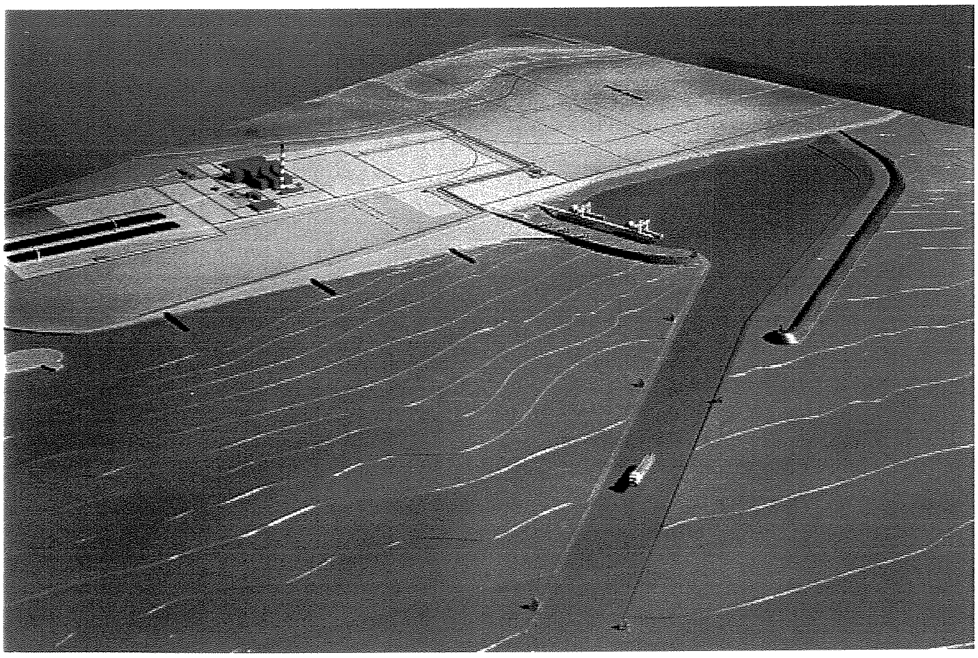
RUBBLE MOUND BREAKWATERS FOR THE NEW PORT OF ENNORE (INDIA), EVALUATION OF CONSTRUCTION



FINAL REPORT
GRADUATION PROJECT
NOVEMBER 1999

HASKONING
Consulting Engineers and Architects

TU Delft
Delft University of Technology
Faculty of Civil Engineering & Geosciences
Department of Hydraulic & Geotechnical Engineering

Student:	**F. Scheffer**
Graduation committee:	**prof. ir. K. d'Angremond (TU Delft)**
	ir. W. Tutuarima (TU Delft)
	dr. ir. P.J. Visser (TU Delft)
	ir. F.R. Kalff (Haskoning)

RUBBLE MOUND BREAKWATERS FOR THE NEW PORT OF ENNORE (INDIA), EVALUATION OF CONSTRUCTION

FINAL REPORT
GRADUATION PROJECT
NOVEMBER 1999

HASKONING
Consulting Engineers
and Architects

TUDelft
Delft University of Technology
Faculty of Civil Engineering & Geosciences
Department of Hydraulic & Geotechnical Engineering

Student: F. Scheffer
Graduation committee: prof. ir. K. d'Angremond (TU Delft)
ir. W. Tutuarima (TU Delft)
dr. ir. P.J. Visser (TU Delft)
ir. F.R. Kalff (Haskoning)

PREFACE

This paper describes the result of the work I carried out for my graduation project at the section Hydraulic Engineering of the faculty of Civil Engineering & Geosciences at Delft University of Technology. Dutch civil engineers are well known for their activities at various projects all over the world. The multi-disciplinary character of large projects as well as the cultural differences between different countries attracts me. I was very happy when Haskoning Consulting Engineers and Architects gave me the opportunity to carry out part of my graduation work on the construction site of a new port near Chennai in India. Haskoning carried out several studies concerning this port, made complete designs and is now supervising the construction of the port.
My graduation work is focussed on the evaluation of construction processes of rock quarrying and breakwaters in order to determine the effects of deviations between planned and actual processes. From the 20th of August until the 5th of December 1998 I staid in India to gather information and assist Haskoning in their supervision activities. After this period the gathered information has been analysed and worked out into this report in Delft, the Netherlands.

First of all I would like to thank Professor d'Angremond and Mr. Tutuarima of Delft University of Technology for their support throughout my graduation project. I would like to thank Mr. Kalff of Haskoning Nijmegen for offering me the opportunity to carry out my graduation project partly on site at the Ennore Coal Port Project. Furthermore I would like to thank all the people of the Haskoning office in Ennore for helping me making my stay in India a pleasant and interesting experience.

Frank Scheffer
Delft, November 1999

SUMMARY

At the east coast of India, 20 kilometres north of Chennai, a new satellite port has been designed and is currently under construction. The project is called the Ennore Coal Port Project. Complete design and supervision of the construction is carried out by HASKONING Consulting Engineers and Architects.

The objective of this graduation project was to evaluate the construction processes of two major contracts of the port construction, viz. quarrying and transportation of rock and breakwater construction.

Breakwater construction:
Two rubble mound breakwaters were designed to withstand a wave height with a return period of hundred years with minimum damage. This resulted in a protection of a single layer Accropode blocks with a maxim weight of 15 tonnes at the deepest section of the northern breakwater. The southern breakwater is protected by natural rock with a maximum grading of 5-12 tonnes. The breakwaters are built by marine based methods (up to -4m Chart Datum) and by land based methods above this level.

Rock quarrying and transportation:
Rock for the breakwaters is quarried at Karikkal, a for this project developed quarry, situated 120 km west of Madras. The rock is sorted into various gradings and then loaded on especially for this purpose constructed skips. The skips are transported on trucks for the first 25 km to a transfer station. From there on the skips will be placed on trains, which transport the skips directly to a stockpile area at the port site. The empty skips are then transported back to Karikkal

A period of three and a half months of the graduation project was spent on the construction site in India. This period was mainly used to gather information to be worked out further in the Netherlands. Deviations in the construction process from earlier made assumptions were investigated. In the Netherlands an analyses of the effects of these deviations on the operational processes, time schedules and realised construction was done.

The analyses shows that for the processes of quarrying and transportation of rock, as well as for the processes of breakwater construction, there are a number of deviations in the actual construction phase from earlier planned processes (such as: realignment of the north breakwater, use of equipment that is not the most suitable for the job and working without an approved work method statement). The main effect of the deviations are delays and difficulties during the production process itself (such as: necessity for resurveys and absence of a supervision tool). Only a few deviations actually effected the end product.

Bulk density calculations for the south breakwater showed that the land based surveys were probably the main source for inaccuracies and that the surveys probably showed more armour material than actually placed. Breakwat computations made clear that the primary armour layer is more stable than designed, due to a reduced slope angle compared to the design. For a few sections of the south breakwater that contain a steep lower slope in the primary armour layer, it is recommended to trim the slope, and place additional rock before

the breakwater is handed over. At sections with relative thin armour layers it is recommended to increase the thickness of the primary armour layer. This reduces the hydraulic loads on the core material because more energy will be lost in the primary armour layer. It is important that the thickness of the primary armour layer reaches at least it's design thickness. To the Client it is recommended to monitor the armour layers at least once a year and directly after bad weather conditions in order to fill up possible gaps and trim the slopes.

The cooling water outlet channel of the North Madras Thermal Power Plant was relocated from the north side to the south side of the south breakwater. The current velocities in the surf zone increased and caused some problems during construction of the breakwater root. When the breakwater was constructed up to about chainage 300 the current velocities decreased, and a more stable situation with a spit appeared. To the Client it is recommended to monitor the bed levels and flow velocities at the location of the cooling water outlet channel at least once a year and immediately after bad weather conditions. Based on that information it can be decided whether protective measures against scour at the south breakwater should be taken or not.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

At the east coast of India, 20 kilometres north of Chennai, a new satellite port has been designed and is currently under construction. The project is called the Ennore Coal Port Project and is partly financed by the Asian Development Bank, the Client for the project is the local harbour authority of the existing port of Chennai. Complete design and supervision of the construction is done by HASKONING Consulting Engineers and Architects. This graduation project is an evaluation of two major contracts of the construction processes of the port, viz. quarrying and transportation of rock and breakwater construction.

Like any other major civil engineering project in the world, the Ennore Coal Port Project has a multi-disciplinary character with a number of contracts and parties involved. For these kind of large civil engineering projects there are standard procedures for most of the processes in the project. The processes are extensively analysed and planned before construction starts. Nevertheless actual construction generally shows deviations from the original planning.

In this graduation work the actual construction is compared with research, planning and design. The first contract that is evaluated is a contract for rock quarrying and transportation. Production methods, progress and possible future developments are discussed. The second contract is a contract for breakwater construction. Here also the production methods and progress are discussed. A technical evaluation is included for one of the constructed breakwaters. Whenever possible, it has been tried to keep calculations out of the text, in order to increase readability. Most of the calculations and direct results thereof are given in the Appendices.

In Chapter 2 the scope of the Ennore Coal Port Project is discussed. With the knowledge of this background information the exact scope of the graduation project is defined in Chapter 3. The standard project procedures are discussed in Chapter 4. Chapter 5 describes the total evaluation of the contract for rock quarrying and transportation. Chapter 6 discusses the contract for breakwater construction and in chapter 7 conclusions and recommendations are presented.

2 THE ENNORE COAL PORT PROJECT

2.1 Background of the Ennore Coal Port Project

With an existing gap between power supply and an ever-increasing demand, it has become India's national policy to improve the power supply in the whole country. The Tamil Nadu Electricity Board (TNEB) has developed a programme to increase the power supply for the state of Tamil Nadu. As a part of this programme a new coal-fired power station has been built at Ennore, 20 kilometres north of Chennai (the official Tamil name of Madras). The North Madras Thermal Power Station (NMTPS) will eventually use about 8.2 million tonnes of coal per year when operating at full capacity. The resources of the coal are the Talcher coalfields in the Indian State of Orissa.

From 1988 to 1990 HASKONING Consulting Engineers and Architects carried out a feasibility study concerning the transport chain of coal from the Talcher coalfields to the NMTPS at Ennore. Several alternatives were studied and it was concluded that the best mode of transport was by train from the Talcher coal fields to the port of Paradip, 250 km south of Calcutta, and from there on by bulk carrier to a new port adjacent to the NMTPS at Ennore.

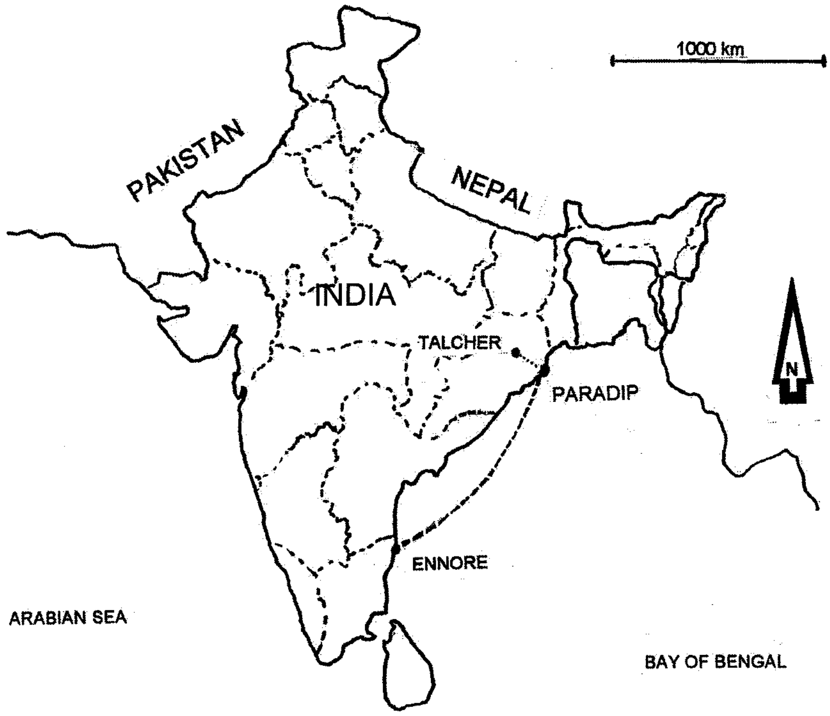


Figure 2-1: Talcher-Paradip-Ennore coal transport chain.

In 1992 the government of India approved the project of developing a new port at Ennore and a loan was obtained from the Asian Development Bank to finance a substantial part of the project cost. Development of the new port has been split up in three phases. In phase I the port is designed for a throughput of 16 million tons of coal annually. The design vessel in this phase is 65,000 DWT. Phase II and III comprise development of additional terminals to receive among others LNG vessels of 150,000 m^3 and iron ore vessels of 120,000 DWT. The Chennai Port Trust (ChPT) was appointed as the Client.

2.2 Design and project studies

For phase I, Haskoning carried out several studies and made complete designs. The design process of the port was split up into a preliminary design stage and a detailed design stage. In the preliminary design alternative port layouts were developed. Figure 2-2 shows two main alternatives, one with a north-eastern and one with a southern orientated entrance. Haskoning evaluated the alternatives in close corporation with the ChPT by using multi-criteria analyses. Evaluation criteria were nautical safety, construction and maintenance cost, basin tranquillity, coastline accretion and erosion, channel siltation and future expansion cost. The alternative with the southern entrance proved to be more promising and was approved by the ChPT to be worked out further in a detailed design. After completion of the detailed design report a strategic port development study, carried out by F. Harris [ref. 1] was finalised. This study envisaged that in phase II larger vessels are planned to be received than originally assumed. The port layout was slightly changed and an additional design report was made. Designs of all the port facilities were finalised by Haskoning in association with Rail India Technical and Economical Services (RITES) of India.

Figure 2-2: Alternative port layouts.

A number of project studies have been done in order to complete the design and minimise project risks. Studies, surveys and investigations were mostly executed by third parties and consisted of:

- soil investigations
- topographic and bathymetric studies
- quarry investigations
- wave measurements

- global and cyclonic wave hindcast
- nautical fast time and real time simulations
- three dimensional physical model tests of one of the breakwaters
- basin tranquillity study
- risk analysis and probabilistic study
- environmental study.

Phase I of the Ennore Coal Port Project consists of the construction of two rubble mound breakwaters, dredging of the entrance channel and port basin, two coal wharves, as well as coastal protection works, onshore infrastructure works and utilities, small craft jetties, tug boats and other small craft and navigational aids (see Figure 2-3).

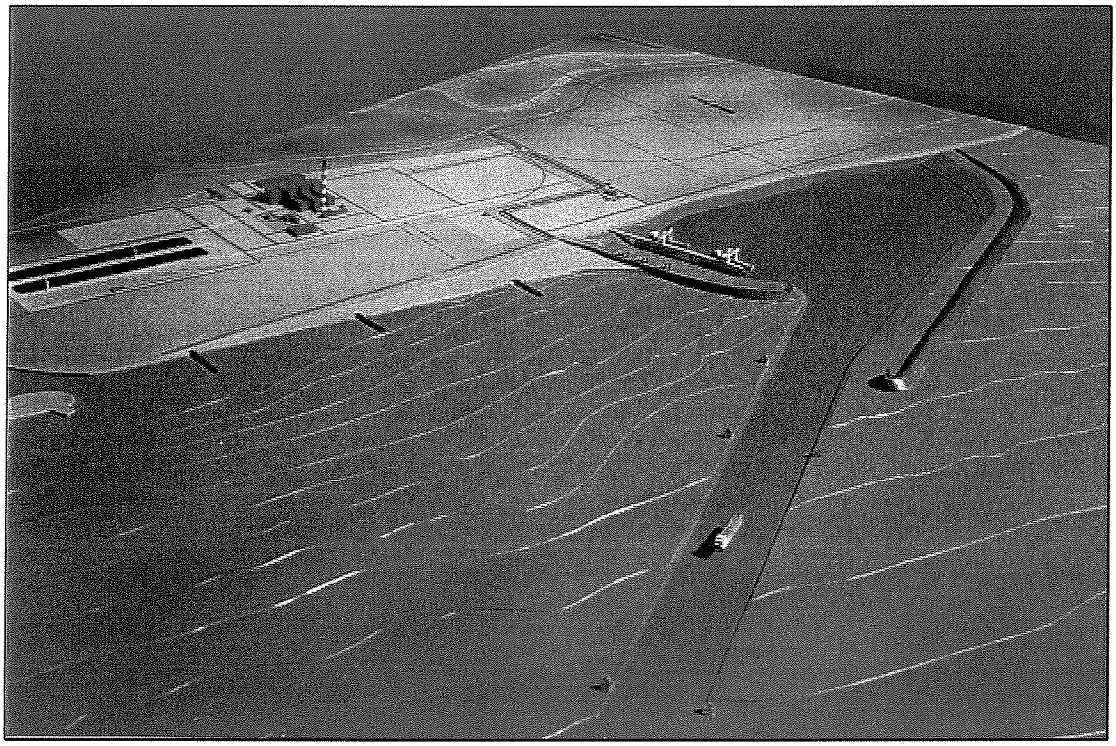


Figure 2-3: Overview of the Ennore Coal Port Project.

Breakwaters:
The rubble mound breakwaters have been designed to withstand a wave height with a return period of hundred years. This resulted in a protection of a single layer Accropode blocks with a maxim weight of 15 tonnes at the deepest section of the north-eastern breakwater. The southern breakwater will be protected by natural rock with a maximum grading of 5-12 tonnes. The breakwaters will be built by marine based methods (up to -4m Chart Datum) and by land based methods above this level.

Quarrying of rock:
Rock for the breakwaters is quarried at Karikkal, a for this project developed quarry, situated 120 km west of Madras. The rock will be sorted into a number of gradings and then loaded

on especially for this purpose constructed open containers, called skips. The skips are transported on trucks for the first 25 km. From there on the skips will be placed on trains, which transport the skips directly to a stockpile area at the port site. The empty skips are then transported back to Karikkal.

Dredging:
The design depth of the entrance channel is 16 m below Chart Datum. The length of this channel is about 3.5 km and the bottom width is 250 metres. This results in a dredging quantity of 3.2 million m^3 sand and clay. A dredging depth of 15 metres is required in the port basin, which implies another dredging quantity of 9.7 million m^3.

Coal wharves:
Two coal wharves have been designed for unloading coal. The coal wharves have a length of 550 metres and will be equipped with continuous ship unloaders. Unloaded coal will be transported to the NMTPS by conveyor belts.

Coastal protection works:
Ennore Creek is situated 3 km south of the port. Ennore Creek is a tidal inlet that has to remain open since cooling water for the NMTPS is taken from it. A 500-m groyne constructed on the south side of the creek will reduce accretion of the mouth. Three groynes of 200m length will fix the coastline between the creek and the port.

Onshore infrastructure works and utilities:
These works consist of port access roads, site roads, administration offices including a control tower, water supply and sewerage systems, electrical power supply, port walls and fencing, lighting and telecommunication works. It also comprises a residential colony for port officers and labourers about 5 km west of the port site, complete with housing, a shopping centre and a school.

Tug boats and other craft:
Berthing and de-berthing operations require the help of special crafts. Three tug boats, two pilot boats and three mooring launches have been designed and will be constructed for these purposes.

Navigational aids:
IALA (International Association of Lighthouse Authorities) guidelines are applied on the navigational aiding system. The system comprises a fairway buoy with Racon (Radar responder beacon), two onshore leading lights on the axis of the entrance channel, five light buoys along the entrance channel, lights on the breakwater heads, all equipped with solar panels, and several lights on the wharves and jetties.

2.3 Tender packages

The project has been divided into five major tender packages and several smaller tender packages. Haskoning has supervised the complete tendering of all the packages.

The five major tender packages are :

1. Rock Quarrying and Transportation.

2. Breakwater Construction.
3. Wharf and Jetties Construction.
4. Dredging.
5. Coastal Protection Works.

The smaller tender packages comprise among others onshore works, tugs and other small craft and navigational aids. The contracts of the Ennore Coal Port are all in FIDIC form. This is because the Asian Development Bank (ADB) and the Ministry of finance require this form in all ADB aided contracts.

2.4 Construction supervision

In association with RITES, Haskoning has been appointed as 'The Engineer' for all phase I contracts. Several contracts depend on the progress of other contracts, for instance the start of the breakwater construction depended on the amount of rock quarried and transported to the site in Ennore. The large number of contracts and the multiple links between various contracts makes co-ordination of the contracts of great importance.

2.5 Project organisation structure

In the project organisation structure the Engineer forms the link between the Contractor and the Client. At the start of the project the communication channels are planned as given in Figure 2-4.

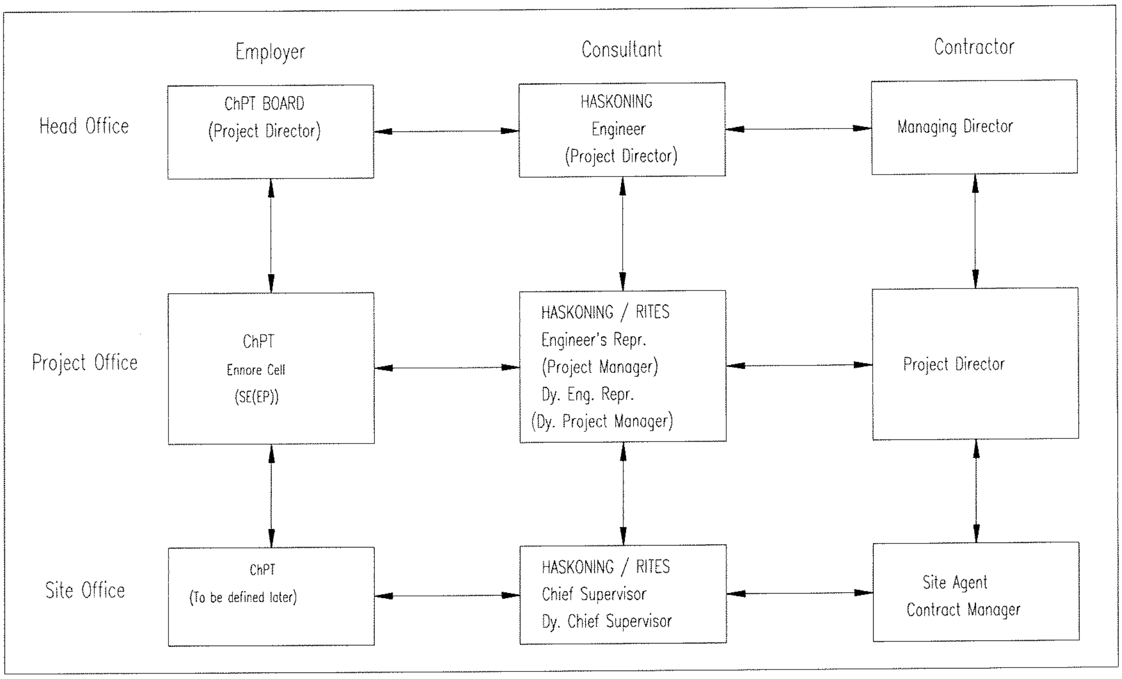


Figure 2-4: Project communication channels.

3 DEFINITION OF THE GRADUATION PROJECT

3.1 General

HASKONING has given me the opportunity to carry out the first period of this graduation project on the construction site of the Ennore Coal Port Project in India. At the beginning of the graduation project several contracts were in the construction phase.
This was the case for three of the five major tender packages: rock quarrying and transportation, breakwater construction and construction of the wharf and jetties. The opportunity of participating in the Engineers activities during the construction phase made it possible to compare the actual construction processes with the planned processes, in which way a link could be made between theory and practice.

It has been decided not to evaluate one contract only but to include the co-ordination between two contracts as well, since this forms an important part of the Engineers activities. Breakwater construction has been chosen because it offered the best perspectives in the field of hydraulic engineering. The contract for rock quarrying and transportation has been included since breakwater construction depends on the availability of quarried rock on site.

3.2 Reason for research

The actual progress of the construction phase differs from the planned construction scheme on various aspects, due to a number of reasons, such as, deviating site conditions, use of deviating equipment and workmanship. This can have great financial consequences for the various parties participating in the project. Good understanding of these deviations can help to decrease the financial risks during the remaining part of the project or in similar projects in the future.

3.3 Objectives of the graduation project

- Making an inventory of deviations in the construction phase from assumptions earlier made for the contracts of rock quarrying and transportation and breakwater construction of the Ennore Coal Port Project.
- Analysis of the operational, economical, time schedules and constructive consequences of these deviations.
- Investigation of the impact, by these deviations, on the design phase provided this knowledge would have been prior available.

3.4 Boundary conditions of the graduation project

- The contract documents are used as a reference. The graduation project focuses on the construction phase, i.e. from the moment the execution starts according to the contracts.
- The construction process has been evaluated until December 1998, which is the moment I left the site of the Ennore Coal Port Project.

3.5 Approach

Three and a half months of the graduation project have been spent on site of the Ennore Coal Port Project. This period has provided understanding in the processes, working conditions and actions of the parties involved. The collected data has been analysed in Delft. The following steps can be identified during the evaluation process:

Rock quarrying and transportation (C1)

1. Make an inventory of:
   - Project studies done for this contract.
   - Contractual requirements and planned progress.
   - Execution methods and activities of the parties involved.
   - Progress of activities in the contract and reasons for delays or problems.

2. Evaluate the differences and derive recommendations regarding the production.

Breakwater construction (C4)

1. Make an inventory of:
   - Project studies done for this contract,
   - Design of the breakwaters
   - Contractual requirements and planned progress
   - Construction methods and sequences (land based and marine based).
   - Important variation orders and instructions.
   - Progress of activities in the contract and reasons for delays or problems.

2. Determine whether the elements of the constructed south breakwater have met the functional requirements.
3. Draft of recommendations regarding the construction process.

Co-ordination C1-C4

1. Make an inventory of the main actions taken in the co-ordination process.

4 STANDARD PROJECT PROCEDURES

4.1 General

Most of the large civil engineering projects in the world go through a number of stages from the first idea up to the completion of all works. The project can consist of one or more works and can be carried out by one ore more contractors within different contracts. However there are standard procedures and phases that almost every project will go through. There are four main phases in each project, the design-, pre-qualification-, tendering- and construction-phase. All four phases will be discussed in the next sections. Figure 4-1 shows a simplified flow chart of these phases with their processes.

4.2 Design phase

In the design phase, the designer receives an assignment with requirements from the Client. Several investigations, studies and surveys are carried out to come to the complete design of the end product. During these studies assumptions are made based on the information as it is then available. The design can be based on an assumed method of construction. The final design will be used for tendering, which is the third project phase.

4.3 Pre-qualification phase

This phase starts with the *tender announcement.* This can be a public announcement or on invitation. In practice a number of contractors (at this stage they will be called tenderers) will subscribe. Not all tenderers that subscribe are suitable candidates for construction of the product. Therefore certain tenderers will be selected based on their experience, equipment owned, financial position and reliability during the *pre-qualification.* After the pre-qualification the *tendering phase* will starts.

4.4 Tendering phase

The pre-qualified tenderers collect the tender documents, which contain the design drawings, bill of quantities, and all other information a contractor needs to know in order to make a bid. Each tenderer then carries out his own investigations, makes his own assumptions, calculations and assessments (technical as well as commercial) and submits a bid and price to the Client before the tender closes. During the tender period tenderers can ask for clarifications of the tender documents on several occasions. With the bid-design the tenderer has to convince the Client and the Engineer that he is able to construct the designed product within the planned time schedule by submitting a planned working method, a list of equipment, manpower and time schedules.

After closing of the tender the submitted bid-designs and prices will be *opened and evaluated* by the Engineer. The Client, advised by the Engineer, will select a contractor based on the price and bid design. This is the *award of tender.* After the award of tender the contract documents will be prepared and signed and the construction phase can start.

4.5 Contract documents

For international construction work it is important that the contracts are clear, effective and complete. There are several organisations that have made a standard set-up for international construction contracts, based on many years of experience. Two main organisations are the

UK-based ICE (Institution of Civil Engineers) and the French originating FIDIC (International Federation of Consulting Engineers). The contracts of the Ennore Coal Port are all in FIDIC form because the Asian Development Bank (ADB) and the Ministry of finance require this form in all ADB aided contracts.

4.6 Construction phase

The construction phase starts with a contract kick-off meeting and is divided into different periods. During the *mobilisation period* the Contractor prepares the site and mobilises equipment and staff to the site. The Contractor has to submit further details of his working methods and methods of quality control. The Engineer must approve these methods before the Contractor can start with the *actual construction* of works. The Contractor constructs the works under supervision of the Engineer. During the construction phase it is possible that the Client desires changes in the scope of works. If the impact of the proposed changes do not greatly effect the scope of works, the Engineer simply instructs the Contractor to apply the changes. The Contractor is paid for these changes according to rates determined in the contract. If the proposed changes are larger or more complex of nature a *variation order* is issued. The prices of the works in a variation order are negotiable and are usually higher than the rates in the contract. When the actual construction of works is completed the Contractor demobilises from the site and *hands over* the works to the Client. The Contractor remains responsible for the state of the works for a certain period after the hand over. This period is called the *defects liability period.* After this period the Client takes over the responsibility and the project ends for both the Contractor and the Engineer.

4.7 Evaluation of projects

The progress of the actual construction process and the quality of the constructed works depends on the performance of the Contractor, weather conditions, political influences, obstructions, strikes, variation orders, third parties and unforeseen happenings.

Various studies such as risk analyses and climatological studies are carried out in the design phase in order to plan the project as accurate as possible. Nevertheless the actual construction process always deviates from the planned project. The deviations may have positive as well as negative consequences for the Contractor, the Engineer and the Client.

Evaluation during and after the construction phase is not always done but can be important and useful for future projects. Optimising processes in each phase of the project can decrease economical risks for the different parties involved. How did reality differ from the planned processes and what are the economical and technical effects of these differences on the project? It can be important to know whether the assumptions made by the designer in the design phase or the Contractor in the tender phase were realistic and what the impact of deviations of the assumptions were. Some of these effects might be the result of exceptional local circumstances and will not be applicable on other projects but there can also be relevant factors that might play a role in future situations.

Optimisation of a process for one party does not automatically result in improvement for the other parties. The Client, Engineer and Contractor will try to optimise processes to comfort their own interests, which are sometimes contradictory.

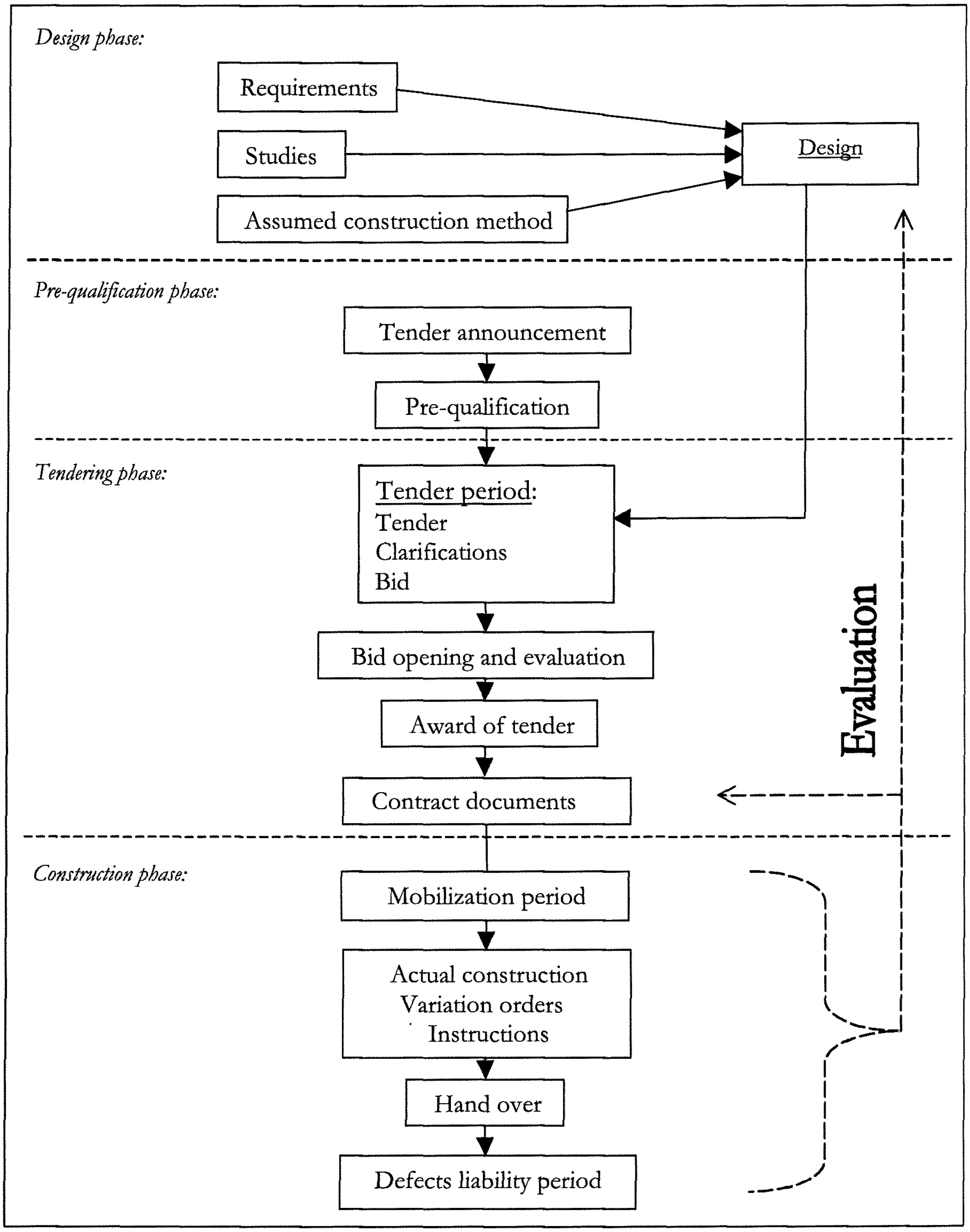


Figure 4-1: Simplified flow chart of the stages in large projects.

5 ROCK QUARRYING AND TRANSPORTATION

5.1 Studies

In the preliminary design phase of the breakwaters it was decided to construct rubble mound breakwaters. It was calculated that approximately 3.1 million tons of rock were required. Several potential locations for a quarry have been selected and visited. The most suitable site was found at Karikkal, 120 km west of Chennai.

Several trial blasts have been carried out in order to obtain data of the rock distribution, availability of sufficient armour rock and the possibility to control the quarry yield curve. The information obtained from the trial blasts has been used in the final design of the breakwaters and in the design of the coastal protection works.

A rock transportation study has been carried out by HASKONING and RITES. The most promising transportation method was by road for the first 25 km to a newly constructed transfer station at Melpakkam and then by rail to the Ennore port site. (See Figure 5-1)

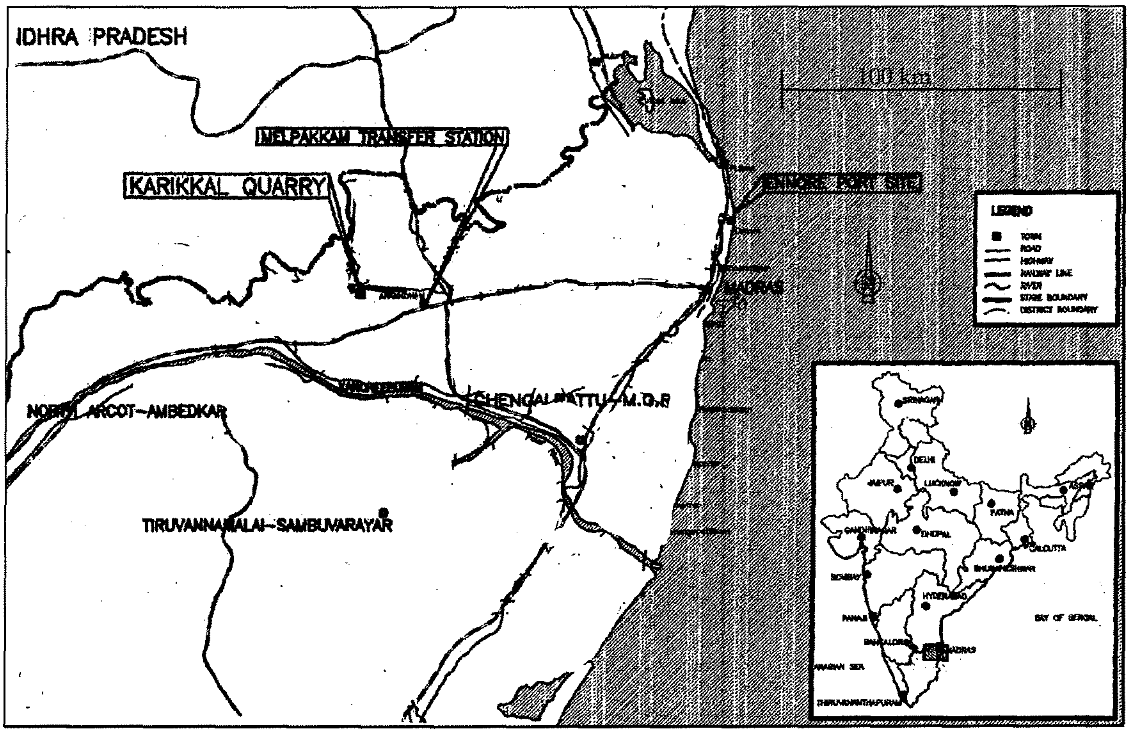


Figure 5-1: Location of Karikkal quarry and Melpakkam transfer station.

Too much handling of the quarried rock itself can cause degradation of the rock. In order to minimise the number of handling operations of the rock, it was decided to use open containers for transportation of the rock. Prototype containers, called skips, (see Figure 5-2) have been developed and tested at full scale handling operations. The results of the tests were satisfactory and it was decided to use the skips for transportation of rock for the contract.

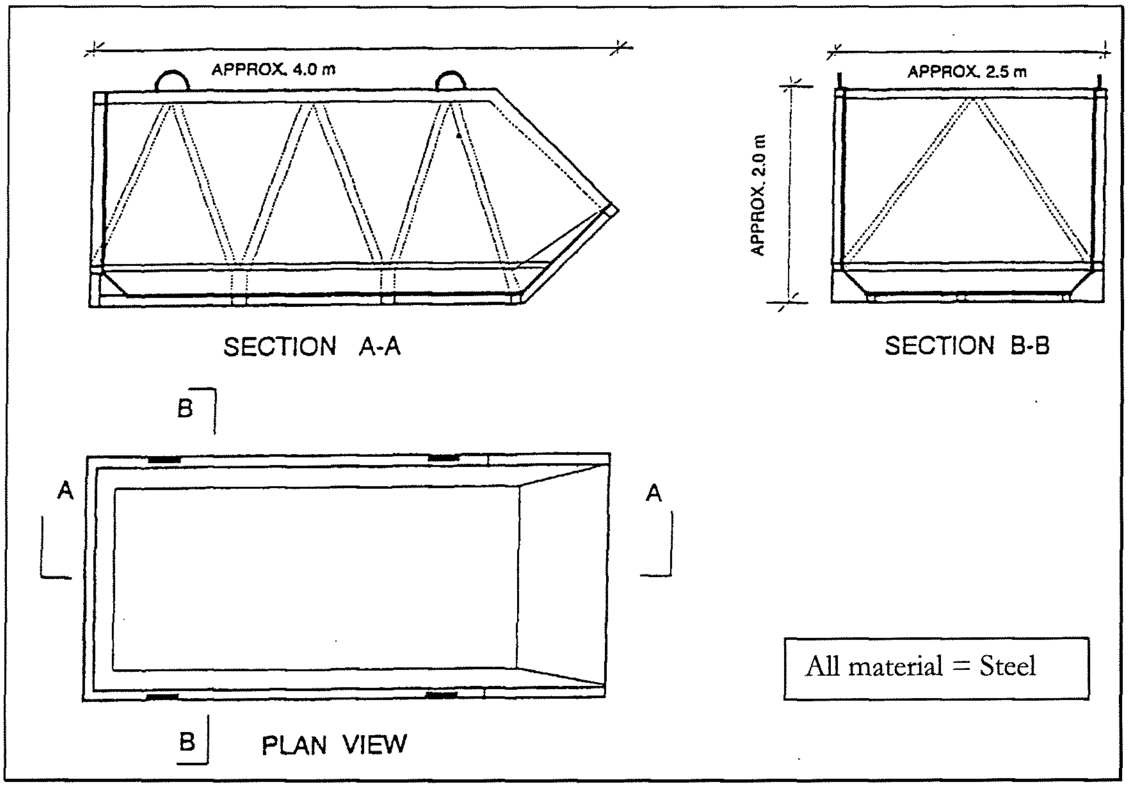


Figure 5-2: Sketch of a prototype skip.

5.2 Contract

5.2.1 General contract information

The contract was awarded to Hindustan Construction Company (HCC) for a bid price of 1.2 billion Indian Rupees (about 28.5 million US$) and signed on June 6th 1996. The commencement date was May 14th 1996. The contract is in FIDIC form, like all contracts in the Ennore Coal Port Project (see also section 4.4). The Client for this contract is the Chennai Port Trust and the Engineer is HASKONING in association with RITES.

5.2.2 Delivery requirements

Rock quality

The final design of the breakwaters contains eight different rock grading classes. The required limits of these grading classes are indicated in Table 5-1. Further requirements are that all rock to be sorted shall be sound, compact, hard, dense, rough, durable and free from seams, fissures, planes of weakness and blasting cracks. The rock must also be rough and angular in shape. If the length to thickness ratio of rock is larger than 3, the rock is called 'flaky'. A maximum of 5% of the rock may be flaky. The average specific gravity must be larger than 2,600 kg/m3 with none of the rock below 2,500 kg/m3.

Grading Class			Wy, weight of rock fragment (kilogrammes)			
			Extreme lower limit	Lower	Upper	Extreme Upper limit
	(kg)	(kg)	Y< 2%	0%<y<10%	70%<Y<100%	97%<Y
A	5.000	12.000	3.300	5.000	12.000	18.000
B	2.500	7.000	1.650	2.500	7.000	10.500
C	1.000	5.000	660	1.000	5.000	7.500
D	500	2.500	330	500	2.500	3.750
E	300	1.000	200	300	1.000	1.500
F	100	500	50	100	500	750
G	1	50	for 1kg: 10%< Y < 15%			
Q.R.	1	1000	for 1kg 0%< Y < 10 %			
y is the percentage, by weight, of rock fragments which are lighter than Wy						

Table 5-1: Rock Grading classes.

Production schedule

The production schedule has been divided into six sections of work. Prior to these sections a period of twenty-four weeks has been planned for preparatory works. The rock quantities and completion dates of each of the sections of work are shown in Table 5-2. The average rock price is about 10 US$ per produced ton. The Delays may cause shortages of certain gradings resulting in delays of the breakwater construction contract and should be minimised as much as possible.

Sections of work	Week Start	Week Ending	Cumulative target Delivery Quantity (in 1000 Tonnes)								
			Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G	Q.R.	Total
1	24	49	13	12	16	12	27	28	84	297	489
2	50	75	29	25	34	27	59	62	183	647	1.066
3	76	101	43	39	53	42	91	95	282	998	1.643
4	102	127	43	54	73	57	124	129	383	1.358	2.221
5	128	153	43	98	117	125	151	172	444	1.646	2.796
6	154	182	43	129	146	173	164	196	464	1.772	3.087

Table 5-2: Rock delivery targets from date of commencement (contract schedule).

Hand over of the exploited quarry

After completion of the sections of work the Contractor will demobilise and hand over the exploited quarry. An overview of the proposed quarry layout, cross sections and quarry volume calculations are given in Appendix I. The quarry is planned to be exploited between the 103 m and 223 m contour lines in such way that the final slope measured over the benches is not steeper than 45 degrees adopting a bench width and height of eight metres.

5.2.3 Scope of works

The first twenty-four weeks of this period are planned for preparatory works. The main activities during this period were the mobilisation and setting up of the site areas. In this contract there are three main areas for the activities of the Contractor: 1) the quarry site in Karikkal, 2) the Melpakkam transfer station and 3) an area at the Ennore port site.

The preparatory works at the project areas mainly consist of the following actions:

- Quarry site at Karikkal:
  - Clearing and disposal of bush, vegetation and overburden on site.
  - Diversion of local infrastructure.
  - Construction of access roads to the public roads.
  - Construction of site offices, workshops and a laboratory.
  - Mobilisation of equipment.
  - Mobilisation of a screening plant for separation of different rock gradings.
- Melpakkam transfer station:
  - Construction of access roads to the public roads.
  - Construction and installation of weighbridges and a site office.
  - Construction of Railway sidings (by Southern Railways).
  - Mobilisation and installation of gantry cranes.
- Ennore Port Site:
  - Construction of access roads to the public roads.
  - Construction of site offices and workshops.
  - Mobilisation of equipment to the site.
  - Construction of Railway sidings (by Southern Railways).

The public roads between the Karikkal quarry and the Melpakkam transfer station are going to be used heavily. These roads must be improved and maintained in good shape before and during actual production. Transportation of the skips from the Melpakkam transfer station to the Ennore port site and vice versa by rail is done by Southern Railways.

The actual production of rock is a repetitive process consisting of the following activities:

- Drilling, blasting and sorting rock at the quarry site.
- Loading the rock into skips at the quarry site.
- Transportation of the loaded skips by road from the quarry site to the transfer station at Melpakkam.
- Weighing of trucks at Melpakkam transfer station.
- Transportation of skips to the Ennore port site by rail (by Southern Railways).
- Stockpiling of the rock at Ennore.
- Return of empty skips to Karikkal

5.2.4 Working method

The working method of the Contractor is not precisely determined in the contract. The Contractor is however obliged to submit a detailed work method statement during the preparatory works. This work method statement has to be approved by the Engineer before the actual production may start, and can be used by the Engineer as supervision tool.

5.2.5 Payments

Every month the Contractor sends his interim bills to the Engineer who verifies, corrects (if necessary) and certifies the bills within 28 days. Then the Engineer sends the bills to the Client who has 28 days to pay the certified amount to the Contractor. At the end of the project, some adjustments to the bills may have to be made, this will be done by sending an additional bill.

When the Contractor fails to complete the sections of work in time, he has to pay liquidated damages until the section of works has been completed. For the first two sections and the final completion the amount of liquidated damages will be 50.000 IRs per day (about 1000 US$) and for sections 3 to 6 it will be 100.000 IRs per day (2000 US$) with a total maximum of ten percent of the contract price.

5.3 Actual construction phase

5.3.1 Preparatory works

Mobilisation of equipment and setting up of the different sites took much longer than planned. The railway sidings and gantry cranes needed for loading and off loading of skips were constructed very slowly. This was partly done by Southern Railways and could not be influenced by the Contractor. Improvement of the road between the quarry and the transfer station in Melpakkam took 5 months longer than planned.

Further it was noticed that the detailed workmethod statement submitted by the Contractor was not approved by the Engineer. Use of land outside the Contractors area and several unclarities about quality control and quarry development were the reason for disapproval. The Contractor changed some items in the work method statement but it still was not approved completely. At that moment, the Engineer could Have instructed the Contractor to stop his activities until the workmethod statement was approved, but this would probably only result in additional delays and would hardly improve the actual production methods. Therefore it was decided to let the Contractor continue his activities without an approved work method statement. One of the effects of this situation is that a useful supervision tool for the Engineer is not available. This complicates decision making by the Engineer on site.

5.3.2 Production phase

The actual production of rock is a repetitive process of the following activities:

- *Drilling:* The quarry yield curve of a quarry is influenced by the drilling pattern and the way of blasting. The main parameters in the drilling process are shown in Figure 5-3. In this quarry holes are drilled by a crawler mounted hydraulic drill and by wagon drills.

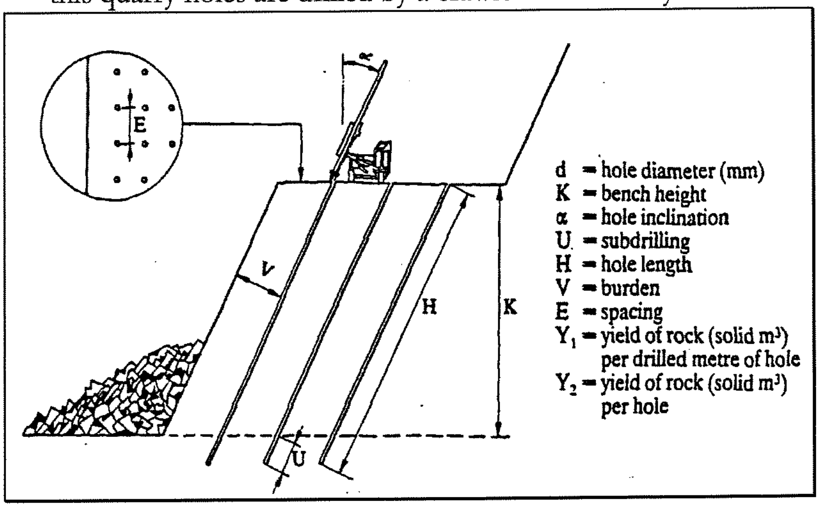


Figure 5-3: Drilling parameters, source [ref. 2].

- *Charging and blasting*: Blasting is done daily during lunch break. The drilled holes are charged with explosives. The explosives consist of a dynamite gel that set's off a relatively small blast, strong enough to fuse the actual explosive, a granular mixture of ammonia and diesel oil called ANFO.

- *Separation and removal of blasted rock:* After blasting the material is separated visually into two groups:

  1. *Rock of grade A to D weighing between 0.5 and 12 tonnes*: Rock of these grades is directly loaded (sorted per grade) into skips which are mounted on a truck at the bench. The rocks should be picked up by a crane with an orange peel grab and weighing arrangement in order to ensure grading limits. In reality however the orange peel grab and weighing equipment are not used. The rocks are selected visually at the bench and loaded into skips by a crane equipped with a chain as well as by excavators. Oversized rocks that are too large for group one will be broken by secondary blasting as well as by hand using a wedge and a hammer.

  2. *Rock of grades E, F, filter material and Quarry run*: Quarry run is loaded directly into skips by excavators. Rock for grades E, F and filter material (up to 1000 kg) is loaded into 15 tons tippers and transported to the rock processing plant. The purpose and processes of this plant are explained below.

- *Processing plant for grades E, F and filter material*: A special plant has been constructed for the production of grade E (300-1000 kg), F (100-500 kg) and Filter (0-50 kg with a controlled minimum of 10% and maximum of 15% smaller than 1 kg). The plant was designed to have a cascade of vibrating grizzlies in order to separate rock at 500, 300 and 100 kg and a crushing and screening plant for filter material.

  Grade E should be obtained by combining the separated fractions of 300-500 kg and 500-1000 kg. Grade F should be obtained by combination of fractions of 100-300 kg and 300-500 kg. During actual production, rock over 700 kg got jammed and blocked the grizzly. It was decided to abandon the grizzly settings for the 100-300 kg fraction and to modify the grizzly settings to a static grizzly. A fraction of 100-700 kg for both grade F and grade E was produced. This processed rock fraction was split up by means of visual judgement. Grade F was produced by removing oversized rock from the fraction with a back-hoe. Grade E was produced by supplementing the oversized F rock with larger rocks, visually sorted at the quarry face.

  Rock fragments smaller than 100 kg are crushed into fragments with a maximum size of 50 kg. The crushed fragments can still contain an excessive amount of fine material which should be removed. The fragments are transported to a screening plant that separates fragments at 1 kg and 4 mm. Material smaller than 4 mm are wasted, fragments from 4 mm to 1 kg (fine fraction) and from 1 kg to 50 kg (coarse fraction) are sorted in two separate silo's. The fine and coarse fractions are discharged in skips in the proportion of 1500 and 13500 kg respectively. A weighbridge is installed to monitor the proportions.

- *Quality Control*: Before the trucks with the loaded skips are transported to Melpakkam transfer station, the trucks stop under a constructed bridge where a visual inspection is done by the Engineer. If the skip contains lighter gradings (Quarry run, grade F and grade G) and there are only a few rocks in the skip that do not fulfil requirements, for instance flaky or weathered rocks, then these rocks will be removed by hand from the skip until the load is approved. If there are more or larger rocks that do not fulfil the requirements, or if there is too much sand and other debris in the skip, then the load will be rejected and the truck with the skip is sent back to the quarry, where it has to be properly reloaded. When the load in the skip is approved the truck driver receives a signed paper with the approval to be handed over to a representative of the Engineer at the weighbridge and the truck with skip is sent to the transfer station at Melpakkam.

- *Weighing of trucks at Melpakkam transfer station*: The amount of rock (in tonnes) that has been produced must be known in order to monitor the progress and to be able to pay the Contractor for delivered rock. At Melpakkam transfer station two weighbridges have been installed for this purpose. Each truck with loaded skip arriving from Karikkal quarry hands over the paper with approval of the load to the Engineers representative. Then the truck is weighed and the data is entered in a database. All empty trucks and skips have been numbered and weighed earlier. Therefore the net weight of the rock in the skip is known.

- *Skip handling and transportation to the Ennore port site (by Southern Railways)*: After weighing the trucks at Melpakkam transfer station skips are unloaded from the trucks and placed into train wagons. The skips are handled by travelling gantry cranes with an attached H-frame designed for lifting the skips. Two train rakes comprising of 40 wagons arrive daily. Each wagon is able to carry three skips which makes a total daily transport of 240 skips possible. This corresponds with a maximum production of about 240 * 15 = 3600 tons per day.

- *Stockpiling rock at Ennore*: Offloading is done by travelling gantry cranes similar to the ones used at Melpakkam transfer station. Offloaded skips are placed on dumper trucks and unloaded at the stockpile.

- *Returning the empty skips:* After unloading, the skips are returned to Karikkal. Handling and transportation is done the same way as at the trip to Ennore.

5.3.3 Quarry development

The plan for quarry development as submitted by the Contractor during the preparatory works never has been approved. Thus the Contractor started developing benches without any long term planning. The quarry was developed up to the 159 m contour line instead of the 223 m contour line. The result is an enormous amount of rock above this level that can not be reached due to high vertical walls. A new (unplanned) bench at the 95 m contour line has been developed in order to be able to produce enough rock. As a result thereof the hand over requirement of a quarry with benches of 8 m height and width and a final slope of 45 degrees can probably not be met. It was also noticed that waste and overburden are mostly pushed outside the Contractors area instead of being removed from the mountain. Further it was noticed that quarry roads are mostly very steep, narrow and not cleaned from overburden which makes these places dangerous to enter, especially during rain.

5.3.4 Payments

According to the contract the Client has to pay the monthly certified bills within 28 days after receipt from the Engineer. In the reality the Client does not do this. The Client thoroughly checks and adapts the bills and pays a changed amount, most of the time much later than 28 days from receipt. The changes made by the Client are mostly in the field of:

- Interest on late or incomplete payments of previous bills.
- Payments for work done under variation orders.
- Payments against claims submitted by the Contractor.
- Arithmetical errors in bills.

The procedures in the contract do not allow the Client to make changes to the certified bills. The right procedure is that arithmetical errors or changes due to payments for claims and variation orders can be corrected at all times by an Interim Payment Certificate made by the Engineer.

5.4 Progress

Progress of the production is recorded in the weighbridge records from Melpakkam transfer station. Weekly reports are sent to the Engineer with details of the rock that is transported to Ennore.

Due to the delays in completion of the railway sidings, an extension of time of sixty days was given to the Contractor. As a result all section completion dates were extended with sixty days. Table 5-3 shows the original completion dates, the extended completion dates and the actual situation in November 1998. It shows that the Contractor had fallen more than 19 weeks behind schedule of section 3 completion.

	Original (contract)	week	Extended: (60 days)	week	Actual
Section 1:	21/04/97	49	20/06/97	58	85
Section 2:	20/10/97	75	19/12/97	84	101
Section 3:	20/04/98	101	19/06/98	110	>129
Section 4:	19/10/98	127	18/12/98	136	
Section 5:	20/04/99	153	18/06/99	162	
Section 6:	08/11/99	182	07/01/00	191	
Overall completion:	31/01/00	194	01/04/00	203	

Table 5-3: Section completion dates.

Details of the newly planned production schedule (including sixty days extension of time) and the actual achieved production per grade are shown in Appendix II. Table 5-4 summarises the production schedules for the delays of each grade per section. It is notable that after a slow start the larger rock gradings (A to D) are ahead on schedule and that the smaller rock gradings are behind on schedule.

	Weeks delay per grade (negative = ahead)								
	Total	A	B	C	D	E	F	G	Q.R.
Section 1:	27	24	6	-2	5	18	27	12	-2
Section 2:	17	14	-3	-9	-6	14	17	10	11
Section 3:	> 19	8	-10	-16	-18	9	12	>19	14
Section 4:		-18	-18	-20	-24				
Section 5:									
Section 6:									
Overall completion:									

Table 5-4: delay of section completion in weeks.

There are various reasons for the delays that occurred. The main reasons are summarised below:

- Frequent breakdown of equipment and lack of spare parts for maintenance. The Contractor explains this occurs because of insufficient income from the project. (The Contractor is paying liquidated damages for not achieved completion dates of sections of work).
- Plant for separation of grades E and F and production of filter material does not work properly.
- Improvement of the road between the quarry and Melpakkam transfer station took 5 months longer than planned
- Complete mobilisation took 3 months longer than planned.

5.5 Future rock production

During the tender phase of the contract for breakwater construction the alignment of the north breakwater was changed (see chapter 6). As a result rock demands for the breakwater and thus for the production schedule of the quarry changed. Not only the total amount of rock but the proportions of the gradings changed as well. A variation order (v.o.) with the changes was issued in July 1998.

The actual production schedule of the quarry shows that the larger grades (A to D) are ahead on the original schedule and that smaller gradings (E to Q.R.) are behind the original planned schedule (see Table 5-4). The effect of deviating production proportions of the different gradings causes the remaining required production proportions of the grades to change ever more.

Changing the rates of the gradings might cause changes in the quarry yield curve which can be moderated by changing the blasting patterns. This can however only be done up to a certain level. In order to find out whether the deviating production schedule will cause problems for the remaining production it is necessary to have a closer look at the quarry yield curves of the actual production and of the remaining demands.

grade	Contract (tonnes)	(%)	V.O. Schedule (tonnes)	(%)	prod. upto jan-99 (tonnes)	(%)	demand aft. jan-99 (tonnes)	(%)
A	43	1	59	2	56	3	4	1
B	129	4	88	3	70	3	18	3
C	146	5	121	5	105	5	16	3
D	173	6	141	5	87	4	55	9
E	164	5	142	5	127	6	16	3
F	196	6	130	5	136	7	0	-
G	464	15	360	13	345	17	15	2
Q.R.	1772	57	1635	61	1151	55	484	80
Total	3087	100	2677	100	2077	100	607	100

Table 5-5: Quarry production quantities.

Table 5-5 shows the absolute and relative rock quantities of the original contract schedule, the variation order schedule, the actual production up to January 1999 and the remaining demand after January 1999.

To produce a quarry yield curve a partial distribution function must be known for each grade. In this case the total production per grade (in tons) is known but the distribution function per grade is not available directly.

Quarry yield curves can be expressed as cumulative weight distributions or as sieve curves. According to the report 'Grading Control on Quarried Rock' by W. St. Nicolaas [ref.3] traditional models for cumulative weight distributions that are used are:

- Log-linear model: This model is mainly used for narrow gradings.
- Schumann model: This model describes in-situ and as-blasted fragmentation curves.
- Rosin-Rammler model: This model is useful for a wide grading.

The Rosin-Rammler model could be used for partial yield curves of the different gradings but only for non-overlapping gradings. In this case the gradings are overlapping and these models for cumulative weight distributions can not be used to produce the quarry yield curve.

For each grade an assumption for the distribution function has to be made. Selection of the rock for the different gradings is done visually at the benches. The weights are estimated by looking at the size of the rocks. Therefore a normal distribution for the D_n of each grade is assumed. These distributions are shown in Figure 5-4 .

In order to calculate the total quarry yield curve of the total of all grades, two steps have to be taken. First each probability density function has to be multiplied with the percentage of the grade of the total production shown in *Table 5-5*. The second step is superposition of the obtained individual curves.
The results are given in
Figure 5-5 and show that the quarry yield curve for the remaining production is more ore less the same as the achieved production. It can be concluded that the deviating production proportions of the different gradings will probably not cause major problems in the field changing blasting patterns.

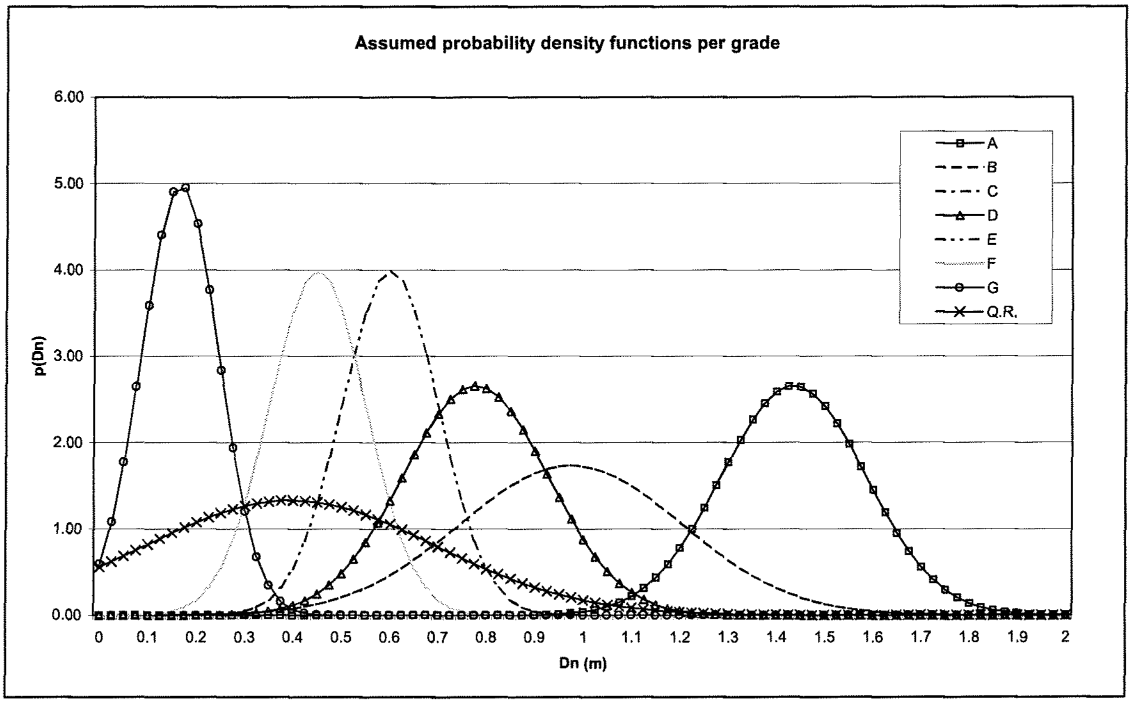


Figure 5-4: Assumed probability density functions for all produced grades.

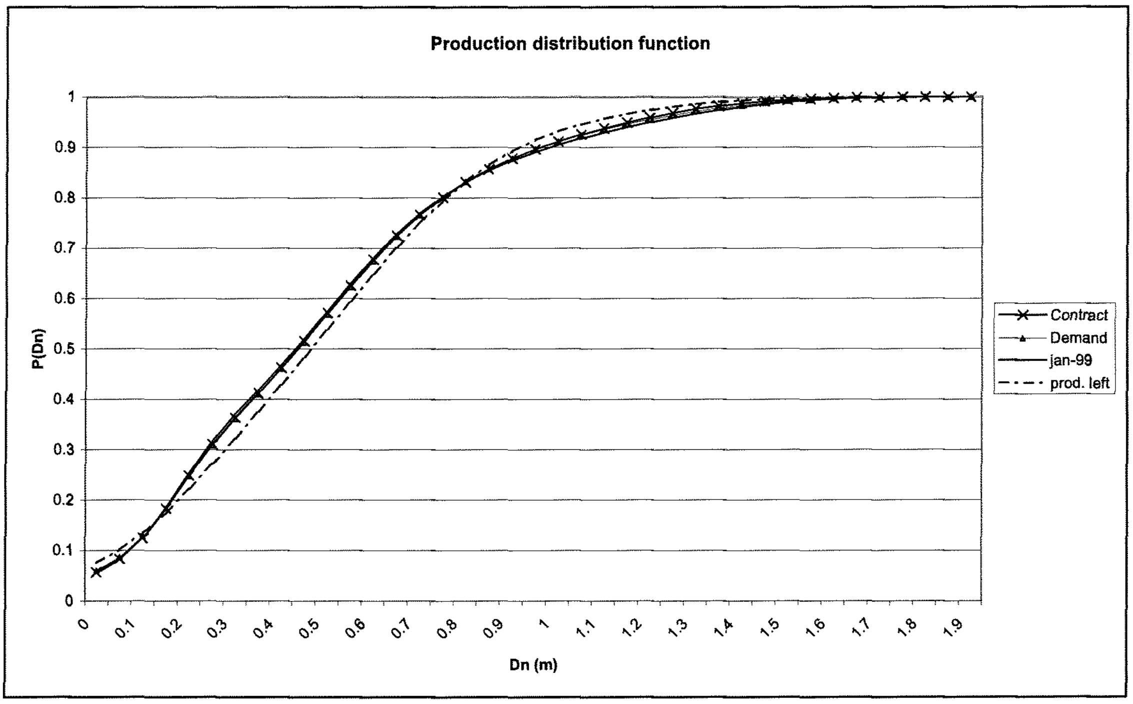


Figure 5-5: Production distribution functions.

6 BREAKWATER CONSTRUCTION

6.1 Detailed breakwater design

This section summarises the design process of the two rubble mound breakwaters. Bases for this section are the 'Detailed design report-Breakwaters' [ref.4] and 'Additional Design report for breakwaters, dredging and navigational aids' [ref. 5].
Requirements and physical site conditions gathered in several studies are used as an input in the design process together with a proposed working method. The requirements are discussed in section 6.1.1, the physical site conditions in section 6.1.2 . The approach and calculations that lead to the complete design are discussed in section 6.1.3. Section 6.1.4 discusses the proposed working method. The main results of the studies and calculations that are carried out, are given in these sections. For more detailed information of the approach and calculations is referred to Appendix III.

6.1.1 Requirements

The main function of the breakwaters is to provide safe conditions for the loading and unloading of vessels during a pre-determined lifetime. At Ennore an expected lifetime of 100 years was selected, being in line with the practice in India. In order to accomplish safe berthing conditions there are several functional requirements for the breakwaters:

- Provide basin tranquillity.
- Protect against sedimentation due to littoral drift.
- Provide visual guidance to vessels.
- Not designed as a survival port during cyclonic conditions.
- 100 years lifetime with a minimum acceptable level of maintenance.

6.1.2 Physical site conditions

Physical site conditions are the main boundary conditions for the design. The conditions that are discussed here are:

- Availability of construction materials.
- Logistic facilities and constraints, existing infrastructure.
- Bathymetry /morphology.
- Hydraulic boundary conditions:
    1. Water levels and tides.
    2. Wave conditions.
    3. Currents.
- Geotechnical conditions.

6.1.2.1 Availability of construction materials

The two main construction materials used in breakwaters are rock and concrete. The availability of rock was studied during the preliminary design phase, when the most suitable site at Karikkal was selected and trial blasts had been carried out. It was concluded that sufficient rock of good quality with a maximum size of 15 tonnes was available. The rock transportation study carried out by Haskoning and Rites restricts the maximum size of a single rock to about 12 tonnes.

No problems were expected with respect to the availability of cement, coarse aggregate and water for concrete construction. The availability of fine aggregates in the area of Chennai is limited. It is assumed that the Contractor makes his own arrangements for obtaining river sand as fine aggregates.

6.1.2.2 Logistic facilities and constraints, existing infrastructure

The following assumptions have been made with respect to logistics:

1. Rock is supplied on land near roots of the breakwaters
2. Site is accessible for heavy equipment
3. Work harbour will have to be constructed
4. Electric power is available at the site
5. Dry dock in Madras for emergency and maintenance docking
6. Area for Contractor is large enough

6.1.2.3 Bathymetry and topography

From July until August 1995 topographic and bathymetric surveys were carried out. The obtained information is used to determine the required quantities as well as the design waves at the structure.

6.1.2.4 Hydraulic boundary conditions

The area around Chennai is exposed to different climates throughout the year. From November until January there is a Northeast monsoon with heavy swell and high waves and chances on cyclones. From May until September is the period of the South-west monsoon with waves less higher and a low long swell.

1. Water levels and tides:

   Ennore has a moderate semidiurnal tide with a range of about 0.60 m. Extreme water levels have been calculated in a cyclonic hindcast study carried out by Delft Hydraulics [ref.6]. A maximum water level rise of 1.6 m to 1.8 m is calculated at the breakwaters.

2. Wave conditions

   - Normal wave conditions:

   The normal wave conditions have been studied by Delft Hydraulics in a Global Hindcast Study [ref.7]. A wave height of 2.25 m with an occurrence of once per year was calculated.

   - Extreme wave conditions:

   Extreme wave conditions will occur during cyclones. In the Cyclone Hindcast Study the extreme wave conditions were calculated using statistical evaluation and extrapolation of cyclonic storm records along the East Coast of India. A maximum deep-water wave for the 1 in100 years event has been calculated with $H_s = 9.1$ m and $T_p = 12.0$ s. For shallow water the results of this study are given in Table 6-1. The study also shows that due to wave breaking a $H_{2\%} / H_s$ ratio of 1.25 can be used.

Sea bottom level	Water level (+m CD)	water depth (m)	h/Lop	Hs/h	Hs,max (m)
3	1.83	4.8	0.021	0.64	3.1
5	1.80	6.8	0.03	0.59	4
6	1.78	7.8	0.035	0.57	4.4
8	1.73	9.7	0.043	0.54	5.2
10	1.68	11.7	0.052	0.52	6.1
11.5	1.66	13.2	0.05	0.5	6.6

Table 6-1: Maximum H_s for the 1/100 years event at various water depths.

3. Currents:
   During the Northeast monsoon the depth averaged flow velocity at 30 metres deep water is about 0.6 m/s southward. During the Southwest monsoon this is about 0.3 m/s northward.

6.1.2.5 Geotechnical conditions

Various onshore and offshore soil investigations have been carried out in order to collect information regarding the soil and subsoil conditions along the alignments of the planned breakwaters. Longitudinal soil profiles along the alignment of the breakwaters show that there is a soft silty to sandy clay layer partly overlain by dense to very loose silty sand. Below this soft clay stiff to hard clay with sand layers or lenses has been encountered.

6.1.3 Design

6.1.3.1 Approach

The objective of the designer is to create the most economical design that meets all the requirements as much as possible. Indian design standards are not available therefore the design is based on international practice. No construction methods were excluded on basis of local practice or availability of equipment in view of the design.

Four alternative designs of rubble mound breakwaters were compared in the preliminary design phase. The different characteristics of the four alternatives are:

1. Natural rock as primary armour with an S shaped berm.
2. Concrete cubes as primary armour for the deeper sections of the breakwaters.
3. Concrete tetrapods as primary armour for the deeper sections of the breakwaters.
4. Concrete Accropodes as primary armour for the deeper sections of the breakwaters.

The stability and functionality of all four alternatives were similar. The fourth alternative came out as the cheapest solution and was chosen to be developed further. Additional information during the detailed design phase was obtained from wave studies, offshore soil investigations and three dimensional model tests. During the three dimensional tests, the stability of the primary armour, stability of the toe, wave transmission and overtopping were tested. The preliminary design was modified where necessary and finalised in the detailed design report. In the additional design report the effects of the newly chosen layout on the detailed design were worked out. The northern breakwater was realigned and extended about 450 metres but the design principle of the breakwater did not change. The typical cross sections as designed in the detailed design report remained almost unchanged. Appendix XII.IV shows a comparison of the centre lines of both alignments.

Figure 6-1 shows a typical cross section of a rubble mound breakwater.

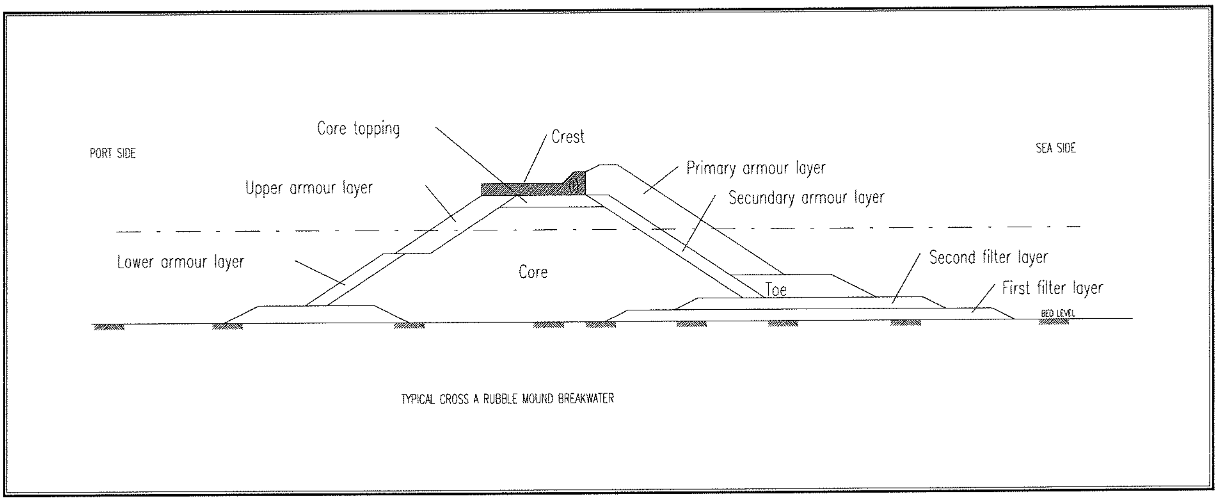


Figure 6-1: Typical cross section of a rubble mound breakwater.

The required properties of the various breakwater parts have to be assessed in the design phase. Combination of these parts all together forms the complete design. The issues in the design are:

- Armour stability due to wave attack
- Crest height/ overtopping
- Sublayers } Filter requirements
- Base and toe }
- Head of the breakwaters
- Geotechnical stability

6.1.3.2 Cost of a structure

The cost of a structure are roughly determined by the construction cost and the maintenance cost. A strong construction is more expensive but requires less maintenance than a less conservative designed structure. In Figure 6-2 the area of optimum cost is given for a structure.

However, deviations of the properties of a structure from the design can have effects on the strenght and thus on the required level of maintenace, and cost, of a structure. The effects of possible deviations on the properties of the end product sould be analysed carefully before the design is completed. An optimum design is not only the design with the optimum cost in Figure 6-2, but has also a strength that is not very sensitive for small deviations that can possibly occur during construction.

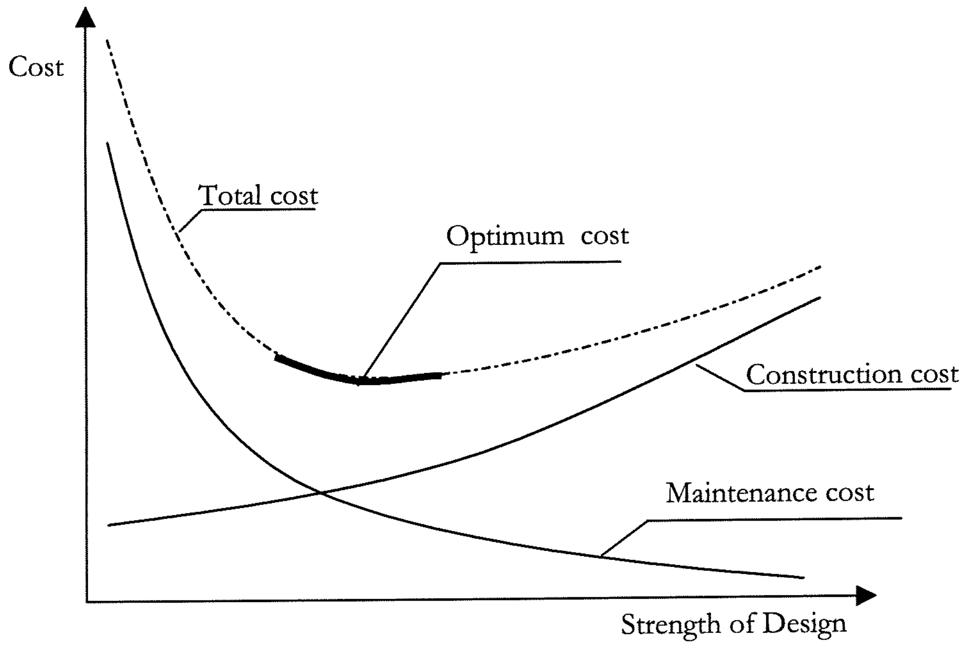


Figure 6-2: Cost of a structure

6.1.3.3 Primary armour at the deepest section of the breakwater

Primary armour at the deeper sections will be made of concrete Accropode units as decided in the preliminary design phase. Accropodes have been developed in the eighties by the French company 'SOGREAH'. When placed correct, they have moderate interlocking capabilities and can be placed in a single layer on a steep slope (1:1.33). Failure of an Accropode layer occurs at very high wave heights compared to tetrapods or cubes but is brittle. At that condition it is likely that failure follows. A safety factor of about 1.5 on the wave height or diameter is used to provide more safety from failure. Table 6-2 shows the selected Accropode sizes for various water depths.

water depth (m - CD)	selected Accropode (tonnes)
11.5 - 11.1	15
11.1 - 10.4	12
10.4 - 7.0	10

Table 6-2: Selected Accropode sizes for the north breakwater.

6.1.3.4 Rock as an armour layer

For the shallower parts of the breakwater (complete south breakwater and a part of the north breakwater) the use of rock is cheaper than the use of concrete units as primary armour layer. Wave studies carried out by Delft Hydraulics [ref. 8] showed that the south breakwater is protected from easterly wave directions by the north breakwater. For a considerable part of the south breakwater and north breakwater wave attack is very oblique to the structure. For the sections with oblique wave attack the following formula has been used for calculation of the required nominal diameter D_n of the rock:

$$D_n = \frac{H_s}{\Delta \cdot 1.25 \cdot 2}$$

This formula is derived from work carried out in the framework of MAST [ref. 9]. In Appendix IV the use of this formula is discussed. The armour size of the remaining sections of the breakwater has been calculated with the computer program Breakwat. An overview of the selected design conditions, required D_n, M_{50} and selected grading is given in Table 6-3. The required unit mass of the top layer has been determined for the deepest part of each breakwater section therefore shallower parts of each section are slightly over-designed. Therefore the Engineer might decide that, during construction, rock that does not entirely match the grading specifications of a certain section could be used for the shallower part of the section.

Break-Water	Section; bed level [m CD]	Water Level [m CD]	Water depth [m]	H_s [m]	M_{50} calculated [tonnes]	Selected grading [tonnes]	M_{50} of selected grading [tonnes]
South	Head / -9.0	1.70	10.70	3.60	5.70	5 –12	7.70
South	Head/ -8.0	1.75	10.25	4.50	7.20	5 –12	7.70
South	-8.0/ -7.5	1.75	9.75	4.90	4.95	5 –12	7.70
South	-7.5/-5.0	1.80	9.30	4.65	4.15	2.5 - 7	4.18
North	-7.0/-5.0	1.80	9.30	4.65	4.15	2.5 - 7	4.18
North / South	-5.0/0.0	1.80	6.80	3.40	1.62	1 - 5	2.20

Table 6-3: Selected design conditions for rock as primary armour.

The armour layers have a thickness of twice the nominal diameter D_n multiplied with a thickness coefficient. For the Port of Ennore a layer thickness coefficient of 0.9 is selected on the basis of Engineering judgement.

6.1.3.5 Crest height

The crest height is determined by allowable overtopping and wave transmission. The port is not a cyclone shelter, therefore a considerable amount of transmission is allowed under extreme conditions. However the acceptable significant wave height caused by transmission should not damage the port facilities and is set to a maximum of 2 m. Calculations and model tests show, that with selected crest heights of + 4.5 m CD (shallow sections) and +5 m (deeper sections) the transmitted wave height under design conditions is limited to about 1.3 meters.

6.1.3.6 Sublayers

The sublayers are designed as 1/10 to 1/15 of the overlaying layer (SPM) [ref.10] based on a 2 layer system. The thickness of the sublayers is, like the thickness of the primary armour layer, two times D_n multiplied with a thickness coefficient of 0.9.

6.1.3.7 Base and toe

The weight of the toe has been designed with the formula given in 'Conceptual design of breakwaters', Delft Hydraulics [ref. 11]. For toe support two one metre thick granular filter layers are chosen.

6.1.3.8 Head of the breakwater

The head of the breakwater is more vulnerable because the armour units are less supported and interlocked due to the curve in the layout of the slope. The head is therefore designed for a lower damage level. Detailing of the head is done in the detailed design phase after the 3 dimensional model tests took place.

6.1.3.9 Geotechnical design

Three main aspects are of importance for the geotechnical design namely: stability, settlement and erosion. Calculations during the preliminary design phase showed that the stability against slope failure was less than the usual safety standard. Several solutions to solve this problem are possible:

1. Remove and replace the soft material by better material
2. Place vertical drains
3. Apply a strong geotextile
4. Design a breakwater with flatter slopes
5. Construct the breakwater in stages; the lower part by floating equipment and the upper part by end dumping.

After obtaining additional information from the borings and cone penetration tests it was recommended to increase the stability by replacing existing soft material with sand for a part of the breakwater (solution 1) and to construct the breakwater in stages (solution 5). Calculations have shown that after compaction of the backfilled sand the strength of the subsoil is sufficient to carry the load of the breakwater.

The compaction requirements are:

- 1m below the top of the fill $-q_c \geq 6$ Mpa.
- 2m below the top of the fill $-q_c \geq 10$ Mpa.
- 3m below the top of the fill $-q_c \geq 12$ Mpa.

Raising the bed level decreases the required rock quantity. The three dimensional model tests showed that raising the bed level by 1 m did not cause instability of the toe and the remaining parts of the breakwater. It was decided to backfill the material to a height of 0.5 m above the original seabed levels plus a variable additional height for settlements.

6.1.3.10 Erosion at the breakwaters
Erosion of loose sand under a breakwater might occur when the breakwater base has not enough filter properties. This process may cause unwanted settlements. The filter layers chosen in section 6.1.3.7 must prevent this process.

Erosion along the breakwater can undercut the toe and makes it unstable resulting in a slip or worse a flow slide of the encountered loose sand. By extending the filter layer over a certain distance from the breakwater this type of failure can be prevented.

Scour development at the head of the north breakwater may cause higher waves attacking the breakwater. 2-D mathematical model calculations of this phenomenon have been carried out in order to calculate the dimensions of a possible scour hole. Results of the calculations show a scour hole of limited size. Therefore the height of the approaching depth limited waves is not likely to be influenced.

6.1.3.11 Crest element
A concrete crest element is placed on top of the breakwater in order to :

- To increase the stability of the crest of the breakwater.
- To retain primary rock armouring.
- To provide access of traffic to the small craft jetties.
- To provide access along the length of the breakwaters for inspection and maintenance vehicles.

6.1.3.12 Total design
Drawings of the total design, are given in Appendix XIII.

6.1.4 Construction aspects

It was decided to construct the breakwaters both by marine based construction methods and land based construction methods in order to increase the construction speed. A feasibility study has shown that the breakwaters could be completed within two years time with an average progress of 40 m per week. This study assumed the following equipment and practices:

- Marine based construction by rock dump vessel up to –4m CD.
- Loading of the rockdump vessel by front-end loaders and backhoe in a work harbour.
- Transportation of rock from the stockpile to the work harbour and head by 20 tonne rear dump trucks.
- Dumping of quarry run on the front and side slopes of the head from the trucks, assisted by a bulldozer; trimming of the slopes by a dragline crane.
- Placing of rocks and Accropode units in the armour layers and toe by a crane.
- Miscellaneous equipment for casting the Accropode units and for loading the units onto trucks at the casting yard; the same for loading rock onto trucks at the stockpile.

6.2 Contract

6.2.1 General contract information

The contract was awarded to a Joint venture of Hindustan Construction Company (HCC) of India and Van Oord ACZ of the Netherlands for a bid price of 2,3 billion Indian Rupees (about 55.4 million US$) and signed on the 22nd of August 1997. Van Oord ACZ carries out the marine based construction works and HCC the landbased construction works. The commencement date was the 7th of August 1997 and the planned completion date the 15th of August 2000. The contract is in FIDIC form like all contracts in the Ennore Coal Port Project (see also section 4.5). The Client for this contract is the ChPT and the Engineer is HASKONING in association with RITES.

6.2.2 Additional design

The detailed design report was used as a basis for the tendering papers. Because the strategic port development study, carried out by F. Harris, [ref. 1] was finalised during the tendering phase of this contract, the additional design report could only be presented as early as the same month of the award of the contract. The changes to the detailed design were known before the contract was signed. The changes were of considerable size. The northern breakwater was realigned and extended about 450 metres. But the nature of the works did not change too much, so the work method remained the same. Only the rock, concrete and dredging quantities changed.
At first sight it seems logical to include these changes in the contract because otherwise a variation order would be needed to implement the changes and it is commonly known that prices of works in a variation order are negotiable and are usually higher than contract prices. In this case however, the changes were considerable and when they would have been included in the contract, the tendering procedure would have to start all over again. The main reason is that it is possible that other tenderers could have made a better competing bid for the additional design than for the design used for tendering. In that case they might be wrongly rejected. Because of these considerations, it was decided to put the changes of the works in a variation order to be issued shortly after the award of the contract. At the time this report was written, negotiations about the prices of the works in the variation order were still going on.

6.2.3 Scope of works

The scope of works in this contract consist of the following main activities:

- Improvement of the foundation of the deeper parts of the North- and South-Breakwater. This will be achieved by dredging, backfilling and compaction.
- Dredging of the coal wharf trench, situated next to the south breakwater.
- Construction and removal of a temporary work harbour in order to facilitate loading of a rock dump vessel.
- Rock dumping, both with land-based (above -4 m CD) and marine-based (below -4m CD) construction methods.
- Casting of Accropodes and placement at the deeper sections of the North Breakwater.
- Construction of concrete crest elements on top of the breakwaters.
- Slope protection works

6.2.4 Planned time schedule

The contract has been divided into 5 sections of work. The completion dates of these sections of work are:

Section 1: Dredging of the coal wharf trench, 15 April 1998.
Section 2: All works on the south breakwater, 28 February 1999.
Section 3: Core placement below -4m CD, 31 March 1999.
Section 4: Rock placement below the crest slap, 15 February 2000.
Section 5: Completion of all works, 15 August 2000.

Figure 6-3 shows the planned timeschedule of the construction works for the contract including the sections of work.

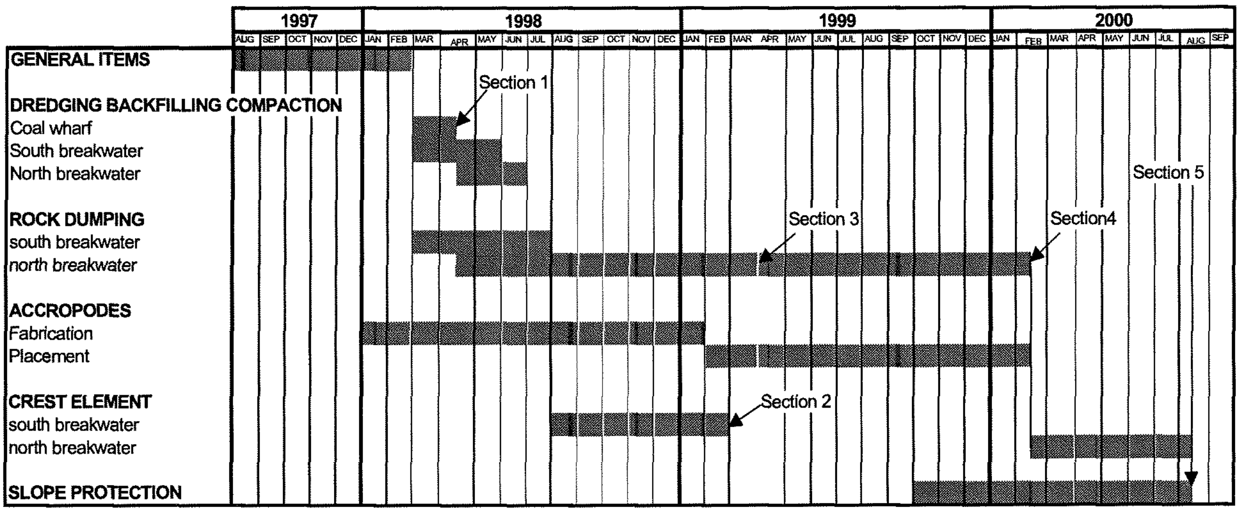


Figure 6-3: Planned time schedule and sections of work.

6.2.5 Working method

The main issue is that the breakwaters are constructed by both land based and marine based construction methods. The contract describes a planned general working method of the Contractor. The Contractor shows here that he is able to complete the construction within the given times pan. During the mobilisation period the Contractor has to submit detailed workmethod statements for various construction activities, which have to be approved by the Engineer. More information about the construction methods is given in section 6.3 where the actual construction methods are described and compared with the methods in the contract.

6.2.6 Tolerances

Tolerances and requirements are boundary conditions for the construction and monitoring of the breakwater. The nature of the construction makes it necessary to adjust the tolerances of different parts of the construction to properties of the materials or the used construction method. The contract prescribes tolerances and requirements for:

Used materials:

Properties of the backfill material

Rock quality
Concrete for crest elements
Concrete for Accropodes

Construction:
Dredging
Backfilling
Rock dumping and placement
Crest construction
Accropode construction and placement

Surveys:
Hydrographic surveys.
Land based surveys.

More information about the requirements and tolerances in the contract is given in Appendix V.

6.2.7 Payments

The Contractor sends his interim bills to the Engineer each month. The Engineer verifies, corrects and certifies the bills within 28 days. Then the Engineer sends the bills to the Client who has 28 days to pay the certified amount to the Contractor. At the end of the project, some adjustments to the bills may have to be made, this is done by sending an additional bill. When the Contractor fails to complete the sections of work in time he has to pay liquidated damages until the section of works has been completed.

6.3 Actual construction process

This section discusses the construction process of the contract largely in chronological order from the commencement date in August 1997 until December 1998. Construction of the concrete crest elements, slope protection works and placement of Accropodes had not yet started in December 1998 and is therefore not discussed.

6.3.1 Improvement of the breakwater foundation

Improvement of the breakwater foundation has been done by removal of soft material and replacement with coarse sand. Locations of the areas to be dredged are shown in Appendix XIII.

Additional soil investigation

Due to the realignment of the north breakwater, the centreline of the new north breakwater shifted out of the range of previous soil investigations. Because earlier studies showed a great variety in the subsoil, the Engineer decided it was necessary to carry out additional research. A variation order for the investigation was issued in march 1998. The variation order comprises borings, sampling and cone penetration tests.

The Contractor assigned Fugro India to carry out the borings and cone penetration tests. Fugro mobilised a small jack-up platform (12 x 12 m) called the 'Sungei Jamuna' to the area. The 'Sungei Jamuna' was assembled in the Port of Chennai and brought to the site by two tug boats.

Already during the first operation the shoes of the 'Sungei Jamuna' sank into the weak subsoil and were hard to retrieve. The small shoes of the platform legs were enlarged with steel plates and operations were resumed. The platform however was still not completely suitable for off-shore working conditions. The shoes of the platform still sank into the bottom on some locations. The platform was also damaged by swell. Two borings and one cone penetration test could not be carried out because of this.

Results of the investigations showed that the layers with soft clay were found deeper than on the original location of the north breakwater. As a consequence it was decided to enlarge the depth of the north breakwater trench from 15 to 18 m at the weaker parts. A variation order was issued with additional quantities for dredging and backfilling.

Dredging
Dredging was done with the trailer suction hopper dredger 'Volvox Hansa' and cutter suction dredger 'Orwell'. The dredged material was dumped at an off-shore location about ten kilometres from the port site. Dredging operations took place 24 hours per day and continued until the post dredging surveys (see section 6.3.7.1 for details) were approved by the Engineer.

Backfilling
After approval of the post dredging surveys, the trenches were filled with coarse material. This material was found on an offshore location situated a few kilometres from the port site. Backfilling was also done by the 'Volvox Hansa' and the 'Orwell'.

During the filling of the hoppers, three samples were taken from each load. These samples were roughly visually checked on particle size (D_{20} should be larger than 0.300 mm). If more than one sample appeared to be unsuitable, the load would have to be dumped at an off-shore disposal area at the Contractor's expense. The visual checks were tested afterwards in a laboratory. Using the ships log it would thus still be possible to locate unsuitable material in the breakwater trench. All laboratory tests however confirmed the visual checks. The samples taken of the material were even significant coarser then the samples taken during studies in the design phase.

Compaction
The properties of the backfill material (coarser sand than expected with a high percentage of shells) made it questionable whether there still was a need for compaction works. Unlike fine sand, coarse sand has even in a loose state a high internal angle of friction. Dumping the sand from trailing suction hopper dredgers gives already a degree of densification.

The contract provides fill strength requirements after compaction. There are specified in terms of cone penetration resistance, q_c, as given below.

- 1m below the top of fill $q_c \geq 6$ Mpa.
- 2m below the top of fill $q_c \geq 10$ Mpa.
- 3m below the top of fill $q_c \geq 12$ Mpa.

The contractual requirements are derived from the relationship between the angle of internal friction and the cone resistance for fine sand. During the design it was not realised that for coarser sand with shells, the requirements for cone resistance would need to be adjusted downwards. Slip circle calculations during the design phase showed that an angle of internal friction of at least 30° is required to ascertain the overall stability of the breakwaters.

The Contractor was instructed to carry out a pilot compaction test. During the tests a small area of the backfilled sand was tested, compacted by means of vibro-compaction and tested again in order to determine the effect and necessity of compaction. Based on the results of the tests it would be decided whether compaction works would still be necessary.

The tests comprised cone penetration tests (CPT), vibro core sampling and laboratory tests of the samples (direct shear box tests, triaxial tests and determination of the particle size distribution). Nine different compaction scenarios were tested, in order to obtain an optimum working method, varying the grid spacing, depth, frequency, duration and time of compaction.

The Contractor sub-contracted 'Alluvial Mining Ltd. of Fugro, India' for the vibro core sampling and 'F.S. Engineers Private Ltd. of Chennai' for the laboratory tests. The vibro compaction was done by the Contractor under guidance of 'Van Splunder Fundering B.V.'

Vibro coring was done using the following equipment:

- Rock dump vessel 'Jan Steen'.
- 200 tons deck mounted crane.
- Vibro-core unit (frame, vibrating block and core).
- Power supply.

Positioning of the 'Jan Steen' was done using Differential Global Positioning System, Dynamic Positioning and anchors. The vibro core unit was lowered by the crane on the deck of the 'Jan Steen' into a pre-determined position on the seabed. Then the vibrating block was used to vibrate the core into the seabed until the required depth was reached. The core was extracted and a sample was taken from the core, sealed and transported to the laboratory.

The following equipment was used for the CPT's:

- Rock dump vessel 'Frans'.
- 40 tons deck mounted crane.
- CPT unit (frame, drive unit, rods and piezo-cone).
- Container (Central Console).

Positioning and placing the CPT unit on the seabed was done the same way as described above for vibro coring. The cone, connected to rods, was inserted into the seabed at a rate of 2cm/s during which the cone end resistance, local friction and pore water pressure were recorded. After reaching the desired depth, the CPT unit was lifted from the bottom.

Vibro compaction was done using the following equipment:

- Rock dump vessel 'Jan Steen'.
- 200 tons deck mounted crane.

- Compaction-unit (frame, vibrating block and compaction needle).
- Power supply.

After positioning (as described above) the vibrating block, connected to the top of the compaction needle, was activated. The vibrating needle was lowered under its own weight to the required depth, stayed there to compact for a certain amount of time. Then the needle was lifted over a specific distance and again stayed there to compact for a certain amount of time. This process was repeated until the needle was lifted over the entire height of the backfill.

Details of the pilot compaction test are discussed in Appendix VI. The most important results are shown in Table 6-4. It can be seen that even after compaction the requirements of cone resistance as stated in the contract are not met. However a stable foundation requires an internal angle of friction of 30 degrees which was already reached without compaction.

	Before compaction	After compaction
Average cone resistance (Mpa)		
1 m depth	2.2	5.1
2 m depth	2.9	5.1
3 m depth	3.1	6.2
Internal angle of friction (degrees)	30-40	40 - 45

Table 6-4: Main results of pilot compaction test.

Based on the test results it was concluded that the back-fill in the trenches provided a good foundation without compaction and that compaction was no longer required. The Contractor was instructed to cancel further compaction activities and the foundation was considered to be completed.

6.3.2 Construction of a temporary work harbour

In order to facilitate loading of a rock dump vessel, it was necessary to construct a temporary work harbour. The location of the work harbour was planned to be constructed at the – 4 m CD contour line along the north breakwater for the original alignment (see Figure 6-4). The new alignment shifted the root of the north breakwater about four hundred metres northwards in the direction of the a shallower area, called the Ennore Shoals. The contract states that the location of the work harbour would shift along with the north breakwater. With the changed alignment, the -4 m CD contour line shifted from chainage 200 to chainage 850 of the north breakwater. This would imply that the north breakwater had to be constructed up to chainage 850 before the construction of the work harbour could start and that during that time the south breakwater could not be constructed by marine based methods. However construction of the south breakwater was planned first in order to stop the northwards sediment transport that occurs nine months per year in an early stage. The dredged coal wharf trench and the constructed work harbour are then more or less protected to sedimentation. The Engineer instructed the Contractor to construct the work harbour at the location of the root of the original north breakwater. The Contractor made a new design for the work harbour (see Figure 6-5A) and started the construction. At that time the land-based construction progress of the root the south breakwater was very low. The northwards sediment transport had not been stopped yet and the root of the work harbour accreted quickly. The direction of the protection bund of the north breakwater was changed from southwards into northwards (see Figure 6-5B) in order to minimise dredging of the work harbour.

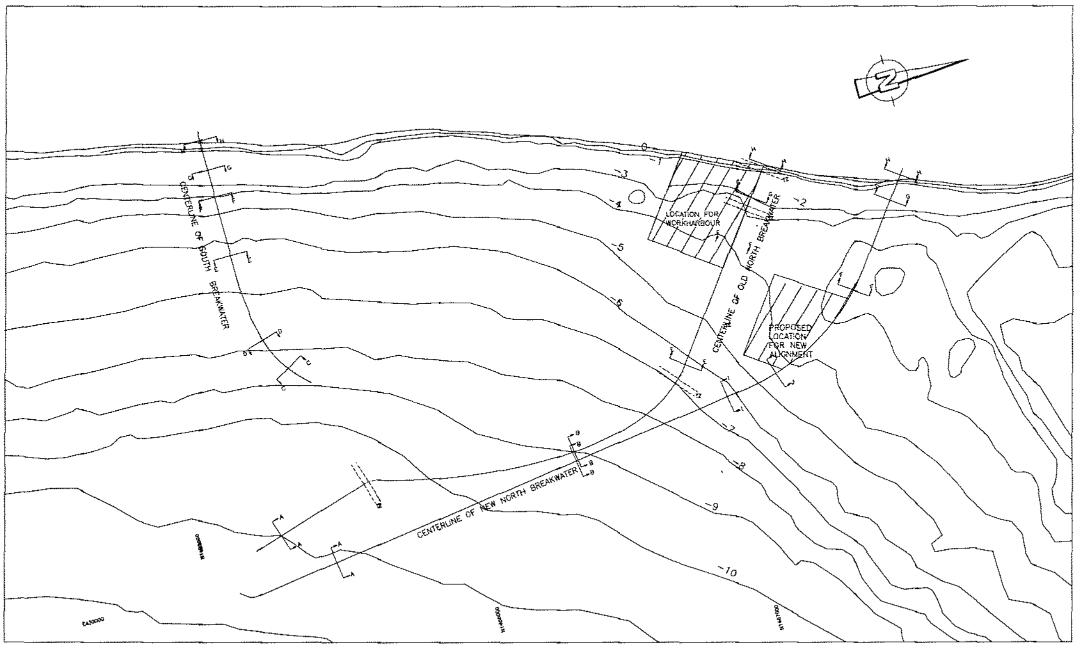


Figure 6-4: Locations of the planned work harbour.

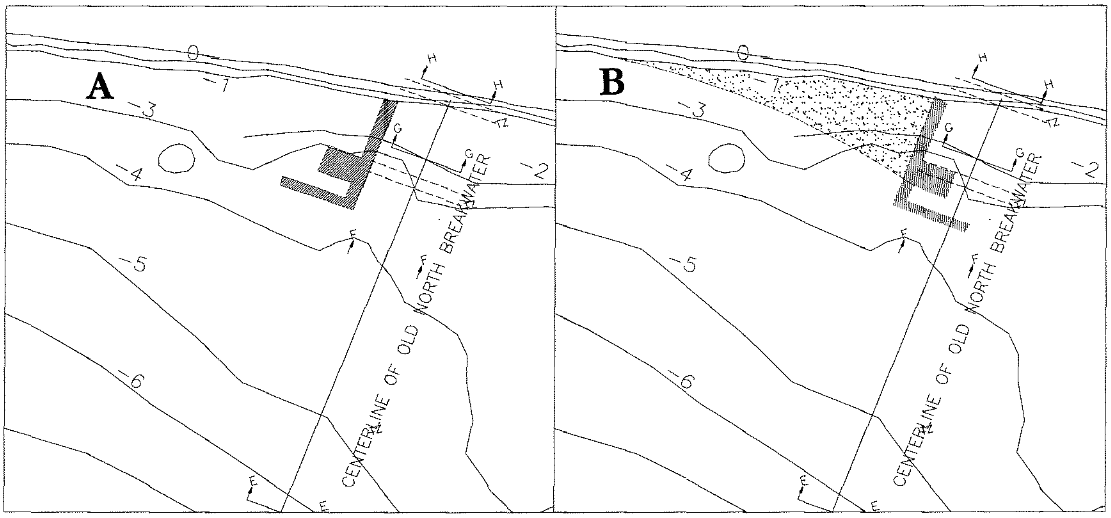


Figure 6-5: Design of the work harbour: A approved design, B changed orientation of protection bund due to accretion at the access bund.

6.3.3 Weighing of rock and transportation from the stockpile to the breakwaters or work harbour

The rock on the stockpile is property of the Client and the Contractor has to pay the Client for the rock per tonne he uses. Therefore two weighbridges are installed next to the stockpile. At the stockpile rock is loaded on trucks. The smaller gradings; quarry run , filter material and small armour rock (grades D,E,F, G and Q.R.) are loaded by back hoe and front-end loader into dump trucks. The larger rock gradings for armour rock (grades A to C) are placed on flat-bed trucks or dump trucks by a crane with the use of a chain with a hook. After loading, the trucks drive to one of the two weighbridges and are weighed there. In an earlier stage all empty trucks have been numbered and weighed with a half-full fuel tank as to calculate the net weight of the rock. At the weighbridge the weight of the loaded rock, the destination of the rock (e.g. grade A in secondary armour layer, south breakwater, land-based), the truck number and driver name are entered in a database by the Contractor. An Engineer's representative supervises the Contractor in the weighbridge. A piece of paper with all necessary information is printed, signed and given to the truck driver. After weighing, the trucks will drive to their destination (the work harbour/south breakwater or north breakwater). The trucks are unloaded there and the printed papers are checked and collected. The empty trucks go back to the stockpile where they are loaded again. A schematisation of a complete truck cycle is shown in Figure 6-6.

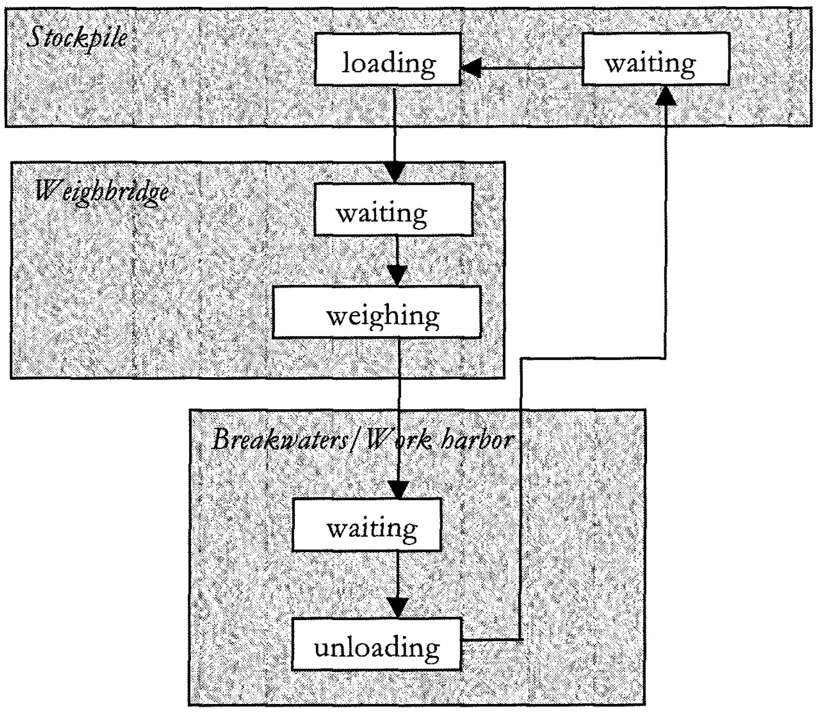


Figure 6-6: Truck-cycle for breakwater construction.

