PROCEEDINGS OF THE FIFTH DREDGING SEMINAR

Prepared by
COASTAL AND OCEAN ENGINEERING DIVISION
Center for Dredging Studies

REPORT NO. CDS-149

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FIFTH DREDGING SEMINAR - 1972

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Place: Trinity Room, Rice Hotel, Houston, Texas

Date: Friday, November 17, 1972

8:00 a.m. Registration

9:00 a.m. *Welcoming Remarks* - Dr. David R. Basco, Texas A&M University.

9:15 a.m. *"Dredge Hulls - Construction and Reconstruction"*, Charles E. Woodbury, P.E. (private conslutant), Tampa, Florida.

9:45 a.m. *"Economic Justification for the Use of a Fully Lined Dredge Pump"*, Ron Rose, Chief Engineer, Mobile Pulley and Machine Works, Mobile, Alabama.

Break

10:45 a.m. *"The Offshore Dredge - A Solution to Beach Restoration"*, Thomas N. Turner, Vice President, Engineering, Ellicott Machine Corp., Baltimore, Maryland.

11:15 a.m. *"Soil Mechanics Applied to Dredging"*, Dr. Wayne A. Dunlap, Professor, Texas A&M University, College Station, Texas.

12:00 Luncheon, Directors Room, Rice Hotel

1:30 p.m. *"Bartav Maintenance Dredging and Water Quality"*, Al Morneault, Generation Environmental and Regulatory Affairs Branch, Florida Power Corp., St. Petersburg, Florida.

2:00 p.m. *"Corps of Engineers Dredging Operations in Galveston"*, Jack Simpson, Chief, Plant Branch, Galveston District Office, Galveston, Texas.

Break

3:00 p.m. *"Present Status of Spoil Disposal Areas Along the Houston Ship Channel"*, Jack Farmer, Vice President, Atlantic, Gulf, & Pacific Co., Houston, Texas.

3:30 p.m. *"Offshore Dredging Problems"*, Jim Bean, President, C.F. Bean, Inc., Belle Chasse, Louisiana.

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DREDGE HULLS - CONSTRUCTION AND RECONSTRUCTION

By

Charles E. Woodbury
Consulting Engineer
Tampa, Fla.

The hydraulic cutterhead dredge in its conventional configuration is a unique vessel, and until it is recognized as such, dredge owners will be plagued with problems caused by hull construction based on the designs of flush deck dry cargo barges for rivers and intercoastal waterways, such as is allowed by ABS rules.

Inasmuch as dredge hulls are the cause of many owners' woes, let's just ask ourselves "What is required of a dredge hull?" The first and most obvious task for a hull is to float itself along with the machinery, superstructure and liquids placed upon and within it. Secondly, the hull must be proportioned to provide an acceptably safe stability under normal working conditions as well as when under tow in a seaway. Third, the hull structure must be of sufficient strength to withstand the complicated stresses caused by the concentrated loads of the trunnions, A-frame mountings, spud wells and gantry, pump, hoists, prime mover and liquids. Further, the hull must have sufficient stiffness to maintain the sometime rather complicated machinery assembly in proper working alignment while external forces of considerable magnitude due to the cutter operation and spudding are applied.

The illustrations of Figs. I, II, III, IV indicate the forces due to the weight of the structure, machinery, etc. as it is acted upon by the buoyant force of the water. The resultant hull deflection is also shown for each case. Fig. I is a conventional arrangement with rigid A-frame forward supporting the ladder, the machinery and fuel load amidship, and the spudding gear aft. Notice should be made of the concentrated loads particularly at the after A-frame members as they meet the hull. The A-frame members create a couple applying a large bending moment to the hull. Fig. II shows the trunnion located to oppose the after A-frame uplift and thus beneficially reduce the development of hull stress. The spudding gear has been replaced by a stern anchor fairlead to illustrate the reduction of hull stress associated with the use of this device. Fig. III illustrates yet another arrangement (the possible variations are countless) which has a cable supported A-frame and eliminates the concentrated load due to the gantry after member, and square frame. If the hog-wire attachments were properly located on the spud gantry it would be theoretically possible to balance the load of the spudding gear and reduce the resultant hull force to zero.

Up to this point we have considered the dredge hull and the more or less static forces it resists. Let us now look at Fig. IV and consider the forces applied during normal digging procedure while working on spuds. Fig. IV indicates that the spudding and digging forces supplement the buoyant forces amidship and tend toward a hogging condition. It must also be considered that the fuel load will vary from zero to maximum over a few days of operation. More important as far as hull stresses are concerned, the cutter/spud forces may vary from zero to maximum within seconds, and under certain conditions may even reverse themselves. This rapid change and/or reversal of stress is the real culprit, causing failure of the hull structure by fatigue.

The designer, in attempting to overcome this problem can (1) distribute his loads carefully to reduce concentration of stress, (2) select materials capable of higher stresses and more resistant to fatigue, (3) proportion the structure to reduce the unit stress to more conservative levels and eliminate stress risers or (4) utilize any combination of the foregoing procedures.

Let us emphasize - the culprits in hull problems are <u>high local stress</u> and <u>fatigue</u>.

A quick comment is called for regarding the use of ABS rules for hull construction. These rules are like most of our building codes: they set out a <u>minimum acceptable</u> design for evenly distributed loads, and <u>do not</u>, repeat <u>do not</u> approach the service requirement of continuous dredging duty. In addition to the hull loads mentioned above, other forces within the hull which must be taken into account include hoistline pull reactions, and transverse bending and twisting of the hull as it reacts to the torsion of the cutter through the trunnions; ABS rules do not cover these requirements.

If we were to idealize a dredge hull we would probably construct a rectangular hull with a continuous flush deck because of its resistance to longitudinal and transverse bending as well as torsion. Because of practical considerations however, the usual dredge has openings in the main deck to accommodate the machinery. Fig. V shows a more or less typical dredge hull and is representative of a great number of dredge hulls in service today. This hull was originally designed and constructed as a flush deck dry deck cargo barge for inland service. The hull was modified for dredge service by construction of machinery hold with coaming. Subsequent alterations included an insert at the bow and a bow extension, and then a widening over its full length, to the condition shown in Fig. V. It is assumed that prior to the widening, the dredge was shore-powered because no fuel bunkers are indicated in the original hull. With the progressive addition of heavier and more powerful machinery the dredge became short on freeboard, and the decks outside of the main deckhouse were raised as shown in Fig. VI, along with a number of other alterations; this illustration being its condition prior to its recent hull modification. This dredge was subsequently put to some rather difficult work and began to develop problems with leaks in the areas marked "Y" and "Z".

Note in Fig. VI that a trough has been provided for the hull suction pipe in the deck forward of the pump hold. Note also the very narrow width of full depth hull at the point marked "X". It is quite apparent the structure at "X" is the only continuous transverse member forward of "Z" to resist the torsion of the ladder, and stabilize the square frame (which had no diagonal stiffeners). The hull, in attempting to resist these forces, is subjected to the high stress and reversals which is manifested in severe cracking of the bottom shell plate. This failure being, no doubt, accelerated by the effects of stress corrosion. The deflection across the hull at "X" allowed the longitudinal deflection to fatigue the hull at "Z" causing cracks in the shell in that area.

The dredge was further plagued with leakage between the tanks created by the widening of the hull, at times leakage was reported between tanks which were not even adjacent. Note the framing detail of Fig. VI.

The original hull had a flanged side shell lapping with the bottom shell. (Which is good construction practice for dry cargo barges but not acceptable for liquids). The bottom shell of the widening tank was lapped over the original shell lap, creating a welding condition which would be described as between poor and terrible. The hull frames in these tanks were spaced at 50% greater intervals than the original hull, and except at the deck, <u>no</u> longitudinal interior shell stiffeners were provided. This construction, if it were not for the keel cooler channels on the exterior of the shell, would not even safely withstand the static pressure of the water in which it is submerged. As for the tank-to-tank leakage, it was found that a vertical filler PL had been added at the original bilge roll creating an unmaintainable area within the hull which was also a conduit for liquids along its entire length.

In order to restore this hull to usefulness the original deck forward of the pump hold was raised to the level of the exterior deck. This created a full depth box section of hull across its entire width supplementing the hull box at location "X", and providing a better proportion of hull structure and eliminating the stress risers of the previous arrangement such as at "Z". Sister frames were added in the outboard tanks and the bilge turn pocket was eliminated with the insertion of a "T" section with all butt seams. Needless to say, the cracked bottom shell plate was replaced.

While the subject dredge hull has been improved and its immediate problems solved, other problems exist in this hull that should be pointed out. When the exterior decks of this hull were raised, a new open box was created which, to a degree, reduced the effectiveness of the original hull box. Also, the extremely light deckhouse construction became part of the hull structure and even a fuel tank. Sec. A-A of Fig. VI illustrates the center compartment in which the major machinery load is concentrated, the original deck and the raised portion. Because the raised deck stiffens the edge of the hull longitudinally, there is a real danger that the machinery load which was formerly carried by the full width of the deck is now carried by the new raised deck only, and depending on the proportions of the structure, can even increase the level of stress in the raised deck above that in the original deck, and because the lower deckhouse is part of this peripheral box serious problems can be expected in this area. The deck openings indicated in Fig. VI and the passageway in the longitudinal bulkhead are so aligned as to create stress risers in the deck plating at both levels.

It is interesting to note the external hull configuration in way of the trunnions. This condition undoubtedly was arrived at through a series of steps, each of which was an expedient measure which appeared to suit the pressures of the moment. This complex shell creates a multiplicity of stress rising corners and jogs while the gains in bouyancy and hull strength are so small as to be insignificant. It would probably improve the total hull capability if the structure were simply removed, and the shell plate restored to a simple, regular outline.

Machinery foundations within the center portion of the dredge hulls are often found to be of rather strange arrangement. Too often the pump bearing base, and the engine are founded upon heavy longitudinal members which in turn rest on extremely light transverse shell framing members. This arrangement virtually ignores the adjacent full depth longitudinal bulkheads and the improvement possible in the founding of the machinery as well as the hull structure by adding a few heavy transverse machinery supports between the bulkheads. Portable dredges are a particularly good example of this condition. The center pontoon of a portable dredge is usually an open top box suspended at its ends by the closed box outboard pontoons. One instance of this condition had a vertically offset chain drive between the engine and the pump shaft, with the chain drive suffering from frequent breakage. The engine was founded at the main deck level on athwartship members and the pump was supported by the transverse bottom shell stiffeners. Close observation of the hull during operation disclosed that the center hull pontoon had considerable deflection longitudinally and the hull members under the pump deflected transversely. These deflections were then multiplied by the overhang of the chain sprocket beyond the structural supports and, all combined, resulted in extreme and abrupt changes in the shaft center distance at the chain causing the breakage problem. The addition of simple bolted connections amidship between the inboard and outboard pontoon virtually eliminated this deflection and solved the chain problem.

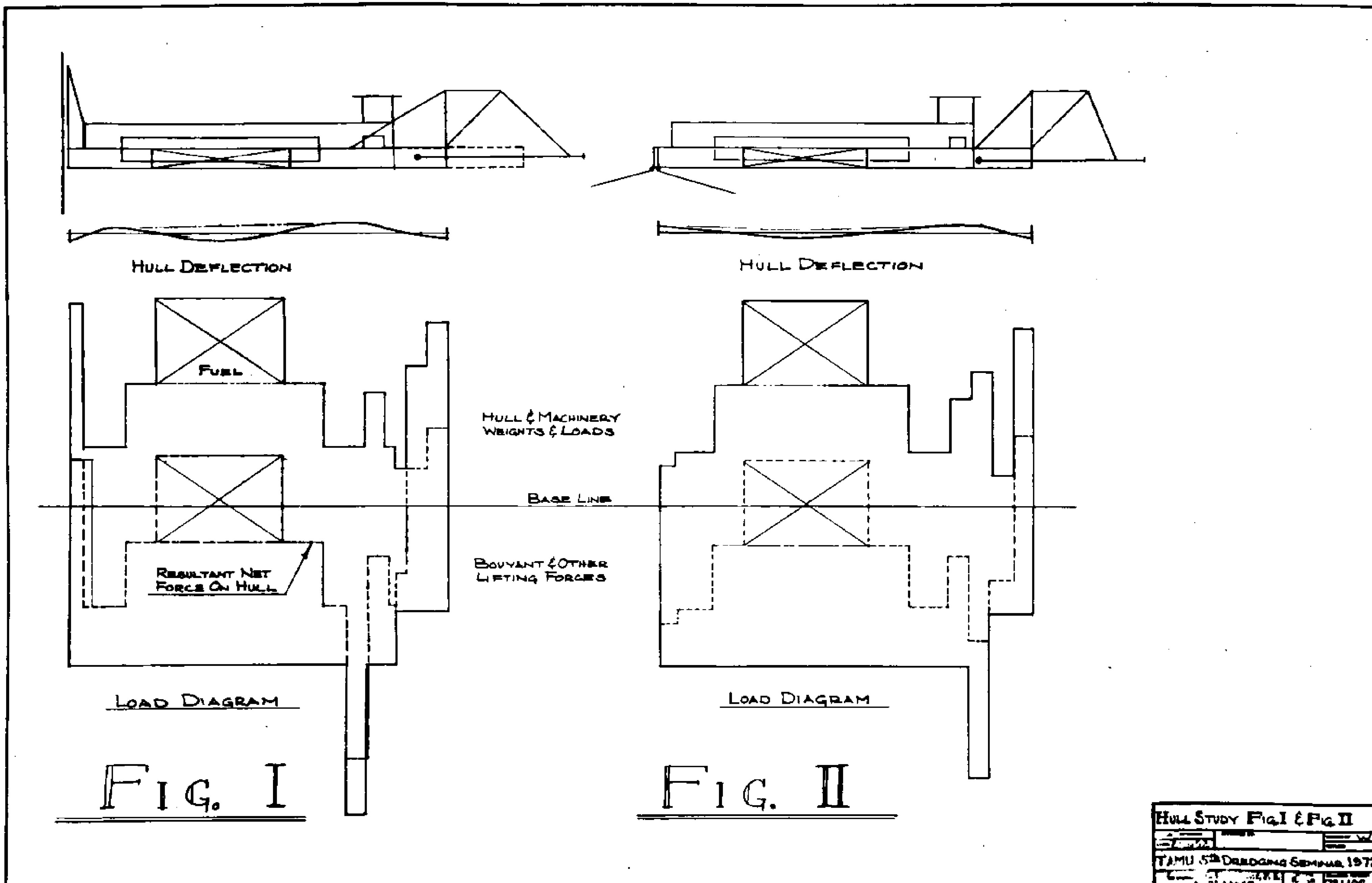
This chain problem investigation revealed another structural phenomena respecting the longitudinal sides of the center pontoon. During operation of the dredge the top of the pontoon side was found to be deflecting inward or away from the outboard pontoon while deflecting downward. This was the result of the ld/bt ratio or the proportions of the side of the pontoon with respect to its length and depth as a ratio to the breadth and thickness of the flange. The same bolted connection mentioned above cured this ld/bt ratio. Our strong emphasis here is to note that a mechanical problem had its roots in the design of the hull and the designer needed only a few angle clips and some well placed bolts to give the inadequate machinery pontoon the benefit of the structural support of the rigid outboard pontoon. However, the center pontoon will still require stiffening of its side bulkhead if the machinery alignment is to be maintained during transport, handling or launching. Reducing the unsupported length of the top edge of this pontoon with a simple thwart, a wider flange, or better yet, a full depth W.T. bulkhead just aft of the pump would provide the pontoon its needed improvement. The bulkhead will not only provide structural support but will also provide an improvement in the safety of the hull.

In further consideration of hull safety it is rather difficult to understand the reluctance of designers to provide, and owners to require, a watertight bulkhead forward and aft of the main pump. Many, many dredges in service today could not survive even a minor pump accident simply because the floodable volume surrounding the main pump would exceed the volume of the normal freeboard of the hull. Inasmuch as it is current practice to provide a flooded section for a self priming capability this danger is even more acute.

Because time and space are limited here in covering a very broad subject, only one other item will be touched upon as we think about better hull performance. We mentioned earlier in passing that the bottom shell plate failure might have been accelerated by stress corrosion. The fact of this matter is that under certain conditions metal under tensile stress is subject to accelerated corrosive attack leading to early failure due to cracking. This can be the cause of much of the failure in dredge hulls, particularly in critical areas. The prevention of this problem can be found in good hull maintenance with thorough cleaning and well applied durable coatings.

Although it has been necessary in a discourse of this type to point out the faults, weaknesses, and short-comings of existing equipment it should be emphasized again and again that for almost every hull problem there is a cure. Some may be complete, final cures, while others may only be a "working" cure, but cures do exist.

For those suffering the ills outlined above or only hoping to avoid them, this word: take a good hard look at your hull - or invite a disinterested "outsider" to have a look, it may have greater capability than it has been given credit for and with alteration, repair, or even a little "tender loving care" its life, safety, and operating capability may be improved or extended. But plan carefully because today's improvement can be tomorrow's problem.


HULL DEFLECTION
HULL DEFLECTION
FUEL
HULL & MACHINERY WEIGHTS & LOADS
BASE LINE
BOUYANT & OTHER LIFTING FORCES
RESULTANT NET FORCE ON HULL
LOAD DIAGRAM
LOAD DIAGRAM
FIG. I
FIG. II
HULL STUDY FIG. I & FIG. II
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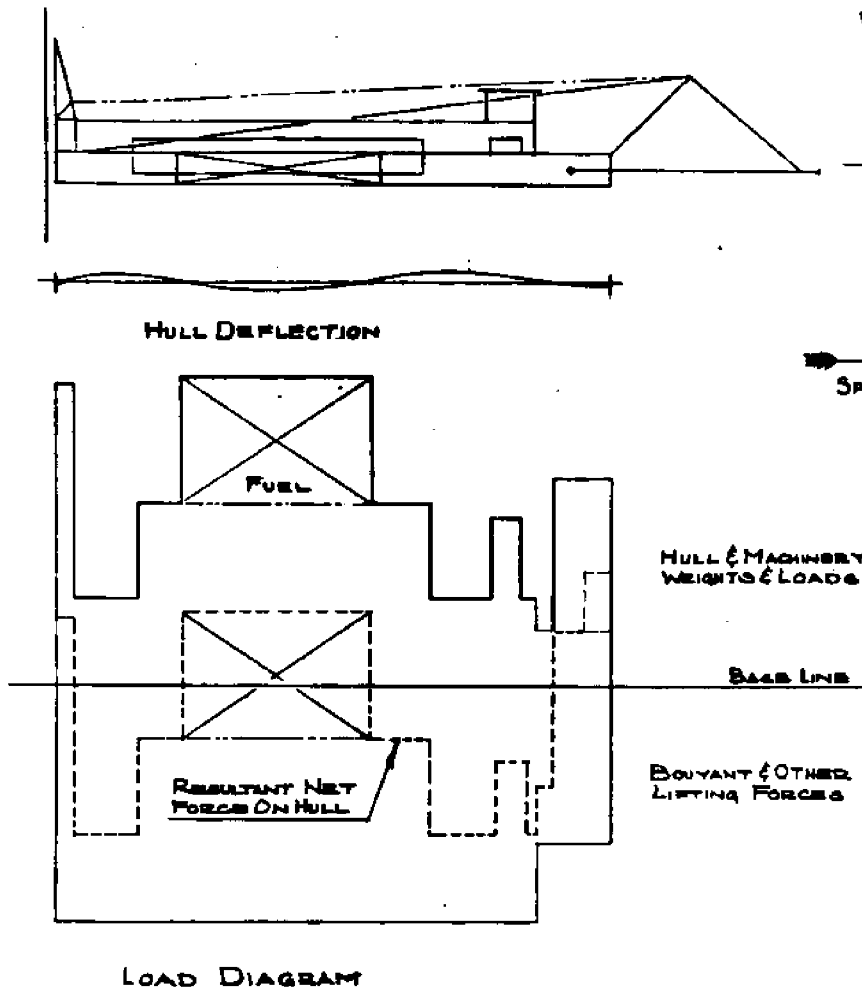

