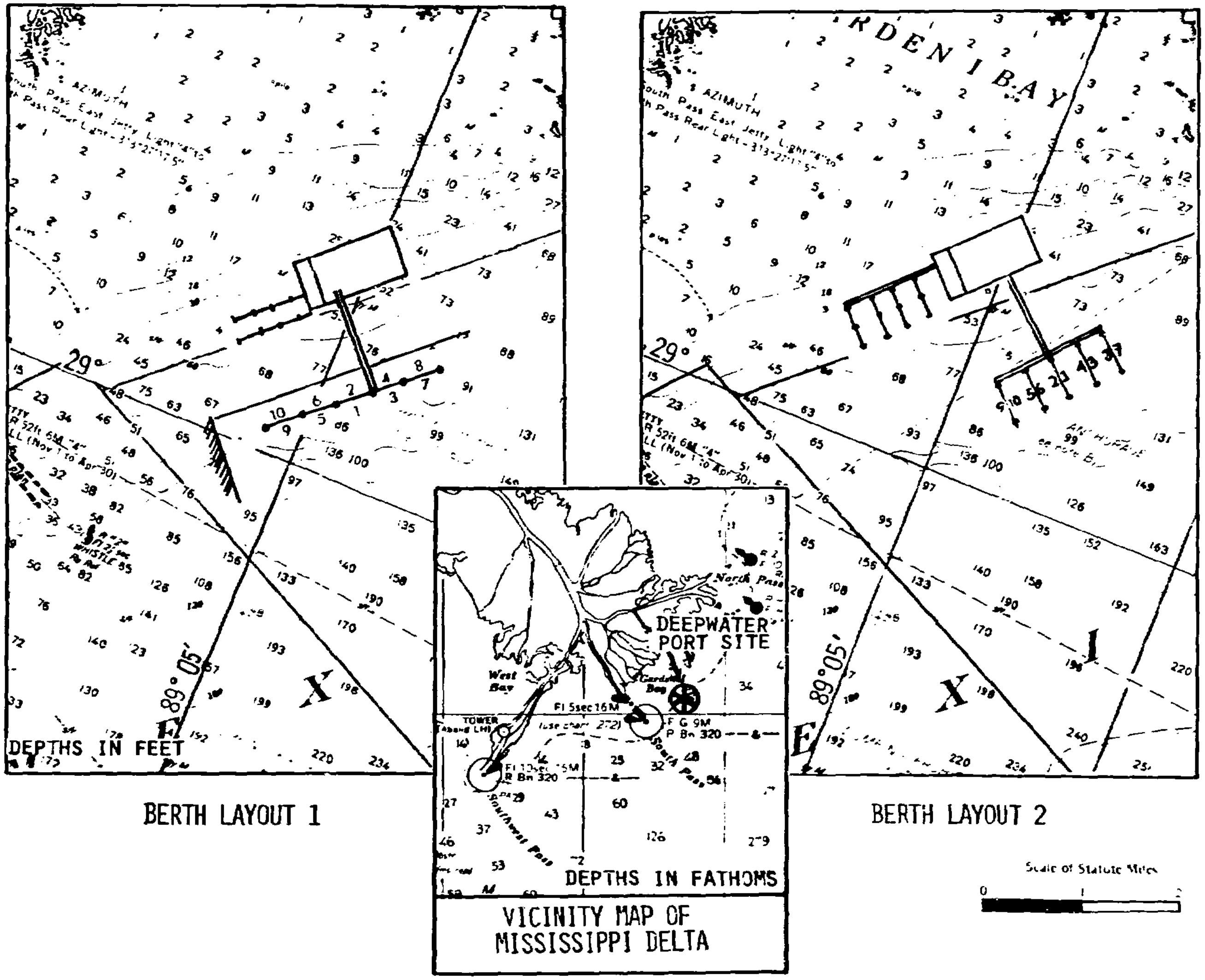
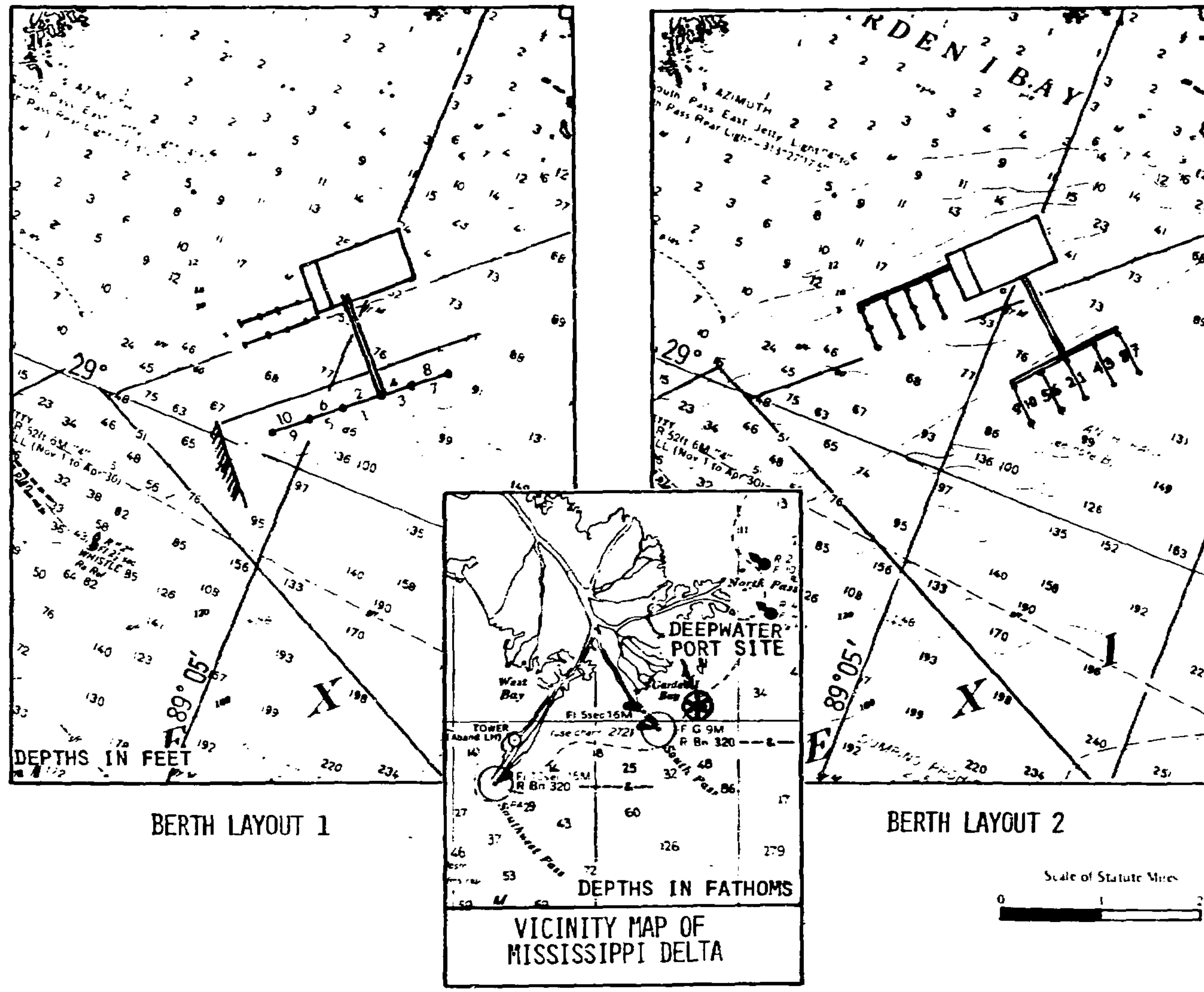


Note: See figure 23 for designation of facilities.

FIGURE 24. LOCATION, ORIENTATION AND LAYOUTS OF BERTHS AND ARTIFICIAL ISLAND OF ALTERNATIVE 4-2

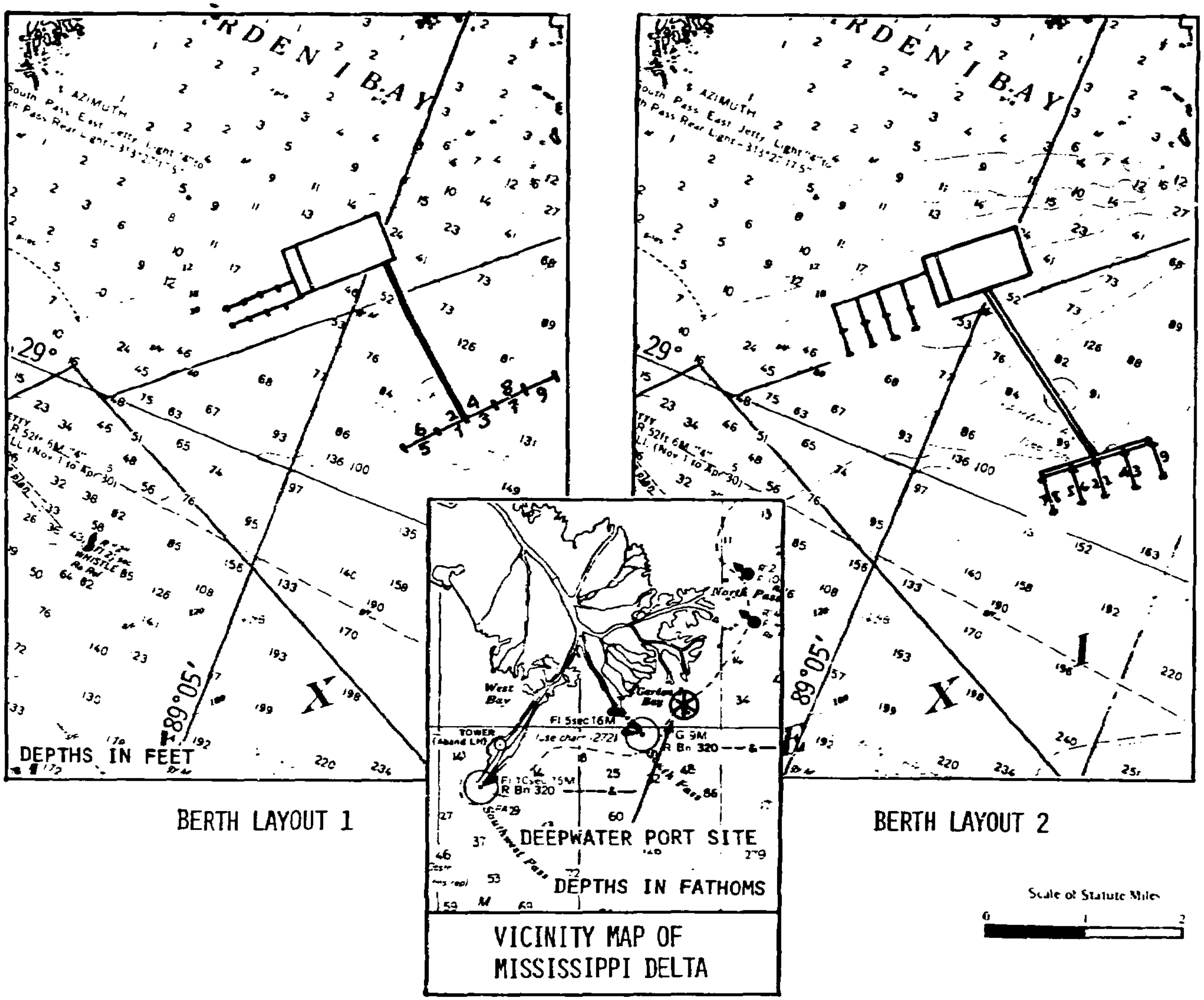
Robert R. Nathan Associates, Inc.



Note: See figure 23 for designation of facilities.

FIGURE 24. LOCATION, ORIENTATION AND LAYOUTS OF BERTHS AND ARTIFICIAL ISLAND OF ALTERNATIVE 4-2

Robert R. Nathan Associates, Inc.



Note: See figure 23 for designation of facilities.

FIGURE 25. LOCATION, ORIENTATION AND LAYOUTS OF BERTHS AND ARTIFICIAL ISLAND OF ALTERNATIVE 4-3

Service Areas

All alternatives would serve the same refinery areas: Houston and vicinity, Beaumont and vicinity, Lake Charles, Baton Rouge, New Orleans, Corpus Christi, and Pascagoula. All would be served by transshipment vessels.

Throughputs

All alternatives consider two sets of throughputs. The lower throughput is set at 100 m.t.a. in 1980 and 450 m.t.a. by 2000. The higher throughput is set at 150 m.t.a. in 1980 and 600 m.t.a. by 2000. It is assumed that the capacity of all refineries concerned would grow approximately in the same proportion.

The 1970 refinery capacities and percentages of the total refining capacity are given in table 41. To facilitate computations, percentages were rounded to 30 percent for Houston and Beaumont; to 10 percent for Lake Charles, Baton Rouge, and New Orleans; and to 5 percent for Corpus Christi and Pascagoula, as shown in table 42.

Table 41. Refining Capacities in 1970

Refinery area	Capacity (1,000 bbl./day)	Percentage of total capacity
Houston and vicinity......	1,499	32.6
Beaumont and vicinity......	1,214	26.4
Lake Charles...	303	6.6
Baton Rouge....	434	9.5
New Orleans....	540	11.7
Subtotal..	3,990	86.8
Corpus Christi.	337	7.3
Pascagoula.....	270	5.9
Subtotal..	607	13.2
Total.........	4,597	100.0

Table 42. Projected Flow
(In millions of long tons)

Refinery area	Percentage of total throughput	Throughput			
		Lower		Higher	
		1980	2000	1980	2000
Houston and vicinity......	30	30	135	45	180
Beaumont and vicinity......	30	30	135	45	180
Lake Charles...	10	10	45	15	60
Baton Rouge....	10	10	45	15	60
New Orleans....	10	10	45	15	60
Subtotal..	90	90	405	135	540
Corpus Christi.	5	5	22.5	7.5	30
Pascagoula.....	5	5	22.5	7.5	30
Subtotal..	10	10	45	15	60
Total..........	100	100	450	150	600

Type of Berths

All three alternatives (4-1, 4-2, and 4-3) consider fixed berths.

Dredging

Since sufficient water depth is available at the approach area, turning basins and berthing areas, it is possible to locate the berths in such a way that no dredging at the berthing areas would be required. However, if no dredging is not a criterion, berths could be constructed in shallower waters. The necessity of orienting the berths in accordance with dominant currents, waves, or winds will further restrict the flexibility of the choice of actual site location.

Two principal layouts will be presented. Layout 1 shows a berth orientation more or less parallel to the depth contour lines, assuming an orientation in accordance with predominant currents in that direction. Layout 2 shows a berth orientation perpendicular to that of layout 1, assuming an orientation in accordance with predominant waves or winds. It should be noted that layout 2 offers better possibilities than layout 1 for locating the berth structures in the required water depth. These possibilities arise, first, because the total width of layout 2 is less than the total length of layout 1 and layout 2 is therefore less influenced by the curvature of the contour lines. Second, in layout 2, it is not necessary to have the dolphins of the various berths in one line, as is required in layout 1. However, in both cases it is possible to have a layout of two separate jetties, the location of each one adjusted to the contour lines as well as possible. Therefore, it will be assumed that no dredging would be required for any subalternative.

Site of Tanks

All three alternatives consider an offshore tank farm on an artificial island.

Vessel Size

Alternative 4-1 will consider 200,000-d.w.t. tankers; alternative 4-2 will consider 300,000- and 400,000-d.w.t. tankers; and alternative 4-3 will consider 500,000-d.w.t. tankers. It is assumed that all tankers using the deepwater port will be of these maximum sizes for each alternative or subalternative. The assumed supertanker dimensions are given in table 43.

Water Depths

The selected water depth of channels, maneuvering areas, etc., is such that all maximum-size tankers would be able to navigate during all stages of the tide.

Pipelines between Supertanker Berths and Artificial Island

These pipes can be laid underwater as well as on a trestle. If a trestle is used, easy access from

Table 43. Vessel Dimensions
(In feet)

Dimension	Vessel Size (1,000 d.w.t.)			
	200	300	400	500
Length........	1,050	1,100	1,262	1,195
Beam..........	173	192	220	208
Draft.........	55	70	70	95

the island to the berth and the reverse can be provided at a given additional cost. Therefore, in this study a trestle has been selected for the connection between supertanker berths and island for alternative 4-1.

Construction Program

The time phasing of the various construction items for the period prior to 1980 is given in table 44 for all alternatives. The entire phasing was simplified in order to facilitate calculations. The total cost of each item will be equally distributed over the pertinent years.

Alternative 4-1

Criteria

1. Site of deepwater port: In Garden Island Bay, Gulf of Mexico.
2. Service area: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge, New Orleans, Corpus Christi, and Pascagoula.
3. Type of berths: Fixed berths.
4. Site of tanks: Artificial island.
5. Draft of tankers: 55 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessel they will serve, are given in table 45.

Table 44. Construction Program of Alternatives 4-1, 4-2, and 4-3

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Breakwater of island........	X	X	X		
Land fill and slope protection of island.......			X		
Tank farm..................				X	X
Supertanker berths..........				X	X
Pipelines to island.........					X
Transshipment berths........					X
Pipelines and boosters to transshipment berths.......					X

Table 45. Throughputs and Size of Vessels Served by Subalternatives

Subalternatives	Vessel Size	Throughput (million tons/year)	
	(d.w.t.)	1980	2000
A...............	200,000	100	450
B...............	200,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge, and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.

8. Type of transshipment: Transshipment vessel.

Requirements

Supertanker berths. The number of berths required for the subalternatives is as follows:

Subalternative A would require four berths by 1980, five berths by 1984, six berths by 1987, seven berths by 1990, eight berths by 1993, nine berths by 1996, and 10 berths by 1999. Four berths would be constructed before 1980 and two berths would be constructed in each of the years 1983, 1989, and 1995.

Subalternative B would require five berths by 1980, six berths by 1984, seven berths by 1986, eight berths by 1988, nine berths by 1990, 10 berths by 1992, 11 berths by 1994, 12 berths by 1996, and 13 berths by 1999. Six berths would be constructed before 1980 and two berths would be constructed in each of the years 1985, 1989, 1993. The last berth would be constructed in 1998.

Dredging The required water depth at the berths would be 63 feet, and at the turning basins and the approach area, 66 feet. Because sufficient water depth is available at the approach area, turning basins and berthing areas, no dredging would be required.

Pipelines from berths to intermediate tank farm. One 48-inch line per berth would be required. Each line would be about 2 miles long, of which 1.2 miles would be supported by trestle and 0.8 miles would be on the island. No booster pumps would be required.

Artificial island. The crude oil storage capacities required would be as follows: subalternative A would require 1.88 x 10^6 long tons by 1980, 2.48 x 10^6 long tons by 1984, 3.25 x 10^6 long tons by 1990, and 4.04 x 10^6 long tons by 1996. Before 1980, 1.88 million long tons of storage capacity would be constructed, and additional storage capacities of 0.60, 0.77 and 0.79 million long tons would be constructed in 1983, 1989 and 1995 respectively.

Subalternative B would require 2.48 x 10^6 long tons by 1980, 3.25 x 10^6 long tons by 1986, 4.04 x 10^6 long tons by 1990, 4.87 x 10^6 long tons by 1994, and 5.29 x 10^6 long tons by 1999. Before 1980, 2.48

million long tons of storage capacity would be constructed, and 0.77, 0.79, 0.83 and 0.42 million long tons would be constructed in 1985, 1989, 1993 and 1998, respectively.

For the general services an area of 30 acres was estimated. The total acreage requirement would be as follows: for subalternative A, 4.04 x 50 + 30 = approximately 230 acres; and for subalternative B, 5.29 x 50 + 30 = approximately 295 acres.

The assumed average water depth at the island is 35 feet, and the assumed required terrain elevation is +20 feet. The land fill requirements are as follows:

Subalternative A = $\frac{43,560}{27} \times 230 \times 55 = 20.4 \times 10^6$ cubic yards

Subalternative B = $\frac{43,560}{27} \times 295 \times 55 = 26.2 \times 10^6$ cubic yards

The main breakwater is about 2.0 miles long; the secondary breakwater, 1.0 mile long.

<u>Transshipment berths</u>. The number of berths required would be as follows: subalternative A would require four berths by 1980, six berths by 1983, eight berths by 1988, and 10 berths by 1993. Four berths would be constructed before 1980 and two berths would be constructed in each of the years 1982, 1987, and 1992.

Subalternative B would require six berths in 1980, eight berths in 1985, 10 berths in 1988, 12 berths in 1992, and 14 berths in 1996. Six berths would be constructed before 1980, and two berths would be constructed in each of the years 1984, 1987, 1991, and 1995.

Pipelines and booster stations from intermediate storage to transshipment berths. One 48-inch line per berth would be required. The average length of a line would be approximately 1.5 miles, of which 1 mile is on land and 0.5 mile supported by trestle.

The pressure loss per line is 15 + 1.5 x 11.13 = 31.7 p.s.i. The horsepower requirement is 31.7 x 36.64 = about 1,000 b.hp. per line.

The location, orientation, and layouts of berths and artificial island are shown in figure 23. The presentation of berths and island is schematic.

Alternative 4-2

Criteria

1. Site of deepwater port: In Garden Island Bay, Gulf of Mexico.
2. Service area: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge, New Orleans, Corpus Christi, and Pascagoula.
3. Type of berths: Fixed berths.
4. Site of tanks: Artificial island.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 46.
7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge, and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.
8. Type of transshipment: Transshipment vessels.

Requirements

Supertanker berths. The number of berths required for the subalternatives is as follows: subalternative A would require three berths by 1980, four berths by 1983, five berths by 1987, six berths by 1991, seven berths by 1995, and eight berths by 1998. Four

Table 46. Throughputs and Size of Vessel Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year) 1980	2000
A..............	300,000	100	450
B..............	300,000	150	600
C..............	400,000	100	450
D..............	400,000	150	600

berths would be constructed before 1980, and one berth would be constructed in each of the years 1986, 1990, 1994, and 1997.

Subalternative B would require four berths by 1980, five berths by 1983, six berths by 1986, seven berths by 1989, eight berths by 1992, nine berths by 1995, and 10 berths by 1997. Four berths would be constructed before 1980, and one berth would be constructed in each of the years 1982, 1985, 1988, 1991, 1994, and 1996.

Subalternative C would require three berths by 1980, four berths by 1984, five berths by 1989, six berths by 1994, and seven berths by 1998. Four berths would be constructed before 1980, and one berth would be constructed in each of the years 1988, 1993, and 1997.

Subalternative D would require four berths by 1980, five berths by 1985, six berths by 1988, seven berths by 1991, eight berths by 1995, and nine berths by 1998. Four berths would be constructed before 1980, and one berth would be constructed in each of the years 1984, 1987, 1990, 1994, and 1997.

Dredging. The required water depths would be 81 feet at the berths and 84 feet at the approach area and turning basins. Sufficient water depth is available for all areas, and it has been assumed that no dredging would be required for any subalternative. However, as discussed in the introduction, no dredging might result in the locating of some berths in water considerably deeper than required.

Pipelines from supertanker berths to intermediate tank farm. One 48-inch line per berth would be required. Each line would be about 2.6 miles long, of which 0.8 mile would be supported by trestle, 1 mile would be underwater, and 0.8 mile would be on the island. No booster pumps would be required.

Artificial island. The crude oil storage capacities required would be as follows: subalternative A would require 2.24×10^6 long tons by 1980, 2.51×10^6 long tons by 1987, 2.87×10^6 long tons by 1991, 3.34×10^6 long tons by 1995, and 3.83×10^6 long tons by 1998. Before 1980, 2.24 million long tons of storage capacity would be constructed; additional storage capacities of 0.27, 0.36, 0.47, and 0.49 million long tons would be constructed in 1986, 1990, 1994, and 1997, respectively.

Subalternative B would require 2.24×10^6 long tons by 1980, 2.51×10^6 long tons by 1983, 2.87×10^6 long tons by 1986, 3.34×10^6 long tons by 1989, 3.83×10^6 long tons by 1992, 4.30×10^6 long tons by 1995, and 4.75×10^6 long tons by 1997. Before 1980, 2.24 million long tons of storage capacity would be constructed; additional storage capacities of 0.27, 0.36, 0.47, 0.49, 0.47, and 0.45 million long tons would be constructed in 1982, 1985, 1988, 1991, 1994, and 1996, respectively.

Subalternative C would require 2.67×10^6 long tons by 1980, 3.04×10^6 long tons by 1989, 3.55×10^6 long tons by 1994, and 4.09×10^6 long tons by 1998.

Before 1980, 2.67 million long tons of storage capacity would be constructed; additional storage capacities of 0.37, 0.51, and 0.54 million long tons would be constructed in 1988, 1993, and 1997, respectively.

Subalternative D would require 2.67×10^6 long tons by 1980, 3.04×10^6 long tons by 1985, 3.55×10^6 long tons by 1988, 4.09×10^6 long tons by 1991, 4.69×10^6 long tons by 1995, and 5.29×10^6 long tons by 1998. Before 1980, 2.67 million long tons of storage capacity would be constructed; additional storage capacities of 0.37, 0.51, 0.54, 0.60, and 0.60 million long tons would be constructed in 1984, 1987, 1990, 1994, and 1997.

For general services an area of 30 acres was estimated. The total acreage requirement would be, for subalternative A, $3.83 \times 50 + 30$ = about 220 acres; for subalternative B, $4.75 \times 50 + 30$ = about 270 acres; for subalternative C, $4.09 \times 50 + 30$ = about 235 acres; and for subalternative D, $5.29 \times 50 + 30$ = about 295 acres.

The assumed average water depth at the island is 35 feet, and the assumed required terrain elevation is +20 feet. The land fill requirements would be as follows:

Subalternative A = $\frac{43,560}{27} \times 220 \times 55 = 19.6 \times 10^6$ cubic yards

Subalternative B = $\frac{43,560}{27} \times 270 \times 55 = 23.9 \times 10^6$ cubic yards

Subalternative C = $\frac{43,560}{27} \times 235 \times 55 = 20.8 \times 10^6$ cubic yards

Subalternative D = $\frac{43,560}{27} \times 295 \times 55 = 26.2 \times 10^6$ cubic yards

The main breakwater is about 2.0 miles long; the secondary breakwater, 1 mile long.

Transshipment berths. Subalternatives A and C would require the same number of transshipment berths as subalternative A of alternative 4-1; subalternatives B and D, would require the same number of transshipment berths as subalternative B of alternative 4-1.

Pipelines and booster stations from intermediate tank farm to transshipment berths. The requirements would be the same as those for alternative 4-1.

The location, orientation and layouts of berths and artificial island are shown in figure 24. The presentation of berths and island is schematic.

Alternative 4-3

Criteria

1. Site of deepwater port: In Garden Island Bay, Gulf of Mexico.
2. Service area: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge, New Orleans, Corpus Christi and Pascagoula.
3. Type of berths: Fixed berths.
4. Site of tanks: Artificial island.
5. Draft of tankers: 95 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 47.

Table 47. Throughputs and Size of Vessel Served by Subalternatives

Subalternative	Vessel size	Throughput (million tons/year)	
	(d.w.t.)	1980	2000
A..............	500,000	100	450
B..............	500,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge, and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.
8. Type of transshipment: Transshipment vessels.

Requirements

Supertanker berths. The number of berths required for the subalternatives is as follows: subalternative A would require three berths by 1980, four berths by 1985, five berths by 1990, six berths by 1994, and seven berths by 1999. Three berths would be constructed before 1980; one berth would be constructed in each of the years 1984, 1989, 1993 and 1998.

Subalternative B would require four berths by 1980, five berths by 1985, six berths by 1989, seven berths by 1993, eight berths by 1996, and nine berths by 1999. Four berths would be constructed before 1980; one berth would be constructed in each of the years 1984, 1988, 1992, 1995 and 1998.

Dredging. The required water depths are 109 feet at the berths and 114 feet at the approach area and turning basins. Sufficient water depth is available for all areas, and it is assumed that no dredging would be required for any subalternative. However as discussed in the introduction, no dredging might result in the locating of some berths in water considerably deeper than required.

Pipelines from supertanker berths to intermediate tank farm. One 48-inch line per berth would be required. Each line would be about 3 miles long, of which 0.4 mile would be supported by trestle, 1.8 miles would be underwater, and 0.8 mile would be on the island. No booster pumps would be required.

Artificial island. The crude oil storage capacities required would be as follows: subalternative A would require 2.17×10^6 long tons by 1980, 2.69×10^6 long tons by 1985, 3.04×10^6 long tons by 1990, 3.47×10^6 long tons by 1994, and 4.07×10^6 long tons by 1999. Before 1980 2.17 million long tons of storage capacity would be constructed; additional storage capacities of 0.52, 0.35, 0.43 and 0.60 million long tons would be constructed in 1984, 1989, 1993, and 1998, respectively.

Texas Area

Six alternatives, numbered 5-1 through 5-6, are considered in the Texas area of the gulf coast.

The location and layout of the deepwater ports in the area and the pipeline route to the various refinery areas are shown in figures 26 through 28. Detailed layouts are shown in figures 29 and 30.

Sites

Alternatives 5-1, 5-2 and 5-3 consider deepwater ports off Freeport in the Gulf of Mexico, whereas alternatives 5-4, 5-5, and 5-6 consider deepwater ports immediately behind the coastline.

Service Areas

All alternatives would serve the same refinery areas: Houston and vicinity, Beaumont and vicinity, Lake Charles, Baton Rouge and New Orleans, all of which would be served by pipelines; and Corpus Christi and Pascagoula, which would be served by transshipment vessels. It is assumed that the intermediate tank farm would be located on shore at Freeport.

Throughputs

All alternatives consider two sets of throughputs. The lower throughput is set at 100 m.t.a. in 1980 and 450 m.t.a. by 2000. The higher throughput is set at 150 m.t.a. in 1980 and 600 m.t.a. by 2000. It is assumed that the capacity of all refineries concerned would grow approximately in the same proportion. As discussed in the preceding section of the Mississippi Delta area, the following flows have been projected: to Houston and Beaumont, 30 percent each of the total throughput; to Lake Charles, Baton Rouge, and New Orleans, 10 percent each; and to Corpus Christi and Pascagoula, 5 percent each. Table 48 gives the projected flows to the various refinery areas.

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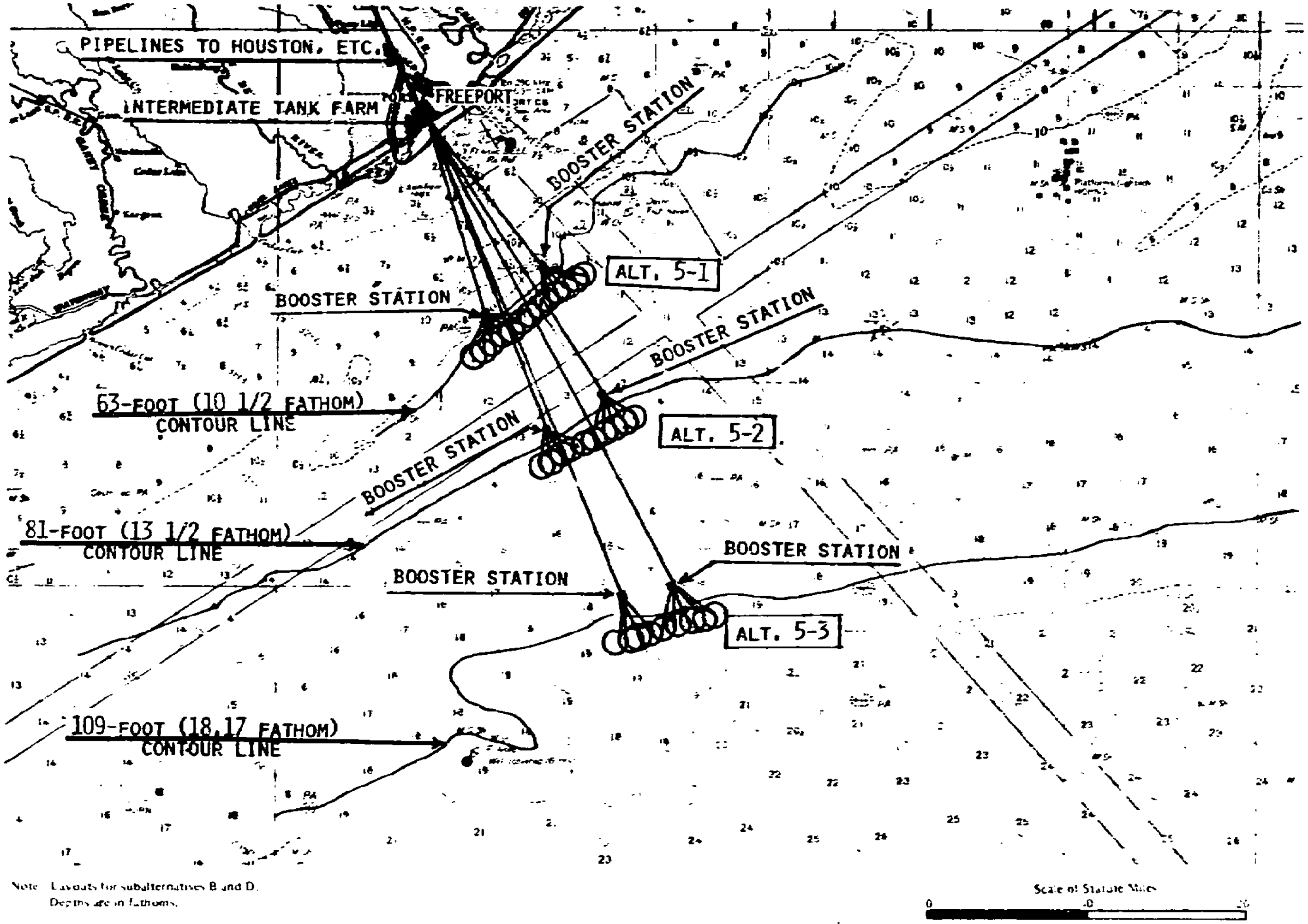

Note: Layouts for subalternatives B and D.
Depths are in fathoms.

FIGURE 26 LOCATION AND LAYOUT OF MONOBUOYS AND SUBMARINE PIPELINES OF ALTERNATIVES 5-1, 5-2 AND 5-3

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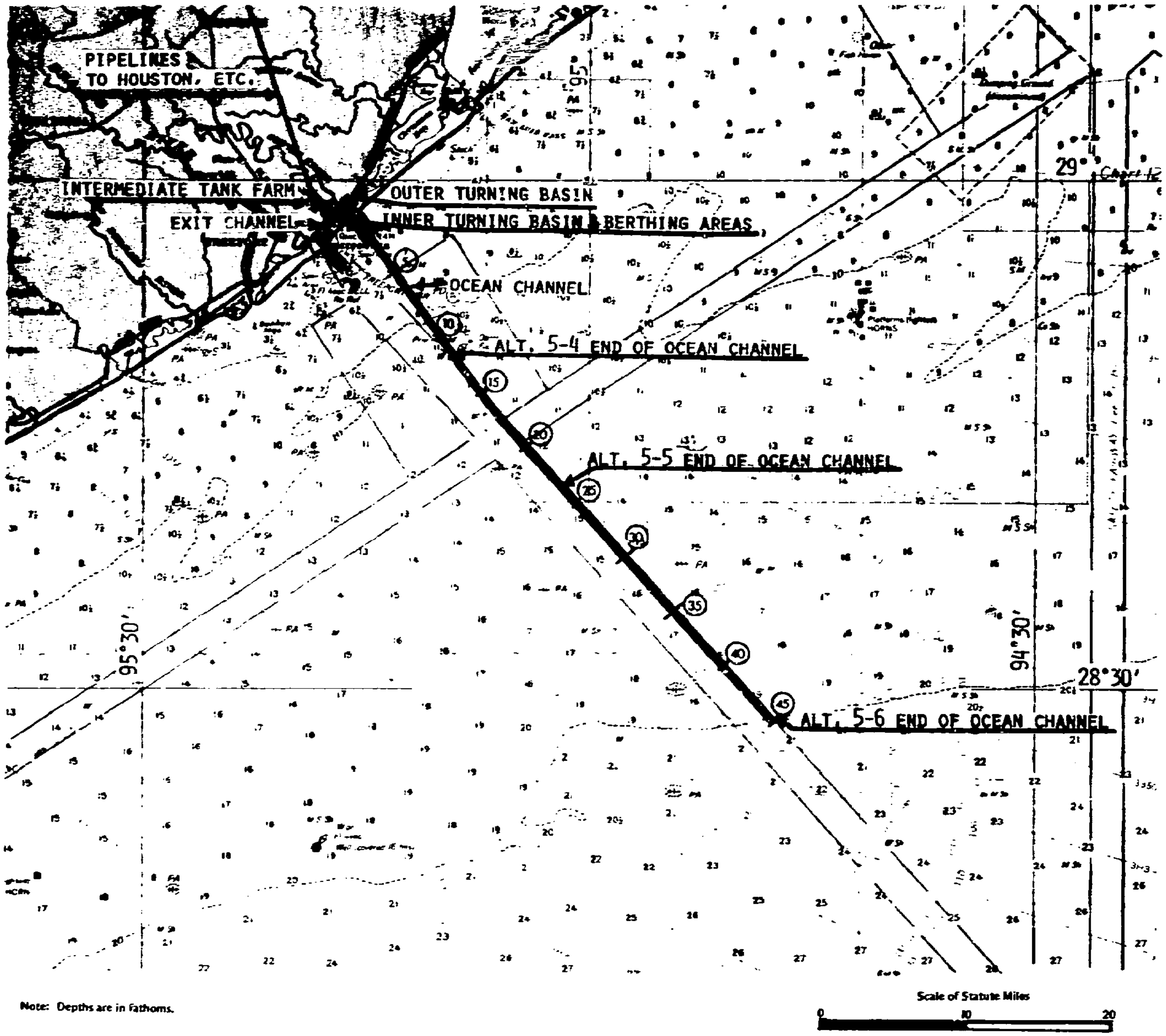