Daily and weekly reports with details of weighed rock are collected by the Engineer in order to calculate necessary payments and monitor the rock quantity available on the stockpile.

6.3.4 Marine based breakwater construction

The filter layers, core and toe for parts of the breakwaters below –4 m CD are constructed the side stone dump vessel 'Frans' which is loaded at the work harbour by two backhoe cranes. Positioning of the 'Frans' is done using Differential Global Positioning System and Dynamic Positioning. For the south breakwater marine based dumping started at about chainage 350 to the head (total length approx.750m) and for the north breakwater from chainage 1100 to the head (a length of 2000 m). The sequence of rock dumping is:

1. First filter layer.
2. Second filter layer.
3. Core.
4. Toe.

Before and after each dumped load a hydrographic survey is taken. This is discussed in section 6.3.7. In the typical cross sections it can be seen that that construction of the toe can only take place after construction of the secondary armour layer (Figure 6-7A). Because all armour layers are constructed by land based construction methods this would mean that the rock dump vessel has to wait until the land-based construction has reached a certain construction level. The rock dump vessel then would have to come very close to the constructed breakwater and dump the rock for the toe. Because this method would significantly slow down the construction process it was decided to slightly change the design. The new design allowed that all marine based constructed layers could be constructed before land-based construction commenced (Figure 6-7 B).

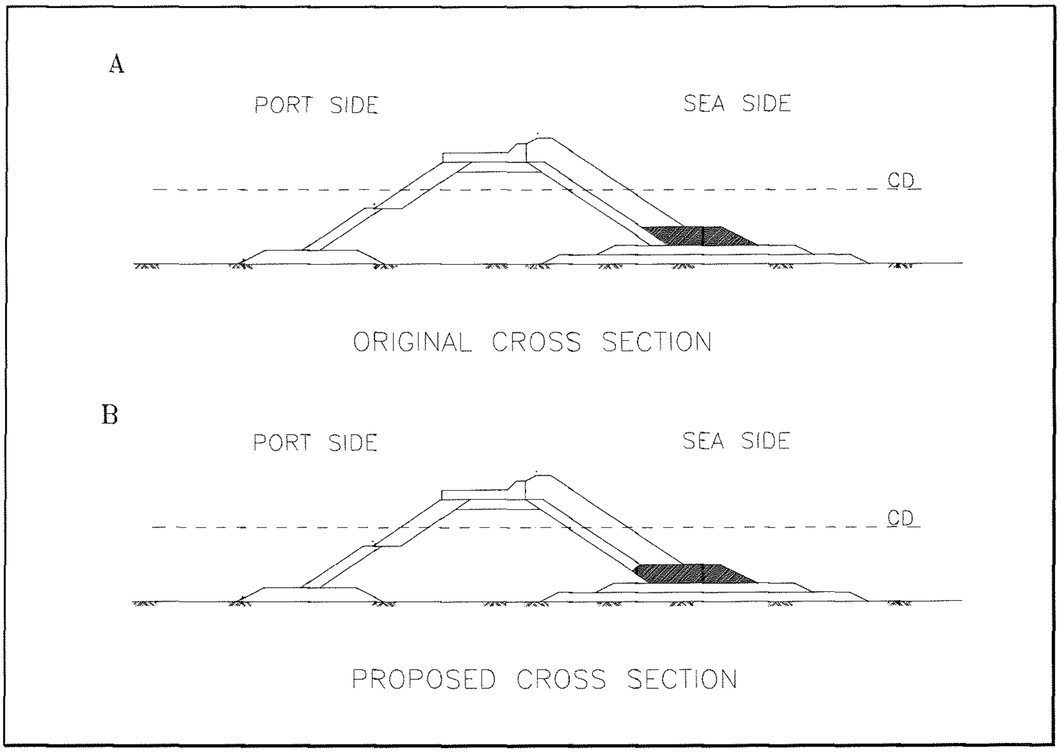


Figure 6-7: Changes in design to comfort marine based working method.

6.3.5 Land based breakwater construction

Up to chainage 350 the south breakwater is completely constructed by land based construction methods. Further on the filterlayers, core and toe are constructed up to –4 m CD by marine based construction methods. Land based construction starts at the root and commenced from there on into the direction of the head. The construction sequence for the land-based construction is:

1. Dumping the filter layers by crane with the use of a tray attached to the crane; first filter layer from chainage 150 up to chainage 350 and the second filter layer from chainage 330 up to chainage 410.
2. Dumping of the core material by 10 tons dump trucks as well as 30 tons dump trucks.
3. Pushing the quarry run of the work front using a bulldozer
4. Shaping the slope using a backhoe.
5. Placing of the armour layers using a 50 tons crane with an attached chain and hook. The upper and lower armour layers on the port side and the secondary armour at the sea side were also directly dumped on the slope from end dumping trucks. This step is done at the same time as the other steps but at a lower chainage.

The core topping layer was constructed in a few large stages starting at the work front and working backwards in the direction of the previous completed section. The core toping layer is made of grade E rock (300-1000 kg) with a thin layer of filter material (1-50 kg) and sand on top to allow trucks and cranes to drive on the layer. The material is dumped by dump trucks and shaped by backhoe. Surveys are taken before and after each constructed layer; the survey methods are discussed in section 6.3.7.

At the start of the construction, the Contractor had trouble to construct the root of the south breakwater. Wave action and currents induced by the cooling water outlet channel of the North Madras Thermal Power Plant, located next to the breakwater caused the seabed to change quickly and part of the dumped rock was washed out. The Contractor continued dumping rock until the rock was not washed out anymore. According to the original design the cooling water outlet channel was located at the north side of the root of the south breakwater. The Client decided that the outlet channel could be constructed at the south side of the breakwater. That would have the advantage that the access road of the south breakwater would not have to cross the channel. Construction of a bridge would then not be necessary. More details and the effects of this relocation are further discussed in section 6.6.3.

The design of cross sections D-D, E-E and C-C of the south breakwater and A-A, B-B, I-I and J-J of the north breakwater show a berm in the core at the port side (Figure 6-8 A). It is not easy to construct such a berm by dumping the rock from the work front. In order to create such a berm, rock would have to be placed by a crane with the use of a tray similar to the way the filter layers are placed. This would slow down the construction speed. The Contractor proposed to slightly modify the design of these cross sections in order to increase construction speed. The changes comprise removal of the berm in the core by increasing the thickness of the lower armour layer (Figure 6-8 B). The Engineer approved the proposed changes because the strength and functionality of the breakwater was not decreased and the construction speed indeed could be increased.

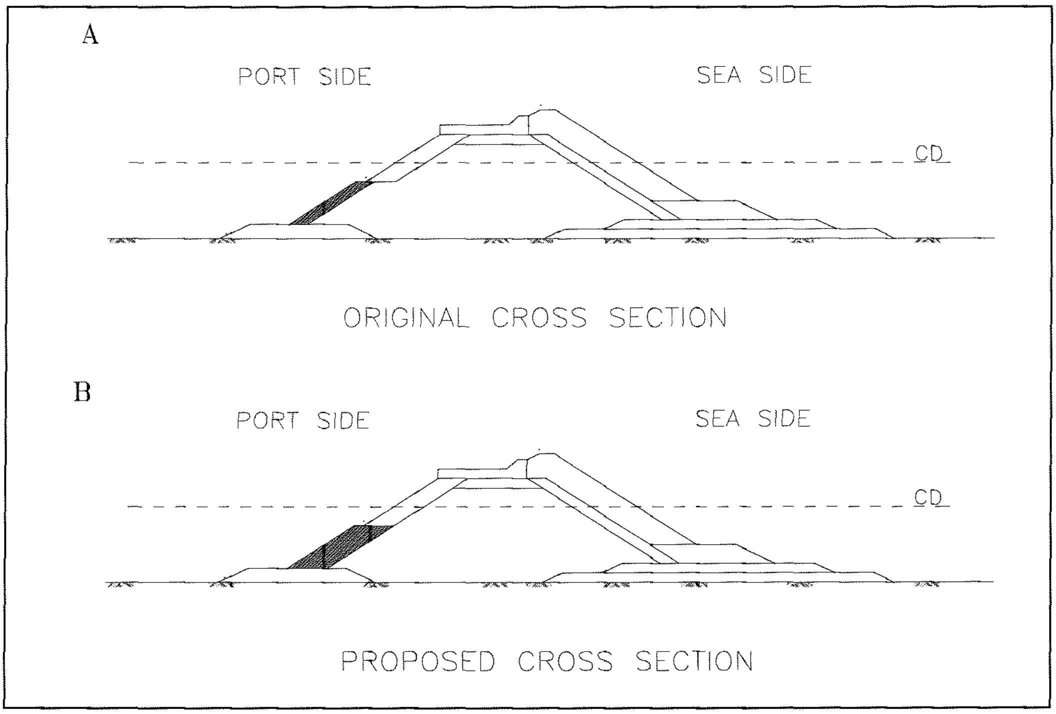


Figure 6-8: Changes in design to comfort land based working method.

The slopes of the breakwater were trimmed using a backhoe. However the backhoe could not reach the entire slope of the breakwater. Especially the rock on the deeper parts of the slope could not be trimmed this way and remained as dumped by the trucks and bulldozer. The surveys had to give insight in the shape of the trimmed slopes.

Placement of armour rock was done by a 75 tons crane with a chain and a hook. It was very time consuming to load and place each rock with the use of a chain and a hook. There were orange peel grabs available which could increase the construction speed but the Contractor did not use them. The largest rocks of the A grade weighed up to 18 tons. These rocks were placed close to the crest of the breakwater because otherwise the used crane would tilt. The lower parts of the armour layer were thus constructed with the smaller rocks of the grading.

6.3.6 Casting of Accropodes

About 5200 9.6 tons, 3800 12 tons and 500 15 tons Accropodes will eventually be placed as primary armour layer on the north breakwater. All the Accropodes are constructed by the Contractor on site of the Ennore Coal Port. The French company 'SOGREAH' has an international patent on the blocks. They only guarantee the functionality of the Accropodes when the Accropodes are constructed and placed to their specifications.

6.3.6.1 Formwork

Accropode forms are made of two identical shells without any fixed formwork base. The shells are placed on a sand bed with a sheet of polyane that separates the form and the sand. Before casting of the Accropodes commenced, design drawings and moulds were checked by the Engineer and by SOGREAH.

6.3.6.2 Concrete batching plant
A concrete batching plant was erected on the port site specially for construction of the Accropodes and the breakwater crest. The concrete batching plant was supposed to operate fully automatically. In reality this could not be achieved and the plant was operated manually which decreased the production rate.

6.3.6.3 Concrete properties
The main requirements for concrete are that it can be handled in the fresh state and that it is strong and durable when hardened. Concrete consists basically of four elements: cement, coarse aggregates, fine aggregates and water. The properties of the concrete are determined by mixing proportions, mixing, transportation, placing, compaction, curing and finally the temperature and humidity of the environment.
The Contractor had difficulties in obtaining the right mixing properties. Trial casting showed a lot of bleeding. The water in the mix did not react completely, rose to the surface and evaporated. This could eventually cause cracks which are of course unacceptable. Bleeding indicates a shortage of fine material in the mix. The water needed more specific surface to react completely. It was concluded that the used fine aggregates were not fine enough. Several mixes with fine sand from different sources were tested. This eventually lead to a mix according to SOGREAH's specifications.
The weather conditions (temperatures sometimes rising above 40 degrees Celsius) made concreting a difficult task. Extreme heat reduced handling times and could cause cracks as well. Therefore crushed ice was added to the water in order to keep temperatures low.

6.3.7 Surveys

The actual breakwaters should be realised according to the design specifications as much as possible. Surveys are an aid for the Engineer to check the work done by the Contractor. Several processes at the project are monitored by surveys:

- The required dredging depth, this is done by a hydrographic survey method.
- The Backfill height of the breakwater foundation, by a hydrographic survey method.
- Marine based rock dumping, by a hydrographic survey method.
- Land based breakwater construction, by a land based survey method.
- Visual surveys.
- Coastline monitoring.

6.3.7.1 Hydrographic survey method
Hydrographic surveys are taken to monitor the marine based construction activities (dredging, backfilling and rock dumping). Before each construction activity a so called in-survey is made in order to obtain a reference level. After the activity has taken place a survey is made again (out-survey) to determine the effect of the construction activity. Hydrographic surveys are taken from the survey vessel 'Kamal'. The vessel is equipped with a global positioning system and echo sounding equipment. Breakwater cross sections are surveyed every ten metres chainage. The vessel navigates in straight lines perpendicular to the centreline of the breakwater and records depths at location with a spacing of 5 metres for the in-survey and 1 metre for the out-survey. The cross section is determined by the

difference in bed levels between the in and out survey. A result of a hydrographic survey is given in Appendix VII .

The sea water level is constantly recorded by a tide gauge stationed in an abandoned ship wreck close to the work harbour. These levels are used to compare the levels recorded by the echo sounding equipment to CD.

6.3.7.2 Land based survey method

Land based surveys are taken to measure a cross section every ten metres chainage (near the root of the breakwater every five metres chainage). First the centreline of the breakwater is marked and the chainage of the cross section that will be surveyed is checked. Two rods are placed on both sides of the breakwater perpendicular to the centreline. A crane is stationed on the breakwater. The survey is taken from a tray attached to the crane with the use of a sounding pole with a spherical end. The tray is placed perpendicular to the breakwater in line with the two sounding poles. The distance to the centreline of the breakwater is measured with a lint and the depth is measured with intervals of one metre. The measured heights are compared to the height of an earlier constructed point on the breakwater in order to obtain the level compared to CD. The entire process is done by the Contractor under supervision of an Engineer's representative. This process is repeated after each constructed layer. The Contractor is only allowed to construct a layer on top of the previous layer when that layer is approved by the Engineer. Appendix VII shows a result of cross section obtained from land-based surveys, compared to the theoretical cross section.

According to the contractual requirements the end of the sounding pole should be spherical with a diameter of half of the D_{n50} value for the material being surveyed. In reality a single sounding pole is used for all layers. Horizontal positioning of the bucket under the crane requires good crane handling skills and is not always done correct. The contract requires an accuracy of 0.5 m horizontally and 0.1 m vertically. It is questionable whether this accuracy is really achieved.

Approval of the constructed breakwater will be partly based on the surveys. Only after approval of the surveys the Contractor may continue the construction of the overlying layers and gets paid for his work. Sometimes this has lead to disputes between the Engineer and the Contractor and it could be questioned whether the surveys that were handed over were carried out correctly. The Contractor occasionally tried to hand over surveys to the Engineer for approval before the 'surveyed' part of the breakwater even had been constructed. These surveys were obviously refused by the Engineer. It is also notable that the surveys of cross sections E-E, D-D and C-C of the south breakwater show the construction of a berm in the core according to the original design. The design was changed into a construction without a berm in the core to comfort the working method (see section6.3.5). The Engineer instructed the Contractor to carry out resurveys under close supervision of the Engineer. In some cases cross sections of the resurveys showed significant deviations of earlier surveyed cross sections. The re-surveys could of course only be done on the toplayers of the breakwater. The surveys of the underlying layers could not be checked this way but were checked on several occasions by removing a part of a constructed layer by crane. This was only done for parts of the breakwater above the water level.

6.3.7.3 Visual survey:
Visual survey's are carried out by walking on the breakwater during low tide. The visible layers are checked and irregularities are written down. Especially in the deeper sections most of the breakwater lies under the water level and can not be checked by visual survey. The result of a visual survey is given in Appendix VII.

6.3.7.4 Coastline monitoring
Due to construction of the new port relative quick changes in coastline profiles will take place. Nine months per year accretion at the south side of the south breakwater and erosion at the north side of the north breakwater takes place due to the northward directed currents. The other three months per year, during the Northeast monsoon, the accretion and erosion take place in reversed directions. The root of the work harbour accreted quickly during construction because the south breakwater was not yet constructed. In order to monitor the changes in coastline, surveys have been taken of the beach. From a known reference point the location of the high water level was measured using an electronic measuring system.

6.3.8 Equipment

An overview of equipment used for breakwater construction is given in Table 6-5. These figures are averages of countings on several occasions on site. It is noticed that a large number of trucks are under repair. Flat tires are the main problems caused by driving on the toplayer of the uncompleted breakwaters. Most of the ten tons dump trucks breakdown frequently because they are designed for transport of earth instead of rock. The steel platework of the trays breaks down and has to be repaired.

SOUTH BREAKWATER	*no*
50 tons crane	2
Back Hoe	1
Shovel	1
NORTH BREAKWATER	*no*
50 tons crane	1
100 tons crane	1
Back hoe	1
Shovel	1
Dozer	1
WORK HARBOUR	*no*
Crane	1
Back Hoe	2
Dozer	1
Shovel	1
TRUCKS	*no*
10 tons dumptruck	13
30 tons dumptruck	6
Flatbed truck	2

STOCKPILE		*no*
Quarry Run	Front end loader	1
Quarry Run	Back Hoe	2
Grade E	Back Hoe	1
Grade D	Front end ld.	1
Grade C	Back Hoe	1
GradeA/ B	50 tons crane	1
ACCROPODES		*no*
	50 tons crane	2
	Till crane	1
	JCB	2
	shovel	1
EQUIPMENT IN WORKSHOP FOR REPAIR		
	10 tons dumptruck	6
	30 tons dumptruck	3
	Flatbed truck	1
	Dozer	1
	Shovel	1

Table 6-5: Equipment on site, models and quantity.

6.3.9 Payments

Similar to the contract for rock quarrying and transportation the Client also the habit to check and adapt certified bills and pays adapted bills late. These practices have already been discussed in section 5.3.4. At this contract the Contractor has threatened to go into suspension on two occasions. This could mean that the Contractor stops his activities on site and even demobilises from site until the Client has paid all bills plus interest. This would slow down the construction and is very undesirable. Suspension has been prevented on both occasions but this took several complicated meetings.

6.4 Construction progress

Progress of the construction must be monitored in order to know whether the construction progress is on schedule or not. In case of delays actions can be taken. A rough time schedule of the main elements in the contract is given in section 6.2.4. Due to the variation order with the new alignment of the north breakwater, issued in October 1997, the original timeschedule changed. These changes of the revised schedule were calculated by comparing the new scope of works with the original scope of works and original timeschedule. In this way the Contractor would be prevented from using an excess amount of time for the additional works.
This meant that the Contractor had to submit detailed time schedules for both the original alignment and the revised alignment, which both had to be approved. It took the Contractor more than one year to deliver a time schedule that was approved for the original alignment. The time schedule for the realignment of the north breakwater took even longer and was approved in November 1998. An extension of time of 250 days was given.
The effect of the extension of time on the overall time schedule is given in Figure 6-9. The completion date of all works shifts from the 15th of August 2000 to the 22nd of April 2001.

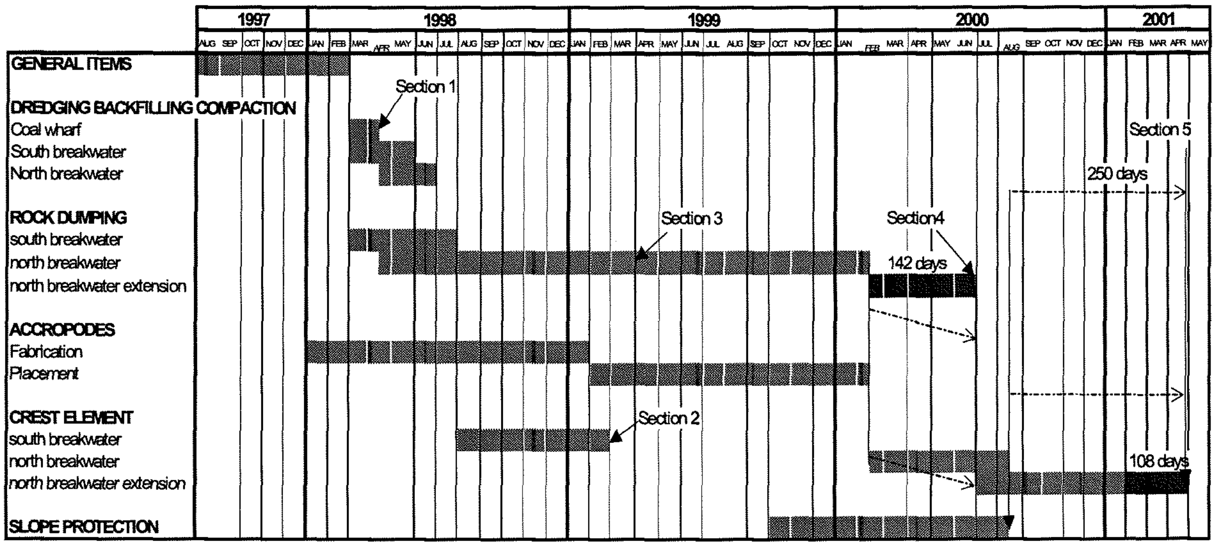


Figure 6-9: Extension of time due to realignment of the north breakwater.

Progress of the Ennore Coal Port Project was reported in monthly progress reports compiled by the Engineer. In these reports progress was described in various ways:

- Financial progress, determined by the total amount of bills that is certified by the Engineer.
- Physical progress is reported in the percentage of approved items that are completed and added to the certified bills.

The progress reports did not show if a certain item of the construction was not constructed at all or if it was not approved. In this section progress of the carious activities is made visible in two manners for the subjects dredging/backfilling/compaction, work harbour construction, Accropode production and rockdumping for the breakwaters:

1. Gantt charts of the overall project schedule and more detailed Gantt charts of the sub-tasks. These charts are included in Appendix VIII and give an indication of the total time span of the different tasks.
2. The actual progress within these time scales compared to the original time schedule. Progress is calculated by using produced quantities compared to the total required quantities of several items on the bill of quantities. Each item is given a certain weight according to the percentage of the price. The total of all items per subject equals 1. Appendix VIII gives details of the calculations. The results of the calculations for the different subjects are made visible in Figure 6-10 to Figure 6-13

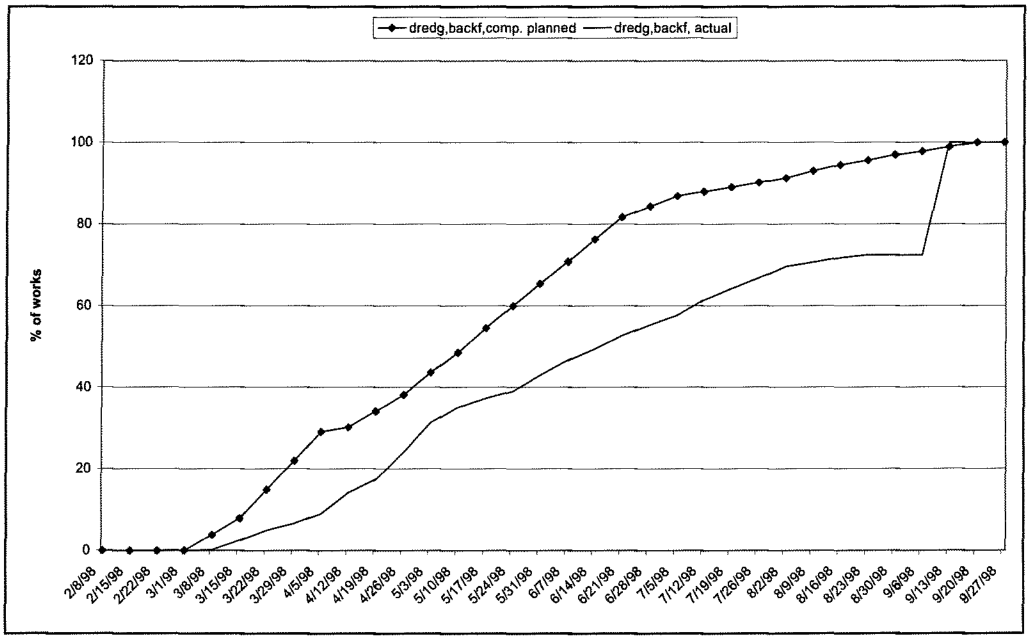


Figure 6-10: Progress of dredging, backfilling and compaction.

Dredging, Backfilling and compaction:

Figure 6-10 represents the progress of dredging, backfilling and compaction. The quantities include the changes due to the variation orders of the realignment and the additional soil investigation. The decision not to compact after the pilot compaction test is represented in Figure 6-10 by the strong increase just before the 100% is reached.

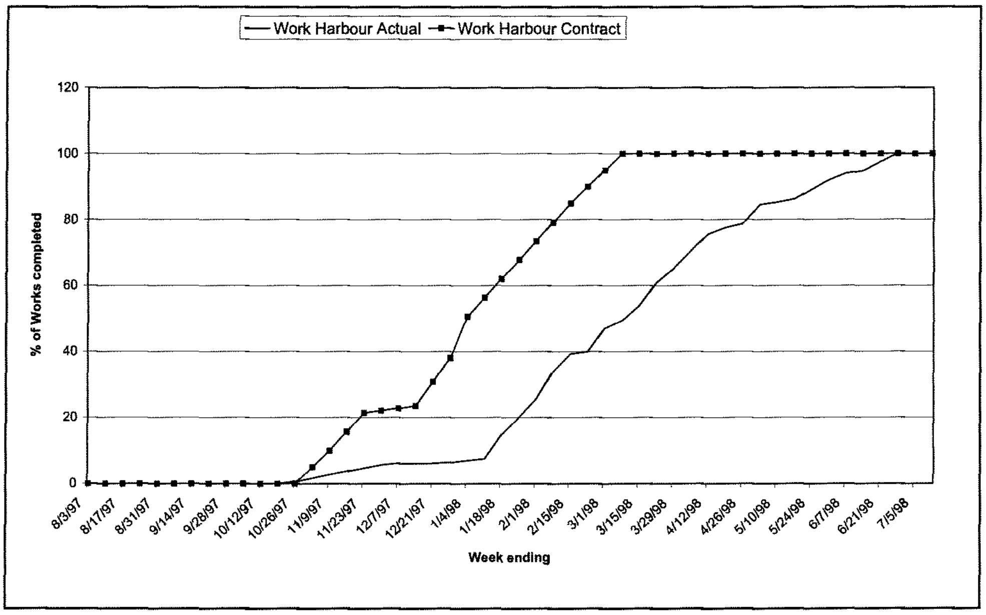


Figure 6-11: Progress of the work harbour construction.

*Construction of the temporary work harbour (*Figure 6-11*):* The completion of the work harbour took four months longer than planned. It took over two and a half months until all parties agreed on the new location of the work harbour with the realignment of the north breakwater. The Contractor submitted several designs and gradually parts of the design were approved. Completion date is stated the 4th of July 1998 when the rock dump vessel 'Frans' commenced it's activities. All dredging and rock dumping at the work harbour after this date is assumed as maintenance.

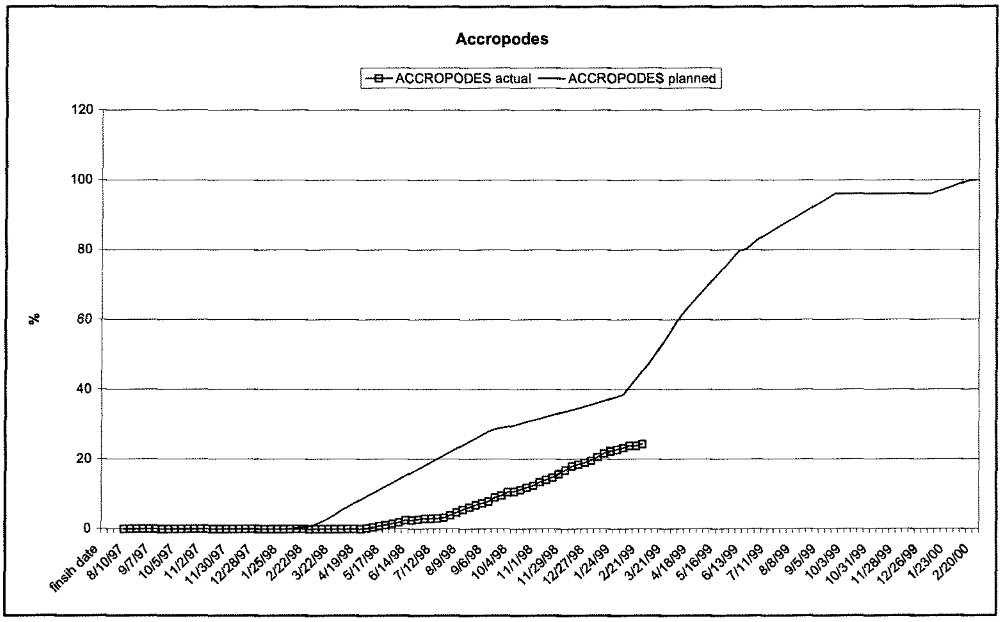


Figure 6-12: Accropode production progress.

Accropode production: The Accropode production is behind the planned schedule due to the following reasons:

- The detailed drawings for the construction of the moulds were received late by the Contractor.
- Erection of the batching plant was not in accordance with SOGREAH's specifications.
- The batching plant can not be operated fully automatically.
- It took extra time before the concrete mixes met the specifications.

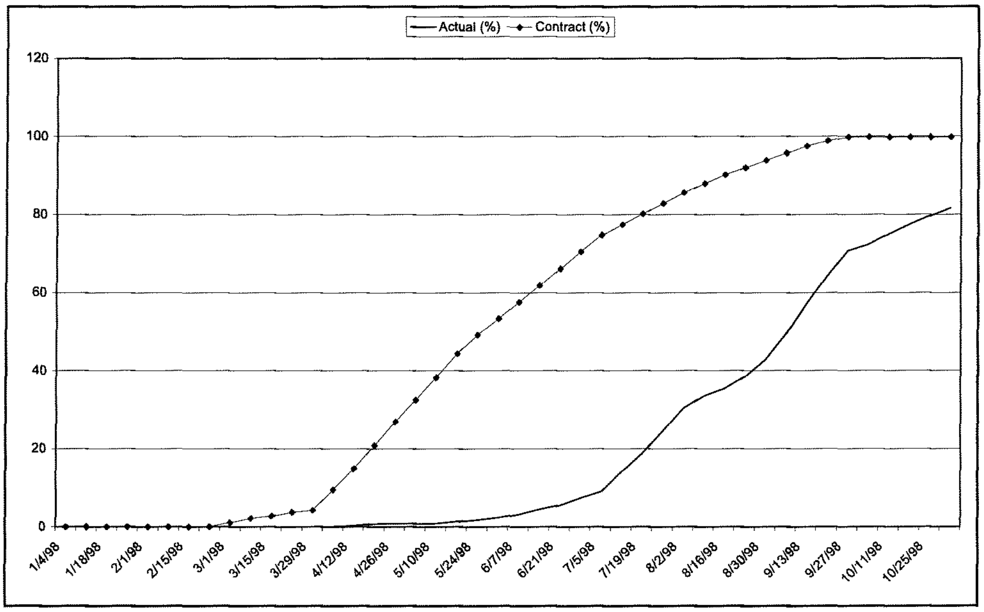


Figure 6-13: South breakwater rockdumping progress.

Rock dumping of the breakwaters: realignment of the north breakwater and changing bed levels changed the rock demand quantities. Details of the demands and rock already used are presented in Appendix II . Figure 6-13 shows the used rock quantities for the construction of the south breakwater. This is not completely representative for the completion of the south breakwater because major parts of the south breakwater have not been approved. These parts must be repaired first, which will cost extra time. The amount of extra time needed for repairs depends on the properties of the south breakwater. The properties are discussed in section 6.5. Reasons for delays are:

- The cooling water outlet of the power plant attacked the root of the south breakwater. This in combination with slow construction speed changed the bed levels considerably especially the first three hundred metres from the root of the south breakwater.
- Erosion on the north side of northern breakwater made it necessary to protect the approach road to the north breakwater with additional rock.
- Part of the equipment is not suitable for the working conditions, frequent breakdown of trucks, and cranes that cannot place large rocks without tending to tilt.
- Fishermen interfered with the marine-based works.

6.5 Properties of the realised south breakwater

6.5.1 General

Due to the nature of rubble mound construction there are deviations in the actual construction compared to the theoretical design drawings. These deviations have to be considered as a normal consequence of the used materials and the construction method. It is also known that the geo-technical stability, layer thickness, rock distribution within a layer and so on influence the functionality, strength and thus the expected lifetime or maintenance level of the breakwaters. In this section the effects of differences of the actual construction from the design are investigated for the south breakwater.

I have chosen to investigate only the properties of the south breakwater because when I left the Ennore port site in December 1998 most of the rock dumping on the south breakwater was completed and crest construction was about to commence. The properties of the north breakwater are not included because construction was in an earlier stage. Evaluation would be less useful.

The breakwater consists roughly of three elements; firstly the breakwater foundation, comprising the sand backfill, secondly a large body of rock in different layers and gradings and finally the concrete crest element. Properties of the breakwater foundation are discussed in section 6.3.1 because determination of the strength of the breakwater foundation was an activity directly carried out by the Contractor. The crest element was not yet under construction in December 1998. Therefore only the properties of the rock body are subject of the investigation in this section.

The calculations have been done based on available information. The original design conditions and methods have been used whenever possible. In this way a fair comparison is made with the design according to the original design philosophy.

6.5.2 Available information

There are several sources of information that can be used for the comparison of the realised breakwater with the design. All sources have their own uncertainties:

Hydrographic surveys: Available every 10 metres chainage for sections of the south breakwater where marine based construction took place. See section 6.3.7.1 for details and Appendix VII for an example.

Land-based surveys: Available every 10 metres chainage for the entire south breakwater. Near the breakwater root available every 5 metres chainage. See also section 6.3.7.2 for details and Appendix VII for an example.

Weighbridge records: These records show the weekly amount of rock transported to the south breakwater or work harbour (marine-based construction) per grade per layer. See also section 6.3.3.

Weekly progress reports: These reports are used to monitor progress of the construction and are compiled by the Engineer. The records show the weekly progress of land based construction in metres along the centre-line per layer of the breakwater. The amount of used rock per layer and per grade and any irregularities (i.e. bad weather) on the breakwater during the week are also reported. Appendix IX shows an example of a weekly report.

Ship's log of the rock dump vessel Frans: This log is kept by the Contractor and contains detailed information of the ship's activities; loading-, sailing- and dumping times as well as destination chainages and amounts of loaded and dumped rock are registered 24 hours a day.

Construction methods: The used construction methods can give additional information about the properties of the end product of the construction. Examples are the changes in design made during construction in order to comfort the working method (discussed in sections' 6.3.4 and 6.3.5).

6.5.3 Approach

The main parameters determining the quality (i.e. expected lifetime and/or expected maintenance intervals) of the constructed breakwater components can be derived from the surveys of the breakwater as they represent the measurement of the actual cross sections of the breakwater. The properties of a cross section determine to a large extent the resistance of the construction against wave attack. This is also the reason why the cross section surveys together with visual surveys form an useful tool for the Engineer in the approval process of constructed breakwater components. Nevertheless the surveys contain certain inaccuracies and do not tell everything about the properties of a cross section. Therefore the available data is extensively analysed to get a better view about the actual cross sections.

The analyses has been done using bulk-density ratio's. Bulk-density ratio's are measures for the amount of rock inside a certain volume (t/m^3). During the design phase theoretically required rock quantities for the breakwater are calculated by multiplying the volumes of the designed structure with a theoretical bulk-density ratio. Bulk-density ratio's can also be used to check whether specifications have been met when the breakwater is realised. Combination of reported rock quantities and volumes derived from surveys gives an indication of actual bulk-density ratio's in the breakwater (see also Figure 6-14). Comparison of the actual bulk density ratio's with the theoretical values can provide additional information about possible irregularities in cross sections of the constructed breakwater. Bulk-density ratio calculations are done per layer and for small sections of the breakwater in order to locate and analyse possible irregularities.

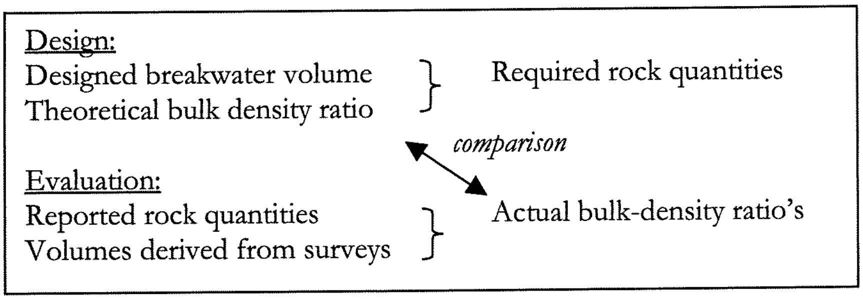


Figure 6-14: Use of bulk density ratio's in breakwater construction.

The data obtained from the bulk-density ratio calculations together with the other available information forms a more solid base on which a comparison of the actual cross sections of the breakwater can be made with the original design.

Special attention is paid to the following elements:

- Armour stability: This is the base for resistance against wave attack. It depends among others on the slope angle, layer thickness and rock size.
- Crest height: The crest height of the design has been determined using the allowable overtopping. Because the breakwater was not yet constructed up to it's final height in December 1998, it is not possible to say something about the actual expected overtopping.
- Sublayers: Used for filtering, parameters are rock size and layer thickness.
- Base and toe.

It must be noted that the calculations in this section have been done for an incomplete structure. The crest has not yet been constructed and the upper part of the primary armour layers can only be placed after crest construction.

6.5.4 Bulk-density ratio calculations

The following steps have been taken for bulk-density ratio calculations:

1. For the design values:
- Determination of the theoretical volumes
- Determination of theoretical bulk-density ratio's
- Calculation of theoretically required rock quantities

2. For the realised construction:
- Derivation of the volumes of the breakwater layers from surveys
- Determination of the reported rock quantities
- Calculation of the actual bulk-density ratio's

6.5.4.1 Theoretical breakwater volumes

The breakwater volumes are determined for every layer per section of 10 metres chainage. The area of each layer in a cross section can be calculated using a theoretical cross section. The volume of each layer per breakwater stretch is determined by linear interpolation of the measured areas between two subsequent cross sections. The theoretical cross section of the breakwater is determined by the sea bed level which is provided by the in-survey of each cross-section.

6.5.4.2 Theoretical bulk-density ratio

The bulk-density ratio (ρ_b) depends on the specific density of rock (ρ_r) and the fictitious porosity (n_v) of the gradings.

$$\rho_b = \rho_r (1 - n_v) \quad [t/m^3]$$

According to [ref. 12] the fictitious porosity for double layers ranges from 35 to 42 %.

In this case the specific density of the rock (ρ_r) is on average 2.66 t/m^3. With mentioned porosity's the theoretical bulk-density factor for rock in the breakwater (ρ_{bt}) will vary between 1.54 t/m^3 and 1.73 t/m^3.

This theoretical value for bulk-density ratio does not include any wastage of rock during the handling process from the stockpile into breakwater. Wastage of rock occurs due to several reasons which are discussed in section 6.5.4.7. Normally this kind of processes give a wastage between 5 and 10 %. The theoretical bulk density ratio including these losses will thus vary between 1.62 t/m^3 and 1.90 t/m^3.

A fictitious porosity of 38% has been chosen for the calculations of theoretical rock amounts. With this porosity the theoretical bulk-density factor for the rock in the breakwater (ρ_{bt}) becomes 1.65 [t/m^3].

$$\rho_{bt} = \rho_r (1 - n_v) = 2.66 * (1 - 0.38) = 1.65 \quad [t/m^3]$$

An expected wastage value of 7.5 % is used for required rock quantity calculations. The theoretical bulk-density ratio including expected wastage becomes 1.65 * 1.075 = 1.77 t/m^3.

6.5.4.3 Theoretical rock quantities

Theoretical rock quantities are calculated by multiplying the theoretical breakwater volumes with the theoretical bulk density ratio of 1.77 t/m3 (including wastage).

6.5.4.4 Actual breakwater volumes

The actual volumes are determined the same way as the theoretical breakwater volumes only this time by using the surveyed cross sections. Please note that some land based surveys were incomplete: the surveys were not always extended far enough from the centre-line of the breakwater. Then the surveyed profile ends 'floating' in the air. To determine the area of a cross section a closed profile is necessary. The floating lines have been extended manually downwards until they cross underlying lines. (see *Figure 6-15*)

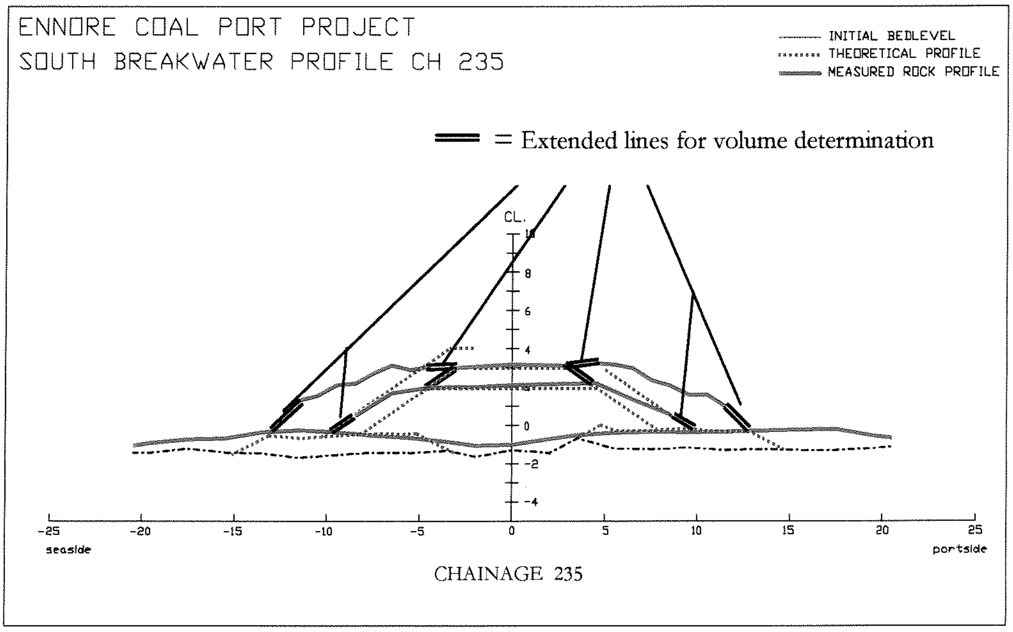


Figure 6-15: Extension of 'floating' lines for volume determination.

6.5.4.5 Actual used rock quantities

Combination of the weighbridge records and the weekly reports gives the amount of rock in each layer per weekly constructed section.

6.5.4.6 Actual bulk density ratio's

The bulk-density ratio's of all layers, both land based and marine based will be calculated by dividing the used rock quantities by the volume of the layers. This will be done as detailed as possible in order to easily spot local deviations of the actual bulk-density factor from the theoretical value. The total amount of rock dumped in each weekly constructed section could be assumed to be spread linearly over that section, but then an error would be introduced in the bulk density calculation: The deviations in volumes, which are interpolated over a length of 10 metres, would be neglected. This error could be considerable, especially in sections with changes in typical cross sections or in sections with strong bed level changes. Therefore the highest detail in a reliable bulk density ratio calculation is determined by the length of each weekly constructed stretch of breakwater.

6.5.4.7 Factors influencing the calculated bulk density ratio's

There are several factors that influence the outcome of the calculated bulk density ratio's. The results of the calculations depend on the accuracy of the input data, the used calculation method and of course the actual situation at the constructed breakwater. The influence of each of these factors is discussed below:

1. Accuracy of the input data:

   Weighbridge records:

   - Weighing accuracy: Weight of the empty trucks is registered with a half-empty fuel tank. This is off course not always the case during construction. The weighbridges have not always been reset to zero after a truck has left. The effect of these inaccuracies can result in a higher as well as a lower value for the bulk density ratio. The net effect of these errors is considered to be very small.

- It might be possible that inaccuracies in these records occur due to delivery of rock to another destination than reported (e.g. south breakwater instead on north breakwater). This is not considered to happen regularly because coupons (with details of the load) that the truck drivers take to the destination are double-checked and no trucks have been seen leaving the site with rock.
- Calibration inaccuracies of the weighbridge. This would result in a structural higher or lower bulk density ratio for all grades.

Weekly progress reports:

- Inaccuracies in these reports might be caused by rounding off completion chainages at the end of a reported week. Also rock reported as dumped at a certain chainage might have been used in an earlier constructed section. These inaccuracies are considered to be small since patchwork is reported separately in the weekly reports.

Land-based Surveys:

- Inaccuracies due to survey methods (described in section 6.3.7.2).
- Changing profiles of unprotected layers in the period between the survey and the construction of the next layer. These changes will occur during bad weather conditions. Construction progress is known during bad weather conditions so that deviations due to these inaccuracies can be located.
- Slow construction at the first 300 metres of the breakwater together with currents induced by the power plant outlet and wave action caused the seabed to change relative fast. The quick changes of the sea bed and layer levels have not been surveyed.

Hydrographic surveys:

- Inaccuracies due to survey methods (described in section 6.3.7.1).
- Changing profiles of unprotected layers in the period between the survey and the construction of the next layer. These changes will mainly occur during bad weather conditions.

2. Accuracy of the calculation method:
   - The calculation method can also induce inaccuracies. In this case linear interpolation between two cross-sections has been done to determine the actual breakwater volume. In reality the breakwater will not change linear between two cross sections. However the section length of 10 metres is considered to be short enough to keep these errors small.

3. Physical explanations:
   The bulk density ratio calculations have been done in order to find out more about the actual construction. There are several physical explanations for deviating bulk-density ratio's.

High values for calculated bulk density ratio's can be the result of:

1. Wastage of rock during construction of the breakwater due to:
   - Dumping and placing of rock outside the surveyed area.
   - Fines in the gradings, which will be washed out when the rock is dumped.
   - Prevailing sea conditions:
     1. Washed out rock by currents and wave action in the breaker zone. These effects were increased by the cooling water outlet of the North Madras Thermal Power Plant.
     2. Washed out rock by currents and wave action caused by weather conditions.

   For all these factors the weight of the rock is recorded in the weighbridge records but the rock is not a part of the surveyed construction.
2. Settlement: due to the weight of the breakwater, the seabed will settle. This will already happen during construction. The bed level sinks and a larger volume has to be filled with rock before the planned crest height is reached.
3. A low porosity of the breakwaters layers gives a slightly higher bulk density ratio than the average theoretical value of 1.65 t/m^3 (excluding waste).

Low values for calculated bulk density ratio's are hard to explain physically. High values for porosity's cause a low bulk density ratio. The theoretical range takes porosity's up to 42 % into account. For the armour layers and sublayers, which both have a thickness of about two times D_{n50}, much higher values of porosity's are not very likely to happen.

6.5.4.8 Results of the calculations

Detailed results and analyses of the calculated bulk-density ratio's are given in Appendix X. The main results are discussed briefly in this section. *Table 6-6* presents the overall results per layer for the entire length of the breakwater.

	Theoretical			Actual		
	volume (m3)	quantity (tons)	bulk-dens. (t/m3)	volume (m3)	quantity (tons)	bulk-dens. (t/m3)
Core landb.	104,784.5	185,468.6	1.77	104,724.4	223,481.4	2.13
1st filter landb.	8,775.0	15,531.8	1.77	No Data	Not included	No Data
2nd filter landb.	1,484.7	2,627.9	1.77	No Data	Not included	No Data
Toe landb.	8,623.3	15,263.2	1.77	9,712.8	14,351.4	1.48
Prim arm sea side landb.	34,584.1	61,213.9	1.77	32,092.4	39,636.5	1.24
Sec arm sea side landb.	14,141.9	25,031.2	1.77	14,210.1	17,884.5	1.26
Upper arm port landb,	10,469.0	18,530.2	1.77	15,824.2	16,125.7	1.02
Lower arm port landb.	5,702.7	10,093.8	1.77	9,349.9	10,452.4	1.12
Core topping landb.	7,512.3	13,296.8	1.77	7,598.7	19,793.7	2.60
marine based layers	121,947.1	215,846.4	1.77	128,326.7	223,179.5	1.74
Total	**318,024.7**	**562,903.8**	**1.77**	**321,839.3**	**564,905.1**	**1.76**

Table 6-6: Overall volumes, rock quantities and bulk-density ratio's of the south breakwater per layer.

Table 6-6 shows that the calculated overall bulk density ratio of the actual constructed breakwater is 1.76 t/m^3 which lies within the expected theoretical range. There are however significant differences between the bulk density ratio's of the various layers. The overall values for the land based constructed core and core-topping layer are higher than the maximum value of the theoretical range. Average bulk-density ratio's for all the armour layers are significant lower than the minimum theoretical value. The average for the marine based constructed layers of 1.74 t/m^3 lies within the range of theoretical expected values.

Analyses of the results per section along the centreline of the breakwater shows that these deviations from the average bulk density ratio's are not caused by a few local excessive values but that they are mainly caused by structural deviations at larger parts of the breakwater. There are physical explanations possible for the higher bulk density ratios of the core and core topping (see section 6.5.4.7). The low bulk density ratio's of the armour layers however can not be explained physically.

Explanations of the combination of high bulk density ratio's for the core topping, low values for the armour layers and averages per chainage according to theoretical values follow from analysis of the used data and the working method of the Contractor:

- Inaccuracies in weighbridge records would result in a mutual higher or lower value for all layers. Since the deviations in bulk density ratio's are opposite for the different layers, it is not likely that the weighbridge records are the main cause.
- Weather conditions were quite favourable during the construction process. Therefore wastage caused by bad weather conditions is not expected to be extremely high.
- Wastage of core material due to an extreme amount of fines in the gradings would not only result in high bulk density ratios for the land-based constructed core and core topping but also for the marine based constructed layers. This is because the core material is loaded from the same stockpile using the same equipment for both marine- and land-based construction methods (see section 6.3.3). Since the marine based constructed layers show bulk density ratio's according to theoretical values this is not a probable cause for the deviations.
- A more logical explanation for the high values of the land based constructed core and core-topping and the low values of the armour layers is that the inaccuracies originate from the land based survey practices (see section 6.3.7). In reality the core probably occupies a larger volume than the surveys show (bulk-density ratio decreases) and the sublayers and armour layers which are constructed on top of the core occupy a smaller volume than visible on the surveys (bulk-density ratio increases).

The bulk density ratio calculations have shown that the accuracy of available data, generated during the construction process, can not be taken for granted. The calculations also have shown that the land-based surveys are probably the main source for inaccuracies. In the further analyses of the cross sections this has been taken into account.

6.5.5 Properties of the actual cross sections

In this section the actual cross sections and the design are compared, using the surveys together with obtained data from the bulk-density ratio calculations.

Every 10-metre chainage a survey has been made. Especially in the deeper sections, where the slope of the seabed is not very steep, variations in surveys and bulk density ratio's between succeeding chainages are very small. It is therefore not necessary to evaluate all available cross sections (about 120 pieces). Evaluation of a characteristic cross section that represents all the cross sections in a certain stretch of breakwater will be sufficient.

A number of twenty two representative cross sections have been chosen by analysing variations in surveys, rock quantities and the bulk density calculations. An aid in the selection process is given in Appendix VIII. The calculated data is expressed in rock quantities per metre breakwater section. Table 6-7 shows the chainages of these cross sections for the stretches of breakwater the represent.

Typical Breakwater Section	Section From chainage To chainage	Representative Cross-section (chainage)
H-H	0 – 50	50
H-H	50 –100	100
H-H	100 –130	130
H-H	130 –150	150
G-G	150 –190	190
G-G	190 –245	235
F-F	255 –275	275
F-F	275 –290	290
F-F	290 –330	330
E-E	340 – 370	370
E-E	380 – 430	430
E-E	430 – 500	500
E-E	500 – 530	530
E-E	530 – 600	600
E-E	600 – 680	680
E-E	680 –720	720
D-D	730 –770	770
D-D	780 – 850	850
C-C	850-900	900
C-C	900-930	930
C-C	930-970	970
C-C	980-1017	1010

Table 6-7: representative cross sections of the breakwater.

The land- and marine-based surveys, results of bulk density ratio calculations, actual dumped rock quantities, visual surveys, weather conditions during construction and construction methods are combined in order to asses the properties of the representative cross sections. The surveyed cross sections with comment are given in Appendix XI. These cross sections will be used for further analyses of the breakwater elements.

6.5.5.1 Armour layer stability:

All the armour layers of the south breakwater are made of natural rock. In the design two different formulae have been used for the calculation of the required D_{n50} of the primary armour layer. For the south breakwater section from the root up to chainage 800 the following formula has been used because of a very oblique wave attack.

$$D_n = \frac{H_s}{\Delta \cdot 1.25 \cdot 2}$$

The remaining section of the breakwater has been calculated using the computer program Breakwat because the wave attack in that section is more perpendicular.

The computer program Breakwat is more useful than the formula for oblique wave attack for comparison of the actual constructed breakwater with the designed breakwater, because more structural parameters can be taken into account in Breakwat (for instance the armour layer thickness and the slope angle). Differences in damage level S and damage profiles for both the design cross sections and the actual cross sections will be considered.

Damage level S

A damage level of three (hardly any damage) has been chosen for the design. Because Breakwat will be also used for sections with oblique wave attack, wave obliquity is neglected (see Figure 6-16). Because of this, larger rocks would be needed for these sections when the requirement of a damage level S of 3 is met (see also Appendix IV). As a result of this Breakwat calculates much higher damage levels for the used rock gradings in the original design. Because these damage levels are in some case much higher than the level S =8 for failure, it is decided to adjusted the wave height in the calculations downwards until a maximum damage level of 8 is reached for the design cross sections. These adjusted wave heights are then used to calculate damage levels of the actual cross sections. In this way it can be seen whether or not the armour layers of the actual construction are more stable than the design.

Structural parameters of the design and of the actual construction have been determined for the representative cross sections. These parameters and the results of the calculations are shown in Table 6-8. The table shows minimum, maximum and average damage levels depending on the slope angles of the cross sections. Most slope angles of the representative cross sections are flat on the upper part of the slope and steeper near the toe. The average slope angle is determined by flattening out the steepest part of the slope in a cross section (see Appendix XI). The results of the calculations show that for most parts of the breakwater the damage level is lower than for the design. This is caused by a less steep slope angle at the actual construction than in the design. There are some parts of the breakwater where the maximum damage level is higher. Breakwat calculates the damage levels for the weakest part in a layer which lies normally around the water level. At the actual cross sections the slopes are only steep near the toe of the breakwater where wave attack is less strong. The best indication are probably the calculated average damage levels which also show a lower or identical damage level as for the design. The calculations with Breakwat show that for the entire breakwater the primary armour layer is more stable than designed. For sections with a higher damage level (thus a steep lower slope) it is recommended to trim the slope, and place additional rock before the breakwater is handed over.

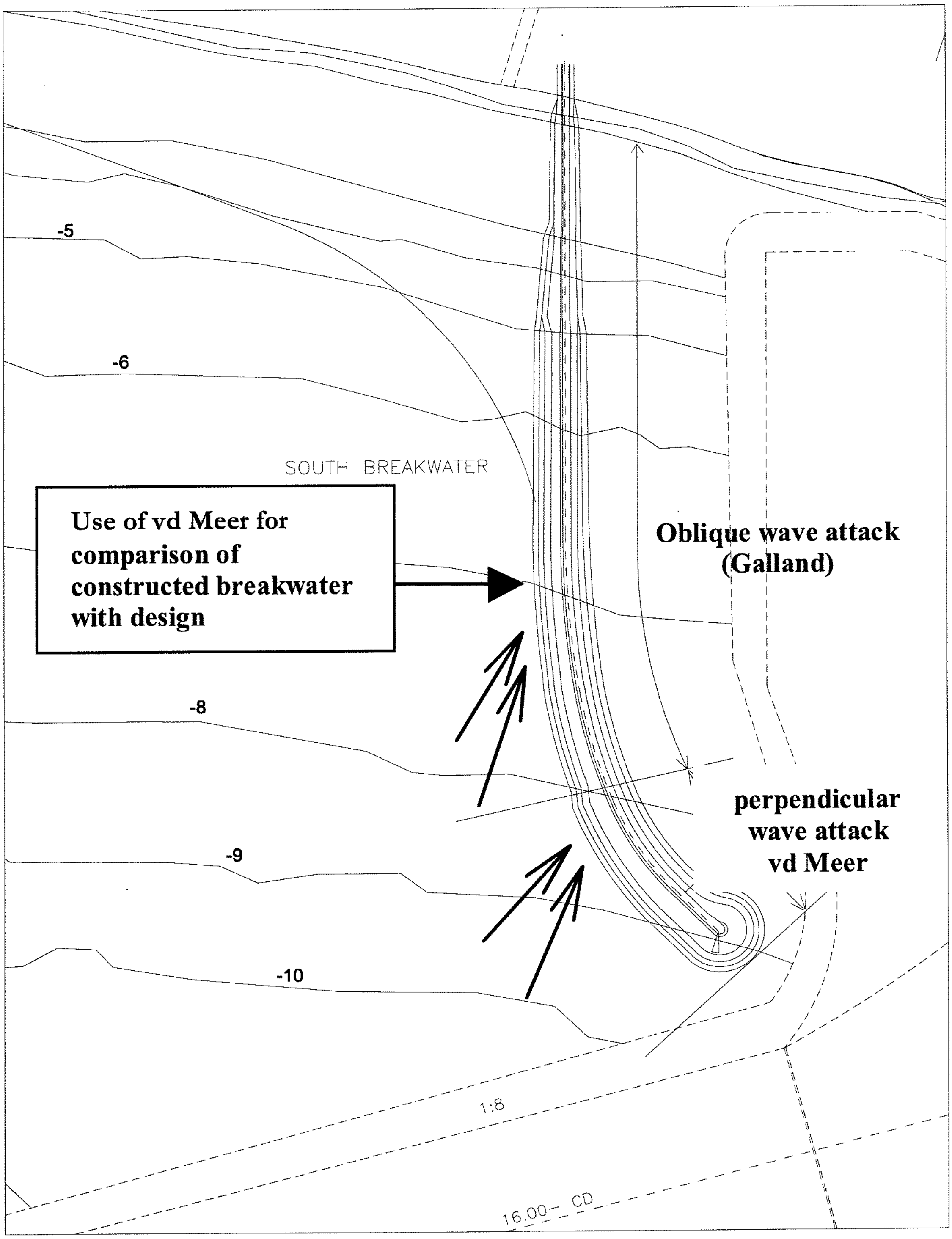


Figure 6-16: Use of van der Meer Formula, for comparison of constructed breakwater with the design, for the entire breakwater.

		cot of the slope angle				Hs used	Calculated damage level S			
		original	Actual cross section			(m)	original	Actual cross section		
Section	Chainage	design	min	max	average		design	max	min	average
H-H	50	-	-	-	-	-	-	-	-	-
H-H	100	-	-	-	-	-	-	-	-	-
H-H	130	-	-	-	-	-	-	-	-	-
H-H	150	-	-	-	-	-	-	-	-	-
G-G	190	1.5	1.1	2.0	1.8	2.06	8	9.3	6.9	7.4
G-G	235	1.5	3.2	3.2	3.2	2.06	8	3.4	3.4	3.4
F-F	275	1.5	2.8	2.8	2.8	2.98	8	2.1	2.1	2.1
F-F	290	1.5	2.0	2.0	2.0	2.98	8	4.8	4.8	4.8
F-F	330	1.5	1.6	1.6	1.6	2.98	8	7.8	7.8	7.8
E-E	370	1.5	2.0	2.0	2.0	3.75	8	3.9	3.9	3.9
E-E	430	1.5	1.5	1.8	1.7	3.75	8	8.0	5.1	5.8
E-E	500	1.5	1.5	1.5	1.5	3.75	8	8.0	8.0	8.0
E-E	530	1.5	1.1	3.0	2.2	3.75	8	12.7	1.4	3.1
E-E	600	1.5	1.5	1.5	1.5	3.75	8	8.0	8.0	8.0
E-E	680	1.5	1.7	3.6	2.5	3.75	8	5.8	0.9	2.2
E-E	720	1.5	1.5	3.5	2.5	3.75	8	8.0	1.0	2.2
D-D	770	1.5	1.6	3.4	2.0	4.91	8	6.8	1.0	3.9
D-D	850	1.5	1.1	2.6	2.0	4.91	8	17.3	2.0	3.4
C-C	900	2	2.1	2.1	2.1	5.95	8	7.1	7.1	7.1
C-C	930	2	1.6	3.5	2.0	5.95	8	14.0	2.0	8.0
C-C	970	2	1.3	3.0	2.0	5.95	8	23.5	2.9	8.0
C-C	1010	2	1.7	3.5	2.2	5.95	8	12.0	2.0	6.4

Table 6-8: Damage level calculations for representative cross sections.

Damage profiles

In the design for armour layers a thickness of twice the nominal diameter D_n multiplied with a thickness coefficient 0.9 has been used. However the actual cross sections show varying layer thicknesses. Using the surveys and the results of the bulk density ratio's, it can be questioned whether the required layer thickness is reached for the lower parts of the armour layers. Breakwat has been used to calculate damage profiles of the actual cross sections. The depth of the turning point between erosion accretion (h_m in Figure 6-17) has been calculated for the cross sections and is given in Table 6-9. From the results can be derived that the turning point lies for most cross sections near the toe of the breakwater. This means that there might be some erosion above the toe. Depending on the actual thickness of the layers this might cause problems in filtering requirements of underlying rock. This process is discussed in section 6.5.5.2. The results of the bulk density calculations pointed out that it might be possible that layer thicknesses of the actual cross sections are thinner than the surveys show. However the only way to really find this out is by sending down a diver who can spot irregularities in the armour layer. For these breakwater sections it is recommended to place additional rock and fill possible voids in the top layer before the breakwater is handed over.

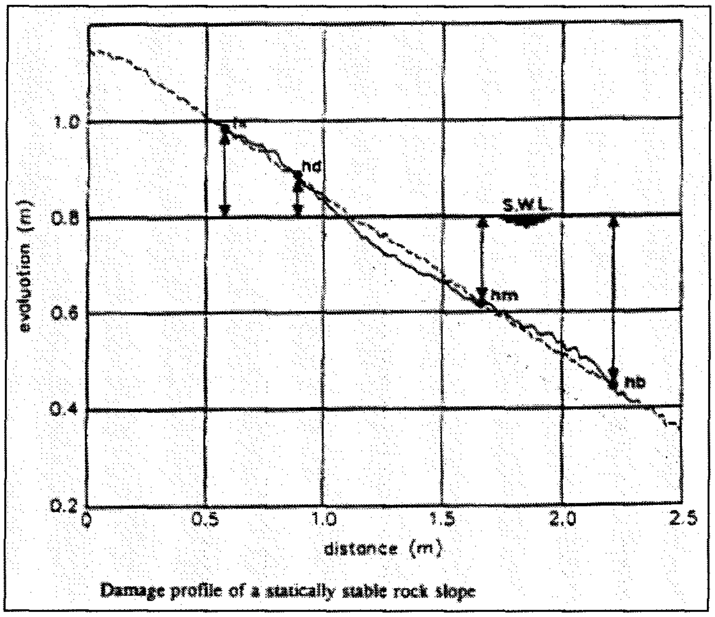


Figure 6-17: Damage profiles of a statically stable rock slope (source [ref. 11]) .

Section	Chainage	Turning depth Erosion / Accretion (in m - SWL)	Section	Chainage	Turning depth Erosion / Accretion (in m - SWL)
H-H	50	-	E-E	500	**3.5**
H-H	100	-	E-E	530	**3.5**
H-H	130	-	E-E	600	**3.5**
H-H	150	-	E-E	680	**3.5**
G-G	190	**2.6**	E-E	720	**3.5**
G-G	235	**2.6**	D-D	770	**4.0**
F-F	275	**3.1**	D-D	850	**4.0**
F-F	290	**3.1**	C-C	900	**4.4**
F-F	330	**3.1**	C-C	930	**4.4**
E-E	370	**3.5**	C-C	970	**4.4**
E-E	430	**3.5**	C-C	1010	**4.4**

Table 6-9: Depth of turning point accretion/erosion of the primary armour layer sea side.

6.5.5.2 Sublayers

In case a sublayer is constructed thinner than designed, the danger might arise that the forces on the core material (situated under the sublayer), caused by the hydraulic loads, are higher than the resisting forces of the core material. In that case core material will be washed out and settlement follows.

Core material of the breakwaters in Ennore has a very wide grading (1-1000 kg). It is likely that with a thin sublayer, the smallest rocks in the core will be washed during design conditions and that some settlement takes place. Larger rocks in the core material will not be washed out and when small rocks are washed an additional sublayer will be formed a natural manner.

Settlement of the layers can be allowed up to a certain extent. However, in case of very thin sublayers it is possible that, due to the settlement, core material will be positioned directly under the primary armour layer. The hydraulic loads on this material can cause loss of larger core material, resulting in more settlement or possibly in failure.

It is difficult to check the actual thickness of a sublayer in a constructed breakwater. Combination of the surveys and bulk density calculations have shown that it might be possible that for some parts of the south breakwater the sublayers as well as the primary armour layers are thinner than designed (see Appendix XI). It is possible to do some spot tests en remove rock of the primary armour layer. This is however difficult to do with rock on a slope, especially with parts of the layer situated under the water level. Another, more practical solution is to increase the thickness of the primary armour layer. This also reduces the hydraulic loads on the core material because more energy will be lost in the primary armour layer. It is therefore important that the thickness of the primary armour layer reaches at least it's design thickness.

6.5.5.3 Base and Toe

The base (primary and secondary filter layer) and toe have been constructed according to the design level and width for practically the entire south breakwater. For toe, at the section between chainage 255 and 850, the same can be said about the thickness as for the sublayers. The possible effects and cure's thereof have already been discussed above.

During construction of the root of the breakwater rock was washed out. This still occurred at chainage 135, where construction of the filter layers started. From the surveys it can not be determined whether there is filter material present or not. This continued up to chainage 255 where the currents induced by wave action and the cooling water outlet channel became less severe. Construction of this section was very difficult due to the currents. By dumping rock faster than it was washed out, construction proceeded. When the breakwater construction reached chainages past chainage 300-350 the currents eased down and the contractor was instructed to place additional filter material at the damaged stretch. Due to accretion from the south the average bottom level rose and the problem seems cured (see also section 6.6.2).

From chainage 255 up to the head the filter material is clearly visible on surveys and mostly constructed as designed.

6.6 Deviating site conditions, effects on the south breakwater

There are differences in the actual physical site conditions from the physical site conditions known during the design. Three differences in the surroundings of the south breakwater that could effect the south breakwater are:

- Relocation of the entrance channel and north breakwater due to additional design.
- Accretion at the south side of the south breakwater.
- Location of the cooling water outlet channel of the North Madras Thermal Power Plant (NMTPP).

6.6.1 Relocation of north breakwater and access channel

The design of the primary armour layer of the south breakwater was partly based on the extreme wave conditions at the breakwater. These conditions were calculated in wave studies carried out by Delft Hydraulics, for the original layout [ref. 8]. The studies showed that the south breakwater was partly protected by the north breakwater from extreme wave attack.

Due to the relocation of the north breakwater and the access channel of the port, it is possible that the extreme wave conditions at the south breakwater changed. The location of the head of the realigned north breakwater was determined by swell approaching the port. Penetration of these waves in the port basin was not acceptable. Additional wave studies were carried out by Delft Hydraulics [ref. 13]. These studies concerned wave penetration inside the port basin and did not comprise calculations in the field of extreme wave conditions.

In this section the effects of the realignment of the north breakwater and the access channel on the extreme wave conditions at the south breakwater are investigated.

The calculations will be done with the use of the computer program HISWA. HISWA is an acronym for HIndcast of Shallow WAter WAves. It is a wave propagation model that takes into account the effects of depth, current, refraction and directional spreading. Energy due to bottom friction and wave breaking as well as energy growth due to wind are incorporated. Diffraction is not included.

The following input data was used in the calculations:

- Computational mesh: An area of 10,000 m by 5,000 m is chosen covering the port area from the 20 m depth contour line to the shore. The mesh size is determined on the basis of the bottom variations. A computational grid of 50 m by 25 m is applied leading to 40.401 grid points.
- The bottom profile: The computational mesh has been placed on drawings of both port layouts using AutoCAD. The drawings contain the contour lines obtained from the bathymetric survey carried out in 1995 and the dredged port basin and access channel. The depth in the grid points are obtained by linear interpolation between known depths.
- Obstacles in the bottom profile: In this case the north breakwater. Both the centrelines of the original and new layouts are exactly obtained from AutoCAD drawings. A crest height of + 5.40 m CD was entered
- The incident wave boundary conditions: The extreme wave conditions at the 20 m depth contour are used. These conditions have been calculated in the wave studies carried out by Delft Hydraulics for Return Periods of 5, 10 , 25, 50 and 100 years with three main directions for each Return Period [ref. 8]. This results in fifteen different sets for both the original and the new layout.

Using this input data, thirty calculation runs have been done with HISWA (Fifteen different wave conditions for two different layouts). In each run HISWA calculated the significant wave height, mean wave period, mean direction and directional spreading at fifteen locations near the south breakwater and access channel.

Details and figures of the computational grid, input data, program listings and calculation results are given in Appendix XII. The results of the calculations show that the realignment of the north breakwater causes reductions of a few percent of the maximum wave heights at locations directly adjacent to the south breakwater. The directions and directional spreading of the incoming waves are roughly the same for both layouts. Reduction of the wave height decreases the load on the breakwater and increases the relative strength of the breakwater.

Changes of a few percent in the height of the design waves are not large enough to justify any changes in the selected gradings of the armour layers. The chosen gradings are still appropriate for the design waves of only a few percent lower. See also the comparison of design formulae for armour rock in Appendix IV.

6.6.2 Accretion at the south side of the south breakwater

Due to the northwards directed accretion takes place at the south side of the breakwater. However this was already foreseen to happen during the design phase, it was not taken into account for at the calculation of the required armour size. The result of this process is of coarse, that the bed level rises. A rising bed levels decreases the maximum incoming wave height which results in a relative safer breakwater. The accretion is influenced by the new location of the cooling water outlet channel. This effects of this process are discussed in section 6.6.3.

6.6.3 Location of the NMTPP cooling water outlet

On the south side of the south breakwater, directly adjacent to the root, the cooling water outlet canal of the North Madras Thermal Power Plant is situated. Originally it was situated inside the future port basin, located 200 metres from the planned root of the south breakwater. When construction of the south breakwater started, this 15 m wide channel would have to be crossed by means of a bridge. It was decided to relocate the outlet channel to the south side of the south breakwater in order to prevent the necessity of the construction of a bridge. The new canal was constructed at it's present location, 35 metres from the root of the south breakwater, and the original canal was closed with murrum. Figure 6-18 shows the locations of the original and the diverted canal and in Appendix XIII the design of the diversion canal is given.

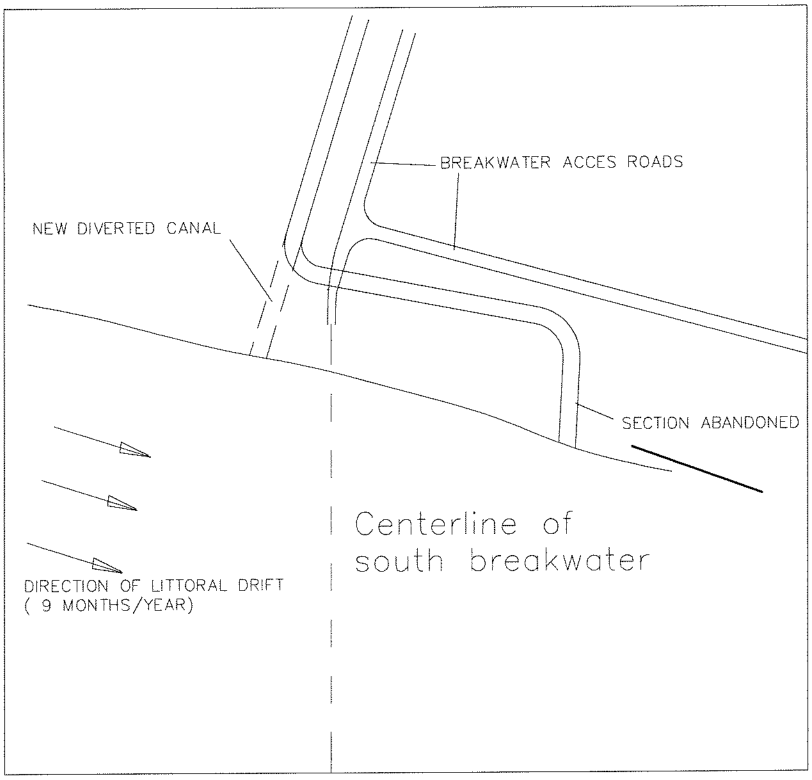


Figure 6-18: Locations of the cooling water outlet canal.

The North Madras Thermal Power Plant has a production capacity of 630 MW, which corresponds with a discharge of 28 m^3/s in the outlet canal.

The changed location has different effects on the south breakwater both during the construction process as after completion of the south breakwater. Construction of a breakwater through the surf zone is always difficult because of currents and wave action in the surf zone and should therefore take place in fairly calm conditions whenever possible.

Construction of the root of the breakwater started at the end of April. In this period the littoral drift is directed northwards. This direction reverses during the north-east monsoon, from November to January.

The outflow from the canal has a velocity of about 2 m/s and contains no sediment. The flow is bend northwards by the currents in the surf zone which increases the current velocities in the surf zone. At the original location the increased flow velocity would have bend away from the location of the breakwater. However at the new location, the increased flow is bend directly towards the location of the breakwater (see Figure 6-19).

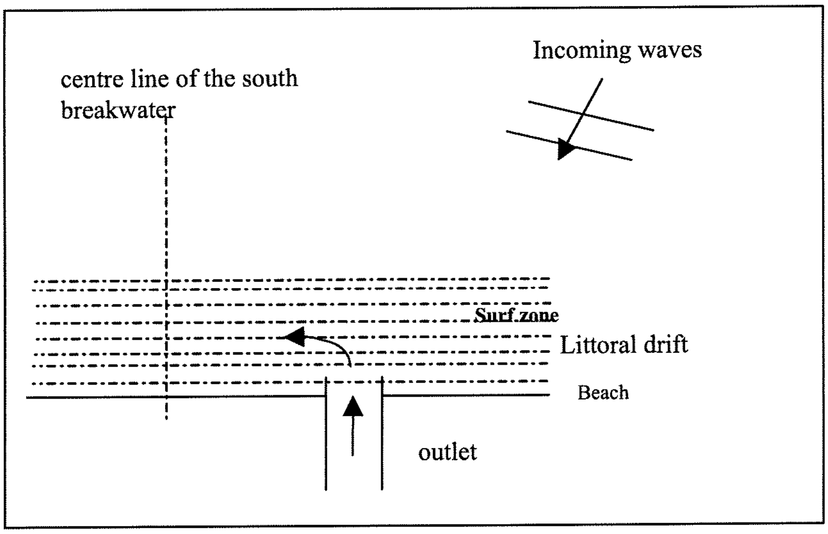


Figure 6-19: Situation before breakwater construction.

At the start of construction of the root, currents were strong enough to wash out dumped rock. By dumping rock quicker that it was washed out, the construction commenced. Only when some length of the breakwater was reached the littoral drift was partly blocked (see Figure 6-20). The direction of the currents became more parallel to the breakwater. At this point there were two processes playing a role:

1. Blocking of the current, parallel to the coastline. The flow velocities in the surf zone decrease and normally accretion takes place at the south side of the breakwater. Erosion takes place at some distance of the north side of the breakwater.
2. A current, induced mainly by the outlet channel, parallel to the breakwater. The water from the outlet canal contains no sediment and has a large transport capacity. This current will still be 'pushed' to the breakwater and can cause a scour hole next to the breakwater.

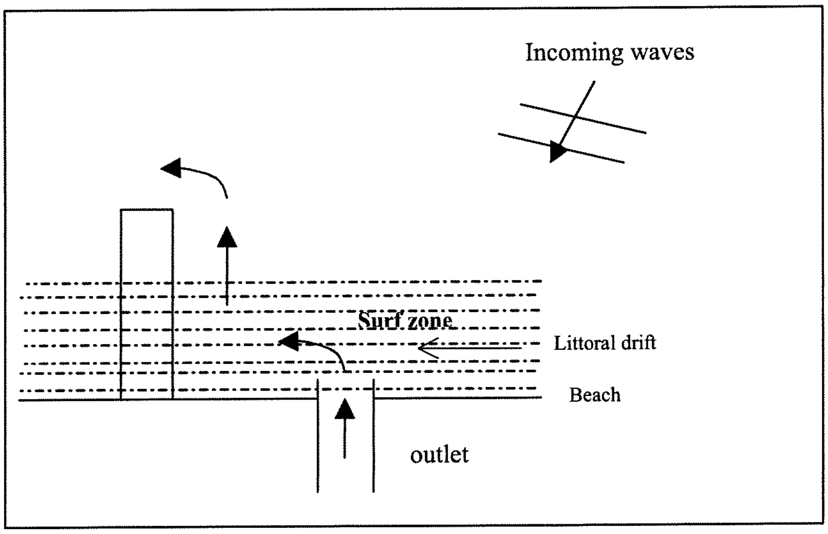


Figure 6-20: Situation during breakwater construction.

During construction, the combination of both processes were clearly visible. Especially in the beginning the scour dominated and on a few occasions parts of the constructed breakwater were damaged (chainages 40-70). At a later stadium when the breakwater was constructed up to about chainage 300 the accretion process became more dominant. A small basin developed near the root of the breakwater with smaller flow velocities as well as a spit. (see Figure 6-21).

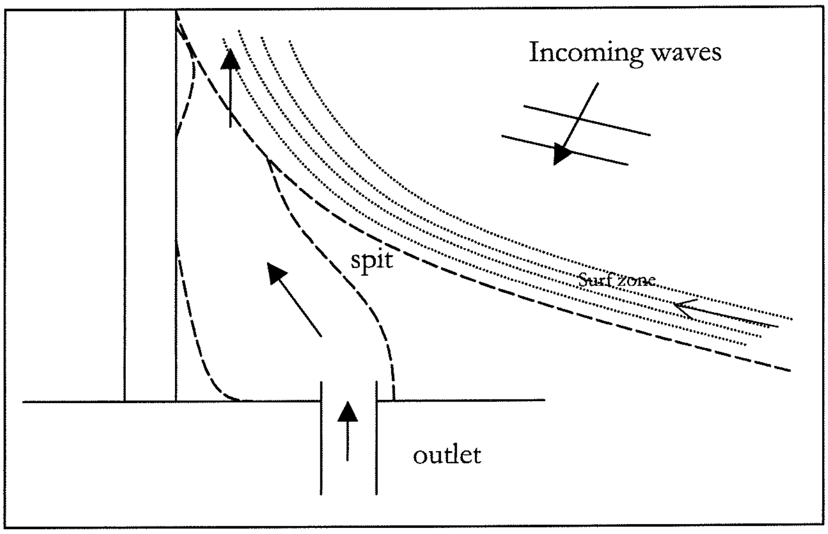


Figure 6-21: Stabilised flow at the root of the breakwater.

Due to accretion, the flow along the coastline became again more parallel near the breakwater. As a result the directions of the outlet and current in the breakerzone became more parallel again which could resulted in higher flow velocities. During personal observations it was noticed that the flow velocities during normal conditions were not very high. However this could be different during bad weather conditions. Then the influence of wave action becomes more important. The direction of the incoming design waves is very oblique to the breakwater (see Figure 6-21) and is more or less opposite to the current near the spit.
Depending on the water level during the conditions and the length and height of the spit it is likely that at some moment the flow finds a shorter route to the sea. It is possible that the flow 'breaks through' the spit or even crosses the root of the breakwater (see Figure 6-22). After the bad weather conditions, the sediment, washed out by the flow from the outlet channel will probably be deposited in the same area. and it is likely that a new spit forms.

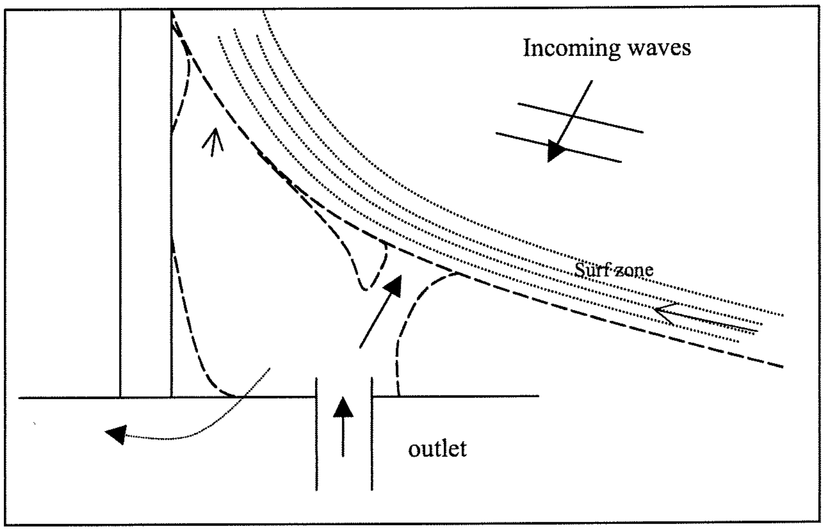


Figure 6-22: Flow breaking through the spit or crossing the breakwater root.

In the future the coastline will be 'fixed' by groynes situated south from the south breakwater. The same process, with different properties as described above, will take place. The sediment supply will probably decrease. This might increase the depth of a possible scour hole next to the breakwater. For the calculation of the properties of such a scour hole next to the breakwater, more information is required about bed levels and flow velocities.

To the Client it is recommended to monitor the bed levels and flow velocities in this area at least once a year and immediately after bad weather conditions. Based on that information it can be decided whether protective measures should be taken or not.

6.7 Co-ordination Quarry-Breakwater construction

When the contract for rock quarrying in and transportation was awarded in May 1996, the start of construction of the breakwater construction was planned in January 1997. In the design phase Delft University of Technology carried out a risk analyses [ref. 16] and used probabilistic models to determine the size of the rock stockpile at the Ennore port site. It was advised to create a stockpile of about 1 million tons of rock, before breakwater construction started.

Due to the slow progress of the rock production the amount of rock available at the stockpile was not enough to start with the construction of the breakwaters at the planned date. It was decided to postpone the award of tender. At the end the contract for breakwater construction was awarded more than six months later in July 1997.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Overview

The objectives of the graduation project were to investigate the deviations in the construction phase from earlier made assumptions, analyse the operational, economical time schedules and structural effects of these deviations and finally, to determine the impact on the design phase if this knowledge would have been prior available. In the previous chapters the deviations have been investigated and analysed. The deviations and effects thereof as discussed in the report are summarised here:

7.1.1 Rock Quarrying and Transportation

In the preparatory phase:

- Mobilisation of equipment, setting up of the different sites and improvement of the road between the quarry and the transfer station in Melpakkam took more time than planned. The railway sidings and gantry cranes, needed for loading and off loading of skips, were completed with 60 days delay. This was partly done by Southern Railways and could not be influenced by the Contractor, therefore he was given 60 days extension of time for all sections to be completed.
- The workmethod statement submitted by the Contractor was, unless contractual obligation, never approved. The main effect of this situation was absence of a useful supervision tool for the Engineer. This complicated decision making by the Engineer on site.

Production methods:

- Rock of grades A to D was selected visually.
- The processing plant for production of the rock grades E, F and filter material did not work as expected. The plant was modified and instead of mechanical separation, the rock for the grades E and F was selected by visual judgement.

Development of the quarry:

- The quarry was developed without a long term planning. This resulted in an enormous amount of rock that can not be reached due to high vertical walls in the quarry face. The hand over requirement of a quarry with benches of 8 m height and width and a final slope of 45 degrees can probably not be met.
- Waste and overburden are mostly pushed outside the Contractors area, instead of being removed from the mountain. Quarry roads are mostly very steep, narrow and not cleaned from overburden which makes these places dangerous to enter, especially during rain

Payments:

- Official payment procedures were not followed by the Client. Bills certified by the Engineer were adjusted and paid late.

Progress:

- After a very slow start, production of the larger rock gradings was ahead schedule. Production of the smaller rock gradings and overall production was behind schedule. Milestones were not completed in time and the Contractor had to pay a considerable amount of liquidated damages.

  The main reasons for delays were:
  - Slow mobilisation.
  - The bad state of the equipment the contractor uses.
  - The adjustments made to the rock separation plant

  The deviations in achieved production proportions of the rock gradings, from planned production proportions, could influence the quarry yield curve of the remaining rock production. A quarry yield curve can only be partly influenced by adjusting blasting patterns. Calculations proved that the deviating proportions hardly changed the quarry yield curve of the remaining rock production. It was concluded that, with an eye on future production methods, no problems were expected.

7.1.2 Breakwater construction

Realignment:

One month prior to the award of the contract an additional design with a relocated north breakwater was presented. The changes were not included in the contract but were put in a variation order, issued shortly after the award of the contract. The main consequences of the changed alignment were:

- Necessity of new soil investigations at the location of the north breakwater. The results showed that additional soil replacement was required.
- A new location and design of the temporary work harbour. It took the Contractor more than four months longer than planned to complete the work harbour.
- Possible changes in wave attack on the south breakwater. These changes have been investigated with the computer program HISWA. A small decrease in the design wave height was calculated for some parts of the south breakwater.
- Unclear time schedule for a long time. It took the Contractor more than one year to deliver a time schedule that was approved for the original alignment. The time schedule for the realignment of the north breakwater took even longer and was approved in November 1998.
- An extension of time of 250 days for completion of all works.

Compaction

Backfill material for the breakwater foundations was coarser than studies carried out in the design phase showed. The necessity of compaction works became questionable. A pilot compaction test was carried out and it appeared that compaction was not longer required.

Marine based construction methods:

The design of the toe of the breakwaters was slightly changed in order to comfort the working method. This had no major consequences for the strength of the designed breakwater.

Land based construction methods:
- The design was slightly changed in order to comfort the working method.
- The equipment used by the contractor is not the most suitable equipment for the job: Slopes could be trimmed only down to about the water level. A chain with a hook was used for armour placement instead of an orange peel grab and the larger rocks were placed close to the breakwater crest in order to prevent tilting of the cranes.

Accropode production:
- The concrete batching plant was operating manually instead of fully automatically. This decreased the production rate.
- It took the Contractor much time to get the concrete mixes and construct the Accropode moulds according to SOGREAH's specifications.

Land based survey practices:
- A single sounding pole is used for all gradings instead of the required sounding pole with a spherical end with a diameter of half the D_{n50} of the layer being surveyed. It's doubtful whether the required accuracy was achieved.
- It is questioned whether all surveys that were handed over to the Engineer were carried out correctly.

Payments:
- Similar to the contract for rock quarrying and transportation, official payment procedures were not followed by the Client. Bills certified by the Engineer were adjusted and paid late. This lead to tension between the different parties.

Properties of the realised south breakwater:
The properties of the state of the partly completed breakwater in December 1998 were studied:
- Available data was combined and bulk density ratio calculations were carried out. It was concluded that land based surveys were probably the main source for inaccuracies. And that the surveys probably showed more armour material than actually placed.
- Breakwat computations showed that the primary armour layer is more stable than designed, due to a reduced slope angle compared to the design.
- It can be questioned whether the armour layers have reached their design thickness under water. Inspection by a diver should give an indication of the existence of possible holes in the primary armour layers. In case of thin armour layers, filter properties of the layers might be reduced, possibly leading to unwanted settlement. A practical solution is to increase the thickness of the primary armour layer in order to achieve more loss of energy in that layer.
- The base and toe have been constructed according to the design level and width for practically the entire south breakwater.

Location of the NMTPP cooling water outlet channel:
The cooling water outlet channel of the North Madras Thermal Power Plant was relocated from the north side to the south side of the south breakwater. The current velocities in the

surf zone increased and caused some problems during construction of the breakwater root. When the breakwater was constructed up to about chainage 300 the current velocities decreased, and a more stable situation with a spit appeared.

7.1.1 Co-ordination Quarry-Breakwater construction

Due to the slow progress of the rock production the amount of rock available at the stockpile was not enough to start with the construction of the breakwaters at the planned date. It was decided to postpone the award of tender. The contract for breakwater construction was awarded more than six months later in July 1997.

7.1.2 Summary

An overview of the results of the analyses is given in Table 7-1. The most important deviations and their effects are summarised. Economical effects are not given in this table but the most important effects will be economical damage for the Client in case of late completion and economical damage for the Contractor in case of not achieving the milestones in time. (this has happened to the Contractor of rock quarrying and transportation. who is paying considerable amounts of liquidated damage.)

Deviating subject	Impact on the construction process	Impact on the completion date	Impact on the end product
Rock Quarrying and transportation			
1 Slow mobilisation	(-)	delayed	(-)
2 Late completion of railway sidings	60 extension of time	delayed	(-)
3 No approved workmethod statement	absence of supervision tool	(-)	(-)
4 Visual rock selection	different production method	(-)	Grading less accurate
5 Seperation plant works different	different production method	delayed	Grading less accurate
6 Narrow benches and steep quarry roads	dangerous working conditions	(-)	(-)
7 Dumping of waste outside Contractors area	different production method	(-)	If not removed a mess on the mountain
8 Frequent breakdown of equipment	train rakes not completely loaded	delayed	(-)
9 Deviating production proportions of the various grades	(-)	(-)	(-)
10 Quarry development	high benches not reachable and unplanned lower bench developed	delayed	Different shape of the mountain at handover
Breakwater construction			
1 New location of north breakwater		250 days extension of time	New design
- additional soil investigation	additional work	(-)	(-)
- New design of workharbour	additional work	delayed	(-)
- deviating wave attack on south breakwater	(-)	(-)	Reduced design wave height
- unclear timeschedule for long time	abcense of supervision tool	(-)	(-)
2 Coarser backfill material	no compaction required	earlier	strong foundation
3 Change of design to comfort working method	Easier production method	earlier	stronger design
4 Manually operated batching plant	Slow Accropode construction	delayed	(-)
5 Workmethod of the contractor			
- armour layer thickness near toe	(-)	(-)	questionable layer thickness
- armour layer slope is less steep	(-)	(-)	stronger armour layer slope
- land based survey practices	resurveys necessary	delayed	questionable
7 Location of cooling water outlet channel	problems at construction of root	delayed	Channel with spit next to the breakwater
8 Accretion at the south breakwater	(-)	(-)	Relatively stronger construction
9 Favourable monsoon conditions	higher construction progress during monsoon	earlier	(-)
Coordination between the two contracts			
1 Late award of breakwater contract due to slow progress of Quarry	(-)	delayed	(-)
General			
1 Incorrect payments by the Client	Undesired complications	(-)	(-)
2 Interference of Client on site	Undesired complications	delayed	(-)

(-) = Minor or no impact

Table 7-1: Deviating subjects and the effects thereof.

7.2 Conclusions

This graduation project shows that for the processes of quarrying and transportation of rock, as well as the processes of breakwater construction, there are a number of deviations in the actual construction phase from earlier planned processes. The main effect of the deviations were delays and difficulties during the production process itself. There are only a few deviations that actually effected the end product.

For rock quarrying and transportation these are:
1. Visual rock selection, due to problems with the rock processing plant influenced the accuracy of the rock gradings.
2. The shape of the quarry at hand over. This is however unimportant for the construction of the port.

For breakwater construction these are :
1. Realignment of the north breakwater.
2. The use of coarse backfill material for the breakwater foundation.
3. Slight changes in design to comfort the working method.
4. Rock placement and survey practices of the Contractor.
5. Relocation of the cooling water outlet channel of the North Madras Thermal Power Plant.

The changes made to the design of the breakwater, to comfort the work method were partly a result of the equipment used by the contractor. Generally the Contractor had difficulties realising details in the construction (berm in the core and precise placement of armour rock). For the supervisor it is important to find out as quickly as possible whether deviations can have an impact on the end product or not and to take appropriate actions.

The design of the breakwater allowed for some deviations in construction because additional safety was gained due to accretion at the south breakwater. The thicknesses of the primary and secondary armour layers did however not leave room for much deviations.
In countries like India it seems inevitable that a Contractor does not use the most suitable equipment for the job. As a result of this, details in a construction are more difficult to construct.
A conservative design allows for more deviations but can increase costs. In the design phase the effects of possible deviations on the properties of the end product should be taken into consideration.

7.3 Recommendations for the remaining construction period

- For sections of the south breakwater with a steep lower slope it is recommended to trim the slope, and place additional rock before the breakwater is handed over.
- At sections with relative thin armour layers it is recommended to increase the thickness of the primary armour layer. This reduces the hydraulic loads on the core material because more energy will be lost in the primary armour layer. It is important that the thickness of the primary armour layer reaches at least it's design thickness.

7.4 Recommendations for the Client

- It is recommended to monitor the armour layers at least once a year and directly after bad weather conditions in order to fill up possible gaps and trim the slopes.
- It is recommended to monitor the bed levels and flow velocities at the location of the cooling water outlet channel at least once a year and immediately after bad weather conditions. Based on that information it can be decided whether protective measures against scour should be taken or not.

REFERENCES

Referenced by text:

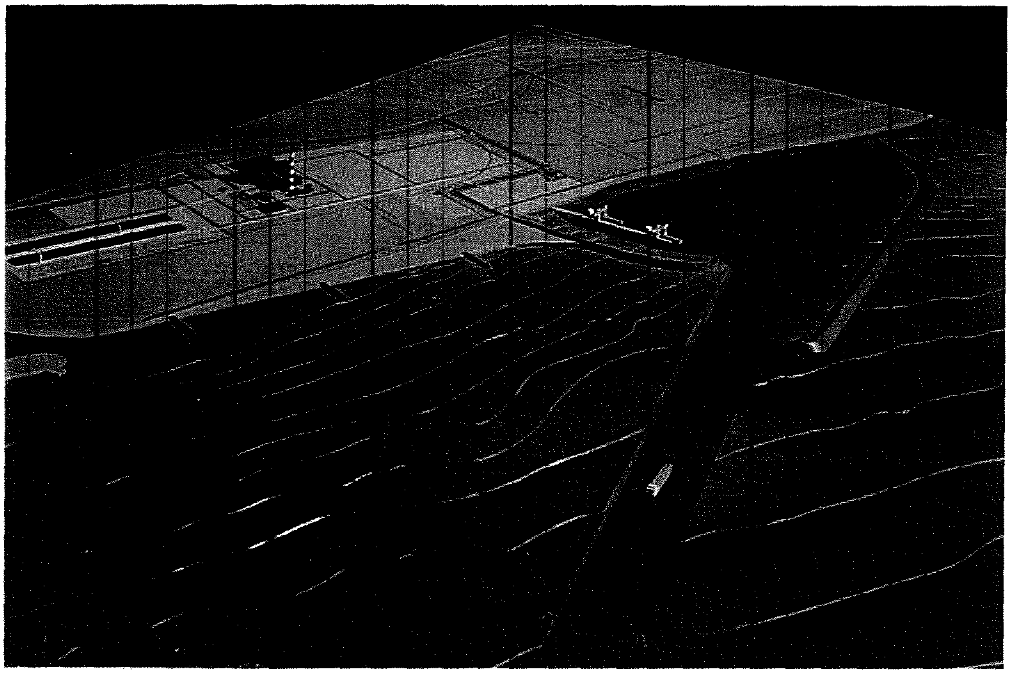
1. Frederic Harris in association with KBN Eng.& Applies sciences Incl., Eng. India Ltd., Kadiyali and Associates, *Strategic development plan for Ennore Port*,1997.
2. J. Naapuri, Tamrock, *Surface Drilling and Blasting*, 1988.
3. W. Sint Nicolaas, *Grading Control on Quarried Rock*, 1997.
4. HASKONING, *Ennore Coal Port Project, Detailed Design Report Breakwaters*, 1996.
5. HASKONING / RITES, *Ennore Coal Port Project, Additional Report to the Detailed Design Reports for Breakwaters, Dredging and Navigational Aids*, 1997.
6. Delft Hydraulics, *Ennore Coal Port Project, Cyclone Hindcast Study, Report phase 1, Part II, Report on numerical modelling*, 1995.
7. Delft Hydraulics, *Ennore Coal Port Project, Global Hindcast Study*, 1995
8. Delft Hydraulics, *Ennore Coal Port Project, Report on PHAROS and HISWA-2D calculations*, 1995.
9. J.C. Galland (EDF, France), MAST G6-S Coastal Structures, Proceedings of final Workshop, Lisbon, *Rubble mound breakwater stability under oblique wave attack*, 1992.
10. US Army Coastal Engineering Research Centre, *Shore Protection Manual, Volume I & II*, 1984.
11. J. v.d. Meer, Delft Hydraulics, *Conceptual design of rubble mound breakwaters*, 1993.
12. CUR Report 169, *Manual on the use of Rock in Hydraulic Engineering*, 1995.
13. Delft Hydraulics, *Ennore Coal Port Project, Additional PHAROS computations,* 1997
14. HASKONING/ RITES, *Ennore Coal Port Project, Pilot Compaction Test*, 1998
15. HASKONIG/ RITES, *Environmental study and investigations*, 1995
16. Delft University of Technology / *'Ennore Coal Port Project, Risk Analysis and Probabilistic Modelling, Final Report'*, 1995.

