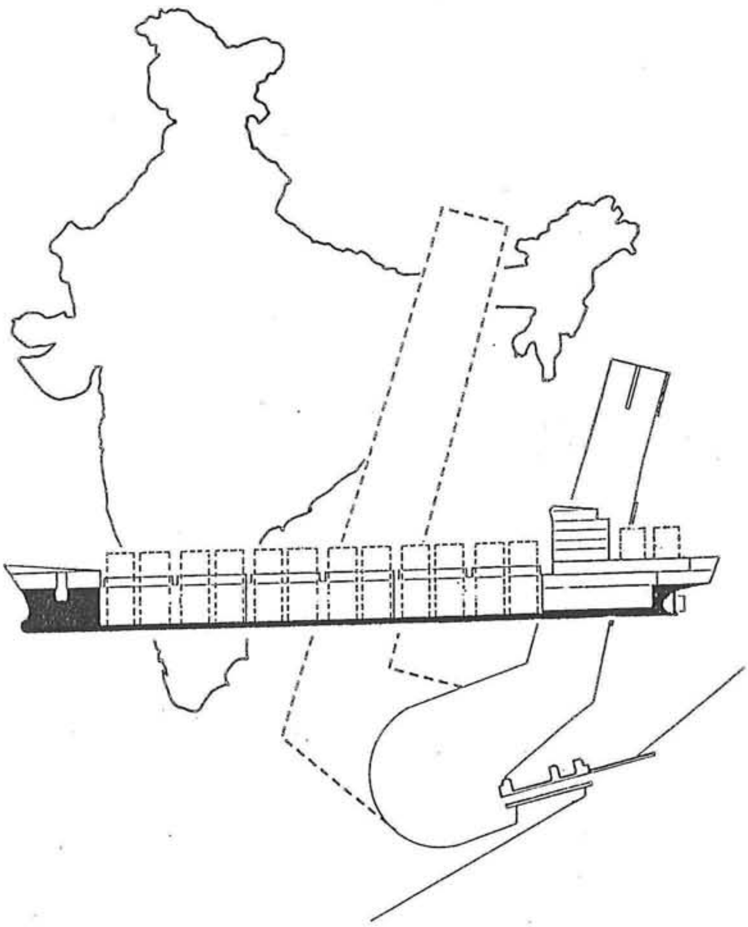
PORT DEVELOPMENT in HALDIA

VOLUME 1



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PORT DEVELOPMENT IN HALDIA

MASTERPLAN BASED ON CONCENTRATION OF ALL PORT ACTIVITIES PRESENTLY TAKING PLACE IN HALDIA AND CALCUTTA

VOLUME 1 TEXT

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PREFACE

In 1986 a study was made of the 'masterplan development of inland waterway transport terminals at Haldia and Calcutta' by the joined consultant offices NEDECO and CES, settled in respectively the Netherlands and India. Due to this study the first ideas emerged to use the development of the port in Haldia as subject for a thesis project. The thesis project was carried out to graduate at the Civil Engineering Faculty, Delft University of Technology in the Netherlands.

The actual work on the thesis project started in December 1986 and resulted in the underlying report, which should be read together with the separate volume containing the accompanying figures and tables. The report has been written having a broad readers-public in mind. Therefore technicians and port development specialists are advised to examine the "Table of Contents" to select and find the subjects having their special interest. Undoubtedly the more experienced users of the English language will notice some failures in the grammar and writing stile of the texts. I hope this will not disturb them too much.

To finish the thesis project a constructive design for a third oil jetty in Haldia will be drawn up, which will be described in another report, yet to be published.

I am much obliged to my mentor professor H. Velsink, especially for his ability to supply me with the necessary information or to direct me to other information sources. The latter often led to interviews and I wish to thank all those who were interviewed for their kind cooperation,

Wilfred Molenaar

May 1988

SYNOPSIS

The ports of Haldia and Calcutta are located landinward along the Hooghly river respectively 43 and 145 kilometer from the Bay of Bengal. In this report a masterplan will be developed to concentrate the port activities of both ports in Haldia.

Roughly 50% of India's population is living in extreme poverty. The Government considers growth of the economy, resulting in a higher employment, to be of paramount importance to solve the poverty problem. In the 7th Five Year Plan, which started in 1984, it was planned to increase the Gross Domestic Product, indicator for economic productivity, with 5% per annum. One of the measures taken to realise the objectives of the 7th Five Year Plan is further port development.

If a ship is heading for Haldia or Calcutta it has to cross respectively 3 or 15 sandbars between the Bay of Bengal and the port, which is only possible during High Water. The dept of the river and, to a lesser extent, the estuary are the most limiting factors for the draught of vessels. Both ports were constructed as impounded dock systems. Especially in Calcutta the dimensions of the locks and the available water depth in the dock restrict the size of the visiting ships. The turn around time of vessels in the port is high and mainly depends on the cargo handling process.

The port of Calcutta can be described as a congested traditional breakbulk port. The combination of outdated quays and sheds, frequent breakdown of equipment and bad management result in an inefficient cargo handling process. Haldia was set up as an auxiliary port for handling mainly bulk cargoes. Consequently appropriate equipment and ample storage area have been provided. The area reserved for port activities in the existing masterplan allows further expansion of the port.

Transport to and from the hinterland in Calcutta is hampered by the overburdened internal port- and metropolis road system. Lack of storage- and parking area are the underlying problem in regard of the port road system. In spite of the difficult road transport the share of railway and inland waterway transport is almost negligible. In Haldia there is only one road- and railway connection with the national systems, however, liquid bulk cargo, a considerable part on the total cargo, is transported by pipeline.

To realise an increased and more efficient throughput, in either Calcutta or Haldia, the efficiency of all port operations, maritime transport, cargo handling and hinterland transport, have to be improved. There are two realistic alternatives for further port development. For mere technical reasons and in order to form an opinion about further port development in Haldia the alternative based on concentration of all port activities in Haldia will be elaborated.

To obtain a cargo-forecast the method of extrapolation, on throughput figures of the past 15 years, has been used in combination with new developments described in the 7th Five Year Plan. Use of the 7th Five Year Plan determined the choice of the target years 1989/90 and 1999/2000. The resulting cargo-forecast has been compared with and afterwards slightly adjusted to a forecast drawn up by the Calcutta Port Trust. In rounded off figures the total amount of cargo increases from 11 million tonnes in 1984/85 to 17 million tonnes in 1989/90 and 25- to 29 million tonnes 1999/2000.

A packing-forecast has been made which ranged cargoes under the liquid bulk, dry bulk, breakbulk or container port traffic class and listed the amount of cargo in the respective classes. For the liquid- and dry bulk class the figures, in tonnes per annum, were easily derived from the cargo-forecast. The breakbulk and container forecast are depending on each other. Due attention had to be paid to forecast the number of containers in the target years. The cargo-forecast, the present figures and estimates for the containerisation degree, tonnage per TEU, number of empty containers and the ratio 20 feet to 40 feet containers were used to draw up the container-forecast. In 1989/90 and 1999/2000 respectively 100,000 TEU and 359,000 TEU or 81,000 Boxes and 276,000 Boxes will be handled in the port.

The berth-productivity has been calculated with the help of, and after establishment of, figures for the shift-productivity, the average number of commission days per annum, and the berth occupancy factor. The number of shifts per day has been fixed at 3. The present shift-productivity per distinguishable port traffic class was taken as starting point to assess the productivity in 1989/90. An annual increase of 2% per annum per gang and, if possible, the use of more loading or unloading equipment have been assumed to find the productivity figures for 1999/2000. An inventory has been made for the circumstances causing an interruption of the work at the berth. After the number of lost days per annum and their correlation had been established the remaining average number of commission days per annum has been calculated. The result amounted to an average number of 292, 311 and 350 commission days per annum for respectively fertilizer, breakbulk and the other berths. In literature berth occupancy factors are recommended for breakbulk berths based on a ship costs to berth costs ratio of 4 to 1. The same figures were used for all the other types of berths.

The nautical infrastructure, in case of the port in Haldia consisting of the approach channel in the estuary, the lock and the basin, was subjected to an optimization procedure to examine to which extent its use can be improved. Within this procedure a few facts were established, such as:

- the dimensions of the 10.7 m draught channel, i.e. a channel providing access to the port for 10.7 draught vessels on 320 days per annum.
- the dominating influence and uncertainty about the annual amount of maintenance dredging to be expected.
- an indication that in far future construction of a 12.2 m draught channel will be feasible.

The ship-forecast lists a number of standard ships with some characteristical features per port traffic class. In 1989/90 and 1999/2000 approximately 2100 and 2500 ships will visit the port of which a considerable number, circa 50%, are breakbulk ships.

Terminal designs were made paying due attention to the required storage facilities and the necessary area for roads and railways on every terminal. The requirements and the layout of terminals for oil and phosphate rock were greatly influenced by the premisses of the oil- and fertilizer industry near the port area. It reduced the necessary storage area in the port.

The masterplan for Haldia has been divided in a riverside and a portside masterplan. A preliminary layout for the riverside masterplan shows the position of the through channel to Calcutta, the oil jetties, the anchorages and the manoeuvring areas. There is enough space for the approach manoeuvres to the lock, the jetties, and for turning the vessels on the river. Nautical experts have to be consulted to assess the final riverside masterplan, which will not be a constraint for further port development in Haldia. After comparison of several alternatives for the shape and size of the basin, and for the arrangement of terminals around the basin, a final layout for the portside masterplan has been selected.

It appears that the developed masterplan, based on concentration of all port activities of Calcutta and Haldia, cannot be implemented before 1989/90 owing to the amount of required facilities. Immediate improvement of the cargo handling process in both ports would partially solve this problem. After 1999/2000 substantial increases of cargo throughput require development of another port besides Haldia and Calcutta.

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1. INTRODUCTION

In northeastern India the Hooghly river, the westernmost side branch of the Ganga, debouches into the Bay of Bengal. The ports of Haldia and Calcutta are located along the river at a distance of respectively 43- and 145 kilometer from sea.

From the 17th century the development of the port in Calcutta was coupled with increased economic activity in Bengal and India. In the seventies of this century the auxiliary port in Haldia has been built in order to relief the old port of Calcutta from the transshipment of mainly bulk cargoes. In the interest of the local and national economy the ports must be further developed in future.

This report will be concerned with the development of a masterplan for Haldia in order to examine the possibility to concentrate the port activities, of both Calcutta and Haldia, in the port of Haldia. The masterplan will be directed to the year 1999/2000 and will be based on a cargo forecast, tendencies in shipping, and a berth productivity forecast.

In the next chapter first some general information about India, West Bengal, and Calcutta will be provided. Besides this, the relation between port development, growth of the economy and the extreme poverty of a considerable part of India's population will be elucidated. The ports of Calcutta and Haldia as well as the circumstances that hamper the efficient execution of port operations will be described in chapter 3. After referring to the necessity of further port development it will be motivated in chapter 4 why a masterplan for Haldia will be drawn up in the following chapters of the report.

In the chapters 5, 6, 7, and 8 respectively the cargo-, packing-, nautical infrastructure and ship-, and berth productivity forecasts will be discussed. The forecasts supply important information for the design of the cargo terminals and the harbour basin, both described in chapter 9. In chapter 10 alternative masterplans will be drawn up and one of them will be selected.

Based on the selected masterplan it will be possible to make comments on the desirability to concentrate all the port activities in Haldia. The resulting conclusions and recommendations are written down in chapter 11.

2. COUNTRY, STATE, METROPOLIS

On the Indian subcontinent many differences or even contradictions can be found regarding the people, their wealth or poverty, religions, traditions, states and governmental bodies, languages, topography, climate, nature. The poverty of a considerable part of the population, 40 or 60% depending on the definition of the poverty line, is one of India's most serious problems. This chapter describes how one of the biggest development countries in the world fights against poverty by stimulating its economy and the role of ports in this policy will be explained. Furthermore it will be elucidated how some of the mentioned present-day differences or contradictions are caused just by a different geographic location or arose from events in the past. If possible, attention has been paid to the specific situation in the state West Bengal and the metropolis Calcutta. The subjects topography, history, population, poverty, economy and ports will be discussed in succession in following sections.

2.1 TOPOGRAPHY

The country, India

India is a part of the Asian continent although it occupies a separate continental plate. The exact position on the worldmap is between 8 and 37 degrees northern-latitude and 68 and 97 eastern-longitude. Figure 1 not only shows the present countryborders of India, Pakistan, Afghanistan, China, Nepal, Bhutan, Burma, and Bangladesh but also the mountain ranges, that act as natural barriers, as well as some typical areas and rivers. Southern India is often called Peninsular India since it is surrounded by the Arabian Sea and the Bay of Bengal. In Figure 2 the mining and industrial areas, and the transactional areas of the the four biggest metropolises, Bombay, Calcutta, Delhi and Madras, are indicated. The inset of the figure gives the present division of India into states and Union Territories.

The state, West Bengal

Due to its position in north-eastern India, West Bengal is surrounded by several countries, other Indian states and Union Territories and the Bay of Bengal, see Figure 3. The odd shape of West Bengal is mainly caused by the partition of the former english colony in India and West- and East Pakistan. The north south axis of the state is 700 kilometer long while the length of the east west axis varies between 20 and 330 km. From north to south the landscape changes from the high Himalaya mountain ranges to the flat coastal area called Sunderbans which lays east of the Hooghly estuary. The small corridor between the northern and southern part of West Bengal is intersected by the Ganga and here the Bhagirathi branches off from the former river. The Farakka Barrage, completed in 1975, regulates the discharge of the Bhagirathi. About 300 km from sea the Bhagirathi changes its name into Hooghly river.

The Metropolis, Calcutta

The Metropolis Calcutta, see Figure 4, is located on the river banks of the Hooghly. East- and westward from the river the land slopes away to marshes and swamplands. This topography has confined the Metropolis area to a stripe on both sides of the river with a width varyingfrom 5 to 10 kilometer, together with a 65 kilometer length this results in an area of approximately 1300 square kilometer. Expansion of the city towards the east is feasible as far as living conditions are considered. Taking into account that the biggest part Calcutta's hinterland lays in the west, and the small number already congested bridges crossing the Hooghly expansion towards the west would be more preferrable.

In fact the old city Calcutta is bounded on all sides by suburbs, Cossipore and Chitpur on the north, Maniktala on the east, Garden Reach on the southwest and Howrah across the river on the westside. The Calcutta port area is situated in Garden Reach close to old Calcutta, which is the nowadays Central Business District (CBD). Besides the mentioned suburbs there are about 20 other suburbs. At present the Calcutta Metropolis Development Authority (CMDA) is working on the dispersal of metropolitan activities to the outer areas in order to unburden the core of the metropolis, see subsection 3.4.2.

2.2 CLIMATE

The tropical monsoonclimate in India is dominated by the moist southwest monsoon prevailing in summer from June to October and the northeast monsoon in winter from November to February. The southwest monsoon is normally moderate in strength but occasionally fresh or strong. It is very warm and humid by day and night, with persistent cloud and frequent rain, often heavy rain. About 85% of the total precipitation falls during the summer season. The northeast monsoon is rather more variable in speed and direction but the strength is moderate to fresh between north and northeast for long spells when well established. The cooler drier air, with brighter weather, provides a welcome relief in most parts of the country. In the transitional period, March to May, between the two different monsoons the highest temperatures occur. As a rough conclusion the year can be divided in three periods; a rainy, a cool and a hot period.

Weather conditions vary considerably through India. The mountain ranges and the proportion of the subcontinent greatly influence e.g. the distribution of precipitation, and minimum and maximum temperatures, shown in Figure 5 and Table 1.

During the southwest monsoon the coastal area in front of the West Ghats has high precipitation numbers because the mountains push wind and clouds upwards. On leeside of the West Ghats it hardly rains but towards the Himalaya where the wind is pushed up again the number of rainfalls and received precipitation increases. For the fertile Gangetic riverplain, located on weatherside of the Himalaya, this is an extra favourable circumstance.
On average temperatures in the south are higher but in the northwest some areas can be earmarked as desert area because extremely high temperatures appear and hardly any rain falls overthere. More specific data about the climate in Calcutta and Haldia will be given in subsection 3.2.3.

2.3 HISTORY

In order to describe a few topics of India's history the past will be roughly divided into three periods, viz. the period before 1690 a period from 1690 to 1947, and the period after 1947, see [21,25]. Appendix A gives a summary of the development of the port of Calcutta [20].

The period before 1690 can be characterised by numerous invasions of peoples conquerring a part of or the complete subcontinent. Usually the invaders entered the subcontinent through the Kyberpas in the northwest and spread over the north in the Gangetic Valley, whilst Peninsular India was penetrated less frequently due to the inaccessibility of the Deccan Plateau. Among the invaders were Alexander the Great, army leader of the Greek around 330 B.C., and Genhis Khan, the famous Mogul leader of the 13th century, as well as Huns from Central Asia and Turkish Muslims. Every time another culture, expressing itself in religion, language and various arts, was brought to India and consequently influencing the existing cultural life.
In northern India Hinduism, Buddhism, and the Sanskrit language developed throughout the first centuries of the era. Only Hinduism penetrated southern India where Dravidian languages were used and traditions were partially formed under the influence of maritime relations with Egypt and the Middle East.
In the seventh century the great reformer Sankarcharya succeeded in the integration of the Buddhist and Hindu philosophies leading to the emergence of Hinduism as the principal religion of India and the virtual extinction of Buddhism in the country. Hinduism as a religion found its final shape and thenceforth did not absorb basic thoughts and accompanying habits from other religions anymore. Hinduism expresses itself in social life through the caste system, which is a very static system based on fixed hierarchic positions of social groups in society. In fact the Hindu religion became the main reason to withstand the later Muslim rulers. During the reign of the Muslims in northern India, after 1215, many Hindus converted themselves to the Islam but others fled, for instance to the kingdom of

the Rayputs, the later state Rajasthan, or Vijayanagar further in the south. Displacement of the Brahmins from leading positions, caused that Sanskrit was lost as a single language for all the peoples and many different languages like Hindi, Bengali, etc., started to develop themselves.

In 1526 the Mogul dynasty was founded which lasted until 1707 and incorporated almost the whole subcontinent. Either Delhi or Agra was capital of the empire. The Taj Mahal, built in Agra, is a beautiful mausoleum and only one monument that shows the achievements in arts, literature and the great economic activity of this period. After the collapse of the Mogul empire a period of strife, regicide, and revolt followed before the English definitively established their rule over India.

Already in 1690 the first British settlement was founded in Calcutta by Job Charnock, an agent of the East India Company (EIC). Charnock chose the location on the eastbank of the river Hooghly partly because of its easy defensive position and partly because of its favourable trading location with good acces to the Bay of Bengal via the river. The disadvantages included the nearness of marshes in the east and swamps in whole the area that made the spot unpleasant to live and even unhealthy. Permission for freedom of trade gave a great impetus to the growth of Calcutta. After the Battle of Plassey, in 1757, the influence of the East India Company grew bigger and bigger and became undefeatable on the Indian subcontinent, however financial mismanagement made the British Government take over the Company. Warren Hastings became India's first Governor-General in 1774. He concentrated most of the British authorities in Calcutta. The interest of the Government finally led to annexation of the whole subcontinent and execution of British authority by Viceroy from 1857. In that year the Mutiny of the Seppoys supported by the Mogul emperor in Delhi was beaten down and the governmental capital was officially transfered to Calcutta. In 1876 Queen Victoria became Emperor of India, 'the brightest jewel in the British imperial crown'.

The British explored the colony energetically. Agriculture was to be improved by enlightment and irrigation, for economic reasons trade crops were planted. Already in 1880 the railway crossed the country facilitating import and export from the ports of Calcutta, Bombay and Madras. The Indian Civil Service was established to organise the Government and education was improved. But besides these profitable developments there were some disadvantages as well. The zamindari system in agriculture and abundant availability of factory products from England drove many poor Indian people in a position of exploitation or unemployment. Among Indian people in higher positions the first ideas about independence emerged.

Nationalism in Bengal was more developed than elsewhere in India since Calcutta was the administrative headquarter of British India and also had become the intellectual centre of the subcontinent. Although Bengal was a Muslim area Hindu people had more administrative, political and economical power. In 1900 the area administered by the local Government of Bengal had become too large to be handled by a single administration, it comprised the current Indian states Orissa, Bihar, West Bengal and Assam, and Bangladesh. The required partition of Bengal made this extensive area the first stage where the mingled conflicts about Indian Independence and between Hindu and Muslims had to be settled by the British Authorities. Agitation against the proposed partition resulted in a shift of the status of the Indian Nationalist Congress Party from a middleclass pressure group to a nationwide mass movement, and included mass meetings, rural unrest, a swadeshi- or own products movement, and even a boycot of foreign cloth. The partition was carried through despite the agitation and the extreme opposition reacted by forming an underground terrorist movement. In 1911 East- and West Bengal were reunited, whilst Bihar and Orissa formed a state and Assam became a chief commissionership. In 1912 the capital was removed from Calcutta to Delhi since the situation in Bengal was too turbulent.

In 1920 Gandhi, popularly known as Mahatma, which means 'great spirit', formulated and secured the needed mass support for a policy of nonviolent noncooperation with the British Government that finally would lead to India's independence. In following years the National Congress Party grew and under Nehru's leadership India's independence was achieved in 1947, however not without the constitution of Pakistan a seperate Muslim-country. This was necessary because leaders of the Muslim minority emphasized the insuperability of Hindu-Muslim antagonism and were afraid to be opposed by the Hindu majority in an united country. Being aware of the mass support for this point of view even Ghandi agreed with the formation of two separate countries. His tolerance for people and other religions could not prevent him from being murdered by a fanatic Hindu in 1948.

The aggravating social problems caused by the demand for Home Rule resulted in regular strikes and riots in Calcutta from 1923 to 1940. Other setbacks were the Japanese air raids in World War II upon the harbourdocks causing damage and loss of life, and during this war the metropolis became for the first time a resort for refugees. The Hindu-Muslim antagonism culminated in the Great Calcutta Killing in 1946, which contributed to the decision to divide the subcontinent between India and Pakistan. The latter was the most serious setback for Calcutta not only because of losing the trade of a part of its former hinterland but also because thousands of refugees from East Pakistan flocked to Calcutta. These refugees increased the already existing social problems and overcrowding.

After the formation of the Democratic Republic of India, in 1950, with Nehru as its first Prime Minister, the country reorganised the Government forming 21 States and 9 Union Territories, similar to the United States of America. Furthermore it tried to maintain an independent position between the superpowers USA and USSR, preferred to develop heavy industry instead of stressing the development of the agricultural sector, started a nuclear research program. A planned economy with Five Year Plans (FYP) was introduced. In 1965 and 1971 there were conflicts with Pakistan, the latter conflict caused by a civil war in East-Pakistan which led to the foundation of Bangladesh.

