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Capital Dredging at New Mangalore Port

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Abstract

The New Mangalore Port is located on the West Coast of India. The port has been developed in three stages. The third stage development was to provide port facilities to cater to the requirements of a three million tonnes per annum (MTPA) grass root refinery being established near Mangalore. The important work relating to the port facilities was deepening the existing port to handle 65000/85000 DWT oil tankers drawing a draft of 14.0 m. This included rock dredging using underwater drilling and blasting. An attempt has been made in this paper to briefly describe the capital dredging carried out during the first and second stage developments of the port. The capital dredging carried out for the third stage development has been covered in more detail.

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Figure 1. Location of New Mangalore Port.

Introduction

The New Mangalore Port is an artificial lagoon harbour located mid way between Mormugao and Cochin on the West-Coast of India. The port was declared as the ninth major port during May 1974 and was commissioned during May 1975. The provisions of the Major Port Trust Act, 1963 were extended to this port with effect from April,1980. Figure 1 shows the location of the port. The Port has been developed in three stages.

First Stage Development

The work on the first stage development commenced during 1960 and was completed during May 1974 involving an outlay of Rs. 445 million. The facilities provided include three alongside berths, one oil jetty and a shallow draft berth.

The first stage development of the port was to cater to the requirement of 30000 DWT vessels drawing a draught of 9.15 m and the following depths were provided in the various zones:

Outer approach channel – 10.7 mCD

Lagoon – 10.1 mCD

Alongside berths – 9.75 mCD

The New Mangalore Port is completely an artificial lagoon harbour. Hence, an approach channel had to be dredged in the sea and a lagoon had to be cut out in the virgin land. The typical soil profile at the port consists of a layer of sand extending to a depth of about –8 to –10 mCD followed by a layer of medium to stiff clay followed by soft and hard rock.

The average elevation of the lagoon area was of the order of +5.0 mCD. Hence the area covered by the lagoon was excavated in dry using the earth moving equipments up to a level of about +1.0 mCD (the average level of groundwater). The excavation below this level was carried out by dredging. The top layer of sand was used for reclaiming the low-lying areas in and around the port. The soil below the sand being clay which was not suitable for reclamation was dumped in the offshore dumping area located at a distance of 4.5 km southwest from the point of intersection of the centre line of the outer approach channel with the –15 m contour. The distance of the dumping ground from the shoreline was about 9.0 km.

The initial dredging of the port was carried out by a small cutter suction dredger fabricated in the port. The work commenced during 1969. The dredger was fabricated on land and slid into a nearby pond created earlier. Once afloat, the dredger was utilised for reclaiming the adjacent low-lying areas within a radius of about 400 m. As this dredger had only limited capacity, the balance dredging was entrusted to the Dredging Corporation of India, Limited (DCI Ltd) during Nov.1970. They deployed two cutter suction dredgers. These dredgers had to be brought inside the lagoon by creating their own floatation by dredging a pilot channel. Once inside the lagoon, the top mantle of dredged sand was used for reclamation of the adjacent low-lying areas.

In view of the large quantity of dredging involved and as suitable dredgers were not available within DCI, the balance portion of the work was entrusted to a consortium of four Dutch dredging companies viz. M/s.Dredging Consortium India B.V. during 1973 after an invitation for global tenders. The first stage development of the port is shown in Figure 2.

The final quantities dredged during the first stage development dredging work were as under:

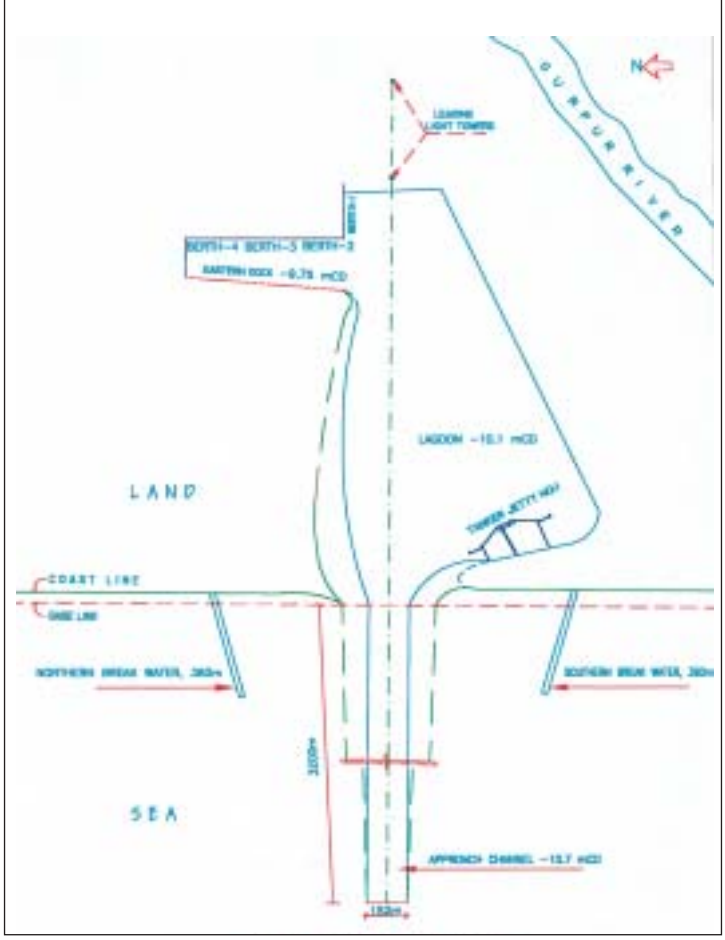


Figure 2. First Stage Development.