General references:

- Delft Hydraulics, *Breakwat Program, version 2.01*, 1993
- Delft University of Technology*, Ennore Coal Port Project, Risk Analysis and Probabylistic Modelling, Final Report*, 1995
- HASKONING/ RITES, *Ennore Coal Port Project, Bid Evaluation Report-Breakwater Construction*, 1997
- HASKONING/ RITES, *Various Monthly Progress Reports of the Ennore Coal Port Project.*
- G.S. Bhageloe, Delft University of Technology/Delft Hydraulics/SM2V*, Golfbrekers met een Enkele Toplaag*, 1998
- HASKONING/ RITES, *Ennore Coal Port Project*, Soil Improvement of New Alignment North Breakwater, 1998
- Thomas Telford Ltd. London, *Breakwaters Design & Construction, Proceedings of the conference organised by the Institution of Civil Engineers and held in London on 4-6 May 1983*. 1983.
- Madras Port Trust/ HASKONING/ RITES/ HCC, *Ennore Coal Port Project, Agreement no. 24, Rock Quarrying and Transportation Contract (ECPP/C1)*, 1996
- Chennai Port Trust/ HASKOING/ RITES/ HCC/Van Oord ACZ, *Ennore Coal Port Project, Agreement no. 33 of 1997, Breakwater Construction (ECPP/C4)*, 1997
- MTI in association with Mantec Consultants PVT Ltd., *Environmental Study construction of Ennore Coal Port*,1995

- HASKONING/ RITES, *Ennore Coal Port Project, Breakwater Construction, Extension of Time due to re-alignment of the North Breakwater*, 1997
- HASKONING/ RITES, *Various Reports, files and Letters on the Ennore Coal Port Project.*

RUBBLE MOUND BREAKWATERS FOR THE NEW PORT OF ENNORE (INDIA), EVALUATION OF CONSTRUCTION



FINAL REPORT
GRADUATION PROJECT
NOVEMBER 1999

APPENDICES

HASKONING
Consulting Engineers and Architects

TU Delft
Delft University of Technology
Faculty of Civil Engineering & Geosciences
Department of Hydraulic & Geotechnical Engineering

Student:	F. Scheffer
Graduation committee:	prof. ir. K. d'Angremond (TU Delft)
	ir. W. Tutuarima (TU Delft)
	dr. ir. P.J. Visser (TU Delft)
	ir. F.R. Kalff (Haskoning)

RUBBLE MOUND BREAKWATERS FOR THE NEW PORT OF ENNORE (INDIA), EVALUATION OF CONSTRUCTION

FINAL REPORT
GRADUATION PROJECT
NOVEMBER 1999

APPENDICES

HASKONING
Consulting Engineers
and Architects

TU Delft
Delft University of Technology
Faculty of Civil Engineering & Geosciences
Department of Hydraulic & Geotechnical
Engineering

Student: F. Scheffer
Graduation committee: prof. ir. K. d'Angremond (TU Delft)
ir. W. Tutuarima (TU Delft)
dr. ir. P.J. Visser (TU Delft)
ir. F.R. Kalff (Haskoning)

APPENDICES

I	:	Proposed quarry layout, cross sections and volume calculations
II	:	Rock Supply And Demand Schedules
III	:	Details of breakwater design calculations
IV	:	Comparison of design formulae for rock armour layers
V	:	Tolerances and requirements
VI	:	Results of the pilot compaction tests
VII	:	Surveys
VIII	:	Progress of Breakwater construction
IX	:	Example of a weekly progress report for landbased construction
X	:	Results of bulk density ratio calculations
XI	:	Representative cross sections for the south breakwater
XII	:	Hiswa calculations
XIII	:	Drawings for breakwater construction

APPENDIX I: **Proposed quarry layout, cross sections and volume calculations**

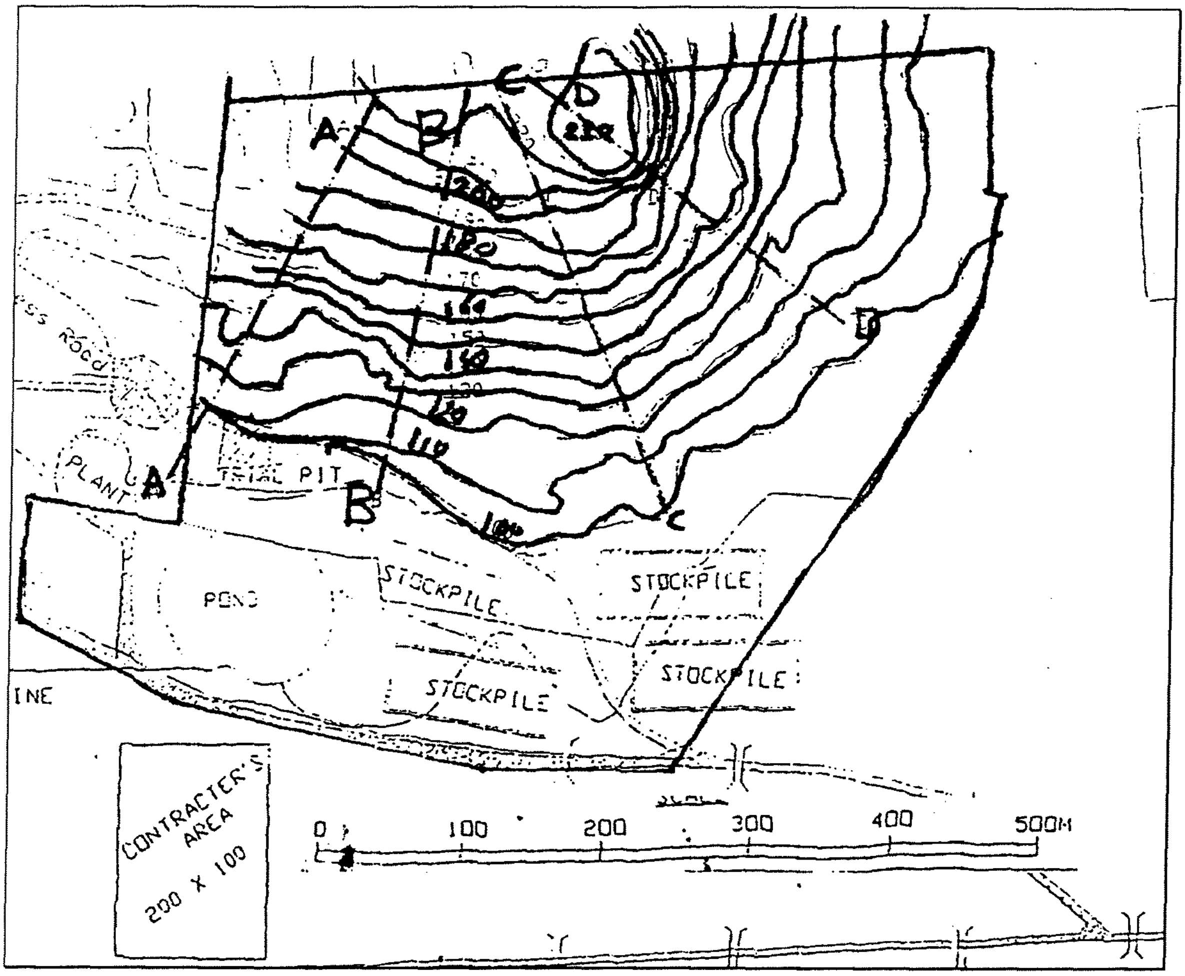


Figure I: Proposed Quarry-Layout

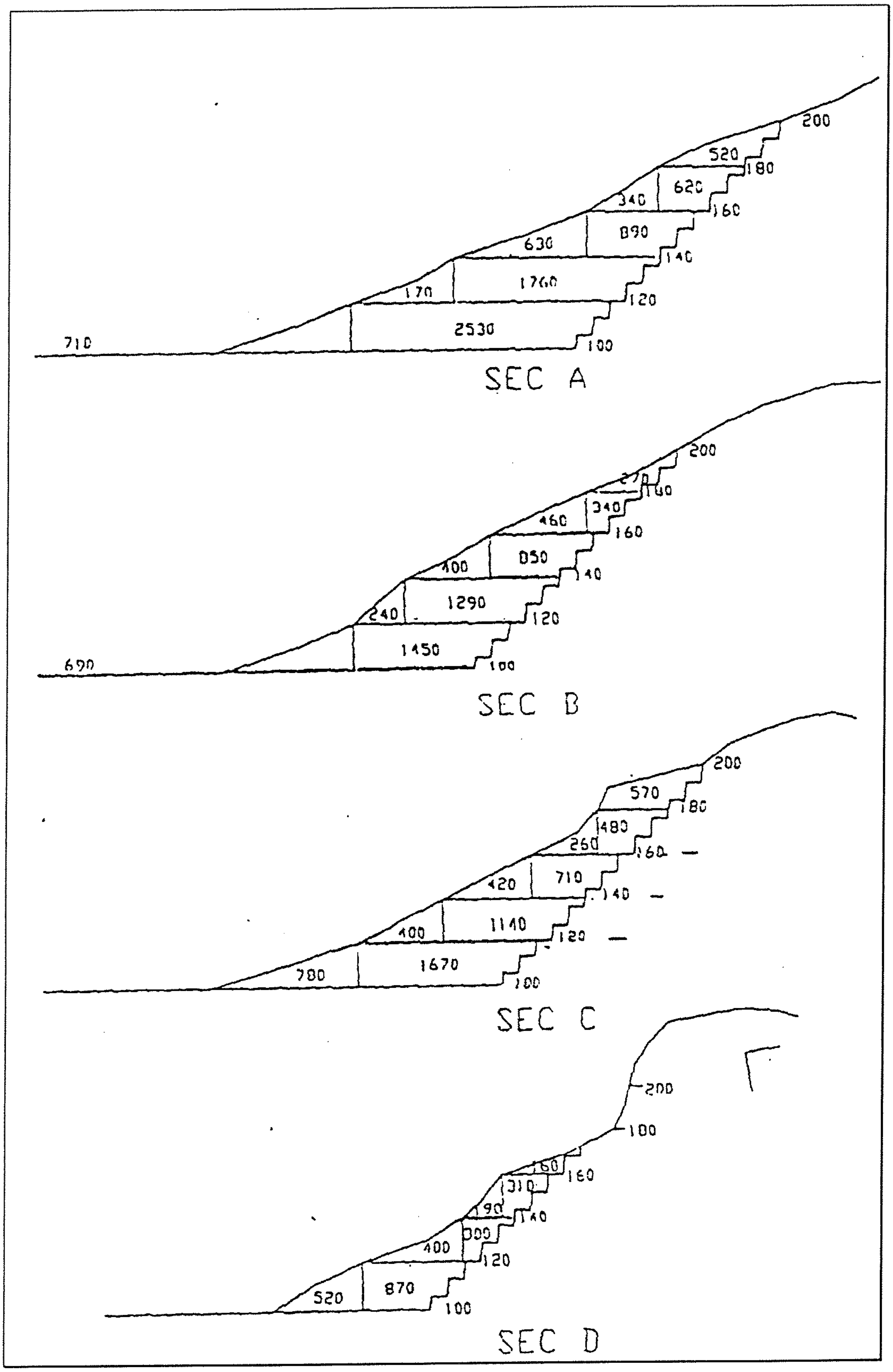


Figure II: Proposed cross sections of the quarry

ENNORE COAL PORT PROJECT

ROCK QUARRYING AND TRANSPORTATION - CONTRACT ECPP / C1

ANNEXURE - IV DETERMINATION OF QUARRY VOLUME

Triangle Contours	Areas as given in annexure V					Avg. Areas								
	sec A	sec B	sec C	sec D	avg AB	avg BC	avg BC	len AB	len BC	len CD	Vol AB	Vol BC	Vol CD	Total Vol
m	sq.m.	sq.m.	sq. m.	sq. m.	sq.m.	sq. m.	sq. m.	m	m	m	cum	cum	cum	cum
180 -200	520	270	570	0	395	420	285	90	90	90	35550	37800	25650	99000
160-180	340	460	260	0	400	360	130	100	110	120	40000	39600	15600	95200
140-160	630	400	420	190	515	410	305	110	130	120	56650	53300	36600	146550
120-140	170	240	400	400	205	320	400	130	150	140	26650	48000	56000	130650
100-120	710	690	780	520	700	735	650	150	190	170	105000	139650	110500	355150

Bench Contours	Areas as given in annexure V					Avg. Areas								
	sec A	sec B	sec C	sec D	avg AB	avg BC	avg BC	len AB	len BC	len CD	Vol AB	Vol BC	Vol CD	Total Vol
m	sq.m.	sq.m.	sq. m.	sq. m.	sq.m.	sq. m.	sq. m.	m	m	m	cum	cum	cum	cum
180 -200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160-180	620	340	480	160	480	410	320	90	90	90	43200	36900	28800	108900
140-160	890	850	710	310	870	780	510	100	110	120	87000	85800	61200	234000
120-140	1760	1290	1140	300	1525	1215	720	110	120	120	167750	145800	86400	399950
100-120	2530	1450	1670	870	1990	1560	1270	125	140	125	248750	218400	158750	625900

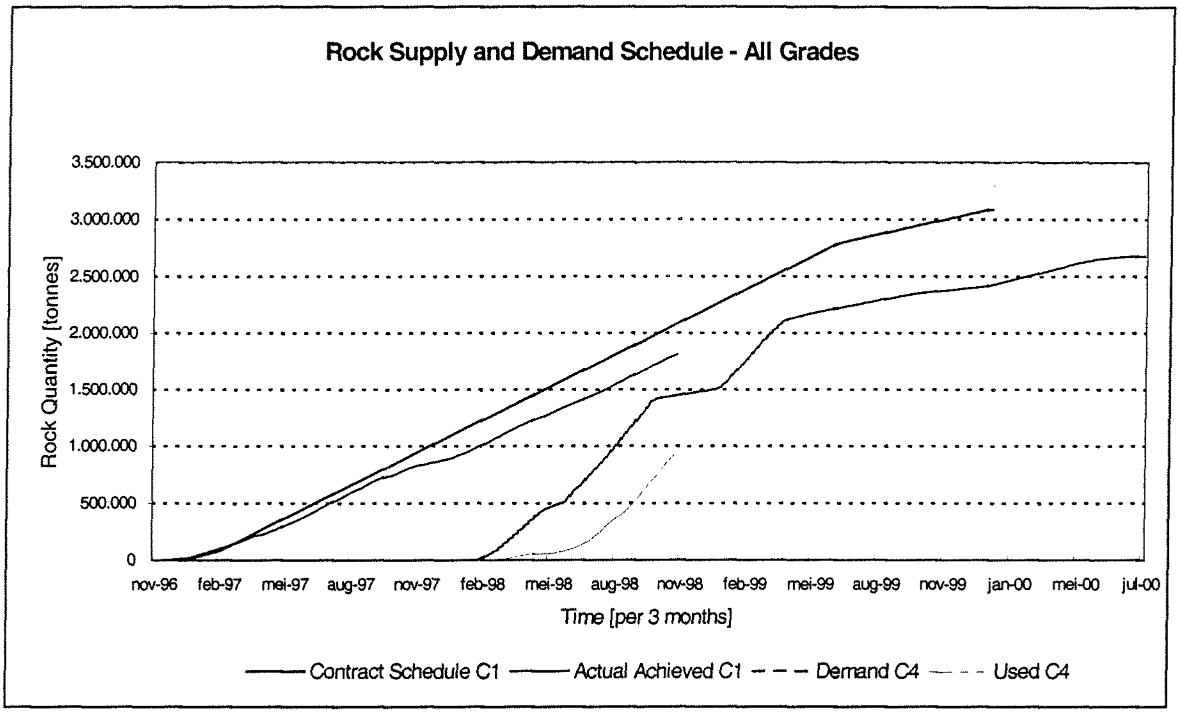
Total Volume for quarrying			
Contours	Triangle	Bench	Total
m	cum	cum	
180-200	99000	0	99000
160-180	95200	108900	204100
140-160	146550	234000	380550
120-140	130650	399950	530600
100-120	355150	625900	981050
Total	826550	1368750	2195300

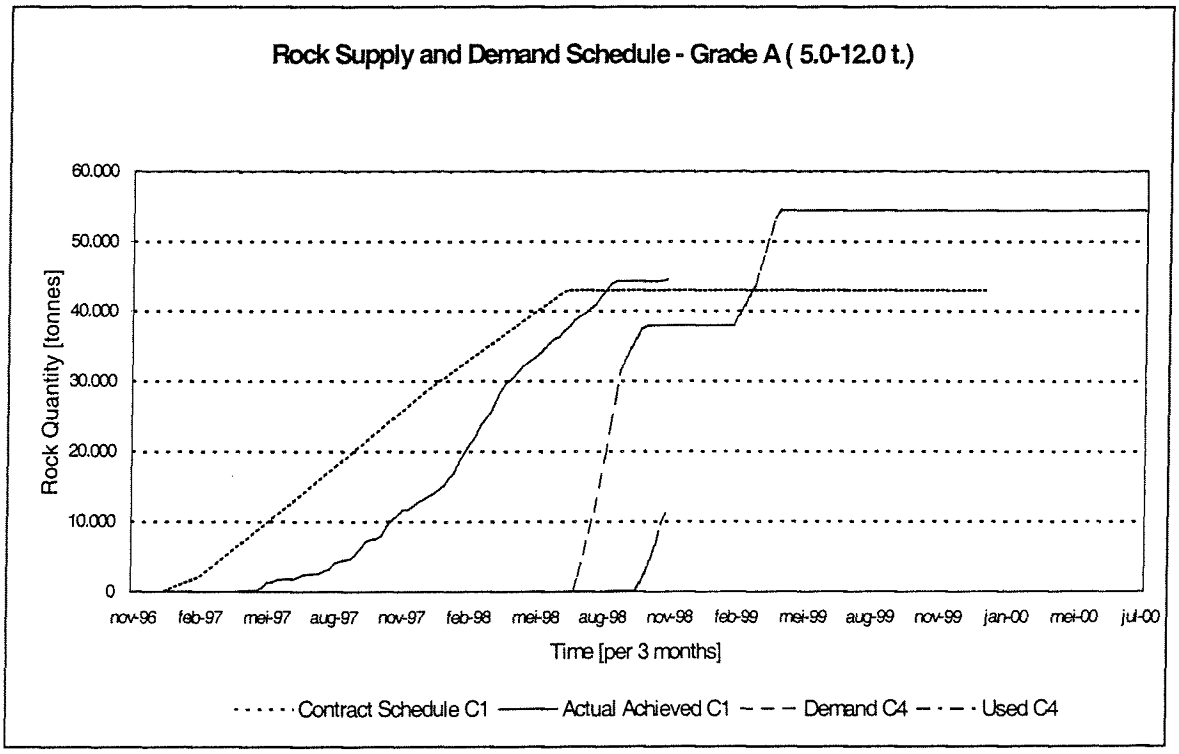
H.C.C.

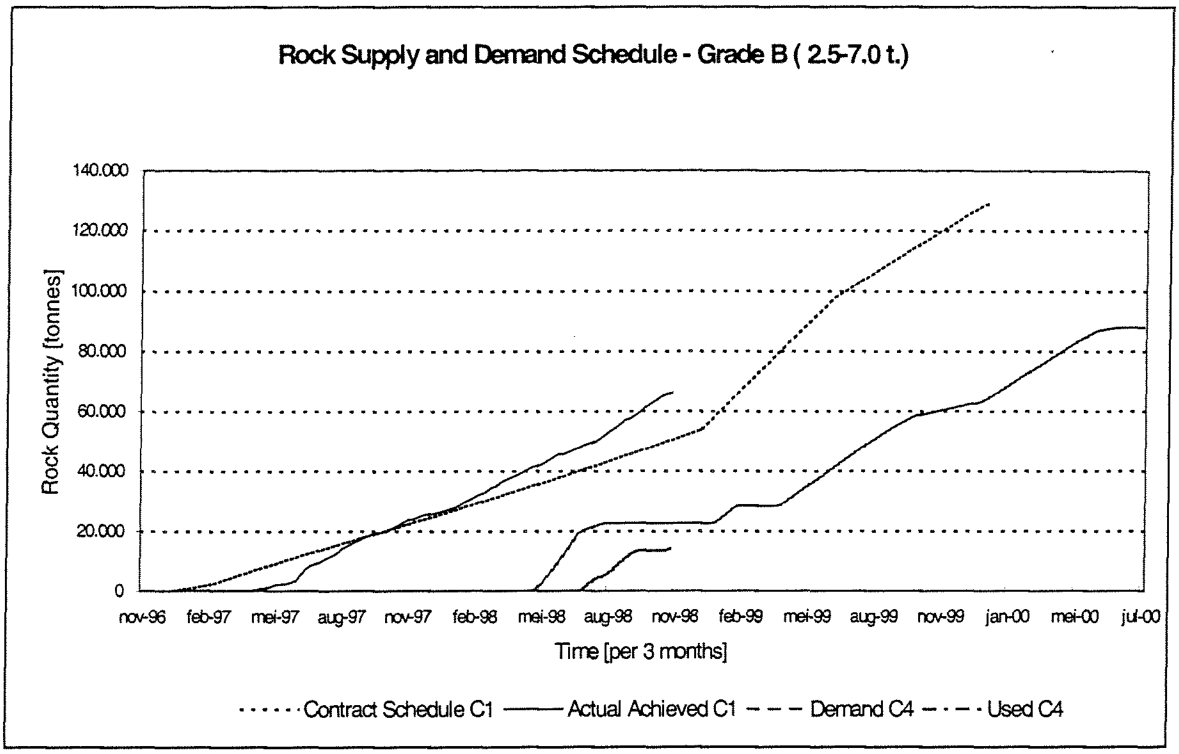
Figure III: Quarry volume calculations

APPENDIX II: Rock Supply And Demand Schedules

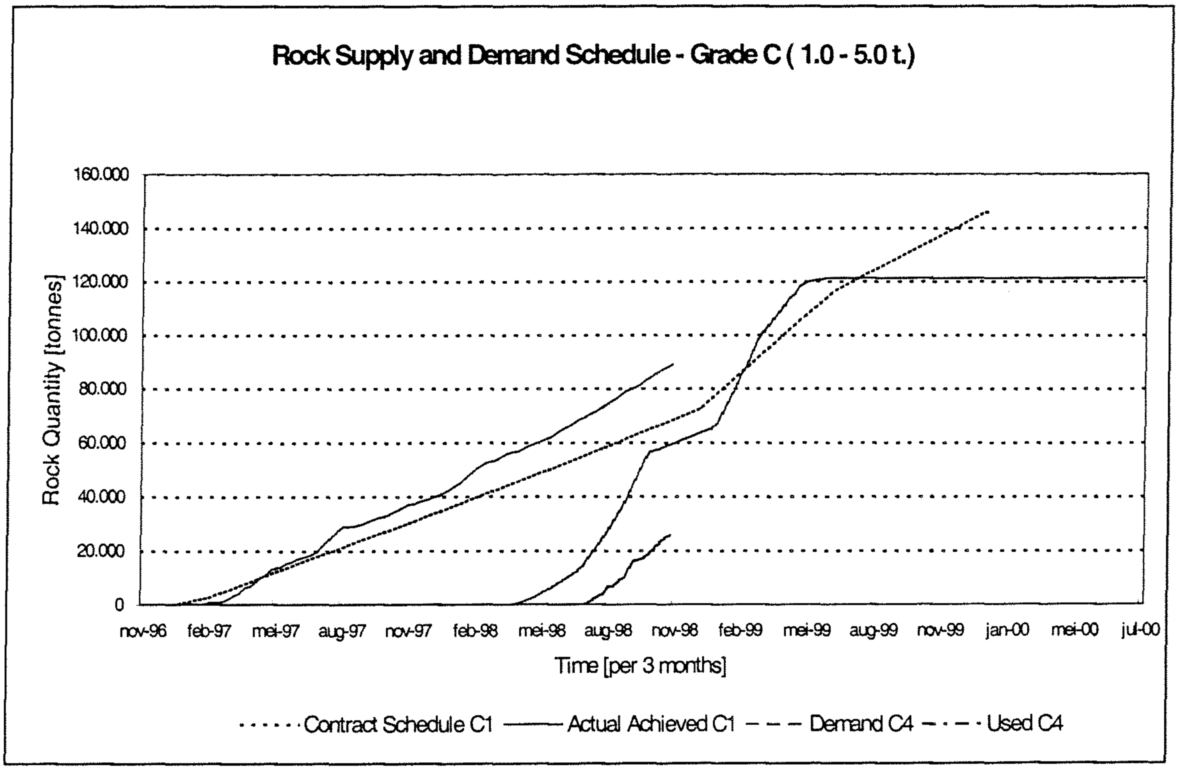
The following figures show rock supply and demand schedules for C1 and C4 where:
C1 = Contract for rock quarrying and transportation
C4 = Contract for breakwater construction



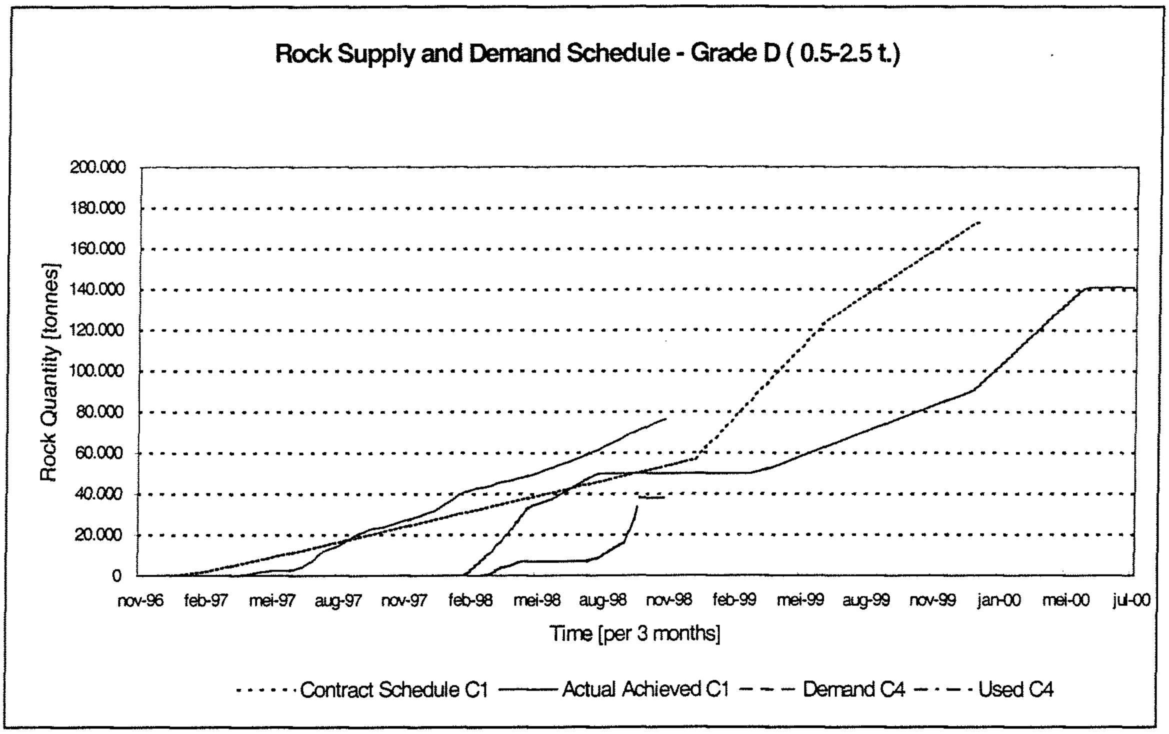


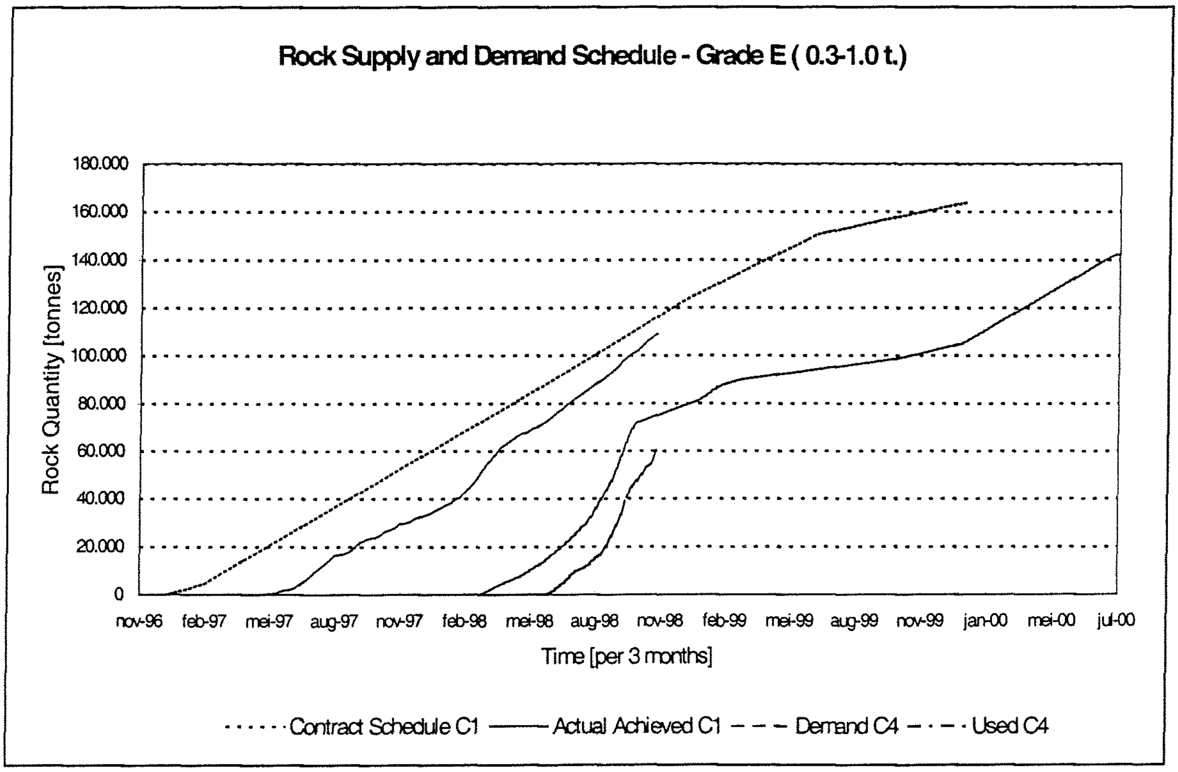


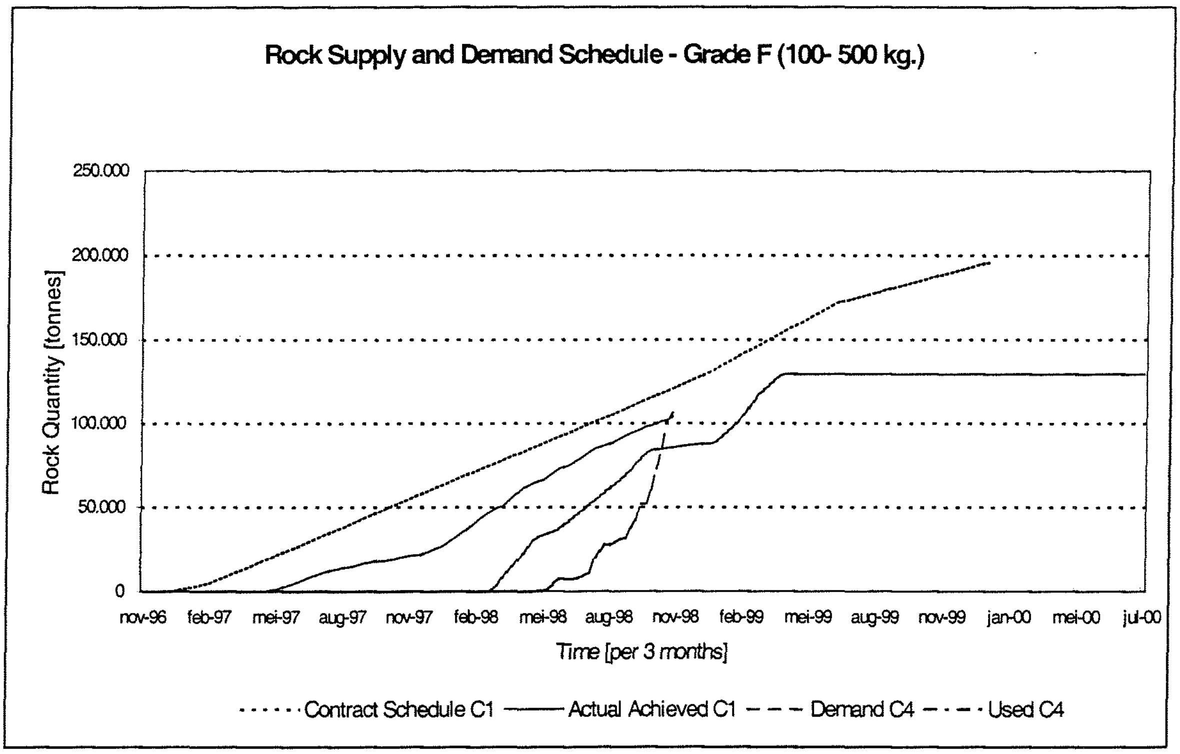
Rock Supply and Demand Schedule - Grade B (2.5-7.0 t.)
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
Rock Quantity [tonnes]
nov-96 feb-97 mei-97 aug-97 nov-97 feb-98 mei-98 aug-98 nov-98 feb-99 mei-99 aug-99 nov-99 jan-00 mei-00 jul-00
Time [per 3 months]
Contract Schedule C1
Actual Achieved C1
Demand C4
Used C4

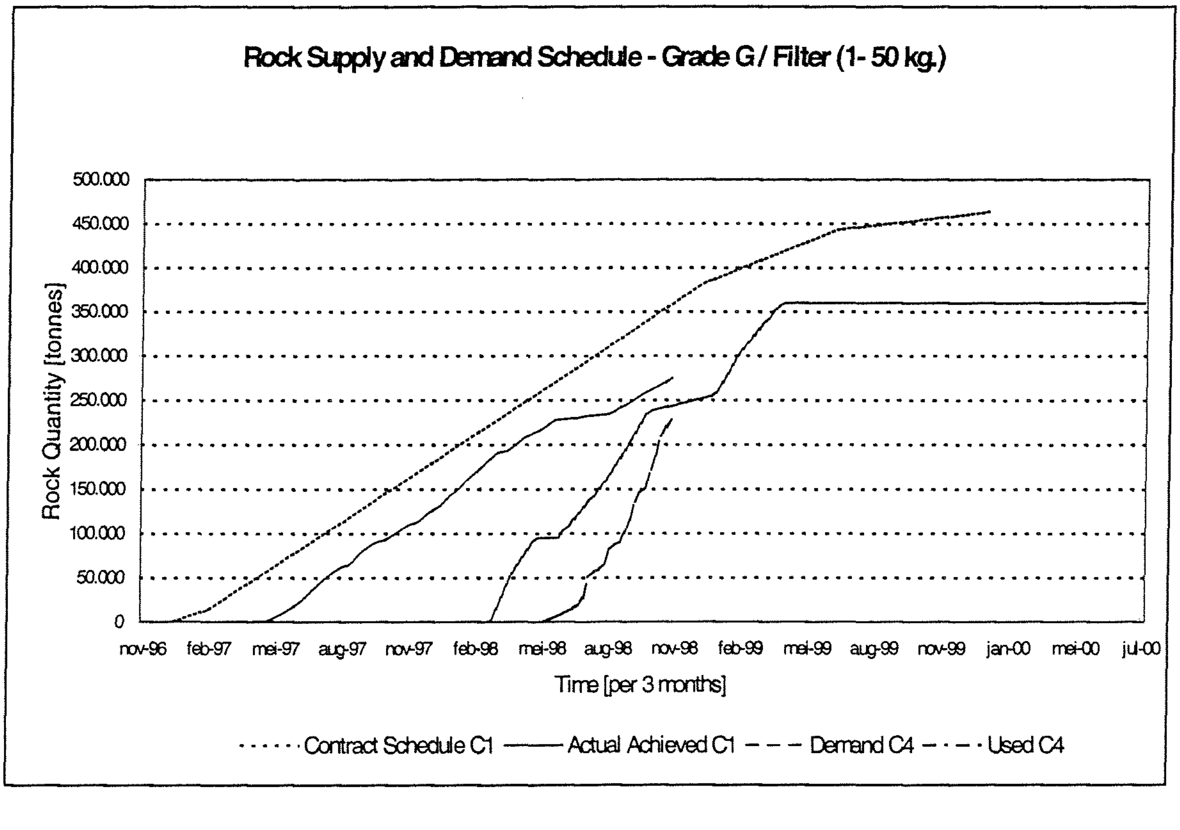


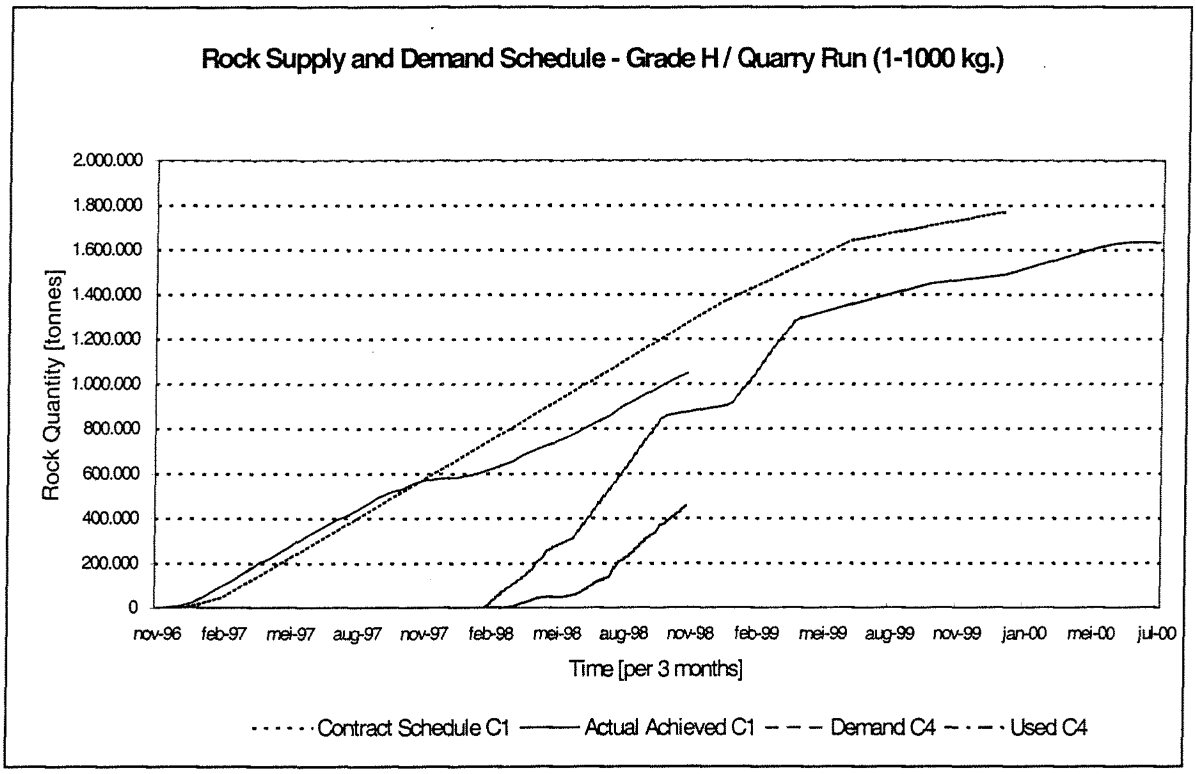
Rock Supply and Demand Schedule - Grade C (1.0 - 5.0 t.)
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
Rock Quantity [tonnes]
nov-96 feb-97 mei-97 aug-97 nov-97 feb-98 mei-98 aug-98 nov-98 feb-99 mei-99 aug-99 nov-99 jan-00 mei-00 jul-00
Time [per 3 months]
Contract Schedule C1
Actual Achieved C1
Demand C4
Used C4


Rock Supply and Demand Schedule - Grade D (0.5-2.5 t.)
Rock Quantity [tonnes]
200.000
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
nov-96 feb-97 mei-97 aug-97 nov-97 feb-98 mei-98 aug-98 nov-98 feb-99 mei-99 aug-99 nov-99 jan-00 mei-00 jul-00
Time [per 3 months]
Contract Schedule C1
Actual Achieved C1
Demand C4
Used C4


Rock Supply and Demand Schedule - Grade E (0.3-1.0 t.)
Rock Quantity [tonnes]
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
nov-96 feb-97 mei-97 aug-97 nov-97 feb-98 mei-98 aug-98 nov-98 feb-99 mei-99 aug-99 nov-99 jan-00 mei-00 jul-00
Time [per 3 months]
Contract Schedule C1
Actual Achieved C1
Demand C4
Used C4


Rock Supply and Demand Schedule - Grade F (100- 500 kg.)
250.000
200.000
150.000
100.000
50.000
0
Rock Quantity [tonnes]
nov-96 feb-97 mei-97 aug-97 nov-97 feb-98 mei-98 aug-98 nov-98 feb-99 mei-99 aug-99 nov-99 jan-00 mei-00 jul-00
Time [per 3 months]
Contract Schedule C1
Actual Achieved C1
Demand C4
Used C4


Rock Supply and Demand Schedule - Grade G / Filter (1- 50 kg.)
500.000
450.000
400.000
350.000
300.000
250.000
200.000
150.000
100.000
50.000
0
Rock Quantity [tonnes]
nov-96 feb-97 mei-97 aug-97 nov-97 feb-98 mei-98 aug-98 nov-98 feb-99 mei-99 aug-99 nov-99 jan-00 mei-00 jul-00
Time [per 3 months]
Contract Schedule C1
Actual Achieved C1
Demand C4
Used C4


Rock Supply and Demand Schedule - Grade H / Quarry Run (1-1000 kg.)
Rock Quantity [tonnes]
2.000.000
1.800.000
1.600.000
1.400.000
1.200.000
1.000.000
800.000
600.000
400.000
200.000
0
nov-96
feb-97
mei-97
aug-97
nov-97
feb-98
mei-98
aug-98
nov-98
feb-99
mei-99
aug-99
nov-99
jan-00
mei-00
jul-00
Time [per 3 months]
Contract Schedule C1
Actual Achieved C1
Demand C4
Used C4

APPENDIX III: Details of breakwater design calculations

III.I Hydraulic boundary conditions

1. Water levels and tides:
   Ennore has a moderate semidiurnal tide with a range of about 0.60 m:

High High Water Level	+ 1.50 m CD
Mean High Water Spring	+ 1.10 m CD
Mean High Water Neap	+ 1.15 m CD
Mean Sea Level	+ 0.84 m CD
Mean Low Water Neap	+ 0.65 m CD
Mean Low water Spring	+ 0.43 m CD
Low Low Water level	- 0.10 m CD

Extreme water levels as calculated in the cyclonic hindcast study carried out by Delft Hydraulics are:

Extreme water levels	water depth		
(m + CD)	15 m	10 m	5 m
astronomical tide	1.1	1.1	1.1
Seasonal variations	0.1	0.1	0.1
wind set-up/ storm surge	0.19	0.24	0.29
Wave set-up	-0.02	0.04	0.11
barometric pressure	0.2	0.2	0.2
seiches and long waves	-	-	-
global sea level rise	-	-	-
Total	1.57	1.68	1.8

Table I: Extreme water levels

2. Wave conditions
   - Normal wave conditions:

The normal wave conditions have been studied by Delft Hydraulics in a Global Hindcast Study. A result of this study is Figure IV which shows the percentage of times per year a certain wave height will be exceeded. The once per year wave height can now be determined. Assuming a six hours storm duration, the exceedence percentage becomes: 6 hours/(365 days*24 hours) *100% = 0.0685 %. The figure shows a 1/1-year wave height of 2.25 m.

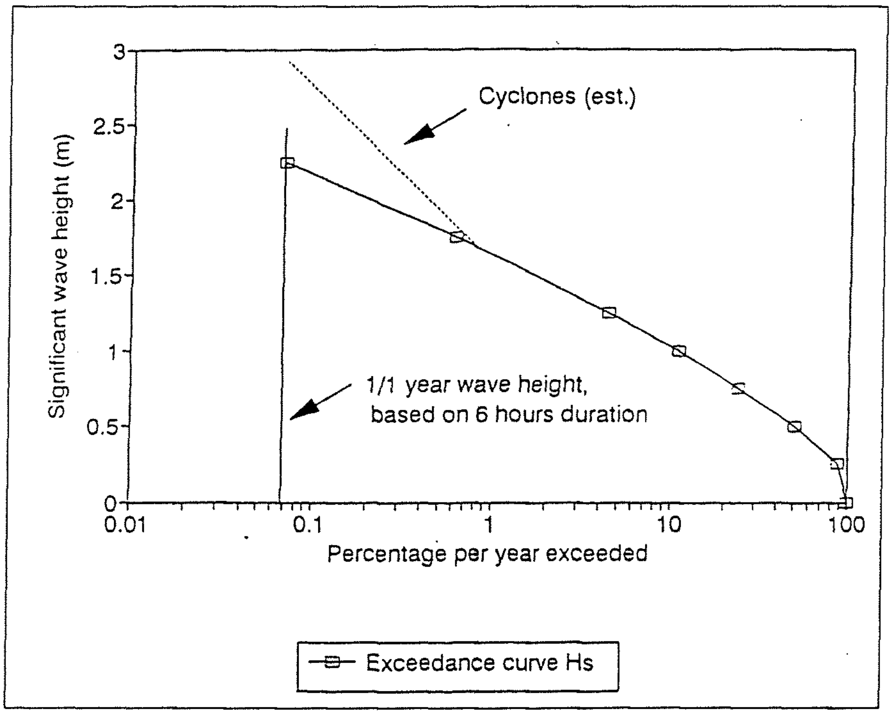


Figure IV: Normal wave conditions

- Extreme wave conditions:

Extreme wave conditions will occur during cyclones. In the Cyclone Hindcast Study the extreme wave conditions were calculated using statistical evaluation and extrapolation of cyclonic storm records along the East Coast of India.

The maximum wave conditions for the 1/100 years event have been calculated for various water depths closer to the shore (viz.-11.5 m, -10 m, -8 m, -6 m, -5 m and -3 m CD). The design water levels for the various depths have been found through interpolation of the results inTable I. The deep-water waves approaching the coast will break due to depth limitations. The CIRIA/CUR manual has been used to establish the maximum significant wave height on the uniform sloping beach. Figure V shows the used graphs. For a deep-water wave steepness s_{op} of 0.040 the lower graph has to be used. At –11.5 m CD the water depth becomes 11.5 + 1.7 = 13.2 m. h/L_{op} becomes 0.058 and from the lower graph can be derived that for slopes gentler than 1:100, which is the case at Ennore, $H_s/h=0.5$. This method has been applied on the other depths as well. The results are given in Table II

Sea bottom level	Water level (+m CD)	water depth (m)	h/Lop	Hs/h	Hs,max (m)
3	1.83	4.8	0.021	0.64	3.1
5	1.80	6.8	0.03	0.59	4
6	1.78	7.8	0.035	0.57	4.4
8	1.73	9.7	0.043	0.54	5.2
10	1.68	11.7	0.052	0.52	6.1
11.5	1.66	13.2	0.05	0.5	6.6

Table II: Maximum H_s for the 1/100 years event at various water depths.

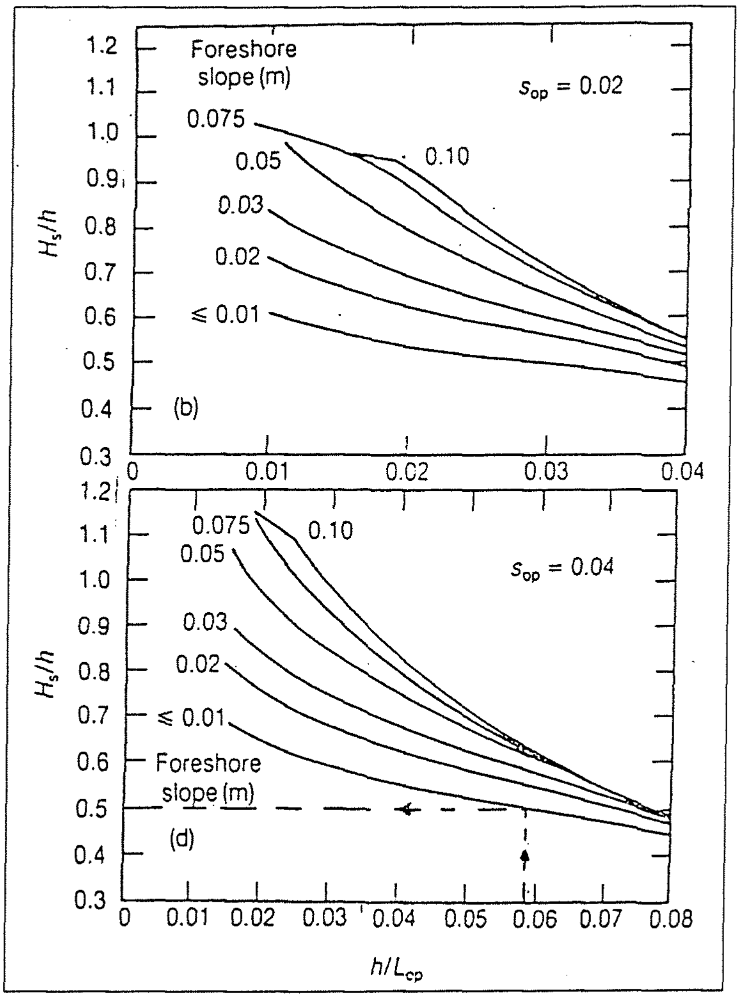


Figure V: Significant wave height in shallow water for uniform foreshore slopes (CUR/CIRIA 1991)

For the stability of armour rock it is necessary to have information about the highest waves in a sea state. Most formula's are based on the significant wave height which gives a good indication of the state of the water. However the highest waves can be much higher, therefore $H_{2\%}$ is also a possible wave height to use for stability calculations. In deep water conditions $H_{2\%} / H_s = 1.40$. The wave height distribution, which is a Raleigh distribution at deep water, will change due to wave breaking (see Figure VI). For slopes of 1:100 physical model tests have been carried out by van der Meer and Janssen. These tests show a reduction Y_h of the ratio (see Figure VII) described by:

$$Y_h = 1 - 0.03(4 - h/H_s)^2$$

For the –11.5 m CD bed level the formula gives:

Water depth:	h = 11.5 + 1.7 = 13.2 m
Depth limited significant wave height:	H_s = 6.6 metres
Reduction factor:	Y_h = 0.89

The $H_{2\%} / H_s$ ratio becomes 0.89* 1.40 = 1.23. For further calculations 1.25 has been assumed.

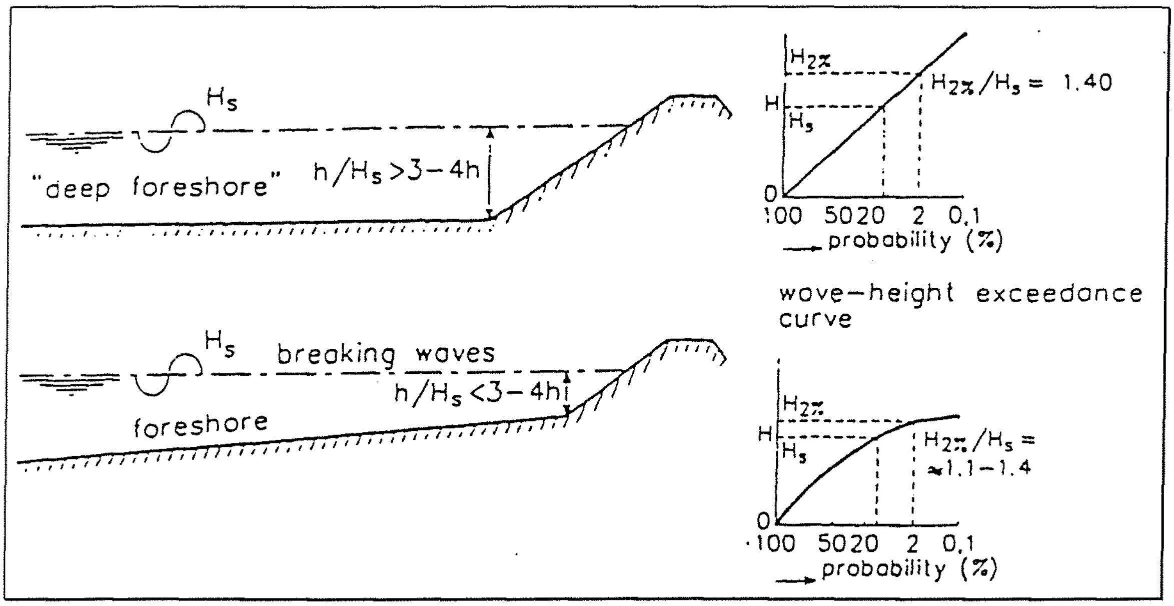


Figure VI: Change of wave height distribution due to breaking at shallow water

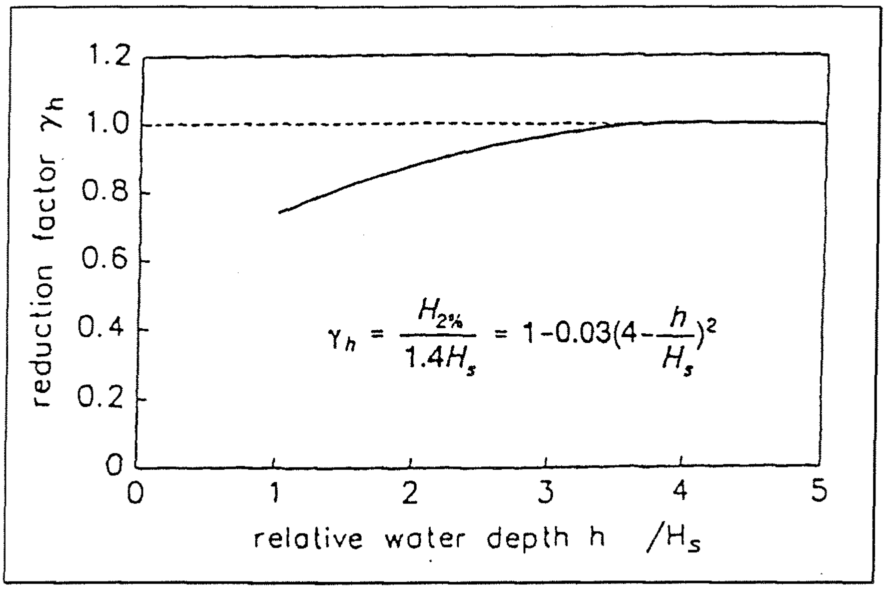


Figure VII: Reduction factor for stability formulae for 1:100 foreshore slope

III.II Geotechnical conditions

Longitudinal soil profiles along the alignment of the breakwaters are presented in Figure VIII and Figure IX. Relevant geotechnical design parameters derived from field and laboratory tests and from mutual correlations are presented in Table III.

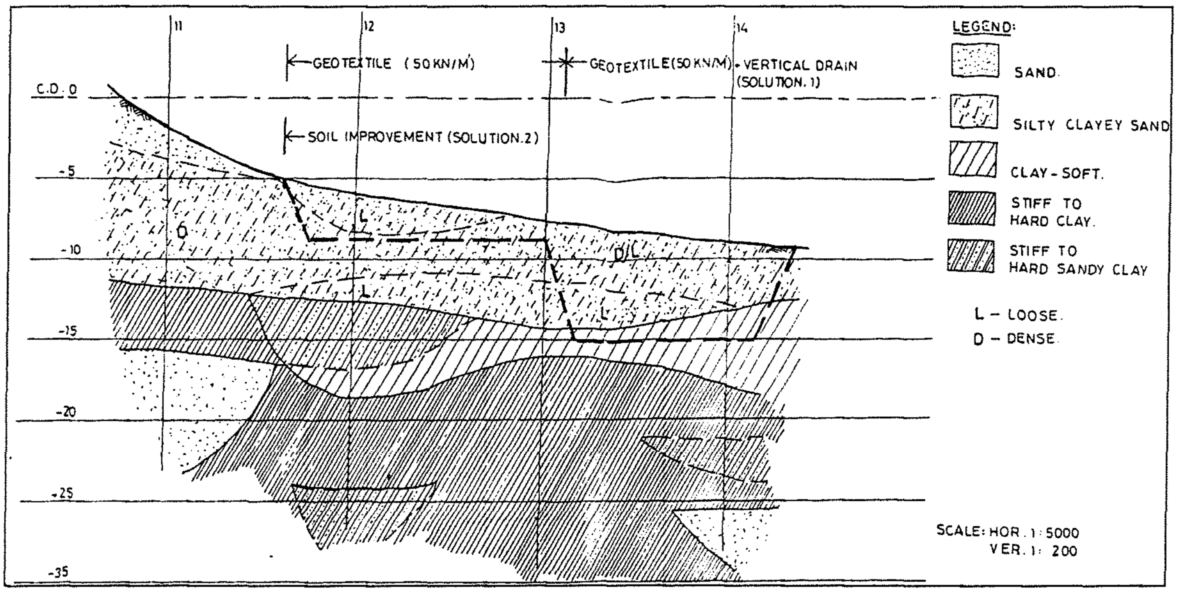


Figure VIII: Longitudinal soil profile of the south breakwater

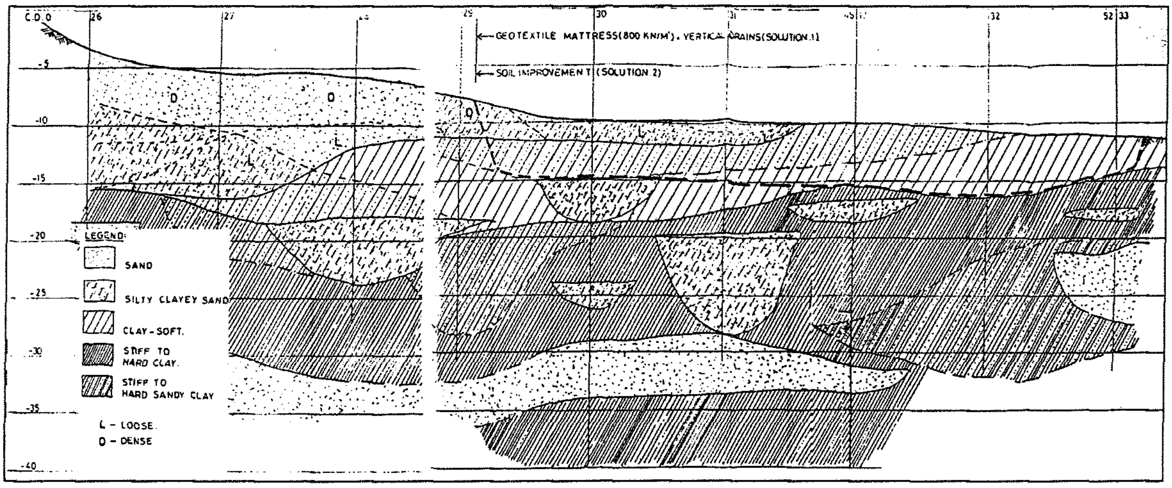


Figure IX: Longitudinal soil profile of the north breakwater

Soil Type	$\gamma d/\gamma s$ (kN/m^3)	c^1 (kN/m^2)	$\phi 1$ (°)	c_{ui} (kN/m^2)	C^1	Cv m^2/year
Dense sand	20/20	-	- 35	-	1000	-
Loose silty sand	17/18	-	15-25	-	20	-
Soft clay	18/18	5	15	5-10	6	2-4
Medium stiff clay	19/19	5	20	10-15	15-20	2-4
Stiff clay	20/20	10	20	15-25	25	2-4
Hard clay	20/20	10	30	40	>50	2-4

Table III: Geotechnical design conditions

γd = dry density
γs = saturated density
c^1 = drained cohesion
ϕ^1 = drained angle of internal friction
c_{ui} = initial undrained compression
C^1 = compression constant:

$$C^1 = \frac{1+e_0}{C_c} \times 2.3$$

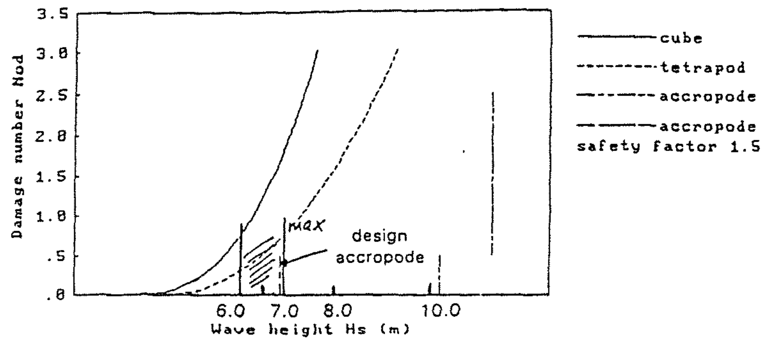
e_0 = initial void ratio
C_c = compression index
C_v = coefficient of consolidation

III.II Primary armour at the deepest section of the breakwater

The damage level of an armour layer made of Accropode units can be expressed in the number of displaced units in a layer (N_{od}). For Accropodes $N_{od} > 0.5$ corresponds with failure. The required size of the armour units has first been calculated by using computer program Breakwat which uses the Van der Meer formulas. Figure X shows the relation between significant wave height H_s and the damage level N_{od} calculated with Breakwat for Accropodes with a weight of 15 tonnes. Three vertical lines show damage levels for Accropodes; the right vertical line represents damage level $N_{od} > 0.5$ which stands for failure; the centre vertical line represents no damage ($N_{od} = 0$) excluding the safety factor of 1.5 and the left vertical line represents the for this construction required level of no damage including the safety factor of 1.5. The design wave height of 6.6 metres at the -11.5 m CD line as calculated in the physical site conditions section corresponds for Accropode units of 15 tons with the left vertical line in the figure (damage level $N_{od} = 0$ and a safety factor of 1.5) which is the line for the optimum design value. This procedure was repeated for other sections of the north breakwater. Finally Accropodes of 15, 12 and 10 tonnes were selected.

06:39 AM Thursday 26 January 1995. program = BREAKWAT Version 2.(
Licensed user: for internal use only Copyright DELFT HYDRAULIC'

Damage curves concrete units



For $H_{2\%}/H_s = 1.25$

Stability curves concrete units:

Combined graph: Cubes, Tetrapods and Accropode

Input :

```
mass of unit             : M     = 15000.000 (kg)
mass density of unit     : rho-a =      2400 (kg/m3)
mass density of water    : rho-w =      1025 (kg/m3)
wave steepness           : sm    =      .040 (-)
number of waves          : N     =      2500 (-)
```

Figure X: Damage curve for 15 tonne Accropode

The three dimensional tests showed that Accropodes of 15 tonnes were stable at the head section of the breakwater. Accropodes of the other sections were also stable at the tested trunk section. Artificially created holes in the armour layer did not induce major damage, this can be explained by the applied safety margin. For the detailed design the following Accropode sizes have been selected for the given water depths:

water depth (m - CD)	selected Accropode (tonnes)
11.5 - 11.1	15
11.1 - 10.4	12
10.4 - 7.0	10

Table IV : Selected Accropode sizes for the north breakwater

III.III Rock as an armour layer

The south breakwater is protected from easterly wave directions by the north breakwater. The most critical wave directions for the south breakwater are from 110 to 150 degrees (due to north). Wave studies carried out by Delft Hydraulics showed that these directions change to 114-131 degrees at the structure due to refraction. The wave height at the head of the northern breakwater for more southerly directions is estimated at 6.0 m. Based on calculations in the wave studies, using the program Pharos, it was assumed that the design wave height at the head of the south breakwater is reduced to 60 % of the design wave height at the head of the northern breakwater (60% of 6.0 m results in 3.6 m).. The same approach the section of the trunk from the head up to the –8 m CD depth line gives a wave height of 75% of the wave height at the head of the northern breakwater (75 % of 6.0 m results in 4.5 m). This wave height is assumed to be perpendicular to the structure. The breakwater section of the trunk from the –8 m CD depth line to the shore has a depth limited and very oblique wave attack. This is also the case for the sections at the northern breakwater with rock as primary armour (-7 m CD to the shore).

The required size of the armour rock for sections with more or less perpendicular wave attack (head to –8 m CD) has been calculated using the computer program Breakwat which uses the Van der Meer formulas. For design conditions of the armour layer an acceptable damage level S = 3 is chosen, this corresponds with hardly any damage (according to the SPM damage is 0 to 5 %). Other design conditions used are; A six hours storm duration (2250 Waves); mass density of rock of 2660 kg/m^3; Wave breaking ratio $H_{2\%}/H_s = 1.25$. A seaward slope angle of $\cot\alpha = 2$ and a notional permeability factor P = 0.4.

For sections with waves very oblique to the structure the following formula has been used for calculation of the required nominal diameter D_n of the rock:

$$D_n = \frac{H_s}{\Delta \cdot 1.25 \cdot 2}$$

This formula has been derived from research work carried out in the framework of MAST see also Appendix IV for further details.
An overview of the selected design conditions, required Dn, M50 and selected grading is given in Table V. The required mass has been determined for the deepest part of each breakwater section so that shallower parts of each section are slightly over designed. Therefor it might be decided by the Engineer that, during construction, rock that does not entirely match the grading specifications of a certain section can be used for the shallower part of the section.

Break-Water	Section; bed level [m CD]	Water Level [m CD]	Water depth [m]	H_s [m]	M_{50} calculated [tonnes]	Selected grading [tonnes]	M_{50} of selected grading [tonnes]
South	Head / -9.0	1.70	10.70	3.60	5.70	5 –12	7.70
South	Head/ -8.0	1.75	10.25	4.50	7.20	5 –12	7.70
South	-8.0/ -7.5	1.75	9.75	4.90	4.95	5 –12	7.70
South	-7.5/-5.0	1.80	9.30	4.65	4.15	2.5 - 7	4.18
North	-7.0/-5.0	1.80	9.30	4.65	4.15	2.5 - 7	4.18
North / South	-5.0/0.0	1.80	6.80	3.40	1.62	1 - 5	2.20

Table V: Selected design conditions for rock as primary armour

For the layer thickness of the armour layers a thickness of two times the nominal diameter D_n multiplied with a thickness coefficient is used. A layer thickness coefficient of 0.9 is selected on basis of Engineering judgement.

III.IV Relation crest height - wave transmission

Considered crest heights are + 4.5 m and + 5.0 m CD which results in crest freeboards R_c of 3.0 and 3.5m (with a water elevation of 1.5 m). Breakwat is used to calculate wave transmission for low rock structures with an armour layer of rock on the seaside, crest and rear. The application in Breakwat is based on many physical tests executed at Delft Hydraulics. The tests available at Delft Hydraulics showed that overtopping behaviour for tetrapods, Accropodes and cubes is almost similar. Results of the calculations with Breakwat and test results for similar crest heights are shown in Table VI.
The results based on the tests show a slightly higher value for transmission than the calculations with Breakwat. This is mainly caused by the fact that for the calculations with Breakwat a crest width of 12 metres is used and that the tests of Delft hydraulics use a crest of about 5 to 6 metres. Based on the values in Table VI it can be concluded that the transmitted wave height under design conditions is limited to about 1.3 meters.

Return period (years)	Tp (s)	Hs at -11.5 m CD (m)	Wave transmission Ht (m)			
			Breakwat		Available tests	
			Rc = 3.0 m	Rc = 3.5 m	Rc = 3.0 m	Rc = 3.5 m
5	9.3	4.2	0.34	0.32	0.60	0.38
10	10.3	5.4	0.65	0.44	0.95	0.90
25	11.1	6.0	0.99	0.76	1.40	1.20
50	11.6	6.5	1.33	1.00	1.70	1.30
100	12.0	6.6	1.34	1.11	1.80	1.40

Table VI: Wave transmission at the breakwater

III.V Base and toe

The weight of the toe has been designed with the formula given in 'Conceptual design of breakwaters', Delft Hydraulics. The required weight as function of the relative toe depth is given in Figure XI. This relationship can be directly calculated because the design wave is related to the water depth (broken wave condition).

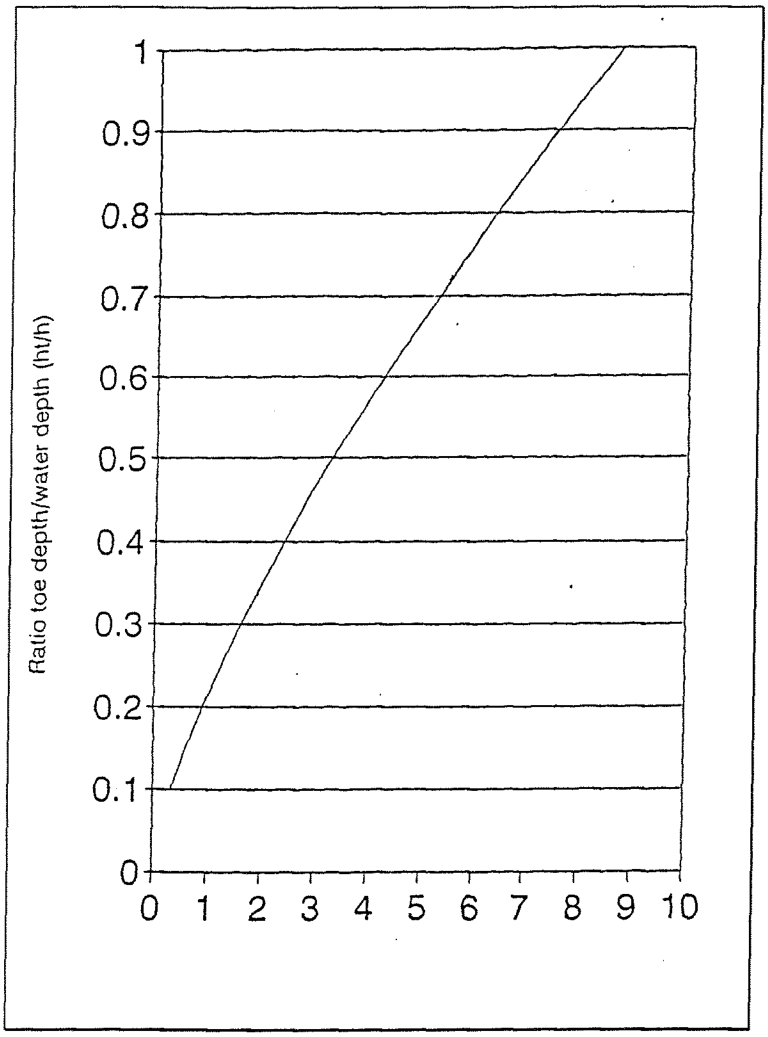


Figure XI: Required mass for toe layer as function of the relative water depth

III.VI Geotechnical design

Two dimensional settlement calculations have been carried out according to the method of Terzaghi/Buisman. A time/settlement relation has been established with the assumption of 25 % secondary settlement after 10000 days. Table VII shows the results of the calculations.

Breakwater	Bottom level	Settlement (m) after 10,000 days			Percentage of settlement after t years				
	(m CD)	toe port side	crest	toe sea side	t = 0.25	0.5	1	3	10
North	-11.5	0.25	0.60	0.25	18	22	27	40	47
	-9.5	0.45	1.00	0.40	26	33	40	62	84
	-7.5	0.30	0.65	0.30	20	23	28	42	56
	-5.5	0.45	0.80	0.40	30	40	53	70	78
South	-9.5	0.30	0.70	0.30	20	23	28	37	52
	-7.5	0.20	0.45	0.25	13	16	18	24	34

Table VII: Expected settlement values

III.VII Erosion at the breakwaters

Scour development at the head of the north breakwater may cause higher waves to attack the breakwater. 2-D mathematical model calculations show that the current in front of head is about 0.30 m/s. Assuming conservative value of D_{50} = 100μm, the Shields parameter ψ_c = 0.09 and the critical depth averaged velocity U_c = 0.40 m/s. Wave orbital motions in front of the breakwater are estimated to be in the order of 2.9 m/s (H = 6.6m, T = 12s). Figure XII shows that initiation of motion under wave attack $U_{d,c}$ = 0.1 m/s. Comparing critical values for currents and waves with actual values shows that the wave attack will cause erosion. With the aid of Figure XIII[ref. 21] normalised scour depths at the head can be estimated. Based on the preliminary design y_{me}/l is estimated at 0.066. The scour depth then becomes about 2.20 m. A slope of 1:6 is applied so that the scour hole in front of the breakwater has the shape of Figure XIV. The dimensions of the scour hole are of limited size so that it is believed that the height of the approaching depth limited waves is not influenced.

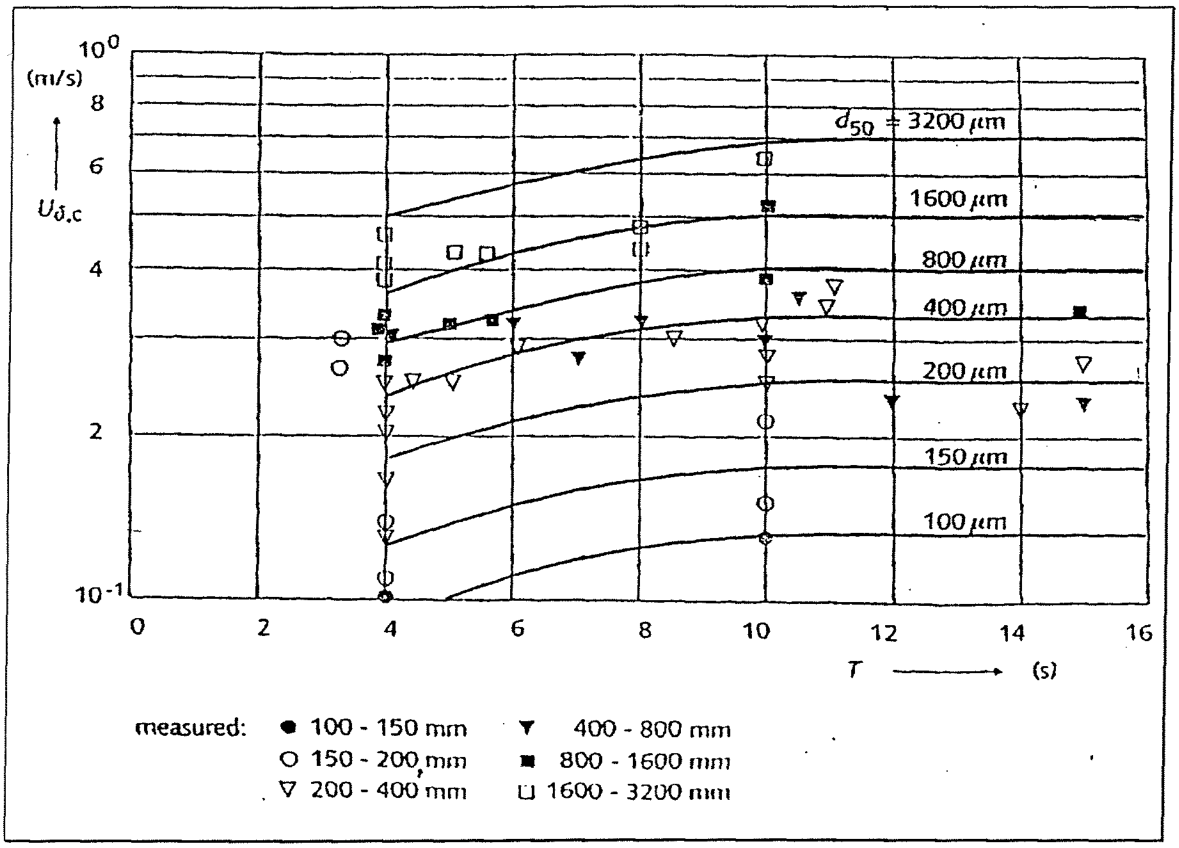


Figure XII: Initiation of motion for waves over a plane bed based on critical velocity

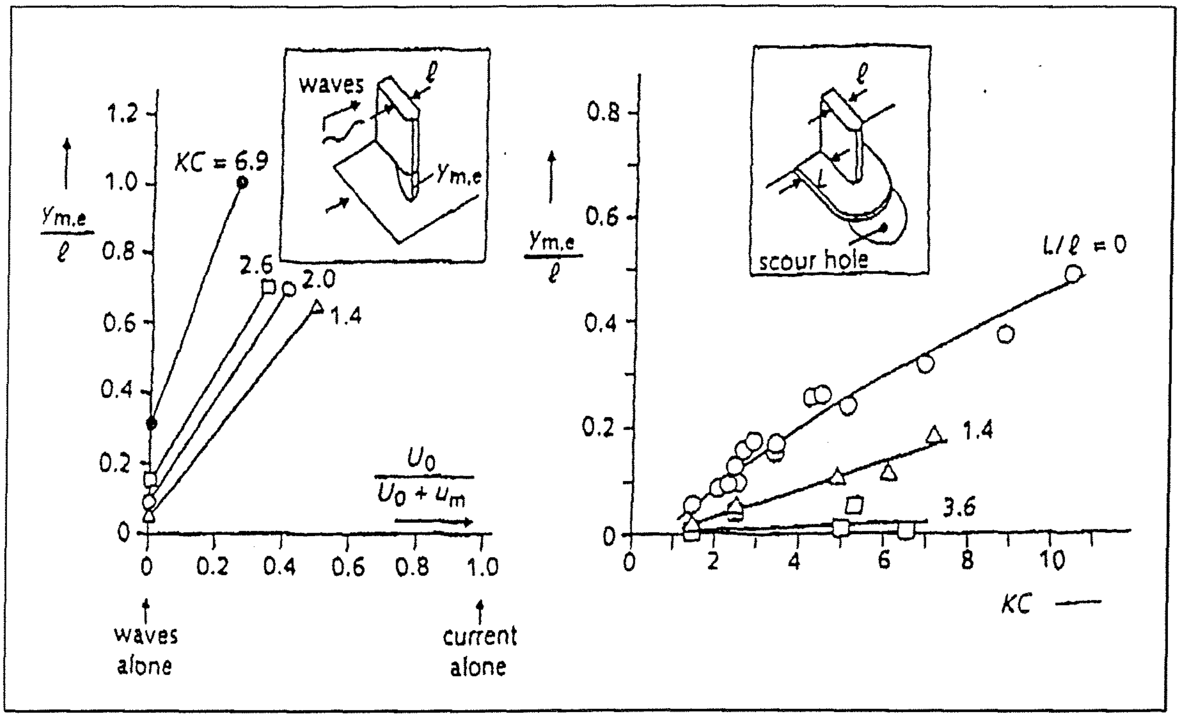


Figure XIII: Normalised scour depth at the head of the breakwater

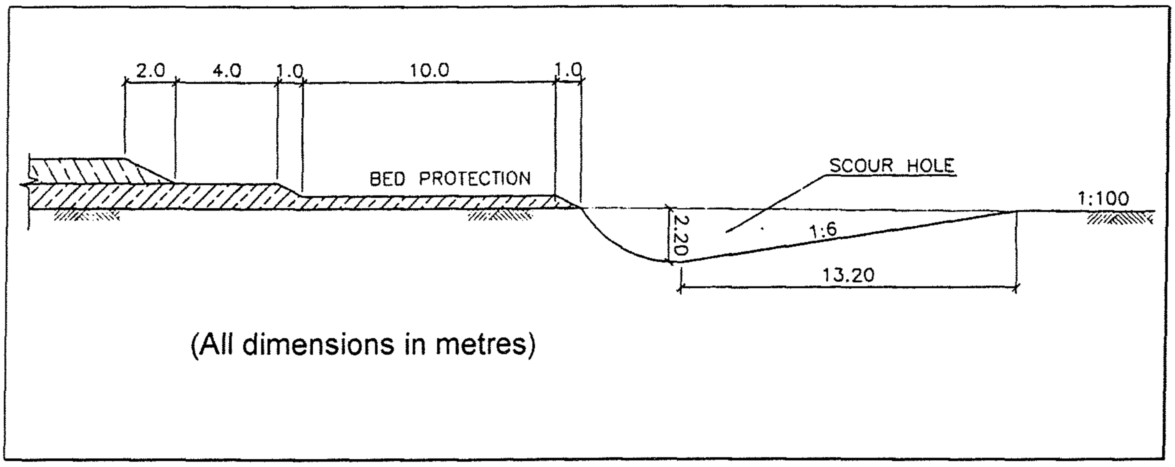


Figure XIV:Schematisation of scour hole in front of the breakwater

APPENDIX IV: Comparison of design formulae for rock armour layers

In the design of the breakwaters two different formulas have been used. For sections of the breakwaters where design waves have a direction more or less perpendicular to the structure (chainages 850 up to the head for the south breakwater), the required mass of the armour rock has been calculated with the computer program Breakwat that uses the formula of van der Meer:

for plunging waves:

$$\frac{H_s}{\Delta \cdot D_{n50}} = C \cdot p^{0,18} \cdot \left(S / \sqrt{n} \right)^{0,2} \cdot \xi^{-0,5}$$

and for surging waves:

$$\frac{H_s}{\Delta \cdot D_{n50}} = C \cdot p^{-0,13} \cdot \left(S / \sqrt{n} \right)^{0,2} \cdot \sqrt{\cot \alpha} \cdot \xi_m^P$$

transition:

$$\xi_{mc} = \left[6,2 \cdot P^{0,31} \sqrt{\tan \alpha} \right]^{\frac{1}{P+0,5}}$$

Deep water:
surging: C = 6,2
plunging: C= 1,0

Shallow Water:
surging: C = 8,7
plunging: C= 1,4

For the sections of the breakwaters where the design waves are very oblique to the structure (from the root up to chainage 720 for the south breakwater), the following formula has been used for the calculation of the required D_n of the rock armour layer:

$$D_n = \frac{H_s}{\Delta \cdot 1.25 \cdot 2}$$

With: 1.25 = $H_{2\%}/H_s$
2 = Stability number, N_s

This formula is derived from work carried out by J-C Galland in the framework of MAST G6-S, titled 'Rubble mound breakwaters stability under oblique waves'. Scale model tests have been done with long crested waves and incidence increasing from 0 degrees up to 75 degrees for quarry rock, tetrapods, Antifer cubes and Accropodes. Results for the armour stability of quarry rock are presented in figure Figure XV. Galland concluded that quarry rock is not very sensitive to damage levels smaller than 5%. For higher damage levels and an angle of incidence larger than 45 degrees it was concluded that some trend was noticeable that could indicate an increase in armour stability for increasing angle of incidence. For angles of incidence larger than 75 degrees stability was so much increased that nearly no damage occurred.

For the sections of the breakwaters where the armour layer has been calculated with the formula derived from this study, angles of incidence of design waves vary between ** and ** degrees (see figure **). With a stability number of 2 as chosen in the used formula it can be seen that for these angles expected damage will be in the range of 6 to 7 %. However in the used formula, the $H_{2\%}/H_s$-ratio has been added to the formula. Rewriting the used formula gives:

$$2 \cdot 1.25 = \frac{H_s}{\Delta \cdot D_n}$$

The effect of adding this ratio to the formula is a higher stability number for a given rock size (2.5 instead of 2). Shifting the stability number from 2 to 2.5 results in an increase of damage levels up to values exceeding 15 % (steep lines in figure).

In order to find out whether adding the $H_{2\%}/H_s$-ratio in the formula could have consequences on the design the effects are made visible in figure Figure XVI. In this figure four design formulae are compared for different significant wave heights:

1. The van der Meer formula for rock on a slope with a slope of 1:2, this formula has been used for designing the armour rock for the sections of the south breakwater between chainage 850 and the head. The selected rock grading for this section (section 1) is also shown in the figure. It can be seen that the selected grading of 5 to 12 tons, well covers the required rock size of 7.7 tons.
2. The van der Meer formula for rock on a slope with a slope of 1:1.5. here this formula is only used for comparison purposes.
3. The following formula derived from the work of Galland without adding the $H_{2\%}/H_s$-ratio. This formula is only used here for comparison.

$$D_n = \frac{H_s}{\Delta \cdot 2}$$

4. The used design formula derived from the work of Galland with addition of the $H_{2\%}/H_s$-ratio. This formula has been used for the south breakwater sections from the root up to chainage 850. The selected rock grading for these sections (sections 2 and 3) are also shown in the figure. It can be seen that the selected grading of these sections (5- 12 tons for section 2 and 2.5-7 tons for section 3) completely cover the required rock size (4.9 tons for section 2 and 4.2 tons for section 3).
   However, in case the choice was made not to add the $H_{2\%}/H_s$-ratio to the design formula, formula 3 (above) should have been used. Formula 3 leeds to a required rock size of 10 tons (instead of 4.9 tons) for section 2 and of 7.8 tons (instead of 4.2 tons) for section 3. In case the van der Meer formulas would have been used in these sections (formula 2) even larger rock sizes were required.

It is concluded that in this case adding the $H_{2\%}/H_s$-ratio to the design formula, probably done to increase safety, has lead to a less conservative design. One should always be careful adding additional safety factors to design formulae. The effects of the factors should be investigated before added. Most design formulas containing the significant wave height already account for higher waves ($H_{1\%}$ or $H_{2\%}$) because they are often based on statistical data obtained from experiments with a range of wave heights (e.g. Raleigh distributed).

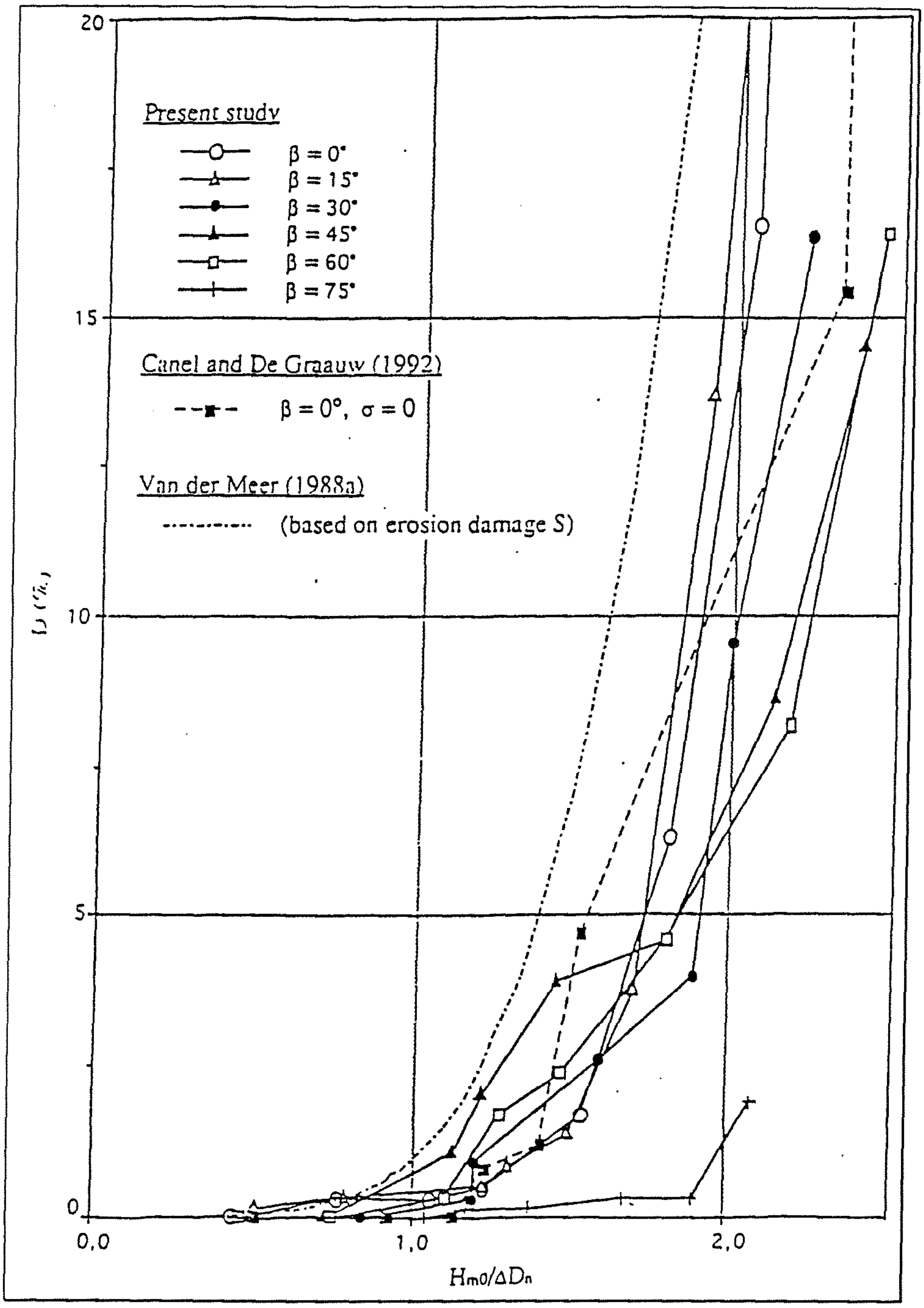


Figure XV: Results of model tests with oblique wave attack

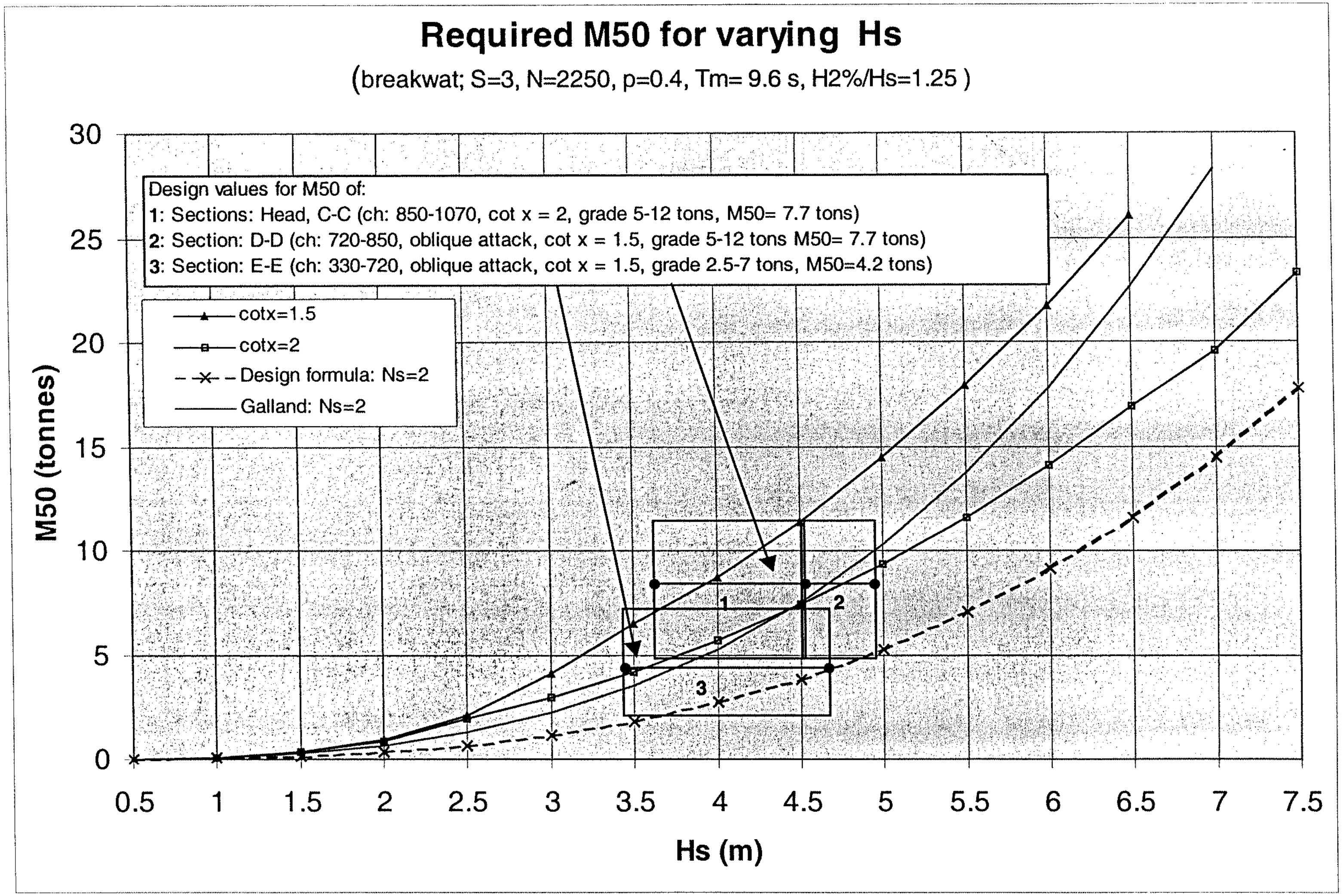


Figure XVI: Comparison of design formulae for armour rock

APPENDIX V: Tolerances and requirements

In the contract for breakwater construction the following tolerances and requirements have been prescribed for surveys, construction and used materials:

- All surveys submitted to the Engineer must be reduced to CD and in (centi-)metres
- Hydrographic survey must be done using echo sounding, and electronic positioning system
- Accuracy of hydrographic surveys : within 1.5 m horizontally and 0.1 m vertically
- Surveys of placed rock layers:
  - Profiles every 10m along the length.
  - No layer shall be covered until the profile of the former layer has been approved.
  - Surveys of placed rock shall not be carried out by hydrographic survey.
  - The surveys shall be carried out using a probe with a spherical end of diameter of half of the D_{n50} value for the material being surveyed.
  - D_n = cube root of volume of stone. In case of a value at n: percentage by weight of stones in the grading having a smaller nominal stone diameter.
  - Measurements must be taken at horizontal intervals of 1 m along the section being surveyed.
  - Required accuracy of floating surveys : within 1.5 m horizontally and 0.1 m vertically
  - Required accuracy of survey on land-based construction: 0.5 m horizontally and 0.1 m vertically.
- Dredging of trenches:
  - Post dredge-, pre fill- and post trench surveys will be carried out.
  - Material to be dredged along the alignment of the SBW: a layer dense/loose silty/clayey sand, app. 5-7 m thick overlaying deposits of soft clay down to the anticipated dredge level of -15 m.
  - Dredging requirements: The axis of the SBW trench runs approx. from the depth - 7.5 m CD contour to the depth contour of - 9 m CD, and has a length of approx. 275 m.; The trench shall be dredged to a depth of -15 m CD, and shall have a bottom width equal to the overall width of the breakwater structure extended by 5 m on each side. The trench sides shall be dredged to an overall slope not flatter than 1:8 from trench bottom up to seabed level.
  - Dredging tolerances; vertical: + 250 mm and - 250 mm; horizontal: -1.0 m (inwards) and +2.0 m; slope: not flatter than 1:8

- Requirements for the material used for trench filling:

Sieve size (mm)	Coarsest material (% passing)	Finest material (% passing)
2	70	97.7
1	18.8	87.5
0.5	3.5	77.8
0.25	1.6	66
0.125	1.2	58
0.063	0.2	55.8

- Particle size requirement $D_{20} > 0.300$ mm.

- Filling tolerances:
  - vertical : + 500mm - 500mm design fill level, for top level of trench fill; + 300 mm under the extended area of 5 m of the filter layer; +200mm - 200 mm average layer over the complete length perpendicular to the centre line.
  - horizontal: + 2.0 m - 1.0 m

- Compacted fill strength requirements
  - specified in terms of cone penetration resistance, q_c:
    - 1m below the top of fill $q_c \geq 6$ Mpa
    - 2m below the top of fill $q_c \geq 10$ Mpa
    - 3m below the top of fill $q_c \geq 12$ Mpa

Breakwater construction with rock:

- Tolerances for filter layers and toe in metres (D_{n50} in metres)

		Horizontal location		
Layers	Thickness of layer (m)	top and bottom of slopes sea side (m)	top and bottom of slopes port side (m)	top and slopes within the breakwater (m)
First filter layer	+ 0.5 - 0.3	+1.0 -1.0	+1.0 -1.0	+2.0 -2.0
Second filter layer	+ 0.5 - 0.3	+1.0 -1.0	Not applicable	+2.0 -2.0
Toe	+ 0.6 D_{n50} -0.4 D_{n50}	+1.0 -1.0	Not applicable	Not applicable
1st + 2nd filter layers	+ 0.5 -0.4			
1st + 2nd filter layers + toe	+ 0.5 -0.5			

- Tolerances for core and armour layers in metres (D_{n50} in metres)

Layer	Horizontal Position (m)	Level (m) (for rock above MSL)	Level (m) (for rock below MSL)
Core	+0.3 -0.3	+ 0.35 D_{n50} * -0.25 D_{n50} *	+ 0.6 D_{n50} * -0.4 D_{n50} *
Core topping layer	+0.3 -0.3	+ 0.35 D_{n50} -0.25 D_{n50}	not applicable
Secondary armour layers	not applicable	+ 0.35 D_{n50} * -0.25 D_{n50} *	+ 0.6 D_{n50} * -0.4 D_{n50} *
Primary armour layers	not applicable	+ 0.35 D_{n50} -0.25 D_{n50}	+ 0.6 D_{n50} -0.4 D_{n50}

Note: * D_{n50} of the overlaying layer of rock

APPENDIX VI: Results of the pilot compaction tests

Objectives:
The main objectives of the pilot compaction tests were:

1. Verify the suitability of the compaction equipment for the work at hand.
2. Ascertain a working method which results in the optimum compaction resolution.
3. Establish whether compaction of the back-fill was necessary.

Approach:
An area close to the head of the south breakwater was selected. The area had a length of 100 m along the centre line of the south breakwater and extended of the full foundation width of the breakwaters plus 5 metres on each side.

Cone penetration tests took place at 16 locations throughout the full depth of the sand backfill. Sand samples were taken at a depth of 2 m and 3 m below the design level of the top of the sand backfill. Laboratory tests were carried out on the sand samples (direct shear box tests, triaxial tests and determination of the particle size distribution).

Once the CPT testing and sampling was completed, compaction of the test area took place. Nine different compaction scenarios were tested, in order to obtain an optimum working method, varying the grid spacing, depth, frequency, duration and time of compaction. Table VIII and show details of these scenario's.

Test Area	Grid Spacing (m x m)	Description
1	9.0 x 9.0	4.5 m x 4 min, 3.5 m x 2 min, 2.5 m x 2min, 1.5 m x 2 min
2	9.0 x 9.0	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1500 rpm
3	4.5 x 4.5	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1500 rpm
4	9.0 x 9.0	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1600 rpm
5	13.5 x 13.5	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1580 rpm
6	9.0 x 9.0	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1580 rpm
7	9.0 x 9.0	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1500 rpm
8	4.5 x 4.5	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1500 rpm
9	3.0 x 3.0	4.5 m x 6 min, 3.5 m x 3 min, 2.5 m x 3min at 1500 rpm

Table VIII: Test areas and compaction scenarios

After compaction took place, again cone penetration tests were carried out in order to determine the effects of compaction.

Results:
Results of the cone penetration tests before and after compaction are given in Table IX and Table X. These tables show the cone resistance and the relative density. The relative density was obtained from the cone resistance measured during the cpt's by using two empirical relationships (JAMILOLKOWSKI and BALDI). Results of the laboratory tests are shown in Table XI.

Evaluation:
From the results a number of conclusions were drawn:

- The values of cone resistance before and after compaction did not meet the requirements laid down in the contract.
- The effect of compacting the back fill according to a 9 x 9 or a 13 x 13 m triangular grid spacing did not appear to result in a uniformly compacted back fill and no significant improvements in the value of cone resistance could be observed.
- The effect of compacting the back fill according to a 4.5 x 4.5 m triangular grid spacing appeared to result in a more uniformly compacted back fill. The values of cone resistance increased after compaction.
- The effect of compacting the back fill according to a 3 x 3 m triangular grid spacing resulted in a uniformly compacted back fill. The values of cone resistance almost doubled after compaction.
- The consistency of the laboratory test results was very good.
- The direct shear box and the Triaxial tests provided very similar results.
- The minimum density (= relative density of 0%) corresponds with a minimum angle of internal friction of 30% is achieved at the minimum density of the backfill.
- An internal angle of friction of 30 degrees, which is required for a stable foundation, has already been reached without compaction.

After testing it was also concluded that the compaction spread was not suitable for the sea conditions prevailing at Ennore. Even in relatively light swell, the deck mounted crane was unable to hoist the compaction unit safely onboard

Based on the test results it was concluded that the back-fill in the trenches provided a good foundation without compaction and that compaction was no longer required.

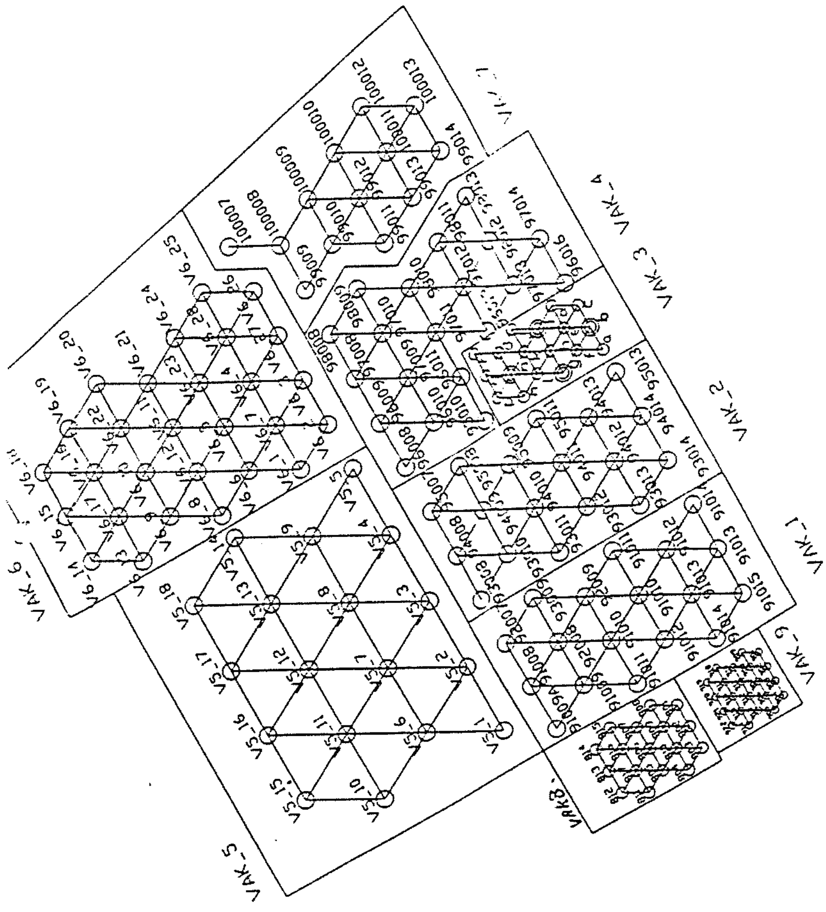


Figure XVII: Plan view of the test areas.

CPT No.	Soil Depth [m]	Cone Resistance [MPa]	Relative Density [%]	CPT No.	Soil Depth [m]	Cone Resistance [MPa]	Relative Density [%]
1A	1	1.5	50	3A	1	1.5	50
	2	2.5	52		2	3.0	55
	3	3.5	58		3	3.0	55
1B	1	2.5	60	3B	1	2.2	60
	2	2.2	50		2	2.2	50
	3	3.0	50		3	3.5	55
1C	1	1.5	50	3C	1	2.0	52
	2	3.2	60		2	3.0	60
	3	3.5	60		3	3.0	50
1D	1	2.5	60	3D	1	2.5	62
	2	4.0	70		2	3.0	58
	3	3.5	58		3	3.0	52
2A	1	2.5	62	4A	1	2.0	55
	2	2.5	52		2	3.0	60
	3	3.0	52		3	2.6	50
2B	1	3.0	70	4B	1	1.5	50
	2	3.0	61		2	2.5	55
	3	3.0	52		3	3.2	55
2C	1	2.5	62	4C	1	2.3	62
	2	4.3	70		2	3.0	58
	3	4.0	60		3	4.0	60
2D	1	2.5	62	4D	1	3.0	70
	2	2.5	55		2	3.8	65
	3	4.2	52		3	3.0	52

Table IX: Results of the cone penetration tests and relative density before compaction

Test Area	CPT No.	Soil Depth [m]	Cone Resist. [MPa]	Relative Density [%]	Grid	CPT No.	Soil Depth [m]	Cone Resist. [MPa]	Relative Density [%]
1	1A	1	2.0	50	4	34	1	3.0	
		2	2.2	40			2	3.5	
		3	3.5	50			3	4.5	
	2	1	3.0	60		35	1	2.5	
		2	3.0	50			2	3.5	
		3	3.0	45			3	3.5	
	3	1	2.0	50	5	24	1	1.5	
		2	3.0	50			2	4.5	
		3	2.5	40			3	3.5	
	4	1	3.5	68		25	1	2.5	
		2	3.5	55			2	2.0	
		3	3.0	40			3	4.0	
	5	1	4.2	75		26	1	2.5	
		2	4.0	60			2	4.2	
		3	3.5	50			3	4.2	
	6	1	4.2	75	6	27	1	3.0	
		2	4.0	60			2	3.0	
		3	3.5	55			3	3.5	
	7	1	3.0	62		28	1	3.5	
		2	4.0	60			2	5.0	
		3	3.2	45			3	4.5	
2	8A	1	3.0	65		29	1	3.5	
		2	4.0	60			2	3.5	
		3	3.0	42			3	3.5	
	9	1	3.0	55	7	30	1	2.5	
		2	4.0	60			2	3.0	
		3	3.0	40			3	2.5	
	10	1	2.5	55		31	1	2.5	
		2	3.5	55			2	8.0	
		3	3.5	45			3	13.5	
	11	1	4.0	70		32	1	2.5	
		2	5.0	70			2	3.5	
		3	5.0	60			3	4.5	
3	12	1	4.0	70	8	20	1	3.5	
		2	5.0	68			2	4.0	
		3	5.5	60			3	4.0	
	13A	1	5.0	8[illegible]		21	1	5.0	
		2	5.5	72			2	5.5	
		3	6.2	70			3	4.5	
	14	1	6.0	65		22	1	4.5	
		2	6.0	73			2	3.5	
		3	5.0	6[illegible]			3	3.5	
4	33	1	2.0			23	1	4.0	
		2	2.0				2	4.0	
		3	3.0				3	5.5	

Table X: Results of the cone penetration tests and relative density after compaction

Sample No.	Shear Box Tests		Triaxial Tests		Particle Size Distribution	
	Density [kg/m³]	Friction Angle [°]	Density [kg/m³]	Friction Angle [°]	D_{20} [mm]	D_{50} [mm]
1B	1.45	30	1.45	32	0.50/0.67	0.80/0.95
	1.60	37	1.60	39		
	1.97	46	1.97	46		
	1.99	47	1.99	46		
1C	1.50	33			0.56/0.50	0.83/0.80
	2.03	48				
	2.10	50				
2B	1.49	33			0.56/0.58	0.83/0.97
	2.05	49				
	2.11	50				
2C	1.40	32	1.40	33	0.52/0.62	0.95/0.98
	1.50	35	1.62	41		
	1.60	39	1.90	49		
	1.62	40				
	1.70	43				
	1.90	48				
3B	1.50	34	1.50	35	0.60/0.55	0.92/0.86
	1.60	39	1.60	38		
	1.70	42	1.70	41		
	1.90	48	1.90	47		
	1.98	49	1.98	48		
3C	1.50	34			0.64/0.64	0.93/0.93
	2.02	48				
	2.08	50				
4B	1.40	34			0.52/0.58	0.95/0.92
	1.88	48				
	2.01	50				
4C	1.40	34	1.40	33	0.60/0.68	1.10/1.18
	1.50	36	1.50	35		
	1.60	40	1.60	38		
	1.70	43	1.70	42		
	1.91	49	1.91	48		
	2.05	51	2.05	49		

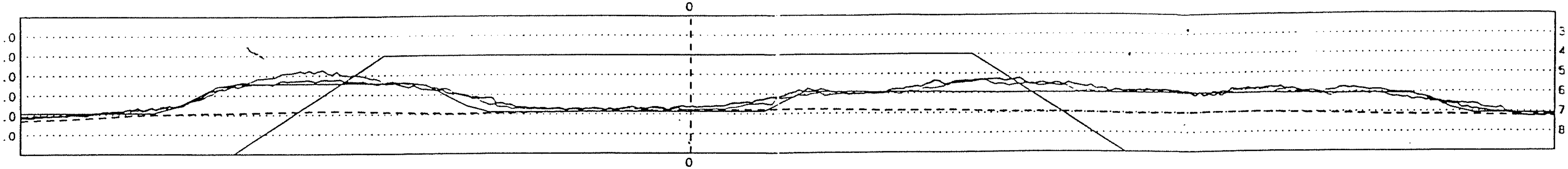
Notes :
1. There are two figures given in each of the columns for Particle size distribution and these correspond with the grain size at a depth of 2 m and 3 m.
2. D_n is a particle size of nominal diameter D whereby n% of the particles by weight are smaller than D

Table XI: Results of laboratory testing of backfill samples.