FIGURE 27. LOCATION AND LAYOUT OF CHANNELS, BASINS, TANK FARM AND PIPELINES OF ALTERNATIVES 5-4, 5-5, AND 5-6

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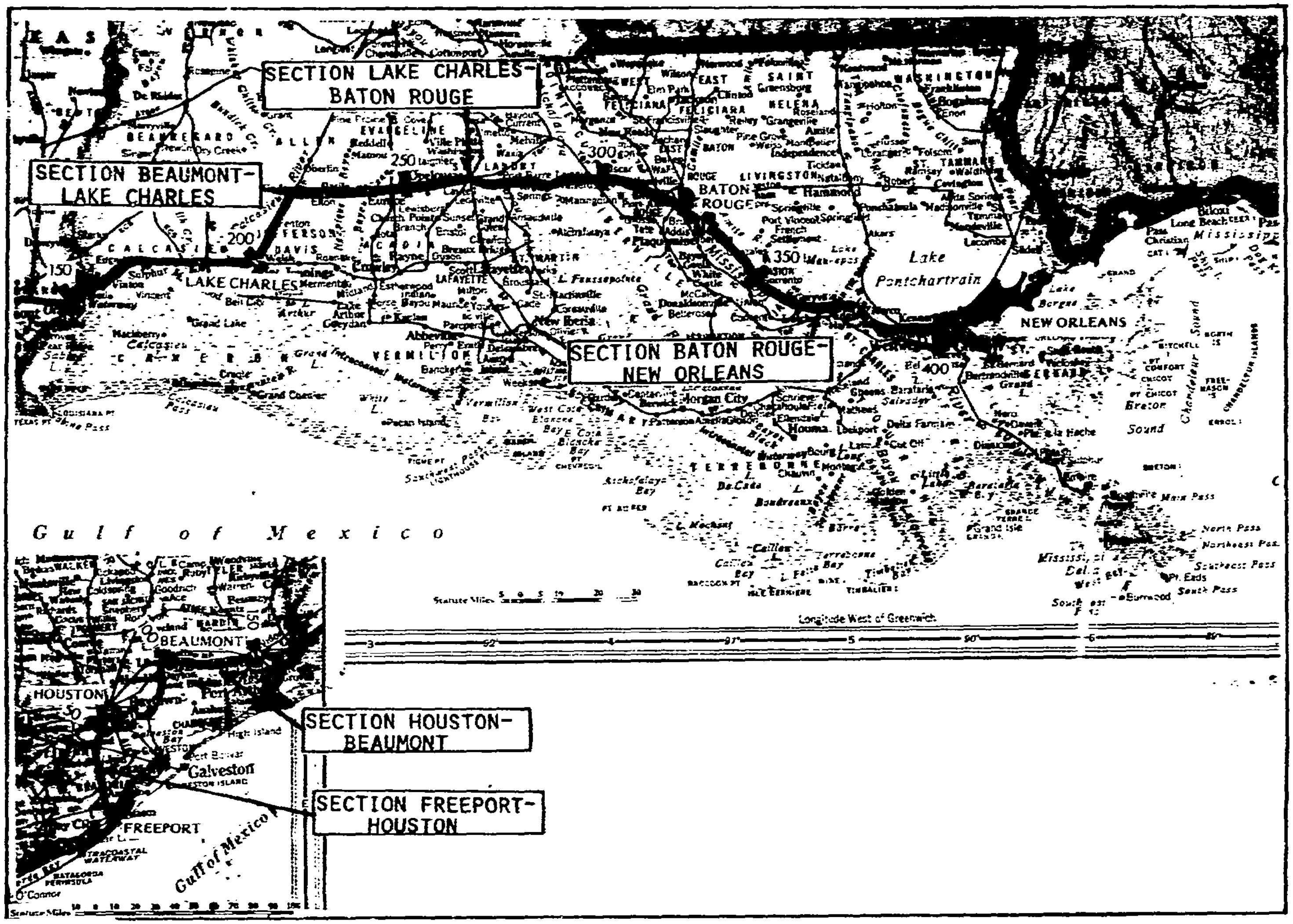
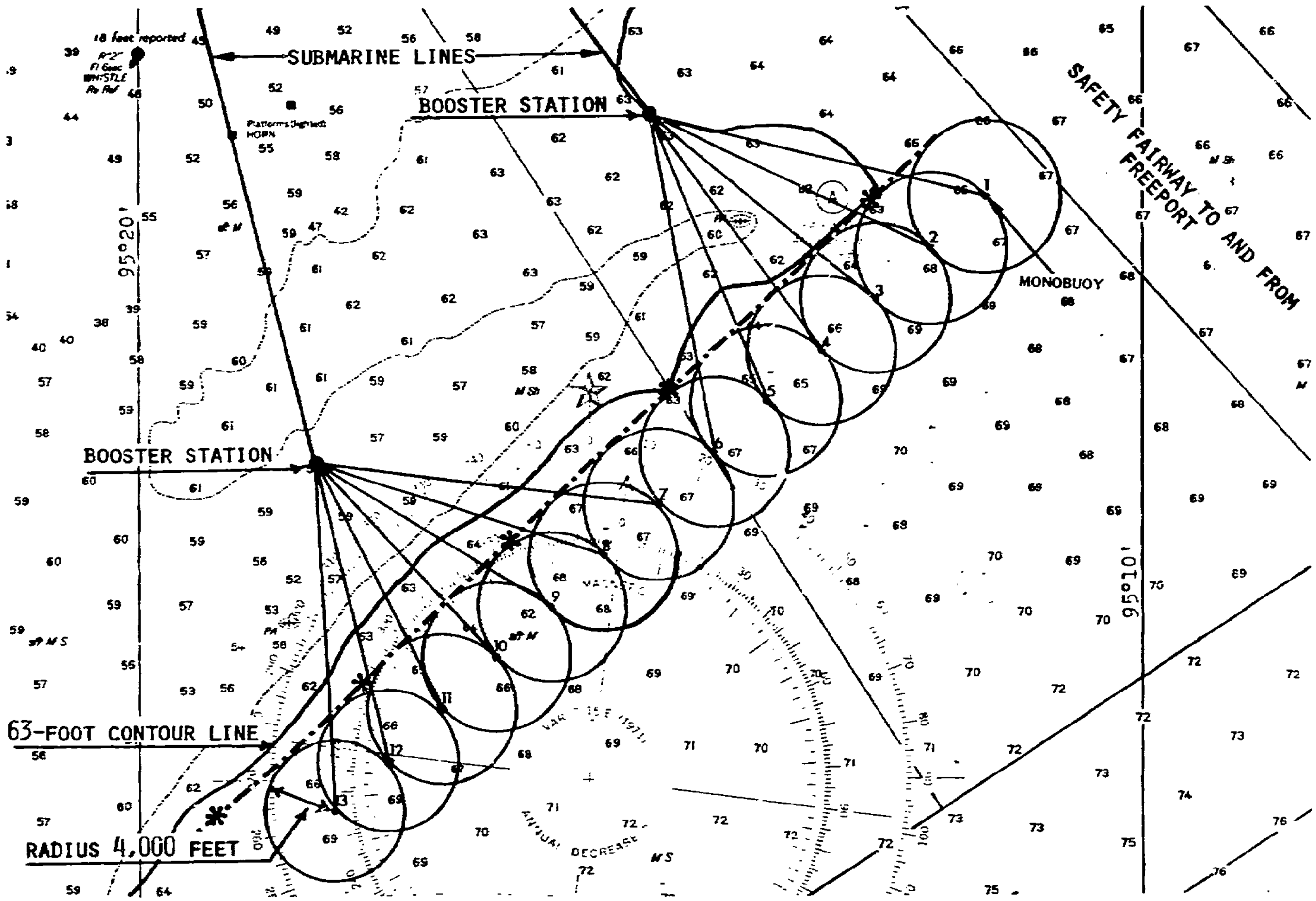


FIGURE 28. ASSUMED PIPELINE ROUTE FROM FREEPORT TO NEW ORLEANS OF ALTERNATIVES 5-1 THROUGH 5-6



Note: Ultimate layout of subalternative B.
Depths are in feet.
* Beacon

FIGURE 29. DETAILED LAYOUT OF MONOBUOYS AND SUBMARINE PIPELINES OF ALTERNATIVE 5-I

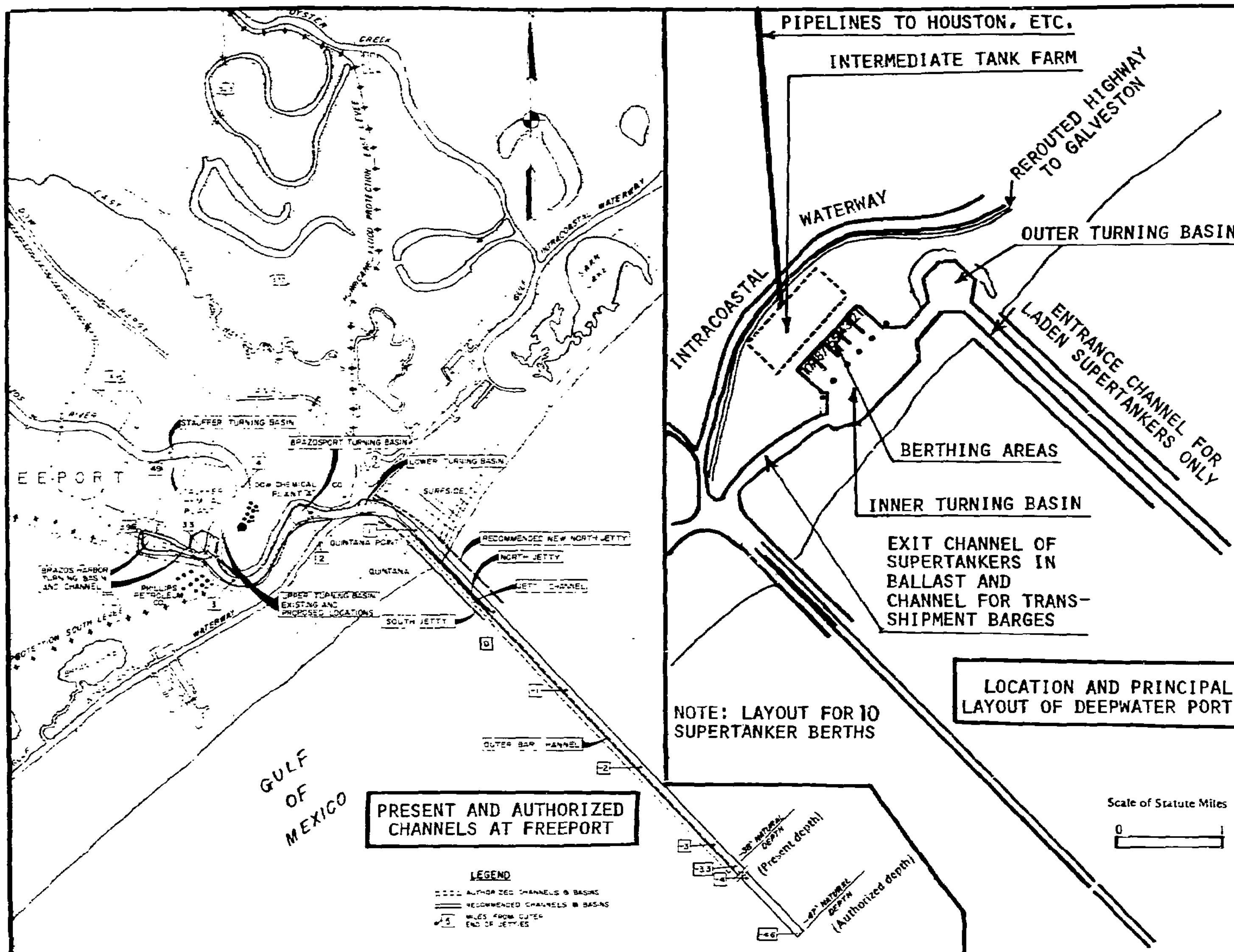


FIGURE 30. PRESENT AND AUTHORIZED CHANNELS AT FREEPORT, AND LOCATION AND PRINCIPAL LAYOUT OF DEEPWATER PORT FOR ALTERNATIVES 5-4, 5-5, AND 5-6

Subalternative B would require 2.69 x 10^6 long tons by 1980, 3.04 x 10^6 long tons by 1985, 3.47 x 10^6 long tons by 1989, 4.07 x 10^6 long tons by 1993, 4.62 x 10^6 long tons by 1996, and 5.20 x 10^6 long tons by 1999. Before 1980 2.69 million long tons of storage capacity would be constructed; additional storage capacities of 0.35, 0.43, 0.60, 0.55, and 0.58 million long tons would be constructed in 1984, 1988, 1992, 1995, and 1998, respectively.

For general services an area of 30 acres was estimated. The total acreage requirement would be, for subalternative A, 4.07 x 50 + 30 = about 235 acres; and for subalternative B, 5.20 x 50 + 30 = about 290 acres.

The assumed average water depth at the island is 35 feet, and the assumed required terrain elevation is +20 feet. The land fill requirements are as follows:

$$\text{Subalternative A} = \frac{43{,}560}{27} \times 235 \times 55 = 20.8 \times 10^6 \text{ cubic yards}$$

$$\text{Subalternative B} = \frac{43{,}560}{27} \times 290 \times 55 = 25.7 \times 10^6 \text{ cubic yards}$$

The main breakwater is about 2.0 miles long; the secondary breakwater, 1 mile long.

Transshipment berths. Subalternative A would require the same number of transshipment berths as subalternative A of alternative 4-1; subalternative B, would require the same number of transshipment berths as subalternative B of alternative 4-1.

Pipelines and booster stations from intermediate tank farm to transshipment berths. The requirements would be the same as those for alternative 4-1.

The location, orientation, and layouts of berths and artificial island are shown in figure 25. The presentation of berths and island is schematic.

Table 48. Projected Flow
(In millions of long tons)

Refinery area	Percentage of total throughput	Throughput Lower 1980	Throughput Lower 2000	Throughput Higher 1980	Throughput Higher 2000
Houston and vicinity......	30	30	135	45	180
Beaumont and vicinity......	30	30	135	45	180
Lake Charles...	10	10	45	15	60
Baton Rouge....	10	10	45	15	60
New Orleans....	10	10	45	15	60
Subtotal...	90	90	405	135	540
Corpus Christi.	5	5	22.5	7.5	30
Pascagoula.....	5	5	22.5	7.5	30
Subtotal...	10	10	45	15	60
Total.........	100	100	450	150	600

Type of Berths

Alternatives 5-1, 5-2, and 5-3 consider monobuoys, whereas alternatives 5-4, 5-5, and 5-6 consider fixed berths.

Site of Tanks

All six alternatives consider an onshore tank farm near Freeport.

Vessel size

Two alternatives (5-1 and 5-4) will consider 200,000-d.w.t. tankers, two alternatives (5-2 and 5-5) will consider 300,000- and 400,000-d.w.t. tankers, and two alternatives (5-3 and 5-6) will consider 500,000-d.w.t. tankers. It is assumed that all tankers using the deepwater port will be of these maximum sizes for each alternative or subalternative. The assumed supertanker dimensions are given in table 49.

Table 49. Vessel Dimensions
(In feet)

Dimension	Vessel Size (1,000 d.w.t.)			
	200	300	400	500
Length.......	1,050	1,100	1,262	1,195
Beam.........	173	192	220	208
Draft........	55	70	70	95

Dredging

Alternatives 5-1, 5-2, and 5-3 do not require dredging. Alternatives 5-4, 5-5, and 5-6 require dredged channels, turning basins, and berthing areas. All submarine and onshore pipelines are expected to be buried.

Water depths

In all alternatives the depth of channels, maneuvering areas, etc., is such that all maximum-size tankers would be able to navigate during all stages of the tide.

Construction Program

The time phasing of the various construction items for the period prior to 1980, is given in table 50 for alternatives 5-1, 5-2, and 5-3, and in table 51 for alternatives 5-4, 5-5, and 5-6. The entire phasing was simplified to facilitate calculations. The total cost of each item will be equally distributed over the pertinent years.

Table 50. Construction Program of Alternatives 5-1, 5-2, and 5-3

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Tank farm..................				X	X
Supertanker berths.........				X	X
Pipelines to tank farm.....					X
Transshipment berths.......					X
Pipelines to refineries....			X	X	X

Table 51. Construction Program of Alternatives 5-4, 5-5, and 5-6

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Dredging...................	X	X	X	X	X
Jetties....................				X	X
Tank farm..................				X	X
Supertanker berths.........				X	X
Pipelines to refineries....			X	X	X
Transshipment berths.......					X

<u>Alternative 5-1</u>

<u>Criteria</u>

1. Site of deepwater port: In the Gulf of Mexico, 13 miles off Freeport.

2. Service area: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge, and New Orleans by pipeline, and refineries at Corpus Christi and Pascagoula by transshipment barge.

3. Type of berths: Monobuoys.

4. Site of tanks: Near Freeport.
5. Draft of tankers: 55 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 52.

Table 52. Throughputs and Size of Vessel Served by Subalternatives

Subalternative	Vessel size	Throughput (million tons/year)	
	(d.w.t.)	1980	2000
A..............	200,000	100	450
B..............	200,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge, and New Orleans, 10 percent each; and Corpus Christi and Pascogoula, 5 percent each.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternative 4-1. Subalternative A would require four buoys by 1980, five buoys by 1984, six buoys by 1987, seven buoys by 1990, eight buoys by 1993, nine buoys by 1996, and 10 buoys by 1999. Four buoys would be installed before 1980; one buoy would be installed in each of the years 1983, 1986, 1989, 1992, 1995, and 1998.

Subalternative B would require five buoys by 1980, six buoys by 1984, seven buoys by 1986, eight buoys by 1988, nine buoys by 1990, 10 buoys by 1992, 11 buoys by 1994, 12 buoys by 1996, and 13 buoys by

1999. Five buoys would be installed before 1980; two buoys would be installed in each of the years 1983, 1987, 1991, and 1995.

Dredging quanties. No dredging would be required.

Water depth of maneuvering area. The water depth of the maneuvering area would be 63 feet (see table 5).

Pipelines from berths to intermediate tank farm. One 48-inch line per monobuoy would be required. Each line would be about 16 miles long, of which 13 miles would be off shore and 3 miles would be on land.

Each offshore line would run from a buoy to a booster station located at a maximum distance of 3.5 miles from the easternmost and westernmost buoys. The ship has a pressure of 150 p.s.i. at the manifold, 70 p.s.i. of which are lost in the hoses. The available pressure remaining at the booster station is thus 150 -70 -(3.5 x 14.1) = 30.6 p.s.i., which is still greater than the required minimum of 25 p.s.i. In both subalternatives, one booster platform would be sufficient for the initial period. Second platforms would be required in 1987 and 1988 for subalternatives A and B, respectively, and would be constructed in 1986 and 1987.

From the booster station(s) to the tank farm the pipeline must run a distance of about 13 miles, of which 10 miles will be off shore and 3 miles on shore. The power requirement per line in both subalternatives would be 13 x 42 x 14.1 = 7,000 b.hp.

Intermediate tank farm. The crude oil storage capacities would be as follows: Subalternative A would require 1.88 x 10^6 long tons by 1980, 2.14 x 10^6 long tons by 1984, 2.48 x 10^6 long tons by 1987, 2.82 x 10^6 long tons by 1990, 3.25 x 10^6 long tons by 1993,

3.66×10^6 long tons by 1996, and 4.04×10^6 long tons by 1999. Before 1980, 1.88 million long tons of storage capacity would be constructed; additional storage capacities of 0.26, 0.34, 0.34, 0.43, 0.41, and 0.38 million long tons would be constructed in 1983, 1986, 1989, 1992, 1995 and 1998, respectively.

Subalternative B would require 2.14×10^6 long tons by 1980, 2.82×10^6 long tons by 1984, 3.66×10^6 long tons by 1988, 4.45×10^6 long tons by 1992, and 5.29×10^6 long tons by 1996. Before 1980, 2.14 million long tons of storage capacity would be constructed; additional storage capacities of 0.68, 0.84, 0.79, and 0.84 million long tons would be constructed in 1983, 1987, 1991, and 1995, respectively.

For general services an area of 30 acres was estimated. The total acreage requirement would be, for subalternative A, $4.04 \times 50 + 30$ = about 230 acres; and for subalternative B, $5.29 \times 50 + 30$ = about 295 acres.

Pipelines from tank farm to refineries. The throughput volumes of the various sections of the pipeline system are given in table 53. The size of all branch lines was set at 42 inches. The pipe sizes and horsepowers that follow were selected in relation to the anticipated throughputs.

Table 53. Throughputs per Section

Section	Portion of total through-put	Subalternative			
		A		B	
		1980	2000	1980	2000
Freeport-Houston.........	0.90	90	405	135	540
Houston-Beaumont.........	0.60	60	270	90	360
Beaumont-Lake Charles....	0.30	30	135	45	180
Lake Charles-Baton Rouge.	0.20	20	90	30	120
Baton Rouge-New Orleans..	0.10	10	45	15	60

1. Freeport-Houston Section. The length of the trunk line was estimated at 65 miles, and that of all branch lines (delivery lines) at 40 miles. The number of refineries served in the Houston-Baytown-Texas City area was set at nine. One river crossing 0.3 mile long has been assumed for the trunk line.

Subalternative A. The throughput for the year 2000, 405 m.t.a. could be carried by four 56-inch lines. Each line would then operate at a maximum capacity of 101.25 m.t.a., which is close to its assumed optimum of 90 m.t.a. Therefore, the following installation program has been selected: before 1980, two 56-inch lines; in 1986, a third 56-inch line; and in 1993, a fourth 56-inch line.

The maximum horsepower requirement would be 65 x 540 = 35,100 b.hp. per line (101.25 m.t.a.). The initial horsepower requirement for the first two lines would be 65 x 54.62 = 3,550 b.hp. per line (45 m.t.a.).

The following horsepower installation program has been selected: before 1980, 17,550 b.hp. per line (80 m.t.a./line), and in 1983, 17,550 b.hp. per line (101.25 m.t.a./line); for the third line, 8,775 b.hp. (62 m.t.a.) in 1986, 8,775 b.hp. (80 m.t.a.) in 1990, and 17,550 b.hp (101.25 m.t.a.) in 1991; and for the fourth line, 8,775 b.hp. (62 m.t.a.) in 1993, 8,775 b.hp. (80 m.t.a.) in 1997, and 17,550 b.hp. (101.25 m.t.a.) in 1998.

Subalternative B. The throughput for the year 2000, 540 m.t.a., could be carried by five 56-inch lines. Each line would then operate at a maximum capacity of 108 m.t.a., which is close to its assumed optimum of 90 m.t.a. Therefore, the following installation program has been selected: before 1980, two 56-inch lines; in 1983, a third 56-inch line; in 1988, a fourth 56-inch line; and in 1994 a fifth 56-inch line.

The maximum horsepower requirement would be 65 x 644 = 42,000 b.hp. per line (108 m.t.a.). The initial horsepower requirement for the first two lines would be 65 x 171 = 11,100 b.hp. per line (67.5 m.t.a.).

The following horsepower installation program has been selected: before 1980, 42,000 b.hp. per line (108 m.t.a./line); for the third line, 10,500 b.hp. (66 m.t.a.) in 1983, 10,500 b.hp. (84.5 m.t.a.) in 1986, and 21,000 b.hp. (108 m.t.a.) in 1987; for the fourth line, 10,500 b.hp. (66 m.t.a.) in 1988, 10,500 b.hp. (84.5 m.t.a.) in 1992, and 21,000 b.hp. (108 m.t.a.) in 1993; and for the fifth line, 10,500 b.hp. (66 m.t.a.) in 1994, 10,500 b.hp. (84.5 m.t.a.) in 1997, and 21,000 b.hp. (108 m.t.a.) in 1998.

2. Houston-Beaumont Section. The length of the trunk line was estimated at 85 miles, and that of the branch lines at 30 miles. The number of refineries served in the Beaumont-Port Arthur area was set at seven. One 0.5-mile-long and one 0.3-mile-long river crossing have been assumed for the trunk line.

Subalternative A. The throughput for the year 2000, 270 m.t.a., could be carried by three 56-inch lines. Each line would then operate at a maximum capacity of 90 m.t.a., which is its assumed optimum. Therefore, the following installation program has been selected: before 1980, one 56-inch line; in 1982 a second 56-inch line; and in 1990, a third 56-inch line.

The maximum horsepower requirement would be 85 x 386.14 = 33,000 b.hp. per line (90 m.t.a.). The initial horsepower requirement for the first line would be 85 x 121.10 = 10,300 b.hp. per line (60 m.t.a.).

The following horsepower installation program has been selected: before 1980, 33,000 b.hp. for the first line (90 m.t.a.); for the second line, 8,250 b.hp. (55 m.t.a.) in 1982, 8,250 b.hp. (70.5 m.t.a.) in 1987, and 16,500 b.hp. (90 m.t.a.) in 1989; and for the third line, 8,250 b.hp. (55 m.t.a.) in 1990, 8,250 b.hp. (70.5 m.t.a.) in 1996, and 16,500 b.hp. (90 m.t.a.) in 1997.

Subalternative B. The throughput for the year 2000, 360 m.t.a., would be carried by four 56-inch lines. Each line would then operate at a maximum capacity of 90 m.t.a., which is its assumed optimum. Therefore, the following installation program has been selected: before 1980, two 56-inch lines; in 1986, a third 56-inch line; and in 1992, a fourth 56-inch line.

The maximum horsepower requirement would be 85 x 386.14 = 33,000 b.hp. per line (90 m.t.a.). The initial horsepower requirement for the first two lines would be 85 x 54.62 = 4,600 b.hp. per line (45 m.t.a.).

The following horsepower installation program has been selected: before 1980, 16,500 b.hp. per line (70.5 m.t.a./line), and in 1983, 16,500 b.hp. per line (90 m.t.a./line); for the third line, 8,250 b.hp. (55 m.t.a.) in 1986, 8,250 b.hp. (70.5 m.t.a.) in 1990, and 16,500 b.hp. (90 m.t.a.) in 1991; and for the fourth line, 8,250 b.hp. (55 m.t.a.) in 1992, 8,250 b.hp. (70.5 m.t.a.) in 1996, and 16,500 b.hp. (90 m.t.a.) in 1998.

3. Beaumont-Lake Charles Section. The length of the trunk line was estimated at 50 miles, and that of all branch lines at 5 miles. The number of refineries served in the vicinity of Lake Charles was set at two. One 0.3-mile-long and three 0.2-mile-long river crossings have been assumed for the trunk line.

Subalternative A. The throughput for the year 2000, 135 m.t.a., could be carried by two 48-inch lines. Each line would then operate at a maximum capacity of 67.5 m.t.a., which is close to its assumed optimum of 65 m.t.a. Therefore, the following installation program has been selected: before 1980, one 48-inch line; and in 1986, a second 48-inch line.

The maximum horsepower requirement would be 50 x 370 = 18,500 b.hp. per line (67.5 m.t.a.). The initial horsepower requirement for the first line would be 50 x 37.84 = 1,900 b.hp. (30 m.t.a.).

The following horsepower installation program has been selected: for the first line, 9,250 b.hp. (52.5 m.t.a.) before 1980 and 9,250 b.hp. (67.5 m.t.a.) in 1983; and for the second line, 2,312 b.hp. (32 m.t.a.) in 1986, 2,313 b.hp. (41 m.t.a.) in 1992, 4,625 b.hp. (52.5 m.t.a.) in 1994, and 9,250 b.hp. (67.5 m.t.a.) in 1996.

Subalternative B. The throughput for the year 2000, 180 m.t.a., could be carried by three 48-inch lines or two 56-inch lines. Each line would then operate at a maximum capacity of 60 or 90 m.t.a. respectively, which is close to or equal to its assumed optimum of 65 or 90 m.t.a. Because bigger pipelines result in lower transportation costs, the two 56-inch lines are preferred over the three 48-inch lines. Therefore, the following installation program has been selected: before 1980, one 56-inch line; and in 1986, a second 56-inch line.

The maximum horsepower requirement would be 50 x 386.14 = 19,400 b.hp. per line (90 m.t.a.). The initial horsepower requirement for the first line would be 50 x 54.62 = 2,730 b.hp. (45 m.t.a.).

The following horsepower installation program has been selected: for the first line, 9,700 b.hp. (70.5 m.t.a.) before 1980, and 9,700 b.hp. (90 m.t.a.) in 1983; and for the second line, 2,425 b.hp (44 m.t.a.) in 1986, 2,425 b.hp. (55 m.t.a.) in 1992, 4,850 b.hp (70.5 m.t.a.) in 1994, and 9,700 b.hp. (90 m.t.a.) in 1996.

4. Lake Charles-Baton Rouge Section. The length of the trunk line was estimated at 130 miles, and that of all branch lines at 5 miles. The number of refineries served in the Baton Rouge region was set

at three. One 0.9-mile-long, one 3-mile-long, and eight 0.2-mile-long river crossings have been assumed for the trunk line.

Subalternative A. The throughput for the year 2000, 90 m.t.a., could be carried by one 48-inch pipeline as well as by one 56-inch pipeline. The initial throughput would be 20 m.t.a.; the 1990 throughput, 55 m.t.a. Although at the latter throughput both lines would have approximately the same transportation cost, the smaller line is more economical for lower throughputs, and therefore the 48-inch line is a more attractive solution and has thus been selected.

The maximum horsepower requirement would be 130 x 833.26 = 108,000 b.hp. (90 m.t.a.). The initial horsepower requirement would be 130 x 12.31 = 1,600 b.hp. (20 m.t.a.).

The following horsepower installation program has been selected: before 1980, 6,750 b.hp. (33.5 m.t.a.); 6,750 b.hp. (43 m.t.a.) in 1983; 13,500 b.hp. (54.5 m.t.a.) in 1986; 27,000 b.hp. (70.5 m.t.a.) in 1989; and 54,000 b.hp. (90 m.t.a.) in 1993.

Subalternative B. The throughput for the year 2000, 120 m.t.a., could be carried by two 48-inch lines. Each line would then operate at a maximum capacity of 60 m.t.a., which is close to its assumed optimum of 65 m.t.a. Therefore, the following installation program has been selected: before 1980, one 48-inch line; and in 1986, a second 48-inch line.

The maximum horsepower requirement would be 130 x 265.02 = 34,500 b.hp. (60 m.t.a.). The initial horsepower requirement would be 130 x 37.84 = 4,900 b.hp. (30 m.t.a.).

The following horsepower installation program has been selected: for the first line, 17,250 b.hp (46.5 m.t.a.) before 1980, and 17,250 b.hp (60 m.t.a.) in 1983; and for the second line, 4,312 b.hp. (28 m.t.a.) in 1986, 4,313 b.hp. (36.5 m.t.a.) in 1992, 8,625 b.hp. (46.5 m.t.a.) in 1994, and 17,250 b.hp. (60 m.t.a.) in 1996.

5. Baton Rouge-New Orleans Section. The length of the trunkline was estimated at 80 miles, and that of all branch lines at 10 miles. The number of refineries served in the New Orleans region was set at six. Two 0.2-mile-long river crossings have been assumed for the trunk line.

Subalternative A. The throughput for the year 2000, 45 m.t.a., could be carried by one 32-inch line as well as by one 36- or 42-inch line. Because the 32-inch line is more economical for the first 10 years than are the bigger lines, it is a more attractive solution and has therefore been selected.

The maximum horsepower requirement would be 80 x 923.87 = 74,000 b.hp. (45 m.t.a.). The initial horsepower requirement would be 80 x 13.70 = 1,100 b.hp. (10 m.t.a.).

The following horsepower installation program has been selected: before 1980, 4,625 b.hp. (15.5 m.t.a.); in 1982, 4,625 b.hp. (21 m.t.a.); in 1985, 9,250 b.hp. (27 m.t.a.); in 1989, 18,500 b.hp. (34.5 m.t.a.); and in 1993, 37,000 b.hp. (45 m.t.a.).

Subalternative B. The throughput for the year 2000, 60 m.t.a., could be carried by one 36-inch pipeline as well as by one 42-inch pipeline. The initial throughput would be 15 m.t.a.; the 1990 throughput, 37.5 m.t.a. Since both the 36-inch and the 42-inch lines would have approximately the same transportation cost at a throughput of 29 m.t.a., which would be reached in 1986, the 42-inch line seems to be a more attractive solution for the entire 20-year period. Therefore, one 42-inch line has been selected.

The maximum horsepower requirement would be 80 x 519.36 = 42,000 b.hp. (60 m.t.a.). The initial horsepower requirement would be 80 x 10.68 = 850 b.hp. (15 m.t.a.).

The following horsepower installation program has been selected: before 1980, 2,625 b.hp. (22 m.t.a.); in 1982, 2.625 b.hp (28.5 m.t.a.); in 1985, 5,250 b.hp. (36.5 m.t.a.); in 1989, 10,500 b.hp (47 m.t.a.); and in 1993, 21,000 b.hp. (60 m.t.a.).

Transshipment berths. The annual throughput of transshipment berths is given in table 54.

Table 54. Annual Throughputs by Transshipment Barge
(In millions of tons)

Service area	Portion of total throughput	Subalternative			
		A		B	
		1980	2000	1980	2000
Corpus Christi and Pascagoula	0.10	10	45	15	60

According to table 20, the number of berths required would be, for subalternatives A and B, two berths by 1980, and none additional from 1980 to 2000.

Pipelines from tank farm to transshipment berths. One 48-inch line would be required. Each line would be 3 miles long and would run on land. Each line would require 1,600 b.hp.

Figures 26 and 29 show the location and layout of the deepwater port. Figure 28 depicts the assumed pipeline route to the various refinery areas.

Alternative 5-2

Criteria

1. Site of deepwater port: In the Gulf of Mexico, 22 miles off Freeport.
2. Service area and type of transshipment: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge and New Orleans, by pipeline; and refineries at Corpus Christi and Pascagoula, by transshipment vessels.
3. Type of berths: Monobuoys.
4. Site of tanks: Near Freeport.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 55.

Table 55. Throughputs and Size of Vessels Served by Subalternatives

Subalternatives	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A..............	300,000	100	450
B..............	300,000	150	600
C..............	400,000	100	450
D..............	400,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge, and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternative 4-2. Subalternative A would require three buoys by 1980, four buoys by 1983, five buoys by 1987, six buoys by

1991, seven buoys by 1995, and eight buoys by 1998. Three buoys would be installed before 1980; one buoy would be installed in each of the years 1982, 1986, 1990, 1994, and 1997.

Subalternative B would require four buoys by 1980, five buoys by 1983, six buoys by 1986, seven buoys by 1989, eight buoys by 1992, nine buoys by 1995, and 10 buoys by 1997. Four buoys would be installed before 1980; one buoy would be installed in each of the years 1982, 1985, 1988, 1991, 1994, and 1996.

Subalternative C would require three buoys by 1980, four buoys by 1984, five buoys by 1989, six buoys by 1994, and seven buoys by 1998. Three buoys would be installed before 1980; one buoy would be installed in each of the years 1983, 1988, 1993, and 1997.

Subalternative D would require four buoys by 1980, five buoys by 1985, six buoys by 1988, seven buoys by 1991, eight buoys by 1995, and nine buoys by 1998. Four buoys would be installed before 1980; one buoy would be installed in each of the years 1984, 1987, 1990, 1994, and 1997.

Dredging Quantities. No dredging would be required.

Water depth of maneuvering area. The required water depth of the maneuvering area would be [illegible]1 feet (see table 5).

Pipelines from berths to intermediate tank farm. One 48-inch line per monobuoy would be required. Each line would be about 25 miles long, of which 22 miles would be off shore and 3 miles on land.

Each offshore line would run from a buoy to a booster station located at a maximum distance of 2.5 miles from the easternmost and westernmost buoys. The ship has a pressure of 150 p.s.i. at the manifold, 70 p.s.i. of which are lost in the hoses. The available pressure remaining at the booster station is thus, in subalternatives A and B, 150 -70 -(2.5 x 17.4) = 36 p.s.i., and in subalternatives C and D, 150 -70 -(2.5 x 21.2) = 27 p.s.i., both of which are greater than the required minimum 25 p.s.i. In all subalternatives one booster platform would be sufficient for the initial period. Second platforms would be required in 1987, 1986, 1989 and 1988 for subalternatives A, B, C, and D, respectively, and would be installed 1 year prior to their requirement. The required horsepower per line is 22.5 x 42 x 14.1 = 13,300 b.hp.

Intermediate tank farm. The crude oil storage capacities required would be as follows: Subalternative A would require 1.81 x 10^6 long tons by 1980, 2.24 x 10^6 long tons by 1983, 2.51 x 10^6 long tons by 1987, 2.87 x 10^6 long tons by 1991, 3.34 x 10^6 long tons by 1995, and 3.83 x 10^6 long tons by 1998. Before 1980, 1.81 million long tons of storage capacity would be constructed; additional storage capacities of 0.43, 0.27, 0.36, 0.47, and 0.49 million long tons would be constructed in 1982, 1986, 1990, 1994, and 1997, respectively.

Subalternative B would require 2.24 x 10^6 long tons by 1980, 2.51 x 10^6 long tons by 1983, 2.87 x 10^6 long tons by 1986, 3.34 x 10^6 long tons by 1989, 3.83 x 10^6 long tons by 1992, 4.30 x 10^6 long tons by 1995, and 4.75 x 10^6 long tons by 1997. Before 1980, 2.24 million long tons of storage capacity would be constructed; additional storage capacities of 0.27, 0.36, 0.47, 0.49, 0.47, and 0.45 million long tons would be constructed in 1982, 1985, 1988, 1991, 1994, and 1996, respectively.

Subalternative C would require 2.15 x 10^6 long tons by 1980, 2.67 x 10^6 long tons by 1984, 3.04 x 10^6 long tons by 1989, 3.55 x 10^6 long tons by 1994, and 4.09 x 10^6 long tons by 1998. Before 1980, 2.15 million long tons of storage capacity would be constructed; additional storage capacities of 0.52, 0.37, 0.51, and 0.54 million long tons would be constructed in 1983, 1988, 1993, and 1997, respectively.

Subalternative D would require 2.67 x 10^6 long tons by 1980, 3.04 x 10^6 long tons by 1985, 3.55 x 10^6 long tons by 1988, 4.09 x 10^6 long tons by 1991, 4.69 x 10^6 long tons by 1995, and 5.29 x 10^6 long tons by 1998. Before 1980, 2.67 million long tons of storage capacity would be constructed; additional storage capacities of 0.37, 0.51, 0.54, 0.60, and 0.60 million long tons would be constructed in 1984, 1987, 1990, 1994, and 1997, respectively.

For general services an area of 30 acres was estimated. The total acreage requirement would be, for subalternative A, 3.83 x 50 + 30 = about 220 acres; for subalternative B, 4.75 x 50 + 30 = about 270 acres; for subalternative C, 4.09 x 50 + 30 = about 235 acres; and for subalternative D, 5.29 x 50 + 30 = about 295 acres.

Pipelines and booster stations from tank farm to refineries. Subalternatives A and C have the same requirements as subalternative A of alternative 5-1. Subalternatives B and D have the same requirements as subalternative B of alternative 5-1.

Transshipment berths. The requirements are the same as those for alternative 5-1.

Pipelines from tank farm to transshipment berths. One 48-inch line would be required. Each line would be 3 miles long, would run on land, and would require 1,600 b.hp.

Figure 26 presents the location and layout of the deepwater port. Figure 25 shows the assumed pipeline route to the various refinery areas.

Alternative 5-3

Criteria

1. Site of deepwater port: In Gulf of Mexico, 34 miles off Freeport.

2. Service area and type of transshipment: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge, and New Orleans, by pipeline; and refineries at Corpus Christi and Pascagoula, by transshipment vessels.

3. Type of berths: Monobuoys.

4. Site of tanks: Near Freeport.

5. Draft of tankers: 95 feet fully loaded.

6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 56.

Table 56. Throughputs and Size of Vessels Served by Subalternatives

Subalternatives	Vessel size (d.w.t.)	Throughput (Million tons/year)	
		1980	2000
A...............	500,000	100	450
B...............	500,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternative 4-3. Subalternative A would require three buoys by 1980, four buoys by 1985, five buoys by 1990, six buoys by 1994, and seven buoys by 1999. Three buoys would be installed before 1980; one buoy would be installed in each of the years 1984, 1989, 1993, and 1998.

Subalternative B would require four buoys by 1980, five buoys by 1985, six buoys by 1989, seven buoys by 1993, eight buoys by 1996, and nine buoys by 1999. Four buoys would be installed before 1980; one buoy would be installed in each of the years 1984, 1988, 1992, 1995, and 1998.

Dredging quantities. No dredging would be required.

Water depth of maneuvering area. The required water depth of the maneuvering area would be 109 feet (see table 5).

Pipelines from berths to intermediate tank farm. One 48-inch line per monobuoy would be required. Each line would be about 37 miles long, of which 34 miles would be off shore and 3 miles on land.

Each offshore line would run from a buoy to a booster station located at a maximum distance of 2.5 miles from the easternmost and westernmost buoys. The ship has a pressure of 150 p.s.i. at the manifold, 70 p.s.i. of which are lost in the hoses. The available pressure remaining at the booster station would thus be 150 -70 -(2.5 x 21.2) = 27 p.s.i., which is greater than the required minimum of 25 p.s.i. In both subalternatives, one booster platform would be sufficient for the initial period. Second platforms would be required in 1990 and 1989 for subalternatives A and B, respectively. It is assumed that the contruction of the second platform would take place during the year prior to its requirement. The required horsepower per line would be 34.5 x 42 x 14.1 = 20,500 b.hp.

Intermediate tank farm. The crude oil storage capacities required would be as follows: Subalternative A would require 2.17 x 10^6 long tons by 1980, 2.69 x 10^6 long tons by 1985, 3.04 x 10^6 long tons by 1990, 3.47 x 10^6 long tons by 1994, and 4.07 x 10^6 long tons by 1999. Before 1980, 2.17 million long tons of storage capacity would be constructed; additional storage capacities of 0.52, 0.35, 0.43, and 0.60 million long tons would be constructed in 1984, 1989, 1993, and 1998, respectively.

Subalternative B would require 2.69 x 10^6 long tons by 1980, 3.04 x 10^6 long tons by 1985, 3.47 x 10^6 long tons by 1989, 4.07 x 10^6 long tons by 1993, 4.62 x 10^6 long tons by 1996, and 5.20 x 10^6 long tons by 1999. Before 1980, 2.69 million long tons of storage capacity would be constructed; additional storage capacities of 0.35, 0.43, 0.60, 0.55, and 0.58 million long tons would be constructed in 1984, 1988, 1992, 1995, and 1998, respectively.

For general services an area of 30 acres was estimated. The total acreage requirement would be, for subalternative A, 4.07 x 50 + 30 = about 235 acres; and for subalternative B, 5.20 x 50 + 30 = about 290 acres.

Pipelines and booster stations from tank farm to refineries. Subalternative A would have the same requirements as subalternative A of alternative 5-1. Subalternative B would have the same requirements as subalternative B of alternative 5-1.

Transshipment berths. The requirements would be the same as those of alternative 5-1.

Pipelines from tank farm to transshipment berths. One 48-inch line would be required. Each line would be 3 miles long, would run on land, and would require 1,600 b.hp.

Figure 26 presents the location and layout of the deepwater port. Figure 28 depicts the assumed pipeline route to the various refinery areas.

Alternative 5-4

Criteria

1. Site of deepwater port: Inland near Freeport.

2. Service area and type of transshipment: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge, and New Orleans, by pipeline; and refineries at Corpus Christi and Pascagoula, by transshipment vessels.

3. Type of berths: Fixed.
4. Site of tanks: Near Freeport.
5. Draft of tankers: 55 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 57.

Table 57. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A...............	200,000	100	450
B...............	200,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternative 4-1. Subalternative A would require four berths by 1980, five berths by 1984, six berths by 1987, seven berths by 1990, eight berths by 1993, nine berths by 1996, and 10 berths by 1999. Four berths would be constructed before 1980; two berths would be constructed in each of the years 1983, 1989, and 1995.