Method of dredging	Qty. in million m^3.
– Departmental cutter suction dredgers in the lagoon. – Contract dredging	3.267
– Outer approach channel	2.776
– Lagoon	7.343
Total	13.386

The dredging work of first stage development commenced during 1970 and was completed during 1974. The total expenditure incurred for the first stage development of the dredging work, including payment of customs duty and such, was Rs.149.3 million (1974).

A brief description of the dredging carried out by the departmental dredgers and the contract dredging is furnished in Annexes I and II respectively.

Second Stage Development — Expansion of Port Facilities for Kudremukh Development

During the year 1976, the Govt. of India approved the scheme for expansion of the New Mangalore Port to cater to the export of 7.5 MTPA of Kudremukh iron ore concentrates to Iran. The port was deepened to provide for 60000 DWT vessels drawing a draught of 12.5 m

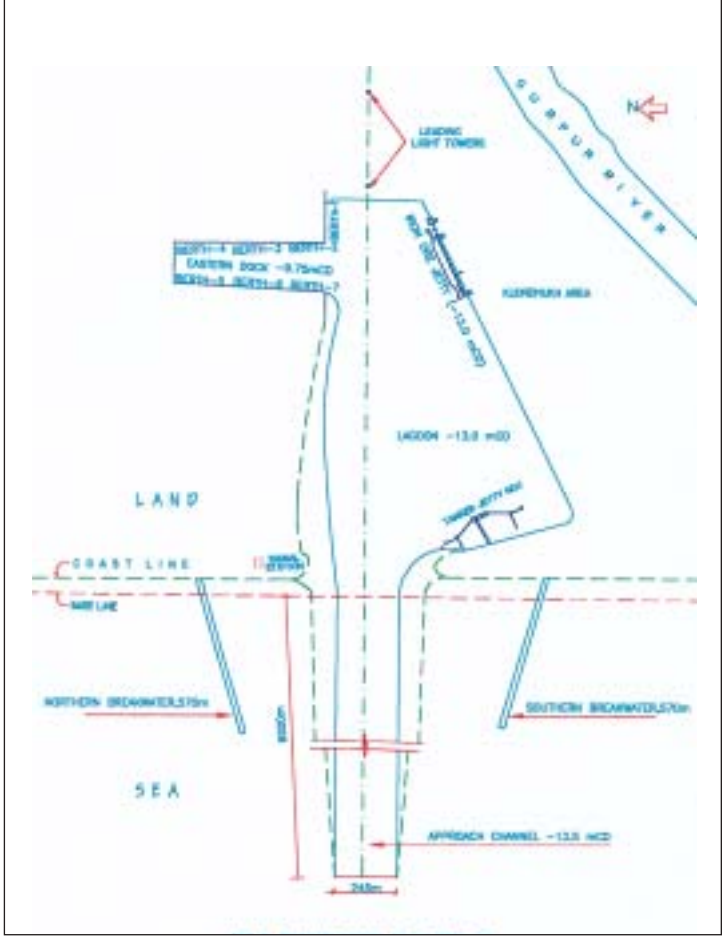
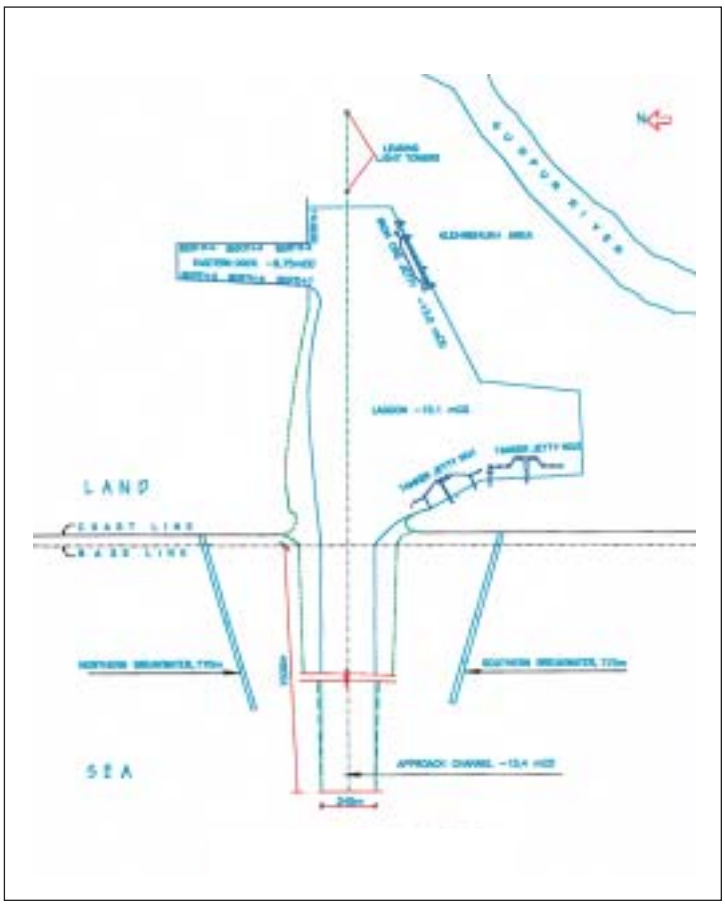


Figure 3. Second Stage Development.