Was India's far history soaked with irreconcilability, based on different languages and religions, this problem certainly did not vanish after the Independence and formation of States and Union Territories. The sorrowful event of Indira Gandhi's assassination in 1984 by a Sikh is merely one recent example of religious strife. The racial, language, and religious contrasts as well as the rapidly growing population and number of people living below the poverty line form major problems for the nowadays Government.

2.4 POPULATION

In the world only China has a bigger population than India. Since the independence steady improving medical conditions resulted in a deminishing deathrate (now 13 per thousand) while the birthrate remained almost the same (34 per thousand), thus causing growth of the population. The average length of life rose from 25 years in the beginning of this century to 32 years in the thirties and 56 years in 1986. Nonetheless mortality between 0 and 5 year forms 45% of the total death rate. The growth of the population is not the reason for poverty and unemployment but it causes that those problems endure. It is obvious that the birthrate has to be brought under control in order to stop growth of the population but the Government of India was not very succesful in her birthcontrol policy which started in the late sixties. Most probably the attempts for realising birthcontrol will become more effective if the standard of life improves and having children is not a necessity anymore. Data for the population proportion in past and future are given in Table 2 as well as the average growth rate per annum. At the start of the next century approximately one milliard people will be living in India.

Studying the upbuilding of ages it can be learned that there is a large group of young people, i.e. India has a young population. The consequences for this moment are that a relatively small group of grown-ups have to earn enough money for supporting the young and the old. One of the consequence of the present upbuilding of ages for the next 15 years will be that 120*10**6 extra jobs have to be created in order to supply every grown-up with an income.

The average density of the population in India is 260 inhabitants per square kilometer, Figure 6 shows a more detailed picture of the density of the population. Although there are 15 metropolises with a population of over one million people the majority of India's population lives in one of the 600,000 villages. Since the ratio urban to rural inhabitants is 1:4 India's population can be classified as a rural population. The higher growth of the urban population is not explained by migration but by the infant mortality rate in the rural areas which is 50% higher than the urban rate.

West Bengal comprises an area of 87,853 sq km. With a population of 55.5*10**6 people the average density of population becomes 632 persons per sq km. In the cities where 30% of the population lives the density is, on average, 5 or 6 times higher.

In 1971 there were 9.2*10**6 people living in Calcutta's agglomeration. At some places in town the density of population mounts up to 32,000 people per sq km. These high densities occur in one of the numerous slum areas where, in total, about 3 million people live.

As a result of the Hindu religion there is a special group of India's population, known as the 'untouchables' or 'outcastes'. In 1981 this group included 15.7% of the population or 108*10**6 people, most of them are living below the poverty line. Based on humanitary considerations the Government officially abolished this caste soon after the independence but special efforts are still necessary to give 'untouchables' a chance to obtain a reasonable existence. An important measure prescribes that among all the government jobs a certain percentage is reserved for people from the 'scheduled castes'or 'scheduled tribes', the nowadays describtion for untouchables.

2.5 POVERTY

In the following paragraphs first the Indian poverty line will be mentioned and elucidated before the origin of poverty, unemployment, and the resulting living conditions will be discussed. The discussion will concentrate on the situation in Calcutta, especially in respect of the last subject [23].

In 1984/85 the poverty line was about 100 Rs/person/month in rural areas and 150 Rs/person/month in the urban areas [21]. This is the amount of money necessary to buy just enough food to keep away from starvation but is not enough for a good health. The Nett National Income per capita in 1984/85 is estimated at 770 Rs/a, which is below the poverty line of either the rural or urban areas. The distibution of National Income over the households is shown in Figure 7. In order to illustrate the poverty of India's population it has been assumed that every household has the same number of family members, which is virtually incorrect. Under this assumption households are equivalent to single persons and as a result the relevance of National Income can be shown. The percentage of households living below the official poverty line amounts to 40%, while 80% of the households is spending two-third of their income on food. Other information about the distribution of incomes and poverty allows a comparison of Calcutta with the rest of India, see the following table.

Per capita income, in 1976/77, in Rupees/annum at 1970/71 prices:

- Calcutta Centre	1922
- Calcutta Metropolis District (CMD)	1133
- West Bengal	755
- India	658

Source: [23]

Conversion of the 1984/85 poverty line with index figures yields approximately 1000 and 1500 Rs/a in 1976/77 respectively for rural and urban areas. Although the figure for Calcutta Centre is above the poverty line and in case of the CMD approaching the poverty line for urban areas, there are 4 million people living below the official poverty line in Calcutta. The difference between rich and poor is enormous.

About a third of India's population, 245*10**6 on 701*10**6 in 1981, had a regular job and was officially registered as having a profession. In all kinds of irregular unofficial jobs many people are trying to earn something in order to make a living for themselves and their relatives. Official unemployment is a luxury of the rich since there are no unemployment benefits in India. These benefits are cost prohibitive due to the number of people involved. Thus the only possibility to supply people, or families, with an income is creating more jobs.

The number of employed people in West Bengal is also a third of the population, i.e. 19.4*10**6 people. For Calcutta there is not a dependable figure available for the percentage of employed people. According to the official statistics there are more jobs in Calcutta than the number of inhabitants but this has to be sett off against the number of non residents and semi permanent immigrants who are not registered. The distributive trades supply 40% of the officially registered jobs, indicative for Calcutta's mercantile character.

For the majority of people in India the living conditions are poor since a lot of civic amenities are still absent in this development country. The CMDA's expenditure in several sectors reveals the major problems of the metropolis as well as the executed policy of the municipalities. Throughout the years most of the expenditures were for the sectors Water Supply, Traffic and Transportation, Sewerage and Drainage and Bustees Improvement.

The WHO called Calcutta the last focus of cholera in Asia. For years the prevalence of cholera was caused by lack of drinking water. Water that was used by the fire brigade and for watering the streets was misused as drinking water. The situation improved since the Farakka Barrage ensures a saline free water supply for the city in the summer months, which was combined with the chlorification of all the supplied water. The total elimination of unfiltered water supply has been recommended. Big parts of the city still remain unsupplied with a sewage system and the present sewers disfunction too often. In unsewered parts of the city unsanitary methods of human waste disposal persist. On top of this the garbage removing system is unsatisfactory. Combined with the lack of drinking water this can only result in bad hygienic conditions.

Bad hygienic conditions, lack of water, and overcrowding of people are especially found in the slums. A slum is officially defined as "a collection of huts standing on a plot of at least 650 square meter". According to this definition there are hundreds of slums but the number of smaller slums might be bigger. The hut usually is a dilapidated and unventilated singlestorey room. Lack of money and lack of family support force one third of the city's population, about 3 million people, to live in a slum. A special category among Calcutta's inhabitants is the group of pavement dwellers. These people, 49,000 in number which is 0.5% of the total population, have no place to go to at all. About 40% of them are children.

All people experience the sultry atmosphere in Calcutta caused by the high temperatures and high humidity. Occasionally fogs and mists occur in the morning alternated by thick blankets of smog in the evening. Thermal generating stations and cars are responsible for this air pollution. Due to the haphazardly grown suburbs there is a lot of unnecessary commuting traffic. The capacity and condition of the present road system is insufficient. The CMDA's policy in the field of Traffic and Transportation will be described in subsection 3.4.2.

2.6 ECONOMY

2.6.1 General considerations about the economy

India's economical life and especially growth of the economy is important because it is one of the demands for creating more jobs. Usually the condition of national economies is evaluated by comparing the Gross Domestic Product (GDP). Although the GDP cannot be used as a prosperity indicator it is possible to use it as an indicator for the production in the economical sectors. Table 3 shows figures for the development of the GDP throughout the years and the contributions of several economical sectors, in absolute numbers and in percentages, to the GDP [18]. Similar to any other country there is an agricultural-, mining-, industrial-, building industry-, energy-, trade-, transport-, and other services sector. Agriculture, industry and transport contributed 36.7%, 15.5% respectively 7.4% to the total GDP in 1984/85. The share of the agricultural sector in the GDP declined during the last decades, i.e. the raise in production in the other sectors (except other services) was relatively higher than the growth of production in this sector. Nonetheless the agricultural sector remained the most important and it is even possible to remark that variation in the annual amount of precipitation is the main reason for similar changes in the GDP. The agricultural and industrial sector will be examined in further detail in following subsections, before looking over the Government's policy with accompanying critisism.

2.6.2 Agricultural sector of the economy

About 70% of India's professional population, 170*10**6 people in 1981, is working in the agricultural sector, 30% of this group as labourer. In the villages merely 10% of the households owns 50% of all the ground. As a result a relatively small group enjoys most of the benefits which are the result of governmental investments in the agricultural sector. If ever the majority of the population has to be allotted with more prosperity a radical shift in the possession of ground has to be extorted.

Under the condition that death from starvation would be banished India increased its agricultural production throughout the years aiming at selfsufficiency, but the country could not escape from importing large quantities of food in 'bad weather' years. Although the objective of selfsufficiency seems to be realised as well as it is expected that import of huge quantities of foodgrains will not be necessary anymore it is not justified to suppose there is an abundant foodsupply. The latter is proved by the high mortality rate among children and the fact that only one third of the total agricultural production is used for business on the trademarkets. Irrigation projects and stimulation of the use of high yielding variety seeds were the main contributors for increasing the production during the so called green revolution. Combined with an increased utilisation of fertilizers these contributors will remain important for improving the quality and quantity of India's agricultural production. In the areas where the green revolution has been carried out succesfully, for instance the Punjab, it is now possible to have two harvests per year one kharif- and one rabi-crop (respectively the summer and winter crop). Though climate is merely one of the reasons there are big differences in the yield as well as in the kind of planted crops in different states. For example wheat is mainly planted in Punjab and Uttar Pradesh, millets like jowar and ragi in Karnataka and Maharastra while rice and the tradecrop jute are planted in Bihar, Orissa and West Bengal. Another tradecrop, tea, can be found in Kerala, Assam, and West Bengal.

2.6.3 Industrial sector of the economy

About 11% of the professional population, or 27*10**6 people are working in the industrial sector [21]. For the industrial sector it is more difficult to venture an opinion about the benefits of governmental investments for the poor and unemployed compared to the agricultural sector. Leaving the latter sector out of consideration the Government distinguishes an organised- and an unorganised sector in all the sectors of the economy. The classification of enterprises, institutions, or governmental bodies is based e.g. on the number of employees in service of the owner or employer and the possession of a formal bank account or bank relation. The industrial professional population of 11% can be divided in 4.2% and 6.8% or 10.5*10**6 and 16.5*10**6 people working in respectively the organised- and unorganised sector [18]. Reliable statistics are only available for the organised sector. From labour point of view 'unorganised' should be considered as a synonym for working under bad conditions of employment e.g. no garantee for continuous work, no fixed and very low wages etc.. In the organised sector unions are active and are taking care of the conditions of employment.

There is a considerable amount of critisism about the performance of the industry. Industry produces too much luxury goods, i.e. products for the rich, at expenditure of too much and scarce raw materials in an inefficient way. More fundamental critisism is also uttered about Government policies. Indian economists point at the fact that industry grows too slowly in recent years (6th FYP) and that too little jobs are created despite the considerable investments. In other words the 'trickling-down' effect of Government policy or investments is too small for the big mass of the population. Four important reasons are given [22]:

- the income of the biggest part of the population is too small to purchase industrial consumer goods.
- diminishing investments of the Government in infrastructure.
- bad performance of national industries, especially in the transport sector.
- industrial policy in respect of national production and export. Import substitution is not executed consequently enough although the license system regulates the height and kind of production as well as the seat of industry. (Despite the license system, which functions since the early fifties, India's industry is still concentrated in the traditional areas).

It is not expected that industry will expand in the next future years although the Government plans to raise the industrial production 8 or 9% per annum in the 7th FYP by improving the utilisation of the existing capacity.

2.6.4 Economic policy in the 7th Five Year Plan

Government of India presents her long term policy in the Five Year Plans (FYP) but for execution by ministries and State Governments single year plans are derived from the FYP. The nucleus of the FYP [17] contains the proportion, the way of financing and the kind of investments in the next five years.

The Government recorded the following as the central objective of the 7th FYP:

> 'To make India a modern, technologically progressive economy with expanding capacity to provide the basic material and requisites of well-being for all people'.

This much comprising objective should be attained by:

- action to sustain and enhance the momentum of economic expansion and technological development.
- adoption of effective promotional measures to raise the productivity and incomes of the poorer sections of the population, poorer regions and poorer States.
- expansion and qualitative improvement in facilities for health, education, and other basic civic amenities.
- measures for for bringing about a sharp reduction in the rate of population growth.

Except the emphasis on a higher efficiency these measures are the continuation of actions in previous FYP's. The measures are translated in an economic policy and several development programmes. Programmes like the National Rural Employment Programme, Welfare of Scheduled Caste/Tribes- and Housing and Urban Development Programme, are described briefly in the 7th FYP. Important in the plan is the allotment of finances, see Table 4. Despite the attention for programmes that contain obvious anti poverty elements large scaled projects, e.g. in the field of irrigation and heavy industry, dominate the 7th FYP.

The Government aims at an annual GDP growth of 5% whereas the annual growth in the economic sectors should amount to 4% in the agricultural-, 8 to 9% in the industry and mining-, 12% in the energy-, 4.8% in the building-, 8% in the transport and 6.6% in the service sector. Furthermore import and export should grow 5.8 and 7% per annum. The Government and critics distinguish the same 'Achilles heel' overlooking the viability of the plan in respect of the necessary finances. This focusses on the Balance of Payments. For development and improvement of industry India has to import but the country cannot compensate the accompanying expenditure immediately. Owing to import and resulting higher industrial production the export can increase however in a following period, too late to compensate import. Also the assumption that export will increase because of higher production is not fully justified. Certainly not if the export possibilities of a commodity depend on the world trade market. These considerations made the Government decide that the Balance of Payments has to be monitored very carefully while paying special attention for raising the export volume. The anticipated higher growth rate for export (7%) can be interpreted as an attempt to compensate import expenditure in advance.

2.7 PORTS IN INDIA

In general it is possible to distinguish four functions of a port, viz., the transport-, commercial or trade-, the industrial-, and the residence and employment function. Of course the transport function dominates the other functions. Due to these functions the port plays an important role in the development of the national economy. The history of many ports shows how a bold policy of extending and modernizing ports stimulated the economy of their hinterland, however, the reverse also occurred. Since the development of the port is in the interest of the national economy and because there are considerable costs involved in port development the Central Government in India administers the seaports. The direct management is given in hands of a Port Trust. In the 7th FYP the Government describes the actions to be undertaken in order to attain a higher port traffic capacity in the 11 major ports of India. The plan pays attention to several developments in the maritime world, like the continuing containerisation, the increasing share of bulk cargoes, and the enhanced draught requirements of seavessels.

Along India's coast line of approximately 5560 kilometer there are 11 major ports and about 22 intermediate and 150 minor ports. Nhava Sheva, the newest (11th) major port, functions as an auxilary port for Bombay and is located 12 kilometers eastward of the old port. Kandla, Bombay, Marmugao, Mangalore and Cochin are situated at the west coast while Tuticorin, Madras, Vishakapatnam, Paradip, and Calcutta and its auxilary port Haldia are on the east coast, see Figure 2. Plans for an auxilary port near Madras, Ennore, are under consideration. The ports in Calcutta and Haldia fall under the management of the Calcutta Port Trust (CPT).

In the fifties there were only 5 major ports accounting for a performance in cargo handling of 19 million tonnes/annum (t/a). Throughout the years the number of major ports and the amount of handled cargo changed to 11 and 107 million t/a in 1986. In national context the cargo troughput of 107 t/a in harbours is small compared to the amount of cargo transported by rail and road. Included in the 107 t/a is national transport and almost all India's import and export cargo since overland transport to and from neighbouring countries hardly exists. On average 85% of all import and export cargo is overseas cargo [36]. In international context it should be noticed that a single port like Rotterdam in the Netherlands is handling 273 million tonnes cargo per annum which leads to the remark that India and its major ports still have a long way to go. In Figure 8 the total cargo throughput of all the major ports and the port traffic capacities planned in the 7th FYP are drawn into a graph. The graph also illustrates the deviating performance of Calcutta and Haldia, whilst the total traffic showed a significant increase the cargo throughput in Calcutta and Haldia remained almost the same throughout the years. This cannot be explained by the increased number of major ports, although Paradip will undoubtedly have taken over a part of Calcutta's former port traffic. The next chapter will deal with the ports of Calcutta and Haldia in detail.

3. THE PORTS OF CALCUTTA AND HALDIA

3.1 INTRODUCTION

The description of the ports of Haldia and Calcutta in this chapter mainly concentrates on the transport function. The port is an indispensable link in the transportchain for cargo and passengers being transported from overseas destinations to inland locations and vice versa. In the port the means of conveyance changes from seavessels to trucks, trains or inland waterway vessels. The answer on the question whether a port functions well or not depends on the acces possibilities of vessels, the efficiency of the cargo handling process resulting in a change of conveyance, and the availability and convenience of transport modes in the hinterland of the port. There are several problems causing that Calcutta and Haldia cannot be characterised as well functioning ports, in the sequel this will be further elucidated.

It is possible to range the operations carried out in or near the port under maritime transport operations, cargo handling operations, and hinterland transport operations, see Figure 9. Cargo handling operations consist of the transshipment and storage of cargo. Since the treatment of passengerships does not constitute a bottleneck in the subject case, only the reception and handling of cargo ships will be taken into consideration. The port operations will be discussed successively in the following sections.

3.2 MARITIME TRANSPORT

It is obvious that maritime transport is only possible owing to the existence of the sea, here the Bay of Bengal, and the use of seavessels. The Hooghly river and estuary can be considered as a waterway between the ports of Haldia and Calcutta and the Bay. The waterway as well as the lock and a small distance in the dock have to be navigated by the vessels in order to reach an empty berth in the port. First the waterway will be described paying attention to its formation and the factors governing its use, then some considerations about the lock will follow, before the actual vessel traffic to the ports will be examined.

3.2.1 Geomorphology of seabed and riverbed

Two geological processes, subsidence of the Indian continental shelf and erosion, have dominated the formation of the river- and seabed in the Gangetic delta and the adjoining Bay of Bengal. The western border of the delta is formed by the Bhagirathi-Hooghly river system while the Ganga and Padma rivers bound the delta in the northeast, the Bay of Bengal functions as the southern border.

The most hidden proces is the subsidence of the Indian continental plate in the northeast. The plate is moving in a northeastern direction where it underthrusts the Asian continental plate. At the junction of these plates tectonic activity resulted in formation of mountain ranges, among them the Himalayan mountain range. The Bay of Bengal is situated in what is called the Ganges Cone between the Indian and Asian continental plates, see Figure 10. Depths in the Cone vary from the 1.2-2.3 km range in the north to the 3.6-5.2 km range near Sri Lanka. The continental shelf more or less surrounds the Cone and according to the definition the shelf is the shallowest 200 meter of the sea. The difference in depth between the Cone and the shelf is bridged over by a very steep piece of seabottom, which is best described as a submarine precipice. In the northern part of the Bay the continental shelf is about 185 km wide, thus the bottom slope is in the order of 1:1000, neglecting all kinds of irregularities. The bottom of the Ganges Cone is covered by enormous amounts of sediments in the pattern of a fan. The Bengal Fan is the largest submarine fan in the world formed after centuries of deposition. All those centuries the necessary sediments were supplied by the Ganga and the Brahmaputra river and these rivers still continue to transport their sediments seawards [8].

Due to erosion, frequently caused by deforestration, the Ganga and Brahmaputra transport sediments with an amount of 500*10**6 tonnes/annum and 900*10**6 tonnes/annum respectively. The Ganga and Brahmaputra join each other in Bangladesh and through the Padma and Meghna rivers water and sediments debouche into the Bay of Bengal, see Figure 11. Different from this situation which exists for about 200 years now, the Ganga used to flow through the Bhagirathi-Hooghly river system. The terrain was such that the Ganga took a preferred, and steeper, slope towards the east, perhaps aided by geological subsidence. Comparison of old and new charts shows that despite the supply of 1400*10**6 tonnes sediments per annum there is not an appreciable delta growth. For explaining the lack of delta growth contributions to the upbuilding of the Bengal Fan should be investigated. It is postulated that a considerable part of the sediments falls into Swatch of No Ground, a remarkable submarine canyon which breaches the continental shelf and leads to the main artery of the Bengal Fan. It is also postulated that siltation is partially compensated by the forementioned subsidence of the Indian continental plate [7]. Although delta growth does not occur there is an extensive system of sandbanks in front of the rivermouths and the Sunderbans, all oriented to Swatch of No Ground.

The entire riverbed in the Bhagirathi-Hooghly system is a composition of sediments with a median diameter varying from 0.065 mm to 0.3 mm. In the estuary the median diameter varies from 0.065 to 0.1 mm. Clay forms a substantial part of the sediments. Flowing water, with a certain minimum velocity, is able to transport these sediments. Deposition of the suspended sediments starts as soon as the flow velocity drops below the required minimum. Bed load transport is of minor importance. Salinity promotes the flocculation of fine sediments. The flocculated particles have a higher fall velocity and consequently require a higher water velocity to remain in suspension.

The deterioration of the Bhagirathi-Hooghly system was set in motion when the Ganga started to change its course to the east, resulting in a decreasing head water supply. This decreased the sediment transport capacity of the river system and enabled the penetration of salt water from the estuary into the more landinward parts of the Hooghly river, both processes causing an increased deposition of sediments. The initial depositions opposed the tidal propagation in the Hooghly, downstream of Calcutta, which entailed a decrease of the flood period and an increase of the ebb period. The latter resulted in higher flood velocities and lower ebb velocities, thus a nett transport capacity of sediments in landward direction arose. The shift of sediments from the downstream end to upstream parts accelerated the initial proces of siltation, and a vicious circle was formed. Sandbars grew in number and size and on top of that another phenomenon which negatively affected the navigability of the river presented itself, i.e. a bore tide occured during every flood period.

The access possibilities for the port of Calcutta had to be garanteed, therefore the Farakka Barrage has been built. It takes care of a minimum inflow of water, without sediments, into the Bhagirathi since 1975. The bigger and more stable discharge of the Bhagirathi-Hooghly river system resulted in a higher transport capacity of sediments, limited the appearance frequency of bore tides, and repelled the salt intrusion from sea. The higher transport capacity reactivated bankerosion in the Bhagirathi, and stopped the excess siltation in the Hooghly. It is estimated that the nett transport of sediments through the river and the estuary mounts up to 30 million tonnes/annum, see Figure 12 for sediment transport in the inner estuary. The figure also shows there is a clockwise transport of sediments around Nayachara Island.