Subalternative B would require five berths by 1980, six berths by 1984, seven berths by 1986, eight berths by 1988, nine berths by 1990, 10 berths by 1992, 11 berths by 1994, 12 berths by 1996, and 13 berths by 1999. Six berths would be constructed before 1980; two berths would be constructed in each of the years 1985, 1989, and 1993. The last berth would be constructed in 1998.

<u>Dredging quantities</u>. The quantities to be dredged would be as follows:

1. Ocean channel. Less than 10 miles off shore the channel width would be 690 feet, and the channel depth, 63 feet. Over 10 miles off shore the width would be 865 feet and the depth, 66 feet.

The total length of channel would be 12 miles; the average depth per mile would be 12, 24, 30, 36, 44, 50, 55, 57, 59, 62, 64, and 65 feet. The total quantity to be dredged per mile, including 3 feet of overdepth dredging would be 9.0, 6.7, 5.6, 4.6, 3.3, 2.3, 1.6, 1.3, 1.0, 0.6, 0.9, and 0.7 x 10^6 cubic yards, or a total of 37.6 x 10^6 cubic yards.

2. Turning basins and inland channels. The cut through the coastline is the approach channel to the outer turning basin. The dimensions of this canal would be: width, 690 feet; depth, 63 feet; and length, 1,300 feet. Dredging quantity, including 3 feet of overdepth dredging and assuming an average terrain elevation of +4 feet, would equal 3.3 x 10^6 cubic yards.

The dimensions of the outer turning basin would be: radius, 1,575 feet; and water depth, 61 feet. Dredging quantity, including 3 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal 6.8 x 10^6 cubic yards.

The dimensions of the channel between outer and inner turning basin would be: water depth 61 feet; length, about 1,700 feet; and width, 605 feet. Dredging quantity, including 3 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal 3.0 x 10^6 cubic yards.

The dimensions of the inner turning basin would be: water depth, 61 feet; length, 3,135 feet (serving four berths), 4,000 feet (serving six berths), 4,865 feet (serving eight berths), 5,725 feet (serving 10 berths), or

6,760 feet (serving 13 berths); and width, 1,575 feet. Dredging quantities, including 3 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would be as follows:

Subalternative A would require dredging of 11.2 x 10^6 cubic yards before 1980, 3.1 x 10^6 cubic yards by 1982, 3.1 x 10^6 cubic yards by 1988, and 3.1 x 10^6 cubic yards by 1994.

Subalternative B would require dredging of 14.3 x 10^6 cubic yards before 1980, 3.1 x 10^6 cubic yards by 1984, 3.1 x 10^6 cubic yards by 1988, and 3.6 x 10^6 cubic yards by 1992.

The dimensions of the berthing areas would be: water depth, 58 feet; length, 1,575 feet; and width, 2,080 feet (4 berths), 2,940 feet (6 berths), 3,810 feet (8 berths), 4,680 feet (10 berths), or 5,715 feet (13 berths). Dredging quantities, including 3 feet of overdepth dredging and assuming an average terrain elevation of 0 feet, would be as follows:

Subalternative A would require dredging of 7.4 x 10^6 cubic yards before 1980, 3.1 x 10^6 cubic yards by 1982, 3.1 x 10^6 cubic yards by 1988, and 3.1 x 10^6 cubic yards by 1994.

Subalternative B would require dredging of 10.5 x 10^6 cubic yards before 1980, 3.1 x 10^6 cubic yards by 1984, 3.1 x 10^6 cubic yards by 1988, and 3.6 x 10^6 cubic yards by 1992.

The dimensions of the exit channel would be: water depth, 1.1 x 0.5 x 55 = 30 feet; width, 690 feet (coastal wind is beam on); and length, about 8,000 feet. Dredging quantity, including 2 feet of overdepth dredging and assuming an average terrain elevation of -5 feet, would equal 5.6 x 10^6 cubic yards.

Total dredging quantities for the ocean channel would equal 37.6 x 10^6 cubic yards. For all inland basins and channels these quantities would equal the following:

Subalternative A would require dredging of 37.3 x 10^6 cubic yards before 1980, 6.2 x 10^6 cubic yards by 1982, 6.2 x 10^6 cubic yards by 1988, and 6.2 x 10^6 cubic yards by 1994.

Subalternative B would require dredging of 43.5 x 10^6 cubic yards before 1980, 6.2 x 10^6 cubic yards by 1984, 6.2 x 10^6 cubic yards by 1988, and 7.2 x 10^6 cubic yards by 1992.

Pipelines from berths to intermediate tank farm. One 48-inch line per berth would be required. Each line would be supported by a trestle for about 800 feet, and would then continue on land for about 2 miles to the tanks of the tank farm. No booster stations are required.

Intermediate tank farm. The crude oil storage capacities required would be the same as those for alternative 4-1. Subalternative A would require 1.88 x 10^6 long tons by 1980, 2.48 x 10^6 long tons by 1984, 3.25 x 10^6 long tons by 1990, and 4.04 x 10^6 long tons by 1996. Before 1980, 1.88 million long tons of storage capacity would be constructed; additional storage capacities of 0.60, 0.77, and 0.79 million long tons would be constructed in 1983, 1989, and 1995, respectively.

Subalternative B would require 2.48 x 10^6 long tons by 1980, 3.25 x 10^6 long tons by 1986, 4.04 x 10^6 long tons by 1990, 4.87 x 10^6 long tons by 1994, and 5.29 x 10^6 long tons by 1999. Before 1980, 2.48 million long tons of storage capacity would be constructed; 0.77, 0.79, 0.83, and 0.42 million long tons would be constructed in 1985, 1989, 1993, and 1998, respectively.

For general services an area of 30 acres was estimated. The total acreage requirement would be, for subalternative A, 4.04 x 50 + 30 = about 230 acres; and for subalternative B, 5.29 x 50 + 30 = about 295 acres.

Pipelines and booster stations from tank farm to refineries. Subalternative A would have the same requirements as subalternative A of alternative 5-1. Subalternative B would have the same requirements as subalternative B of alternative 5-1.

Transshipment berths. The requirement would be the same as that for alternative 5-1.

Pipelines from tank farm to transshipment berths. One 48-inch line per berth would be required. Each line would be 3 miles long, would run on land, and would require 1,600 b.hp.

Figures 27 and 30 show the location and layout of the deepwater port. Figure 28 shows the assumed pipeline route to the various refinery areas.

Alternative 5-5

Criteria

1. Site of deepwater port: Inland, near Freeport.
2. Service area and type of transshipment: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge and New Orleans, by pipeline; and refineries at Corpus Christi and Pascagoula, by transshipment vessels.
3. Type of berths: Fixed.
4. Site of tanks: Near Freeport.
5. Draft of tankers: 70 feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 58.

Table 58. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.	Throughput (million tons/year)	
		1980	2000
A..............	300,000	100	450
B..............	300,000	150	600
C..............	400,000	100	450
D..............	400,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.

Requirements

Supertanker berths. The number of berths required would be the same as that for alternative 4-2. Subalternative A would require three berths by 1980, four berths by 1983, five berths by 1987, six berths by 1991, seven berths by 1995, and eight berths by 1998. Four berths would be constructed before 1980; one berth would be constructed in each of the years 1986, 1990, 1994, and 1997.

Subalternative B would require four berths by 1980, five berths by 1983, six berths by 1986, seven berths by 1989, eight berths by 1992, nine berths by 1995, and 10 berths by 1997. Four berths would be constructed before 1980; one berth would be constructed in each of the years 1982, 1985, 1988, 1991, 1994, and 1996.

Subalternative C would require three berths by 1980, four berths by 1984, five berths by 1989, six berths by 1994, and seven berths by 1998. Four berths would be constructed before 1980; one berth would be constructed in each of the years 1988, 1993, and 1997.

Subalternative D would require four berths by 1980, five berths by 1985, six berths by 1988, seven berths by 1991, eight berths by 1995, and nine berths by 1998. Four berths would be constructed before 1980; one berth would be constructed in each of the years 1984, 1987, 1990, 1994, and 1997.

Dredging quantities. The quantities to be dredged would be as follows:

1. Ocean channel. Less than 10 miles offshore, the channel width would be 770 feet, and the channel depth, 81 feet, for subalternatives A and B; for subalternatives C and D these dimensions would be 880 feet and 81 feet, respectively. Over 10 miles offshore, the width would be 960 feet and the depth 84 feet for subalternatives A and B, and 1,100 feet and 84 feet for subalternatives C and D.

The total length of channel would be 24 miles; the average depth per mile would be 12, 24, 30, 36, 44, [illegible] 55, 57, 59, 62, 64, 65, 66, 66, 66, 66, 66, 67, 68, 69, 73, 77, 79, and 82 feet. The total quantity to be dredged per mile, including 4 feet of overdepth dredging, would be, for subalternatives A and B, 14.1, 11.4, 10.1, 8.8, 7.2, 6.0, 5.0, 4.7, 4.3, 3.7, 4.8, 4.6, 4.4, 4.4, 4.4, 4.4, 4.4, 4.2, 4.0, 3.8, 3.0, 2.2, 1.7, and 1.[illegible] million cubic yards, or a total of 126.7 x 10^6 cubic yards; and for subalternatives C and D, 15.7, 12.7, 11.2, 9.8, 8.0, 6.7, 5.7, 5.3, 4.9, 4.3, 5.5, 5.0, 5.0, 5.0, 5.0, 5.0, 5.0, 4.8, 4.5, 4.3, 3.4, 2.4, 2.0, and 1.3 million cubic yards, or a total of 142.8 x 10^6 cubic yards.

2. Turning basins and inland channels. The cut through the coastline is the approach channel to the outer turning basin. The dimensions of this canal would be: depth, = 81 feet; width of subalternatives A and B, 770 feet, and of subalternatives C and D,

880 feet; and length, 1,300 feet. Dredging quantities, including 4 feet of overdepth dredging and assuming an average terrain elevation at +4 feet, would equal: for subalternatives A and B, 4.5 x 10^6 cubic yards; and for subalternatives C and D, 4.9 x 10^6 cubic yards.

The dimensions of the outer turning basin would be: water depth, 77 feet; and radius of subalternatives A and B, 1,650 feet, and of subalternatives C and D, 1,900 feet. Dredging quantities, including 4 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal: for subalternatives A and B, 10.1 x 10^6 cubic yards; and for subalternatives C and D, 12.9 x 10^6 cubic yards.

The dimensions of the channel between outer and inner turning basin would be: depth, 77 feet; length, 1,700 feet; and width of subalternatives A and B, 670 feet, and of subalternatives C and D, 770 feet. Dredging quantities, including 4 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal for subalternatives A and B, 4.4 x 10^6 cubic yards, and for subalternatives C and D, 4.8 x 10^6 cubic yards.

The dimensions of the inner turning basin would be: depth, 77 feet; width of subalternatives A and B, 1,650 feet, and of subalternatives C and D, 1,900 feet; and length of subalternatives A and B, 3,380 feet (serving four berths), 4,340 feet (serving six berths), 5,300 feet (serving eight berths), and 6,260 feet (serving 10 berths), and of subalternatives C and D, 3,880 feet (serving four berths), 4,980 feet (serving six berths), 5,200 feet (serving seven berths), and 6,300 feet (serving nine berths). Dredging quantities, including 4 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal the following: for subalternative A, 15.9 x 10^6 cubic yards before 1980, 4.5 x 10^6 cubic yards by 1985, and 4.5 x 10^6 cubic yards by 1993; for subalternative B, 15.9 x 10^6 cubic yards before 1980, 4.5 x 10^6 by 1981, 4.5 x 10^6 cubic yards by 1987, and 4.5 x 10^6 cubic yards by 1993; for subalternative C, 21.0 x 10^6 cubic yards before 1980, and 7.2 x 10^6 cubic yards by 1987;

and for subalternative D, 21.0 x 10^6 cubic yards before 1980, 6.0 x 10^6 cubic yards by 1983, and 7.2 x 10^6 cubic yards by 1989.

The dimensions of the berthing areas would be: depth, 74 feet; length of subalternatives A and B, 1,650 feet, and of subalternatives C and D, 1,900 feet; and width of subalternatives A and B, 2,300 feet (four berths), 3,265 feet (six berths), 4,225 feet (eight berths), and 5,185 feet (10 berths), and of subalternatives C and D, 2,640 feet (four berths), 3,740 feet (six berths), 3,960 feet (seven berths), and 5,060 feet (nine berths). Dredging quantities, including 4 feet of overdepth dredging and assuming an average terrain elevation of 0 feet, would equal the following: for subalternative A, 11.0 x 10^6 cubic yards before 1980, 4.5 x 10^6 cubic yards by 1985, and 4.5 x 10^6 cubic yards by 1993; for subalternative B, 11.0 x 10^6 cubic yards before 1980, 4.5 x 10^6 cubic yards by 1981, 4.5 x 10^6 cubic yards by 1987, and 4.5 x 10^6 cubic yards by 1993; for subalternative C, 14.5 x 10^6 cubic yards before 1980, and 7.2 x 10^6 cubic yards by 1987; and for subalternative D, 14.5 x 10^6 cubic yards before 1980, 6.0 x 10^6 cubic yards by 1983, and 7.2 x 10^6 cubic yards by 1989.

The dimensions of the exit channel would be: depth, 1.1 x 0.5 x 70 = 39 feet; width of subalternatives A and B, 770 feet, and of subalternatives C and D, 830 feet; and length, about 8,000 feet. Dredging quantities, including 2 feet of overdepth dredging and assuming an average terrain elevation of -5 feet, would equal: for subalternatives A and B, 9.3 x 10^6 cubic yards; and for subalternatives C and D, 10.6 x 10^6 cubic yards.

Total dredging quantities for the ocean channel would equal: for subalternatives A and B, 125.7 x 10^6 cubic yards; and for subalternatives C and D, 142.8 x 10^6 cubic yards. For all inland basins and channels these quantities would equal the following:

Subalternative A would require dredging of 55.2 x 10^6 cubic yards before 1980, 9.0 x 10^6 cubic yards by 1985, and 9.0 x 10^6 cubic yards by 1993. Subalternative B would require dredging of 55.2 x 10^6 cubic yards before 1980, 9.0 x 10^6 cubic yards by 1981, 9.0 x 10^6 cubic yards by 1987, and 9.0 x 10^6 cubic yards by 1993. Subalternative C would require dredging of 68.7 x 10^6 cubic yards before 1980, and 14.4 x 10^6 cubic yards by 1987. Subalternative D would require dredging of 68.7 x 10^6 cubic yards before 1980, 12.0 x 10^6 cubic yards by 1983, and 14.4 x 10^6 cubic yards by 1989.

<u>Pipelines from berths to intermediate tank farm.</u> One 48-inch line per berth would be required. Each line would be supported by a trestle for about 800 feet, and would then continue about 2 miles on land to the tanks of the tank farm. No booster stations are required.

<u>Intermediate tank farm.</u> The crude oil storage capacities required would be the same as those for alternative 4-2. Subalternative A would require 2.24 x 10^6 long tons by 1980, 2.51 x 10^6 long tons by 1987, 2.87 x 10^6 long tons by 1991, 3.34 x 10^6 long tons by 1995, and 3.83 x 10^6 long tons by 1998. Before 1980, 2.24 million tons of storage capacity would be constructed; additional storage capacities of 0.27, 0.36, 0.47, and 0.49 million long tons would be constructed in 1985, 1989, 1994, and 1997 respectively.

Subalternative B would require 2.24 x 10^6 long tons by 1980, 2.51 x 10^6 long tons by 1983, 2.87 x 10^6 long tons by 1986, 3.34 x 10^6 long tons by 1989, 3.83 x 10^6 long tons by 1992, 4.30 x 10^6 long tons by 1995, and 4.75 x 10^6 long tons by 1997. Before 1980, 2.24 million long tons of storage capacity would be constructed; additional storage capacities of 0.27, 0.36, 0.47, 0.49, 0.47, and 0.45 million long tons would be constructed in 1982, 1985, 1988, 1991, 1994, and 1996, respectively.

Subalternative C would require 2.67×10^6 long tons by 1980, 3.04×10^6 long tons by 1989, 3.55×10^6 long tons by 1994, and 4.09×10^6 long tons by 1998. Before 1980, 2.67 million long tons of storage capacity would be constructed; additional storage capacities of 0.37, 0.51, and 0.54 million long tons would be constructed in 1988, 1993, and 1997 respectively.

Subalternative D would require 2.67×10^6 long tons by 1980, 3.04×10^6 long tons by 1985, 3.55×10^6 long tons by 1988, 4.09×10^6 long tons by 1991, 4.69×10^6 long tons by 1995, and 5.29×10^6 long tons by 1998. Before 1980, 2.67 million long tons of storage capacity would be constructed; additional storage capacities of 0.37, 0.51, 0.54, 0.60 and 0.60 million long tons would be constructed in 1984, 1987, 1990, 1994, and 1997, respectively.

For general services an area of 30 acres was estimated. The total average requirement would be: for subalternative A, $3.83 \times 50 + 30 =$ about 220 acres; for subalternative B, $4.75 \times 50 + 30 =$ about 270 acres; for subalternative C, $4.09 \times 50 + 30 =$ about 235 acres; and for subalternative D, $5.29 \times 50 + 30 =$ about 295 acres.

Pipelines and booster stations from tank farm to refineries. Subalternatives A and C would have the same requirements as subalternative A of alternative 5-1. Subalternatives B and D would have the same requirements as subalternative B of alternative 5-1.

Transshipment berths. The requirements would be the same as those for alternative 5-1.

Pipelines from tank farm to transshipment berths. One 48-inch line per berth would be required. Each line would be 3 miles long, would run on land, and would require 1,600 b.hp.

Figures 27 and 30 show the location and layout of the deepwater port. Figure 28 shows the assumed pipeline route to the various refinery areas.

Alternative 5-6

Criteria

1. Site of deepwater port: Inland, near Freeport.
2. Service area and type of transshipment: Refineries at Houston, Beaumont, Lake Charles, Baton Rouge and New Orleans, by pipeline; and refineries at Corpus Christi and Pascagoula, by transshipment vessels.
3. Type of berths: Fixed.
4. Site of tanks: Near Freeport.
5. Draft of tankers: 9[illegible] feet fully loaded.
6. Subalternatives: The throughputs of the various subalternatives, and the size of the vessels they will serve, are given in table 59.

Table 59. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel size (d.w.t.)	Throughput (million tons/year)	
		1980	2000
A.............	500,000	100	450
B.............	500,000	150	600

7. Projected flow: Houston and Beaumont, 30 percent each; Lake Charles, Baton Rouge, and New Orleans, 10 percent each; and Corpus Christi and Pascagoula, 5 percent each.

Requirements

Supertanker berths. The number of berths required would be the same as those for alternative 4-3.

Subalternative A would require three berths by 1980, four berths by 1985, five berths by 1990, six berths by 1994, and seven berths by 1999. Three berths would be constructed before 1980; one berth would be constructed in each of the years 1984, 1989, 1993, and 1998.

Subalternative B would require four berths by 1980, five berths by 1985, six berths by 1989, seven berths by 1993, eight berths by 1996, and nine berths by 1999. Four berths would be constructed before 1980; one berth would be constructed in each of the years 1984, 1988, 1992, 1995 and 1998.

Dredging quantities. The quantities to be dredged would be as follows:

1. Ocean channel. Less than 10 miles off shore, the channel width would be 830 feet and the channel depth, 109 feet. Over 10 miles off shore, the width would be 1,040 feet and the depth 114 feet.

The total channel length would be 45 miles; the average depth per mile would be 12,24, 30, 36, 44, 50, 55, 57, 59, 62, 64, 65, 66, 66, 66, 66, 66, 67, 68, 69, 73, 77, 79, 82, 85, 87, 89, 90, 91, 92, 93, 94, 95, 96, 98, 100, 102, 104, 106, 108, 110, 111, 113, 115, and 118 feet. The total quantity to be dredged per mile, including 5 feet of overdepth dredging, would be 22.6, 19.4, 17.8, 16.2, 14.2, 12.8, 11.6, 11.2, 10.7, 10.0, 13.0, 12.7, 12.4, 12.4, 12.4, 12.4, 12.4, 12.1, 11.8, 11.6, 10.6, 9.6, 9.1, 8.3, 7.6, 7.1, 6.6, 6.4, 6.2, 5.9, 5.7, 5.4, 5.2, 5.0, 4.5, 4.0, 3.6, 3.2, 2.7, 2.3, 1.9, 1.7, 1.2, 0.8, 0.2 million cubic yards, or a total of 394.5×10^6 cubic yards.

2. Turning basins and inland channels. The cut through the coastline is the approach channel to the outer turning basin. The dimensions of this channel would be: width, 830 feet; depth, 109 feet; and length, 1,300 feet. Dredging quantity, including 5 feet of overdepth dredging and assuming an average terrain elevation at +4 feet, would equal 6.6×10^6 cubic yards.

The dimensions of the o ter turning basin would be: radius, 1,800 feet; and w ter depth, 105 feet. Dredging quantity, including 5 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal 17.6 x 10^6 cubic yards.

The dimensions of the channel between outer and inner turning basin would be: width, 725 feet; water depth, 105 feet; and length, 1,700 feet. Dredging quantity, including 5 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal 7.0 x 10^6 cubic yards.

The dimensions of the inner turning basin would be: water depth, 105 feet; width at bottom, 1,800 feet; and length, 3,465 feet (serving three berths), 4,300 feet (serving four berths), 5,335 feet (serving six berths), 5,545 feet (serving seven berths), and 6,585 feet (serving nine berths). Dredging quantities, including 5 feet of overdepth dredging and assuming an average terrain elevation at -4 feet, would equal the following: for subalternative A, 28.8 x 10^6 cubic yards before 1980, 7.3 x 10^6 cubic yards by 1983, and 7.3 x 10^6 cubic yards by 1992; and for subalternative B, 35.7 x 10^6 cubic yards before 1980, 7.3 x 10^6 cubic yards by 1983, and 8.7 x 10^6 cubic yards by 1991.

The dimensions of the berthing areas would be: water depth, 100 feet; length, 1,800 feet; and width, 1,665 feet (three berths), 2,495 feet (four berths), 3,535 feet (six berths), 3.745 feet (seven berths), and 4,785 feet (nine berths). Dredging quantities, including 5 feet of overdepth dredging and assuming an average terrain elevation of 0 feet, would equal the following: for subalternative A, 11.7 x 10^6 cubic yard yards before 1980, 7.3 x 10^6 cubic yards by 1983, and 7.3 x 10^6 cubic yards by 1992; and for subalternative B, 17.6 x 10^6 cubic yards before 1980, 7.3 x 10^6 cubic yards by 1983, and 8.7 x 10^6 cubic yards by 1991.

The dimensions of the exit channel would be: water depth, 1.1 x 0.5 x 95 = 52 feet; width at bottom, 830 feet; and length, about 8,000 feet. Dredging quantity, including 3 feet of overdepth dredging and assuming an average terrain elevation of -5 feet, would equal 14.5 x 10^6 cubic yards.

Total dredging quantities for the ocean channel would equal 394.5 x 10^6 cubic yards. For all inland channels these quantities would equal the following: subalternative A would require dredging of 86.2 x 10^6 cubic yards before 1980, 14.6 x 10^6 cubic yards by 1983, and 14.6 x 10^6 cubic yards by 1992. Subalternative B would require dredging of 99.0 x 10^6 cubic yards before 1980, 14.6 x 10^6 cubic yards by 1983, and 17.4 x 10^6 cubic yards by 1991.

<u>Pipelines from berths to intermediate tank farm.</u> One 48-inch line per berth would be required. Each line would be supported by a trestle for about 800 feet, and would then continue about 2 miles on land to the tanks of the intermediate tank farm. No booster station would be required.

<u>Intermediate tank farm.</u> The crude oil storage capacities required would be the same as those for alternative 4-3. Subalternative A would require 2.17 x 10^6 long tons by 1980, 2.69 x 10^6 long tons by 1985, 3.04 x 10^6 long tons by 1990, 3.47 x 10^6 long tons by 1994, and 4.07 x 10^6 long tons by 1999. Before 1980, 2.17 million long tons of storage capacity would be constructed; additional storage capacities of 0.52, 0.35, 0.43, and 0.60 million long tons would be constructed in 1984, 1989, 1993 and 1998, respectively.

Subalternative B would require 2.69 x 10^6 long tons by 1980, 3.04 x 10^6 long tons by 1985, 3.47 x 10^6 long tons by 1989, 4.07 x 10^6 long tons by 1993, 4.62 x 10^6 long tons by 1996, and 5.20 x 10^6 long tons by 1999. Before 1980, 2.69 million long tons of storage capacity would be constructed; additional storage capacities of 0.35, 0.43, 0.60, 0.55, and 0.58 million long tons would be constructed in 1984, 1988, 1992, 1995, and 1998, respectively.

For general services an area of 30 acres was estimated. The total average requirement would be: for subalternative A, 4.07 x 50 + 30 = about 235 acres; and for subalternative B, 5.20 x 50 + 30 = about 290 acres.

Pipelines and booster stations from tank farm to refineries. Subalternative A would have the same requirements as subalternative A of alternative 5-1. Subalternative B would have the same requirements as subalternative B of alternative 5-1.

Transshipment berths. The requirements would be the same as those for alternative 5-1.

Pipelines from tank farm to transshipment berths. One 48-inch line per berth would be required. Each line would be 3 miles long, would run on land, and would require 1,600 b.hp.

Figures 27 and 30 show the location and layout of the deepwater port. Figure 28 shows the assumed pipeline route to the various refinery areas.

Los Angeles-Long Beach Area

Two crude oil alternatives, numbered 6-1 and 6-2, are considered in this part of the Pacific coast. These alternatives differ from each other in service area: the deepwater port considered in alternative 6-1 would serve the Los Angeles-Long Beach refinery area, whereas that of alternative 6-2 would serve the Los Angeles-Long Beach as well as the San Francisco refinery area.

The location and layout of the deepwater port at Los Angeles and the assumed pipeline route to San Francisco of alternative 6-2 are shown in figures 31 and 32.

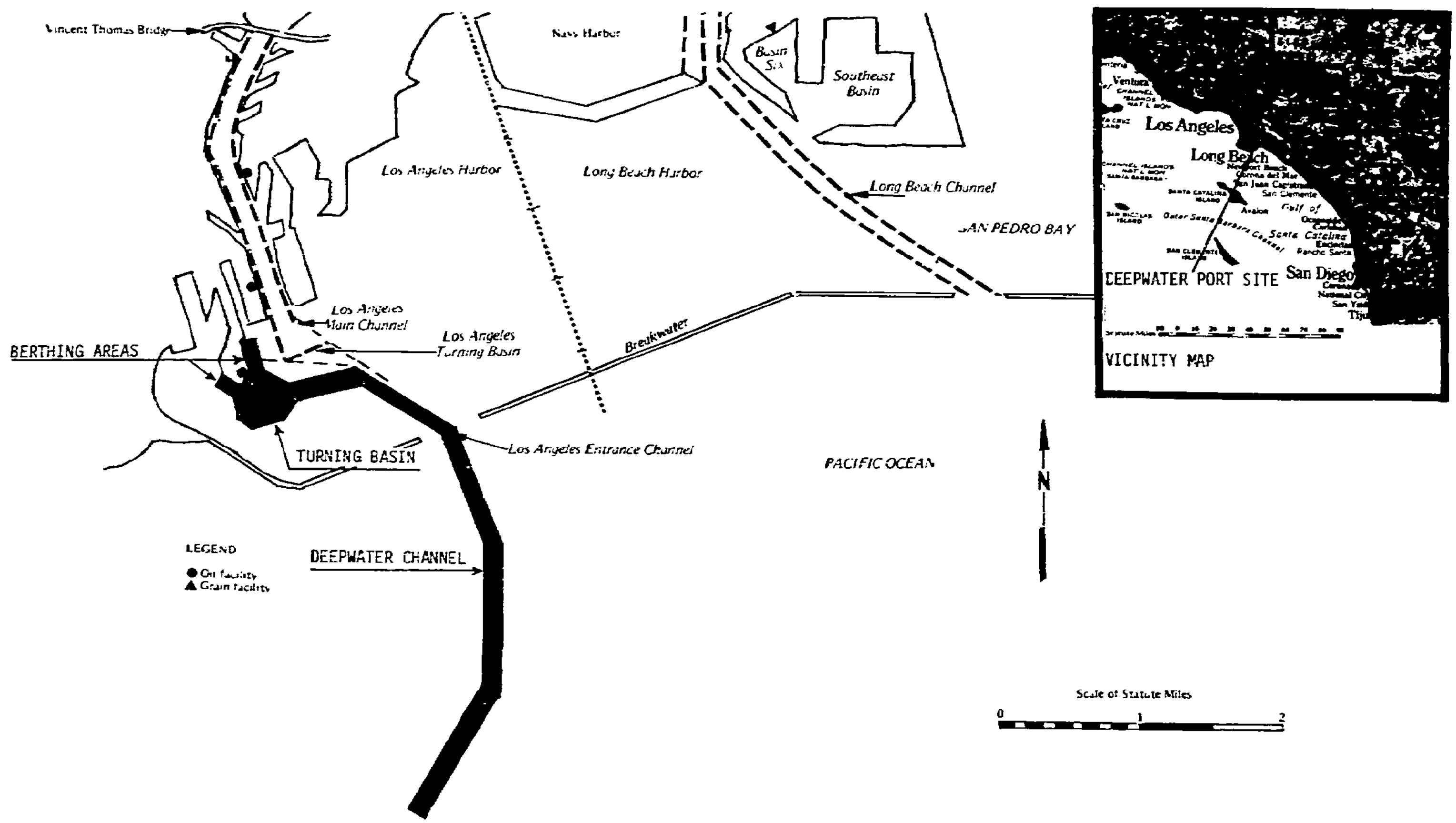


FIGURE 31 LOCATION AND LAYOUT OF CHANNEL, TURNING BASIN AND BERTHING AREAS OF DEEPWATER PORT OF ALTERNATIVES 6-1 AND 6-2

Robert R. Nathan Associates, Inc.

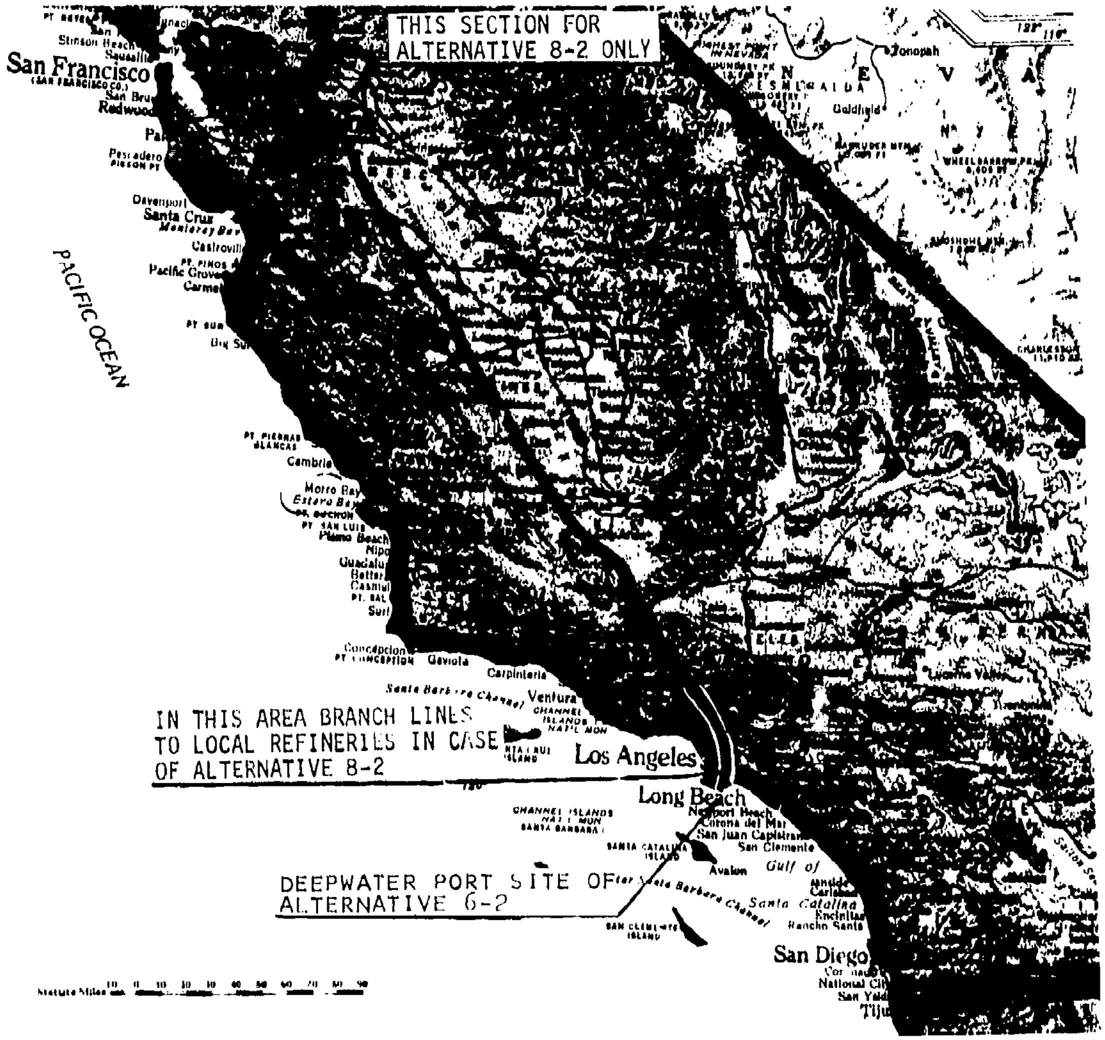


FIGURE 32. PIPELINE ROUTE BETWEEN LOS ANGELES AND SAN FRANCISCO, ALTERNATIVES 6-2 AND 8-2

Sites

Both alternatives consider a deepwater port in the Los Angeles Outer Harbor area, protected by the San Pedro Breakwater.

Transshipment

Both alternatives consider transshipment by pipeline only.

Throughputs

The throughputs of the deepwater ports are set at 28 m.t.a. in 1980 and 111 m.t.a. by 2000 for the Los Angeles-Long Beach area, and 15 m.t.a. in 1980 and 60 m.t.a. by 2000 for the San Francisco area. For both areas combined, the throughputs would be 43 m.t.a. in 1980 and 171 m.t.a. by 2000.

Type of Berths

Both alternatives consider fixed berths.

Site of Intermediate Tank Farm

It is assumed that each of the four major oil companies in the Los Angeles-Long Beach area which would participate in the common facility would have sufficient tankage at their refineries. This tankage would be directly connected by pipeline with the new berths. For the pipeline system to the San Francisco area, it is assumed that an intermediate tank farm would be situated at an unspecified location an arbitrary distance of 10 miles from the new deepwater berths.

Vessel Size

Both alternatives will consider 300,000- and 400,000-d.w.t. tankers. It is assumed that all tankers using the deepwater port would be of these maximum sizes for each alternative and subalternative. The assumed tanker dimensions are given in table 60.

Table 60. Vessel Dimensions
(In feet)

Dimension	Vessel size (1,000 d.w.t.)	
	300	400
Length.....	1,100	1,262
Beam.......	192	220
Draft......	70	70

Dredging

Both alternatives would require a dredged ocean and bay channel, a dredged turning basin, and dredged berthing areas.

Construction Program

The time phasing of the various construction items for the period prior to 1980 are given in table 61 for alternative 6-1, and in table 62 for alternative 6-2. The entire planning was simplified to facilitate calculations. The total cost of each item will be equally distributed over the pertinent years.

Table 61. Construction Program of Alternative 6-1

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Dredging...............			X	X	
Supertanker berths......					X
Pipelines to refineries.					X

Table 62. Construction Program of Alternative 6-2

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Dredging...............			X	X	
Supertanker berths.....					X
Pipelines to local refineries............					X
Pipelines to intermediate tank farm.....					X
Intermediate tank farm.				X	X
Pipeline to San Francisco refineries......				X	X

Alternative 6-1

Criteria

1. Site of deepwater port: Outer Harbor of Los Angeles, at the inside of the breakwater of San Pedro Bay.
2. Service area: Refineries in the Los Angeles-Long Beach area.
3. Type of transshipment: Pipeline only.
4. Site of intermediate tank farms: At the existing refinery tank farms of the individual oil companies.
5. Type of berths: Fixed.
6. Throughput: 28 and 111 m.t.a. in 1980 and 2000, respectively.
7. Draft of tankers: 70 feet fully loaded.
8. Subalternatives: Subalternative A would handle 300,000 d.w.t. tankers; subalternative B, 400,000 d.w.t. tankers.

Requirements

Supertanker berths. Subalternative A would require two berths by 1980 and three berths by 1993 (the one additional berth being constructed in 1992).

Subalternative B would require two berths by 1980 and three berths by 1996 (the one additional berth being constructed in 1995).

<u>Dredging quantities</u>. The mean tidal range is 3.8 feet at the site of the deepwater port. Since this site is located 1.5 miles from the shoreside of the breakwater and 80 feet of water is found at approximately 3 miles from the breakwater, no tidal rise will be taken into account in determining the channel depths.

1. Ocean and bay channel. The ocean and bay channel would have the following dimensions: depth, 81 feet; width at bottom of subalternative A, 770 feet, and of subalternative B, 880 feet; and length, about 4.5 miles. The depth per mile would be about 45, 55, 75, and 80 feet. Total quantity to be dredged, including 4 feet of overdepth dredging, would equal: for subalternative A, 7.0 + 5.0 + 1.6 + 0.4 million = 14.0 x 10^6 cubic yards; and for subalternative B, 7.8 + 5.7 + 1.8 + 0.5 million = 15.8 x 10^6 cubic yards.

2. Turning basin. The turning basin would have the following dimensions: depth, 77 feet; and radius, of subalternative A, 1,650 feet, and of subalternative B, 1,900 feet. Dredging quantity, including 4 feet of overdepth dredging and assuming an average depth of 40 feet, would equal: for subalternative A, 4.8 x 10^6 cubic yards; and for subalternative B, 6.2 x 10^6 cubic yards.

3. Berthing area. The berthing area would have the following dimensions: depth, 74 feet; width, of subalternative A, 1,535 feet (three berths), and of subalternative B, 1,760 feet (three berths); length, of subalternative A, 1,650 feet, and of subalternative B, 1,900 feet. Dredging quantity, including 4 feet of overdepth dredging and assuming an average depth of 40 feet, would equal: for subalternative A, 3.8 x 10^6 cubic yards; and for subalternative B, 5.0 x 10^6 cubic yards.

Total dredging quantities would be as follows: Subalternative A would require dredging of 14.0×10^6 cubic yards for the ocean and bay channel, and of 8.6×10^6 cubic yards for the turning basin and berthing area. Subalternative B would require dredging of 15.8×10^6 cubic yards for the ocean and bay channel, and of 11.2×10^6 cubic yards for the turning basin and berthing area.

Pipelines from supertanker berths to refinery tank farms. Four 48-inch lines would be required. The average length of each line would be 10 miles. The pressure loss would be 15 + 10 x 17.4 = 189.0 p.s.i. and 15 + 10 x 21.2 = 227.0 p.s.i. for subalternatives A and B, respectively. A small booster pump would be required; for subalternative A, (189 -125) x 47 = 3,000 b.hp. per line would be required; for subalternative B, (227 -125) x 52 = 5,300 b.hp. per line.

Tankage capacity. The refinery tank farm of each participating oil company should have sufficient storage capacity to meet the port requirements.

The location and layout of the deepwater port at Los Angeles is shown in figure 31.

Alternative 6-2

Criteria

1. Site of deepwater port: Outer Harbor of Los Angeles, inside the breakwater of San Pedro Bay. The site is the same as that for alternative 6-1.
2. Service area: Four major refineries in the Los Angeles and Long Beach area, and six major refineries in the San Francisco area.
3. Type of transshipment: Separate pipelines to the four major refineries in the Los Angeles-Long Beach area, and one common carrier pipeline to the San Francisco area.
4. Site of intermediate tank farms: For the four pipelines to the major refineries in the Los Angeles-Long Beach area, no intermediate storage will

be considered between supertanker berths and refineries. For the pipeline to San Francisco, an intermediate tank farm will be assumed 10 miles from the berths at an unspecified location.

5. Type of berths: Fixed.

6. Throughput: To the Los Angeles-Long Beach area, 28 and 111 m.t.a., and to the San Francisco area, 15 and 60 m.t.a. in 1980 and 2000, respectively. For both areas combined the throughputs would be 43 and 171 m.t.a. in 1980 and 2000, respectively.

7. Draft of tankers = 70 feet fully loaded.

8. Subalternatives: Subalternative A would handle 300,000 d.w.t. tankers; subalternative B, 400,000 d.w.t. tankers.

Requirements

Supertanker berths. Subalternative A would require two berths by 1980, three berths by 1986 (the one additional berth being constructed in 1985), and four berths by 1997 (the one additional berth being constructed in 1996). Subalternative B would require two berths by 1980 and three berths by 1988 (the one additional berth being constructed in 1987).

Dredging quantities. No tidal rise would be taken into consideration (see alternative 6-1).