Figure 4. Third Stage Development.



involving an outlay of Rs. 385 million. The following depths were provided in the various zones, by taking advantage of 1.0 m tide:

Outer approach channel	– 13.5 mCD
Lagoon	– 13.0 mCD
Iron ore berth	– 13.0 mCD

The total quantity of dredging involved was 9.35 million m^3 as under:

Outer approach channel:	5.29 million m^3
Lagoon	4.06 million m^3

The dredging work was carried out by the DCI, Ltd. during the period from October 1977 to December 1981.

In addition to the above, certain stray rock patches were also encountered in the lagoon during the first stage development at a depth of about – 8.2 mCD. These rock patches covered an area of about 47,500 m^2.
These rocks were removed by under water drilling and blasting. For underwater drilling and blasting, a four-legged jack-up platform fitted with four overburden drilling equipment was used. Two grab dredgers assisted by split barges carried out the dredging of the blasted rock. A total quantity of 31,200 m^3 of rock was removed.

The details of the capital dredging and the underwater blasting carried out during the second stage development of the port is furnished in Annexes III and IV respectively.

Construction of additional general cargo berths on the western side of eastern dock

On completion of Kudremukh Development Scheme, the work on the construction of additional general cargo berths on the western side of the eastern dock arm was commenced during 1981 and was commissioned during 1984. The berth was constructed in dry on land. A quantity of about 0.14 million m^3 of soil in front of the berth was later dredged by a cutter suction dredger and the soil was used for reclamation in the adjacent areas.

The work on the balance portion of the additional general cargo berth on the western side of the eastern dock arm was commenced during 1987 and completed during 1989. This berth was also constructed in dry on land.
In connection with this development, a total quantity of 0.14 million m^3. of soil was dredged by the cutter suction dredger and the soil was used for reclamation in the adjacent areas. The details of the dredging carried out in connection with the additional general cargo berths are detailed in Annex V.

With the completion of this balance portion of the additional general cargo berths on the western side,

Figure 5. Dry excavation and disposal.

the eastern dock arm had six general cargo berths, three on the eastern side and three on the western side, providing a wharf length of 594 m each on either side. The second stage development of the port including the additional general cargo berths is shown in Figure 3.

Third Stage Development Expansion of Port Facilities for the Proposed Refinery

The New Mangalore Port was entrusted with the work of providing port facilities for a 3 MTPA grass-roots refinery constructed by M/s. Mangalore Refinery and Petrochemicals Ltd. (MRPL) at an estimated cost of Rs. 2381 million. The port facilities were to be provided for handling 65000/85000 DWT tankers drawing a draught of 14 m. The capital dredging of the new dock arm, outer approach channel and lagoon was an important item to be covered under this expansion work. Based on the pre-qualification criteria six firms were pre-qualified to quote for the capital dredging work and the work was awarded to M/s. HAM Dredging, Netherlands at an evaluated cost of Rs.1129 million.

The design depths to be provided in the various regions were:

Outer approach channel	–15.4 mCD
Lagoon and the new dock arm	–15.1 mCD
Area covered by rock	–15.6 mCD

The third stage development of the port is shown in Figure 4. The work was commenced during February 1995 with a time limit for completion of the work as 17 months. However owing to some difficulties, the work was delayed and was completed in all respects during December 1996. The quantity of work executed in various zones is as described below:

Area	Quantity in million m^3
Dry excavation in the new dock arm	– 0.317
Cutter suction dredging in the new dock arm and reclamation on the beach	– 2.428
Dredging in the lagoon & offshore dumping	– 2.950
Dredging in the outer approach channel and offshore dumping	–5.870
Total	11.565

In addition, 0.21 million m^3 of overburden dredging, including 34,320 m^3 of rock had been drilled, blasted and removed in the lagoon.

The contract also included maintenance dredging in the outer approach channel during the intervening monsoon periods of 1994-95 and 1995-96 involving a quantity of 6.83 million m^3. This was dredged by a trailer suction hopper dredger and the material was disposed off in the offshore dumping area.

In the new oil dock arm, where the new oil jetty has been constructed, the existing ground level was about +5 mCD. The soil from the existing ground level up to +1.00 mCD (Average water level) was removed by dry excavation using poclains of two m^3 capacity. Four-m^3-capacity dumpers were deployed for transportation of the excavated soil to the low-lying areas within the harbour estate. Figure 5 shows the dry excavation disposal in progress.