APPENDIX VII: Surveys

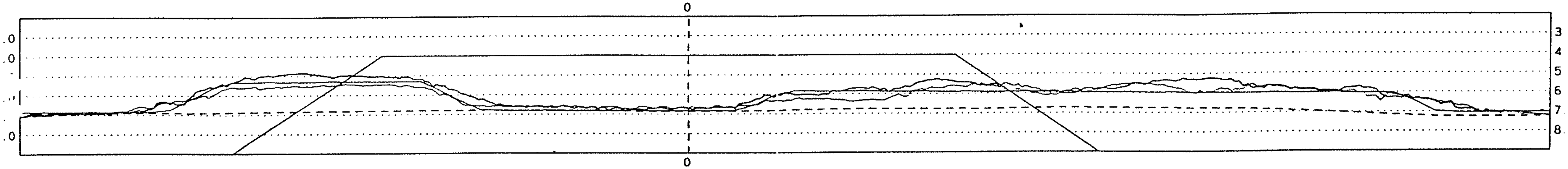
VII.I	: Hydrographic Survey
VII.II	: Land based Survey
VII.III	: Visual Survey

Ennore Coal Port Project HCC Van Oord ACZ JV
Post G-grade South Breakwater 05/09/98 Kp 0.82 - 0.89 Accept 034



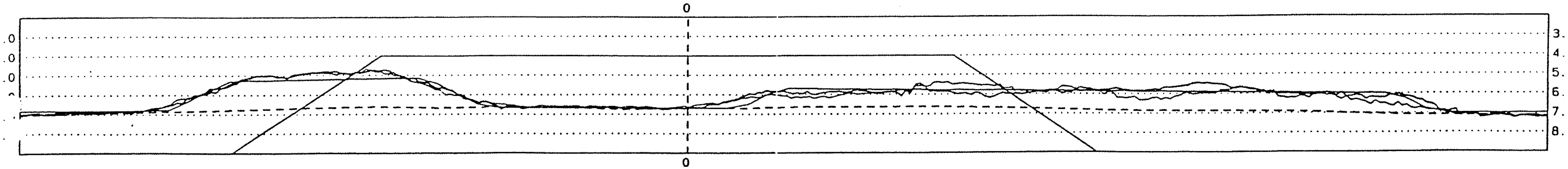
LINE : 850 Crossline SCALE : DIST 1: 200 DEPTH 1: 200
FILE(S) : G3F0904_ G3P0903_ G760_100 R3N_3_02
DATE(S) : 4-sep-98 3-sep-98 no date no date

Ennore Coal Port Project HCC Van Oord ACZ JV
Post G-grade South Breakwater 05/09/98 Kp 0.82 - 0.89 Accept 034



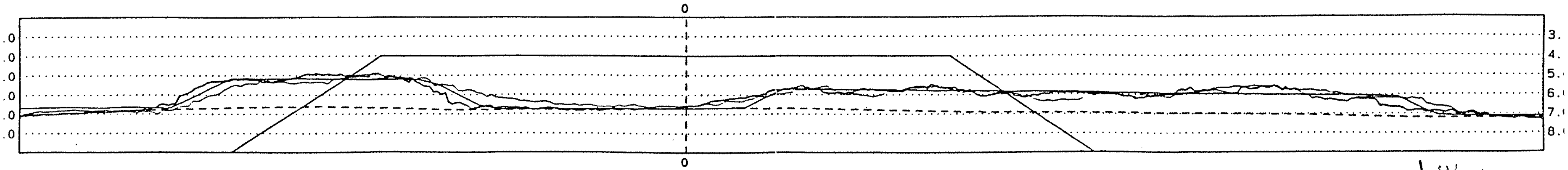
LINE : 840 Crossline SCALE : DIST 1: 200 DEPTH 1: 200
FILE(S) : G3F0904_ G3P0903_ G760_100 R3N_3_02
DATE(S) : 4-sep-98 3-sep-98 no date no date

Ennore Coal Port Project HCC Van Oord ACZ JV
Post G-grade South Breakwater 05/09/98 Kp 0.82 - 0.89 Accept 034



LINE : 830 Crossline SCALE : DIST 1: 200 DEPTH 1: 200
FILE(S) : G3F0904_ G3P0903_ G760_100 R3N_3_02
DATE(S) : 4-sep-98 3-sep-98 no date no date

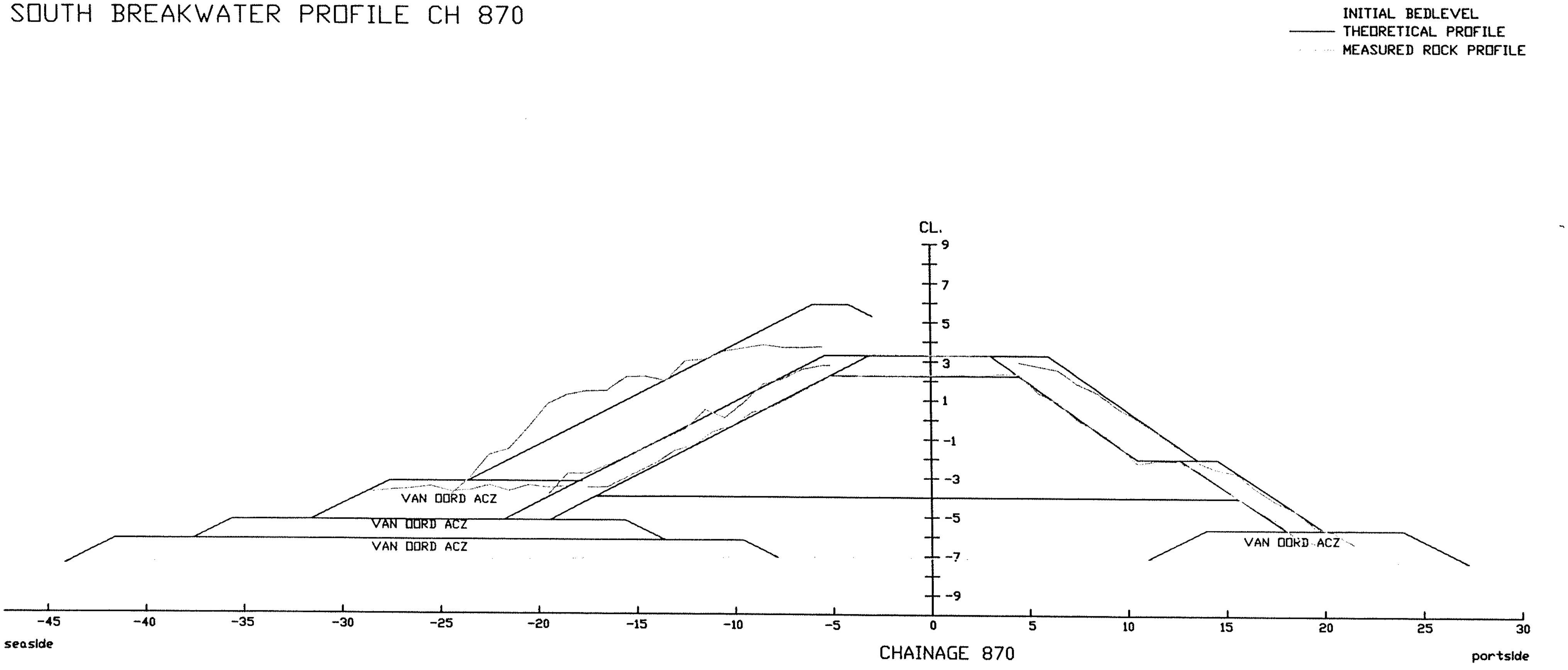
Ennore Coal Port Project HCC Van Oord ACZ JV
Post G-grade South Breakwater 05/09/98 Kp 0.82 - 0.89 Accept 034



LINE : 820 Crossline SCALE : DIST 1: 200 DEPTH 1: 200
FILE(S) : G3F0904_ G3P0903_ G760_100 R3N_3_02
DATE(S) : 4-sep-98 3-sep-98 no date no date

VII. 1

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 870



VII.11

Summary of visual survey of the south breakwater carried out on 10th of November 1998

Chainage	Port side	Sea side
130	crest too low	crest too low
140-170	Washed out filter material visible on the outside	
160	hardly any armour layer	
170-180		No armour visible under water
190-210	E-layer too thin	
200-230	Turning point, no armour layer on the outside	Quarry run visible: armour layer too thin
260-290		Too much rock on lower slope, slope too flat
270-330	No primary armour on upper side	
310-350		Holes in the armour layer
330-390	Holes in the armour layer	Holes in the armour layer
410		Wronly placed armour, replace armour layer
390-440	Quarry run visible: armour layer too thin	
440-460		No primary armour layer placed
460		
500	Underlayer visible: armour layer too thin	
520	Underlayer visible: armour layer too thin	
590-650	Holes in the armour layer	
650	Lower armour layer not visible	
660-690	Wronly placed armour, replace armour layer	Too much rock on lower slope, slope too flat
730-750	size of armour rock too small	Holes in the armour layer
790		Too much rock on lower slope, slope too flat
820-840	Holes in the armour layer	
850-890	No primary armour on upper side	
900-920	Armour layer too thin	
920	slope steep	
930-940	Wide crest because of turning point	
970-980	lower armour contains quarry run	

APPENDIX VIII: Progress of Breakwater construction

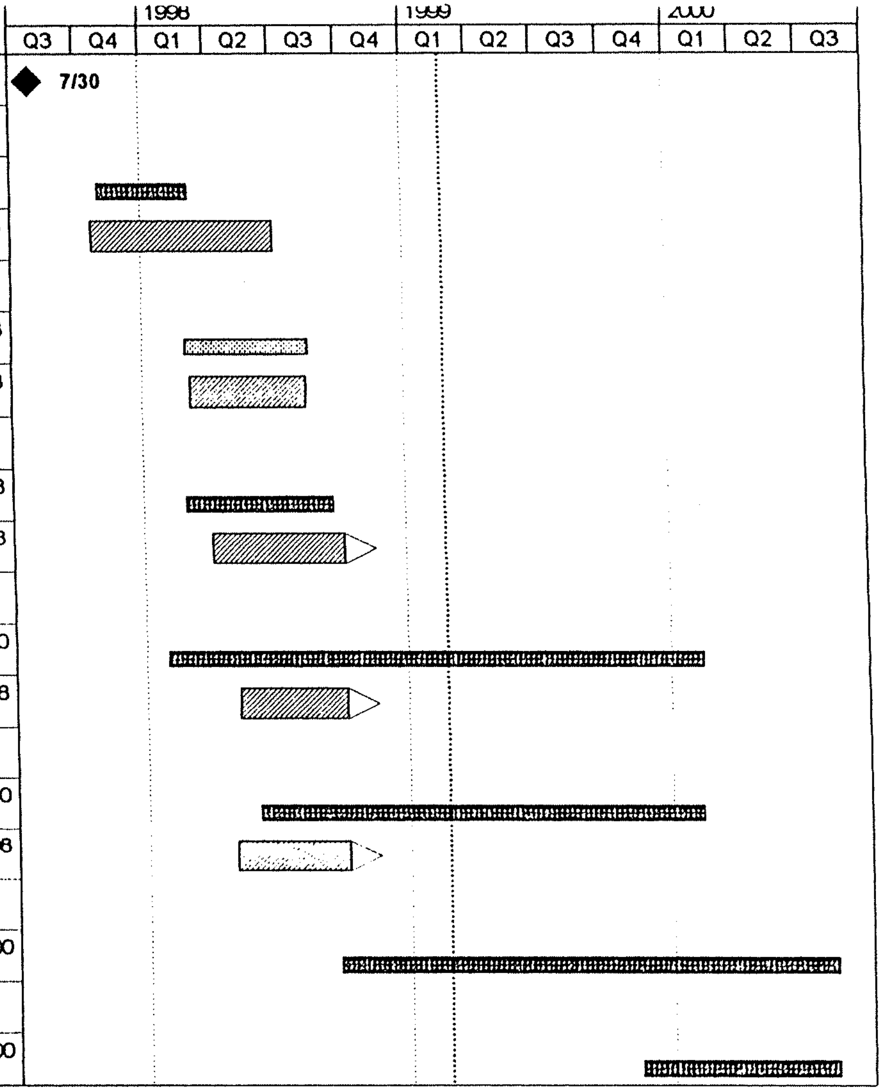
VIII.I : Progress calculations of construction processes
VIII.II : Gantt charts for construction processes

VIII.I : Progress calculations of construction processes

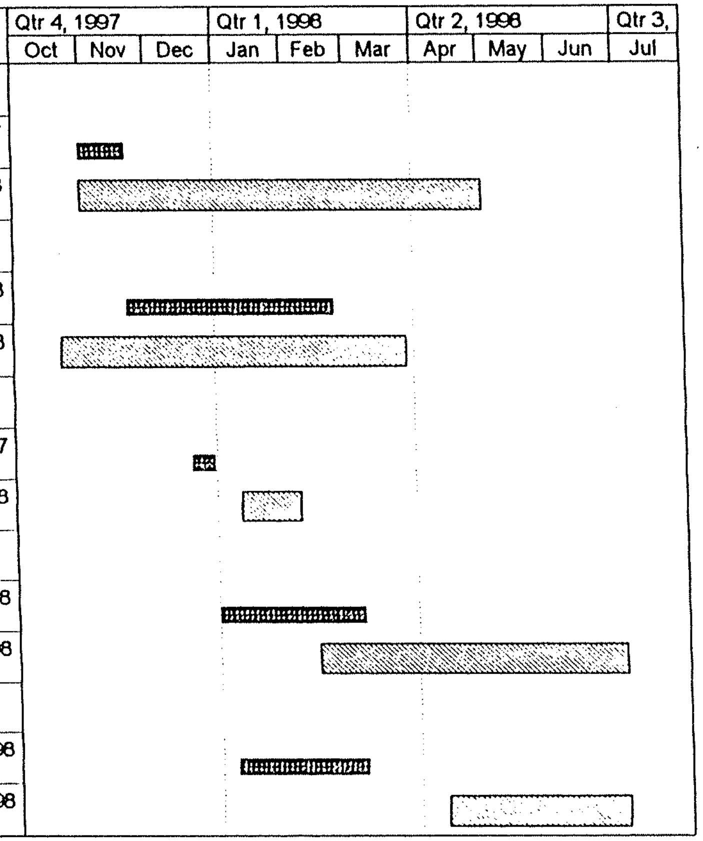
VIII.II : Gantt charts for construction processes

V.III.I : Main processes
V.III.II : Workharbour construction
V.III.III : Dredging
V.III.IV : Rock dumping south breakwater
V.III.V : Rock dumping north breakwater
V.III.VI : Accropodes

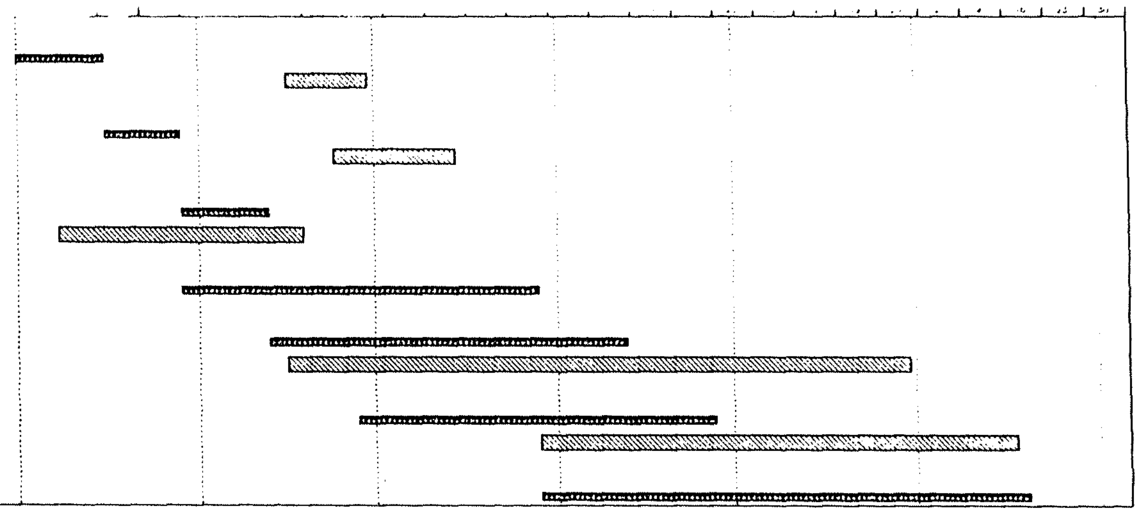
ID		Task Name	Duration	Start	Finish
1		Letter of Acceptance	0 days	Wed 7/30/97	Wed 7/30/97
2		**Workharbour**			
3		Planned	127 days	Sat 11/1/97	Sun 3/8/98
4		Actual	254 days	Thu 10/23/97	Sat 7/4/98
5		**DREDG, BACKF,COMP.**			
6		Planned	172 days	Sun 3/1/98	Thu 8/20/98
7		Actual	163 days	Sun 3/8/98	Tue 8/18/98
8		**SBW Rock dumping**			
9		Planned	206 days	Sun 3/1/98	Wed 9/23/98
10		Actual	229 days	Sun 4/5/98	Fri 11/20/98
11		**Accropodes**			
12		Planned	745 days	Sat 1/31/98	Tue 2/15/00
13		Actual	194 days	Sun 5/10/98	Fri 11/20/98
14		**NBW Rock dumping**			
15		Planned	618 days	Fri 6/5/98	Sun 2/13/00
16		Actual	201 days	Sun 5/3/98	Fri 11/20/98
17		**CREST ELEMENT**			
18		Planned	692 days	Wed 9/23/98	Tue 8/15/00
19		**SLOPE PROTECTION**			
20		Planned	273 days	Tue 11/16/99	Tue 8/15/00



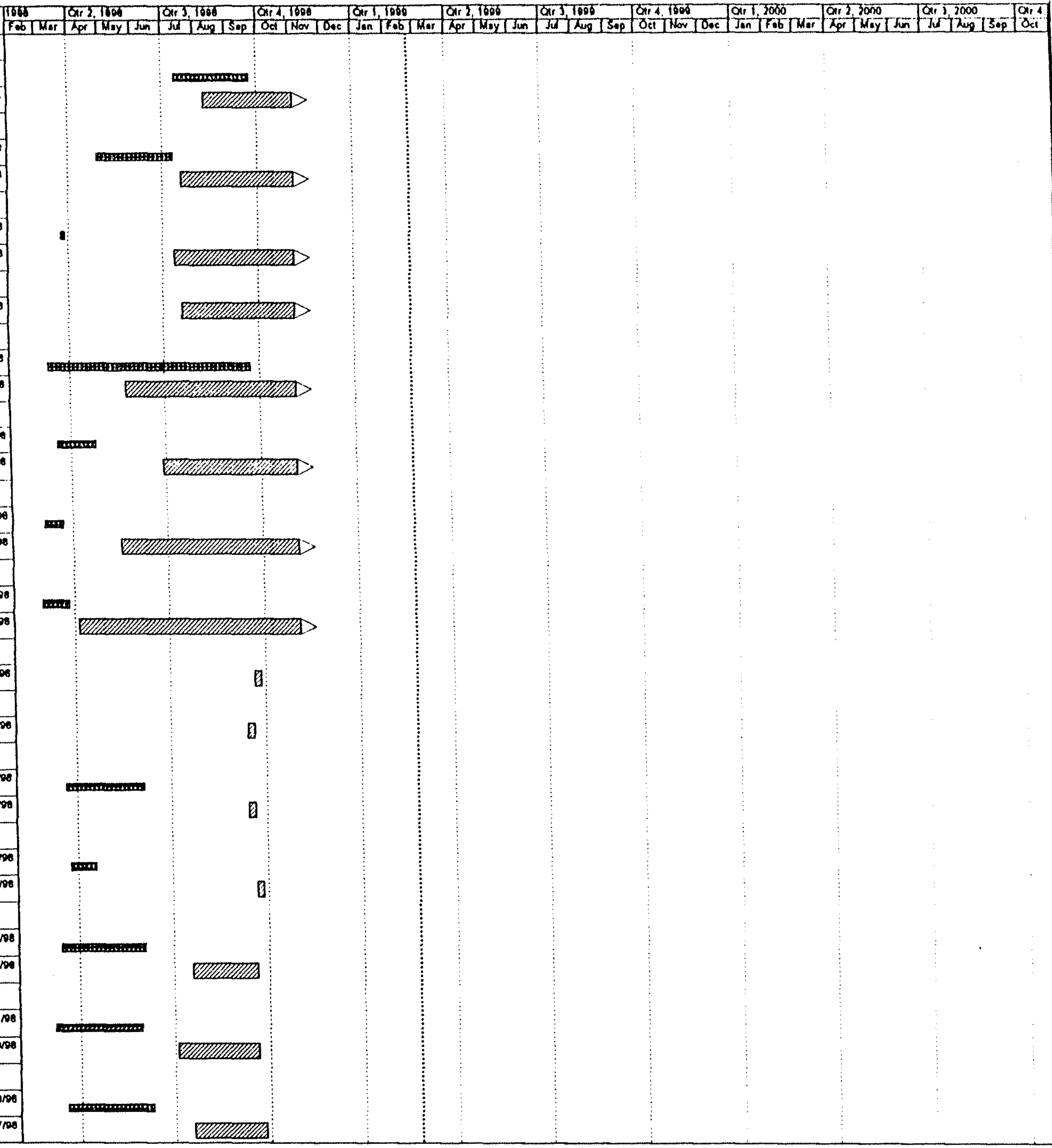
ID		Task Name	Duration	Start	Finish
1		**Approval of Design for execution**			
2		Planned	21 days	Sat 11/1/97	Sat 11/22/97
3		*Actual*	183 days	Sat 11/1/97	Sun 5/3/98
4		**Casting of blocks P**			
5		Planned	94 days	Sat 11/22/97	Tue 2/24/98
6		*Actual*	157 days	Thu 10/23/97	Sun 3/29/98
7		**Provision of access road**			
8		Planned	10 days	Sun 12/21/97	Wed 12/31/97
9		*Actual*	27 days	Mon 1/12/98	Sun 2/8/98
10		**Rock for approach bund+head**			
11		Planned	66 days	Thu 1/1/98	Sun 3/8/98
12		*Actual*	139 days	Sun 2/15/98	Sat 7/4/98
13		**Dredging & block placing**			
14		Planned	59 days	Thu 1/8/98	Sun 3/8/98
15		*Actual*	82 days	Mon 4/13/98	Sat 7/4/98



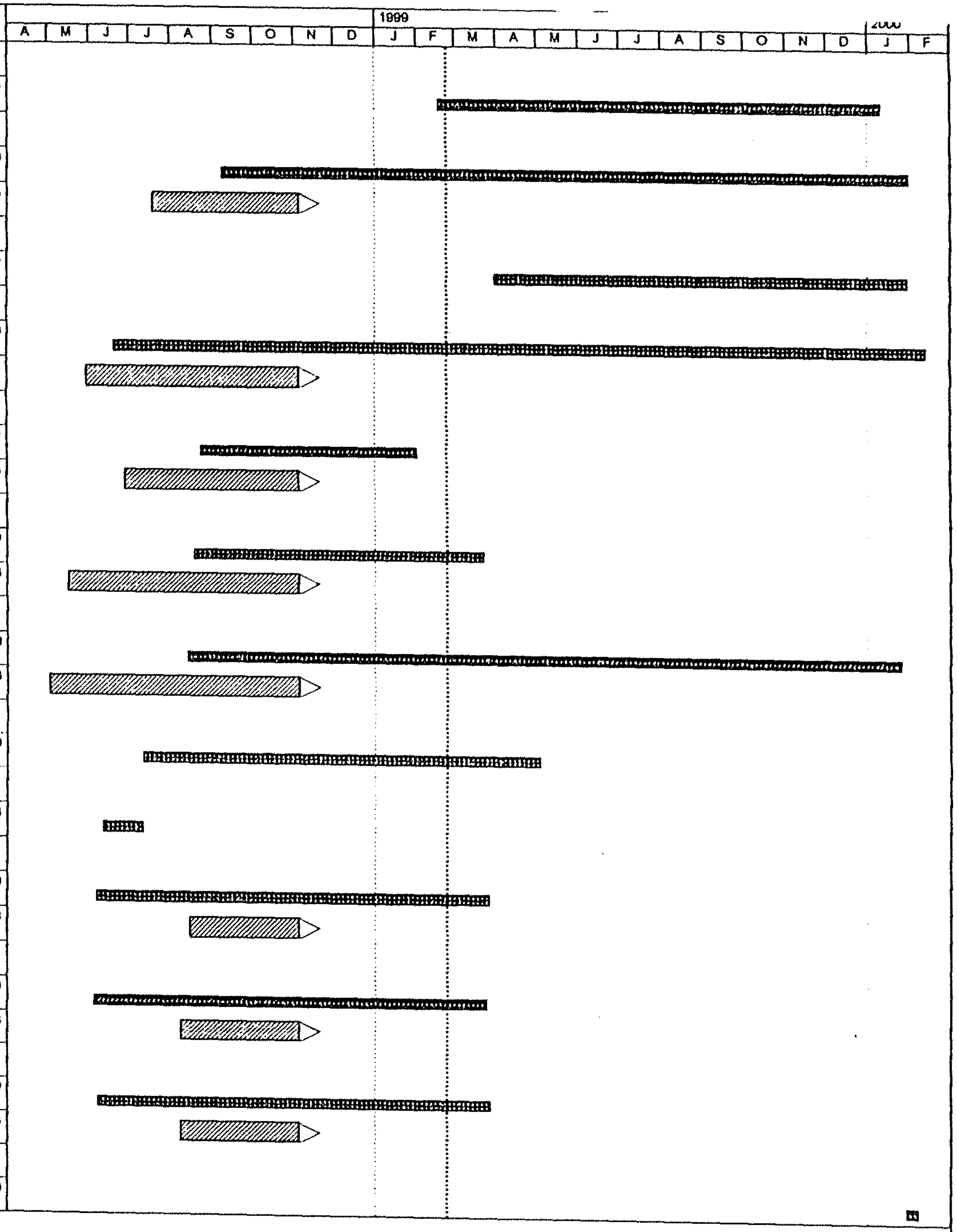
1		**Dred.,trans.dump mat.frm SBW**			
2		planned	15 days	Sun 3/1/98	Mon 3/16/98
3		Actual	14 days	Thu 4/16/98	Thu 4/30/98
4		**Dred.,trans.place sandfill in SBW tr.**			
5		planned	13 days	Mon 3/16/98	Sun 3/29/98
6		Actual	21 days	Fri 4/24/98	Fri 5/15/98
7		**Dred,trans,place mat from Coal Wharf**			
8		planned	15 days	Sun 3/29/98	Mon 4/13/98
9		Actual	42 days	Sun 3/8/98	Sun 4/19/98
10		**Compact placed sand in SBW tr.**			
11		planned	61 days	Sun 3/29/98	Fri 5/29/98
12		**Dred.,trans.dump mat.frm NBW**			
13		planned	61 days	Mon 4/13/98	Sat 6/13/98
14		Actual	106 days	Thu 4/16/98	Fri 7/31/98
15		**Dred.,trans.place sandfill in NBW tr.**			
16		planned	61 days	Tue 4/28/98	Sun 6/28/98
17		Actual	81 days	Fri 5/29/98	Tue 8/18/98
18		**Compact placed sand in NBW tr.**			
19		planned	83 days	Fri 5/29/98	Thu 8/20/98



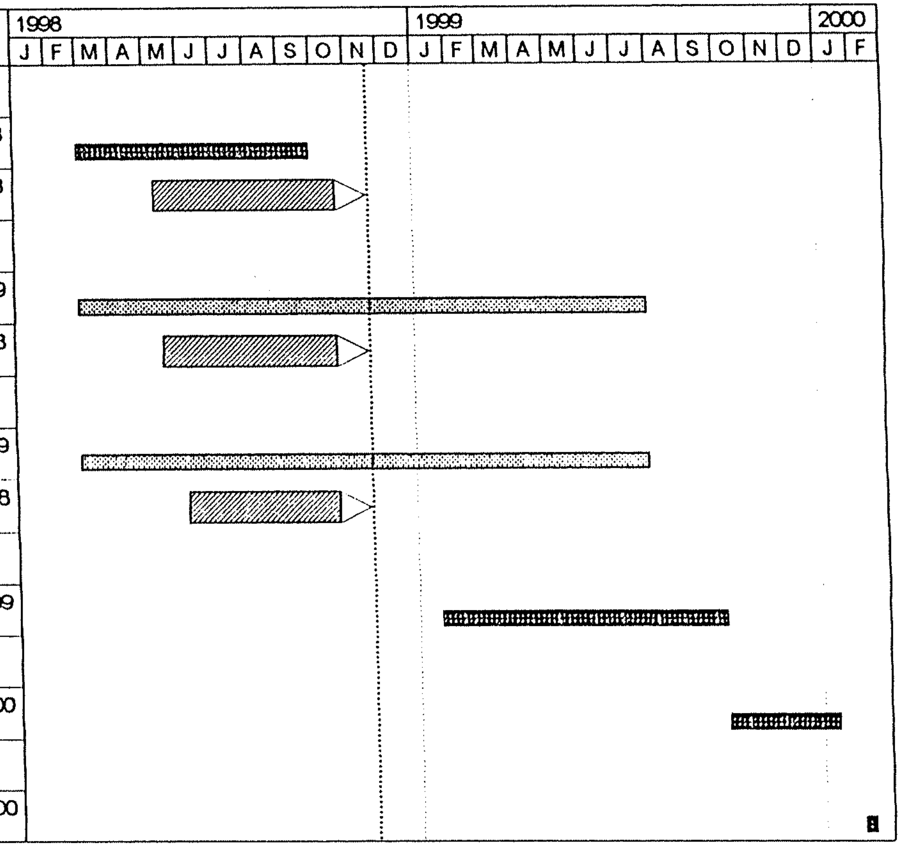
ID	O	Task Name	Duration	Start	Finish
1		A (5-12 t.) Land Based			
2		Planned	73 days	Sun 7/12/98	Wed 9/23/98
3		Actual	102 days	Mon 8/10/98	Fri 11/20/98
4		B (2.5-7 t.) land based			
5		Planned	74 days	Wed 4/29/98	Sun 7/12/98
6		Actual	124 days	Sun 7/19/98	Fri 11/20/98
7		C (1-5 t.) land based			
8		Planned	4 days	Wed 3/25/98	Sun 3/29/98
9		Actual	131 days	Sun 7/12/98	Fri 11/20/98
10		D (0.5-2.5 t.) land based			
11		Actual	124 days	Sun 7/19/98	Fri 11/20/98
12		E (0.3-1.0 t.) land based			
13		Planned	196 days	Wed 3/11/98	Wed 9/23/98
14		Actual	180 days	Sun 5/24/98	Fri 11/20/98
15		F (100-500 kg.) land based			
16		Planned	37 days	Thu 3/19/98	Sat 4/25/98
17		Actual	145 days	Sun 6/28/98	Fri 11/20/98
18		G (1-50 kg.) land based			
19		Planned	18 days	Thu 3/5/98	Mon 3/23/98
20		Actual	187 days	Sun 5/17/98	Fri 11/20/98
21		Q.R.(1-1000 kg.) land Based			
22		Planned	26 days	Sun 3/1/98	Fri 3/27/98
23		Actual	229 days	Sun 4/5/98	Fri 11/20/98
24		B (2.5 -7 t.) Marine Based			
25		Actual	7 days	Sun 9/20/98	Sun 9/27/98
26		C (1-5 t.) Marine Based			
27		Actual	7 days	Sun 9/13/98	Sun 9/20/98
28		D (0.5-2.5 t.) Marine Based toe			
29		Planned	76 days	Sat 3/21/98	Fri 6/5/98
30		Actual	7 days	Sun 9/13/98	Sun 9/20/98
31		E (0.3-1.0 t.) Marine Based			
32		Planned	25 days	Wed 3/25/98	Sun 4/19/98
33		Actual	7 days	Sun 9/20/98	Sun 9/27/98
34		F (100-500kg.) Marine Based			
35		Planned	81 days	Sun 3/15/98	Thu 6/4/98
36		Actual	63 days	Sun 7/19/98	Sun 9/20/98
37		G (1-50kg.) Marine Based			
38		Planned	84 days	Sun 3/8/98	Sun 5/31/98
39		Actual	78 days	Sat 7/4/98	Sun 9/20/98
40		Q.R.(1-1000 kg.) Marine Based			
41		Planned	83 days	Wed 3/18/98	Tue 6/9/98
42		Actual	70 days	Sun 7/19/98	Sun 9/27/98



ID	Task Name	Duration	Start	Finish
1	B land based			
2	Planned	328 days	Wed 2/17/99	Tue 1/11/00
3	C land based			
4	Planned	510 days	Wed 9/9/98	Tue 2/1/00
5	Actual	124.38 days	Sun 7/19/98	Fri 11/20/98
6	D land based			
7	Planned	306 days	Wed 3/31/99	Mon 1/31/00
8	E land based 4.122+4.123+4.124			
9	Planned	603 days	Sat 6/20/98	Sun 2/13/00
10	Actual	173.38 days	Sun 5/31/98	Fri 11/20/98
11	F land based 4.125+4.127			Tue 2/2/99
12	Planned	162 days	Mon 8/24/98	Tue 2/2/99
13	Actual	145.38 days	Sun 6/28/98	Fri 11/20/98
14	G land based			
15	Planned	216 days	Wed 8/19/98	Tue 3/23/99
16	Actual	187.38 days	Sun 5/17/98	Fri 11/20/98
17	Q.R. land Based			
18	Planned	530 days	Fri 8/14/98	Wed 1/26/00
19	Actual	201.38 days	Sun 5/3/98	Fri 11/20/98
20	C Marine Based			
21	Planned	296 days	Sun 7/12/98	Tue 5/4/99
22	D Marine Based toe			
23	Planned	30 days	Fri 6/12/98	Sun 7/12/98
24	F Marine Based			
25	Planned	293 days	Sun 6/7/98	Sat 3/27/99
26	Actual	96.38 days	Sun 8/16/98	Fri 11/20/98
27	G Marine Based			
28	Planned	293 days	Fri 6/5/98	Thu 3/25/99
29	Actual	103.38 days	Sun 8/9/98	Fri 11/20/98
30	Q.R. Marine Based			
31	Planned	293 days	Mon 6/8/98	Sun 3/28/99
32	Actual	103.38 days	Sun 8/9/98	Fri 11/20/98
33	Obtain trans place Rock K Armour			
34	Planned	9 days	Sat 1/29/00	Mon 2/7/00



ID		Task Name	Duration	Start	Finish
1		**Fabri trans & place block of 9.6 t.**			
2		Planned	213 days	Sun 3/1/98	Wed 9/30/98
3		Actual	194 days	Sun 5/10/98	Fri 11/20/98
4		**Fabri trans & place block of 12 t.**			
5		Planned	517 days	Sun 3/1/98	Sat 7/31/99
6		Actual	187 days	Sun 5/17/98	Fri 11/20/98
7		**Fabri trans & place block of 15.12 t.**			
8		Planned	517 days	Sun 3/1/98	Sat 7/31/99
9		Actual	166 days	Sun 6/7/98	Fri 11/20/98
10		**Placement of 9.6 t Accropodes**			
11		Planned	259 days	Thu 1/21/99	Thu 10/7/99
12		**Placement of 12 t Accropodes**			
13		Planned	100 days	Thu 10/7/99	Sat 1/15/00
14		**Placement of 15.12 t Accropodes**			
15		Planned	10 days	Sat 2/5/00	Tue 2/15/00



APPENDIX IX: Example of a weekly progress report for landbased construction

Weekly Report - South Breakwater Land Based

Week no: 45 — Date:22-6-98 to 28-6-98

Progress															
Chainage	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340
	Port Side														
Upper Arm. Layer															
Lower Arm. Layer															
First Filter Layer															
Core															
Core Topping Layer															
Crest Element															
First Filter layer															
Second Filter Layer															
Toe															
Sec. Arm. Layer															
Prim. Arm. Layer															
	Sea Side														

Materials used	**Tonne/week**	**Cumulative**	**Remarks**
Rock Grade A	0	0	
Rock Grade B	0	0	
Rock Grade C	0	0	
Rock Grade D	0	0	
Rock Grade E	575.92	2626.34	Pr.Arm. 250.96 ,Toe 324.96.
Rock Grade F	323.06	323.06	Sec. Arm.seaside
Rock Grade G	3090.02	8580.34	Port side and Sea side
Rock Grade H	7055.34	32318.34	Core

Survey	**Date**	**Time**	**Remarks (Also, refer survey file)**
1	6/22/98	11	Grade G Ch.285(North) and pre bed I.290
2	6/24/98	16	Pre bed I. Ch.300
3	6/25/98	6	Pre bed I. Ch.310
4	6/26/98	6	Grade Ch.310 and Pre bed I.Ch.320
5	6/27/98	16	Grade G Ch.320
6	6/28/98	6	Pre bed I. Ch.330

Constructed up to	**Chainage**	**Date**	**Approved up to**	**Chainage**	**Date**
Filter Layer (G)	330	6/28/98			
Core (H)	309	6/28/98			
Prim. Arm. Port S.	296	6/28/98			
Sec. Arm. Sea S.	296	6/28/98			
Toe Sea side	280	6/28/98			

General Remarks :

Dumping of Quarry Run (Core) continued without surveys and approval.

APPENDIX X : Results of the bulk density ratio calculations

X.I : Breakwater volumes
X.II : Rock quantities
X.III : Bulk density ratio's
X.IV : Combination of results expressed in rock quantities per 'm

X.I : Breakwater volumes

This appendix comprises:

- Short description of calculated values (theoretical and actual volumes).
- Textual summary of the calculation results.
- Graphs and source data of the breakwater volumes compared to the theoretical breakwater volumes per constructed layer. Volumes are calculated both cumulative and per 10 metres breakwater section.

Theoretical breakwater volumes:

The breakwater volumes are determined for every layer per section of 10 metres chainage. The area of each layer in a cross section can be calculated using a theoretical cross section. The volume of each layer per breakwater stretch is determined by linear interpolation of the measured areas between two following cross sections. The theoretical cross section of the breakwater is determined by the sea bed level which is determined by the in-survey of each cross-section.

Actual breakwater volumes:

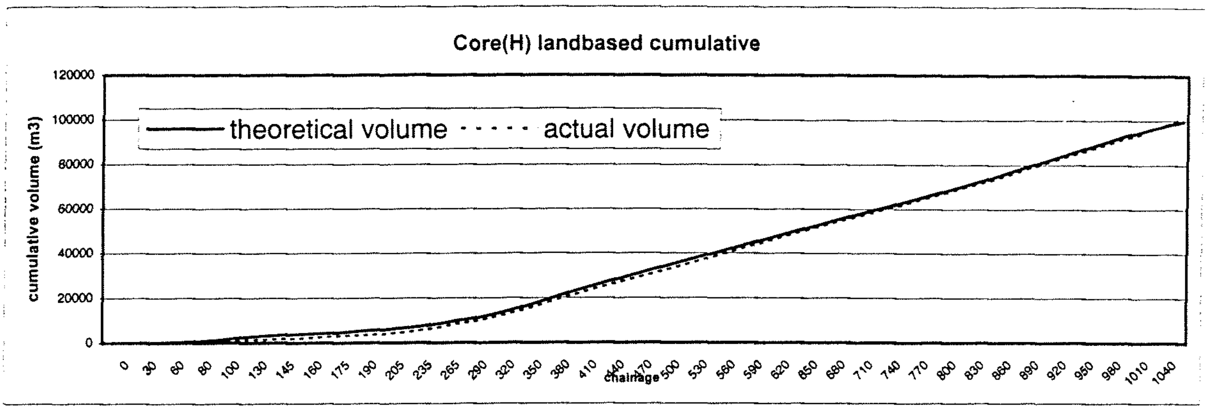
The actual volumes are determined the same way as the theoretical breakwater volumes only this time by using the surveyed cross sections.

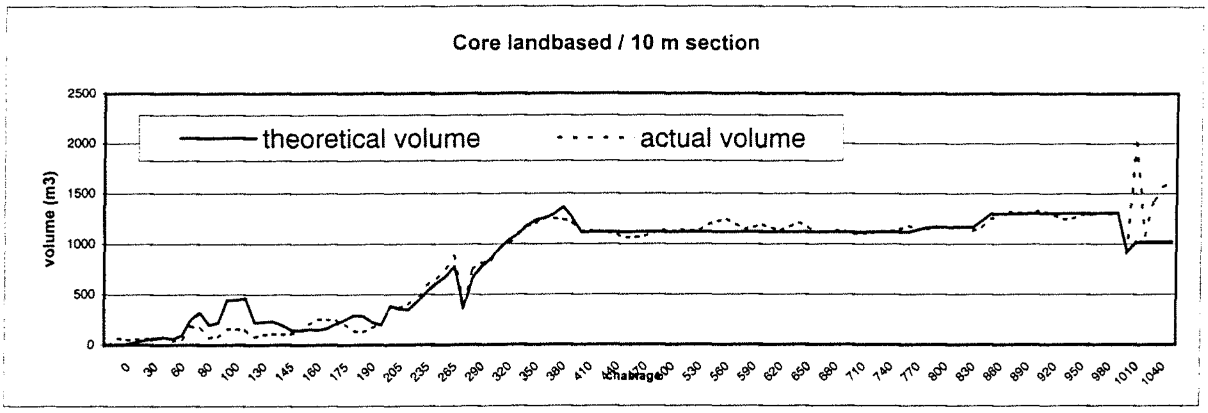
Analyses of the calculated volumes:

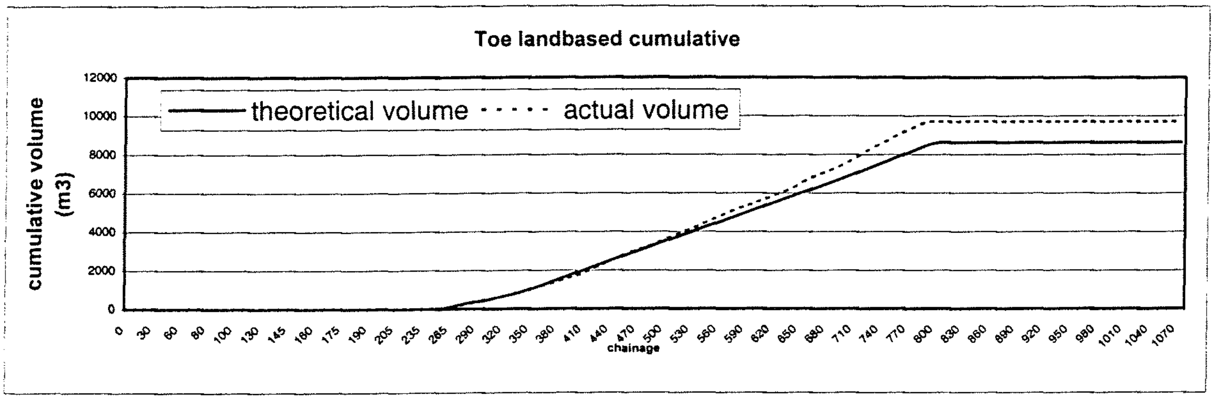
- The core volumes of the surveys are practically the same as the theoretical values along the breakwater except for the first 200 metres of the breakwater. There the surveyed volumes are lower than the theoretical values but the impact on the total volume of these deviations can be neglected.
- Actual volumes of land based filter material could not be calculated. Most of the surveys did not show clearly the existence of a filter layer due to quick bed level changes. Theoretical volumes have been calculated (based on the in-surveys) an are normally presented.
- The surveyed toe volumes (land based) are gradually higher (13 %) than the theoretical volumes.
- The primary armour (seaside) volumes determined from the surveys are 5% less than the theoretical values. The theoretical volumes are however calculated for the completed layer and the surveyed layer is not yet complete. An additional amount of rock (about 12% of the theoretical value) can only be placed after construction of the concrete crest.
- The secondary armour layer (seaside) volumes calculated from the surveys are practically the same as the theoretical values for most parts of the breakwater. Between chainages 205 and 290, 670 and 700 the surveys show high values and between chainage 860 and the head the surveys show low values compared to the theoretical values.
- For the upper armour layer (port side) as well as the lower armour (port side) the 'survey' volumes show considerably higher volumes (50 % and 63 %) than the theoretical values. The surveyed volumes are higher along the entire breakwater.
- The core topping volumes of the surveys and theory are practically the same.
- The marine based surveys show slightly higher (5%) volumes along the entire breakwater than the theoretical volumes.

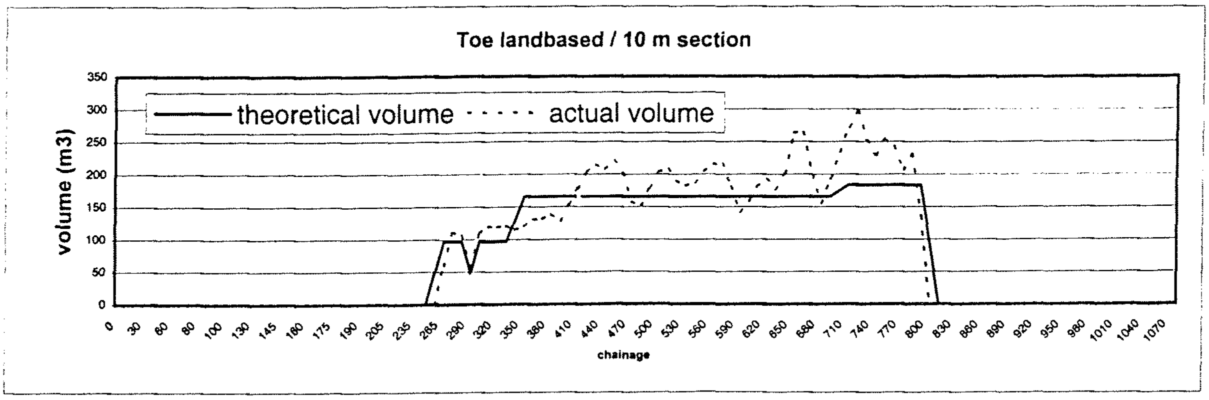
- The 'survey' volumes of all the layers together are lower than the theoretical values for the first 300 metres of the breakwater (due to the core and filter layers) and higher for the remaining part of the breakwater.

Volumes of the south breakwater

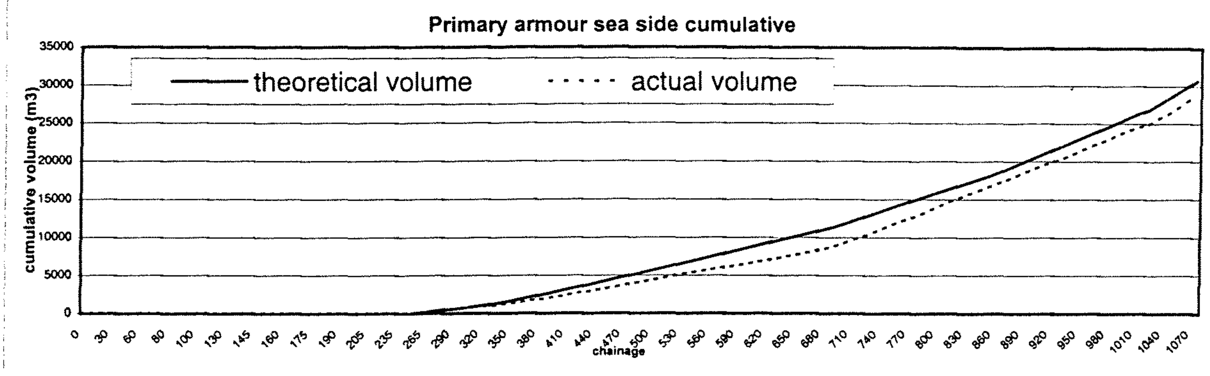


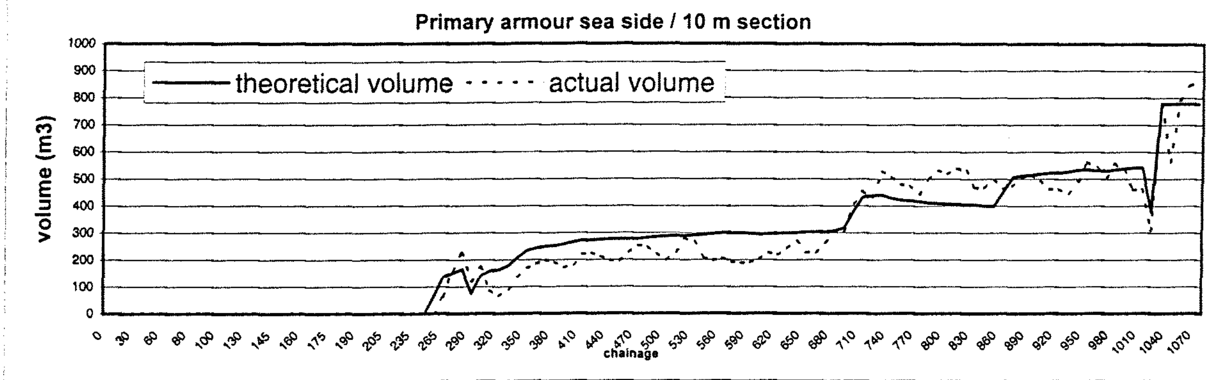


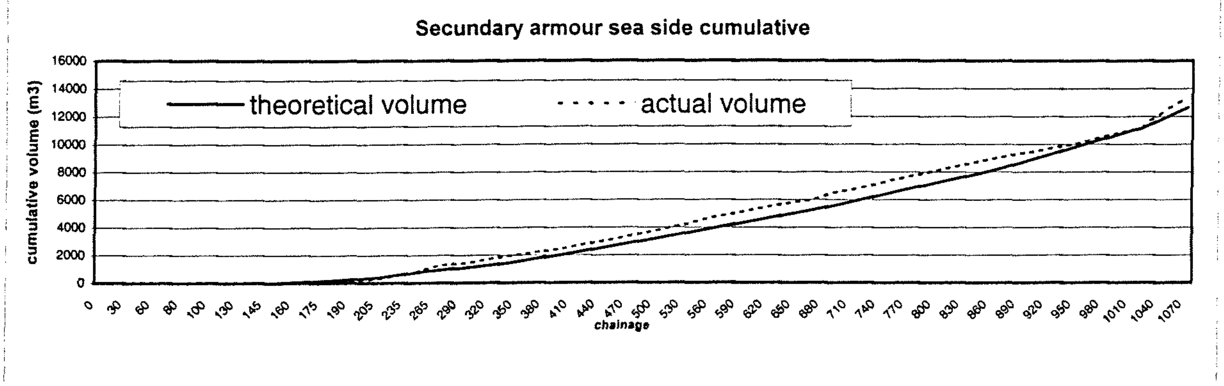


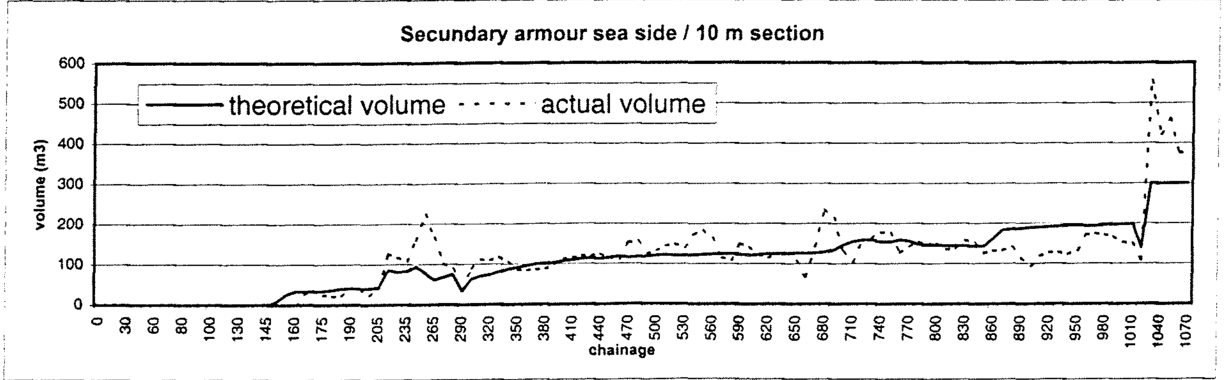


Volumes of the south breakwater

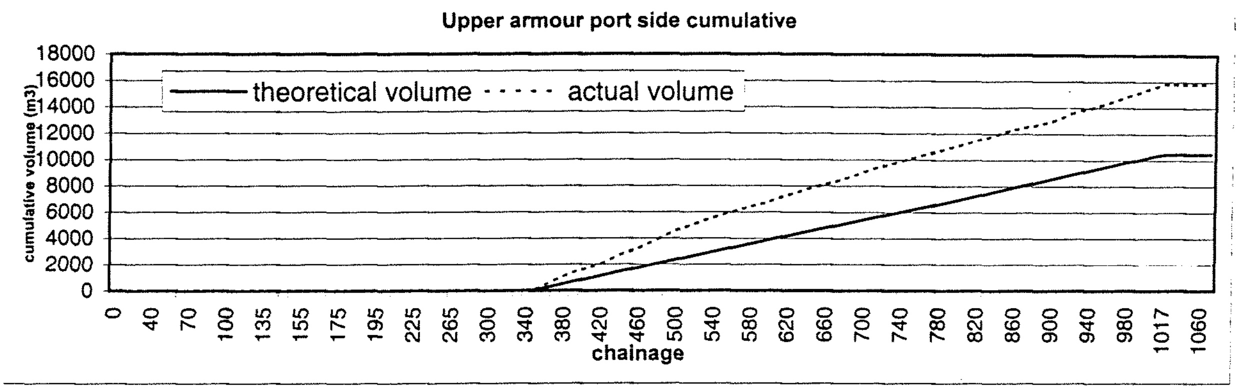


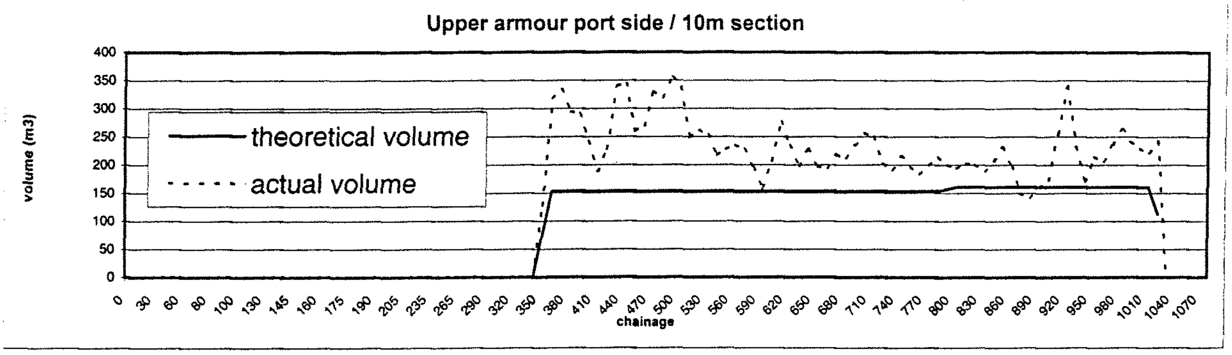


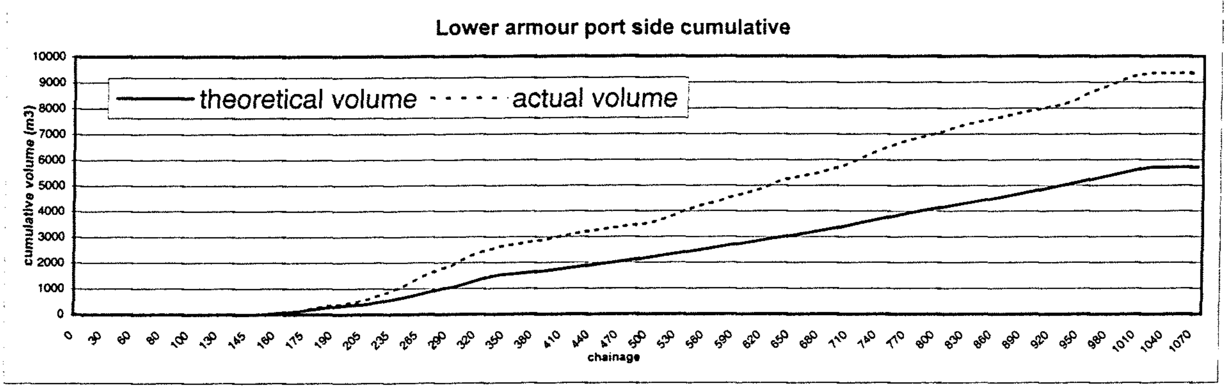


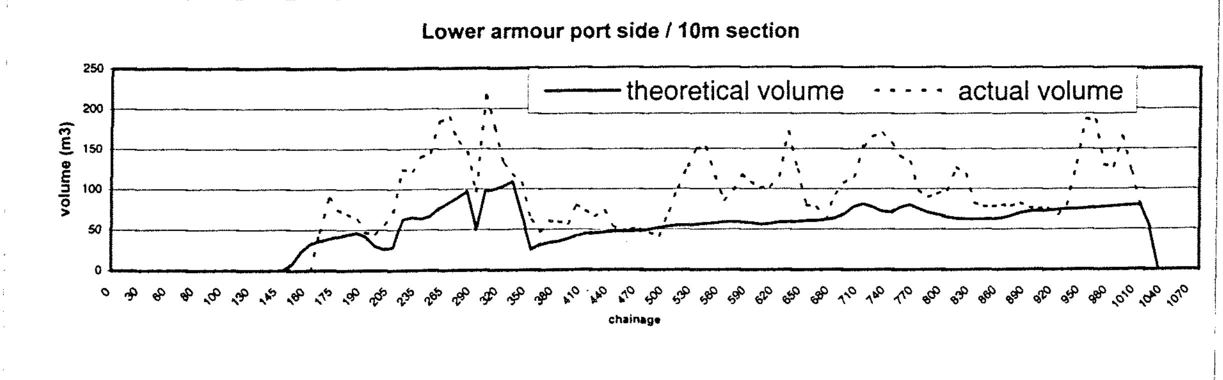


Volumes of the south breakwater

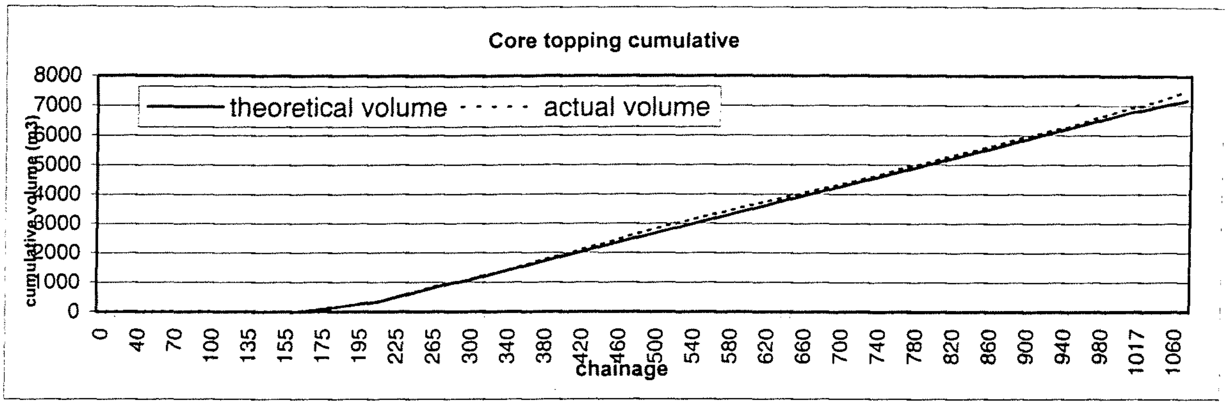


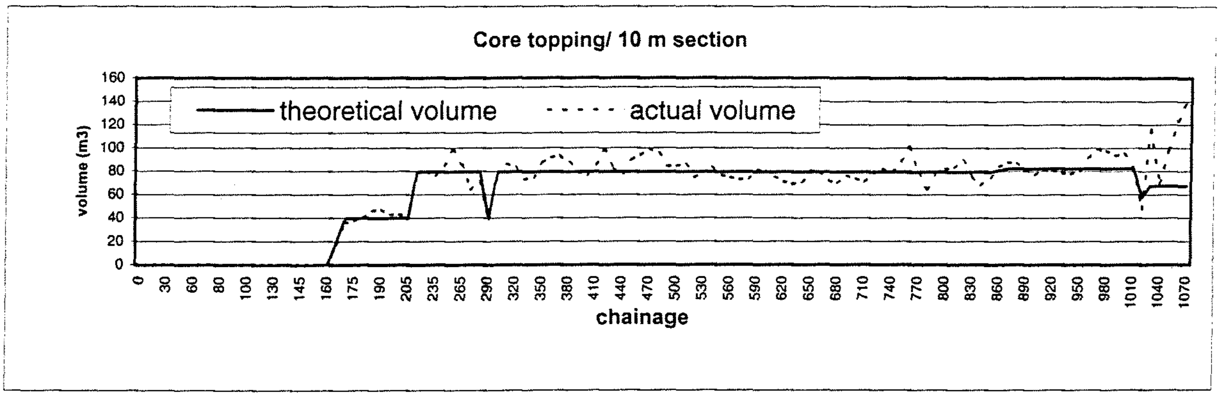


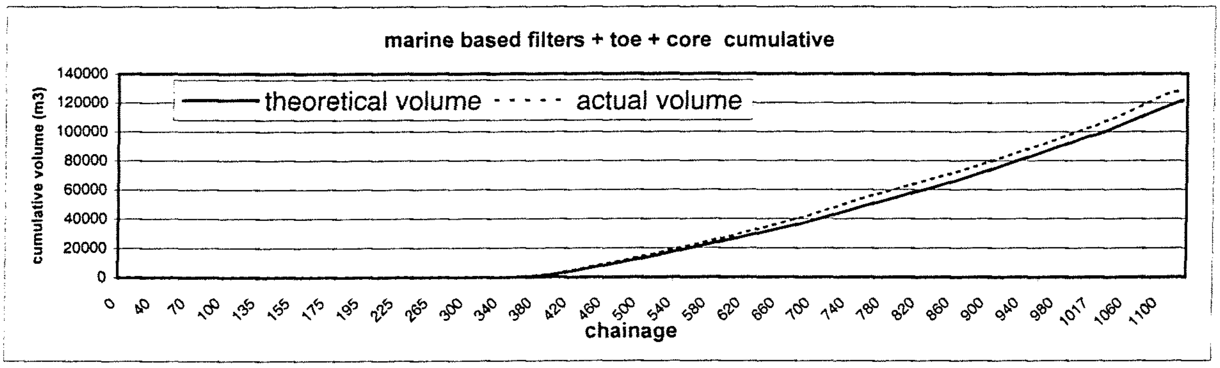


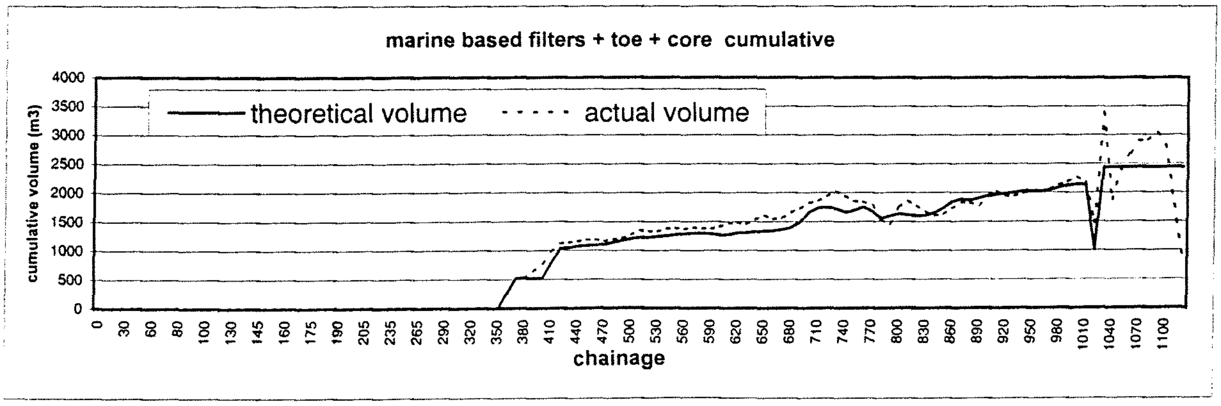


Volumes of the south breakwater

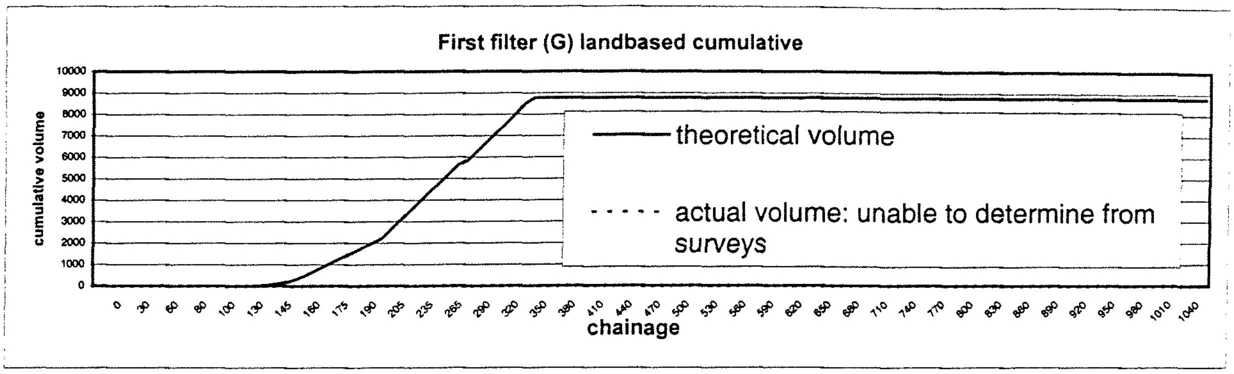


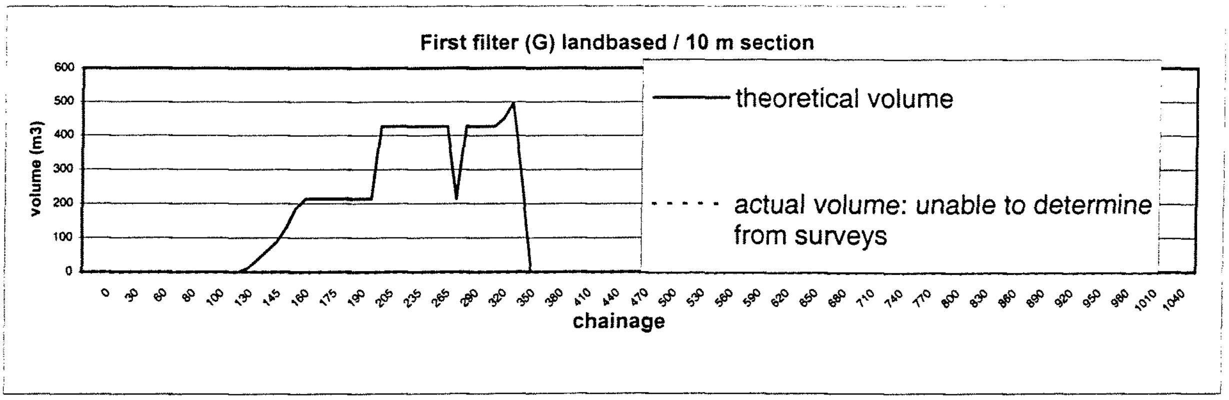


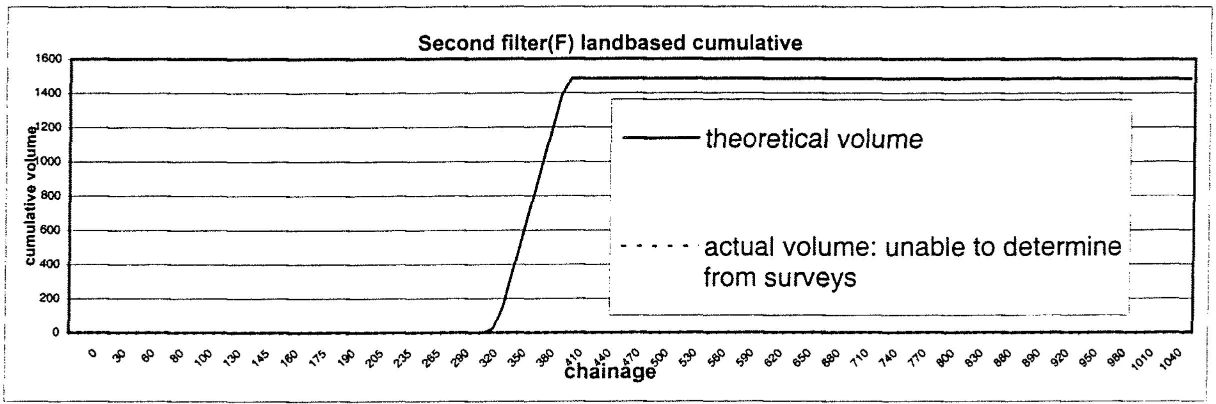


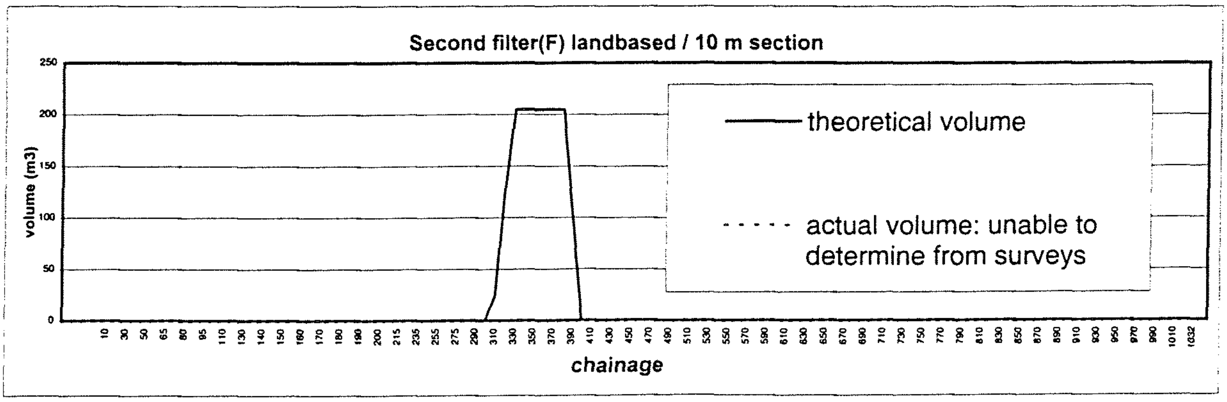


Volumes of the south breakwater

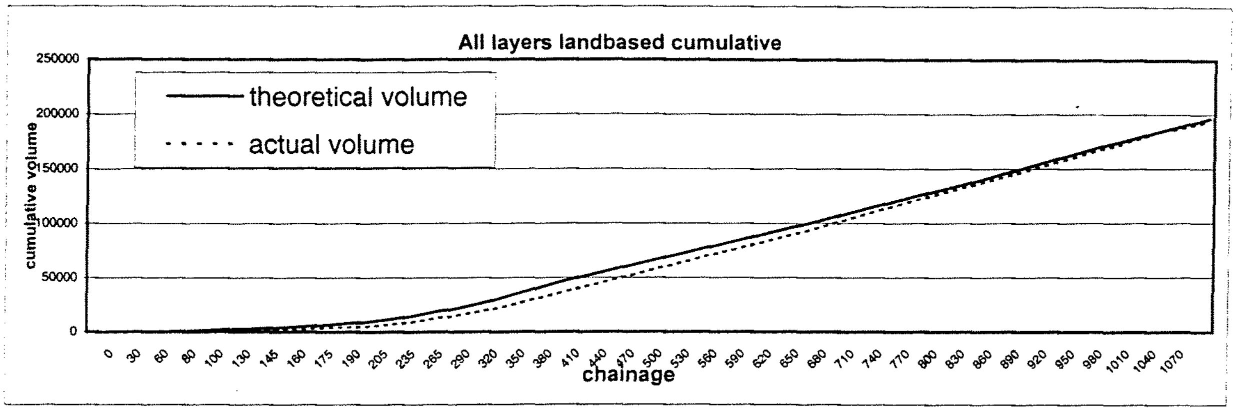


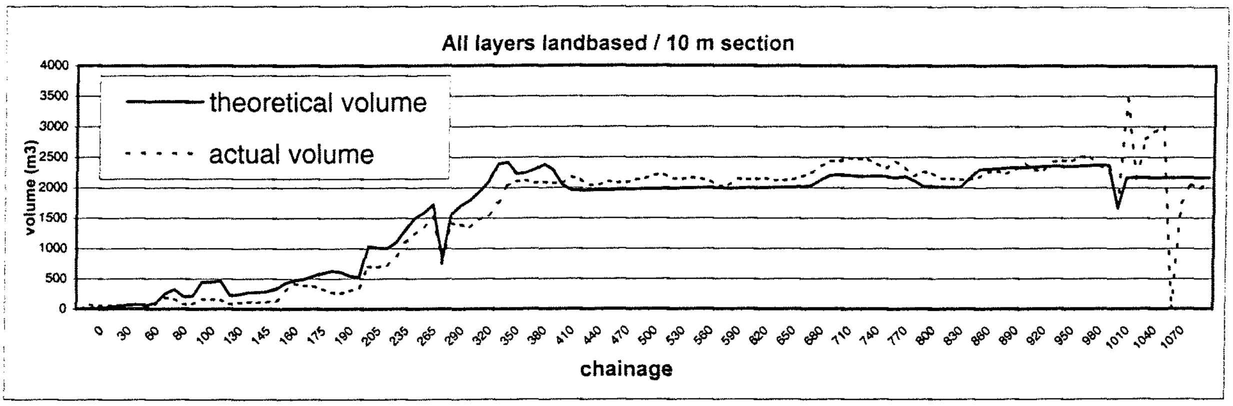


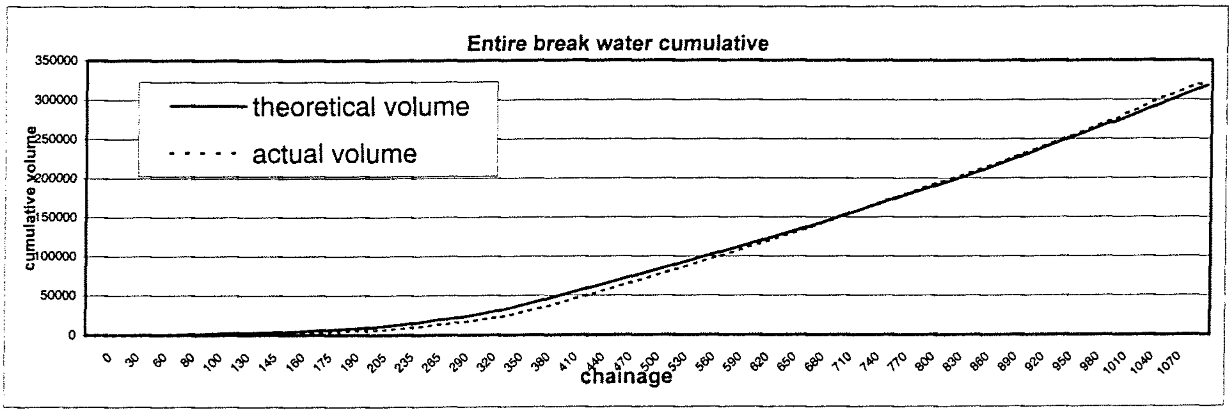


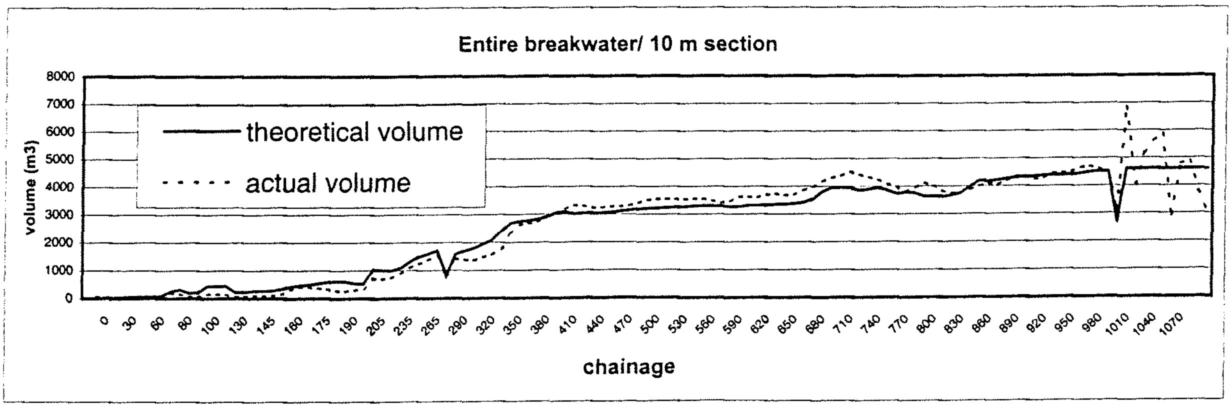


Volumes of the south breakwater









Volumes of the south breakwater

layer:		Core (landbased)					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume (m3)	cumulative volume (m3)
0	H	1.20	0.00	0.00	8.64	0.00	0.00
10	H	0.00	6.00	6.00	4.89	67.62	67.62
20	H	1.88	9.40	15.40	5.39	51.36	118.97
30	H	4.37	31.25	46.65	6.47	59.28	178.25
40	H	5.18	47.75	94.40	6.28	63.77	242.01
50	H	7.52	63.50	157.90	8.01	71.48	313.49
60	H	7.58	75.50	233.40	8.34	81.77	395.26
65	H	15.52	57.75	291.15	5.04	33.44	428.70
70	H	23.46	97.45	388.60	18.41	58.62	487.32
80	H	26.90	251.80	640.40	18.62	185.16	672.48
90	H	37.86	323.80	964.20	14.69	166.53	839.00
95	H	41.97	199.56	1163.76	15.20	74.71	913.71
100	H	46.07	220.09	1383.85	15.72	77.29	916.29
110	H	43.10	445.85	1829.70	15.72	157.17	1073.45
120	H	46.08	445.90	2275.60	15.48	155.99	1229.44
130	H	46.79	464.35	2739.95	15.29	153.85	1383.29
135	H	42.06	222.13	2962.08	16.23	78.79	1462.08
140	H	49.41	228.68	3190.75	23.02	98.10	1560.18
145	H	44.56	234.93	3425.68	21.43	111.12	1671.30
150	H	34.26	197.05	3622.73	20.84	105.67	1776.97
155	H	25.29	148.88	3771.60	22.69	108.82	1885.79
160	H	31.97	143.15	3914.75	31.58	135.68	2021.47
165	H	30.39	155.90	4070.65	50.51	205.23	2226.70
170	H	28.81	148.00	4218.65	51.53	255.10	2481.80
175	H	37.50	165.76	4384.41	49.29	252.05	2733.85
180	H	46.18	209.19	4593.60	50.00	248.22	2982.07
185	H	54.80	252.44	4846.04	33.00	207.50	3189.57
190	H	63.41	295.51	5141.55	22.52	138.80	3328.37
195	H	51.14	286.38	5427.93	28.78	128.25	3456.62
200	H	38.87	225.03	5652.95	39.52	170.75	3627.37
205	H	39.28	195.38	5848.33	38.03	193.86	3821.23
215	H	38.13	387.05	6235.38	36.80	374.15	4195.37
225	H	33.13	356.30	6591.68	37.63	372.19	4567.56
235	H	36.54	348.35	6940.03	42.30	399.66	4967.21
245	H	49.86	432.00	7372.03	55.37	488.34	5455.55
255	H	56.42	531.40	7903.43	62.00	586.85	6042.40
265	H	65.60	610.10	8513.53	71.09	665.44	6707.84
275	H	69.77	676.85	9190.38	81.10	760.93	7468.77
285	H	86.16	779.65	9970.03	94.88	879.88	8348.64
290	H	58.39	361.38	10331.40	64.65	398.82	8747.46
300	H	74.41	664.00	10995.40	85.29	749.69	9497.15
310	H	80.88	776.45	11771.85	77.01	811.49	10308.64
320	H	89.95	854.15	12626.00	91.20	841.06	11149.69
330	H	102.98	964.65	13590.65	99.20	952.00	12101.69
340	H	105.63	1043.05	14633.70	102.40	1008.00	13109.69
350	H	113.82	1097.25	15730.95	118.29	1103.45	14213.14
360	H	123.50	1186.60	16917.55	117.29	1177.90	15391.04
370	H	124.42	1239.60	18157.15	122.22	1197.55	16588.59
380	H	126.61	1255.15	19412.30	131.51	1268.63	17857.21
390	H	133.17	1298.90	20711.20	119.24	1253.73	19110.94
400	H	139.79	1364.80	22076.00	129.14	1241.91	20352.85
410	H	111.42	1256.05	23332.05	114.06	1216.02	21568.87
420	H	111.67	1115.45	24447.50	111.42	1127.39	22696.25
430	H	112.27	1119.70	25567.20	115.00	1132.06	23828.31
440	H	111.91	1120.90	26688.10	111.44	1132.16	24960.47
450	H	111.89	1119.00	27807.10	111.18	1113.10	26073.56
460	H	111.52	1117.05	28924.15	106.76	1089.69	27163.25
470	H	111.89	1117.05	30041.20	105.41	1060.82	28224.07
480	H	111.89	1118.90	31160.10	107.50	1064.52	29288.59
490	H	111.89	1118.90	32279.00	107.68	1075.90	30364.48
500	H	111.89	1118.90	33397.90	113.34	1105.13	31469.61
510	H	111.89	1118.90	34516.80	113.96	1136.52	32606.13
520	H	111.89	1118.90	35635.70	111.00	1124.81	33730.93
530	H	111.89	1118.90	36754.60	117.45	1142.25	34873.18
540	H	111.89	1118.90	37873.50	108.63	1130.41	36003.59
550	H	111.89	1118.90	38992.40	118.69	1136.62	37140.21
560	H	111.89	1118.90	40111.30	118.94	1188.14	38328.35
570	H	111.89	1118.90	41230.20	125.65	1222.92	39551.26
580	H	111.89	1118.90	42349.10	123.51	1245.78	40797.04
590	H	111.89	1118.90	43468.00	115.80	1196.52	41993.56
600	H	111.89	1118.90	44586.90	114.01	1149.03	43142.58

		Core (landbased)					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume (m3)	cumulative volume (m3)
610	H	111.89	1118.90	45705.80	119.06	1165.33	44307.91
620	H	111.89	1118.90	46824.70	118.64	1188.46	45496.37
630	H	111.89	1118.90	47943.60	113.30	1159.68	46656.04
640	H	111.89	1118.90	49062.50	114.28	1137.92	47793.96
650	H	111.89	1118.90	50181.40	119.74	1170.12	48964.08
660	H	111.89	1118.90	51300.30	122.77	1212.55	50176.63
670	H	111.89	1118.90	52419.20	111.11	1169.38	51346.01
680	H	111.89	1118.90	53538.10	111.73	1114.19	52460.20
690	H	111.89	1118.90	54657.00	109.99	1108.60	53568.80
700	H	111.89	1118.90	55775.90	117.50	1137.44	54706.23
710	H	111.89	1118.90	56894.80	108.73	1131.15	55837.38
720	H	111.89	1118.90	58013.70	111.55	1101.40	56938.78
730	H	111.89	1118.90	59132.60	109.28	1104.17	58042.95
740	H	111.89	1118.90	60251.50	111.86	1105.73	59148.68
750	H	111.89	1118.90	61370.40	114.29	1130.74	60279.41
760	H	111.89	1118.90	62489.30	111.03	1126.57	61405.98
770	H	111.89	1118.90	63608.20	118.37	1146.98	62552.96
780	H	111.89	1118.90	64727.10	118.06	1182.14	63735.10
790	H	116.39	1141.40	65868.50	112.02	1150.40	64885.50
800	H	116.39	1163.90	67032.40	116.90	1144.60	66030.10
810	H	116.55	1164.70	68197.10	118.32	1176.10	67206.20
820	H	116.55	1165.50	69362.60	114.41	1163.65	68369.85
830	H	116.72	1166.35	70528.95	121.17	1177.92	69547.77
840	H	116.72	1167.20	71696.15	114.56	1178.67	70726.44
850	H	116.72	1167.20	72863.35	111.14	1128.50	71854.94
860	H	129.76	1232.40	74095.75	122.16	1166.50	73021.44
870	H	129.78	1297.70	75393.45	127.00	1245.80	74267.24
880	H	129.80	1297.90	76691.35	131.64	1293.20	75560.44
890	H	130.01	1299.05	77990.40	132.51	1320.77	76881.21
900	H	130.03	1300.20	79290.60	130.49	1315.04	78196.25
910	H	130.23	1301.30	80591.90	130.53	1305.10	79501.35
920	H	130.24	1302.35	81894.25	135.19	1328.59	80829.94
930	H	130.26	1302.50	83196.75	129.72	1324.55	82154.48
940	H	130.48	1303.70	84500.45	126.86	1282.88	83437.36
950	H	130.46	1304.70	85805.15	122.43	1246.44	84683.80
960	H	130.45	1304.55	87109.70	127.79	1251.10	85934.90
970	H	130.66	1305.55	88415.25	129.90	1288.45	87223.34
980	H	130.68	1306.70	89721.95	128.80	1293.50	88516.84
990	H	130.89	1307.85	91029.80	132.58	1306.90	89823.74
1000	H	130.89	1308.90	92338.70	127.35	1299.65	91123.39
1010	H	131.05	1309.70	93648.40	129.15	1282.49	92405.88
1017	H	131.05	917.35	94565.75	129.00	903.51	93309.39
1032	H		1021.88	95587.63	138.81	2008.58	95317.97
1040	H		1021.88	96609.50	132.82	1086.54	96404.51
1050	H		1021.88	97631.38	154.81	1438.16	97842.67
1060	H		1021.88	98653.25	158.95	1568.79	99411.46
1070	H		1021.88	99675.13	165.20	1620.74	101032.20
1070 P	H		1021.88	100697.00	82.47	0.00	101032.20
A	H		1021.88	101718.88	87.77	900.82	101933.03
B	H		1021.88	102740.75	85.07	925.11	102858.14
C	H		1021.88	103762.63	87.92	929.35	103787.48
1070 S	H		1021.88	104784.50	86.87	936.97	104724.45
Head	H		10218.75	104784.50		11415.06	104724.45

layer: First filter layer (landbased)

chainage	grade	Theoretical profile area (m2)	Theoretical profile section volume (m3)	Theoretical profile cumulative volume (m3)	Surveyed profile area (m2)	Surveyed profile section volume (m3)	Surveyed profile cumulative volume (m3)
0	-	0.00	0.00	0.00	0.00	0.00	0.00
10	-	0.00	0.00	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00		0.00	0.00
135	-	0.00	0.00	0.00		0.00	0.00
140	-	5.00	12.50	12.50		0.00	0.00
145	-	10.00	37.50	50.00		0.00	0.00
150	-	15.00	62.50	112.50		0.00	0.00
155	-	20.00	87.50	200.00		0.00	0.00
160	-	31.38	128.44	328.44		0.00	0.00
165	G	42.75	185.31	513.75		0.00	0.00
170	G	42.75	213.75	727.50		0.00	0.00
175	G	42.75	213.75	941.25		0.00	0.00
180	G	42.75	213.75	1155.00		0.00	0.00
185	G	42.75	213.75	1368.75		0.00	0.00
190	G	42.75	213.75	1582.50		0.00	0.00
195	G	42.75	213.75	1796.25		0.00	0.00
200	G	42.75	213.75	2010.00		0.00	0.00
205	G	42.75	213.75	2223.75		0.00	0.00
215	G	42.75	427.50	2651.25		0.00	0.00
225	G	42.75	427.50	3078.75		0.00	0.00
235	G	42.75	427.50	3506.25		0.00	0.00
245	G	42.75	427.50	3933.75		0.00	0.00
255	G	42.75	427.50	4361.25		0.00	0.00
265	G	42.75	427.50	4788.75		0.00	0.00
275	G	42.75	427.50	5216.25		0.00	0.00
285	G	42.75	427.50	5643.75		0.00	0.00
290	G	42.75	213.75	5857.50		0.00	0.00
300	G	42.75	427.50	6285.00		0.00	0.00
310	G	42.75	427.50	6712.50		0.00	0.00
320	G	42.75	427.50	7140.00		0.00	0.00
330	G	42.75	427.50	7567.50		0.00	0.00
340	G	47.38	450.63	8018.13		0.00	0.00
350	G	52.00	496.88	8515.00		0.00	0.00
360	-	0.00	260.00	8775.00		0.00	0.00
370	-	0.00	0.00	8775.00		0.00	0.00
380	-	0.00	0.00	8775.00		0.00	0.00
390	-	0.00	0.00	8775.00		0.00	0.00
400	-	0.00	0.00	8775.00		0.00	0.00
410	-	0.00	0.00	8775.00		0.00	0.00
420	-	0.00	0.00	8775.00		0.00	0.00
430	-	0.00	0.00	8775.00		0.00	0.00
440	-	0.00	0.00	8775.00		0.00	0.00
450	-	0.00	0.00	8775.00		0.00	0.00
460	-	0.00	0.00	8775.00		0.00	0.00
470	-	0.00	0.00	8775.00		0.00	0.00
480	-	0.00	0.00	8775.00		0.00	0.00
490	-	0.00	0.00	8775.00		0.00	0.00
500	-	0.00	0.00	8775.00		0.00	0.00
510	-	0.00	0.00	8775.00		0.00	0.00
520	-	0.00	0.00	8775.00		0.00	0.00
530	-	0.00	0.00	8775.00		0.00	0.00
540	-	0.00	0.00	8775.00		0.00	0.00
550	-	0.00	0.00	8775.00		0.00	0.00
560	-	0.00	0.00	8775.00		0.00	0.00
570	-	0.00	0.00	8775.00		0.00	0.00
580	-	0.00	0.00	8775.00		0.00	0.00
590	-	0.00	0.00	8775.00		0.00	0.00
600	-	0.00	0.00	8775.00		0.00	0.00

First filter layer (landbased)

chainage	grade	Theoretical profile area (m2)	Theoretical profile section volume (m3)	Theoretical profile cumulative volume (m3)	Surveyed profile area (m2)	Surveyed profile section volume (m3)	Surveyed profile cumulative volume (m3)
610	-	0.00	0.00	8775.00		0.00	0.00
620	-	0.00	0.00	8775.00		0.00	0.00
630	-	0.00	0.00	8775.00		0.00	0.00
640	-	0.00	0.00	8775.00		0.00	0.00
650	-	0.00	0.00	8775.00		0.00	0.00
660	-	0.00	0.00	8775.00		0.00	0.00
670	-	0.00	0.00	8775.00		0.00	0.00
680	-	0.00	0.00	8775.00		0.00	0.00
690	-	0.00	0.00	8775.00		0.00	0.00
700	-	0.00	0.00	8775.00		0.00	0.00
710	-	0.00	0.00	8775.00		0.00	0.00
720	-	0.00	0.00	8775.00		0.00	0.00
730	-	0.00	0.00	8775.00		0.00	0.00
740	-	0.00	0.00	8775.00		0.00	0.00
750	-	0.00	0.00	8775.00		0.00	0.00
760	-	0.00	0.00	8775.00		0.00	0.00
770	-	0.00	0.00	8775.00		0.00	0.00
780	-	0.00	0.00	8775.00		0.00	0.00
790	-	0.00	0.00	8775.00		0.00	0.00
800	-	0.00	0.00	8775.00		0.00	0.00
810	-	0.00	0.00	8775.00		0.00	0.00
820	-	0.00	0.00	8775.00		0.00	0.00
830	-	0.00	0.00	8775.00		0.00	0.00
840	-	0.00	0.00	8775.00		0.00	0.00
850	-	0.00	0.00	8775.00		0.00	0.00
860	-	0.00	0.00	8775.00		0.00	0.00
870	-	0.00	0.00	8775.00		0.00	0.00
880	-	0.00	0.00	8775.00		0.00	0.00
890	-	0.00	0.00	8775.00		0.00	0.00
900	-	0.00	0.00	8775.00		0.00	0.00
910	-	0.00	0.00	8775.00		0.00	0.00
920	-	0.00	0.00	8775.00		0.00	0.00
930	-	0.00	0.00	8775.00		0.00	0.00
940	-	0.00	0.00	8775.00		0.00	0.00
950	-	0.00	0.00	8775.00		0.00	0.00
960	-	0.00	0.00	8775.00		0.00	0.00
970	-	0.00	0.00	8775.00		0.00	0.00
980	-	0.00	0.00	8775.00		0.00	0.00
990	-	0.00	0.00	8775.00		0.00	0.00
1000	-	0.00	0.00	8775.00		0.00	0.00
1010	-	0.00	0.00	8775.00		0.00	0.00
1017	-	0.00	0.00	8775.00		0.00	0.00
1032	-	0.00	0.00	8775.00		0.00	0.00
1040	-	0.00	0.00	8775.00		0.00	0.00
1050	-	0.00	0.00	8775.00		0.00	0.00
1060	-	0.00	0.00	8775.00		0.00	0.00
1070	-	0.00	0.00	8775.00		0.00	0.00
1070 P		0.00	0.00	8775.00		0.00	0.00
A	-	0.00	0.00	8775.00		0.00	0.00
B	-	0.00	0.00	8775.00		0.00	0.00
C	-	0.00	0.00	8775.00		0.00	0.00
1070 S		0.00	0.00	8775.00		0.00	0.00
Head	-	0	0	8775.00		0.00	0.00

layer:

		Second filter layer (landbased)					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume (m3)	cumulative volume (m3)
0	-	0.00	0.00	0.00	0.00	0.00	0.00
10	-	0.00	0.00	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00	0.00	0.00
165	-	0.00	0.00	0.00	0.00	0.00	0.00
170	-	0.00	0.00	0.00	0.00	0.00	0.00
175	-	0.00	0.00	0.00	0.00	0.00	0.00
180	-	0.00	0.00	0.00	0.00	0.00	0.00
185	-	0.00	0.00	0.00	0.00	0.00	0.00
190	-	0.00	0.00	0.00	0.00	0.00	0.00
195	-	0.00	0.00	0.00	0.00	0.00	0.00
200	-	0.00	0.00	0.00	0.00	0.00	0.00
205	-	0.00	0.00	0.00	0.00	0.00	0.00
215	-	0.00	0.00	0.00	0.00	0.00	0.00
225	-	0.00	0.00	0.00	0.00	0.00	0.00
235	-	0.00	0.00	0.00	0.00	0.00	0.00
245	-	0.00	0.00	0.00	0.00	0.00	0.00
255	-	0.00	0.00	0.00	0.00	0.00	0.00
265	-	0.00	0.00	0.00	0.00	0.00	0.00
275	-	0.00	0.00	0.00		0.00	0.00
285	-	0.00	0.00	0.00		0.00	0.00
290	-	0.00	0.00	0.00		0.00	0.00
300	-	0.00	0.00	0.00		0.00	0.00
310	-	0.00	0.00	0.00		0.00	0.00
320	-	0.00	0.00	0.00		0.00	0.00
330	-	0.00	0.00	0.00		0.00	0.00
340	F	4.97	24.85	24.85		0.00	0.00
350	F	20.50	127.35	152.20		0.00	0.00
360	F	20.50	205.00	357.20		0.00	0.00
370	F	20.50	205.00	562.20		0.00	0.00
380	F	20.50	205.00	767.20		0.00	0.00
390	F	20.50	205.00	972.20		0.00	0.00
400	F	20.50	205.00	1177.20		0.00	0.00
410	F	20.50	205.00	1382.20		0.00	0.00
420	-	0.00	102.50	1484.70		0.00	0.00
430	-	0.00	0.00	1484.70		0.00	0.00
440	-	0.00	0.00	1484.70		0.00	0.00
450	-	0.00	0.00	1484.70		0.00	0.00
460	-	0.00	0.00	1484.70		0.00	0.00
470	-	0.00	0.00	1484.70		0.00	0.00
480	-	0.00	0.00	1484.70		0.00	0.00
490	-	0.00	0.00	1484.70		0.00	0.00
500	-	0.00	0.00	1484.70		0.00	0.00
510	-	0.00	0.00	1484.70		0.00	0.00
520	-	0.00	0.00	1484.70		0.00	0.00
530	-	0.00	0.00	1484.70		0.00	0.00
540	-	0.00	0.00	1484.70		0.00	0.00
550	-	0.00	0.00	1484.70		0.00	0.00
560	-	0.00	0.00	1484.70		0.00	0.00
570	-	0.00	0.00	1484.70		0.00	0.00
580	-	0.00	0.00	1484.70		0.00	0.00
590	-	0.00	0.00	1484.70		0.00	0.00
600	-	0.00	0.00	1484.70		0.00	0.00

		Second filter layer (landbased)					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume (m3)	cumulative volume (m3)
610	-	0.00	0.00	1484.70		0.00	0.00
620	-	0.00	0.00	1484.70		0.00	0.00
630	-	0.00	0.00	1484.70		0.00	0.00
640	-	0.00	0.00	1484.70		0.00	0.00
650	-	0.00	0.00	1484.70		0.00	0.00
660	-	0.00	0.00	1484.70		0.00	0.00
670	-	0.00	0.00	1484.70		0.00	0.00
680	-	0.00	0.00	1484.70		0.00	0.00
690	-	0.00	0.00	1484.70		0.00	0.00
700	-	0.00	0.00	1484.70		0.00	0.00
710	-	0.00	0.00	1484.70		0.00	0.00
720	-	0.00	0.00	1484.70		0.00	0.00
730	-	0.00	0.00	1484.70		0.00	0.00
740	-	0.00	0.00	1484.70		0.00	0.00
750	-	0.00	0.00	1484.70		0.00	0.00
760	-	0.00	0.00	1484.70		0.00	0.00
770	-	0.00	0.00	1484.70		0.00	0.00
780	-	0.00	0.00	1484.70		0.00	0.00
790	-	0.00	0.00	1484.70		0.00	0.00
800	-	0.00	0.00	1484.70		0.00	0.00
810	-	0.00	0.00	1484.70		0.00	0.00
820	-	0.00	0.00	1484.70		0.00	0.00
830	-	0.00	0.00	1484.70		0.00	0.00
840	-	0.00	0.00	1484.70		0.00	0.00
850	-	0.00	0.00	1484.70		0.00	0.00
860	-	0.00	0.00	1484.70		0.00	0.00
870	-	0.00	0.00	1484.70		0.00	0.00
880	-	0.00	0.00	1484.70		0.00	0.00
890	-	0.00	0.00	1484.70		0.00	0.00
900	-	0.00	0.00	1484.70		0.00	0.00
910	-	0.00	0.00	1484.70		0.00	0.00
920	-	0.00	0.00	1484.70		0.00	0.00
930	-	0.00	0.00	1484.70		0.00	0.00
940	-	0.00	0.00	1484.70		0.00	0.00
950	-	0.00	0.00	1484.70		0.00	0.00
960	-	0.00	0.00	1484.70		0.00	0.00
970	-	0.00	0.00	1484.70		0.00	0.00
980	-	0.00	0.00	1484.70		0.00	0.00
990	-	0.00	0.00	1484.70		0.00	0.00
1000	-	0.00	0.00	1484.70		0.00	0.00
1010	-	0.00	0.00	1484.70		0.00	0.00
1017	-	0.00	0.00	1484.70		0.00	0.00
1032	-		0.00	1484.70		0.00	0.00
1040	-		0.00	1484.70		0.00	0.00
1050	-		0.00	1484.70		0.00	0.00
1060	-		0.00	1484.70		0.00	0.00
1070	-		0.00	1484.70		0.00	0.00
1070 P			0.00	1484.70		0.00	0.00
A			0.00	1484.70		0.00	0.00
B			0.00	1484.70		0.00	0.00
C			0.00	1484.70		0.00	0.00
1070 S			0.00	1484.70		0.00	0.00
Head	-		0	1484.70		0.00	0.00

Volumes of the south breakwater

layer:

		Toe (landbased)					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume (m3)	cumulative volume (m3)
0	-	0.00	0.00	0.00	0.00	0.00	0.00
10	-	0.00	0.00	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00	0.00	0.00
165	-	0.00	0.00	0.00	0.00	0.00	0.00
170	-	0.00	0.00	0.00	0.00	0.00	0.00
175	-	0.00	0.00	0.00	0.00	0.00	0.00
180	-	0.00	0.00	0.00	0.00	0.00	0.00
185	-	0.00	0.00	0.00	0.00	0.00	0.00
190	-	0.00	0.00	0.00	0.00	0.00	0.00
195	-	0.00	0.00	0.00	0.00	0.00	0.00
200	-	0.00	0.00	0.00	0.00	0.00	0.00
205	-	0.00	0.00	0.00	0.00	0.00	0.00
215	-	0.00	0.00	0.00	0.00	0.00	0.00
225	-	0.00	0.00	0.00	0.00	0.00	0.00
235	-	0.00	0.00	0.00	0.00	0.00	0.00
245	-	0.00	0.00	0.00	0.00	0.00	0.00
255	E	9.66	48.30	48.30	0.00	0.00	0.00
265	E	9.66	96.60	144.90	12.07	60.36	60.36
275	E	9.66	96.60	241.50	10.26	111.63	171.99
285	E	9.66	96.60	338.10	11.00	106.26	278.24
290	E	9.66	48.30	386.40	11.74	56.84	335.08
300	E	9.66	96.60	483.00	10.19	109.63	444.70
310	E	9.66	96.60	579.60	13.76	119.75	564.45
320	E	9.66	96.60	676.20	10.07	119.17	683.62
330	E	9.66	96.60	772.80	14.17	121.20	804.82
340	D	16.57	131.15	903.95	8.80	114.85	919.67
350	D	16.57	165.70	1069.65	15.10	119.48	1039.14
360	D	16.57	165.70	1235.35	11.09	130.91	1170.05
370	d	16.57	165.70	1401.05	15.22	131.55	1301.59
380	D	16.57	165.70	1566.75	12.56	138.94	1440.53
390	D	16.57	165.70	1732.45	13.14	128.54	1569.06
400	D	16.57	165.70	1898.15	17.60	153.73	1722.79
410	D	16.57	165.70	2063.85	18.06	178.29	1901.07
420	D	16.57	165.70	2229.55	22.63	203.44	2104.51
430	D	16.57	165.70	2395.25	20.43	215.30	2319.80
440	D	16.57	165.70	2560.95	21.05	207.38	2527.18
450	D	16.57	165.70	2726.65	23.11	220.78	2747.95
460	D	16.57	165.70	2892.35	17.31	202.09	2950.04
470	D	16.57	165.70	3058.05	14.30	158.03	3108.07
480	D	16.57	165.70	3223.75	16.06	151.77	3259.83
490	D	16.57	165.70	3389.45	19.86	179.59	3439.42
500	D	16.57	165.70	3555.15	21.00	204.30	3643.72
510	D	16.57	165.70	3720.85	20.53	207.65	3851.37
520	D	16.57	165.70	3886.55	17.56	190.45	4041.82
530	D	16.57	165.70	4052.25	18.84	182.00	4223.82
540	D	16.57	165.70	4217.95	18.59	187.13	4410.94
550	D	16.57	165.70	4383.65	22.29	204.40	4615.34
560	D	16.57	165.70	4549.35	20.81	215.52	4830.85
570	D	16.57	165.70	4715.05	22.51	216.57	5047.42
580	D	16.57	165.70	4880.75	13.78	181.42	5228.84
590	D	16.57	165.70	5046.45	14.62	141.99	5370.83
600	D	16.57	165.70	5212.15	17.11	158.66	5529.49

		Toe (landbased)					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume . (m3)	cumulative volume (m3)
610	D	16.57	165.70	5377.85	19.00	180.57	5710.06
620	D	16.57	165.70	5543.55	19.49	192.45	5902.51
630	D	16.57	165.70	5709.25	15.87	176.82	6079.33
640	D	16.57	165.70	5874.95	24.40	201.39	6280.72
650	D	16.57	165.70	6040.65	28.40	264.03	6544.74
660	D	16.57	165.70	6206.35	24.50	264.50	6809.24
670	D	16.57	165.70	6372.05	15.26	198.81	7008.04
680	D	16.57	165.70	6537.75	15.81	155.34	7163.38
690	D	16.57	165.70	6703.45	22.81	193.08	7356.46
700	D	18.37	174.70	6878.15	23.96	233.84	7590.30
710	D	18.37	183.70	7061.85	30.57	272.64	7862.94
720	D	18.37	183.70	7245.55	28.93	297.52	8160.46
730	D	18.37	183.70	7429.25	21.47	252.02	8412.48
740	D	18.37	183.70	7612.95	24.47	229.70	8642.18
750	D	18.37	183.70	7796.65	26.40	254.35	8896.53
760	D	18.37	183.70	7980.35	22.20	243.00	9139.53
770	D	18.37	183.70	8164.05	19.29	207.45	9346.98
780	D	18.37	183.70	8347.75	26.94	231.15	9578.13
790	D	18.37	183.70	8531.45	0.00	134.70	9712.83
800	-	0.00	91.85	8623.30	0.00	0.00	9712.83
810	-	0.00	0.00	8623.30	0.00	0.00	9712.83
820	-	0.00	0.00	8623.30	0.00	0.00	9712.83
830	-	0.00	0.00	8623.30	0.00	0.00	9712.83
840	-	0.00	0.00	8623.30	0.00	0.00	9712.83
850	-	0.00	0.00	8623.30	0.00	0.00	9712.83
860	-	0.00	0.00	8623.30	0.00	0.00	9712.83
870	-	0.00	0.00	8623.30	0.00	0.00	9712.83
880	-	0.00	0.00	8623.30	0.00	0.00	9712.83
890	-	0.00	0.00	8623.30	0.00	0.00	9712.83
900	-	0.00	0.00	8623.30	0.00	0.00	9712.83
910	-	0.00	0.00	8623.30	0.00	0.00	9712.83
920	-	0.00	0.00	8623.30	0.00	0.00	9712.83
930	-	0.00	0.00	8623.30	0.00	0.00	9712.83
940	-	0.00	0.00	8623.30	0.00	0.00	9712.83
950	-	0.00	0.00	8623.30	0.00	0.00	9712.83
960	-	0.00	0.00	8623.30	0.00	0.00	9712.83
970	-	0.00	0.00	8623.30	0.00	0.00	9712.83
980	-	0.00	0.00	8623.30	0.00	0.00	9712.83
990	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1000	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1010	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1017	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1032	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1040	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1050	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1060	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1070	-	0.00	0.00	8623.30	0.00	0.00	9712.83
1070 P		0.00	0.00	8623.30	0.00	0.00	9712.83
A		0.00	0.00	8623.30	0.00	0.00	9712.83
B		0.00	0.00	8623.30	0.00	0.00	9712.83
C		0.00	0.00	8623.30	0.00	0.00	9712.83
1070 S		0.00	0.00	8623.30	0.00	0.00	9712.83
Head	-		0	8623.30	0	0.00	9712.83

layer: **Primary armour sea side**

chainage	grade	Theoretical profile area (m2)	Theoretical profile section volume (m3)	Theoretical profile cumulative volume (m3)	Surveyed profile area (m2)	Surveyed profile section volume (m3)	Surveyed profile cumulative volume (m3)
0	-	0.00	0.00	0.00	0.00	0.00	0.00
10	-	0.00	0.00	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00	0.00	0.00
165	-	0.00	0.00	0.00	0.00	0.00	0.00
170	-	0.00	0.00	0.00	0.00	0.00	0.00
175	-	0.00	0.00	0.00	0.00	0.00	0.00
180	-	0.00	0.00	0.00	0.00	0.00	0.00
185	-	0.00	0.00	0.00	0.00	0.00	0.00
190	-	0.00	0.00	0.00	0.00	0.00	0.00
195	-	0.00	0.00	0.00	0.00	0.00	0.00
200	-	0.00	0.00	0.00	0.00	0.00	0.00
205	-	0.00	0.00	0.00	0.00	0.00	0.00
215	-	0.00	0.00	0.00	0.00	0.00	0.00
225	-	0.00	0.00	0.00	0.00	0.00	0.00
235	-	0.00	0.00	0.00	0.00	0.00	0.00
245	-	0.00	0.00	0.00	0.00	0.00	0.00
255	C	12.97	64.85	64.85	0.00	0.00	0.00
265	C	14.50	137.35	202.20	12.74	63.69	63.69
275	C	15.66	150.80	353.00	19.73	162.35	226.03
285	C	17.33	164.95	517.95	25.93	228.33	454.36
290	C	12.41	74.35	592.30	22.32	120.64	574.99
300	C	15.90	141.55	733.85	12.43	173.78	748.77
310	C	15.74	158.20	892.05	4.97	87.02	835.79
320	C	17.05	163.95	1056.00	8.00	64.85	900.64
330	C	18.78	179.15	1235.15	10.07	90.35	990.99
340	B	23.26	210.20	1445.35	16.87	134.70	1125.69
350	B	23.55	234.05	1679.40	16.66	167.67	1293.36
360	B	25.10	243.25	1922.65	20.01	183.39	1476.74
370	B	25.03	250.65	2173.30	19.93	199.70	1676.44
380	B	25.40	252.15	2425.45	18.41	191.69	1868.13
390	B	26.17	257.85	2683.30	15.67	170.42	2038.54
400	B	26.98	265.75	2949.05	20.69	181.80	2220.34
410	B	27.31	271.45	3220.50	23.13	219.08	2439.42
420	B	27.32	273.15	3493.65	21.93	225.27	2664.69
430	B	27.70	275.10	3768.75	20.51	212.20	2876.89
440	B	27.69	276.95	4045.70	19.04	197.76	3074.65
450	B	27.68	276.85	4322.55	19.62	193.29	3267.94
460	B	27.69	276.85	4599.40	25.59	226.04	3493.98
470	B	28.05	278.70	4878.10	25.17	253.81	3747.78
480	B	28.45	282.50	5160.60	24.62	248.94	3996.72
490	B	28.55	285.00	5445.60	20.15	223.82	4220.53
500	B	28.91	287.30	5732.90	19.30	197.26	4417.79
510	B	28.92	289.15	6022.05	26.23	227.67	4645.46
520	B	28.92	289.20	6311.25	29.69	279.63	4925.08
530	B	29.28	291.00	6602.25	23.79	267.43	5192.51
540	B	29.40	293.40	6895.65	17.77	207.82	5400.33
550	B	29.94	296.70	7192.35	21.57	196.74	5597.06
560	B	29.95	299.45	7491.80	19.73	206.52	5803.58
570	B	29.97	299.60	7791.40	18.83	192.79	5996.37
580	B	29.94	299.55	8090.95	18.76	187.95	6184.31
590	B	29.58	297.60	8388.55	19.09	189.25	6373.56
600	B	29.21	293.95	8682.50	21.40	202.46	6576.02
610	B	29.94	295.75	8978.25	23.99	226.95	6802.96
620	B	29.95	299.45	9277.70	19.68	218.33	7021.29
630	B	29.95	299.50	9577.20	28.80	242.40	7263.69
640	B	30.33	301.40	9878.60	24.85	268.23	7531.92
650	B	30.34	303.35	10181.95	20.67	227.57	7759.49
660	B	30.33	303.35	10485.30	24.85	227.60	7987.09
670	B	30.70	305.15	10790.45	28.12	264.85	8251.93
680	B	31.08	308.90	11099.35	32.92	305.19	8557.12
690	B	32.83	319.55	11418.90	28.35	306.35	8863.47
700	A	43.21	380.20	11799.10	53.53	409.40	9272.87
710	A	43.22	432.15	12231.25	37.37	454.50	9727.37
720	A	44.92	440.70	12671.95	49.00	431.85	10159.22
730	A	43.23	440.75	13112.70	56.84	529.22	10688.44
740	A	42.74	429.85	13542.55	44.93	508.87	11197.31
750	A	41.78	422.60	13965.15	51.10	480.15	11677.46
760	A	42.07	419.25	14384.40	44.05	475.75	12153.21
770	A	41.54	418.05	14802.45	45.12	445.85	12599.06
780	A	41.00	412.70	15215.15	54.61	498.67	13097.73
790	A	41.12	410.60	15625.75	52.05	533.32	13631.04
800	A	40.59	408.55	16034.30	51.67	518.60	14149.64
810	A	40.72	406.55	16440.85	55.99	538.30	14687.94
820	A	40.80	407.60	16848.45	50.10	530.44	15218.38
830	A	40.22	405.10	17253.55	43.49	467.95	15686.33
840	A	39.87	400.45	17654.00	49.82	466.57	16152.90
850	A	40.00	399.35	18053.35	49.96	498.91	16651.80
860	A	50.24	451.20	18504.55	43.08	465.20	17117.00
870	A	51.26	507.50	19012.05	51.43	472.55	17589.54
880	A	51.29	512.75	19524.80	49.77	506.00	18095.54
890	A	51.73	515.10	20039.90	53.15	514.58	18610.12
900	A	52.15	519.40	20559.30	45.84	494.91	19105.02
910	A	52.28	522.15	21081.45	46.84	463.36	19568.38
920	A	52.55	524.15	21605.60	45.98	464.09	20032.47
930	A	53.00	527.75	22133.35	43.64	448.10	20480.57
940	A	53.74	533.70	22667.05	54.53	490.84	20971.40
950	A	53.29	535.15	23202.20	58.37	564.50	21535.90
960	A	52.84	530.65	23732.85	50.25	543.12	22079.02
970	A	53.28	530.60	24263.45	50.96	506.04	22585.06
980	A	53.74	535.10	24798.55	60.69	558.25	23143.30
990	A	54.11	539.25	25337.80	46.02	533.58	23676.88
1000	A	54.14	541.25	25879.05	46.07	460.48	24137.35
1010	A	54.20	541.70	26420.75	46.29	461.80	24599.15
1017	A	54.18	379.33	26800.08	42.30	310.07	24909.21
1032	A		778.40	27578.48	61.70	780.02	25689.24
1040	A		778.40	28356.89	79.05	563.00	26252.24
1050	A		778.40	29135.29	79.66	793.55	27045.79
1060	A		778.40	29913.69	89.69	846.75	27892.54
1070	A		778.40	30692.10	82.41	860.49	28753.03
1070 P	A		778.40	31470.50	21.32	0.00	28753.03
A	A		778.40	32248.90	62.92	616.95	29369.98
B	A		778.40	33027.30	53.82	889.36	30259.34
C	A		778.40	33805.71	55.89	837.96	31097.30
1070 S	A		778.40	34584.11	70.49	995.07	32092.37
Head	A		7784.03	34584.11		7183.16	32092.37