1. Ocean and bay channel. The dimensions would be the same as for alternative 6-1. Total dredging quantity would be: for subalternative A, 14.0×10^6 cubic yards; and for subalternative B, 15.8×10^6 cubic yards.

2. Turning basin. The dimensions would be the same as for alternative 6-1. Total dredging quantity would be: for subalternative A, 4.8×10^6 cubic yards; and for subalternative B, 6.2×10^6 cubic yards.

3. Berthing areas. By 1980 the requirements would be the same as those of alternative 6-1 (for three berths). Subalternative A would require dredging

of 3.8×10^6 cubic yards; and subalternative B, 5.0×10^6 cubic yards. Subalternative A would require the dredging in 1995 of about 1.9×10^6 cubic yards for the fourth berth. Total dredging quantities would be as follows: Subalternative A would require dredging of 14.0×10^6 cubic yards for the ocean and bay channel, and of 10.5×10^6 cubic yards for the turning basin and berthing area. Subalternative B would require dredging of 15.8×10^6 cubic yards for the ocean and bay channel, and of 11.2×10^6 cubic yards for the turning basin and berthing area.

Pipelines from supertanker berths to intermediate tank farm. The requirements for the pipelines to the Los Angeles-Long Beach refinery area would be the same as those for alternative 6-1. For the pipelines to the San Francisco refinery area, two 48-inch lines could take care of the quantity. The distance to the intermediate tank farm was arbitrarily set at 10 miles. The pressure losses per line would be the same as those calculated for alternative 6-1. The booster pumps would require a capacity of 3,000 and 5,300 b.hp. per line for subalternatives A and B, respectively.

Intermediate tank farm. For pipelines to the Los Angeles-Long Beach refineries, the assumptions are the same as those discussed in alternative 6-1. For the pipeline to San Francisco area, the assumptions are as follows: In both 1980 and 2000 35 percent of the total deepwater port throughput would be destined to the San Francisco area. Therefore, 35 percent of the total storage requirements, as calculated using the formula on intermediate storage, will be considered to be required for the pipeline to San Francisco.

The total storage requirement would be: for subalternative A, 1.54×10^6 long tons by 1980, 1.81×10^6 long tons by 1986, and 2.24×10^6 long tons by 1997; and for subalternative B, 1.80×10^6 long tons by 1980, and 2.15×10^6 long tons by 1988.

Applying the 35 percent division rule results in the following required storage for the line to San

Francisco: for subalternative A, 0.55 x 10^6 long tons by 1980, 0.65 x 10^6 long tons by 1986 (the additional 0.10 x 10^6 long tons of storage being installed in 1985), and 0.80 x 10^6 long tons by 1997 (the additional 0.15 x 10^6 long tons of storage being installed in 1996); and for subalternative B, 0.65 x 10^6 long tons by 1980 and 0.77 x 10^6 long tons by 1988 (the additional 0.12 x 10^6 long tons of storage being installed in 1987).

For the tank farm serving the pipeline system to the San Francisco refineries, an acreage of about 50 x 0.80 + 10 = 50 acres would be required.

Pipeline system to the San Francisco area. One 42-inch line would be sufficient for the entire period from 1980 through 2000. The total length of the line was estimated at 385 miles. The total length of the branch lines to the six refineries was assumed at 20 miles, and the diameter of the branch lines at 24 inches. Three river crossings of the main line, each 0.3 mile long, are anticipated on the entire route.

The following approximate horsepowers would be required: by 1980, 385 x 10.68 = 4,100 b.hp.; and by 2000, 385 x 519.36 = 200,000 b.hp. The following installations would be made: by 1980, 25,000 b.hp. (28.5 m.t.a.); in 1985, 25,000 b.hp. additional (36.5 m.t.a.); in 1989, 50,000 b.hp. additional (47 m.t.a.); and in 1993, 100,000 b.hp. additional (60 m.t.a.).

The location and layout of the deepwater port at Los Angeles and the assumed pipeline route to the San Francisco refineries are shown in figures 31 and 32.

San Francisco Area

Five crude oil alternatives, numbered 7-1 through 7-5, are considered on this part of the Pacific coast.

The location and layout of the deepwater ports, as well as the assumed pipeline routes of alternatives 7-1, 7-3 and 7-5, are shown in figures 33 through 37.

Sites

Two alternatives (7-1 and 7-3) consider a deeper channel to Richmond only, whereas two alternatives (7-2 and 7-4) consider a deeper channel to Richmond and to the facilities along San Pablo Bay, Carquinez Strait and Suisun Bay. Alternative 7-5 considers a new deepwater port in Monterey Bay.

Types of Berths

Alternatives 7-1 through 7-4 consider fixed berths. Alternative 7-5 considers monobuoys.

Intermediate Tank Farm

Alternatives 7-1, 7-3 and 7-5 would require an intermediate tank farm.

Transshipment

All alternatives consider either direct unloading at the existing berth locations, or unloading at a new location with transshipment by pipeline to the existing refineries.

Refineries

Six refineries are located in the San Francisco area. The capacities of these refineries as of January 1, 1972, are given in table 63.

One refinery, Standard Oil of California, is located at Richmond; its crude oil handling facility is at Richmond Long Wharf. The other refineries and their crude oil handling facilities are located along San Pablo Bay, Carquinez Strait and Suisun Bay; the

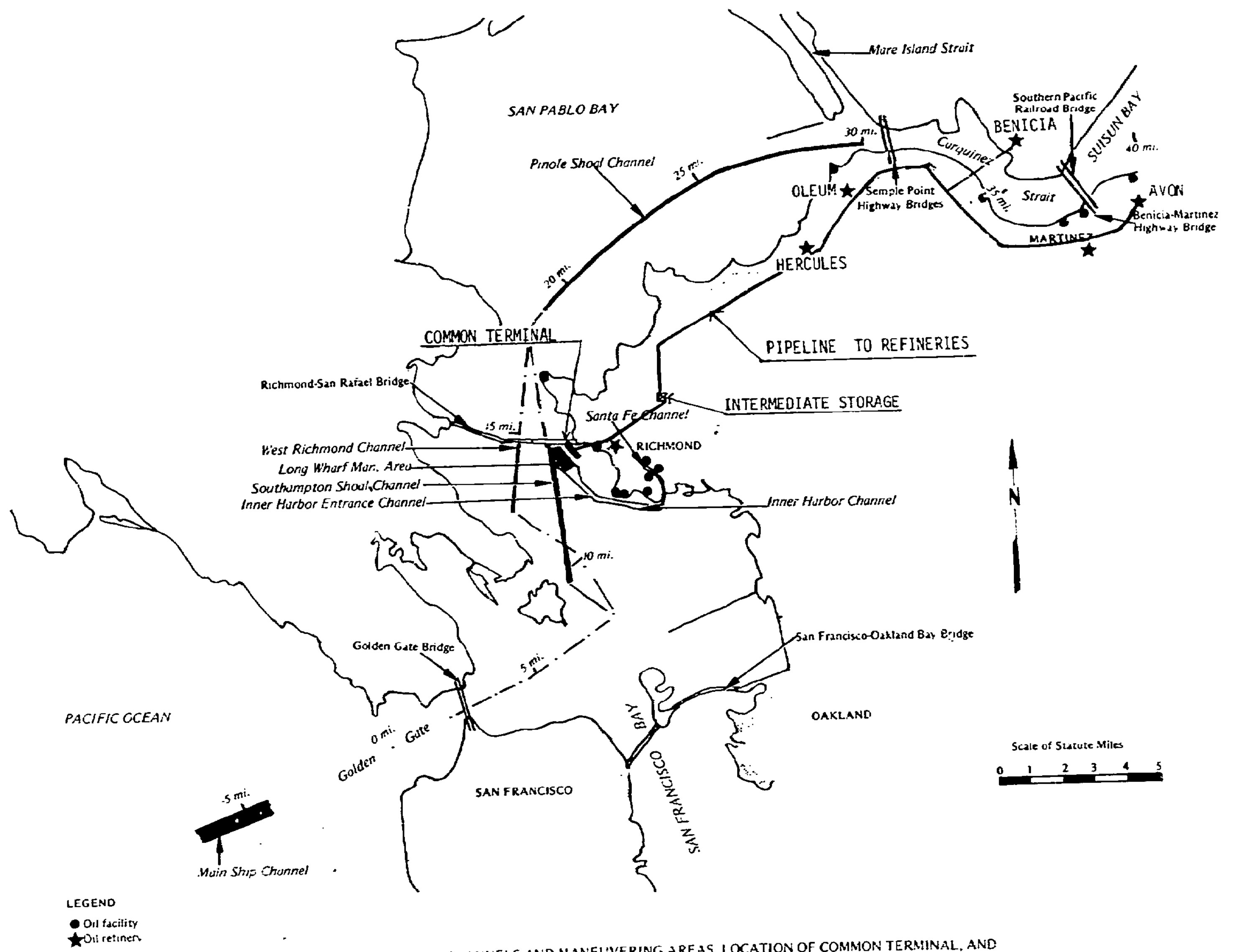


FIGURE 33. IMPROVED CHANNELS AND MANEUVERING AREAS, LOCATION OF COMMON TERMINAL, AND ASSUMED PIPELINE ROUTE OF ALTERNATIVES 7-1 AND 7-3

Robert R. Nathan Associates, Inc.

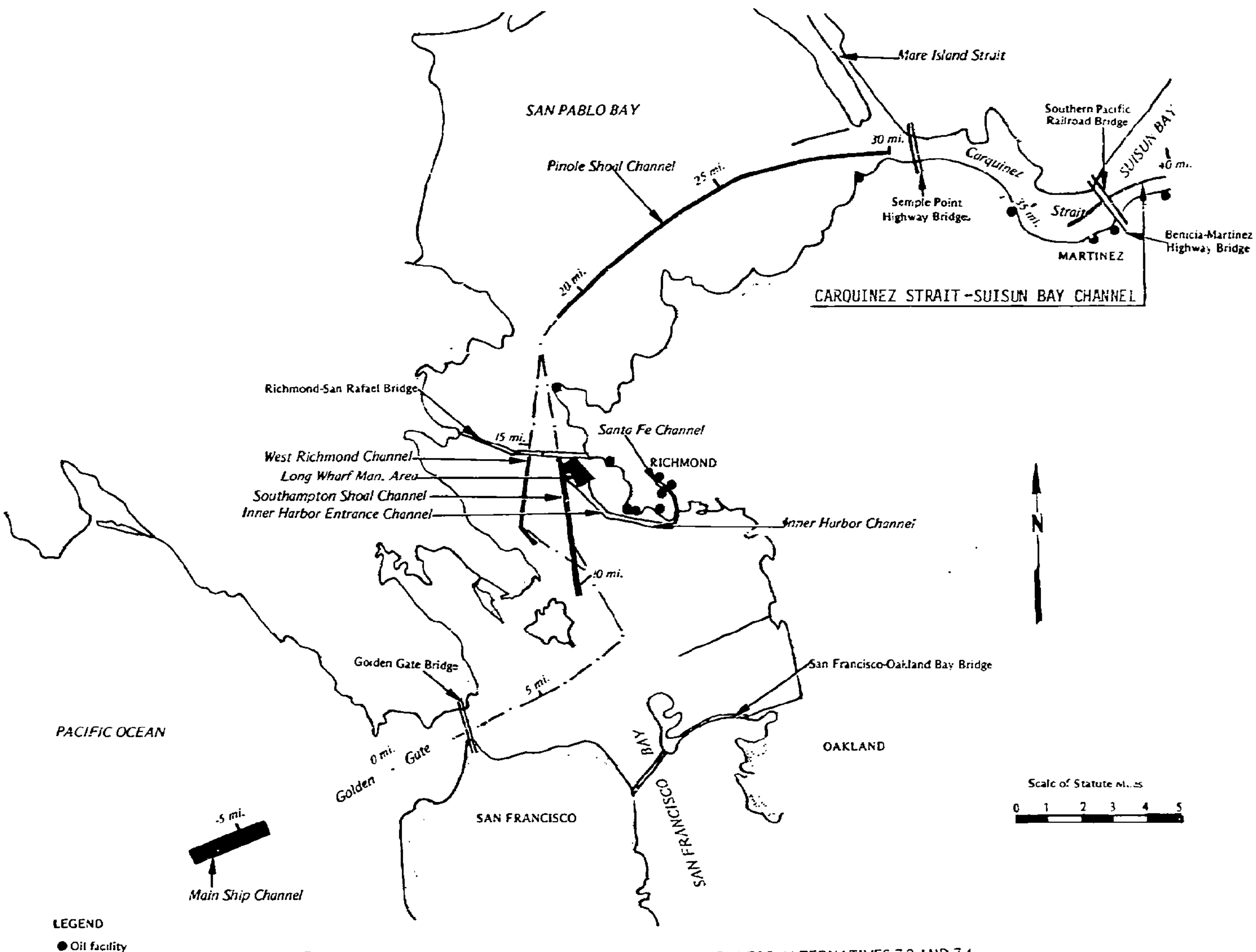


FIGURE 34. IMPROVED CHANNELS AND MANEUVERING AREAS FOR ALTERNATIVES 7-2 AND 7-4

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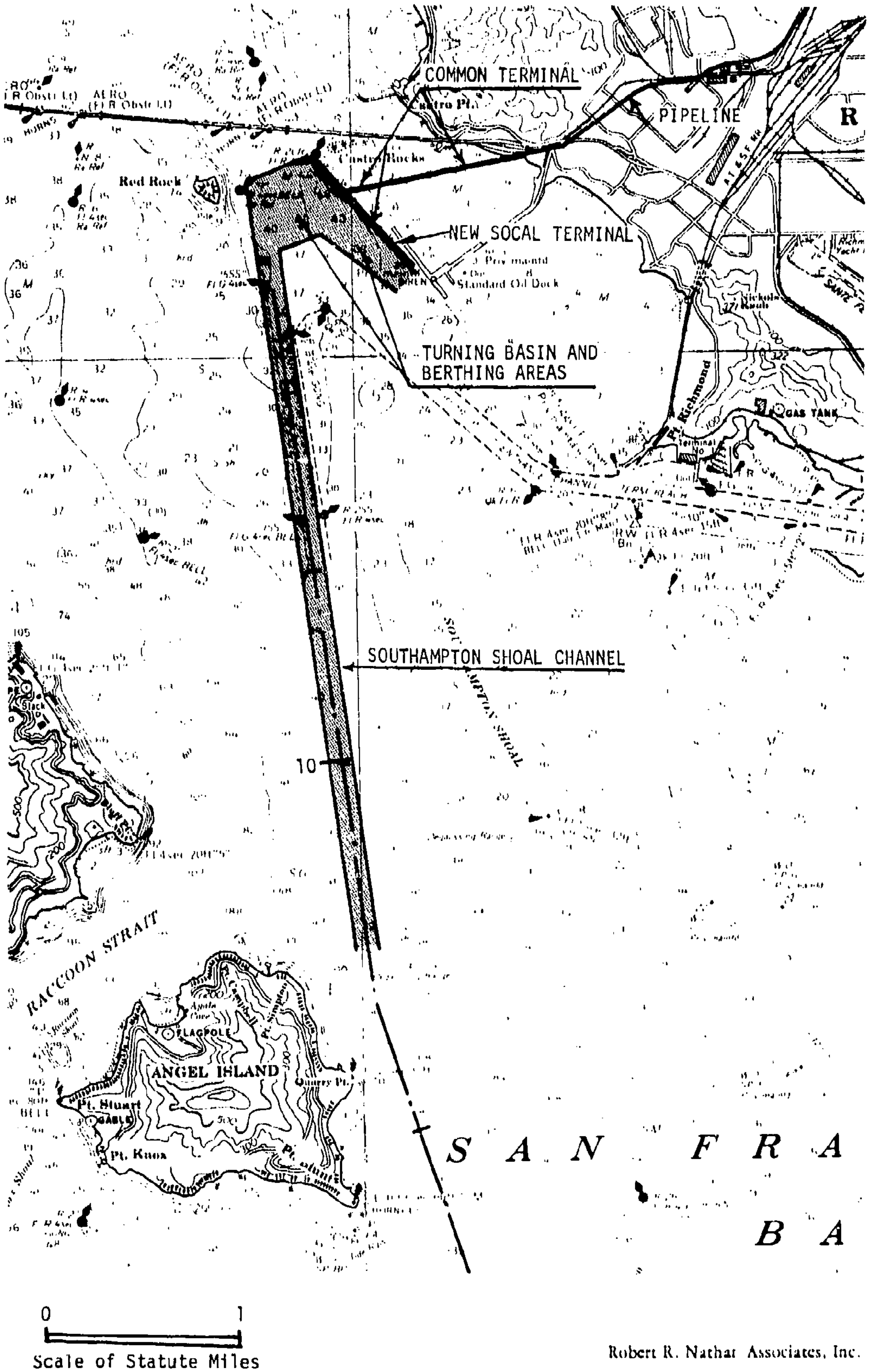

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FIGURE 35. IMPROVED SOUTHAMPTON SHOAL CHANNEL AND RICHMOND LONG WHARF MANEUVERING AREA OF ALTERNATIVES 7-1 AND 7-3

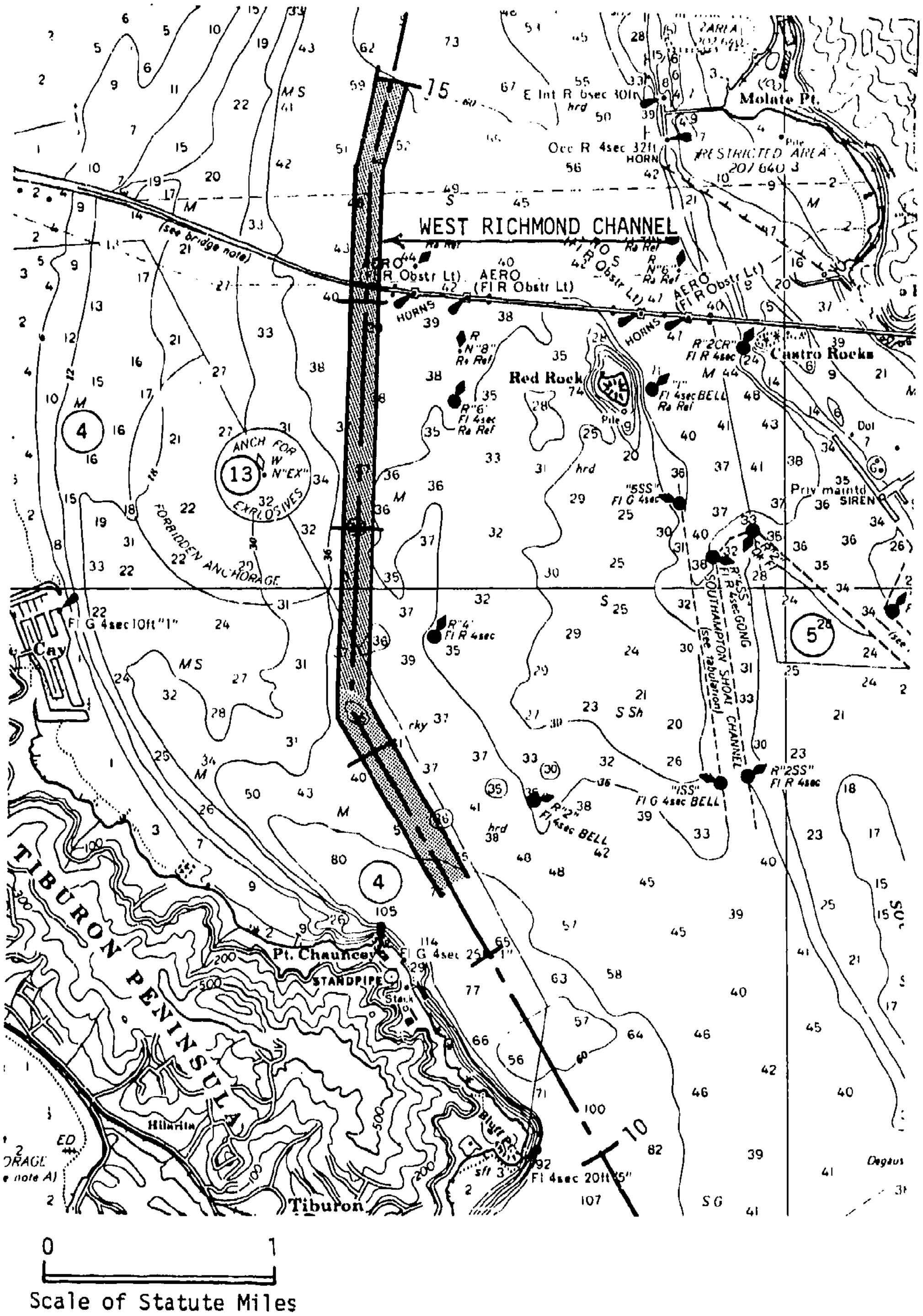

FIGURE 36. WEST RICHMOND CHANNEL OF ALTERNATIVES 7-2 AND 7-4

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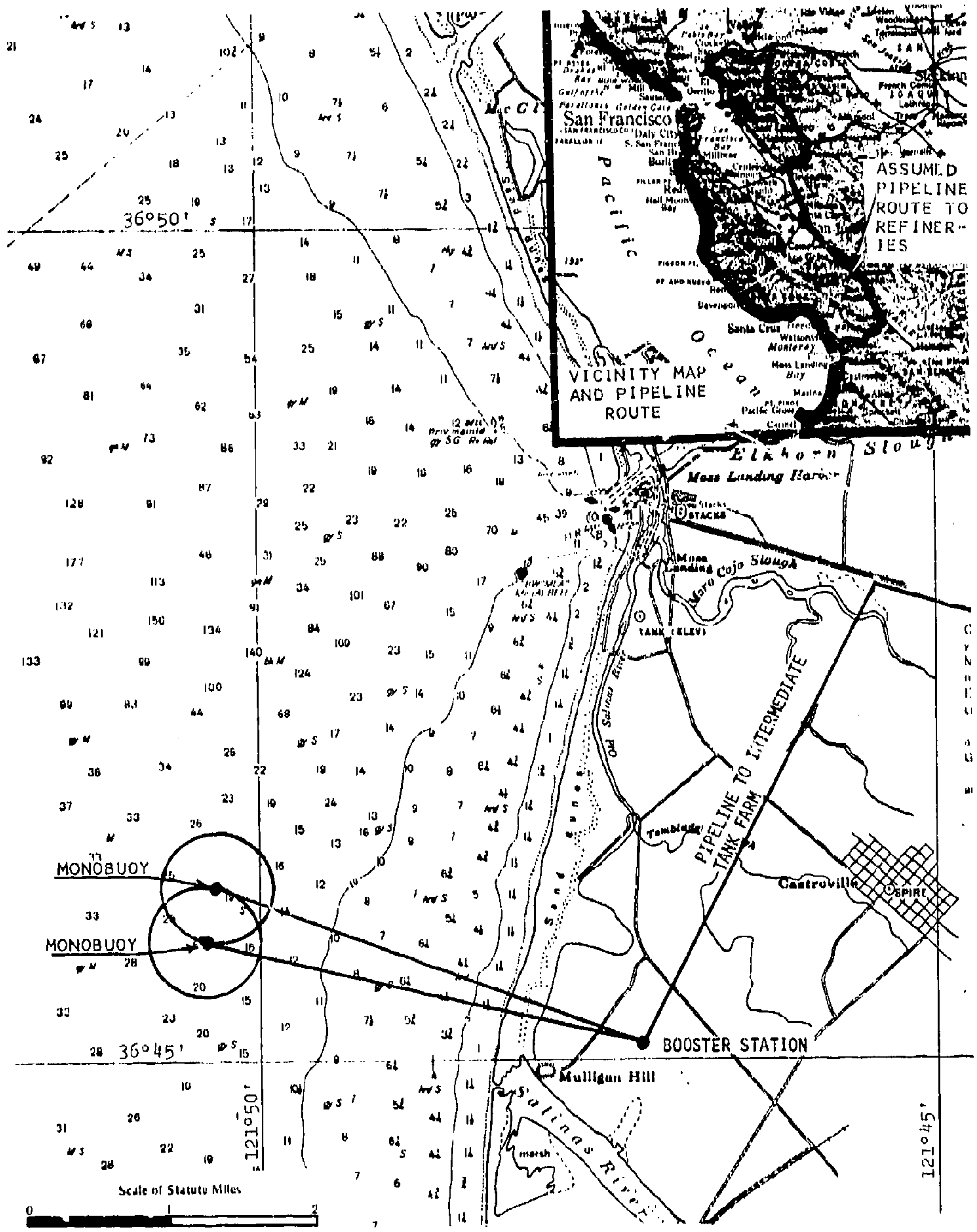

FIGURE 37. LOCATION AND LAYOUT OF MONOBUOYS AND PIPELINES OF ALTERNATIVE 7-S

Table 63. Refining Capacities of San Francisco Refineries

Name	Location	Refining capacity (bbl./day)	Percentage of total refining capacity
Standard Oil Co. of California..........	Richmond	190,000	31.3
Gulf Co.	Hercules	26,000	4.3
Union Oil Co. of California..........	Oleum	95,000	15.6
Humble Oil Co.	Benicia	86,000	14.2
Shell Oil Co.	Martinez	100,000	16.5
Phillips Petroleum Co.	Avon	110,000	18.1
Total................		607,000	100.0

easternmost terminal is the Avon Pier, located at a distance of approximately 39 statute miles from the coast. In alternatives 7-1 and 7-3, the deep-draft channel is anticipated to be dredged to Socal's Long Wharf facility. Northwest of this facility would be located the common unloading facility. In alternatives 7-2 and 7-4 the deep-draft channel would be dredged to Socal's Long Wharf facility as well as to the other facilities along San Pablo Bay, Carquinez Strait and Suisun Bay, up to the Avon Pier in Suisun Bay.

Throughputs

The total throughput was set at 15 m.t.a. in 1980 and 60 m.t.a. by 2000.

Projected Flow

To simplify the calculations of the individual terminal requirements, it is assumed that in 1980 the import of crude oil would be distributed among the six refineries in proportion to their present refining capacities. However, it is also assumed that in 2000 the import quantities would be equal for all six refineries. Table 64 presents the projected flows.

Table 64. Projected Crude Oil Flow

Name	Percentage of total throughput		Annual throughput (million long tons)	
	1980	2000	1980	2000
Standard Oil Co. of California...	31.3	16.7	4.7	10.0
Gulf Oil Co.	4.3	16.6	0.7	10.0
Union Oil Co. of California...	15.6	16.7	2.3	10.0
Humble Oil Co. ..	14.2	16.7	2.1	10.0
Shell Oil Co. ...	16.5	16.6	2.5	10.0
Phillips Petroleum Co.	18.1	16.7	2.7	10.0
Total	100.0	100.0	15.0	60.0

Vessel Sizes

Due to the hypothesized different water depths, different vessels would be considered in the various deepwater port alternatives. It is assumed that all tankers using the port alternatives would be of the maximum size as established per alternative. Table 65 reviews the established dimensions of the considered vessels.

Dredging

Alternatives 7-1 through 7-4 would require dredged ocean and bay channels, dredged turning basins and dredged berthing areas. Alternative 7-5 would not require any dredging.

Table 65. Vessel Dimensions
(In feet)

Dimension	Vessel size (1,000 d.w.t.)		
	157	250	400
Length.................	980	1,095	1,160
Beam...................	164	190	200
Draft..................	50	58.5	83

Construction Program

The time phasing of the various construction items used for the period prior to 1980 is given in table 66 for alternatives 7-1 through 7-4, and in table 67 for alternative 7-5. The entire phasing was simplified to facilitate calculations. The total cost of each item will be equally distributed over the pertinent years.

Table 66. Construction Program of
Alternatives 7-1 Through 7-4

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Dredging					
alternatives 7-1, 7-2, and 7-3..............			X	X	X
alternative 7-4........	X	X	X	X	X
Supertanker berths......					X
Intermediate tank farm					
alternatives 7-1 and 7-3...............				X	X
Pipeline to Carquinez refineries					
alternatives 7-1 and 7-3..............					X

Table 67. Construction Program of Alternative 7-5

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Supertanker berths.....					X
Pipeline to intermediate tank farm.....					X
Intermediate tank farm..................				X	X
Pipeline to San Francisco refineries......					X

Alternative 7-1

Criteria

1. Site of deepwater port: Richmond's Long Wharf area.
2. Service area: Refineries in the Richmond-Martinez area.
3. Type of transshipment: Pipeline only.
4. Site of intermediate tank farm: At an unspecified location about 5 miles from the berths. This tank farm would serve the five refineries located outside the Richmond area.
5. Type of berths: Fixed.
6. Throughput: 15 and 60 m.t.a. in 1980 and 2000, respectively. Of this volume an assumed 10.3 m.t.a. in 1980 and 50 m.t.a. by 2000 would be transshipped by pipeline to the refineries outside the Richmond area, and 4.7 m.t.a. in 1980 and 10 m.t.a. by 2000 would go directly to Socal's Richmond refinery.
7. Tanker characteristics: 157,000 d.w.t. with 50-foot draft fully loaded.

Requirements

Supertanker berths. Assuming that all vessels would be of the maximum size, the following number of berths would be required: Socal would require one berth by 1980, and no additional berths between 1980 and 2000. The common terminal would require one berth by 1980 and two berths by 1983. It is assumed that all three berths would be constructed before 1980.

Dredging quantities. The quantities to be dredged would be as follows:

1. Ocean channel. Because the Main Ship Channel is presently being dredged from 50 to 55 feet, it will be assumed that the existing depth of this channel is 55 feet. The channel is located less than 10 miles off shore; therefore, the required dimensions would be: width, 655 feet; and depth, 58 feet. Taking into account 5 feet of tide would result in a required depth of 53 feet, which is less than the "existing" 55 feet. Hence, no additional dredging of the Main Ship Channel would be required.

2. Southampton Shoal Channel. The required dimensions would be: width, 575 feet; and depth, 55 feet, or taking 5 feet of tide into account, 50 feet. Its length would be approximately 4 miles. The present average depth per mile is: 40, 40, 33 and 37 feet. Total quantity per mile, including 2.5 feet of overdepth dredging, would be: 1.5, 1.5, 2.5 and 1.8 million cubic yards, or a total of 7.3×10^6 cubic yards.

3. Turning basin and berthing area. The average dimensions of the combined area would be: length, $3 \times 1.5 \times 980 = 4{,}410$ feet; width, 1,300 feet; depth, 50 to 48 feet, therefore, 49 feet; and the average present depth, 41 feet. Dredging quantity would be 2.3 $\times 10^6$ cubic yards, including 2.5 feet of overdepth dredging.

Total dredging quantities would equal, for the ocean channel, none; and for the inland basin and channel, 9.6×10^6 cubic yards.

Pipelines. From the common berths to the intermediate tank farm, one 48-inch line per berth would be required. The length of each line is set at 5 miles, of which 1 mile would be on trestle and 4 miles on land. No booster pumps would be required. From Socal's berth to their Richmond refinery, it is assumed that there is sufficient piping from the existing berths to the tank farm's manifold.

Intermediate tank farm. The required crude oil storage to serve the common terminal would be 1.03 x 10^6 long tons, to be installed before 1980. Socal would require 0.89 x 10^6 long tons, which is presently available.

For general services an area of 20 acres is assumed to be sufficient. Including crude oil storage the total acreage requirement would be 1.03 x 50 + 20 = about 70 acres.

Pipeline from intermediate tank farm to refineries. One 32-inch line is considered an attractive solution for a throughput ranging from 10 m.t.a. in 1980 to 45 m.t.a. by 2000. The length of the line was estimated at 25 statute miles. The length of the branch lines is considered negligible.

To calculate the horsepower requirements an average booster length of 20 miles has been assumed. Initially 20 x 13.70 = 274 b.hp. would be required; ultimately, 20 x 923.87 = 18,400 b.hp. The following installation program has been selected to meet the requirements: 1,150 b.hp. (15.5 m.t.a.), before 1980, 1,150 b.hp. (21 m.t.a.) in 1982, 2,300 b.hp. (27 m.t.a.) in 1985, 4,600 b.hp. (34.5 m.t.a.) in 1990, and 9,200 b.hp. (45 m.t.a.) in 1993.

The location and layout of the deepwater port and the assumed pipeline route to the refineries along the San Pablo Bay, Carquinez Strait and Suisun Bay are shown in figures 33 and 35.

Alternative 7-2

Criteria

1. Site of deepwater port: At the existing waterfront facilities from Richmond to Avon.

2. Service area: Refineries in the Richmond-Martinez area.

3. Type of transshipment: All unloading would take place directly at the individual terminals.

4. Intermediate tank farms: No common-use intermediate tank farm would be required. Each oil company would require sufficient storage for its own operations, as it does now.

5. Type of berths: Fixed.

6. Throughput: 15 and 60 m.t.a. in 1980 and 2000 respectively. In 1980 each of the waterfront facilities of the six refineries would handle between 0.7 and 4.7 m.t.a., which would increase to 10 m.t.a. by 2000.

7. Tanker characteristics: 157,000 d.w.t. with 50-foot draft fully loaded.

Requirements

Supertanker berths. The following number of berths would be required: by 1980, one per oil company, or a total of six; between 1980 and 2000, none additional. It has been assumed that none of the existing waterfront facilities would be able to handle the hypothesized bigger tankers, and that six new berths would therefore have to be constructed before 1980.

Dredging quantities. The quantities to be dredged would be as follows:

1. Ocean channel. The same dimensions would be required as in alternative 7-1. Hence, no dredging would be required.

2. Southampton Shoal Channel. The same dimensions would be required as in alternative 7-1. Hence, 7.3×10^6 cubic yards of dredging would be required.

3. West Richmond Channel. The approximate dimensions would be: length, 4 miles; width, 575 feet; depth, 55 -5 = 50 feet. Average present depth per mile would be 48, 38, 38, and 48 feet. Total dredging quantity, including 2.5 feet of overdepth dredging, would equal 0.1 + 1.8 + 1.8 + 0.1 million cubic yards, or a total of 3.8 x 10^6 cubic yards.

4. Pinole Shoal Channel. The approximate dimensions would be: length, 11 miles; width, 575 feet; depth, 50 feet. Average present depth per mile would be 48, 40, 40, 40, 35, 35, 35, 35, 35, 35, and 48 feet. Total dredging quantity, including 2.5 feet of overdepth dredging, would equal 0.1 + 1.5 + 1.5 + 1.5 + 2.1 + 2.1 + 2.1 + 2.1 + 2.1 + 2.1 + 0.1 million cubic yards, or a total of 17.3 x 10^6 cubic yards.

5. Carquinez Strait-Suisun Bay Channel. The approximate dimensions would be: length, 4 miles; width, 575 feet; and depth, 50 feet. Average present depth per mile would be 40, 40, 35, and 35 feet. Total dredging quantity, including 2.5 feet of overdepth dredging, would equal 1.5 + 2.1 + 2.1 + 1.5 million cubic yards, or a total of 7.2 x 10^6 cubic yards.

6. Six turning basins and berthing areas. The average dimensions of each of the six combined areas would be: length, 1.5 x 980 = 1,470 feet; width, 1.5 x 980 = 1,470 feet; and depth, 50 feet. Average present depth would be 41 feet. Dredging quantity, including 2.5 feet of overdepth dredging, would equal 6.0 x 10^6 cubic yards.

Total dredging quantities would equal, for the ocean channel, none; and for inland channels and basins, 41.6 x 10^6 cubic yards.

Pipelines from berths to refineries. It is assumed that each terminal would require a 1-mile-long, 48-inch line; five pipelines would be installed on land and one on trestle, connecting each new berth with the existing manifold. No booster pumps would be required.

The locations of the deepwater ports and channels are shown in figures 34 and 36.

Alternative 7-3

Criteria

1. Site of deepwater port: Richmond's Long Wharf area.
2. Service area: Refineries in the Richmond-Martinez area.
3. Type of transshipment: Pipeline only.
4. Site of intermediate tank farm: At an unspecified location about 5 miles from the berths. This tank farm would serve the five refineries located outside the Richmond area.
5. Type of berths: Fixed.
6. Throughput: 15 and 60 m.t.a. in 1980 and 2000 respectively. Of this volume an assumed 10.3 m.t.a. in 1980 and 50 m.t.a. by 2000 would be transshipped by pipeline to the refineries outside the Richmond area; 4.7 m.t.a. in 1980 and 10 m.t.a. by 2000 would go directly to Socal's Richmond refinery.
7. Tanker characteristics: 250,000 d.w.t. with 58.5-foot draft fully loaded.

Requirements

Supertanker berths. The following number of berths would be required: Socal would require one berth in 1980, and no additional berths between 1980 and 2000; Common Terminal would require one berth in 1980 and two berths in 1985. It is assumed that two berths would be installed before 1980, and that the second common terminal berth would be constructed in 1984.

Dredging quantities. The quantities to be dredged would be as follows:

1. Ocean channel. The required dimensions of the Main Ship Channel would be: width, 760 feet; and depth, 67 feet. Taking into account 5 feet tide would

result in a required depth of 62 feet. The existing depth would be 55 feet; the length of the channel would be approximately 5 statute miles. Including 3 feet of overdepth dredging, the total dredging quantity would equal approximately 7.7×10^6 cubic yards.

2. Southampton Shoal Channel. The required dimensions would be: width, 665 feet; and depth, 64 feet, or, including 5 feet of tide, 59 feet. The channel length would be approximately 4 miles; average present depth per mile would be 40, 40, 33 and 37 feet. Total dredging quantity per mile, including 3 feet of overdepth dredging, would equal 3.1, 3.1, 4.3 and 3.6 million cubic yards, or a total of 14.1×10^6 cubic yards.

3. Turning basin and berthing area. The average dimensions of the combined area would be approximately: length, 3 x 1.5 x 1,095 = 4,925 feet; width, 1,300 feet; depth, 59 to 57 feet, therefore, 58 feet; and average present depth, 41 feet. Dredging quantity, including 3 feet of overdepth dredging, would equal 4.8×10^6 cubic yards.

Total dredging quantities would equal, for the ocean channel, 7.7×10^6 cubic yards; and for the inland basin and channel, 18.9×10^6 cubic yards.

Pipelines. From the common berths to the intermediate tank farm, one 48-inch line per berth would be required. The length of each line was set at 5 miles, of which 1 mile would be on trestle and 4 miles on land. No booster pumps would be required. From Socal's berth to its Richmond refinery, it is assumed a new 1-mile-long, 48-inch line would be required, to be installed on trestle, connecting the new berth with the existing manifold.

Intermediate tank farm. The required crude oil storage to serve the common terminal would be 1.13×10^6 long tons, to be installed before 1980. An additional storage of $1.32 - 1.13 = 0.19 \times 10^6$ long tons would be installed during 1984. Socal would require 1.13×10^6 long tons. There is presently available a storage capacity of 17 x 10^6 barrels, which is equivalent to approximately 2.3 x 10^6 long tons of crude oil. Thus no additional storage capacity would be required by Socal.

For general services an area of 20 acres is assumed to be sufficient. Including crude oil storage the total acreage requirement would be 1.32 x 50 + 20 = approximately 85 acres.

Pipeline from intermediate tank farm to refineries. The requirements would be the same as for alternative 7-1; thus, one 25-mile-long, 32-inch line would be sufficient until the year 2000.

The same installation program of booster stations selected for alternative 7-1 could be adopted: Before 1980, 1,150 b.hp. (15.5 m.t.a.); in 1982, 1,150 b.hp. additional (21 m.t.a.); in 1985, 2,300 b.hp. additional (27 m.t.a.).; in 1990, 4,600 b.hp. additional (34.5 m.t.a.); and in 1993, 9,200 b.hp. additional (45 m.t.a.).

The location and layout of the deepwater port and the assumed pipeline route to the refineries along San Pablo Bay, Carquinez Strait, and Suisun Bay are shown in figures 33 and 35.

Alternative 7-4

Criteria

1. Site of deepwater port: At the existing waterfront facilities from Richmond to Avon.
2. Service area: Refineries in the Richmond-Martinez area.
3. Type of transshipment: All unloading would take place directly at the individual terminals.
4. Intermediate tank farms: No common-use intermediate tank farm would be required. Each oil company would require sufficient storage for its own operations, as it does now.

5. Type of berths: Fixed.

6. Throughput: 15 and 60 m.t.a. in 1980 and 2000 respectively. In 1980 each of the waterfront facilities of the six refineries would handle between 0.7 and 4.7 m.t.a., which would increase to 10 m.t.a. by 2000.

7. Tanker characteristics: 250,000 d.w.t. and 58.5-foot draft fully loaded.

Requirements

Supertanker berths. The following number of berths would be required: by 1980, one per oil company, or a total of six; between 1980 and 2000, none additional. It is assumed that none of the existing waterfront facilities would be able to handle the hypothesized bigger tankers, and that six new berths would therefore have to be constructed before 1980.

Dredging quantities. The quantities to be dredged would be as follows:

1. Ocean Channel. The same dimensions would be required as in alternative 7-3. Hence, 7.7 x 10^6 cubic yards of dredging would be required.

2. Southampton Shoal Channel. The same dimensions would be required as in alternative 7-3. Hence, 14.1 x 10^6 cubic yards of dredging would be required.