Figure 6. Ham 218 at work.

Figure 7. Geopotes 15 at work.

The general soil profile in the port area was sand up to a depth of about –8 to –10 mCD which was followed by medium and stiff clay, soft rock and hard rock.

Ever since the construction of the breakwaters during the first stage development, there has been slight erosion south of the south breakwater over the years. This was mainly a result of the small net southerly drift. In order to arrest this erosion and also to provide for a future buffer stock, a quantity of about 2.43 million m^3 of sand from the new oil dock arm from +1.0 mCD to about –10.0 mCD was pumped south of the south breakwater by the cutter suction dredger *HAM 218*.

Figure 6 shows working of *HAM 218*. The soil which was mainly medium to stiff clay obtained from further deepening viz. from –10.0 to –15.1 mCD was not suitable for reclamation. This material was dredged by the trailer suction dredger. However some of the material in front of the jetty, corners and such, which was initially dredged by the cutter suction dredger, was temporarily deposited in the lagoon area. This was re-handled by the trailer suction dredger and was disposed of in the offshore dumping area.

The dredging in the lagoon involved deepening from the existing levels of about –13.0 mCD, which mainly involved medium to stiff clay which was not suitable for reclamation. This dredging was mainly carried out by trailing suction hopper dredger *Geopotes 15*. Figure 7 shows the working of *Geopotes 15*. This material was also disposed of in the offshore dumping area located at a distance of 7 km˙ southwest from the point of intersection of the center line of the outer approach channel with the –15 m contour.

Similarly, the dredging in the outer approach channel involved deepening of the channel from the existing depth of about –13.5 to –15.4 mCD which also mainly involved medium and stiff clay. This soil was also not being suitable for reclamation was disposed of in the same offshore dumping area. This offshore disposal area was finalised after conducting radioactive tracer studies. The location of the disposal ground for capital dredging for all the three stages of development and also the maintenance dredging is shown in Figure 8.

The contract specified a side slope of 1:20 in the outer approach channel area west of the breakwaters with a transition to 1:10 at the baseline on the area east of the breakwaters. This involved dredging of stiff clay within the zone covered by the breakwaters. Part of this material was "double handled", namely, in areas which were shallower than the loaded draft of the trailer suction dredger, the soil was cut by the cutter suction dredger in the first instance and was discharged in the outer approach channel which was rehandled by the trailer suction dredger subsequently as done in the case of new oil dock arm. The "double handling" method by the use of the trailing suction hopper and the cutter suction dredgers is shown in Figure 9.

The positioning of the trailer suction dredger, cutter suction dredger, water injection dredger and the survey vessel was carried out with a 4000 RS/DS DGPS positioning system. The system provided real-time differential DGPS positioning, with the aid of the reference station placed ashore. The exact location of the dredgers and vessels was depicted on PC screens on board the various dredgers and the vessels.

An automatic tide gauge installed near the additional general cargo berth carried out the tidal observation.