At the moment fifteen sandbars have to be dredged in order to provide the required depth for navigation of seavessels to the port of Calcutta. A ship has to cross three of these sandbars in the estuary if it is heading for Haldia. Main obstacle on the route to Calcutta is the Balari Bar 10 km upstream of Haldia dock. If it was neglected the Balari Bar could even accomplish a shift to the east of the channel running along the Haldia dock, which would cause serious problems for this port. Heavy dredging of the Balari Bar not only prevents these problems but also has a positive effect on the construction of a guide wall extending from Nayachara Island. The guide wall is a more structural and permanent solution for keeping the channel at its present position and deminishing maintenance dredging of the Balari Bar.

The improvement of the Hooghly could be accelerated if revetment works were constructed in the Bhagirathi. The revetment will prevent erosion in the Bhagirathi, however, since the transport capacity of the water remains unchanged the unprotected downstream parts of the river will be eroded. It is possible that repetition of this procedure in downstream parts of the river would finally accomplish the desired improvement of the Hooghly river, and would also lead to scouring of the estuary. Under any circumstance it will be a more permanent solution to decrease the necessary maintenance dredging [10].

3.2.2 Hydraulic phenomena

Currents

Currents in the Bay of Bengal generally respond to the prevailing winddirection although the rotation of the earth causes a small deviation [8]. Tidal streams issuing from the filling and emptying of the estuaries heavily affect currents.

In agreement with this the water in the biggest and more southern part of the Bay of Bengal, south of 15 degrees north latitude, flows in a western direction during the northeast monsoon, see Figure 13. This rather constant current, prevailing 50 to 75 % of the time, generates a gyre in the northern part of the Bay. The gyre has an eastern flow direction in front of the Hooghly rivermouth. The constancy of this current is rather low, less than 50% of the time, while current velocities vary from nil to 0.26 m/s.

During the southwest monsoon the direction of currents is opposite to that of the other monsoon season. This time the current generated by the gyre has a western direction in front of the rivermouth. The constancy of this current lays in the 50 to 75% range and velocities vary upto a maximum of 0.39 m/s.

The rise and fall of the tides that fill or empty the Hooghly estuary causes currents with a set roughly perpendicular on the forementioned currents along the rivermouth. The appearing flowvelocities vary from nil to 3.60 m/s. The big variation originates from the difference in strength of the northeast and southwest monsoon, the difference in neap and spring tides, and the differences in the discharge of the river due to freshets in the wet monsoon period. Compared to 0.26 or 0.39 m/s a velocity of 3.60 m/s is very high, therefore the set of the resulting current near the rivermouth usually is determined by the filling and emptying of the estuary.

Storms, especially cyclones, have the potential to generate currents with velocities exceeding 1 m/s. This velocity may increase near coasts owing to the piling up of water against the coastline.

On the Hooghly river currents are influenced by the discharge of its tributaries and the semi-diurnal tidal streams. Usually tidal streams dominate the currents caused by discharge of the river. Ebb and flood currents can be observed 154 km upstream of Calcutta.

Tidal variation of waterlevels

As a result of the semi-diurnal tide the waterdepth in the river varies considerably. The following figures for the tidal ranges [11] give an impression of the variation in waterlevels:

Tide period	tidal range m
low neap	1.0
mean neap	1.7
average	3.0 to 3.3
mean spring	4.2
high spring	5.4

Depending on the season and place on the river deviations from above mentioned figures are possible in the nil to 0.3 m range.

The variable waterlevels combined with the rapid riverbed changes cause that data about available draughts highly depend on the prevailing conditions in respect of tides, toplevel and position of bars. Generally the Balari Bar controls the available depth. In 1986 it was reported that this bar restricted the draught to 5.2 m at average high tide [5].

Bore tides are high tidal waves with a sudden and fast rise of waterlevels, Figure 14 gives a small impression of the phenomenon. Depending on the velocity of the wave and the wavefront propagation the steepness of the wave exceeds the critical slope for surging or plunging waves. There are two reasons for the development of bore tides in the river. The first reason is the huge quantity of water that is pushed into the estuary when the flood period establishes itself. The second reason is the tapered shape of the estuary. In subsequent cross sections of the river the available depth and width decrease relatively quick.

In the Hooghly estuary the first occurrence of the bore is near Diamond Harbour, it is kept under control by the bends at Diamond Harbour and Hooghly Point. Then it develops itself quickly due to the contracted reaches above Hooghly Point. Between Hooghly Point and Calcutta vessels have to take precautions for the occurrence of a bore tide. At Calcutta bore tides occur, roughly with a frequency of ten times per year and usually during spring tides. In the past waterlevels suddenly rose 2.5 m, when the wavefront passed, followed by another 3.5 m when the body of the wave passed [10]. Nowadays the instant rise of waterlevels is limited to about 0.5 m [5].

Short waves

Waves and swell are generated by local winds. Little is known about swell. Observations in the outer estuary, 35 km south from Sagar, indicate average wave heights of 1.0 to 1.5 m with periods of 4 to 5 seconds during the southwest monsoon. Maximum heights are 2.0 to 2.5 m with periods of 8 seconds [11]. In the inner estuary a wave height of 0.7 to 0.8 m has been observed with a period of 6 seconds [14].

3.2.3 Climatologic conditions

Wind

Wind is of importance due to its direct and indirect effect on vessels and port operations. The indirect effect on currents and short waves has been described in the previous subsection.

Some important aspects from the direct effect of wind are its strength, frequency of occurrence and direction.

The strength of windforce is expressed in Beaufort on a scale from nil to 12. Windforce, accompanying description for windcirculation and windspeeds are given in Table 5. Above 8 Beaufort ships should either be at open sea with enough space for manoeuvring or safely anchored. The river cannot be navigated at all. Depending on the kind of cargo, equipment and location cargo handling is influenced from 6 Beaufort. Above windforce 8 all port operations have to be stopped.

The frequency distribution of windforces and winddirection combined with the location under consideration determine the number of events per annum that vessels cannot sail and port operations are impossible. For storms a recent 50-year period has been recorded [8] to count the number of storms. The results are listed in Table 6. The average annual frequency of severe or cyclonic storms is equal to 2 but varies from nil to 4. Especially in the transitional periods between the two monsoon seasons heavy storms occur more frequent.

In accordance with the monsoon climate the prevailing winddirections are southwest or northeast. Haldia is nearer to sea than Calcutta and the dock is not sheltered by a built-up area like the docks in Calcutta. Therefore the influence of wind, in respect of ship manoeuvres as well as for other port operations, has to be examined more carefully in Haldia. Some data about direction, frequency and windspeed are given in Table 7 for Sagar Island and Calcutta.

Rain

The average precipitation is 1500 to 2000 mm/a, of which 80% occurs from May through September during the wet monsoon. Data about the distribution throughout the year are given in Table 7. Especially for (bulk) commodities like fertilizer rain causes serious problems for cargo handling.

Temperatures

The height of the prevailing temperatures has a negative effect on the productivity of labourers. Although Indian people are used to high temperatures it has to be taken into account for the cargo handling performance. Some figures are given in Table 7.

3.2.4 The locks in Calcutta and Haldia

Kidderpore dock in Calcutta was constructed in the eighties of the previous century [20]. The reason to construct an impounded dock was originating from the high tidal variation of the waterlevel on the river. The variation caused problems in keeping ships afloat at the open roadstead, resulted in frequent adjustment of moorings and hampered cargo handling. In the dock a fixed waterlevel is maintained. Vessels achieve access to the dock by means of a lock. For the same reason Netaji Subhas dock and the dock in Haldia were also constructed as impounded docks. In case of the dock in Haldia an extra reason that most probably has contributed to the decision to built an impounded dock is the high sediment transport in the estuary. Since a harbour basin usually is more or less protected for waves and currents there would be a considerable deposition of sediments in the basin. The siltation would necessitate regular and extensive maintenance dredging.

Disadvantages of locked basins are the cost involved in constructing the lock, the delays to shipping owing to lock operations, and the rigid limitation on the maximum size of vessels.

The largest vessel that can enter Kidderpore dock has a length over all (LOA) of 157 m with a beam of 21.3 m. For Netaji Subhas dock these figures are 172 m and 24.4 m. The deepest draught along the berths in these docks is 8.7 m. The depth in the dock limits the dead weight tonnage (DWT) of a general cargo vessel to 7,500 DWT, whilst the mentioned LOA and beam correspond to general cargo vessels of about 15,000 DWT with a draught of 9.5 m. Owing to the shape of the ship's hull other type of ships have a smaller DWT.

In Haldia the maximum available water area in the big lock chamber of the lock has a length of 300 m and a width of about 40 m. The smaller lock chamber has a length of 199 m. Some manoeuvring strips have to be substracted from this area. The depth of the basin varies between 13.7 and 14.8 m. In respect of depth and length a container vessel of circa 50,000 DWT will be able to enter the dock. The depth limits the size of a bulk cargo vessel to approximately 65,000 DWT, whilst the width of the lock is sufficient for a collier or tanker with a DWT in the order of magnitude of 130,000 DWT. Montly dredging in the vicinity of the lock is necessary due to serious siltation.

3.2.5 Vessel Traffic

The vessel traffic of a port manifest itself in the dimensions of the visiting ships, the number of shipcalls, and last but not least the distribution of these visits throughout the year.

Vessels have to face several obstacles, like navigating the river and manoeuvring in and around the locks, before they are safely moored alongside a berth in one of the docks. These obstacles limit the size of the ships in the river and the docks. Table 8 gives some examples of vessels observed in Calcutta and Haldia in 1985/86. It is useful to have a closer look at the waterway to Haldia and Calcutta, see Figure 15 and 16.

Sandheads, where the pilot gets on board, is located approximately 90 km from Sagar Island in southsouthwesterly direction. The 10 m depth contour line, below Mean Low Water Spring (MLWS), is passed 45 km from Sagar Island. The presence of several sea reefs forces vessels to sail through either Beaumonts Gut or Gasper Channel, both extensions of Eastern Channel. Western Channel is closed due to growing sandbars, which is accelerated by the construction of groynes.

From Sagar Roads the vessels sail through Jellingham- and Haldia Channel at the western side of the estuary. The latter channel passes the dock at Haldia before it is forced by the Balari Bar to join Rangafala Channel at the eastern side of the estuary. The route via Bedford Channel, that also ends up in the Rangafala Channel, is shorter compared to the one via Haldia but this channel has a couple of sandbars at its northern reaches. However, recently (October 1987) the route along Bedford Channel has been reopened [15].

North of the Balari Bar, near Diamond Harbour the width of the estuary has become too small for a system of alternating ebb and flood channels, upstream there is only one navigation channel available for seavessels. The channel is hard to negotiate owing to the combination of riverbends and sandbars. On a total of 10 riverbends there are 4 bends with a radius smaller than 1500 m. The width of the channel is on average 800 m on the reaches from Hooghly Point to the Hiraganj Reaches, and 400 m on the following navigable reaches. On several sandbars a depth of merely 0.5 m below MLWS is available [9].

An Export Processing Zone has been created at Falta. At Budge Budge an oil terminal has been built. The maximum length of a tanker is restricted to 186 m during neap tides, which corresponds with a 25,000 DWT tanker. Since the chances are relatively high that vessels are not able to negotiate one of the sandbars on one tide there are anchorages at several places along the river, which can be used to moore the ship and wait for the next tide. From the rivermouth to Calcutta there are anchorages at Sagar Roads, Haldia, Kalpi, Diamond Harbour, Royapur, Mayapur, Uluberia and Garden Reach. At the anchorages the length and draught of vessels is restricted to 152 and 5.5 m [1,2].

Some measures are carried out to garantee safe acces to the docks and to increase the permissible size of the ships.
Pilotage is compulsory for all vessels of over 100 DWT. The pilot takes the ship from Sandheads to Sagar, Haldia, Budge Budge or Calcutta. He has the most updated information about the condition of the river. The information is obtained by a continuous survey and charting of the river. There has been taken care of the usual navigational aids, like lighthouses, light vessels, channel buoys, etc..
It is obvious that the mentioned available depths below MLWS on sandbars are not sufficient for the majority of vessels visiting the ports of Calcutta and Haldia. Dredging work on the shallowest sandbars and crossings is one solution for increasing the permissible draught of ships. Another solution, which has been applied continuously for many years now, is to sail to the docks during high tides. Ships have to sail on top of the tidal wave and have to reach either their destination or deeper water before the waterlevels have dropped too much. Therefore a ship has to be able to maintain a certain speed to be garanteed of enough depth. The Calcutta Port Trust publishes a monthly Estimated Fresh Draft Forecast which informs pilots and responsible shipofficers about the available draught related to sailing velocities. For instance in February 1986 the fresh water draught for vessels sailing with a speed of over 22.2 km/hr varied from 4.8 to 6.8 m if the vessel was heading for Calcutta. If it had Haldia as its destination the draught varied from 6.6 to 8.0 m. When a ship leaves the docks an extra draught of 0.1 to 0.2 m is available. Special arrangements have to be made for vessels that sail with a speed lower than 13.0 km/hr.
Last but not least it is possible to enable large ships to navigate the river by not loading them to their maximum draught. This decreases the efficient utilization of ship capacities.

In recent years the total number of shipcalls to the ports of Calcutta and Haldia is on average 1230 per annum [2]. Haldia respectively Calcutta receive 400 and 830 ships, some of these ships visit both harbours.
The frequency of shipcalls is higher in the months October to March during the dry monsoon period. The number and frequency of shipcalls are depending on the number of berths in the harbour and their availability, i.e. whether the berth is already occupied or not. These factors can be described with the help of the berth occupancy factor (BOF) and the turn around time (TAT), see [2]. BOF and TAT are greatly influenced by the cargo handling performance. Resulting figures for the BOF are given in Table 9. The pre-berthing detention of vessels, the waiting time of vessels before a berthing place is available, is given seperately in Table 10 but is also included in the TAT. The TAT is measured from Sandheads to Sandheads. In the TAT 1 and 2 days are included for the actual sailing time to Haldia respectively Calcutta. If the sailing time and pre-berthing detention time are subtracted from the TAT this results in the berthing time of vessels.

A higher BOF is only equivalent to a larger TAT if in a certain period, for instance one year, the same number of vessels is taken into consideration. The long berthing periods for instance for coal and fertilizer are a direct consequence of the cargo handling performance.

3.3 CARGO HANDLING

3.3.1 General considerations about cargo handling

A ship lays tied up alongside a quay or jetty when its cargo is handled. Exceptions are ships being lightered, or ships carrying LASH barges. In the subject case these situations will not be taken into further consideration. During the cargo handling process the cargo is moved vertically from the shipsholes to the quay, horizontally from the quay to a place storage, and from the storage it is taken out of the harbour by truck or train. This is a rough description of the process when a ship is unloaded, the reverse sequence describes cargo handling when a ship is loaded. A short version of the proces, called direct delivery, does not include storage of cargo, i.e. the cargo is directly loaded on trucks or trainwagons and immediately transported out of the port area, and vice versa.

In the past the kind of packing used for cargoes and the carrying ships were not as diversified as at present. This resulted in a more or less uniform layout for berths and sheds. In modern port planning the length of a berth is fully determined by the kind of cargo assigned to the berth. For transporting this cargo a special kind of ships and special equipment is used. Since the port of Haldia started to function in 1977 the specially equipped berths handled the majority of bulk cargoes. The effects on cargo throughput are clearly illusstrated by the performance figures of Calcutta and Haldia, see Figure 17. Although not fully justified Calcutta could be characterised as a traditional breakbulk port whilst Haldia is a modern liquid and dry bulk port.

Civil works like quays, jetties, shed, warehouses, roads and railways are indispensable for cargo handling. Equally indispensable is mechanical equipment like cranes, bulk loading or unloading systems, conveyor belts, stacker reclaimers, forklifts etc.. Since 80% of the cargo in Calcutta is handled manual instead of mechanised the importance of the factor labour is easily understood. Given the necessary equipment the skill and productivity of the workforce is decisive for achieving a quick and large cargo throughput. In Table 11 some data about the shift productivity in the ports are presented. It has to be concluded that the average productivity is much too low and consequently the cargo handling process does not meet the needs made upon it.

Civil works, equipment, and labour will be discussed successively in the next subsections the first two items seperately for Calcutta and Haldia, the last item in one subsection.

3.3.2 Cargo handling facilities in Calcutta

Civil works

In Calcutta the quays are located in Kidderpore dock 1 and 2, and in Netaji Subhas dock, three docks with respectively 12, 10, and 11 berths, see Figure 18 to 20. The Garden Reach jetties along the river near Netaji Subhas dock are abandonned. In both docks there are several lay-up berths and buoy moorings where ships can wait for a berth. It is possible to load or unload ships at the buoy moorings using barges. The river moorings are able to accommodate 23 ships. At Budge Budge 6 jetties are in use.

In the Kidderpore dock 1 all the berths (12) are general cargo berths, in Kidderpore dock 2 there are 8 general cargo berths and 2 mechanical coal loading berths. In the past one of the berths was reserved for all the foodgrain transports. The average quay width in Kidderpore dock 1 is either 15.2 or 18.3 m, and in Kidderpore dock 2 the width is either 12.2 or 21.3 m.

Netaji Subhas dock has 7 general cargo berths, one heavy lift berth and 3 lighterage berths. Widths of the quays in Netaji Subhas dock vary from 12.2 to 21.3 m. All the quays are able to bear loads of 3 to 5 tonnes per square meter [12,13]. The small width and low bearing capacity of the quays are a remainder of the past. Owing to the small width of the quays only little cargo can remain at this place in the port area, otherwise the quay gets blocked for all traffic. Unfortunately the quays are fully blocked regularly due to lack of horizontal transport equipment and other open storage space, and as a result of bad management. Berth lengths show a variation of 108 to 229 m in Kidderpore dock 1, 141 to 195 m in Kidderpore dock 2 and 152 to 200 m in Netaji Subhas dock.

At Netaji Subhas dock berth D, where already the majority of containers was handled, the area will be changed into a full fledged container terminal with all the appropriate equipment [6]. Kidderpore dock berth 3 also handles a substantial amount of containers but in fact every berth has to handle containers from time to time because general cargo ships regularly have them on board.

In Calcutta only 10% of the cargo is directly delivered, 90% of the cargo is transported to a shed, warehouse or open storage [2,13].

The two and three storied sheds in Kidderpore dock 2 and Netaji Subhas dock are another clear remainder of the past. These sheds have concrete floors. If equipment is not available labourers carry the cargo upstairs to the first or second floor. A slipway is used to remove the cargo from the upper floors. The effective use of the sheds is negatively influenced by this way of cargo handling because the vertical space is not fully utilized. Cargo often remains too long in the sheds and warehouses at the option of the owners. This negatively influences efficient use of these storage facilities.

Equipment

The number of level luffing full portal electric cranes varies from 3 to 5 at the general cargo berths in the docks. These cranes have a 3 tonnes lifting capacity at 27 m radius and 5 tonnes at a 15 m radius. At the coal berths in Kidderpore dock a mechanical coal loading plant was present. These plants are decommissioned because the entire coal traffic will be handled in Haldia. Berth 23 in Kidderpore dock 2 has a mechanical grain handling plant. There is a 200 tonnes crane at the heavy lift berth in Netaji Subhas dock. In addition to all these cranes there are some floating heavy lift cranes and private 20 tonnes mobile cranes available. Nevertheless ships, especially container vessels, regularly use their own gear.

At the yard of every berth and in every shed there are yard cranes and lifts with capacities varying from 2 to 4 tonnes. The rolling stock comprises 39 forklifts, 30 tractors (agricultural), and 121 trailers, which is not sufficient for 33 berths in three dock areas.

It is reported that the mechanical equipment frequently breakes down due to bad maintenance [13]. Break down of a crane immediately stops the cargo handling process at a berth, while break down of e.g. forklifts can be partially compensated by extra labour. The latter directly leads to a inefficient use of the sheds as well as it leads to more damage to the cargo.

3.3.3 Cargo handling facilities in Haldia

As stated before Haldia shows the characteristics of modern port planning. Berths are designed and equipped for handling a specific port traffic class and ample storage area is available [1,5]. Inside the dock of Haldia 7 berths are available, outside the dock 2 jetties are in use, see Figure 21.

The coal berth is equipped with 2 coal loaders of 1500 tonnes/hour (t/hr) rated capacity, a store-yard of 177,000 tonnes capacity, and 2 stacker reclaimers of respectively 1500 or 1000 t/hr.

There is an ore berth, having two loaders of 300 t/hr rated capacity and a store-yard for 300,000 tonnes of ore. This facility is presently being converted into a second coal loading berth.

The fertilizer berth, has been equipped with unloading equipment having a capacity of 6000 tonnes/day, for the unloading of raw materials sent to the fertilizer industry located in the adjacent industrial area. The berth has been connected to the fertilizer plant via a long, overhead conveyor belt.

The two existing general cargo berths are located opposite the bulk handling facilities. At present one berth is used for the unloading of coke. The other berth is equipped with a container gantry crane of 30 tonnes lifting capacity, a shed of 9000 m**2 and a stacking area for approximately 1000 containers. Furthermore ,there is a transtainer on a marshalling yard of approximately 17,000 m**2 where trains can be loaded. Container handling is executed by forklift, trucks and mobile crane. A third general cargo berth, to be built next to the others, is under consideration.

There is a concrete jetty with a length of 230 m and a width of 19 m inside the dock, presently used as a lay-up berth for working directly to or from barges.

Outside the dock system, on the banks of the river Hooghly, two oil jetties are located. At the downstream jetty crude oil is unloaded from tankers with a maximum length of 238 m or 90,000 dwt. The jetty, which serves the adjacent refinery of the Indian Oil Corporation, is connected by a pipeline to the Barauni Oil Refinery in Bihar. The smaller upstream jetty for inland barges serves as a loading facility for the distillation products of the refinery. An additional jetty for deep sea vessels is under construction inbetween the lock and the first oil jetty.

Data about the rolling stock in Haldia were not available.

Within the existing masterplan of Haldia area has been reserved for expansion of the present basin with another basin leg. The area reserved for port activities will double the area which is used at this moment. If necessary a second lock could be constructed.

3.3.4 Labour

Owing to frequent breakdown of equipment 80% of the cargo is handled manually instead of mechanised in Kidderpore dock and Netaji Subhas dock. About 10,800 man are employed by the Calcutta Dock Labour Board (CDLB). The CDLB supplies the labour to stevedoring firms that are responsible for moving the cargo out of the ship to the quay. The Calcutta Port Trust (CPT) is responsible for the cargo handling from quay to storage and successively out of the port. About 31,600 CPT employees, 1,100 desk- and 30,500 waterfront workers, carry this task. It has been observed that the separate responsibilities hamper efficient cargo handling [13]. In Haldia the CPT has the responsibility for the whole cargo handling process. Table 12 gives information about the categories and number of employees of the CPT, excluded the upper management [2].

