7.4 Dredging Improvement

7.4.1 Improvement Measures

Since dredging along Orinoco started in 1956, dredging is undertaken by the trailing suction method and dredged spoils are disposed by the side casting method immediately adjacent to the channel (see Fig. 7-4-1). It is the first and only method in the world wherein dredging is conducted as mentioned above. As a result of disposing dredged materials adjacent to the channel, most of the materials return back.

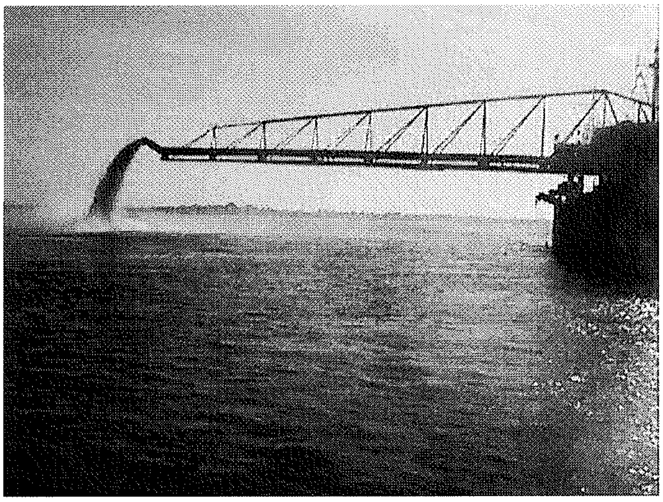
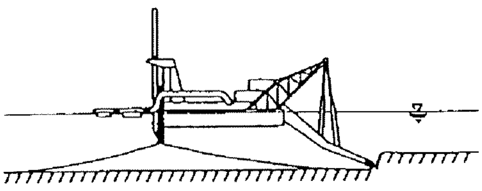
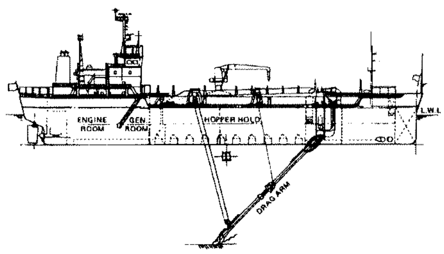


Fig. 7-4-1 Orinoco Dredge

The standard method of dredging is the cutter suction dredge or Hopper trailing suction dredge (see Fig. 7-4-2). The reasons why the standard method is not adopted, are discussed hereunder.



Cutter Suction Dredge



Trailing Suction Hopper Dredge

Fig. 7-4-2 Standard Method of Dredging

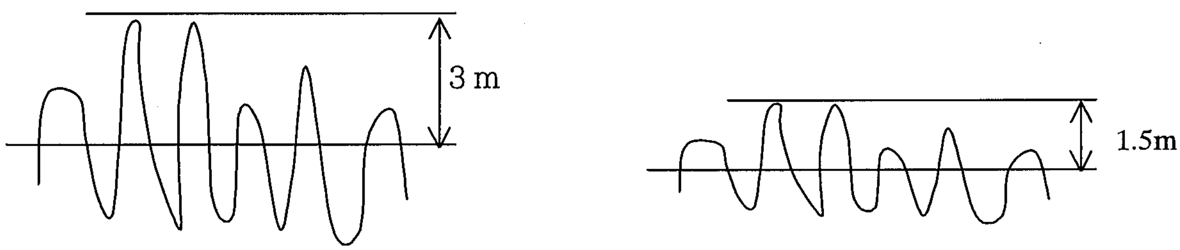
Dredging along a river by the Cutter Suction Dredge will cause obstruction to navigation. Moreover, the cutter is easily subject to the influence of wind and wave actions making dredging quite difficult.

In the case of the trailing suction hopper, dredged spoils are loaded onto its hopper and brought outside the channel to designated disposal areas. The channel along Boca Grande is about 80 kilometers long and the average distance of the disposal site is about 40 kilometers away and would take 8 hours, round trip. This method is therefore inefficient and costly.

In view of the foregoing, the existing method appears to be appropriate provided that the necessary improvements as described hereafter are made.

(1) Equipment for Orinoco and Guayana Dredges to Record the Dredging Activities.

According to the bathymetrical drawings of INC on April and September 1997, the uneven dredged bottom of the channel is about 3 m as shown in the Fig. 7-4-3 (a). The navigable depth of the channel in this case should be based on the highest spot of the unevenly dredged bottom. In order to attain an average depth of 13.2 m which is the design depth, the existing depth of 10.2 m should be dredged further by 3 m. In Japan, the maintenance dredging is being undertaken based on the precise locations of extremely uneven dredged bottom thus making it possible to reduce the height of the uneven bottom to 1.5 m.



(a) Existing Condition **(b) With Positioning System**

Fig. 7-4-3 Cross Section of Dredged Bottom

As can be seen in the Fig. 7-4-3, the uneven dredged bottom of 3 m in height can be reduced to 1.5 m by introduction of precision location system. By this means the channel depth is deepened by 1.5 m. As a result, it is expected that depth of the channel will be increased from 10 m to 11.5 m. Therefore, it would be possible to navigate safely Panamax size vessels with a load of 52,500 tons of cargoes that require 11m draft, instead of 43,500 tons of cargoes with 9.5m draft as shown in Fig. 7-4-4.