Volumes of the south breakwater

layer:

chainage	grade	Secundary armour sea side: Theoretical profile: area (m2)	section volume (m3)	cumulative volume (m3)	Surveyed profile: area (m2)	section volume (m3)	cumulative volume (m3)
0	-	0.00	0.00	0.00		0.00	0.00
10	-	0.00	0.00	0.00		0.00	0.00
20	-	0.00	0.00	0.00		0.00	0.00
30	-	0.00	0.00	0.00		0.00	0.00
40	-	0.00	0.00	0.00		0.00	0.00
50	-	0.00	0.00	0.00		0.00	0.00
60	-	0.00	0.00	0.00		0.00	0.00
65	-	0.00	0.00	0.00		0.00	0.00
70	-	0.00	0.00	0.00		0.00	0.00
80	-	0.00	0.00	0.00		0.00	0.00
90	-	0.00	0.00	0.00		0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00		0.00	0.00
110	-	0.00	0.00	0.00		0.00	0.00
120	-	0.00	0.00	0.00		0.00	0.00
130	-	0.00	0.00	0.00		0.00	0.00
135	-	0.00	0.00	0.00		0.00	0.00
140	-	0.00	0.00	0.00		0.00	0.00
145	E	0.00	0.00	0.00		0.00	0.00
150	E	3.38	8.44	8.44		0.00	0.00
155	E	6.75	25.31	33.75		0.00	0.00
160	E	6.70	33.61	67.36		0.00	0.00
165	E	6.64	33.34	100.70	10.30	25.75	25.75
170	E	6.84	33.69	134.39	4.13	36.06	61.81
175	E	7.03	34.66	169.05	5.91	25.08	86.89
180	E	7.71	36.84	205.89	2.40	20.76	107.65
185	E	8.38	40.21	246.10	6.24	21.58	129.23
190	E	8.11	41.23	287.33	10.58	42.04	171.27
195	E	7.84	39.88	327.20	5.43	40.03	211.31
200	E	8.36	40.50	367.70	3.41	22.10	233.41
205	E	8.88	43.10	410.80	12.77	40.44	273.85
215	E	8.27	85.75	496.55	12.70	127.35	401.20
225	E	7.82	80.45	577.00	10.79	117.49	518.68
235	E	8.78	83.00	660.00	10.78	107.87	626.55
245	E	9.99	93.85	753.85	21.23	160.03	786.58
255	F	5.73	78.60	832.45	23.75	224.88	1011.45
265	F	6.46	60.95	893.40	9.47	166.12	1177.57
275	F	7.20	68.30	961.70	10.92	101.95	1279.52
285	F	7.82	75.10	1036.80	6.97	89.41	1368.93
290	F	5.63	33.63	1070.43	7.32	35.71	1404.64
300	F	7.09	63.60	1134.03	10.34	88.31	1492.94
310	F	7.07	70.80	1204.83	11.85	110.98	1603.92
320	F	7.71	73.90	1278.73	9.94	108.98	1712.90
330	F	8.51	81.10	1359.83	13.47	117.06	1829.96
340	E	9.05	87.80	1447.63	8.04	107.54	1937.50
350	E	9.34	91.95	1539.58	9.02	85.28	2022.78
360	E	9.93	96.35	1635.93	7.82	84.20	2106.98
370	E	10.13	100.30	1736.23	9.54	86.81	2193.78
380	E	10.12	101.25	1837.48	7.84	86.90	2280.68
390	E	10.74	104.30	1941.78	11.73	97.87	2378.55
400	E	10.86	108.00	2049.78	10.78	112.58	2491.13
410	E	11.07	109.65	2159.43	12.47	116.27	2607.40
420	E	11.47	112.70	2272.13	11.63	120.49	2727.89
430	E	11.23	113.50	2385.63	12.25	119.38	2847.27
440	E	11.14	111.85	2497.48	12.57	124.10	2971.37
450	E	12.00	115.70	2613.18	10.25	114.12	3085.49
460	E	11.53	117.65	2730.83	11.86	110.56	3196.05
470	E	11.52	115.25	2846.08	18.84	153.47	3349.52
480	E	11.89	117.05	2963.13	12.26	155.46	3504.98
490	E	11.82	118.55	3081.68	12.90	125.76	3630.74
500	E	12.42	121.20	3202.88	13.55	132.23	3762.97
510	E	12.03	122.25	3325.13	15.28	144.17	3907.14
520	E	12.02	120.25	3445.38	14.59	149.35	4056.49
530	E	12.12	120.70	3566.08	13.53	140.60	4197.09
540	E	12.23	121.75	3687.83	20.76	171.48	4368.56
550	E	12.39	123.10	3810.93	16.07	184.16	4552.72
560	E	12.41	124.00	3934.93	16.70	163.85	4716.56
570	E	12.47	124.40	4059.33	6.23	114.63	4831.19
580	E	12.49	124.80	4184.13	15.44	108.32	4939.50
590	E	12.17	123.30	4307.43	14.66	150.48	5089.98
600	E	12.03	121.00	4428.43	13.78	142.19	5232.17

chainage	grade	Secundary armour sea side: Theoretical profile: area (m2)	section volume (m3)	cumulative volume (m3)	Surveyed profile: area (m2)	section volume (m3)	cumulative volume (m3)
610	E	12.52	122.75	4551.18	10.60	121.91	5354.07
620	E	12.41	124.65	4675.83	12.22	114.08	5468.15
630	E	12.42	124.15	4799.98	12.14	121.78	5589.92
640	E	12.63	125.25	4925.23	13.65	128.95	5718.87
650	E	12.68	126.55	5051.78	7.51	105.81	5824.68
660	E	12.56	126.20	5177.98	6.04	67.74	5892.42
670	E	12.74	126.50	5304.48	22.62	143.29	6035.71
680	E	12.91	128.25	5432.73	24.46	235.40	6271.10
690	E	13.81	133.60	5566.33	18.43	214.43	6485.53
700	E	15.46	146.35	5712.68	7.27	128.50	6614.03
710	E	15.46	154.60	5867.28	13.53	103.98	6718.01
720	E	16.14	158.00	6025.28	17.62	155.76	6873.76
730	E	15.46	158.00	6183.28	14.89	162.58	7036.34
740	E	15.27	153.65	6336.93	20.56	177.28	7213.62
750	E	15.46	153.65	6490.58	14.70	176.30	7389.92
760	E	16.31	158.85	6649.43	10.61	126.52	7516.43
770	E	14.79	155.50	6804.93	17.66	141.33	7657.76
780	E	14.57	146.80	6951.73	13.13	153.95	7811.71
790	E	14.69	146.30	7098.03	16.44	147.85	7959.56
800	E	14.41	145.50	7243.53	13.71	150.73	8110.29
810	E	14.47	144.40	7387.93	13.25	134.78	8245.07
820	E	14.50	144.85	7532.78	14.06	136.56	8381.63
830	E	14.27	143.85	7676.63	17.60	158.28	8539.91
840	E	14.27	142.70	7819.33	12.74	151.68	8691.58
850	E	14.27	142.70	7962.03	12.47	126.05	8817.63
860	E	18.20	162.35	8124.38	13.89	131.82	8949.45
870	E	18.42	183.10	8307.48	12.56	132.26	9081.71
880	E	18.63	185.25	8492.73	15.28	139.21	9220.91
890	E	18.81	187.20	8679.93	7.63	114.54	9335.45
900	E	18.98	188.95	8868.88	11.20	94.14	9429.59
910	E	19.04	190.10	9058.98	12.42	118.09	9547.68
920	E	19.15	190.95	9249.93	13.08	127.46	9675.13
930	E	19.33	192.40	9442.33	12.38	127.28	9802.41
940	E	19.62	194.75	9637.08	12.26	123.21	9925.62
950	E	19.44	195.30	9832.38	14.36	133.09	10058.71
960	E	19.10	192.70	10025.08	19.83	170.94	10229.65
970	E	19.45	192.75	10217.83	14.98	174.04	10403.68
980	E	19.62	195.35	10413.18	19.05	170.12	10573.80
990	E	19.79	197.05	10610.23	14.30	166.72	10740.51
1000	E	19.79	197.90	10808.13	16.26	152.78	10893.29
1010	E	19.81	198.00	11006.13	13.55	149.04	11042.32
1017	E	19.81	138.67	11144.80	17.32	108.03	11150.35
1032	E		299.72	11444.51	56.70	555.13	11705.48
1040	E		299.72	11744.23	49.10	423.20	12128.68
1050	E		299.72	12043.94	43.10	461.00	12589.68
1060	E		299.72	12343.66	31.97	375.35	12965.03
1070	E		299.72	12643.37	43.42	376.95	13341.98
1070 P	E		299.72	12943.09	17.30	0.00	13341.98
A	E		299.72	13242.80	18.74	218.66	13560.64
B	E		299.72	13542.52	18.97	219.91	13780.55
C	E		299.72	13842.23	18.31	213.01	13993.56
1070 S	E		299.72	14141.95	17.96	216.50	14210.05

Head	E		2997.15	14141.95		3059.70	14210.05

layer:

chainage	grade	Upper armour port side: Theoretical profile: area (m2)	section volume (m3)	cumulative volume (m3)	Surveyed profile: area (m2)	section volume (m3)	cumulative volume (m3)
0	-	0.00	0.00	0.00	0.00	0.00	0.00
10	-	0.00	0.00	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00	0.00	0.00
165	-	0.00	0.00	0.00	0.00	0.00	0.00
170	-	0.00	0.00	0.00	0.00	0.00	0.00
175	-	0.00	0.00	0.00	0.00	0.00	0.00
180	-	0.00	0.00	0.00	0.00	0.00	0.00
185	-	0.00	0.00	0.00	0.00	0.00	0.00
190	-	0.00	0.00	0.00	0.00	0.00	0.00
195	-	0.00	0.00	0.00	0.00	0.00	0.00
200	-	0.00	0.00	0.00	0.00	0.00	0.00
205	-	0.00	0.00	0.00	0.00	0.00	0.00
215	-	0.00	0.00	0.00	0.00	0.00	0.00
225	-	0.00	0.00	0.00	0.00	0.00	0.00
235	-	0.00	0.00	0.00	0.00	0.00	0.00
245	-	0.00	0.00	0.00	0.00	0.00	0.00
255	-	0.00	0.00	0.00	0.00	0.00	0.00
265	-	0.00	0.00	0.00	0.00	0.00	0.00
275	-	0.00	0.00	0.00	0.00	0.00	0.00
285	-	0.00	0.00	0.00	0.00	0.00	0.00
290	-	0.00	0.00	0.00	0.00	0.00	0.00
300	-	0.00	0.00	0.00	0.00	0.00	0.00
310	-	0.00	0.00	0.00	0.00	0.00	0.00
320	-	0.00	0.00	0.00	0.00	0.00	0.00
330	-	0.00	0.00	0.00	0.00	0.00	0.00
340	C	0.00	0.00	0.00	0.00	0.00	0.00
350	C	15.32	76.60	76.60	25.70	128.50	128.50
360	C	15.32	153.20	229.80	37.88	317.92	446.42
370	C	15.32	153.20	383.00	28.89	333.88	780.30
380	C	15.32	153.20	536.20	29.97	294.33	1074.62
390	C	15.32	153.20	689.40	28.19	290.81	1365.43
400	C	15.32	153.20	842.60	20.22	242.03	1607.46
410	C	15.32	153.20	995.80	17.45	188.33	1795.78
420	C	15.32	153.20	1149.00	28.21	228.28	2024.06
430	C	15.32	153.20	1302.20	39.93	340.68	2364.74
440	C	15.32	153.20	1455.40	28.87	344.00	2708.74
450	C	15.32	153.20	1608.60	23.23	260.50	2969.24
460	C	15.32	153.20	1761.80	30.60	269.17	3238.41
470	C	15.32	153.20	1915.00	35.56	330.82	3569.23
480	C	15.32	153.20	2068.20	28.37	319.65	3888.88
490	C	15.32	153.20	2221.40	42.64	355.03	4243.91
500	C	15.32	153.20	2374.60	24.87	337.53	4581.43
510	C	15.32	153.20	2527.80	24.72	247.94	4829.37
520	C	15.32	153.20	2681.00	27.65	261.87	5091.24
530	C	15.32	153.20	2834.20	23.03	253.40	5344.64
540	C	15.32	153.20	2987.40	20.30	216.61	5561.25
550	C	15.32	153.20	3140.60	25.18	227.36	5788.61
560	C	15.32	153.20	3293.80	21.88	235.27	6023.87
570	C	15.32	153.20	3447.00	23.74	228.09	6251.96
580	C	15.32	153.20	3600.20	15.29	195.17	6447.13
590	C	15.32	153.20	3753.40	16.59	159.44	6606.57
600	C	15.32	153.20	3906.60	24.78	206.89	6813.45

chainage	grade	Upper armour port side: Theoretical profile: area (m2)	section volume (m3)	cumulative volume (m3)	Surveyed profile: area (m2)	section volume (m3)	cumulative volume (m3)
610	C	15.32	153.20	4059.80	30.48	276.31	7089.76
620	C	15.32	153.20	4213.00	16.55	235.12	7324.88
630	C	15.32	153.20	4366.20	23.24	198.93	7523.81
640	C	15.32	153.20	4519.40	22.39	228.14	7751.95
650	C	15.32	153.20	4672.60	16.97	196.79	7948.74
660	C	15.32	153.20	4825.80	21.98	194.73	8143.47
670	C	15.32	153.20	4979.00	21.65	218.13	8361.60
680	C	15.32	153.20	5132.20	20.94	212.94	8574.54
690	C	15.32	153.20	5285.40	26.05	234.95	8809.49
700	C	15.32	153.20	5438.60	25.11	255.81	9065.30
710	C	15.32	153.20	5591.80	24.82	249.66	9314.96
720	C	15.32	153.20	5745.00	15.87	203.46	9518.42
730	C	15.32	153.20	5898.20	22.44	191.54	9709.96
740	C	15.32	153.20	6051.40	20.71	215.71	9925.67
750	C	15.32	153.20	6204.60	18.84	197.72	10123.38
760	C	15.32	153.20	6357.80	17.77	183.04	10306.42
770	C	15.32	153.20	6511.00	21.92	198.45	10504.87
780	C	15.32	153.20	6664.20	20.98	214.50	10719.37
790	C	16.07	156.95	6821.15	19.09	200.35	10919.72
800	C	16.07	160.70	6981.85	19.69	193.90	11113.62
810	C	16.07	160.70	7142.55	20.87	202.78	11316.40
820	C	16.07	160.70	7303.25	19.29	200.76	11517.16
830	C	16.07	160.70	7463.95	18.64	189.60	11706.76
840	C	16.07	160.70	7624.65	22.88	207.58	11914.33
850	C	16.07	160.70	7785.35	23.42	231.50	12145.83
860	C	16.07	160.70	7946.05	16.08	197.48	12343.31
870	C	16.07	160.70	8106.75	13.87	149.71	12493.02
880	C	16.07	160.70	8267.45	14.68	142.73	12635.75
890	C	16.07	160.70	8428.15	17.40	160.39	12796.13
900	C	16.07	160.70	8588.85	17.10	172.51	12968.64
910	C	16.07	160.70	8749.55	34.01	255.57	13224.21
920	C	16.07	160.70	8910.25	34.06	340.33	13564.54
930	C	16.07	160.70	9070.95	12.32	231.85	13796.39
940	C	16.07	160.70	9231.65	21.73	170.20	13966.59
950	C	16.07	160.70	9392.35	21.22	214.73	14181.31
960	C	16.07	160.70	9553.05	20.15	206.85	14388.16
970	C	16.07	160.70	9713.75	27.16	236.54	14624.70
980	C	16.07	160.70	9874.45	25.62	263.87	14888.57
990	C	16.07	160.70	10035.15	22.74	241.78	15130.35
1000	C	16.07	160.70	10195.85	23.17	229.54	15359.89
1010	C	16.07	160.70	10356.55	21.27	222.18	15582.07
1017	C	16.07	112.49	10469.04	47.92	242.17	15824.25
1032	-			10469.04		0.00	15824.25
1040	-			10469.04		0.00	15824.25
1050	-			10469.04		0.00	15824.25
1060	-			10469.04		0.00	15824.25
1070	-			10469.04		0.00	15824.25
1070 P				10469.04		0.00	15824.25
A	-			10469.04		0.00	15824.25
B	-			10469.04		0.00	15824.25
C	-			10469.04		0.00	15824.25
1070 S				10469.04		0.00	15824.25
Head	-		0	10469.04		0.00	15824.25

Volumes of the south breakwater

layer: Lower armour port side

chainage	grade	Theoretical profile area (m2)	Theoretical profile section volume (m3)	Theoretical profile cumulative volume (m3)	Surveyed profile area (m2)	Surveyed profile section volume (m3)	Surveyed profile cumulative volume (m3)
0	-	0.00	0.00	0.00	0.00	0.00	0.00
10	-	0.00	0.00	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00	0.00	0.00
145	E	0.00	0.00	0.00	0.00	0.00	0.00
150	E	3.10	7.75	7.75	0.00	0.00	0.00
155	E	6.20	23.25	31.00	0.00	0.00	0.00
160	E	6.87	32.68	63.68	0.00	0.00	0.00
165	E	7.54	36.03	99.70	18.94	47.35	47.35
170	E	8.06	38.99	138.69	16.80	89.34	136.69
175	E	8.57	41.56	180.25	13.17	74.90	211.59
180	E	9.00	43.93	224.18	14.67	69.58	281.17
185	E	9.43	46.08	270.25	10.28	62.36	343.52
190	E	7.15	41.45	311.70	8.39	46.66	390.19
195	E	4.87	30.05	341.75	9.69	45.19	435.38
200	E	5.46	25.81	367.56	13.17	57.14	492.52
205	E	6.04	28.74	396.30	15.71	72.19	564.71
215	E	6.45	62.45	458.75	9.21	124.58	689.28
225	E	6.58	65.15	523.90	15.29	122.50	811.78
235	E	6.05	63.15	587.05	12.67	139.81	951.59
245	E	7.27	66.60	653.65	16.31	144.92	1096.50
255	E	8.02	76.45	730.10	20.48	183.95	1280.45
265	E	8.57	82.95	813.05	17.32	189.00	1469.45
275	E	9.30	89.35	902.40	14.37	158.49	1627.93
285	E	10.16	97.30	999.70	14.88	146.25	1774.18
290	E	9.75	49.78	1049.48	23.99	97.16	1871.33
300	E	9.75	97.50	1146.98	19.29	216.39	2087.72
310	E	10.17	99.60	1246.58	15.79	175.40	2263.12
320	E	10.57	103.70	1350.28	10.31	130.48	2393.60
330	E	11.25	109.10	1459.38	13.47	118.88	2512.48
340	E	2.14	66.95	1526.33	8.04	107.54	2620.02
350	E	2.84	24.90	1551.23	4.17	61.03	2681.05
360	E	3.38	31.10	1582.33	5.39	47.81	2728.85
370	E	3.41	33.95	1616.28	6.58	59.88	2788.73
380	E	3.62	35.15	1651.43	5.29	59.39	2848.12
390	E	3.98	38.00	1689.43	6.00	56.48	2904.60
400	E	4.35	41.65	1731.08	10.04	80.23	2984.82
410	E	4.54	44.45	1775.53	4.66	73.52	3058.34
420	E	4.54	45.40	1820.93	8.48	65.70	3124.04
430	E	4.73	46.35	1867.28	6.05	72.65	3196.68
440	E	4.73	47.30	1914.58	4.76	54.05	3250.73
450	E	4.73	47.30	1961.88	4.95	48.55	3299.28
460	E	4.73	47.30	2009.18	5.36	51.56	3350.83
470	E	4.92	48.25	2057.43	4.64	50.01	3400.84
480	E	5.11	50.15	2107.58	4.52	45.78	3446.61
490	E	5.30	52.05	2159.63	3.86	41.87	3488.48
500	E	5.49	53.95	2213.58	10.62	72.40	3560.88
510	E	5.49	54.90	2268.48	9.61	101.18	3662.05
520	E	5.49	54.90	2323.38	16.03	128.20	3790.25
530	E	5.68	55.85	2379.23	14.00	150.13	3940.38
540	E	5.68	56.80	2436.03	16.32	151.62	4092.00
550	E	5.87	57.75	2493.78	6.65	114.89	4206.88
560	E	5.87	58.70	2552.48	10.53	85.93	4292.81
570	E	5.87	58.70	2611.18	9.22	98.79	4391.60
580	E	5.87	58.70	2669.88	14.36	117.94	4509.53
590	E	5.68	57.75	2727.63	7.47	109.15	4618.68
600	E	5.49	55.85	2783.48	12.72	100.95	4719.63
610	E	5.87	56.80	2840.28	7.87	102.96	4822.58
620	E	5.87	58.70	2898.98	15.30	115.84	4938.42
630	E	5.87	58.70	2957.68	18.82	170.61	5109.03
640	E	6.06	59.65	3017.33	5.99	124.03	5233.05
650	E	6.06	60.60	3077.93	10.03	80.07	5313.12
660	E	6.06	60.60	3138.53	5.32	76.73	5389.85
670	E	6.25	61.55	3200.08	7.02	61.71	5451.56
680	E	6.44	63.45	3263.53	11.75	93.89	5545.44
690	E	7.37	69.05	3332.58	9.70	107.26	5652.70
700	E	8.23	78.00	3410.58	13.30	114.99	5767.69
710	E	8.05	81.40	3491.98	17.36	153.28	5920.97
720	E	7.45	77.50	3569.48	15.65	165.03	6085.99
730	E	6.96	72.05	3641.53	18.08	168.64	6254.63
740	E	7.19	70.75	3712.28	13.22	156.49	6411.12
750	E	8.23	77.10	3789.38	15.08	141.48	6552.60
760	E	7.84	80.35	3869.73	11.71	133.93	6686.53
770	E	7.17	75.05	3944.78	7.95	98.30	6784.83
780	E	6.94	70.55	4015.33	9.97	89.62	6874.44
790	E	6.65	67.95	4083.28	8.70	93.37	6967.81
800	E	6.35	65.00	4148.28	10.99	98.45	7066.26
810	E	6.27	63.10	4211.38	14.49	127.38	7193.64
820	E	6.20	62.35	4273.73	9.12	118.01	7311.64
830	E	6.22	62.10	4335.83	7.35	82.32	7393.96
840	E	6.22	62.20	4398.03	8.24	77.96	7471.91
850	E	6.29	62.55	4460.58	7.39	78.18	7550.09
860	E	6.48	63.85	4524.43	8.60	79.94	7630.03
870	E	6.83	66.55	4590.98	7.09	78.41	7708.43
880	E	7.19	70.10	4661.08	9.41	82.46	7790.89
890	E	7.21	72.00	4733.08	5.95	76.79	7867.68
900	E	7.22	72.15	4805.23	9.16	75.57	7943.24
910	E	7.36	72.90	4878.13	6.18	76.70	8019.94
920	E	7.48	74.20	4952.33	7.48	68.27	8088.20
930	E	7.50	74.90	5027.23	8.50	79.88	8168.08
940	E	7.50	75.00	5102.23	17.87	131.87	8299.95
950	E	7.62	75.60	5177.83	19.49	186.82	8486.76
960	E	7.74	76.80	5254.63	17.65	185.70	8672.46
970	E	7.79	77.65	5332.28	8.30	129.77	8802.23
980	E	7.83	78.10	5410.38	17.26	127.80	8930.03
990	E	7.95	78.90	5489.28	15.70	164.76	9094.79
1000	E	7.95	79.50	5568.78	8.38	120.38	9215.17
1010	E	7.95	79.50	5648.28	7.95	81.63	9296.80
1017	E	7.61	54.46	5702.74	6.95	52.12	9348.92
1032			0.00	5702.74		0.00	9348.92
1040			0.00	5702.74		0.00	9348.92
1050			0.00	5702.74		0.00	9348.92
1060			0.00	5702.74		0.00	9348.92
1070			0.00	5702.74		0.00	9348.92
1070 P			0.00	5702.74		0.00	9348.92
A			0.00	5702.74		0.00	9348.92
B			0.00	5702.74		0.00	9348.92
C			0.00	5702.74		0.00	9348.92
1070 S			0.00	5702.74		1.00	9349.92
Head	-		0	5702.74		1.00	9349.92

Volumes of the south breakwater

layer:

		Core topping layer					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume (m3)	cumulative volume (m3)
0	-	0.00	0.00	0.00	0.00	0.00	0.00
10	-	0.00	0.00	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00	0.00	0.00
165	E	7.95	19.88	19.88	7.05	17.63	17.63
170	E	7.95	39.75	59.63	7.27	35.80	53.43
175	E	7.95	39.75	99.38	7.58	37.11	90.54
180	E	7.95	39.75	139.13	8.56	40.34	130.88
185	E	7.95	39.75	178.88	9.86	46.06	176.93
190	E	7.95	39.75	218.63	9.08	47.35	224.28
195	E	7.95	39.75	258.38	8.06	42.83	267.11
200	E	7.95	39.75	298.13	9.14	43.00	310.11
205	E	7.95	39.75	337.88	7.59	41.83	351.94
215	E	7.95	79.50	417.38	8.16	78.76	430.70
225	E	7.95	79.50	496.88	7.74	79.50	510.20
235	E	7.95	79.50	576.38	7.57	76.53	586.73
245	E	7.95	79.50	655.88	9.44	85.03	671.75
255	E	7.95	79.50	735.38	10.27	98.55	770.30
265	E	7.95	79.50	814.88	6.86	85.66	855.96
275	E	7.95	79.50	894.38	5.91	63.85	919.81
285	E	7.95	79.50	973.88	8.28	70.95	990.75
290	E	7.95	39.75	1013.63	7.32	38.99	1029.74
300	E	7.95	79.50	1093.13	8.36	78.39	1108.12
310	E	7.95	79.50	1172.63	8.96	86.61	1194.73
320	E	7.95	79.50	1252.13	7.74	83.50	1278.23
330	E	7.95	79.50	1331.63	6.87	73.07	1351.30
340	E	7.95	79.50	1411.13	8.03	74.52	1425.82
350	E	7.95	79.50	1490.63	9.43	87.28	1513.10
360	E	7.95	79.50	1570.13	8.90	91.60	1604.70
370	E	7.95	79.50	1649.63	9.81	93.51	1698.21
380	E	7.95	79.50	1729.13	7.66	87.33	1785.54
390	E	7.95	79.50	1808.63	8.12	78.90	1864.43
400	E	7.95	79.50	1888.13	7.21	76.66	1941.09
410	E	7.95	79.50	1967.63	9.84	85.26	2026.35
420	E	7.95	79.50	2047.13	9.93	98.85	2125.20
430	E	7.95	79.50	2126.63	6.57	82.50	2207.70
440	E	7.95	79.50	2206.13	8.99	77.80	2285.50
450	E	7.95	79.50	2285.63	8.89	89.40	2374.90
460	E	7.95	79.50	2365.13	9.84	93.65	2468.55
470	E	7.95	79.50	2444.63	10.03	99.37	2567.91
480	E	7.95	79.50	2524.13	9.05	95.41	2663.32
490	E	7.95	79.50	2603.63	7.80	84.25	2747.56
500	E	7.95	79.50	2683.13	9.14	84.70	2832.26
510	E	7.95	79.50	2762.63	8.03	85.85	2918.11
520	E	7.95	79.50	2842.13	6.93	74.79	2992.90
530	E	7.95	79.50	2921.63	8.74	78.35	3071.25
540	E	7.95	79.50	3001.13	8.05	83.96	3155.21
550	E	7.95	79.50	3080.63	7.25	76.50	3231.71
560	E	7.95	79.50	3160.13	7.72	74.87	3306.58
570	E	7.95	79.50	3239.63	6.85	72.89	3379.46
580	E	7.95	79.50	3319.13	7.87	73.64	3453.10
590	E	7.95	79.50	3398.63	8.39	81.34	3534.44
600	E	7.95	79.50	3478.13	7.74	80.69	3615.13

		Core topping layer					
		Theoretical profile			Surveyed profile		
chainage	grade	area (m2)	section volume (m3)	cumulative volume (m3)	area (m2)	section volume (m3)	cumulative volume (m3)
610	E	7.95	79.50	3557.63	7.34	75.42	3690.54
620	E	7.95	79.50	3637.13	6.93	71.36	3761.90
630	E	7.95	79.50	3716.63	6.86	68.96	3830.86
640	E	7.95	79.50	3796.13	7.34	71.00	3901.86
650	E	7.95	79.50	3875.63	8.76	80.50	3982.35
660	E	7.95	79.50	3955.13	7.15	79.57	4061.92
670	E	7.95	79.50	4034.63	7.30	72.24	4134.16
680	E	7.95	79.50	4114.13	6.69	69.94	4204.10
690	E	7.95	79.50	4193.63	8.59	76.40	4280.49
700	E	7.95	79.50	4273.13	6.21	73.97	4354.46
710	E	7.95	79.50	4352.63	7.94	70.71	4425.17
720	E	7.95	79.50	4432.13	7.65	77.90	4503.07
730	E	7.95	79.50	4511.63	8.85	82.47	4585.54
740	E	7.95	79.50	4591.13	7.12	79.85	4665.38
750	E	7.95	79.50	4670.63	10.61	88.66	4754.04
760	E	7.95	79.50	4750.13	9.58	100.96	4855.00
770	E	7.95	79.50	4829.63	6.07	78.25	4933.25
780	E	7.95	79.50	4909.13	6.86	64.65	4997.90
790	E	7.95	79.50	4988.63	8.96	79.10	5077.00
800	E	7.95	79.50	5068.13	7.47	82.15	5159.15
810	E	7.95	79.50	5147.63	9.15	83.10	5242.25
820	E	7.95	79.50	5227.13	8.74	89.45	5331.70
830	E	7.95	79.50	5306.63	6.35	75.45	5407.15
840	E	7.95	79.50	5386.13	7.21	67.79	5474.94
850	E	7.95	79.50	5465.63	7.79	74.99	5549.92
860	E	8.23	80.90	5546.53	9.07	84.32	5634.24
870	E	8.23	82.30	5628.83	8.49	87.83	5722.07
880	E	8.23	82.30	5711.13	9.03	87.61	5809.68
890	E	8.23	82.30	5793.43	7.29	81.59	5891.27
900	E	8.23	82.30	5875.73	8.11	77.01	5968.27
910	E	8.23	82.30	5958.03	8.09	81.00	6049.27
920	E	8.23	82.30	6040.33	8.00	80.43	6129.70
930	E	8.23	82.30	6122.63	7.75	78.75	6208.44
940	E	8.23	82.30	6204.93	7.80	77.74	6286.18
950	E	8.23	82.30	6287.23	8.35	80.73	6366.90
960	E	8.23	82.30	6369.53	9.89	91.20	6458.10
970	E	8.23	82.30	6451.83	9.87	98.81	6556.91
980	E	8.23	82.30	6534.13	9.72	97.97	6654.88
990	E	8.23	82.30	6616.43	8.96	93.43	6748.30
1000	E	8.23	82.30	6698.73	10.06	95.13	6843.43
1010	E	8.23	82.30	6781.03	6.72	83.91	6927.34
1017	E	8.23	57.61	6838.64	6.89	47.63	6974.97
1032	E		67.37	6906.00	8.62	116.30	7091.26
1040	E		67.37	6973.37	8.88	69.99	7161.26
1050	E		67.37	7040.73	10.75	98.13	7259.38
1060	E		67.37	7108.10	13.92	123.31	7382.69
1070	E		67.37	7175.47	14.05	139.83	7522.52
1070 P	E		67.37	7242.83	6.37	0.00	7522.52
A	E		67.37	7310.20	6.51	19.52	7542.04
B	E		67.37	7377.56	6.29	19.40	7561.44
C	E		67.37	7444.93	5.70	18.84	7580.28
1070 S	E		67.37	7512.30	6.04	18.45	7598.72

Head	E		673.66	7512.30		623.75	7598.72

Volumes of the south breakwater

	All layers land based			
	theoretical		surveyed	
chainage	section volume (m3)	cumulative volume (m3)	section volume (m3)	cumulative volume (m3)
0	0.00	0.00	0.00	0.00
10	6.00	6.00	67.62	67.62
20	9.40	15.40	51.36	118.97
30	31.25	46.65	59.28	178.25
40	47.75	94.40	63.77	242.01
50	63.50	157.90	71.48	313.49
60	75.50	233.40	81.77	395.26
65	57.75	291.15	33.44	428.70
70	97.45	388.60	58.62	487.32
80	251.80	640.40	185.16	672.48
90	323.80	964.20	166.53	839.00
95	199.56	1163.76	74.71	913.71
100	220.09	1383.85	77.29	916.29
110	445.85	1829.70	157.17	1073.45
120	445.90	2275.60	155.99	1229.44
130	464.35	2739.95	153.85	1383.29
135	222.13	2962.08	78.79	1462.08
140	241.18	3203.25	98.10	1560.18
145	272.43	3475.68	111.12	1671.30
150	275.74	3751.41	105.67	1776.97
155	284.94	4036.35	108.82	1885.79
160	337.88	4374.23	135.68	2021.47
165	430.45	4804.68	295.96	2317.42
170	474.18	5278.85	416.30	2733.72
175	495.49	5774.34	389.14	3122.86
180	543.45	6317.79	378.90	3501.76
185	592.23	6910.01	337.49	3839.25
190	631.69	7541.70	274.85	4114.10
195	609.80	8151.50	256.31	4370.41
200	544.84	8696.34	292.99	4663.40
205	520.71	9217.05	348.32	5011.72
215	1042.25	10259.30	704.83	5716.55
225	1008.90	11268.20	691.67	6408.22
235	1001.50	12269.70	723.86	7132.08
245	1099.45	13369.15	878.31	8010.38
255	1306.60	14675.75	1094.22	9104.60
265	1494.95	16170.70	1230.25	10334.85
275	1588.90	17759.60	1359.19	11694.04
285	1720.60	19480.20	1521.06	13215.09
290	820.93	20301.13	748.14	13963.24
300	1570.25	21871.38	1416.17	15379.40
310	1708.65	23580.03	1391.25	16770.65
320	1799.30	25379.33	1348.03	18118.68
330	1937.60	27316.93	1472.56	19591.24
340	2094.13	29411.05	1547.15	21138.39
350	2394.18	31805.23	1752.68	22891.07
360	2420.70	34225.93	2033.71	24924.78
370	2227.90	36453.83	2102.86	27027.64
380	2247.10	38700.93	2127.19	29154.83
390	2302.45	41003.38	2076.74	31231.56
400	2383.60	43386.98	2088.93	33320.49
410	2285.00	45671.98	2076.75	35397.24
420	2047.60	47719.58	2069.41	37466.65
430	1953.05	49672.63	2174.75	39641.40
440	1955.40	51628.03	2137.24	41778.63
450	1957.25	53585.28	2039.73	43818.36
460	1957.25	55542.53	2042.75	45861.11
470	1957.65	57500.18	2106.31	47967.42
480	1967.00	59467.18	2081.50	50048.92
490	1972.90	61440.08	2086.20	52135.12
500	1979.75	63419.83	2133.54	54268.66
510	1983.60	65403.43	2150.97	56419.63
520	1981.65	67385.08	2209.09	58628.72
530	1984.85	69369.93	2214.15	60842.87
540	1989.25	71359.18	2149.02	62991.88
550	1994.85	73354.03	2140.65	65132.53
560	1999.45	75353.48	2170.08	67302.61
570	2000.00	77353.48	2146.66	69449.26
580	2000.35	79353.83	2110.20	71559.46
590	1995.95	81349.78	2028.16	73587.62
600	1988.10	83337.88	2040.85	75628.47

	All layers land based			
	theoretical		surveyed	
chainage	section volume (m3)	cumulative volume (m3)	section volume (m3)	cumulative volume (m3)
610	1992.60	85330.48	2149.42	77777.89
620	2000.10	87330.58	2135.64	79913.52
630	1999.65	89330.23	2139.17	82052.69
640	2003.60	91333.83	2159.65	84212.34
650	2007.80	93341.63	2124.88	86337.21
660	2007.45	95349.08	2123.40	88460.61
670	2010.50	97359.58	2128.40	90589.01
680	2017.90	99377.48	2186.88	92775.89
690	2039.50	101416.98	2241.06	95016.95
700	2130.85	103547.83	2353.94	97370.88
710	2203.45	105751.28	2435.92	99806.80
720	2211.50	107962.78	2432.91	102239.71
730	2206.10	110168.88	2490.64	104730.34
740	2189.55	112358.43	2473.62	107203.96
750	2188.65	114547.08	2469.39	109673.34
760	2193.75	116740.83	2389.77	112063.11
770	2183.90	118924.73	2316.61	114379.72
780	2165.35	121090.08	2434.67	116814.39
790	2186.40	123276.48	2339.08	119153.47
800	2115.00	125391.48	2188.43	121341.90
810	2018.95	127410.43	2262.44	123604.34
820	2020.50	129430.93	2238.86	125843.19
830	2017.60	131448.53	2151.52	127994.71
840	2012.75	133461.28	2150.23	130144.93
850	2012.00	135473.28	2138.12	132283.05
860	2151.40	137624.68	2125.25	134408.29
870	2297.85	139922.53	2166.55	136574.84
880	2309.00	142231.53	2251.20	138826.04
890	2316.35	144547.88	2268.65	141094.69
900	2323.70	146871.58	2229.17	143323.85
910	2329.45	149201.03	2299.81	145623.66
920	2334.65	151535.68	2409.14	148032.80
930	2340.55	153876.23	2290.40	150323.20
940	2350.15	156226.38	2276.73	152599.93
950	2353.75	158580.13	2426.30	155026.22
960	2347.70	160927.83	2448.89	157475.11
970	2349.55	163277.38	2433.64	159908.75
980	2358.25	165635.63	2511.50	162420.25
990	2366.05	168001.68	2507.16	164927.40
1000	2370.55	170372.23	2357.95	167285.35
1010	2371.90	172744.13	2281.04	169566.38
1017	1659.91	174404.04	1663.53	171229.91
1032	2167.36	176571.39	3460.03	174689.94
1040	2167.36	178738.75	2142.73	176832.67
1050	2167.36	180906.11	2790.84	179623.51
1060	2167.36	183073.47	2914.20	182537.70
1070	2167.36	185240.83	2998.01	185535.71
1070 P	2167.36	187408.19	0.00	185535.71
A	2167.36	189575.55	1755.96	187291.67
B	2167.36	191742.91	2053.78	189345.45
C	2167.36	193910.27	1999.16	191344.61
1070 S	2167.36	196077.63	2167.98	193512.58
	0	0		0.00
	0	0		0.00

Head	21673.59	196077.63	22282.67	193512.58

Volumes of the south breakwater

	All layers marine based			
	theoretical		surveyed	
chainage	section volume (m3)	cumulative volume (m3)	section volume (m3)	cumulative volume (m3)
0	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00
120	0.00	0.00	0.00	0.00
130	0.00	0.00	0.00	0.00
135	0.00	0.00	0.00	0.00
140	0.00	0.00	0.00	0.00
145	0.00	0.00	0.00	0.00
150	0.00	0.00	0.00	0.00
155	0.00	0.00	0.00	0.00
160	0.00	0.00	0.00	0.00
165	0.00	0.00	0.00	0.00
170	0.00	0.00	0.00	0.00
175	0.00	0.00	0.00	0.00
180	0.00	0.00	0.00	0.00
185	0.00	0.00	0.00	0.00
190	0.00	0.00	0.00	0.00
195	0.00	0.00	0.00	0.00
200	0.00	0.00	0.00	0.00
205	0.00	0.00	0.00	0.00
215	0.00	0.00	0.00	0.00
225	0.00	0.00	0.00	0.00
235	0.00	0.00	0.00	0.00
245	0.00	0.00	0.00	0.00
255	0.00	0.00	0.00	0.00
265	0.00	0.00	0.00	0.00
275	0.00	0.00	0.00	0.00
285	0.00	0.00	0.00	0.00
290	0.00	0.00	0.00	0.00
300	0.00	0.00	0.00	0.00
310	0.00	0.00	0.00	0.00
320	0.00	0.00	0.00	0.00
330	0.00	0.00	0.00	0.00
340	0.00	0.00	0.00	0.00
350	0.00	0.00	0.00	0.00
360	260.00	260.00	265.25	265.25
370	520.00	780.00	505.75	771.00
380	520.00	1300.00	530.40	1301.40
390	520.00	1820.00	638.58	1939.98
400	520.00	2340.00	777.28	2717.26
410	777.05	3117.05	971.25	3688.51
420	1034.65	4151.70	1116.00	4804.51
430	1051.75	5203.45	1137.76	5942.27
440	1074.75	6278.20	1156.81	7099.08
450	1084.20	7362.40	1185.75	8284.83
460	1089.75	8452.15	1189.10	9473.93
470	1107.95	9560.10	1169.53	10643.46
480	1139.80	10699.90	1198.53	11841.99
490	1173.65	11873.55	1219.20	13061.19
500	1206.40	13079.95	1272.70	14333.89
510	1224.45	14304.40	1348.00	15681.89
520	1230.05	15534.45	1334.10	17015.99
530	1244.80	16779.25	1330.18	18346.17
540	1257.05	18036.30	1378.23	19724.40
550	1272.85	19309.15	1386.10	21110.50
560	1292.15	20601.30	1370.95	22481.45
570	1297.85	21899.15	1397.65	23879.10
580	1298.40	23197.55	1379.75	25258.85
590	1286.25	24483.80	1375.55	26634.40
600	1264.10	25747.90	1412.20	28046.60

	All layers marine based			
	theoretical		surveyed	
chainage	section volume (m3)	cumulative volume (m3)	section volume (m3)	cumulative volume (m3)
610	1279.00	27026.90	1472.44	29519.04
620	1307.10	28334.00	1486.94	31005.98
630	1309.80	29643.80	1451.27	32457.25
640	1323.75	30967.55	1533.82	33991.07
650	1338.00	32305.55	1609.14	35600.21
660	1340.30	33645.85	1544.09	37144.30
670	1362.00	35007.85	1561.63	38705.93
680	1396.70	36404.55	1655.83	40361.76
690	1497.10	37901.65	1725.97	42087.73
700	1667.35	39569.00	1819.32	43907.05
710	1739.95	41308.95	1859.17	45766.22
720	1747.45	43056.40	1933.37	47699.59
730	1723.80	44780.20	2027.70	49727.29
740	1660.25	46440.45	1942.60	51669.89
750	1695.15	48135.60	1853.78	53523.67
760	1753.10	49888.70	1847.48	55371.14
770	1669.10	51557.80	1776.63	57147.77
780	1557.10	53114.90	1527.03	58674.80
790	1597.45	54712.35	1462.14	60136.94
800	1637.20	56349.55	1751.14	61888.08
810	1607.25	57956.80	1853.82	63741.90
820	1600.60	59557.40	1779.13	65521.03
830	1604.25	61161.65	1676.83	67197.86
840	1657.25	62818.90	1596.62	68794.48
850	1733.05	64551.95	1622.05	70416.53
860	1845.50	66397.45	1722.90	72139.43
870	1889.75	68287.20	1824.55	73963.98
880	1869.00	70156.20	1826.65	75790.63
890	1905.35	72061.55	1781.90	77572.53
900	1942.70	74004.25	1941.45	79513.98
910	1969.40	75973.65	2037.35	81551.33
920	1986.10	77959.75	1942.20	83493.53
930	2004.30	79964.05	1935.20	85428.73
940	2025.05	81989.10	1976.70	87405.43
950	2033.85	84022.95	2031.60	89437.03
960	2028.85	86051.80	2012.50	91449.53
970	2045.20	88097.00	2061.95	93511.48
980	2083.85	90180.85	2132.75	95644.23
990	2123.45	92304.30	2189.80	97834.03
1000	2145.80	94450.10	2268.35	100102.38
1010	2134.35	96584.45	2178.50	102280.88
1017	1006.88	97591.33	1473.96	103754.84
1032	2435.58	100026.91	3385.43	107140.26
1040	2435.58	102462.49	1870.40	109010.66
1050	2435.58	104898.07	2391.88	111402.54
1060	2435.58	107333.65	2675.53	114078.07
1070	2435.58	109769.23	2887.80	116965.87
1070 P	2435.58	112204.80	2904.50	119870.37
A	2435.58	114640.38	3028.13	122898.50
B	2435.58	117075.96	2820.13	125718.63
C	2435.58	119511.54	1779.25	127497.88
1070 S	2435.58	121947.12	828.85	128326.73

Head	24355.79	121947.12	24571.895	128326.73

Volumes of the south breakwater

	All layers land + Marine based			
	theoretical		surveyed	
chainage	section volume (m3)	cumulative volume (m3)	section volume (m3)	cumulative volume (m3)
0	0.00	0.00	0.00	0.00
10	6.00	6.00	67.62	67.62
20	9.40	15.40	51.36	118.97
30	31.25	46.65	59.28	178.25
40	47.75	94.40	63.77	242.01
50	63.50	157.90	71.48	313.49
60	75.50	233.40	81.77	395.26
65	57.75	291.15	33.44	428.70
70	97.45	388.60	58.62	487.32
80	251.80	640.40	185.16	672.48
90	323.80	964.20	166.53	839.00
95	199.56	1163.76	74.71	913.71
100	220.09	1383.85	77.29	916.29
110	445.85	1829.70	157.17	1073.45
120	445.90	2275.60	155.99	1229.44
130	464.35	2739.95	153.85	1383.29
135	222.13	2962.08	78.79	1462.08
140	241.18	3203.25	98.10	1560.18
145	272.43	3475.68	111.12	1671.30
150	275.74	3751.41	105.67	1776.97
155	284.94	4036.35	108.82	1885.79
160	337.88	4374.23	135.68	2021.47
165	430.45	4804.68	295.96	2317.42
170	474.18	5278.85	416.30	2733.72
175	495.49	5774.34	389.14	3122.86
180	543.45	6317.79	378.90	3501.76
185	592.23	6910.01	337.49	3839.25
190	631.69	7541.70	274.85	4114.10
195	609.80	8151.50	256.31	4370.41
200	544.84	8696.34	292.99	4663.40
205	520.71	9217.05	348.32	5011.72
215	1042.25	10259.30	704.83	5716.55
225	1008.90	11268.20	691.67	6408.22
235	1001.50	12269.70	723.86	7132.08
245	1099.45	13369.15	878.31	8010.38
255	1306.60	14675.75	1094.22	9104.60
265	1494.95	16170.70	1230.25	10334.85
275	1588.90	17759.60	1359.19	11694.04
285	1720.60	19480.20	1521.06	13215.09
290	820.93	20301.13	748.14	13963.24
300	1570.25	21871.38	1416.17	15379.40
310	1708.65	23580.03	1391.25	16770.65
320	1799.30	25379.33	1348.03	18118.68
330	1937.60	27316.93	1472.56	19591.24
340	2094.13	29411.05	1547.15	21138.39
350	2394.18	31805.23	1752.68	22891.07
360	2680.70	34485.93	2298.96	25190.03
370	2747.90	37233.83	2608.61	27798.64
380	2767.10	40000.93	2657.59	30456.23
390	2822.45	42823.38	2715.32	33171.54
400	2903.60	45726.98	2866.21	36037.75
410	3062.05	48789.03	3048.00	39085.75
420	3082.25	51871.28	3185.41	42271.16
430	3004.80	54876.08	3312.51	45583.67
440	3030.15	57906.23	3294.05	48877.71
450	3041.45	60947.68	3225.48	52103.19
460	3047.00	63994.68	3231.85	55335.04
470	3065.60	67060.28	3275.84	58610.88
480	3106.80	70167.08	3280.03	61890.91
490	3146.55	73313.63	3305.40	65196.31
500	3186.15	76499.78	3406.24	68602.55
510	3208.05	79707.83	3498.97	72101.52
520	3211.70	82919.53	3543.19	75644.71
530	3229.65	86149.18	3544.33	79189.04
540	3246.30	89395.48	3527.25	82716.28
550	3267.70	92663.18	3526.75	86243.03
560	3291.60	95954.78	3541.03	89784.06
570	3297.85	99252.63	3544.31	93328.36
580	3298.75	102551.38	3489.95	96818.31
590	3282.20	105833.58	3403.71	100222.02
600	3252.20	109085.78	3453.05	103675.07

	All layers land + Marine based			
	theoretical		surveyed	
chainage	section volume (m3)	cumulative volume (m3)	section volume (m3)	cumulative volume (m3)
610	3271.60	112357.38	3621.86	107296.93
620	3307.20	115664.58	3622.58	110919.50
630	3309.45	118974.03	3590.44	114509.94
640	3327.35	122301.38	3693.47	118203.41
650	3345.80	125647.18	3734.02	121937.42
660	3347.75	128994.93	3667.49	125604.91
670	3372.50	132367.43	3690.03	129294.94
680	3414.60	135782.03	3842.71	133137.65
690	3536.60	139318.63	3967.03	137104.68
700	3798.20	143116.83	4173.26	141277.93
710	3943.40	147060.23	4295.09	145573.02
720	3958.95	151019.18	4366.28	149939.30
730	3929.90	154949.08	4518.34	154457.63
740	3849.80	158798.88	4416.22	158873.85
750	3883.80	162682.68	4323.16	163197.01
760	3946.85	166629.53	4237.24	167434.25
770	3853.00	170482.53	4093.24	171527.49
780	3722.45	174204.98	3961.70	175489.19
790	3783.85	177988.83	3801.22	179290.41
800	3752.20	181741.03	3939.57	183229.98
810	3626.20	185367.23	4116.26	187346.24
820	3621.10	188988.33	4017.99	191364.22
830	3621.85	192610.18	3828.35	195192.57
840	3670.00	196280.18	3746.85	198939.41
850	3745.05	200025.23	3760.17	202699.58
860	3996.90	204022.13	3848.15	206547.72
870	4187.60	208209.73	3991.10	210538.82
880	4178.00	212387.73	4077.85	214616.67
890	4221.70	216609.43	4050.55	218667.22
900	4266.40	220875.83	4170.62	222837.83
910	4298.85	225174.68	4337.16	227174.99
920	4320.75	229495.43	4351.34	231526.33
930	4344.85	233840.28	4225.60	235751.93
940	4375.20	238215.48	4253.43	240005.36
950	4387.60	242603.08	4457.90	244463.25
960	4376.55	246979.63	4461.39	248924.64
970	4394.75	251374.38	4495.59	253420.23
980	4442.10	255816.48	4644.25	258064.48
990	4489.50	260305.98	4696.96	262761.43
1000	4516.35	264822.33	4626.30	267387.73
1010	4506.25	269328.58	4459.54	271847.26
1017	2666.79	271995.37	3137.48	274984.75
1032	4602.94	276598.30	6845.45	281830.20
1040	4602.94	281201.24	4013.13	285843.33
1050	4602.94	285804.18	5182.72	291026.05
1060	4602.94	290407.12	5589.73	296615.77
1070	4602.94	295010.06	5885.81	302501.58
1070 P	4602.94	299612.99	2904.50	305406.08
A	4602.94	304215.93	4784.09	310190.17
B	4602.94	308818.87	4873.91	315064.08
C	4602.94	313421.81	3778.41	318842.49
1070 S	4602.94	318024.75	2996.83	321839.31
	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0
Head	46029.38	318024.75	46854.57	321839.31

X.II : Rock quantities

This appendix comprises:

- Short description of calculated values (theoretical and actual quantities).
- Textual summary of the calculation results.
- Graphs and source data of the calculated rock quantities, shown per weekly constructed breakwater section.

Theoretical rock quantities:

Theoretical rock quantities are calculated by multiplying the theoretical breakwater volumes with the theoretical bulk density ratio of 1.77 t/m3 (including wastage).

Actual used rock quantities:

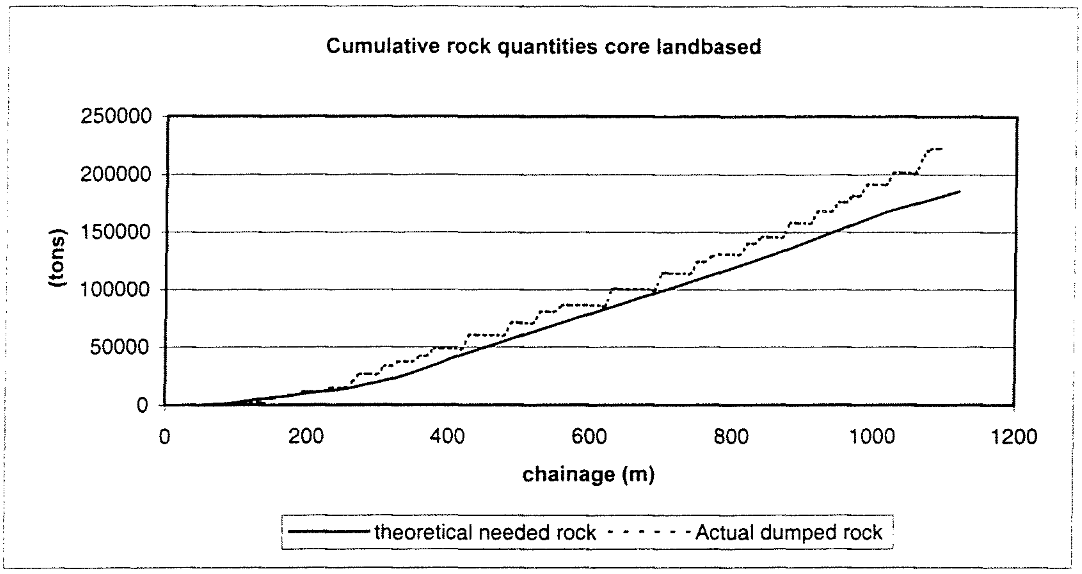
Combination of the weighbridge records and the weekly reports gives the amount of rock in each layer per weekly constructed section.

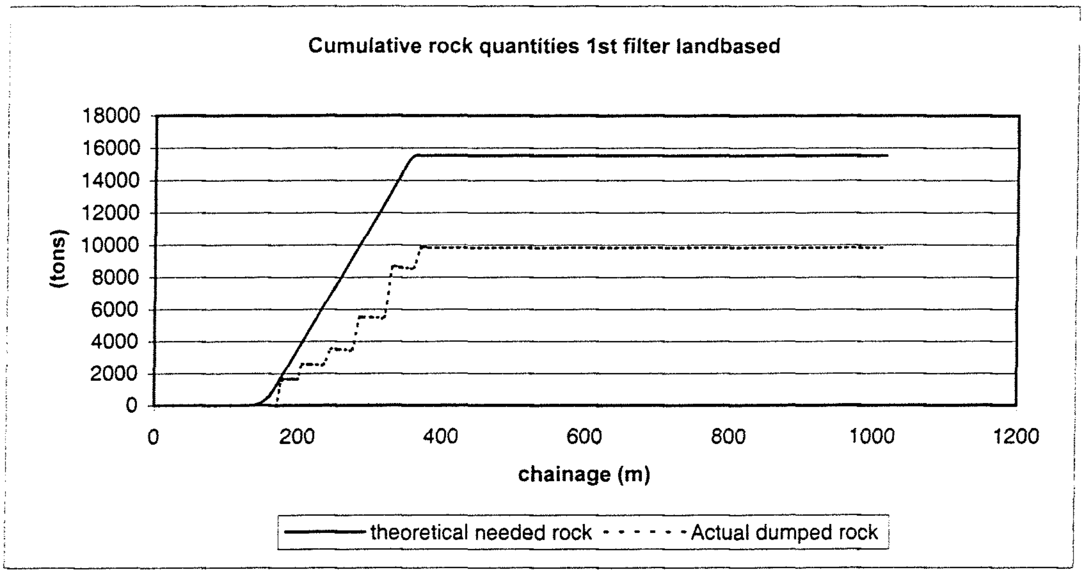
Analyses of the calculated rock quantities:

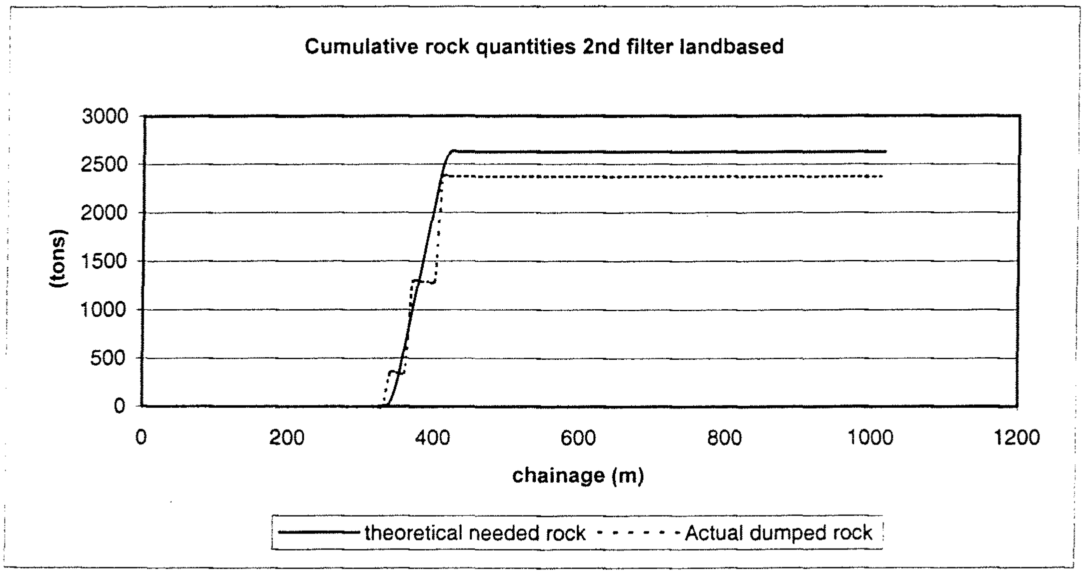
- For the core (land based) the dumped rock quantities are 20 % higher than the theoretical values. At chainage 275 there has been dumped more rock than theoretical needed. This is also done gradually from chainage 800 up to the head.
- Only 64 % of the theoretical quantity of rock for the first filter layers (land based) has been dumped into the breakwater. For the second filter layers this is 90 %.
- The dumped rock quantities of the toe (land based) are 6 % lower than theoretically needed. Up to chainage 400 the quantities are according to the theoretical values.
- The primary armour (seaside) and secondary armour (seaside) show a gradually growing shortage along the centre-line of the breakwater. The total amount of rock actual dumped in the breakwater is only 65 % of the theoretical quantity for the primary armour layer and 71% for the secondary armour layer.
- Actual used rock quantities for the lower armour layer (port side) are lower than the theoretical values between chainage 170 and 300. For the remaining part the quantities are according to the theoretical values.
- Actual used rock quantities for the upper armour (port side) 12 % lower than the theoretical values and gradually growing along the breakwater.
- The quantity of rock used in the core-topping layer is 50% higher than the theoretical value. This is mainly due to the use of filter material and quarry run to fill the gaps in the layer to make the layer suitable for equipment to drive on. A few times the smaller rocks have been washed out during bad weather and had to be replaced.
- The marine based dumped rock quantities show slightly higher (3%) values along the entire breakwater than the theoretical rock quantities.

The rock quantities of all the layers together are according the theoretical values except for the relative lower values between chainages 400 and 600 and the higher values just before the breakwater head.

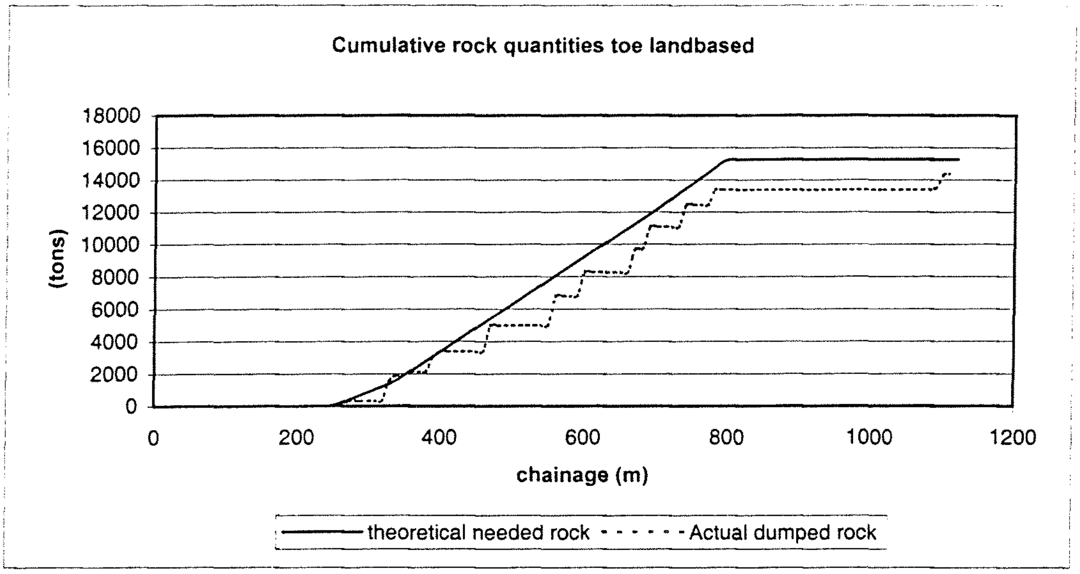
Rock quantites of the south breakwater

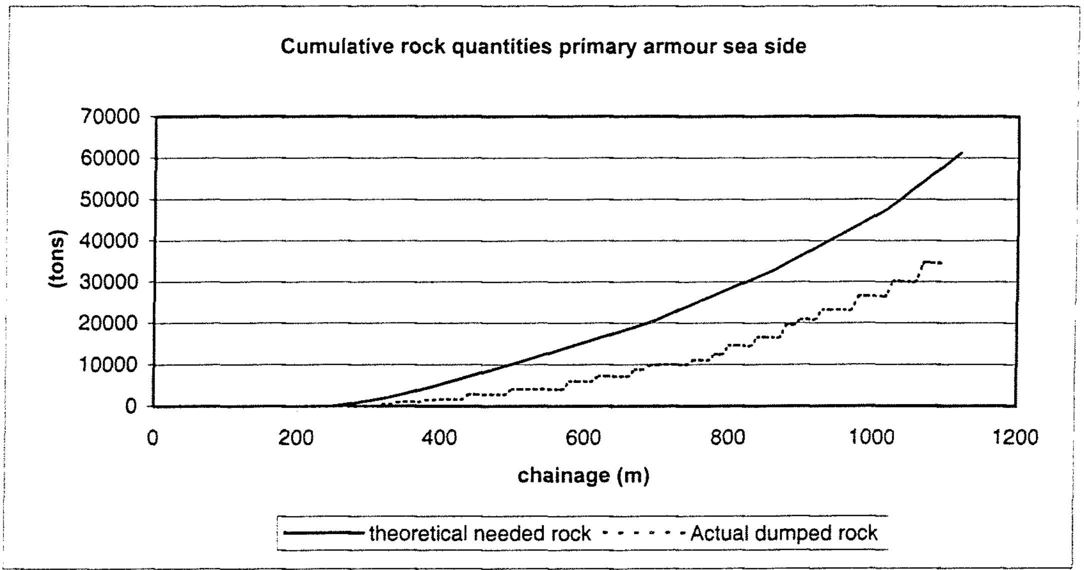


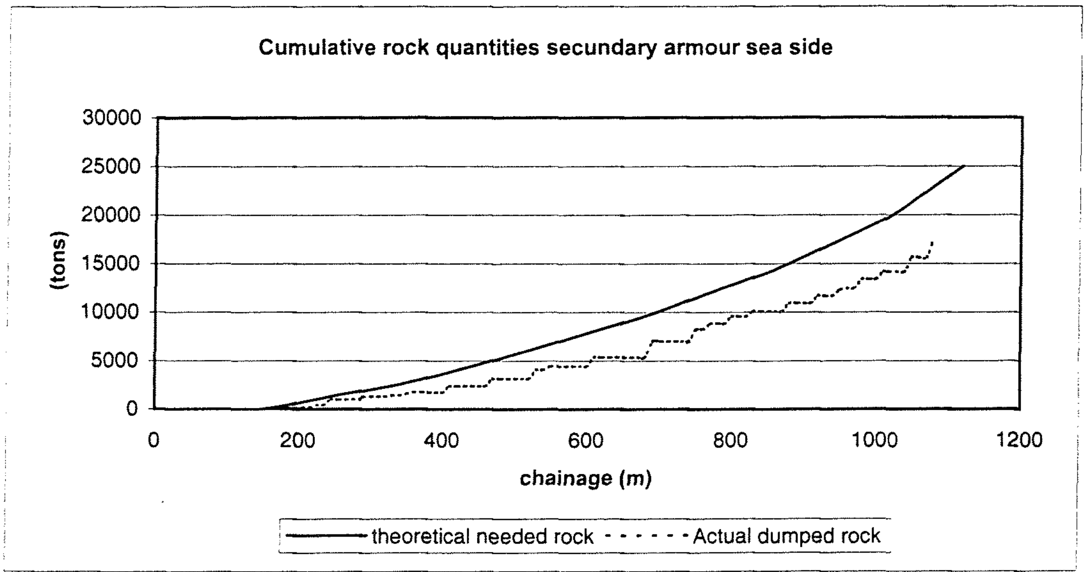




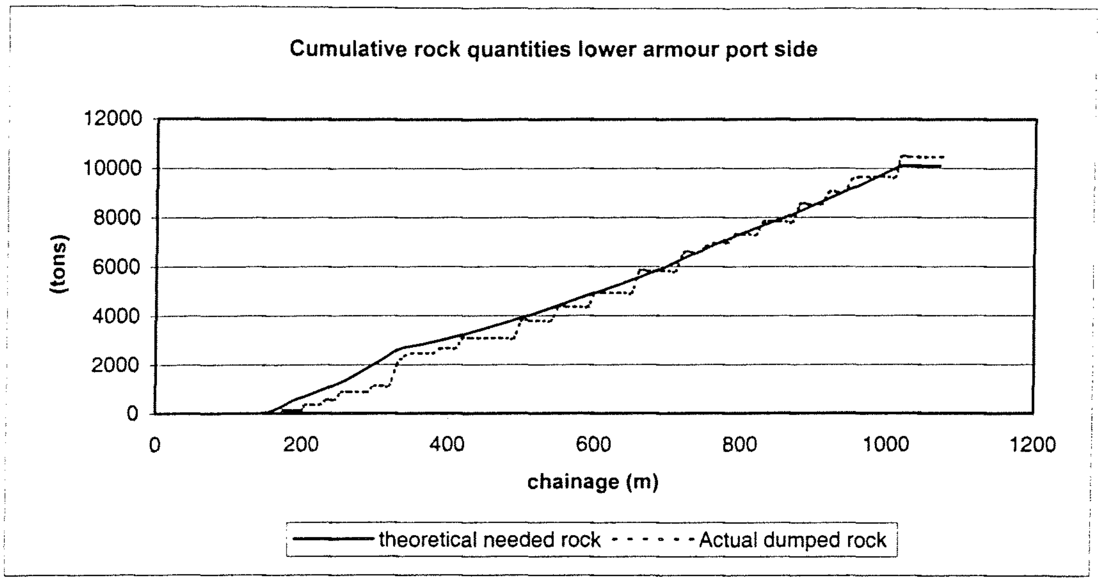
Rock quantites of the south breakwater

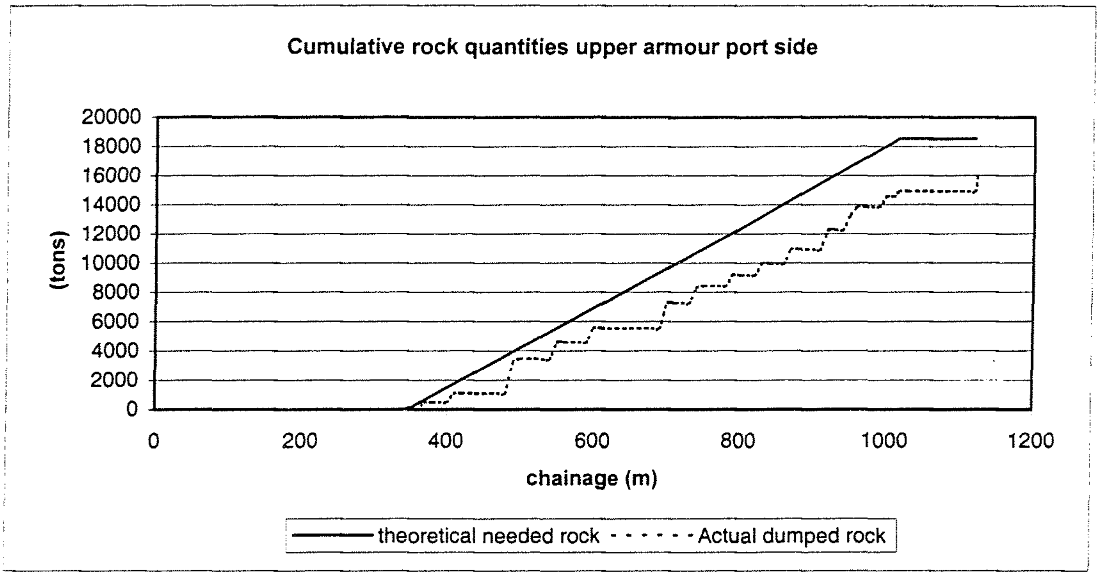


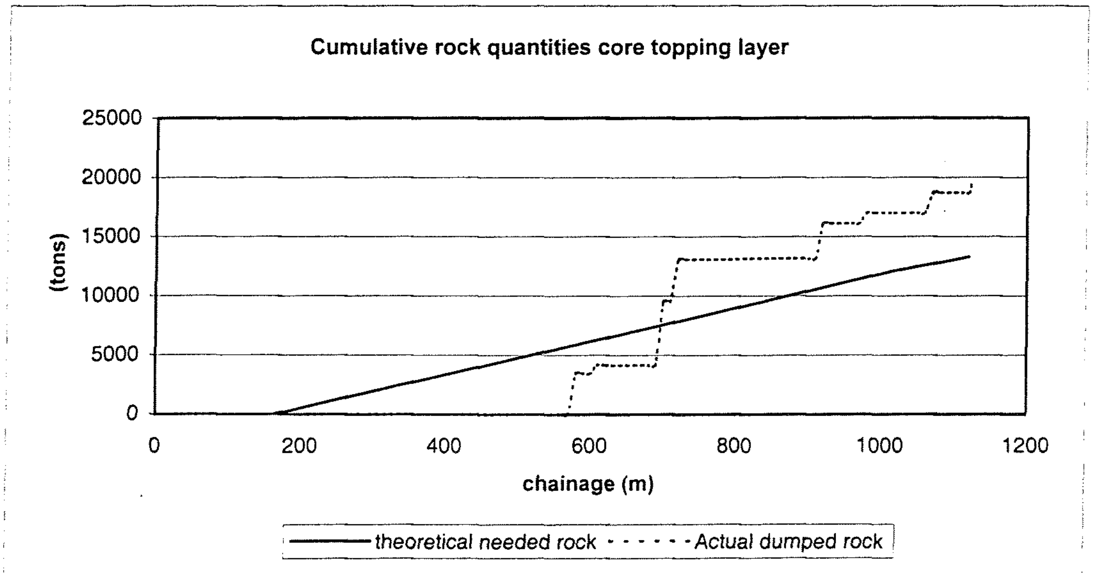




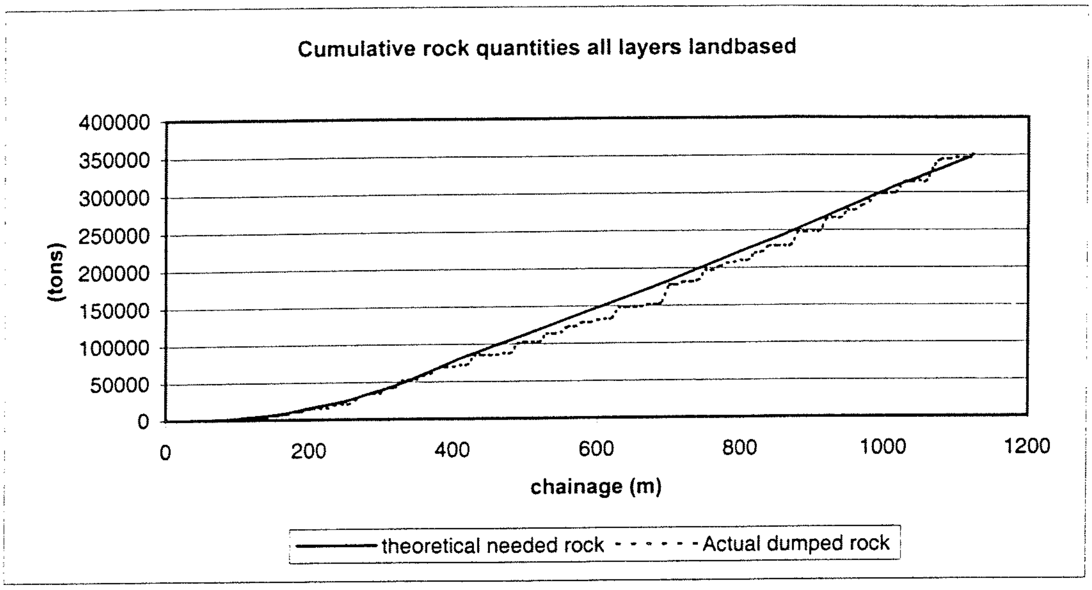
Rock quantites of the south breakwater

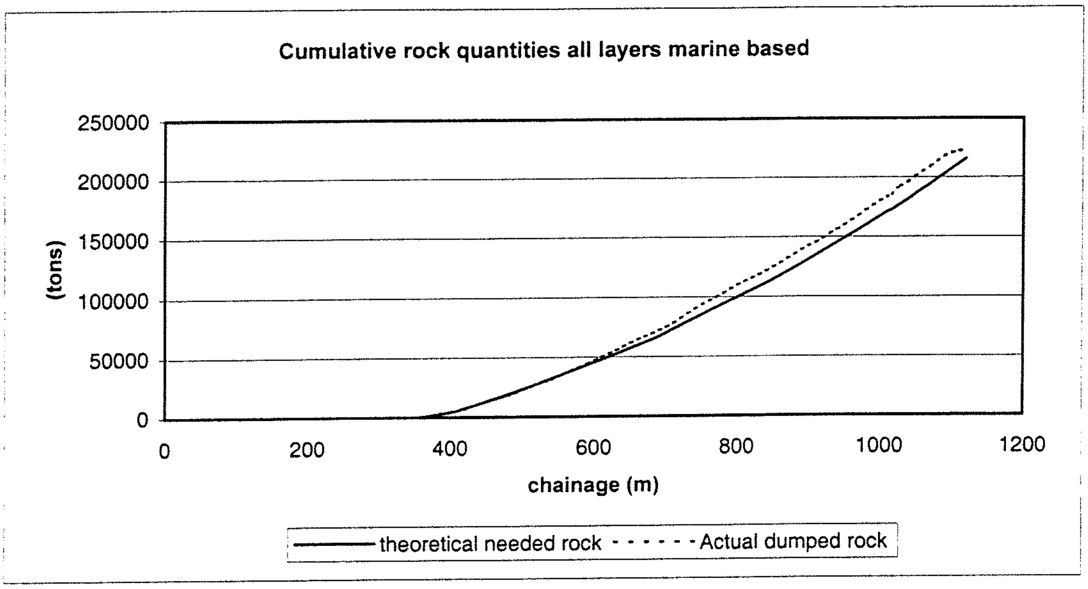


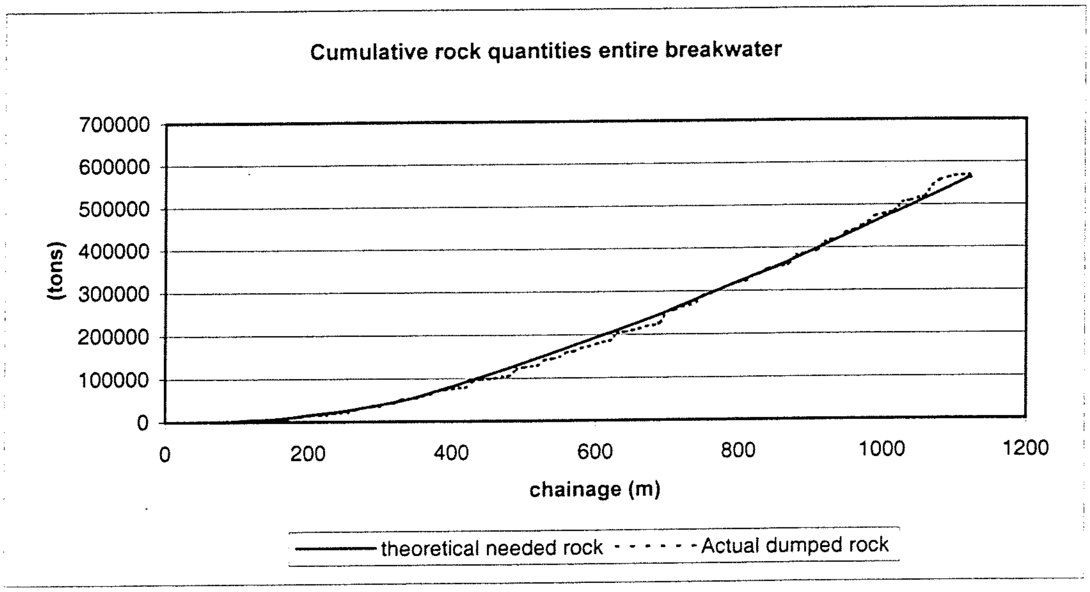




Rock quantites of the south breakwater







Rock quantities of the south breakwater

layer: Core (landbased)

chainage	grade	Theoretical profile: section amount (tonnes)	Theoretical profile: cumulative amount (tonnes)	Acual dumped: section amount (tonnes)	Acual dumped: cumulative amount (tonnes)
0	H	0	0		0.00
10	H	10.62	10.62		0.00
20	H	16.64	27.26		0.00
30	H	55.31	82.57		0.00
40	H	84.52	167.09		0.00
50	H	112.40	279.48		0.00
60	H	133.64	413.12		0.00
65	H	102.22	515.34	760.900	760.90
70	H	172.49	687.82	*601.620*	1362.52
80	H	445.69	1133.51		1362.52
90	H	573.13	1706.63		1362.52
95	H	353.23	2059.86	945.900	2308.42
100	H	389.55	2449.41		2308.42
110	H	789.15	3238.57		2308.42
120	H	789.24	4027.81		2308.42
130	H	821.90	4849.71		2308.42
135	H	393.16	5242.87		2308.42
140	H	404.75	5647.63		2308.42
145	H	415.82	6063.44	3207.100	5515.52
150	H	348.78	6412.22		5515.52
155	H	263.51	6675.73		5515.52
160	H	253.38	6929.11	1341.400	6856.92
165	H	275.94	7205.05		6856.92
170	H	261.96	7467.01		6856.92
175	H	293.40	7760.41	1937.280	8794.20
180	H	370.26	8130.67		8794.20
185	H	446.81	8577.49		8794.20
190	H	523.06	9100.54		8794.20
195	H	506.88	9607.43	2896.840	11691.04
200	H	398.29	10005.72		11691.04
205	H	345.81	10351.54		11691.04
215	H	685.08	11036.61		11691.04
225	H	630.65	11667.26		11691.04
235	H	616.58	12283.84	3336.240	15027.28
245	H	764.64	13048.48		15027.28
255	H	940.58	13989.06		15027.28
265	H	1079.88	15068.94	*5415.840*	20443.12
275	H	1198.02	16266.96	6022.480	26465.60
285	H	1379.98	17646.94		26465.60
290	H	639.63	18286.58		26465.60
300	H	1175.28	19461.86		26465.60
310	H	1374.32	20836.17	7055.340	33520.94
320	H	1511.85	22348.02		33520.94
330	H	1707.43	24055.45	3925.980	37446.92
340	H	1846.20	25901.65		37446.92
350	H	1942.13	27843.78		37446.92
360	H	2100.28	29944.06	4743.220	42190.14
370	H	2194.09	32138.16		42190.14
380	H	2221.62	34359.77	6517.380	48707.52
390	H	2299.05	36658.82		48707.52
400	H	2415.70	39074.52		48707.52
410	H	2223.21	41297.73		48707.52
420	H	1974.35	43272.08		48707.52
430	H	1981.87	45253.94	11563.820	60271.34
440	H	1983.99	47237.94		60271.34
450	H	1980.63	49218.57		60271.34
460	H	1977.18	51195.75		60271.34
470	H	1977.18	53172.92		60271.34
480	H	1980.45	55153.38		60271.34
490	H	1980.45	57133.83	10644.800	70916.14
500	H	1980.45	59114.28		70916.14
510	H	1980.45	61094.74		70916.14
520	H	1980.45	63075.19		70916.14
530	H	1980.45	65055.64	9710.920	80627.06
540	H	1980.45	67036.10		80627.06
550	H	1980.45	69016.55		80627.06
560	H	1980.45	70997.00	5597.460	86224.52
570	H	1980.45	72977.45		86224.52
580	H	1980.45	74957.91		86224.52
590	H	1980.45	76938.36		86224.52
600	H	1980.45	78918.81		86224.52
610	H	1980.45	80899.27		86224.52
620	H	1980.45	82879.72		86224.52
630	H	1980.45	84860.17	13871.940	100096.46
640	H	1980.45	86840.63		100096.46
650	H	1980.45	88821.08		100096.46
660	H	1980.45	90801.53		100096.46
670	H	1980.45	92781.98		100096.46
680	H	1980.45	94762.44		100096.46
690	H	1980.45	96742.89		100096.46
700	H	1980.45	98723.34	14043.310	114139.77
710	H	1980.45	100703.80		114139.77
720	H	1980.45	102684.25		114139.77
730	H	1980.45	104664.70		114139.77
740	H	1980.45	106645.16		114139.77
750	H	1980.45	108625.61	10010.600	124150.37
760	H	1980.45	110606.06		124150.37
770	H	1980.45	112586.51	4514.340	128664.71
780	H	1980.45	114566.97	1964.680	130629.39
790	H	2020.28	116587.25		130629.39
800	H	2060.10	118647.35		130629.39
810	H	2061.52	120708.87		130629.39
820	H	2062.94	122771.80	9260.320	139889.71
830	H	2064.44	124836.24		139889.71
840	H	2065.94	126902.19	5801.540	145691.25
850	H	2065.94	128968.13		145691.25
860	H	2181.35	131149.48		145691.25
870	H	2296.93	133446.41		145691.25
880	H	2297.28	135743.69	12172.200	157863.45
890	H	2299.32	138043.01		157863.45
900	H	2301.35	140344.36		157863.45
910	H	2303.30	142647.66		157863.45
920	H	2305.16	144952.82	10115.640	167979.09
930	H	2305.43	147258.25		167979.09
940	H	2307.55	149565.80		167979.09
950	H	2309.32	151875.12	7789.940	175769.03
960	H	2309.05	154184.17		175769.03
970	H	2310.82	156494.99	5825.020	181594.05
980	H	2312.86	158807.85		181594.05
990	H	2314.89	161122.75	9642.260	191236.31
1000	H	2316.75	163439.50		191236.31
1010	H	2318.17	165757.67		191236.31
1017	H	1623.71	167381.38		191236.31
1028	H	1808.72	169190.10	10205.080	201441.39
1039	H	1808.72	170998.82		201441.39
1049	H	1808.72	172807.53		201441.39
1059	H	1808.72	174616.25		201441.39
1070	H	1808.72	176424.97	14770.170	216211.56
1080	H	1808.72	178233.69	5698.180	221909.74
1090	H	1808.72	180042.41	468.080	222377.82
1100	H	1808.72	181851.13	1103.600	223481.42
1110	H	1808.72	183659.85		223481.42
1120	H	1808.72	185468.57		223481.42
1123					223481.42
1123					223481.42

1060	H	18087.19	185468.57	32245.110	223481.42

layer:

chainage	grade	First filter layers (landbased) — Theoretical profile: section amount (tonnes)	First filter layers (landbased) — Theoretical profile: cumulative amount (tonnes)	First filter layers (landbased) — Acual dumped: section amount (tonnes)	First filter layers (landbased) — Acual dumped: cumulative amount (tonnes)
0	-	0.00	0.00		0.00
10	-	0.00	0.00		0.00
20	-	0.00	0.00		0.00
30	-	0.00	0.00		0.00
40	-	0.00	0.00		0.00
50	-	0.00	0.00		0.00
60	-	0.00	0.00		0.00
65	-	0.00	0.00		0.00
70	-	0.00	0.00		0.00
80	-	0.00	0.00		0.00
90	-	0.00	0.00		0.00
95	-	0.00	0.00		0.00
100	-	0.00	0.00		0.00
110	-	0.00	0.00		0.00
120	-	0.00	0.00		0.00
130	-	0.00	0.00		0.00
135	-	0.00	0.00	0.00	0.00
140	-	22.13	22.13		0.00
145	-	66.38	88.50		0.00
150	G	110.63	199.13		0.00
155	G	154.88	354.00		0.00
160	G	227.33	581.33		0.00
165	G	328.00	909.34		0.00
170	G	378.34	1287.68		0.00
175	G	378.34	1666.01	1266.18	1266.18
180	G	378.34	2044.35	375.66	1641.84
185	G	378.34	2422.69		1641.84
190	G	378.34	2801.03		1641.84
195	G	378.34	3179.36		1641.84
200	G	378.34	3557.70		1641.84
205	G	378.34	3936.04	905.94	2547.78
215	G	756.68	4692.71		2547.78
225	G	756.68	5449.39		2547.78
235	G	756.68	6206.06		2547.78
245	G	756.68	6962.74	956.14	3503.92
255	G	756.68	7719.41		3503.92
265	G	756.68	8476.09		3503.92
275	G	756.68	9232.76		3503.92
285	G	756.68	9989.44	2006.78	5510.70
290	G	378.34	10367.78		5510.70
300	G	756.68	11124.45		5510.70
310	G	756.68	11881.13		5510.70
320	G	756.68	12637.80		5510.70
330	G	756.68	13394.48	3090.02	8600.72
340	G	797.61	14192.08		8600.72
350	G	879.47	15071.55		8600.72
360	-	460.20	15531.75		8600.72
370	-	0.00	15531.75	1220.24	9820.96
380	-	0.00	15531.75		9820.96
390	-	0.00	15531.75		9820.96
400	-	0.00	15531.75		9820.96
410	-	0.00	15531.75		9820.96
420	-	0.00	15531.75		9820.96
430	-	0.00	15531.75		9820.96
440	-	0.00	15531.75		9820.96
450	-	0.00	15531.75		9820.96
460	-	0.00	15531.75		9820.96
470	-	0.00	15531.75		9820.96
480	-	0.00	15531.75		9820.96
490	-	0.00	15531.75		9820.96
500	-	0.00	15531.75		9820.96
510	-	0.00	15531.75		9820.96
520	-	0.00	15531.75		9820.96
530	-	0.00	15531.75		9820.96
540	-	0.00	15531.75		9820.96
550	-	0.00	15531.75		9820.96
560	-	0.00	15531.75		9820.96
570	-	0.00	15531.75		9820.96
580	-	0.00	15531.75		9820.96
590	-	0.00	15531.75		9820.96
600	-	0.00	15531.75		9820.96

chainage	grade	First filter layers (landbased) — Theoretical profile: section amount (tonnes)	First filter layers (landbased) — Theoretical profile: cumulative amount (tonnes)	First filter layers (landbased) — Acual dumped: section amount (tonnes)	First filter layers (landbased) — Acual dumped: cumulative amount (tonnes)
610	-	0.00	15531.75		9820.96
620	-	0.00	15531.75		9820.96
630	-	0.00	15531.75		9820.96
640	-	0.00	15531.75		9820.96
650	-	0.00	15531.75		9820.96
660	-	0.00	15531.75		9820.96
670	-	0.00	15531.75		9820.96
680	-	0.00	15531.75		9820.96
690	-	0.00	15531.75		9820.96
700	-	0.00	15531.75		9820.96
710	-	0.00	15531.75		9820.96
720	-	0.00	15531.75		9820.96
730	-	0.00	15531.75		9820.96
740	-	0.00	15531.75		9820.96
750	-	0.00	15531.75		9820.96
760	-	0.00	15531.75		9820.96
770	-	0.00	15531.75		9820.96
780	-	0.00	15531.75		9820.96
790	-	0.00	15531.75		9820.96
800	-	0.00	15531.75		9820.96
810	-	0.00	15531.75		9820.96
820	-	0.00	15531.75		9820.96
830	-	0.00	15531.75		9820.96
840	-	0.00	15531.75		9820.96
850	-	0.00	15531.75		9820.96
860	-	0.00	15531.75		9820.96
870	-	0.00	15531.75		9820.96
880	-	0.00	15531.75		9820.96
890	-	0.00	15531.75		9820.96
900	-	0.00	15531.75		9820.96
910	-	0.00	15531.75		9820.96
920	-	0.00	15531.75		9820.96
930	-	0.00	15531.75		9820.96
940	-	0.00	15531.75		9820.96
950	-	0.00	15531.75		9820.96
960	-	0.00	15531.75		9820.96
970	-	0.00	15531.75		9820.96
980	-	0.00	15531.75		9820.96
990	-	0.00	15531.75		9820.96
1000	-	0.00	15531.75		9820.96
1010	-	0.00	15531.75		9820.96
1017	-	0.00	15531.75		9820.96
1028	-	0.00	15531.75		9820.96
1039	-	0.00	15531.75		9820.96
1049	-	0.00	15531.75		9820.96
1059	-	0.00	15531.75		9820.96
1070	-	0.00	15531.75		9820.96
1080	-	0.00	15531.75		9820.96
1090	-	0.00	15531.75		9820.96
1100	-	0.00	15531.75		9820.96
1110	-	0.00	15531.75		9820.96
1120	-	0.00	15531.75		9820.96
1123					9820.96
1123					9820.96

1060	-	0.00	15531.75		9820.96

layer:

chainage	grade	second filter layers (land based)			
		Theoretical profile		Acual dumped	
		section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	-	0.00	0		0.00
10	-	0.00	0.00		0.00
20	-	0.00	0.00		0.00
30	-	0.00	0.00		0.00
40	-	0.00	0.00		0.00
50	-	0.00	0.00		0.00
60	-	0.00	0.00		0.00
65	-	0.00	0.00		0.00
70	-	0.00	0.00		0.00
80	-	0.00	0.00		0.00
90	-	0.00	0.00		0.00
95	-	0.00	0.00		0.00
100	-	0.00	0.00		0.00
110	-	0.00	0.00		0.00
120	-	0.00	0.00		0.00
130	-	0.00	0.00		0.00
135	-	0.00	0.00		0.00
140	-	0.00	0.00		0.00
145	-	0.00	0.00		0.00
150	-	0.00	0.00		0.00
155	-	0.00	0.00		0.00
160	-	0.00	0.00		0.00
165	-	0.00	0.00		0.00
170	-	0.00	0.00		0.00
175	-	0.00	0.00		0.00
180	-	0.00	0.00		0.00
185	-	0.00	0.00		0.00
190	-	0.00	0.00		0.00
195	-	0.00	0.00		0.00
200	-	0.00	0.00		0.00
205	-	0.00	0.00		0.00
215	-	0.00	0.00		0.00
225	-	0.00	0.00		0.00
235	-	0.00	0.00		0.00
245	-	0.00	0.00		0.00
255	-	0.00	0.00		0.00
265	-	0.00	0.00		0.00
275	-	0.00	0.00		0.00
285	-	0.00	0.00		0.00
290	-	0.00	0.00		0.00
300	-	0.00	0.00		0.00
310	-	0.00	0.00		0.00
320	-	0.00	0.00		0.00
330	-	0.00	0.00	0.00	0.00
340	F	43.98	43.98	350.06	350.06
350	F	225.41	269.39		350.06
360	F	362.85	632.24		350.06
370	F	362.85	995.09	936.84	1286.90
380	F	362.85	1357.94		1286.90
390	F	362.85	1720.79		1286.90
400	F	362.85	2083.64		1286.90
410	F	362.85	2446.49	1082.38	2369.28
420	-	181.43	2627.92		2369.28
430	-	0.00	2627.92		2369.28
440	-	0.00	2627.92		2369.28
450	-	0.00	2627.92		2369.28
460	-	0.00	2627.92		2369.28
470	-	0.00	2627.92		2369.28
480	-	0.00	2627.92		2369.28
490	-	0.00	2627.92		2369.28
500	-	0.00	2627.92		2369.28
510	-	0.00	2627.92		2369.28
520	-	0.00	2627.92		2369.28
530	-	0.00	2627.92		2369.28
540	-	0.00	2627.92		2369.28
550	-	0.00	2627.92		2369.28
560	-	0.00	2627.92		2369.28
570	-	0.00	2627.92		2369.28
580	-	0.00	2627.92		2369.28
590	-	0.00	2627.92		2369.28
600	-	0.00	2627.92		2369.28

chainage	grade	second filter layers (landbased)			
		Theoretical profile		Acual dumped	
		section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	-	0.00	2627.92		2369.28
620	-	0.00	2627.92		2369.28
630	-	0.00	2627.92		2369.28
640	-	0.00	2627.92		2369.28
650	-	0.00	2627.92		2369.28
660	-	0.00	2627.92		2369.28
670	-	0.00	2627.92		2369.28
680	-	0.00	2627.92		2369.28
690	-	0.00	2627.92		2369.28
700	-	0.00	2627.92		2369.28
710	-	0.00	2627.92		2369.28
720	-	0.00	2627.92		2369.28
730	-	0.00	2627.92		2369.28
740	-	0.00	2627.92		2369.28
750	-	0.00	2627.92		2369.28
760	-	0.00	2627.92		2369.28
770	-	0.00	2627.92		2369.28
780	-	0.00	2627.92		2369.28
790	-	0.00	2627.92		2369.28
800	-	0.00	2627.92		2369.28
810	-	0.00	2627.92		2369.28
820	-	0.00	2627.92		2369.28
830	-	0.00	2627.92		2369.28
840	-	0.00	2627.92		2369.28
850	-	0.00	2627.92		2369.28
860	-	0.00	2627.92		2369.28
870	-	0.00	2627.92		2369.28
880	-	0.00	2627.92		2369.28
890	-	0.00	2627.92		2369.28
900	-	0.00	2627.92		2369.28
910	-	0.00	2627.92		2369.28
920	-	0.00	2627.92		2369.28
930	-	0.00	2627.92		2369.28
940	-	0.00	2627.92		2369.28
950	-	0.00	2627.92		2369.28
960	-	0.00	2627.92		2369.28
970	-	0.00	2627.92		2369.28
980	-	0.00	2627.92		2369.28
990	-	0.00	2627.92		2369.28
1000	-	0.00	2627.92		2369.28
1010	-	0.00	2627.92		2369.28
1017	-	0.00	2627.92		2369.28
1028	-	0.00	2627.92		2369.28
1039	-	0.00	2627.92		2369.28
1049	-	0.00	2627.92		2369.28
1059	-	0.00	2627.92		2369.28
1070	-	0.00	2627.92		2369.28
1080	-	0.00	2627.92		2369.28
1090	-	0.00	2627.92		2369.28
1100	-	0.00	2627.92		2369.28
1110	-	0.00	2627.92		2369.28
1120	-	0.00	2627.92		2369.28
1123					2369.28
1123					2369.28

1060	-	0.00	2627.92		2369.28

Rock quantities of the south breakwater

layer:

		Toe (landbased)			
		Theoretical profile		Acual dumped	
chainage	*grade*	section *amount* (tonnes)	cumulative *amount* (tonnes)	section *amount* (tonnes)	cumulative *amount* (tonnes)
0	-	0.00	0.00	0	0.00
10	-	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00
165	-	0.00	0.00	0.00	0.00
170	-	0.00	0.00	0.00	0.00
175	-	0.00	0.00	0.00	0.00
180	-	0.00	0.00	0.00	0.00
185	-	0.00	0.00	0.00	0.00
190	-	0.00	0.00	0.00	0.00
195	-	0.00	0.00	0.00	0.00
200	-	0.00	0.00	0.00	0.00
205	-	0.00	0.00	0.00	0.00
215	-	0.00	0.00	0.00	0.00
225	-	0.00	0.00	0.00	0.00
235	-	0.00	0.00	0.00	0.00
245	-	0.00	0.00	0.00	0.00
255	E	85.49	85.49	0.00	0.00
265	E	170.98	256.47		0.00
275	E	170.98	427.46	325.00	325.00
285	E	170.98	598.44		325.00
290	E	85.49	683.93		325.00
300	E	170.98	854.91		325.00
310	E	170.98	1025.89		325.00
320	E	170.98	1196.87		325.00
330	E	170.98	1367.86	1257.00	1582.00
340	E	232.14	1599.99	314.80	1896.80
350	D	293.29	1893.28		1896.80
360	D	293.29	2186.57	239.24	2136.04
370	D	293.29	2479.86		2136.04
380	D	293.29	2773.15		2136.04
390	D	293.29	3066.44	893.00	3029.04
400	D	293.29	3359.73	357.00	3386.04
410	D	293.29	3653.01		3386.04
420	D	293.29	3946.30		3386.04
430	D	293.29	4239.59		3386.04
440	D	293.29	4532.88		3386.04
450	D	293.29	4826.17		3386.04
460	D	293.29	5119.46		3386.04
470	D	293.29	5412.75	1602.00	4988.04
480	D	293.29	5706.04		4988.04
490	D	293.29	5999.33		4988.04
500	D	293.29	6292.62		4988.04
510	D	293.29	6585.90		4988.04
520	D	293.29	6879.19		4988.04
530	D	293.29	7172.48		4988.04
540	D	293.29	7465.77		4988.04
550	D	293.29	7759.06		4988.04
560	D	293.29	8052.35	1805.20	6793.24
570	D	293.29	8345.64		6793.24
580	D	293.29	8638.93		6793.24
590	D	293.29	8932.22		6793.24
600	D	293.29	9225.51	1461.07	8254.31