Unions in West Bengal, and in the port, have quite a long tradition. In some situations it has been proven that the gained rights, often translated in rules and regulations that cannot be altered, are working contra productive regarding the cargo throughput. However, in respect of the safety of the work the activities are certainly justified. The following unions were active in the port in 1984/85:

- HMS: Calcutta Port Shramik Union
- INTUC: National Union of Waterfront Workers
- CITU: Calcutta Port and Shore Mazdoor Union

In 1984/85 there were 12 and 6 incidents of work stoppages at Calcutta and Haldia respectively, besides the all India Port Strike. In 1984/85 and 1985/86 there were 12 respectively 5 fatal accidents.

3.4 HINTERLAND TRANSPORT

3.4.1 General considerations about hinterland transport

In the hinterland of the ports there are two main industrial areas, see Figure 2. The first and biggest area is the Chota Nagpur Damodar valley. The mining industries produce e.g. coal and iron ore. India's iron and steel industry is concentrated in this area. The second industrial area comprises the metropolis Calcutta and its surroundings along the Hooghly.

Most of the cargo handled at the quay in Calcutta, roughly 85% in 1984/85, is transported out of or into the port by trucks. Trains and barges transported respectively 10 and 5% of the total cargo in 1984/85. For Calcutta these figures give a good impression of the importance of the hinterland transport modes. Data for Haldia were not available. Due to the share of bulk cargoes pipeline and railway transport will be more important. In the next subsections road-, railway-, and inland waterway transport will be discussed in succession. The Figures 18 and 22 show roads and railways in the port areas of Calcutta and Haldia.

3.4.2 Road transport

In the dock area of Calcutta a primary and secundary road network can be distinguished. All the cargo has to enter or leave the port using the primary network roads. The capacity of the roads in this network is too small and there are some bottlenecks that can cause a total shut off for the flow of vehicular traffic in the whole port area. The secondary network connects the roads within the separate dock areas to the primary network roads. Arbitrary parked trucks and containers along the roads of the secondary network frequently restrict width and subsequently the capacity of this network. Thus the complete network is overburdened and definitively causes longer dwelltimes of cargoes in the storage facilities of the port area.

After leaving the primary network roads trucks have to use the public road system which is also overburdened, caused by daily commuting traffic between the CBD and the haphazardly grown suburbs of Calcutta. Old Calcutta, next to the port area and set up by Europeans, has a typical net grid road system but in the other suburbs only a north-south orientation of roads and highways can be recognised due to the small number of bridges and arbitrary expansion. The condition of the surfaced roads is poor.

At the moment there are 3 bridges across the Hooghly, the most southern Howrah or Rabindra Setu Bridge connects the CBD with Howrah. A fourth bridge at Prinsep Ghat, south of the Howrah Bridge is under construction [24]. Its main purpose is to unburden Howrah Bridge and the CBD from cargo transport to and from the port area. A fifth and sixth bridge have been taken into consideration, one of them should be built near Budge Budge. The CMDA proposed an infrastructure based on inner and outer railway- and roadrings with accompanying Public Transport facilities, see Figure 23. The least CMDA is aiming at by supplying this infrastructure is taking away the port and unnecessary commuting traffic from the core of the metropolis.

Outside the city area the National Highways, the NH 2, 6 and 34, are the main road connections between Calcutta and the hinterland.

The port road system in Haldia is conveniently arranged and has a sufficient capacity. Traffic with destination the hinterland or Calcutta has to use the NH 41 which is connected to the NH 6.

See Figure 24 for the NH system.

3.4.3 Railway transport

The port of Calcutta has its own railway system with a track length of 350 km and a route length of 36 km and has its own rolling stock. The Port Railways function as the terminal agents for Eastern and South Eastern Railways, affording facilities to receive and despatch cargoes from and to any part of the country. Records of CPT reveal a decline in the contribution of the railways to transport the cargo imported and exported by ocean going vessels. In 1980/81 approximately 50% of the cargo handled at the quays at Calcutta was transported from and to the hinterland by railways. In 1984/85 this figure had been reduced to 11%.

A single track railway line connects Haldia with Panchkura on the Howrah-Kharagpur mainline of the South Eastern Railways. The port has its own internal railway system connecting the Haldia dock basin and the industrial establishments in the port area with the South Eastern Railways. Recently (1987) appreciable quantities of containerised tea arrived in Haldia, and will arrive in future years. The tea is containerised in the container freight station at Amingaon, near Gauhati and Pandu in Assam, and directly transported by rail in to Haldia for export purposes.

See Figure 25 for the railway system.

3.4.4 Inland waterways

Inland waterways vessels transport a minor part of the total port traffic to and from the hinterland. In fact the inland and sea vessels use the same infrastructure, e.g. the Hooghly, however the barges involved enjoy a more favourable nautical situation compared to seavessels since they are smaller. In Calcutta the inland vessel wharf, the so called Calcutta jetties, are located along the river near Howrah bridge. Near the dock system in Haldia there is terminal consisting of a pontoon berth and a fixed jetty for inland waterway vessels.

The Government of India plans to revitalise inland waterway services. In 1982 the Government declared the Ganga- Bhagirathi system as the National Waterway no.1, and development and maintenance funds have been allocated in the 7th FYP for the improvement of the waterway. The governmental Central Inland Water Transport Corporation, CIWTC, has undertaken new activities such as construction of new ships and new river terminals. On behalf of CIWTC a masterplan for the terminals has been made by the dutch consultants firm NEDECO. The recommendations include reconstruction of the western side of Kidderpore dock 2 and construction of another jetty and pontoon berth in Haldia. This inland waterway terminal has been planned at a location near the Indian Oil Corporation and Hindustan Fertilizer properties, about 500 m upstream of the present barge jetty.

See Figure 26 for the inland waterways.

4. PORT DEVELOPMENT IN CALCUTTA AND HALDIA

Maintaining both harbours in Calcutta and Haldia?

4.1 NECESSITY AND POSSIBILITIES OF FURTHER PORT DEVELOPMENT

It is a matter of common knowledge that a port has to watch and follow new developments in the maritime world and in the field of cargo handling systems in order to survive. Ignoring new developments will result in a less attractive service level for visiting vessels and a loss of traffic. In the worst case a port will suffer from congestion and this will lead to a further decline in cargo throughput. If a port wants to cater for a bigger share of the trade, anticipating on new developments and a continuous endeavour to realise a more efficient and higher cargo throughput, is a sheer necessity.

In India a considerable part of the traffic in each major port has been and will be assigned by the Government. The planning within the 7th FYP reveals that port capacities have to be increased aiming at a higher and sufficient cargo throughput, sufficient in respect of stimulating the growth of India's economy.

The combination of the natural efforts of the port to maintain and increase its productivity, as well as the Government's striving, incite the port management to realise a higher and more efficient cargo throughput. The following problem definition can be formulated:

Inherent in the survival of a port is the continuous improvement of the services for the maritime traffic, the cargo handling process, and the traffic to and from the hinterland. Increase of the cargo throughput is required, now and in the far future, owing to the role of the port in the national economy.

Measures taken on account of this broad problem definition have to improve the complete transport process that guides the cargo flow to, through, and out of the port. All the operations in the process are linked with each other, therefore the improvement of one isolated step will have a negligible effect on the final result of the complete process. Under this condition an extensive development scheme, requiring considerable expenditures, will be necessary in Calcutta and Haldia since both ports face, more or less to the same extent, problems in every step of the transport process, as described in the previous chapter.

Considering the ports of Calcutta and Haldia as one system there are three obvious alternatives for further port development:

1 - concentrate development in Calcutta only
2 - concentrate development in Haldia only
3 - concentrate development in both ports

Virtually alternative 1 is just a theoretical possibility. Especially regarding the cargo handling of liquid and dry bulk cargoes Haldia is not only the more suitable port at this moment but it offers better opportunities for expansion of the facilities in future as well. This alternative will not be taken into further consideration. The advantages and disadvantages of alternative 2, in comparison with alternative 1, will be described in the next section. Basic idea behind the third alternative would be to maintain both ports in Calcutta and Haldia with a fixed distribution of tasks. Regarding the construction of completely new facilities again it is possible to distribute or to concentrate this in one of the two ports. This alternative offers the opportunity for a thorough reconstruction of the port in Calcutta while transport of the cargo will be concentrated temporarily in Haldia.

The limited availability of funds, and the volume of the necessary investments implies that a choice will have to be made between the two remaining alternatives.

4.2 SELECTION OF ALTERNATIVE PORT DEVELOPMENT SCHEMES

Owing to the importance of port development for the society the evaluation of alternative schemes will be based on their technical, town and country planning, socio-economic and financial effects. Methods often used to select the best alternative are the multi-criteria evaluation and the cost-benefit analyses [19]. Although these methods are not only taking monetary effects into account, on the contrary, they do demand fixation of the financial and economic costs and benefits coupled with the proposed port development scheme as far as possible. The cost involved in a port development project highly depend on the technical possibilities and can only be determined after establishment of the technical solution that meets the demands made upon it. Production of detailed masterplans for the ports of Calcutta and Haldia will be necessary to estimate the expenditure required for execution of the alternatives. Only then a realistic choice between alternatives can be made.

This report will only be concerned with further elaboration of the existing masterplan of Haldia under the assumption that all port operations in Calcutta and Haldia will be concentrated in the latter port. There are two reasons to take the displacement of Calcutta port as starting point. First of all the result of the work will show whether or not it is possible to move the port of

Calcutta to Haldia, hitherto this was only a premisse. Secondly, from a technical point of view it seems that Haldia offers a more favourable prospect for realisation of an efficient and growing cargo throughput in the long run. Some arguments to support this idea will be put forward:

- Regarding the vessel traffic the admissible draughts and the dimensions of the locks have to be taken into consideration. Due to the relative nearness of the sea it will take less efforts to increase the admissible draught for Haldia than for Calcutta. The lock in Haldia is bigger than the locks in Calcutta and on top of this the masterplan for Haldia provides space for construction of another, and even bigger, lock.
- Comparing the cargo handling processes in Calcutta and Haldia the first can be characterised as manual and the latter as mechanised. Although many arguments can be put forward to prefer cargo handling processes based on labour, mechanisation is unavoidable since the port has to follow the developments in the maritime world. For application of modern mechanical handling systems the layout and infrastructure, including all the civil works, of the docks in Calcutta would have to be thoroughly rearranged and even demolished and rebuilt. In the early seventies when the masterplan for Haldia was prepared it was already possible to anticipate on the developments of mechanised handling methods and consequently enough space is available to apply these systems. On the management side of the cargo handling process Haldia is again in favour of Calcutta since an adequate organisation avoiding all the disadvantages, in respect of rules, regulations and fixed procedures and industrial relations, that hamper the management in Calcutta can be set up.
- The connections with the hinterland in Haldia will have to be developed in future and are a drawback at this moment. Calcutta already has its connections with the hinterland but these are heavily congested.
- Regarding the establishment of all port related industries and other concerns Calcutta is in favour of Haldia since the latter is still a little township in development.
- The feasibility of further expansion in the far future, in either Calcutta or Haldia, after establishment of the presently required throughput, has to be taken into consideration. Future expansion will be more difficult in Calcutta due to its cramped position in the centre of the metropolis.

Once more it is emphasized that only an evaluation procedure which includes the alternative to maintain the port of Calcutta will justify further port development. A considerable part of the work done to elaborate the masterplan of Haldia can be used to draw up the required masterplans for the alternative based on maintaining both ports.

4.3 DEVELOPMENT OF A MASTERPLAN FOR HALDIA

Combination of the problem definition for port development in section 4.1, with the choice in the preceding section, to confine attention to concentration of all port activities in Haldia, results in a specified problem definition:

> Haldia is not equipped for handling all the cargo that is transported at present through both of the ports in Calcutta and Haldia. In future even more cargo will have to be handled in this port.

The matching objectives are defined as follows:

- development of a masterplan for Haldia based on a larger and more efficient cargo throughput.
- answer the question whether or not it is possible to take over the port activities of Calcutta in Haldia and draw conclusions from the elaborated masterplan regarding further port development in both ports.

In appendix B a survey of three planning procedures has been included to put development of a masterplan for Haldia in the right perspective [27]. The procedures for national ports- and individual port masterplanning, and for port project planning consist of a comprehensive list of activities. While drawing up the masterplan for Haldia, in the sequel of this report, most of the listed civil engineering activities in the procedures for individual port masterplanning and port project planning will be further elaborated. Just like in the previous chapter only the transport function of the port will be taken into consideration. Attention will be confined to the required civil works, taking as starting point that it will be possible to bring e.g. the productivity of equipment and workforce in agreement with the assumptions. Subjects like passenger-, RoRo-, and LASH traffic, the use of lighters, necessary rolling stock, bunker or dry dock facilities will not be discussed although they certainly need attention in the final port development proposals. The most important subject that will remain unelaborated are the road-, railway- and inland waterway connections with Haldia's hinterland. Finally costs and benefits can only be taken into account in a qualitative way.

An important aspect in the problem definition is the future situation. Not only the present problems have to be solved sufficiently but an attempt has to be made to prevent the same or other predictable problems, regarding the functions of the port, in future times as well. Therefore any development plan will have to incorporate sufficient flexibility. The masterplan consists of a view of the future situation as it will be after a series of individual developments. The most tangible result of preparing a masterplan for Haldia will be a layout of the port area in future time based on explicit forecasts.

Forecasts have to be produced for every aspect or factor, influencing the port performance, which is likely to change in following years. In following chapters a cargo-, packing-, berth-productivity and ship-forecast will be drawn up. Any deviation from the forecast in the next years might cause a completely different development of the port and subsequently change the long term layout of the port. Therefore continuous adjustments of forecasts and layout after observing significant new trends will be necessary in order to meet the needs of the port in future.

5. CARGO-FORECAST

5.1 INTRODUCTION

The essence of port traffic forecasting is to find out the kind and tonnages of commodities that will move through the port as well as the way of packaging on shore and as maritime cargo. The cargo-forecast will be concerned with the kind and the tonnages of commodities. The way of packaging will be discussed in the next chapter.

A simple method for making a cargo-forecast is to extrapolate past and present trends to chosen target years for every commodity that has already been handled in the port. The method overlooks new developments and the results are unreliable if in past years the amount of cargo has been subject to severe unexplained fluctuations. New developments include, for example, new products offered for transport, increased or decreased growth rates due to over or under supply of the market. New developments planned by the Government of India and affecting ports can be found in or derived from the Five Year Plans (FYP) which the Government of India uses to lay down its policies. This policy cannot be neglected since it is proven that the Government manages to realise the chosen objectives fairly well. Unfortunately these developments are given on national level for all the major ports in India and not specified for every single port. On a lower level information or opinions about new developments usually can be obtained by consulting regional institutes or companies. This information source could not be used for the forecast given in this chapter.

To obtain the cargo-forecast for Haldia the result of the extrapolation method is used [2,18] in combination with new developments described in the 7th FYP [17]. The figures used for extrapolation are taken from the past period 1970/71 to 1984/85, a 15 year period. The chosen target years are 1989/90 and 1999/2000, these years are also used in the 7th FYP. The most adjacent forecast period to 1989/90 is covered quite accurately by the 7th FYP and the risk taken by extrapolation is not too big since the period is relatively short. The forecasted figures for 1999/2000 will be more unreliable since the period from 1890/90 to 1999/2000 is further away and because it is a longer period.

For the most important commodities that are handled in the ports of Calcutta and Haldia a prelimunary forecast will be drawn up in section 5.2. Some information will be given about:

- the product itself.
- transported tonnage in the past.
- developments in India as a whole and in the hinterland of Haldia.
- the question whether it is a principal import or export commodity.
- seasonal supply and demand variations.

The Calcutta Port Trust (CPT) also produces forecasts. The CPT-forecast will be compared with the one based on extrapolation and information from the 7th FYP in section 5.3.

5.2 FORECASTS FOR MAIN COMMODITIES

5.2.1 Petrol Oil and Lubricants

The abbreviation POL will be frequently used for Petrol Oil and Lubricants. After production crude oil usually is transported to refineries where it is converted into fuel oil, like petrol and kerosene, and other products like lubricants, naphta, bitumen, etc. .
Oil is used as energy resource in several sectors of India's society, Figure 27 shows its distribution.

Among her natural resources India possesses several oilfields which have already been made productive and a number of potential oilfields as shown in Figure 28. Most of the oilfields are located in western India and 60-75% of the oil is produced at offshore oilfields. Since 1980 production at the Cambay Basin increased rapidly resulting in an almost threefold higher domestic production of oil in 1985. This period was covered by the 6th FYP, in the 7th FYP expectations for increased production are modest. For raising the production from about 30*10**6 Tonnes/annum (t/a) to 35*10**6 t/a in respectively 1984/85 and 1989/90 it is anticipated that the Upper Assam Bassin, located in the hinterland of Haldia and Calcutta, will double its production. Starting with a production level of 2.2*10**6 t/a in 1984/85 reaching a height of 4.4*10**6 t/a in 1989/90.

To meet the needs of the total domestic demand and to compensate for some small export quantities oil has to be imported. POL is India's biggest import commodity, and in Haldia and Calcutta POL traffic has been contributing about 50% to the total cargo flow in recent years, 1978 to 1985. In Table 13 figures for domestic production import and export are given for past years as well as the targets for the 7th FYP. Instead of using the figures from 1970/71 to

1984/85 a shorter period has been considered, 1980/81 to 1984/85, due to the recent development of the Cambay Basin. From Table 13 it can be seen that imports decreased considerably in the years 1981/82 until 1984/85. Owing to the second world oil crisis in 1979/80, which was caused to obtain and indeed resulted in higher oilprices, the Government of India realised that the level of oil imports heavily burdened the Balance of Trade and in this way negatively affected India's economy. On the other hand unsatisfactory availability of oil has restricted and will restrict the growth of e.g. the industrial sector and this would have a more negative effect on economic development. Government of India expects and accepts a growing oil import in the next future years but will carefully monitor the Balance of Trade and stimulate import-substitution and higher exports wherever possible to compensate the negative effects of higher imports.

Import and export have a direct influence on the amount of cargo to be handled in ports. Figures about POL handled at all major ports in India and the specific figures for Haldia and Calcutta are also shown in Table 13. The western location of the main oilfields causes that more than 50% of all oil and refinery products are transported through ports, for the remainder pipelines and railways play an important role.

The future POL-cargo to be handled in Haldia in 1989/90 and 1999/2000 is determined by using growth rates for domestic production and imports assuming that:

- the rate of growth per annum is constant in the period 84/85 to 89/90 and 90/91 to 99/2000.
- the ratio of the growth rates for domestically produced crude oil and refinery products remains the same in the following years. Owing to this assumption the growth rate for the production of refinery products in the second forecast period and the total domestic production can be assessed.
- the proportion domestically produced oil handled in all the major ports will be 55%. This is an average of the years 82/83 to 84/85 and the forecasted figure for 89/90, and is in agreement with the recently established production and transport of oil in the Cambay Basin.
- a higher growth rate of 9.4% in Haldia in the first period to 1989/90 because the Upper Assam field lays in its hinterland and will increase its production in this period. This higher rate agrees with the anticipated growth of the total amount of cargo in Haldia and Calcutta given in the 7th FYP.
- in the second the growth rate for Haldia will be equal to other ports.
- export quantities are negligible.

Table 14 shows the used growth rates.

The calculation results in minimum and maximum figures for the amount of POL to be handled in Haldia, in 10**6 t/a:

	89/90	1999/2000
minimum	7.98	11.58
maximum	7.98	14.42

The average import export ratio in recent years amounts to 85% to 15%, see Table 15. POL transport does not show a relevant seasonal variation.

5.2.2 Coal

Coal is India's most abundant indigenous natural resource and until recent years mainly used to generate power. The use of oil and water for power generation increased in recent years as well as the amount of generated power and the use of coal in other industries. Considering the oilprices on the worldmarket it is not surprising that the Government of India decided that coal should be the kingpin of India's energy policy and should replace oil wherever possible. Besides this the Government wants to stimulate a bigger utilization of soft- and hardcokes in respectively households and industries. In Figure 29 the use of coal is shown in several sectors of India's economy in past and future decades.

Figure 2 shows that India's coalfields are located in the eastern parts of the country. The railways usually take care of 'door to door delivery' transport of coal from the mines to e.g. powerplants. Though coal is a bulk-transport commodity in ports the amount of cargo handled in India's ports has always been small compared to the amount carried by rail, approximately 2 to 3%.

The production of 147,44 million tonnes coal in 1984/85 should be increased to 226*10**6 and 417*10**6 t/a in respectively 1989/90 and 1999/2000. Especially the Singrauli-field in eastern Madhya Pradesh is expected to raise its production. It is foreseen that in 1989/90 a small amount of coal, about 11*10**6 tonnes, has to be imported to meet the needs of the domestic demand. Most probably the imported coal will be high caloric coking coal since the resources from this coal in India are relatively small compared to other, medium- and low caloric coal, resources.

All imported coal has to be handled in one of the major ports. Data about coal production and traffic in ports are given in Table 16.

To forecast the amount of coal cargo in Haldia in the target years 1989/90 and 1999/2000 the following assumptions have been made:

- Haldia handles one-third of all coal cargo based on the figures for major ports and Haldia and Calcutta in 1979/80 and 1984/85.
- the growth rate of imported coal in the period from 1989/90 to 1999/2000 will be equal to either the rate of growth in previous years, 18.3% per annum for import, or to the growth rate of coal production, 6.3% per annum.

Owing to the first assumption 3.52*10**6 tonnes coal will be handled in Haldia in 1989/90. Combining the first and second assumption coal cargo in Haldia will grow to either 6.5 or 19.0*10**6 tonnes in 1999/2000. The resulting amounts of coal to be handled in Haldia, in 10**6 t/a, are:

	84/85	89/90	99/2000
minimum: 6.3%	1.708	3.52	6.52
maximum: 18.3%	1.708	3.52	19.00

The import export ratio of coal was 91% to 9% in the past tree years, see Table 17. Virtually it is more correct to mention a loading unloading ratio in case of coal instead of an import export ratio since most of the coAl remains within the country.

The bulk commodity coal is not showing a significant seasonal variation.

5.2.3 Fertilizer

The government's longterm objective of agricultural selfsufficiency has to be realised by an increased agricultural production. Besides irrigation the use of fertilizers is a method to improve production in the agricultural sector. Although India is one of the biggest importers of fertilizer in the world the consumption in kilogram per hectare (kgs/ha) is still very low compared to other countries, which is illusstrated with the following summary:

Fertilizer consumption in kgs/ha.