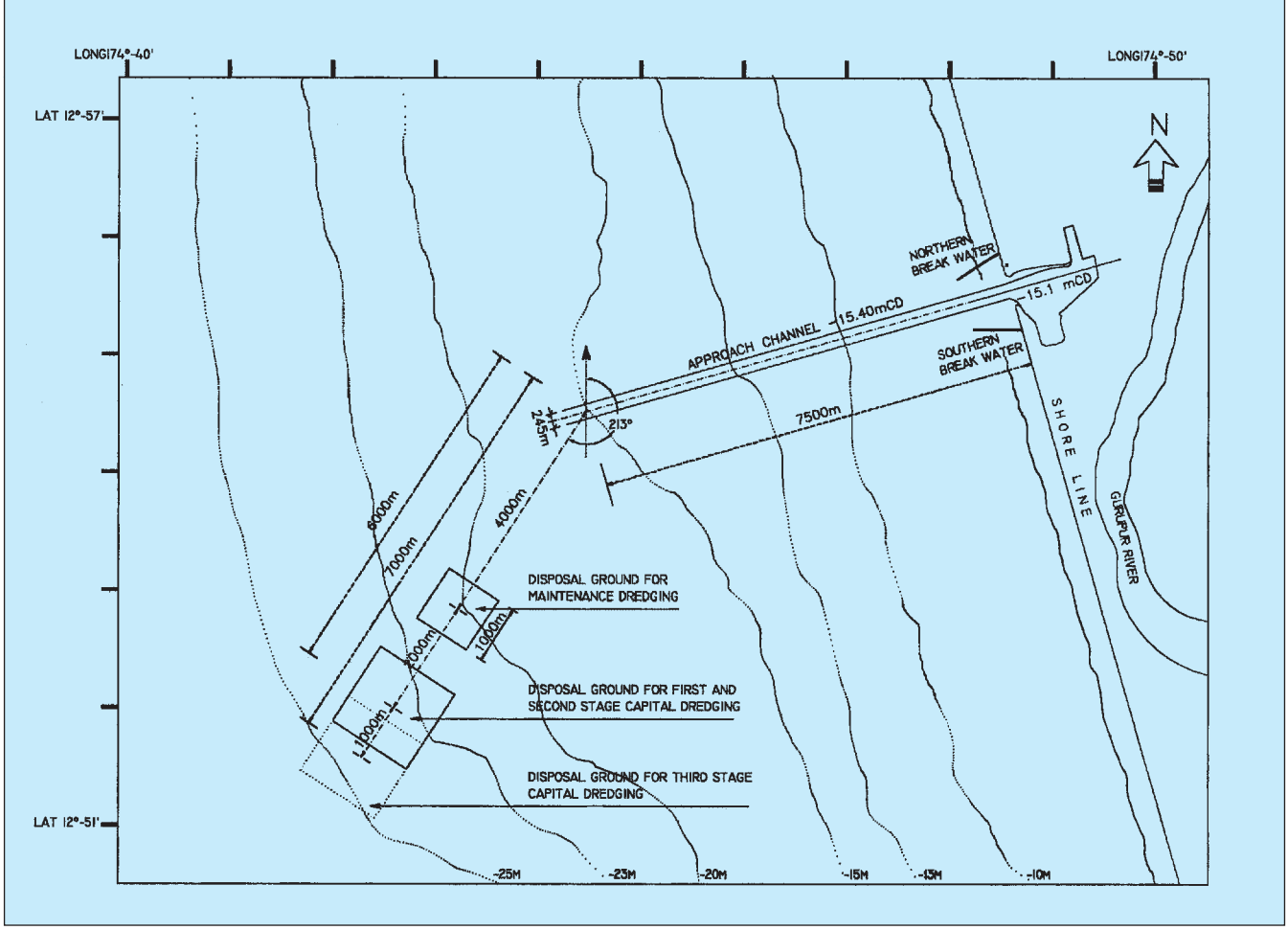


Figure 8. Location of disposal ground.

The gauge was fitted with a radio transmitter which would transmit the tidal information continuously and the receivers installed on board the dredgers/vessels received this information so that tidal corrections could be applied to the depths round the clock.

The survey vessel was equipped with the following instruments:
- Atlas Deso - 22 Echo Sounder
- Tide Receiver
- Heave Compensator
- DGPS Receiving unit
- Personal Computer

The survey data was recorded on a floppy disc which was transferred to the dredgers for continuous monitoring. The same survey data was also analysed subsequently in the office for the preparation of charts.

The furrows created by the dragheads of the trailer suction dredgers were levelled using a novel technique of "water injection". The water injection is a method where a density current consisting of water with a high segmentive ratio is created. The furrows are thus filled up. Figure 10 shows the "water injection" dredger *HAM 924* in action.

During the second stage development of the port, the stray rock patches in the lagoon were cleared up to –13.50 mCD. In the contract relating to the third stage development the rock patches were to be

Figure 9. Double handling method in progress.

cleared up to –15.60 mCD which involved underwater blasting and dredging of about 34,320 m^3 of rock spread over an area of 74,000 m^2. A pre-blast survey of the cracks in the buildings in and around the working area was carried out. The rock area was initially delineated by jet probing.

The jet probing was carried out from the floating drill pontoon *HAM 910*, which had a central well of

Figure 10. Water injection dredger Ham 924 at work.

9.40 x 5.30 m equipped with a gantry. Figure 11 shows the drilling platform *HAM 910*. On the gantry four drill towers of 12 m length equipped with Over Burden drilling system (OD) were installed. The pontoon was held in position by six anchors. The anchor winches were controlled from a centralised control panel. Based on the jet probings carried out initially, the settings of the drilling platform in the area covered by rock were pre-plotted. As the accuracy required for the location of the platform was of a high order, a system having an accuracy of better than the DGPS viz. "Axyle" was deployed.

With a central well of 9.40 x 5.30 m and four drill towers, holes with a grid spacing of 1.77 x 1.88 m were adopted. This resulted in 24 holes in each setting. A 70-mm drill hole was drilled using the OD equipment to the required depth. Figure 12 shows the drilling in progress.

The holes were drilled 2 m deeper than the design depth [called as undercut] to provide for proper breakage of the rock. On reaching the required depth, the explosives were loaded into the drilled holes. The explosive used was slurry explosive "KELVEX 800"/50 mm dia x 400 mm cartridge with a plastic casing which had screwed ends on either side so that they could be easily coupled. The full depth of the hole was packed with explosives.

Two VA-OD short delay millisecond electric delay detonators, which were pre-checked, were used in each hole as a matter of precaution. On completion of the charging of all the holes, the detonator leads from individual holes were connected in parallel/series connection, depending upon the number of holes in the circuit. The circuit was also checked for continuity and resistance. The blasting was done normally during daylight hours only, once in the morning and the second in the

Figure 11. Drilling Platform Ham 910.

evening. The number of settings blasted used to depend upon the number of holes to be blasted and a maximum of two wells were blasted at a time.