		Toe (landbased)			
		Theoretical profile		Acual dumped	
chainage	*grade*	section *amount* (tonnes)	cumulative *amount* (tonnes)	section *amount* (tonnes)	cumulative *amount* (tonnes)
610	D	293.29	9518.79		8254.31
620	D	293.29	9812.08		8254.31
630	D	293.29	10105.37		8254.31
640	D	293.29	10398.66		8254.31
650	D	293.29	10691.95		8254.31
660	D	293.29	10985.24		8254.31
670	D	293.29	11278.53	1443.30	9697.61
680	D	293.29	11571.82		9697.61
690	D	293.29	11865.11	1378.30	11075.91
700	D	309.22	12174.33		11075.91
710	D	325.15	12499.47		11075.91
720	D	325.15	12824.62		11075.91
730	D	325.15	13149.77		11075.91
740	D	325.15	13474.92	1363.44	12439.35
750	D	325.15	13800.07		12439.35
760	D	325.15	14125.22		12439.35
770	D	325.15	14450.37		12439.35
780	D	325.15	14775.52	937.60	13376.95
790	D	325.15	15100.67		13376.95
800	D	162.57	15263.24		13376.95
810	-	0.00	15263.24		13376.95
820	-	0.00	15263.24		13376.95
830	-	0.00	15263.24		13376.95
840	-	0.00	15263.24		13376.95
850	-	0.00	15263.24		13376.95
860	-	0.00	15263.24		13376.95
870	-	0.00	15263.24		13376.95
880	-	0.00	15263.24		13376.95
890	-	0.00	15263.24		13376.95
900	-	0.00	15263.24		13376.95
910	-	0.00	15263.24		13376.95
920	-	0.00	15263.24		13376.95
930	-	0.00	15263.24		13376.95
940	-	0.00	15263.24		13376.95
950	-	0.00	15263.24		13376.95
960	-	0.00	15263.24		13376.95
970	-	0.00	15263.24		13376.95
980	-	0.00	15263.24		13376.95
990	-	0.00	15263.24		13376.95
1000	-	0.00	15263.24		13376.95
1010	-	0.00	15263.24		13376.95
1017	-	0.00	15263.24		13376.95
1028	-	0.00	15263.24		13376.95
1039	-	0.00	15263.24		13376.95
1049	-	0.00	15263.24		13376.95
1059	-	0.00	15263.24		13376.95
1070	-	0.00	15263.24		13376.95
1080	-	0.00	15263.24		13376.95
1090	-	0.00	15263.24	130.82	13507.77
1100	-	0.00	15263.24	817.56	14325.33
1110	-	0.00	15263.24	26.04	14351.37
1120	-	0.00	15263.24		14351.37
1123					14351.37
1123					14351.37
1060	-	0.00	15263.24		14351.37

layer:

chainage	grade	Prim armour sea side			
		Theoretical profile		Acual dumped	
		section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	-	0.00	0.00	0	0.00
10	-	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00
165	-	0.00	0.00	0.00	0.00
170	-	0.00	0.00	0.00	0.00
175	-	0.00	0.00	0.00	0.00
180	-	0.00	0.00	0.00	0.00
185	-	0.00	0.00	0.00	0.00
190	-	0.00	0.00	0.00	0.00
195	-	0.00	0.00	0.00	0.00
200	-	0.00	0.00	0.00	0.00
205	-	0.00	0.00	0.00	0.00
215	-	0.00	0.00	0.00	0.00
225	-	0.00	0.00	0.00	0.00
235	-	0.00	0.00	0.00	0.00
245	-	0.00	0.00	0.00	0.00
255	C	114.78	114.78	0.00	0.00
265	C	243.11	357.89	0.00	0.00
275	C	266.92	624.81		0.00
285	C	291.96	916.77		0.00
290	C	131.60	1048.37		0.00
300	C	250.54	1298.91		0.00
310	C	280.01	1578.93		0.00
320	C	290.19	1869.12	535.32	535.32
330	C	317.10	2186.22		535.32
340	C	372.05	2558.27	392.72	928.04
350	B	414.27	2972.54	126.22	1054.26
360	B	430.55	3403.09		1054.26
370	B	443.65	3846.74		1054.26
380	B	446.31	4293.05	443.02	1497.28
390	B	456.39	4749.44		1497.28
400	B	470.38	5219.82	135.56	1632.84
410	B	480.47	5700.29		1632.84
420	B	483.48	6183.76		1632.84
430	B	486.93	6670.69		1632.84
440	B	490.20	7160.89	1171.26	2804.10
450	B	490.02	7650.91		2804.10
460	B	490.02	8140.94		2804.10
470	B	493.30	8634.24		2804.10
480	B	500.03	9134.26		2804.10
490	B	504.45	9638.71		2804.10
500	B	508.52	10147.23	1266.22	4070.32
510	B	511.80	10659.03		4070.32
520	B	511.88	11170.91		4070.32
530	B	515.07	11685.98		4070.32
540	B	519.32	12205.30		4070.32
550	B	525.16	12730.46		4070.32
560	B	530.03	13260.49		4070.32
570	B	530.29	13790.78		4070.32
580	B	530.20	14320.98	1848.44	5918.76
590	B	526.75	14847.73		5918.76
600	B	520.29	15368.03		5918.76

layer:

chainage	grade	Prim armour sea side			
		Theoretical profile		Acual dumped	
		section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	B	523.48	15891.50		5918.76
620	B	530.03	16421.53	1267.76	7186.52
630	B	530.12	16951.64		7186.52
640	B	533.48	17485.12		7186.52
650	B	536.93	18022.05		7186.52
660	B	536.93	18558.98		7186.52
670	B	540.12	19099.10	1584.00	8770.52
680	B	546.75	19645.85		8770.52
690	B	565.60	20211.45	1013.50	9784.02
700	B	672.95	20884.41	93.88	9877.90
710	A	764.91	21649.31	122.54	10000.44
720	A	780.04	22429.35		10000.44
730	A	780.13	23209.48		10000.44
740	A	760.83	23970.31		10000.44
750	A	748.00	24718.32	1046.52	11046.96
760	A	742.07	25460.39		11046.96
770	A	739.95	26200.34		11046.96
780	A	730.48	26930.82	1449.48	12496.44
790	A	726.76	27657.58		12496.44
800	A	723.13	28380.71	2052.16	14548.60
810	A	719.59	29100.30		14548.60
820	A	721.45	29821.76		14548.60
830	A	717.03	30538.78		14548.60
840	A	708.80	31247.58	2025.14	16573.74
850	A	706.85	31954.43		16573.74
860	A	798.62	32753.05		16573.74
870	A	898.28	33651.33		16573.74
880	A	907.57	34558.90	2926.76	19500.50
890	A	911.73	35470.62		19500.50
900	A	919.34	36389.96	1425.68	20926.18
910	A	924.21	37314.17		20926.18
920	A	927.75	38241.91		20926.18
930	A	934.12	39176.03	2283.62	23209.80
940	A	944.65	40120.68		23209.80
950	A	947.22	41067.89		23209.80
960	A	939.25	42007.14		23209.80
970	A	939.16	42946.31		23209.80
980	A	947.13	43893.43	3335.00	26544.80
990	A	954.47	44847.91		26544.80
1000	A	958.01	45805.92		26544.80
1010	A	958.81	46764.73		26544.80
1017	A	671.41	47436.14		26544.80
1028		1377.77	48813.91	3552.30	30097.10
1039		1377.77	50191.69		30097.10
1049		1377.77	51569.46		30097.10
1059		1377.77	52947.23		30097.10
1070		1377.77	54325.01	4442.96	34540.06
1080		1377.77	55702.78		34540.06
1090		1377.77	57080.55		34540.06
1100		1377.77	58458.33		34540.06
1110		1377.77	59836.10		34540.06
1120		1377.77	61213.87		34540.06
1123	B patchw			1168.88	35708.94
1123	A patchw			3927.52	39636.46
1060	A	13777.73	61213.87	7995.26	39636.46

Rock quantities of the south breakwater

layer:		Sec armour sea side			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	-	0.00	0.00	0	0.00
10	-	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00
145	E	0.00	0.00	0.00	0.00
150	E	14.93	14.93	0.00	0.00
155	E	44.80	59.74		0.00
160	E	59.49	119.23		0.00
165	E	59.01	178.24		0.00
170	E	59.63	237.87		0.00
175	E	61.35	299.22	91.00	91.00
180	E	65.20	364.42		91.00
185	E	71.18	435.60		91.00
190	E	72.97	508.57		91.00
195	E	70.58	579.14		91.00
200	E	71.69	650.83		91.00
205	E	76.29	727.12	134.00	225.00
215	E	151.78	878.89		225.00
225	E	142.40	1021.29	217.00	442.00
235	E	146.91	1168.20		442.00
245	E	166.11	1334.31	540.00	982.00
255	F	139.12	1473.44		982.00
265	F	107.88	1581.32		982.00
275	F	120.89	1702.21		982.00
285	F	132.93	1835.14		982.00
290	F	59.52	1894.65	323.06	1305.06
300	F	112.57	2007.22		1305.06
310	F	125.32	2132.54		1305.06
320	F	130.80	2263.34		1305.06
330	F	143.55	2406.89	135.06	1440.12
340	F	155.41	2562.30		1440.12
350	F	162.75	2725.05	147.52	1587.64
360	E	170.54	2895.59	159.10	1746.74
370	E	177.53	3073.12		1746.74
380	E	179.21	3252.33		1746.74
390	E	184.61	3436.94		1746.74
400	E	191.16	3628.10		1746.74
410	E	194.08	3822.18	640.36	2387.10
420	E	199.48	4021.66		2387.10
430	E	200.90	4222.56		2387.10
440	E	197.97	4420.53		2387.10
450	E	204.79	4625.32		2387.10
460	E	208.24	4833.56		2387.10
470	E	203.99	5037.55	786.56	3173.66
480	E	207.18	5244.73		3173.66
490	E	209.83	5454.56		3173.66
500	E	214.52	5669.09		3173.66
510	E	216.38	5885.47		3173.66
520	E	212.84	6098.31		3173.66
530	E	213.64	6311.95	898.00	4071.66
540	E	215.50	6527.45		4071.66
550	E	217.89	6745.34	365.00	4436.66
560	E	219.48	6964.82		4436.66
570	E	220.19	7185.01		4436.66
580	E	220.90	7405.90		4436.66
590	E	218.24	7624.14		4436.66
600	E	214.17	7838.31		4436.66

layer:		Sec armour sea side			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	E	217.27	8055.58	937.00	5373.66
620	E	220.63	8276.21		5373.66
630	E	219.75	8495.96		5373.66
640	E	221.69	8717.65		5373.66
650	E	223.99	8941.64		5373.66
660	E	223.37	9165.02		5373.66
670	E	223.91	9388.92		5373.66
680	E	227.00	9615.92		5373.66
690	E	236.47	9852.40	1640.00	7013.66
700	E	259.04	10111.43		7013.66
710	E	273.64	10385.08		7013.66
720	E	279.66	10664.74		7013.66
730	E	279.66	10944.40		7013.66
740	E	271.96	11216.36		7013.66
750	E	271.96	11488.32	1245.00	8258.66
760	E	281.16	11769.48		8258.66
770	E	275.24	12044.72	586.00	8844.66
780	E	259.84	12304.55		8844.66
790	E	258.95	12563.50		8844.66
800	E	257.54	12821.04	727.00	9571.66
810	E	255.59	13076.63		9571.66
820	E	256.38	13333.01		9571.66
830	E	254.61	13587.63	528.00	10099.66
840	E	252.58	13840.21		10099.66
850	E	252.58	14092.78		10099.66
860	E	287.36	14380.14		10099.66
870	E	324.09	14704.23		10099.66
880	E	327.89	15032.12	842.00	10941.66
890	E	331.34	15363.47		10941.66
900	E	334.44	15697.91		10941.66
910	E	336.48	16034.39		10941.66
920	E	337.98	16372.37	741.00	11682.66
930	E	340.55	16712.92		11682.66
940	E	344.71	17057.62		11682.66
950	E	345.68	17403.30	629.00	12311.66
960	E	341.08	17744.38	163.00	12474.66
970	E	341.17	18085.55		12474.66
980	E	345.77	18431.32	919.00	13393.66
990	E	348.78	18780.10		13393.66
1000	E	350.28	19130.38		13393.66
1010	E	350.46	19480.84	755.00	14148.66
1017	E	245.45	19726.29		14148.66
1028	E	530.50	20256.78		14148.66
1039	E	530.50	20787.28		14148.66
1049	E	530.50	21317.77	1472.00	15620.66
1059	E	530.50	21848.27		15620.66
1070	E	530.50	22378.76		15620.66
1080	E	530.50	22909.26	2047.00	17667.66
1090	E	530.50	23439.76		17667.66
1100	E	530.50	23970.25		17667.66
1110	E	530.50	24500.75		17667.66
1120	E	530.50	25031.24		17667.66
1123	F-patchw			216.88	17884.54
1123					17884.54
1060	E	5304.96	25031.24	3519.00	17884.54

Rock quantities of the south breakwater

layer:

		Upp armour port side			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	-	0.00	0.00	0	0.00
10	-	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00
160	-	0.00	0.00	0.00	0.00
165	-	0.00	0.00	0.00	0.00
170	-	0.00	0.00	0.00	0.00
175	-	0.00	0.00	0.00	0.00
180	-	0.00	0.00	0.00	0.00
185	-	0.00	0.00	0.00	0.00
190	-	0.00	0.00	0.00	0.00
195	-	0.00	0.00	0.00	0.00
200	-	0.00	0.00	0.00	0.00
205	-	0.00	0.00	0.00	0.00
215	-	0.00	0.00	0.00	0.00
225	-	0.00	0.00	0.00	0.00
235	-	0.00	0.00	0.00	0.00
245	-	0.00	0.00	0.00	0.00
255	-	0.00	0.00	0.00	0.00
265	-	0.00	0.00	0.00	0.00
275	-	0.00	0.00	0.00	0.00
285	-	0.00	0.00	0.00	0.00
290	-	0.00	0.00	0.00	0.00
300	-	0.00	0.00	0.00	0.00
310	-	0.00	0.00	0.00	0.00
320	-	0.00	0.00	0.00	0.00
330	-	0.00	0.00	0.00	0.00
340	C	0.00	0.00	0.00	0.00
350	C	135.58	135.58		0.00
360	C	271.16	406.75		0.00
370	C	271.16	677.91	487.00	487.00
380	C	271.16	949.07		487.00
390	C	271.16	1220.24		487.00
400	C	271.16	1491.40		487.00
410	C	271.16	1762.57	621.00	1108.00
420	C	271.16	2033.73		1108.00
430	C	271.16	2304.89		1108.00
440	C	271.16	2576.06		1108.00
450	C	271.16	2847.22		1108.00
460	C	271.16	3118.39		1108.00
470	C	271.16	3389.55		1108.00
480	C	271.16	3660.71		1108.00
490	C	271.16	3931.88	2084.00	3192.00
500	C	271.16	4203.04	259.00	3451.00
510	C	271.16	4474.21		3451.00
520	C	271.16	4745.37		3451.00
530	C	271.16	5016.53		3451.00
540	C	271.16	5287.70		3451.00
550	C	271.16	5558.86	1138.00	4589.00
560	C	271.16	5830.03		4589.00
570	C	271.16	6101.19		4589.00
580	C	271.16	6372.35		4589.00
590	C	271.16	6643.52		4589.00
600	C	271.16	6914.68	949.00	5538.00

layer:

		Upp armour port side			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	C	271.16	7185.85		5538.00
620	C	271.16	7457.01		5538.00
630	C	271.16	7728.17		5538.00
640	C	271.16	7999.34		5538.00
650	C	271.16	8270.50		5538.00
660	C	271.16	8541.67		5538.00
670	C	271.16	8812.83		5538.00
680	C	271.16	9083.99		5538.00
690	C	271.16	9355.16		5538.00
700	C	271.16	9626.32	1739.00	7277.00
710	C	271.16	9897.49		7277.00
720	C	271.16	10168.65		7277.00
730	C	271.16	10439.81		7277.00
740	C	271.16	10710.98	1025.00	8302.00
750	C-mar-b.	271.16	10982.14	**126.00**	8428.00
760	C	271.16	11253.31		8428.00
770	C	271.16	11524.47		8428.00
780	C	271.16	11795.63		8428.00
790	C	277.80	12073.44	736.00	9164.00
800	C	284.44	12357.87		9164.00
810	C	284.44	12642.31		9164.00
820	C	284.44	12926.75		9164.00
830	C	284.44	13211.19	792.00	9956.00
840	C	284.44	13495.63		9956.00
850	C	284.44	13780.07		9956.00
860	C	284.44	14064.51		9956.00
870	C	284.44	14348.95	963.00	10919.00
880	C	284.44	14633.39		10919.00
890	C	284.44	14917.83		10919.00
900	C	284.44	15202.26		10919.00
910	C	284.44	15486.70		10919.00
920	C	284.44	15771.14	1343.00	12262.00
930	C	284.44	16055.58		12262.00
940	C	284.44	16340.02		12262.00
950	C	284.44	16624.46	971.00	13233.00
960	C	284.44	16908.90	605.00	13838.00
970	C	284.44	17193.34		13838.00
980	C	284.44	17477.78		13838.00
990	C	284.44	17762.22		13838.00
1000	C	284.44	18046.65	714.72	14552.72
1010	C	284.44	18331.09		14552.72
1017	C	199.11	18530.20	358.00	14910.72
1028		0.00	18530.20		14910.72
1039		0.00	18530.20		14910.72
1049		0.00	18530.20		14910.72
1059		0.00	18530.20		14910.72
1070		0.00	18530.20		14910.72
1080		0.00	18530.20		14910.72
1090		0.00	18530.20		14910.72
1100		0.00	18530.20		14910.72
1110		0.00	18530.20		14910.72
1120		0.00	18530.20		14910.72
1123	patchwork			1215.00	16125.72
1123					16125.72

1060		0.00	18530.20		16125.72

layer:		Low armour port side			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	-	0.00	0.00	0	0.00
10	-	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00
145	E	0.00	0.00	0.00	0.00
150	E	13.72	13.72	0.00	0.00
155	E	41.15	54.87	0.00	0.00
160	E	57.83	112.70		0.00
165	E	63.76	176.47		0.00
170	E	69.01	245.48		0.00
175	E	73.57	319.04	136.00	136.00
180	E	77.75	396.79		136.00
185	E	81.55	478.34		136.00
190	E	73.37	551.71		136.00
195	E	53.19	604.90		136.00
200	E	45.69	650.59		136.00
205	E	50.87	701.45	220.00	356.00
215	E	110.54	811.99		356.00
225	E	115.32	927.30		356.00
235	E	111.78	1039.08	208.00	564.00
245	E	117.88	1156.96		564.00
255	E	135.32	1292.28	310.00	874.00
265	E	146.82	1439.10		874.00
275	E	158.15	1597.25		874.00
285	E	172.22	1769.47		874.00
290	E	88.10	1857.57		874.00
300	E	172.58	2030.15	250.00	1124.00
310	E	176.29	2206.44		1124.00
320	E	183.55	2389.99		1124.00
330	E	193.11	2583.09	866.00	1990.00
340	E	118.50	2701.60	343.00	2333.00
350	E	44.07	2745.67	128.00	2461.00
360	E	55.05	2800.72		2461.00
370	E	60.09	2860.81		2461.00
380	E	62.22	2923.02		2461.00
390	E	67.26	2990.28	203.00	2664.00
400	E	73.72	3064.00		2664.00
410	E	78.68	3142.68		2664.00
420	E	80.36	3223.04	419.00	3083.00
430	E	82.04	3305.08		3083.00
440	E	83.72	3388.80		3083.00
450	E	83.72	3472.52		3083.00
460	E	83.72	3556.24		3083.00
470	E	85.40	3641.64		3083.00
480	E	88.77	3730.41		3083.00
490	E	92.13	3822.54		3083.00
500	E	95.49	3918.03	707.38	3790.38
510	E	97.17	4015.20		3790.38
520	E	97.17	4112.37		3790.38
530	E	98.85	4211.23		3790.38
540	E	100.54	4311.76		3790.38
550	E	102.22	4413.98	565.00	4355.38
560	E	103.90	4517.88		4355.38
570	E	103.90	4621.78		4355.38
580	E	103.90	4725.68		4355.38
590	E	102.22	4827.90		4355.38
600	E	98.85	4926.75	570.00	4925.38

layer:		Low armour port side			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	E	100.54	5027.29		4925.38
620	E	103.90	5131.19		4925.38
630	E	103.90	5235.08		4925.38
640	E	105.58	5340.67		4925.38
650	E	107.26	5447.93		4925.38
660	E	107.26	5555.19	894.00	5819.38
670	E	108.94	5664.13		5819.38
680	E	112.31	5776.44		5819.38
690	E	122.22	5898.66		5819.38
700	E	138.06	6036.72		5819.38
710	E	144.08	6180.80		5819.38
720	E	137.18	6317.97	759.00	6578.38
730	E	127.53	6445.50		6578.38
740	E	125.23	6570.73		6578.38
750	E	136.47	6707.19	249.00	6827.38
760	E	142.22	6849.41	122.00	6949.38
770	E	132.84	6982.25		6949.38
780	E	124.87	7107.13		6949.38
790	E	120.27	7227.40	350.00	7299.38
800	E	115.05	7342.45		7299.38
810	E	111.69	7454.13		7299.38
820	E	110.36	7564.49		7299.38
830	E	109.92	7674.41	528.00	7827.38
840	E	110.09	7784.50		7827.38
850	E	110.71	7895.22		7827.38
860	E	113.01	8008.23		7827.38
870	E	117.79	8126.03		7827.38
880	E	124.08	8250.10	715.00	8542.38
890	E	127.44	8377.54		8542.38
900	E	127.71	8505.25		8542.38
910	E	129.03	8634.28		8542.38
920	E	131.33	8765.62	490.00	9032.38
930	E	132.57	8898.19		9032.38
940	E	132.75	9030.94		9032.38
950	E	133.81	9164.75	500.00	9532.38
960	E	135.94	9300.69	113.00	9645.38
970	E	137.44	9438.13		9645.38
980	E	138.24	9576.36		9645.38
990	E	139.65	9716.02		9645.38
1000	E	140.72	9856.73		9645.38
1010	E	140.72	9997.45		9645.38
1017	E	96.39	10093.84	807.00	10452.38
1028	E	0.00	10093.84		10452.38
1039	E	0.00	10093.84		10452.38
1049	E	0.00	10093.84		10452.38
1059	E	0.00	10093.84		10452.38
1070	E	0.00	10093.84		10452.38
1080	E	0.00	10093.84		10452.38
1090	E	0.00	10093.84		10452.38
1100	E	0.00	10093.84		10452.38
1110	E	0.00	10093.84		10452.38
1120	E	0.00	10093.84		10452.38
1123	E	0.00			10452.38
1123					10452.38

1060		0.00	10093.84		10452.38

layer:		Core topping			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	-	0.00	0.00	0	0.00
10	-	0.00	0.00	0.00	0.00
20	-	0.00	0.00	0.00	0.00
30	-	0.00	0.00	0.00	0.00
40	-	0.00	0.00	0.00	0.00
50	-	0.00	0.00	0.00	0.00
60	-	0.00	0.00	0.00	0.00
65	-	0.00	0.00	0.00	0.00
70	-	0.00	0.00	0.00	0.00
80	-	0.00	0.00	0.00	0.00
90	-	0.00	0.00	0.00	0.00
95	-	0.00	0.00	0.00	0.00
100	-	0.00	0.00	0.00	0.00
110	-	0.00	0.00	0.00	0.00
120	-	0.00	0.00	0.00	0.00
130	-	0.00	0.00	0.00	0.00
135	-	0.00	0.00	0.00	0.00
140	-	0.00	0.00	0.00	0.00
145	-	0.00	0.00	0.00	0.00
150	-	0.00	0.00	0.00	0.00
155	-	0.00	0.00	0.00	0.00
160	-	0.00	0.00		0.00
165	E	35.18	35.18		0.00
170	E	70.36	105.54		0.00
175	E	70.36	175.89		0.00
180	E	70.36	246.25		0.00
185	E	70.36	316.61		0.00
190	E	70.36	386.97		0.00
195	E	70.36	457.32		0.00
200	E	70.36	527.68		0.00
205	E	70.36	598.04		0.00
215	E	140.72	738.75		0.00
225	E	140.72	879.47		0.00
235	E	140.72	1020.18		0.00
245	E	140.72	1160.90		0.00
255	E	140.72	1301.61		0.00
265	E	140.72	1442.33		0.00
275	E	140.72	1583.04		0.00
285	E	140.72	1723.76		0.00
290	E	70.36	1794.12		0.00
300	E	140.72	1934.83		0.00
310	E	140.72	2075.55		0.00
320	E	140.72	2216.26		0.00
330	E	140.72	2356.98		0.00
340	E	140.72	2497.69		0.00
350	E	140.72	2638.41		0.00
360	E	140.72	2779.12		0.00
370	E	140.72	2919.84		0.00
380	E	140.72	3060.55	0.00	0.00
390	E	140.72	3201.27		0.00
400	E	140.72	3341.98		0.00
410	E	140.72	3482.70		0.00
420	E	140.72	3623.41		0.00
430	E	140.72	3764.13		0.00
440	E	140.72	3904.84		0.00
450	E	140.72	4045.56		0.00
460	E	140.72	4186.27		0.00
470	E	140.72	4326.99		0.00
480	E	140.72	4467.70		0.00
490	E	140.72	4608.42		0.00
500	E	140.72	4749.13		0.00
510	E	140.72	4889.85		0.00
520	E	140.72	5030.56		0.00
530	E	140.72	5171.28		0.00
540	E	140.72	5311.99		0.00
550	E	140.72	5452.71		0.00
560	E	140.72	5593.42		0.00
570	E	140.72	5734.14		0.00
580	E	140.72	5874.85	3440.00	3440.00
590	E	140.72	6015.57		3440.00
600	E	140.72	6156.28		3440.00

layer:		Core topping			
		Theoretical profile		Acual dumped	
chainage	grade	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	**G**	140.72	6297.00	**720.30**	4160.30
620	E	140.72	6437.71		4160.30
630	E	140.72	6578.43		4160.30
640	E	140.72	6719.14		4160.30
650	E	140.72	6859.86		4160.30
660	E	140.72	7000.57		4160.30
670	E	140.72	7141.29		4160.30
680	E	140.72	7282.00		4160.30
690	E	140.72	7422.72		4160.30
700	E	140.72	7563.43	5371.00	9531.30
710	E	140.72	7704.15		9531.30
720	**G**	140.72	7844.86	**3538.34**	13069.64
730	**G**	140.72	7985.58	**12.22**	13081.86
740	E	140.72	8126.29		13081.86
750	E	140.72	8267.01		13081.86
760	E	140.72	8407.72		13081.86
770	E	140.72	8548.44		13081.86
780	E	140.72	8689.15		13081.86
790	E	140.72	8829.87		13081.86
800	E	140.72	8970.58		13081.86
810	**G**	140.72	9111.30	**84.48**	13166.34
820	E	140.72	9252.01		13166.34
830	E	140.72	9392.73		13166.34
840	E	140.72	9533.44		13166.34
850	E	140.72	9674.16		13166.34
860	E	143.19	9817.35		13166.34
870	E	145.67	9963.02		13166.34
880	E	145.67	10108.69		13166.34
890	E	145.67	10254.36		13166.34
900	E	145.67	10400.03		13166.34
910	E	145.67	10545.70		13166.34
920	E	145.67	10691.38	2939.00	16105.34
930	E	145.67	10837.05		16105.34
940	E	145.67	10982.72		16105.34
950	E	145.67	11128.39		16105.34
960	E	145.67	11274.06		16105.34
970	E	145.67	11419.73		16105.34
980	E	145.67	11565.40	888.00	16993.34
990	E	145.67	11711.07		16993.34
1000	E	145.67	11856.74		16993.34
1010	E	145.67	12002.41		16993.34
1017	E	101.97	12104.38		16993.34
1028	E	119.24	12223.62		16993.34
1039	E	119.24	12342.86		16993.34
1049	E	119.24	12462.10		16993.34
1059	E	119.24	12581.34		16993.34
1070	E	119.24	12700.57	1711.00	18704.34
1080	E	119.24	12819.81		18704.34
1090	E	119.24	12939.05		18704.34
1100	E	119.24	13058.29		18704.34
1110	E	119.24	13177.52		18704.34
1120	E	119.24	13296.76		18704.34
1123	G patchw			1089.34	19793.68
1123					19793.68

1060	E	1192.38	13296.76	1711.00	19793.68

Rock quantities of the south breakwater

layer:	All layers land based			
	Theoretical profile		Acual dumped	
chainage	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	0.00	0.00	0.00	0.00
10	10.62	10.62	0.00	0.00
20	16.64	27.26	0.00	0.00
30	55.31	82.57	0.00	0.00
40	84.52	167.09	0.00	0.00
50	112.40	279.48	0.00	0.00
60	133.64	413.12	0.00	0.00
65	102.22	515.34	760.90	760.90
70	172.49	687.82	601.62	1362.52
80	445.69	1133.51	0.00	1362.52
90	573.13	1706.63	0.00	1362.52
95	353.23	2059.86	945.90	2308.42
100	389.55	2449.41	0.00	2308.42
110	789.15	3238.57	0.00	2308.42
120	789.24	4027.81	0.00	2308.42
130	821.90	4849.71	0.00	2308.42
135	393.16	5242.87	0.00	2308.42
140	426.88	5669.75	0.00	2308.42
145	482.19	6151.94	3207.10	5515.52
150	488.06	6640.00	0.00	5515.52
155	504.34	7144.34	0.00	5515.52
160	598.04	7742.38	1341.40	6856.92
165	761.90	8504.27	0.00	6856.92
170	839.29	9343.56	0.00	6856.92
175	877.01	10220.58	3430.46	10287.38
180	961.91	11182.48	375.66	10663.04
185	1048.24	12230.72	0.00	10663.04
190	1118.09	13348.81	0.00	10663.04
195	1079.35	14428.16	2896.84	13559.88
200	964.36	15392.52	0.00	13559.88
205	921.66	16314.18	1259.94	14819.82
215	1844.78	18158.96	0.00	14819.82
225	1785.75	19944.71	217.00	15036.82
235	1772.66	21717.37	3544.24	18581.06
245	1946.03	23663.40	1496.14	20077.20
255	2312.68	25976.08	310.00	20387.20
265	2646.06	28622.14	5415.84	25803.04
275	2812.35	31434.49	6347.48	32150.52
285	3045.46	34479.95	2006.78	34157.30
290	1453.04	35932.99	323.06	34480.36
300	2779.34	38712.33	250.00	34730.36
310	3024.31	41736.64	7055.34	41785.70
320	3184.76	44921.41	535.32	42321.02
330	3429.55	48350.96	9274.06	51595.08
340	3706.60	52057.56	1400.58	52995.66
350	4237.69	56295.25	401.74	53397.40
360	4284.64	60579.89	5141.56	58538.96
370	3943.38	64523.27	2644.08	61183.04
380	3977.37	68500.64	6960.40	68143.44
390	4075.34	72575.97	1096.00	69239.44
400	4218.97	76794.95	492.56	69732.00
410	4044.45	80839.40	2343.74	72075.74
420	3624.25	84463.65	419.00	72494.74
430	3456.90	87920.55	11563.82	84058.56
440	3461.06	91381.60	1171.26	85229.82
450	3464.33	94845.94	0.00	85229.82
460	3464.33	98310.27	0.00	85229.82
470	3465.04	101775.31	2388.56	87618.38
480	3481.59	105256.90	0.00	87618.38
490	3492.03	108748.93	12728.80	100347.18
500	3504.16	112253.09	2232.60	102579.78
510	3510.97	115764.06	0.00	102579.78
520	3507.52	119271.58	0.00	102579.78
530	3513.18	122784.77	10608.92	113188.70
540	3520.97	126305.74	0.00	113188.70
550	3530.88	129836.62	2068.00	115256.70
560	3539.03	133375.65	7402.66	122659.36
570	3540.00	136915.65	0.00	122659.36
580	3540.62	140456.27	5288.44	127947.80
590	3532.83	143989.10	0.00	127947.80
600	3518.94	147508.04	2980.07	130927.87
610	3526.90	151034.94	1657.30	132585.17
620	3540.18	154575.12	1267.76	133852.93
630	3539.38	158114.50	13871.94	147724.87
640	3546.37	161660.87	0.00	147724.87
650	3553.81	165214.68	0.00	147724.87
660	3553.19	168767.86	894.00	148618.87
670	3558.59	172326.45	3027.30	151646.17
680	3571.68	175898.13	0.00	151646.17
690	3609.92	179508.05	4031.80	155677.97
700	3771.60	183279.65	21247.19	176925.16
710	3900.11	187179.76	122.54	177047.70
720	3914.36	191094.11	4297.34	181345.04
730	3904.80	194998.91	12.22	181357.26
740	3875.50	198874.41	2388.44	183745.70
750	3873.91	202748.32	12677.12	196422.82
760	3882.94	206631.26	122.00	196544.82
770	3865.50	210496.76	5100.34	201645.16
780	3832.67	214329.43	4351.76	205996.92
790	3869.93	218199.36	1086.00	207082.92
800	3743.55	221942.91	2779.16	209862.08
810	3573.54	225516.45	84.48	209946.56
820	3576.29	229092.74	9260.32	219206.88
830	3571.15	232663.89	1848.00	221054.88
840	3562.57	236226.46	7826.68	228881.56
850	3561.24	239787.70	0.00	228881.56
860	3807.98	243595.67	0.00	228881.56
870	4067.19	247662.87	963.00	229844.56
880	4086.93	251749.80	16655.96	246500.52
890	4099.94	255849.74	0.00	246500.52
900	4112.95	259962.69	1425.68	247926.20
910	4123.13	264085.81	0.00	247926.20
920	4132.33	268218.14	15628.64	263554.84
930	4142.77	272360.92	2283.62	265838.46
940	4159.77	276520.68	0.00	265838.46
950	4166.14	280686.82	9889.94	275728.40
960	4155.43	284842.25	881.00	276609.40
970	4158.70	289000.95	5825.02	282434.42
980	4174.10	293175.06	5142.00	287576.42
990	4187.91	297362.96	9642.26	297218.68
1000	4195.87	301558.84	714.72	297933.40
1010	4198.26	305757.10	755.00	298688.40
1017	2938.04	308695.14	1165.00	299853.40
1028	3836.23	312531.37	13757.38	313610.78
1039	3836.23	316367.59	0.00	313610.78
1049	3836.23	320203.82	1472.00	315082.78
1059	3836.23	324040.04	0.00	315082.78
1070	3836.23	327876.27	20924.13	336006.91
1080	3836.23	331712.49	7745.18	343752.09
1090	3836.23	335548.72	598.90	344350.99
1100	3836.23	339384.95	1921.16	346272.15
1110	3836.23	343221.17	26.04	346298.19
1120	3836.23	347057.40	0.00	346298.19
1123	0.00	0.00	3690.10	349988.29
1123	0.00	0.00	3927.52	353915.81

1060	38362.25	347057.40	45470.37	353915.81

layer:	All layers marine based			
	Theoretical profile		Acual dumped	
chainage	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00
110	0.00	0.00	0.00	0.00
120	0.00	0.00	0.00	0.00
130	0.00	0.00	0.00	0.00
135	0.00	0.00	0.00	0.00
140	0.00	0.00	0.00	0.00
145	0.00	0.00	0.00	0.00
150	0.00	0.00	0.00	0.00
155	0.00	0.00	0.00	0.00
160	0.00	0.00	0.00	0.00
165	0.00	0.00	0.00	0.00
170	0.00	0.00	0.00	0.00
175	0.00	0.00	0.00	0.00
180	0.00	0.00	0.00	0.00
185	0.00	0.00	0.00	0.00
190	0.00	0.00	0.00	0.00
195	0.00	0.00	0.00	0.00
200	0.00	0.00	0.00	0.00
205	0.00	0.00	0.00	0.00
215	0.00	0.00	0.00	0.00
225	0.00	0.00	0.00	0.00
235	0.00	0.00	0.00	0.00
245	0.00	0.00	0.00	0.00
255	0.00	0.00	0.00	0.00
265	0.00	0.00	0.00	0.00
275	0.00	0.00	0.00	0.00
285	0.00	0.00	0.00	0.00
290	0.00	0.00	0.00	0.00
300	0.00	0.00	0.00	0.00
310	0.00	0.00	0.00	0.00
320	0.00	0.00	0.00	0.00
330	0.00	0.00	0.00	0.00
340	0.00	0.00	0.00	0.00
350	0.00	0.00	0.00	0.00
360	460.20	460.20	470.00	470.00
370	920.40	1380.60	881.00	1351.00
380	920.40	2301.00	1019.69	2370.69
390	920.40	3221.40	1045.95	3416.63
400	920.40	4141.80	1159.43	4576.06
410	1375.38	5517.18	852.91	5428.97
420	1831.33	7348.51	1322.24	6751.21
430	1861.60	9210.11	2193.90	8945.11
440	1902.31	11112.41	2097.10	11042.22
450	1919.03	13031.45	1837.56	12879.78
460	1928.86	14960.31	1618.79	14498.57
470	1961.07	16921.38	1723.78	16222.36
480	2017.45	18938.82	1776.77	17999.13
490	2077.36	21016.18	1894.76	19893.89
500	2135.33	23151.51	2576.27	22470.16
510	2167.28	25318.79	2423.75	24893.91
520	2177.19	27495.98	2314.57	27208.48
530	2203.30	29699.27	1951.07	29159.55
540	2224.98	31924.25	1900.53	31060.08
550	2252.94	34177.20	2574.67	33634.75
560	2287.11	36464.30	2726.79	36361.54
570	2297.19	38761.50	2634.22	38995.76
580	2298.17	41059.66	2516.07	41511.83
590	2276.66	43336.33	2786.30	44298.13
600	2237.46	45573.78	2836.21	47134.34

layer:	All layers marine based			
	Theoretical profile		Acual dumped	
chainage	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	2263.83	47837.61	2913.83	50048.17
620	2313.57	50151.18	2667.41	52715.58
630	2318.35	52469.53	2785.97	55501.55
640	2343.04	54812.56	2882.75	58384.29
650	2368.26	57180.82	3150.27	61534.56
660	2372.33	59553.15	2792.91	64327.47
670	2410.74	61963.89	2631.14	66958.61
680	2472.16	64436.05	2431.91	69390.52
690	2649.87	67085.92	2755.98	72146.50
700	2951.21	70037.13	2547.47	74693.97
710	3079.71	73116.84	3217.78	77911.75
720	3092.99	76209.83	3993.37	81905.12
730	3051.13	79260.95	4121.91	86027.02
740	2938.64	82199.60	3772.46	89799.48
750	3000.42	85200.01	3823.39	93622.87
760	3102.99	88303.00	2846.16	96469.03
770	2954.31	91257.31	2987.54	99456.57
780	2756.07	94013.37	3176.76	102633.33
790	2827.49	96840.86	3704.80	106338.13
800	2897.84	99738.70	3345.80	109683.93
810	2844.83	102583.54	2989.93	112673.87
820	2833.06	105416.60	2748.11	115421.97
830	2839.52	108256.12	2730.83	118152.80
840	2933.33	111189.45	3077.13	121229.94
850	3067.50	114256.95	3409.52	124639.46
860	3266.54	117523.49	3286.63	127926.09
870	3344.86	120868.34	3874.37	131800.46
880	3308.13	124176.47	3425.39	135225.85
890	3372.47	127548.94	3824.70	139050.54
900	3438.58	130987.52	3478.36	142528.91
910	3485.84	134473.36	2700.99	145229.90
920	3515.40	137988.76	3462.36	148692.26
930	3547.61	141536.37	3741.76	152434.02
940	3584.34	145120.71	3650.46	156084.48
950	3599.91	148720.62	3523.16	159607.64
960	3591.06	152311.69	3910.62	163518.26
970	3620.00	155931.69	3993.20	167511.45
980	3688.41	159620.10	4445.91	171957.36
990	3758.51	163378.61	4192.50	176149.86
1000	3798.07	167176.68	3765.71	179915.56
1010	3777.80	170954.48	3331.29	183246.85
1017	1782.18	172736.65	2291.11	185537.97
1028	4310.97	177047.63	6541.02	192078.99
1039	4310.97	181358.60	3902.85	195981.83
1049	4310.97	185669.58	4649.07	200630.90
1059	4310.97	189980.55	4046.83	204677.74
1070	4310.97	194291.53	4368.16	209045.90
1080	4310.97	198602.50	4368.56	213414.46
1090	4310.97	202913.48	4562.11	217976.57
1100	4310.97	207224.45	2598.51	220575.08
1110	4310.97	211535.43	1508.77	222083.86
1120	4310.97	215846.40	1095.62	223179.48
1123	0.00	0.00	0	0
1123	0	0	0	0
	0.00	0.00	0	0
	0.00	0.00	0	0
1060	43109.75	215846.40	37641.51	223179.48

Rock quantities of the south breakwater

layer:	All layers land + marine based			
	Theoretical profile		Acual dumped	
chainage	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
0	0.00	0.00	0.00	0.00
10	10.62	10.62	0.00	0.00
20	16.64	27.26	0.00	0.00
30	55.31	82.57	0.00	0.00
40	84.52	167.09	0.00	0.00
50	112.40	279.48	0.00	0.00
60	133.64	413.12	0.00	0.00
65	102.22	515.34	760.90	760.90
70	172.49	687.82	601.62	1362.52
80	445.69	1133.51	0.00	1362.52
90	573.13	1706.63	0.00	1362.52
95	353.23	2059.86	945.90	2308.42
100	389.55	2449.41	0.00	2308.42
110	789.15	3238.57	0.00	2308.42
120	789.24	4027.81	0.00	2308.42
130	821.90	4849.71	0.00	2308.42
135	393.16	5242.87	0.00	2308.42
140	426.88	5669.75	0.00	2308.42
145	482.19	6151.94	3207.10	5515.52
150	488.06	6640.00	0.00	5515.52
155	504.34	7144.34	0.00	5515.52
160	598.04	7742.38	1341.40	6856.92
165	761.90	8504.27	0.00	6856.92
170	839.29	9343.56	0.00	6856.92
175	877.01	10220.58	3430.46	10287.38
180	961.91	11182.48	375.66	10663.04
185	1048.24	12230.72	0.00	10663.04
190	1118.09	13348.81	0.00	10663.04
195	1079.35	14428.16	2896.84	13559.88
200	964.36	15392.52	0.00	13559.88
205	921.66	16314.18	1259.94	14819.82
215	1844.78	18158.96	0.00	14819.82
225	1785.75	19944.71	217.00	15036.82
235	1772.66	21717.37	3544.24	18581.06
245	1946.03	23663.40	1496.14	20077.20
255	2312.68	25976.08	310.00	20387.20
265	2646.06	28622.14	5415.84	25803.04
275	2812.35	31434.49	6347.48	32150.52
285	3045.46	34479.95	2006.78	34157.30
290	1453.04	35932.99	323.06	34480.36
300	2779.34	38712.33	250.00	34730.36
310	3024.31	41736.64	7055.34	41785.70
320	3184.76	44921.41	535.32	42321.02
330	3429.55	48350.96	9274.06	51595.08
340	3706.60	52057.56	1400.58	52995.66
350	4237.69	56295.25	401.74	53397.40
360	4744.84	61040.09	5611.56	59008.96
370	4863.78	65903.87	3525.08	62534.04
380	4897.77	70801.64	7980.09	70514.13
390	4995.74	75797.37	2141.95	72656.07
400	5139.37	80936.75	1651.99	74308.06
410	5419.83	86356.57	3196.65	77504.71
420	5455.58	91812.16	1741.24	79245.95
430	5318.50	97130.65	13757.72	93003.67
440	5363.37	102494.02	3268.36	96272.04
450	5383.37	107877.38	1837.56	98109.60
460	5393.19	113270.57	1618.79	99728.39
470	5426.11	118696.69	4112.34	103840.74
480	5499.04	124195.72	1776.77	105617.51
490	5569.39	129765.12	14623.56	120241.07
500	5639.49	135404.60	4808.87	125049.94
510	5678.25	141082.85	2423.75	127473.69
520	5684.71	146767.56	2314.57	129788.26
530	5716.48	152484.04	12559.99	142348.25
540	5745.95	158229.99	1900.53	144248.78
550	5783.83	164013.82	4642.67	148891.45
560	5826.13	169839.95	10129.45	159020.90
570	5837.19	175677.15	2634.22	161655.12
580	5838.79	181515.93	7804.51	169459.63
590	5809.49	187325.43	2786.30	172245.93
600	5756.39	193081.82	5816.28	178062.21

layer:	All layers land + marine based			
	Theoretical profile		Acual dumped	
chainage	section amount (tonnes)	cumulative amount (tonnes)	section amount (tonnes)	cumulative amount (tonnes)
610	5790.73	198872.55	4571.13	182633.34
620	5853.74	204726.30	3935.17	186568.51
630	5857.73	210584.02	16657.91	203226.42
640	5889.41	216473.43	2882.75	206109.16
650	5922.07	222395.50	3150.27	209259.43
660	5925.52	228321.02	3686.91	212946.34
670	5969.33	234290.34	5658.44	218604.78
680	6043.84	240334.18	2431.91	221036.69
690	6259.78	246593.97	6787.78	227824.47
700	6722.81	253316.78	23794.66	251619.13
710	6979.82	260296.60	3340.32	254959.45
720	7007.34	267303.94	8290.71	263250.16
730	6955.92	274259.86	4134.13	267384.28
740	6814.15	281074.01	6160.90	273545.18
750	6874.33	287948.33	16500.51	290045.69
760	6985.92	294934.26	2968.16	293013.85
770	6819.81	301754.07	8087.88	301101.73
780	6588.74	308342.81	7528.52	308630.25
790	6697.41	315040.22	4790.80	313421.05
800	6641.39	321681.61	6124.96	319546.01
810	6418.37	328099.99	3074.41	322620.43
820	6409.35	334509.34	12008.43	334628.85
830	6410.67	340920.01	4578.83	339207.68
840	6495.90	347415.91	10903.81	350111.50
850	6628.74	354044.65	3409.52	353521.02
860	7074.51	361119.16	3286.63	356807.65
870	7412.05	368531.21	4837.37	361645.02
880	7395.06	375926.27	20081.35	381726.37
890	7472.41	383398.68	3824.70	385551.06
900	7551.53	390950.21	4904.04	390455.11
910	7608.96	398559.17	2700.99	393156.10
920	7647.73	406206.90	19091.00	412247.10
930	7690.38	413897.29	6025.38	418272.48
940	7744.10	421641.39	3650.46	421922.94
950	7766.05	429407.44	13413.10	435336.04
960	7746.49	437153.94	4791.62	440127.66
970	7778.71	444932.64	9818.22	449945.87
980	7862.52	452795.16	9587.91	459533.78
990	7946.42	460741.58	13834.76	473368.54
1000	7993.94	468735.52	4480.43	477848.96
1010	7976.06	476711.58	4086.29	481935.25
1017	4720.22	481431.80	3456.11	485391.37
1028	8147.20	489579.00	20298.40	505689.77
1039	8147.20	497726.20	3902.85	509592.61
1049	8147.20	505873.40	6121.07	515713.68
1059	8147.20	514020.60	4046.83	519760.52
1070	8147.20	522167.80	25292.29	545052.81
1080	8147.20	530315.00	12113.74	557166.55
1090	8147.20	538462.20	5161.01	562327.56
1100	8147.20	546609.40	4519.67	566847.23
1110	8147.20	554756.60	1534.81	568382.05
1120	8147.20	562903.80	1095.62	569477.67
1123	0.00	562903.80	3690	573167.77
1123	0	562903.80	3928	577095.29
	0.00	0.00	0	0
1060	81472.00	562903.80	83111.88	577095.29

X.III : Bulk density ratio's

This appendix comprises:

- Short description of calculated values (theoretical and actual quantities).
- Textual summary of the calculation results.
- Graphs and source data of the calculated bulk density ratio's, shown per weekly constructed breakwater section.

Theoretical bulk-density ratio:

In these calculations a theoretical bulk-density ratio (including expected wastage) of 1.77 t/m^3 has been used.

Actual bulk density ratio's:

The bulk-density ratio's of all layers, both land based and marine based have been calculated by dividing the used rock quantities by the volume of the layers. This has been done as detailed as possible in order to easily spot local deviations of the actual bulk-density factor from the theoretical value. The total amount of rock dumped in each weekly constructed section could be assumed to be divided linearly over that section, but then an error would be introduced in the bulk density calculation: The deviations in volumes, which are interpolated over a length of 10 metres, would be neglected. This error could be considerable in sections with changes in typical cross sections or in sections with strong bed level changes. Therefor the highest detail in a reliable bulk density ratio calculation is determined by the length of each weekly constructed stretch of breakwater.

Analyses of the calculated bulk density ratios:

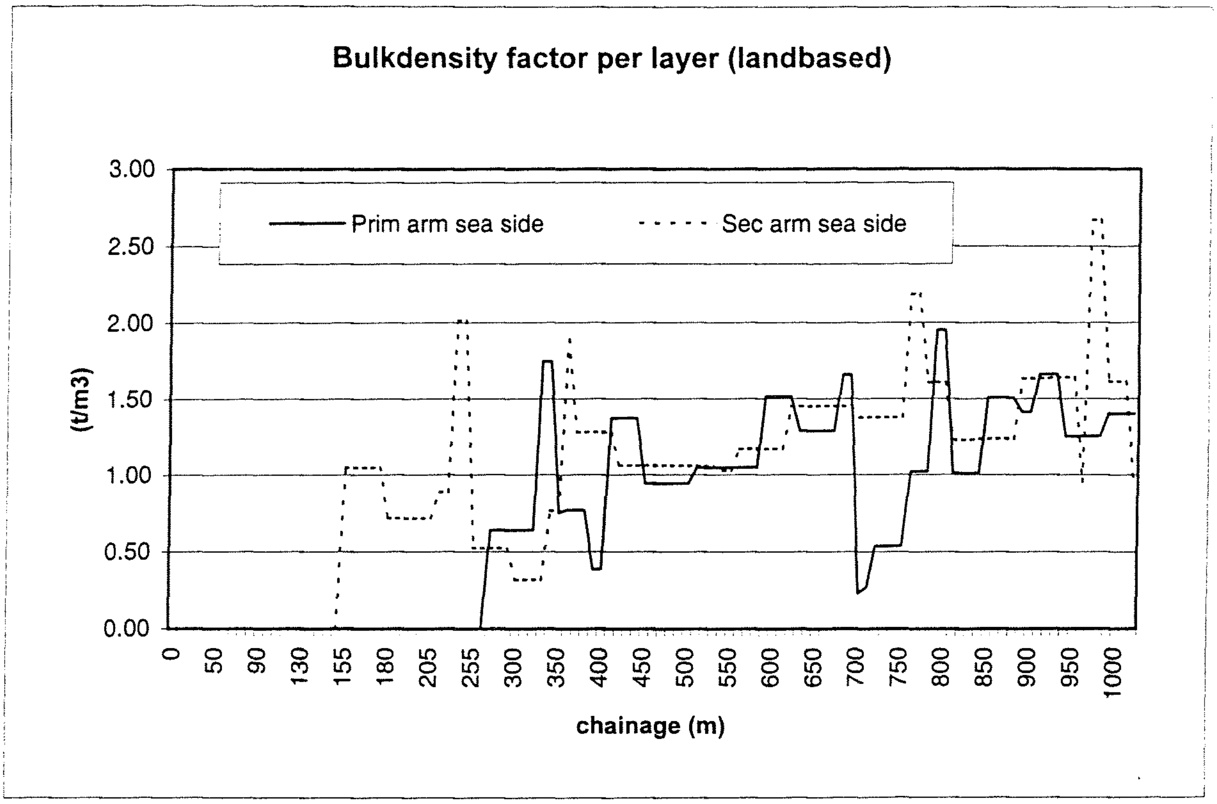
- For the core the average bulk density factor of 2.13 t/m^3 is high. The bulk density ratio's are within the range of expectation for the first 65 metres. From there on they become very high. The main reason for these high values is the low construction speed at the root of the breakwater. A lot of rock was washed out by currents and wave action in the breaker zone. These effects were increased by the cooling water outlet of the North Madras Thermal Power Plant. The bulk-density ratio of 10.26 for the core at chainage 70 is the result of repairs of the damaged core between chainage 40 and 70. This is also the case at chainage 275. Between chainages 275-340, 360-440, 500-540 and 790-990 the values are high as well. Sections between chainages 340-360,440-490, 540-780 (a total length of 300 metres) are in the range of the expected theoretical bulk density values.
- The average bulk density factor (1.48 t/m3) of the land based constructed toe is too low. For chainages 265-340, 370-400, 570-600 and 680-690 (total length 145 metres) the bulk density ratios are higher than expected. The remaining part (370 metres) show unrealistic low bulk density ratio's of 1.0-1.2 t/m^3. Without losses this corresponds with fictitious porosities (n_v) of 56-64%.

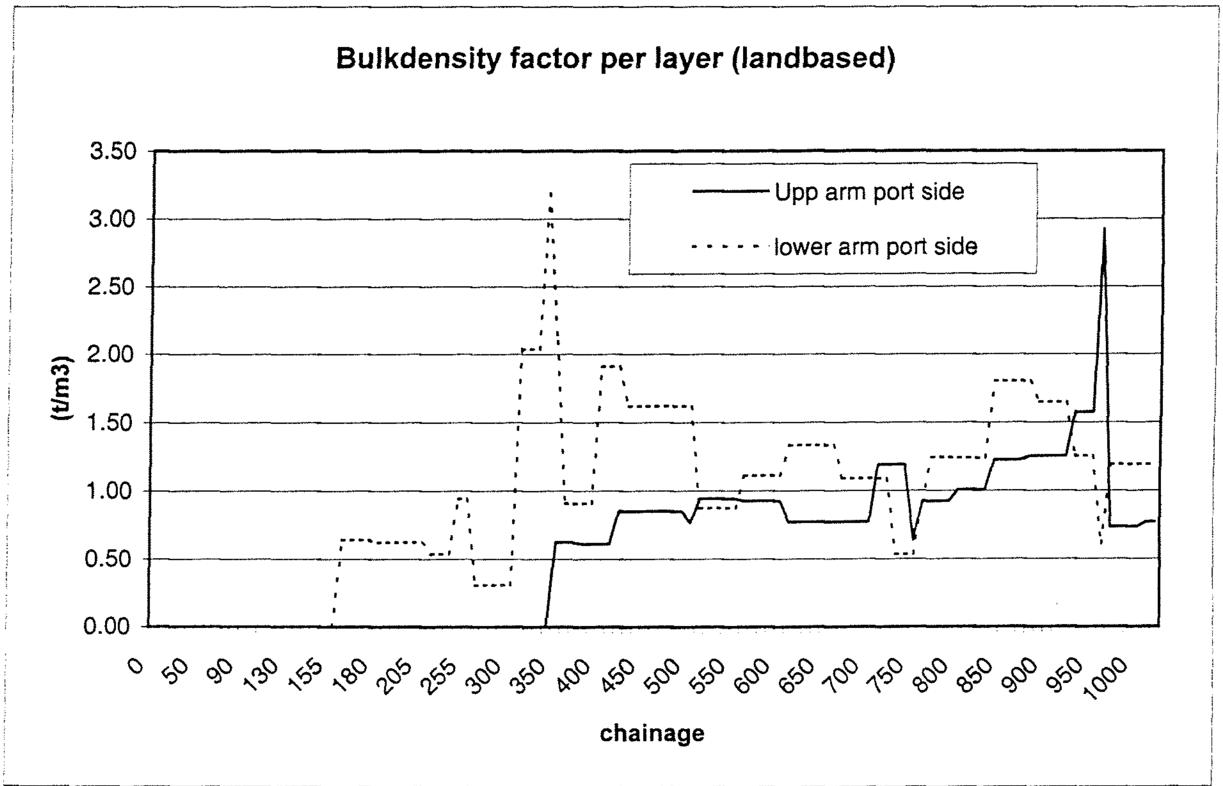
$$n_v = (1 - \rho_b / \rho_r) = (1 - 0.96 / 2.66) = 0.64 \ [-]$$

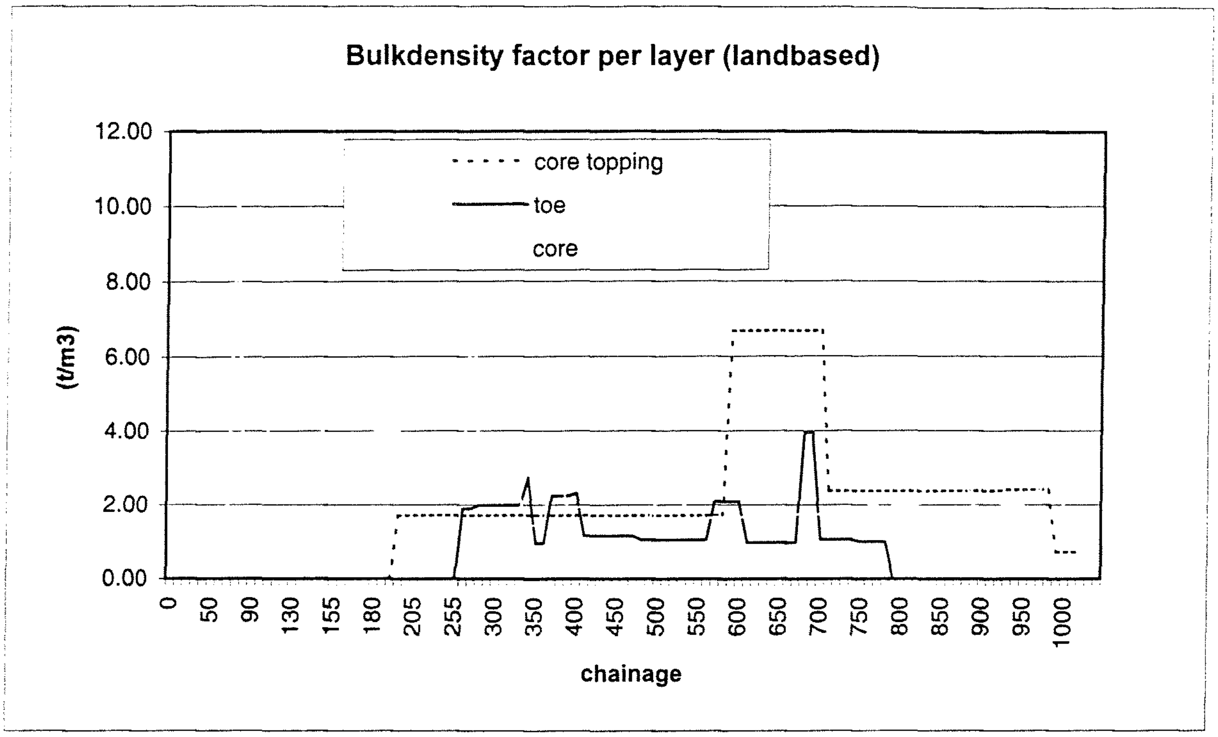
- For all the armour layers (primary seaside, secondary seaside, upper port side and lower port side) the average bulk density ratios are too low. Some short parts of the breakwater have bulk density ratios within the range of the expected theoretical bulk density values but the rest of the values are extremely low. Calculated bulk density ratios of 0.6 t/m^3 are no exception. This corresponds with a fictitious porosity of 77% which is physically not possible for layers with a thickness of about 2 * D_{n50}.

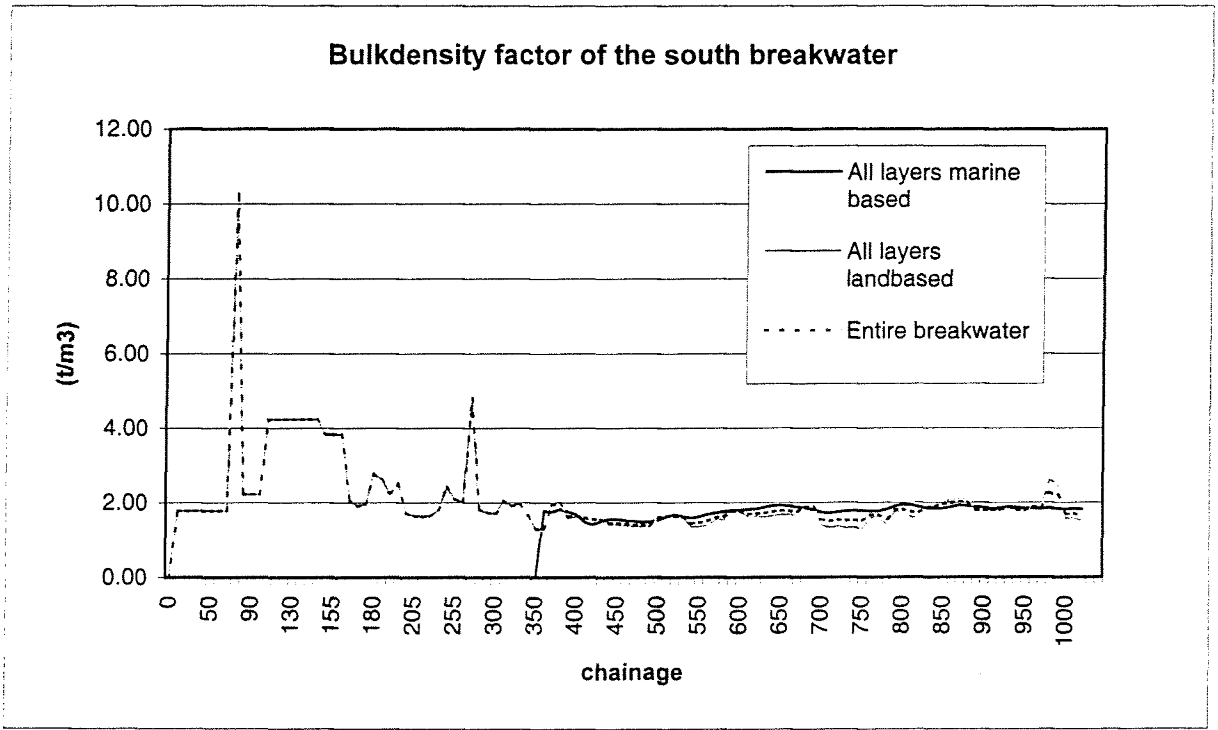
- The bulk density ratio of the core topping is as expected up to chainage 590. The section between chainage 590 and 700 shows an extreme high value of 6.7 t/m^3. The bulk density ratio for the remaining part of the breakwater is around 2.4 t/m^3, which is high. These high values are partly caused by losses of filter material and quarry run dumped on top of the E layer. Without these gradings however the bulk density is still higher than expected (average of 1.95 t/m3)
- The bulk density ratio's of the marine based layers are close to the average value of 1.74 (t/m^3) along the entire breakwater, except for chainages 440-500 where the values are slightly lower.

The bulk-density ratios of all the layers together are high at the first part of the breakwater. This is mainly due to the problems with the core construction in the breaker zone. Between chainages 440 and 500 the values are lower than the theoretical values. Chainages 870-890 and 980-1000 show higher overall values due to losses in the core. The bulk density ratios of the remaining part of the breakwater are within the range of the theoretical expected values.


Bulkdensity factor per layer (landbased)
Prim arm sea side
Sec arm sea side
3.00
2.50
2.00
1.50
1.00
0.50
0.00
(t/m3)
0
50
90
130
155
180
205
255
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
chainage (m)


Bulkdensity factor per layer (landbased)
Upp arm port side
lower arm port side
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
(t/m3)
0
50
90
130
155
180
205
255
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
chainage


Bulkdensity factor per layer (landbased)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
(t/m3)
core topping
toe
core
0
50
90
130
155
180
205
255
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
chainage


Bulkdensity factor of the south breakwater
12.00
10.00
8.00
6.00
4.00
2.00
0.00
(t/m3)
All layers marine based
All layers landbased
Entire breakwater
0
50
90
130
155
180
205
255
300
350
400
450
500
550
600
650
700
750
800
850
900
950
1000
chainage

Bulk density south breakwater

	Bulk density ratio for the south breakwater (t/m3)									
Chainage	Core	Toe	Primary Armour Sea side	Secundary Armour Sea side	Upper Armour Port side	Lower Armour Port side	Core Topping	all layers land based	all layers marine based	entire break water
0	1.77	0	0	0	0	0	0	0.00	0.00	0.00
10	1.77	0	0	0	0	0	0	1.77	0.00	1.77
20	1.77	0	0	0	0	0	0	1.77	0.00	1.77
30	1.77	0	0	0	0	0	0	1.77	0.00	1.77
40	1.77	0	0	0	0	0	0	1.77	0.00	1.77
50	1.77	0	0	0	0	0	0	1.77	0.00	1.77
60	1.77	0	0	0	0	0	0	1.77	0.00	1.77
65	1.77	0	0	0	0	0	0	1.77	0.00	1.77
70	10.26	0	0	0	0	0	0	10.26	0.00	10.26
80	2.22	0	0	0	0	0	0	2.22	0.00	2.22
90	2.22	0	0	0	0	0	0	2.22	0.00	2.22
95	2.22	0	0	0	0	0	0	2.22	0.00	2.22
100	4.23	0	0	0	0	0	0	4.23	0.00	4.23
110	4.23	0	0	0	0	0	0	4.23	0.00	4.23
120	4.23	0	0	0	0	0	0	4.23	0.00	4.23
130	4.23	0	0	0	0	0	0	4.23	0.00	4.23
135	4.23	0	0	0	0	0	0	4.23	0.00	4.23
140	4.23	0	0	0	0	0	0	4.23	0.00	4.23
145	4.23	0	0	0	0	0	0	4.23	0.00	4.23
150	3.83	0	0	0	0	0	0	3.83	0.00	3.83
155	3.83	0	0	1.05	0	0	0	3.83	0.00	3.83
160	3.83	0	0	1.05	0	0.64	0	3.83	0.00	3.83
165	2.72	0	0	1.05	0	0.64	0	2.08	0.00	2.08
170	2.72	0	0	1.05	0	0.64	0	1.90	0.00	1.90
175	2.72	0	0	1.05	0	0.64	0	1.95	0.00	1.95
180	4.01	0	0	0.72	0	0.62	0	2.78	0.00	2.78
185	4.01	0	0	0.72	0	0.62	0	2.63	0.00	2.63
190	4.01	0	0	0.72	0	0.62	0	2.24	0.00	2.24
195	4.01	0	0	0.72	0	0.62	1.71	2.51	0.00	2.51
200	2.21	0	0	0.72	0	0.62	1.71	1.71	0.00	1.71
205	2.21	0	0	0.72	0	0.62	1.71	1.65	0.00	1.65
215	2.21	0	0	0.89	0	0.54	1.71	1.62	0.00	1.62
225	2.21	0	0	0.89	0	0.54	1.71	1.63	0.00	1.63
235	2.21	0	0	2.02	0	0.54	1.71	1.80	0.00	1.80
245	3.11	0	0	2.02	0	0.94	1.71	2.42	0.00	2.42
255	3.11	0	0	0.52	0	0.94	1.71	2.09	0.00	2.09
265	3.11	1.89	0	0.52	0	0.31	1.71	2.01	0.00	2.01
275	7.91	1.89	0.64	0.52	0	0.31	1.71	4.82	0.00	4.82
285	2.48	1.99	0.64	0.52	0	0.31	1.71	1.81	0.00	1.81
290	2.48	1.99	0.64	0.52	0	0.31	1.71	1.73	0.00	1.73
300	2.48	1.99	0.64	0.32	0	0.31	1.71	1.71	0.00	1.71
310	2.48	1.99	0.64	0.32	0	2.04	1.71	2.05	0.00	2.05
320	2.19	1.99	0.64	0.32	0	2.04	1.71	1.90	0.00	1.90
330	2.19	1.99	1.75	0.32	0	2.04	1.71	1.96	0.00	1.96
340	1.44	2.74	1.75	0.77	0	3.19	1.71	1.65	0.00	1.65
350	1.44	0.96	0.75	0.77	0.62	2.10	1.71	1.29	0.00	1.29
360	1.44	0.96	0.77	1.89	0.62	0.91	1.71	1.24	1.77	1.30
370	2.64	2.24	0.77	1.28	0.62	0.91	1.71	1.97	1.75	1.93
380	2.64	2.24	0.77	1.28	0.61	0.91	1.71	2.02	1.82	1.98
390	1.94	2.24	0.38	1.28	0.61	0.91	1.71	1.57	1.76	1.62
400	1.94	2.32	0.38	1.28	0.61	1.91	1.71	1.63	1.68	1.65

Bulk density south breakwater

	Bulk density ratio for the south breakwater (t/m3)									
Chainage	Core	Toe	Primary Armour Sea side	Secundary Armour Sea side	Upper Armour Port side	Lower Armour Port side	Core Topping	all layers land based	all layers marine based	entire Breakwater
410	1.94	1.16	1.37	1.28	0.61	1.91	1.71	1.64	1.47	1.59
420	1.94	1.16	1.37	1.06	0.85	1.91	1.71	1.62	1.41	1.54
430	1.94	1.16	1.37	1.06	0.85	1.62	1.71	1.57	1.51	1.55
440	1.63	1.16	1.37	1.06	0.85	1.62	1.71	1.40	1.56	1.46
450	1.63	1.16	0.94	1.06	0.85	1.62	1.71	1.38	1.55	1.45
460	1.63	1.16	0.94	1.06	0.85	1.62	1.71	1.38	1.52	1.43
470	1.63	1.16	0.94	1.06	0.85	1.62	1.71	1.35	1.51	1.41
480	1.63	1.05	0.94	1.06	0.85	1.62	1.71	1.35	1.48	1.40
490	1.63	1.05	0.94	1.06	0.85	1.62	1.71	1.34	1.48	1.39
500	2.15	1.05	0.94	1.06	0.77	1.62	1.71	1.61	1.54	1.59
510	2.15	1.05	1.05	1.06	0.94	0.87	1.71	1.64	1.62	1.63
520	2.15	1.05	1.05	1.06	0.94	0.87	1.71	1.61	1.68	1.64
530	2.15	1.05	1.05	1.06	0.94	0.87	1.71	1.62	1.63	1.62
540	1.62	1.05	1.05	1.03	0.94	0.87	1.71	1.35	1.59	1.44
550	1.62	1.05	1.05	1.03	0.94	0.87	1.71	1.35	1.62	1.46
560	1.62	1.05	1.05	1.17	0.93	1.11	1.71	1.38	1.68	1.50
570	1.67	2.09	1.05	1.17	0.93	1.11	1.71	1.52	1.72	1.60
580	1.67	2.09	1.05	1.17	0.93	1.11	1.71	1.52	1.75	1.61
590	1.67	2.09	1.51	1.17	0.93	1.11	6.68	1.76	1.80	1.77
600	1.67	2.09	1.51	1.17	0.93	1.11	6.68	1.74	1.80	1.77
610	1.67	0.98	1.51	1.17	0.77	1.33	6.68	1.61	1.82	1.69
620	1.67	0.98	1.51	1.45	0.77	1.33	6.68	1.63	1.82	1.71
630	1.67	0.98	1.29	1.45	0.77	1.33	6.68	1.61	1.87	1.71
640	1.74	0.98	1.29	1.45	0.77	1.33	6.68	1.63	1.92	1.75
650	1.74	0.98	1.29	1.45	0.77	1.33	6.68	1.67	1.93	1.78
660	1.74	0.98	1.29	1.45	0.77	1.33	6.68	1.67	1.91	1.77
670	1.74	0.98	1.29	1.45	0.77	1.09	6.68	1.64	1.89	1.75
680	1.74	3.96	1.66	1.45	0.77	1.09	6.68	1.89	1.85	1.87
690	1.74	3.96	1.66	1.45	0.77	1.09	6.68	1.93	1.80	1.87
700	1.74	1.06	0.23	1.38	0.77	1.09	6.68	1.41	1.74	1.55
710	1.80	1.06	0.27	1.38	1.19	1.09	2.37	1.32	1.71	1.49
720	1.80	1.06	0.54	1.38	1.19	1.09	2.37	1.38	1.75	1.54
730	1.80	1.06	0.54	1.38	1.19	0.53	2.37	1.31	1.77	1.52
740	1.80	1.06	0.54	1.38	1.19	0.53	2.37	1.32	1.78	1.52
750	1.80	1.00	0.54	1.38	0.64	0.53	2.37	1.30	1.79	1.51
760	1.99	1.00	1.02	2.19	0.92	0.91	2.37	1.58	1.76	1.66
770	1.99	1.00	1.02	2.19	0.92	1.24	2.37	1.61	1.76	1.68
780	1.66	1.00	1.02	1.61	0.92	1.24	2.37	1.40	1.82	1.56
790	2.00	0.00	1.95	1.61	0.92	1.24	2.37	1.74	1.89	1.80
800	2.00	0.00	1.95	1.61	1.01	1.24	2.37	1.73	1.95	1.83

Bulk density south breakwater

Chainage	Bulk density ratio for the south breakwater (t/m3)									
	Core	Toe	Primary Armour Sea side	Secundary Armour Sea side	Upper Armour Port side	Lower Armour Port side	Core Topping	all layers land based	all layers marine based	Entire Breakwater
810	2.00	0	1.01	1.23	1.01	1.24	2.37	1.60	1.93	1.75
820	2.00	0	1.01	1.23	1.01	1.24	2.37	1.60	1.88	1.73
830	2.46	0	1.01	1.23	1.01	1.24	2.37	1.88	1.84	1.86
840	2.46	0	1.01	1.24	1.22	1.80	2.37	1.91	1.84	1.88
850	2.52	0	1.51	1.24	1.22	1.80	2.37	2.04	1.84	1.95
860	2.52	0	1.51	1.24	1.22	1.80	2.37	2.06	1.88	1.98
870	2.52	0	1.51	1.24	1.22	1.80	2.37	2.10	1.92	2.02
880	2.52	0	1.51	1.24	1.25	1.80	2.37	2.10	1.90	2.01
890	1.92	0	1.41	1.63	1.25	1.65	2.37	1.75	1.88	1.81
900	1.92	0	1.41	1.63	1.25	1.65	2.37	1.75	1.86	1.80
910	1.92	0	1.66	1.63	1.25	1.65	2.37	1.79	1.83	1.81
920	1.92	0	1.66	1.63	1.25	1.65	2.37	1.77	1.85	1.80
930	2.02	0	1.66	1.64	1.57	1.25	2.41	1.87	1.88	1.88
940	2.02	0	1.25	1.64	1.57	1.25	2.41	1.77	1.87	1.82
950	2.02	0	1.25	1.64	1.57	1.25	2.41	1.74	1.84	1.78
960	2.29	0	1.25	0.95	2.92	0.61	2.41	1.90	1.84	1.87
970	2.29	0	1.25	2.67	0.74	1.19	2.41	1.90	1.83	1.87
980	3.71	0	1.25	2.67	0.74	1.19	2.41	2.60	1.85	2.26
990	3.71	0	1.40	1.61	0.74	1.19	0.72	2.51	1.83	2.20
1000	1.86	0	1.40	1.61	0.74	1.19	0.72	1.56	1.82	1.69
1010	1.86	0	1.40	1.61	0.77	1.19	0.72	1.58	1.83	1.70
1017	1.86	0	1.40	0.95	0.77	1.19	0.72	1.50	1.82	1.65
Head	2.82	0	1.11	1.15	0	0	3.46	2.07	1.77	1.93

X.IV : Combination of results expressed in rock quantities per 'm

The bulk density calculations have shown that there are differences between the surveys, the theoretical values and actual quantities. Bulk density ratio's are however relative values and do not give much insight in the scale of variations in tonnes or in cubic metres. Therefore all data is combined and expressed in rock quantities per metre breakwater. This representation will give more insight in the actual situation and can be used for determination of the properties of the actual cross sections. Here again theoretical values, values according to the surveys and actual dumped rock quantities will be compared:

Theoretical quantities:

$$S_t = A_t * \rho_{bt}$$

With: St = Theoretical required rock quantities per metre breakwater (in t/m')
A_t = Theoretical cross section (in m^2)
ρ_{bt} = Theoretical bulk density = 1.77 t/m^3
The boundaries of the theoretical values are shown as well:
Lower boundary: ρ_{bt} = 1.62 t/m^3
Upper boundary: ρ_{bt} = 1.90 t/m^3

Survey quantities:
These are the rock quantities that should be in the breakwater in case the surveyed cross sections actually contained the amount of rock according to the theoretical bulk density ratio.

$$S_{su} = A_s * \rho_{bt}$$

With: S_{su} = Rock quantities per metre breakwater, that should be in the breakwater according to the surveys (t/m')
A_s = Surveyed cross section (m^2)
ρ_{bt} = Theoretical bulk density = 1.77 (t/m3)

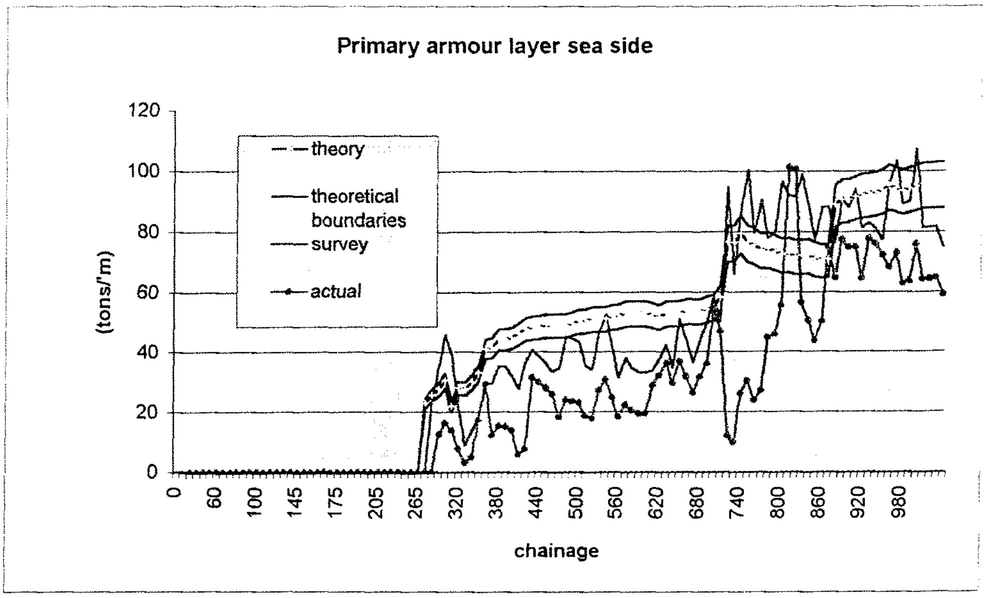
Actual dumped rock quantities:

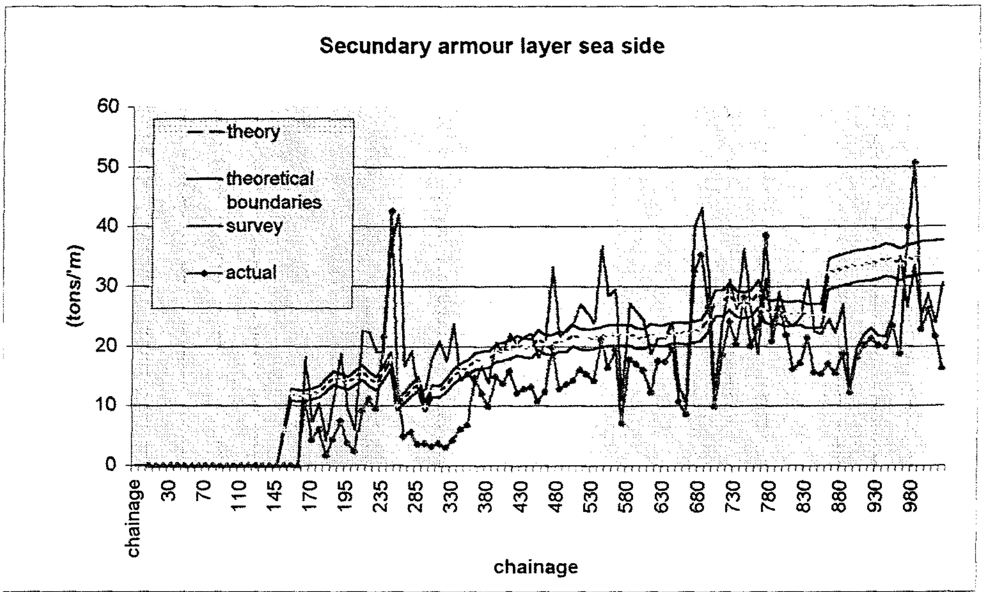
$$S_{su} = A_s * \rho_{bc}$$

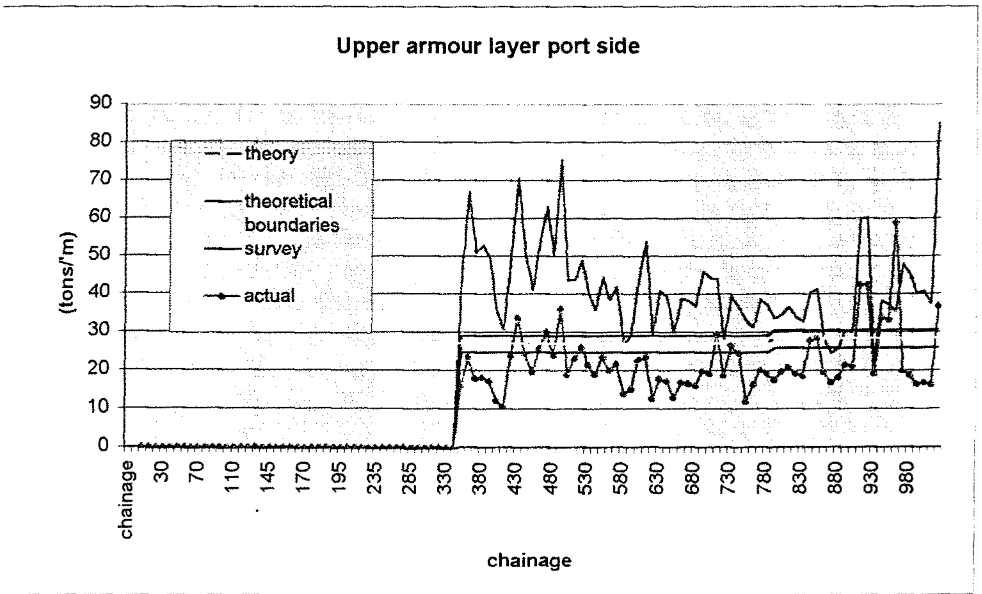
With: S_{su} = Amount of rock actual dumped per metre breakwater (t/m')
A_s = Surveyed cross section (m^2)
ρ_{bc} = Calculated bulk densities (t/m3)

- Using the combination of the surveyed area and the calculated bulk density ratio instead of the length of the weekly constructed section and the amounts of rock used prevents the introduction of an extra error.

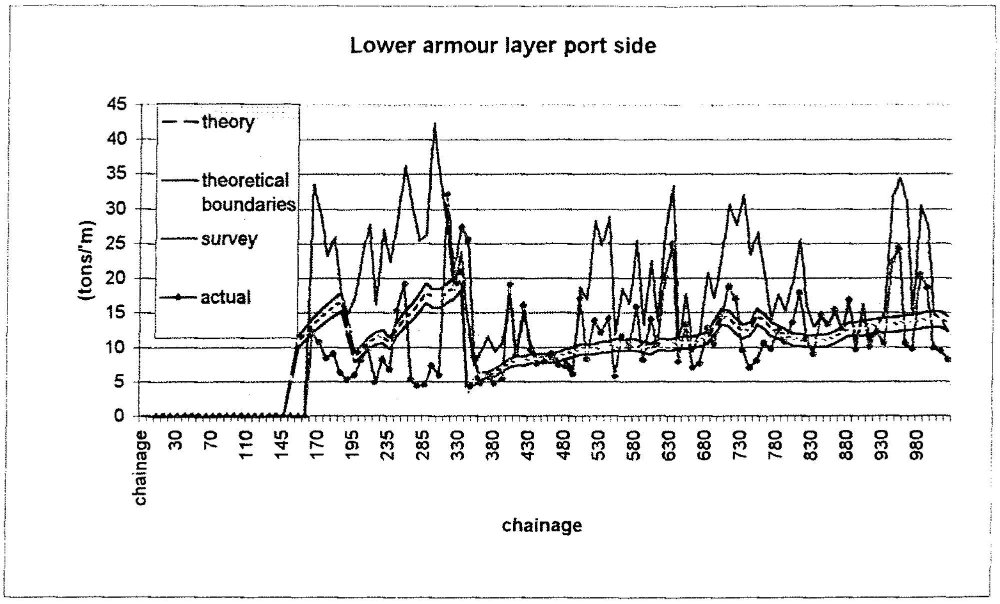
Rock quantities per 'm of the south breakwater

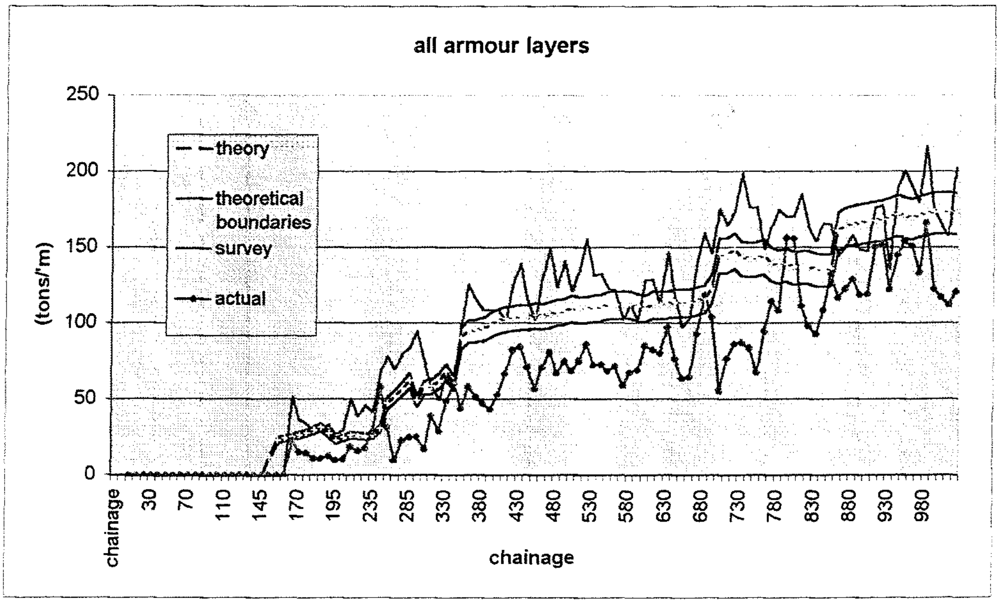




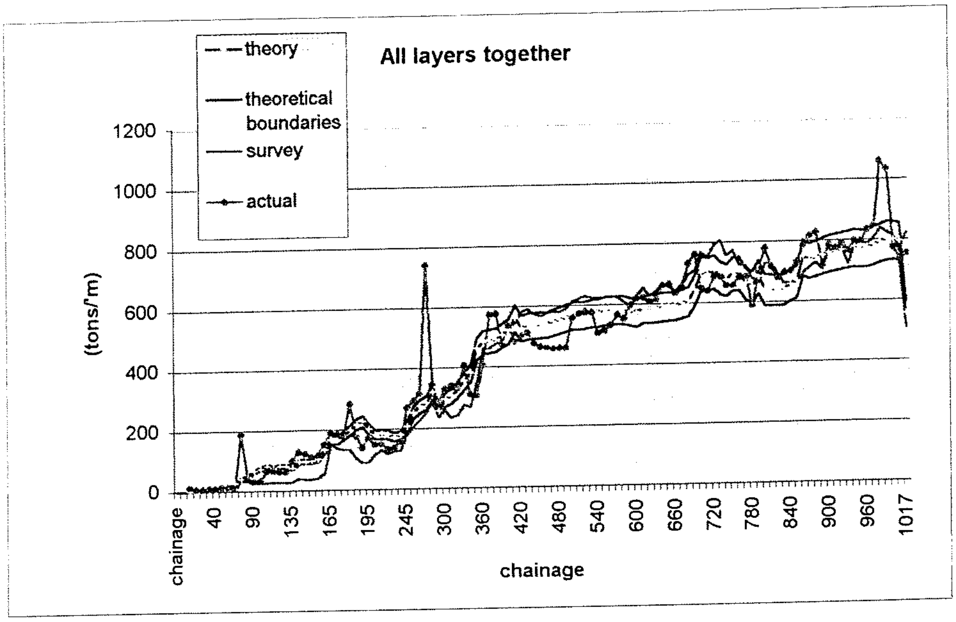


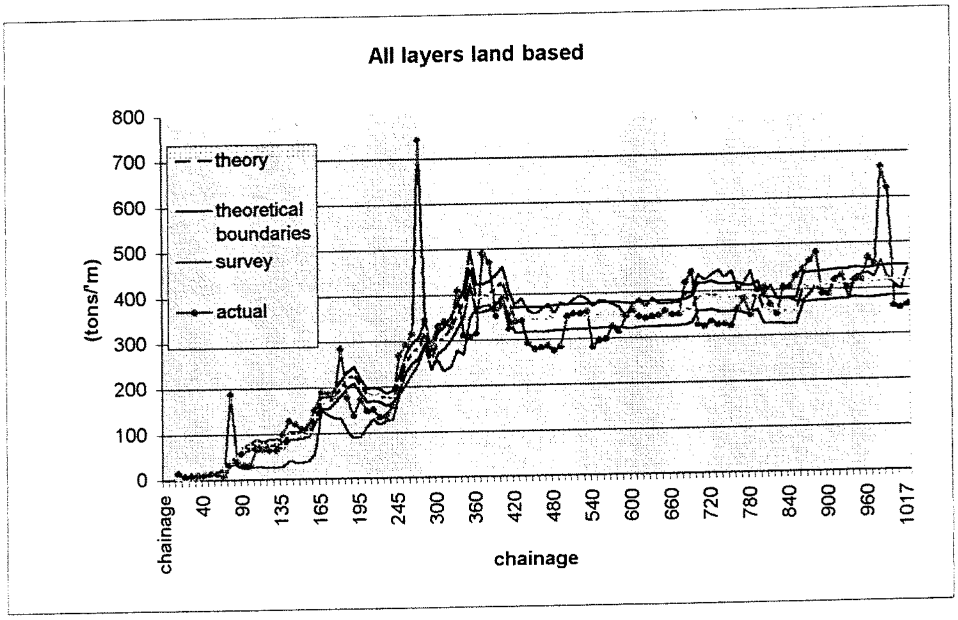
Rock quantities per 'm of the south breakwater

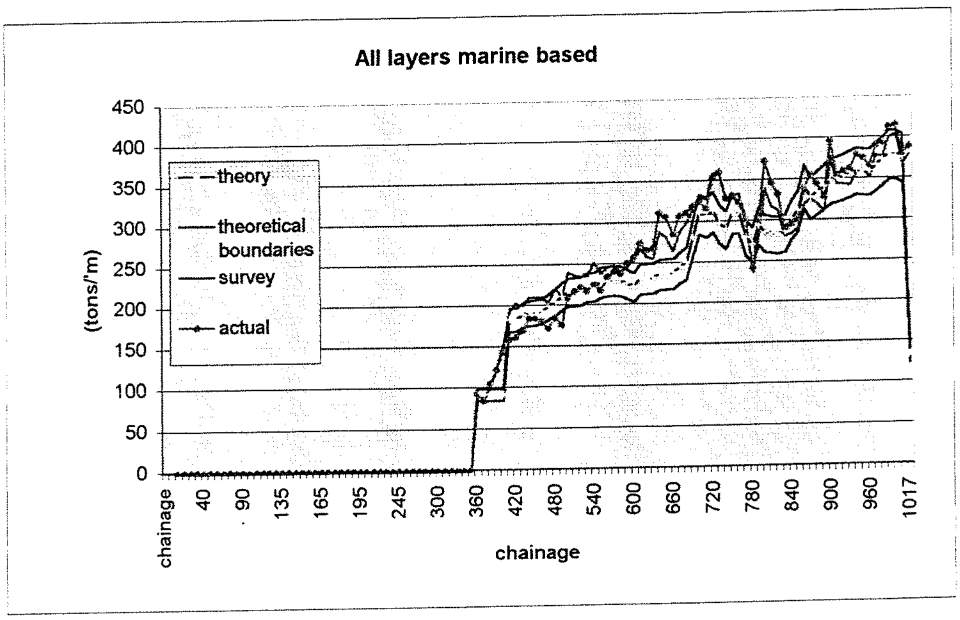




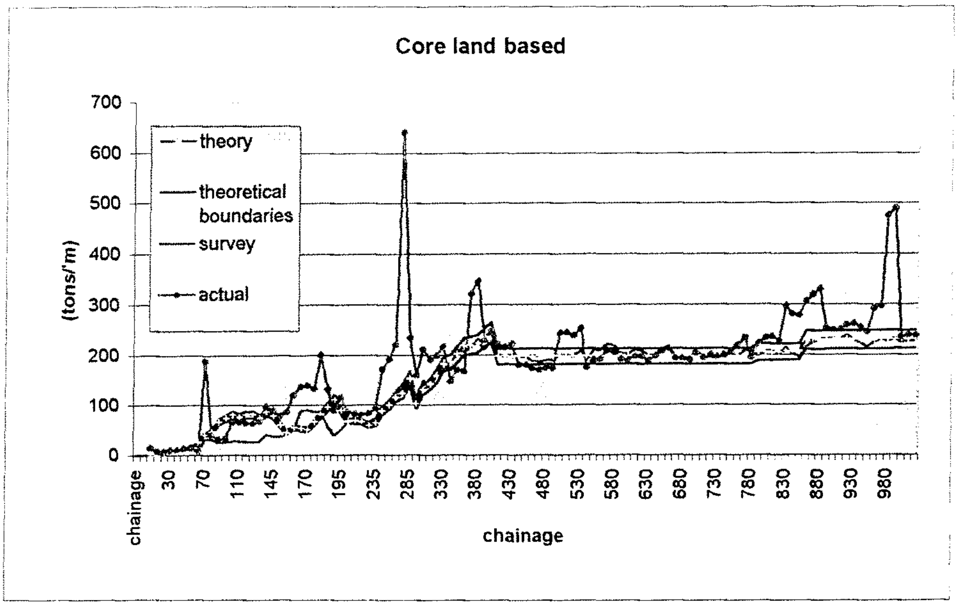
Rock quantities per 'm of the south breakwater

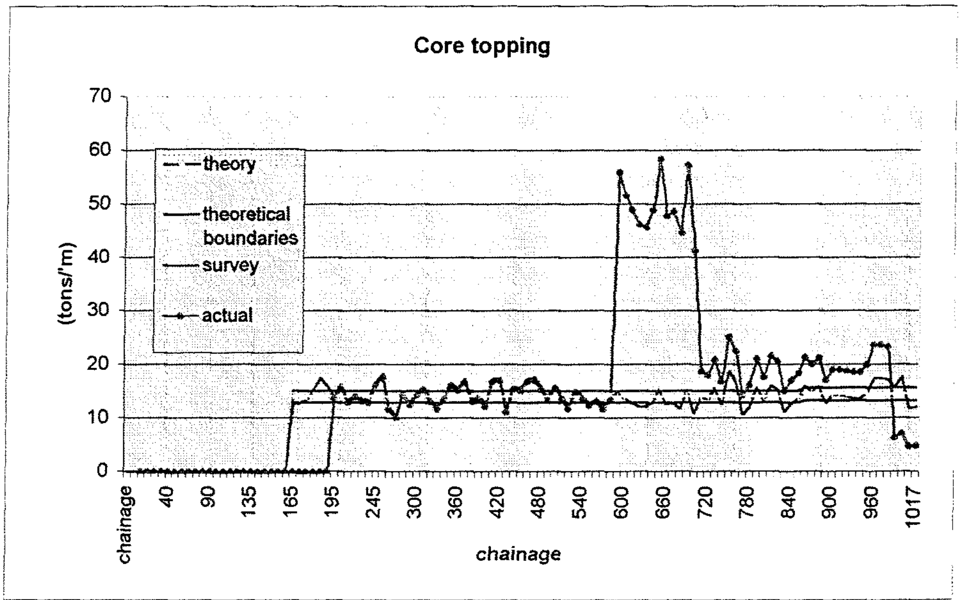




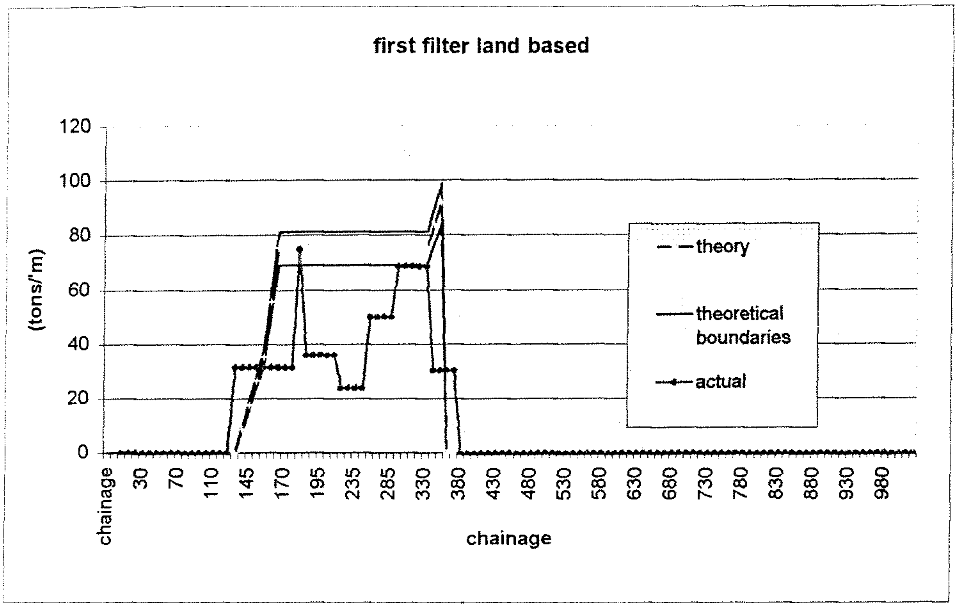


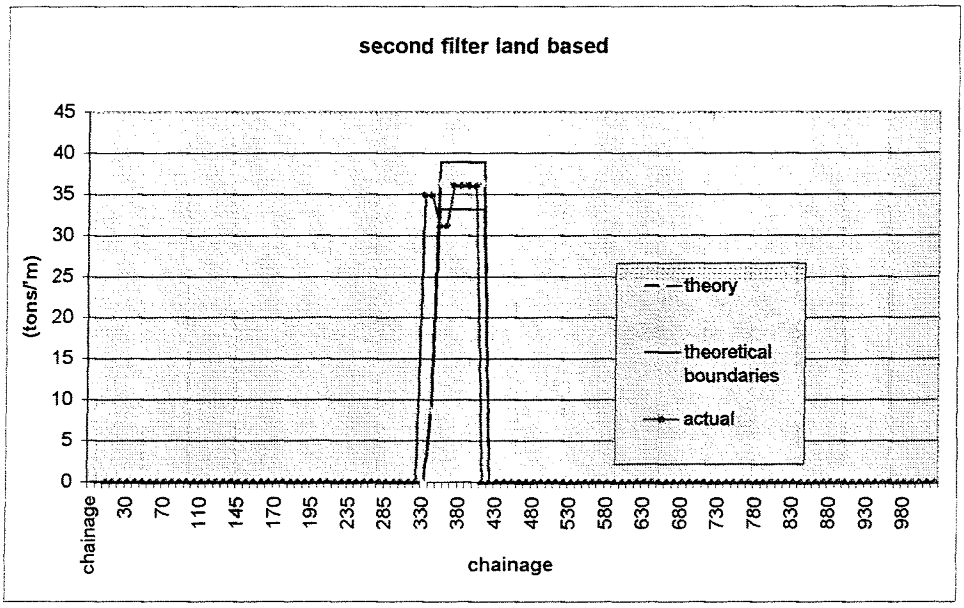
Rock quantities per 'm of the south breakwater

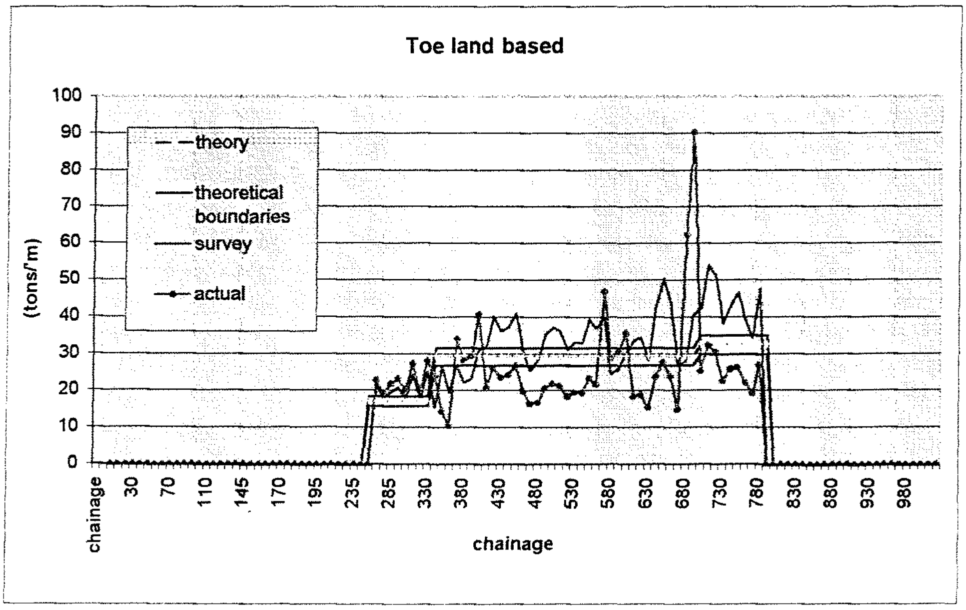




Rock quantities per 'm of the south breakwater







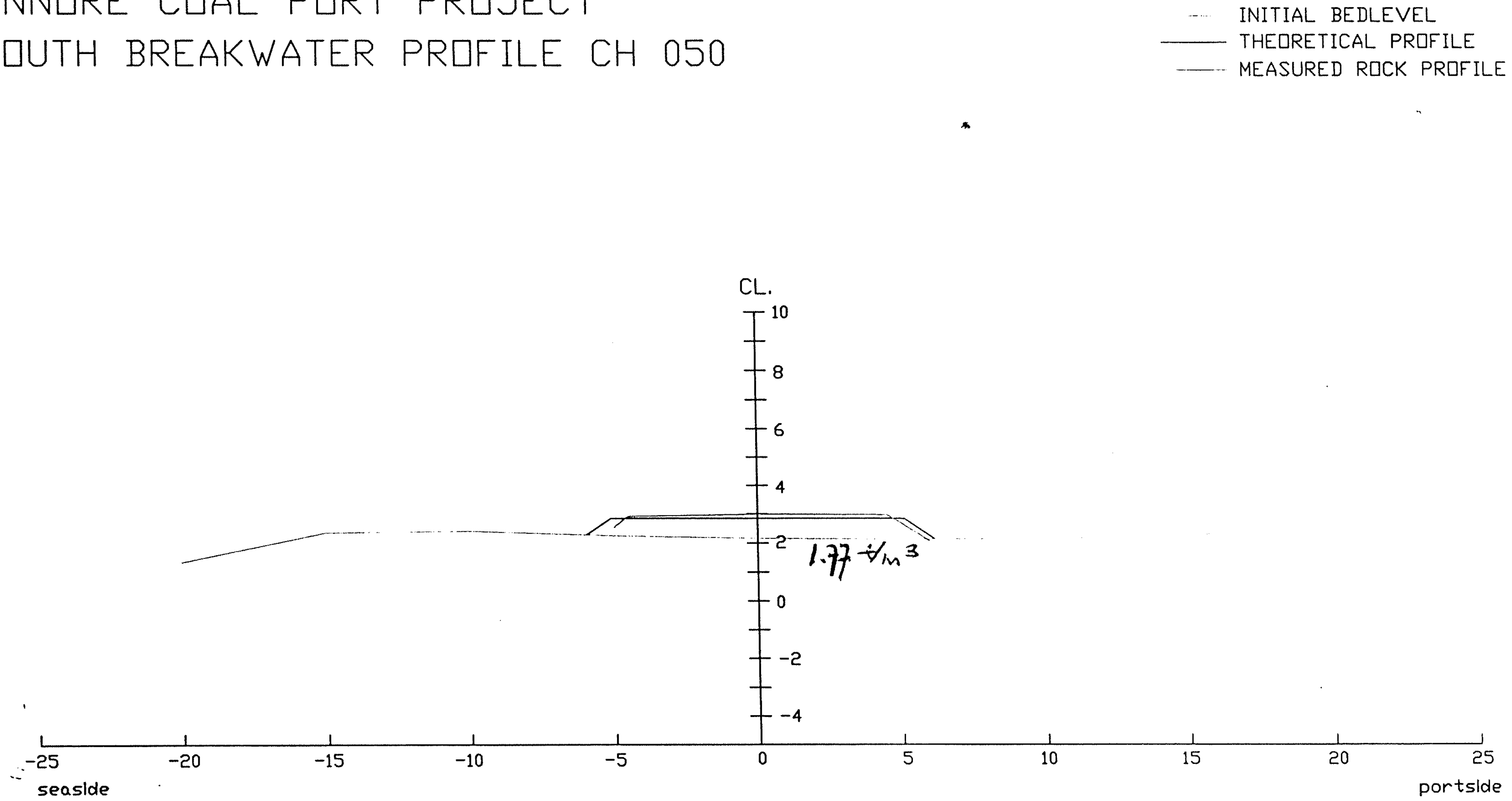
APPENDIX XI: Representative cross sections of the south breakwater

XI.I : Surveyed cross sections plus calculated bulk density ratio's
XI.II : Example of cross slope angle determination (chainage 530)
XI.III : Possible actual cross section by combining available data

XI.I : Surveyed cross sections plus calculated bulk density ratio's

All representative cross sections, as a result of the surveys are given. The calculated bulk density ratio's are added and possible explanations for deviations thereof.

