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LIVERMORE

STRATEGIC STORAGE, SUPERPORTS & SALT DOMES
A SYNTHESIS

T. M. Palmieri

22 February 1974

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Work done under the auspices of the U.S. Atomic Energy Commission

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&
SUPERPORTS
&
SALT DOMES

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INTRODUCTION

With the recent ominous manifestations of our dependence on energy supplied by foreign oil, this nation has been forced to consider its oil-import situation as a part of its national security.

The AEC is concerned because the problem relates both to energy and to the national security. Our interest at LLL derives from those concerns and also from the possibility that our technical capabilities can be used to help solve these problems.

I have been studying one small part of the oil problem, that of storing oil as a temporary hedge against a possible crisis. Even this limited topic is itself quite complicated, and to reach some conclusions logically, it will be necessary to develop several loosely connected subjects simultaneously. As the title indicates, those subjects are Strategic Storage, Superports, and Salt Domes.

Below I have attempted to summarize briefly each of the topics.

SUMMARY

There is presently before the Senate a bill that would establish emergency reserves of petroleum. These planned reserves would allow us to sustain ourselves for at least 90 days in the event of a boycott on imports.

However, the cost of such reserves is impressive. Consider that in 1978 our imports will equal about 10 million barrels per day (MMb/D). If salt domes were leached to provide capacity for storing 10 MMb, each facility would cost about $8M, another $5M for pipelines, and the cost of the oil could be anybody's guess. In light of recent events, $10/bbl might be a good guess - in which case 90 days storage would cost about 9 billion dollars. Such a formidable pricetag will cause much discussion before action is taken on the bill.

There are other aspects of the oil-storage problem that seem, at first glance, to have little to do with strategic storage. The other aspects concern the arrival of very large tankers and the construction of superports to accommodate them. These transportation facilities are due to appear in the next few years and they will necessarily involve enormous storage facilities.

Two superports are already designed, off the coasts of Texas and Louisiana, and they are presently awaiting the legal green-light to start construction. Several more are presently being considered.

As an example of the storage facilities involved, the Texas superport will include a tank farm with a capacity of 25 MMbl. This tank farm will cover about 100 acres.

There is a striking contrast in the different approaches being taking to accommodate these two needs for storage. For strategic reserves much consideration has been given to the alternative approaches to storage, complete with cost analyses for each method. For volumes greater than 1 MMb, the results are that steel tanks are both very expensive and not very safe.

For the storage facilities at Superport sites, there seems to be no consideration of other means of storage besides tanks. Discussion often centers around the location of the tank farm, onshore or offshore, but there is no discussion of the safer, less expensive concepts that are considered for Strategic Storage - particularly geo-storage facilities.

Which brings us to salt domes. It happens that the site chosen for the Louisiana port is in the middle of a large field of salt domes, several of which might be used for the proposed temporary storage. With pipelines, refineries and other facilities already in place at these ports, it is also reasonable to ask whether added capacity for strategic storage might be included as part of the planned storage facilities.

The government is presently developing a national policy for deep-water port development in the United States. Delays in the formulation of that policy have been responsible for holding up construction of the ports already planned. Senator Jackson's office feels that a statement on Support Policy should emerge from Committee during the 93rd. Congress, which could mean as long as six months. So there is still time to consider geo-storage, and the possibility of strategic storage at superport sites.

OUR IMPORT SITUATION

As background, to help appreciate the need for strategic storage, consider the following data.

The sources of our daily petroleum supply, listed in Table I, show that we presently import 37% of our oil, 19% of it as crude oil. These 1974 predictions are based on pre-boycott data.

TABLE I (Ref.1)

Total Demand	=	19.8	MMbbl/day
Stored Inventory Change	=	1.0	"
Domestic Production	=	10.8	"
Crude Imports	=	3.7	"
Product Imports	=	3.7	"
Other Supply	=	∿.5	"

Projections: First Quarter 1974 U.S. Demand for Petroleum. The numbers have units of 10^6 barrels = MMbbl, where 1 bbl = 42 gallons.