FIG. III

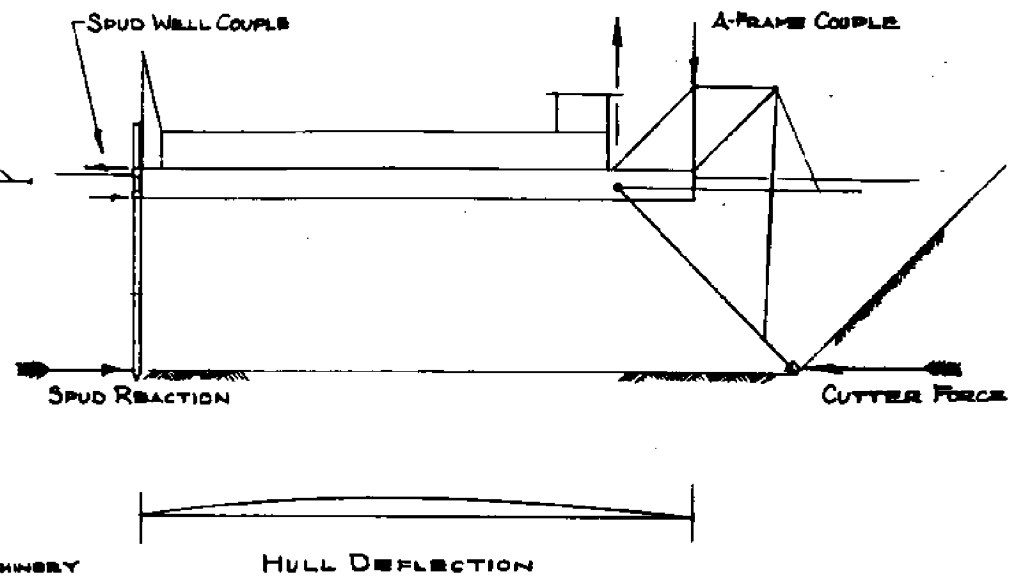

FIG. IV

HULL STUDY FIG. III & FIG. IV

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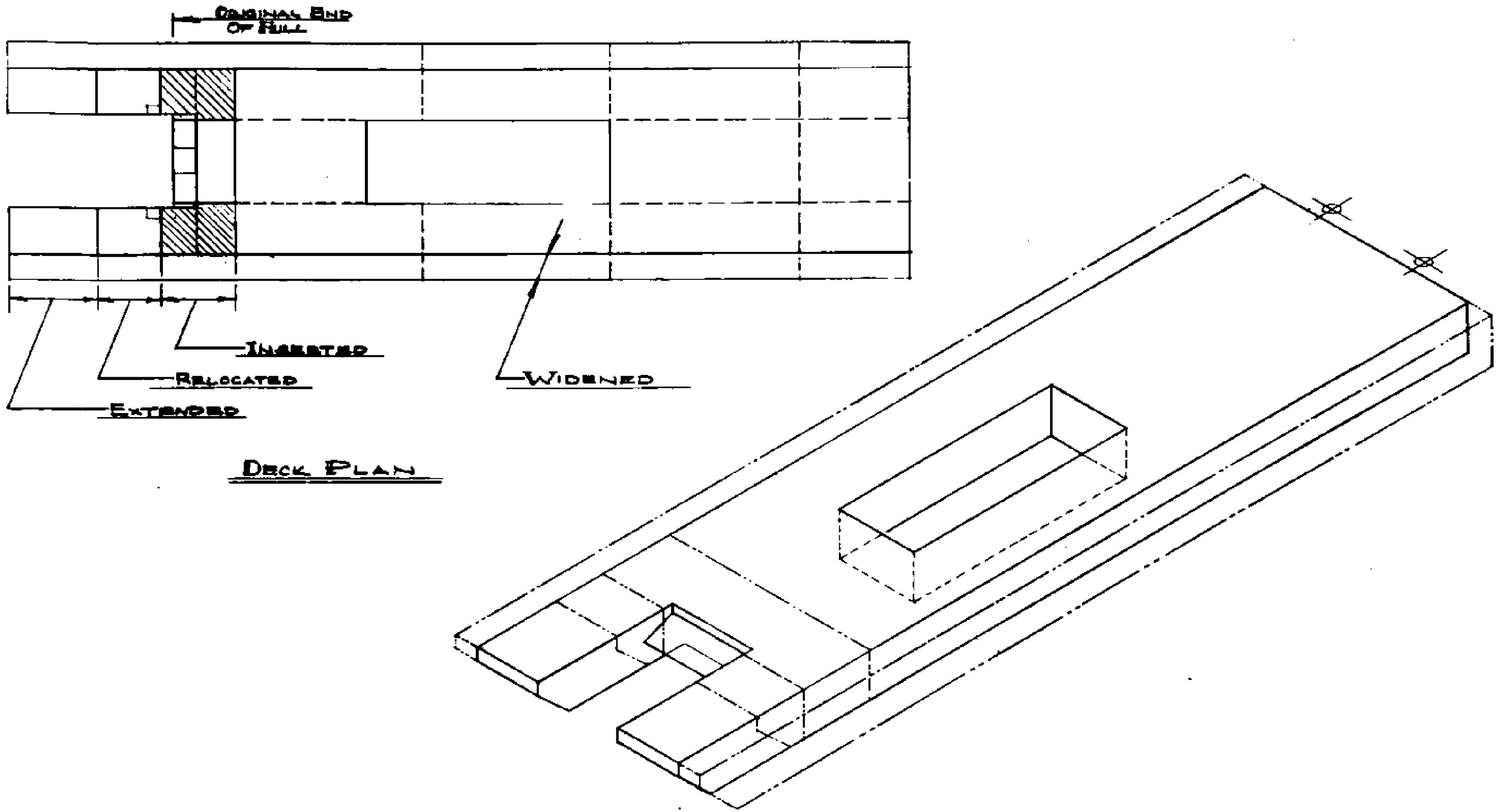

FIG. V

HULL STUDY FIG. V
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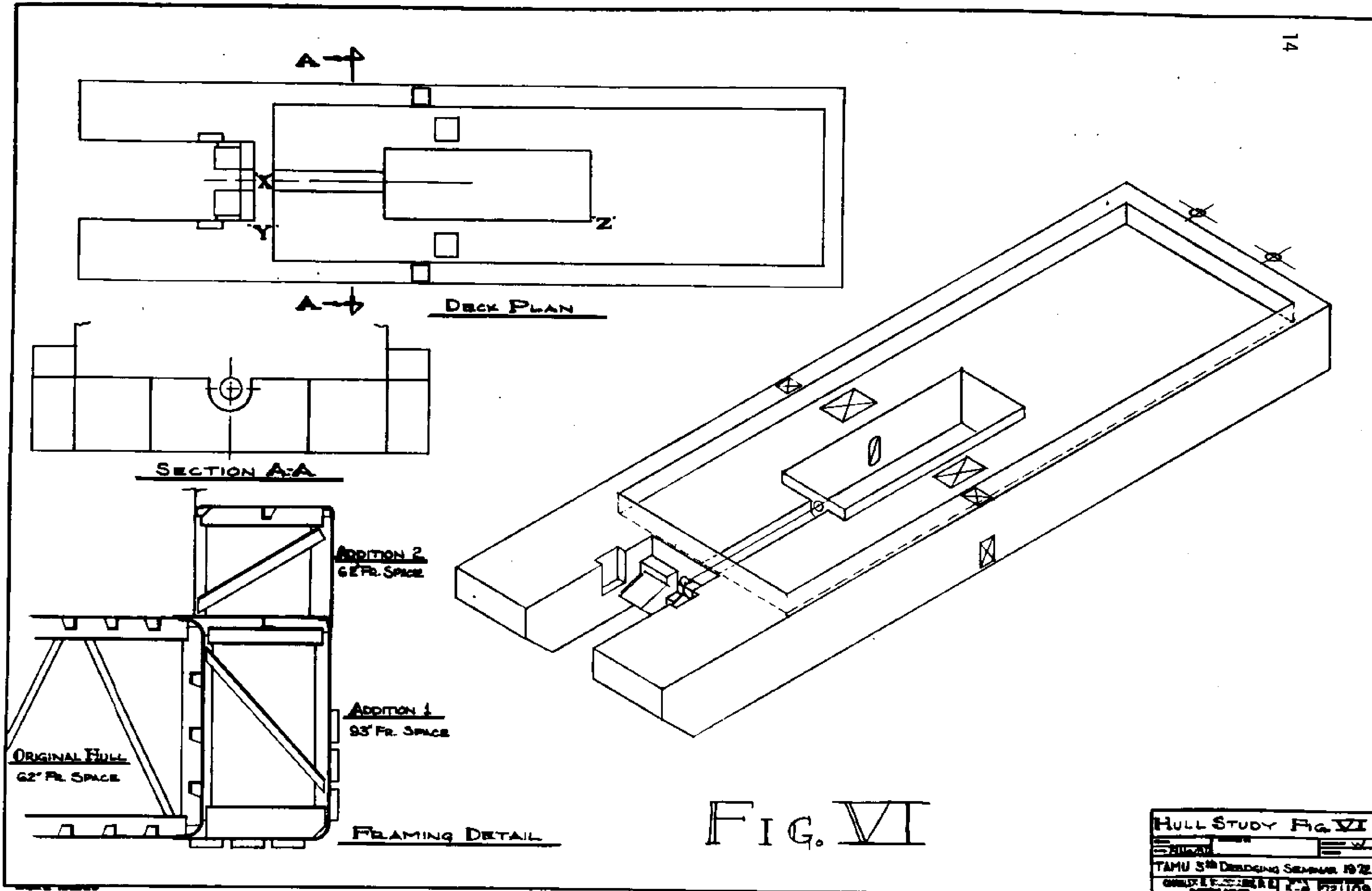
A
A
X
Y
Z
DECK PLAN
SECTION A-A
ADDITION 2
62' FR. SPACE
ADDITION 1
93' FR. SPACE
ORIGINAL HULL
62' FR. SPACE
FRAMING DETAIL
FIG. VI
HULL STUDY FIG. VI
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ECONOMIC JUSTIFICATION FOR THE USE OF A FULLY LINED DREDGE PUMP

By

Ronald R. Rose
Chief Engineer
Mobile Pulley and Machine Works

We feel that the fully lined dredge pump will be the standard of the industry in the years to come.

The fully lined dredge pump is hydraulically exactly the same as any conventional, flat faced dredge pump. Therefore, we can limit our discussion today to economics and not be concerned about cavitation, impeller vane angles and other things that pump engineers like to discuss.

The fully lined dredge pump has a much higher initial cost than a conventional pump. The initial cost will run 75 to 100 percent higher, as we will see later in a detailed examination of the costs. The big question is "How do you, the dredge contractor, justify this considerable extra investment?" --- which may be as much as $60,000 extra for a large pump.

The initial investment is offset by the following factors:

1. Reduction in dredge downtime to replace worn parts. We will later see that this is true only for one type of lined pump.

2. Longer wear life on the pump shell liner due to better abrasion resistant material and more complete usage of the shell liner.

3. Lower replacement cost of the pump shell liner.

Many parts of the fully lined pump are the same as any flat faced conventional pump. Major parts which are the same for both pumps are:

1) impeller
2) suction side liner
3) engine side liner
4) suction throat ring
5) stuffing box
6) impeller and thrust shafts
7) bearings
8) bedplate

Today's discussion will be confined to the "water end" of the pump since the shaft, bearings, and bedplate are determined by horsepower, pump size, and speed. Therefore, they will be the same regardless of the type water end used.

There is one disadvantage to the lined pump which may make it impractical or impossible to install on some existing dredges. The fully lined pump is considerably larger in diameter than the conventional pump. Therefore, on dredges which have a minimum of space in the pump "well", it may not be possible to install a larger pump.

Types of Dredge Pumps

A. Conventional Pumps

There are basically two types of conventional pumps in service; namely, what I call the flat faced design and the curved face design.

The flat faced design is pretty well the accepted standard of the industry.

The curved suction inlet will increase the pump efficiency by about 3 to 5 per cent. This improvement in hydraulic flow pattern and increased pump efficiency will be offset by the increased cost of the impeller, suction side liner and suction throat ring. These parts will cost about 13 per cent more which is $800 extra for a 20" pump. In addition to the increased cost, the "wear life" of the same parts will be less. The slurry which recirculates between the impeller and suction liner is easily trapped in this passage causing increased abrasion.

B. Fully Lined Pumps

There are basically two types of fully lined dredge pumps. The first type will be referred to as a "Horizontal Split Outer Shell", the second being what we call a "Face Plate Type".

One of the main advantages of the lined pumps is that a better abrasion resistant material can be used for the inner shell liner. For the majority of dredge jobs, the recommended material would be an alloy cast iron having a 550/600 BHN hardness. This material is readily available from several sources here in the U.S. This alloy cast iron is not recommended where severe shock is encountered when pumping rock. Other materials such as alloy cast steel and manganese steel can be used for the pump shell liner.

The "Horizontal Split Outer Shell" pump mechanically has two advantages over the face plate type. First it requires slightly less space because the outer shell follows the involute as compared to the face plate type where the outer housing is circular. Secondly, the side doors are smaller and thus a smaller area is subjected to the internal pressure.

The face plate type pump has a major advantage in that the worn parts can be replaced much quicker. We will examine this in detail later. For example, the 42" dredge "Triton" presently has a horizontal split pump and it requires up to four days to replace the worn parts. We are presently making a face plate type pump for this dredge in order to decrease this downtime to approximately one day.

The horizontal split type has an outer shell made in two pieces which fit closely around the shell liner. The side doors are very much the same as a conventional pump.

The face plate type has a large circular outer shell with a flat face plate (suction door). When the face plate is removed there is easy access to all the wearing parts. The outer shell and discharge transition does not have to be moved when replacing worn parts. The outer shell and face plate can be made from cast or fabricated stee. We have found that cast steel gives us the best results from both a quality and cost view point.

<u>Comparison of Pump Costs</u>

We will investigate the costs of two size pumps:

A. 16" pump which has a 60" impeller and a prime mover of 1500 HP.

B. 27" pump which has an 88" impeller and a prime mover of 5000 HP.

1. A conventional flat suction type dredge pump.

   Materials of construction:

   a. Alloy cast steel 250/300 BHN: impeller and pump shell.

   b. Alloy cast iron 550/600 BHN: side liners and suction throat ring.

   c. Cast steel: side doors and stuffing box.

   Note: The following prices assume a manufacturer's standard pump design. Therefore, there are no engineering or pattern charges included. A custom design conventional pump may increase the prices $5,000 to $10,000.

   Cost - 16" pump water end - $21,000.

   Cost - 27" pump water end - $46,000.

2. A horizontal split fully lined pump.

   Materials of construction:

   a. Alloy cast steel 250/300 BHN: impeller

   b. Alloy cast iron 550/600 BHN: pump shell liner, side liners, suction throat ring.

   c. Cast steel: discharge transition, outer shell, side doors, stuffing box.

   Note: For both types of lined pumps the prices assume a custom design. Engineering and pattern charges are included. If a second pump is made a considerable reduction in price would be realized.

   Cost - 16" pump water end - $41,000.

   Cost - 27" pump water end - $93,000.

3. A face plate type fully lined pump:

   Materials of construction are the same as the pump above.

Cost - 16" pump water end - $38,000.

Cost - 27" pump water end - $84,000

As our cost study develops we can best show the results by plotting the information on a curve of pump cost versus time in months. A separate curve will be made for both the 16" and 27" pumps, which we will see later.

How do we justify this extra initial investment for a fully lined pump?

I - Reduction in dredge downtime to replace worn parts.

A sixteen inch dredge will rent to the Corps of Engineers in this area for approximately $130 per hour, which will be lost revenue when changing pump parts, and have a labor cost of $50 per hour, which is an expense, thus giving an hourly value of $180 per hour.

By the same reasoning a 27" dredge will be valued at $390 per hour when shut down for pump repairs ($300 rental plus $90 labor).

The time required to replace worn parts is largely dependent upon auxiliary equipment available to handle parts and experience of the crew. The procedure involved in changing parts on a conventional pump is fairly well known to all of us.

The horizontal split type lined pump is disassembled as follows:

a. suction cleanout removed.
b. suction door removed and a new liner and suction throat ring installed.
c. discharge transition piece removed.

d. impeller removed.

e. outer shell unbolted from engine door.

f. outershell and inner shell moved forward to clear impeller shaft.

g. unbolt split of outer shell and remove top half.

h. remove inner shell liner from bottom half of the outer shell and replace with a new inner shell liner.

i. replace worn engine side liner.

The assembly is done the same in reverse order. As can be seen this is a considerable task especially for a large pump.

The face plate type lined pump is a much quicker job.

a. remove suction cleanout.

b. face plate removed and new liner and throat ring installed.

c. remove impeller using a specially designed lifting hook.

d. remove worn inner shell liner by taking out wedges and using special lifting hook.

e. replace worn engine liner using lifting hook.

The assembly is done the same in reverse. Note that the outer shell and discharge transition have <u>not</u> been moved.

The following tables show the time required to replace worn parts and the value of this downtime:

<u>Table I</u>

Replacing impeller, suction liner and suction throat ring.

	16" Pump		27" Pump	
	Time	Value	Time	Value
Conventional	6 hrs.	$1080	8 hrs.	$3120
Horizontal Split Type	6 hrs.	$1080	8 hrs.	$3120
Face Plate Type	7 hrs.	$1260	9 hrs.	$3510

Table II

Replacing impeller, side liners, suction throat ring, and pump shell or pump shell liner.

	16" Pump		27" Pump	
	Time	Value	Time	Value
Conventional	20 hrs.	$3600	24 hrs.	$9360
Horizontal Split Type	30 hrs.	$5400	36 hrs.	$14040
Face Plate Type	10 hrs.	$1800	12 hrs.	$4680

We will use this data a little later in plotting our cost curves.

II - Wear life of Parts

For this discussion, we will assume the following job conditions.

a) The slurry being pumped contains a medium to coarse abrasive sand.

b) The discharge pressure of the 16" pump is an average of 100 psi and for 27" pump an average of 140 psi.

c) Utilizing the horsepower previously specified we can expect a production rate of 420,000 cubic yards per month (600 hours) for the 16" dredge and 900,000 cubic yards per month for the 27" dredge.

We can expect the life of the parts to be as shown in Tables III and IV.

Table III - 16" Pump

	Cubic Yards x 10^6	Months
Impeller	1.5	3.6
Engine Side Liner	6.0	14.4
Suction Side Liner	1.5	3.6
Suction Throat Ring	1.5	3.6
Pump Shell	3.0	7.2
Pump Shell Liner	6.0	14.4

Table V - Cost of Parts

	16" Pump	27" Pump
Impeller & Sleeve	$4,000	$7,500
Engine Liners	1,500	3,800
Suction Liners	1,500	2,800
Suction Throat Ring	700	900
Pump Shell & Seals	9,500	16,000
Pump Shell Liner & Seals	7,000	13,000

By using Tables I, II, III, IV, and V, we can determine the cost of operating these pumps over a period of time. Using the 16" conventional pump as an example we can calculate the cost as follows:

Time (months)	Parts Replaced	Cost of Part		Value Downtime		Total Cost
3.6	Impeller, suction liner & throat ring	$ 6,200	+	$ 1,080	=	$ 7,280
7.2	Same plus pump shell	$15,700	+	$ 3,600	=	$19,300
10.8	Same as first change	$ 6,200	+	$ 1,080	=	$ 7,280
14.4	Same as second change Plus engine liners	$17,200	+	$ 3,600	=	$20,800

After this the cycle repeats itself. This data can be plotted on the cost curves for each pump as shown.

Conclusions

The faceplate type lined pump has a lower initial cost and lower operating cost than the horizontal split type lined pump.

When compared to the conventional pump, both types of lined pumps will justify the extra initial cost.

1) The horizontal split pump pays for the extra cost in:
   a) 20.1 months for a 16" pump
   b) 15.6 months for a 27" pump
2) The faceplate pump pays for the extra cost in:
   a) 18.3 months for a 16" pump
   b) 9.3 months for a 27" pump

The face plate type lined pump will pay for the complete initial cost in 43 months for a 16" pump and 29.5 months for a 27" pump.

You will remember that the downtime costs were figured on rental rates which are rather low. The per yard pay was only 18.5 cents for the 16" unit and 20 cents for the 27" unit. On a better paying job the payback time would be quicker.

The payback time is shorter for large pumps than small ones.

THE OFFSHORE DREDGE
A SOLUTION TO BEACH RESTORATION

By

Thomas M. Turner
Vice President
Ellicott Machine Corporation

INTRODUCTION - America's beaches are eroding significantly, and in many localities are severely damaged or destroyed. Most Americans have a vital interest in the condition of our Nation's shoreline but unfortunately are unaware of the critical nature of the problem. It is essential that some organization take the lead in informing the public of the problem, in developing solutions, and then aggressively insisting upon the funding and implementation of the beach restoration and protection programs before this great natural resource is further deteriorated. It is to this purpose that my talk today is addressed.

THE SHORELINE PROBLEM - In 1968 the Congress charged the Corps of Army Engineers with the responsibility of conducting a National Shoreline Study to appraise the condition of the Nation's shorelines, and for developing suitable means for protecting, restoring and managing the shorelines to minimize erosion-induced damage. This report, a comprehensive document of great significance to the Nation, has received incredibly little publicity and has elicited little or no concern on the part of the general public.