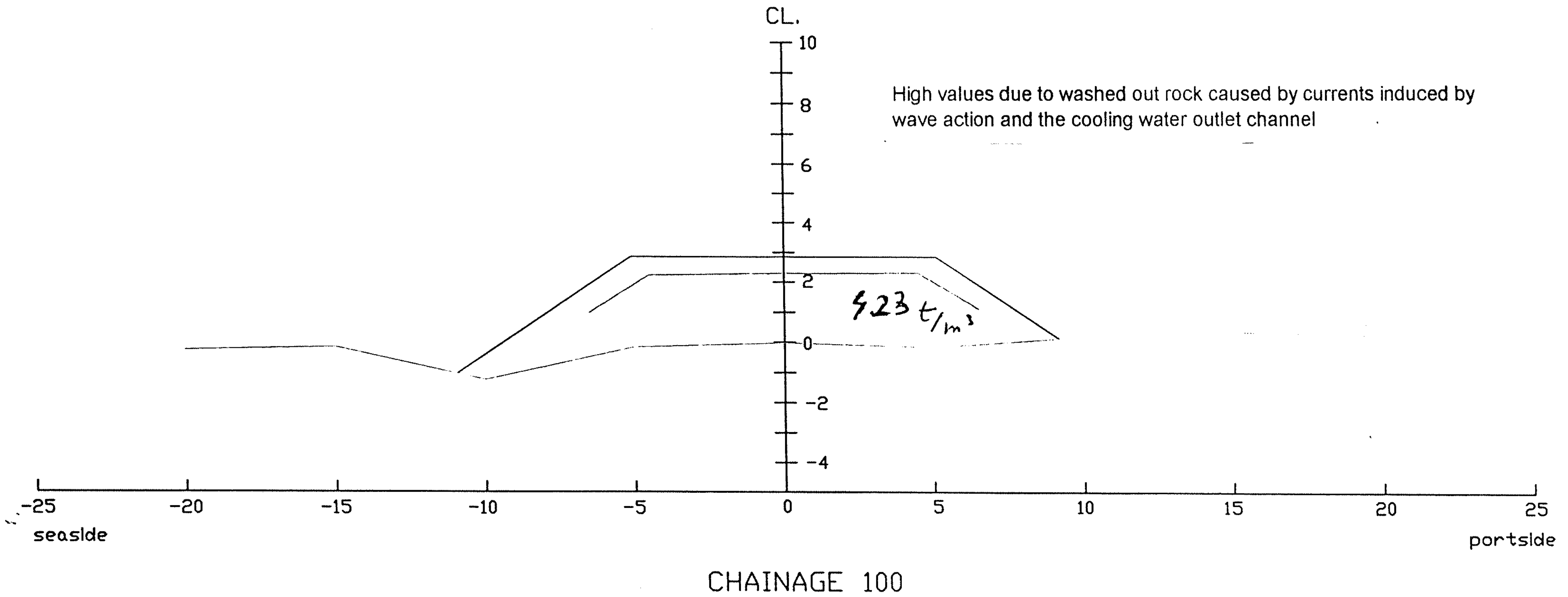
ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 050



CHAINAGE 050

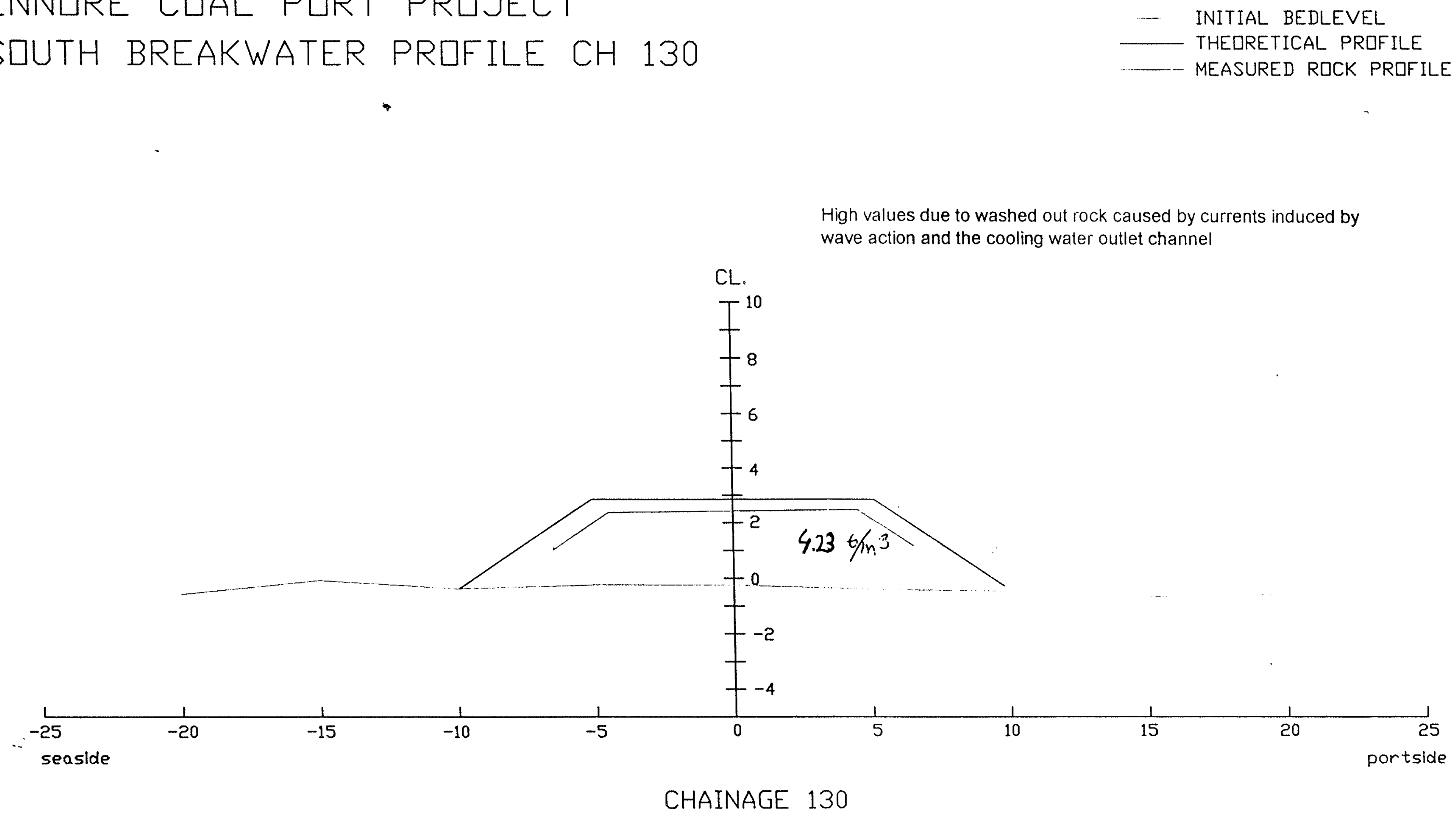
ENNORE COAL PORT PROJECT

SOUTH BREAKWATER PROFILE CH 100

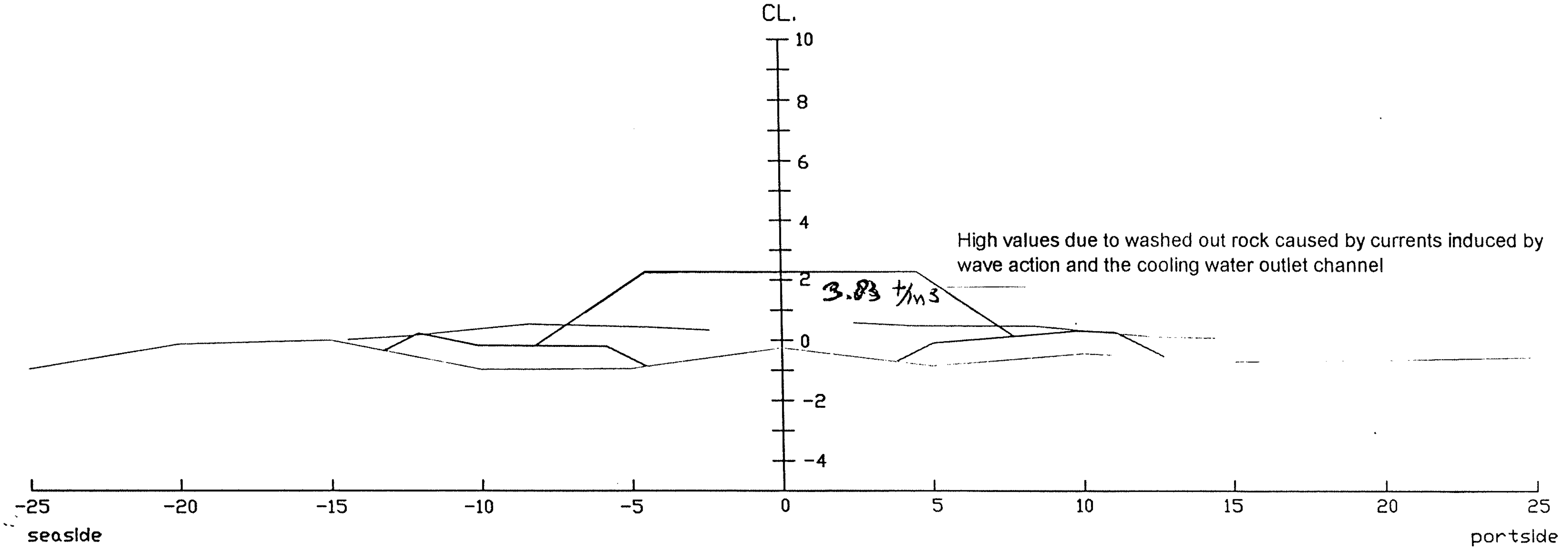


ENNORE COAL PORT PROJECT

SOUTH BREAKWATER PROFILE CH 130

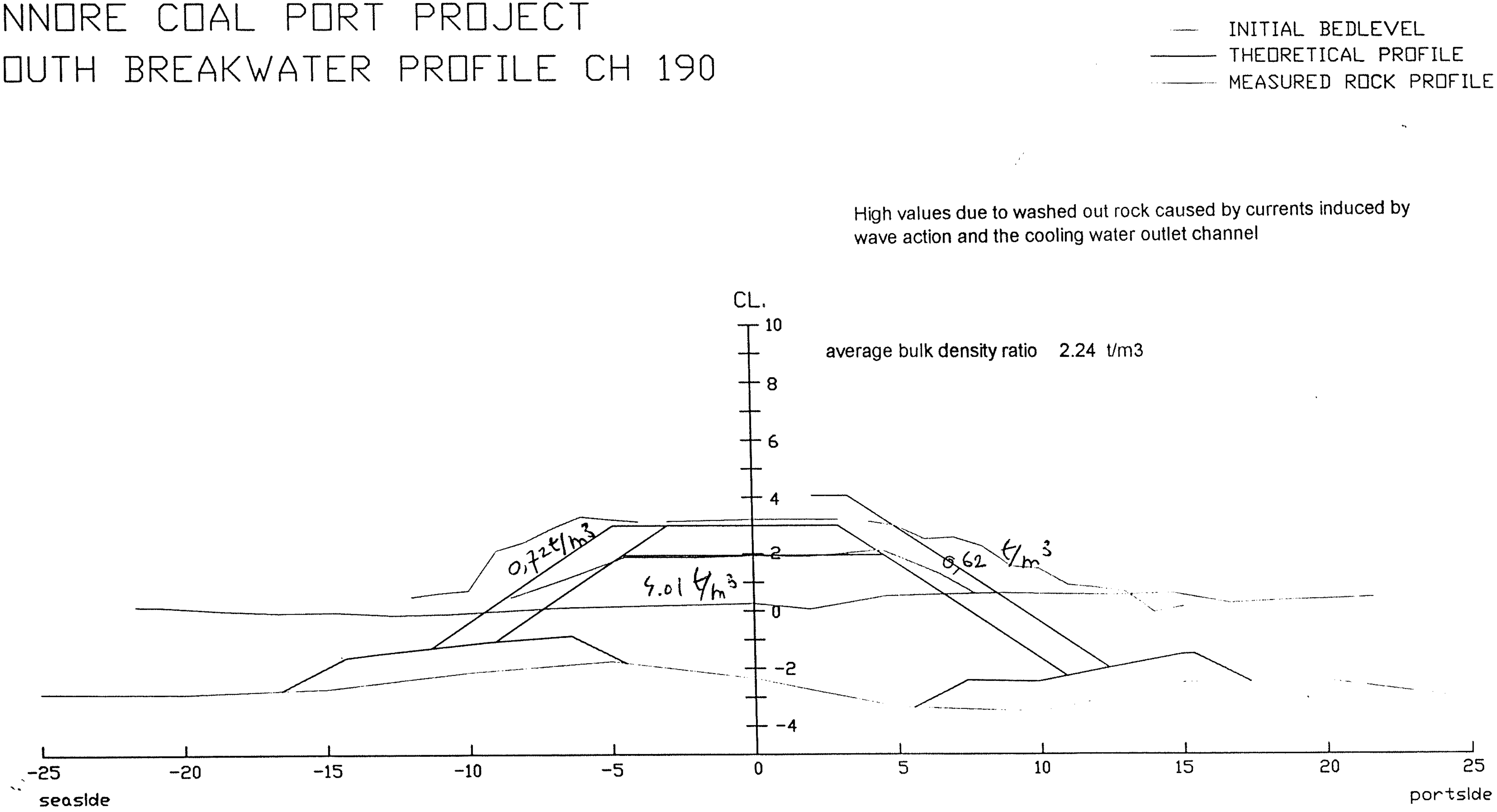


ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 150



CHAINAGE 150
TRANSITION ZONE

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 190



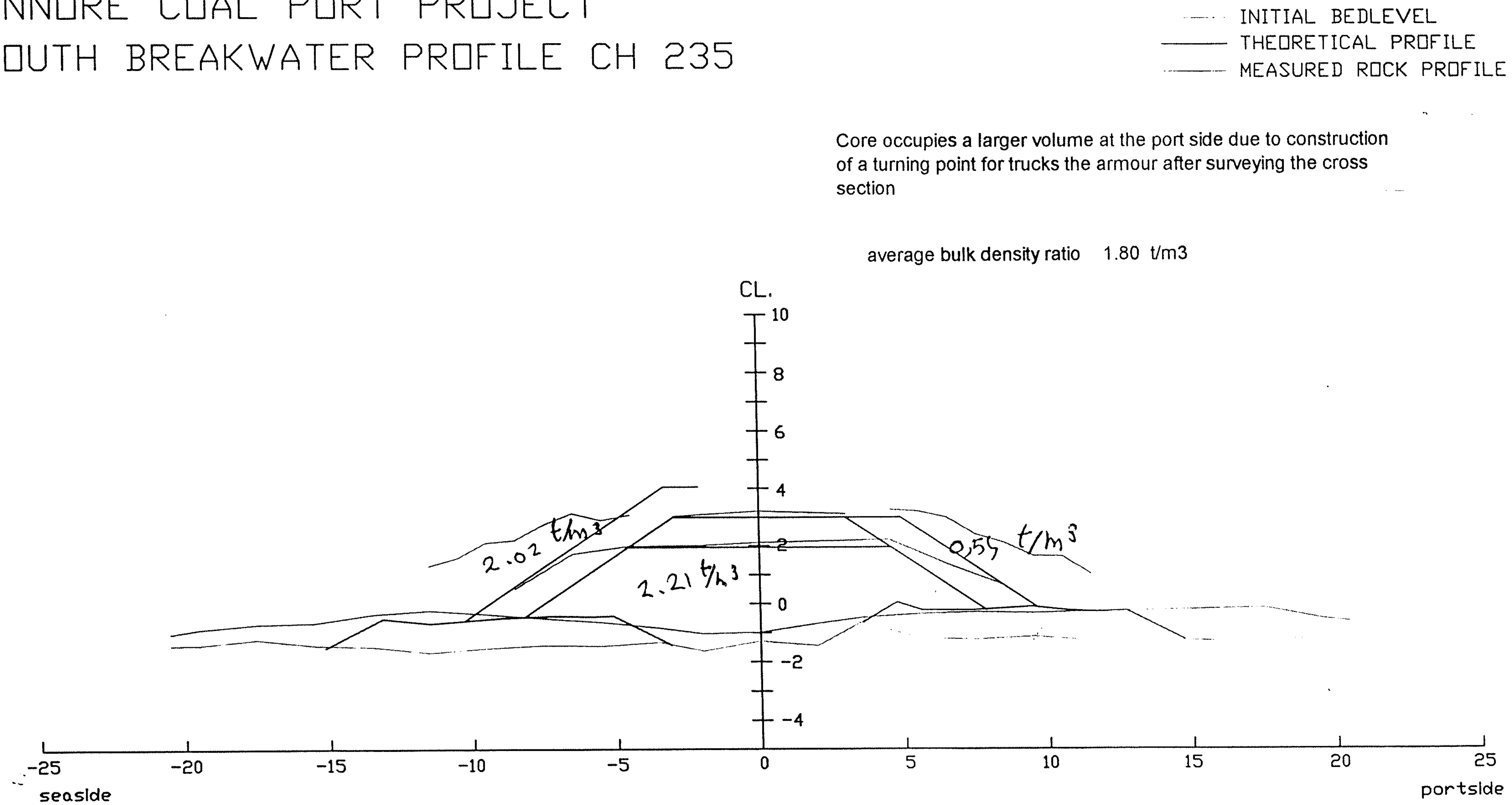
CHAINAGE 190

G-G

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 235

Core occupies a larger volume at the port side due to construction of a turning point for trucks the armour after surveying the cross section

average bulk density ratio 1.80 t/m3

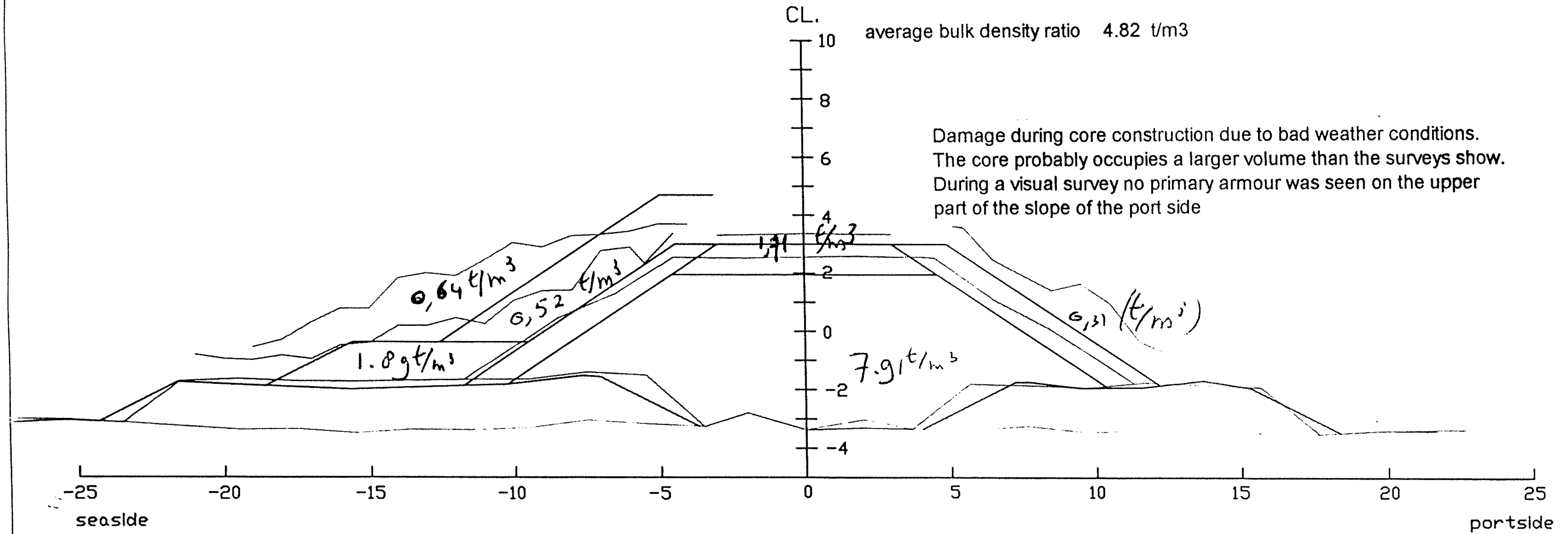


CHAINAGE 235

ENNORE COAL PORT PROJECT

SOUTH BREAKWATER PROFILE CH 275

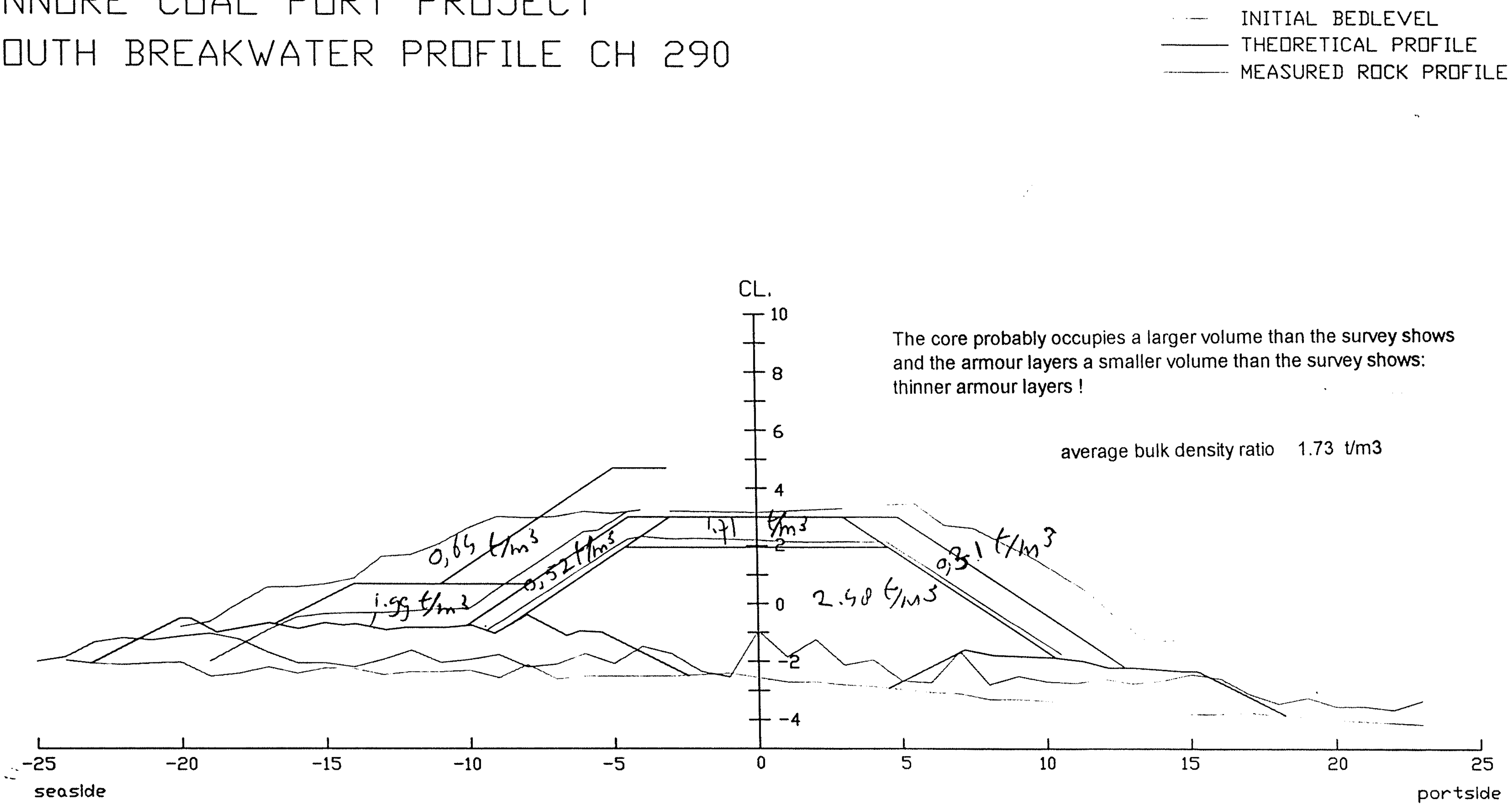
- INITIAL BEDLEVEL
- THEORETICAL PROFILE
- MEASURED ROCK PROFILE



CHAINAGE 275

F-F

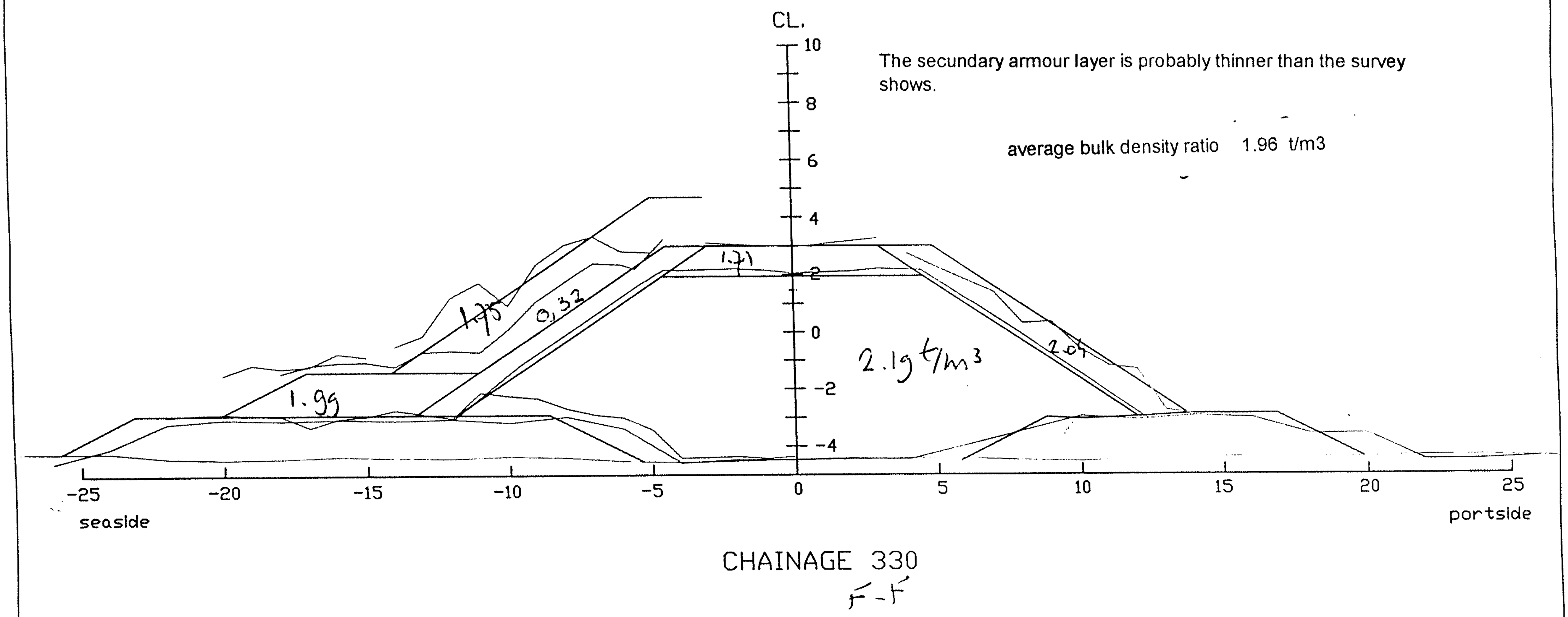
ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 290



CHAINAGE 290

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 330

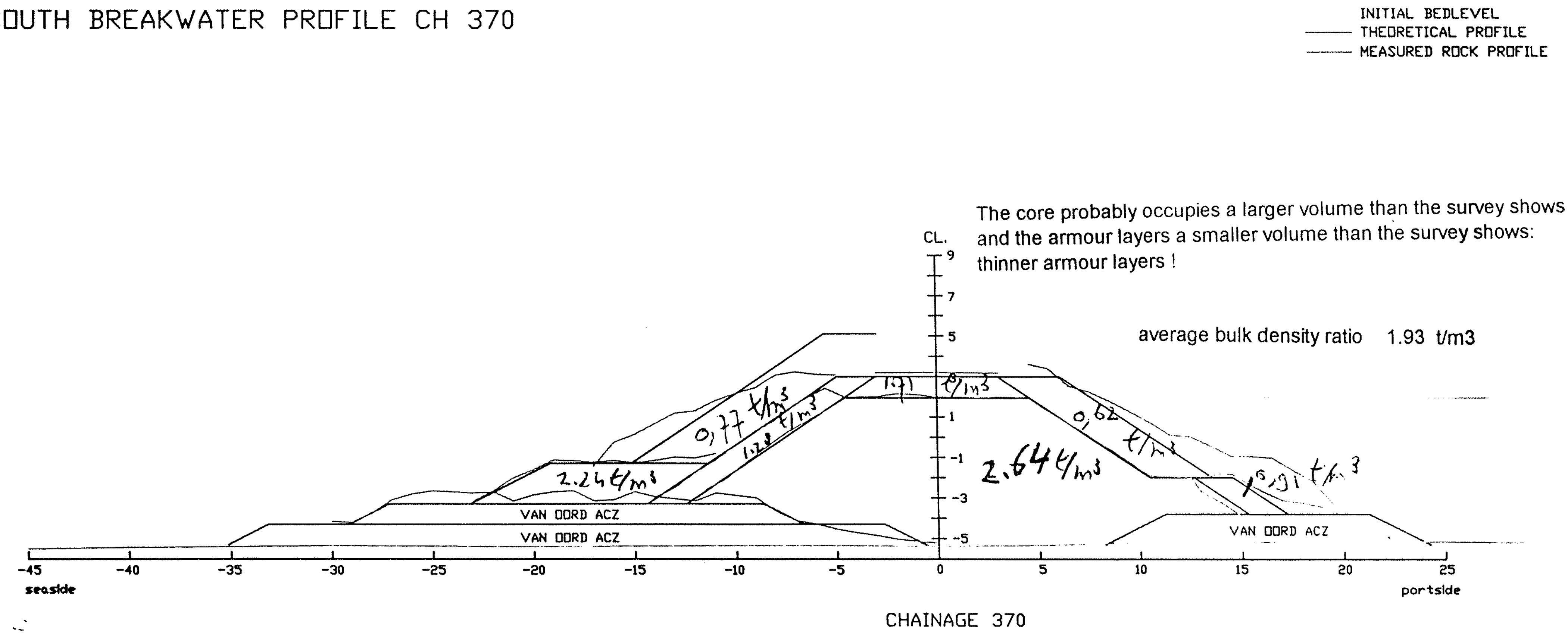
INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE



ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 370

The core probably occupies a larger volume than the survey shows and the armour layers a smaller volume than the survey shows: thinner armour layers !

average bulk density ratio 1.93 t/m3



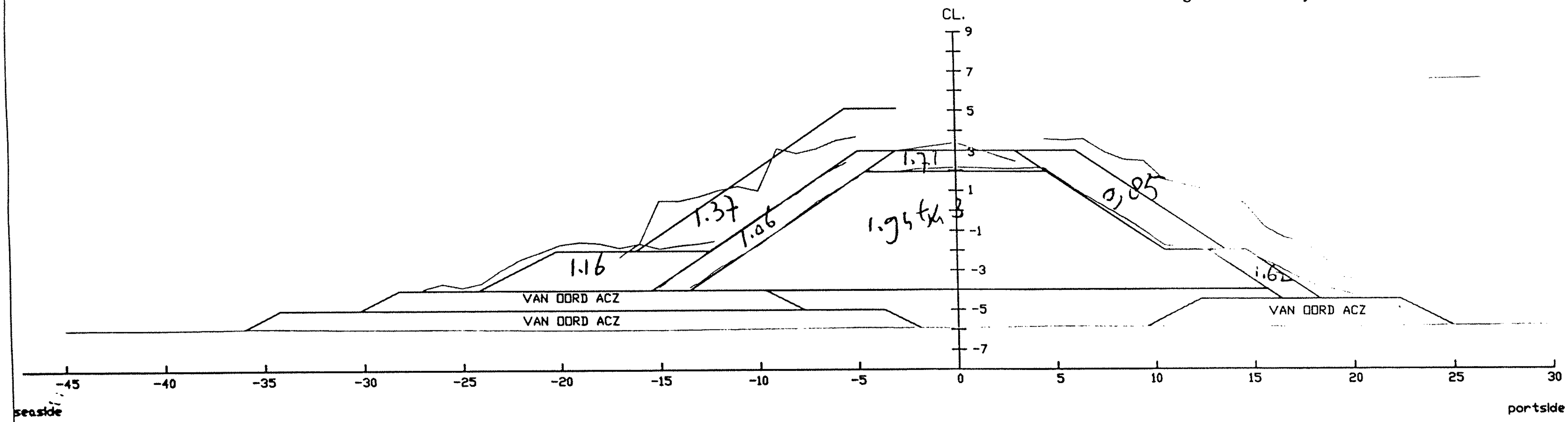
6 t

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 430

INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

Core occupies a larger volume at the port side, during a visual inspection core material was visible throug the port side armour layer

average bulk density ratio 1.55 t/m3



CHAINAGE 430

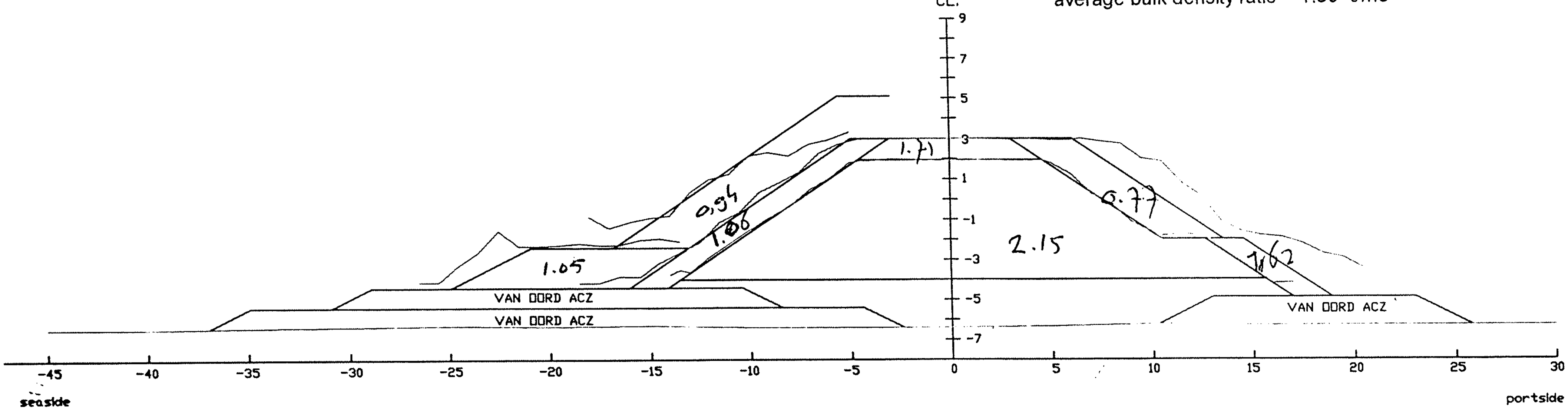
1.55

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 500

INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

Core occupies a larger volume and the armour layers are thinner than surveys show .During a visual inspection core material was visible throug the port side armour layer

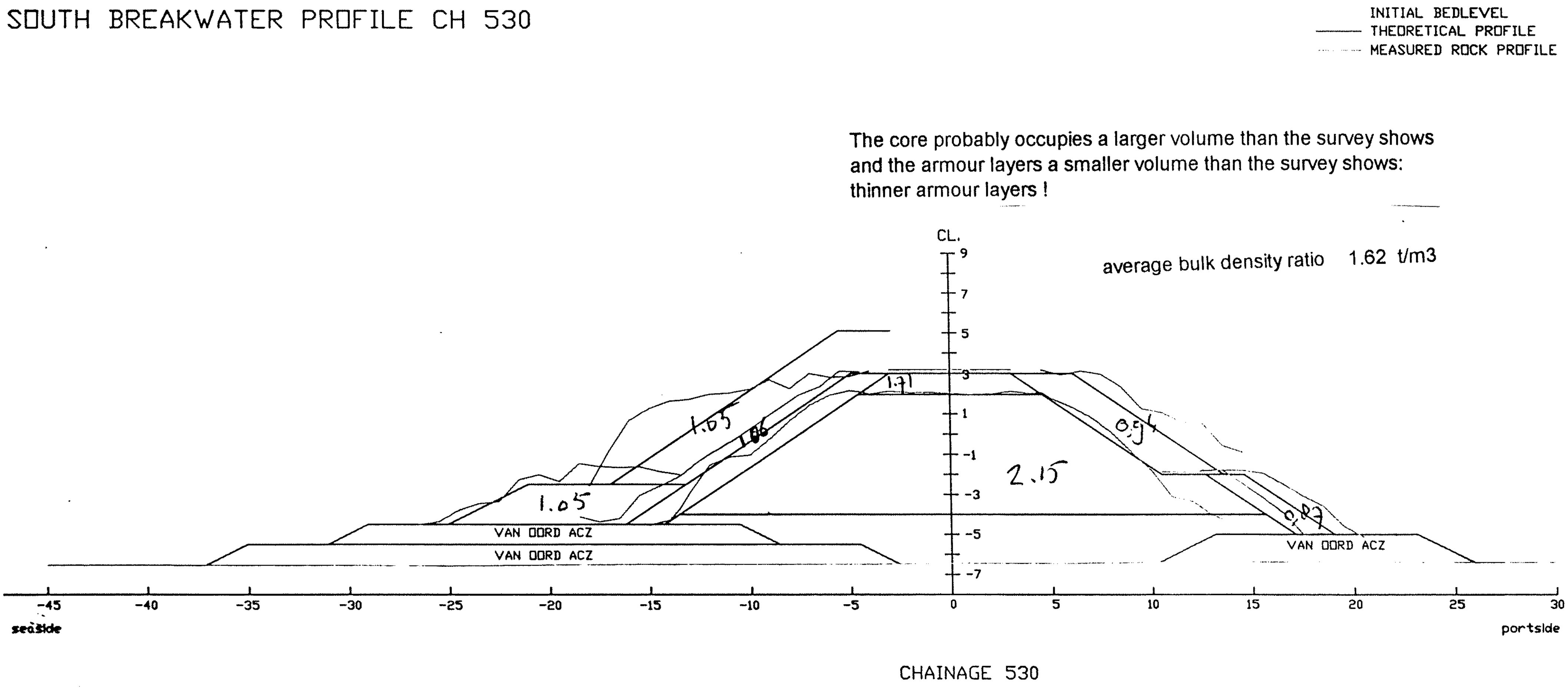
average bulk density ratio 1.59 t/m3



CHAINAGE 500

ENNORE COAL PORT PROJECT

SOUTH BREAKWATER PROFILE CH 530

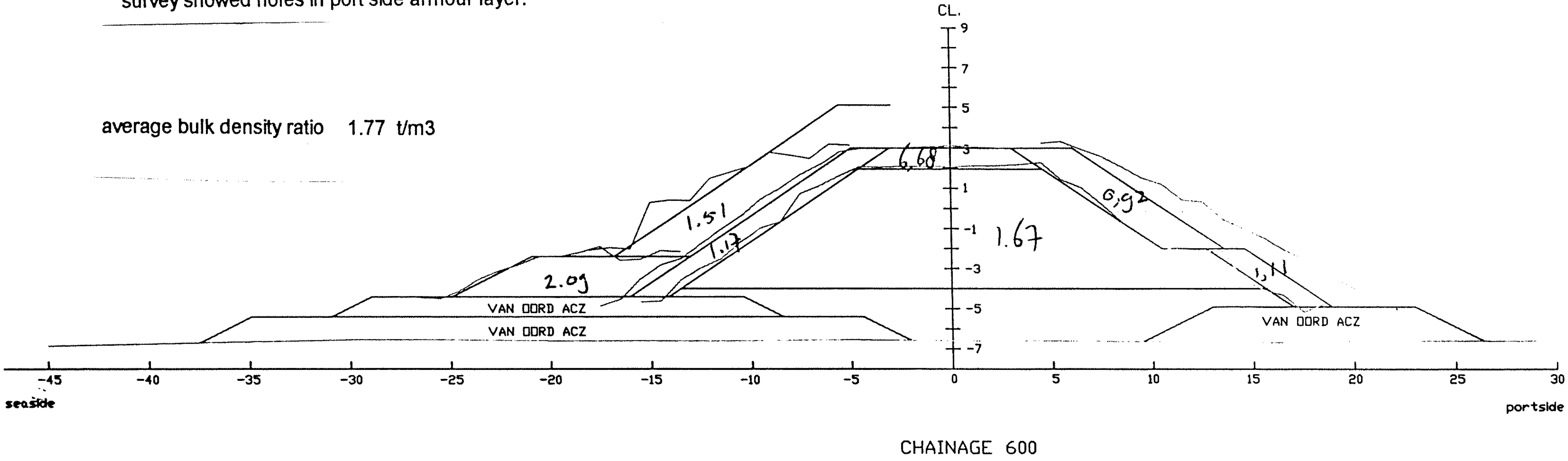


ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 600

INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

Fine material on the core topping was partly washed out. Visual survey showed holes in port side armour layer.

average bulk density ratio 1.77 t/m3

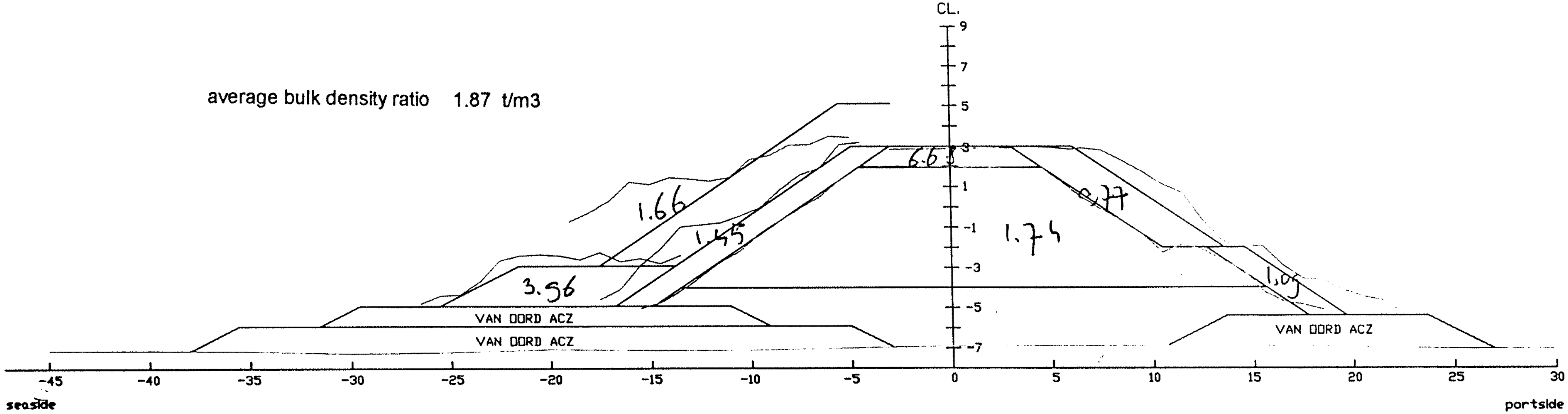


ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 680

INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

Fine material on the core topping was partly washed out. Visual survey showed wrongly placed armour layer on the port side. Toe probably larger than survey shows

average bulk density ratio 1.87 t/m3



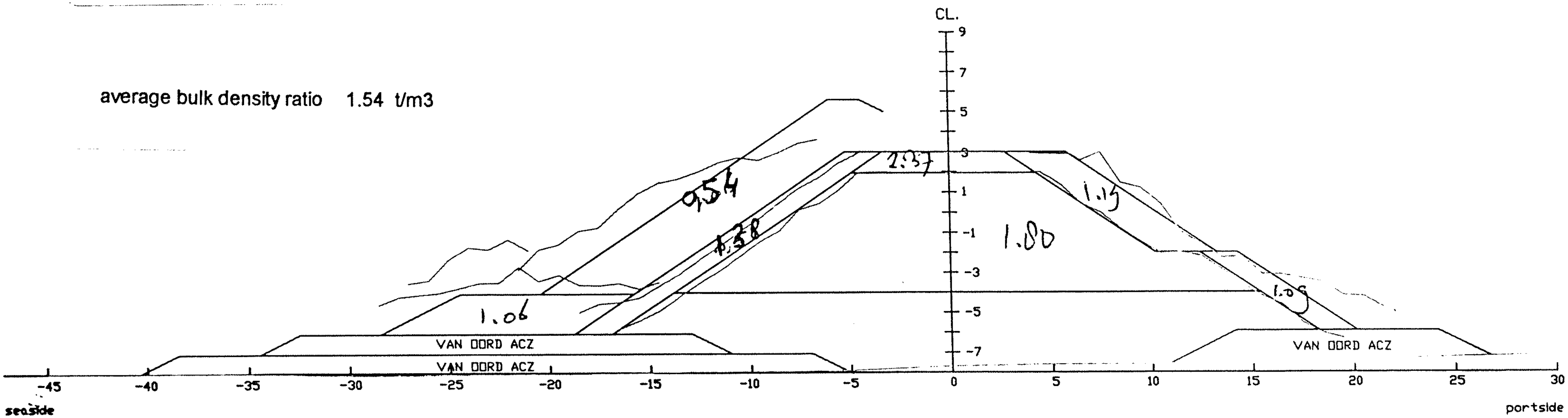
CHAINAGE 680

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 720

INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

All values except core topping are low, no irregularities spotted during visual inspection

average bulk density ratio 1.54 t/m3



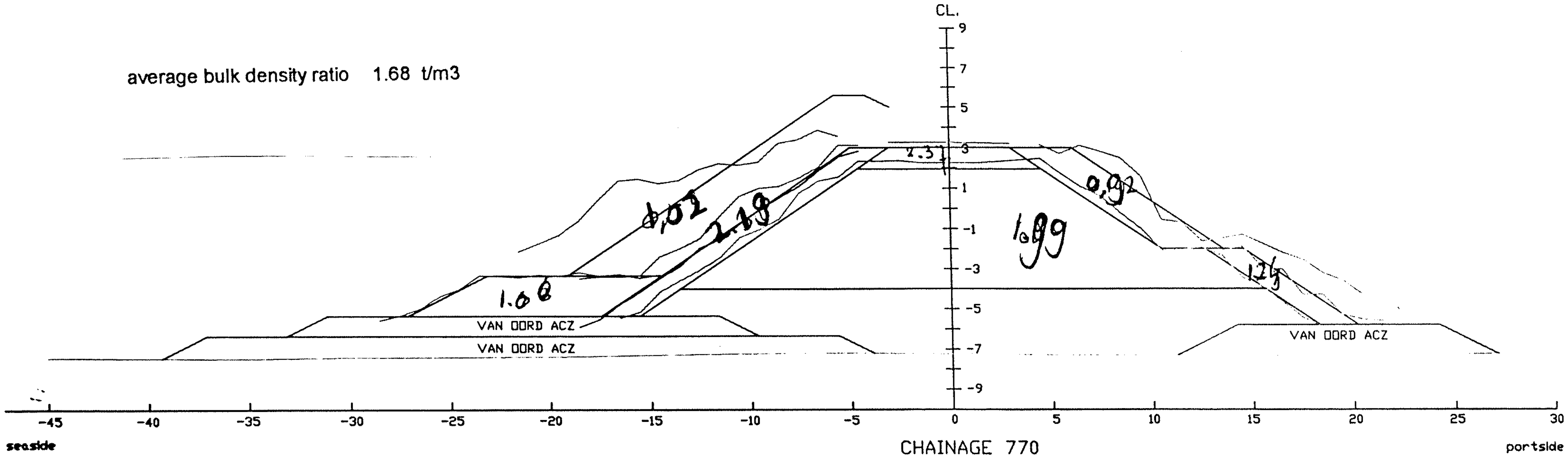
CHAINAGE 720

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 770

INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

Core and secundary armour layer probably occupy a larger volume and the other armour layers probably are thinner than surveys show.

average bulk density ratio 1.68 t/m3



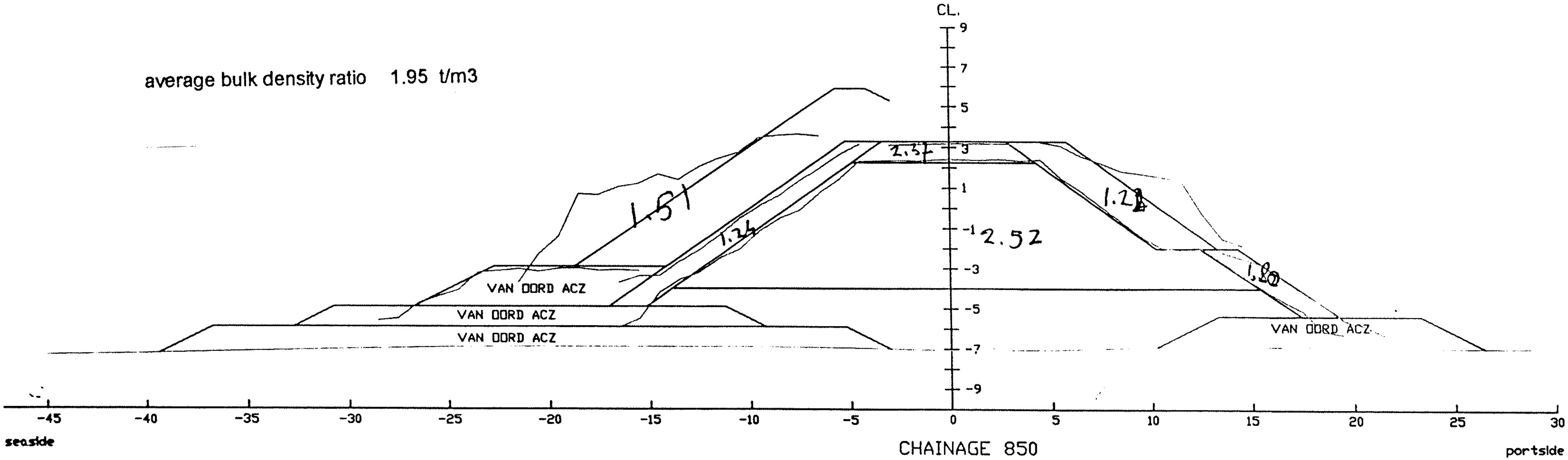
ENNORE COAL PORT PROJECT

SOUTH BREAKWATER PROFILE CH 850

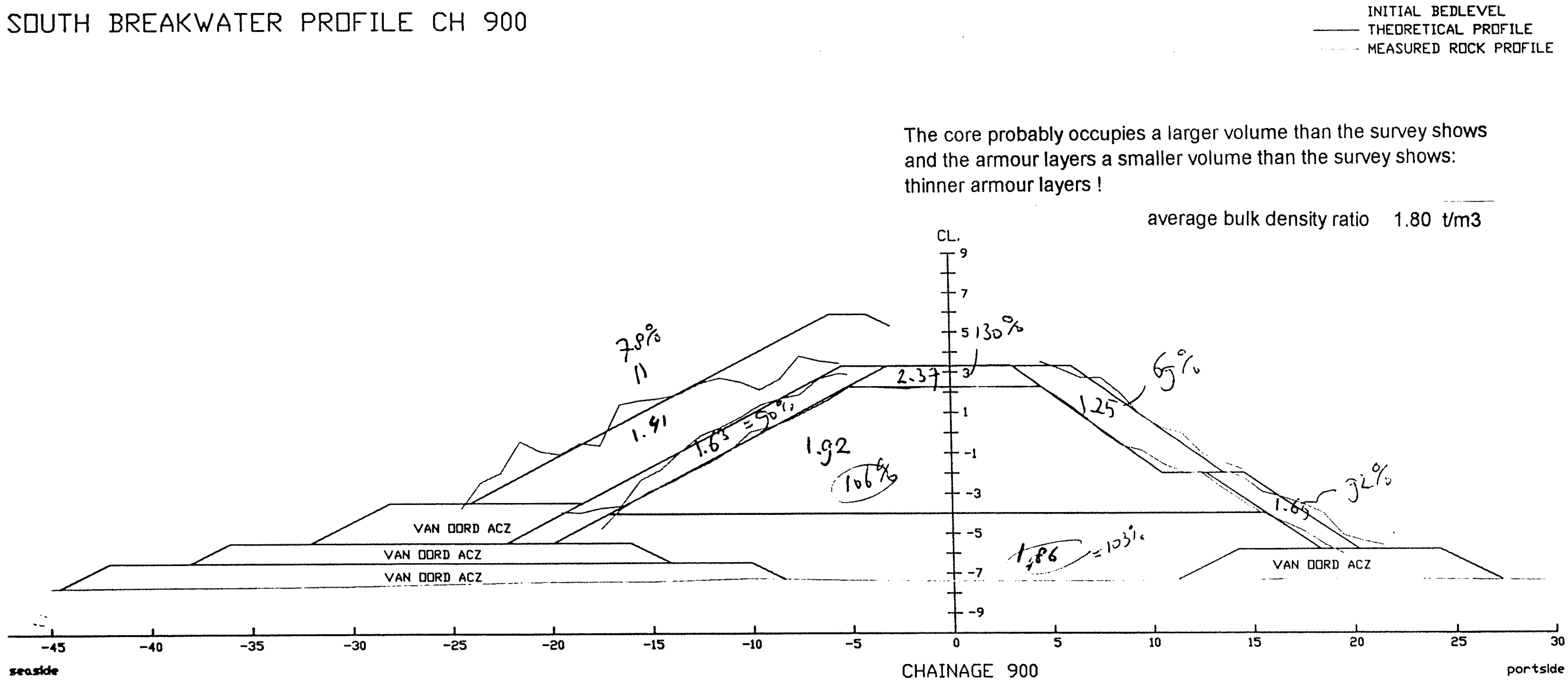
INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

The core probably occupies a larger volume than the survey shows
and the armour layers a smaller volume than the survey shows:
thinner primary and lower armour layers !

average bulk density ratio 1.95 t/m3



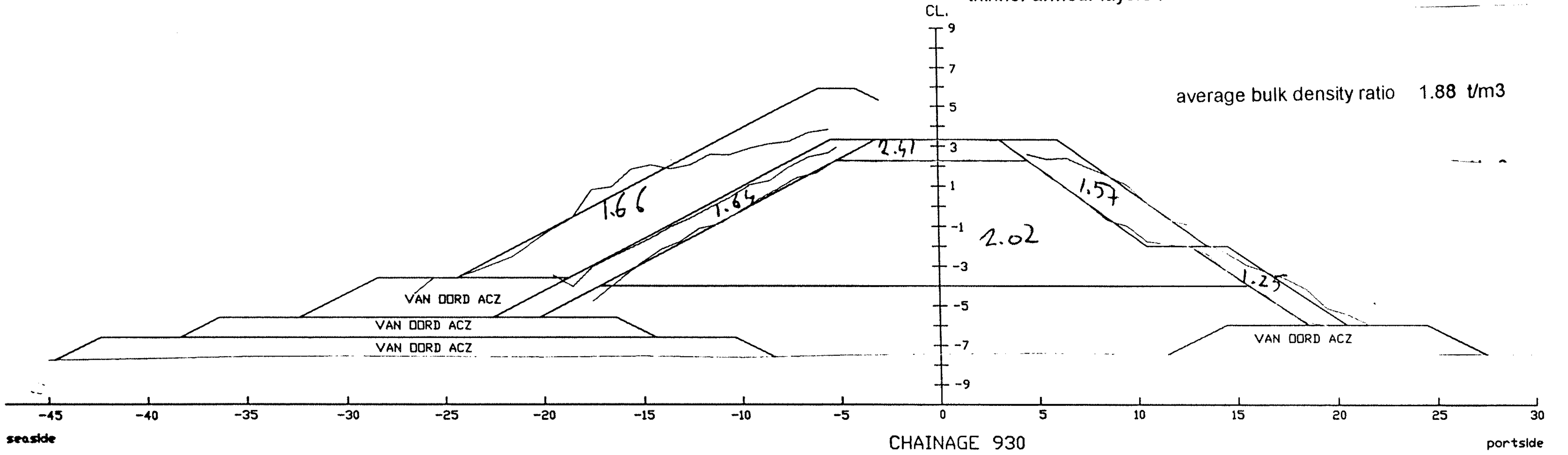
ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 900



ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 930

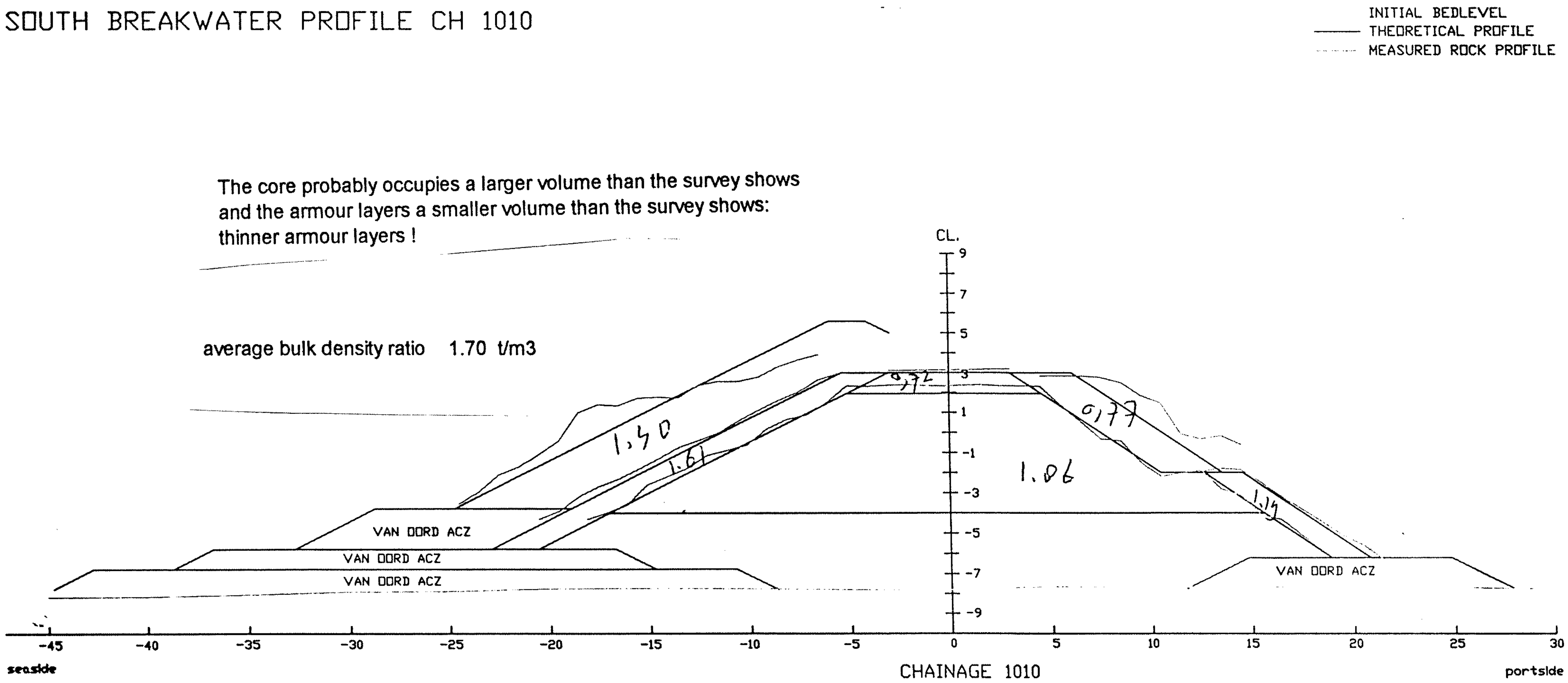
INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE

The core probably occupies a larger volume than the survey shows and the armour layers a smaller volume than the survey shows: thinner armour layers !



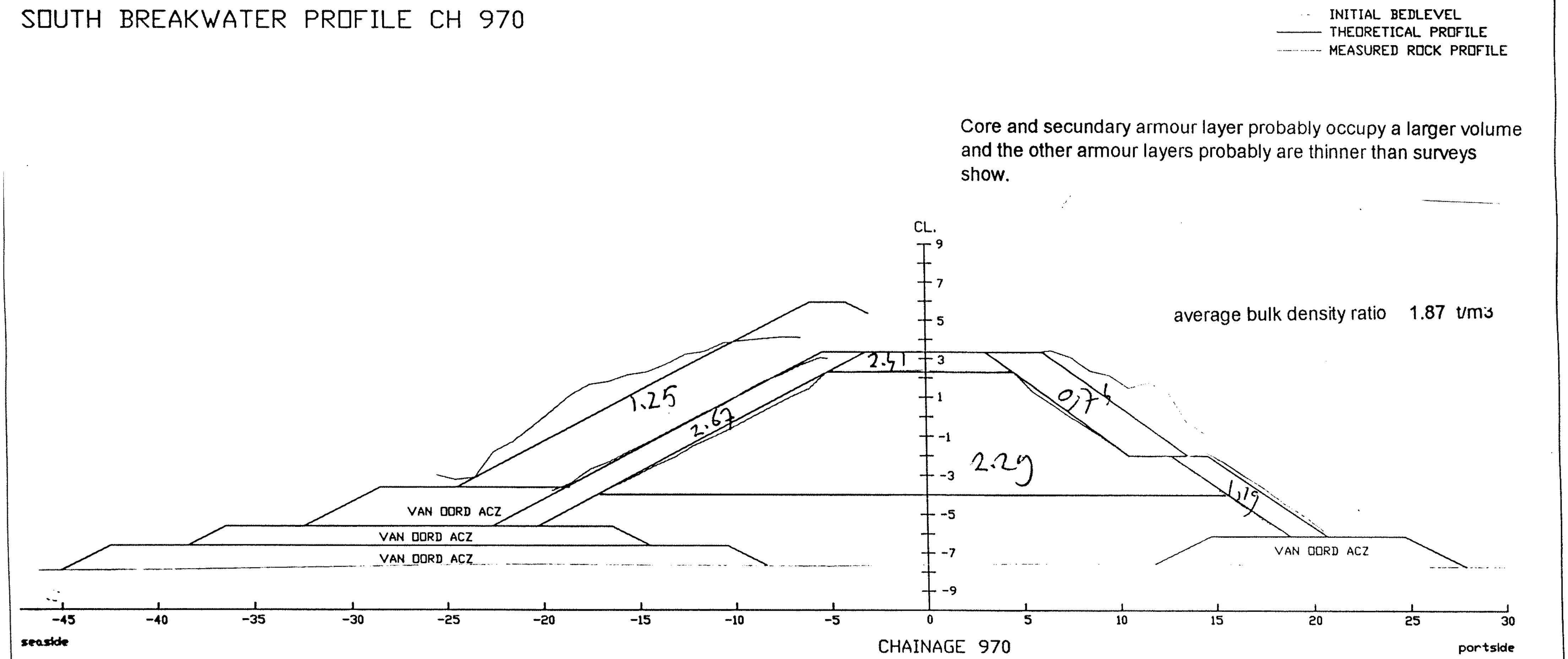
ENNORE COAL PORT PROJECT

SOUTH BREAKWATER PROFILE CH 1010

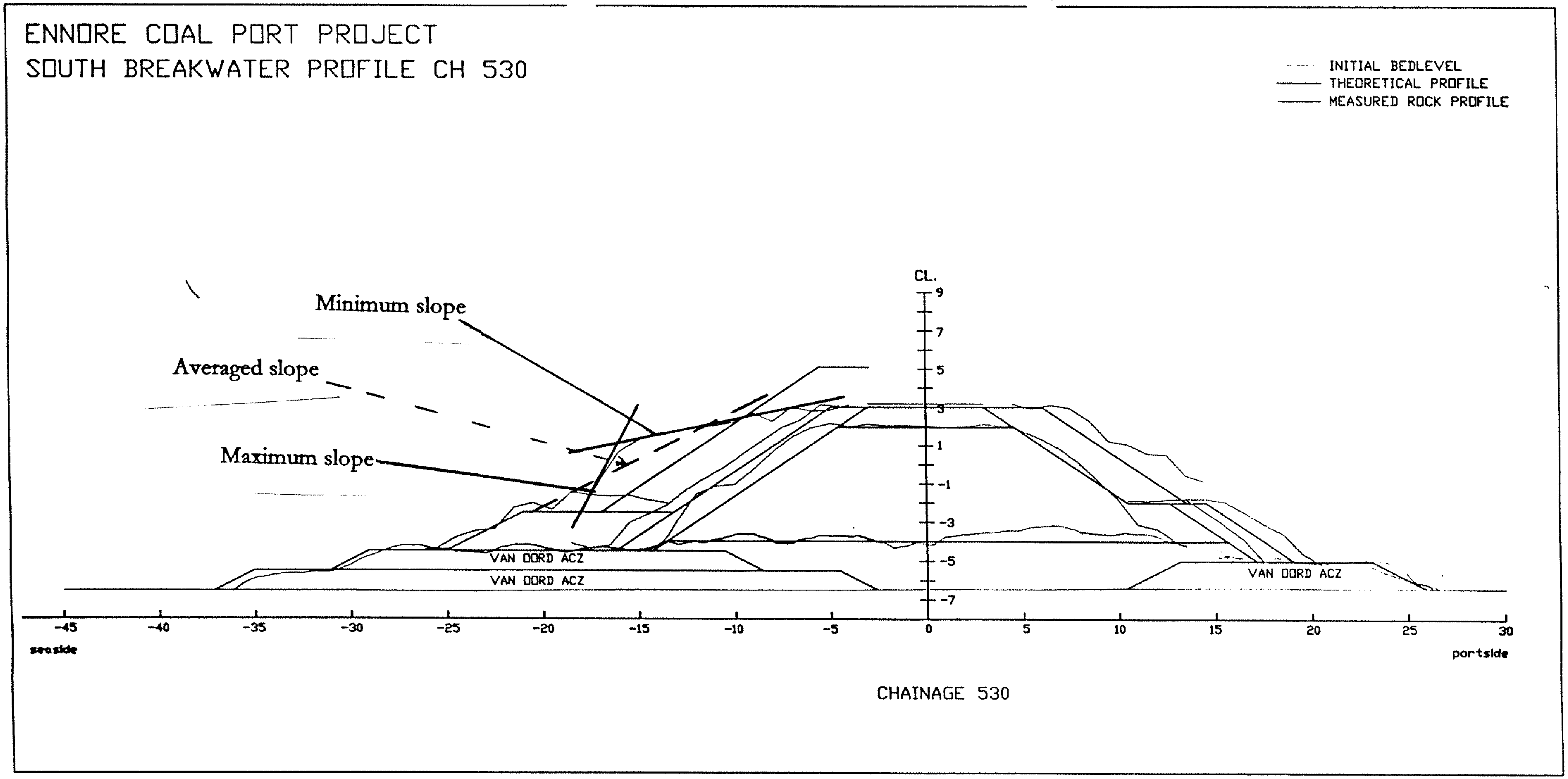


ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 970

Core and secundary armour layer probably occupy a larger volume and the other armour layers probably are thinner than surveys show.



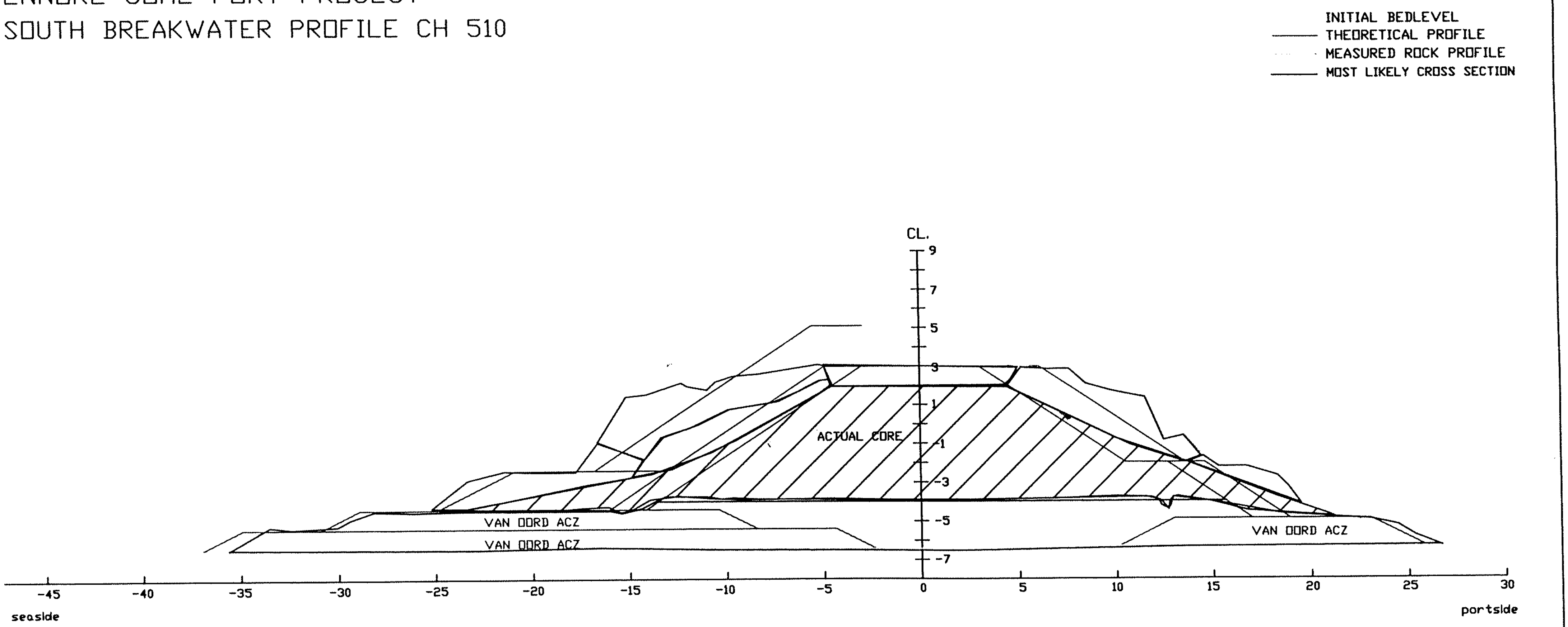
XI.II : Example of cross slope angle determination (chainage 530)



ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 530
INITIAL BEDLEVEL
THEORETICAL PROFILE
MEASURED ROCK PROFILE
Minimum slope
Averaged slope
Maximum slope
CL.
VAN OORD ACZ
VAN OORD ACZ
VAN OORD ACZ
seaside
portside
CHAINAGE 530

XI.III : Possible actual cross section by combining available data

ENNORE COAL PORT PROJECT
SOUTH BREAKWATER PROFILE CH 510



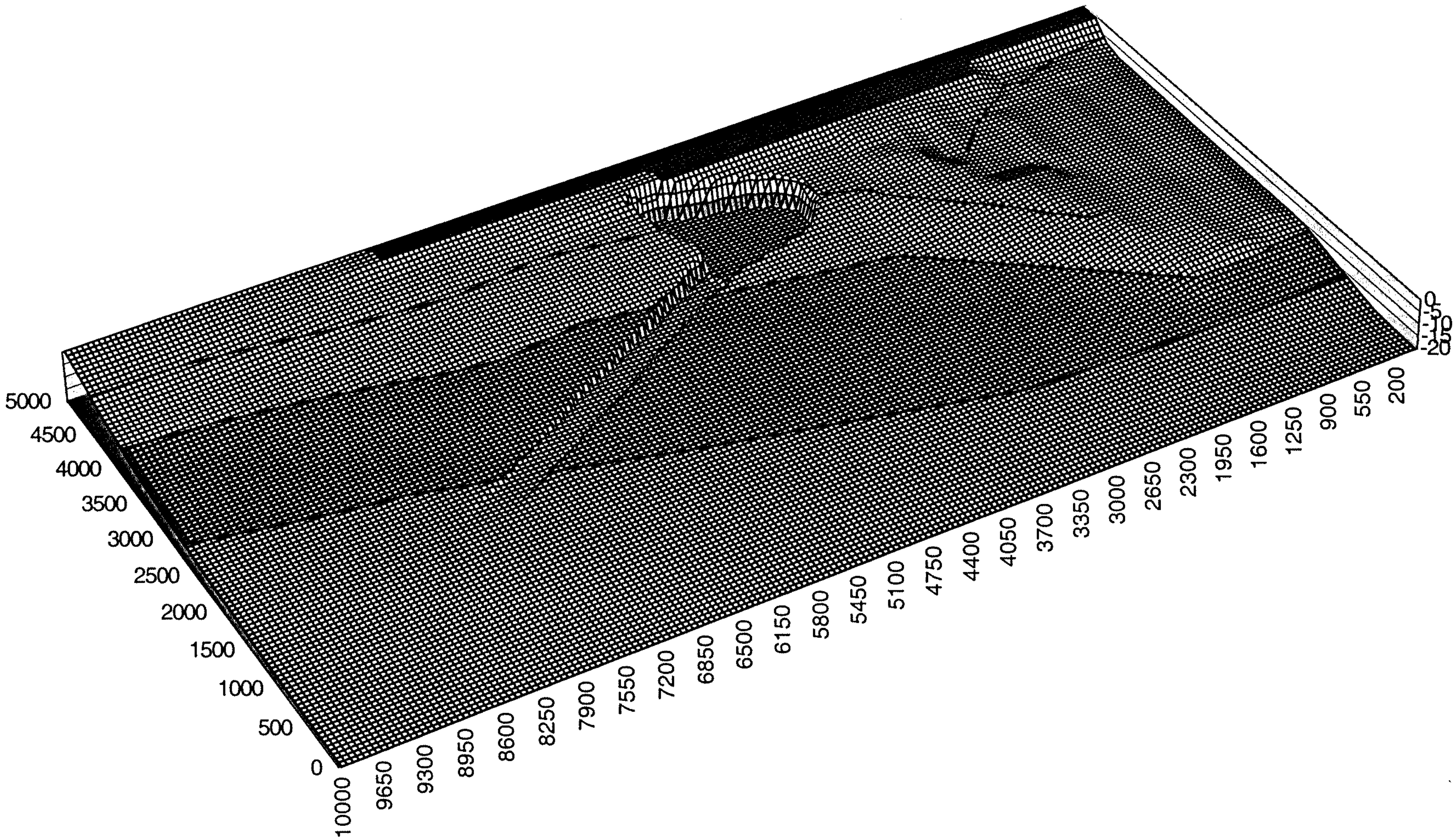
CHAINAGE 510

APPENDIX XII: Hiswa calculations

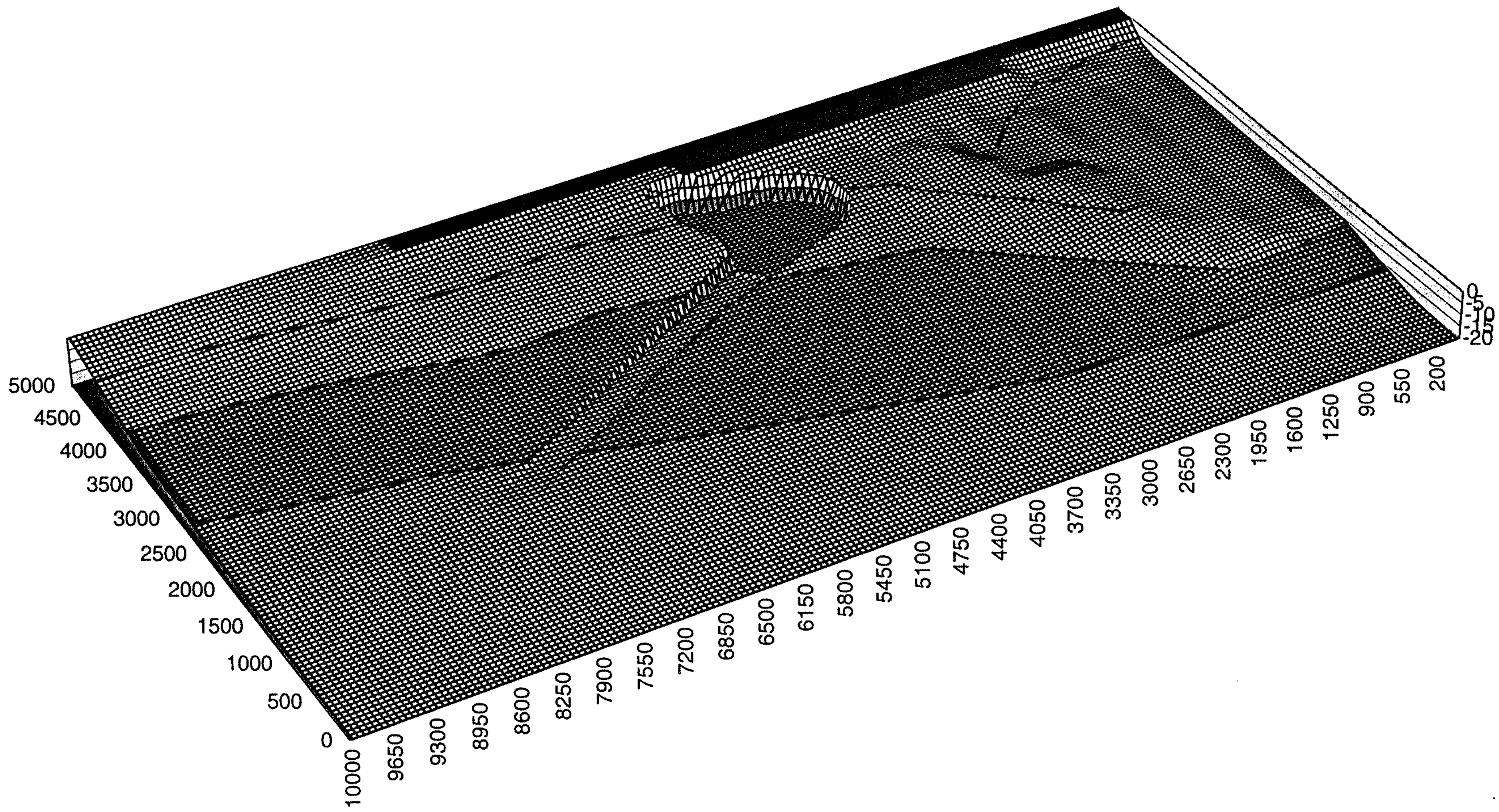
XII.I	: Bottom profiles (old and new alignment)
XII.II	: Program listings (1 for old alignment, 1 for new alignment)
XII.III	: Input data for Hiswa calculations
XII.IV	: Selected output locations
XII.V	: Results of the computations
XII.VI	: Significant wave height comparison for old and new alignment

XII.I : Bottom profiles (old and new alignment)

ORIGINAL ALIGNMENT BOTTOM PROFILE



NEW ALIGNMENT BOTTOM PROFILE



XII.II : Program listings (1 for old alignment, 1 for new alignment)

PROGRAM LISTING FOR HISWA CALCULATION RUN O1

```
$
$*********Heading************
$
PROJ 'ECPP' 'O1'
 'EXTREME WAVE CONDITIONS'
 'Hs=3.69 m Tm=7.44 dir=77.6 degr N level 1.4 m +CD'
 'wind: 18 m/s 65 degr N'
$
$*************Model input*****
$
SET LEVEL = 1.40
input grid BOTTOM 0., 0., 0., 100, 200, 50., 50.
READ BOTTOM 'D:\HISWA\OLD.BOT' 1., 1, 0, FREE
GRID 5000., 10000., 120., 200, 200, 24 FIXED 0., 0., 0.
INC PAR 3.69, 7.44, 26.20, 5.
BOUNDARY LEFT EXT
BOUNDARY RIGHT EXT
WIND 18., 38.8
OBST DAM 5.4, 2.6, 0.15, LINE 3126., 4990., 3369., 4589., 3380.,
4558., &
3384., 4383., 3391., 4199., 3448., 3889., 3528., 3660., 3665.,
3472., &
3786., 3400., 4193., 3229., 4583., 3070
$
POINTS 'setO1' 4450., 5200., 4300., 5150., 4200., 5100., &
4050., 5050., 3900., 5000., 3800., 4900., 3700., 4800., 3700., &
4700., 3550., 4650., 3700., 5200., 3700., 5000., 3450., 4850., &
3350., 5000., 3250., 5200., 2800., 5200.
$
$*******Model output****
$
TABLE 'setO1' PAPER HSIGN DIR PERIOD DSPR
STOP
```

PROGRAM LISTING FOR HISWA CALCULATION RUN N1

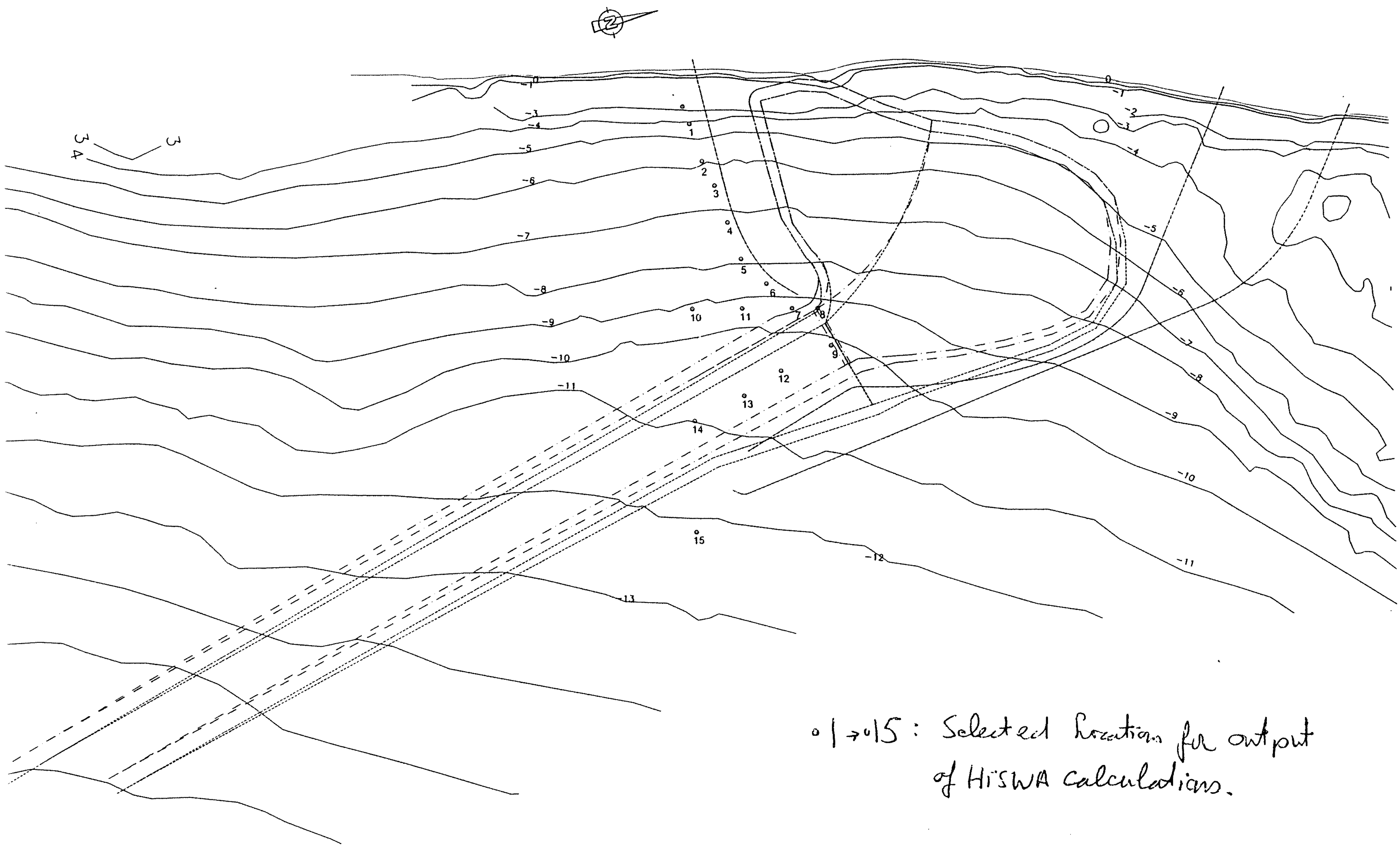
```
$
$*********Heading************
$
PROJ 'ECPP' 'N1'
 'EXTREME WAVE CONDITIONS'
 'Hs=3.69 m Tm=7.44 dir=77.6 degr N level 1.4 m +CD'
 'wind: 18 m/s 65 degr N'
$
$*************Model input*****
$
SET LEVEL = 1.40
input grid BOTTOM 0., 0., 0., 100, 200, 50., 50.
READ BOTTOM 'D:\HISWA\NEW.BOT' 1., 1, 0, FREE
GRID 5000., 10000., 120., 200, 200, 24 FIXED 0., 0., 0.
INC PAR 3.69, 7.44, 26.20, 5.
BOUNDARY LEFT EXT
BOUNDARY RIGHT EXT
WIND 18., 38.8
OBST DAM 5.4, 2.6, 0.15, LINE 2968., 5051., 2952.,5008., &
2983., 4920., 3220., 4333., 3496., 3657., 3706., 3144., &
3851., 2926., 4057., 2766., 4507., 2588
$
POINTS 'setN1' 4450., 5200., 4300., 5150., 4200., 5100., &
4050., 5050., 3900., 5000., 3800., 4900., 3700., 4800., 3700., &
4700., 3550., 4650., 3700., 5200., 3700., 5000., 3450., 4850., &
3350., 5000., 3250., 5200., 2800., 5200.
$
$*******Model outpt****
$
TABLE 'setN1' PAPER HSIGN DIR PERIOD DSPR
STOP
```

XII.III: Input data for Hiswa calculations

INPUT DATA FOR HISWA CALCULATIONS

RUN	Hsig (m)	Tm (s)	Dir-N (degr)	Dir-grid (degr)	ms (-)	Wind (m/s)	Wind dir-grid (degr)	Water level (m) CD
O1	3.69	7.44	77.60	26.20	5	18	38.8	1.40
O2	3.82	7.44	106.70	-2.90	4	18	-6.2	1.40
O3	3.51	7.44	132.40	-28.60	7	18	-51.2	1.40
O4	4.97	8.24	79.80	24.00	6	24	38.8	1.50
O5	5.17	8.24	106.00	-2.20	5	24	-6.2	1.50
O6	4.71	8.24	129.50	-25.70	9	24	-51.2	1.50
O7	6.19	8.88	81.20	22.60	7	30	38.8	1.65
O8	6.42	8.88	105.60	-1.80	5	30	-6.2	1.65
O9	5.85	8.88	127.60	-23.80	10	30	-51.2	1.65
O10	6.9	9.28	82.20	21.60	8	34	38.8	1.75
O11	7.13	9.28	105.30	-1.50	6	34	-6.2	1.75
O12	6.55	9.28	126.00	-22.20	15	34	-51.2	1.75
O13	7.58	9.60	82.80	21.00	8	38	38.8	1.90
O14	7.75	9.60	105.00	-1.20	6	38	-6.2	1.90
O15	7.28	9.60	125.20	-21.40	15	38	-51.2	1.90
N1	3.69	7.44	77.60	26.20	5	18	38.8	1.40
N2	3.82	7.44	106.70	-2.90	4	18	-6.2	1.40
N3	3.51	7.44	132.40	-28.60	7	18	-51.2	1.40
N4	4.97	8.24	79.80	24.00	6	24	38.8	1.50
N5	5.17	8.24	106.00	-2.20	5	24	-6.2	1.50
N6	4.71	8.24	129.50	-25.70	9	24	-51.2	1.50
N7	6.19	8.88	81.20	22.60	7	30	38.8	1.65
N8	6.42	8.88	105.60	-1.80	5	30	-6.2	1.65
N9	5.85	8.88	127.60	-23.80	10	30	-51.2	1.65
N10	6.9	9.28	82.20	21.60	8	34	38.8	1.75
N11	7.13	9.28	105.30	-1.50	6	34	-6.2	1.75
N12	6.55	9.28	126.00	-22.20	15	34	-51.2	1.75
N13	7.58	9.60	82.80	21.00	8	38	38.8	1.90
N14	7.75	9.60	105.00	-1.20	6	38	-6.2	1.90
N15	7.28	9.60	125.20	-21.40	15	38	-51.2	1.90

XII.IV : Selected output locations



°1 → °15 : Selected location for output of HISWA calculations.

XII.V : Results of the computations

EXTREME WAVE CONDITIONS RP=5
Hs=3.69 m Tm=7.44 dir=77.6 degr N level 1.4 m +CD
wind: 18 m/s 65 degr N

Table: set01

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.307	3.13	7.457	15.63
2	2.406	1.33	7.457	14.69
3	2.313	-0.10	7.456	13.75
4	2.147	-1.87	7.456	11.74
5	1.946	-3.06	7.456	11.52
6	1.383	-4.73	7.455	14.07
7	1.090	-8.94	7.455	17.09
8	0.908	-14.62	7.455	25.11
9	0.755	-11.50	7.455	30.99
10	2.907	6.91	7.458	12.40
11	2.032	-0.78	7.456	13.26
12	1.060	-19.89	7.454	24.98
13	2.153	-7.46	7.455	17.91
14	3.667	13.58	7.458	21.04
15	3.579	16.57	7.457	17.48

EXTREME WAVE CONDITIONS RP=5
Hs=3.69 m Tm=7.44 dir=77.6 degr N level 1.4 m +CD
wind: 18 m/s 65 degr N

Table: setN1

Loc	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.226	1.10	7.456	15.95
2	2.191	-0.71	7.456	15.37
3	2.041	-1.94	7.456	14.90
4	1.845	-3.88	7.456	13.36
5	1.621	-5.38	7.455	13.06
6	1.209	-5.43	7.455	15.93
7	0.962	-2.74	7.454	19.34
8	0.809	1.69	7.454	22.52
9	0.722	-8.99	7.454	30.66
10	2.364	1.27	7.457	11.76
11	1.538	-4.93	7.455	13.81
12	0.969	-16.34	7.454	25.76
13	1.465	-15.04	7.454	17.97
14	3.089	6.12	7.458	16.98
15	3.579	16.57	7.457	17.48

EXTREME WAVE CONDITIONS RP=5
Hs=3.82 m Tm=7.44 dir=106.7 degr N level 1.4 m +CD
wind: 18 m/s 110 degr N

Table: set02

Loc	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.431	-1.44	7.463	19.56
2	2.744	-3.74	7.463	18.60
3	2.875	-5.60	7.463	16.88
4	2.969	-8.32	7.463	12.86
5	2.956	-9.01	7.463	12.03
6	2.433	-11.89	7.463	11.99
7	2.052	-18.24	7.463	11.92
8	1.873	-31.95	7.464	14.07
9	1.531	-42.39	7.462	18.20
10	3.400	-3.76	7.462	15.14
11	3.101	-7.51	7.463	13.86
12	2.235	-35.78	7.462	15.04
13	3.316	-21.94	7.461	18.33
14	3.838	-10.58	7.460	23.68
15	3.803	-4.85	7.458	20.74

EXTREME WAVE CONDITIONS RP=5
Hs=3.82 m Tm=7.44 dir=106.7 degr N level 1.4 m +CD
wind: 18 m/s 110 degr N

Table: setN2

Loc	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.424	-2.73	7.463	19.78
2	2.727	-5.26	7.463	18.96
3	2.842	-7.30	7.463	17.42
4	2.882	-10.71	7.463	13.00
5	2.771	-12.26	7.463	11.62
6	2.292	-14.40	7.463	11.99
7	1.920	-14.08	7.463	13.11
8	1.612	-15.82	7.463	14.68
9	1.638	-39.79	7.463	16.91
10	3.230	-7.74	7.463	13.73
11	2.709	-12.12	7.463	12.29
12	2.176	-34.54	7.463	14.66
13	2.788	-27.23	7.462	15.11
14	3.700	-12.43	7.461	20.84
15	3.803	-4.85	7.458	20.74

EXTREME WAVE CONDITIONS RP=5
Hs=3.51 m Tm=7.44 dir=132.4 degr N level 1.4 m +CD
wind: 18 m/s 155 degr N

Table: set03

Loc	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.450	-8.81	7.462	21.12
2	2.777	-11.41	7.462	19.78
3	2.921	-12.78	7.462	18.07
4	3.019	-15.14	7.462	13.56
5	3.014	-14.43	7.462	12.76
6	2.701	-15.73	7.463	11.69
7	2.389	-21.40	7.464	10.52
8	2.372	-36.17	7.466	10.05
9	2.056	-48.50	7.466	9.28
10	3.070	-15.49	7.462	13.80
11	3.099	-13.22	7.462	13.72
12	2.829	-40.56	7.464	11.58
13	3.493	-32.34	7.461	16.04
14	3.490	-31.04	7.461	16.90
15	3.524	-24.63	7.458	15.93

EXTREME WAVE CONDITIONS RP=5
Hs=3.51 m Tm=7.44 dir=132.4 degr N level 1.4 m +CD
wind: 18 m/s 155 degr N

Table: setN3

Loc	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.447	-9.27	7.462	21.43
2	2.776	-11.94	7.462	20.28
3	2.924	-13.36	7.463	18.81
4	3.024	-16.37	7.463	13.76
5	3.002	-16.94	7.463	11.96
6	2.665	-18.24	7.464	11.25
7	2.309	-17.25	7.465	11.37
8	2.019	-19.58	7.466	11.66
9	2.259	-45.10	7.467	9.32
10	3.141	-16.70	7.462	13.29
11	2.978	-16.38	7.463	12.26
12	2.824	-39.26	7.465	11.22
13	3.253	-33.94	7.463	13.74
14	3.489	-29.69	7.462	16.73
15	3.524	-24.63	7.458	15.93

EXTREME WAVE CONDITIONS RP=10
Hs=4.97 m Tm=8.24 dir=79.8 degr N level 1.5 m +CD
wind: 24 m/s 65 degr N

Table: set04

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.523	5.46	8.251	16.54
2	2.816	4.22	8.251	16.32
3	2.902	2.51	8.251	15.32
4	2.880	-0.23	8.251	12.40
5	2.688	-1.64	8.251	12.02
6	1.969	-1.94	8.250	14.76
7	1.603	-5.06	8.250	17.26
8	1.340	-9.28	8.250	24.54
9	1.211	-5.87	8.249	27.50
10	3.784	7.12	8.251	12.22
11	2.812	0.70	8.250	13.78
12	1.574	-12.70	8.249	26.27
13	2.894	-6.47	8.249	18.46
14	4.642	11.04	8.250	20.41
15	4.656	14.89	8.249	16.48

EXTREME WAVE CONDITIONS RP=10
Hs=4.97 m Tm=8.24 dir=79.8 degr N level 1.5 m +CD
wind: 24 m/s 65 degr N

Table: setN4

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.508	3.98	8.251	16.96
2	2.758	2.68	8.251	17.16
3	2.775	1.27	8.251	16.82
4	2.612	-1.32	8.251	14.94
5	2.312	-2.80	8.250	14.34
6	1.785	-1.08	8.250	16.98
7	1.475	2.96	8.249	19.39
8	1.310	7.16	8.249	20.65
9	1.191	-1.55	8.249	27.32
10	3.248	2.33	8.251	12.08
11	2.185	-2.15	8.250	15.03
12	1.460	-8.37	8.249	26.71
13	2.061	-11.30	8.250	20.04
14	4.083	5.53	8.251	16.69
15	4.656	14.89	8.249	16.48

EXTREME WAVE CONDITIONS RP=10
Hs=5.17 m Tm=8.24 dir=106.0 degr N level 1.5 m +CD
wind: 24 m/s 110 degr N

Table: set05

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.592	0.49	8.257	20.08
2	2.951	-1.64	8.257	19.22
3	3.134	-3.41	8.257	17.64
4	3.338	-6.64	8.257	12.86
5	3.513	-7.61	8.257	11.81
6	3.122	-10.34	8.258	12.12
7	2.663	-16.60	8.258	12.36
8	2.367	-30.12	8.259	15.29
9	1.951	-38.87	8.257	20.56
10	4.096	-3.26	8.256	14.40
11	3.927	-6.37	8.257	13.91
12	2.821	-33.92	8.257	16.63
13	4.192	-21.33	8.255	18.21
14	4.787	-11.91	8.254	22.23
15	4.842	-4.66	8.251	18.89

EXTREME WAVE CONDITIONS RP=10
Hs=5.17 m Tm=8.24 dir=106.0 degr N level 1.5 m +CD
wind: 24 m/s 110 degr N

Table: setN5

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.587	-0.46	8.258	20.26
2	2.942	-2.77	8.257	19.53
3	3.123	-4.63	8.257	18.20
4	3.304	-8.43	8.257	13.39
5	3.392	-10.37	8.258	11.55
6	2.985	-12.42	8.258	12.37
7	2.534	-11.80	8.258	13.90
8	2.135	-12.87	8.258	15.58
9	2.104	-35.99	8.259	19.73
10	3.968	-6.43	8.257	13.31
11	3.498	-10.61	8.258	12.37
12	2.777	-32.46	8.258	16.31
13	3.590	-25.85	8.257	15.59
14	4.722	-12.65	8.256	19.98
15	4.842	-4.66	8.251	18.89

EXTREME WAVE CONDITIONS RP=10
Hs=4.71 m Tm=8.24 dir=129.5 degr N level 1.5 m +CD
wind: 24 m/s 155 degr N

Table: set06

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.614	-6.63	8.260	21.48
2	2.989	-9.20	8.259	20.16
3	3.190	-10.66	8.259	18.37
4	3.430	-13.46	8.259	13.15
5	3.654	-13.21	8.259	12.27
6	3.527	-14.41	8.260	11.55
7	3.235	-20.36	8.260	10.63
8	3.115	-35.27	8.263	10.40
9	2.664	-47.65	8.263	10.48
10	3.957	-14.39	8.259	13.03
11	4.062	-12.40	8.258	13.62
12	3.719	-39.90	8.260	11.86
13	4.630	-32.01	8.257	15.76
14	4.636	-30.89	8.258	16.19
15	4.655	-22.93	8.254	14.74

EXTREME WAVE CONDITIONS RP=10
Hs=4.71 m Tm=8.24 dir=129.5 degr N level 1.5 m +CD
wind: 24 m/s 155 degr N

Table: setN6

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.610	-6.93	8.260	21.79
2	2.986	-9.52	8.260	20.68
3	3.188	-11.05	8.260	19.09
4	3.422	-14.40	8.260	13.58
5	3.616	-15.31	8.260	11.47
6	3.479	-16.57	8.261	11.03
7	3.157	-15.89	8.261	11.53
8	2.746	-18.05	8.263	12.00
9	2.956	-44.00	8.265	10.42
10	4.017	-15.38	8.259	12.66
11	3.890	-15.10	8.260	12.02
12	3.749	-38.39	8.262	11.41
13	4.361	-33.10	8.260	13.57
14	4.672	-29.29	8.259	15.97
15	4.655	-22.93	8.254	14.74

EXTREME WAVE CONDITIONS RP=25
Hs=6.19 m Tm=8.88 dir=81.2 degr N level 1.65 m +CD
wind: 30 m/s 65 degr N

Table: set07

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.670	6.22	8.884	16.82
2	2.999	5.23	8.884	16.81
3	3.127	3.57	8.884	15.85
4	3.179	0.49	8.884	12.47
5	3.035	-1.09	8.884	11.88
6	2.252	-1.13	8.884	14.53
7	1.841	-4.16	8.884	16.71
8	1.532	-8.12	8.884	23.77
9	1.408	-5.21	8.883	26.05
10	4.153	7.10	8.884	11.98
11	3.207	1.31	8.884	13.73
12	1.799	-11.02	8.882	25.65
13	3.247	-6.13	8.883	18.15
14	5.029	9.17	8.883	19.65
15	5.149	13.55	8.882	15.54

EXTREME WAVE CONDITIONS RP=25
Hs=6.19 m Tm=8.88 dir=81.2 degr N level 1.65 m +CD
wind: 30 m/s 65 degr N

Table: setN7

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.661	5.00	8.885	17.19
2	2.968	4.02	8.884	17.61
3	3.054	2.61	8.884	17.27
4	2.968	-0.41	8.884	14.96
5	2.658	-1.99	8.884	14.19
6	2.069	0.15	8.884	16.61
7	1.727	4.34	8.883	18.58
8	1.548	7.87	8.883	19.35
9	1.404	-0.57	8.883	25.39
10	3.679	2.87	8.885	11.95
11	2.511	-1.26	8.884	14.87
12	1.688	-6.28	8.883	25.72
13	2.349	-9.91	8.883	19.96
14	4.556	5.06	8.884	16.23
15	5.149	13.55	8.882	15.54

EXTREME WAVE CONDITIONS RP=25
Hs=6.42 m Tm=8.88 dir=105.6 degr N level 1.65 m +CD
wind: 30 m/s 110 degr N

Table: set08

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.734	1.07	8.889	20.35
2	3.106	-1.01	8.889	19.58
3	3.300	-2.79	8.889	18.02
4	3.523	-6.20	8.889	13.03
5	3.735	-7.20	8.889	11.86
6	3.394	-9.79	8.890	12.23
7	2.924	-15.99	8.891	12.53
8	2.576	-29.47	8.893	15.75
9	2.144	-37.85	8.891	21.14
10	4.367	-3.18	8.888	14.26
11	4.243	-5.98	8.889	14.02
12	3.066	-33.48	8.889	17.17
13	4.531	-21.36	8.887	18.30
14	5.152	-12.52	8.886	21.96
15	5.259	-4.65	8.883	18.45

EXTREME WAVE CONDITIONS RP=25
Hs=6.42 m Tm=8.88 dir=105.6 degr N level 1.65 m +CD
wind: 30 m/s 110 degr N

Table: setN8

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.729	0.21	8.890	20.54
2	3.098	-2.02	8.890	19.89
3	3.291	-3.87	8.890	18.60
4	3.495	-7.78	8.890	13.73
5	3.625	-9.76	8.890	11.69
6	3.271	-11.69	8.891	12.57
7	2.807	-10.93	8.891	14.17
8	2.374	-11.80	8.891	15.80
9	2.323	-34.81	8.892	20.41
10	4.244	-6.11	8.889	13.30
11	3.803	-10.08	8.890	12.49
12	3.040	-31.85	8.892	16.92
13	3.919	-25.58	8.890	15.88
14	5.120	-12.97	8.888	19.87
15	5.259	-4.65	8.883	18.45

EXTREME WAVE CONDITIONS RP=25
Hs=5.85 m Tm=8.88 dir=127.6 degr N level 1.65 m +CD
wind: 30 m/s 155 degr N

Table: set09

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.757	-5.56	8.894	21.56
2	3.146	-8.11	8.894	20.33
3	3.358	-9.68	8.893	18.45
4	3.624	-12.69	8.893	12.94
5	3.909	-12.57	8.893	12.09
6	3.866	-13.73	8.894	11.51
7	3.631	-19.81	8.894	10.69
8	3.442	-34.85	8.898	10.75
9	2.905	-47.10	8.897	11.26
10	4.325	-13.66	8.893	12.74
11	4.469	-11.92	8.892	13.60
12	4.090	-39.49	8.894	12.12
13	5.150	-31.53	8.891	15.77
14	5.190	-30.39	8.892	16.07
15	5.234	-21.46	8.887	14.19

EXTREME WAVE CONDITIONS RP=25
Hs=5.85 m Tm=8.88 dir=127.6 degr N level 1.65 m +CD
wind: 30 m/s 155 degr N

Table: setN9

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.754	-5.78	8.894	21.86
2	3.143	-8.34	8.894	20.82
3	3.355	-9.95	8.894	19.18
4	3.613	-13.50	8.894	13.45
5	3.859	-14.50	8.894	11.30
6	3.809	-15.70	8.895	10.97
7	3.563	-15.21	8.895	11.64
8	3.094	-17.25	8.897	12.18
9	3.254	-43.27	8.899	11.20
10	4.367	-14.58	8.893	12.42
11	4.261	-14.40	8.894	11.96
12	4.160	-37.87	8.897	11.67
13	4.891	-32.50	8.894	13.59
14	5.279	-28.72	8.893	15.78
15	5.234	-21.46	8.887	14.19

EXTREME WAVE CONDITIONS RP=50
Hs=6.90 m Tm=9.28 dir=82.2 degr N level 1.75 m +CD
wind: 34 m/s 65 degr N

Table: set010

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.759	6.61	9.284	16.89
2	3.101	5.72	9.284	16.94
3	3.241	4.10	9.284	16.01
4	3.312	0.91	9.284	12.45
5	3.187	-0.72	9.284	11.74
6	2.373	-0.59	9.283	14.35
7	1.942	-3.51	9.283	16.37
8	1.610	-7.02	9.283	23.25
9	1.496	-4.42	9.283	24.99
10	4.330	7.16	9.284	11.74
11	3.385	1.73	9.283	13.61
12	1.885	-9.81	9.282	25.21
13	3.399	-5.80	9.282	17.77
14	5.187	8.28	9.283	18.99
15	5.339	12.89	9.281	14.84

EXTREME WAVE CONDITIONS RP=50
Hs=6.90 m Tm=9.28 dir=82.2 degr N level 1.75 m +CD
wind: 34 m/s 65 degr N

Table: setN10

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.750	5.46	9.284	17.20
2	3.076	4.63	9.284	17.71
3	3.178	3.28	9.284	17.40
4	3.115	0.12	9.284	14.91
5	2.799	-1.49	9.284	14.04
6	2.184	0.90	9.283	16.33
7	1.829	5.24	9.283	18.07
8	1.650	8.44	9.282	18.56
9	1.493	0.32	9.282	24.10
10	3.870	3.23	9.284	11.74
11	2.640	-0.72	9.283	14.67
12	1.770	-4.92	9.282	24.98
13	2.453	-9.07	9.283	19.67
14	4.763	4.96	9.284	15.77
15	5.339	12.89	9.281	14.84

EXTREME WAVE CONDITIONS RP=50
Hs=7.13 m Tm=9.28 dir=105.3 degr N level 1.75 m +CD
wind: 34 m/s 110 degr N

Table: set011

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.825	1.62	9.288	20.28
2	3.206	-0.40	9.287	19.54
3	3.404	-2.18	9.287	17.98
4	3.635	-5.65	9.287	12.83
5	3.870	-6.66	9.287	11.65
6	3.541	-9.16	9.288	12.08
7	3.051	-15.38	9.289	12.45
8	2.643	-28.49	9.290	15.89
9	2.198	-36.26	9.288	21.49
10	4.526	-2.90	9.287	13.81
11	4.436	-5.42	9.287	13.85
12	3.149	-32.52	9.287	17.33
13	4.725	-20.59	9.285	17.92
14	5.320	-12.58	9.285	20.93
15	5.438	-4.37	9.281	17.20

EXTREME WAVE CONDITIONS RP=50
Hs=7.13 m Tm=9.28 dir=105.3 degr N level 1.75 m +CD
wind: 34 m/s 110 degr N

Table: setN11

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.820	0.81	9.288	20.44
2	3.197	-1.35	9.288	19.83
3	3.394	-3.19	9.288	18.52
4	3.605	-7.13	9.288	13.57
5	3.751	-9.12	9.288	11.46
6	3.403	-10.96	9.289	12.42
7	2.924	-10.20	9.289	14.14
8	2.460	-10.87	9.289	15.73
9	2.364	-33.10	9.289	20.88
10	4.404	-5.57	9.288	12.95
11	3.959	-9.43	9.288	12.29
12	3.107	-30.73	9.289	17.07
13	4.064	-24.65	9.288	15.62
14	5.321	-12.56	9.287	19.09
15	5.438	-4.37	9.281	17.20

EXTREME WAVE CONDITIONS RP=50
Hs=6.55 m Tm=9.28 dir=126.00 degr N level 1.75 m +CD
wind: 34 m/s 155 degr N

Table: set012

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.850	-5.09	9.291	21.47
2	3.248	-7.63	9.291	20.22
3	3.465	-9.26	9.291	18.28
4	3.741	-12.38	9.290	12.48
5	4.064	-12.26	9.290	11.69
6	4.078	-13.21	9.291	11.25
7	3.921	-19.39	9.292	10.51
8	3.629	-34.08	9.294	10.60
9	2.993	-46.32	9.293	11.39
10	4.496	-13.67	9.290	11.87
11	4.712	-11.80	9.290	13.29
12	4.317	-38.63	9.290	11.92
13	5.476	-31.01	9.287	15.02
14	5.460	-30.22	9.288	14.88
15	5.451	-20.46	9.283	12.22

EXTREME WAVE CONDITIONS RP=50
Hs=6.55 m Tm=9.28 dir=126.00 degr N level 1.75 m +CD
wind: 34 m/s 155 degr N

Table: setN12

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.847	-5.22	9.291	21.71
2	3.244	-7.73	9.291	20.67
3	3.462	-9.37	9.291	19.00
4	3.730	-12.99	9.291	13.04
5	4.007	-13.95	9.291	10.89
6	4.006	-15.00	9.292	10.65
7	3.835	-14.72	9.292	11.46
8	3.305	-16.72	9.293	12.04
9	3.341	-42.36	9.295	11.29
10	4.543	-14.38	9.291	11.71
11	4.483	-13.88	9.291	11.65
12	4.381	-36.84	9.293	11.39
13	5.220	-31.47	9.290	13.03
14	5.566	-28.40	9.290	14.51
15	5.451	-20.46	9.283	12.22

EXTREME WAVE CONDITIONS RP=100
Hs=7.58 m Tm=9.60 dir=82.80 degr N level 1.90 m +CD
wind: 38 m/s 65 degr N

Table: set013

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.863	6.76	9.604	17.15
2	3.212	5.88	9.604	17.23
3	3.359	4.29	9.604	16.33
4	3.444	0.98	9.604	12.62
5	3.344	-0.69	9.604	11.80
6	2.521	-0.60	9.603	14.35
7	2.073	-3.58	9.603	16.24
8	1.717	-7.16	9.603	23.14
9	1.598	-4.87	9.603	24.91
10	4.476	6.91	9.604	11.82
11	3.567	1.70	9.604	13.68
12	2.008	-10.08	9.602	25.03
13	3.563	-6.13	9.602	17.82
14	5.326	7.46	9.603	19.00
15	5.494	12.23	9.601	14.80

EXTREME WAVE CONDITIONS RP=100
Hs=7.58 m Tm=9.60 dir=82.80 degr N level 1.90 m +CD
wind: 38 m/s 65 degr N

Table: setN13

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.855	5.68	9.604	17.44
2	3.191	4.89	9.604	17.98
3	3.308	3.55	9.604	17.67
4	3.269	0.25	9.604	15.03
5	2.969	-1.46	9.604	14.05
6	2.334	0.86	9.603	16.26
7	1.964	5.09	9.603	17.93
8	1.773	8.09	9.603	18.41
9	1.602	-0.23	9.602	23.95
10	4.033	3.13	9.604	11.83
11	2.806	-0.75	9.604	14.65
12	1.895	-5.26	9.602	24.78
13	2.603	-9.23	9.603	19.63
14	4.927	4.42	9.604	15.85
15	5.494	12.23	9.601	14.80

EXTREME WAVE CONDITIONS RP=100

Hs=7.75 m Tm=9.60 dir=105.00 degr N level 1.90 m +CD

wind: 38 m/s 110 degr N

Table: set014

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.929	1.85	9.608	20.37
2	3.312	-0.17	9.608	19.64
3	3.511	-1.95	9.608	18.09
4	3.742	-5.47	9.607	12.90
5	3.983	-6.50	9.608	11.68
6	3.653	-8.93	9.608	12.17
7	3.158	-15.05	9.609	12.58
8	2.727	-27.95	9.610	16.24
9	2.280	-35.34	9.608	21.91
10	4.655	-2.77	9.607	13.78
11	4.571	-5.25	9.608	13.88
12	3.242	-32.09	9.607	17.68
13	4.856	-20.42	9.605	17.96
14	5.464	-12.48	9.605	20.87
15	5.584	-4.19	9.601	17.08

EXTREME WAVE CONDITIONS RP=100

Hs=7.75 m Tm=9.60 dir=105.00 degr N level 1.90 m +CD

wind: 38 m/s 110 degr N

Table: setN14

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.923	1.08	9.608	20.54
2	3.303	-1.06	9.608	19.95
3	3.501	-2.89	9.608	18.67
4	3.712	-6.87	9.608	13.73
5	3.861	-8.89	9.608	11.57
6	3.514	-10.64	9.609	12.58
7	3.029	-9.80	9.609	14.32
8	2.558	-10.32	9.609	15.90
9	2.453	-32.16	9.609	21.28
10	4.529	-5.39	9.608	12.96
11	4.079	-9.20	9.609	12.38
12	3.199	-30.20	9.609	17.46
13	4.179	-24.36	9.608	15.77
14	5.466	-12.42	9.607	19.04
15	5.584	-4.19	9.601	17.08

EXTREME WAVE CONDITIONS RP=100
Hs=7.28 m Tm=9.60 dir=125.20 degr N level 1.90 m +CD
wind: 38 m/s 155 degr N

Table: set015

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.956	-4.69	9.611	21.50
2	3.355	-7.22	9.611	20.25
3	3.573	-8.87	9.610	18.30
4	3.851	-12.01	9.610	12.47
5	4.185	-11.92	9.610	11.68
6	4.199	-12.94	9.611	11.25
7	4.039	-19.13	9.611	10.54
8	3.704	-33.75	9.614	10.78
9	3.055	-45.80	9.612	11.92
10	4.634	-13.22	9.610	11.89
11	4.866	-11.44	9.610	13.30
12	4.409	-38.31	9.610	12.10
13	5.637	-30.50	9.607	15.11
14	5.619	-29.63	9.608	15.00
15	5.614	-19.72	9.603	12.21

EXTREME WAVE CONDITIONS RP=100
Hs=7.28 m Tm=9.60 dir=125.20 degr N level 1.90 m +CD
wind: 38 m/s 155 degr N

Table: setN15

Loc.	Hsign [m]	Dir [degr]	Per [sec]	DirSpr [degr]
1	2.952	-4.81	9.611	21.74
2	3.351	-7.31	9.611	20.70
3	3.570	-8.97	9.611	19.01
4	3.839	-12.63	9.611	13.04
5	4.121	-13.62	9.611	10.88
6	4.120	-14.71	9.612	10.66
7	3.947	-14.47	9.612	11.51
8	3.398	-16.42	9.613	12.11
9	3.406	-41.83	9.615	11.81
10	4.677	-13.94	9.611	11.73
11	4.614	-13.56	9.611	11.65
12	4.470	-36.48	9.613	11.58
13	5.359	-31.03	9.610	13.09
14	5.736	-27.79	9.610	14.60
15	5.614	-19.72	9.603	12.21

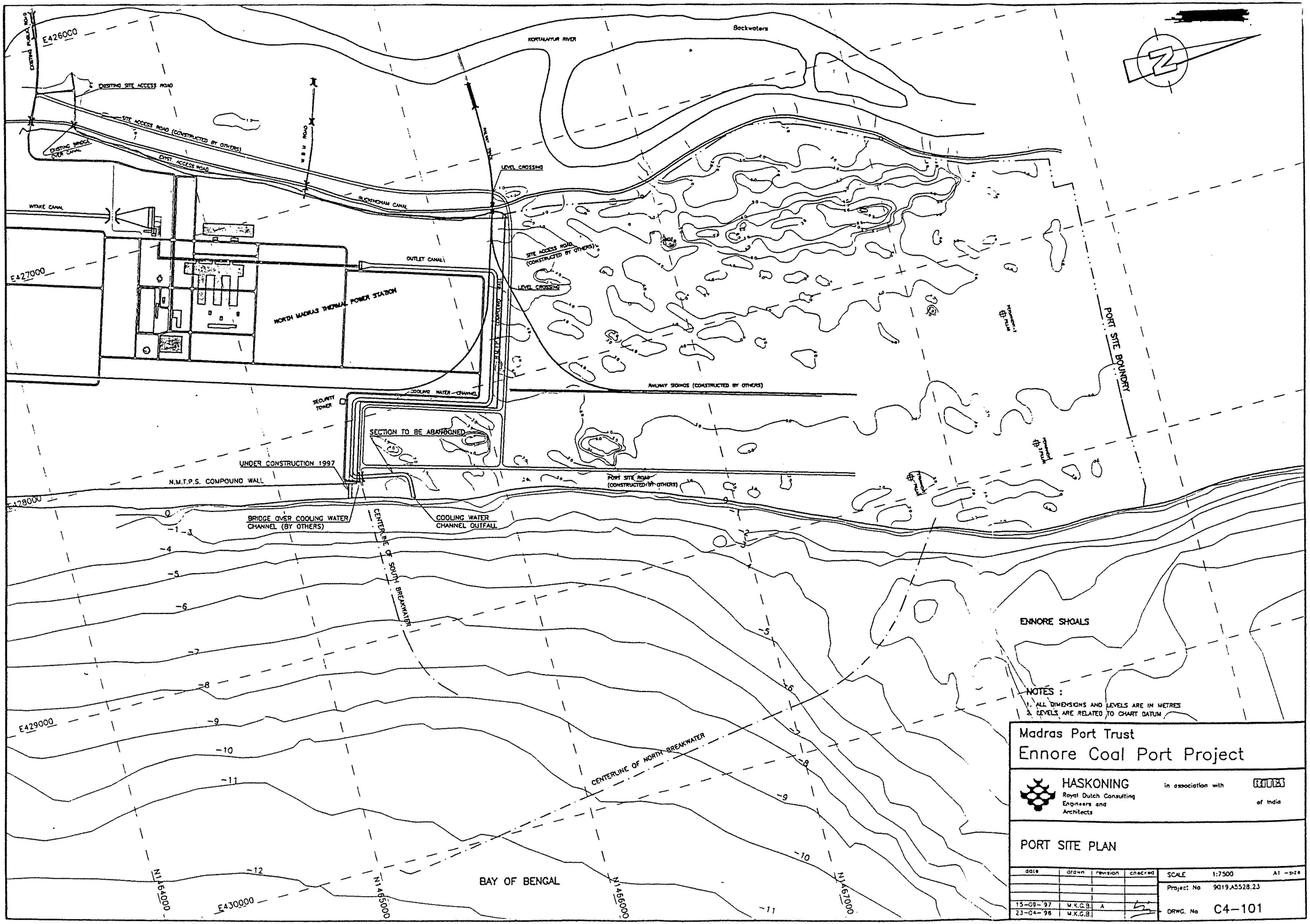
XII.VI : Significant wave height comparison for old and new alignment

Significant wave height at calculated locations for the new alignment compared to same conditions for the original alignment.