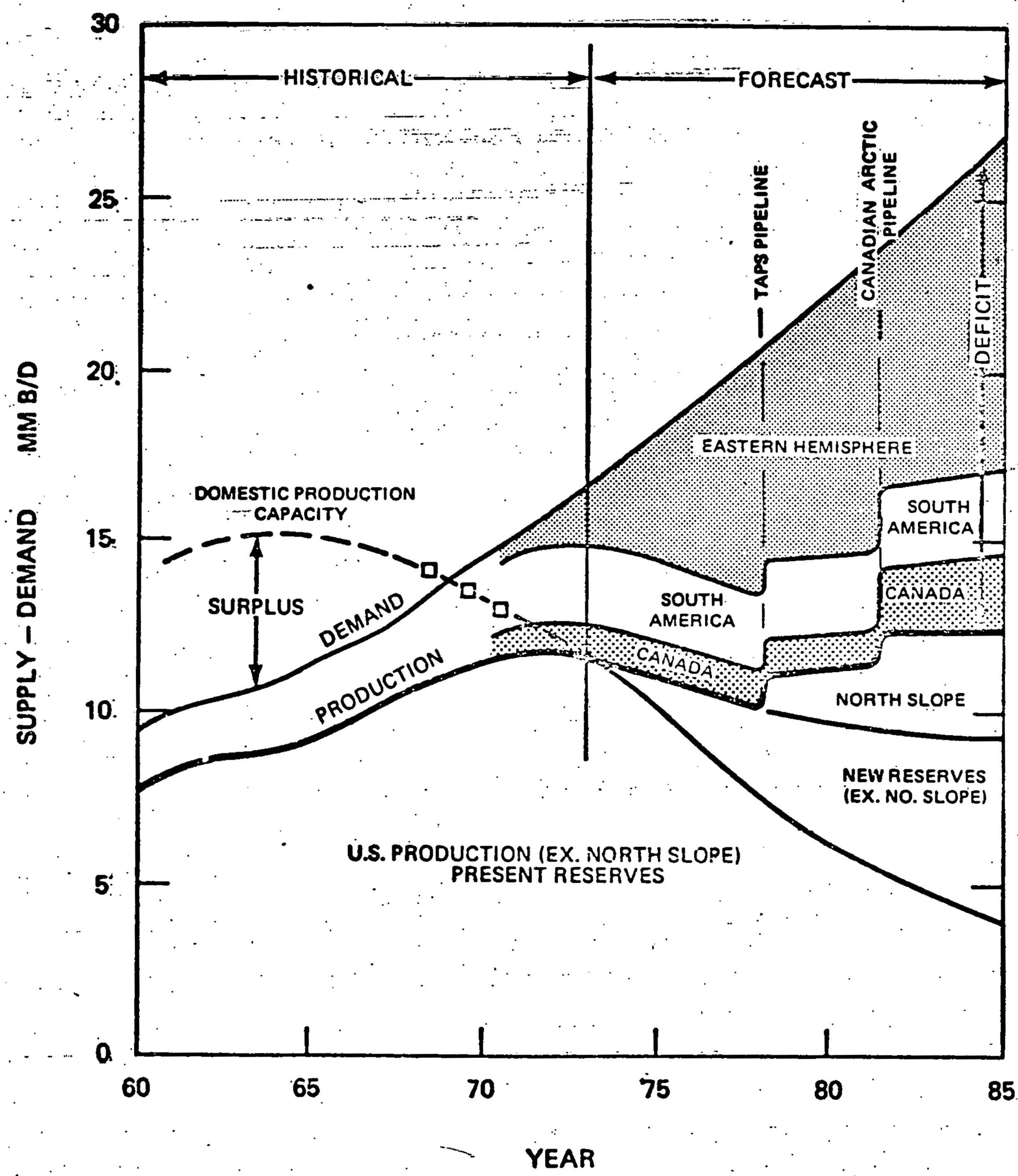
Table II shows an example of an insecure source of imports, Arab oil, and our increasing dependency on this source. Again the data is pre-boycott.

TABLE II (Ref.2)

YEAR	TOTAL IMPORTS	ARAB OIL	% ARAB OIL
1975	7.5 MMb/day	3.75 MMb/day	50%
1980	11.25 "	7.50 "	66%
1985	15.00 "	10.00 "	66%

Projected U.S. Dependence on Foreign Oil Imports

Figure 1 shows the state of U.S. oil consumption projected through 1985. This is based on continuing trends as of 1973(Ref.2).



Things worthy of note in this figure are:

1. that our surplus capacity was exhausted in 1969, but we still could have handled a crisis by increasing our production;

2. that at present our production is running at 100% of our capacity. That is, our wells are working at their maximum efficient withdrawal rate, and our refineries are working at 100% capacity. Hence, a cut in the imports of refined products would cause great difficulty. Even if we could buy more crude, we cannot process it in the U.S.;

3. that the situation is getting worse very year.

In general the recommendations to alleviate this situation have been;

a. to increase refinery capacity in order to lessen our dependence on refined imports,

b. to increase exploration, hence the number of producing wells, in order to lessen our dependence on crude imports,

c. to create strategic storage capacity as a buffer against an emergency.

THE CASE FOR STRATEGIC STORAGE

The embodiment of the concept of strategic storage is a bill by Senator H.M. Jackson, S.1586, introduced in the Senate on April 16, 1973 (again pre-boycott).

This bill is known as the Petroleum Reserves and Import Policy Act of 1973. It would among other things:

1. set up and maintain capacity to replace imports for at least ninety days;

2. limit oil and gas imports to a level consistent with national security;

3. encourage increases in domestic production.

To appreciate the cost involved in different approaches to this storage, consider Table III, compiled from testimony at hearings on S.1586.

TABLE III (Ref.3)

ALTERNATIVE	QUANTITY*	CAPITAL COST FACILITY	TOTAL CAPITAL COST**	ANNUAL COST	COMMENTS
eveloped, shut-in reserves such as Elk Hills	1.36 x 10^9 bbl =1,363 MMbbl (Est.Total)	Exists	$ 2.11/bbl	$.013/bbl	Reasonable output= .75(MMb/d) Emergency output= 1.24(MMb/d) Long term storage, takes 2-3 years to develop.
alt Dome (solution mined, on shore)	1 MMbl	4.40/bbl	10.50/bbl	.73	Leakage possible, brine disposal problem, 90% recovery, 130 domes offer good possibilities.
	2 MMbl	2.48/bbl	8.00/bbl	.54	
	10 MMbl	.83/bbl	5.30/bbl	.33	
anks	1 MMbl	4.14/bbl	8.34/bbl***	.74	4 acres/MMbl, high safety risk, geographically flexible.
bandoned Mines	10 MMbl	.54/bbl	5.00/bbl	.31	Best where available.
uclear Cavity	1 MMbl	High 4.14/bbl	10.34/bbl	.72	Lack experience, possible leakage, possible oil contamination, possible ground water contamination****
		Low 2.07/bbl	8.27/bbl	.57	

* Typical quantity of one such facility considered for purposes of calculation.