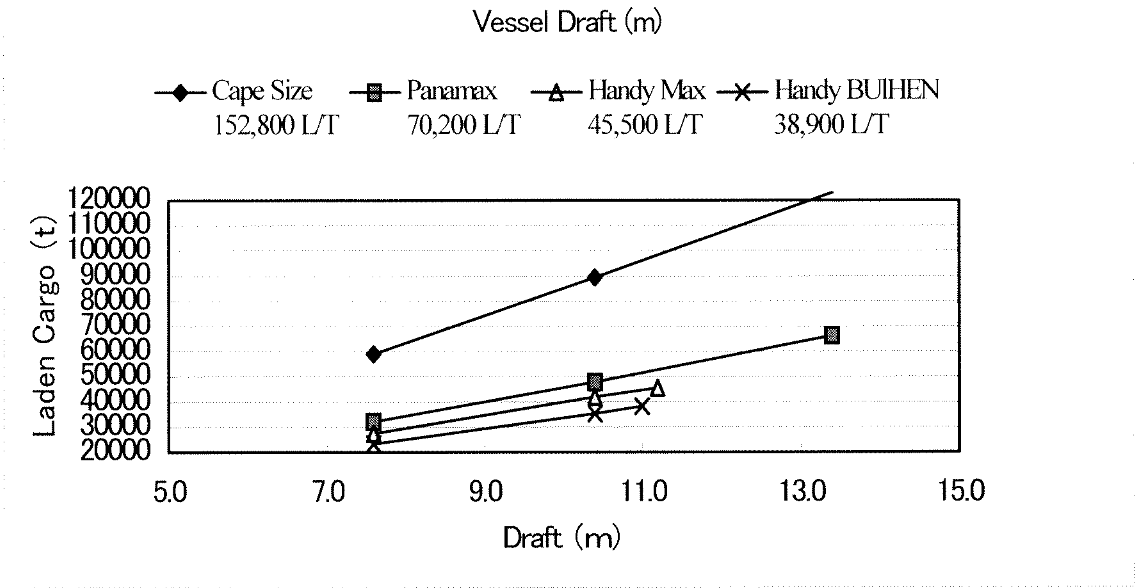
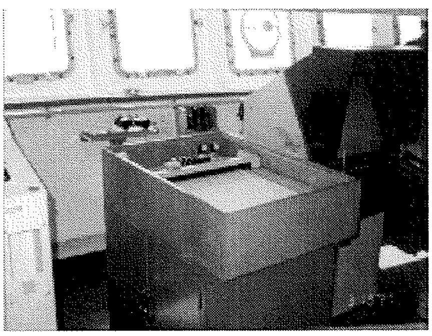


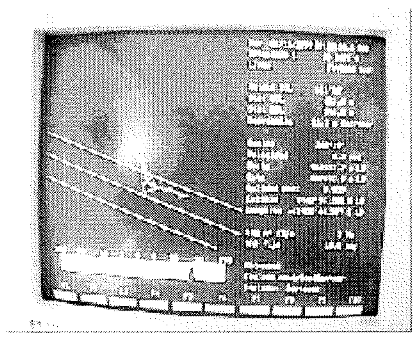
Fig. 7-4-4 Relationship between Laden Cargo and Draft for Vessels

The location of the drag head will be determined by the coordinate of GPS, gyroscope and direction of the dredge. Presently, the channel is provided with transmittal stations from which data are received through satellite to identify the location of the dredge. The dredge are also provided with transmission and receiving equipment to receive and transmit data through the transmitted stations.

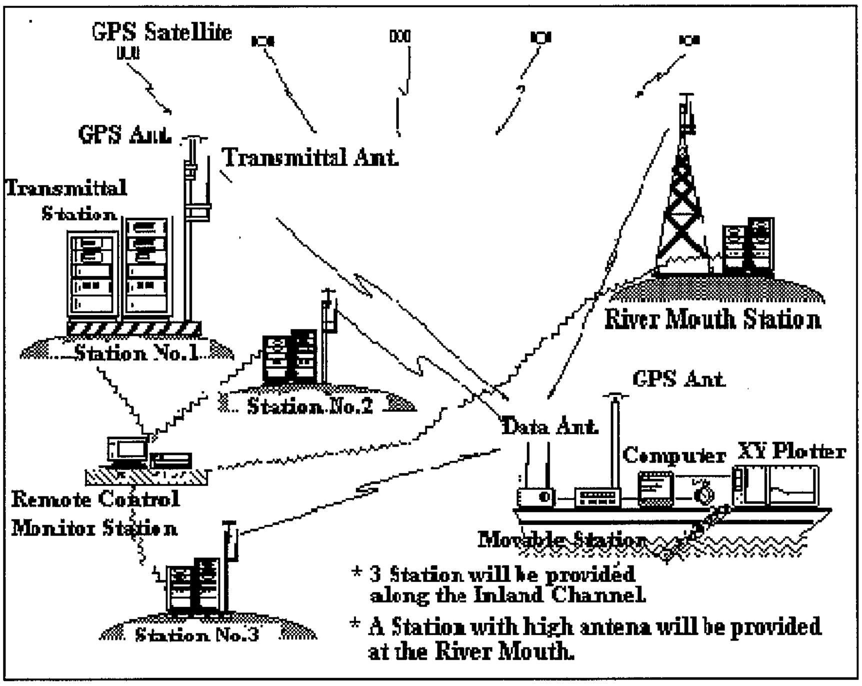
In order to complete the system, the dredge should be provided with track display, computer, drag head positioning system integrated with the direction of the gyro display software to identify the depth and precise locations of high spots as shown in Fig. 7-4-5.