Let me summarize very briefly some of the findings of this report:

1. 2700 miles of shoreline is eroding at such a rate as to termed "critical".

2. The cost of protective works for these 2700 miles is estimated as $1.8 billion over a 15 year period, approximately the same figure proposed by President Nixon in July 1972 to repair the flood damage in several northeastern states. (1.7 billion).

3. $900 million is the estimated cost of the high priority work needed over the next five years for 1220 miles of shoreline where continued erosion is likely to endanger life, public safety, property, scarce wild life habitats or landmarks of historical or national significance.

4. While the report states various methods of shore protection may be used, "artificial fill with periodic nourishment to restore and preserve a beach is the preferred method".

5. The estimated average beach nourishment cost for the critical 2700 miles is $73 million per year.

In this environment-conscious society, it is probable that the majority of us will agree with the report's recommended approach to shoreline protection, i.e., the restoring and nourishing of the beaches with sand to retain their natural beauty. To accomplish this, vast quantities of sand are required, but inland sources of sand have been so restricted by various environmental protective organizations as to practically cut off the supply. This means that these large quantities of sand must be obtained offshore, implying a unique dredging operation. Let us examine the requirements of an offshore dredge capable of fulfilling the Nation's beach restoration program.

REQUIREMENTS OF AN OFFSHORE DREDGE

1. First, and foremost, the dredge must be capable of operation in the sea conditions encountered offshore. Conventional dredges have sustained severe damage and costly delays as they attempted to operate in open water. Obviously, a dredge must be designed for the conditions it will encounter. As the dredge hull rises and falls, the suction head must remain in contact with the bottom, and must not receive the weight of the hull at any time. An analysis of wave data obtained along the Continental United States coasts indicates that any dredge which can operate safely and efficiently in seas with a mean wave height of 3.3 feet and a maximum wave height of 6.6 feet (2 meters) would establish a 95% on-the-job record. The only type of dredge operating today capable of this is the trailing suction dredge, either hopper or sidecaster type. These dredges have a high first cost and operating cost, leaving them almost exclusively in the hands of Government agencies, rather than private contractors.

2. The offshore dredge should be able to dig to depths where removal of the sand will not affect the shoreline. This can be as little as 30' depending upon beach materials and contour; and if capable of digging to 82', will make available high quantities of sand off the U.S. coast, all that will be required for years to come. Such depths require a submerged to pump to suppliement nature's barometric pressure. As an example of the effect of barometric

limitation, a standard dredge has one-half the output at 50' depth that it has at 10'; at 82' approximately one-third. Few trailing suction dredges have been built for 82' depth, and none operate with submerged pumps.

3. An offshore dredge requires high capacity to meet the requirements of the vast sand-moving operations required by the Nation's beaches. A recent study commissioned by the Corps of Engineers suggests that the minimum capability of such an offshore dredge should be approximately 2000 cubic yards per hour on a 20 hr/day basis. On a six day per week basis, this provides a capability of one million cubic yards per month. Unfortunately, the hopper dredge is normally incapable of this capacity because of its transit time.

4. The offshore dredge should have low operating costs per cubic yard, including all maintenance and investment depreciation. While the cost/benefit ratio used by the Corps necessarily varies somewhat from area to area, the justifiable cost of placing a cubic yard of sand on the beach has been estimated to be in the neighborhood of $1. The hopper dredge would seldom, if ever, achieve this figure.

5. The offshore dredge should have a high operating efficiency, which means that its ability to dredge at a high continuous rate would not be affected appreciably by sea conditions or by the need to interrupt dredging to transport the pay load. Again, the hopper dredge is lacking.

The above should not be interpreted as saying that the trailing suction dredge will play no part in the restoration of the Nation's beaches. There will undoubtedly be local conditions that require the unique capabilities of such dredges, but probably they will play a minor role.

<u>THE COMPENSATED CUTTER HEAD DREDGE</u> - The major role will be played by a modern, efficient cutter head dredge with the cutter pressure-compensated to adjust to the varying sea and soil conditions. Such a dredge, warranted to operate in seas of at least 2 meters, is now commercially available with a delivery time of one year or less. (SLIDE) This dredge has approximately 7000 horsepower aboard; is configured with 30" I.D. pipe; is equipped with electric or hydraulically driven submerged pump and cutter drive to dig to 82' (25 meters); and has an articulated, compensated ladder assuring high dredge efficiency, and preventing the dredge's destruction when operating in open water. The principle of the gas-charged, hydraulic compensating device has been proven on floating drill rigs. Its unique application to the cutter head dredge can be seen in this artist's conception. Note that the hull is more or less conventional, but the ladder and attendant forward frames are novel, for which a patent has been applied. Note that the ladder is articulated with the conventional trunnions at the hull, but with two additional trunnions just ahead of the cutter module. The need for two additional trunnions is clear from model tests which indicated that only one additional trunnion would allow destruction of the mechanism when the cutter and hull trunnion were in a straight line with the additional trunnion.

To understand the compensating principle, let's assume the weight of the cutter module is 100,000 pounds and that all of this weight is carried by the hydraulic cylinders and the soil reaction. Now assume that the soil requires 50,000 pounds cutting force leaving 50,000 pounds for the cylinders, easily adjustable by the operator. As the dredge rises on a swell, the cylinders will lift only 50,000 pounds; this causes the cylinder rods to extend, in order for the soil resistance to supply the other 50,000 pounds. As the dredge falls the rods will retract, reversing the procedure. The cutter remains in constant contact with the bottom, assuring high dredge efficiency, while the entire ladder is protected against the heave, roll, and surge of the hull.

A recently completed report analyzed in detail the operating costs of this dredge, and concluded that it can place sand on the beach for $1 per cubic yard.

THE CONTRACTUAL PROBLEM - Is this then the solution to our problem? Unfortunately, it is only a partial solution. It does solve the technical problem of acquiring sand and depositing it on the beaches under open seas conditions at a reasonable price; however, it does not solve the contractural problems that we, in a free democracy, impose upon ourselves when doing business with our Government. In order to explain this contractural problem, let me cite you a simple example of a ten million cubic yard project, which we will assume can be completed in one year at a price of $1/cubic yard. Assuming the equipment investment in dredge and pipeline is $5,000,000 and the allowed rate of depreciation is 10% per year, the depreciation expense is $500,000. Further assuming the project is successful and the contractor makes a profit of $1,500,000, he retains $720,000 after 52% corporate taxes. This plus depreciation provides a cash flow of $1,220,000. But now, the job is complete; he has no further work for his dredge; and, even if he applies all his cash to the loan, he still owes $3,780,000 on his investment. Not only is this risky for the contractor, but his bank may not lend him the money. Result? He probably raises his bid to amortize the equipment on the one year job, increasing his price by $9,400,000, thus increasing the unit cost to $1.94/cubic yard. ($5,000,000 investment minus $500,000 depreciation, divided by .48 tax complement equals $9,400,000). This is clearly an inordinate price, probably killing the project.

SOLUTION - How then do we solve this contractual problem? It can only be solved by a coordinated Federal plan for the release of beach restoration projects. It must assure relatively continuous work for the new equipment, allowing for a normal rate of equipment write-off. The Report on the National Shoreline Study previously quoted, indicates that $900 million of critical shore restoration must be accomplished within the next 5 years, or $180 million per year. An analysis of the Regional Inventory Report of the South Atlantic Gulf Region indicates that approximately 75% of the beach restoration will be accomplished by sand fill, i.e., dredging. Assuming this 75% is representative of all regions, this amounts to $135 million per year, and using the $1 per cubic yard justifiable price, represents 135 million cubic yards per year of offshore dredging, or 11 million cubic yards per month. Using 1 million yards per month as the capability of an offshore dredge, this means there is an immediate need for 11 offshore dredges. This does not include the additional $73 million per year estimated by the Corps to be required for beach nourishment, which adds an additional six dredges for a total of 17. In the unlikely event that these figures are 50% in error, we need an immediate 8 dredges.

Why then, with this report in the hands of the Congress has not <u>one</u> offshore dredge been built and the work begun? The answer lies partially in the contractual example given earlier, partially in the hesitation of numerous Government agencies which overlap one another in their attempts to minimize disruption of the environment, but largely it is due to the fact that the serious threat to our shorelines has not been recognized by the public, and therefore, the necessary political priority has not been assigned. With the National Shoreline Study outlining the problem, and with the equipment obtainable to do the job, the only missing ingredient is the coordinated Federal plan to utilize the offshore dredges on a continuous basis. If the political priority is assigned, the plan developed, and the projects funded, <u>the dredges will be built by</u> private enterprise. Competent dredging operators are anxious to bid on such projects, and are more than willing to acquire the equipment to do the job, if only they can obtain the assurance of continuous work to justify their capital investment.

THE CHALLENGE - Gentlemen, I leave you with a challenge. In order for our beaches to survive as our generation has known them, it is necessary that appropriate action be taken and taken promptly. In this day of social consciousness and desire to protect our environment, there has seldom been a more propitious moment to put forth this viable plan to preserve and protect our shorelines.

I submit that each individual and company with an interest in the preservation of our shorelines commit himself to the furtherance of a national coastline program which insures the preservation and improvement of this great natural resource. Each of us should acquaint our friends, associates and government representatives with the pressing need for appropriate political action leading to the necessary funding for restoring the beaches so essential to the health, welfare and ecology of the Nation. I suggest we recognize the urgency, accept the challenge, and get on with the job immediately.

SOIL MECHANICS APPLIED TO DREDGING

By

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INTRODUCTION - It is not the purpose of this talk to tell you something about dredging; that would be presumptuous on my part. What I can do is tell you something about my field - Soil Mechanics - and how I think a better knowledge of soil mechanics can help the dredging industry. In the short period of time that I have been associated with dredging, I have seen too many indications of how a lack of soil mechanics background has severely hampered the dredging industry. Unfortunately, there have also been instances where design engineers were completely uninformed about what to expect in dredged construction. Perhaps the answer to this is a two-way educational process. By becoming fairly proficient in soil mechanics, especailly in the terminology, the dredging industry would be able to communicate with the designer in language he understands, thereby educating him in dredging capabilities.

First, let me briefly discuss soil mechanics. It should be understood that soil mechanics is a relatively recent field in civil engineering, having been initiated in 1925 by Dr. Karl Terzaghi. The properties of soils are much more complex than those of most other materials, and this prevented soil mechanics from developing as rapidly as structural mechanics or fluid mechanics, for example.

Even if our knowledge of mechanical properties of soils were complete, we would still have to contend with the extreme variability of soils imposed by nature's depositional processes.

The application of soil mechanics to areas on the fringe of the classical approach often occurs slowly. This seems to have been the case in the dredging industry. I know of only one firm which appears to be dedicated to handling soils problems in the dredging industry. Unfortunately, they are not located in this country.

The dredging contractor should be aware of three things concerning the soil before bidding or contracting a job:

a) the <u>kind</u> of soils,

b) the <u>condition</u> of the soils, and

c) their arrangement (or stratigraphy).

Of course, the designer needs this information too, and it is usually presented to the contractor on the bid documents. But quite often this doesn't tell the complete story or doesn't give the contractor adequate information. I would like to discuss these three things in some detail.

<u>KIND OF SOIL</u> - First, consider the <u>kind</u> of soil. It is not sufficient to describe a soil by local terminology, by color, or by grain size. To translate information from one job to the next, and thus build up our experience, the soil should be properly classified by a method which will (a) describe the engineering properties of the soil as well as (b) provide an effective means of communciating this information.

There are several different soil classification methods to choose from, but most of them (such as those used by agronomists and geologists) are not related to engineering properties. In engineering, three schemes are commonly used. The American Association of State Highway Officials (8) and the Federal Aviation Administration (1) methods have obvious limitations. That leaves the Unified Soil Classification System (USCS) first put forth in 1947 as the Airfield Classification System, but since revised to cover nearly all engineering uses (6). It is understood and used nearly universally.

The USCS is based on texture (or grain size), plasticity (or behavior of the fines) and engineering behavior. Grain sizes recognized are:

Cobbles - larger than 3 inches

Gravel - from 3 inches to the No. 4 sieve

Sand - from No. 4 sieve to No. 200 sieve (0.074 mm)

Fines (Silt or Clay) - smaller than 0.074 mm.

However, naturally occurring soils may have all of these sizes in them and this is why a classification scheme is needed.

Details of the classification scheme can be found in most soil mechanics texts or in Reference 6. In the short time available, I want to show you how simple the method is.

Briefly there are three main groups: coarse grained soils, fine grained soils and highly organic materials (Figure 1).

Highly organic soils are distinguished visually; they contain large amounts of fibrous organic material. They are given the classfication symbol, P_t, and they are to be avoided, if possible.

A soil should be classified as coarse-grained if 50% or more of the total soil was larger than the No. 200 sieve (0.074 mm). Coarse grained soils are the sands and gravels. Conversely, if the majority of the soil were smaller than the No. 200 sieve, it would be classed as fine grained.

For simplicity look at the fine grained soils first. These are the silts and clays. We distinguish between these two based on their plasticity characterisitcs. To do this, two simple tests are used. One determines the amount of moisture required to just make the soil a liquid. This moisture content, expressed as a percent, is termed the liquid limit. The plastic limit is the minimum moisture content at which the soil can be manipulated without crumbling. It is determined by rolling the soil out in a thread using the palm of the hand until the thread just crumbles when it reaches a diameter of 1/8 inch. The numerical difference between the liquid limit and the plastic limit is termed the plasticity index. These are inexpensive tests which can be performed by nearly any soils laboratory.

Using the liquid limit and plasticity index, a chart is entered (Fig. 2) to classify the soils. This chart is based on considerable engineering experience. One line, termed the A-line, is used to distinguish between soils that have silt properties and those having clay properties. If the combination of liquid limit and plasticity index plots about the A-line, the soil gets the designation "C" (clay); below the A-line it sets the designation "M" for silt (from the Swedish "MO" meaning rock flour). The soils are further divided on the basis of their plasticity, high (H) or low (L). The dividing point is a liquid limit of 50. Thus, clays would be classified as CL or CH and silts as ML or MH. In addition, there is a group of soils which contains organic colloids, but are not characterized by significant amounts of fibrous organic material. These are designated "O" for organic and may further be classed as OL or OH. In the cross-hatched zone, soils have the characteristics of both silts and clays and are given the dual classification, CL-ML.

Coarse grained soils are divided into sands and gravels based on the size which predominates. The designation "G" is given for gravels and "S" for sands.

If the gravel or sand is very clean, less than 5% silt and clay, it is classified as well-graded (GW or SW) if all of the sizes are present and there is good distribution of the sizes, or poorly graded if the material is uniform in size as a beach sand (SP) or pea gravel (GP). If the sand or gravel is dirty, greater than 12% silt and clay, it is classified as clayey (GC, SC) or silty (GM, SM) according to the way the fine material plots on Fig. 2.

There are two extraordinary facets about this system. It is easy to learn, and it is accompanied by visual or field indentification means which can be learned in about 2 hours, achieves about 90% confidence, and requires no equipment.

The use of a soil classification system certainly won't eliminate dredging problems. But the system discussed will allow you to identify soil types that are troublesome, and communicate information about them.

For example, there are two soil groups that appear to cause considerable problems in the dredging industry - the SM and ML soils. They are not necessarily difficult to excavate or pump; the problems occur when they are placed. Because of their small size and lack of bond between grains, they can be easily moved by currents and under the appropriate conditions, they may even "liquify". The liquified soil is dense enough to cause pipelines to float in it, and it may also flow while in the liquified state.

CONDITION OF THE SOIL - The second item mentioned earlier was the condition of ths soil - is it weak or strong, loose or dense? More specifically, we are interested in the shear strength of the soil.

Shear strength of soils is a result of two components,

(a) A cohesive component or "glue" between grains which is independent of the load applied to the soil. This is not exhibited by clean sands and gravels.

(b) A frictional component which is proportional to the load applied to the soil. This is present in all soils although its effects may be masked out by the manner in which the soil is tested.

There are several types of laboratory and field tests used to measure the shear strength of the soil. These are considered briefly below:

(a) Direct Shear Test - A soil sample is trimmed to a convenient size, usually 2.5-inch diameter by 1-inch high and fitted into a split box (Fig. 3). A normal load, designated P, is applied to the top of the sample. A shearing force, S, is then applied to the sample causing it to fall along the dotted line shown in the figure. The test result for one normal load is shown in Fig. 4a. If identical samples are tested at higher normal loads, the maximum shear strength increases. A plot of the maximum shear strengths achieved versus their respective normal loads will define a straight line (Fig. 4b). Where this line intersects the origin is the cohesive componenet, or often called, the angle of internal friction.

These values of c and ϕ characterize the shear strength of the soil. Unfortunately they are not sacred numbers for a particular soil, but they vary depending on the mobility of the water in the voids of the soil. In clays and some silts, the water is very immobile and it will escape from the voids only after long periods of time. A test which is carried out so slowly that the water can fully escape is termed a "drained" test, and Figure 4b represents typical results from such a test.

If the soil is sheared without the water escaping the results will be as shown in Fig. 5a. The frictional component does not appear to be present, or put another way, the shear strength is independent of the applied normal load. During the construction period - which is relatively short compared to the speed with which the water can move out of clays and silts - the shear strength will not change, and thus dredging contractors are usually interested in this strength, which is termed the "undrained" shear strength.

In sands and gravels, the water is very mobile and it will usually drain during shear unless precautions are taken to prevent it or unless the materials are sheared too rapidly to drain. The test results from a drained shear test on a sand or gravel will appear as in Fig. 5b. (Note the absence of a cohesive component of shear strength).

If no water escapes during shear the sand will also behave as if it had no frictional resistance (such as Fig. 5a) and, in fact, if the load is applied rapidly enough the shear strenth may fall to zero. Earthquake shocks and loads due to high wave overpressures are two ways this occurs. As mentioned earlier, a pipeline might float in such a material. The phenomenon is most prevalent in the fine silty sands and coarse silts.

It is worth mentioning that the direct shear test is suitable for testing all materials - gravels, sands, clays, etc.

(b) <u>The unconfined compression</u> test is performed on a cylindrical specimen whose length is about twice the diameter (Fig. 6). The peak strength is termed the unconfined compressive strength. The test is performed rapidly and clay soils will not drain during the test procedure, so the undrained strength is obtained. (The test is obviously not suitable for sands since a cylinder of the material will not stand unsupported.) One half the unconfined strength is also the shear strength so it gives the same results as the undrained direct shear test.

(c) The triaxial compression test uses a sample similar to the unconfined compression sample but an all round confining pressure can be applied to the soil. The specimen is placed in a pressurized cylinder to do this (Fig. 7). A rubber membrane surrounds the specimen and prevents the external pressure from reaching the specimen interior. The results obtained from this test will be the same as for the direct shear test but the triaxial test has the additional advantage that it is easier to control the drainage conditions.

(d) The vane shear test is becoming popular as a means of measuring the shear strength of soils both in the laboratory and in the field (4). The principles are the same for both lab and field vanes only the size is different. The laboratory vane is usually about 1/2" x 1/2" (Figure 8a). It is lowered into the soil and the maximum torque required to rotate the vane is measured (Fig. 8b). From this the shear strength can be readily obtained. The vane shear test is limited to the determination of the undrained strength of clays whose shear strength is less than about 2,000-2,500 psf. Its simplicity and low cost make it well adapted to many areas of interest - including the dredging industry.

ARRANGEMENT OF THE SOIL - The arrangement, or stratigraphy of the soil is determined most often by making one or more core borings in the area of interest, and classifying the soil samples that are recovered from the borings. The results are usually presented as a soil profile, or cross-section (Fig. 9) which shows the various types of material and the depths to which they extend. It should be obvious that depths at which the soil changes from one type to another should be accurately documented or the soil profile is liable to present misleading results. Here again, soil classification is important: from a purely visual standpoint naturally occurring soils may provide many variations in a small area, although proper classification may show them to fall in a single class with similar engineering properties. One of the significant problems which we have faced for many years is the shortage of qualified personnel to perform accurate field classifications. For this reason, classification based on laboratory tests is almost a necessity.

Sampling of submerged soils presents many problems and considerable expertise is needed. An alternative approach is the use of various geophysical methods such as high resolution profiling. However, these methods are not capable of determining the type of material involved, although they may distinguish layering or changes in the soil with depth. For this reason they serve as an important supplement to borings but not as a substitute for them.

The sampling program not only provides information for classification, it also serves to provide the samples for strength testing and other tests not discussed herein. As such, considerable thought must be given to the type of sampling device used.

The selection of the sampling tool is significantly influenced by the type of soil being sampled. The characteristics of clay mentioned earlier - the bond or cohesion between grains and relative immobility of the water - make it possible to insert a sampler into the soil and extract an intact and relatively undisturbed sample. Because of the immobility of the water in the voids the insertion can take place without changing the water content or density of the soil. Then lab tests can be made on the sample to determine a reliable estimate of the undisturbed strength.