3. West Richmond Channel. The approximate dimensions would be: length, 4 miles; width, 665 feet; and depth, 64 -5 = 59 feet. The average present depth per mile, would be 48, 38, 38, and 48 feet. Total dredging quantity, including 3 feet of overdepth dredging, would equal 1.9 + 3.5 + 3.5 + 1.9 million cubic yards, or a total of 10.8 x 10^6 cubic yards.

4. Pinole Shoal Channel. The approximate dimensions would be: length, 11 miles; width, 665 feet; and depth, 59 feet. Average present depth per mile

would be 48, 40, 40, 40, 35, 35, 35, 35, 35, 35 and 48 feet. Total dredging quantity, including 3 feet of overdepth dredging, would equal 1.9 + 3.1 + 3.1 + 3.1 + 3.9 + 3.9 + 3.9 + 3.9 + 3.9 + 3.9 + 1.9 million cubic yards, or a total of 36.5 x 10^6 cubic yards.

5. Carquinez Strait-Suisun Bay Channel. The approximate dimensions would be: length, 4 miles; width, 665 feet; and depth, 59 feet. Average present depth per mile would be 40, 40, 35, and 35 feet. Total dredging quantity, including 3 feet of overdepth dredging, would equal 3.1 + 3.1 + 3.9 + 3.9 million cubic yards, or a total of 14.0 x 10^6 cubic yards.

6. Six turning basins and berthing areas. The average dimensions of each of the six combined areas would be: length, 1.5 x 1,095 = 1,645 feet; width, 1.5 x 1,095 = 1,645 feet; and depth, 60 feet. Average present depth would be 41 feet. Dredging quantity, including 3 feet of overdepth dredging, would equal 13.2 x 10^6 cubic yards.

Total dredging quantities would equal, for the ocean channel, 7.7 x 10^6 cubic yards; and for the inland channels and basins, 88.6 x 10^6 cubic yards.

<u>Pipelines from berths to refineries</u>. It is assumed that each terminal would require a 1-mile-long, 48-inch line; five pipelines would be installed on land and one on trestle, connecting each new berth with the existing manifold.

The locations of the deepwater ports and channels are shown in figures 34 and 36.

<u>Alternative 7-5</u>

<u>Criteria</u>

1. Site of deepwater port: Monterey Bay, about 2 miles off Moss Landing.

2. Service area: Refineries in the Richmond-Martinez area.

3. Type of transshipment: Pipeline only.

4. Site of intermediate tank farm: At an unspecified location about 10 miles from the berths.

5. Type of berths: Monobuoys.

6. Throughput: 15 and 60 million long tons per year in 1980 and 2000, respectively.

7. Tanker characteristics: 400,000 d.w.t. and 83-foot draft fully loaded.

Requirements

Supertanker berths. The following number of berths would be required: two berths by 1980, and no additional berths between 1980 and 2000.

Dredging quantities. No dredging is required.

Water depth. A depth of 1.15 x 83 = 95 feet would be required.

Pipelines from supertanker berths to intermediate tank farm. One 10-mile-long, 48-inch line per berth would be required, of which 2.2 miles would be underwater and 7.8 miles on land. A small booster station would be required with a capacity of about (10 x 21.2 + 70 -150) x 52 = 7,000 b.hp. per line.

Intermediate tank farm. In 1980 the required crude oil storage would be 1.80×10^6 long tons. Allowing 15 acres for general services, the total land requirement would be approximately 50 x 1.80 + 15 = 105 acres.

Pipeline systems to the San Francisco area. One 42-inch line would be sufficient for the entire period 1980 through 2000. The total length of the line was estimated at 130 miles. The total length of the branch lines to the refineries was estimated at 10 miles; its size was set at 24 inches. No river crossings are taken into account, since their number and length is small in relation to the total pipeline length.

The following approximate horsepowers would be required: 130 x 10.68 = 1,400 b.hp. by 1980, and 130 x 519.36 = 68,000 b.hp. by 2000. The following installations would be made: 8,500 b.hp. (28.5 m.t.a.) before 1980, 8,500 b.hp. additional (36.5 m.t.a.) in 1985, 17,000 b.hp. additional (47 m.t.a.) in 1989, and 34,000 b.hp. additional (60 m.t.a.) in 1993. (The maximum throughput in million long tons per year of each system is indicated in parentheses.)

The location and layout of the deepwater port and the assumed pipeline route to the San Francisco refineries is shown in figure 37.

Bellingham-Ferndale (Washington) Area

Two crude oil alternatives, numbered 8-1 and 8-2, are considered in this part of the Pacific. These alternatives differ from each other in service area: the deepwater port considered in alternative 8-1 would serve the six refineries of the San Francisco area, while that of alternative 8-2 would serve the six refineries of San Francisco and the four major refineries of Los Angeles and Long Beach.

The location of the deepwater port and intermediate tank farm and the assumed pipeline routes are shown in figures 32 and 38.

Sites

Both alternatives consider a deepwater port in the Strait of Georgia, between Point Whitehorn and Sandy Point. This portion of the coast is located about 12 miles northwest of the port of Bellingham. It is about 10 miles long, and the 120-foot contour line parallels the coast at a distance of 900 to 3,000 feet.

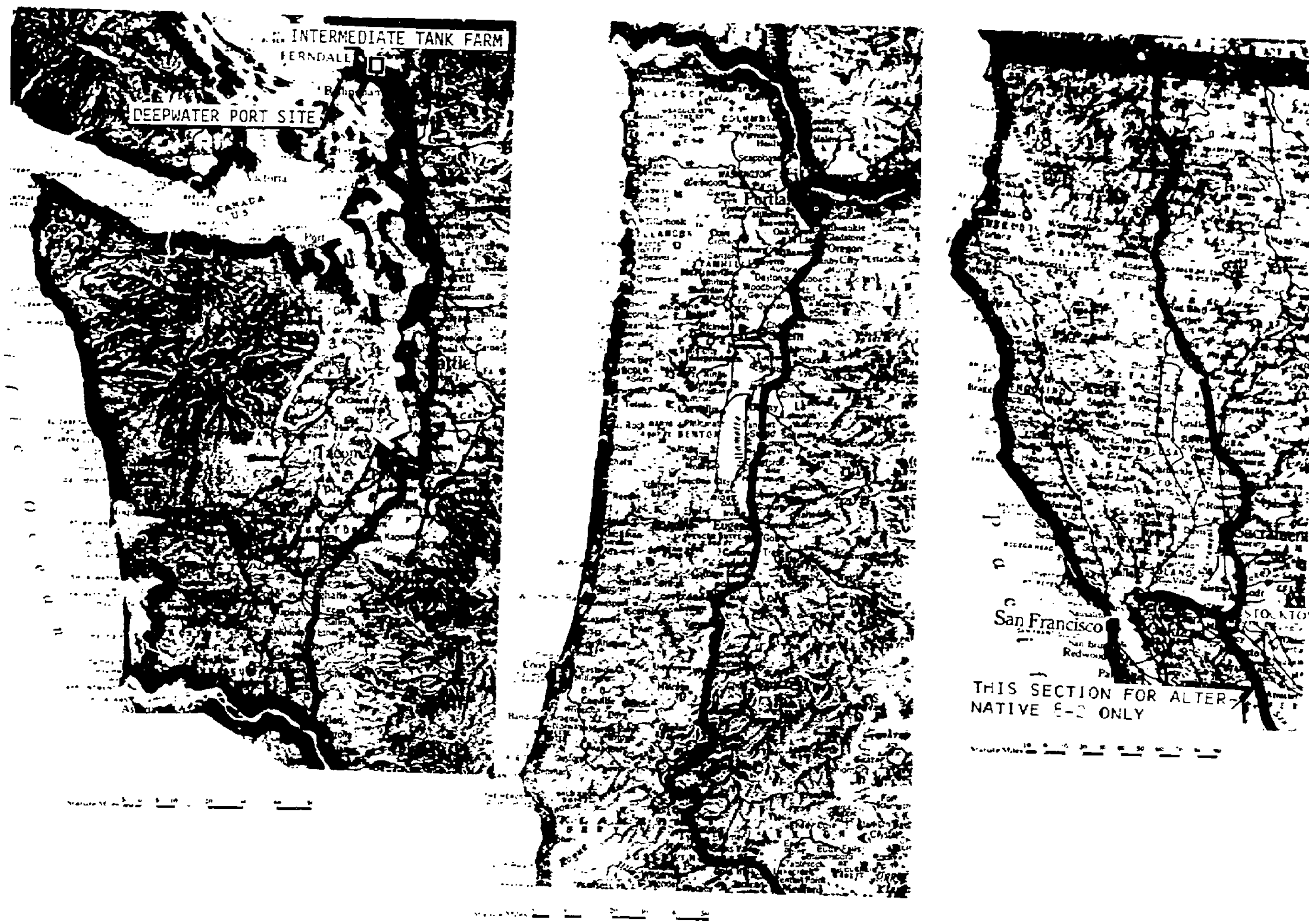

FIGURE 38. PIPELINE ROUTE BETWEEN FERNDALE, WASHINGTON, AND SAN FRANCISCO, ALTERNATIVES S-1 AND S-2

Robert R. Nathan Associates, Inc.

Transshipment

Both alternatives consider transshipment by pipeline only.

Throughputs

The throughputs of the deepwater ports are set at 15 m.t.a. in 1980 and 60 m.t.a. by 2000 for the San Francisco area, and 28 m.t.a. in 1980 and 111 m.t.a. by 2000 for the Los Angeles-Long Beach area. For both areas combined the throughputs would equal 43 m.t.a. in 1980 and 171 m.t.a. by 2000.

Type of Berths

Both alternatives consider fixed berths.

Site of Intermediate Tank Farm

It is assumed that this tank farm would be located at an unspecified site 5 miles from the berths.

Vessel Size

Both alternatives will consider 400,000-d.w.t. tankers only. It is assumed that all tankers using the deepwater facility will be of the maximum size. The assumed tanker dimensions are presented in table 68.

Table 68. Vessel Dimensions
(In feet)

Dimension	400,000 d.w.t.
Length.................	1,160
Beam...................	200
Draft..................	83

Dredging

Neither alternative would require any dredged channel, turning basin or berthing area, since sufficient water depth is available in the Strait of Juan de Fuca, the Rosario Strait and the Strait of Georgia.

Supply of Local Refineries

It has been assumed that the refineries at Ferndale, Anacortes and Tacoma will continue to use or will expand their facilities, if necessary, for the import of crude oil, and that they will therefore not participate in the common waterfront facilities and common pipeline to San Francisco and Los Angeles-Long Beach.

Construction Program

The time phasing of the various construction items used for the period prior to 1980 is given in table 69. The entire planning was simplified to facilitate calculations. The total cost of each item will be equally distributed over the pertinent years.

Table 69. Construction Program of Alternatives 8-1 and 8-2

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Tank farm..............				X	X
Supertanker berths......					X
Pipeline to refineries..			X	X	X

Alternative 8-1

Criteria

1. Site of deepwater port: Between Point Whitehorn and Sandy Point in the Strait of Georgia.

2. Service area: Six refineries in the San Francisco area.

3. Type of transshipment: Pipeline only.

4. Site of intermediate tank farm: At an unspecified location about 5 miles from the berths.

5. Type of berths: Fixed.

6. Throughput: 15 and 60 m.t.a. in 1980 and 2000 respectively.

7. Tanker characteristics: 400,000 d.w.t. and 83-foot draft fully loaded.

Requirements

Supertanker berths. The following number of berths would be required: two berths by 1980, and no additional berths between 1980 and 2000.

Dredging quantities. No dredging is required.

Pipelines from supertanker berths to intermediate tank farm. One 5-mile-long, 48-inch line per berth would be required, of which 2000 feet would be on a trestle and the remainder on land. No booster pumps would be required since the pressure at the end of the line would be $150 - 15 - 5 \times 21.2 = 29$ p.s.i.

Intermediate tank farm. The crude oil storage required in 1980 would be 1.80×10^6 long tons.

Allowing 15 acres for general services, the total land requirement would be approximately $50 \times 1.80 + 15 = 105$ acres.

Pipeline system to the San Francisco area. One 42-inch line would be sufficient for the entire period 1980 through 2000. The total length of the line was estimated at 950 miles. The total length of the branch lines to the six refineries was estimated at 10 miles. However, these branch lines will not be given further consideration because of their insignificance with respect to the trunk line. Also, river crossings will not be taken into consideration because their total length is insignificant in relation to the total length of the pipeline system. The assumed route of the pipeline is shown in figure 38.

The following approximate horsepowers would be required: 950 x 10.68 = 10,100 b.hp. by 1980, and 950 x 519.36 = 494,000 b.hp. by 2000. The following installations would be made: 61,750 b.hp. (28.5 m.t.a.) by 1980, 61,750 b.hp. additional (36.5 m.t.a.) in 1985, 123,500 b.hp. additional (47 m.t.a.) in 1989, and 247,000 b.hp. additional (60 m.t.a.) in 1993. (The maximum throughput in million long tons per year of each system is indicated in parentheses.)

The locations of the deepwater port and the intermediate tank farm, and the assumed pipeline route to the San Francisco refineries, are shown in figure 38.

Alternative 8-2

Criteria

1. Site of deepwater port: Between Point Whitehorn and Sandy Point, in the Strait of Georgia, Washington.

2. Service area: Six refineries in the San Francisco area and four in the Los Angeles-Long Beach area.

3. Type of transshipment: Pipeline only.

4. Site of intermediate tank farm: At an unspecified location about 5 miles from the berths.

5. Type of berths: Fixed.

6. Throughput: 43 and 171 m.t.a. in 1980 and 2000, respectively. To the San Francisco area would go 15 m.t.a. in 1980 and 60 m.t.a. in 2000; to the Los Angeles-Long Beach area, 28 m.t.a. in 1980 and 111 m.t.a. in 2000.

7. Tanker characteristics: 400,000 d.w.t. and 83-foot draft fully loaded.

Requirements

Supertanker berths. The following number of berths would be required: two berths by 1980, and three berths by 1988 (the one additional berth being constructed in 1987).

Dredging quantities. No dredging is required.

Pipelines from supertanker berths to intermediate tank farm. One 5-mile-long, 48-inch line per berth would be required, of which 2000 feet would be on a trestle and the remainder on land. No booster pumps would be required since the pressure at the end of the line would be 150 -15 -5 x 21.2 = 29 p.s.i.

Intermediate tank farm. The following crude oil storage would be required: 1.80 x 10^6 long tons in 1980 and 2.15 x 10^6 long tons in 1988 (the additional 0.35 x 10^6 long tons of storage being constructed in 1987).

Allowing 20 acres for general services, the total land requirement would be approximately 2.67 x 50 + 20 = 155 acres.

Pipeline system to California refineries. The pipeline system to California refineries would have two sections. The first section would run from Ferndale, Washington, to Stockton, California; the second section would run from Stockton to the Los Angeles-Long Beach refinery area. At Stockton, a branch line would connect the refineries of the San Francisco area with the trunk line.

1. Ferndale-Stockton section. This section would be about 900 miles long. Its assumed route is shown in figure 38. Since the ultimate throughput capacity would be 171 m.t.a., two 56-inch lines would be required. Each line would transport 85.5 m.t.a., which is close to its assumed optimum capacity of 90 m.t.a. For the first period, however, one 56-inch line would be sufficient, since 43 m.t.a. would be the initial throughput. The second line would be required by 1987, and would be installed in 1985 and 1986.

Designing both lines at a maximum throughput of 85.5 m.t.a., the following horsepowers would be required: the first line would require 900 x 47 = 42,300 b.hp. by 1980, and 900 x 333 = 300,000 b.hp. by 1987. The second line would require 900 x 333 = 300,000 b.hp. by 2000.

The following installations would be required: for the first line, 150,000 b.hp. (67 m.t.a.) before 1980, and 150,000 b.hp. additional (85.5 m.t.a.) in 1983; and for the second line, 37,500 b.hp. (42 m.t.a.) in 1986, 37,500 b.hp. additional (52 m.t.a.) in 1992, 75,000 b.hp. additional (67 m.t.a.) in 1994, and 150,000 b.hp. additional (85.5 m.t.a.) in 1996.

The maximum throughput capacity of each system in millions of long tons per year is indicated in parentheses. The year the additional booster capacity would be installed is assumed to be the year prior to its requirement.

2. Stockton-Los Angeles-Long Beach Section. The length of this section would be 335 miles. Although the initial capacity would be only 28 m.t.a., the ultimate throughput capacity would be 111 m.t.a. It is assumed that two 42-inch lines would meet the need best. Each line would transport 55.5 m.t.a. by 2000, which is close to its assumed optimum of 50 m.t.a. For the first period, however, one 42-inch line would be sufficient, since 28 m.t.a. would be its initial throughput. The second line would be required by 1987, and would be installed in 1985 and 1986.

Designing both lines at a maximum throughput of 55.5 m.t.a., the following horsepowers would be required: the first line would require 335 x 62 = 20,800 b.hp. by 1980 and 335 x 414 = 140,000 b.hp. by 1987. The second line would require 335 x 414 = 140,000 b.hp. by 2000.

The following installations would be required: for the first line, 70,000 b.hp. (44 m.t.a.) by 1980, and 70,000 b.hp. additional (55.5 m.t.a.) by 1983; and for the second line, 17,500 b.hp. (26 m.t.a.) in 1986, 17,500 b.hp. additional (34 m.t.a.) in 1992, 35,000 b.hp. additional (44 m.t.a.) in 1994, and 70,000 b.hp. additional (55.5 m.t.a.) in 1996.

The maximum throughput capacity of each system in millions of long tons per year is indicated in parentheses. The year the additional booster capacity would be installed is assumed to be the year prior to its requirement.

3. Stockton-San Francisco section. This branch line would be about 50 miles long. Since its throughput would be the same as that of the pipeline system for alternative 8-1, one 42-inch line and the same booster pressures per mile would be required. Since the length of this branch line is 50 ÷ 950 = 0.0526 times that of the trunk line of alternative 8-1, all horsepower requirements would be smaller in the same proportion. Therefore, the following horsepowers would be required: .0526 x 61,750 = 3,250 b.hp. by 1980, 3,250 b.hp. additional in 1985, 6,500 b.hp. additional in 1989, and 13,000 b.hp. additional in 1993.

It should be noted that all branch lines to the individual refineries are deleted from review due to their insignificance to the total project requirements.

The location of the deepwater port and the intermediate tank farm, and the assumed pipeline routes to San Francisco and Los Angeles-Long Beach, are shown in figures 32 and 38.

V. COST ESTIMATES OF CRUDE PETROLEUM PORTS

Unit Costs

First Cost

The main cost components of a deepwater port are the construction and/or installation cost of:

1. Berths
2. Channels and maneuvering areas
3. Pipelines
4. Tank farm
5. Artificial island
6. Land (acquisition cost)

The cost of each component will be evaluated in the following sections; however, all components do not necessarily apply to each type of port construction alternative. The year 1970 was selected as the basis year for the cost evaluation.

Berths

Supertankers. The two principal types of berths selected and applied in this detailed study are fixed berths (islands and marginal piers) and monobuoys. Because no berths that could accommodate tankers in the

100,000 to 500,000-d.w.t. class have yet been constructed in the United States, no factual U.S. construction figures exist. Since a study of this nature cannot evaluate cost data at a preliminary engineering level, cost estimates presented in recent studies have been used. The costs of the supertanker berths presented herein are based on cost estimates prepared by Divcon in June 1968 in a study entitled, Cost Study and Design of Marine Terminal Facilities Delaware Bay Transportation Company Delaware Bay, U.S.A. Since the 1970 cost of steel construction in general was reported to be 16 percent higher than in 1968, all costs estimated by Divcon have been increased in this report by 16 percent. For a 250,000-d.w.t. design vessel and a water depth of 72 feet at fixed berths and of 75 feet at monobuoys, Divcon's 1968 estimates were as follows:

1. For a marginal fixed pier with two berths, the jacket alternate is the cheapest solution. This amounted to $10.25 million, excluding the cost of the pumping platform, or $5.125 million per berth.

2. For an island fixed pier, the jacket alternate is again the cheapest solution. This amounted to $7.86 million for two berths, excluding the cost of the pumping platform.

3. For a monobuoy, the cost was estimated at $5.96 million for three buoys, excluding the pumping platform, or about $2 million per buoy.

In 1970 figures, the costs for estimates 1, 2, and 3 would be $5.95, $9.1, and $2.3 million, respectively.

To relate these costs to different vessel deadweight tonnages, water depths, and forces due to currents, waves and wind, multiplication factors will be established. In principle, it is impossible to establish these multipliers properly without hydraulic model test studies, since the forces are of a complex dynamic nature that depends on various spring constants. However, since the applied deadweight tonnage (250,000) and water depth (72 feet) are in the range of our study parameters, it is felt that the approach which was used is acceptable, considering its purpose and its relative importance in comparing identical cases.

For fixed berths it is assumed that the cost would be proportional with deadweight tonnage and water depth. Hence

$$C_2 = \frac{d.w.t._2}{d.w.t._1} \times \frac{w.d._2}{w.d._1} \times C_1$$

where

C_1 and C_2

are the costs of berths 1 and 2, respectively; $d.w.t._1$ and $d.w.t._2$ are the deadweight tonnages of the design vessel of berths 1 and 2, respectively; $w.d._1$ and $w.d._2$ are the water depths at berths 1 and 2 during berthing procedures.1/ The reasoning underlying this formula is that both increased deadweight tonnage and increased water depth would increase the overturning moments of the breasting and mooring dolphin structures and would result in an increase of the structural dimensions and required strength of the dolphins. The increase of the forces on the dolphin structures would normally be less than the proportional increase of the deadweight tonnage. However, the construction and installation difficulties would also be greater for greater depths and heavier construction units. Therefore, it is felt that the linear relation, as established, is a reasonable and acceptable approach.

In addition to the differences in deadweight tonnage and water depth, the forces on the structures and the difficulties of installation would be much greater at exposed locations than at sheltered locations. Therefore, for each site a theoretical exposure factor will be established which relates the cost of a certain berth

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1/ In this and subsequent formulas, subscript 1 indicates the design conditions of the base case, and subscript 2, the conditions of the considered alternative. Thus, in this formula, $d.w.t._1$ would be 250,000 d.w.t., and $w.d._1$ would be 72 feet.

at the site in the Lower Delaware Bay, selected by the Delaware Bay Transportation Company, with the cost of the same berth at another considered site. In the Lower Delaware Bay, berthing and moored vessels would be affected by crosscurrents and low waves. The difficulty of installation would also be affected by the currents and waves. At locations where these effects on the construction and installation costs are anticipated to be lower than, equal to, or higher than those at the Delaware Bay site, the applied exposure factors are respectively smaller than, equal to, or greater than 1.0. The selected exposure factor values are arbitrary and are based solely on judgment.

The forces on monobuoys are mainly determined by the deadweight tonnage of the tanker and the degree of exposure. It is assumed that the effects of variations in the tanker's deadweight tonnage and in water depth at the berth on the construction cost, and of variations in water depth at the berth and in forces due to exposure on the installation cost, are significantly smaller than in the case of fixed berths. The water depth at the buoy is of significance with respect to the length and weight of the anchor chains, and therefore to the buoyancy of the buoy; and with respect to the installation difficulties of the hoses between buoy and pipeline. The influence of these two factors is expressed in the formula

$$C_2 = C_1 \sqrt{\frac{d.w.t._2 \times exp_2}{d.w.t._1}}$$

where

C_1 and C_2

are the cost of buoys 1 and 2, respectively; $d.w.t._1$ and $d.w.t._2$ are the deadweight tonnages of tankers to be accommodated by buoys 1 and 2, respectively; and exp_2 is the exposure factor at the site of buoy 2.

The use of the square root is arbitrary; its purpose is to reduce the effect of variations in size.

The costs of the considered berth structures are presented by alternative and subalternative in tables 70, 71, and 72. The costs of marginal piers and monobuoys are presented by one-berth units; those of island piers, by one- and two-berth units. In the case of island piers, the cost of one berth is set at 65 percent of the cost of two. This is an experienced value based on the fact that both berths would use the same mooring dolphins and sometimes the same unloading platform.

Table 70. Cost of Marginal Berths[a]
(In millions of dollars)

Alternative	Sub-alt.	Vessel size (1,000 d.w.t.)	Water depth (feet)	Exposure factor	Cost of one berth
Base.........	--	250	72	1.00	5.95
2-1 through 2-4.........	A,B	300	74	1.00	7.3
2-1 through 2-4.........	C,D	400	74	1.00	9.8
6-1, 6-2.....	A	300	74	0.75	5.5
6-1, 6-2.....	B	400	74	0.75	7.3
7-1, 7-2.....	--	157	53	1.00	2.7
7-3, 7-4.....	--	250	62	1.00	5.1
8-1, 8-2.....	--	400	96[b]	1.00	12.7

a/ Including the cost of all mechanical equipment on the berths, such as unloading arms and manifold.
b/ 83 feet (draft) + 4 feet (clearance) + 9 feet (tide).

Table 71. Cost of Island Piers[a/]
(In millions of dollars)

Alternative	Sub-alt.	Vessel size (1,000 d.w.t.)	Water depth (feet)	Exposure factor	Cost	
					Two berths	One berth
Base......	--	250	72	1.00	9.1	--
1-1, 1-2..	A,B	300	74	.75	8.4	5.5
1-1, 1-2..	C,D	400	74	.75	11.2	7.3
2-5, 4-2..	A,B	300	85	1.3	16.8	10.9
2-5, 4-2..	C,D	400	85	1.3	22.4	14.6
4-1.......	A,B	200	75[b/]	1.3	9.9	6.4
4-3.......	A,B	500	120[b/]	1.3	28.0[c/]	18.2[c/]
5-4.......	A,B	200	58	0.6	3.5	2.3
5-5.......	A,B	300	74	0.6	6.7	4.4
5-5.......	C,D	400	74	0.6	9.0	5.8
5-6.......	A,B	500	100	0.6	11.2[c/]	7.4[c/]

a/ Including the cost of all mechanical equipment on the berths, such as unloading arms and manifold.
b/ Because of layout restrictions, the water depths are greater than the minimum required depths.
c/ Berthing speed is expected to be lower than in other cases.

Table 72. Cost of Monobuoys[a]
(In millions of dollars)

Alternative	Sub-alt.	Vessel size (1,000 d.w.t.)	Exposure factor	Multi-plier	Cost of one buoy
Base..........		250	1.0	1.0	2.3
1-3, 5-2......	A,B	300	1.5	1.35	3.1
1-3, 5-2......	C,D	400	1.5	1.55	3.6
5-1...........	A,B	200	1.5	1.1	2.6
5-3...........	A,B	500	1.5	1.75	4.1
7-5...........	--	400	1.5	1.55	3.6

a/ Including all mechanical equipment.

Transshipment barges. In a recent preliminary engineering study for the New York District of the U.S. Army Corps of Enginee s, Van Houten Associates, Inc., of New York estimated a cost of $1.1 million[1] for an island pier (including unloading arms) suitable to accommodate 40,000-d.w.t. tankers. The costs of 40,000-d.w.t. transshipment berths were established in relation to this value and to the rate of exposure, and are given in table 73.

Table 73. Cost of Transshipment Berths
(In million of dollars)

Alternative	Cost of one island pier (two berths)
Base.................	0.95
2-5..................	1.0
4-1,4-2, 4-3.........	1.0
5-1 through 5-6......	0.8

1/ This cost would be $0.95 million at a 1970 cost level.

Channels and Maneuvering Areas

The dredging cost will be based on experienced or estimated cost, on existing or planned disposal areas or disposal practice by local authorities, and on the soil characteristics, if available. In addition, the use of newly developed dredgers will be assumed where applicable.

New York area, alternatives 1-1 and 1-2. The present dimensions of the Ambrose Channel are: length, 10.2 statute miles; width, 2,000 feet; and depth, 45 feet. Dredging to 60 feet was estimated at $30 million in 1966 (see Annex B-1, appendix table 1). Although no dredging quantities were presented in this table, they would equal approximately

$$\frac{10.2 \times 5{,}280 \times (2000 + 3 \times 15) \times 15}{27} = 60 \text{ to } 65 \times 10^6 \text{ cubic yards.}$$

This would result in a unit dredging cost of approximately $0.45 per cubic yard at 1966 cost levels. It is assumed that dredged quantities would be disposed of in the Atlantic, because the Corps has used various disposal areas in this ocean for many years. Allowing for a cost increase of 25 percent during the period 1966 to 1970, and for a modest increase of about 10 percent for possible further offshore dumping combined with the use of bigger and modern equipment, the unit cost was established at $0.60 per cubic yard for the Ambrose Channel.1/ It is not anticipated that the dredged material would be significantly different from the soil encountered thus far.

It is anticipated that the sand fill required for island construction would be dredged from the berthing areas and turning basin. This would take place when the breakwater construction was substantially completed. Under these conditions a cutter head dredger equipped with a floating pipeline would be able to execute the work. It is estimated that, including the cost of leveling the island, the work could cost $0.40 per cubic yard. For the remainder of the amount to be dredged for the berthing areas and turning basin, a

1/ Recent information quotes $0.90 per cubic yard.

cost of $0.80 per cubic yard was established since the dredged material will be disposed of in the Atlantic, as was the case for the Ambrose Channel.[1]

Delaware Bay area, alternatives 2-1 through 2-5. No data are available with respect to the soil conditions of channels A, B, and D. Therefore, a cost was established in relation with that of the New York area. Taking into account the various distances to deep water, the following costs were established: channel A, $0.40 per cubic yard; channel B, $0.80 per cubic yard; and channel D, $0.90 per cubic yard.[2]

It is anticipated that the quantity and quality of sand fill required for the construction of the artificial island would not be found close enough to the site to permit the use of a cutter head dredger. Therefore, the cost was based on the use of a trailing hopper dredger in conjunction with a suction dredger. Including losses during the construction of the island, the cost was set at $1.00 per cubic yard.

Mississippi Delta area, alternatives 4-1 through 4-3. For the cost of the sand fill of the artificial island, the same basis was used as for that in the Delaware Bay. Therefore, a cost of $1.00 per cubic yard will be applied.

Freeport area, alternatives 5-4 through 5-6. Soil borings up to 90 feet deep are available at the existing ocean channel. They show various clay layers ranging in consistency from soft to hard (the harder clay is called Beaumont clay). It cannot be predicted how far these layers extend into the gulf. Therefore, arbitrary values were selected, which might very well be low. These values are: for the ocean channel, $1.00 per cubic yard; and for the inland basins and channels, $1.30 per cubic yard.

Jetties would be required at both sides of the channel to the deepwater harbor to protect the channel

1/ Recent information quotes $0.90 per cubic yard.
2/ Recent information quotes $1.15 per cubic yard on the average.

in the shore area. The presently authorized 45-foot channel to Freeport will require relocation of the present North Jetty. The cost of constructing a new jetty was estimated at about $5 million by the Galveston District of the Corps of Engineers. The offshore section of the jetty would be about 3,300 feet long; its tip would be located in about 17 feet of water. The required depth at the tip of the jetties in alternatives 5-4 through 5-6 is assumed to be about one-third to one-fourth of the hypothesized ocean channel depths. The depths at the tips of the jetties were set at 21, 24, and 27 feet, and these depths occur at distances of 0.7, 1.2 and 2.0 miles off shore, for alternatives 5-4, 5-5, and 5-6, respectively. Each of these respective jetties would require an amount of stone 2.5, 4.0 and 6.5 times greater than the proposed new North Jetty. Therefore, the cost of each jetty was established at: 2.5 x $5 million = $12.5 million for alternative 5-4; 4.0 x $5 million = $20.0 million for alternative 5 5; and 6.5 x $5 million = $32.5 million for alternative 5-6.

Los Angeles Area, Alternatives 6-1 and 6-2. According to the Interim Review Report on Los Angeles-Long Beach Harbors,1/ a volume of 13.8 million cubic yards would be dredged at a cost of $7.6 million. Therefore, a unit cost of $0.55 per cubic yard was applied. The same unit cost will be used in this study.

San Francisco Area, Alternatives 7-1 through 7-4. According to a Corps of Engineers' study,2/ maintenance dredging of the Oakland area would cost $0.55 per cubic yard if a disposal area in the Pacific were used (a 32-mile round-trip distance). The 1970 cost would be about $0.75 per cubic yard. The round-trip distance for Richmond and Pinole Shoal Channels would be 28 and

1/ Department of the Army, Corps of Engineers, Interim Review Report on Los Angeles-Long Beach Harbors, Los Angeles District, June 1971, p. E-6.

2/ Department of the Army, Corps of Engineers, Committee on Tidal Hydraulics, San Francisco Bay, California; Disposal of Dredge Spoil, Supplement 1 to Appendix V, Sedimentation and Shoaling and Model Tests to Report of Survey on San Francisco Bay and Tributaries, California, Vicksburg, Mississippi, December 1965, p. 23.

56 miles, respectively, according to this study.[1/] Because the unit cost of maintenance dredging should be lower than that of first-cost dredging and because no sufficient soil data are available, the following unit costs were established: for the channel to Richmond, $1.00 per cubic yard; and for Pinole Shoal and Carquinez Strait-Suisun Bay Channel, $1.50 per cubic yard. It is anticipated that the main portion of the dredged material of the latter channel would be used for landfill within diked areas.[2/]

Pipelines

To determine the various cost components of installed pipelines, a survey on the cost of recently installed lines was undertaken. Detailed cost breakdowns of gasline projects are available through the Interstate Commerce Commission (ICC). Detailed costs on petroleum product lines are not obtainable because these projects do not require authorization by ICC and because the companies involved are reluctant to release detailed information. The annual tabulation of the total cost and of the four main cost components of transmission lines given in the Oil and Gas Journal could not be used, since analyses showed differences of over 100 percent in costs per mile. For instance, an analysis of six of the thirteen 36-inch onshore transmission lines, as published in the August 2, 1971, Oil and Gas Journal (p. 104), showed costs per mile as presented in order of increasing length in table 74.

The two main components of the total cost are those of material and labor. The primary reasons for the variation in material cost are the variation in the wall thickness of the pipe and the included cost of valves, tie-overs, headers, pig traps, etc. The variation in labor cost arises from the presence of river crossings. The reason that the variation in cost is not a function of length in this tabulation is that the

1/ The disposal area would be located west of Seal Rocks, approximately 2 miles off the Golden Gate, within the ocean bar.

2/ It is reported that the dredging cost would run close to $2.00 per cubic yard if dumping were allowed only at the 100-fathom line, which is located 35 miles off the entrance of the Golden Gate.

Table 74. Cost Components of 36-Inch Transmission Lines

(In thousands of dollars per mile)

Length of line (miles)	State	Right-of-way and damages	Material	Labor	Miscellaneous	Total
4.13.............	Kentucky	50.5	136.7	154.0	16.3	357.5
9.80.............	Oklahoma	1.4	119.5	46.2	15.2	182.3
36.04.............	Louisiana	19.5	168.0	100.9	23.9	312.3
51.12.............	Kentucky	6.5	105.0	67.6	7.2	186.3
153.1.............	New Mexico-Illinois	5.4	94.0	55.3	8.0	162.7
202.2.............	Kentucky-Louisiana	8.1	129.4	92.9	16.2	246.6

mileage shown is a total of sections of various lengths installed along a pipeline length often 5 to 20 times longer than the shown mileage.

Seven specific 1969 projects have been analyzed to determine the four cost components of 36- and 42-inch onshore lines, of 36-inch river crossings, and of 36-inch offshore lines. The ICC docket numbers of these projects are CP 69-115, CP 69-139 and CP 69-184 for the onshore lines; CP 69-346 for the river crossings; and CP 69-326, CP 69-327 and CP 69-336 for the offshore lines. All material costs will be transformed to an equivalent cost for pipes with a wall thickness of 0.500 inches.

Onshore lines. The following paragraphs will analyze projects CP 69-115, CP 69-139, and CP 69-184, as filed at ICC.

1. Project CP 69-115.

Company: Texas Gas Transmission Corporation.

Route: From Monroe, Louisiana, to Louisville, Kentucky, mainly parallel the Mississippi River and Ohio River; total length, about 550 miles.

Total length of new pipelines: 41.74 miles of 36-inch onshore line (seven sections) and 2.4 miles of 42-inch onshore line (one section). Lengths of the seven sections of 36-inch line: 1.95, 3.30, 3.75, 4.16, 8.04, 10.08, and 10.46 miles. The cost was presented in three sections 34.28, 3.30, and 4.16 miles long.

Locations of sections: Monroe, Louisiana; Cleveland, Mississippi; Memphis, Tennessee; and Louisville, Kentucky.

Table 75 presents the total cost and a breakdown by the four components of the four sections of the line, as filed. Table 76 shows the same cost components, but per mile, and in addition shows the two main components (materials and installation) separately by pipe and valves, traps, etc.

For the various sections, the unit costs listed in table 77 were applied. It should be noted that in

Table 75. Cost Components of Transmission Lines of Project CP 69-115

(In thousands of dollars)

Section	Land survey and right of way	Materials	Installation	Engineering and supervision	Total
34.28 miles of 36-inch.......	494	4,103	3,068	96	7,761
3.30 miles of 36-inch.......	21	541	512	13	1,087
4.16 miles of 36-inch.......	64	682	712	19	1,477
2.4 miles of 42-inch.......	36	768	413	15	1,232

Table 76. Cost Components Per Mile of Transmission Lines of Project CP 69-115

(In thousands of dollars per mile)

Land survey and right of way	Materials		Installation		Engineering and supervision	Total
	Pipe and coating	Valves, traps, etc.	Pipe	Valves, traps, etc.		
14.4....	106.2	13.5	73.9	15.6	2.8	226.4
6.4....	128.2	35.7	107.9a/	47.3	3.9	329.4
15.4....	128.1	35.8	127.4b/	43.7	4.6	355.0
15.0....	195.4	124.6	84.5	87.5	6.3	513.3

a/ Including $18.2 thousand for rock trenching, or $89.7 thousand without rock trenching.
b/ Including $32.5 thousand for rock trenching, or $94.9 thousand without rock trenching.

this table different unit costs of material and installation for the same pipe size were applied depending on location of the particular section. Valves for 36-inch lines were listed at $30,000 to $38,000 material cost each, and $25,000 installation cost each. Pig traps were listed at $20,000 material cost each and $11,000 installation cost each.

Table 77. Unit Costs of Various Pipe Sizes
(In dollars)

Diameter and wall thickness (inches)	Pipe and coating		Installation	
	Foot	Mile	Foot	Mile
36/.360	16.75	88,440	14.00	73,920
36/.430	19.70	104,016	14.00	73,920
36/.516	23.85	125,928	14.00	73,920
	23.50	124,080	17.00	89,760
42/.602	37.00	195,360	16.00	84,480

If the material costs of the five pipes of table 77 are transformed to the costs for pipes with a wall thickness of 0.500 inch, the material cost per mile would be $128,833, $120,949, $122,023, $120,233, and $162,259, respectively. This results in an average material cost of $123,010 per mile for the 36-inch, 0.500-inch wall-thickness line. The average installation cost of the 36-inch line was $77,880, and that of the 42-inch line was $84,480.

The average survey and right-of-way costs per mile of the four sections of table 76 were $14,410, $6,364, $15,385, and $15,000, respectively, and that of engineering and supervision, $2,800, $3,939, $4,567, and $6,250, respectively. The averages of these values would be $12,790 and $4,390.

2. Project CP 69-139.

Company: Texas Gas Transmission Corporation.
Route: From Columbia, Louisiana, to Kenton, Tennessee.

Length of sections: 1.44, 1.57, 0.87, 1.63, and 2.53, or a total of 8.04 miles of 36-inch onshore pipe.

The basic cost data are presented in table 78.

Table 78. Unit Cost
(In dollars)

Diameter and wall thickness (inches)	Pipe and coating		Installation	
	Foot	Mile	Foot	Mile
36/.360............	16.75	88,440	13.50	71,280
36/.430............	19.70	104,016	13.50	71,280

If the above pipes are transformed to a wall thickness of .500 inch, the material costs are $122,755 and $120,867 per mile, or an average cost of $121,810. The costs of right-of-way and damages were $51,456 or $6,400 per mile, and the costs of survey, field engineering, and supervision were $22,802, or $2,836 per mile.

3. Project CP 69-184.

Company: Transcontinental Gas Pipeline Corporation.

Route: From Louisiana via Mississippi, Alabama, and Virginia to Frederick, Maryland.

Total length of lines installed: 33.07 miles of 24-inch pipe, 33.19 miles of 30-inch pipe, and 67.07 miles of 42-inch pipe. Only the latter one will be analyzed, since this cost analysis does not consider pipes smaller than 36-inch.

Length of the 42-inch sections: 6.36 miles (Louisiana, Mississippi), 5.50 miles (Mississippi), 4.63 miles (Alabama), 13.89 miles (Alabama), 10.42 miles (Virginia), and 25.35 miles (Maryland).

The unit material cost (per foot) ranged from $21.34 to $21.67 for a .390-inch wall thickness, from $24.46 to $25.78 for a .469-inch wall thickness, and from $30.39 to $31.51 for a .562-inch wall thickness.

For pipes with a wall thickness of .500 inch, these values would be \$27.36, \$27.78, \$26.08, \$27.48, \$27.04, and \$28.03, respectively. The average value would be \$27.30.