Plotter



Display



Dredge provided with GPS Antenna and transmitter Antenna

Fig 7-4-5 System Drawings with GPS

(2) Disposal of Dredged Materials by Bottom Dumping Barge

Through the side casting pipe of 86m - 114m length which is shorter than the navigation channel width of 100m - 120m in Rio Grande, the dredged soil is discharged immediately adjacent to the dredging routes in the channel. Therefore, the considerable return of disposed material into the channel is unavoidable. Especially, in Boca Grande, Rio Orinoco Dredge that is suitable in calm condition, is operated under the wind-whipped weather condition. The side casting pipe of the dredge can not be fully opened as the stability of the dredge under the reduced wind pressure should be maintained, and return ratio would increase. In the previous surveys, the return ratio in the outer channel is reported as 75% though it is only 25% for inland channel.

In order to eliminate a possible return of disposed material into the channel by the present method of side casting, the use of dumping barge is recommended for dredged materials disposal outside of the channel.

Two conveyors comprising of a barge of 3,500 cubic meter capacity and a 4,000PS pusher boat will be needed. Dredged materials are loaded onto the dumping barge and transported to the nearest suitable site outside the channel for disposal. Since the depths along the outside of the channel at Boca Grande is in a range of 5 to 6 m, fully loaded barge of only 4 m draft can safely navigate along these areas.

By introducing the dumping barge system, it is expected to increase the dredging efficiency up to 80% - 100% by eliminating the return of soil, although the time efficiency may decrease up to 50% - 80% than the present side casting method. Based on the above improvement, the overall efficiency would be expected to increase at least by 1.6 times and, by simple calculation, the average dredging cost would decrease from 2.6 \$ per m^3 to about 1.63 \$ per m^3 as shown in Table 7.4.1.

Table 7.4.1 Dredging Efficiency & Average Dredging Cost

	Present Method Disposal of Dredged Soil Through Side Casting Pipe	Improved Method Disposal of Dredged Soil by Bottom Dumping Barge
Dredging Volume in Boca Grande	10,000,000m^3	10,000,000m^3
Dredging Efficiency	25 % Return Ratio = 75 %	80% − 100% Return Ratio = 20 − 0 %
Time Efficiency	100 %	50 % − 80% Loss Time = 5-20 minuets/Trip
Overall Efficiency	25 %	40 %
Ratio of Efficiency	1	1.6 times
Average Dredging Cost Estimated	US\$ 2.60	US\$ 1.63

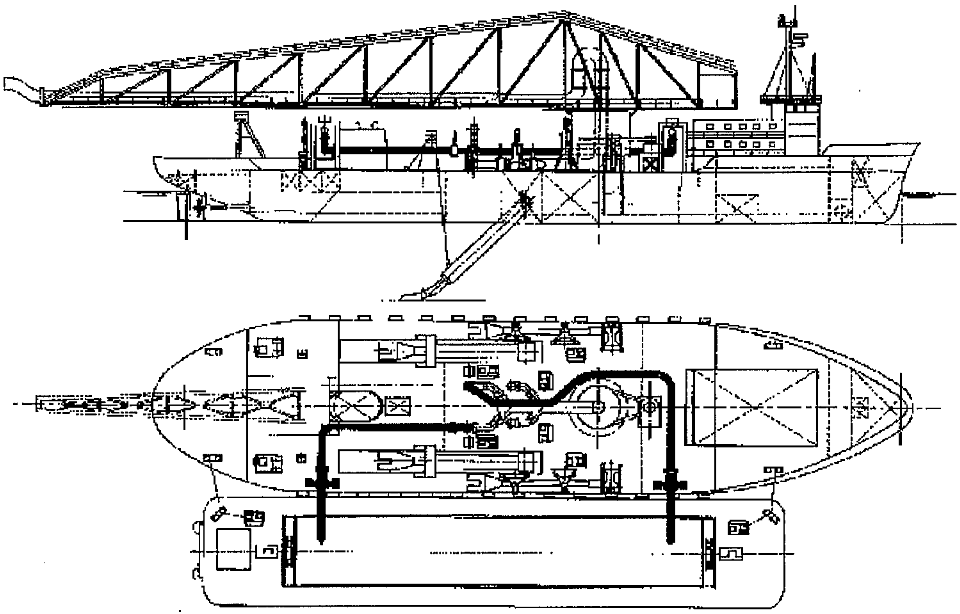


Fig. 7-4-6 Loading Operator (e.g. Orinoco Dredge)