This is not true in sands, and even if relatively undisturbed samples could be obtained, subsequent preparation (trimming into the test devices, etc.) would probably result in undesirable disturbance. Thus, a means of obtaining shear strength in place is desired, although a sample should be brought to the surface for classification purposes.

A typical method of sampling clays in the U.S. is the Shelby tube sampler (Fig. 10). The use of a thin (but strong-walled) tube such as this insures that the sample will not be disturbed by displacement during insertion of the tube into the soil. The drilling or coring rig (Fig. 11) which advances the bore hole subsequently forces the sampling tube into the soil at the bottom of the hole. After extracting the sample from the sampling tube, it is tested by one of the methods previously described.

The strength of soft, difficult-to-sample clay soils can be determined in place by the field version of the vane shear test. The device is inserted into the soil at the bottom of the boring, and the torque required to shear the soil is measured at the ground surface. Subsequently, a sample should be brought to the surface for classification.

The determination of the in place strength of sands is done most commonly through use of the Standard Penetration Test (SPT) (2). The test utilizes a 2-foot long split sampling tube, 2-inches in outside diameter and 1 3/8-inches inside diameter, which is lowered to the bottom of a drill hole and subsequently driven into the soil with a 140-pound hammer dropped 30-inches (Fig. 12). After seating the split tube 6-inches, the number of hammer blows to drive it an additional 1-foot is counted, and this is referred to as the blow count, N. For sands, it has been found that both the degree of denseness (relative density) and the angle of internal friction are closely related to the blow count, as shown in Table I.

Similar relationships have been presented for the undrained shear strength of clays, but they are not reliable and their use is to be discouraged. However, the SPT is an excellent device for delineating zones and layers of hard and soft clays.

TABLE 1

STANDARD PENETRATION TEST
NON-COHESIVE SOILS

BLOWS PER FOOT, N	RELATIVE DENSITY
0-4	Very Loose
4-10	Loose
10-30	Medium
30-50	Dense
Over 50	Very Dense

As a result of the large volume of the split sampling tube used in the SPT, it must displace soil when driven into the ground, and the sample returned to the surface in the tube is highly disturbed and suitable only for classification purposes.

The above equipment can be utilized for sampling soils lying underwater, but special support equipment and techniques are required primarily because it is necessary to re-enter the bore hole several times to obtain the deeper samples. This presents problems when done from a floating platform. Often, in dredging projects only shallow samples are necessary and sampling can be preformed from vessels regularly used or available in the dredging industry. For sampling the upper 1 meter of sediment, box corers can be used; gravity type piston corers are capable of obtaining relatively undisturbed samples of the upper 10 meters of sediment. The excellent references by Hvorslev (7) on sampling in general and that of Bouma (5) on marine sampling are recommended for additional information in these areas.

CONCLUSIONS - Dredging presents many problems of varying nature, but with few exceptions soil is a common factor in dredging operations. It has not been the intent of this paper to discuss problems which many of you face everyday, e.g., the stability of dredged dikes, the power required for a cutterhead dredge to operate in various soils, the settling time of soils in suspension, and others too numerous to mention. Rather, I have tried to install a few basic ideas which are background information needed to solve the many problems that occur. By adopting a suitable system of soil classification, experience information related to soils can be translated from one project to the next. Knowledge of shear strength and how it is obtained can be utilized in design of dikes, and also ease of dredging various deposits. A well conceived exploration program will lead to a better knowledge of soil types and variations found in natural soil deposits, with an attendant saving in construction costs.

Finally, let me urge those of you in the dredging industry to make your problems known to the soil mechanics profession. Both of us may benefit.

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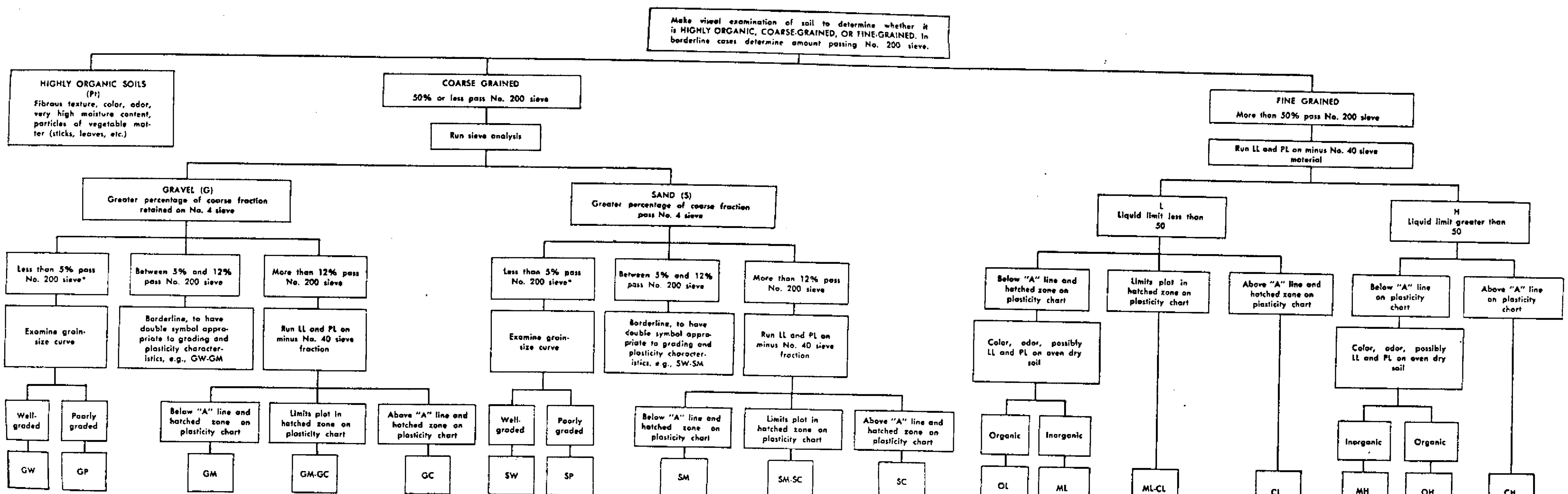


Note Sieve sizes are U. S. Standard.

* If fines interfere with free-draining properties use double symbol such as GW-GM, etc.

Figure 1. Unified Soil Classification System

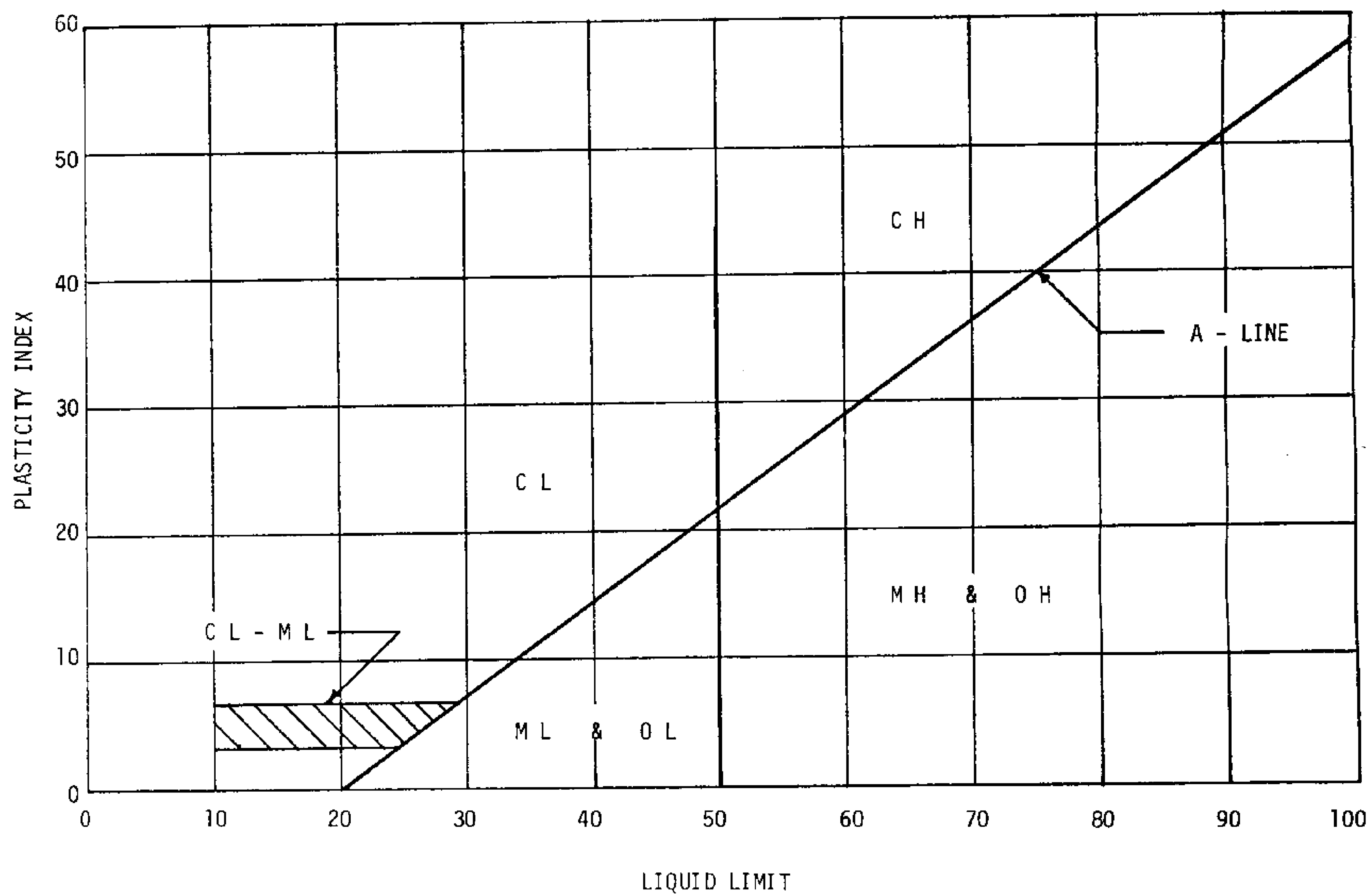


Figure 2. Plasticity Chart

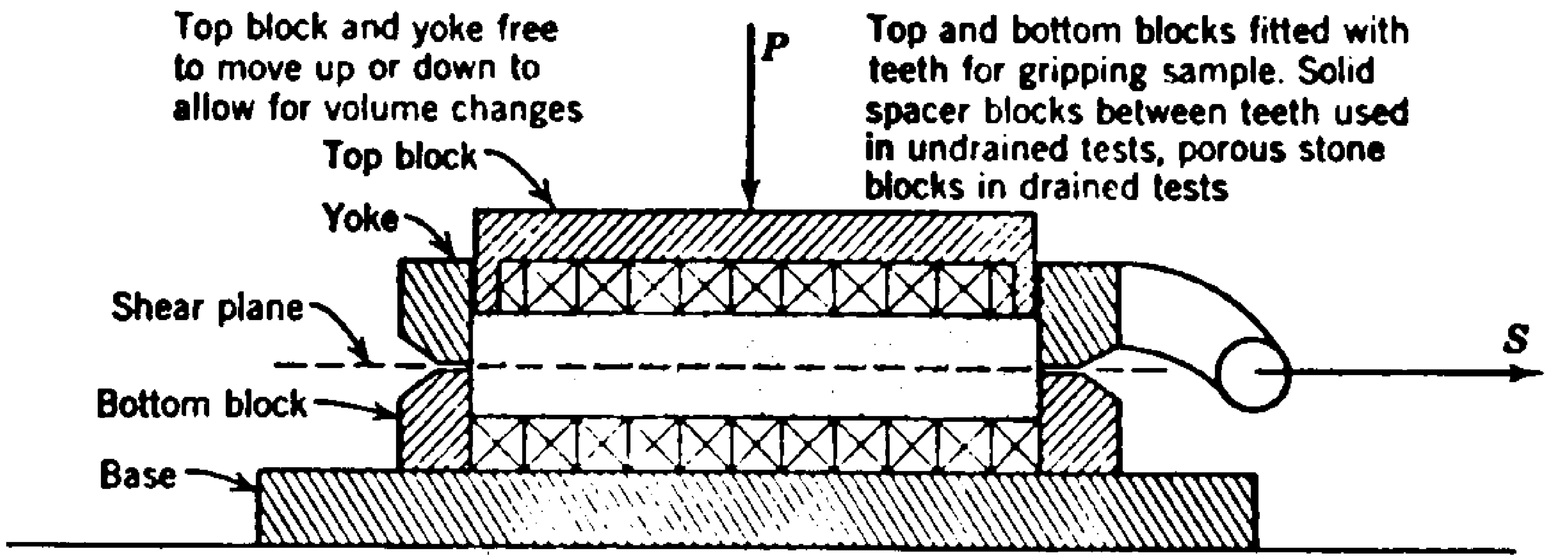


Figure 3. Direct Shear Box Apparatus

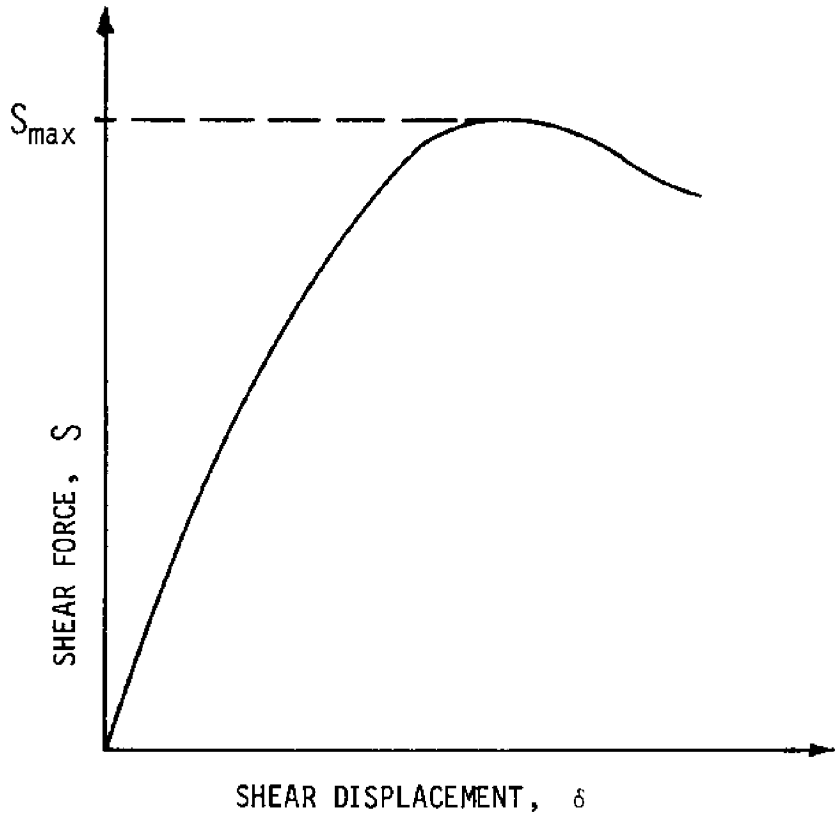


Figure 4a. Typical Direct Shear Results for One Normal Load

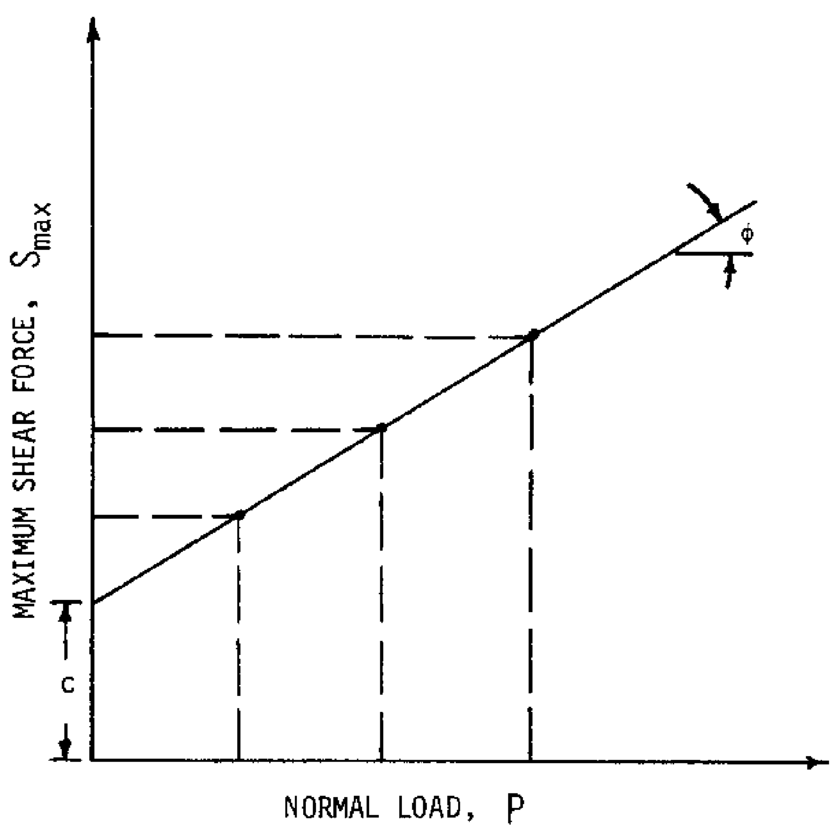


Figure 4b. Typical Direct Shear Results for Three Normal Loads. Drained Test on Cohesive Soil.

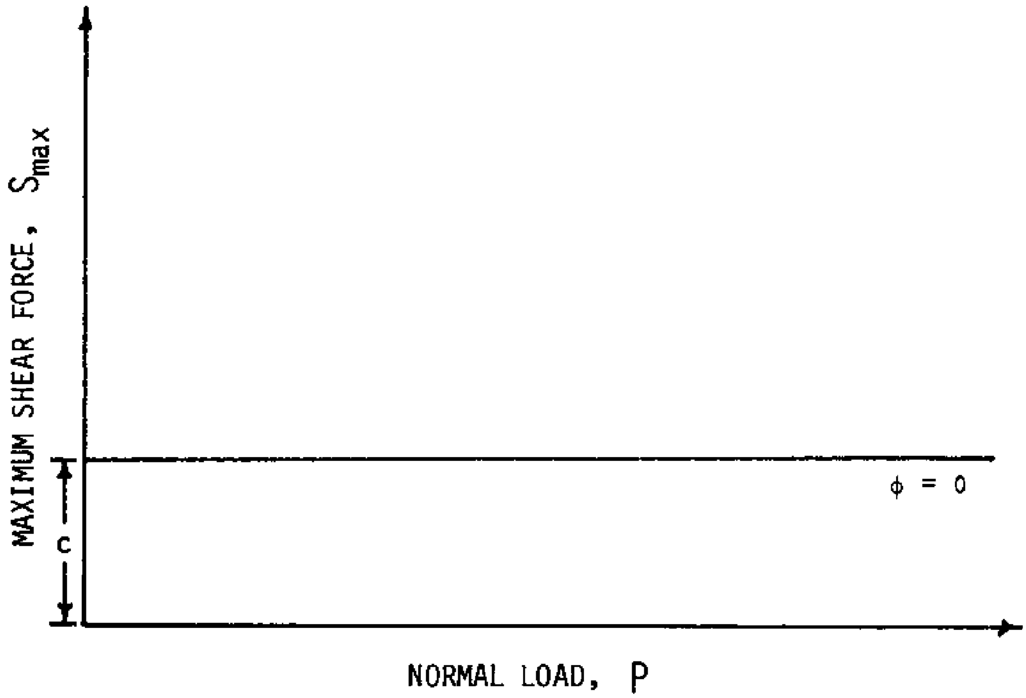


Figure 5a. Typical Results for Undrained Shear Tests. All Soil Types.