** Includes facility, pipeline, cost of land, and cost of oil taken as $4/bbl. In the case of Elk Hills, the price of the oil is taken as $2.06/bbl.

*** Due to freedom of location, assumes that pipeline already exists.

**** To which I would add, in the case of a nuclear cavity in a salt dome there is no brine disposal problem.

Note that as far as the storage facility itself, salt domes and nuclear cavities are cheapest. The higher final price for these methods of storage is due to the cost of pipelines to service them.

Although storage at closed-in wells seems to compete well with the other alternatives, Elk Hills is the only such facility. Testimoney at the hearings left the impression that more such facilities would be extremely expensive.

The administration voiced a strong opinion against strategic storage. They see it as one isolated part of a larger problem that includes conservation and other contingencies such as rationing. The logistics of such storage pose formidable problems also - such as what happens to the price of oil when "they" realize that we are buying and storing oil to protect ourselves from "them". In testimony before the Interior Affairs Committee, both Love (ex-Director of the Energy Policy Office, Office of the President) and Wakefield (at that time Assistant Secretary of the Interior, presently Asst. Director of Federal Energy Agency for International Programs) favored dropping the bill.

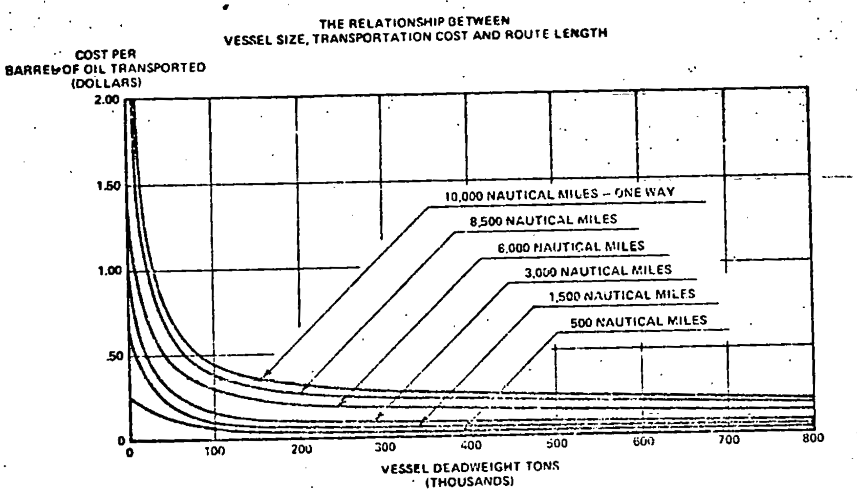
The bill has yet to be acted upon in Congress.

On the other hand, there is a growing need for storage capacity for an entirely different purpose - that having to do with the coming Very Large Crude Carriers (VLCCs) and superports to accommodate them.

THE CASE FOR SUPERTANKERS

The need for supertankers is a result of the ever-increasing size of deliveries, and the large distances over which oil is transported. Figure 2 (Ref.4a) shows that the advantage of supertankers is greatest over long distances.

FIGURE 2



Source: Cooke, Robert, *Modern Concepts of Ocean Transportation of Petroleum*, American Society of Mechanical Engineers, August 1967.

The cost per barrel for several specific cases is shown in Table IV (Ref. 4b).

TABLE IV

Table IV–ECONOMICS OF DEEPWATER REDISTRIBUTION TERMINALS

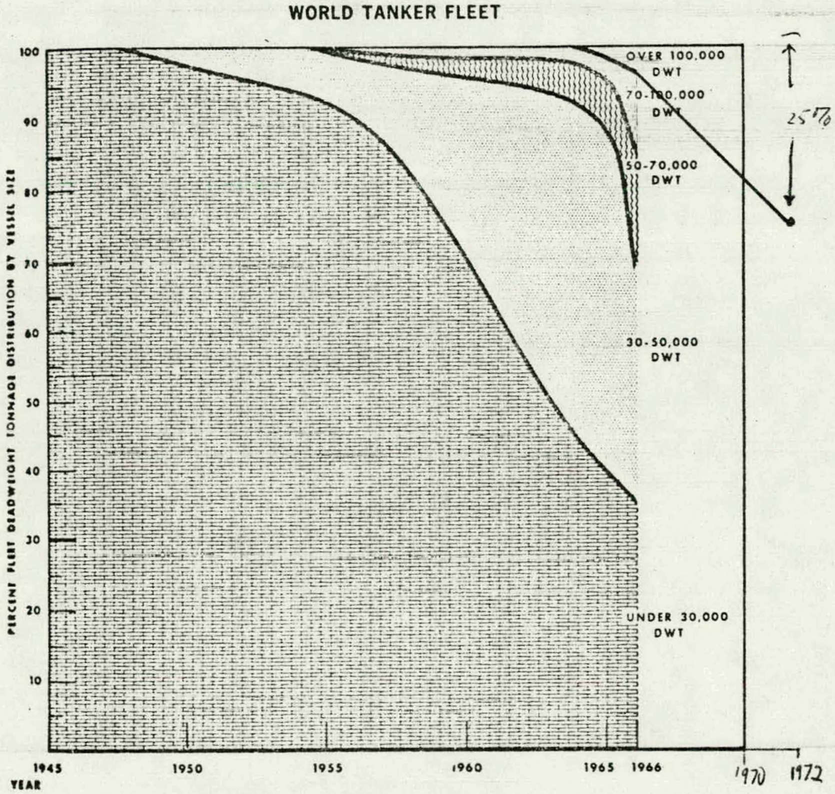
Voyage	Distance in miles	COST $/BBL. SIZE OF TANKER x 1,000 D.W.T.				
		500	300	200	100	50
Kuwait-Mediterranean via Cape of Good Hope	11,086	.242	.305	.374	.576	.835
Kuwait-North America via Cape of Good Hope	11,856	.259	.326	.400	.616	.894
Kuwait-Japan	6,615	.160	.202	.248	.381	.552
Distribution	500	–	–	–	.064	.079

Source: McPhee, W. S., *Crude Oil Transshipment Terminals*, presented at Society of Marine Port Engineers, Fort Schuyler, N.Y., March 1969.