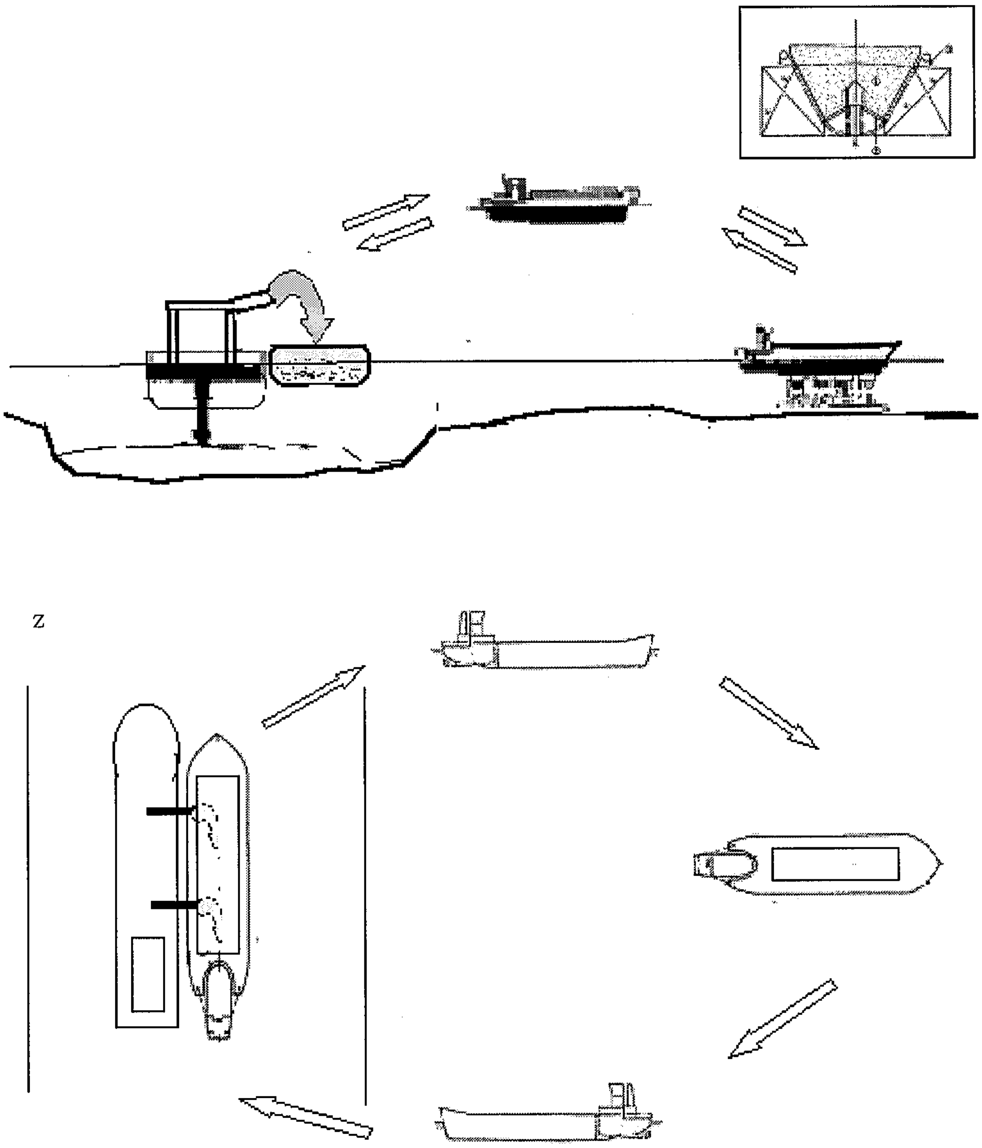


Fig. 7-4-7 System of Dredging Work by Bottom Dumping Barge

Calculated hereunder is the required time and disposal of dredged spoils using the bottom dumping barge method.

Loading Inside the Channel

Berthing Alongside: 5-20 min.
Loading time : 20 min.
Total 25-40 min.

15 hrs./day/(25 to 40) = 22 to 36 times
(22 to 36) x 1750 m3 = 38500 to 63000 m^3/ s
(from channel to Disposal Site)
38,500 to 63,000 m^3/day x 300 days =
11,550,000 to 18,900,000 m^3/year

Disposal Outside of the Channel

Dredging of Fluff at Boca Grande
Barge capacity: 3,500 m^3
Solid content at 50% void: 1750 m^3

Disposal will take about 25 min.
from Channel to disposal areas.
5 miles x 1.8 = 9 km (RT)
one way = 4.5 km

7.4.2 Other Improvement Measures

In order to enhance the dredging activities, it is suggested to examine the following improvements either by performing laboratory experiments, calculations and/or using the experiences in the dredging operation.

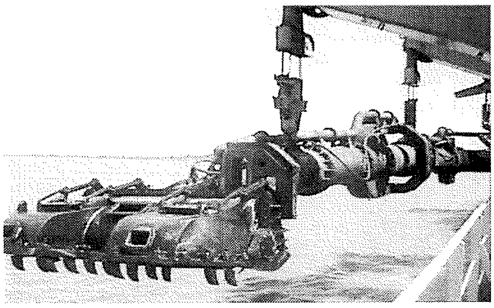
(1) Deepening of Drag Suction Head for Fluff Dredging

At present, no previous study is available on the physical properties of the fluff. But, sounding data at Boca Grande shows a general profile of the bottom deposits clearly indicating a series of fluff deposits having different densities. In general, it seems that as the fluff deposit get deeper, the unit weight of the deposit becomes heavier due to consolidation process by its own weight with time after being subjected to agitation.

It is recommended to dredge deeper layer of fluff deposits as much as possible in order to attain the designated channel depth of 13.2 meters for keeping safe navigable depth. Dredging of deeper fluff layer will be facilitated by possible decrease of water with restraint of pump rotation. In addition, dredging should be carried out at suitable speed of movement to minimize the resistance of fluff deposits.

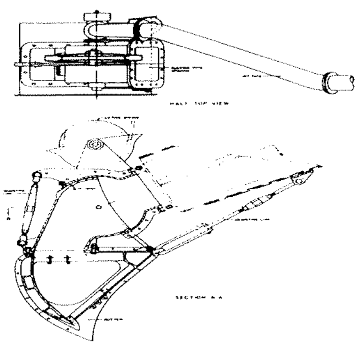
In order to pursue this dredging, the head of the dredge should be made narrower to maintain minimum resistance to fluffs. It would be possible to select the most suitable type of dredge head by further studies. Various types of dredge head is shown in Fig.7-4-8.