Netherlands	U.K.	China	USSR	World-average	India
789	294	155	81	80	31

Source: [18]

From these figures it can be learned that fertilizer utilization can increase considerably before reaching its final level, i.e. there is a big demand for fertilizers. The demand is bigger than the supply by domestic production and imports. Monitoring the Balance of Trade Government of India has to limit the growth of the imported amount of fertilizer but stimulate the growth of domestic production. The targets for domestic production are about 8.5*10**6 and 16.0*10**6 T respectively in 1989/90 and 1999/2000.

Depending on the chosen raw materials nitrogenous, raw material N, phosphatic, raw material P2O5, or potassic, raw material K, fertilizers are produced. In India there are a number, approximately 40, nitrogenous- and phosphatic fertilizer production-plants mainly located along the coastline, near harbours, and in the Gangetic riverbasin, as shown in Figure 30. Government of India observed a very low utilization of fertilizers in the northeastern states.
The domestic production of fertilizer requires facilities for transport of raw materials and finished products to and from the plants.

Figures about domestic production and import can be found in Table 18 as well as the amount of fertilizer handled in Haldia and Calcutta. Unfortunately the overall figures for fertilizer include finished fertilizer as well as the raw materials. To illustrate the figures some graphics have been drawn and presented in Figure 31.

To calculate the amount of fertilizer cargo to be handled in Haldia in the target years the following has been assumed:

- considering the equal spread of fertilizer plants in agricultural production areas there is no fertilizer transport due to domestic production, i.e. indigenous produced fertilizer is not handled in ports. All fertilizer cargo in ports is import-cargo.
- for the period 1989/90 to 1999/2000 either the growth rate of fertilizer imports will be maintained at 6.6% per annum, equal to the previous period, or the rate will decrease to nil. Arbitrary a lineair decrease from 6.6% per annum in 89/90 to 0 in 1999/2000 has been chosen. The decline is a result of Government of India's import substitution policy. In order to increase the domestic production in the second forecast period import of more raw materials will be necessary. Thus, in fact it is incorrect to assume that the growth of all the imports will stop while, at the same time, the domestic production increases.
- the past percentages of imports handled in Haldia and Calcutta will be the same in future, i.e. 27.5% of all fertilizer imports is transported through Haldia. This can be easily understood considering the size of its hinterland and the under utilization of fertilizers in the north-eastern states.
- the new HFC fertilizer plant in Haldia which reaches full production (675*10**3 t/a) in 1990/91 will not influence the imported amount of handled fertilizer in Haldia.

For Haldia the calculation results in 1,375*10**3 T fertilizer to be handled in 1989/90 and 1960 to 2,613*10**3 T in 1999/2000.

With an artifice the above figures have been split up in tonnages for finished fertilizer and rock phosphate, both commodities are only imported. In the past years the shares of finished fertilizer and the raw materials, phosphate rock in this case, were respectively 61% and 39% of the total traffic related to fertilizer, see Table 19. It is assumed these shares will remain the same.
Owing to the utilization in agriculture the transport of fertilizers shows seasonal variations, however, there were no data available on this subject.

5.2.4 Iron, Steel and Machinery

The iron, steel and machinery industry, included in India's basic industries, suffers from a poor utilization of available capacity. Modernisation and production improvement should result in a higher output in future years. Higher outputs from 7.6% and 5.2% per annum are anticipated in the periods 84/85 to 89/90 and 89/90 to 1999/2000 and have to be realised in India's main industrial areas, the latter shown in Figure 2.

Watching the data presented in Table 20 it can be concluded that imports amount to 20% of the domestic production in 1989/90 and about 10% in 1999/2000, while export quantities are so far neglected. This indicates that already a substantial part of iron, steel and machinery requirements is met from domestic production, and that for this commodity India will grow to selfsuffinciency.

In the 7th FYP the Government of India mentions that during the period 1984/85 to 1989/90 the amount of import cargo will be around 1.5*10**6 t/a but will increase in the nineties. Considering this fact and other data in Table 20 it is expected that exports have to grow in order to compensate the higher imports, assuming stockpiling will be avoided. Due to growing import and export the cargo flow through the ports will increase.

To fix the amount of iron, steel- and machinery cargo in Haldia the following assumptions have been used:

- iron, steel and machinery industry will not increase production in order to meet the need of possible foreign markets.
- export will grow with an estimated compound rate of 5 to 10% per annum, based on 5.2% per annum growth of the domestic production and taking into account the explosive growth rate of 20% per annum for export in the period 1984/85 to 1989/90.
- import is balancing the export
- Haldia will transport 20% of the total import and export. This seems reasonable since it has one of India's main industrial areas in its hinterland.

Table 21 illustrates the forecast calculation for a 5.2% per annum or 10% per annum export growth rate in the period 1989/90 to 1999/2000. The calculation results in 0.39*10**6 t/a to be handled in 1989/90 and 440*10**3 to 600*10**3 t/a in 1999/2000 which is not a bigger throughput for this kind of cargo watching the 600*10**3 t/a handled in 1979/80.

In Haldia and Calcutta circa 80% of the iron, steel and machinery cargoes were import cargoes in the past years, whilst 20% was exported, see Table 22.
The trade in iron, steel and machineries is not subject to seasonal variations. In general the cargo is ranged under the heavy loads.

5.2.5 Gunnies

Gunnies, included are jute and jute products, are strong coarse materials used for making sacks, bales, bags, etc.. Raw materials for gunnies are e.g. jute or coconut fibres. Weather conditions influence the size of the crops, consequently also the price of the raw material, the production in the jutemill-industry and the price of the finished material. Production of synthetic fibres for packaging materials is much more man-controlled and considering the price of these products they are strongly competing jute-products. Whether it is likely or not that synthetic fibres will substitute jute completely is not known but it is remarkable that the Government of India does not give any projection in the 7th FYP for the jute demand, production or export quantities in the year 1999/2000. Nonetheless for the period 1984/84 to 1989/90 a growth rate of 3.5% per annum in production is envisaged due to an increasing domestic demand. Another source [5] assumes almost the same growth rate for the latter period in the nineties.

Calcutta has always been known as a jute exporting harbour because of the jute producing area in its hinterland. This area is spread over the states Orissa, Bihar, West Bengal, and Assam, and is India's one and only jute producing area. All jute exports are transported through Haldia and Calcutta. Table 23 gives data about production, export and handled quantities in Haldia and Calcutta.

To determine the amount of cargo in Haldia in the target years some assumptions have been used:

- differences in data about export and jute cargo handled in Haldia are caused by the inclusion of jute in the commodity gunnies used by CPT, and because of insufficient attention for right statistical data especially in more back dated years. Therefore export quantities and the amount of cargo transported through Haldia level each other.

- the growth rate per annum for production and export in the nineties will be 0 or 3.4% per annum, i.e. the possibility of decreasing production is neglected.

Calculations result in 270*10**3 and 381*10**3 t/a of jute or jute products to be handled in Haldia in respectively 1989/90 and 1999/2000.

Raw jute peak-period: September to December. Jute products show no prominent peaking characteristics.

5.2.6 Foodgrains

Rice, wheat, other cereals, pulses, oilseeds, sugarcane etc. are all included in the word foodgrains, a word clearly indicating the use of all these agricultural products. For years, right from the 1st FYP, Government of India has been strengthening the agricultural sector with the execution of irrigation works and stimulating the use of high yielding variety seeds and fertilizers. This policy will be maintained in future years. Besides decreasing the dependence on the monsoon rainfall efforts will be made to even out inter-crop and regional imbalances.

According to the 7th FYP foodgrains will not be taken into account as one of the major port commodities anymore in this and following periods. It implies that India is selfsufficient in foodsupply, nonetheless adverse weather conditions can heavily affect the still vulnarable agricultural production. For instance in 1982/83 the monsoon brought little rain causing a bad harvest which resulted in higher imports of foodgrains. Figure 32 shows one graph representing the import of foodgrains as a percentage of domestic production. It illustrates both India's grown selfsufficiency, on average the percentage diminishes throughout the years and even export was possible, and the vulnarability for adverse weather, resulting in higher imports e.g. in 66/67, 75/76, 82/83. The second graphic shows the foodgrain cargoflow handled in Haldia and Calcutta, striking is its relation with in- or decreasing import.

In agreement with Government of India data and policies no or just minor quantities of foodgrains are included in the forecast for Haldia. This would not be justified if in future Government of India decides that the performance in India's agricultural sector is sound enough to stimulate exports in order to improve the Balance of Trade. (Minor quantities will be included in the commodity 'All other Cargo').

5.2.7 Tea

There are two characteristically tea producing areas in India, the states Kerala and Tamil Nadu near the ports of Cochin and Madras, and the states Assam and West Bengal delivering tea cargo to

Tea is one of India's principal export commodities, approximately 35% of the total production is exported. In 1983 the amount of 195*10**3 t exported tea corresponded to 16% of the world's tea export. Declining prices on the world market will lead to decreasing export earnings in future although production of tea in India is modestly increasing. For the period 1984/85 to 1989/90 Government of India expects a growth rate of 3.5% per annum for the production of tea, other sources [5] anticipate on a growth rate of 1.9% per annum in the nineties.

Table 24 gives the data that will be used to forecast the cargo in Haldia. The forecast for tea is based on the following assumptions:

- growth rates of 3.5 and 1.9% per annum towards the target years. Per year a 10% insecurity in achievements of tea production-targets should be taken into account due to good or bad weather conditions.
- 25% of the tea production will be transported through the port of Haldia.

Calculation results in 176*10**3 to 195*10**3 tonnes and 212*10**3 to 235*10**3 tonnes to be transported in respectively 1989/90 and 1999/2000.

During the months July to September the moved quantities on average are 50% higher compared to the other months.

5.2.8 All other Cargo

Among all other cargo e.g. iron ore and salt can be found as well as wood etc.. In the 7th FYP Government of India plans to realise a growth rate from 8 to 9% per annum in industrial production. It is assumed that the amount of other cargo, which is less directly related to industrial production, will increase according to the mentioned industrial growth rate.

From 1,882*10**6 t/a in 1984/85 this cargo will increase 2,830*10**6 and 6,400*10**6 t/a in respectively 1989/90 and 1999/2000. Other assumptions:

- average 8.5% per annum growth rate in the period 1984/85 to 1989/90.
- same growth rate in the nineties.

The amount of cargo with import and export destinations was almost in balance in previous years, see Table 25.

Since various goods are included in this commodity no seasonal varations are expected in the demand and supply.

5.2.9 Preliminary cargo-forecast

The preliminary cargo-forecast aggregated from the commodity-forecasts is shown in Table 26. In absolute figures the total amount of cargo changes as follows:

in 10**6 t/a	1984/85	1989/90	1999/2000
Total	10.524	16.541-16.560	27.473-43.649

From these figures it can be seen that the average annual growth rate in the period 1984/85 to 1989/90 would be 9.5%, whilst the Government of India anticipated in the 7th FYP an annual growth rate of 9.4%.

5.3 RESULTING CARGO-FORECAST

The preliminary cargo-forecast has been compared with the forecast assessed by the CPT, see Table 27. Although there are some differences it is justified to conclude that the forecasts are in agreement with each other for all the commodities, coal excepted. The forecast figures for coal in 1989/90 are almost similar, 3.52 and 3.30 million tonnes, whilst the figures for 1999/2000 deviate considerably, a range of 6.50 million to 19.0 million tonnes for the cargo-forecast and 4.20 million tonnes for the CPT-forecast. Most probably the CPT will have better reasons to mention an amount of 4.2 million tonnes of coal than the figures derived in this chapter that are based on several assumptions. In hindsight the difference is explained as follows:

- a substantial part of the coal production will be transported to to a thermal power station near Madras.
- traditionally the coal would be transported through Calcutta, however, the future traffic has been assigned to the port of Paradip.

In the final cargo-forecast, see Table 28, the CPT figure for coal has been taken over. The total amount of cargo has been listed below.

in 10**6 t/a	1984/85	1989/90	1999/2000
Total	10.524	16.541-16.560	25.173-28.949

For the first period to 1989/90 the result is the same, in the second period the deviation between the minimum and maximum figure dimishes.

6. PACKING-FORECAST

6.1 INTRODUCTION

Cargoes are classified as general cargo or bulk cargo. The general cargo class is usually further subdivided in breakbulk, unitized, neo-bulk and container cargoes. Based on the nature of goods, and the kind of packing, four classes of port traffic found in the ports of Haldia and Calcutta will be defined, viz. liquid or liquefied bulk, dry bulk, breakbulk cargo and last but not least containers. Here making a packing-forecast will be defined as predicting the amount of cargo in each class of port traffic. The resulting figures will be used to estimate the productivity when cargoes are being transshipped, which differs per port traffic class, see the next chapter, and to assess and to estimate the kind and number of vessels that will visit the port, see section 8.3.

There are reasons for treating the container-forecast more extensively and separatly from the other port traffic forecasts. The use of containers is a relatively new development, certainly in countries such as India. The method used to obtain a container-forecast is rather extensive and cumbersome compared to the other port traffic forecasts. Since the result of the container-forecast influences the predictions for the breakbulk traffic it will be drawn up in the next section. In the last section of this chapter the resulting packing-forecast will be drawn up.

6.2 CONTAINER-FORECAST

6.2.1 General considerations about the use of containers

The container is merely a big box, with standard sizes, that can be loaded with a number of breakbulk or general cargo 'parcels'. Loading and unloading of containers, which is called respectively stuffing and stripping, usually takes place in a container freight station (CFS) or at the factories. If a container is completely filled with cargo having the same origin and/or destination the efficiency of container use is increasing because the necessary stuffing and stripping actions are reduced. The advantage of moving only one box, containing a number of parcels, compared to moving the same number of parcels separately is obvious. In general use of a container reduces the necessary transport actions, e.g. the number of ship to shore movements, and vice versa, and subsequently the turn around time of ships in ports diminishes. Savings on packaging is another advantage of cargo transport in containers.

However not all the general cargo is suitable for transport in a container and a disadvantage of containers is the introduction of some extra work, viz. stuffing and stripping especially if not the complete container load has the same origin and/or destination. The size and weight of (full) containers requires special equipment and adjusted civil works to handle them which results in higher investments in port facilities compared to the traditional cargo handling facilities. The container trade balances the total number of import and export containers. If the containerisable amount of cargo is unequal for the import and export traffic than partially filled or empty containers will be transported besides the fully loaded import and export containers.

The world wide use of containers has grown rapidly from the late sixties into the eigthies, as shown in Table 29. In first instance container trade developed in and between the industrialized countries on the northern shipping routes but the trade is spreading all over the world now. The proportionate share of the developing countries involved in container trade increased from 10% in 1970 to 25% in 1982 and this percentage will grow [16]. In general the developing countries in Asia have been extremely positive as regards containerisation. Indigeneous container shipping operations were rapidly introduced and in the majority of instances subsequently are expanding not less rapidly. The use of containers is a reflection of a relatively mature industry which provides a wide variety of manufactures suitable for container transport. If the use of containers is more or less established the container trade can be considered as an engine for economic growth.

The container throughput in Indian ports is shown in Table 30. To describe container throughput the unit TEU is frequently used. TEU stands for Twenty feet Equivalent Unit which is related to the length dimension of the container.

Although the importance of a container forecast is obvious it is difficult to obtain a realistic one. The consequences of a wrong forecast can either be severe congestion in the handling of containers resulting in loss of cargo or unused expensive facilities.

6.2.2 Forecasting the amount of containers

The following method has been used to obtain a container forecast for Haldia, expressed in the annual number of boxes:

- determine the amount of cargo that will be transported in containers:
    - fix the amount of cargo to be considered for containerisation.
    - predict the containerisation degree for the considered commodities.
- establish the tonnage transported per twenty feet container box.
- estimate the number of empty containers.
- determine the ratio 20 to 40 feet containers to convert the annual number of TEU's in number of boxes.

The commodities gunnies, tea, iron and steel, machineries, and all other cargo, see Table 31, can be considered for containerisation.

To find the containerisation degree for every commodity in the target years the next steps were taken:

- the containerisation degree of the separate commodities in 2004/2005 has been established [5]. The result for 2004/2005:

Commodity	Containerisation degree
Newsprint	-
Iron & steel	20%
Machinery	50%
Pig iron	-
Sugar	-
Gunnies	75%
Tea	100%
All other cargo	50%

- from the available statistics the average containerisation degree per commodity for the past 3 years [2] has been calculated, see Table 31.
- The assumption that the containerisation degree grows rectilineair from the calculated average, set in the year 1984/85, to the established values in 2004/2005 makes it possible to compute the values in 1989/90 and 1999/2000.

The extrapolation method has been used since there are no signs for an exponential growth of the containerisation degree. Table 32 shows the resulting containerisation degrees for each commodity. The average degree for all the containerisable commodities increases from 14% in 1984/85 to about 23 and 42% in respectively 1989/90 and 1999/2000.

Multiplying the amount of cargo that is considered for containerisation with the respective containerisation degree yields the total tonnage per annum transported in container boxes, see Table 33.

The available statistics have been used to determine the tonnage transported in an imported and exported container, expressed in tonnes/TEU. Dividing the total import and export tonnages per annum by the respective tonnage per box results in the annual number of full container loads (FCL's) expressed in TEU/annum, see Table 34. It is assumed that the tonnage per TEU remains the same in the next decade.

To obtain the total number of TEU's the number of empty containers has to be added to the FCL's. For the export container flow the available statistics were used to estimate the number of empties as a percentage of the FCL's. A percentage of 18% was found, see Table 35. The same table reveals that the total number of import and export containers was more or less equal in recent years, however, this was accompanied by the transport of a considerable amount of empty import containers.

The number of empty import containers has been established by postulating that they will continue to balance the total number of import and export containers, i.e.:

empty import = empty export + full export - full import.

Owing to the computations in this step the total number of containers handled in one year will be found, expressed in TEU's per annum.

To arrive at the number of boxes handled in one year the ratio 20 to 40 feet (20' to 40') containers has to be determined. Again present day statistics were used this time in combination with a reasonable estimate of this ratio in 1999/2000. It is assumed that 30% of the number of boxes will be of the 40' type in 1999/2000. In a graph representing the course of the 20' to 40' ratio throughout the years a nearly rectilineair line has been drawn to connect the known values, see Figure 33. The result for 1989/90 is that 23% of the total number of boxes will be of the 40' type. The transport capacity of a 40' box is twice the transport capacity of a 20' box. The total transport capacity of all the boxes has to be equivalent to the actual transported number of TEU's. Thus the number of boxes is the annual number of TEU's divided by 1.23 and 1.30 respectively in 1989/90 and 1999/2000.

The final result of all the previous calculations can be found in the Tables 36 and 37. Approximately 39,000 TEU's were handled in 1984/85. About 100,000 and 359,000 TEU's/annum will be handled in respectively 1989/90 and 1999/2000, which is equivalent to 81,000 and 276,000 boxes.

6.3 RESULTING PACKING-FORECAST

Liquid bulk, dry bulk cargoes and containers are usually transported in large homogeneous quantities, cargoes in the breakbulk class show a big variety regarding goods and size of the consignements. In fact liquid and dry bulk cargoes remain unpacked. The packing-forecast for liquid bulk and dry bulk is easily derived from the cargo-forecast. Adding the figures for the separate commodities in the cargo-forecast to each other if they fall under the same port traffic class yields the figure needed for the packing-forecast. The total amount of general cargo has to be divided in traditional breakbulk cargo and cargo transported in containers, a pre-eminent packing. Commodities like tea, gunnies, iron and steel, machineries, leather, chemicals, carpets etc., are ranged under the breakbulk or container port traffic class depending on their packing. Breakbulk cargoes are packed in sacks, bales, chests, drums, bundled on pallets, or remain completely unpacked if the pieces are big enough and do not need protection.

In the Tables 38 and 39 the resulting packing-forecast for all the distinguished port traffic classes has been given, see also Table 28 with the cargo-forecast.

7. BERTH-PRODUCTIVITY FORECAST

In agreement with the division in port traffic classes for cargoes a similar division can be made for the types of berths. In the past special loading and unloading equipment has been developed for each class of port traffic in order to raise the productivity of the equipment and to decrease the transport time of cargoes. The amount of cargo handled at a berth in one year is defined as the berth-productivity and is expressed in tonnes/annum. The amount of cargo per port traffic class in the packing-forecast and the berth-productivity determine how many berths will be necessary to handle all the supplied cargo. The berth-productivity depends on the productivity per shift, the number of shifts per day, the number of working days per annum, and the berth occupancy factor (BOF) [28]. Except the number of shifts per day, which will be set at 3 shifts per day, these factors will be discussed in the following sections. It will be found that the kind of cargo influences the productivity per shift and the number of working days per annum. In section 7.4 the results of the separately treated factors will be integrated to assess the berth-productivity for every port traffic class in the chosen target years.

7.1 PRODUCTIVITY PER SHIFT

7.1.1 Methods to assess the shift productivity

The productivity per shift at a berth depends on the capacity of the specific equipment and the achievements of the workforce. In a more theoretical approach these factors can be analysed further and finally expressed in the effective capacity of the equipment, the number of effective working hours per shift, and the productivity per gang [27,28]. Quantification and computation will yield the productivity per shift.

Another method to determine the productivity per shift uses the shift productivity figures of the most recent years. As explained the shift productivity is in fact derived from, for instance, the productivity per gang. The factors determining the shift productivity are disregarded by the direct use of the available figures for the shift productivity. Of course it is possible to use the shift productivity figures to estimate the numerical values of the contributing factors. The figures for the shift productivity in Table 11 served for guidance to set a target for the shift productivity in 1989/90. In general the highest known or slightly higher productivities have been chosen having in mind that the present performance should be improved. The shift productivity in the target year 1999/2000 has been calculated assuming an annual increase in productivity of 2% per annum in the nineties and taking as starting point the year 1989/90. Usually an annual raise in productivity varying from nil to 4% can be expected due to training of the workforce [29]. Another possibility to increase the shift productivity is to use more loading or unloading equipment at the quay. Data from other ports were used to check the proposed figures and, if necessary, to adjust them [13,30,31]. The productivity per shift will be discussed successively for liquid bulk, dry bulk, breakbulk, and container berths.

7.1.2 Productivity of liquid bulk transshipment

Crude oil and refinery products are the main cargoes in the liquid bulk port traffic class. Usually these cargoes are transported in large quantities. The nature of these cargoes enables the application of pipelines, hoses and pumps in the loading and discharging process. The safety requirements are high because oil is inflammable.

Crude oil and oil products are both mainly discharged in Haldia. At present the productivity rates have a range from 1065 to 1408 tonnes/hour (t/hr) see Table 11. After the berthing procedures of a tanker and connecting the hoses and manifolds the loading or discharging proces remains relatively undisturbed. A constant rate determined by the pump- and pipe capacity can be maintained. It is assumed that in 1989/90 the production will be 1500 t/hr Improvement of the productivity by training programs for the workforce will not have much effect since the only human interference in the loading and unloading process is the work done to connect the manifolds. Therefore the productivity in 1999/2000 will also be 1500 t/hr. Assuming a shift has 6 effective hours yields a shift productivity of 9000 tonnes/shift (t/sh).