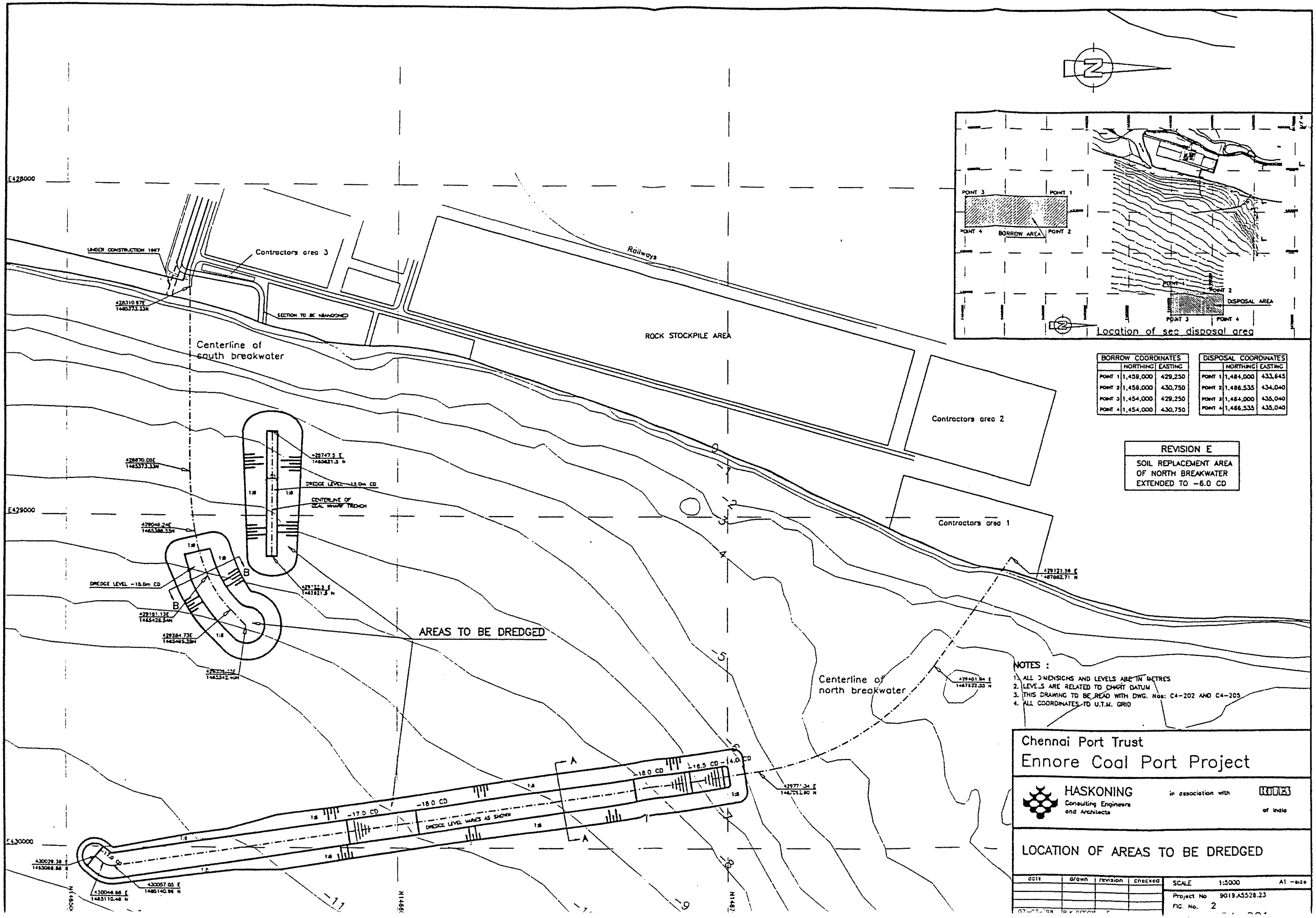
HISWA RUN Nr	N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	N 11	N 12	N 13	N 14	N 15
Return period (years)	5	5	5	10	10	10	25	25	25	50	50	50	100	100	100
location.	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign	Hsign
1	96%	100%	100%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
2	91%	99%	100%	98%	100%	100%	99%	100%	100%	99%	100%	100%	99%	100%	100%
3	88%	99%	100%	96%	100%	100%	98%	100%	100%	98%	100%	100%	98%	100%	100%
4	86%	97%	100%	91%	99%	100%	93%	99%	100%	94%	99%	100%	95%	99%	100%
5	83%	94%	100%	86%	97%	99%	88%	97%	99%	88%	97%	99%	89%	97%	98%
6	87%	94%	99%	91%	96%	99%	92%	96%	99%	92%	96%	98%	93%	96%	98%
7	88%	94%	97%	92%	95%	98%	94%	96%	98%	94%	96%	98%	95%	96%	98%
8	89%	86%	85%	98%	90%	88%	101%	92%	90%	102%	93%	91%	103%	94%	92%
9	96%	107%	110%	98%	108%	111%	100%	108%	112%	100%	108%	112%	100%	108%	111%
10	81%	95%	102%	86%	97%	102%	89%	97%	101%	89%	97%	101%	90%	97%	101%
11	76%	87%	96%	78%	89%	96%	78%	90%	95%	78%	89%	95%	79%	89%	95%
12	91%	97%	100%	93%	98%	101%	94%	99%	102%	94%	99%	101%	94%	99%	101%
13	68%	84%	93%	71%	86%	94%	72%	86%	95%	72%	86%	95%	73%	86%	95%
14	84%	96%	100%	88%	99%	101%	91%	99%	102%	92%	100%	102%	93%	100%	102%
15	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

APPENDIX X.III: Drawings for breakwater construction

C4-101 : Port site plan
C4-201 : Location of areas to be dredged
C4-202 : Soil replacement north breakwater longintudinal section
C4-203 : Soil replacement south breakwater longintudinal section
C4-302 : North breakwater longitudinal section
C4-303 : South breakwater longitudinal section
C4-304 : North breakwater cross sections
C4-305 : South breakwater cross sections
C4-306 : North breakwater head plan and elevation
C4-308 : South breakwater head plan and elevation
C4-204 : Soil replacement north breakwater cross section
C4-205 : Soil replacement south breakwater cross section
C4-206 : Location of additional boreholes for variation order C4-02 Soil investigation
C4-301 : Plan of north and south breakwaters
C4-402 : South breakwater crest arangement and sections
C4-401 : North breakwater crest arangement and sections
C4-309 : Pilot compaction area (south breakwater)
C2-700 : Diversion of NMTPS outlet channel general layout plan and cross sections.



[redacted]
Backwaters
KORTALAIYUR RIVER
E426000
EXISTING PUBLIC ROAD
EXISTING SITE ACCESS ROAD
SITE ACCESS ROAD (CONSTRUCTED BY OTHERS)
EXISTING BRIDGE OVER CANAL
EXIST. ACCESS ROAD
BUCKINGHAM CANAL
RAILWAY TRACK
LEVEL CROSSING
INTAKE CANAL
OUTLET CANAL
SITE ACCESS ROAD (CONSTRUCTED BY OTHERS)
LEVEL CROSSING
E427000
NORTH MADRAS THERMAL POWER STATION
RAILWAY SIDINGS (CONSTRUCTED BY OTHERS)
PORT SITE BOUNDARY
COOLING WATER CHANNEL
SECURITY TOWER
SECTION TO BE ABANDONED
UNDER CONSTRUCTION 1997
N.M.T.P.S. COMPOUND WALL
PORT SITE ROAD (CONSTRUCTED BY OTHERS)
E428000
BRIDGE OVER COOLING WATER CHANNEL (BY OTHERS)
CENTERLINE OF SOUTH BREAKWATER
COOLING WATER CHANNEL OUTFALL
ENNORE SHOALS
NOTES :
1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
E429000
CENTERLINE OF NORTH BREAKWATER
BAY OF BENGAL
N1464000
N1465000
N1466000
N1467000
E430000
Madras Port Trust
Ennore Coal Port Project
HASKONING
Royal Dutch Consulting Engineers and Architects
in association with
of India
PORT SITE PLAN
date
drawn
revision
checked
15-09-97
M.K.C.B.
A
23-04-96
M.K.C.B.
SCALE 1:7500
A1 -size
Project No 9019.A5528.23
DRWG. No C4-101



BORROW COORDINATES		
	NORTHING	EASTING
POINT 1	1,459,000	429,250
POINT 2	1,459,000	430,750
POINT 3	1,454,000	429,250
POINT 4	1,454,000	430,750

DISPOSAL COORDINATES		
	NORTHING	EASTING
POINT 1	1,484,000	433,645
POINT 2	1,488,535	434,040
POINT 3	1,484,000	435,040
POINT 4	1,466,535	435,040

REVISION E

SOIL REPLACEMENT AREA OF NORTH BREAKWATER EXTENDED TO -6.0 CD

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. THIS DRAWING TO BE READ WITH DWG. Nos: C4-202 AND C4-205
4. ALL COORDINATES TO U.T.M. GRID

Chennai Port Trust

Ennore Coal Port Project

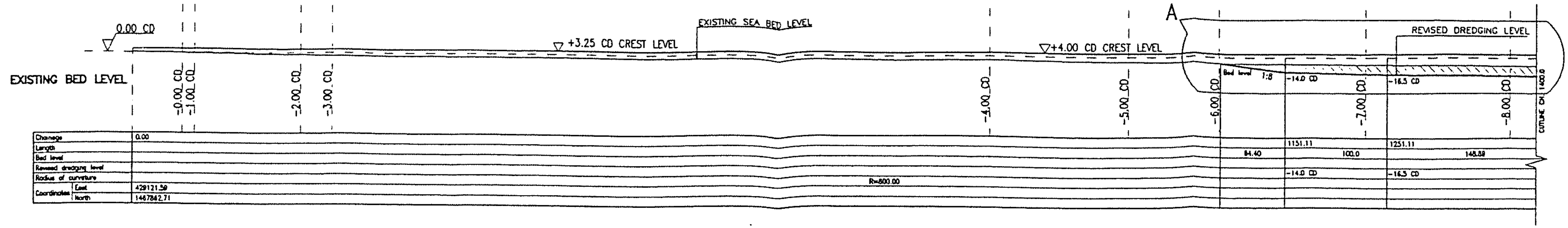
HASKONING
Consulting Engineers
and Architects

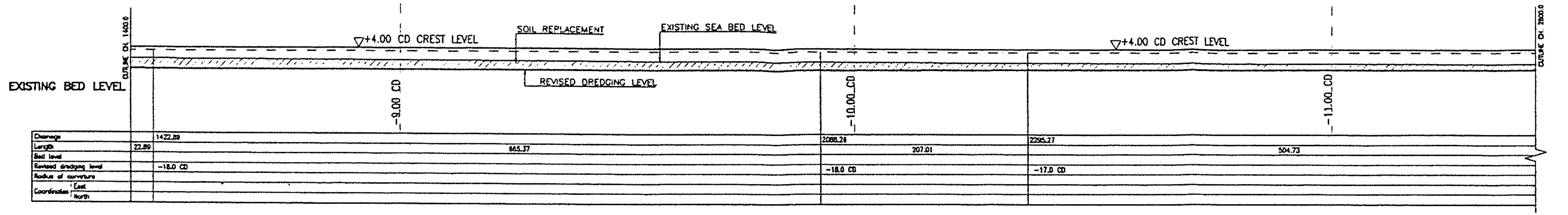
in association with RITES of India

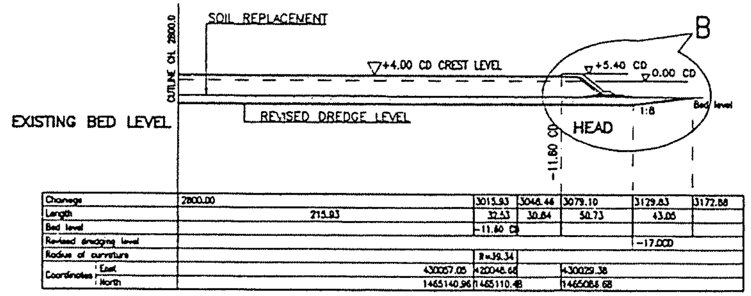
LOCATION OF AREAS TO BE DREDGED

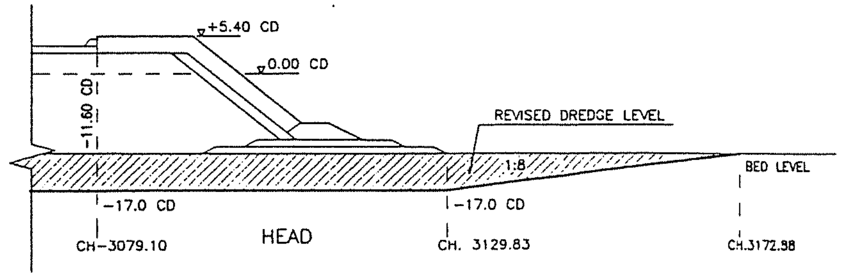
date	drawn	revision	checked
07-07-'98	R.K. REDDY	E	

SCALE 1:5000 A1 -size
Project No 9019.A5528.23
FIG. No. 2

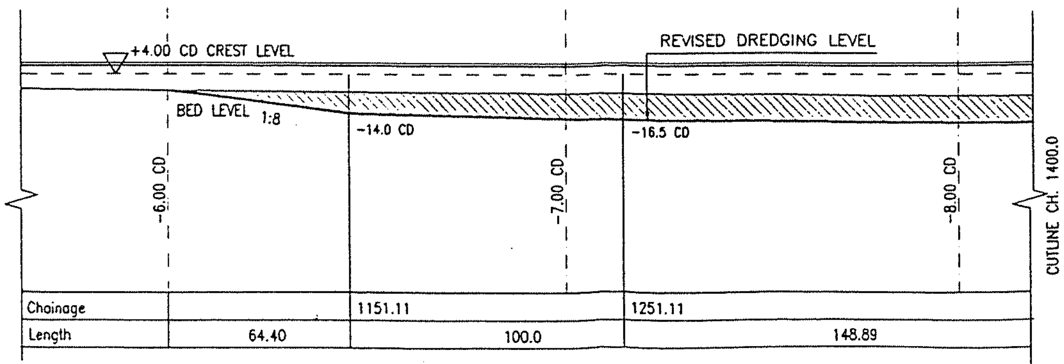








DETAILS AT B



DETAILS AT A

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. GRID ACCORDING TO U.T.M.

Madras Port Trust

Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects

in association with RITES of India

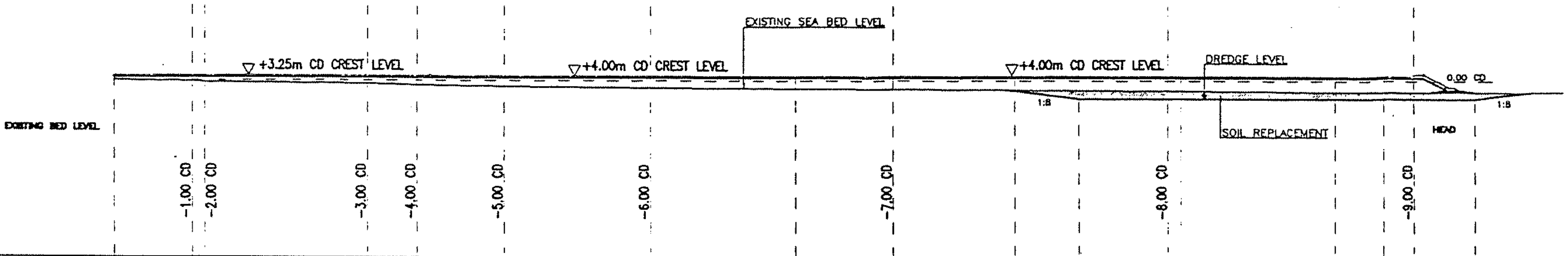
SOIL REPLACEMENT NORTH BREAKWATER
LONGITUDINAL SECTION

date	drawn	revision	checked
08-07-'98	R.K.Reddy	C	
15-09-'97	M.K.C.B.	B	
03-06-'96	M.K.C.B.	A	

SCALE 1:2000 , 1000 A1-size

Project No 9019.A5528.23

FIG. No. 3



Chainage		0.00	318.83	558.03	739.22	792.00	878.78	1003.02	1070.00	1120.00
Length		318.83	240.20	180.19	137.54		126.26	66.96		
Bed level		-5.00 CD						-9.00 CD		
Dredging level						-15.00 CD				-15.00 CD
Radius of curvature				R=1063.24	R=618.03		R=321.96	-		
Coordinates	East	428310.87		428670.00	429048.24		429181.13	429284.73	429332.33	
	North	1465373.33		1465373.33	1465388.55		1465426.54	1465465.29	1465542.40	

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. GRID ACCRDING TO U.T.M.

Madras Port Trust

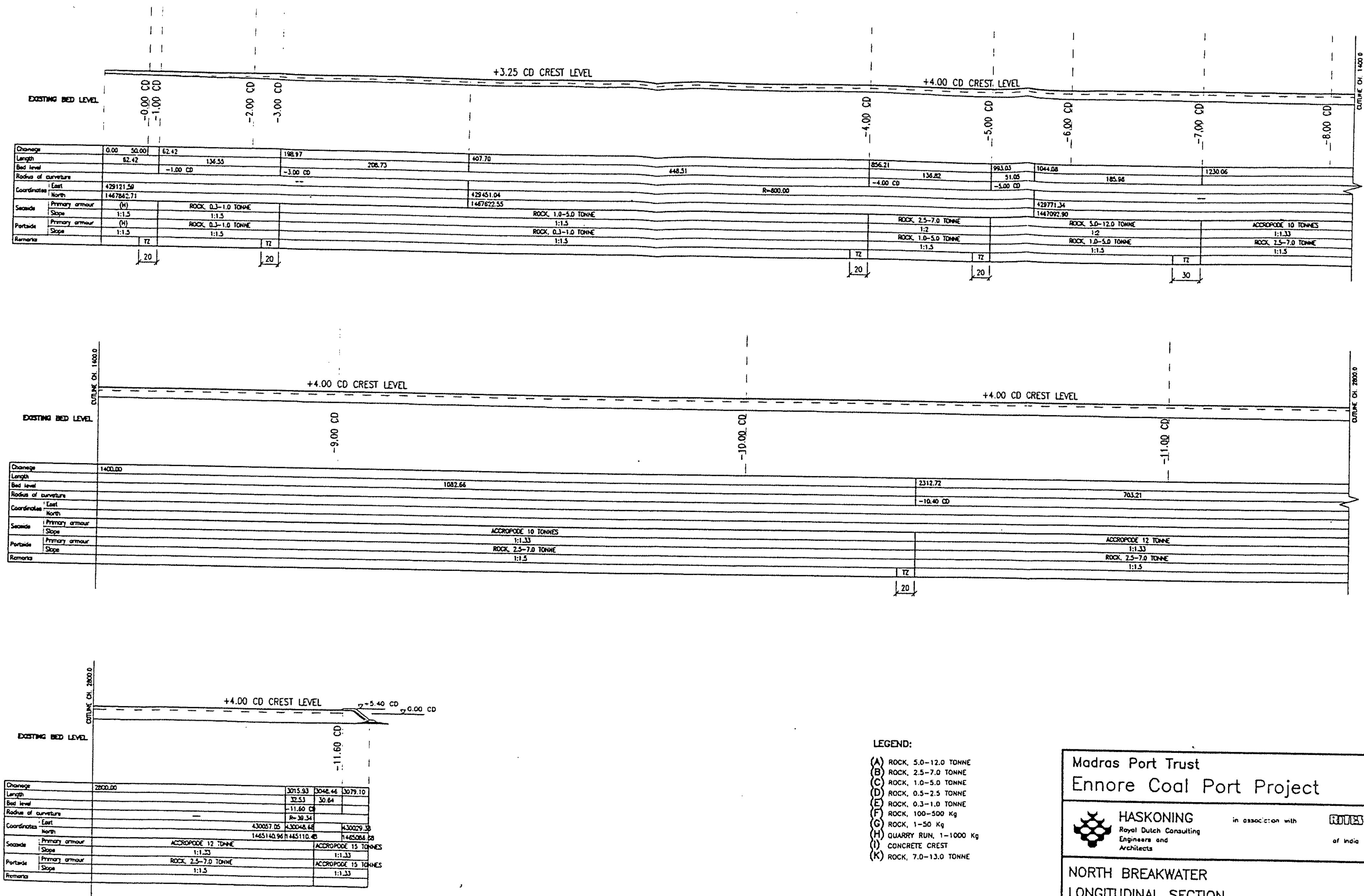
Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects

In association with RITES of India

SOIL REPLACEMENT SOUTH BREAKWATER LONGITUDINAL SECTION

date	drawn	revision	checked	SCALE	1:2000	A1-size
				Project No	9019 A5528 21	



LEGEND:

- (A) ROCK, 5.0-12.0 TONNE
- (B) ROCK, 2.5-7.0 TONNE
- (C) ROCK, 1.0-5.0 TONNE
- (D) ROCK, 0.5-2.5 TONNE
- (E) ROCK, 0.3-1.0 TONNE
- (F) ROCK, 100-500 Kg
- (G) ROCK, 1-50 Kg
- (H) QUARRY RUN, 1-1000 Kg
- (I) CONCRETE CREST
- (K) ROCK, 7.0-13.0 TONNE

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. ALL COORDINATES ACCORDING TO U.T.M GRID
4. TZ= TRANSITION ZONE

Madras Port Trust

Ennore Coal Port Project

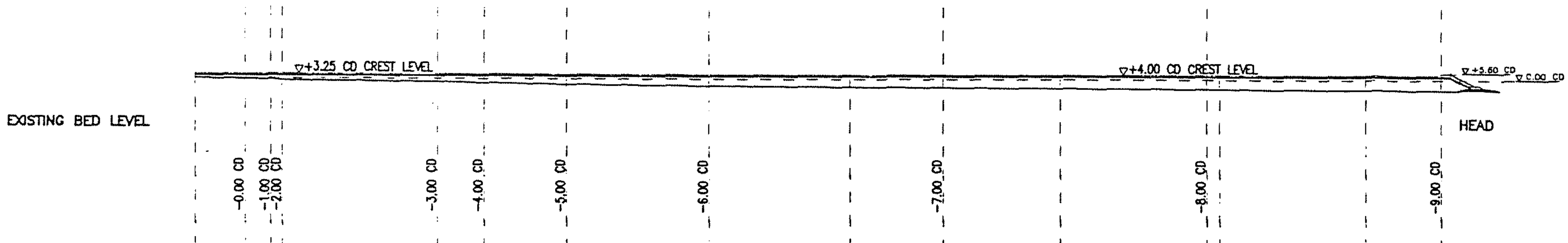
HASKONING
Royal Dutch Consulting Engineers and Architects
in association with RITES of India

NORTH BREAKWATER
LONGITUDINAL SECTION

date	drawn	revision	checked
15-09-'97	MKGB	A	

SCALE 1:2000 A1-size

Project No 9019.A5528.23



Chainage	0.00 42.03	82.96	205.22	318.83	559.03 732.73	739.22 868.17	878.78	1003.02	1070.00
Length	83.96	144.24	110.81	240.20	180.19	137.54	128.26	66.98	
Bed level		-1.00 CD	-3.00 CD	-5.00 CD	-7.50 CD	-8.00 CD			
Radius of curvature	-				R=1063.24	R=419.03	R=321.96	-	
Coordinates East	428310.97				428870.00	429046.24	429181.13	429284.73	429332.33
Coordinates North	1485373.33				1485373.33	1485388.66	1485426.54	1485495.29	1485542.40
Seaside Primary armour	(H)	ROCK, 0.3-1.0 TONNE	ROCK, 1.0-6.0 TONNE	ROCK, 2.5-7.0 TONNE		ROCK, 5.0-12.0 TONNE	ROCK, 5.0-12.0 TONNE		
Seaside Slope	1:1.5	1:1.5	1:1.5	1:1.5		1:1.5	1:2		
Portside Primary armour	(H)	ROCK, 0.3-1.0 TONNE	ROCK, 0.3-1.0 TONNE	ROCK, 1.0-6.0 TONNE		ROCK, 1.0-6.0 TONNE	ROCK, 1.0-6.0 TONNE	ROCK, 5.0-12.0 TONNE	
Portside Slope	1:1.5	1:1.5	1:1.5	1:1.5		1:1.5	1:1.5	VAR.	
Remarks	TZ	TZ	TZ		TZ	TZ		HEAD	

20 20 20 20 20

LEGEND:

(A) ROCK, 5.0-12.0 TONNE
(B) ROCK, 2.5-7.0 TONNE
(C) ROCK, 1.0-5.0 TONNE
(D) ROCK, 0.5-2.5 TONNE
(E) ROCK, 0.3-1.0 TONNE
(F) ROCK, 100-500 Kg
(G) ROCK, 1-50 Kg
(H) QUARRY RUN, 1-1000 Kg
(I) CONCRETE CREST

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES

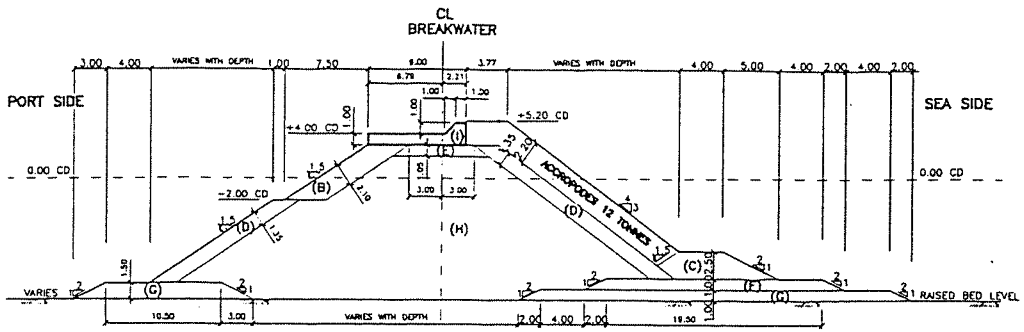
Madras Port Trust

Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects
in association with RITES of India

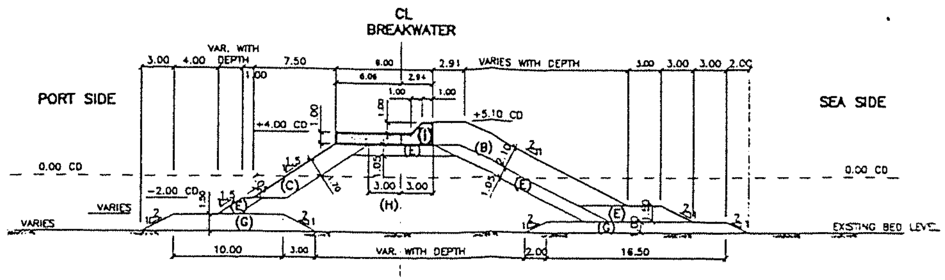
SOUTH BREAKWATER LONGITUDINAL SECTION

date	drawn	revision	checked	SCALE	1:2000	A1-size



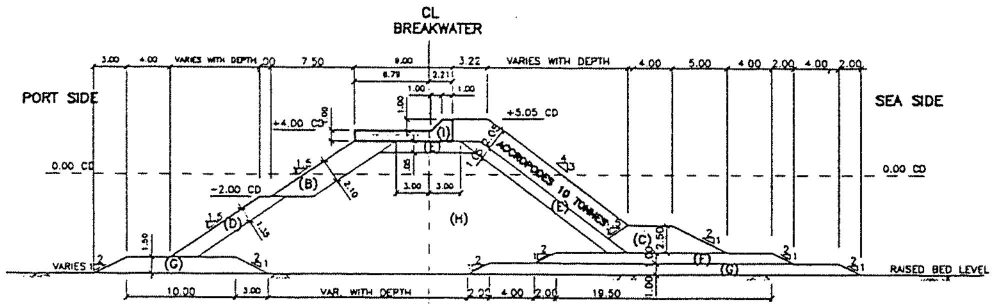
TYPICAL CROSS SECTION OF NORTH BREAKWATER
FOR TRUNK SECTION FROM HEAD TO −10.40 CD (EXISTING BED LEVEL)

CROSS SECTION A–A



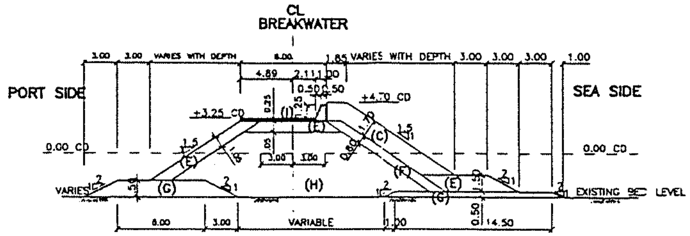
TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM −5.00 TO −4.00 CD (EXISTING BED LEVEL)

CROSS SECTION J–J



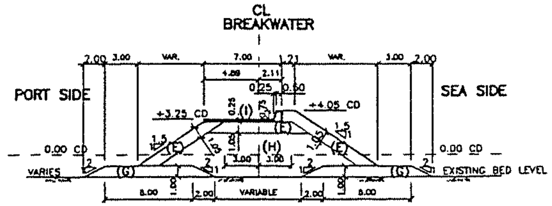
TYPICAL CROSS SECTION OF NORTH BREAKWATER
FOR TRUNK SECTION FROM −10.40 CD TO −7.00 CD (EXISTING BED LEVEL)

CROSS SECTION B–B



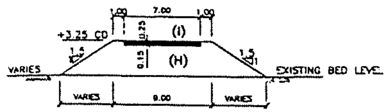
TYPICAL CROSS SECTION OF NORTH BREAKWATER
FOR TRUNK SECTION FROM −4.00 CD TO −3.00 CD (EXISTING BED LEVEL)

CROSS SECTION F–F



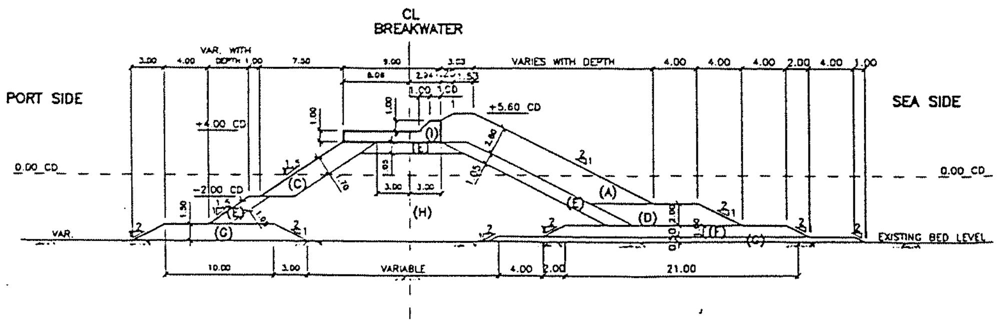
TYPICAL CROSS SECTION OF NORTH BREAKWATER
FOR TRUNK SECTION FROM
−3.00 CD TO −1.00 CD (EXISTING BED LEVEL)

CROSS SECTION G–G



TYPICAL CROSS SECTION OF NORTH BREAKWATER
FOR TRUNK SECTION FROM
−1.00 CD (EXISTING BED LEVEL) TO ROOT

CROSS SECTION H–H



TYPICAL CROSS SECTION OF NORTH BREAKWATER
FOR TRUNK SECTION FROM −7.00 CD TO −5.00 CD (EXISTING BED LEVEL)

CROSS SECTION I–I

LEGEND:

- (A) ROCK, 5.0–12.0 TONNE
- (B) ROCK, 2.5–7.0 TONNE
- (C) ROCK 1.0–5.0 TONNE
- (D) ROCK 0.5–2.5 TONNE
- (E) ROCK, 0.3–1.0 TONNE
- (F) ROCK, 100–500 Kg
- (G) ROCK, 1–50 Kg
- (H) QUARRY RUN, 1–1000 Kg
- (I) CONCRETE CREST

CL = CENTER LINE

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. THIS DRAWING TO BE READ IN CONJUNCTION WITH DWG. No: C4–301 AND C4–302 — REVISION–B

Madras Port Trust

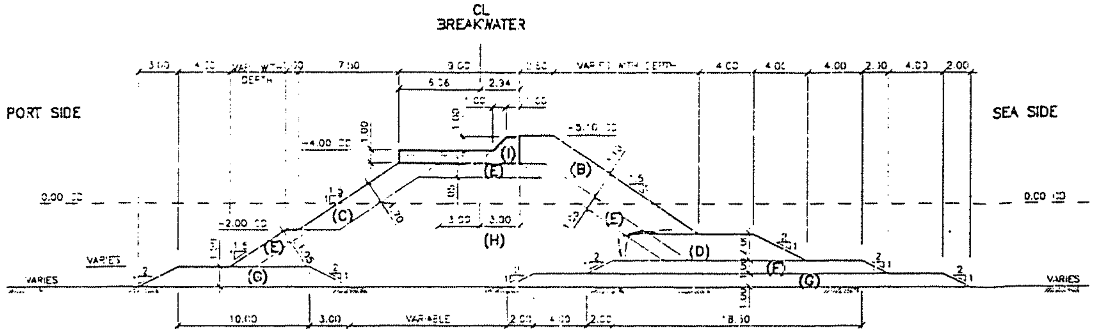
Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects

In association with RITES of India

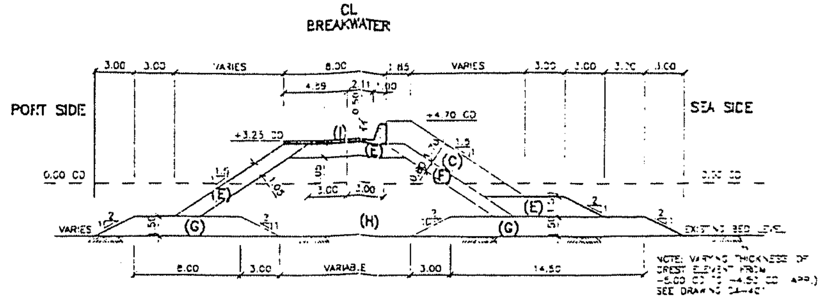
NORTH BREAKWATER
CROSS SECTIONS

date	drawn	revision	checked	SCALE 1:250	A1-size
13-03-98	ARK			Project No 3019.A5525 22	



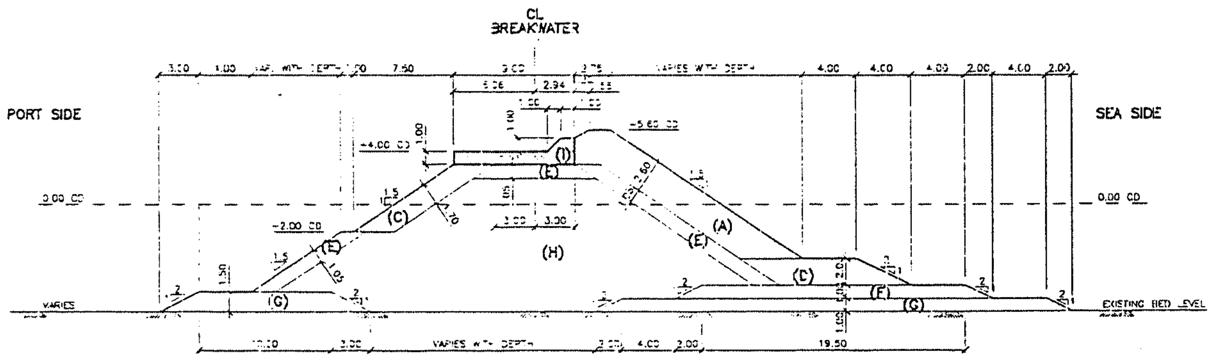
TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM –7.50 CD TO –5.00 CD (EXISTING BED LEVEL)

CROSS SECTION E–E



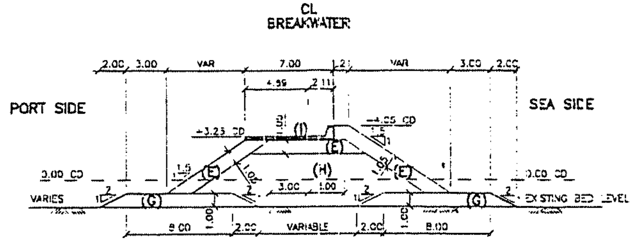
TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM –5.00 CD TO –3.00 CD (EXISTING BED LEVEL)

CROSS SECTION F–F



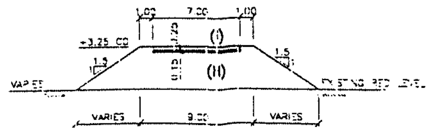
TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM –8.00 CD TO –7.50 CD (EXISTING BED LEVEL)

CROSS SECTION D–D



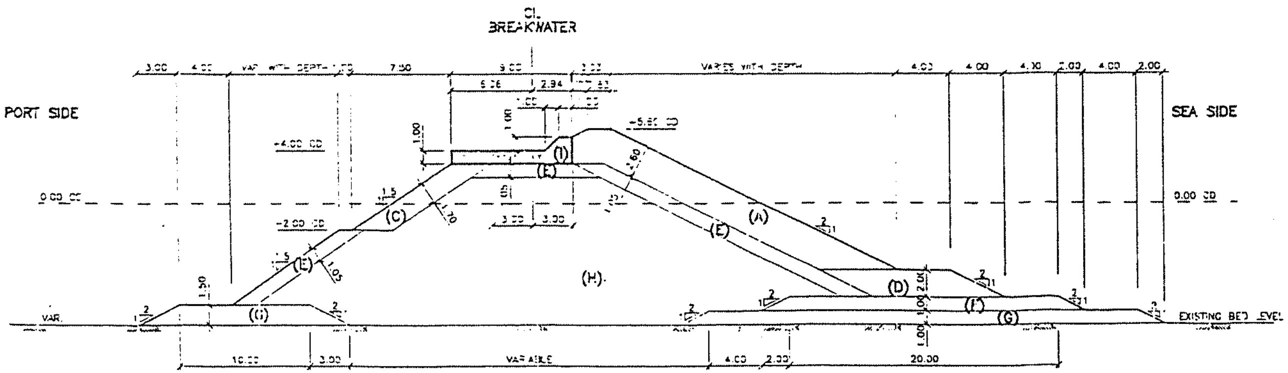
TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM –3.00 CD TO –1.00 CD (EXISTING BED LEVEL)

CROSS SECTION G–G



TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM –1.00 CD (EXISTING BED LEVEL) TO ROOT

CROSS SECTION H–H



TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM HEAD TO –8.00 CD (EXISTING BED LEVEL)

LEGEND:

(A) ROCK, 3.0–12.0 TONNE
(B) ROCK, 2.5–7.0 TONNE
(C) ROCK, 1.0–3.0 TONNE
(D) ROCK, 0.5–2.5 TONNE
(E) ROCK, 0.3–1.0 TONNE
(F) ROCK, 100–500 Kg
(G) ROCK, 1–50 Kg
(H) QUARRY RUN, 1–1000 Kg
(I) CONCRETE CREST

CL = CENTER LINE

NOTES :

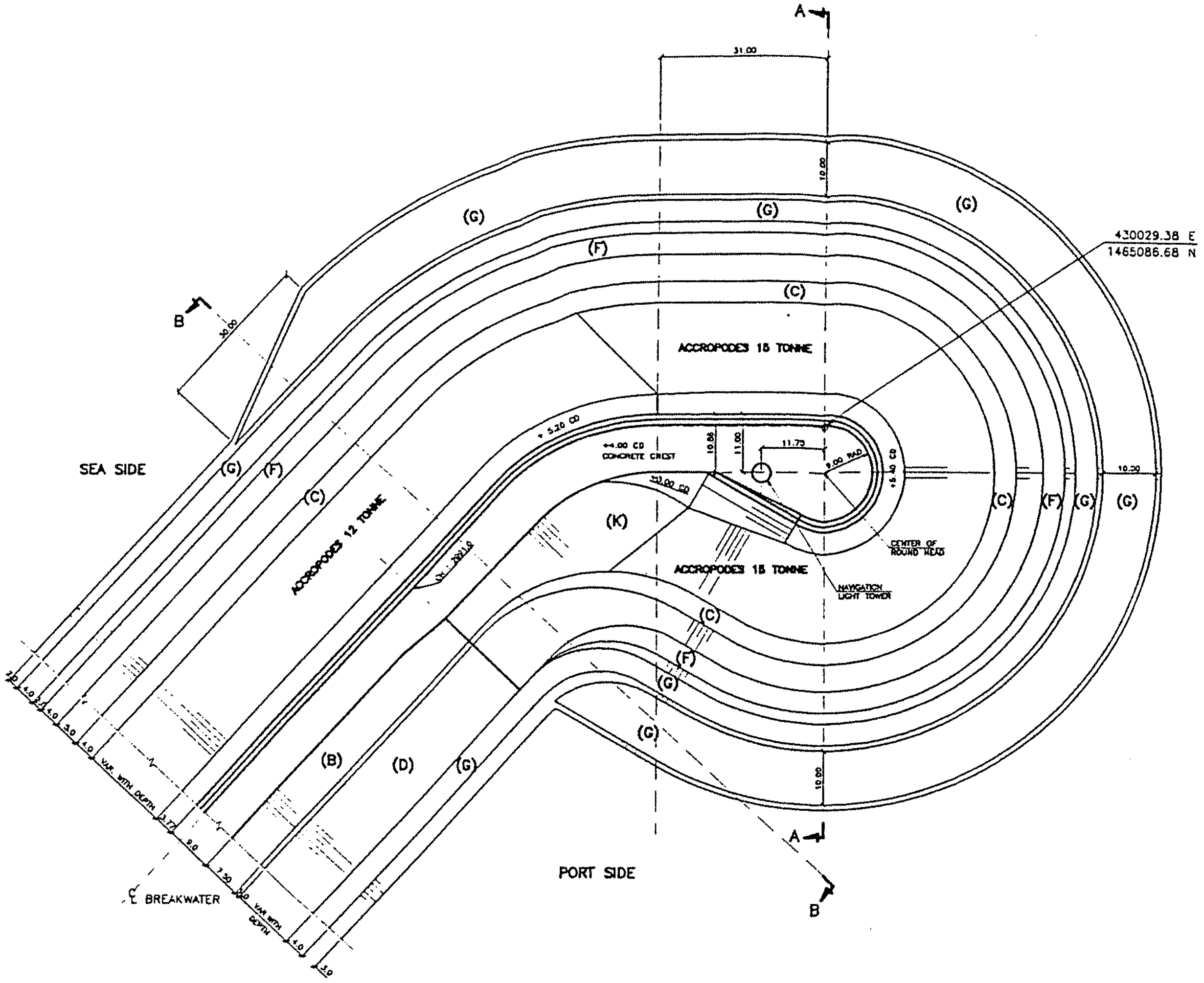
1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM

Madras Port Trust
Ennore Coal Port Project

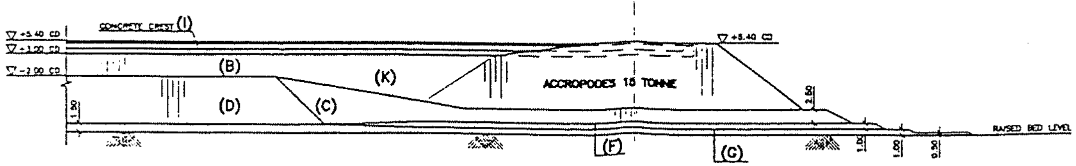
HASKONING
Royal Dutch Consulting Engineers and Architects
in association with

SOUTH BREAKWATER
CROSS SECTIONS

SCALE 1:200



PLAN



PORT SIDE ELEVATION

LEGEND:

(A) ROCK, 5.0–12.0 TONNE
(B) ROCK, 2.5–7.0 TONNE
(C) ROCK, 1.0–5.0 TONNE
(D) ROCK, 0.5–2.5 TONNE
(E) ROCK, 0.3–1.0 TONNE
(F) ROCK, 100–500 Kg
(G) ROCK, 1–50 Kg
(H) QUARRY RUN, 1–1000 Kg
(I) CONCRETE CREST
(K) ROCK, 7.0–13.0 TONNE

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. ALL COORDINATES ACCORDING TO U.T.M. GRID
4. THIS DRAWING TO BE READ IN CONJUNCTION WITH DWG. No: C4–307 AND C4–404 > REVISION–B

Madras Port Trust

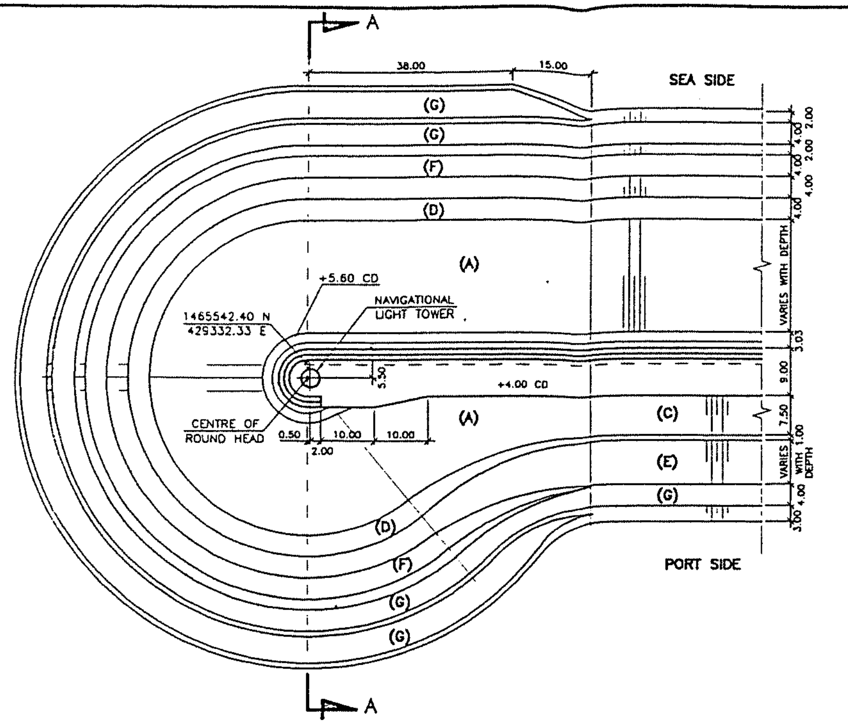
Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects
in association with RITES of India

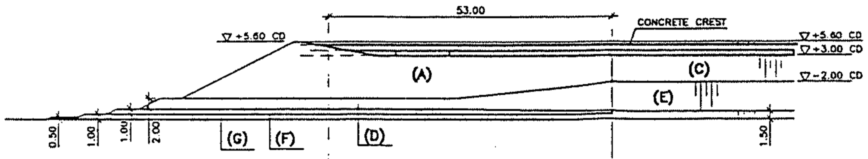
NORTH BREAKWATER HEAD PLAN AND ELEVATION

date	drawn	revision	checked
13-03-'98	ARK	B	
15-09-'97	M.K.C.B.	A	

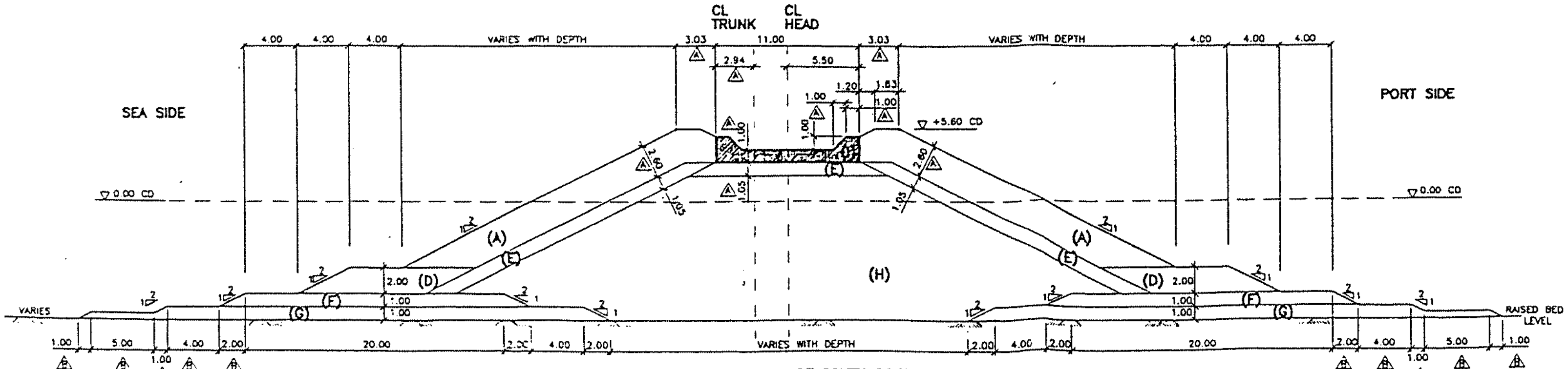
SCALE 1:500 A1-size
Project No [illegible]
DRWG. No C4–306



PLAN
SCALE 1:500



PORT SIDE ELEVATION
SCALE 1:500



TYPICAL CROSS SECTION OF SOUTH BREAKWATER HEAD

LEGEND:

(A) ROCK, 5.0–12.0 TONNE
(B) ROCK, 2.5–7.0 TONNE
(C) ROCK, 1.0–3.0 TONNE
(D) ROCK, 0.5–2.5 TONNE
(E) ROCK, 0.3–1.0 TONNE
(F) ROCK, 100–500 Kg
(G) ROCK, 1–50 Kg
(H) QUARRY RUN, 1–1000 Kg
(I) CONCRETE CREST
CL = Center line

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. ALL COORDINATES ACCORDING TO U.T.M. GRID
4. △ & △ INDICATES REVISION

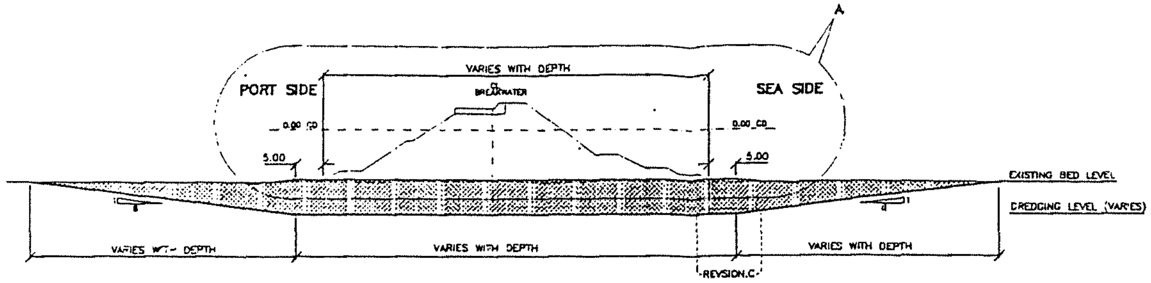
Madras Port Trust

Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects
In association with RITES of India

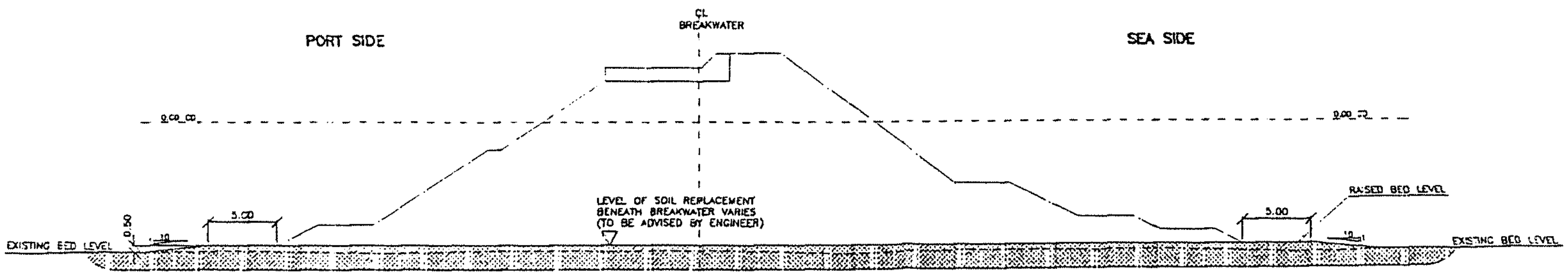
SOUTH BREAKWATER HEAD
PLAN ELEVATION AND CROSS SECTION

date	drawn	revision	checked	SCALE	1:200 / 1:500	A1-size
				Project No	9019.A5575.[illegible]	



TYPICAL CROSS SECTION OF NORTH BREAKWATER AT -9.00 CD (EXISTING BED LEVEL)
FOR SECTION FROM CH. 1373.5 TO HEAD

CROSS SECTION A–A
SCALE 1:500



DETAIL – A
SCALE 1:200

CL = CENTER LINE

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. THIS DRAWING TO BE READ WITH DWG. No: C4-201 AND 202

Madras Port Trust
Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects
in association with RITES of India

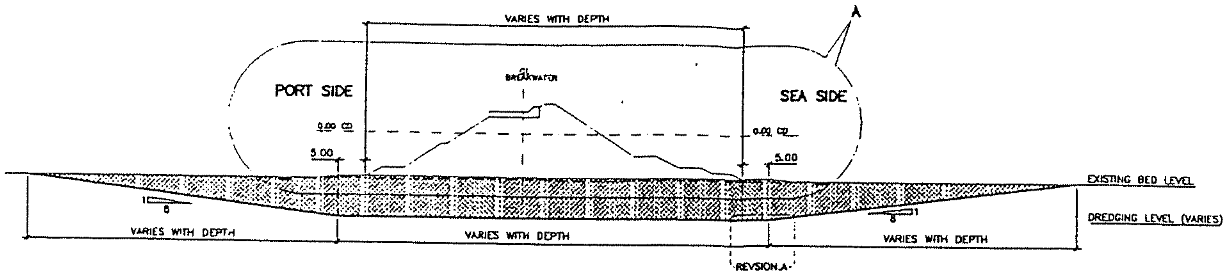
SOIL REPLACEMENT NORTH BREAKWATER CROSS SECTION

date	drawn	revision	checked
11-05-'98	ARK	C	
13-03-'98	ARK	B	
15-09-'97	M.K.C.B.	A	

SCALE 1:500 1:200 A1-size

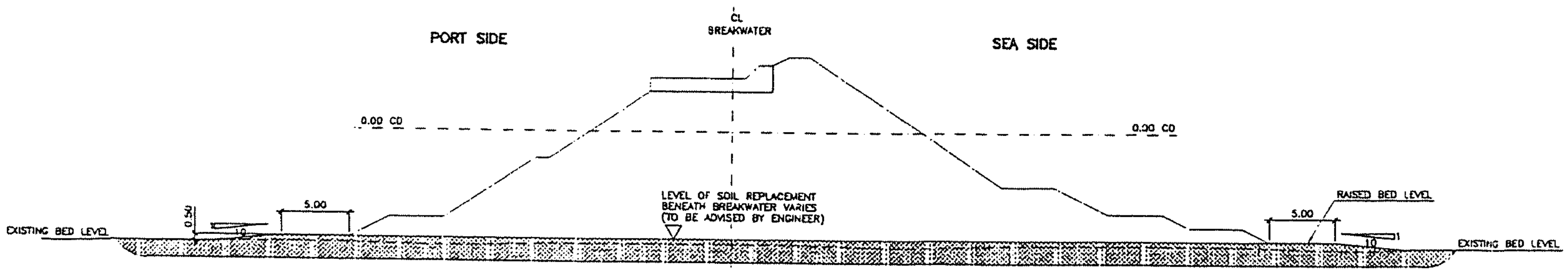
Project No B015.A5528.23

DRWG No C4–204



TYPICAL CROSS SECTION OF SOUTH BREAKWATER AT -8.00 CD (EXISTING BED LEVEL)
FOR TRUNK SECTION FROM CH. 731.0 TO HEAD

CROSS SECTION B–B
SCALE 1:500



DETAIL – A
SCALE 1:200

CL = CENTER LINE

NOTES :

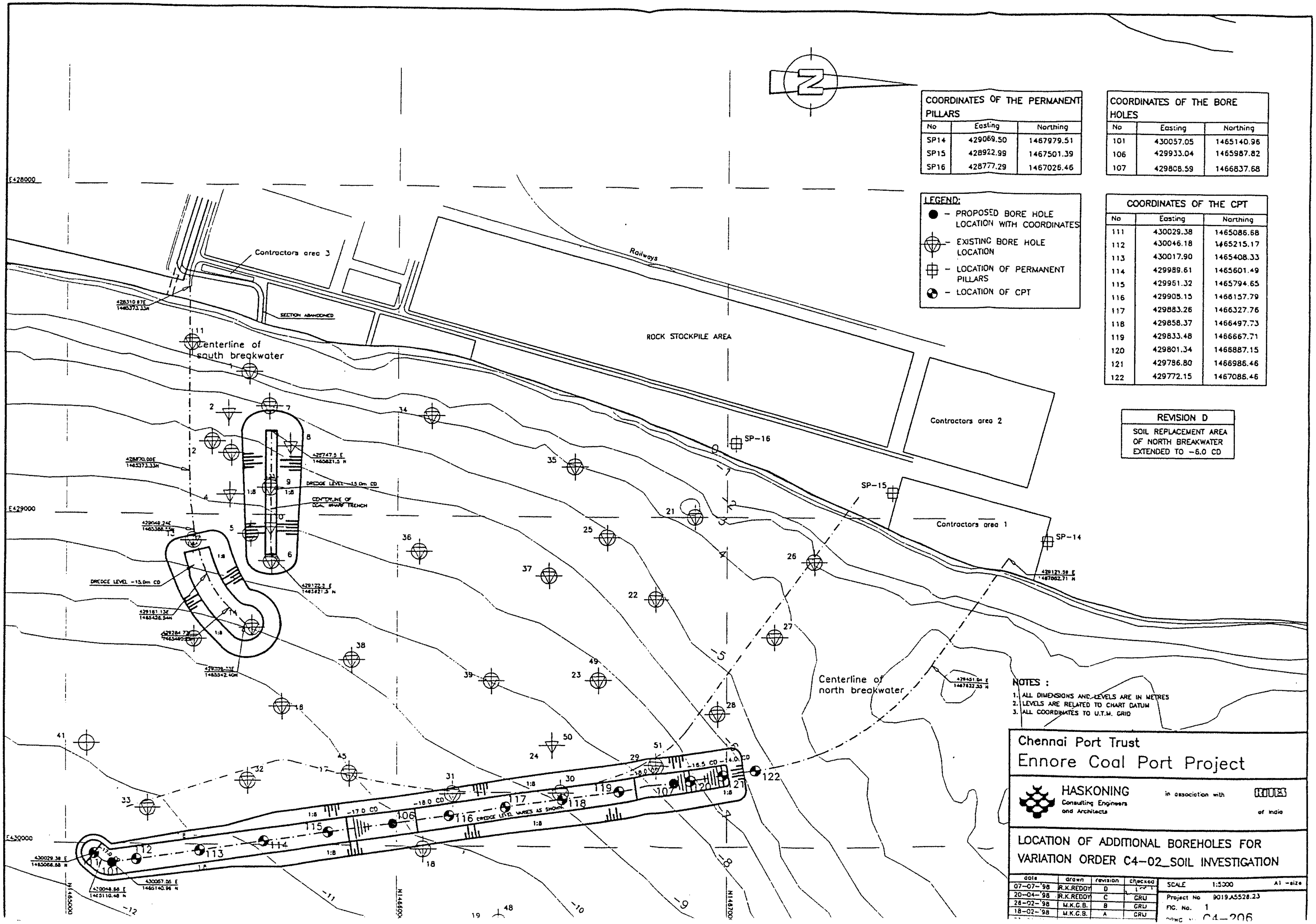
1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. THIS DRAWING TO BE READ WITH DWG. No: C4-201 AND 203

Madras Port Trust
Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects
in association with RITES of India

SOIL REPLACEMENT SOUTH BREAKWATER
CROSS SECTION

date	drawn	revision	checked	
				SCALE 1:500 1:200 A1-size
				Project No 9019.A5526.21
11-05-'98	R.K.Reddy	A		C4-205



COORDINATES OF THE PERMANENT PILLARS		
No	Easting	Northing
SP14	429069.50	1467979.51
SP15	428922.99	1467501.39
SP16	428777.29	1467026.46

COORDINATES OF THE BORE HOLES		
No	Easting	Northing
101	430057.05	1465140.96
106	429933.04	1465987.82
107	429808.59	1466837.68

LEGEND:
- ● – PROPOSED BORE HOLE LOCATION WITH COORDINATES
- EXISTING BORE HOLE LOCATION
- LOCATION OF PERMANENT PILLARS
- LOCATION OF CPT

COORDINATES OF THE CPT		
No	Easting	Northing
111	430029.38	1465086.68
112	430046.18	1465215.17
113	430017.90	1465408.33
114	429989.61	1465601.49
115	429951.32	1465794.65
116	429905.15	1466157.79
117	429883.26	1466327.76
118	429858.37	1466497.73
119	429833.48	1466667.71
120	429801.34	1466887.15
121	429786.80	1466986.46
122	429772.15	1467086.46

REVISION D
SOIL REPLACEMENT AREA OF NORTH BREAKWATER EXTENDED TO –6.0 CD

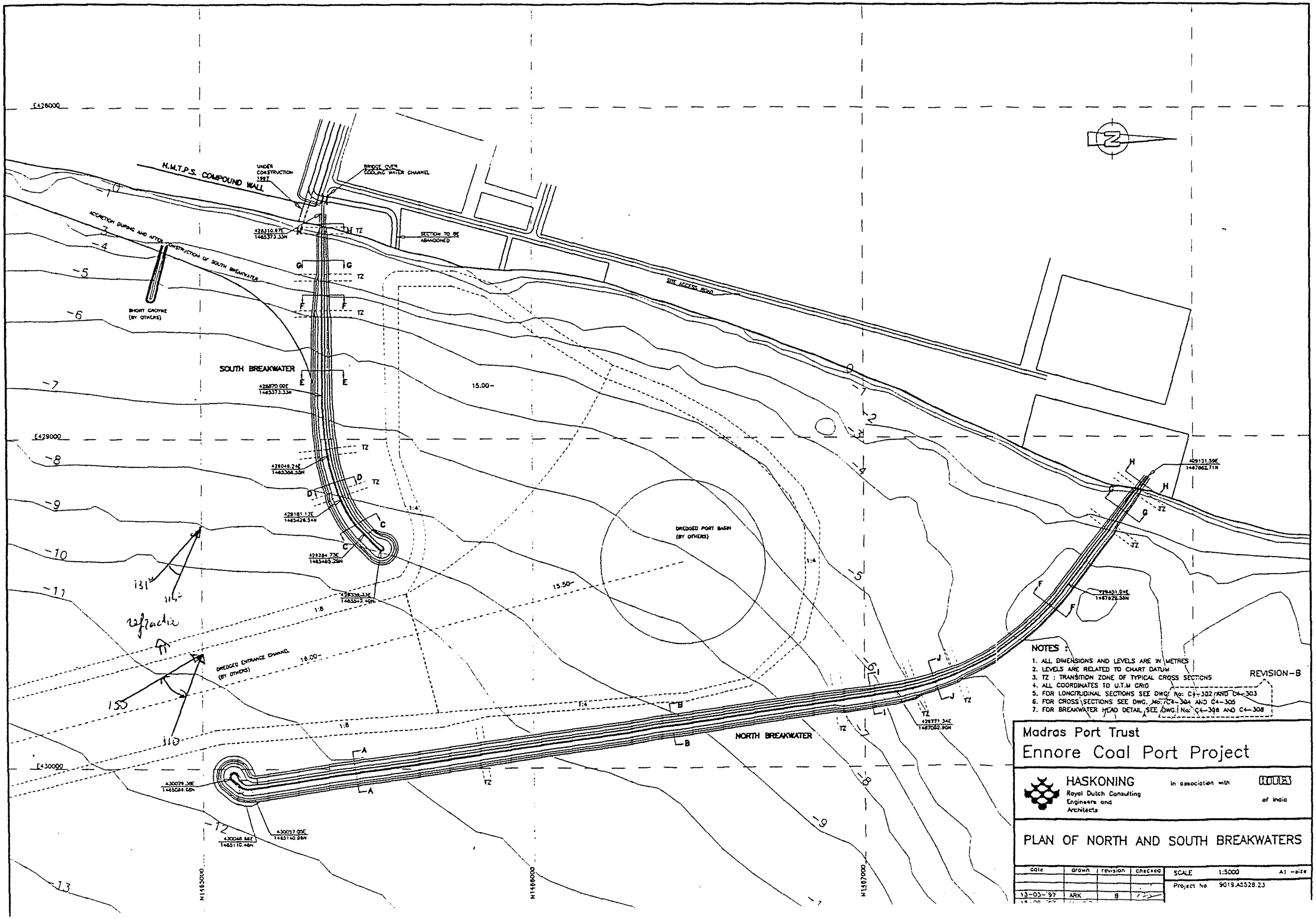
Chennai Port Trust
Ennore Coal Port Project

HASKONING Consulting Engineers and Architects in association with RITES of India

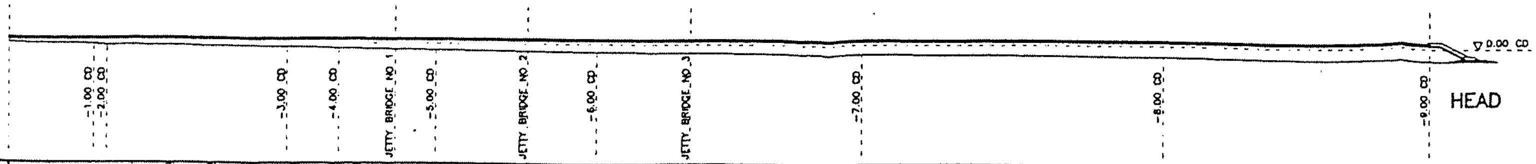
LOCATION OF ADDITIONAL BOREHOLES FOR VARIATION ORDER C4–02_SOIL INVESTIGATION

date	drawn	revision	checked
07-07-'98	R.K.REDDY	D	
20-04-'98	R.K.REDDY	C	GRU
26-02-'98	M.K.C.B.	B	GRU
18-02-'98	M.K.C.B.	A	GRU

SCALE 1:5000 A1-size
Project No 9019.A5528.23
FIG. No. 1
DRWG No. C4–206



N.M.T.P.S. COMPOUND WALL
UNDER CONSTRUCTION 1997
BRIDGE OVER COOLING WATER CHANNEL
SECTION TO BE ABANDONED
ACCRETION DURING AND AFTER CONSTRUCTION OF SOUTH BREAKWATER
SHORT GROYNE (BY OTHERS)
SITE ACCESS ROAD
SOUTH BREAKWATER
NORTH BREAKWATER
DREDGED PORT BASIN (BY OTHERS)
DREDGED ENTRANCE CHANNEL (BY OTHERS)
15.00
15.50
16.00
E428000
E429000
E430000
N1465000
N1466000
N1467000
NOTES :
1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CHART DATUM
3. TZ : TRANSITION ZONE OF TYPICAL CROSS SECTIONS
4. ALL COORDINATES TO U.T.M GRID
5. FOR LONGITUDINAL SECTIONS SEE DWG. No: C4–302 AND C4–303
6. FOR CROSS SECTIONS SEE DWG. No: C4–304 AND C4–305
7. FOR BREAKWATER HEAD DETAIL SEE DWG. No: C4–308 AND C4–308
REVISION–B
Madras Port Trust
Ennore Coal Port Project
HASKONING
Royal Dutch Consulting Engineers and Architects
In association with
of India
PLAN OF NORTH AND SOUTH BREAKWATERS
date
drawn
revision
checked
13-03-'97
ARK
B
SCALE
1:5000
A1 -size
Project No
9019.A5528.23



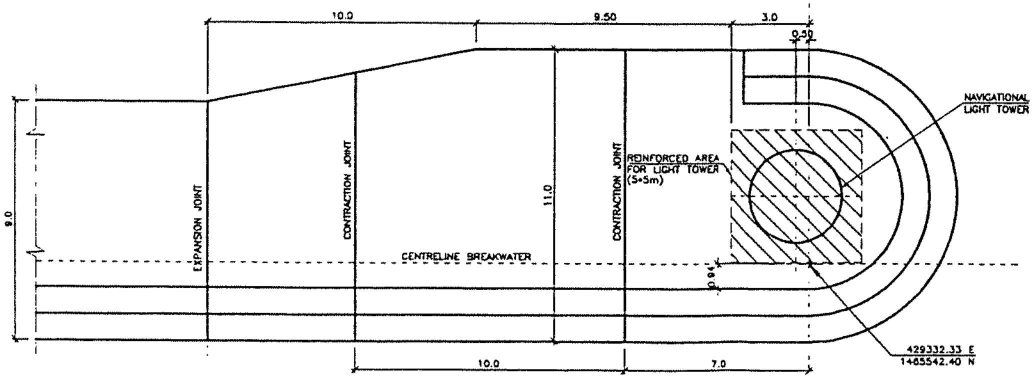
Chainage in metres	0.00, 31.00, 61.00, 92.00, 122.00, 134.00, 188.00, 218.00, 250.00, 266.00, 282.06, 285.06, 291.06, 318.83, 323.06, 352.06, 382.06, 385.06, 394.06, 421.06, 448.06, 475.06, 502.06, 505.06, 514.06, 544.06, 559.03, 574.06, 604.06, 634.06, 664.06, 694.06, 724.06, 739.22, 754.06, 784.06, 814.06, 844.06, 874.06, 876.76, 904.06, 934.06, 964.06, 994.06, 1003.02, 1024.00, 1047.50, 1070.00
Length in metres	31, 30, 31, 32, 32, 32, 32, 32, 16, 16.08, 12, 24.77, 4, 23, 29, 30, 12, 27, 27, 27, 27, 12, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 23.44, 10, 12.5
Radius in cl. breakwater	R=1063.24; R=619.03; R=321.96
Coordinates of centerline breakwater E / N	428310.97 / 1465373.33; 428870.00 / 1465373.33; 429049.24 / 1465388.55; 429181.13 / 1465426.54; 429284.73 / 1465495.29; 429645.09 / 1465879.60
Slab level in metres+CD	+3.25; variable; +4.00; +4.00; +4.00; +4.00; +4.00; +4.00
Slab thickness in mm	250; 250–1000; 1000; 1000; 1000; 1000; 1000; 1000
B1 in mm / B2 in mm	3500 / 3500; 4890 / 2110; 4890 / 2110; 4890 / 3110; 4890 / 3110; 6060 / 2940; 6060 / 2940; 6060 / 2940
H (mm)	–; 1000; 1500; 1500; 1500; 2000
W (mm)	–; 750; 1000; 1000; 1000; 2000
No contraction joints spaced equally	2, 2, 2, 2, 2, 2, 2, 2, 1, 1, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 1
Location expansion joint	
Slab Type	'R'; 'U'; 'R'; 'U'; 'R'; 'U'; 'R'; 'U'

LEGEND:
'R' – REINFORCED
'U' – UNREINFORCED

SEE DRWG.NO: C4–403

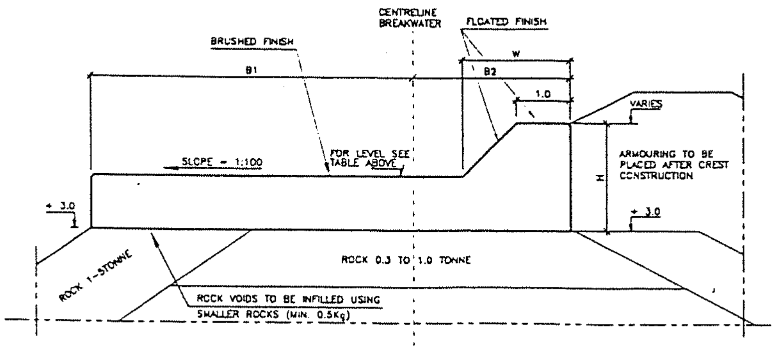
LONGITUDINAL SECTION SHOWING ARRANGEMENT OF CREST ELEMENTS

NOT TO SCALE



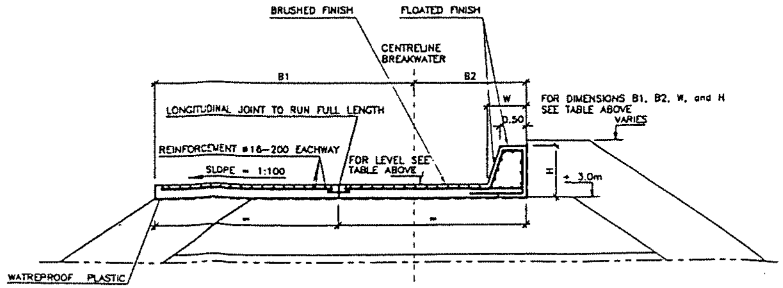
PLAN OF CREST AT HEAD

SCALE 1:100



UNREINFORCED CREST SECTION

SCALE 1:50



REINFORCED CREST SECTION

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES / MILLIMETRES
2. LEVELS ARE RELATED TO CHART DATUM
3. ALL COORDINATES ACCORDING TO U.T.M. GRID
4. INFILL ROCKS USED FOR LEVELLING SHALL NOT BE LESS THAN 0.5kg.
5. CONCRETE IN UNREINFORCED SLAB TO BE CLASS A (M30)
6. CONCRETE IN REINFORCED SLAB TO BE CLASS B (M30)
7. ALL CHAMFERS TO BE 50mm
8. 75mm COVER TO ALL REINFORCEMENT.
9. FOR JOINT DETAILS & LIGHT TOWER SEE DWG. C4–404.

Madras Port Trust

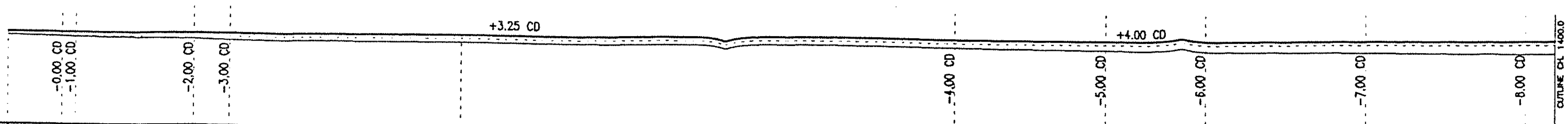
Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects

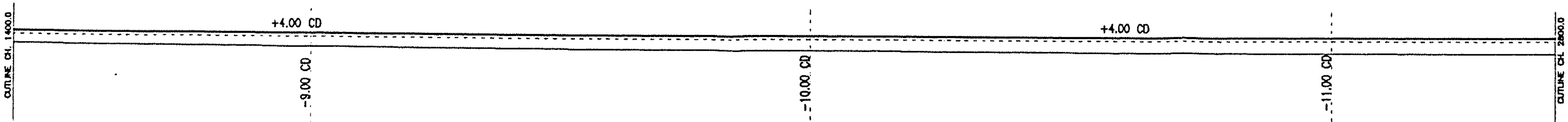
In association with RITES of India

SOUTH BREAKWATER
CREST ARRANGEMENT AND SECTIONS

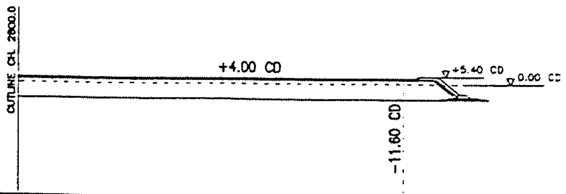
date	drawn	revision	checked	SCALE 1:100 1:50	A1–size
				Project No 9019.A5526.21	



Row	Values (in order along chainage)
Chainage	0.00, 30.00, 60.00, 90.00, 120.0, 150.0, 180.0, 210.0, 240.0, 270.0, 300.0, 330.0, 360.0, 390.0, 420.0, 450.0, 480.0, 510.0, 540.0, 570.0, 600.0, 630.0, 660.0, 690.0, 720.0, 750.0, 780.0, 810.0, 840.0, 856.0, 870.0, 900.0, 930.0, 960.0, 990.0, 1020.0, 1050.0, 1080.0, 1110.0, 1140.0, 1170.0, 1200.0, 1230.0, 1260.0, 1290.0, 1320.0, 1350.0, 1380.0
Length	30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 16, 14, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 20
Radius of curvature	R=800.00
Coordinates East	429121.59 (ch. 0.00); 429451.04 (ch. 420.0); 429771.34 (ch. 1050.0)
Coordinates North	1467862.71 (ch. 0.00); 1467622.55 (ch. 420.0); 1467092.90 (ch. 1050.0)
Slab level in metres+CD	+3.25; VARIES (840.0–870.0); +4.00
Slab thickness in mm	250; VARIES (840.0–870.0); 1000
B1 in mm	3500; VAR.; 4890; 4890; VAR.; 4890; 4890; VAR.; 6060; 6060; VAR.; 6790
B2 in mm	3500; VAR.; 2110; 2110; VAR.; 3110; 3110; VAR.; 2940; 2940; VAR.; 2210
H (mm)	–; 750; 1500; 2000
W (mm)	–; 750; 1000; 2000
No contraction joints spaced equally	2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2
Location expansion joint	
Slab type	REINFORCED (0.00–856.0); UNREINFORCED (856.0–1400.0)



Row	Values (in order along chainage)
Chainage	1410.0, 1440.0, 1470.0, 1500.0, 1530.0, 1560.0, 1590.0, 1620.0, 1650.0, 1680.0, 1710.0, 1740.0, 1770.0, 1800.0, 1830.0, 1860.0, 1890.0, 1920.0, 1950.0, 1980.0, 2010.0, 2040.0, 2070.0, 2100.0, 2130.0, 2160.0, 2190.0, 2220.0, 2250.0, 2280.0, 2310.0, 2340.0, 2370.0, 2400.0, 2430.0, 2460.0, 2490.0, 2520.0, 2550.0, 2580.0, 2610.0, 2640.0, 2670.0, 2700.0, 2730.0, 2760.0, 2790.0
Length	10, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 10
Radius of curvature	
Coordinates East	
Coordinates North	
Slab level in metres+CD	+4.00; +4.00
Slab thickness in mm	1000; 1000
B1 in mm	6790
B2 in mm	2210
H (mm)	2000; 2000
W (mm)	2000; 2000
No contraction joints spaced equally	2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2
Location expansion joint	
Slab type	UNREINFORCED; UNREINFORCED



Row	Values (in order along chainage)
Chainage	2820.0, 2850.0, 2880.0, 2910.0, 2940.0, 2970.0, 3000.0, 3030.0, 3059.8, 3079.1
Length	20, 30, 30, 30, 30, 30, 30, 30, 28.86, 20.24
Radius of curvature	—; R=39.34
Coordinates East	430057.05; 430048.88; 430029.38
Coordinates North	1465140.96; 1465110.48; 1465085.68
Slab level in metres+CD	+4.00
Slab thickness in mm	1000
B1 in mm	6790; 6790; VARIES; VARIES; VARIES
B2 in mm	2210; 2210; 2210; 2210; VARIES
H (mm)	2000
W (mm)	2000
No contraction joints spaced equally	2, 2, 2, 2, 2, 2, 2, 2, 2, 1
Location expansion joint	
Slab type	UNREINFORCED

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES / MILLIMETRES
2. LEVELS ARE RELATED TO CHART DATUM
3. ALL COORDINATES ACCORDING TO U.T.M. GRID
4. FOR PLAN AND SECTIONS OF CREST DETAILS SEE DWG C4-405
5. FOR DETAILS OF 'H', 'W', 'B1' & 'B2' SEE DWG. C4-405

REVISION-C

Madras Port Trust

Ennore Coal Port Project

HASKONING
Royal Dutch Consulting Engineers and Architects

in association with RITES of India

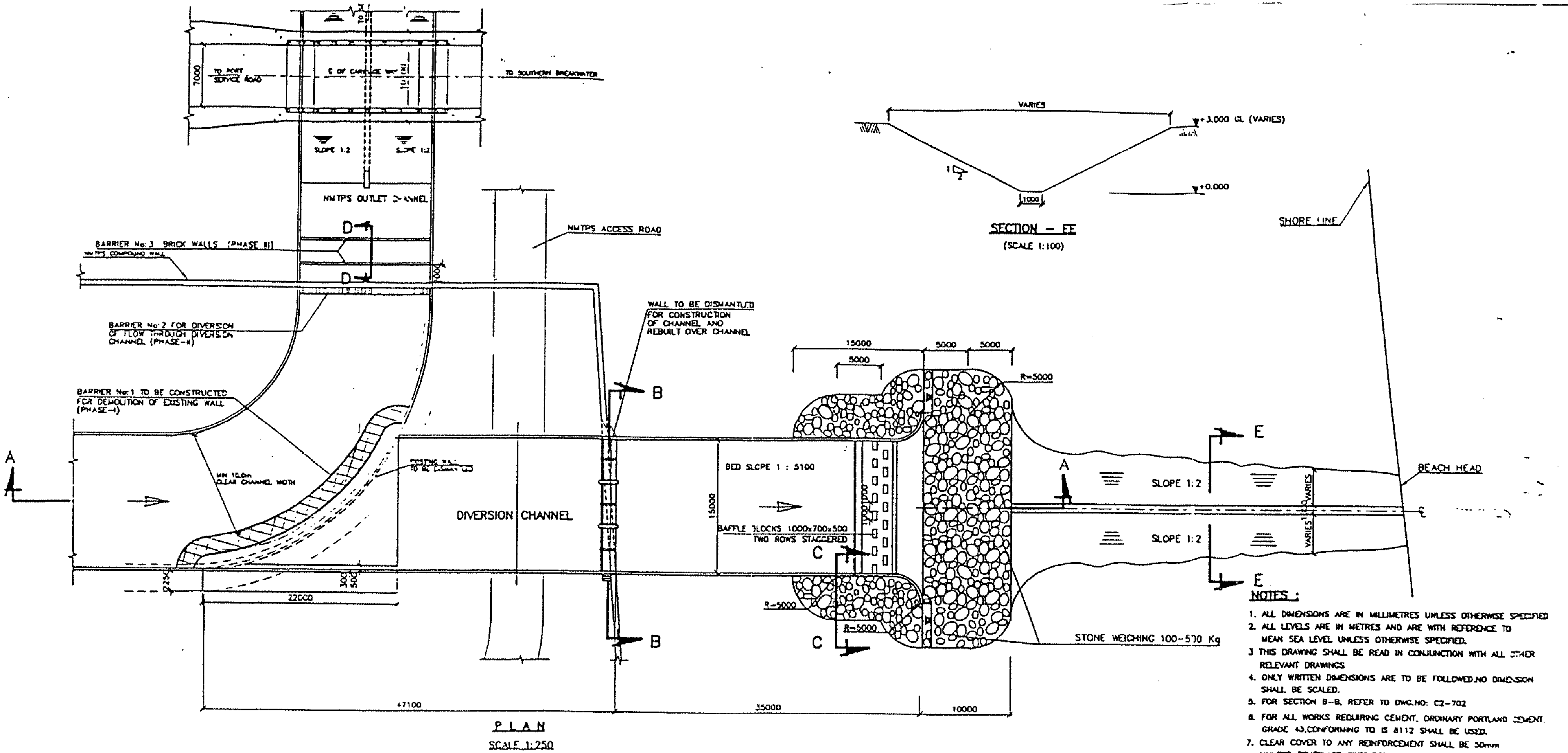
NORTH BREAKWATER — CREST ARRANGEMENT

date	drawn	revision	checked
13-03-'98	ARK	C	
15-09-'97	M.K.G.B.	B	
13-08-'96	M.K.G.B.	A	

SCALE 1:2000 A1-size

Project No 9019.A5528.23

DRWG. No. C4-401



PLAN

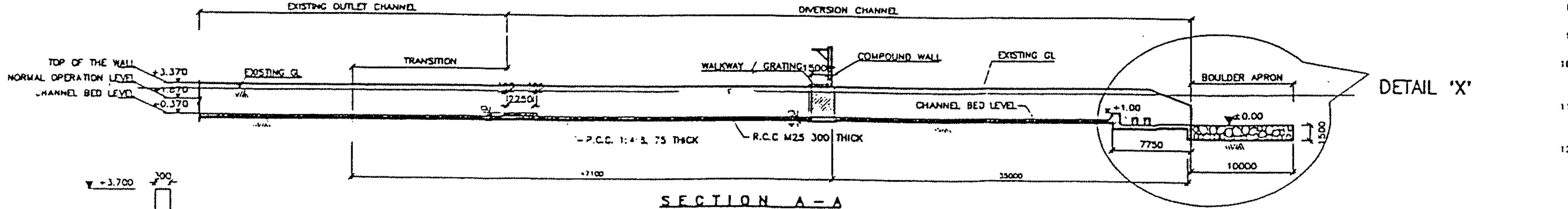
SCALE 1:250

SECTION - FF

(SCALE 1:100)

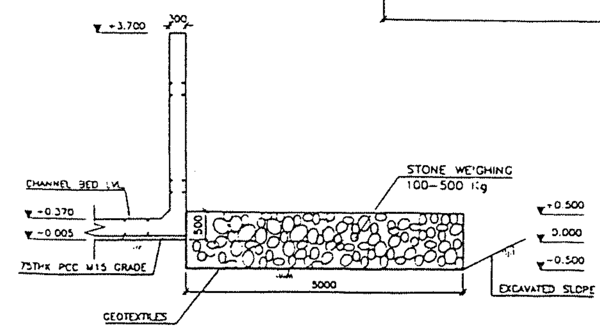
NOTES :

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS OTHERWISE SPECIFIED
2. ALL LEVELS ARE IN METRES AND ARE WITH REFERENCE TO MEAN SEA LEVEL UNLESS OTHERWISE SPECIFIED.
3. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH ALL OTHER RELEVANT DRAWINGS
4. ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.NO DIMENSION SHALL BE SCALED.
5. FOR SECTION B-B, REFER TO DWG.NO: C2-702
6. FOR ALL WORKS REQUIRING CEMENT, ORDINARY PORTLAND CEMENT, GRADE 43,CONFORMING TO IS 8112 SHALL BE USED.
7. CLEAR COVER TO ANY REINFORCEMENT SHALL BE 50mm UNLESS OTHERWISE SPECIFIED.
8. REINFORCEMENT BARS SHOWN AS ø SHALL BE MILD STEEL BARS, GRADE S-240, CONFORMING TO IS 432 (PART 1)
9. REINFORCEMENT BARS SHOWN AS ¥ SHALL BE HIGH YIELD STRENGTH DEFORMED BARS, GRADE S-415, CONFORMING TO IS 1786-1985
10. LAPS WHEREEVER PROVIDED SHALL BE STAGGERED AND MINIMUM LAP LENGTH OF 50 x DIAMETER OF BAR SHALL BE PROVIDED UNLESS OTHERWISE SPECIFIED
11. WELDING OF BARS SHALL BE DONE ONLY AFTER OBTAINING PERMISSION FROM THE ENGINEER AND WELDING SHALL CONFORM TO CLAUSE 1606 OF MOST SPECIFICATIONS
12. THE NUMBER AND POSITION OF LAPS, HOOKS, BENDS ETC. SHALL BE PROVIDED TO SUIT HANDLING AND SITE CONDITIONS AND AS DIRECTED BY ENGINEER. ADDITIONAL SPACERS, CHAIRS ETC. SHALL BE PROVIDED TO SUIT THE SITE CONDITIONS AND AS DIRECTED BY THE ENGINEER.

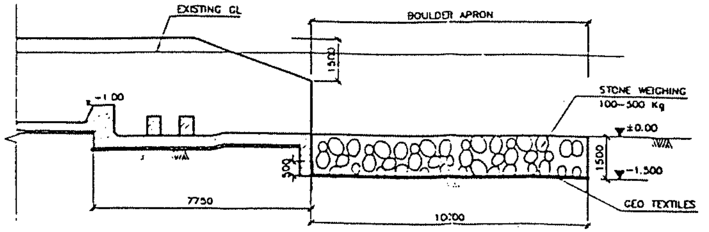


SECTION A-A

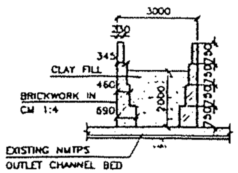
SCALE 1:250



SECTION C-C



DETAIL AT 'X'



SECTION - DD

Madras Port Trust

Ennore Coal Port Project

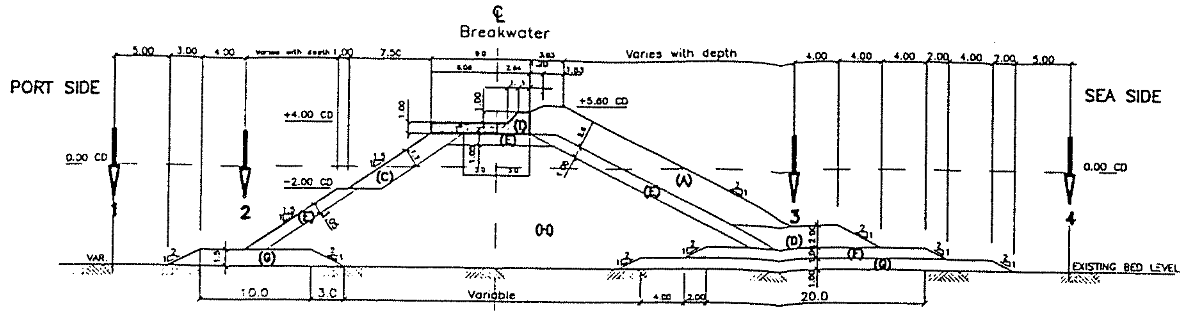
HASKONING
Royal Dutch Consulting Engineers and Architects

in association with

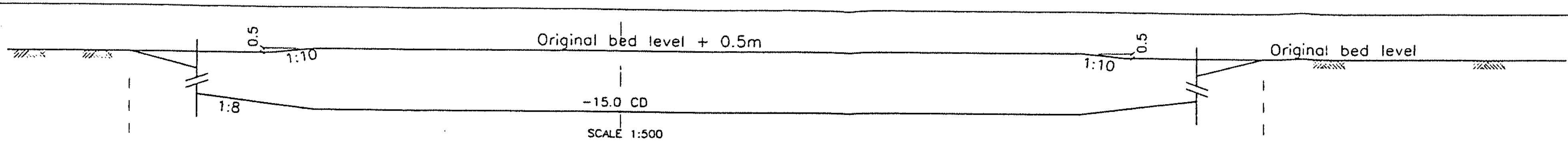
of India

DIVERSION OF NMTPS OUTLET CHANNEL
GENERAL LAYOUT PLAN AND CROSS SECTIONS

date	drawn	revision	checked	SCALE 1:250, 1:100, 1:50	A1-size
03-12-'96				Project No 9019.A5528.21	

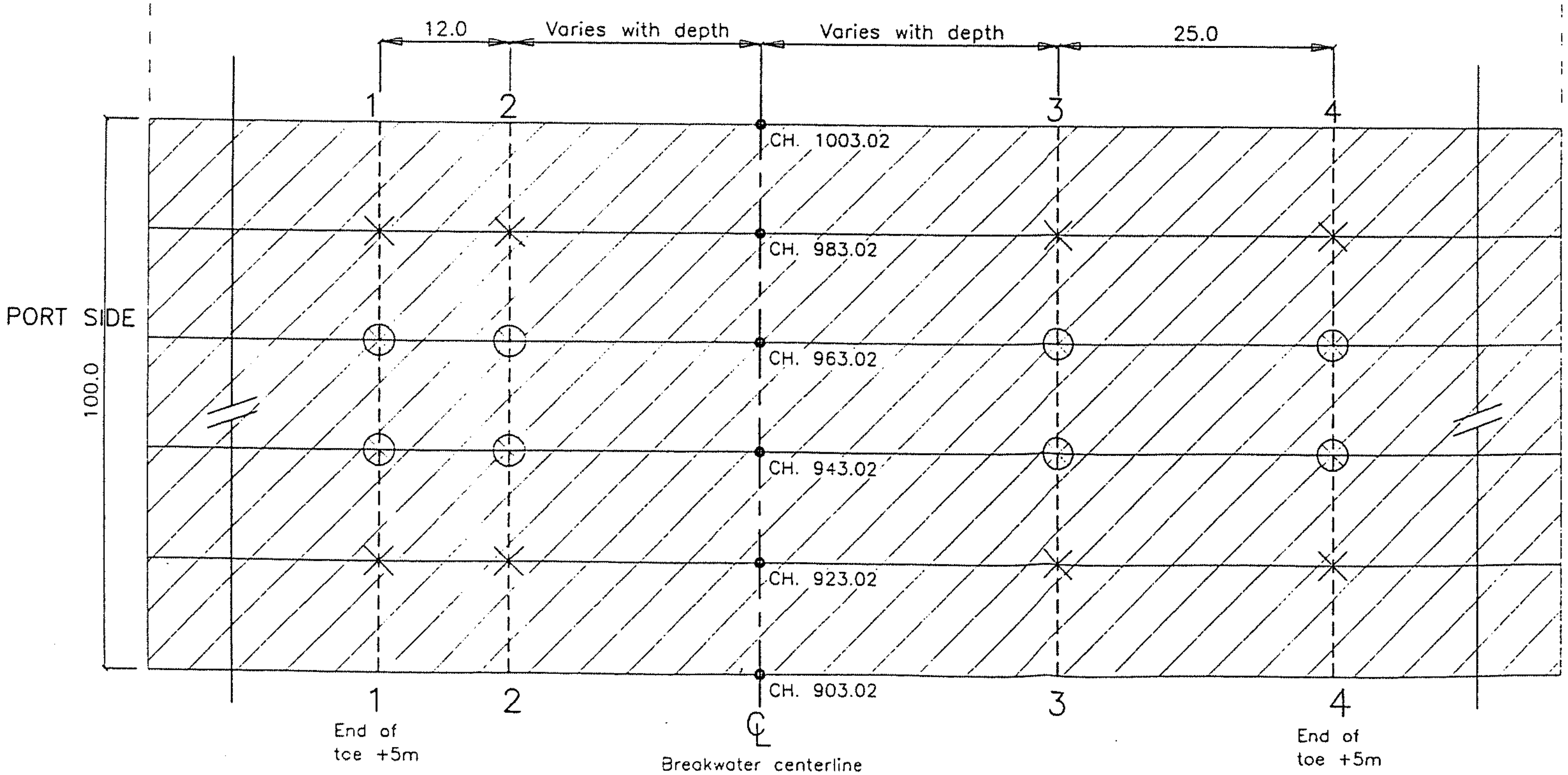


TYPICAL CROSS SECTION OF SOUTH BREAKWATER
FOR TRUNK SECTION FROM HEAD TO -8.00 CD
SCALE 1:500



SCALE 1:500

PLAN VIEW OF PILOT COMPACTION AREA



LEGEND

- X CPT
- O Sand sampling
- Hatched: Area to be compacted

NOTES :

1. ALL DIMENSIONS AND LEVELS ARE IN METRES
2. LEVELS ARE RELATED TO CD

Madras Port Trust
Ennore Coal Port Project

HASKONING Consulting Engineers and Architects in association with RITES of India

PILOT COMPACTION AREA (SOUTH BREAKWATER)

date	drawn	revision	checked	SCALE	A3-size
				Project No	9019.A5528.21