The unit installation cost (per foot) varied between \$11.85 and \$16.47; an average value would be \$14.16.

The cost components are: right-of-way and damages, \$20,486 per mile; material, \$144,144 per mile (equivalent 0.500 inch); installation, \$74,765 per mile; and survey and engineering, \$7,037 per mile.

The results of the analysis of these three projects are presented in table 79.

The total average unit costs are \$210,200 per mile for a 36-inch line and \$257,300 per mile for a 42-inch line. If the cost of a 36-inch line were transformed into that of a 42-inch line using the ratio of the diameters, this would result in 42/36 x \$210,200 = \$245,200. This proves that the total costs of pipelines relate to each other approximately in proportion to their diameters.

Transforming the average total unit cost of the 42-inch lines into that of 48-inch lines would result in 48/42 x \$257,300 = \$294,057. At 1970 cost levels this would be approximately \$300,000. Therefore, average total unit costs were established for onshore lines as presented in table 80.

The unit costs of table 80 will be applicable for all alternatives except 1-3, 8-1, and 8-2. For alternative 1-3, it is anticipated that the pipelines would traverse the center of Long Branch, New Jersey. The costs of right-of-way and damages and of installation would be considerably higher than the average unit costs. The total cost of all lines between the shore and the intermediate tank farm will be increased by an arbitrary value of 50 percent. For alternative 8-1 and 8-2, the pipelines to the California refineries would have to traverse mountainous areas of Oregon and north California. Therefore, the total unit cost will be

Table 79. Summary of Unit Costs of ICC Projects
(In thousands of dollars per mile)

Project	Diameter (inches)	Right-of-way and damages	Material (0.500" wall thickness)	Installation	Miscellaneous	Total
CP 69-115....	36	12.79	123.01	77.88	4.39	218.07
CP 69-115....	42	15.00	162.29	84.48	6.30	268.07
CP 69-139....	36	6.40	121.81	71.28	2.84	202.33
CP 69-184....	42	20.49	144.14	74.77	7.04	246.44

Table 80. Average Total Unit Cost of Onshore Lines on 1970 Cost Basis

(In thousands of dollars per mile)

Diameter	Cost
24	150
32	200
36	225
42	263
48	300
56	350

increased by an arbitrary value of 30 percent, applicable for a 300-mile-long section. This 30 percent corresponds with an installation cost twice as high as that included in the regular total average unit cost (see table 79).

River crossings. The cost of pipelines crossing water bodies, such as rivers and canals, will be based on analysis of Project CP 69-346. The rivers crossed are in the Northwest United States. The main cost components of the various crossings are presented in table 81; the costs presented in the ICC files were transformed to unit costs per mile.

Based on table 81 and judgment, extrapolations were made for the costs of crossings up to 1 mile long. These are presented in table 82.

Offshore submarine lines. The cost of submarine lines will be based on analysis of Projects CP 69-326, CP 69-327, and CP 69-336. The main cost components of these projects, all transformed to a unit cost per mile, are presented in table 83.

Averaging the three major cost components of the 16-inch lines and expressing these averages on a 20-inch line cost basis would result in the following values in thousands of dollars per mile:

Table 81. Unit Cost of River Crossings

(In thousands of dollars per mile)

Project code	Diameter (inch)	Length (miles)	River	Location of crossing	Material (.625" wall thickness)	Installation	Contingency (percentage)
CP 69-346....	36	0.2	Kootenai	Bonners Ferry, Idaho	295	1,445	10
CP 69-346....	36	0.4	Pend Oreille	Sand Point, Idaho	231	1,120	10
CP 69-346....	36	0.3	Snake	Starbuck, Washington	---1,843---		11
CP 69-346....	36	0.2	Umatilla	Stanfield, Oregon	---1,325---		8
CP 69-346....	36	2.4[a/]	Sprague	Klamath Falls, Oregon	275	466	8

a/ Text is not explicit on length of river crossing.

Table 82. Total Cost of River Crossings
(In millions of dollars)

Length (miles)	Pipe sizes (inches)		
	36	48	56
0.1................	0.20	0.27	0.31
0.2................	0.40	0.53	0.62
0.3................	0.50	0.67	0.78
0.4................	0.60	0.80	0.93
0.5................	0.73	0.97	1.14
0.6................	0.84	1.12	1.31
0.7................	0.95	1.27	1.48
0.8................	1.04	1.39	1.62
0.9................	1.12	1.49	1.74
1.0................	1.20	1.60	1.87

1. Unit material cost = $\frac{(47.1 + 45.6)}{2} \times \frac{20}{16} = 57.9$

2. Unit installation cost = $\frac{(79.2 + 66.0)}{2} \times \frac{20}{16}$ $= 90.8$

3. Unit survey, etc., cost = $\frac{(6.9 + 5.3)}{2} \times \frac{20}{16}$ $= 7.6$

Averaging these cost components with those of CP 69-336 results in values of 65.1, 99.0, and 8.6, respectively. The total of these components is 190.0, including an arbitrary value of 10 percent for the cost of right of way. On the assumption that the cost of submarine lines is proportional to their diameter, an equivalent value of 48/20 x 190 = 456 for 48-inch lines would apply on a 1969 cost basis. The total cost of 48-inch submarine lines on a 1970 cost basis was set at $500,000 per mile.

<u>On-trestle lines.</u> For offshore lines on trestles a cost <u>value three times</u>[1/] higher than that for onshore

1/ The value of three is based on experience and judgment.

Table 83. Unit Cost of Submarine Transmission Lines

(In thousands of dollars per mile)

Project code	Diameter (inch)	Wall thickness (inch)	State	Total length (miles)	Number of sections	Right of way, damages, landing fee	Material (.500" wall thickness)	Installation	Survey, field engineering, and supervision
CP 69-326	16	.500	Louisiana	5.5	1	--	47.1	79.2	6.9
CP 69-327	16	.406	Louisiana a/	12.2	1	0.0	45.6	66.0	5.3
CP 69-336	20	.500 .562	Louisiana a/	28.2	1	0.0	61.2 76.3	107.2	9.6

a/ Text is not explicit that line is located in Louisiana.

lines was selected, which would equal $900,000 per mile for 48-inch lines. This ratio will depend on the water depth, bottom and wave conditions.

Risers. The cost of risers will not be taken into consideration since it is insignificant with respect to the total cost of long submarine lines.

Booster platforms. The 1968 costs of booster platforms (pumping platforms) estimated by Divcon were in the range of $0.70 million or, at a 1970 cost level, $0.81 million. The cost depends on the size of the structure and of the boosters, the water depth, and the rate of exposure.

Costs of booster platforms were established based on Divcon's estimate and on judgment regarding the influence of water depth, size, and rate of exposure on the cost, and are given in table 84.

Table 84. Cost of Booster Platforms

(In millions of dollars)

Alternative	Water depth (feet)	Number of booster pumps	Cost of one platform
Base..............	55	3	0.81
1-3, 2-1, 2-3.....	66	5	1.00
5-1...............	60	7	0.80
5-2...............	80	5	1.00
5-3...............	100	5	1.30

Booster pumps. A figure of $150 per b.hp. was established.

Meters and valves. The cost of meters and valves combined was established at $1 million per berth and per refinery.

Tank Farm

In their study of the cost of a deepwater port off Big Stone Beach, the Delaware Bay Transportation Company projected a storage capacity of 17 million barrels, equivalent to approximately 2.35 million long tons of crude oil. Their 1970 estimated cost was approximately $60 million, including all tank farm piping. This figure would result in a unit cost of $25.5 per long ton. In their recent study for the New York District of the U.S. Army Corps of Engineers, Van Houten Associates, Inc., gave a cost of $4.00 per barrel of storage, including all tank-farm piping. This figure is equivalent to $29.2 per long ton of storage, or $25.2 per long ton at a 1970 cost level.

Based on the above figures, a value of $26 per ton of storage was selected. The cost of all tank-farm piping is included in this figure.

Artificial Island

The cost of an artificial island is determined by the cost of the breakwater(s) and of the sand fill. Since the cost of the sand fill is given in the section entitled "Channels and Maneuvering Areas," this section will deal only with that of the breakwater.

The cost of a breakwater is determined mainly by the water depth, design wave characteristics, anticipated conditions of the sea during the construction period, the type of structure and construction selected, and the cost of labor and material. Because no data on design or construction cost of breakwaters at the selected sites are available, very rough estimates of cost will be used in this report.

In a current study for a breakwater in about 20 feet of water at City Island in the westernmost area of Long Island Sound, a preliminary cost estimate arrived at $4,000 per foot of breakwater length, or about $20 million per statute mile.

<u>For alternatives 1-1 and 1-2</u>, an average water depth of 15 feet would apply. Establishing the top of the breakwater at +25 feet, establishing the influence of the water depth by the formula

$$\left(\frac{\text{water depth } +25}{45}\right)^2$$

and assuming an exposure factor of 1.25 compared with City Island, the unit cost would be:

$$\left(\frac{40}{45}\right)^2 \times 1.25 \times 20 = \$20 \text{ million per mile.}$$

<u>For alternatives 2-2 and 2-4</u>, an average water depth of 2 feet would apply. With the top of the breakwater at +25 feet and with an exposure factor of 1.00, the unit cost would be:

$$\left(\frac{27}{45}\right)^2 \times 20 = \text{approximately } \$7 \text{ million per mile.}$$

<u>For alternative 2-5</u>, applying an average water depth of 45 feet and an exposure factor of 1.50, the unit cost would be:

$$\left(\frac{70}{45}\right)^2 \times 1.5 \times 20 = \text{approximately } \$75 \text{ million per mile.}$$

<u>For alternatives 4-1 through 4-3</u>, applying an average water depth of 35 feet and an exposure factor of 1.50, the unit cost would be:

$$\left(\frac{60}{45}\right)^2 \times 1.5 \times 20 = \text{approximately } \$55 \text{ million per mile.}$$

It is anticipated that no breakwater structure will be applied on the land side of the artificial island. A sand slope will be used instead. The angle of internal friction might be 1 to 4 above the waterline, and 1 to 8 or 1 to 10 below the waterline. A simple slope protection would be required which would reach deep enough below low-water level to protect the slope against wave attack. A cost of $2 million per mile was established for this kind of protection applicable for all alternatives.

Land

The costs per acre that were established for the various hypothesized onshore sites are as follows:

1. New Shrewsbury, New Jersey: $10,000 (alternative 1-3)
2. Big Stone Beach, Delaware: $5,000 (alternatives 2-1, 2-3)
3. Freeport, Texas: $2,000 (alternatives 5-1 through 5-6)
4. Los Angeles, California: $20,000 (alternative 6-2)
5. Richmond, California: $20,000 (alternatives 7-1, 7-3)
6. Moss Landing, California: $10,000 (alternative 7-5)
7. Ferndale, Washington: $5,000 (alternatives 8-1, 8-2).

The cost of the construction of artificial islands is covered in the cost of breakwaters and sand fill.

Operating Cost

The operation of a deepwater port is divided into the following components:

1. Marine operations
2. Unloading and loading operations at the berths
3. Tank farm operations
4. Pipeline operations
5. Personnel transport.

The costs given for these components will provide only for the cost of personnel and equipment directly related to the operations. It is anticipated that all facilities would operate on a 7-day-a-week program and that four 8-hour shifts would therefore be required. The average annual labor cost of a person is set at $15,000.

Marine Operations

The minimum amount of personnel required for marine operations is given in table 85.

Table 85. Personnel Requirements by Number of Berths

Personnel	Number of supertanker berths				Number of transshipment berths	
	Fixed		Buoy			
	1-8	9-16	1-8	9-16	1-8	9-16
Dock master......	1	1	1	1	--	--
Assistant dock master..........	4	4	4	4	--	--
Foremen..........	4	8	4	8	4	8
Oarsmen..........	24	48	12	24	16	32
Total...........	33	61	21	37	20	40

In the case of fixed berths, tugs would be required to assist tankers during their maneuvering in the channels and at the berths. The number of tugs used during these operations would vary from two to six, depending on the horsepower capacity of the tugs, the deadweight tonnage and loading condition of the tanker, and the conditions of currents, waves and wind. Because of the amount of labor involved in tug operations, the present trend in the United States as well as abroad is toward the use of a small number of very powerful tugs.

For this study, the requirement for fixed berths will be set at three 4,000 shaft-horsepower (s.hp.) tugs for supertanker operations and one 4,000 s.hp. tug for transshipment barge operations. It is anticipated that this number would provide safe and smooth operations.

Launches are required to transport oarsmen to the hooks on the mooring dolphins and to assist in transporting the ropes and wires from tankers to dolphins.

In the case of monobuoys, no tugs, but two powerful launches, are required. The launches are required to transport the floating hoses to and from the tanker. The annual cost of a 4,000 s.hp. tug was estimated at $660,000, that of a powerful launch at $175,000, and that of a small launch at $65,000. According to table 11 of chapter III, the berth occupancy time at a fixed berth varies from 27 to 44 hours. It has been anticipated that each tanker would require an average tug assistance time of 10 tug-hours for maneuvering, berthing and deberthing. Since the average berth occupancy time of a supertanker would be 1.5 days, each berth would require 10/1.5 = 7 tug-hours per day. Three tugs operating 75 percent of the time would have 3 x 24 x .75 = 54 tug-hours available. This means that they could serve 54/7 = 8 berths. For nine or more berths, more tugs would be required. This number is set at two. It is anticipated that a team of oarsmen would spend 3.5 hours in berthing and deberthing a supertanker. Since the average berth occupancy time of such a tanker would be 1.5 days, each berth would require 3.5/1.5 = 2.3 team-hours per day. One team operating 75 percent of the time would have 24 x .75 = 18 hours available. This means that they could serve 18/2.3 = 8 berths. For nine berths and over, four additional shifts of oarsmen would be required. For monobuoys the requirement of launches and oarsmen will also double for nine or more berths.

For transshipment berths, it is anticipated that one extra tug would be required to assist a tug-barge combination during berthing and deberthing operations, and that this extra tug would spend about 1 hour per barge. Since the average berth occupancy time of a transshipment barge would be 6 hours, or 0.25 days, each berth would require 1/0.25 = 4 tug-hours per day. One tug operating 75 percent of the time would have 24 x .75 = 18 hours available. This means that one tug would serve 18/4 = 4.5 berths, or that two tugs could serve nine berths. To keep the computations comparable with those for supertanker berths, it is assumed that these two tugs would be required for eight berths and less, and that two more tugs would be required for nine or more berths. The annual operating cost of two tugs, each with a capacity in the range of 1,000 s.hp., is set at $635,000.

Table 86 presents the annual operating cost of the various berths concepts.

Table 86. Annual Operating Cost by Number of Berths

(In millions of dollars)

Item	Number of supertanker berths				Number of transshipment berths	
	Fixed		Buoy			
	1-8	9-16	1-8	9-16	1-8	9-16
Personnel...	0.495	0.915	0.315	0.555	0.300	0.600
Launches....	0.065	0.130	0.350	0.700	0.065	0.130
Tugs........	2.000	4.000	--	--	0.635	1.270
Total.......	2.560	5.045	0.665	1.255	1.000	2.000

In the foregoing it has been assumed that the tugs and oarsmen required at the deepwater port would be used exclusively at the deepwater port. However, if a deepwater port were to be located near other port facilities, the same tugs and oarsmen could be used by all facilities. This would considerably reduce the operating cost of the deepwater port, especially for three berths and less. How great a reduction this would be would depend on the distances between the deepwater port and the other facilities and on the necessity for tug assistance at the other facilities in comparison with the deepwater port. Assuming that other facilities in the vicinity would share the use of tugs and oarsmen, an arbitrary reduction factor of 50 percent will be taken into account in the case of alternative 1-1, subalternatives A and C of alternative 1-2, and alternatives 6-1, 6-2, 7-1, 7-3, 8-1, and 8-2.

Unloading and Loading Operations at the Berths

During the entire period of unloading a supertanker or loading a transshipment barge, one operator would be present at the berth. Therefore, four operators would be required for each berth per week. The annual labor cost would amount to $60,000 per berth

Tank Farm Operations

The number and kind of personnel required on the tank farm depend on the metering system of the tanks and the possibility of operating the valves from a central control room (remote control system). In this study, five persons per shift will be assumed a sufficient number; thus, 20 persons would be required, at an annual cost of $300,000. The cost of personnel handling the bunkering facilities will not be included in the cost of the tank farm operations, since they provide a service whose cost is separate from that of crude oil handling. The cost of personnel handling the oil separation and cleaning system and the floating oil spill abatement equipment, if present, will also be excluded. These costs are excluded because these personnel would provide a service only in an emergency, and because most probably all these costs would be compensated by the payments of fines, etc., by the company responsible for the spill. The cost of the pumphouse personnel is included in the operating cost of booster stations and pipelines. In case of alternative 6-1, no intermediate tank farm would be required. However, management of the terminal facilities would be required, and the annual cost of labor and expenses of this management was set at $300,000.

Pipeline Operations

Since one person at a time would be present at a booster station, four persons per week would be required.

The average distance between booster stations is arbitrarily set at 50 miles. Hence, the labor cost would be $60,000 per 50 miles of pipe. In addition to the booster station operators, there should be one or more mobile repair teams. Personnel would also be required for the management of the pipeline system and for its administrative staff. To determine the order of magnitude of the labor cost of pipeline management, administrative staff and repair teams, the 1970 annual balance sheets of the Colonial and Plantation Pipeline Companies were analyzed. The balance sheet, called "operating expense accounts" of the Plantation Pipeline Company, states that $977,775 was expended for "general salaries and wages." The same item on the balance of the Colonial Pipeline Company amounted to $2,010,149. Since the management of a crude line would be much simpler than that of a product line (because a product line carries small volumes of various products, and these products have great ranges in viscosity) an annual labor cost of $0.6 million was selected. Assuming a cost of $0.4 million for supplies, utilities, and expenses, a total management cost of $1 million would result.

All booster pumps are assumed to be electrically driven. The price of electricity was set at $0.008 per kilowatt-hour (kwh) or $70.08 per kilowatt-year for all alternatives. Since 746 watts are equivalent to 1 b.ph., the operating cost of one b.ph. would amount to $52.28 per year. It is assumed that all booster pumps would operate 24 hours a day. This assumption is correct for the pipelines between tank farm and refineries, but not for the pipelines between berths and tank farm. However, because the energy requirement for the latter pipelines is small in comparison to the former, the error is acceptable for this study.

Personnel Transport

The cost of transporting personnel to and from an artificial island will depend primarily on the distance between shore facilities and the island. The following costs were established: $500,000 per year for alternatives 1-1, 1-2, 2-2 and 2-4; and $1 million per year for alternatives 2-5 and 4-1 through 4-3.

Maintenance Cost

Based on experiences with existing port facilities, the following annual maintenance costs were established as percentages of the first cost:[a]

Fixed berths.................	1.5
Monobuoys....................	13.5
Piping.......................	0.2
Booster pumps and valves.....	2.5
Storage tanks................	1.5
Breakwaters and jetties......	1.0
Instruments and meters.......	0.3

The maintenance costs of dredging works will depend on the effects of littoral drift, currents, and waves, and on the amount and kind of material suspended in the water, which will differ by location and channel depth. It will also depend on the total quantity to be dredged, the type of dredger, and the location of the disposal area. Because of insufficient basic data on these factors and their effects, the following assumptions on the relationship between first costs and maintenance were made:

1. For ocean and bay channels subject to intense wave and current actions, 2.5 percent of first cost (alternatives 1-1, 1-2, 2-1 through 2-5, 6-1 and 6-2 outside the breakwater, and 7-1 through 7-4 [Main Ship Channel]); or 2.0 percent of first cost (alternatives 5-4 through 5-6) for channels of great length.

2. For inland channels, turning basins and berthing areas subject to currents and suspended river materials, 1.0 percent of first cost (alternatives 1-1, 1-2, 6-1 and 6-2 inside the breakwater, and 7-1 through 7-4); or 0.5 percent of first cost (alternatives 5-4 through 5-6) for protected areas with little tidal movement.

1/ Although the maintenance cost is expressed as a percentage of the first cost, it should be noted that in many cases there is no relationship between first cost and maintenance cost. The relationship was established only to provide a means of calculation.

Total Costs

Applying the unit costs derived in the preceding sections to the engineering requirements of the selected alternatives and subalternatives results in total first costs, total annual operating and maintenance costs. These are given in table 87. A breakdown of the first costs into five components is given in table 88.

Table 87. First, Operating and Maintenance Costs of Crude Petroleum Alternatives

(In millions of dollars)

Code [a]	Alternative	1980 volume (m.t.a.)	Cost: 1975-79 first	Cost: 1980 Operating	Cost: 1980 Maintenance	2000 volume (m.t.a.)	Cost: 1980-2000 first	Cost: 2000 Operating	Cost: 2000 Maintenance
				New York Area					
0010	1-1-A	30	132.7 [b]	3.3	1.9	35	0	3.3	1.9
0020	1-1-B	35	132.9 [b]	3.4	1.9	70	1.4	3.7	2.9
0030	1-1-C	30	148.9 [c]	3.3	2.2	35	0	3.3	2.2
0040	1-1-D	35	149.1 [c]	3.4	2.2	70	1.4	3.7	2.2
0050	1-2-A	100	230.7 [d]	5.7	2.5	150	8.1	7.8	2.7
0060	1-2-B	150	317.3 [e]	9.3	3.1	300	31.4	13.9	3.7
0070	1-2-C	100	252.9 [f]	5.7	2.9	150	8.1	7.8	3.1
0080	1-2-D	150	345.8 [g]	9.3	3.5	300	35.8	13.9	4.2
0090	1-3-A	100	175.5	6.1	2.5	150	6.8	7.9	2.7
0100	1-3-B	150	254.1	8.4	3.4	300	34.5	13.3	4.4
0110	1-3-C	100	188.0	6.7	2.9	150	6.8	8.6	3.1
0120	1-3-D	150	269.9	9.1	3.9	300	38.2	14.7	5.0
				Delaware Bay Area					
0130	2-1-A	70	139.1 [h]	5.7	1.5	115	27.1	7.3	1.7
0140	2-1-B	115	204.1 [h]	7.8	2.1	230	36.9	11.0	2.7

Continued. . . .

Table 87. First, Operating and Maintenance Costs of Crude Petroleum Alternatives (continued)

(In millions of dollars)

Code a/	Alternative	1980 volume (m.t.a.)	Cost			2000 volume (m.t.a.)	Cost		
			1975-79 first	1980			1980-2000 first	2000	
				Operating	Maintenance			Operating	Maintenance
	- - - - - - - - - - - - - - Delaware Bay Area - - - - - - - - - - - - - -								
0150	2-1-C	70	151.9 h/	5.7	1.8	115	32.3	7.3	2.2
0160	2-1-D	115	221.3 h/	7.8	2.6	230	42.2	11.0	3.2
0170	2-2-A	70	150.1 h/	6.2	1.7	115	22.8	7.8	2.0
0180	2-2-B	115	214.1 h/	7.9	2.1	230	33.0	11.1	2.7
0190	2-2-C	70	162.4 h/	6.2	1.8	115	27.4	7.8	2.3
0200	2-2-D	115	231.2 h/	7.9	2.4	230	37.8	11.1	3.0
0210	2-3-A	100	216.8 h/	6.4	2.0	150	3.3	7.1	2.1
0220	2-3-B	150	250.5 h/	8.9	2.5	300	72.8	13.1	3.2
0230	2-3-C	100	2[illegible].7 h/	6.8	2.2	150	3.3	7.6	2.3
0240	2-3-D	150	2[illegible].7 h/	9.5	2.9	300	78.4	13.9	3.7
0250	2-4-A	100	225.9 h/	6.1	2.0	150	3.6	7.0	2.1
0260	2-4-B	150	257.8 h/	8.8	2.5	300	72.8	13.0	3.2
0270	2-4-C	100	242.8 h/	6.1	2.2	150	3.6	7.0	2.3
0280	2-4-D	150	280.0 h/	8.8	2.8	300	77.9	13.0	3.6
0290	2-5-A	100	209.8 i/	5.6	2.5	150	0	5.6	2.5
0300	2-5-B	150	264.5 i/	5.7	3.1	300	25.4	6.1	3.4
0310	2-5-C	100	236.5 i/	5.6	2.8	150	0	5.6	2.8
0320	2-5-D	150	289.5 i/	5.7	3.6	300	31.7	6.1	4.0

Continued. . . .

Table 87. First, Operating and Maintenance Costs of Crude Petroleum Alternatives (continued)

(In millions of dollars)

Code[a]	Alter-native	1980 volume (m.t.a.)	Cost			2000 volume (m.t.a.)	Cost		
			1975-79 first	1980			1980-2000 first	2000	
				Oper-ating	Main-tenance			Oper-ating	Main-tenance
				Mississippi Delta Area					
0330	4-1-A	100	220.0	5.6	2.2	450	114.3	10.1	3.6
0340	4-1-B	150	260.8	6.0	2.7	600	144.7	10.7	4.5
0350	4-2-A	100	243.0	5.6	2.6	450	98.9	7.5	3.8
0360	4-2-B	150	252.1	5.8	2.6	600	149.2	10.5	4.5
0370	4-2-C	100	266.6	5.6	2.9	450	95.5	7.5	4.1
0380	4-2-D	150	276.8	5.8	2.9	600	158.7	10.5	5.0
0390	4-3-A	100	252.6	5.6	3.0	450	129.8	7.5	4.7
0400	4-3-B	150	288.2	5.8	3.1	600	171.2	10.4	5.4
				Freeport, Texas Area					
0410	5-1-A	100	324.5	8.7	3.1	450	312.1	30.2	8.0
0420	5-1-B	150	393.0	11.3	3.9	600	429.2	34.9	10.1
0430	5-2-A	100	328.2	9.2	3.1	450	325.4	30.9	7.9
0440	5-2-B	150	40[illegible].9	12.0	4.0	600	423.6	36.5	9.6
0450	5-2-C	100	338.7	9.2	3.4	450	307.3	30.2	8.0
0460	5-2-D	150	420.2	12.0	4.4	600	411.0	35.7	10.0

Continued. . . .

Table 87. First, Operating and Maintenance Costs of Crude Petroleum Alternatives (continued)

(In millions of dollars)

Code[a]	Alternative	1980 volume (m.t.a.)	Cost: 1975-79 first	Cost: 1980 Operating	Cost: 1980 Maintenance	2000 volume (m.t.a.)	Cost: 1980-2000 first	Cost: 2000 Operating	Cost: 2000 Maintenance
	Freeport, Texas Area								
0470	5-3-A	100	362.2	10.3	3.7	450	337.0	32.9	8.8
0480	5-3-B	150	451.4	13.6	4.9	600	446.5	39.2	10.8
0490	5-4-A	100	399.9	9.0	2.9	450	283.3	29.6	5.7
0500	5-4-B	150	480.2	11.1	3.5	600	373.0	33.2	6.7
0510	5-5-A	100	543.1	9.0	5.2	450	266.8	27.1	7.8
0520	5-5-B	150	592.7	11.0	5.5	600	380.0	33.0	8.7
0530	5-5-C	100	593.0	9.0	5.9	450	257.4	27.0	8.4
0540	5-5-D	150	642.6	11.0	6.1	600	384.1	32.9	9.4
0550	5-6-A	100	877.9	8.9	11.1	450	300.6	27.0	14.0
0560	5-6-B	150	963.1	11.0	11.7	600	394.6	32.9	15.0
	Los Angeles Area								
0570	6-1-A	28	43.4	2.4	0.5	111	6.5	2.4	0.5
0580	6-1-B	28	50.6	2.9	0.6	111	8.3	2.9	0.7
0590	6-2-A	43	178.2	4.9	1.0	171	46.8	12.1	2.0
0600	6-2-B	43	188.7	5.6	1.2	171	37.7	12.7	2.0

Continued. . . . .

Table 87. First, Operating and Maintenance Costs of Crude Petroleum Alternatives (continued)

(In millions of dollars)

Code[a]	Alter-native	1980 volume (m.t.a.)	Cost			2000 volume (m.t.a.)	Cost		
			1975-79 first	1980			1980 2000 first	2000	
				Oper-ating	Main-tenance			Oper-ating	Main-tenance
				San Francisco Area					
0610	7-1	15	63.3[j]	2.9	0.7	60	2.6	3.5	0.7
0620	7-2	15	80.8[k]	2.9	0.8	60	0	2.9	0.8
0630	7-3	15	85.8[l]	2.8	1.1	60	15.7	3.5	1.3
0640	7-4	15	167.3[m]	2.9	1.9	60	0	2.9	1.9
0650	7-5	15	108.6	2.5	1.9	60	9.0	4.9	2.1
				Ferndale, Washington Area					
0660	8-1	15	367.3	5.7	1.9	60	64.9	23.1	3.5
0670	8-2	43	570.4	11.7	2.9	171	562.4	46.9	6.6

a/ Code numbers shown for each alternative are those used in the computer computation of benefits and costs (Annex F).
b/ To be increased by $17.8 million or 13 percent for revised dredging cost.

Continued. . . .

Table 87. First, Operating and Maintenance Costs of Crude Petroleum Alternatives (continued)

c/ To be increased by $20.2 million or 14 percent for revised dredging cost.
d/ To be increased by $18.1 million or 8 percent for revised dredging cost.
e/ To be increased by $18.4 million or 6 percent for revised dredging cost.
f/ To be increased by $20.4 million or 8 percent for revised dredging cost.
g/ To be increased by $20.9 million or 6 percent for revised dredging cost.
h/ To be increased by $14.6 million or 5 to 11 percent for revised dredging cost.
i/ To be increased by $9.0 million or 3 to 4 percent for revised dredging cost.
j/ To be increased by $9.6 million or 15 percent for revised dredging cost.
k/ To be increased by $26.4 million or 33 percent for revised dredging cost.
l/ To be increased by $23.9 million or 28 percent for revised dredging cost.
m/ To be increased by $64.3 million or 38 percent for revised dredging cost.

Table 88. First Cost Components of Crude Oil Alternatives

(In millions of dollars)

Alternative	1975-79 Dredging	1975-79 Berths and pipelines to tank farm	1975-79 Tank farm	1975-79 Artificial island or onshore land	1975-79 Pipeline to refineries	1975-79 Total	1980-2000 Dredging	1980-2000 Berths and pipelines to tank farm	1980-2000 Tank farm	1980-2000 Artificial island or onshore land	1980-2000 Pipeline to refineries	1980-2000 Total
1-1-A	42.5[a]	9.0	40.0	23.0	18.2	132.7[a]	0	0	0	0	0	0
1-1-B	42.5[a]	9.0	40.0	23.0	18.4	132.9[a]	0	0	0	0	1.4	1.4
1-1-C	48.7[b]	11.8	46.8	23.4	18.2	148.9[b]	0	0	0	0	0	0
1-1-D	48.7[b]	11.8	46.8	23.4	18.4	149.1[b]	0	0	0	0	1.4	1.4
1-2-A	44.5[c]	15.1	47.0	26.1	98.0	230.7[c]	0	0	0	0	8.1	8.1
1-2-B	47.3[d]	18.2	58.2	30.9	162.7	317.3[d]	0	5.8	7.0	0	18.6	31.4
1-2-C	50.7[e]	19.7	56.0	28.5	98.0	252.9[e]	0	0	0	0	8.1	8.1
1-2-D	54.7[f]	23.8	69.2	35.4	162.7	345.8[f]	0	7.6	9.6	0	18.6	35.8
1-3-A	0	38.9	47.0	1.0	88.6	175.5	0	0	0	0	6.8	6.8
1-3-B	0	51.5	58.2	1.4	143.0	254.1	0	11.3	7.0	0	16.2	34.5
1-3-C	0	42.2	56.0	1.2	88.6	188.0	0	0	0	0	6.8	6.8
1-3-D	0	55.9	69.4	1.6	143.0	269.9	0	12.4	9.6	0	16.2	38.2
2-1-A	19.4[g]	28.4	40.0	0.5	50.8	139.1[g]	0	13.6	7.0	0	6.5	27.1
2-1-B	19.4[g]	43.5	47.0	0.6	93.6	204.1[g]	0	13.7	11.2	0	12.0	36.9
2-1-C	19.4[g]	34.3	46.8	0.6	50.8	151.9[g]	0	16.7	9.1	0	6.5	32.3
2-1-D	19.4[g]	51.6	56.0	0.7	93.6	221.3[g]	0	16.7	13.5	0	12.0	42.2

Continued. . . . .

Table 88. First Cost Components of Crude Oil Alternatives (continued)

(In millions of dollars)

Alternative	1975-79 Dredging	Berths and pipelines to tank farm	Tank farm	Artificial island or onshore land	Pipeline to refineries	Total	1980-2000 Dredging	Berths and pipelines to tank farm	Tank farm	Artificial island or onshore land	Pipeline to refineries	Total
2-2-A	19.4 g/	17.6	40.0	14.0	59.1	150.1 g/	0	8.8	7.0	0	7.0	22.8
2-2-B	19.4 g/	26.5	47.0	14.8	106.4	214.1 g/	0	8.8	11.2	0	13.0	33.0
2-2-C	19.4 g/	22.6	46.8	14.5	59.1	162.4 g/	0	11.3	9.1	0	7.0	27.4
2-2-D	19.4 g/	33.9	56.0	15.5	106.4	231.2 g/	0	11.3	13.5	0	13.0	37.8
2-3-A	19.4 g/	42.1	47.0	0.5	107.8	216.8 g/	0	0	0	0	3.3	3.3
2-3-B	19.4 g/	55.6	58.2	0.7	116.6	250.5 g/	0	13.7	7.0	0	52.1	72.8
2-3-C	19.4 g/	50.9	56.0	0.6	107.8	234.7 g/	0	0	0	0	3.3	3.3
2-3-D	19.4 g/	67.4	69.4	0.8	117.7	274.7 g/	0	16.7	9.6	0	52.1	78.4
2-4-A	19.4 g/	26.5	47.0	14.0	119.0	225.9 g/	0	0	0	0	3.6	3.6
2-4-B	19.4 g/	35.2	58.2	15.0	130.0	257.8 g/	0	8.8	7.0	0	57.0	72.8
2-4-C	19.4 g/	33.9	56.0	14.5	119.0	242.8 g/	0	0	0	0	3.6	3.6
2-4-D	19.4 g/	45.2	69.4	16.0	130.0	280.0 g/	0	11.3	9.6	0	57.0	77.9
2-5-A	4.8 h/	31.3	47.0	117.9	8.8 i/	209.8 h/	0	0	0	0	0 i/	0
2-5-B	4.8 h/	38.2	58.2	152.0	11.3 i/	264.5 h/	0	12.9	7.0	0	5.5 i/	25.4
2-5-C	4.8 h/	40.5	56.0	126.4	8.8 i/	236.5 h/	0	0	0	0	0 i/	0
2-5-D	4.8 h/	49.4	69.4	154.6	11.3 i/	289.5 h/	0	16.6	9.6	0	5.5 i/	31.7

Continued. . . . .

Table 88. First Cost Components of Crude Oil Alternatives (continued)

(In millions of dollars)

Alternative	1975-79						1980-2000					
	Dredging	Berths and pipelines to tank farm	Tank farm	Artificial island or onshore land	Pipeline to refineries	Total	Dredging	Berths and pipelines to tank farm	Tank farm	Artificial island or onshore land	Pipeline to refineries	Total
4-1-A	0	25.1	48.8	132.5	13.6 i/	220.0	0	37.8	56.1	0	20.4 i/	114.3
4-1-B	0	37.7	64.4	138.3	20.4 i/	260.8	0	45.5	73.0	0	26.2 i/	144.7
4-2-A	0	39.5	58.2	131.7	13.6 i/	243.0	0	39.2	41.3	0	18.4 i/	98.9
4-2-B	0	39.5	58.2	136.0	18.4 i/	252.1	0	58.8	65.2	0	25.2 i/	149.2
4-2-C	0	50.7	69.4	132.9	13.6 i/	266.6	0	41.2	36.9	0	17.4 i/	95.5
4-2-D	0	50.7	69.4	138.3	18.4 i/	276.8	0	66.4	68.1	0	24.2 i/	158.7
4-3-A	0	50.7	56.4	132.9	12.6 i/	252.6	0	62.0	49.4	0	18.4 i/	129.8
4-3-B	0	62.0	70.0	137.8	18.4 i/	288.2	0	81.7	65.3	0	24.2 i/	171.2
5-1-A	0	45.4	48.9	0.5	229.7 j/	324.5	0	68.0	56.2	0	187.9 j/	312.1
5-1-B	0	56.6	55.6	0.6	280.2 j/	393.0	0	90.0	81.8	0	257.4 j/	429.2
5-2-A	0	52.1	47.0	0.4	228.7 j/	328.2	0	86.0	52.5	0	186.9 j/	325.4
5-2-B	0	69.0	58.2	0.5	279.2 j/	406.9	0	103.0	65.2	0	255.4 j/	423.6
5-2-C	0	53.5	56.0	0.5	228.7 j/	338.7	0	71.0	50.4	0	185.9 j/	307.3
5-2-D	0	71.0	69.4	0.6	279.2 j/	420.2	0	88.5	68.1	0	254.4 j/	411.0
5-3-A	0	76.6	56.4	0.5	228.7 j/	362.2	0	101.7	49.4	0	185.9 j/	337.0
5-3-B	0	101.6	70.0	0.6	279.2 j/	451.4	0	126.8	65.3	0	254.4 j/	446.5

Continued. . . . .

Table 88. First Cost Components of Crude Oil Alternatives (continued)

(In millions of dollars)

Alternative	1975-79 Dredging	1975-79 Berths and pipelines to tank farm	1975-79 Tank farm	1975-79 Artificial island or onshore land	1975-79 Pipeline to refineries	1975-79 Total	1980-2000 Dredging	1980-2000 Berths and pipelines to tank farm	1980-2000 Tank farm	1980-2000 Artificial island or onshore land	1980-2000 Pipeline to refineries	1980-2000 Total
5-4-A	111.0	9.9	48.8	0.5	229.7 j/	399.9	24.3	15.0	56.1	0	187.9 j/	283.3
5-4-B	119.0	15.0	64.4	0.6	281.2 j/	480.2	25.6	18.0	73.0	0	256.4 j/	373.0
5-5-A	238.5	16.3	58.2	0.4	229.7 j/	543.1	23.4	16.2	41.3	0	185.9 j/	266.8
5-5-B	238.5	16.3	58.2	0.5	279.2 j/	592.7	35.1	24.3	65.2	0	255.4 j/	380.0
5-5-C	272.5	20.9	69.4	0.5	229.7 j/	593.0	18.7	16.9	36.9	0	184.9 j/	257.4
5-5-D	272.5	20.9	69.4	0.6	279.2 j/	642.6	34.3	27.3	68.1	0	254.4 j/	384.1
5-6-A	571.5	20.8	56.4	0.5	228.7 j/	877.9	38.0	25.2	51.5	0	185.9 j/	300.6
5-6-B	588.0	25.3	70.0	0.6	279.2 j/	963.1	41.6	33.3	65.3	0	254.4 j/	394.6
6-1-A	12.6	11.0	0	0	19.8	43.4	0	5.5	0	0	1.0	6.5
6-1-B	14.8	14.6	0	0	21.2	50.6	0	7.3	0	0	1.0	8.3
6-2-A	12.6	17.9	14.4	1.0	132.3	178.2	1.0	11.0	6.5	0	28.3	46.8
6-2-B	14.8	22.2	17.0	1.0	133.7	188.7	0	7.3	3.1	0	27.3	37.7
7-1	9.6 k/	12.3	26.8	1.4	13.2	63.3 k/	0	0	0	0	2.6	2.6
7-2	57.0 l/	17.8	0	0	6.0	80.8 l/	0	0	0	0	0	0
7-3	29.3 m/	13.2	29.4	1.7	12.2	85.8 m/	0	7.2	4.9	0	3.6	15.7
7-4	128.3 n/	33.0	0	0	6.0	167.3 n/	0	0	0	0	0	0

Continued. . . .

Table 88. First Cost Components of Crude Oil Alternatives (continued)

(In Millions of dollars)

Alternative	1975-79						1980-2000					
	Dredging	Berths and pipelines to tank farm	Tank farm	Artificial island or onshore land	Pipeline to refineries	Total	Dredging	Berths and pipelines to tank farm	Tank farm	Artificial island or onshore land	Pipeline to refineries	Total
7-5	0	15.7	46.8	1.1	45.0	108.6	0	0	0	0	9.0	9.0
8-1	0	28.8	46.8	0.5	291.2	367.3	0	0	0	0	64.9	64.9
8-2	0	28.8	46.8	0.8	494.0	570.4	0	14.4	9.1	0	538.9	562.4

a/ See footnote b, table 87.
b/ See footnote c, table 87.
c/ See footnote d, table 87.
d/ See footnote e, table 87.
e/ See footnote f, table 87.
f/ See footnote g, table 87.
g/ See footnote h, table 87.
h/ See footnote i, table 87.
i/ Barge transshipment facilities only.
j/ Including barge transshipment facilities.
k/ See footnote j, table 87.
l/ See footnote k, table 87.
m/ See footnote l, table 87.
n/ See footnote m, table 87.