7.1.3 Productivity of dry bulk transshipment

The dry bulk commodity coal is loaded in the ports of Haldia and Calcutta while a relatively small amount of coking coal, 9% of the coal quantity, finished fertilizer and rock phosphate, the raw material for fertilizer, are discharged from the ships.

Coal is loaded into the vessels with 2 shiploaders each having a rated capacity of 1500 t/hr. The two coal supplying stacker cum reclaimers have a reclaiming capacity of 1000 t/hr each. In recent years the average loading rate amounted to 565 t/hr. The productivity per shift varied from 1650 to 2050 t/sh which implies that on average a shift had only 3 effective working hours. Assuming a productivity of 650 t/hr in 1989/90 and 6 effective shift hours the performance will be 3900 t/sh. With a shiploader output of 780 t/hr and the same number of working hours per shift the shift output will be 4700 t/sh in 1999/2000.

The unloading rate of coaking coal amounted to 1080 t/sh. It is assumed that in 1989/90 and 1999/2000 the productivity will be respectively 1200 and 1500 t/sh.

Fertilizer as a finished product is transported unpacked or in bags. A slight rainfall or even heavy fog can affect finished fertilizer, thus these weather conditions prevent fertilizer from being discharged. Phosphate rock is transported unpacked as a typical dry bulk commodity. The material is very dusty and absorbs moisture very readily, which has already hampered the unloading process before in Haldia.

A grabbing crane or crane with a hook is used to take the cargo from the ship, a grab in case of unpacked finished fertilizer and phosphate rock, a hook if the finished fertilizer has been bagged. Unpacked fertilizer is discharged at a rate of 53 to 81 tonnes/grab/shift, whereas bagged fertilizer is discharged at a rate of 125 tonnes/hook/shift, due to a higher specific weight phosphate rock is discharged at a rate of 69 to 115 tonnes/grab/shift. For bagged and unpacked finished fertilizer, and for phosphate rock a productivity of 125 tonnes/grab/shift is proposed in 1989/90. With 2 grabbing cranes working at one ship this results in a shift productivity of 250 t/sh. This is far below the rated capacity of the equipment, which amounts to 2000 t/sh. To propose a figure for the productivity in 1999/2000 it is assumed that the unloading equipment has an effective capacity of 1000 t/sh. The efficiency of the workforce using the equipment will be taken into account with a reduction factor of 0.8, this leads to a shift productivity of 800 t/sh.

7.1.4 Productivity of breakbulk transshipment

The breakbulk port traffic class comprises many kind of goods and various packings are used when they are transported, see section 6.3. It results in a big variety in size, shape, and specific weight of the cargoes. However all those cargoes have to be handled by the same crane, therefore the output per hook for the crane, and consequently the shift productivity, is a rough average to which a high deviation is possible depending on the specific cargo.

At present the average productivity varies from 77 to 85 tonnes/hook/shift. For 1989/90 and 1999/2000 a productivity of respectively 100 and 125 tonnes/hook/shift is expected. With two cranes working at one ship this results in a shift productivity of 200 and 250 t/sh respectively in 1989/90 and 1999/2000. It is possible that in 1999/2000 training of the workforce has resulted in the use of 3 cranes per ship. However, the effectivity of each crane decreases if more cranes are used per ship, therefore the output of 2.5 cranes will be taken into account for the shift productivity. With 125 tonnes/hook/shift the productivity will be 310 t/sh.

7.1.5 Productivity of container transshipment

The average productivity of the porttainer in Haldia mounts up to 25 Boxes/shift and had a maximum of 78 Boxes/shift. For 1989/90 and 1999/2000 the productivity will be set at 80 and 100 Boxes/shift, for one porttainer. It is assumed that in 1999/2000 two porttainers will work at one ship, consequently the shift productivity will be 200 Boxes/shift.

7.2 AVERAGE NUMBER OF COMMISSION DAYS PER ANNUM

On a certain number of days in one year berths cannot be used for cargo handling or ships cannot sail for various reasons. The number of these 'out of work' days varies throughout the years, and also varies per type of berth. This depends on the kind of cargo being transshipped at the berth under consideration. Substracting the number of out of work days from the ordinary 365 days in one year yields the number commission days in one year. Saturdays and Sundays, local holidays and national or religious feasts, strikes, weather conditions determined by wind and rain, maintenance or dredging activities are the most obvious examples of circumstances causing interruptions in the work pattern on berths and ships. A simple addition of all the days lost owing to these circumstances to arrive at the total number out of work days is not justified. Some of the circumstances are correlated, i.e. they occur at the same moment and should not be counted twice. Not all the port operations are influenced to the same extent by the mentioned circumstances.

If the only variable would be the number of commission days the performance in a port improves or gets worse with an increasing and decreasing number of commission days. Therefore the highest number of commission days in one year is preferrable. In order to determine the required port facilities in future the average number commission days per year has to be established. The following has been done:

- for each mentioned circumstance the number of days lost per annum will be determined.
- for every port operation the average non-correlated out of work days per annum will be established.
- for each berth group the average non-correlated out of work days per annum will be established.
- after the previous steps a simple substaction will be allowed to arrive at the average number of commission days per year.

Saturdays and Sundays

It is reported that Saturdays are ordinary working days [32]. Work can be arranged on Sundays. From an economic point of view it is unwise to consider 52 Sundays per year as non working days. The investment in port facilities outbalances the operational costs involved, especially in a country with a low wages level like India.

Local holidays, national- and religious feasts

Republic day, Independence day, and Gandhi's birthday are mentioned as non working days [32]. It is assumed this will not change in future years.

Strikes

West Bengal has a reputation in respect of strikes. Table 40 supplies some information used to make a rough estimate of the number of working days lost due to strikes. The average of the number of lost mandays in the previous years and the number of dock-workers have been taken into account to arrive at 5 lost days per year.

Wind

The frequency as well as the duration of the period with wind exceeding windforce 6 or 7 is important for determining the time lost for port operations. Using the wind arrows in Figure 34 yields that windforce 6 and 7 are exceeded respectively 17.7 and 1.6% of the total time in one year [8]. The percentages are equal to 65 and 6 days per annum. It is assumed that storms or cyclones are included in the observations. Port operations, i.e. cargo handling and ship manoeuvres are difficult on 59 days (65 minus 6) in one year. The number of days with a complete stop of the port operations will be fixed at 6 days per annum.

Rain

Similar to wind not only the frequency but also the duration of rainfalls has to be known to determine the number of working days lost due to rain. Rain has to be taken into account for two reasons, viz.:

- some cargoes are affected by (rain) water, e.g. fertilizer or paper reels are worthless after contact with water.
- heavy rain slows down the loading and unloading process because the dock-workers have to be more careful.

Exact data about the duration of rainfalls related to the number of milimeters precipitation were not available. Fortunately a graph with the number of rainy days related to the cumulative rainfall could be obtained, see Figure 35 [26]. The following rough assumptions have been made:

Breakbulk cargoes
- if a cumulative rainfall of 10 mm is observed on one day the production of one shift will be lost.
- if a cumulative rainfall of 20 mm is observed on one day the production of two shifts will be lost.
- if a cumulative rainfall of 30 mm is observed on one day the production of three shifts, equivalent to one day, will be lost.

Fertilizer

- for this cargo the number of cumulative milimeters has been set at 5, 10, and 20 mm resulting in respectively 1, 2, and 3 lost shifts.

The main steps in the calculation were:

- determine the number of days in the monsoon period with more than 10, 20, and 30 mm rainfall using the above mentioned graph.
- the number of these days is expressed as a percentage of 122 days, which is the average length of the monsoon period.
- calculate the number of last days using the specific rainfall days and the related weighing factor of shifts lost per day.
- rain will also fall when the monsoon season has passed, therefore it is assumed that the number of lost days in the monsoon season has to be multiplied with 1.25 to arrive at the total number of working days lost per annum.

For the breakbulk port traffic class 45 days per annum will be considered as lost for port operations. This figure amounts to 64 days per annum for the dry bulk commodity fertilizer.

Maintenance dredging

Virtually ordinary dredging of sediments will not be necessary within the dock area since it is protected for intruding sediments by the lock. However cargo that has fallen into the water during the cargo handling process will have to be removed. For this activity it is assumed a berth cannot be used on one day in a year. The circumstances are quite different at the oil jetties located at the river banks. Here the opposing phenomena of siltation and scour occur. It is assumed that these phenomena will result in one working day lost per annum. It has to be kept in mind that a berth will not always be used, see section 7.3 about the BOF. With a little management more time will be available for maintenance dredging than just the one day being reserved here.

Correlation of circumstances

As stated before a few of the circumstances that cause a loss of working days are related to each other. Since a small number of days is involved in case of local holidays, strikes, and maintenance dredging only the correlation of wind and rain will be reconsidered.

In general extreme wind and rain conditions occur at the same time for instance during storms or cyclones. These extreme conditions are included in both the figures proposed for wind and rain. Simply adding these figures is theoretically not justified and would also be too pessimistic. The solution for this problem has been found in using the decisive figure for either wind or rain. Except for breakbulk and fertilizer cargoes 350 days per annum will be taken into account, see Table 41. For breakbulk and fertilizer respectively 311 and 292 days per annum can be used for cargo handling.

7.3 BERTH OCCUPANCY FACTOR

In general a berth is not in use all the time since there will not always be a ship for loading or unloading its cargo. Division of the time the berth is actually used for transshipment of the ship's cargo by the time the berth is available yields the BOF. The berth-productivity varies in agreement with the BOF. Therefore it could be decided to increase the BOF as far as possible, which would result in maximum utilization of the berth. However, the total port costs paid to transport cargo through the port are made up of berth costs and ship costs [27,28].

A fixed and a variable component determine the berth costs. The fixed component is independent of the tonnage throughput and includes the capital costs of quays, sheds, cranes etc.. For instance, labour and staff costs, fuel, and maintenance are ranged under the variable costs which do depend on the tonnage throughput. When costs are expressed in cost per tonnes than the fixed costs per tonnes decrease if the throughput increases. The costs owing to the variable expenses remain fairly stable until the berth becomes under pressure to achieve high tonnage throughputs. Then more costly methods of cargo handling will be necessary and consequently the variabele costs per tonnes increase. Addition of the variable and fixed costs per tonnes yields the berth cost, see Figure 36, which has a minimum due to the different behaviour of the contributing components at low and high throughput values.

The cost of ship's time in port is also made up of two components, viz. the time the ship spends at the berth and the time the ship spends waiting for an empty berth. The cost involved, expressed in cost per tonnes, as a function of the throughput is shown in Figure 36. As traffic increases the waiting time and resulting costs increase, whilst the berthing time and costs decrease.

Since the total port costs are the result of berth and ship costs an optimum between these costs has to be found when the total should be minimized. Based on a ratio of ship cost to berth cost of 4 to 1, for breakbulk berths and ships, the ship waiting time will be kept in reasonable limits if the BOF does not exceed the following figures [27]:

number of berths	maximum BOF (percentage)
1	40
2	50
3	55
4	60
5	65
6 or more	70

The use of the maximum BOF for berth-productivity calculations implies that the number of berths is known in advance. In an iterative procedure starting with an estimated number of required berths, the BOF, the berth-productivity, and the number of berths will be determined. Of course the initial estimated value has to be in agreement with the calculated value. After assessment of the number of berths, with the iterative method, and the ship-forecast it is possible to refine the procedure for determining the number of berths. Then the BOF will be defined as the arrival rate of ships divided by the product of the number of berths and the service rate. The arrival rate and the service rate are expressed in ships per day and can be described with the help of statistical distributions. Input of an economic evaluation criterion will be necessary to assess the required number of berths.

7.4 RESULTING BERTH-PRODUCTIVITY

In the preceding sections the factors influencing the berth-productivity have been discussed. The following formula can be used to obtain the annual berth-productivity, Bep:

$$Bep = p * s * w * BOF$$

in which:

- p = productivity in tonnes/shift or boxes/shift
- s = the number of shifts per day = 3
- w = the number of working days per annum
- BOF = berth occupancy factor

The maximum BOF for breakbulk berths has also been used to compute the productivity of the other types of berths. The resulting berth-productivities are listed in Table 42 together with the number of required berths.

Since the same unloading equipment is used for finished fertilizer and phosphate rock the same berths can be used by the respective vessels. This allows the use of one BOF of 70% for all the berths together instead of 70% and 60% in

1989/90 and 60% and 50% in 1999/2000 for respectively a separate fertilizer and phosphate berth group.

8. NAUTICAL INFRASTRUCTURE AND SHIP-FORECAST

8.1 INTRODUCTION

Water and its boundaries can serve as a broad definition for nautical infrastructure, here the expression is used to describe the approach channel, the lock, and the basin of the port. The nature of goods, economics of scale, and the available nautical infrastructure determine the kind and size of vessels to be expected in the port. Oil, containers, or breakbulk make different demands upon the vessel used for maritime transport. In general reduction of transport costs leads to utilization of the largest possible vessels. However, in Haldia the size of the vessels is restricted by the available nautical infrastructure. The available depth in the outer estuary, the approach channel in the inner estuary, the lock and the basin should be marked as the governing factor restricting the reception of larger seavessels, see section 3.2.

In the next section it will be examined how the use of the present nautical infrastructure can be improved. After assessment of the dimensions of the nautical infrastructure it is possible to draw up the ship-forecast. The ship-forecast has to supply information about the kind of vessels to be expected in the port, the dimensions of these vessels, and the amount of cargo loaded into or from every type of ship. This information used in combination with the packing-forecast enables the establishment of the number of ships visiting the port. The length of the vessels and their representation on the total number will allow assessment of the berth length as a weighed average. In section 8.3 the final ship-forecast for the target years 1989/90 and 1999/2000 will be described.

8.2 IMPROVEMENT OF THE NAUTICAL INFRASTRUCTURE

Depth, width, length, and layout of the available water areas largely determine the quality of the nautical infrastructure, climatologic and hydrologic conditions play a significant role, whilst ship characteristics have some influence as well. Important aspects about the quality of the nautical infrastructure are the downtime and safety level, which are strongly related to each other. In a given situation, for instance when the channel dimensions are fixed, the downtime of the channel increases or decreases with lower or higher safety demands. Collisions or ships running aground, both owing to loss of controll in steering the vessel are the result of an unsafe situation and have to be avoided. As stated before a port has to follow the trade and the possibilities to provide access to the port for larger vessels have to be examined. With the help of engineering techniques like dredging, to construct a bigger channel or to deepen the basin, construction of a new lock, or the use of tugboats, the nautical infrastructure can be improved. A project aiming at improvement of the nautical infrastructure will require high investments. Before the project starts a careful decision-making procedure, evaluating the costs and the benefits, will be carried out [19]. In the next subsection such an procedure will be described and in following subsections steps of this procedure will be further elaborated.

8.2.1 Design procedure to improve the nautical infrastructure

Within a design procedure, aiming at providing access to the port for larger vessels, under the condition that the resulting benefits outweigh the involved cost, the following steps will be taken:

- assess the dimensions of a design ship that must be able to enter and leave the port. The downtime has to be specified, i.e. the maximum number of hours per day and/or the maximum number of days per annum that this ship has to wait before it can sail through the lock or the approach channel. A safety criterion has to be defined as well.
- determine the required dimensions of the approach channel, lock and basin. Whether to choose deterministic or probabilistic models in order to design the channel will be described in the next section.
  The present lock has fixed dimensions and will be used to its ultimate limits in respect of ship size and capacity. If the lock does not meet the need of the prescribed design ship construction of a new and bigger lock is necessary. In the first situation the costs will be negligible, the reverse is true in the second situation. In first instance the present basin depth will not need adjustment, similar to the lock. However, if the depth has to be increased the involved costs have to be determined.
- based on the respective designs for the channel, lock, and basin the construction and maintenance costs will have to be determined. Depending on the available nautical infrastructure a ship-forecast has to be drawn up as well.
- calculate the resulting benefits caused by:
  - reduction of ship waiting cost due to the decreased downtime.
  - the decreased transport price of cargoes owing to utilization of larger vessels resulting in lower cost per tonnes cargo.
  - for certain cargoes the transport price will decrease because a direct shipping line to the port can be established and contrary to the preceding situation it is possible to avoid extra cargo handling in so called main line ports, where the cargo had to be loaded in a smaller ship.

- evaluate the costs and benefits, see appendix C. As long as the result of this evaluation is positive the choice of the design ship is not violated and the same steps are repeated with a larger design vessel.

Since the same steps of the design procedure are repeated until the best result has been obtained the procedure can also be described as an optimization procedure. Looking over the described procedure it is obvious that the separate steps are closely related to each other. For instance the design ship and the downtime have to be prescribed before any channel can be designed, and it will be useless to provide a 15 m draught channel at high costs while the lock and the basin do not allow this draught. Nonetheless, for matters of convenience within this report, the limits in the use of and possible improvements of the approach channel, the lock, and the basin will be examined separately. However, the relation with the other steps in the optimization procedure will not be forgotten.

8.2.2 Design vessel and downtime of the port

In agreement with the optimization procedure and as a starting point for the next subsections a design ship in combination with a downtime has to be chosen. The CPT is determined to provide access to the port for 10.7 m draught vessels for about 320 days per annum. Eventually admissible draughts of 12.2 and 13.7 m are pursued [1]. The chosen design ships have the following features [33,34]:

design ships

type	tanker	container	dimensions
DWT	85,000	25,000	tonnes
Displacement	105,000	34,000	m**3
LOA	300	212	m
Beam	36.5	30.0	m
Draught	10.7	10.7	m

Two ships have been chosen since the tanker will be decisive for the channel dimensions whilst the container ship dominates the assessment of lock and basin dimensions. In section 10.2 it will be motivated that the tanker will not enter the lock and basin at all.

8.2.3 Dimensions of the approach channel

The available depth, width, and the layout of the approach channel determine the admissible ship sizes and have to be improved in future in order to enable larger ships to enter the port. Safety is in fact largely determined by the manoeuvrability of the vessel which depends on the characteristics of the vessel and the environmental conditions. Ship characteristics are the reactions of the ship on the rudder and propellor revolution changes, turning ability, and stopping distance. Shallow water, waves and swell, currents and wind are the most important environmental conditions influencing the manoeuvrability of the ship. In the following paragraphs the depth and width of the channel will be assessed while the mentioned factors are taken into account.

Depth of the approach channel

The main factors which influence the depth of the entrance channel are:

- draught of the vessels to be received
- vertical ship motions in waves
- squat and trim
- vertical tide and actual bottomprofile
- sedimentation in relation to the dredging cycle
- safety and manoeuvring margins
- safety level of channel transits and downtime of the channel

To find the optimal channel depth, these factors have to be studied in an integrated way [38,39]. In principle two methods of integration can be distinguished, respectively the deterministic and the probabilistic method. The principle of the deterministic approach is shown in Figure 37. The required channel depth is obtained by adding the separately quantified contributions of all relevant factors. A drawback of deterministic summation is that the trade-off between the depth of the channel on the one hand and safety of channel transits and accessibility to the port on the other hand, cannot be made. This requires a statistical quantification of all relevant factors influencing channel operation, which is taken as starting point for the probabilistic approach. However, there has to be sufficient data available in order to allow the conversion of this information into stochastical distributions. With the help of the distributions all possible circumstances during the life of the channel will contribute to the design in a weigthed form. The weights are proportional to the frequency of occurrence of the circumstances. Since the probabilistic approach quantifies uncertainties with respect to safety of channel transits and port accessibility, both in relation with the channel depth, this method has to be preferred. Lack of data, e.g. on the wave climate, and the deviations on the average bottom profile, prevents the application of the probabilistic method, consequently the deterministic method has to be used.

The influence of the mentioned factors will be discussed and quantified below.

Since the design ship has a draught of 10.7 m this figure has to be used for determining the optimal channel depth.

A channel opened for 320 per annum has a downtime of 45 days per annum. This means that on 45 days high water (HW) does not reach a level high enough to allow the design ship to sail through the channel. Note that in this definition of downtime implicitely leads to waiting time since the ship will not arrive exactly at HW. With a tide period of 12.42 hours, equivalent to 12 hours and 25 minutes, 45 days is convertable to 87 tides. The final channel depth has to be determined with regard to the level of this specific tidal level. The lowest HW occurs during neap tides and on their turn neap tides can be divided in high and low neap tides. In one year there are about 353 neap tides, again computed with the same tide period, which is about four times as much as the the 87 critical neap tides. The levels of low and mean neap tide with regard to MSL are given in subsection 3.2.2, lineair interpolation results in a reference level of 0.70 + MSL.

Squat of a vessel is the sinkage resulting from the return currents along the sides and under the keel. From a number of expressions, see [40], Tuck-Tailor's formula has been chosen to estimate the squat. This formula is applicable to unrestricted water for all ship types. Computations with this formula result in a maximum squat of 1.10 m for the proposed design ship, see Figure 38 for further elaboration. This value was found for the tanker.

The keel clearance necessary for ship motions generated by waves is assessed with the help of a formula derived from a probabilistic method. As safety criterion a 1% chance on hitting the bottom during one transition of the channel has been chosen. Spectral analyses of waves and determination of a ship response function are included in the method. Although the underlying theory is complicated, for further elucidation see [37,38,39], the result is fortunately presented in a few serviceable formulas. Formulas, computations, and results are given in Figure 39. Although the wave climate in the inner and outer estuary is different, see subsection 3.2.2, the decisive value for the required keel clearance is the same and equal to 0.4 m. This keel clearance is necessary under average wave conditions whilst under maximum wave conditions circa 4 m extra keel clearance, thus water depth, would have to be provided. Maximum wave heights coincide with extreme weather conditions which were considered as lost working days, see section 7.3. Since ships are not supposed to sail through the channel under these circumstances the obvious advantage arises of not being forced to provide such a large keel clearance.

To the previous depth requirement a nett keel clearance of 1.0 m is added to provide the free space between the keel and the bottom, which is a generally accepted value for safety and manoeuvring margins.

No extra depth will be added for dredging tolerances, sounding inaccuracies or sedimentation. Since the channel will be dredged continuously throughout the year the sediment layers accumulating above the channel bottom will have relatively low densities. The reported depth of the channel is often taken to be the contour line where the length of the ship and the factor 1/4 the result of the maximum drift angle. Substitution of 1.5B for 1/4L yields 2.5B. Under the rather extreme current conditions and the slightly curved alignement of the approach channel to Haldia the width of a manoeuvring lane is fixed at 3B.

Since the exact location of the ship with regard to the bank of the channel is unknown a channel strip having a width of 1.5B, the bank clearance has to be provided on both sides of the channel. In case of a two lane channel a strip inbetween the two manoeuvring lanes, the ship clearance, has to be provided for which a width of about B will be sufficient.