Upon completion of charging the drilling rig was moved about 50 to 100 m depending upon the explosive charge. The blasting exploder machine was kept on the barge and the connection was made to the machine. A safe blasting procedure was evolved so that all the affected persons were pre-warned before the actual blasting operation took place. The blast design was so made that the expected charge per delay was about 100 kg and the maximum charge was 500 kg /blast. Vibration readings from the initial blasts were taken at three locations. From the results a regression curve was drawn in order to arrive at the safe charge.

The underwater blasting operations carried out were regularly monitored for ground vibrations and air blasts on or near important structures. The vibrations were monitored by microprocessor-based seismographs and software was used to analyse the readings. The ground vibrations recorded were well within the threshold values.

The blasted rock along with the overburden was dredged by a grab dredger viz. *Kathleen Ann*. Figure 13 shows the working of the grab dredger *Kathleen Ann*. A 200-tonne grab crane was mounted on a flat top barge of size 49 x 16 x 2.84 m equipped with rock grabs. The material was discharged into split dumb barges of size 39 x 10 x 3.4 m with 660 m^3 hopper capacity, which were towed by the launch *HAM 1400*. The loading of blasted rock into the hopper barge is shown in Figure 14. The material was disposed of in the extended alignment of the breakwaters.

Upon completion of the dredging and underwater blasting, clearance of the outer approach channel, lagoon including the area covered by rock was done by "Sweeping" to confirm that the seabed in the dredged area was clear to the design depths. The "Sweeping" in the lagoon except the areas covered by rock patches was carried out by a rigid horizontal sweep bar of 12 m long suspended from the "A" frame of the carrier barge of size 40 x 16 x 2.5 m towed by the survey launch *HAM 1400*. An overlap of 2 m was maintained between the two successive 8 m lines.

Figure 15 shows the sweeping operation with the carrier barge towed by *HAM 1400*. The "Sweeping" in the outer approach channel and the new dock arm area was carried out by the water injection dredger *HAM 924* without the water injection process, towed by the tug *Taurus*; with the lines spaced at 15 m as the width of the water injection pipe was 22 m. The "Sweeping" in the rock area was carried out by a rigid horizontal pipe mounted on the pontoon *HAM 910* with a line spacing of 10 m. The same pontoon was also used for

Figure 12. Overburden drilling in process.

Figure 13. Grab dredger Kathleen Ann at work.

simultaneous post-dredging lead-line sounding of the rock patches with a grid pattern of 5 x 2 m.

The pre-dredging sounding of the entire area was taken by the dual frequency echo sounder Atlas Deso – 22. For the final sounding the same echo sounder was also used. The quantities were calculated on cross-section spaced at 30 m intervals, and soundings at 10 m intervals. Interim quantities were calculated using Digital Terrain Modelling and the final quantities by the "Simpson Rule". The rock quantities were calculated based on the pre-sounding as recorded by the jet probings and the post- soundings by the use of lead line.

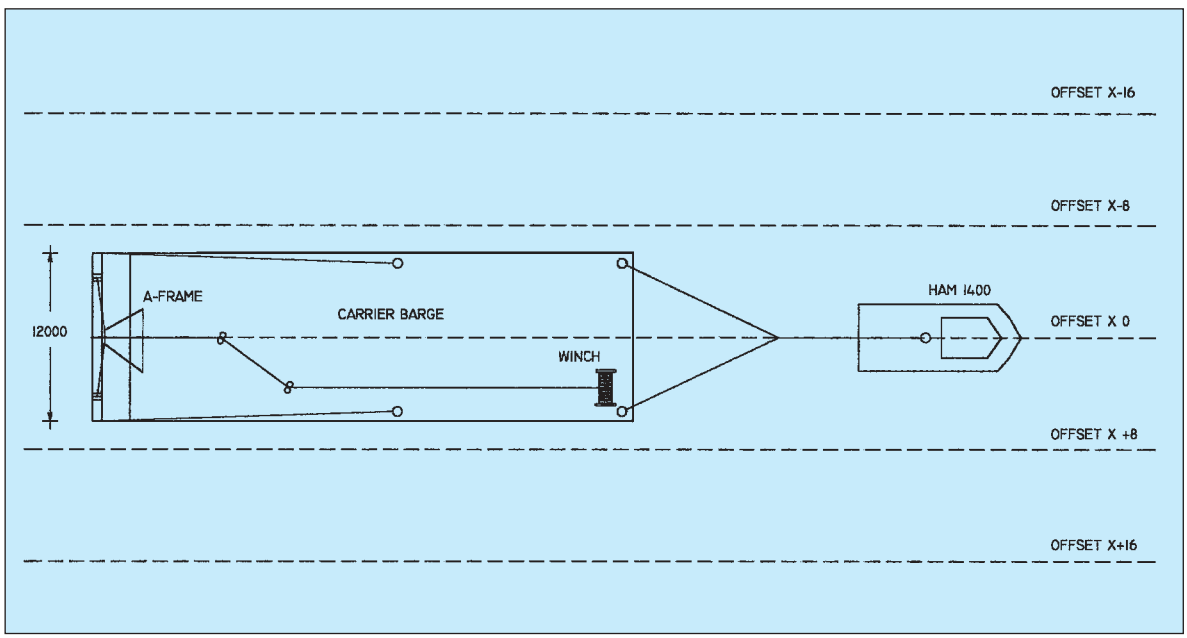
Figure 14. Loading of blasted rock into hopper barge.