VI. DESIGN CRITERIA FOR DRY BULK PORTS

Channels and Maneuvering Areas

The dimensions of channels and maneuvering areas relate to vessel dimensions, and to the estimated force of currents and waves to which the vessel would be exposed, in the manner that was established in chapter III for the oil alternatives. Therefore, the dimensions of ocean channels, entrance channels, turning basins, and berthing areas given in tables 5 and 6 for oil tankers also apply to bulk carriers.

The dimensions of the bulk carriers selected for the various alternatives are established in Annex E. Table 89 reviews these dimensions.

Table 89. Bulk Carrier Dimensions
(In feet)

Vessel Dimensions	Symbol	Vessel size (1,000 d.w.t.)				
		120	128	179	250	250
Length......	L	860	875	1,015	1,095	1,050
Beam........	B	140	137	170	190	180
Draft.......	D	50	52	52	58.5	65

Supercarrier Berths

There is no significant difference between arrival patterns of bulk carriers and those of tankers. Therefore, the practicably permissible mean berth occupancy factors as derived in table 9 for tankers also apply for bulk carriers.

Optimum loading and unloading rates are a function of additional port time costs of all vessels compared to the cost of additional handling equipment and/or berths. Because these optimum rates cannot be determined in this analysis, the following assumptions will be made:

1. Average coal loading rates for 128,000 d.w.t. carriers would equal 10,000 tons per hour; for 179,000 d.w.t. carriers, 11,000 tons per hour; and for 250,000 d.w.t. carriers, 12,000 tons per hour.

2. Average iron ore unloading rates for 250,000 d.w.t. carriers would equal 6,000 tons per hour.

3. Average grain loading rates for 120,000 d.w.t. vessels would equal 6,000 tons per hour; and for 250,000 d.w.t. vessels, 12,000 tons per hour.

Total berth occupancy times were estimated using the above assumptions and allowing the same amount of time for maneuvering and clearance for bulk carriers as was established for oil tankers in the case of fixed berths, and are presented in table 90.

With an assumed berth occupancy of 1.0, the berth occupancy times given in table 90 would result in the number of vessel callings per year and corresponding annual throughput capacities given in table 91.

Table 90. Berth Occupancy Times of Bulk Carriers by Commodity and Vessel Size

(In hours)

Item	Coal			Iron ore	Grain	
	Vessel size (1,000 d.w.t.)					
	128	179	250	250	120	250
Berthing.............	4	4	4	4	4	4
Clearance............	2	2	2	2	2	2
Loading/unloading....	13	16	21	41	21	21
Deberthing...........	3	3	3	3	3	3
Total................	22	25	30	50	30	30

Table 91. Vessel Callings and Annual Throughput at a Berth Occupancy Factor of 1.0

Commodity and vessel size (d.w.t.)	Number of vessel callings/year	Annual throughput (million long tons)
Coal		
128,000......	380	49
179,000......	335	60
250,000......	280	70
Iron ore		
250,000......	160	40
Grain		
120,000......	280	34
250,000......	280	70

Taking into account the practicably permissible mean berth occupancy factors established in table 9 and the number of berths available, the maximum permissible annual throughputs can be determined for different numbers of berths. Table 92 presents this relation.

Table 92. Annual Throughput Volumes
(In millions of long tons)

Commodity and vessel size (d.w.t.)	Throughputs by number of berths	
	1	2
Coal		
128,000......	13	50
179,000......	16	61
250,000......	19	73
Iron ore		
250,000......	11	42
Grain		
120,000......	9	35
250,000......	19	73

Intermediate Storage

Imports

For iron ore the same formula applies as was derived for oil, since the same relationship exists between inflow and outflow. Thus

$$S = 1.2\left(\frac{168}{t} n\ d - 0.024\ A\right) w$$

where

t = berth occupancy time in hours
n = number of berths
d = d.w.t. of super carrier in 10^6 long tons
A = annual throughput in millions of long tons
w = number of weeks of inclement weather

If $t = 50$, $n = 1$, $d = .250$, $A = 11$ and $w = 5/7$, the storage required would be 0.5 million long tons. If $n = 2$ and $A = 17.1$, the storage would be 1.1 million long tons.

Assuming a density of 14 to 18 cubic feet per long ton, or an average density of 16 cubic feet per long ton, 0.5 million long tons would have a volume of $0.5 \times 16 = 8 \times 10^6$ cubic feet. Assuming that the stockpile were triangular with a height of 30 feet and a base of 85 feet, a volume of 8×10^6 cubic feet would be approximately 6,300 feet long. The required net area would then amount to $85 \times 6{,}300 = 535{,}000$ square feet. Including an assumed 50 percent for grade segregations and slopes, 30 percent for ownership segregation, and 25 percent for marginal areas, the total surface requirement would be $1.50 \times 1.30 \times 1.25 \times 535{,}000 = 1{,}300{,}000$ square feet, or 30 acres for 0.5 million long tons. Storage of 1.1×10^6 long tons of iron ore would therefore require about $1.1/0.5 \times 30 = 65$ acres.

Exports

For grain and coal, the storage formula given for imports cannot be applied because of numerous differences in specific qualities of the product. In the case of metallurgical coal exports, product variation arises from differences in performance characteristics of coal mined at different sources. Among characteristics of particular importance to the market are the product's coking abilities, its tendency to swell, and its content of sulfur, ash, and volatile matter.

To obtain coal with acceptable technical and quality characteristics for charging into a metallurgical coke oven, foreign steel companies blend coal from a number of mines in the United States and from other countries. This blending is required because no single mine produces the precise combination of required qualities, because qualities vary among different mines, and because one mine is incapable of exporting the quantities of coal required by foreign steel companies. To achieve a satisfactory blend therefore requires careful control of the quantities and qualities of coal to be delivered to any one buyer, and, consequently, to be loaded into a vessel for delivery to such buyer.

In the case of grains, there are differences both in the basic cereal (e.g., wheat, corn, sorghum, soybeans, etc.) as well as within each group. Thus there are different grades of wheat, which are distinguished by the market in purchases and prices. The same phenomenon applies to the other cereals.

Coal

There is no precedent for ground storage of overseas export coal at the port of shipment such as would be required at an offshore island loading deep-draft vessels. Export coal is presently shipped to port and stored in cars until it is loaded into vessels. The Norfolk and Western (N&W) Railroad and the Chesapeake and Ohio (C&O) Railroad, which own and operate the coal-dumping facilities at Norfolk and Newport News, serve approximately 375 and 150 individual coal mines, respectively. Each car of coal loaded at the mine is consigned to either a foreign buyer or to a U.S. export firm. Ships are chartered and scheduled by individual buyers, and each ship load is therefore composed of coal that is consigned to particular buyer and that originated in a number of mines, was delivered to port over a period of time, and was stored in cars until a sufficient number was accumulated to make a full cargo.

The dumping of individual coal cars into the vessel and sequence of dumping are directed by either the representative of the foreign buyer or of the U.S. export firm which takes responsibility for delivering a blend of coals meeting contract specifications. Under this system, the average waiting time of coal cars at Norfolk is understood to be from 12 to 14 days, and the capacity at the Norfolk and Western yards is understood to be 14,000 cars. The average car capacity is 78 tons. The total average rate of dumping is 1,500 cars per day (approximately 1,000 by the N&W and 500 by the C&O); with an average waiting time of 12 days, this figure gives a storage equivalent of 18,000 cars, or approximately 1.4 million tons.

The feasibility of ground storage either at present ports of export or at an offshore island, as an alternative to the current practice of car storage, has not been demonstrated, and the storage requirements have not been determined. In this circumstance, storage requirements can be calculated only on the basis of broad assumptions, the validity or feasibility of which cannot be demonstrated. For purposes of the present study, the assumptions employed are as follows:

1. Maintenance of present standards of grade and ownership segregation in ground storage would triple the ground storage requirement over what it would be without the necessity for such segregation. The basis for this assumption is that the stockpile would consist of a great number of pyramids instead of prisms and, since the volume of a pyramid is one-third that of a prism if the three basic dimensions of pyramid and prism (length, width, and height) are the same, an area three times larger would be required.

2. The possibility of reducing the coal to 10 "standard" grades would reduce the storage area requirement by 75 percent.

Assumption 1. Assuming a triangular stockpile with a height of 20 feet, a base of 60 feet, and an average density of 48 cubic feet per long ton, then a storage volume of 1.4 million long tons would be approximately 112,000 feet long. The required net area would amount to $60 \times 112{,}000 = 6.7 \times 10^6$ square feet. If an extra 200 percent for slopes and for grade and ownership segregation, and an extra 25 percent for marginal areas, are included, the total surface requirement would be $3.00 \times 1.25 \times 6.7 \times 10^6 = 25.1 \times 10^6$ square feet, or 575 acres.

The size of the largest cargoes being loaded at Hampton Roads is presently in the range of 70,000 tons; however, this figure might increase to 90,000 tons when wide-beam vessels are used. If it is assumed that the storage requirements of ports serving larger vessels will increase at least by a factor of d.w.t. of larger carrier/90,000, this factor would be approximately

1.2, 1.4, and 1.7 for 128,000-, 179,000-, and 250,000-d.w.t. carriers, respectively. The required acreage would be approximately 700, 800, and 1,000 acres, respectively.

Assumption 2. Reducing the total number of different grades by systematic blending of all existing grades to 50, 30, or even 10 "standard" grades would substantially reduce the volume of coal stored at the deep-water port compared with present practice, and would also reduce the required ground area. In this study it is not possible to determine the minimum feasible number of grades. By way of a theoretical exercise, the assumption will be made that a reduction in the number of grades would be considered, and that this would reduce the storage area by 75 percent. The required acreage would be 175, 200, and 250 acres for 128,000-, 179,000-, and 250,000-d.w.t. carriers, respectively. For one berth, the storage area is assumed to be five-eighths of the above acreages.

Grains

Because grain also varies by ownership, kind and quality, it is impossible to determine the amount of storage that grain in general would require. However, considering the possible variations, it seems unlikely that the required storage would be less than five and eight times the average vessel size for one and two berths, respectively. Therefore, a storage capacity of 0.6 and 1.25 million long tons for one berth and 0.96 and 2.0 million long tons for two berths for 120,000-, and 250,000-d.w.t. carriers, respectively, will be considered.

Assuming an average density of grains of 48 cubic feet per long ton, an average effective silo height of 40 feet, and a marginal area of 40 percent, then for 1 million long tons the required acreage would amount to $(1.4 \times 48 \times 10^6)/(40 \times 43{,}560)$, or approximately 40 acres. The required acreage would be 24, 50, 40, and 80 acres for 0.6, 1.25, 0.96, and 2.0 million long tons, respectively.

Transshipment Vessels

The size of the transshipment barges would be in the 40,000 d.w.t. range, as established in Annex E.

The time required for maneuvering, berthing, and deberthing of transshipment vessels for dry bulk is assumed to be the same as that for crude oil transshipment movements. The average unloading rates for coal and grain, and the average loading rate for iron ore, were established at 5,000 tons per hour. Self-unloading via conveyor belts for coal and unloading through a fluidizing pressure system for grain have been assumed; for iron ore loading, dumping from conveyor belts would be adequate to achieve the assumed rate. Table 93 presents the total berth occupancy time of all transshipment vessels.

Table 93. Berth Occupancy Time of Transshipment Barges

(In hours)

Item	Time
Maneuvering, berthing, and mooring	1
Loading or unloading.........	8
Deberthing and maneuvering...	1
Total	10

With an assumed berth occupancy factor of 1.0 and a total number of 350 working days per year, the number of barge callings per year would be 24/10 x 350 = 840. The corresponding annual throughput capacity would be 840 x 40,000 = 34 million tons per year. The type of transshipment berth is assumed to be fixed.

Since the permissible berth occupancy factors are the same as those established for supertanker berths, the maximum annual throughput can be related with the number of transshipment berths. Table 94 gives these throughputs for one to three berths. The maximum throughput of a single commodity considered in any alternative is 45.6 million tons per year.

Table 94. Annual Throughput Volumes

(In millions of long tons per year)

Number of berths	Permissible berth occupancy factor	Throughput
1.............	.27	9
2.............	.51	35
3.............	.62	63

It is assumed that all transshipment berths will be equipped to handle one commodity only. However, in preliminary engineering studies of deepwater ports handling more than one commodity, consideration should also be given to the possibility that a berth would be able to handle more than one commodity.

VII. ENGINEERING REQUIREMENTS FOR DRY BULK PORTS

Coal

Three alternatives, numbered 2-6, 2-7, and 3-1, will be considered. Alternative 2-6 considers only coal, whereas 2-7 considers a deepwater port for coal and iron ore combined.

Sites

Alternatives 2-6 and 2-7 consider deepwater ports in the Lower Delaware Bay, whereas alternative 3-1 considers a deepwater port at Hampton Roads.

Links to Existing Ports

The deepwater port of all alternatives would be linked to the N&W facilities at Norfolk and the C&O facilities at Newport News; the deepwater ports of alternatives 2-6 and 2-7 might also be linked to Baltimore, depending on the hypothesized vessel size.

Throughputs

Alternatives 2-6 and 2-7 consider two sets of throughputs. The higher throughput is set at 45.4 m.t.a. in 1980 and 43.7 m.t.a. by 2000 if 250,000 d.w.t. carriers drawing 65 feet are utilized. The lower throughput is set at 11.5 m.t.a. in 1980 and 6.4 m.t.a. by 2000 if 250,000 d.w.t. carriers drawing 58.5 feet are utilized. Alternative 3-1 considers a throughput of 46.1 m.t.a. in 1980 and 46.6 m.t.a. by 2000.

Intermediate Storage

Alternative 3-1 considers a continuation of the present system of operations at Hampton Roads, with railroad cars at the shunting yard awaiting unloading upon request. In this case, the railroad cars provide the necessary storage. In alternatives 2-6 and 2-7, an artificial island would provide storage for the coal. The storage area would be in accordance with the two assumptions made in chapter VI; that is, (1) all present grades would be stored; and (2) only a restricted number of blended grades would be stored.

Vessel Sizes

Alternatives 2-6 and 2-7 will consider 250,000 d.w.t. carriers drawing 65 or 58.5 feet. Alternative 3-1 will consider 128,000 and 179,000 d.w.t. carriers drawing 52 feet. The assumed dimensions of the vessels, in feet, are given in table 95.

Table 95. Assumed Dimensions of 128,000, 179,000, and 250,000 Deadweight Ton Carriers

Dimension	Vessel size (1,000 d.w.t.)			
	128	179	250	
Length.................	875	1,015	1,095	1,050
Beam...................	137	170	190	180
Draft..................	52	52	58.5	65

Transshipment barges are hypothesized in the 40,000-d.w.t. range, drawing 30 to 36 feet, for alternatives 2-6 and 2-7. Alternative 3-1 would not employ transshipment barges, since this alternative considers direct loading into the supercarrier.

Dredging

All alternatives would require dredged channels. Alternative 3-1 would also require dredged turning basins and berthing areas.

Water Depths

In all alternatives the depth of channels, etc., is such that all maximum-draft carriers would have to await high tide to approach the facilities. For alternatives 2-6 and 2-7, a value of 4.0 feet for average tidal rise will be applied; this value is 2.5 feet for alternative 3-1, which is the average tidal range of the Thimble Shoal Channel.

Construction Program

The time phasing of the various construction items for the period prior to 1980 is given in table 96 for alternatives 2-6 and 2-7, and in table 97 for alternative 3-1. The entire phasing was simplified to facilitate calculations. The total cost of each item will be distributed equally over the pertinent years.

Table 96. Construction Program of Alternatives 2-6 and 2-7

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Breakwater of island....	X	X			
Sand fill and slope protection.............			X		
Berths and trestles.....				X	X
Mechanical and electrical equipment..........				X	X
Dredging................				X	X
Breakwater at iron ore berth (alternative 2-7)......			X	X	X

Iron Ore

Three alternatives, numbered 2-7, 4-5, and 4-6, will be considered. Alternative 2-7 considers a

Table 97. Construction Program of Alternative 3-1

Construction item	Year of construction				
	1975	1976	1977	1978	1979
Dredging.............			X	X	X

deepwater port for iron ore and coal combined; alternative 4-5 considers a deepwater port for iron ore only, and alternative 4-6 considers a deepwater port for iron ore and grain combined.

Sites

Alternative 2-7 considers a deepwater port in the Lower Delaware Bay, whereas alternatives 4-5 and 4-6 consider deepwater ports in Garden Island Bay, in the Mississippi Delta.

Links to Existing Ports

The deepwater port of alternative 2-7 would be linked to the terminal facilities at Sparrows Point, Baltimore, and to those at Philadelphia-Trenton. The deepwater ports of alternatives 4-5 and 4-6 would be linked to the existing ports of Houston, Mobile and Baton Rouge.

Throughputs

Alternative 2-7 considers one set of throughputs: 12.5 m.t.a. in 1980 and 17.1 m.t.a. by 2000. Alternatives 4-5 and 4-6 also consider one set of throughputs: 7.6 m.t.a. in 1980 and 10.4 m.t.a. by 2000.

Intermediate Storage

All three alternatives would require intermediate storage on an artificial island.

Vessel Sizes

Each alternative considers 250,000 d.w.t. carriers drawing 65 or 58.5 feet. The assumed lengths and breadth of these carriers are the same as those given in table 95 for coal carriers. The transshipment barges are hypothesized in the 40,000-d.w.t. range, drawing 30 to 36 feet.

Water Depth

For alternative 2-7, 4 feet of tide will be taken into account for determining the required water depths. For alternatives 4-5 and 4-6, no tidal rise will be taken into account, since the mean tidal range is about 1 foot in the gulf.

Construction Program

The time phasing of the various construction items for the period prior to 1980 is given in table 98 for alternatives 4-5 and 4-6. The construction program of alternative 2-7 is given in table 96. The entire phasing was simplified to facilitate calculations. The total cost of each item will be distributed equally over the pertinent years.

Grains

Three alternatives, numbered 4-4, 4-6, and 5-7, will be considered. Alternative 4-4 considers a deepwater port for grain only, whereas alternative 4-6 considers one for grain and iron ore combined, and alternative 5-7 considers one for grain and crude oil combined.

Sites

Alternatives 4-4 and 4-6 consider deepwater ports in Garden Island Bay, Gulf of Mexico; alternative 5-7 considers a deepwater port at Freeport, Texas.

Table 98. Construction Program of Alternatives 4-5 and 4-6

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Breakwater of island....	X	X	X		
Land fill and slope protection of island...			X		
Breakwater at iron ore berth..............				X	X
Mechanical and electrical equipment..........				X	X
Grain silos (alternative 4-6)............				X	X
Dredging for iron ore berth..............					X
Berths and trestles.....				X	X

Links to Existing Ports

The deepwater ports of alternatives 4-4 and 4-6 would be linked with the existing ports on the Mississippi River and on the Texas and Louisiana coasts. The deepwater port of alternative 5-7 would link the existing ports of Texas.

Throughputs and Vessel Sizes

Alternatives 4-4 and 4-6 consider two sets of throughputs. The higher throughput was set at 32.8 m.t.a. in 1980 and 58.9 m.t.a. by 2000 if 250,000-d.w.t. carriers drawing 65 feet are used. The lower throughput was set at 18.0 m.t.a. in 1980 and 23.6 m.t.a. by 2000 if 250,000-d.w.t. carriers drawing 58.5 feet, or 120,000-d.w.t. carriers drawing 50 feet are utilized. Alternative 5-7 considers the lower throughput alone, in combination with the three vessel sizes mentioned above. The assumed length and breadth of the 250,000-d.w.t. grain carriers are the same as those given in table 95 for coal carriers; for a 120,000-d.w.t. grain carrier drawing 50 feet, the length and breadth are 860 and 140 feet, respectively.

The transshipment barges are hypothesized in the 40,000-d.w.t. range, drawing 30 to 36 feet.

Intermediate Storage

Alternatives 4-4 and 4-6 consider silos on an artificial island, whereas alternative 5-7 considers silos on shore.

Dredging and Water Depths

Alternatives 4-4 and 4-6 would not require dredged channels or berthing areas for the grain facilities. Alternative 5-7 would require dredged channels, turning basins, and berthing areas.

Construction Program

The time phasing of the various construction items for the period prior to 1980 is given in table 99 for alternative 4-4 and in table 100 for alternative 5-7. (The construction program of alternative 4-6 is given in table 98.) The entire phasing was simplified to facilitate calculations. The total cost of each item will be distributed equally over the pertinent years.

Table 99. Construction Program of Alternative 4-4

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Breakwater of island....	X	X	X		
Land fill and slope protection of island...			X		
Mechanical and electrical equipment.........				X	X
Silos..................				X	X
Berths and trestles.....				X	X

Table 100. Construction Program of Grain Facilities of Alternative 5-7

Construction item	Year of construction or installation				
	1975	1976	1977	1978	1979
Dredging................			X		
Mechanical and electrical equipment..........				X	X
Silos..................				X	X
Berths and trestles.....				X	X

Description

Alternative 2-6

Criteria

1. Commodity: Coal.
2. Site of deepwater port: Delaware Bay, about 10 miles southeast of Big Stone Beach, Delaware.
3. Links to existing ports: Hampton Roads, Virginia, and Baltimore, Maryland.
4. Site of storage: Artificial island.
5. Size of supercarriers: 250,000 d.w.t.
6. Subalternatives: The throughputs of the various subalternatives, as well as the draft of the vessels they will serve, are given in table 101.

Table 101. Throughputs and Drafts of Vessels Served by Subalternatives

Subalternative	Vessel draft fully loaded (feet)	Throughput (million tons/year)	
		1980	2000
A...............	65	45.4	43.7
B...............	58.5	11.5	6.4

Requirements

Supercarrier berths. Subalternative A would require two berths by 1980, while subalternative B would require one berth by 1980. Neither subalternative would require any additional berths in the period from 1980 to 2000.

Dredging quantities. All quantities will include an overdepth of 3 feet for advanced maintenance dredging. The channels are the same as those for alternatives 2-1 through 2-4, except for the water depth, since it is assumed that the supercarriers considered would draw 5 and 12.5 feet less than the supertankers. No dredging would be required for turning basins and berthing areas.

1. Channel A. The required depths would be 1.2 x 65 = 78 feet, and 1.2 x 58.5 = 70 feet, for subalternatives A and B, respectively. The following dimensions would be required:

a. Length = about 2 miles

b. Required depth = 81 and 73 feet, including overdepth, for subalternatives A and B, respectively

c. Average present bottom depth = 67 feet

d. Width at bottom = approximately 1,000 feet

e. Quantities to be dredged:

(1) Subalternative A = 5.7 x 10^6 cubic yards

(2) Subalternative B = 2.4 x 10^6 cubic yards

2. Channel B. The required depths would be 1.15 x 65 -4 (tide) + 3 = 74 feet, and 1.15 x 58.5 -4 + 3 = 66 feet, for subalternatives A and B, respectively. The following dimensions would be required:

a. Length = 2.5 miles

b. Average present bottom depth = 57 feet

c. Width at bottom = approximately 900 feet

d. Quantities to be dredged:

(1) Subalternative A = 7.9×10^6 cubic yards
(2) Subalternative B = 4.1×10^6 cubic yards

3. Channel C. No dredging would be required, since the minimum present water depth is 76 feet.

4. Channel D. The required depths would be 1.1 x 65 = 71 feet, and 1.1 x 58.5 = 64 feet, for subalternatives A and B, respectively. The average depth is 68 feet. Dredging quantities would be negligible for subalternative A, and zero for subalternative B.

5. Total dredging quantities. The total quantity to be dredged would be as follows: for subalternative A, $5.7 + 7.9 = 13.6 \times 10^6$ cubic yards; and for subalternative B, $2.4 + 4.1 = 6.5 \times 10^6$ cubic yards.

Trestle between supercarrier berths and artificial island. If the artificial island is located in 4 to 20 feet of water, a trestle length of approximately 1.5 miles per berth would be required for both subalternatives.

Artificial island. The storage requirement for subalternative A would be 1,000 acres under assumption 1 and 250 acres under assumption 2. The storage requirement for subalternative B would be 625 acres under assumption 1 and 155 acres under assumption 2.

The breakwaters and corresponding slope protections would be approximately 2.5 and 1.0 miles long for subalternative A, assumptions 1 and 2, respectively; and 1.7 and 0.8 miles long for subalternative B, assumptions 1 and 2, respectively. The corresponding average water depths were estimated at 15, 8, 12, and 6 feet. The required sand fill would be: for subalternative A, assumption 1, $(1{,}000 \times 43{,}560 \times 35)/27 = 56.5 \times 10^6$ cubic yards, and assumption 2, $(250 \times 43{,}560 \times 28)/27 = 11.3 \times 10^6$ cubic yards; and for subalternative B, assumption 1, (625 x 43,560 x 32)/27 = 32.3 x 10^6 cubic yards, and assumption 2, (155 x 43,560 x 26)/27 = 6.5 x 10^6 cubic yards.

Transshipment berths. Subalternative A would require three berths by 1980; for subalternative B, one berth by 1980 would probably be sufficient. Neither subalternative would require any additional berths in the period from 1980 to 2000.

Each berth would have a trestle to the island which would be about 1 mile long.

Alternative 2-7

Criteria

1. Commodity: Coal and iron ore.
2. Site of deepwater port: Delaware Bay, about 10 miles southeast of Big Stone Beach, Delaware.
3. Link to existing ports: Hampton Roads, Virginia, and Baltimore, Maryland, for coal; and Baltimore and Philadelphia-Trenton for iron ore.
4. Site of storage: Artificial island.
5. Size of supercarriers: 250,000 d.w.t.
6. Subalternatives: The throughputs of the various subalternatives, as well as the draft of the vessels they will serve, are given in table 102.

Table 102. Throughputs and Drafts of Vessels Served by Subalternatives

Subalternative	Vessel draft fully loaded (feet)	Throughput (million tons/year)			
		Coal		Iron ore	
		1980	2000	1980	2000
A........	65	45.4	43.7	12.5	17.1
B........	58.5	11.5	6.4	12.5	17.1

Requirements

Supercarrier berths. Subalternative A would require two coal and two iron ore berths by 1980; subalternative B would require one coal and two iron ore berths by 1980. Neither subalternative would require an additional berth in the period from 1980 to 2000.

Dredging quantities. In addition to the approximate dredging required in alternative 2-6, a dredged berthing area for two iron ore carriers would be required. For both subalternatives A and B, the approximate dimensions of this area would be: length, 2 x 1.5 x 1,100 = 3,300 feet; width, 4 x 200 = 800 feet; and depth, between 62 and 68 feet. The dredging volume would be 2.7×10^6 cubic yards. The total dredging quantities would be: for subalternative A, 13.6 + 2.7 = 16.3×10^6 cubic yards; and for subalternative B, 6.5 + 2.7 = 9.2×10^6 cubic yards.

Trestle between supercarrier berths and artificial island. If the artificial island is located in 4 to 20 feet of water, a trestle length of approximately 1.5 miles would be required for the coal facilities and for the iron ore facilities. It is anticipated that a breakwater would be required to provide calm water at the iron ore unloading facilities. The breakwater would be about 1/2 mile long and would be located in about 40 feet of water.

Artificial island. The storage requirements for coal would be: for subalternative A, assumption 1, 1,000 acres, and assumption 2, 250 acres; and for subalternative B, assumption 1, 625 acres, and assumption 2, 155 acres.

The storage requirement for iron ore would be 65 acres for both subalternatives. The total requirement would be: for subalternative A, assumption 1, 1,065 acres, and assumption 2, 315 acres; and for subalternative B, assumption 1, 690 acres, and assumption 2, 220 acres.

The breakwaters and slope protection would be approximately 2.6 and 1.1 miles long for subalternative A, assumptions 1 and 2, respectively; and 1.8 and 0.9 miles long for subalternative B, assumptions 1 and 2, respectively. The corresponding average water depths were estimated at 15, 8, 12, and 6 feet. The required sand fill will be: for subalternative A, assumption 1, $(1{,}065 \times 43{,}560 \times 35)/27 = 60.1 \times 10^6$ cubic yards, and assumption 2, $(315 \times 43{,}560 \times 28)/27 = 14.2 \times 10^6$ cubic yards; and for subalternative B, assumption 1, $(690 \times 43{,}560 \times 32)/27 = 35.6 \times 10^6$ cubic yards, and assumption 2, $(220 \times 43{,}560 \times 26)/27 = 9.2 \times 10^6$ cubic yards.

Transshipment berths. Subalternative A would require three coal berths and two iron ore berths by 1980; subalternative B would require one coal berth and two iron ore berths by 1980. Neither subalternative would require any additional berths in the period from 1980 to 2000.

The length of each trestle was estimated at 1.0 mile.

Figure 39 presents the location and layout of the deepwater port and the artificial island.

Alternative 3-1

Criteria

1. Commodity: Coal.
2. Site of deepwater port: Present facilities at Norfolk and Newport News.
3. Site of storage: Railroad cars in shuttling yard.
4. Subalternatives: The throughput of the various subalternatives, as well as the size of the vessels they will serve, are given in table 103.

Requirements

Supercarrier berths. Since the anticipated throughput is of the same order of magnitude as the

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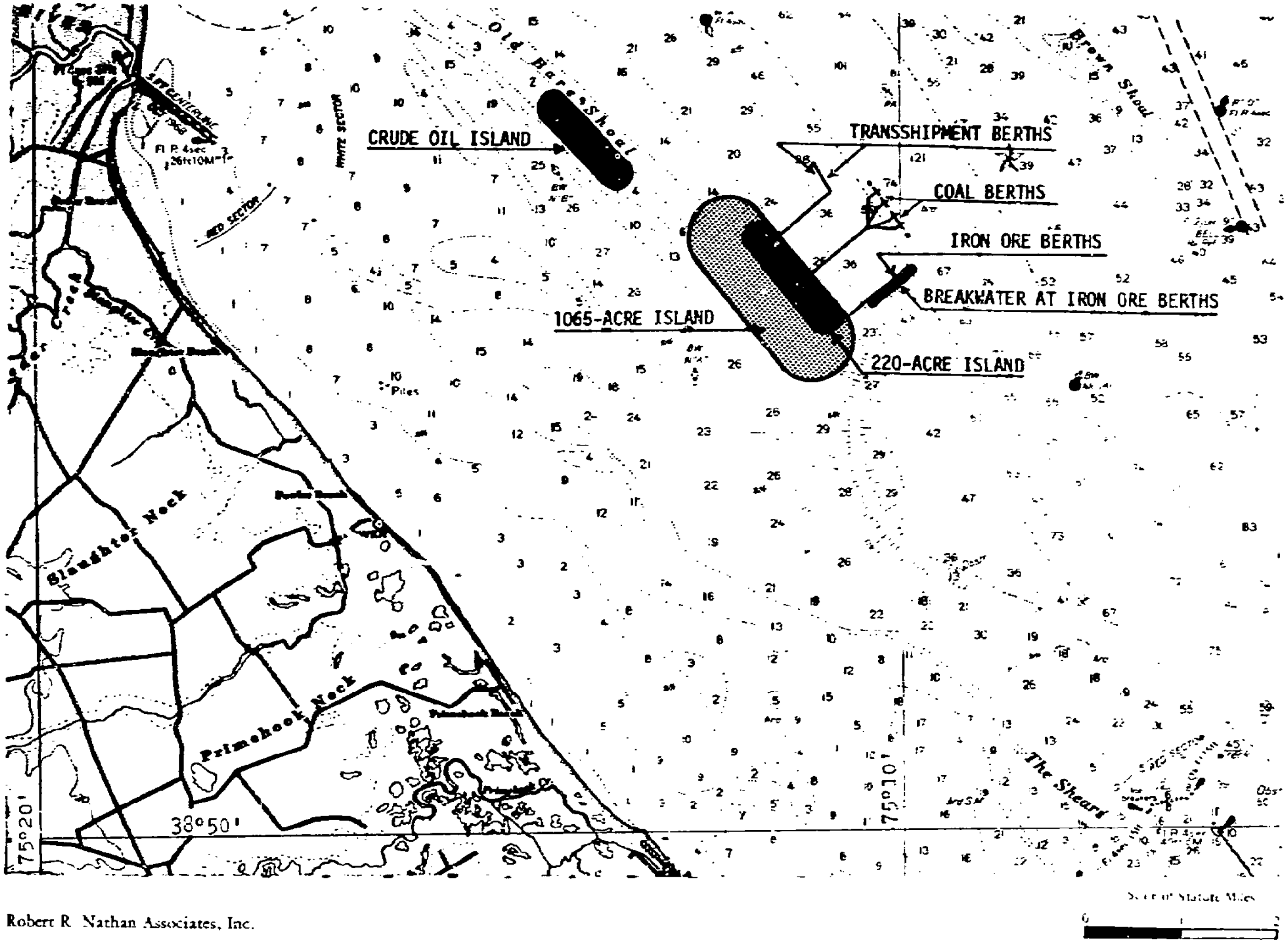

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FIGURE 39. LOCATION AND LAYOUT OF DEEPWATER BERTHS, TRESTLES, BREAKWATER AND ARTIFICIAL ISLAND OF ALTERNATIVE 2-7

Table 103. Throughputs and Size of Vessels Served by Subalternatives

Subalternative	Vessel dimensions		Throughput (million tons/year)	
	Size (d.w.t.)	Draft (feet)	1980	2000
A.............	128,000	52	46.1	46.6
B.............	179,000	52	46.1	46.6

present throughput, the number of berths presently available would be sufficient. (Table 92 shows that two berths are sufficient.)

Dredging quantities. All quantities will include an overdepth of 3 feet for advanced maintenance dredging. In determining the channel depth, 2.5 feet of total rise will be taken into account.

1. New ocean channel. A new ocean channel would be located off shore between miles 14.3 and 3.3, and would be 11 miles long. The required water depth would be about 60 feet. The present average water depth per mile is 57, 53, 55, 50, 50, 50, 50, 52, 52, 55, and 55 feet, respectively; the average depth of the channel would be approximately 53 feet. The width of the channel could vary between 5B and 4B (B = beam of vessel); however, due to the channel's orientation with respect to possible crosscurrents, a width of 5B will be applied for its entire length. Consequently, the width would be 685 and 850 feet for subalternatives A and B, respectively. The dredging quantity, including 3 feet of advanced maintenance dredging, would be 15.4×10^6 cubic yards for subalternative A and 18.9×10^6 cubic yards for subalternative B.

2. Thimble Shoal Channel. The maximum available depth of the Thimble Shoal Channel over the South Tunnel of the Chesapeake Bay Bridge and Tunnel is 55 feet. The dimensions of the channel would be: length, 13.5 miles; width, 550 and 680 feet for subalternative A

and B, respectively; and depth, 58 feet. The total quantity to be dredged would be 20.2 x 10^6 and 24.7 x 10^6 cubic yards for subalternatives A and B, respectively.

3. Entrance Reach. This channel would be approximately 2 miles long; 55 feet deep, excluding overdepth; and 480 and 595 feet wide for subalternatives A and B, respectively. The total quantity to be dredged would be 2.6 x 10^6 and 3.2 x 10^6 cubic yards for subalternatives A and B, respectively.

4. Newport News Channel. This channel would be approximately 4.8 miles long; 55 feet deep, excluding overdepth; and 480 and 595 feet wide for subalternatives A and B, respectively. The total quantity to be dredged would be 6.3 x 10^6 cubic yards and 7.7 x 10^6 cubic yards for subalternatives A and B, respectively.

5. Norfolk Harbor and Craney Island Reaches. This channel would be approximately 6.3 miles long; 55 feet deep, excluding overdepth; and 480 and 595 feet wide for subalternatives A and B, respectively. The total quantity to be dredged would be 8.3 x 10^6 and 10.2 x 10^6 cubic yards for subalternatives A and B, respectively.

6. Berthing areas. Three areas, each 52 feet deep, and approximately 1,310 feet long and 410 feet wide for subalternative A, and approximately 1,520 feet long and 510 feet wide for subalternative B, would require 0.2 x 10^6 cubic yards and 0.3 x 10^6 cubic yards each, respectively.

7. Dredging quantities. Total dredging quantities would be: ocean channels, 35.6 x 10^6 and 43.6 x 10^6 cubic yards; and Inland channels, 17.8 x 10^6 and 22.0 x 10^6 cubic yards, for subalternatives A and B, respectively. No major additional modifications are assumed to be required.

Alternative 4-4

Criteria

1. Commodity: Grain.
2. Site of deepwater port: Garden Island Bay, Gulf of Mexico.
3. Links to existing ports: All grain evacuating ports on the Mississippi River and the Texas and Louisiana coasts.
4. Site of storage: Artificial island.
5. Subalternatives: The throughputs of the various subalternatives, as well as the dimensions of the vessels they will serve, are given in table 104.

Table 104. Throughputs and Dimensions of Vessels Served by Subalternatives

Subalternative	Vessel dimensions		Throughput (million tons/year)	
	Size (d.w.t.)	Draft (feet)	1980	2000
A.............	250,000	65	32.8	58.9
B.............	250,000	58.8	18.0	23.6
C.............	120,000	50	18.0	23.6

Requirements

Supercarrier berths. Subalternatives A and C would require two berths by 1980, and no additional berths in the period from 1980 to 2000. Subalternative B would require one berth by 1980, and it is assumed that no additional berths would be required in the period from 1980 to 2000, since this is a loading operation.

Dredging. Subalternatives A, B, and C would require water depths at the berthing area of 75, 67, and 58 feet, respectively; they would require depths at the turning basin and approach area of 78, 70, and 60 feet, respectively. Since sufficient water depth is available at the approach area, turning basin and berthing area, no dredging would be required.

Trestle between supercarrier berth and artificial island. If the artificial island is located in 35 feet of water, a trestle length of approximately 1/2 mile per berth would be required, for all subalternatives.

Artificial island. The required silo storage capacity would be: for subalternative A, 2.0 million long tons; for subalternative B, 1.25 million long tons; and for subalternative C, 0.96 million long tons. The required acreage for the grain storage would be: for subalternative A, 80 acres; for subalternative B, 50 acres; and for subalternative C, 40 acres. Including an additional 10 acres for general services, the total acreage for each alternative would be 90, 60, and 50 acres, respectively.

With an assumed water depth of 35 feet and an assumed terrain elevation of + 20 feet, the land fill requirement would be: for subalternative A, $(90 \times 43,560)/27 \times 55 = 8.0 \times 10^6$ cubic yards; for subalternative B, $(60 \times 43,560)/27 \times 55 = 5.3 \times 10^6$ cubic yards; and for subalternative C, $(50 \times 43,560)/27 \times 55 = 4.4 \times 10^6$ cubic yards.

For subalternatives A, B, and C, the length of the breakwater was estimated at 1.2, 0.9, and 0.8 miles, respectively, and the length of the slope protection at 0.8, 0.6, and 0.5 miles, respectively.

Transshipment berths. Subalternative A would require three berths by 1980; subalternatives B and C would require two berths by 1980. No alternatives would require any additional berths in the period from 1980 to 2000.

The length of each trestle was estimated at 0.2 mile.

Alternative 4-5

Criteria

1. Commodity: Iron ore.
2. Site of deepwater ports: Garden Island Bay, Gulf of Mexico.
3. Links to existing ports: Mobile, Houston and Baton Rouge.
4. Site of storage: Artificial island.
5. Supercarrier dimensions: 250,000 d.w.t.
6. Subalternatives: The throughputs of the various subalternatives, as well as the drafts of the vessels they will serve, are given in table 105.

Table 105. Throughputs and Drafts of Vessels Served by Subalternatives

Subalternative	Vessel draft, fully loaded (feet)	Throughput (million tons/year)	
		1980	2000
A................	65	7.6	10.4
B................	58.5	7.6	10.4

Requirements

Supercarrier berths. One berth would be sufficient for both subalternatives since the maximum throughput is less than 11 m.t.a.

Dredging. For subalternatives A and B, the required water depth at the berth would be 75 and 67 feet, respectively, and at the turning basin and approach area, 78 and 70 feet, respectively. Sufficient water depth is available at the approach area. However, it is anticipated that a breakwater would be required to provide calm water at the berth. To restrict the cost of the breakwater, it is assumed that the breakwater would be located in 40 feet of water. The dredging volume of the turning basin would be approximately (2 x 1,100 x 2 x 1,100 x 35)/27 = 6.3 x 10^6 cubic yards; that of the berthing area would be (1.5 x 1,100 x 3 x 200 x 35)/27 = 1.3 x 10^6 cubic yards, or a total of 7.6 x 10^6 cubic yards. The breakwater would be about 0.3 miles long.

Trestle between supercarrier berth and artificial island. If the artificial island is located in 35 feet of water, a trestle length of approximately 1/2 mile for both subalternatives would be required.

Artificial island. The storage required for one berth would be approximately 0.5 x 10^6 long tons. The acreage required would be approximately 23 acres for iron ore and 10 acres for general services, for a total of approximately 33 acres.

The assumed water depth would be 35 feet, and the assumed terrain elevation, + 20 feet. The land fill requirement would be (43,560/27) x 33 x 55 = 2.9 x 10^6 cubic yards.

The length of the breakwater was estimated at 0.7 miles, and that of the slope protection at 0.25 miles.