Addition of all the requirements yields a channel width, expressed in a multiple of the ship beam, equal to 6B and 10B, at the full depth keel level of the design ship, for respectively a one lane or a two lane channel. The intensity of the vessel traffic determines whether a one lane or a two lane channel should be dredged. When ships are sailing in the opposite direction in a one lane channel and meet each other in the same cross section the interaction between ships and the surrounding water will necessitate very carefull manoeuvring. This will definitively result in delays if the intensity is high but in fact this situation should be considered as unsafe unless extra manoeuvring space is available, which leads to a two lane channel. Another solution would be to prohibit sailing in opposite directions at the same time, which results in ship waiting time or extra downtime of the port. The present intensity of vessel traffic already requires a two lane approach channel and the future developments will not cause a dramatical fall in this intensity, on the contrary see subsection 3.2.5 and Table 43, thus a two lane channel will be dredged.

Using the design ship beam of 36.5 m results in a channel width at the bottom of 365 m. The following considerations leading to the use of another decisive beam of the design ship are based on further elaboration of the ship-forecast, see section 8.3. For 95% of the total number of ships the beam will be less than 30 m in 1989/90. Therefore encounters of large vessels sailing in the opposite direction will have a low frequency of occurrence compared to encounters of smaller vessels or one large and one small vessel. Moreover the largest vessels visiting the port are either liquid or dry bulk carriers that will only sail with their maximum load in one direction. During the journey in the other direction these carriers will sail with a draught of, for instance, 50% of their maximum draught. Hence it will not be necessary to provide a width of 365 m at the full depth keel level since this width is required at a keel level several meters above the full depth keel level. Due to the slope of the channel banks the width can be smaller at the bottom and the full depth keel level, whilst the maximum required width at a higher keel level will be provided as well. Even if a rather steep slope of the channel banks is assumed the extra width of the channel, for example 3 m above the channel design level, would be 60 m, which is about 2B. A final consideration which justifies the construction of a channel, in first instance, with a small width is the fact that the required width can still be provided by extra dredging or apparent imperfections can be improved with operational measures. However, it should be clearly understood that providing a channel with the optimal dimensions at once is far more preferrable. Owing to the above mentioned reasons the channel width at the full depth keel level and the bottom of the channel will be fixed at 300 m.

8.2.4 Dredging costs of the approach channel

The cost of providing an approach channel are determined by the construction costs of dredging the channel and the annual maintenance dredging. The construction and maintenance costs depend on the amount of bottom material to be dredged and the price to be paid per dredged cubic meter.

In the previous paragraphs it has been described that a channel with a depth of 12.50 m below MSL, and a width of 300 m at the bottom level has to provided. A bank slope of 1:10 will be assumed, which is the steepest admissible slope. Figure 41 shows the course of the bottom along the axis of Haldia and Jellingham channel, across the Auckland Bar, and along Sagar Roads and a part of Gasper channel as reported on the Admiralty Chart [9]. The depth is measured at intervals of 1.5 km and a lineair course has been assumed inbetween two successive depth measurements. Drawing the desired channel design level into the picture makes it possible to assess the height and the length of the volume of bottom material that has to be excavated by means of dredging. To calculate this volume the width and the slope are introduced in the calculations and the shape of the dredged volume is simplified with rectangles and triangles. Owing to this simplification and the large intervals between depth measurements the result of the computations should be used with some caution. In case of a 10.7 draught channel a volume of about 45.5 million m**3 has to be excavated. A volume of 5.5 million m**3 has to be substracted from this figure since this amount is already removed in order to provide the present channel, suitable for 8.0 m draught vessels. To construct a 12.2 m draught channel totally 91.3 million m**3, or an extra 45.8 million m**3 compared to the 10.7 m draught channel, has to be excavated.

Without human interference or other major disturbances the natural bottom of the estuary is in fact the reflection of a dynamic equilibrium caused and maintained by variations in the flow of water and sediment transport capacities. In the morphological science this phenomenon is explained with the help of fluid mechanics and sediment transport formulas. Aided by these theories the consequences of any interference in the dynamic equilibrium can be predicted, at least qualitatively. In general changing flow of the water, e.g. caused by river training works or a newly dredged channel, will result in different sediment transport capacities of the water. This manifests itself in erosion and deposition of sediments. Depending on the scale of the interference, largescaled, permanent or temporarily, changes in the flow conditions will either cause a return to the old equilibrium or result in another new dynamic equilibrium. To assess the annual amount of maintenance dredging several rough estimates have to be made. In the subject case where a channel is dredged for the port of Haldia it has to be predicted what will happen with the artificial bottom. There are three reasons to support the assumption that the former bottom level will be restored, viz.:

- as appears from rough estimates for the actual concentrations of sediments in the water of the estuary, the annual total transport of sediments through the channels of the estuary is enormous. The amounts are of a bigger order of magnitude than the amount of material that has to be excavated to construct the channel, see Figure 12.
- the present figures for the annual maintenance dredging required to provide a 8.0 m draught channel exceed the amount for the excavation which was computed in the previous paragraph. Although question marks should be put behind the correctness of both figures the order of magnitude is the same.
- due to construction of the channel the depth increases considerably at some places compared to the old situation, however, in combination with the width, the cross sectional area of the estuary remains almost the same. Therefore it is assumed that the excavations for the channel will not cause drastic changes in the flow of water or the dynamic equilibrium.

The previous considerations lead to the assumption that the annual amount maintenance dredging will be at least equal to the amount of capital dredging. The only difference between capital and maintenance dredging will be the density of the dredged mud, respectively in the range of 1200-1500 kg/m**3 and 500-1200 kg/m**3.

The impact of the annual recurring costs, involved in providing an approach channel, on the optimization procedure for the nautical infrastructure is decisive. To justify the project the CPT will carry out a financial analyses, while the Government will demand an economic evaluation, which may have a different result. This will be elucidated with the following simplified example:

- suppose the cost of dredging is 1 US/m**3.
- suppose 45.8 million m**3 has to be dredged every year in order to provide a 12.2 m draught channel, i.e. the possibility that the channel has to be dredged more than once per annum is neglected. Thus the price of maintaining the channel is 45.8 million US per annum.
- the trades enjoying the benefits of a deeper draught channel will have to bear the costs. The container-, coal-, and a part of the POL trade will use larger vessels. Only a part of the POL trade since refinery products are transported in smaller vessels compared to crude oil tankers.

From CPT point of view:

- in 1989/90 about 10 million tonnes bulk cargo and 100,000 TEU's will be handled in Haldia. Assuming the maximum increase of the transport price per tonnes bulk cargo is 3 US, the container trade has to furnish the remaining 15.8 million US. This results in 158 US extra per transported TEU. The savings for the container trade are in the same order of magnitude. At the moment handling a container in Colombo or Signapore, main line ports, costs circa 80 US per TEU while it takes circa 200 US to transport the container from these ports to Haldia by feeder vessel. Container handling in the main line ports will be superfluous if direct shipping lines, using larger vessels, to Haldia are opened, and saves 80 US per TEU. It is assumed that the savings resulting from the use of a larger vessel will be sufficient to balance the difference between the extra cost of 158 US for the deeper channel and the 80 US per TEU saved on cargo handling.
- compared to 1989/90 the situation in 1999/2000 improves since the costs can be spread over 15 million tonnes bulk cargo and 360,000 TEU's.

From Government of India point of view:

- suppose Indian flag vessels will transport 50%, 90%, and 30% of respectively the POL, coal and container cargoes. The Government has interests in the national owned shipping companies as well as in ports. For the Government the extra port revenue on Indian vessels, used to maintain the channel, will be equal to the extra expenses on shipping companies. In the cost-benefit analyses a proportional share of the trades bearing the costs of the channel has to be excluded from the cost distibution calculations. In 1989/90 3.7 million tonnes bulk cargo and 70,000 TEU's will have to bear the costs of the deep draught channel. The contribution of bulk cargo transport deminishes to circa 10 million US, which means the transport per TEU would be increased with circa 495 US if the costs have to be balanced. This is cost prohibitive and the deep draught channel should not be dredged.
- in 1999/2000 it is possible to spread the cost of providing a deep draught channel over 5.9 million tonnes bulk cargo and 252,000 TEU's. This is a favourable development since the extra costs on transporting the bulk cargoes and container could be fixed at an acceptable 3 US per tonnes and 112 US per TEU. It will be feasible to provide the deeper channel.

In the foregoing example the economic evaluation has been restricted to the same items of income and expenditure as used in the financial analyses, which is virtually incorrect. Discounting of costs and benefits was not necessary because the same amount of dredging is required and consequently the same costs return every year, see appendix C. The above example indicates it will be feasible to construct a 12.2 m draught channel. A similar calculation is applicable to the 10.7 m draught channel yielding approximately the same extra costs. It is not known when the 10.7 m draught channel will be ready, nor how the involved costs will be settled. Whether or not the extra costs on a 12.2 m draught channel can also be paid on top of the increased charges owing to construction of the 10.7 m draught channel is not known. In following sections and chapters it is assumed that in 1999/2000 a 10.7 m draught channel will be available.

8.2.5 Dimensions of the lock and the basin

There is a significant difference in the dimensions of water areas in the lock and the basin compared to the approach channel although the safety demands are equal. The costs of civil works and land 'surrounding' the water are much too high and incite reduction of the required water areas. To garantee safety of ship manoeuvres in the restricted water tugboats are used to keep the course of the ship under control. The tugboats will have the following tasks when assisting a vessel arriving at the port:

- ty up the vessel in the approach channel and keep the vessel on the right track while it brings the sailing speed down.
- tow the vessel when it makes the turn on the river to end up either at an anchorage, to wait for the lock, or in the axis of the lock, for further lock approaches.
- control the course of the vessel during the approach manoeuvres along the axis of the lock and when the vessel enters the lock. The tugboat towing in front of the vessel will have to enter the lock as well. Depending on the size of the vessel and the organisation of tugboat services it will be decided whether the tugs that were towing behind the vessel stay in the lock or return to the river.
- control the course of the vessel when it leaves the lock. Tugboats have to ty up again if only one river tugboat came through the lock with the vessel.
- swing the vessel through a certain angle in the turning circle.
- tow the vessel to its berth and assist during the mooring operations.

Similar to an arrival is the departure of a vessel from the port. The vessel has to wait at a river anchorage before sailing down the river to the Bay of Bengal if the draught requires a higher water level. Depending on the vessel traffic situation and the governing current and wind conditions the smaller vessels might turn on the river themselves, contrary to the larger vessels that will always need tugboat assistance since the diameter of their turning circle is too big. The size of the vessel, the pull force of the tugboats, current and wind conditions will determine the number of tugboats assisting one vessel. Especially on the river unfavourable current and wind conditions will result in an interruption of all the operations, whilst in the basin only the wind is a factor of nuisance during the manoeuvres. Above perpendicular cross currents of 2 m/s and windforce Beaufort 7 the operations will be stopped.

After some reflections on the dimensions of the present lock, with regard to the design ship, the capacity of the lock will be discussed since it determines whether a second lock will be necessary or not. The present basin dimensions will be discussed afterwards.

The layout and dimensions of the lock and lead in jetty are shown in Figure 42. Note that the bottom level in the basin is higher than the sill level. Contrary to the chosen 10.7 m draught channel the bottom of a 12.2 m draught channel would have had a level below the sill of the lock. The local mean water level (LMWL) is 0.41 m higher than MSL owing to the water slope in the estuary. Variations in the water level due to the tide are indicated with regard to LMWL.

Lowest recorded Low Water, -3.30 m LMWL, leaves 10 m water depth above the sill which is sufficient for vessels with a draught of circa 9.0 m. An increase in draught of the vessels requires the use of higher water levels that occur during the High Water period. The higher the necessary water level the shorter the available period of time. The time available to use the lock will not be a restriction, compared to the channel, as long as the required channel depth does not exceed 14.00 m, or the channel bottom level is not below -13.30 m LMWL.

The width of the lock without fenders is 39.6 m. Currently fenders are under construction. It is assumed that the fender and a 1 m manoeuvring strip on both sides of the lock reduce the admissible ship beam to about 35 m, which is sufficient since the beam of the design ship is 30.0 m.

Although the total length of the lock is 424 m the resulting length available for the ships, the clear length, is 300 m between the outer doors, which is long enough for the design ship of 212 m, and about 199 m between the outer and intermediate door.

Depending on the length of the vessel and the space required for tugboats the big or the little lock chamber will be used. The areas required for both the vessel and the tugboats have to fit in either the small or the big lock chamber, which is possible.

Capacity will be defined as the maximum number of ships per unit of time being able to pass the lock. The intensity is the actual number of ships that has to be handled. To examine whether the lock has sufficient capacity or not, the complete lock process, including the manoeuvres in the adjacent areas of the basin and the river, has to be taken into consideration. Of importance is the time required for:

- manoeuvring the vessel into the lock aided by tugboats.
- closing of the lock gate, filling or emptying the lock chamber, opening of the opposite lock gate.
- sailing the vessel out of the lock.

The entrance manoeuvres of fully loaded vessels require more time than the manoeuvres of empty, or nearly empty vessels, nevertheless, the entrance time is assessed at 40 minutes in both cases. It is assumed that 30 minutes are needed for closing and opening the lock gates, and adjusting the water levels. The time needed for adjusting the water level is in fact subject to large variations owing to the changing tides on the river, and the size of the lock chamber. Ship and tugboat will leave the lock in 10 minutes. Addition of the required time yields 80 minutes for a lock cyclus during which one vessel either enters or leaves the port basin.

If lock operations are restricted to the flood period only, which is the present practise, the capacity will be 8 ships per day, assuming the flood period lasts for 5 hours. The average intensity in 1989/90 and 1999/2000 will be respectively 9 to 12 and 12 to 14 ships per day. Thus the lock capacity would be grossly insufficient and necessitate construction of a second lock. Continuous operation of the lock results in a capacity of 18 ships per day. Even if the irregular arrival pattern of ships is kept in mind the capacity will be sufficient. This last solution makes a demand upon the depth in the river in the vicinity of the lock and the anchorages. Under all circumstances the vessels with the maximum draught will have to pass the lock during the flood period or have to be moored at an anchorage with sufficient water depth.

The available depth in the basin is 13.7 m, which is more than enough for a 10.7 m draught vessel. A 12.2 m draught vessel would have a keel clearance of 1.5 m, which is sufficient. If ever the depth of the basin should be further increased serious problems can be expected at places where constructions are depending on the present bottom level. Little is known about the incorporated flexibility of the present constructions, with regard to a lower bottom level.

In new parts of the basin a bigger depth and flexibility of constructions can respectively should be provided. Since a draught of 13.7 m has been mentioned by the CPT a future basin depth of about 15 m has to be kept in mind.

8.3 SHIP-FORECAST

The ship-forecast supplies information about the dimensions of a certain number of standard ships, the share of the forecasted cargo commodity transported by the standard ship, the amount of cargo unloaded from or loaded into the ship, and the total number of ships visiting the port. The size

9. TERMINAL AND BASIN DESIGN

A terminal consists of the berth and matching back-up area where the cargo is usually stored temporarily to wait for further transport. In this back-up area all kinds of facilities are needed to store the cargo and to transport the cargo in or out of the port. In the next sections the design of the terminals for every port traffic class will be discussed. Object of making these designs is to determine the area requirement for terminals and, to a lesser extent, the shape of the area that has to be reserved in the masterplan of the port. In order to allow the vessels access to the berths there have to be made several demands upon the basin. These demands will be discussed in the last section of this chapter. Throughout the whole chapter reference can be made to [27,28,30].

9.1 <u>LIQUID BULK CARGO TERMINAL</u>

All the relevant data from the previous forecast chapter related to the transport of POL are summed up in Table 45.

Contrary to the equipment used for breakbulk or container cargoes the equipment for oil and oil products does not require manoeuvring areas to handle the cargo. The approach bridge to the jetty head provides enough space for placing the necessary pipelines. Currently one oil jetty along the river is in function and the ore berth within the basin is also used for oil transport, while a second jetty is under construction on the river stretch between the lock and the first jetty. As soon as the forecasted cargo exceeds a certain limit, for instance twice the berth productivity of 4.7 million tonnes/annum, construction of a third oil jetty has to be started.

The dimensions of the storage area for POL are mainly determined by the number and sizes of tanks, as well as the intermediate distance of tanks. The dimensions of the tanks depend upon the size of the vessels and the interval between ship arrivals. It is assumed that one tank will contain the cargo of a 85,000 DWT tanker. Applying a stowage factor of 1.2 m**3/t this requires a tank with a volume of approximately 100,000 m**3. For safety reasons every tank has to be surrounded by a concrete or earth wall, bunds, at such distances that in the event of the collapse of a full tank the oil stays within the bund. Supposing the bund has to be one meter higher than the level in the bund, then a 5 m high bund has to enclose an area of 25,000 square meter, or 160*160 m**2, to meet the safety needs. The dwelltime, the time expressed in days that cargo will remain in the storage facility, will determine the total storage capacity required. In case of POL cargoes the dwelltime determines the necessary number of tanks. It is assumed that operational storage for a period of one month is required, i.e. the dwelltime is about 30 days. The following formula will yield the necessary number of tanks, No-tanks:

$$\text{No-tanks} = \frac{\text{MaxT} * S * dw}{V * 365}$$

$$= \frac{14,420*10^{3} * 1.2 * 30}{100,000 * 365} = 14.2$$

where:

- MaxT = the maximum amount of forecasted cargo in tonnes/annum
- S = the stowage factor of oil and oil products, viz. 1.2 m**3/t
- dw = the dwelltime of the oil in the tanks, expressed in days
- V = the volume of a storage tank, in m**3
- 365 = the number of days per annum

The result of the computation is rounded off to 15 tanks which requires an area of 384,000m**2, equal to 15 multiplied with 160*160 m**2. By using the above formula it is assumed that ship arrivals are equally spread throughout the year. Whether or not oils can be stored in the same tank depends on the nature of the oil or the deriviates, therefore, more tanks, or a number of smaller tanks, might have to be provided. Moreover the management might decide to store an extra amount of oil, called the strategic reserve, on the premisses. Besides the area for tanks space has to be added for pipelanes, pumping stations, roads, buildings etc..

The area of the Indian Oil Corporation Ltd. is located next to the dock area at the eastern side and contains about 2 million square meter, see Figure 21. There will be tanks for storage of oil at this moment to handle the present throughput, data about these tanks were not available. For the storage area no layout has been made since the current layout of the refinery is unknown. Suffice it is to remark that far more than the required operational storage area is available on the premisses of the Indian Oil Corporation Ltd., a demand of 384*10**3 m**2 versus an availability of 2,000*10**3 m**2. Thus the detailed layout of the tank area is left to the concern of the Indian Oil Corporation.

9.2 DRY BULK CARGO TERMINALS

The dry bulk cargo terminal will be split up into terminals for coal loading, coking coal unloading, and unloading finished fertilizer and raw materials for the production of fertilizer.

9.2.1 Coal loading terminal

All data related to the transport of coal is listed in Table 46.

Reduction of the ship's berthing time requires an unhampered high capacity loading or unloading process. In general the capacity of the equipment used for this process will not be matched by the capacity of the hinterland transport systems. A stockpile acts as a buffer between two transport systems and has to be big enough to cope with the different capacities. The inflow of cargo into the stockpile is determined by the interval between ship arrivals, the shipload size and the loading or unloading rate of the equipment on the quay. In fact the outflow is determined by similar factors, however, the size of the load is smaller owing to the means of conveyance, which is usually a truck or a train. The mentioned factors have a stochastic nature and statistical distributions are used to describe them in a simulation model. The model [27] records the flow of the bulk commodity in and out of the terminal over a period of time and calculates the maximum and average amounts of the commodity present. Through repeated use of the model, an estimate of the average and maximum stockpile size can be determined. The result of the simulation is presented in a graph where the curves, annotated with the annual throughput, give a relationship between the the average shipload size and the stockpile capacity, see Figure 43. The probability a ship with the average shipload will face a delay is less than one percent. It might be more expensive to maintain a stockpile of this size than bearing the cost of delay for either the ship or the hinterland transport. This has not been taken into further consideration.

The required average and maximum stockpile in 1999/2000 is assessed by using the graph and the fact that coal will be carried in 25,000 DWT ships. The necessary average and maximum stockpile capacities are respectively 110,000 and 210,000 tonnes. Provisions for the dead stock have been made by assuming that an extra tonnage of 5% on the total has to be stored as well. This leads to stockpile capacities of 116,000 and 220,000 tonnes.

The shape of the stockpile is determined by the characteristics of the material, the equipment used to stack and reclaim the coal, and the bearing capacity of the ground. One feature of coal is the ability to combust spontaneously due to heating of the coal as it absorbs oxygen from the air. Indirectly this results in height restrictions for the stockpile. Based upon the available drawings it is assumed that a stockpile in Haldia has a width of 20 m, which is very small, moreover a triangular shape has been assumed. The angle of repose is the angle between a horizontal surface and the cone slope obtained when granular cargo is emptied on this surface. For coal the angle of repose varies from 30 to 45 degrees. Considering the small width of the stockpile it is assumed that the angle of repose, and not the dimensions of the stacker reclaimer, determines the height of the stockpile.

With an effective length of 400 m, a width of 20 m, and a height of 7 m the storage volume in a stockpile is about 28,000 m**3, see Figure 44, which is a very small volume. In this case the height of the stockpile will not constitute a problem regarding the danger of combustion or the bearing capacity of the ground. Using the stowage factor of 1.4 m**3/t for coal yields the capacity of the stockpile expressed in tonnes, thus 28,000 m**3 is equivalent to 20,000 tonnes. The number of stockpiles necessary for storing the average- and maximum stock will be respectively 6 and 11. The area required for the maximum stock alone is approximately 90,000 m**2. Some additional ground area has to be provided for the tracks of the stacker reclaimer units, conveyor belt systems, and railway track of the South Eastern Railway, which supplies the coal to the port.

While determining the required storage area already the present situation was taken into consideration. The existing terminal with 2 berths and the storage area available match with each other and are able to handle the forecasted cargo in both target years.

9.2.2 Coking coal unloading terminal

All data related to the transport of coking coal are summed up in Table 47.

The procedure to determine the required stockpile for coking coal is similar to the one used for coal. Virtually both cargoes can be handled without too many complications at the same terminal, and partially with the same equipment. Only the direction of the cargo flow will be the opposite. It would be appropriate, from an efficiency and financial point of view, to use the same facilities for coal and coking coal. However some calculations on the capacity of the coal berths reveal it is not possible to handle both amounts of forecasted cargo with the present facilities which were assigned to the coal trade in the previous subsection. Unless the berth productivity figures of either the loading of coal or the unloading of coking coal or both are increased, it will be necessary to provide a separate berth for handling coking coal.