(a)



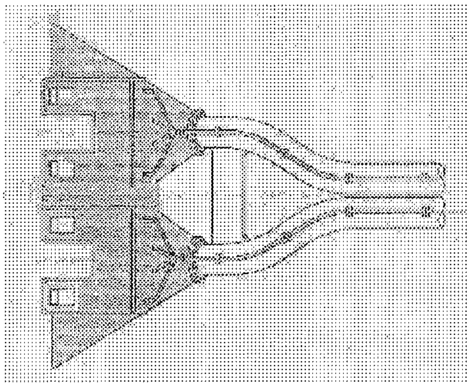
Existing Head Currently in Used
(Applicable to Sandy Materials)

(b)



Applicable to Soft Clayey Materials

(c)



(Applicable to Fluff, subject to further studies)

Fig. 7-4-8 Types of Dredge Head

As mentioned above, it is required to develop a drag head that can be moved to the lower layer of the fluff and it can suck fluff with low liquidity properly into the discharge pipe. When dense fluff in the lower layer is dredged, it should be properly mixed with the appropriate amount of the liquid fluff or seawater. Also it is necessary to adjust the length and rotational speed of the impeller to obtain the appropriate fluff discharge increasing the efficiency of dredging.

(2) Lowering the Height of the Discharge Pipe

In order to dispose the dredged spoils as far as possible, the height of the discharge pipe of Rio Orinoco is raised to 17 m above water level. Disadvantages of this method are as follows:

- Water could not rise with short impeller length due to abrasion. As a result, replacement of impeller will be frequent. Therefore, operating time of the dredge will be reduced.

- Higher the height of discharge pipe, it will subject the dredge to instability.

- Fuel consumption will rise.

- The engine must be operated at high speed to attain high horsepower, hence, raising the engine temperature to extremely unacceptable high level. This would cause damage to the engine, hence, reducing the operating time of the dredge.

In order to solve above mentioned disadvantages, it is proposed to lower the discharge height of the pipe.

Advantage of Lowering the Height of the Discharge Pipe as follows:

- The length of the impeller although short due to abrasion, is usable.

- Volume of discharge could be controlled by adjustment of the engine revolution. By this means, the most efficient performance of production could be attained.

- It will stabilize the dredge, hence, operating time will be increased

- Does not require high horsepower thereby reducing fuel consumption.

- Reduction in engine speed will lower temperature of engine thus damages could be avoided. As a result, operating time of the dredge will increase.

- Lowering the discharge pipe near the deck of the dredge will prevent severe abrasion of the impeller. Each pump should be provided with one discharge pipe 890 mm in diameter. The pipe should not be merged into one big pipe in order to avoid the occurrence of backflow and accumulation of sand inside the pump which causes severe abrasion to the impeller.

Two (2) alternatives of reducing the height of the discharge pipe are as follows:

1) End of discharge pipe to be rotational for both the Outer Channel, and Inner Channel

   The end of the discharge pipe Orinoco will be provided with a rotational pipe which could be rotated to 180 degrees to lower its elevation by 5 meters as shown in the Fig. 7-4-9.

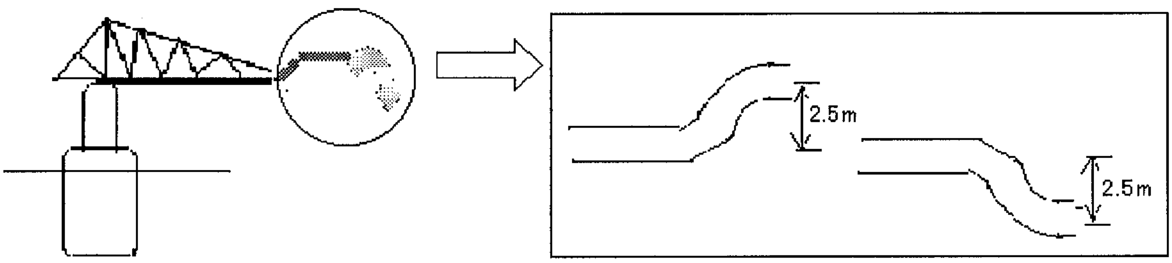
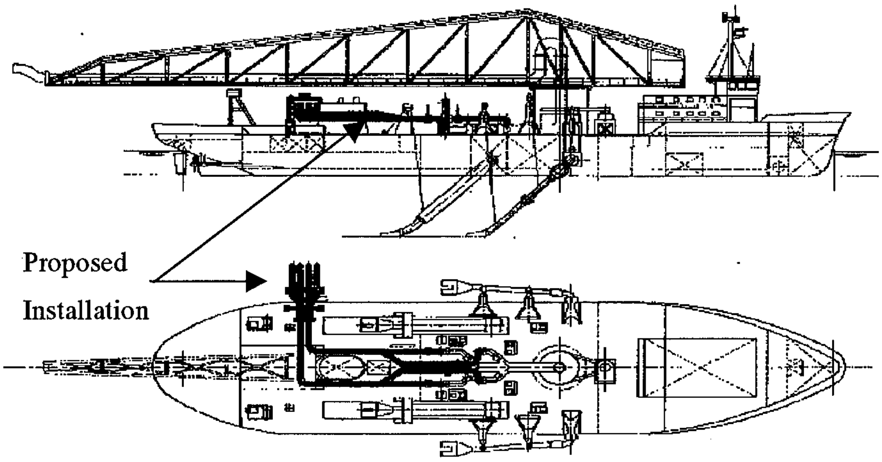