Transshipment berths. Because this alternative is a loading operation, it is assumed that one berth with a practical maximum throughput capacity of 9 m.t.a. would be sufficient, even when the maximum projected throughput is 10.4 m.t.a. The trestle would be 0.2 mile long.

Alternative 4-6

This alternative is a combination of alternatives 4-4 and 4-5.

Criteria

1. Commodities: Grain and iron ore.
2. Site of deepwater port: Garden Island Bay, Gulf of Mexico.

3. Links to existing ports: As defined for alternatives 4-4 and 4-5.

4. Site of storage: Artificial island.

5. Subalternatives: The throughputs of the various subalternatives, as well as the dimensions of the vessels they will serve, are given in table 106.

Requirements

Supercarrier berths. The number of berths required would be the same as that for alternatives 4-4 and 4-5. Subalternatives A, C, and D would require one iron ore and two grain berths by 1980; subalternative B would require one iron ore and one grain berth by 1980. No subalternative would require any additional berths in the period from 1980 to 2000.

Dredging. The only dredging required would be that of the turning basin and berthing area of the iron ore berth; the total dredging quantity would be 7.6×10^6 cubic yards. The breakwater would be about 0.3 mile long and would be located in about 40 feet of water.

Trestle between supercarrier berths and artificial island. The length of the trestle would be 1/2 mile for each of the commodities.

Artificial island. The required silo storage capacity would be: for subalternative A, 2.0 million long tons of grain; for subalternative B, 1.25 million long tons of grain; and for subalternatives C and D, 0.96 million long tons of grain.

The combined total acreage would be: for subalternative A, 80 + 23 + 10 = 113 acres; for subalternative B, 50 + 23 + 10 = 83 acres; and for subalternatives C and D, 40 + 23 + 10 = 73 acres.

For subalternatives A, B, and C and D, the land fill requirement would be 10.0×10^6, 7.3×10^6, and 6.4×10^6 cubic yards, respectively.

Table 106. Throughputs and Dimensions of Vessels Served by Subalternatives

Subalternative	Grain				Iron ore			
	Vessel dimensions		Throughput (m.t.a.)		Vessel dimensions		Throughput (m.t.a.)	
	Size (d.w.t.)	Draft (feet)	1980	2000	Size (d.w.t.)	Draft (feet)	1980	2000
A.	250,000	65	32.8	58.9	250,000	65	7.6	10.4
B.	250,000	58.5	18.0	23.6	250,000	58.5	7.6	10.4
C.	120,000	50	18.0	23.6	250,000	65	7.6	10.4
D.	120,000	50	18.0	23.6	250,000	58.5	7.6	10.4

The length of breakwater was estimated at 1.4, 1.1 and 1.0 mile, and that of the slope protection at 1.0, 0.8 and 0.7 miles, for subalternatives A, B, and C and D, respectively.

Transshipment berths. The number of transshipment berths required would be the same as that for alternatives 4-4 and 4-5. Subalternative A would require one iron ore and three grain berths by 1980; subalternatives B, C and D would require one iron ore and two grain berths by 1980. No subalternative would require any additional berths in the period from 1980 to 2000.

Figure 40 presents the location, orientation and layout of berths, breakwater and artificial island.

Alternative 5-7

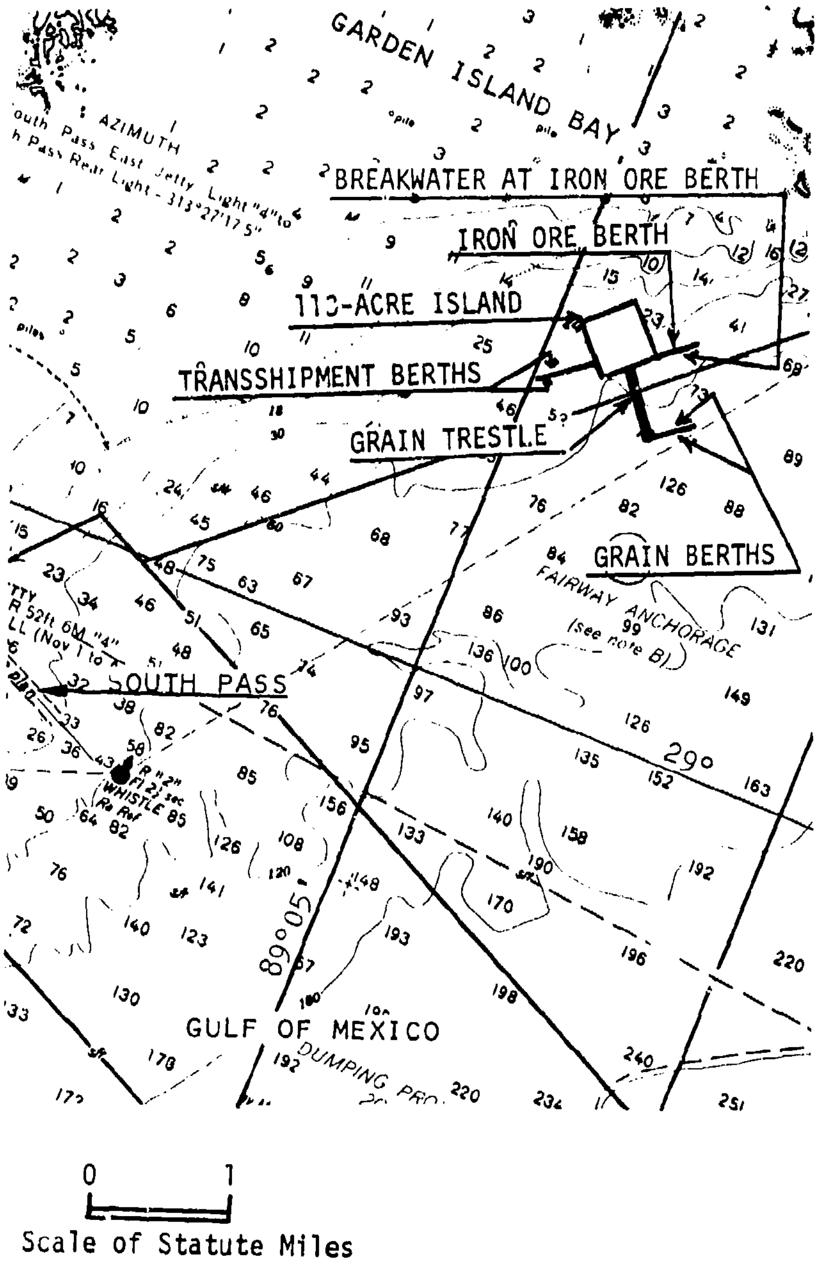
Alternative 5-7 does not stand on its own. It is always combined with one of the alternatives numbered 5-4 through 5-6.

Criteria

1. Site of deepwater port: Inland near Freeport, Texas.
2. Link to existing ports: All existing Texas ports.
3. Site of storage: Near Freeport.
4. Subalternatives: The throughputs of the various subalternatives, as well as the dimensions of the vessels they will serve, are given in table 107.

Requirements

Supercarrier berths. Subalternative A would require one berth by 1980, and it is assumed that no additional berth would be required in the period from 1980 to 2000, since this is a loading operation. Subalternative B would require two berths by 1980, and no additional berths in the period from 1980 to 2000.



Note: Location reference, figures 23-25.

FIGURE 40. LOCATION, ORIENTATION AND LAYOUT OF BERTHS, BREAKWATER AND ARTIFICIAL ISLAND OF ALTERNATIVE 4-6

Table 107. Throughputs and Dimensions of Vessels Served by Subalternatives

Subalternative	Vessel dimensions		Throughput (million tons/year)	
	Size (d.w.t.)	Draft (feet)	1980	2000
A............	250,000	65 and 58.5	18.0	23.6
B............	120,000	50	18.0	23.6

Dredging. Since the grain operations are always in addition to the oil operations, no dredging requirements apply for all channels, except for the turning basin and berthing area. This additional volume is estimated at 10.0 x 10^6 cubic yards.

Acreage. Subalternatives A and B would require storage capacity of 1.25 and 0.96 million long tons, and an acreage of 50 and 38 acres would be required for subalternatives A and B, respectively.

Transshipment berths. For both subalternatives, two berths would be required. The length of the conveyor belts is set at 1 mile for both berths combined.

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VIII. COST ESTIMATES OF DRY BULK PORTS

Unit Costs

First Cost

The main cost components of a deepwater port handling dry bulk commodities are the construction and/or installation cost of:

1. Berths and breakwater at berths
2. Channels and maneuvering areas
3. Trestles
4. Artificial island
5. Mechanical and electrical equipment
6. Silos, in case of grain.

The cost of each component will be evaluated in the following sections; however, all components do not necessarily apply to each type of port construction alternative. The year 1970 was selected as the base year for the cost evaluation.

Berths and Breakwater at Berths

Supercarrier berths. Only fixed berths (islands and marginal piers) are considered for the handling of dry bulk. The cost of the berths will be evaluated using those costs established for the supertankers, excluding the cost of equipment, which will be assumed to be 10 percent of that required for the oil berth. The multiplication factor is 0.9. Furthermore, it will be assumed that the cost of the breasting dolphins would constitute 40 percent of the total civil cost of the berth. For loading operations (coal and grain), the cost of the breasting dolphins would be about 50 percent of the cost for unloading operations (oil and iron ore) for the same design vessel and exposure factor, because the mass of a berthing ballasted empty vessel would be 50 percent or less of the mass of a berthing laden vessel. The multiplication factor would be 0.80.

1. Delaware Bay area, alternatives 2-6 and 2-7. All coal and iron ore berths would be marginal piers. The base case for cost evaluation would be the base case of table 70 (a design vessel of 250,000 d.w.t., and a water depth of 72 feet). The cost, in millions of dollars, of one coal berth would be: for a 250,000 d.w.t. vessel with a draft of 65 feet, 0.9 x 0.8 x 68/72 x \$5.95 = \$4.1; and for a 250,000 d.w.t. vessel with a draft of 58.5 feet, 0.9 x 0.8 x 62/72 x \$5.95 = \$3.7. The cost, in millions of dollars, of one iron ore berth would be: for a 250,000 d.w.t. vessel with a draft of 65 feet, 0.9 x 68/72 x \$5.95 = \$5.1; and for a 250,000 d.w.t. vessel with a draft of 58.5 feet, 0.9 x 62/72 x \$5.95 = \$4.6.

2. Hampton Roads, alternative 3-1. According to information from local authorities, all existing berths could be utilized at no additional expense.

3. Mississippi Delta area, alternatives 4-4 through 4-6. One berth would be constructed as a marginal pier, whereas two berths would be constructed as an island pier. The base case for cost evaluation would be the \$9.9 million island pier of alternative 4-1 (a design vessel of 200,000 d.w.t. and a water depth of 75 feet). The cost, in millions of dollars, of two grain berths would be: for a 250,000 d.w.t. vessel with a draft of 65 feet, 0.9 x 0.8 x 71/75 x \$9.9 = \$6.7; for a 250,000 d.w.t. vessel with a draft of 58.5 feet, 0.9 x 0.8 x 65/75 x \$9.9 = \$6.2; and for a 120,000 d.w.t. vessel with a draft of 50 feet, 0.9 x 0.8 x 120/250 x 55/75 x \$9.9 = \$2.5. The cost, in millions of dollars of two iron ore berths would be: for a 250,000 d.w.t. vessel with a draft of 65 feet, 0.9 x 71/75 x \$9.9 = \$8.4; and for a 250,000 d.w.t. vessel with a draft of

58.5 feet, 0.9 x 65/75 x $9.9 = $7.7. One berth would cost about 35 percent less than a two-berth island.

4. Freeport area, alternative 5-7. One berth would be a marginal pier, whereas two berths would be an island pier. The base case for cost evaluation would be the $3.5 million island pier of alternative 5-4 (a design vessel of 200,000 d.w.t. and a water depth of 58 feet). The cost, in millions of dollars, of two grain berths would be: for a 250,000 d.w.t. vessel with a draft of 65 feet, 0.9 x 0.8 x 250/200 x 68/58 x 3.5 = $3.7; and for a 120,000 d.w.t. vessel with a draft of 50 feet, 0.9 x 0.8 x 120/200 x 53/58 x 3.5 = $1.4.

<u>Transshipment berths</u>. Since the number of transshipment berths does not exceed four, and the cost of a two-berth oil island pier was estimated in the range of $0.8 to $1.0 million, these same cost figures will be applied for this study. Therefore, the costs for a two-berth island pier would be: for alternatives 2-6, 2-7 and 5-7, $0.8 million; and for alternatives 4-4 through 4-6, $1.0 million.

<u>Breakwater at berths</u>. The cost of the breakwater protecting the iron ore berths would amount to $(65/45)^2 \times 20$ = $42 million per mile for alternative 2-7, and to $(65/45)^2 \times 1.5 \times 20$ = $63 million per mile for alternatives 4-5 and 4-6.

<u>Channels and Maneuvering Areas</u>

<u>Delaware Bay area, alternatives 2-6 and 2-7</u>. The cost to be applied will be the same as for oil alternatives 2-1 through 2-4.

Channel A = $0.40 per cubic yard, and Channel B = $0.80 per cubic yard. For the berthing area at the iron ore facility of alternative 2-7, the cost of Channel D will be applied, which is $0.90 per cubic yard.

Hampton Roads area, alternative 3-1. Local authorities advised the use of the following preliminary cost figures:

Channel	Cost/cubic yard ($)
New Ocean Channel	0.40
Thimble Shoal Channel	0.75
Entrance Reach	0.90
Newport News Channel	0.90
Craney Island Reach	0.90

Mississippi Delta. For the turning basin and berthing area at the iron ore berth of alternatives 4-5 and 4-6, a cost of $0.50 per cubic yard will be applied.

Freeport, Texas. A cost of $1.30 per cubic yard will be applied for alternative 5-7.

Trestles

Detailed estimates of the cost of trestles are not available. The cost would vary by water depth, load (mechanical equipment), and load condition due to rate of exposure (wind, waves and current). The following figures will be applied: for alternatives 2-6 and 2-7, $3.0 million per mile; and for alternatives 4-4 through 4-6, $5.0 million per mile. Each berth will be assumed to require one trestle.

Artificial Island

The cost of breakwaters and sand fill to be applied will be the same as that derived for the various oil alternatives.

Delaware Bay area, alternatives 2-6 and 2-7. For both alternatives the breakwater would be in an average water depth of about 25 feet; its cost would be $(50/45)^2 \times 20$ = $25 million per mile. The cost of the slope protection would be $2 million per mile; that of the sand fill, $1.00 per cubic yard.

Mississippi Delta, alternatives 4-4 through 4-6. All breakwaters would be in an average water depth of 35 feet, and would cost approximately $55 million per mile. The cost of the slope protection would be $2 million per mile; the cost of the sand fill, $1.00 per cubic yard.

Mechanical and Electrical Equipment

It has been estimated that the cost of mechanical and electrical equipment to handle one coal or iron ore supercarrier would be $15 to $20 million, depending on the length of the trestle. Considering the length of the trestles in various alternatives, a cost of $20 million for mechanical and electrical equipment on berths (supercarrier and transshipment), trestles and island will be applied. This cost is for one berth.

For grain a cost of $5 million per mile of trestle will be applied.

Grain Silos

The new 4,200,000-bushel grain silos of Seattle's Pier 86 were reported to have been constructed at a cost of about $8.0 million during 1969 and 1970. A 1971 study by the Port of Tacoma considers extending the existing port grain elevator facility by a million-bushel storage elevator at a cost of $2,255,000, including the cost of design, inspection, administration and contingencies. Since the deepwater ports of the gulf are anticipated to export various grains, a weighted average for the relationship between long tons and bushels will be applied. It was found that 1 long ton is equivalent to 39 bushels. Therefore, in this study a figure of $2 million per million bushels, or $78,000,000 per million long tons, of grain will be applied.

Miscellaneous

For drainage and surfacing of the coal and iron ore islands, a figure of $10,000 per acre will be applied.

Operating Cost

The main cost components of a deepwater port handling dry bulk are the cost of:

1. Marine operations
2. Loading and unloading operations at the berths
3. Island operations
4. Personnel transport.

The costs given for these components will provide only for the cost of personnel and equipment directly related to the operations. It is anticipated that all facilities would operate on a 7-day-a-week program and that four 8-hour shifts would therefore be required. The average annual labor cost of a person is set at $15,000.

Marine Operations

The same requirements for personnel, launches, and tugs would apply as for tankers in the case of fixed berths. Since the total number of supercarrier and transshipment berths combined in most of the alternatives is less than six, a cost of $2.56 million would be applied for all berths combined. When the total number of berths is in excess of six, it will be assumed that an additional $1 million would be required for the separate operations at the supercarrier and transshipment berths.

Loading and Unloading Operations at the Berths

During the entire period of loading or unloading a supercarrier or loading or unloading a transshipment barge, one operator would be present at each berth. Therefore, four operators would be required for each berth per week. The annual labor cost would amount to $60,000 per berth.

Island Operations

It will be assumed that for management, supervision, and administration, an annual labor cost of

$1 million per commodity would be required. In addition to this, the annual cost of supplies, utilities, and expenses could be $300,000 per commodity. The energy cost is set at $0.15 per long ton of throughput.

Personnel Transport

The cost of transporting personnel to and from the island would be the same as that for the deepwater ports handling crude oil. For ports in the Lower Delaware Bay and those in the Mississippi Delta, the annual cost will be assumed at $500,000 and $1 million, respectively.

Maintenance Cost

The following annual maintenance costs were established as percentages of the first cost:

Berths and trestles	1.5
Breakwater	1.0
Mechanical and electrical equipment:	
Coal and iron ore	8.0
Grain	3.0
Grain silos	2.0
Dredging:	
Delaware Bay, ocean channels to Hampton Roads and the Mississippi Delta	2.5
Inland channels at Hampton Roads	1.0
Inland basins at Freeport	0.5

Total Costs

Applying the unit costs as derived in the foregoing sections to the engineering requirements of the selected alternatives and subalternatives results in total first costs, total annual operating costs and total annual maintenance costs. These are given in table 108. A breakdown of the first costs into five components is given in table 109.

Table 108. Summary of Total First Cost and Total Annual Operating and Maintenance Costs of Dry Bulk Alternatives

(In millions of dollars)

Code no.a/	Alternative			Com. and throughput (mil. L. tons)						First cost 1975-79b/	Annual operating cost		Annual maintenance cost	
	No.	Sub.	As-sump-tion	Coal		Iron ore		Grain						
				1980	2000	1980	2000	1980	2000		1980	2000	1980	2000
0680...	2-6	A	1	45.6	43.7	--	--	--	--	210.1	11.4	11.3	4.5	4.5
0690..	2-6	A	2	45.6	43.7	--	--	--	--	116.8	11.4	11.3	4.1	4.1
0700..	2-6	B	1	11.5	6.4	--	--	--	--	120.2	6.0	5.6	2.3	2.3
0710..	2-6	B	2	11.5	6.4	--	--	--	--	65.5	6.0	5.6	2.1	2.1
0720..	2-7	A	1	45.6	43.7	12.5	17.1	--	--	306.4	16.0	16.2	8.1	8.1
0730..	2-7	A	2	45.6	43.7	12.5	17.1	--	--	212.6	16.0	16.2	7.8	7.8
0740..	2-7	B	1	11.5	6.4	12.5	17.1	--	--	215.5	9.6	9.6	6.2	6.2
0750..	2-7	B	2	11.5	6.4	12.5	17.1	--	--	160.2	9.6	9.6	6.0	6.0
0760..	3-1	A	--	46.1	46.6	--	--	--	--	37.2	--	--	0.7	0.7
0770..	3-1	B	--	46.1	46.6	--	--	--	--	45.9	--	--	0.9	0.9
0780..	4-4	·	--	--	--	--	--	32.8	58.9	256.0	11.1	13.0	4.3	4.3
0790..	4-4	B	--	--	--	--	--	18.0	23.6	167.8	8.0	8.4	2.7	2.7
0800..	4-4	C	--	--	--	--	--	18.0	23.6	141.9	8.0	8.4	2.3	2.3
0810..	4-5	A	--	--	--	7.6	10.4	--	--	99.4	6.2	6.4	2.4	2.4
0820..	4-5	B	--	--	--	7.6	10.4	--	--	94.0	6.2	6.4	2.4	2.4
0830..	4-6	A	--	--	--	7.6	10.4	32.8	58.9	322.0	14.7	16.9	6.4	6.4
0840..	4-6	B	--	--	--	7.6	10.4	32.8	58.9	321.6	14.7	16.9	6.4	6.4
0850..	4-6	C	--	--	--	7.6	10.4	18.0	23.6	233.8	10.6	11.3	4.9	4.9
0860..	4-6	D	--	--	--	7.6	10.4	18.0	23.6	233.4	10.6	11.3	4.9	4.9
0870..	4-6	E	--	--	--	7.6	10.4	18.0	23.6	207.8	10.7	11.3	4.5	4.5
0880..	4-5	F	--	--	--	7.6	10.4	18.0	23.6	207.4	10.7	11.3	4.5	4.5
0890..	5-7	A	--	--	--	--	--	18.0	23.6	121.5	5.4	5.8	2.3	2.3
0900..	5-7	B	--	--	--	--	--	18.0	23.6	97.7	5.7	6.1	1.8	1.8

a/ Code numbers shown for each alternative are those used in the computer computation of benefits and costs (Annex F).

b/ First cost period 1980-2000 is zero for all alternatives.

Table 109. Summary of First Cost of Dry Bulk Alternatives[a]

(In millions of dollars)

Code no.[b]	Alternative			1975-79					
	No.	Sub.	As-sump-tion	Dredg-ing	Berths and trestles	Artificial island and misc.	Silos	Machinery and equipment	Total
0680..	2-6	A	1	8.6	27.4	134.1	--	40.0	210.1
0690..	2-6	A	2	8.6	27.4	40.8	--	40.0	116.8
0700..	2-6	B	1	4.2	11.6	84.4	--	20.0	120.2
0710..	2-6	B	2	4.2	11.6	29.7	--	20.0	65.5
0720..	2-7	A	1	11.0	53.4	162.0	--	80.0	306.4
0730..	2-7	A	2	11.0	53.4	68.2	--	80.0	212.6
0740..	2-7	B	1	6.6	36.8	112.1	--	60.0	215.5
0750..	2-7	B	2	6.6	36.8	56.8	--	60.0	160.2
0760..	3-1	A	--	37.2	--	--	--	--	37.2
0770..	3-1	B	--	45.9	--	--	--	--	45.9
0780..	4-4	A	--	--	16.4	75.6	156.0	8.0	256.0
0790..	4-4	B	--	--	9.6	56.0	97.6	4.6	167.8
0800..	4-4	C	--	--	10.6	49.5	74.8	7.0	141.9
0810..	4-5	A	--	3.8	9.6	61.0	--	20.0	94.4
0820..	4-5	B	--	3.8	9.2	61.0	--	20.0	94.0
0830..	4-6	A	--	3.8	25.8	108.4	156.0	28.0	322.0
0840..	4-6	B	--	3.8	25.4	108.4	156.0	28.0	321.6
0850..	4-6	C	--	3.8	19.0	88.8	97.6	24.6	233.8

continued--

Table 109. Summary of First Cost of Dry Bulk Alternatives[a] continued--
(In millions of dollars)

Code no.[b]	Alternative			1975-79					
	No.	Sub.	As-sump-tion	Dredg-ing	Berths and trestles	Artificial island and misc.	Silos	Machinery and equipment	Total
0860..	4-6	D	--	3.8	18.6	88.8	97.6	24.6	233.4
0870..	4-6	E	--	3.8	20.2	82.0	74.8	27.0	207.8
0880..	4-6	F	--	3.8	19.8	82.0	74.8	27.0	207.4
0890..	5-7	A	--	13.0	8.3	--	97.6	2.6	121.5
0900..	5-7	B	--	13.0	7.3	--	74.8	2.6	97.7

a/ First cost period 1980-2000 is zero for all alternatives.
b/ Code numbers shown for each alternative are those used in the computer computation of benefits and costs (Annex F).

IX. COMBINATION OF CRUDE PETROLEUM AND DRY BULK PORTS

Although table 3 presents 20 alternatives combining crude petroleum and dry bulk ports, it is not intended to evaluate these alternatives in the same way as those dealing with crude oil or dry bulk only, as has been done in the preceding chapters. All main components are the same in principle. Therefore, this chapter will illuminate only those issues or components influenced by such a combination of ports. An additional reason for not treating the combination alternatives in the same way as the component alternatives is the number of possible subalternatives. Many crude oil alternatives have four subalternatives; combining these with two to six dry bulk subalternatives would result in eight to 24 subalternatives.

Issues of importance for a combination port are the safety of the maneuvering and unloading tankers and the safety of the oil storage, and the influence on the berth layout. In principle, the first cost and the annual operating and maintenance cost of the combination alternatives would be the sum of the costs of the individual alternatives. In other words, the first cost of alternative 2-8 would be the sum of the first costs of alternatives 2-1 and 2-6. In various alternatives, however, some cost items would be duplicated; in these cases, the total costs would be less than the sum of the two components. Cost items which should be considered for reduction in case of combination ports are those of dredged channels, artificial islands, marine operations and personnel transport. Each item will be discussed separately by port area in the following sections.

Delaware Bay Area

Safety

All fully loaded supertankers and supercarriers have to follow the same route between the deepwater lines of Channel A (figure 16) and the natural deepwater area at the berths (figures 19 and 21). This route is about 45 miles long and consists of four channel sections having a total length of approximately 10 miles. Therefore, fully loaded incoming supertankers and iron ore carriers and fully loaded outgoing coal supercarriers have ample opportunity to pass each other at three sections having a total length of approximately 35 miles. At these sections, sufficient water depth and width exist for safe passage.

The deepwater area at the berths is wide enough for safe maneuvering and for safe waiting if all berths are occupied and therefore can handle combined traffic. The safety of unloading the supertankers will not be influenced by the unloading and loading operations of the coal and iron ore supercarriers and transshipment barges because of the distance between the locations of these operations. If crude oil and dry bulk are stored on one artificial island (which an optimum layout of the deepwater ports for the various commodities makes unlikely in the Lower Delaware Bay), then a minimum distance between the storages would be required.

Berth Layout

The natural deepwater body at the deepwater berths is about 18,000 feet long. The length of one berth varies with the length of the vessel, and in the pertinent alternatives ranges from 1.5 x 1,262 feet to 1.5 x 1,050 feet. This means that approximately ten 1,800-foot-long marginal berths could be installed, if necessary. The maximum total number of berths would be five crude oil, two coal, and one iron ore berths. The orientation of the latter is perpendicular to the orientation of the others. Therefore, it may be concluded that there is sufficient space to accommodate all berths.

Dredged Channels

Since the fully loaded supertankers and supercarriers would follow the same route from the Atlantic Ocean to berths and vice versa, all fully loaded vessels would use the same channels. The dimensions of the channels would be determined by the dimensions of the vessels with the largest drafts and beams, which in the pertinent alternatives (2-8 through 2-15) are supertankers. Therefore, in these alternatives the first cost of channel dredging, as calculated for dry bulk alternatives 2-6 and 2-7, do not apply. This cost was estimated at $8.6 and $4.2 million in subalternative 2-6 for 250,000-d.w.t. carriers drawing 65 and 58.5 feet, respectively. It should be noted that the first cost of dredging in the case of alternative 2-7 is $2.4 million higher, which reflects the dredging cost of the berthing area of the iron ore berth. This cost is still applicable where iron ore operations are considered. Therefore, it may be concluded that in all eight combination alternatives the total first cost of dredging is the sum of the first costs of dredging as calculated for the crude petroleum and dry bulk ports, minus $8.6 or $4.2 million, depending on the draft of the dry bulk carrier considered.

Artificial Islands

This paragraph does not apply to alternatives 2-8, 2-9, 2-12, and 2-13, because these alternatives include alternatives 2-1 or 2-3, which consider onshore storage. For the remaining four alternatives, a combination of the two separate islands would theoretically be possible. However, it is very unlikely that this would be proposed, given the characteristics of the requirements for the crude petroleum and dry bulk ports. The crude petroleum berths would be located at the northernmost portion of the natural deepwater body to keep the submarine pipelines to the coast at Big Stone Beach as short as possible. A naturally shallow area is found close to this routing. Disregarding conditions of environment, soil, and hydraulics, this area would be suitable for the construction of an artificial island.

The dry bulk port would be located in the southernmost portion of the natural deepwater body to keep the trestles between berths and artificial island as short as possible. A naturally shallow area, located approximately 3 miles southeast of the first shallow area, would accommodate the dry bulk island. As figure 39 shows, these two islands would not require the same location and do not interfere physically with each other. Therefore, it may be concluded that combinations of the two islands are not likely to be necessary or required for the combination alternatives that are considered, because this would result in either longer pipelines or longer trestles.

Marine Operations

For the crude oil alternatives, the annual cost of the marine operations; that is, the cost of tug assistance and the employment of oarsmen, would be $2.56 million. For the dry bulk alternatives, this cost is $2.56 million for six berths and less, and $3.56 million for seven or more berths. If, in the case of combined activities, the total number of berths is eight or less, then $2.56 million may be deducted from the total operating cost (for instance, alternatives 2-1 and 2-2, subalternatives A and C, in combination with alternative 2-6). If the number of berths is nine or more, then the deduction would be less.

Because of the different criteria for crude oil and dry bulk ports, it is not possible in general to present a figure which might be deducted from the total operating cost. However, this figure will be in the order of magnitude of $1 to $2 million. The number of crude berths varies from a minimum of two by 1980 to a maximum of five by 2000. The number of coal berths varies from two to five, whereas the total number of iron ore berths is four. Therefore, it may be concluded that in most of the cases $1 to $2 million, and in some cases, $2.56 million, could be deducted from the total operating costs.

Personnel Transport

The personnel shuttle service between shore and deepwater ports could easily be combined. Therefore,

$0.5 million could be deducted from the total operating costs.

Maintenance Cost

Only the maintenance cost of the dry bulk channels could be deducted from the total sum. The annual maintenance cost of these channels would be 2.5 percent of the first cost. This would result in $0.21 million and $0.11 million, for a first cost of $8.6 and $4.2 million, respectively. This reduction is a very insignificant amount of the total maintenance cost.

Conclusion

Taking the above deductions into account, it can be concluded that the total sum of first cost could be reduced by about 1 to 3 percent; of annual operating cost, by 5 to 10 percent; and of maintenance costs, by 1 to 3 percent, depending on the alternative and subalternative considered.

Mississippi Delta Area

Safety

Because no dredged channels are required, all vessels would follow different approach lanes to and from the berths. Vessels move in a water body restricted in width only when maneuvering to and from the berths located at the land side of the trestle in the case of crude oil berths oriented as depicted in Layout 1.

Berth Layout and Artificial Island

If two separate islands are built, the layout of the various berths could be independent of each other. However, combining the two islands would result in a reduction of the length of the breakwater. This reduction would be in the order of 0.2 to 0.4 miles, and would reduce the total cost of the breakwater by $11 to

$22 million. Because the area of the combined island would be the same or somewhat greater than the sum of the two individual islands, and because the average water depth would be approximately the same, no reduction of sand fill cost would result from combining the two islands into one.

Marine Operations

For the crude oil alternatives the annual cost of the marine operations (i.e., the cost of tug assistance and the employment of oarsmen) would be $3.56 million by 1980 and $7 million by 2000. For the dry bulk alternatives, this cost would be $2.56 or $3.56 million, depending on alternative and subalternative. In the case of combination alternatives, a somewhat better utilization of tugs and oarsmen could be made, as in case of dry bulk operations alone. However, it is unlikely that this could reduce the marine operating cost by more than $1.0 million at the average.

Personnel Transport

The personnel shuttle service between shore and deepwater ports could easily be combined. Therefore, $1.0 million could be deducted from the total operating cost.

Maintenance Cost

Only the maintenance cost of the breakwater could be reduced, since the first cost of the breakwater would be less. The annual maintenance cost was set at 1.0 percent of the first cost. This would result in a reduction of $0.11 to $0.22 million, depending on the reduction of the first cost.

Conclusion

Taking the above deductions into account, it can be concluded that the total sum of first cost could be reduced by 3 to 4 percent; of annual operating cost, by 10 to 15 percent; and of annual maintenance costs, by 2 to 3 percent, depending on alternative and subalternative.

Freeport, Texas Area

The cost calculations of alternative 5-7 have already taken into account the combination with the crude petroleum operations. Only the safety aspects of maneuvering in the ocean channel, and this channel's requirements for local widening to allow passage of fully laden incoming supertankers and outgoing grain carriers, remain to be discussed.

The incoming fully loaded supertankers and the outgoing fully loaded grain supercarriers would use the same deepwater channel. Because the channel width is based on one-way traffic, allowance should be made so that vessels could pass each other safely. The draft of the grain supercarriers was established at 50, 58.5, and 65 feet; and of the supertankers, at 55, 70, and 95 feet. The depth of the ocean channel section located over 10 miles off shore would be 60, 70, or 78 feet when based on the drafts of the various grain carriers. These depths exist 10, 21, and 25 statute miles offshore, respectively.

Assuming that one section of the 21- or 25-mile-long ocean channel would be dredged at a width allowing two-way traffic, this section would be located about 11 statute miles off shore. The existing depth at these locations would be about 60 feet. Assuming that this section would be approximately 2 miles long and that the additional width would be equal to 4 times the beam of the grain supercarrier, the additional dredging, including 3.5 feet of overdepth, would amount to approximately 4 and 8 million cubic yards for the 21- and 25-mile-long channel, respectively. Assuming a unit dredging cost of $0.75 per cubic yard, the additional dredging cost would amount to approximately $3 and $6 million, respectively. This amount would increase the total first cost of the combination alternatives by less than 1 percent. Consequently, the assumed annual maintenance cost would increase by approximately $0.06 million or $0.12 million, or by less than 1 percent.

X. TEXAS-EAST COAST PETROLEUM PRODUCTS PIPELINE

Introduction

The road distance between Houston, Texas, and New York, New York, is 1,636 miles. Assuming that the center of the refinery area would be between Houston and Beaumont-Port Arthur and that the center of the delivery area would be between Philadelphia and New York, the total length of the pipeline system would be approximately 1,550 miles.

The present flow of products through the Colonial pipeline is about 65 percent gasoline, 10 percent kerosine, and 25 percent distillates. It will be assumed that the same group of products would be transported by the Texas-East Coast Products Pipeline. The assumed principal physical characteristics of these products are given in table 110.

Table 110. Physical Characteristics of Products

Product	Specific gravity	Viscosity at 60°F. (cS)	Barrels/ long ton
Gasoline.....	0.73	0.7	8.65
Kerosine.....	0.81	2.5	7.90
Distillate...	0.87	6.0	7.37

Anticipating that, for a given pipeline and installed horsepower, the throughputs of the three products would be different, calculations will be made to determine the difference in required horsepower for a constant annual throughput of each product.

Throughputs and Selected Line Sizes

The projected total volumes of this pipeline system are 50 million long tons in 1980 and 150 million long tons in 2000. Since the optimum capacity of a 56-inch pipeline is between 70 and 85 m.t.a., it will be assumed that by 1980 the pipeline system would consist of one 56-inch line, and that by 2000 two 56-inch pipelines would be utilized.

Horsepower Calculations

Considering the above data, the comparative horsepower calculations will be made for a 56-inch line and an annual throughput of 80 million long tons.

Calculation Example for Gasoline

Annual throughput (A) = 80 million long tons

Outside pipe diameter (O) = 56 inches

Design throughput (B) =

$$\frac{80 \times 10^6 \times 8.65}{365 \times 24} \times 1.2 = 95 \times 10^3 \text{ barrels/hour}$$

Inside diameter (D) = 56-2 = 54 inches

Reynolds number (R) =

$$\frac{2,214 \times 95 \times 10^3}{54 \times 0.7} = 5,500 \times 10^3$$

Friction coefficient (f) = 0.0108

Pressure drop per mile (p) =

$$\frac{34.87 \times 0.0108 \times 95^2 \times 10^6 \times 0.73}{54^5} = 5.4 \text{ p.s.i.}$$

Horsepower (h) = $\frac{95,000}{2,450 \times .78}$ = 49.7 b.hp./p.s.i.

Required horsepower (H) =

5.4 x 49.7 = 268 b.hp./mile

Calculation Example
for Kerosine

$$A = 80 \text{ million long tons}$$
$$O = 56 \text{ inches}$$
$$B = \frac{80 \times 10^6 \times 7.9}{365 \times 24} \times 1.2 = 86 \times 10^3 \text{ barrels/hour}$$
$$D = 54 \text{ inches}$$
$$R = \frac{2,214 \times 86 \times 10^3}{54 \times 2.5} = 1,450 \times 10^3$$
$$f = 0.012$$
$$p = \frac{34.87 \times 0.012 \times 86^2 \times 10^6 \times 0.81}{54^5} = 5.5 \text{ p.s.i/mile}$$
$$h = \frac{86,000}{2,450 \times .78} = 45.0 \text{ b.hp./p.s.i.}$$
$$H = 5.5 \times 45.0 = 247 \text{ b.hp./mile}$$

Calculation Example
for Distillate

$$A = 80 \text{ million long tons}$$
$$O = 56 \text{ inches}$$
$$B = \frac{80 \times 10^6 \times 7.37}{365 \times 24} \times 1.2 = 80 \times 10^3 \text{ barrels/hour}$$
$$D = 54 \text{ inches}$$
$$R = \frac{2,214 \times 80 \times 10^3}{54 \times 6.0} = 546 \times 10^3$$
$$f = 0.014$$
$$p = \frac{34.87 \times 0.014 \times 80^2 \times 10^6 \times 0.87}{54^5} = 5.9 \text{ p.s.i./mile}$$
$$h = \frac{80,000}{2,450 \times .78} = 41.8 \text{ b.hp./p.s.i.}$$
$$H = 5.9 \times 41.8 = 247 \text{ b.hp./mile}$$

Since the difference in required horsepower between gasoline on the one hand, and kerosine and distillate on the other hand, is only about 10 percent, no differentiation in throughput will be made by product. The average required horsepower for the product line would be (268 + 247 + 247)/3 = 254 b.hp. per mile. According to table 21, the required horsepower for a 56-inch crude oil line would be 274.6 b.hp. at a throughput of 80 m.t.a., so that the products lines would require a horsepower capacity which is 93.2

percent of that of the previously evaluated crude oil lines. So as not to repeat the same type of calculations, the required horsepower capacities for varying throughputs of products will be taken at 93.2 percent of the horsepower capacity required for a 56-inch crude line as presented in table 21.

Therefore, the required average horsepower per mile of product line would be for a throughput of 50 m.t.a., 0.932 x 72.99 = 68.0 b.hp./mile; for a throughput of 60 m.t.a., 0.932 x 121.10 = 112.9 b.hp./mile; for a throughput of 70 m.t.a., 0.932 x 188.70 = 175.9 b.hp./mile; and for a throughput of 80 m.t.a., 0.932 x 274.60 = 255.9 b.hp./mile.

Installation Program

It should be noted that the installation phasing is given in a very simplified approach to be used for calculation purposes only. It will be assumed that installation of the first 56-inch line will take place during 1977-79. The second line is assumed to start operation when the first line reaches a capacity of 80 m.t.a., which is assumed to be by 1986.

Therefore, the second line is assumed to be installed during 1983-85, and would have an ultimate capacity of 70 m.t.a. by 2000.

The required horsepower would be: for the first 56-inch line, 68.0 b.hp./mile by 1980, and 255.9 b.hp./mile by 1986; and for the second 56-inch line, 175.9 b.hp./mile by 2000.

The following horsepower installation program will be assumed: for the first line, 128 b.hp./mile during 1979, and 128 b.hp./mile during 1982; and for the second line, 88 b.hp./mile during 1985, and 88 b.hp./mile during 1995.

Cost

Unit Cost

The following first cost and annual operating and maintenance costs, per mile or per b.hp., will be applied. All unit costs are in accordance with those established in chapter V for crude oil pipelines.

First cost

The first cost of a 56-inch pipeline would equal \$350,000 per mile, and that of booster pumps would equal \$150 per b.hp.

Annual Operating Cost

Pipeline management costs would equal \$1 million per 1,550 miles. Booster station personnel costs would equal \$60,000 per 50 miles, or \$1,200 per mile. Energy costs would equal \$52.28 per b.hp.

Annual Maintenance Cost

The annual maintenance cost of pipelines would equal 0.2 percent of first cost; that of booster pumps would equal 2.5 percent of first cost.

Total Cost

Table 111 presents the total first and annual operating and maintenance cost of the pipeline system.

Table 111. Total First and Annual Operating and Maintenance Cost of the Texas-East Coast Products Pipeline

(In millions of dollars)

Code no.a/	1980 vol. (m.t.a.)	Cost			2000 vol. (m.t.a.)	Cost		
		1977-79 first	1980			1980-2000 first	2000	
			Oper.	Main.			Oper.	Main.
0900..	50.0	572.2	10.8	1.8	150.0	613.2	36.2	4.7

a/ Code number is that used in the computer computation of benefits and costs (Annex F).