Conclusion

The Detailed Project Report for providing port facilities for the refinery for the third stage development was prepared by M/s. Consulting Engineering Services (India) Pvt. Ltd., (CES) , New Delhi, during 1985. The detailed engineering for the entire port facilities was also done by M/s. CES during 1993. The hydraulic model studies and other studies was carried out by the Central Water and Power Research Station, Pune. The radioactive traces studies were carried out by Bhaba Atomic Research Centre, Mumbai.

The work of dredging for the third stage development was awarded to M/s. HAM Dredging after competitive bidding during November 1995 and the work was completed during December 1996.

Figure 15. Sweeping operation with carrier barge towed by HAM 1400.



Annex I. Details of Dredging Carried Out by the Departmental Dredgers for the First Stage Development

I. Design criteria

The design depths provided in the various zones of the harbour to cater to 30000 DWT vessels drawing a draught of 9.15 m. were as under:

Outer approach channel	.. – 10.7 mCD
Lagoon	.. – 10.1 mCD
Alongside berths	.. – 9.75 mCD
Width of the outer approach channel	152 m

II. Equipment used

(1) Midget Dredger: The Midget Dredger was a non-self propelled, electrically driven, 300 mm cutter suction dredger with an installed HP of 350, capable of reclaiming within a radius of 400 m up to an elevation of about +4.0 m and was capable of dredging up to a depth of 10 m.

(2) MOT Dredge II: The MOT Dredge II was a self propelled 550 mm cutter suction dredger with an installed HP of 2300˙ she had a rated out put of 500 m^3 per hour in medium sand, with a total pipeline of 600 m at a terminal elevation of 6 m and was capable of dredging up to a depth of 13.50 m.

(3) MOT Dredge IV: The MOT Dredge IV was a non-self-propelled, twin dredge pump, 800 mm dia cutter suction dredger, with a total installed HP of about 8000˙ she had a rated output of 1500 m^3 per hour of solids for a total pipeline of 2000 m at a terminal elevation of 5 m., capable of dredging up to 22 m.

III. Quantity and Cost of Dredging:

Sl.No.	Dredger	Quantity (Million m^3)	Total cost (Rs. in million)
1.	Midget Dredger	0.835	2.32
2.	MOT Dredge II	0.970	20.75
3.	MOT Dredge IV	1.460	22.20
Total		3.265	45.27

Thus, the average rate per m^3 worked out to be about Rs.14.00 (1973).

IV. Disposal of the dredged material

The dredged material was utilised for reclamation in the adjacent low-lying areas within a radius of 1.50 km.

Annex II. Details of Dredging Carried Out by Contract Dredging for the First Stage Development

I. Design criteria

As indicated in Annex I.

II. Equipments used

(1) Cutter suction dredger *HAM 208*

The *HAM 208* was a non-self-propelled, twin dredge pump 700 mm dia cutter suction dredger with a total installed HP of 6000˙ she had a rated out put of 1000 m^3 per hour of solids, for a total pipeline of about 2000 m at a terminal elevation of 5 m.

(2) Trailing suction hopper dredger - A.D. *Geopotes I*

A self-propelled, twin screw single tube trailing suction hopper dredger of 3170 m^3 capacity with a total installed HP of 7700.

(3) Toran Electronic Position Fixing System.

(4) Tugs and survey launches - 4 Nos., Oil barge, floating pipeline (700 mm dia.) of 600 m length, reclamation pipeline (700 mm dia) of 2520 m.

The total cost of the equipments mobilised was about Rs.70 million (1974).

III. Quantity of dredging

(a) Trailer suction hopper dredger

Location	Qty. in million m^3
(i) Lagoon	1.528
(ii) Outer approach channel	3.256
(b) Cutter suction dredger in the dock arm, lagoon and oil jetty	5.840
Total	10.624

The total cost of the contract dredging including escalation, variation in exchange rate, customs duty and so on was Rs.104 million. The average rate per m^3 considering all costs worked out to Rs.9.79 (1974).

IV. Disposal of the dredged material

Out of the 10.624 million m^3, a quantity of 4.78 million m^3 of sand which was suitable for reclamation was used within a radius of about 2 km. The balance quantity of 5.844 million m^3 consisting of silt and clay not suitable for reclamation was disposed off in the offshore disposal area located at a distance of 4.5 km southwest from the intersection of the centre line of the outer approach channel with the –15 m contour at a depth of about –20 mCD. The location of the disposal area was finalised after carrying out the radioactive tracer studies.