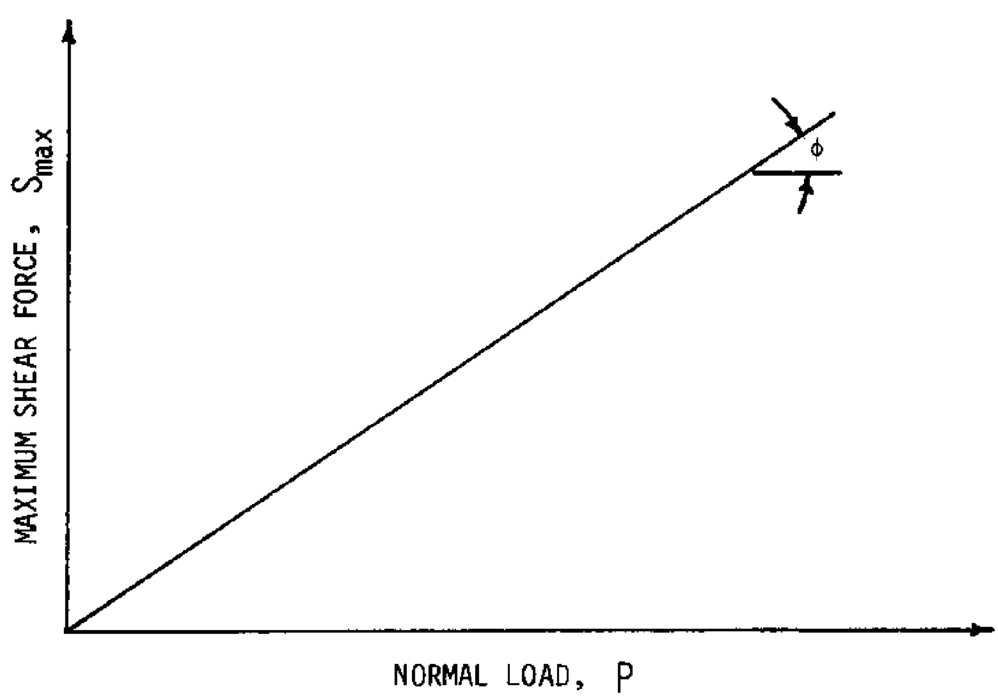


Figure 5b. Typical Results for Drained Shear Test on Sands or Gravels.