Fig. 7-4-9 Lowering the Discharge Pipe by Rotation

2) Lowering the discharge pipe near the deck of the dredge as shown in the Fig. 7-4-10 for the Outer Channel



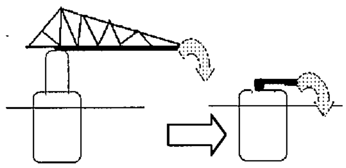


Fig. 7-4-10 Lowering the Discharge Pipe on Boat

Items to be remodeled are as follows:

- Installation of additional dredge valves.
- Installation of four (4) dredge pipes.
- Installation of supporting structure for intake/discharge pipe.
- Installation of additional flake connection for the dredge pipe.
- Installation of additional dredge valve, oil pressure devices including pipes, panels and pertinent devices. (Existing oil pressure source devices of the dredge will be used).
- Design of the Remodeling

Tabulated hereunder is the required engine horsepower in relation to the height of the discharge pipe when the velocity is 6 m.

Height of Discharge Pipe	Horsepower (PS)
17 m	1672
12 m	1366
5 m	944

For details, see the Fig. 7-4-11 and calculation sheets Table 7.4.2 attached hereafter.

Lowering the height of the discharge pipe is proposed as a tentative measure to improve the current agitation method until the barge system is introduced to dispose the dredged materials outside of the channel.

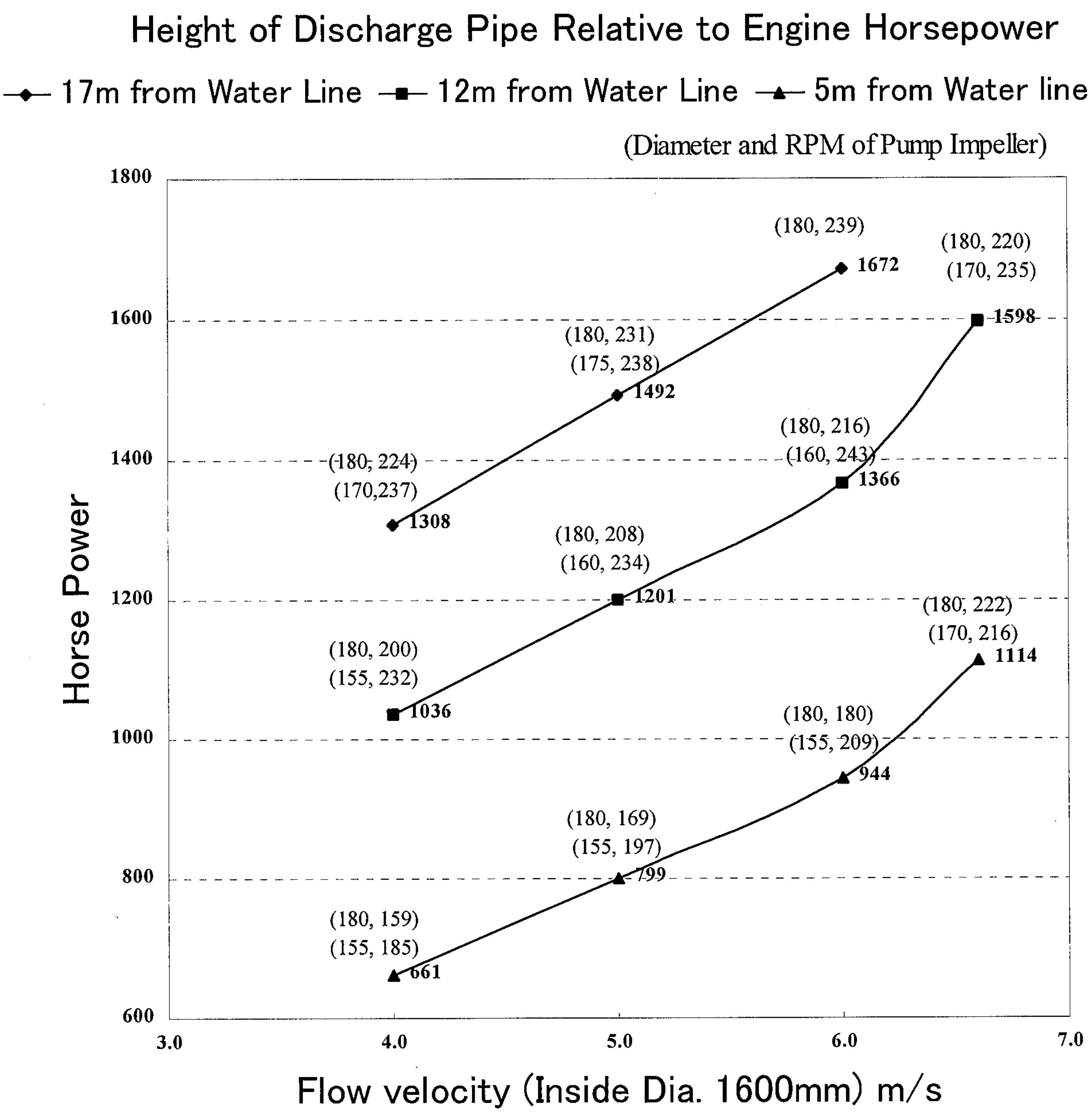


Fig. 7-4-11 Height of Discharge Pipe Relative to Engine Horsepower

Table 7.4.2 Orinoco Dredge: Result of Lowering the Discharge Pipe (Diameter and r.p.m of Impeller, Change in Horsepower)