Annex III. Details of Capital Dredging Carried Out for the Second Stage Development

I. Design criteria

The design depths provided in various zones for handling 60000 DWT ore carriers drawing a draft of 12.5 m taking advantage of 1 m tide were as under:

Outer approach channel	– 13.5 mCD
Lagoon	– 13.0 mCD
Iron ore berth	– 13.0 mCD
Width of the outer approach channel	245 m

II. Equipments used

(1) MOT Dredge VIII: 6500 m^3 twin screw, twin tube trailer suction hopper dredger with a total installed HP of about 15000 capable of dredging up to 25 m.
(2) MOT Dredge III: 3400 m^3 twin screw, twin tube trailer suction hopper dredger with a total installed HP of about 10000 capable of dredging up to 22 m.
(3) MOT Dredge VI: 3700 m^3 twin screw, twin tube trailer suction hopper dredger with a total installed HP of about 10,000 capable of dredging up to 22 m.
(4) MOT Dredge VII: 800 mm dia non-self-propelled cutter suction dredger, twin dredge pump with a total installed HP of 8500 capable of dredging up to 22 m. She had a rated output of 1150 m^3/hour of solids for a total pipeline of 3000 m at a terminal elevation of 5 m.

III. Quantity of dredging carried out

Location	Qty. in million m^3
Outer approach channel	5.294
Lagoon	4.067
Total	9.361

NOTE: Out of the above a quantity of 2.50 million m^3 which was dredged by the cutter suction dredger, was re-handled by the trailer suction dredgers by double handling, on the slopes of the outer approach channel and the lagoon.

The total cost of capital dredging including escalation, customs duty and such was Rs.238.5 million.
The average rate per m^3 considering all costs worked out to about Rs.25.50 (1981).

IV. Disposal of the dredged material

As the work involved deepening of the existing harbour and the material involved was mostly clay, the dredged material was disposed of in the offshore dumping area as in the first stage development.

Annex IV. Details of Underwater Blasting Work Carried Out for the Second Stage Development

I. Design criteria

The design depths provided in the lagoon in the areas covered by rock was 0.5 m more than the normal depths viz. –13.5 mCD, to provide for additional keel clearance owing to the hard rock bottom.

II. Equipments used

(1) Jack-Up Type Drill Rig (Model MK-II):

Overall length	27.58 m
Breadth	18.18 m
Depth	2.01 m
Draught	0.70 m

Fitted with four jack-up spuds and 4 nos. drill towers mounted on a central well capable of drilling up to 20 m assisted by 4 nos. of air compressors.

(2) Pontoon mounted crawler crane:
150 tonnes capacity, mounted on a pontoon of 45 x 15 x 3.6 m.

(3) Pontoon mounted crawler crane:
100 tonne capacity, mounted on a pontoon of 40 x 16 x 2.5 m.

(4) Self-propelled 750 m^3 "hydroklapp barge"

(5) Non-self-propelled split barge of 150 m^3 capacity.

(6) Tug MK-II Type - 1 No.

(7) 100 Tonne deck loading barge - 1 No.

(8) Sweeping pontoon - 1 No.

III. Quantity of dredging carried out

A. Drilling and Blasting:	
Rock area	47500 sqm
Quantity of over-burden	237800 m^3
Quantity of rock	31200 m^3
Total quantity of explosives used (Dynamax A 40 mm size)	81.5 tonnes
Millisecond electric delay detonators VA-OD type	12520 nos
B. Shaped charge blasting :	
10 litre containers	750 nos.
Explosives used (Supergel & Kelvex 800)	9100 kg.

Pentolite booster	75 kg. (300 Nos.)
Detonating cord	7400 m.
Ordinary electric detonators	105 nos.
Total cost excluding removal of overburden	Rs. 39 million (1981)
Quantity of rock removed	31200 m^3
Therefore cost of underwater drilling and blasting per m^3	Rs. 1250
Total cost of removing overburden	Rs. 7.5 million (1981)
Quantity of overburden	237800 m^3
Cost of overburden dredging per m^3	Rs. 32.54
Cost of rock dredging only excluding drilling and blasting per m^3	Rs. 80
Total cost of blasting using shaped charges	Rs. 674000
Total quantity of rock removed	945 m^3
Cost of shaped charge blasting per m^3	Rs. 720

IV. Disposal of the dredged material

The overburden along with the blasted rock was disposed of in the extended alignment of the breakwaters.

Annex V. Details of Capital Dredging Carried Out for the Construction of Additional General Cargo Berths on the Western Side of Eastern Dock

I. Design criteria

Alongside depth – 9.75 mCD

Note: The design depth could not be achieved in some portions owing to stray rock patches:

II. Equipment used

MOT Dredge VII : A non-self propelled, twin dredge pump, 800 mm dia cutter suction dredger with a total installed H.P.of 9500. She had a rated output of 1150 m^3 per hour of solids for a maximum pipeline of 3000 m for medium soil at a terminal elevation of 5 m capable of dredging upto 22 m.

III. Quantity and cost of dredging

Area	Dredger	Quantity (million m^3)	Total cost (Rs.in millon)
Additional general cargo berth	MOT Dredge VII	0.14	8.8
Balance portion of the additional general cargo berth	MOT Dredge VII	0.14	33.0 *
Total		0.28	41.8

* The higher cost is owing to direct dredging of weathered rock by the cutter suction dredger.

IV. Disposal of dredged material

The dredged material was used for reclaiming the nearby low-lying areas.

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