Here it is seen that for Arab oil coming to the U.S. a savings of \$0.36/ bbl can be realized by shipping in a tanker of 500,000 DWT rather than one of 100,000 DWT. (There are from 6 to 8 barrels per ton depending on the density of the oil.)

The situation is more acute than the cost considerations would indicate. The smaller tankers that serve U.S. ports are aging. As they grow older, they are being replaced by larger vessels. Hence, the number of vessels upon which we depend is gradually decreasing. The evolution of the world tanker fleet is shown in Figure 3 (Ref. 4c).

Figure 3
WORLD TANKER FLEET



SOURCE: FIGURE 3 DRAWN USING DATA FROM SUN OIL COMPANY, ANALYSIS OF WORLD TANK SHIP FLEET, 1954 - 1966.

To give an idea of the size of these giants, the ship Universe Japan is a 326,000 DWT vessel. It delivers 2.35 MMb of crude oil. It is 170 feet longer and 70 feet wider than the Queen Elizabeth (Ref. 5).

SUPERPORTS

Comparing Table V (Ref. 6) with Table VI (Ref. 4d), we can see the relative size of U.S. ports when considered on an international scale.

TABLE V

U.S. TANKER PORTS

Port	Maximum Vessel Size (DWT)	Port	Maximum Vessel Size (DWT)
Alaska--Nisiki	60,000	Massachusetts--Boston	50,000
California--Long Beach	100,000	New Jersey--Newark	25,000
California--Los Angeles	100,000	New York	55,000
California--Port San Louis Obispo	20,000	Pennsylvania--Philadelphia	55,000
California--San Diego	35,000	Texas--Baytown	30,000
California--San Francisco	35,000	Texas--Beaumont	80,000
Florida--Jacksonville	30,000	Texas--Brownsville	35,000
Florida--Miami	20,000	Texas--Corpus Christi	50,000
Florida--Port Everglades	35,000	Texas--Freeport	30,000
Hawaii--Honolulu	35,000	Texas--Houston	55,000
Louisiana--Baton Rouge	45,000	Texas--Port Arthur	55,000
Louisiana--New Orleans	45,000	Texas--Texas City	45,000
Maine--Portland	80,000	Virginia--Hampton Roads	50,000
Maryland--Baltimore	55,000	Washington--Seattle	45,000

Source: International Petroleum Encyclopedia, 1972 Edition.

TABLE VI

Table 9.–REPRESENTATIVE CRUDE PETROLEUM LOADING PORTS OF THE WORLD

Country	Port	Existing berthing depth (MLW)	Estimated maximum vessel size (DWT)	Future developments
Venezuela	Lake Maracaibo Ports.	44'	70,000	Depths within the lake are adequate for large vessels but the Canal entrance is 44' deep.
Venezuela	Puerto LaCruz	60'	150,000	
Colombia	Buenaventura	39'	40,000	
Indonesia	Palembang-Pladju	38'	40,000	
Kuwait	Mina Al Ahmadi	100'	500,000	
Libya	Marsa El Brega	100'	500,000	New single point mooring in 140' of water expected.
Nigeria	Forcados	70'	250,000	Offshore facility in Gulf of Guinea with the potential for 500,000 d.w.t. tankers.
Saudi Arabia	Ras Tanura	90'	400,000	
Iran	Kharg Island	70'	250,000	Expansion of an island terminal of 105' depth for 500,000 d.w.t. tankers.
Abu Dhabi	Das Island	70'	250,000	
Iraq	Khor AlAmya	73'	250,000	
Egypt	Port Said	62'	175,000	
Neutral Zone	Ras Al Khafji	60'	150,000	

Source: Division of Ports, Maritime Administration, March 1971.