Height of Discharge Pipe		17m				12m				5m			
Velocity (Pipe Diameter :1600mm)	(m/s)	6.6	6.0	5.0	4.0	6.6	6.0	5.0	4.0	6.6	6.0	5.0	4.0
Q m3/4pump	(m3/h)	48,000	43,407	36,173	28,938	48,000	43,407	36,173	28,938	48,000	43,407	36,173	28,938
Q m3/1pump	(m3/h)	12,000	10,852	9,043	7,234	12,000	10,852	9,043	7,234	12,000	10,852	9,043	7,234
	(m3/s)	3.33	3.01	2.51	2.01	3.33	3.01	2.51	2.01	3.33	3.01	2.51	2.01
efficiency		0.8	0.8	0.7	0.6	0.8	0.8	0.7	0.6	0.8	0.8	0.7	0.6
Intake Resistance	(m)	3.0				3.0				3.0			
Suction lifting	(m)	15m x 0.15=2.3				15m x 0.15=2.3				15m x 0.15=2.3			
Pipe Friction	(m)	6.1	5	3.5	2.2	6.1	5.0	3.5	2.2	6.1	5	3.5	2.2
Lifting Height	(m)	17m x 1.15=19.6				12 m x 1.15=13.8				5 m x 1.15=5.8 m			
Velocity Head	(m)	2.2	1.8	1.3	0.8	2.2	1.8	1.3	0.8	2.2	1.8	1.3	0.8
Total Water Head	(m)	33.2	31.7	29.7	27.9	27.40	25.90	23.90	22.10	19.1	17.9	15.9	14.1
Horse Power	PS	1,937	1,672	1,492	1,308	1,598	1,366	1,201	1,036	1,114	944	799	661
Impeller Dia.(m)		rpm of Impeller of pump				rpm of Impeller of pump				rpm of Impeller of pump			
1.80	(r.p.m)		239	231	224	222	216	208	200	186	180	169	159
1.75	(r.p.m)			238	231	229	222	214	205	191	185	174	164
1.70	(r.p.m)				237	235	229	220	211	196	190	179	169
1.60	(r.p.m)							234	225	209	202	190	179
1.55	(r.p.m)								232	216	209	197	185

Horse Power of Pump Engine: 6,800Ps/2pumps

Diameter of Impeller: Max 1.80m

r.p.m of Impeller: Max 240

Min. length of Impeller: 85% of Max. Diameter

Unit weight of soil and water: 1.15t/m3

Calculation of pump operation

Total Water Head (H)=Suction Head(V)+Delivery Head(P)+Velocity Head($v^2/2g$)

V=Intake resistance head + Suction lifting head + Pipe fricton head

P=Pipe fricton head (Pf) + Lifting water head

$$Pf = \frac{\text{friction coefficient x (velicity inside pipe)2 x the length of pipe}}{\text{2 x g x (pipe diameter)}}$$

$$\text{Shaft Horse Power (Ps)} = \frac{\text{1000 x 1.05 x Quantity of water (Qm3/s) x H}}{\text{(75 x efficiency)}}$$

(3) Revision of Disposal Method from Hopper to Side Casting for Guayana at Boca Grande

Frequent occurrence of trouble is observed in the discharge system of Guayana particularly on its bottom closing and opening. It is therefore suggested to shift discharging mode from hopper to side cast method so that the dredging operation could increase from the present 600hr to 2,000 hr per annum. However, it is required to analyze the maximum possible length of the dredging arm with stability of Guayana dredge.

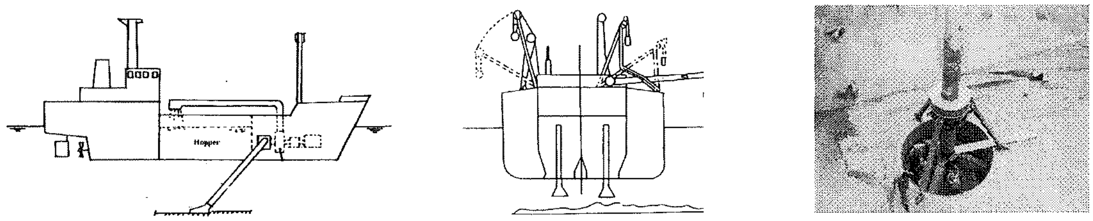


Fig. 7-4-12 Disposal System of Guayana, Using Hopper of Gua0yana

(4) Finish dredging at Boca Grande before rainy season.