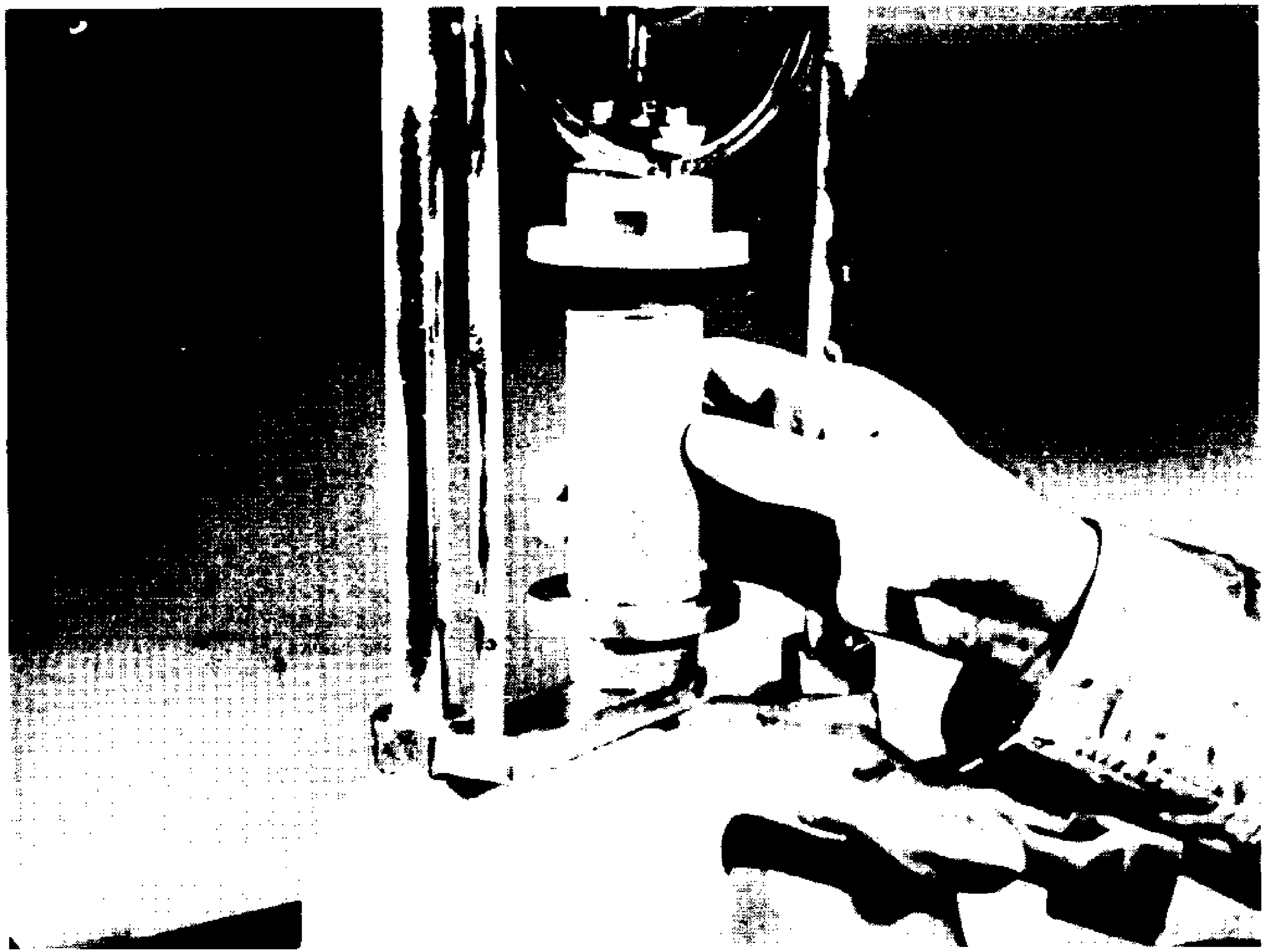


Figure 6. Unconfined Compression Test Apparatus

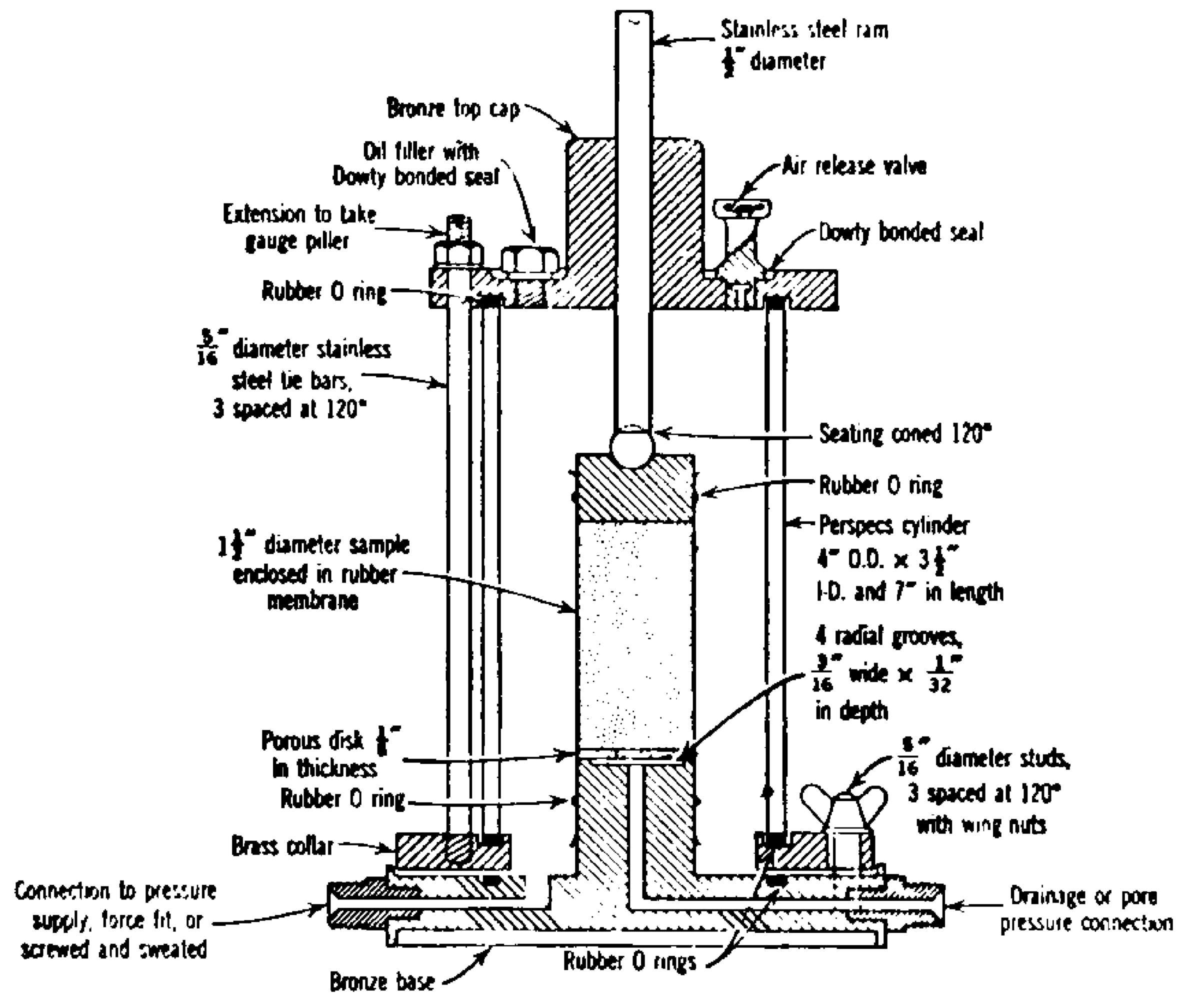


Figure 7. Triaxial Compression Test Apparatus

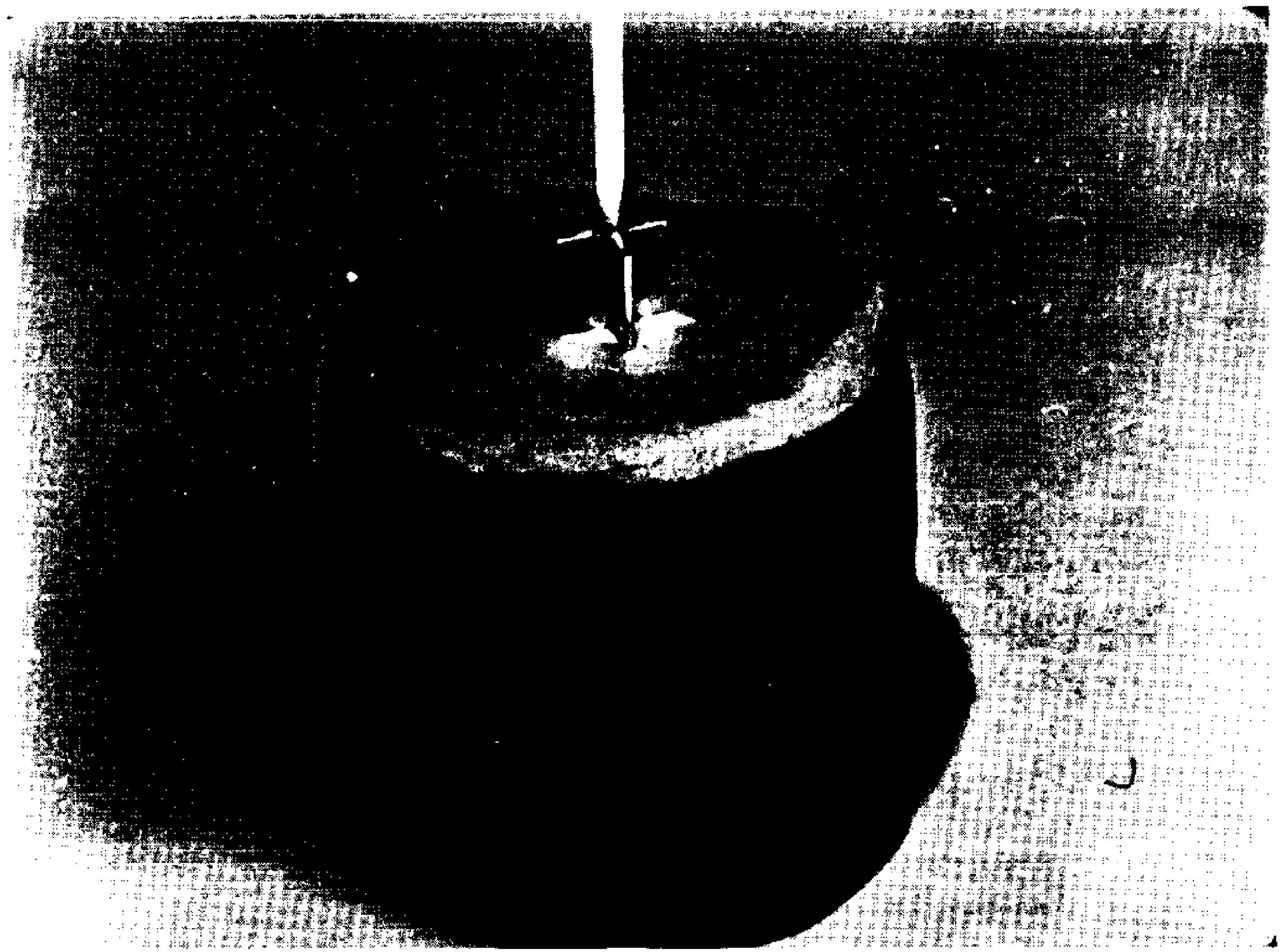


Figure 8a. Laboratory Vane Shear Test Apparatus

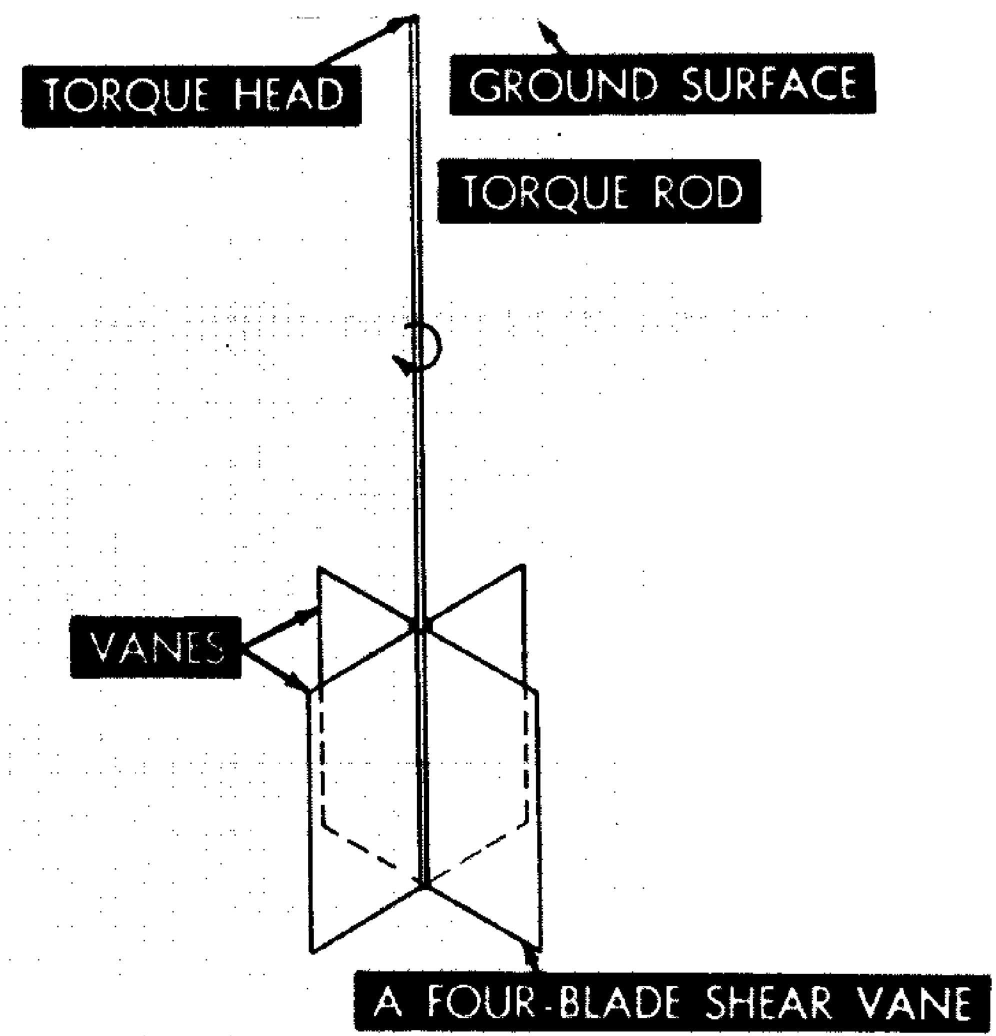


Figure 8b. Principle of Operation for Vane Shear Apparatus

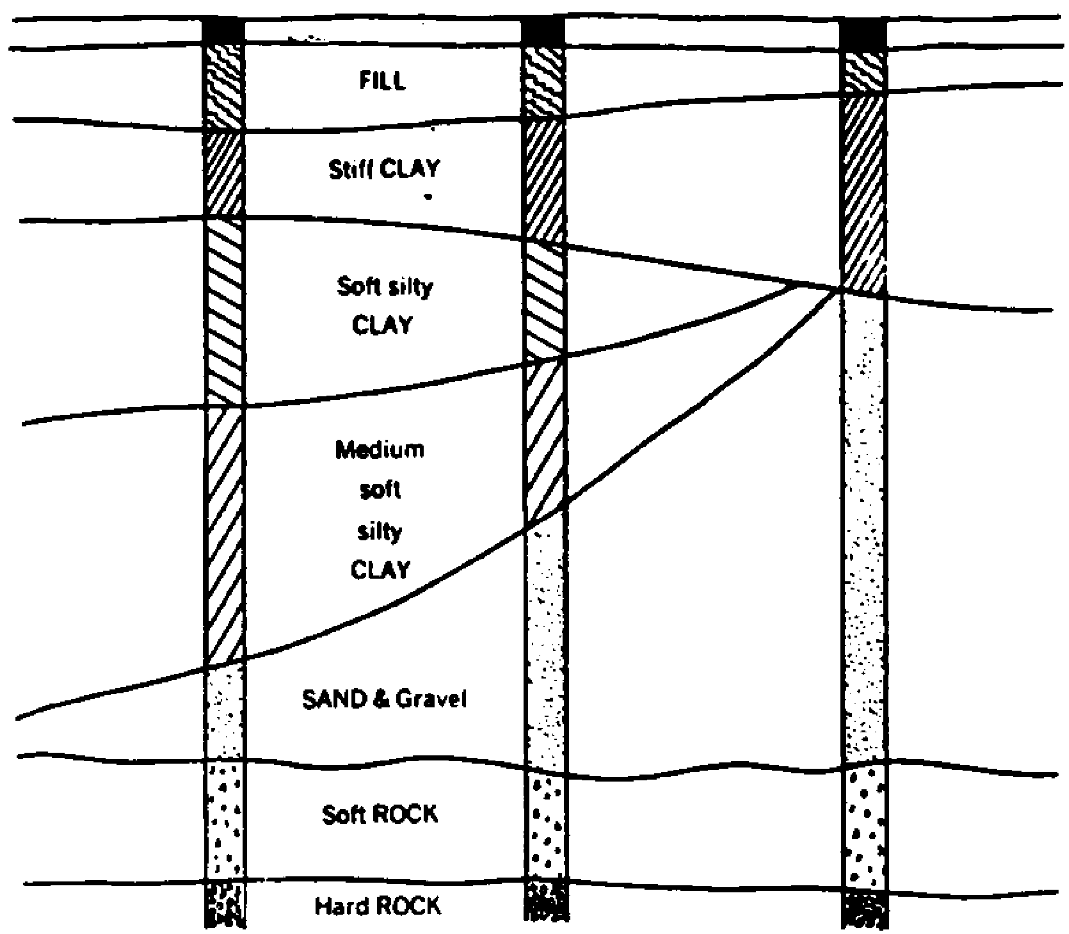


Figure 9. Typical Soil Profile

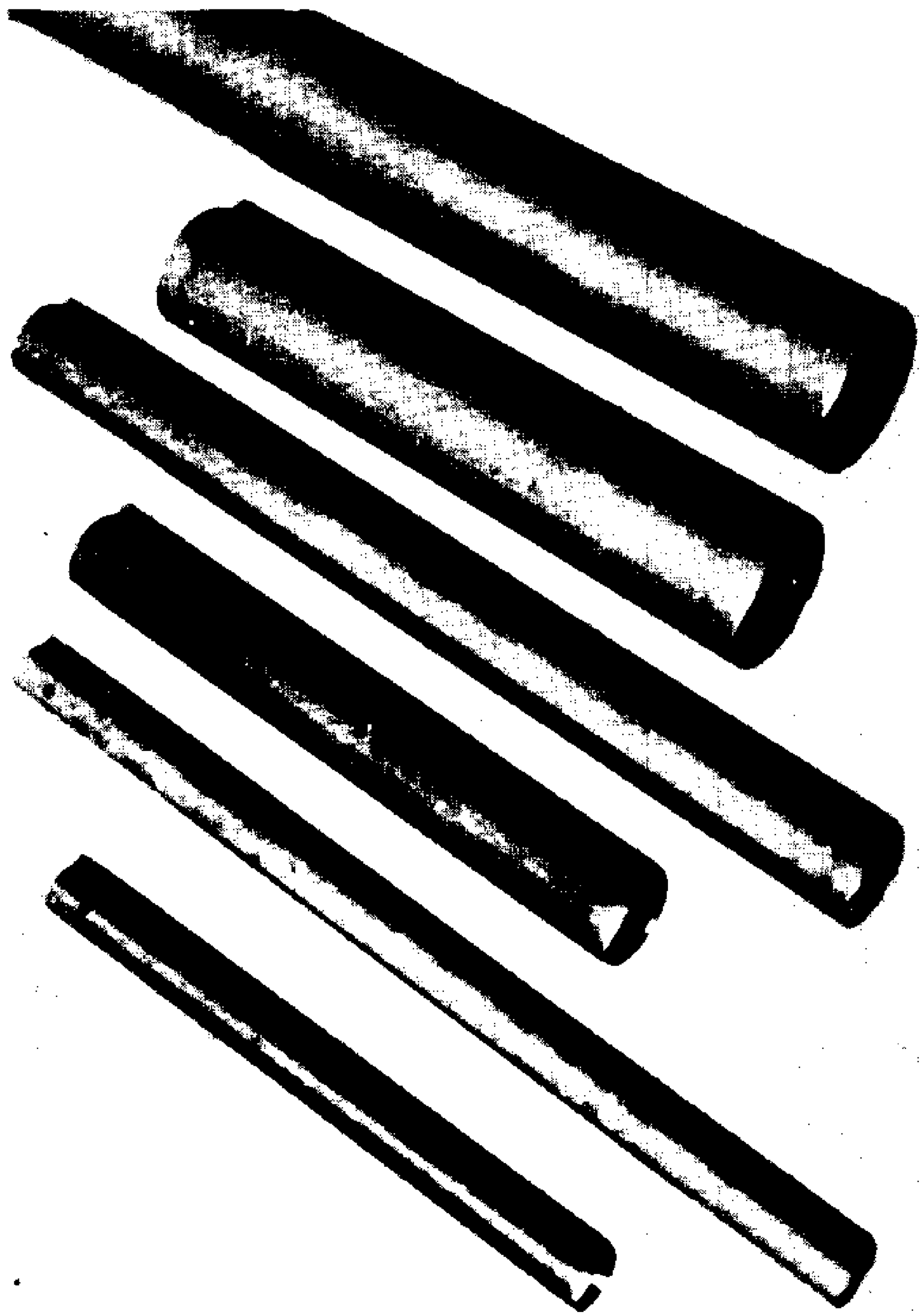


Figure 10. Thin Wall Shelby Tube Samplers

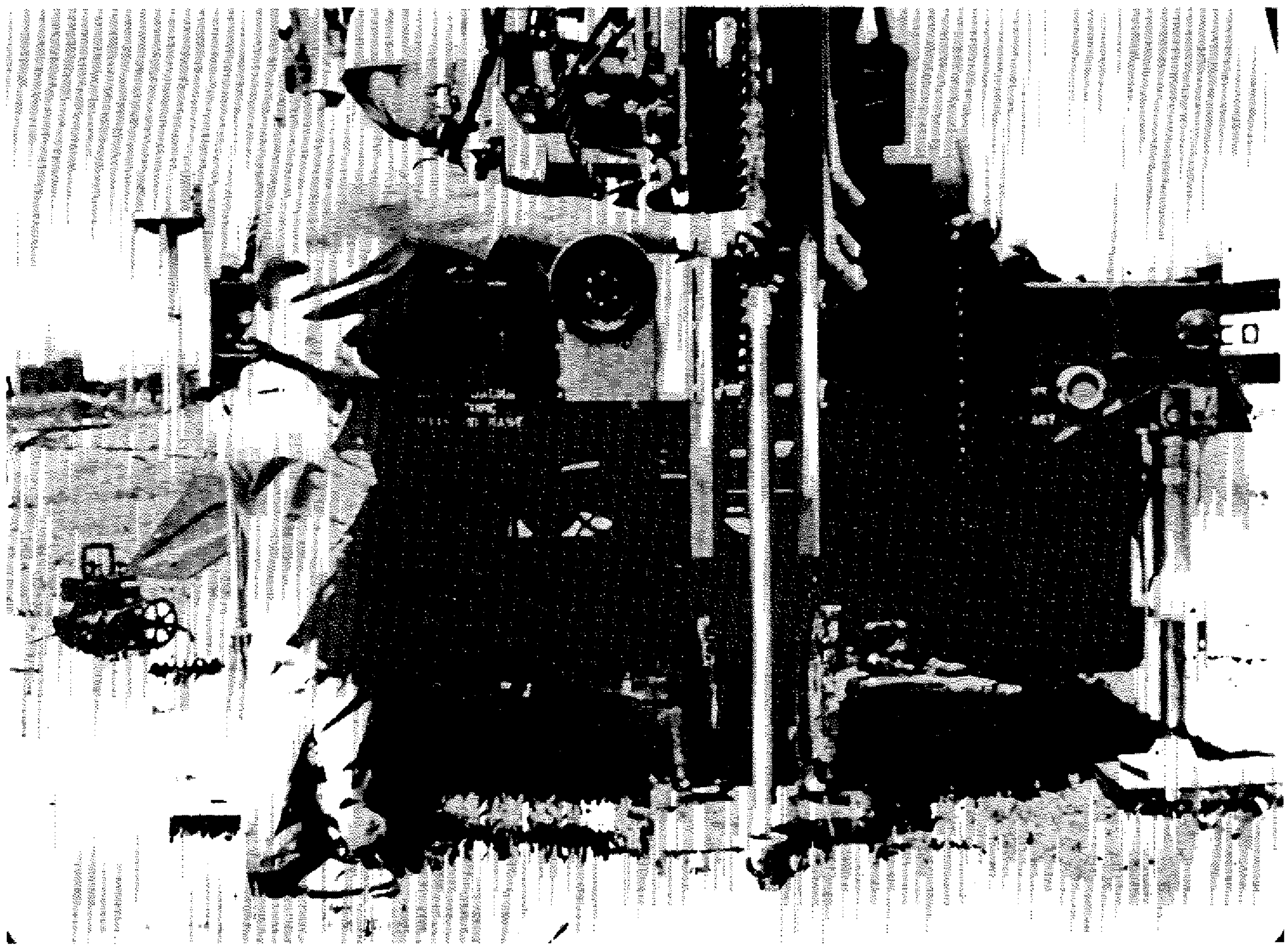


Figure 11. Coring Rig Used to Advance Bore Hole and Sample Soils

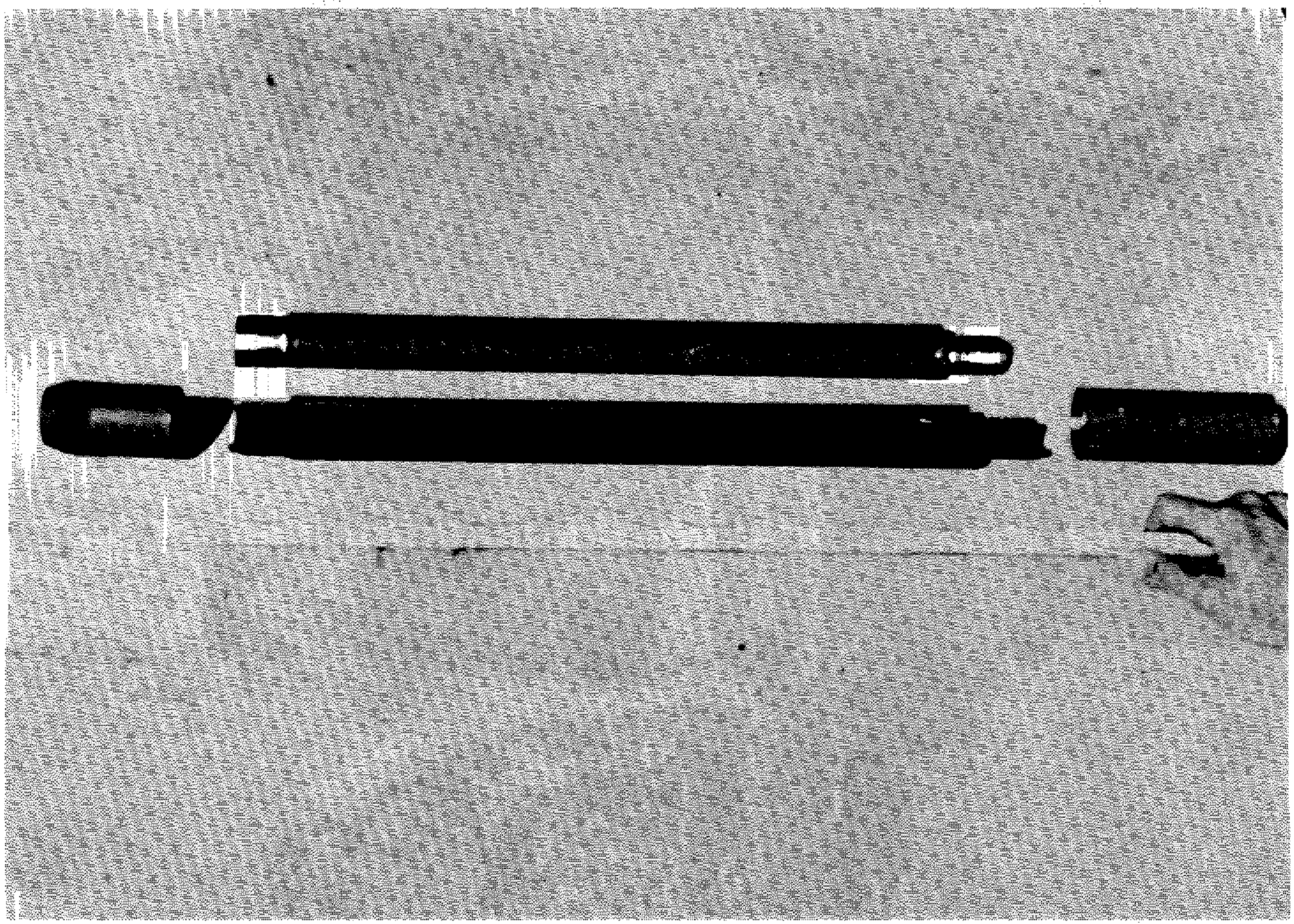


Figure 12. Split Sampling Tube Used in Standard Penetration Test

BARTOW MAINTENANCE DREDGING AND WATER QUALITY

By

A.W. Morneault
Florida Power Corporation

<u>NEED FOR THE PROJECT</u> - The Bartow Maintenance Dredging Project was initiated to correct the siltation of a channel utilized for fuel-oil delivery to the Florida Power Corporation Paul L. Bartow electric power generating station. The channel, originally dredged to a 34-foot design depth, provides a route through Tampa Bay to the Bartow Plant. In addition to supplying fuel to the Bartow Plant, fuel oil delivered to the plant is stored and sent by barge to the company's two nearby generating plants, Higgins and Bayboro, and in the near future, by 34 mile pipeline to the Anclote generating plant.

Since 1958, the turning basin tanker slip and the east-west channel had become silted due to cross currents and other natural conditions in Tampa Bay. This situation had caused ship traffic into Bartow Plant to be limited to ships with a draft of 29.5 feet or less at mean low water. Due to this restriction, Florida Power Corporation had been paying a penalty to the oil companies.

In order to adequately handle the increase in ship traffic expected in 1973 and 1974, an engineering evaluation was initiated to determine the extent of siltation in the ship channel. Dredging required in the maintenance project included returning the tanker slip, turning basin, and east-west channel to the 34-foot design depth. Engineering bottom profiles indicated a total volume of 414,273.51 cubic yards were to be removed; 31,840.9 cubic yards of which were from state-owned submerged lands in Tampa Bay.

PROJECT DEVELOPMENT BY TODAY'S STANDARDS - Since 1969, with the initiation of the National Environmental Policy Act (Public Law 91-190), the Water Quality Improvement Act of 1970 and the Federal Water Pollution Control Act (Public Law 91-224) proposed constructions which involve dredging or discharge in navigable waters must be conducted in such a manner that the proposed activity will not violate applicable water quality standards. Also under these regulations, the term "Environmental Impact" became an important consideration in the analysis of a project under review by a permitting agency. Therefore, dredging, by necessity, changed from "underwater excavation" to the process of removing valuable submerged land without degrading the surrounding marine environment.

The concept of "environmental dredging", or performing dredging operations while maintaining environmental quality, has become of critical concern within recent years. Development of new concepts in silt control and water quality of the dredging operation are the result of these new environmental policy acts and strict enforcement of the existing water quality criteria.

To provide for maximum environmental control, engineering criteria for assurance of compliance with regulatory codes and standards were developed by Florida Power Corporation. In the development of these engineering criteria directed at reducing the environmental impact of dredging operations, three general types of equipment or construction were utilized for such control: hydraulic dredging equipment, silt retention devices, and upland spoil retention areas.

Hydraulic dredging equipment utilizes a cutting head and suction line. Material removed by the cutter head is immediately drawn into the suction line limiting silt and turbidity around the cutting head. Thus, the silt plumes around the dredge itself, which are usually associated with dredging, were in this project nonexistent.

Silt retention devices contain turbidity within a dredging area. These devices, resembling a curtain or apron, are placed around the dredge and supported by floatation buoys. The curtains extend into the water several feet. As deeper waters are encountered, additional sections are attached to the curtain bottom. General success has been achieved in restricting turbid water to within the curtain confines.

The most recent innovation toward water quality is the compartmentalized upland spoil area - holding pond. The upland spoil area is diked into several large ponds by retention mounds and connected by spillways. Effluent placed into the first pond travels sequentially through each pond before final release to the environment. By utilizing spoil pond holdup, additional time is realized for natural deposition of the silt from the water.

The Bartow Maintenance Dredging Project engineering design contained all three of the previously cited controls. (See Figure I). In addition, the Bartow Project also incorporated the water quality control specification into the project bid specifications. These specifications attempted to clearly delineate work requirements, objectives and operative procedures.

PERMITS AND LICENSES REQUIRED - Upon completion of the dredging bid specifications, permit applications were submitted sequentially to the Pinellas County Water and Navigation Control Authority, Florida Board of Trustees of the Internal Improvement Trust Fund, Florida Department of Pollution Control, and the U.S. Army Corps of Engineers. In addition to the above agencies, the following state and federal agencies were involved in the approval of the project: Southwest Florida Water Management District, State of Florida Game and Freshwater Fish Commission, Florida Department of Natural Resources, and the U.S. Environmental Protection Agency. Final approval for the project, culminating 42 weeks of review by various regulatory agencies, was received on March 17, 1972, with the receipt of the U.S. Army Corps of Engineers permit.

Key provisos specified in the received permits were: use of silt retention curtain, limit of 50 Jackson Turbidity Units (JTU) above ambient for turbidity, right of the Game and Freshwater Fish Commission to terminate the dredging operation, and mandatory agency notification of stoppages in the operation.

BARTOW TURBIDITY MONITORING

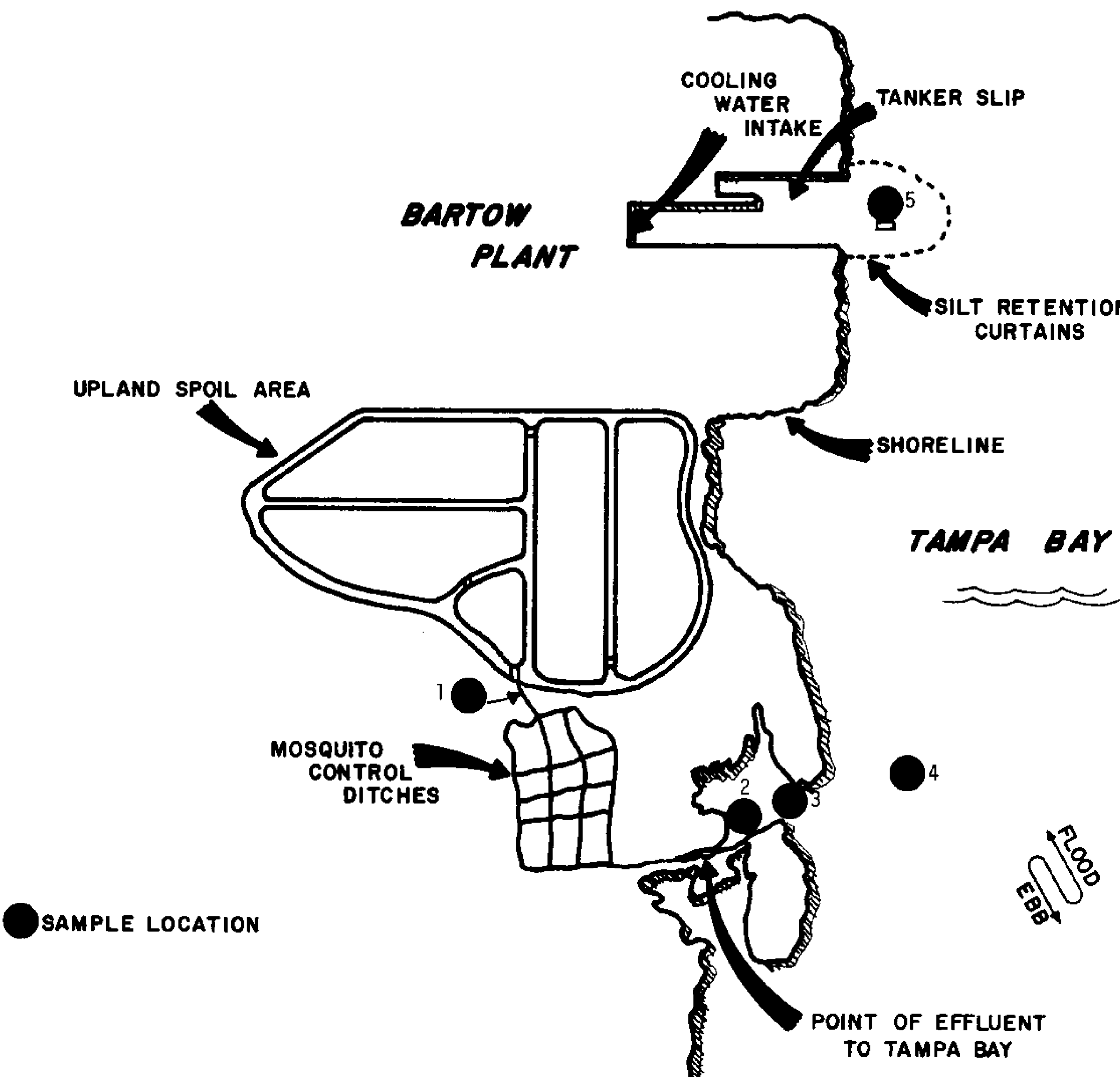


FIGURE I

<u>WATER QUALITY PROGRAM</u> - In the course of developing the bid specifications, a section called Water Quality Program was added to delineate responsibilities to the following three categories: Water Quality Control (dredging responsibility), Water Quality Assurance, and Water Quality Surveillance.

Based on these documents placed in the bid specifications, a complete Water Quality Program was developed to provide environmental assurance of the dredging operation (See Figure 2).