Table 8.–REPRESENTATIVE CRUDE PETROLEUM UNLOADING PORTS OF THE WORLD

Country	Port	Existing berthing depth (MLW)	Estimated maximum vessel size (DWT)	Future developments
U.S.A.	Philadelphia	40'	50,000	
U.S.A.	Portland, Maine	45'	80,000	
U.S.A.	New York	35'	40,000	
U.S.A.	Los Angeles	54'	150,000	
U.S.A.	Long Beach	54'	150,000	Dredging to 62' will be completed in 1971.
Holland	Rotterdam	64½'	200,000	To be completed in 1972 is the outer port Maasvlakte to accommodate 500,000 d.w.t. tankers.
Belgium	Antwerp	50'	90,000	
W. Germany	Hamburg	45'	65,000	Plans a terminal on the island of Scharhorn with a depth of 82'.
W. Germany	Heligoland	120'	800,000	In the planning stage.
W. Germany	Wilhelmshaven	48'	80,000	Dredging in process for 250,000 d.w.t. tankers.
France	Le Havre	70'	250,000	Plans for an artificial island 17 miles off coast with 100' depths.
France	Dunkirk	46'	75,000	Planned island terminal (by 1975) to accommodate vessels of 500,000-750,000 d.w.t. (8 miles off coast).
France	Marseille	70'	250,000	
Spain	Algeciras	85'	325,000	
Spain	Bilbao	40'	50,000	Iberport planned and approved with 100' depths.
U.K.	Milford Haven	63'	190,000	Shoreside being dredged to accommodate 250,000-300,000 tonners.
U.K.	Foulness	90'	400,000	In the feasibility study state.
U.K.	Liverpool	60'	150,000	Plans island terminal 11 miles off coast in Liverpool Bay with 100' depth.
U.K.	Glasgow	65'	200,000	Depths have the potential to accommodate 500,000 tonners.
U.K.	Tetney Haven	56'	110,000	This single point mooring system will eventually handle 200,000 d.w.t. tankers.
Ireland	Bantry Bay	90'	326,000	
Italy	Trieste	61'	160,000	Dredging to accommodate 200,000 d.w.t. tankers under study.
Italy	Genoa	52½'	100,000	An island terminal under construction to handle 500,000 tonners.
Sweden	Göteborg	68'	200,000	
Japan	Kiire	100'	500,000	Will handle 372,000 d.w.t. tanker expected in service by 1972 and 470,000 d.w.t. under construction for delivery in early 1973.
Japan	Tokyo Bay	65'	200,000	
Japan	Niigata	70'	250,000	
Japan	Yokkaichi	70'	250,000	
Canada	Point Tupper	90'	326,000	
Canada	St. John (Canaport)	85'	350,000	
New Foundland	Come-by-Chance	85'	326,000	Planned for construction.
Okinawa	Heianza	100'	500,000	
Bahamas	Freeport	80'	300,000	

Source: Division of Ports, Maritime Administration, March 1971.

As far as imports to the U.S., the oil is transported to Canada or the Carribean via VLCCs, then it is transshipped to U.S. ports via smaller carriers. The proposed U.S. superports would enable the U.S. to bypass the expense of the transshipment and they would make us less dependent on foreign port facilities.

The Congress is presently holding hearings and collecting data so that the U.S. can formulate a national policy concerning this new type of port. The argument in favor of such facilities is that they will result in lower costs for oil. The argument against the facilities is that they will result in lower costs for <u>foreign</u> oil - thus, favoring overseas spending and tending to plan for our increasing dependence on foreign oil rather than trying to reverse the trend (Ref. 4e).

The national policy will concern:

1. the optimum number of such facilities, so that our total imports can be handled most efficiently;

2. the form that these ports will take - dredged harbors vs. several types of deepwater, offshore terminals;

3. the environmental risks.(The grounding of the Torry Canyon (118,000 DWT) resulted in a spill of 700,000 barrels of oil.) (Ref. 4f).

At present, the design of two such superports is already complete and construction can begin whenever the legal problems are resolved. They are the deepwater terminals off the coast of Freeport, Texas, called Seadock, and that off Louisiana, called LOOP, see Fig. 4 (Ref.7). Several other sites are considered in a voluminous report by the Army Corps. of Engineers. They are at Delaware Bay (see Figs. 5 & 6), Chesapeake Bay, Los Angeles-Long Beach, San Francisco, and Puget Sound. Besides those alternatives there are only two others, to my knowledge. Standard Oil of California has proposed a port of San Luis Obispo with pipelines to Richmond and Los Angeles (Ref.7), and Puerto Rico is considering its own refinery and superport, possibly on Mona Island (Ref.8).

The proposed port in Louisiana is shown in Figure 4 (Ref. 9)