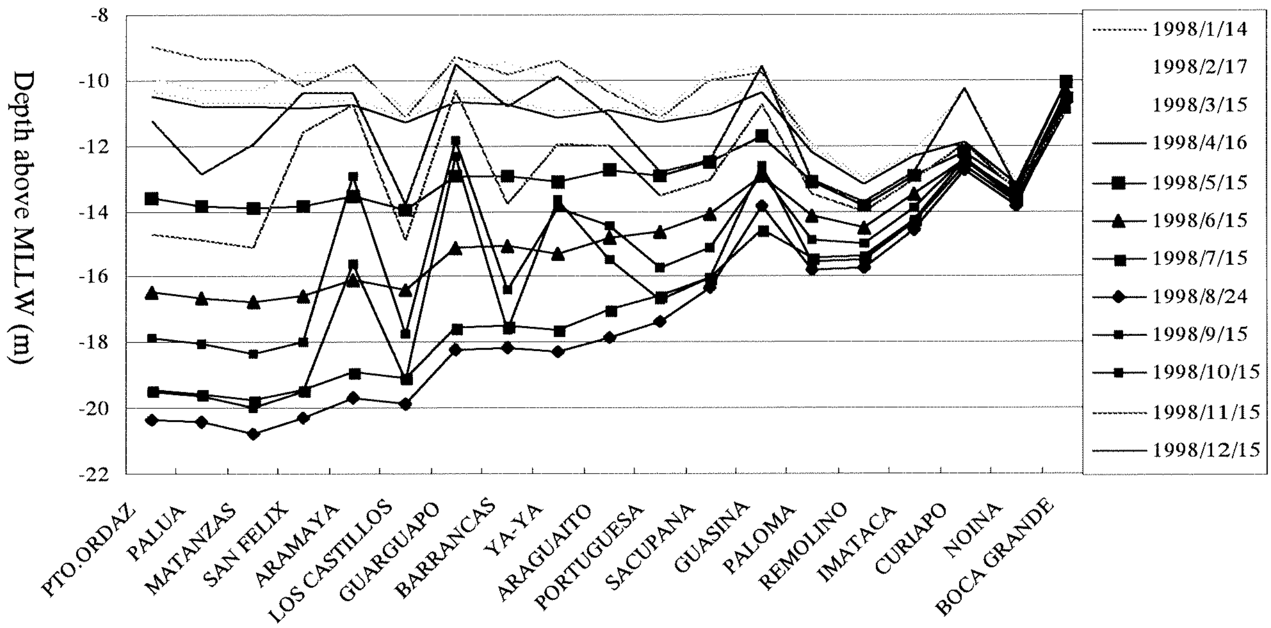


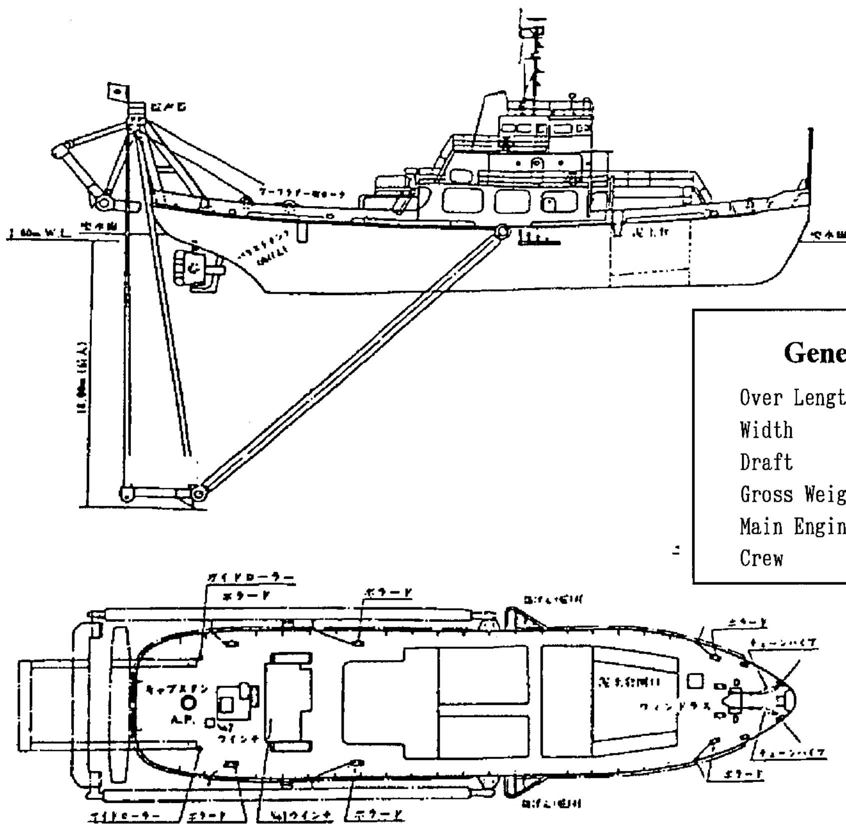
Fig. 7-4-13 Channel Bottom During Rainy Season

As can be seen in the above Fig. 7-4-13, the bottom elevation at Boca Grande is apparently the shallowest during the rainy season. At present, though dredging is carried out throughout the year, it is quite difficult to satisfy the required designed depth of the navigation channel. Therefore, as a first step improvement consideration, if dredging in the Boca Grande section is completed before rainy season starts then it would be possible to have the satisfied navigation channel for both inland and outer channels during rainy season, since in rainy season the inland channel has enough depth for the normal navigation. It is therefore strongly suggested that dredging at Boca Grande be conducted prior to the start of the wet season

(5) Provision of Bed Leveler to Drag Tip

As described earlier, areas dredged by trailing suction equipment are extremely irregular. For safe navigation, the areas of high spots should be removed or leveled down. This could be pursued by means of a bed leveler equipment which would not only level the irregularly dredged bottom but will also provide a deeper navigable channel depth.

Fig. 7-4-14 hereunder shows a bed leveler used in Nagoya Port, Japan for example. By using the bed leveler, the difference between the design depth and the average dredged depth was reduced from 1.5 m to 0.3 m. Consequently total cost of dredging decreased remarkably.



General Specifications

Over Length	: 41.5m
Width	: 10.0m
Draft	: 4.5m
Gross Weight	: 534tons
Main Engine	: 1,100ps
Crew	: 16

Fig. 7-4-14 Proposed Bed Leveler Equipment