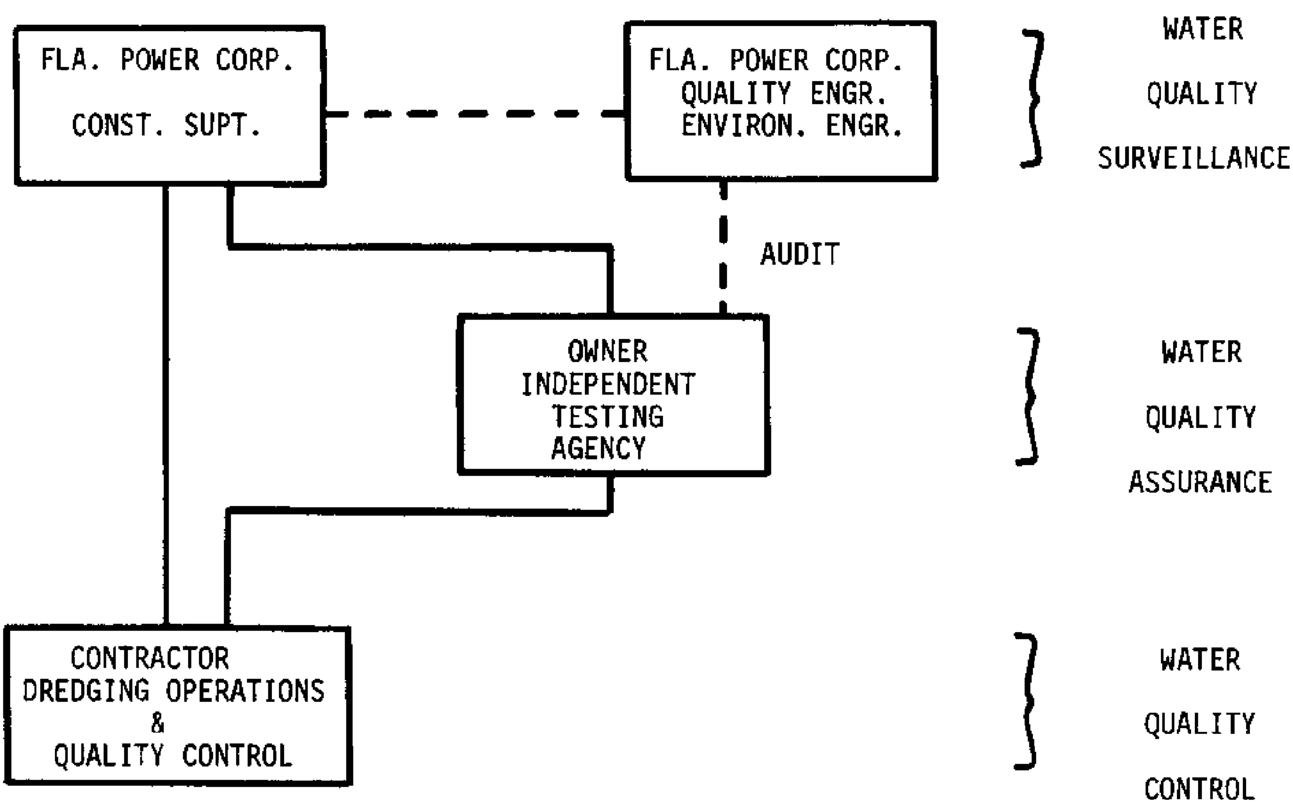
<u>WATER QUALITY CONTROL</u> - The Hendry Corporation of Tampa, Florida was selected as the dredging contractor, Hendry Corporation had submitted, along with their bid, a complete Water Quality Control (QC) plan which delineated their responsibilities and duties, measuring techniques, monitoring frequency, reports and means to control turbidity if limits were exceeded.

The operating criterion used by the dredger was to test only when the dredge was operating or when effluents were being released from spoil ponds. QC Water Quality Reports were furnished to the Water Quality Surveillance Engineer.

The objective of this testing program was to control the dredging operation on a first priority basis.

<u>WATER QUALITY ASSURANCE</u> - In order to protect Florida Power Corporation and to assure that the proper tests were being performed under the Water Quality Control Program, an independent testing agent was selected to conduct the Water Quality Assurance Program (QA). The testing agent selected was Florida Testing Laboratories, Inc.

BARTOW WATER QUALITY PROGRAM



WATER QUALITY PROGRAM

FIGURE 2

The goal and responsibilities of this independent third party testing agency were to provide assurance to the Florida Power Corporation Water Quality Surveillance Engineer that the dredging operation was in compliance with the Water Quality standards and applicable Water Quality provisions of permits issued.

In order to adequately provide this assurance, 24 hour coverage of the project was implemented. The duties of this agent were to check the dredge and silt curtain to assure no leakage of high turbidity water occurred, to inspect the spoil material transport pipe line for leaks, to inspect the perimeter of the spoil pond, and to obtain turbidity measurements at various monitoring points to assure that water quality standards were being met. A log was sent to the Water Quality Surveillance Engineer for each day's work experience in the form of a QA Water Quality Report.

The prime responsibility of this testing agent was to verify the work performed by the Water Quality Control agent of the dredger.

<u>WATER QUALITY SURVEILLANCE</u> - As part of the Water Quality Program, a Water Quality Surveillance Guide was developed using the bid specifications as a guide. In the surveillance guide, a complete program was specified including recording procedures and responsibilities. Water Quality Surveillance was assigned to the Surveillance Engineer (Florida Power Engineer). His responsibilities were:

a. To verify that the Water Quality Assurance (FTL) and the Water Quality Control Agent of the dredger perform their duties indicated in the Water Quality Control Program, respectively.

b. To analyze the Water Quality Reports received from QC and QA and make comparisons to the Water Quality Criteria outlined in Ch 17-3 of the Florida Administrative Code.

c. To periodically render a surveillance inspection to the job site to verify turbidity levels and to inspect the dredging operation, pipeline, and spoil pond.

d. To inform or verify with the on-site Florida Power Construction Supervisor, or his alternate, of any high turbidity condition that had been reported by the Water Quality Assurance agent or by the Water Quality Control Agent.

e. To obtain assistance from the Environmental Section of the Florida Power - Generation Environmental and Regulatory Affairs Department for an evaluation impact of any reported siltation from the dredging project.

The Surveillance Guide clarified the Water Quality Program of the bid specifications in the following areas:

1. Turbidity measurement procedure at the point of effluent of settling pond.

   a. The effluent of Pond 5 of the settling pond empties into the mosquito control ditch (shown as Point 1 on Figure 1). The monitoring of this effluent enables the QC or QA agent to evaluate the silt concentration of the ponds.

BARTOW SPOIL CONTROL

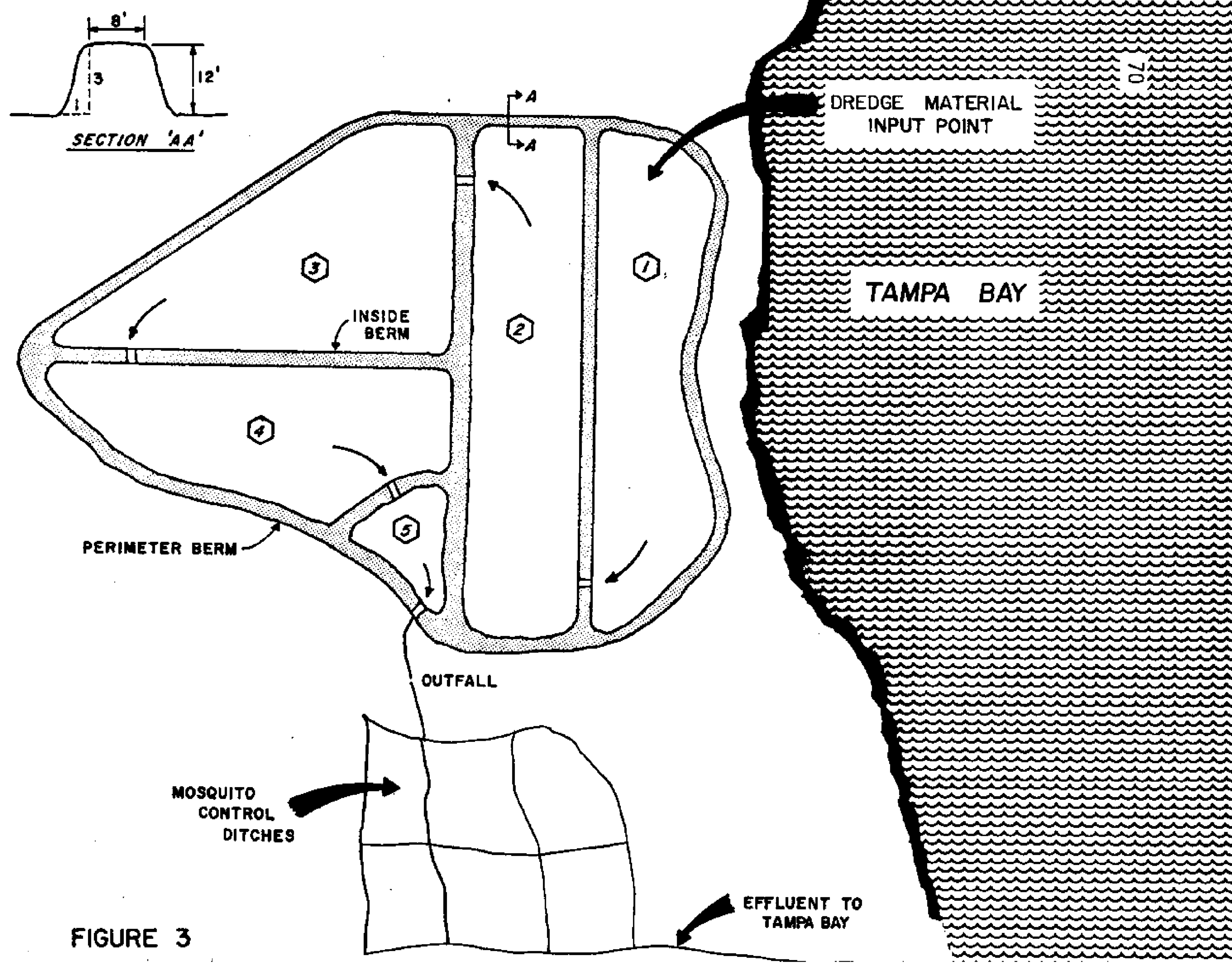


FIGURE 3

b. A turbidity measurement shall be taken of the effluent water at the end of the sluice box of Pond 5 prior to entering the mosquito control ditch. This reading shall be recorded in the QC and QA Water Quality Reports for future pond evaluation by QS agent.

2. Turbidity measurement at the point of effluent of the mosquito control ditch into Tampa Bay.

a. The effluent of the mosquito control ditch empties into Tampa Bay through a bayou. This effluent must be monitored as per the provisos of permits issued.

b. The effluent shall be monitored hourly by the Water Quality Control Agent of the Dredger in order that compliance with the Ch 17-3 Water Quality Standard - Turbidity is verified. This effluent shall be measured at three points as follows:

(1) The point of effluent measurement shall be taken at a point 25 feet downstream from the point of entry into the bayou (this is identified as Point 2 in Figure 1).

(2) An intermediate turbidity measurement shall be taken at the point where the bayou narrows as it enters Tampa Bay. (This is identified as Point 3 in Figure 1). This monitoring point is referred to the compliance point.

(3) A final turbidity measurement shall be taken 300 feet out into Tampa Bay from the narrow point of the bayou. This reading shall be called the natural background turbidity reading in Tampa Bay. (This is identified as Point 4 on Figure 1).

(4) The determination of noncompliance shall be made by subtracting the reading of Point 4 from Point 3.

All the above readings shall be taken at the surface if waters are less than 3 feet deep. Otherwise, the readings shall be taken at the point of mid-depth.

3. Turbidity measurements around the dredging source with a silt restraining curtain in place around the dredger. In compliance with the bid specifications and permit provisos, the following precedure shall be followed.

a. Background readings shall be taken at a point 300 feet outside the silt restraining curtain in the upstream direction of flow in an area unaffected by dredging.

b. A secondary reading shall be taken 300 feet in the downstream area affected by the dredging.

c. A reading shall be taken 25-75 feet outside the silt restraining curtain in the downstream direction.

d. Turbidity levels of all three sampling areas stated above shall be documented in the hourly reports. The turbidity reading level due to dredging, shall be determined by subtracting the reading obtained from sampling point in a. from sampling point in c. above.

All turbidity readings obtained in the above procedures shall be reported in Jackson Standard Candle Units (JTU).

In all the above monitoring points mentioned, the location in which to take the readings shall be subjected to change upon the review with the regulatory agencies by the Management of the Florida Power Corporation.

The Water Quality Surveillance also has the responsibility of overviewing the project and report periodically the status and conditions of the dredging operations.

PREDREDGING CONDITIONS - The upland spoil area preparation was begun in January, 1972, for the construction of the retention mounds forming the spoil area. The Florida Power Corporation plan utilized a spoil area encompassing 47.68 acres which would be divided into five compartments, or ponds, connected by (See Figure 3) a spillway route. The selection of the pond size was made at a 1 to 1.5 ratio of spoil removed to available spoil area volume. The anticipated holding time, or time for the effluent to travel the path to final effluent release point, was in excess of 12 hours. Dredge material input to the spoil area was to pond 1.

The spoil area was constructed south of the Bartow Plant on Company-owned property upland of the mean high water line. A system of existing mosquito control ditches were incorporated into the operation, providing a path from pond #5 to Tampa Bay. The mosquito control ditches also enchanced the holding time before release to the Bay.

The spoil retention mounds were constructed by bulldozer and dragline to an elevation of 15 feet above mean low water with an eight foot top width. The composition of the berms was uncompacted silt and sand. However, the intial structure was sufficient to permit vehicular traffic on the berm top.

Spillways were placed at the outfalls of ponds #1-5. On ponds #1-4 spillways consisted of two (2) four foot diameter pipes laid between the berms separating the ponds. A single spillway consisting of one (1) five foot pipe was made at the outfall of pond #5. To provide a screening action to preclude clogging of the pipes, wire mesh fencing was placed in front of the pipes of pond #1, 2 and 5. The spillway at the outfall of pond #5 was directed into the mosquito control ditches by a wooden sluice, later replaced with a half section of corregated pipe.

To control the volume of liquid effluent released, a weir arrangement was constructed. By the addition of wooden boards across each spillway-pipe opening, the flow of the effluent from each pond was effectively controlled.

To minimize additional suspension of dredge material by high velocity dredge material input to pond #1, a spray system was implemented. The piping, a 24-inch diameter pipe, from the dredge was laid to pond 1. The terminal pipe into pond 1 was welded at the end to provide an upward turn. Dredge material and liquid effluent were thus sprayed laterally into pond #1, resembling a large fountain.

The completion of all upland pre-dredging construction activities was made in April, 1972.

<u>PREDREDGING SURVEILLANCE</u> - In order that existing environmental conditions were known, a company biologist and surveillance engineer surveyed the environs in and around the spoil pond area prior to

initial operations. A report and photo assay on the area existing natural state was prepared. By comparison with a post operational survey, an assessment could then be made to determine if any adverse effects upon the site environment were caused by the dredging operation.

ON-SITE PROJECT CONTROL - Initially the presence of the on-site Florida Power project supervisor was limited to an 8 hour day. After the first two weeks of operation, on-site project supervision was provided for 24 hours a day, seven days a week. The action was necessary to assure FPC with positive control of the dredging contractor, QS and QA. Tampa Bay Engineering was hired to act for this on-site supervision.

DREDGING CONDITIONS - On May 15, 8 A.M., the dredging operation commenced. Hendry Corp. selected the initial dredge area to be the tanker and barge slip area. This area was selected to provide a least risk test of the effectiveness of the silt retention curtain. The initial plan by Hendry specified placement of the curtain across the mouth of the tanker slip, enabling the dredge to excavate the area interior to the current flow generated by the plant cooling water intake structure. (See Point #5 in Figure 1).

On May 17, 1972, at 2000 hours, sufficient water and bottom sediment were pumped into the spoil pond area to render an outflow of water from the weir of pond 5.

Commencing with this time and day, the water quality program governing the control of weir 5 was placed into operation on a 24 hour basis. As shown on Figure 1, the monitoring points are shown circled 1 to 4. Point #4 was selected to be the ambient background control point in Tampa Bay and Point #3, the limiting point of compliance. If #3 was greater than 50 JTU above the #4 value, the operation was terminated. During the course of the dredging operation, the ambient background turbidity levels averaged 25 JTU. The ambient rarely exceeded 25 JTU (minimum detectable) value of the Standard Jackson Candle Turbidimeter. (Note: The Jackson Turbidimeter was chosen as the turbidity monitoring instrument due to its acceptability by the Florida Department of Pollution Control). Monitoring results were considered valid as of June 1, 1972, when equilibrium was achieved.

The first month of dredging had been anticipated to be a period of adjustment and refinement in the dredging program. This "debugging" period was expected to challenge the water quality program and the mechanism for termination of the dredging operation due to excessive (greater than 50 JTU above ambient) turbidity releases. During the entire dredging operation the order to terminate a release to the environment or stop dredging was issued 55 times.

Problems during the first two weeks of the actual dredging operation resulted from operational procedure ambiguities arising from interpretation of the dredging specifications. Specifically, the authority for termination of dredging or effluent to the environment was not being responded to for assurance of compliance. The resolution of this problem between the company and the Contractor was to provide a written order of termination to be delivered from the company supervisor to the dredge captain. Compliance with the written order was to initiate at the moment of receipt.

CONTINUANCE OF THE DREDGING TOWARD COMPLETION - The history of the entire project was relatively uniform with two significant exceptions: Hurricane Agnes, and the "end-of-life" situation. Hurricane Agnes reached the Gulf Coast of Florida on June 18, 1972, with heavy rains and tides 3 to 5 feet above mean high water. The dredging operation was suspended on June 16. One June 17, the pond #5 weir was opened to prevent rising water levels from posing a significant threat to the spoil area berm integrity. Dredging resumed on June 26. Although no significant releases were made during this period, interior berm erosion had occurred. Erosion to the perimeter berms was minimal due to restoration actions which had been completed approximately ten (10) days prior to Hurricane Agnes.

During the latter half of July, increased terminations restricted the available dredging time. Investigations as to the causes of the increased amounts of silt release revealed decreasing effectiveness of the spoil ponds due to the filling of the ponds at a greater rate than expected. Further analysis revealed a density change in the removed material from the dense sand-like Bay bottom to a loose "clam-chowder" like soup in the spoil pond. Utilization of floculants by the Contractor were of limited success in reducing the mixture to less than a mud-like ooze. Analysis provided a general "expansion factor" of 1.6 to 1 for a unit volume of removed material.

POND MANAGEMENT DURING OPERATION - The initial segmented pond concept was developed so that silt-laden water could be controlled by adjusting water levels in each pond. As the ponds became filled with silt, additional boards were installed in ponds #1-5 weirs to regulate ratio of water to silt. It was found that at least two feet of water was needed to provide the necessary settling time in the five sections of spoil pond. This water level also prevented channelization of silt laden water.

As the dredging project proceeded, silt levels in the pond had risen to a point of insufficient volume in the pond to maintain a two foot level of water above the silt. Consequently, channelization of the silt laden water occured. This, in turn, reduced the settling time in the ponds to allow silt and sediment to settle out.

The mosquito control ditches provided an area of potential additional settling time prior to release to Tampa Bay. Thus, within this complex of ditches, a series of silt restraining curtains were installed to assist in silt control. This proved to be an effective control addition which allowed project completion in compliance fashion.

POST DREDGING CONDITIONS - On August 30, 1972, at 2:30 P.M., the dredging project was completed. Post-operative surveillance and documentation were initiated to provide comparison to baseline pre-operative studies. In addition, post-operative surveillance provided design consideration for mosquito control ditch restoration and spoil area stabilization.

In retrospect, the Bartow Water Quality Program was a definite environmental success. The development of a prompt and responsive water quality program was facilitated by the lessons learned in the first two weeks of operation. Responsiveness by the Contractor was developed by the complete commitment of the company to adhere to the provisions of the applicable permits and water quality standards. A prime company goal is to minimize environmental impact of its operations.

EVALUATION OF THE PROJECT AND ITS RESULTS - Several areas of the project presented unique problems and precipitated actions and changes which were unforseeable prior to actual operation. Of these, the following is a list of the predominant areas of concern: Spoil Area Sizing and Deterioration, Silt Curtain Effectiveness, Quality Control, Quality Assurance and Quality Surveillance time input, and On-Site Supervision.

SPOIL AREA SIZING AND EFFICIENCY - The Generation Environmental and Regulatory Affairs (GERA) Department of Florida Power Corporation was assigned the responsibility to develop a computer program capable of providing pertinent information needed to develop relationships concerning some of the problem areas listed above.[1] By utilizing the General Electric Mark II Computer System, analysis of the turbidity data furnished by Q.C. and Q.A. was initiated in the following areas of concern: Spoil Pond Efficiency and Operational Efficiency.

[1] Computer program for dredging analysis was developed and run by Bert C. Simpson, Nuclear Affairs, GE&RA.

The efficiency of the Spoil ponds was calculated because of its importance in evaluating the overall effect of the spoil ponds on the dredging operation. The "Spoil Pond Efficiency" was computed as follows:

$$\text{Spoil Pond Efficiency (\%)} = \left[\frac{\text{Spoil Pond Volume (Cubic Yards)}}{\text{(Expansion Factor) (Volume of Spoil Removed)}}\right] 100\%$$

The "Operational Efficiency" is directly dependent upon the size of the ponds, the settling time and the turbidity of the effluent being emitted from ponds. The "Operational Efficiency" was computed by averaging the information in Figure 4 as follows:

$$\text{Operational Efficiency (\%)} = \left[\text{Time Average } \left(\frac{\text{Hours Dredge in Operation}}{\text{Unit Time}}\right) \Big/ \text{Total Project Time}\right] 100\%$$

The Spoil Pond Efficiency was calculated to be 92.8 percent, which represent approximately 7.2 percent of the dredge material was returned to the environment. The Operational Efficiency was determined from Figure 4 to be 63 percent. Although only 7.2 percent of the silt was returned to the environment, this value can probably be reduced by increasing the Operational Efficiency. The low value of Operating Efficiency is a result of inadequate pond sizing and the long settling periods required to reduce the turbidity of the effluent to an allowable level before the effluent to the environment.