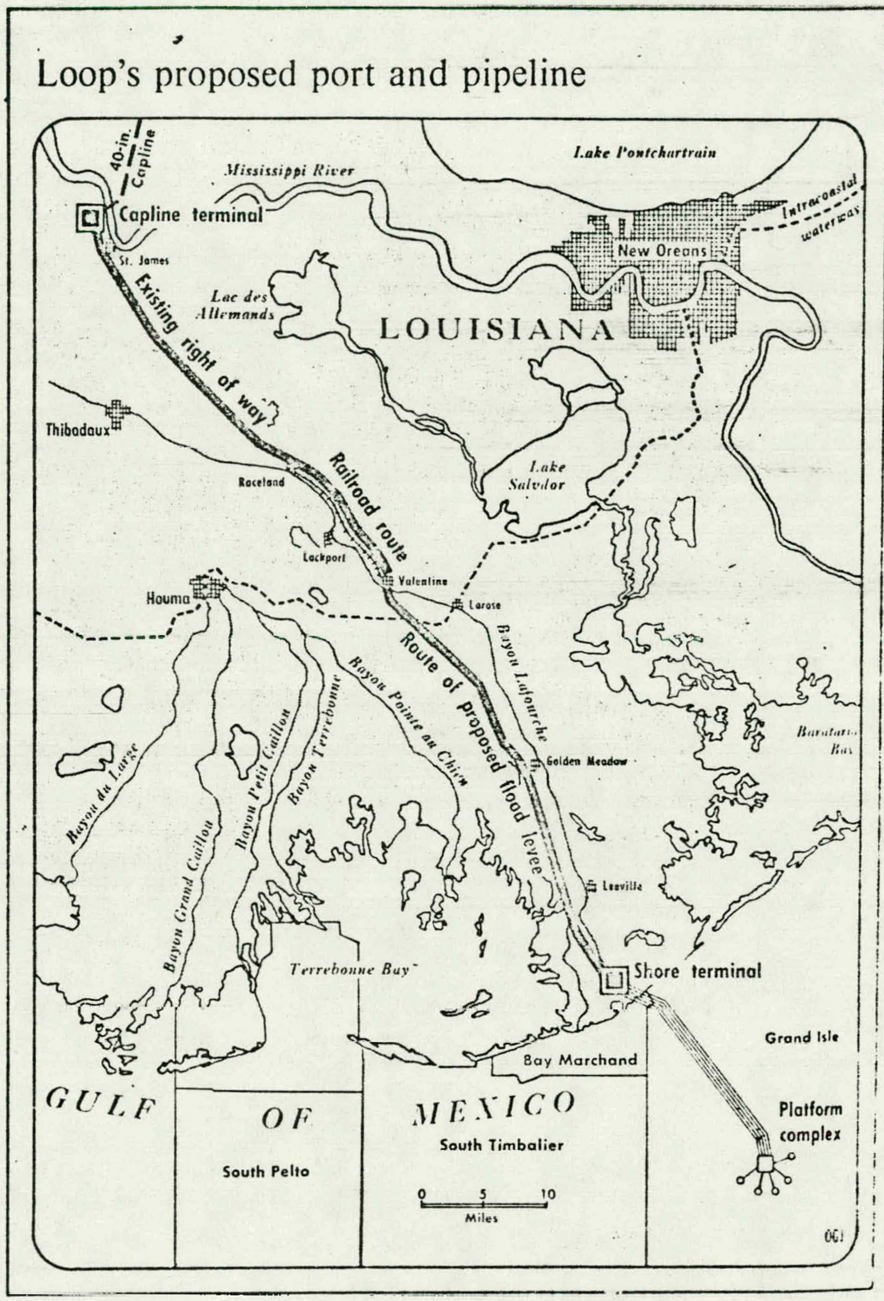
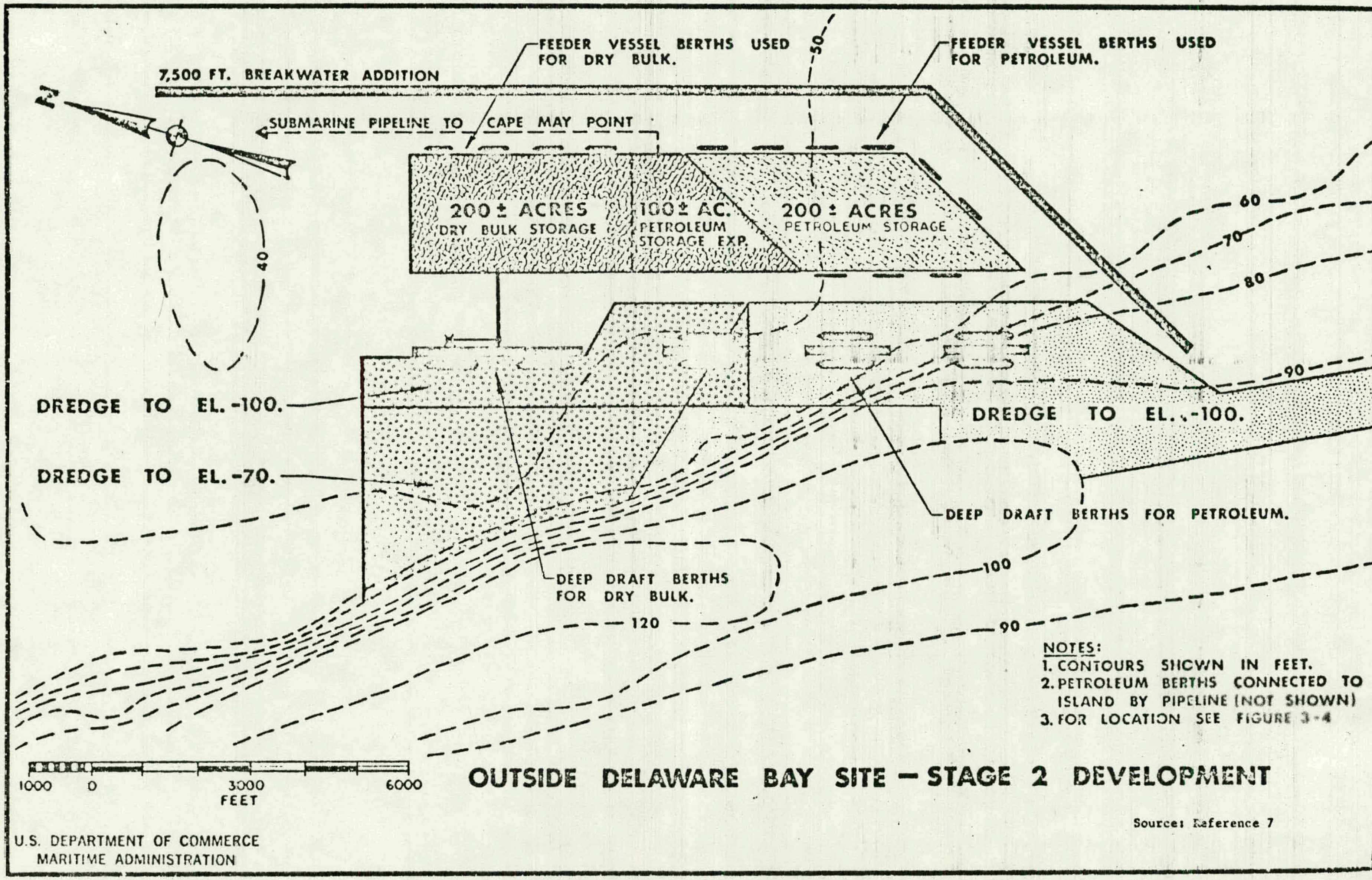


FIGURE 4

One conception of the docking configuration for the Delaware Bay site is shown in Figures 5 & 6 (Ref. 10).



FEEDER VESSEL BERTHS USED FOR DRY BULK.
FEEDER VESSEL BERTHS USED FOR PETROLEUM.
7,500 FT. BREAKWATER ADDITION
N
SUBMARINE PIPELINE TO CAPE MAY POINT
50
200 ± ACRES
DRY BULK STORAGE
100 ± AC.
PETROLEUM
STORAGE EXP.
200 ± ACRES
PETROLEUM STORAGE
60
70
80
40
90
DREDGE TO EL. -100.
DREDGE TO EL. -100.
DREDGE TO EL. -70.
DEEP DRAFT BERTHS FOR PETROLEUM.
100
DEEP DRAFT BERTHS
FOR DRY BULK.
120
90
NOTES:
1. CONTOURS SHOWN IN FEET.
2. PETROLEUM BERTHS CONNECTED TO ISLAND BY PIPELINE (NOT SHOWN)
3. FOR LOCATION SEE FIGURE 3-4
1000 0 3000 6000
FEET
OUTSIDE DELAWARE BAY SITE — STAGE 2 DEVELOPMENT
Source: Reference 7
U.S. DEPARTMENT OF COMMERCE
MARITIME ADMINISTRATION

FIGURE 5

EXHIBIT 17

MODEL OF OFFSHORE INSTALLATION

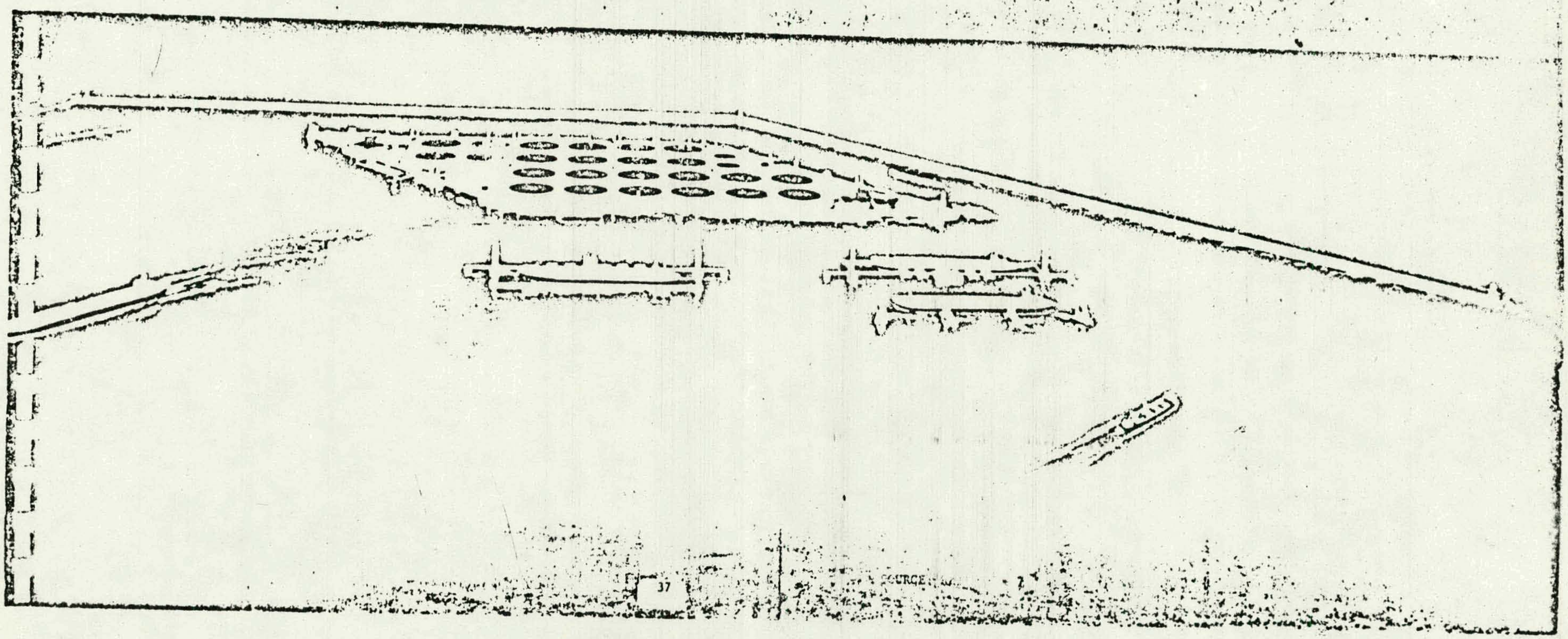


FIGURE 6

STORAGE

The plans for LOOP include onshore storage in tanks, each of which will have a capacity of 800,000 bbl. . The plans for Seadock call for 500,000 bbl. tanks, with total storage capacity of 25,000,000 bbl. (already the equivalent of 8 days supply of crude imports).

The preliminary design in Figure 5 shows that in Delaware most of the area of the superport will be devoted to storage, 500 ± acres in this case. Obviously, a major part of the expense for the superports will go to constructing these immense storage facilities.

There are problems with the storage concepts that have been proposed for superports. First there seems to have been no consideration given to either the safety hazards or the strategic fragility of such immense tank farms. Second, there seems to have been no consideration of the lower cost that might be achieved by using geo-storage facilities.