The amount of dredging time per day was reduced during the latter half of the project due to the filling of the ponds with silt at a

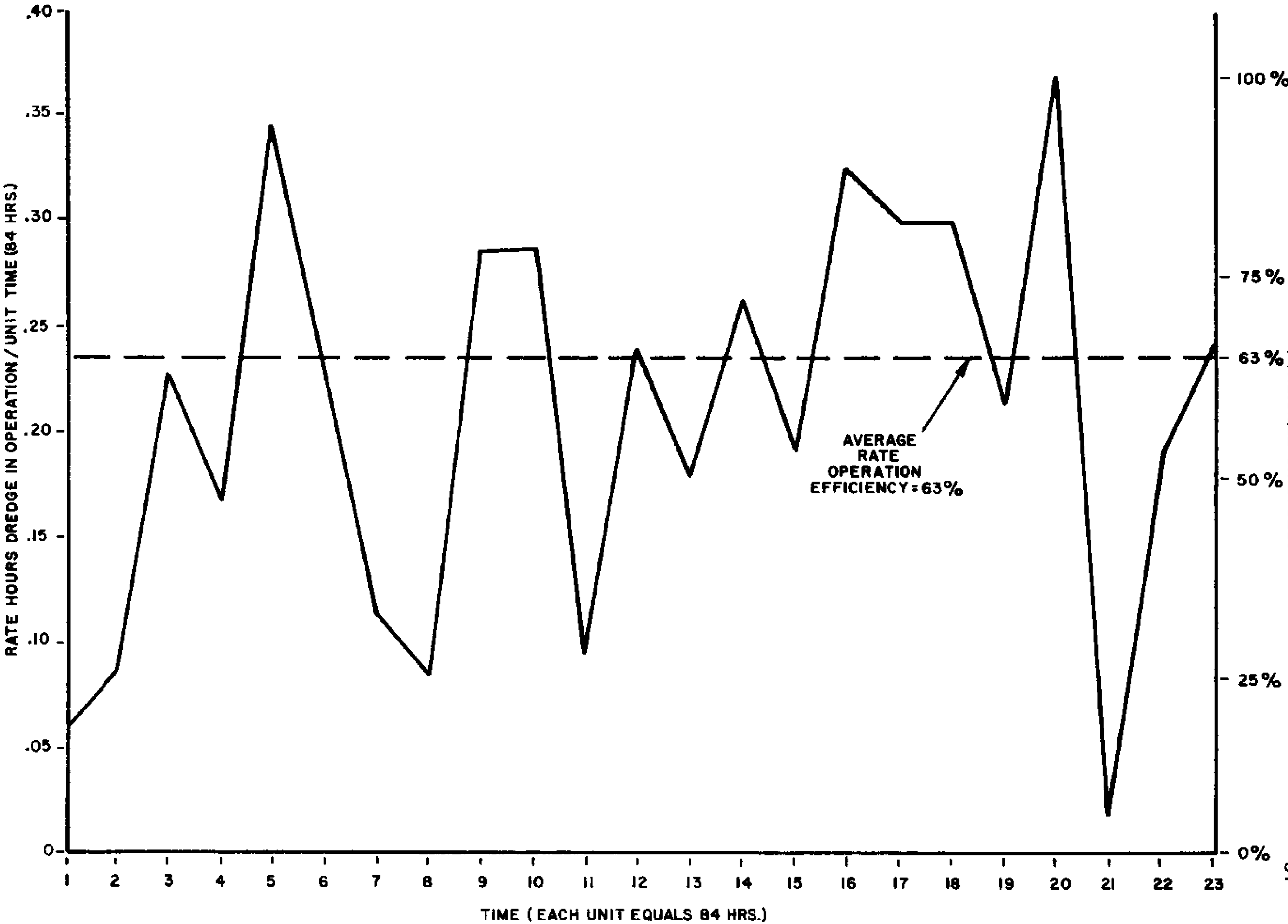


FIGURE 4 - EFFICIENCY OF OPERATION - RATE VS TIME

greater rate than expected, which in turn decreased the allowed settling time of the effluent in the ponds. Reduction in the allowed settling time resulted in larger turbidity readings being recorded by the Water Quality Program at Control Point 3. The poor Operating Efficiency (63%) was a direct result of the reduction in the allowed dredging time. The increase in the turbidity readings at Control Point 3 represents the inefficiency of the spoil ponds which was indirectly caused by the low Operating Efficiency.

Although a direct mathematical relationship was not developed between the Operation Efficiency and Spoil Pond Efficiency, it was determined that by increasing the Operating Efficiency through adequate pond sizing, an increase in the spoil ponds can be accomplished by utilizing a 1.0 to 2.0 ratio, spoil removed to available spoil area volume. This increase in ratio over the 1 to 1.5 ratio used in the Bartow Project is required to allow for the undesirable effects of pond fillage and for the volume of water contained within the spoil ponds during the settling period. Increased pond sizing will permit a faster, more efficient, dredging operation and improve the control of the silt being returned to the environment.

During the dredging operation, deteriorization of the berms of the ponds occured. On several different occasions, dredging operations were ordered ceased and repairs ordered to the pond berms to render the ponds safe to hold the silt laden water.

The existing ponds berms were constructed by a dragline and were not compacted or protected from erosion from rainfall or from the wave action of water in the ponds.

During each ordered shutdown the contractor was ordered to render repairs to the berms of the ponds.

During the latter part of the dredging operation, silt curtains were placed across pond 3 and pond 5 to aid in settling out the silt in the water.

In evaluating the spoil pond efficiency, several problems areas were found to be predominant in this project. It was observed that the overall pond volume was not sufficient to allow the material to be dredged and still have sufficient room to settle out silted water.

<u>SILT CURTAIN EVALUATION</u> - During the entire project, the proviso of using a silt curtain around the dredge cutting head was complied with.

The effectiveness of this silt curtain to retain silt was not fully established for use around the dredge. During the project the silt curtain was used in water 30 or more feet deep even though the curtain only extended 5 feet below the surface.

During the entire project, silt levels within the silt curtain did not exceed 50 J.T.U. above those levels outside the curtain. Thus, the value of the silt retention curtain was not demonstrated at the point of the dredging operation. The hydraulic dredge provided sufficient suction to prevent release of significant silt and turbidity. Although the curtains were of very limited value around the dredge, the curtains were utilized with success in the mosquito control ditches to reduce releases to Tampa Bay.

WATER QUALITY CONTROL EVALUATION - From the initiation of the dredging project on May 15, 1972, and prior to the subsequent completion on August 30, 1972, a period of 108 days passed. During this time the water quality program collected 3,000 readings out of a total possible 10,368 hourly readings for a 29% efficiency of data.

This low efficiency was do to time lost by boats not operating or low tides rendering inaccessibility to the monitoring area of points 2 to 4.

The cost of the water quality program was 7.6% of the total project cost.

In retrospect, the major problems encountered during this project are inconsistency of readings, and the compliance with water quality control specifications.

WATER QUALITY ASSURANCE EVALUATION - The water quality assurance program was initially set up to sample 10% of the data sampled by the water quality control agent and was responsible to assure FPC of compliance of the WQC to the dredging specifications.

This water quality assurance program represented 3.6% of the total project cost.

The number of data points received was 1534 which represents 15% of 10,368 data points which were to be collected by Q.C.

In retrospect, many operating problems which faced QA primarily concerned physically obtaining samples. Low tides prevented several samples from being taken at the southern compliance point.

Night navigation also was a problem but this was solved by placing a standard road construction marker at the entrance of the bayou to aid night navigation.

Analysis of the data collected QA and QC resulted in a standard deviation of ±122 JTU. This wide range indicates that some of the data taken by QA or QC did not relate to actual conditions at the site.

WATER QUALITY SURVEILLANCE EVALUATION - The initial water quality surveillance program provided for periodic surveillance of the construction project. Initially this over taxed the surveillance engineer. Thus to alleviate this problem an on-site construction supervisor was provided on a 24 hour per day basis.

This action, in effect enabled the Q.S. to provide periodic surveillance activity. The on site Construction Supervision was provided by utilizing a consulting engineering firm, Tampa Bay Engineering (TBE). However, the effectiveness of TBE as a 24 hour on-site supervisor revealed this method as a significant improvement over the initial on-call system.

The cost of providing the surveillance program and the on-site supervision were 1.0% and 3.6% of the total project cost.

The GERA Computer Analysis was utilized to establish relationships used to determine the success of the Bartow Water Quality Program to control the turbidity of the effluent released below 75 J.T.U. (50 J.T.U. greater than the 25 J.T.U. ambient turbidity). Based on the turbidity data recorded by Q.A., it was calculated that only 7% of the readings exceeded the control limit of 75 J.T.U. Analysis of the Q.C. turbidity data revealed that 7.5% of the readings exceeded 75 J.T.U. The low frequency of occurance of the non-compliance situations is directly dependent on the capability of the spoil ponds and their (spoil ponds) ability to improve the quality of the returning water. The result is protection of the area environment.

The Water Quality Program of the Bartow Dredging Project provided valuable, real controls for protection of environmental quality. During the entire dredging operation there were no objections or reports filed by any regulatory agency. In addition, based upon post-operative surveillance reports, there will be no adverse long term environmental effects from the operation.

By utilizing the rigid controls over the project, over 470,000 cubic yards of dredge material were prevented from spreading over the marine areas of Tampa Bay. Although the upland spoil area is committed to a limited productivity role, the grass beds and fishing grounds around the Bartow site have been protected.

<u>OVERALL CONCLUSIONS AND RECOMMENDATIONS</u> - As previously stated, the Bartow Maintenance Dredging project Water Quality Program was succesful. Much valuable experience was gained as to problems which had occured and the solutions that were founded. In this view, the following <u>recommendations</u> are made to improve the Water Quality Program.

1. Strengthen the water quality control program to include penalties for non-compliance of the dredger.

2. Eliminate the use of a silt curtain in waters greater than 10 feet.

3. Do not use old mosquito control ditches to convey effluents from spoil ponds to the main body of water.

4. Develop a strong WQA and WQS program with a sampling analysis performed weekly to verify sampling techniques and obtain standard deviation.

5. Develop a spoil pond with compartments to handle a volume of 2 times the volume being dredged to allow sufficient settling time to remove silt before returning the water back to the bay or river.

6. Install weirs between ponds with open pipes so that maintenance and control of water can be maintained at all times.

At present, the Florida Power Corporation Anclote Dredging Project is before the U.S. Army Corps of Engineers for permitting. The information and results of working experience gained from the Bartow Dredging Project have been incorporated in the Anclote Project. Increased spoil pond sizing, revised operative and reporting procedures specified in the Anclote Dredging Specification are the direct result of the Bartow experience.

The posture exhibited by Florida Power Corporation in its environmental commitment has been to attempt to meet the high standards for water quality. In its 1972 Corporate Objectives, the management of Florida Power reaffirmed this pledge "Conduct the business of today and the plans for the future for the production of reliable, adequate and economical electric service in a manner that effectively balances minimum environmental impact with the overal public interest."

PRESENT STATUS OF SPOIL DISPOSAL AREAS ALONG THE HOUSTON SHIP CHANNEL

By

Jack Farmer
Vice President
Atlantic, Gulf & Pacific Co.

My subject today concerns the present status of Spoil Disposal areas along the Houston Ship Channel from Morgan's Point to, and including, the Turning Basin.

The map which covers this area shows existing spoil areas in red, additional areas in brown and suggested additional areas in green. The green areas have been previously used and easements for use again could probably be obtained for the deposit of virgin material, material that would enhance the value of the land. The capacity of the available spoil areas for this reach of channel, approximately 25 miles, is 17,100,000 cubic yards. The ultimate or lifetime capacity is 62,100,000 cubic yards. In the ten year period from 1962 through July 1972, maintenance dredging contracts totaling approximately 14,000,000 cubic yards were done, and during the same period contracts for channel improvements, deepening and widening, totaled approximately 25,000,000 cubic yards. Total yardage for the past ten year period, for maintenance and improvements, was 39,000,000 cubic yards.

Using the shoaling rates for the various increments of the channel that applied in the past ten years, we estimate that in the ten years ahead of us contracts for about 23,500,000 cubic yards of maintenance dredging will be necessary. If the shoaling rate remains constant, the ultimate capacity of the existing spoil areas will be reached in approximately 26.4 years. This is figuring maintenance of existing channel width and depth, not any improvements, which are badly needed now. If the Port of Houston is to maintain it's ranking among U.S. Ports, the channel will have to be widened and deepened to be able to safely accommodate the larger ships now being built.

It is obvious that plans for additional spoil capacity for the Houston Ship Channel have to be made. Since land suitable for this purpose is practically unobtainable, the next alternative seems to be a major program for the rehabilitation of the existing areas. The elevation of the enclosure dikes in many of the areas has reached the maximum possible, the only solution left is to remove as much of the deposited material as possible in order to regain the needed capacity for dredge spoils.

Some experimentation has been done in the use of flocculants to accelerate the settlement of the fines pumped on most maintenance jobs. If these prove to be economically feasible, it is possible that life and capacity of some of the marginal areas can be increased. I do not know what the final solution to this problem will be - I do feel that we will find the answers, as these problems are much easier to solve than finding a transport system for liquid and bulk cargo that is cheaper than waterbourne.

Thank you! It is always a pleasure to participate in these programs, and I want to express my appreciation to Dr. Basco for inviting me.

OFFSHORE DREDGING PROBLEMS

By

Jim Bean
President
C.F. Bean, Inc.

Dr. Basco has asked me to share with you some of my thoughts concerning the problems of offshore dredging. I would like to thank him for this opportunity.

For years our industry has attacked and solved many of the problems of conventional cutter head dredging as it relates to projects located in protected waters. We face today, however, a challenge which we must accept. Our dredging market is expanding offshore.

We can compare this to the situation the oil industry confronted some 20-odd years ago. The potential for offshore oil grew to the point that they had to take action. Their first attempts centered around the use of their existing inshore equipment. They soon realized that new equipment and methods had to be developed. They proceeded forward and started a technological evolution of grand and prosperous proportions.

It is very possible that the Drillers' market was much more attractive than that which we dredgers are facing today. However, I feel that the market is certainly available and will grow as rapidly as we develop our capability to handle this challenge. It is obvious that the designers of offshore projects have given us a great opportunity. Their imagineering has conceived offshore dredging projects, the magnitude of which we have never seen.

We are constantly hearing of proposed offshore terminals to accommodate the present-day supertankers with drafts up to 90 feet. Large quantities of dredging will be required for these ports, either as excavations or fills for storage islands or breakwaters.

Offshore airports are being planned in many cities around the world. The quantities of dredging required for just one project such as this could conceivably absorb all of the present annual dredging capability in this country.

The quantity of beach nourishment presently required is hard to imagine.

The magnitude of the offshore market is beginning to come into focus. We must now decide whether or not we will accept this opportunity.

During the past several years, our company has had several experiences in offshore cutterhead dredging. I would like to share with you the general conclusions we reached.

It is obvious that the dredging function is unchanged. We still must transport material from its original state to a distant location. The hydraulic principles are the same. It is only the environment in which we must work that has changed. We must learn to operate in rough water.

The successful offshore dredge operator will have to solve two major problems. First, he must stabilize the dredging platform and, secondly, he must maintain the integrity of the pipeline to the disposal area.

Let us consider the first question. The dredge hull moves about by the forces of the waves. This motion causes the cutter to break its cutting rhythm resulting in lost production. Additionally, as the hull thrusts forward, the cutter is forced into the ground causing extreme shock loading in the ladder and trunnions. Hull motion is compounded by the fact that the dredge operates on cables rather than on spuds. The slack in the wires allows more dredge motion, but also reduces the shock loading in the hull which would be expected if one were operating on spuds. The result is a compromise of production for lack of sufficient hull structure.

We can look to the oil industry for possible solutions to this problem. The use of hulls which reduce reaction to the sea is seen as a possibility. We have all seen pictures of the large, modern semi-submersible drill vessels which have their primary flotation well below the wave action with only a slight water-plane area.

The use of extremely larger hulls can be considered. The greater the mass of the hull, the lesser the reaction to waves. Mooring the larger hulls creates new problems of anchoring which must be considered.

Other considerations are designing a dredging platform which is attached directly to the ocean floor. The machinery deck is well above the surface, with the waves acting only on the legs. These forces are then transmitted directly to the bottom. Mobility becomes the real problem with this solution.

The true adventurer may even consider the use of computer operated thruster systems.

The second major problem, that of the attached pipeline, is going to require real imagination. I feel that this is the "Meat" of the challenge. Attention must be given to the fact that the stresses in this pipeline as a result of the wave action are tremendous. The structural integrity of the pipeline must be maintained. Consideration must be given to the end connections as the tensile load becomes very significant. We experienced failures at both the hull connection and the submerged line connection of the floating pipeline. These failures were due to the tensile loads mentioned previously. These loads are a result of the wave action against the flotation tanks, as well as currents caused by tidal action.

Flexibility is designed into the floating line for two reasons. First, it allows the hull to move about and, secondly, it reduces the stress build-up which would be experienced in a stiff pipe. Progress is being made in the development of a floating rubber hose; however, I have no experience in its use.

There are several other dredge-oriented problems which we experienced that I shall now touch on briefly. As previously mentioned, the dredge is moored to anchors. These anchors were a source of concern. Moving them in heavy seas is very difficult. Additionally, once they have been placed on the bottom, securing a "hold" with them was not simple because of the uneven bottom consisting of thin layers of sand with coral outcroppings.

This irregular bottom condition caused many problems with the submerged pipeline. This line was welded steel which extended from the beach to the point at which the floating pipeline was attached.

The outcroppings of rock on many occasions caused excessive lengths of the pipe to become unsupported resulting in buckling failures. The line would then have to be removed, repaired, and re-installed. Generally, supports had to be placed under the pipe by divers before pumping started. Installation of this pipeline could only take place during periods of calm seas, which on occasion resulted in quite lengthy delays of the dredging operation.

Many problems were encountered which do not relate directly to the pumping operation. Weather forecasting was not always reliable and, as a result, we sometimes departed to safe harbor prematurely. Conversely, on at least one occation, we failed to depart in time. We found ourselves unable to secure a towing vessel of sufficient power in time and were forced to weather a threatening hurricane at the dredging site. During this period of severe sea conditions, the ladder was tossed about to such an extent that the trunnions were torn loose in the hull. This damage occurred while the ladder was lifted to a position just below the surface and was not in contact with the bottom. I mention this to exemplify the magnitude of the forces that exist. As a matter of fact, we are still experiencing leakage as a result of this incident.

I would now like to mention some of the problems which we might classify as project oriented. The conventional operation is usually blessed with sufficient borrow material to maintain full production at all times. This was seldom the case on the beach nourishment projects. Generally, the borrow material was found in troughs between parallel reefs. The thickness of these layers varied but seldom exceeded 12 - 15 feet in the center of the pit and tapered to nothing at the sides. As a result of the shallow layers, we often encountered the coral with the cutter. These shallow borrow areas caused us to move the dredge often resulting in frequent movement of anchors and submerged pipelines.

We encountered several unique problems on the beach. The fill operation was hampered many times by the presence of spectators. Most dredging projects occur in isolated areas and are seldom observed by the general public. The beach restoration work offers the people a rare and interesting site. While it may be beneficial to show the taxpayers how their money is being spent, the crowds of onlookers became quite hazardous. This situation was compounded by the fact that the dredge was mining many attractive sea shells, which were gathered by collectors as they were discharged onto the beach. It was not at all unsual to have 200 people scattered around the pipeline well into the night. The situation was very hazardous, but attempts to have them removed were futile.

The close proximity to the residential community necessitated that noise be held to a minimum.

The measurement for payment presented a little difficulty since the wave action affected the outer slope as it was being pumped. This usually required an understanding between the contractor and the owner.

All of the problems I've mentioned have solutions. It is my opinion that the solutions lie in three general areas; research, public relations, and money. It is obvious that much research is required to develop the equipment and techniques necessary to perform within the economic parameters of the projects.

There is a great need to coordinate our efforts with the project planners. We as an industry cannot afford the investment required unless we are assured that the projects are large enough to provide us a return. All too often we are asked to bid on very small projects where we are forced to use conventional equipment which necessitates higher unit prices. This situation will not exist on the larger projects mentioned earlier.

Securing the investment dollars is certainly paramount in the solution process. Unfortunately, our industry lacks the glamour of certain others in the investment world.

Concluding, I would like to say that we, as an industry, have little alternative but to accept the challenge. Our future depends upon our ability to operate successfully in this hazardous environment.

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