At this point, two questions need to be answered;

1. Would it be feasible to locate the temporary storage facilities underground?

2. Might the temporary storage facilities be expanded to help satisfy the desire for strategic storage?

The answer to these questions depends on the specific location, and the LOOP site provides a good case to consider.

SALT DOMES

Figure 7 (Ref.11) shows the location of salt domes in Louisiana and Mississippi. I have superimposed the LOOP pipeline on this map.

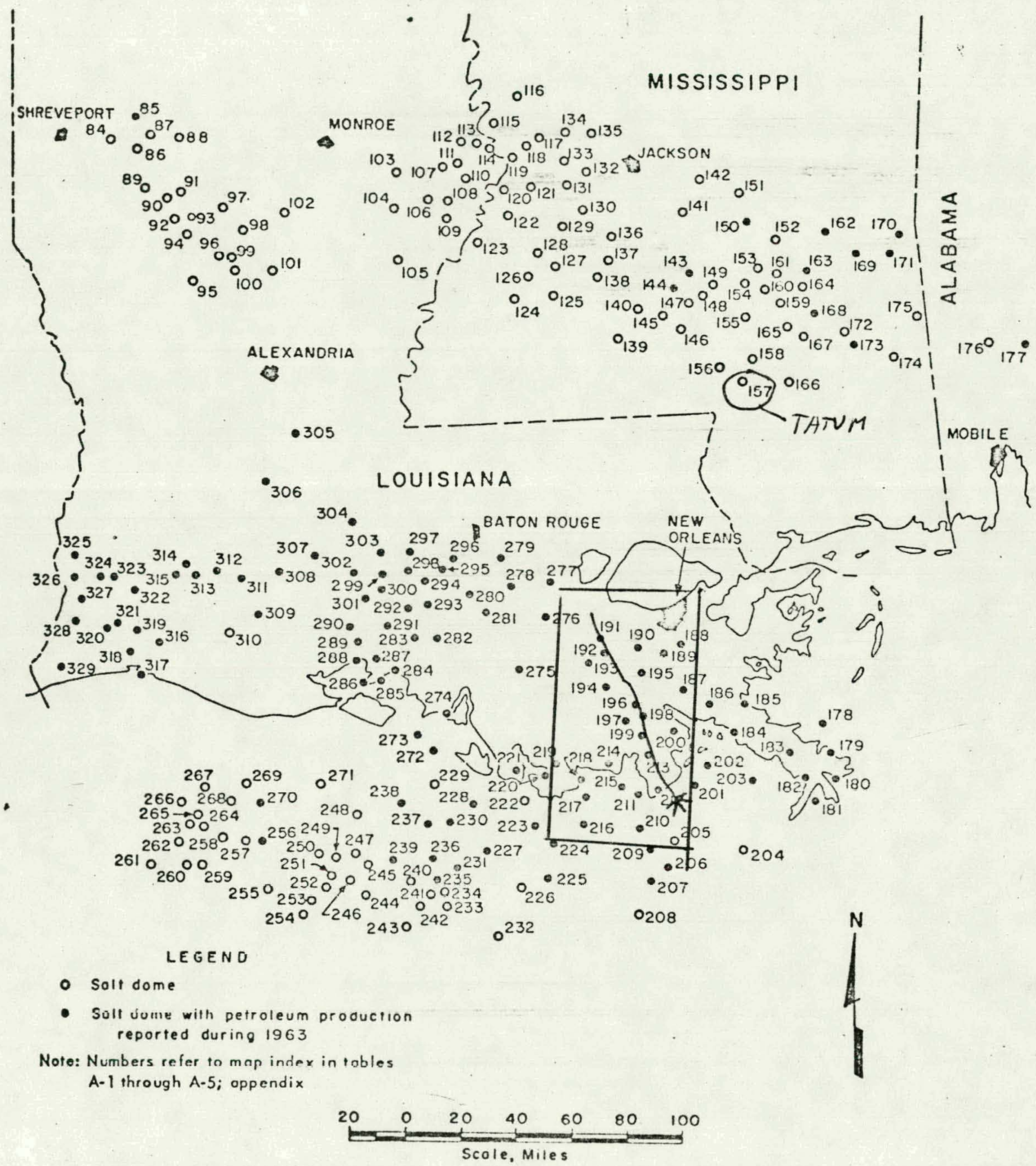


FIGURE 7

There are about seven salt domes within two miles of this pipeline, all of which are presently associated with oil production. A study is in order to determine which of these domes would provide the port with a suitable site for storage.

If more than one dome proves suitable, it would be reasonable to suggest that several could be developed to provide facilities for Strategic Reserves. From Table III we see that such a plan would avoid some of the expense associated with strategic storage in salt domes - these sites would be near pipelines.

The same logic applies for any of the other superports being considered. It must first be determined whether underground cavities will suit their needs for temporary storage. Where underground cavities do satisfy those needs, it should be possible to increase the size, or the number of such cavities in order to satisfy the strategic requirement as well.

RECOMMENDATIONS

1. A study should be initiated in order to investigate;
   a. the feasibility and economics of salt dome storage at the LOOP site,

   b. the feasibility and economics of large-volume storage at the other proposed superport sites.

2. We should undertake a technology assessment study to determine;
   a. if the existing technologies are adequate for producing the necessary volumnes that would be needed,

   b. how those technologies might be improved,

   c. the appropriate technology for a given geographic location.

3. When the particular needs of the superports have been studied, and when the technology has been developed, the next step should be a demonstration. The final recommendation is then to create a useful storage facility as a demonstration project.

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