Using the graph in Figure 43 with the input of a 25,000 DWT ship and adding an extra dead stock percentage of 5% on the values read in the graph yields the required average and maximum stockpile capacities. In 1999/2000 the average and maximum stockpile size will be respectively 85,000 and 115,000 tonnes coking coal. Hence, 4 wind row stockpiles with the same cross sectional area and length as the one used for coal will be necessary.

9.2.3 Finished fertilizer unloading terminal

All data from preceding chapters in respect of the fertilizer traffic are summed up in Table 48.

It is assumed that finished fertilizer will be supplied as a dry bulk commodity to the terminal. Currently a bagging and stitching plant is under construction near the phosphate rock berth, which indicates that at least a part of the supplied bulk fertilizer will leave the port as a breakbulk cargo since it will be packed in bags. Figure 45 shows the possible methods to transport fertilizer through a terminal, for every method facilities are required, which some times can be shared. The shortest route through the terminal, in respect of necessary actions, is in fact the direct loading of trains or trucks at the quay that immediately leave the port. Since the transport capacities of the ship unloaders and the trains and the trucks will not match with each other a stockpile will be necessary to act as a buffer. Method 2 includes storage of the fertilizer in the stockpile, followed by loading on trains or trucks as a bulk cargo and departure from the port. From the stockpile the fertilizer can be transported through the bagging and stitching plant immediately followed by further transport as breakbulk cargo on trucks or trains, which is method 3 in Figure 45. Method 4 is a more probable alternative compared to method 3 since the difficulties in matching the production, of the bagging and stitching plant with further transport, will require a storage facility for bagged fertilizer, which is included in this method. Obviously the sort of facilities and amount of facilities required for transporting the fertilizer through the terminal is increasing from method one to four, together with the number of performed activities.

Compared to a dry bulk stockpile, storage facilities for fertilizer as a breakbulk cargo put a heavier demand on ground area. Method 2 has to be preferred regarding the efficiency of the complete fertilizer handling process, the required facilities, and the area involved for the process. For the transport of dry bulk fertilizer the utilisation of trainwagons is more appropriate than use of trucks, inherent to the use of trains is a longer distance across which the fertilizer will be transported. Complementary to this is the transport of fertilizer by trucks on shorter distances. It is assumed that 90% of the fertilizer will leave the port by train after storage in the stockpile, method 2. The remaining 10% will be handled in the bagging and stitching plant, stored in a shed, and subsequently leave the port by truck for local distribution, method 4.

The required stockpile is again determined with the help of Figure 43. Although the annual number of 25,000 DWT ships is smaller than the number of 15,000 DWT ships the first value is used to find a stockpile requirement of 92,000 and 171,000 tonnes for respectively the average and maximum stockpile. Assuming a stowage factor of 0.88 t/m**3 enables the conversion to the stock volume, which yields respectively 105,000 and 195,000 m**3.

Finished fertilizer has to be protected against rain and therefore the stockpile has to be covered. A cross section of the sheds used is shown in Figure 46. A width of 50 m, walls of 3 m height, and a roof under an angle of approximately 30 degrees result in a cross sectional area of 500 square meter. The roof angle of 30 degrees is equal to the angle of repose of finished fertilizer. Dividing the required stock volume by the cross sectional area yields a shed length of 390 m for the maximum stock.

The bagging and stitching plant has an annual production of about 32 million bags, 50 kg each, which is equivalent to 9,100 bags per day, based on 350 productive days per annum. It is assumed that an area 2,100 square meter will provide enough space for a shed containing the plant.

Owing to the packing in bags the fertilizer can be handled as a breakbulk cargo. Consequently the shed used for storage of the bagged fertilizer can be designed as an ordinary breakbulk shed. The formula used to determine the required shed area will be further elucidated in the next section, which deals with breakbulk terminal design. The dwelltime, a crucial variable in the formula, is assumed to be 10 days. With an annual throughput of 159,400 tonnes, an extra area factor of 1.30, a stacking height of 3 m, an average occupance rate of 0.7, and a density factor of 0.88 t/m**3 use of the formula yields a required shed area of 3,100 square meter. The used area factor has been fixed at 1.30 instead of 1.65 for a breakbulk shed because uniform products require less open area. A shed of 80 m length and 40 m width will be sufficient.

The total area for the stockpile, the plant and the shed amounts to 24,800 square meter. In addition space for railtracks, roads and some offices will be required, see Figure 47 for the layout of the fertilizer terminal. Anticipating on future developments, which might result in changing the fertilizer terminal into a breakbulk terminal, a wide apron has been provided.

9.2.4 Rock phosphate unloading terminal

All data in respect of the transport of raw materials for the fertilizer production, phosphate rock, are summed up in Table 49.

Using the already applied method for determining the dimensions of the necessary stockpile yields an average and maximum tonnage of respectively 85,000 and 160,000 tonnes. Since the stowage factor for phosphate rock is 0.9 m**3/t these figures change to 95,000 and 178,000 m**3 when the tonnage is converted into cubic meter. Similar to the previous dry bulk stockpiles the height of the triangular shaped cross sectional area is determined by the angle of repose of the material and the width of the stockpile. A width of 20 m in combination with an angle of 30 degrees for phosphate rock results in a stockpile height of about 5.5 m and a cross sectional area of 55 square meter. Division of the required volume by this area yields the stockpile length, 1,750 and 3,300 m for respectively the average and maximum stockpile.

The material requires protection for weather influences, thus an A-shaped shed has to be built around the stockpile. Dust descending from the relatively soft rock causes that a dust protection has to be provided.

To find the required area behind the fertilizer quays would not constitute a problem, however, considering the location of the Hindustan Fertilizer Corporation Ltd. it is assumed that a overhead conveyor belt will be used to transport the phosphate rock directly from the quay to the Corporation's production area. Thus no area is required for the handling of phosphate rock on the terminal.

9.3 BREAKBULK CARGO TERMINAL

All data, in respect of of terminal design, from the previous chapter are listed in Table 50.

Since the handling of breakbulk cargoes requires a spacious apron for the manoeuvres of the mechanical equipment and adjacent storage area quays are used instead of a jetty. The required waterfront area per berth, or the quay length, is determined with the help of Figure 48 [27]. Using the average ship length, in the year 1999/2000, of 165 m, some extra space, the berthing gap, of 15 m, and a factor of 1.1 results in a quay length of 200 m. The factor 1.1 is the result of experiments showing there is a general relationship between the average berth length and the amount of ship waiting time, see Figure 48. If the average berth length exceeds the average ship length plus the berthing gap with 10%, extra waiting time because of a too short berth will not occur. In general area has to be available for the apron, transit sheds, warehouses, open storage, roads, railtracks, parking of cars and trucks, and offices. In first instance the space requirements of a single berth will be determined, however from a layout point of view it might be feasible to draw up the plan for 2 or 3 berths together at once.

Inevitably a buffer is needed between cargo handling systems having different capacities which results in a demand for storage area. The cost involved in providing and maintaining the facilities required for storage of cargoes will incite the port in reducing the demand for these facilities. Storage in open, i.e. uncovered, area will be preferrable compared with storage in sheds and warehouses. In a given situation with a certain amount of storage facilities quick removal of cargo is necessary in order to avoid congestion. The transit sheds and open storage are used to store the cargo immediately after unloading or just before loading of the ship. The warehouse and, again, open storage provide space for goods that have a longer dwelltime in the port area. The formula below will be used to find the required area, A, for sheds and warehouses:

$$A = \frac{c * P * dw * f1 * f2}{m * h * o * 365} \quad [m**2]$$

c = fraction of the annual berth throughput that is actually stored in the transit shed or warehouse.
P = berth productivity in tonnes/annum, see data above.
dw = dwelltime of the cargo in days.
f1 = ratio of gross and nett storage area, space is required for manoevres with equipment, 1.5 is a reasonable estimate.
f2 = factor taking into account that cargoes within the shed are not as closely packed as in the ship, e.g. because consignements are kept apart. Assume a value of 1.1.
m = the allowed average occupance rate, which is applied to anticipate on e.g.seasonal variations. A value of 0.7 is often used.
h = average stacking height of cargo in the shed, assume 2 m.
o = average density of the cargo such as it is stowed in the ship. Suppose o is 0.6 t/m**3.

Around the sheds and warehouses space has to be provided for loading bays and manoeuvres of e.g. forklifts and trucks.

Many goods are not affected by adverse weather conditions and do not require covered storage. In the open storage area e.g. vehicles, agricultural and road-building equipment, construction steel, oil in drums, etc. can be found. If necessary the use of a tarpaulin will be sufficient to protect these kind of goods from rain. The surface of the area has to be constructed under a certain slope to take care of the flowing-off of water. The required open storage area will be computed with the same formula as used for the sheds.

The coefficient c, the berth-productivity P, the dwelltime dw and the resulting area A for the transit shed, warehouse and open storage are given in the table below for both the target years:

	1989/90			1999/2000			Difference in A
	c	dw	A	c	dw	A	
transit shed	0.7	20	9,700	0.7	10	7,700	-2,000
warehouse	0.3	40	8,500	0.2	20	4,500	-4,000
open storage	0.3	30	6,300	0.3	20	6,750	+ 450
Total			24,500			18,950	-5,550

The total required area decreases whilst the berth-productivity grows from 131*10**3 t/a in 1989/90 to

202*10**3 t/a in 1999/2000. A more careful look at the values used for the mentioned variables reveals, in this case, the dominating influence of the dwelltime, which has to be decreased from the first to the second target year. The excessive dwelltime in 1989/90 is a reflection of the present unsatisfactory situation in Calcutta and Haldia [4], and also takes into account that the latter port is still under development. Observations in many ports in the world, especially in developing countries, confirm that an average of 10 days is the minimum dwelltime to be taken into account for computing the shed capacity [27]. The dwelltime in 1999/2000 has been related to these 10 days. Of course the computed shed area for 1999/2000 will be provided, however, this does not meet the demand made upon shed capacity in 1989/90. To bridge the gap it is assumed that more cargo will be stored in the open storage in the next years.

Figure 49 shows the layout for a breakbulk terminal with 2 berths.

9.4 CONTAINER TERMINAL

All the relevant data from the previous forecast chapter regarding the design of the terminal are listed in Table 51.

Similar to the breakbulk terminal a spacious apron for manoeuvres is required and a quay with the storage area adjacent to it is preferred. The import-, export- and empty container stacks, the container freight station (CFS), roads, railways, offices and parkings will also make a demand upon the terminal area. In the preceding layouts the length of the berths was the governing factor for the shape of the terminal. Given the length and the assessed area requirements, for storage, roads etc., the depth of the terminal was more or less determined. Contrary to the procedure for the other terminals first the required storage area for the container terminal will be determined. Compared to the other terminals the size of the container terminal is of a bigger order of magnitude and consequently governs the terminal layout. At the outline of the terminal there is bound to be enough space for the necessary berths.

The area requirement, A, of the stacks is determined with the help of the following expression:

$$A = \frac{P * dw * a}{r * m * 365} \qquad [m**2]$$

P is the annual throughput in TEU's, since three berths together are under consideration the number to be substituted in the formula is the maximum figure for respectively import-, export-, and empty containers.

The dwelltime, denoted by dw, occurring at this moment in the ports of Haldia and Calcutta proves that container handling is not yet a smooth operation. The average mounts up to 20 or 25 days dwelltime consequently this means even longer and more excessive delays occur [4,6]. It is assumed that in 1989/90 the dwelltime will be 20, 15, and 30 days for respectivelythe import-, export-, and empty container stack. These values will have to be decreased to 10, 7, and 15 days in 1999/2000 which is in agreement with acceptable delays observed in other ports in the world [28]. The total dwelltime of the contents of a container in the port is determined by the time it stays packed in the container at the stack and unpacked in the CFS. It would be too pessimistic to add the maximum dwelltimes for the stack and the CFS to find the period that the container cargo spends in the port. As a consequence too much ground area would have to be provided. Therefore it is assumed that if the cargo also passes the CFS the dwelltime at the import- and export stack will be respectively 10 and 8 days in 1989/90 and 5 and 4 days in 1999/2000. Under this assumption the dwelltime in the CFS remains unchanged.

The variable a stands for the required ground area per TEU and is depending on the stacking height of the containers and on the equipment used for stacking the containers. The ground- or slot area of a 20 feet container is approximately 15 square meter. The moment that 2 or 3 containers are placed on top of each other the required area per TEU reduces to respectively 7.5 and 5 square meter, whilst the slot area remains the same. Comparison of a gantry crane and a forklift illustrates the influence of the equipment, used to stack the containers, on the necessary stack area. Where a gantry crane only needs space for two rail tracks and spans several rows of containers standing next to each other the forklift needs aisles for manoeuvring between every row of containers. Since a rail mounted gantry crane is used at this moment in Haldia other systems , e.g. straddle carriers are not taken into consideration. Regarding the required area per TEU there is no difference in the use of gantry cranes or straddle carriers. A cost benefit analyses which takes into account the investment, the ease of use and simplicity of the equipment, the maintenance costs, the convenience of operations, and the required skill of the personnel has to be made to enable the choise of the equipment. The variable a will be fixed at 13 square meter per TEU assuming the containers will be stacked 3 high on a slot.

The ratio average to maximum stacking height, the latter is 3 containers high, is expressed in the variable r. For operational reasons containers will not always be stacked to their maximum height. It would be too complicated to prevent that a box is at the bottom of a stack when it has to be transported. In short it is not a problem to stack the container but to take it away from the stack. The average stacking height observed in Haldia and Calcutta is 2.5 [6], hence the ratio r is equal to 0.8. At the import stack a relatively large number of containers arrives more or less at the same moment when the ship is unloaded. If the containers are removed from the port by truck they will leave the stack one by one in an arbitrary sequence. Removal by train results in somewhat larger shipments. The chances are higher, compared to the export and empty container stack, that a box is found at the ground level. Contrary to the import stack the export containers leave the stack in relatively large shipments, which offers the opportunity to stack them more efficiently when they arrive at the stack. Since empty containers only have to be sorted in accordance with type and owner it is quite simple to stack them efficiently. Owing to the previous considerations r for the import-, export- and empty container stack will be fixed at respectively 0.7, 0.8 and 0.9.

To cope with irregular variations in the supply to and departure of containers from the stack the acceptable average occupance rate, denoted by m, is added to the expression above and fixed at 0.7.

Input of data and use of the formula results in an area requirement of 62,200-, 45,200-, and 85,600 square meter for respectively the import-, export-, and empty container stack in 1999/2000. Substitution of the data for 1989/90 yields area requirements of 26,100-, 25,700-, and 52,600 square meter.

To determine the area required for the CFS a formula, again, similar to the one given in the section dealing with the breakbulk terminal is used:

$$A = \frac{Pc * 29/h * dw * f1 * f2}{m * 365} \quad [m**2]$$

Only Pc, the factor 29, and dw will be discussed more extensively in the sequel since the values for h, f1, f2, and m are already elucidated before and fixed at respectively 2, 1.5, 1.1, and 0.7, see section 9.3.

Pc denotes the annual number of TEU's being stuffed or stripped in the CFS. Compared to the stacks the CFS needs a relatively big area owing to the unfavourable gross/nett area ratio, consequently the number of containers stuffed and stripped in the CFS should be kept as low as possible. At least once during the transport from origin to destination the container has to be stuffed and stripped, in case of loaded containers. Under the present conditions, while the use of containers is still developing itself in India, ports are among the most experienced concerns regarding handling of containers, which includes stuffing and stripping. Therefore it seems justified to assume that the port will have to provide facilities to stuff and strip a considerable share of all the transported containers. The long term perspective is different since the development of inland container depots has been taken in hand. Owing to the previous considerations the percentage of containers handled in the CFS is estimated to be 80% and 50% in respectively 1989/90 and 1999/2000. This is a percentage of the total number loaded import and export containers. Thus 58,400 and 134,500 TEU's will be handled in the CFS in 1989/90 and 1999/2000.

The factor 29 represents the maximum contents of a 20 feet container which is equal to 29 m**3. Use of the factor 29 together with Pc replaces P and o in the breakbulk shed formula.
Currently the average dwelltime of containers in the port varies between 20 and 25 days [4]. It is assumed that the dwelltime of cargoes in the CFS does not differ too much from these values and will be 20 and 10 days in respectively 1989/90 and 1999/2000. A frequently observed dwelltime in other ports is an average of 5 days, thus the assumed values are not satisfactory from an efficiency or service level point of view. On top of it a large area is needed for the CFS since its size varies rectilineair with the dwelltime.
With the help of the formula and the above assumptions the CFS area requirement in the years 1989/90 and 1999/2000 can be computed which results in the figures 111,000 and 126,000 square meter in the two target years. Fixing the width of the CFS shed at 70 m yields a total shed length of 1590 and 1800 m, which will be spread over a number of sheds.

To determine the quay length the average ship length is used, adding 15 m and multiplying the result with the previously mentioned factor 1.1 yields lengths of about 200 and 220 m in respectively 1989/90 and 1999/2000. The masterplan is drawn up aiming at the situation in 1999/2000, thus a quay length of 220 m is assumed. See Figure 50 for a preliminar layout of the container terminal.

9.5 BASIN DESIGN

The basin resembles a street in a living-area with cars parked on both sides and a junction at its end where other streets can be entered. Instead, the basin has berths with tied up ships along its side and a turning circle, and adjacent water areas, connecting the respective parts of the basin. The water areas in the basin are used either to provide access to the berths and/or moorings or to moore the vessel. The size of the vessel and the costs of land make opposite demands upon the dimensions of the basin. In respect of accomodating the vessels the dimensions should be increased but the involved costs require a minimalization of the basin.
The vertical dimension, the depth of the basin has been discussed in subsection 8.2.5. The present depth of 13.7 m is sufficient but in future further deepening of the basin to a depth of about 15.5 m might be necessary.
Virtually not the length of the basin but the outline of the basin has to be long enough to provide the required waterfront area for all the terminals, thus depends on the length of the vessels. If the number of terminals decreases the length of the outline decreases as well. In 1999/2000 the outline has to be about 8 km long, which is determined with the maximum number of terminals. An 8 km outline results in a basin length of about 4 km since both sides can be used to locate the terminals, see also subsection 10.3.2.

To establish the width of the basin two situations [30] have to be considered, see Figure 51. In the first situation, when the basin is short, a few times the length of the vessel, the basin width will be kept too small to turn the vessel. With the help of tugboats the vessel will sail backwards to the turning circle. The basin width is mainly determined by the beam of the vessel and the required manoeuvring margins for both the vessel and the tugboats. In the second situation it must be possible to turn the vessel at the berth because the distance that has to be covered while sailing backwards to the turning circle is too big. Consequently the length of the vessel is a decisive factor in order to determine the basin width. Since the basinlength will be about 4 km the demand that it must be possible to turn the vessel will be applied to establish the width of the basin. Although it is not completely correct, the average beam and average length of all the vessels are used to compute the width of the basin, which results in 300 m.

10. MASTERPLANNING FOR HALDIA

10.1 INTRODUCTION

The final result of this chapter will be a layout of the port in Haldia that arranges all the necessary facilities in a suitable way to cope with the forecasted amount of cargo and realise an efficient throughput in 1989/90 and 1999/2000. The layout is not the complete result of the masterplanning activities for the port although it is the most visible or tangible part of it. Masterplanning includes the production of the forecasts making it possible to determine the kind, size and number of the required facilities. The layout can be considered as the solution for a demand and supply problem. The proposed terminal and water areas, based on the forecasts, make a demand upon space. The present masterplan of Haldia provides space, however, not unlimited space. Inch and pinch work yields several solutions for the demand and supply problem. Criteria have to be found in order to compare these alternatives in a more or less objective procedure.

Within the masterplan a portside and a riverside can be distinguished. The riverside will be defined as the area in front of the lock, the characteristical activities in this area are concerned with the nautical operations. Hence, the portside is defined as the area behind the lock. Here cargo handling dominates the activities. After description of the alternative portside layouts the criteria to evaluate the suitability of these alternatives will be described.In the sequel first the riverside masterplan will be discussed shortly followed by a more extensive discussion of the portside masterplan.

10.2 RIVERSIDE MASTERPLAN

Included in the riverside masterplan are the position and shape of the approach channel to Haldia, the existing through channel to Calcutta, the manoeuvring areas for the turn on the river and the approach of the lock, the anchorages and the river jetties. Figure 52 shows the existing situation once more as well as a possible layout for the riverside masterplan.

The through channel to Calcutta should be located at the most eastward position under Nayachara Island in order to provide the largest possible water area for other purposes. A maximum eastward position of the channel might result in dredging costs which can only be avoided by shifting the channel in a westward direction to deeper water. Consequently the water area between the channel and the western river bank will decrease.

Obviously the manoeuvring area where the ship is turned followed by the approach of the lock, anchorage or jetty is dominating the layout of the riverside masterplan. The exact position of the manoeuvring area depends on safety considerations regarding the risk of a ship unable to complete the turn even though tugboats are at hand. The consequences could be running aground of the ship at the river bank, a collision with another moving ship or one at an anchorage, hitting a river jetty or hitting the ship plus damaging the jetty. The whole matter should be subject to an extensive and detailed investigation by nautical experts and more information will be necessary about the river conditions.

The distance from the anchorages of vessels waiting to enter the lock and the port should be as small as possible. However, the anchorages should obstruct neither the navigation in and out of the lock nor the navigation to and from the oil jetties or the turning manoeuvres on the river.

The position of the existing jetty, the one under construction, and the jetty to be built in future is close to the manoeuvring lane along the axis of the present lock.
From safety point of view handling oil at jetties along the river outside the basin has to be preferred compared to handling oil within the dock. An accident with a tanker or at the oil berth will endanger all the ships in the basin and the lock will prevent any escape. However, working the ships at jetties along the river includes some disadvantages. The disadvantages are caused by the tidal range, current, and siltation rate or erosion. The tidal range imposes demands on the loading and unloading arms connecting the manifolds of the ship with the pipelines on the jetty. The combination of tidal range and currents will result in considerable forces on the berthing and mooring dolphins of the jetty. The dolphins will have to be specially designed for fast changing conditions with heavy loads. At the present oil jetty the situation at the river bank and near the jetty is carefully monitored because of erosion. In respect of maintaining the required depth for the vessels this is a favourable circumstance. In the reverse situation, if accretion occurs the depth has to be maintained by dredging, this has been taken into account in the annual number of commission days, see section 7.2. As soon as the forecasted cargo exceeds a certain limit, for instance twice the berth productivity of 4.7 million tonnes/annum, construction of the third oil jetty next to the other jetties has to be started. It has to checked whether the financial income owing to the total oil traffic will exceed the expenditures on constructing the facilities, maintenance, and operational costs like labour.

In the riverside masterplan the required areas are indicated in case a second lock would be constructed in future. A considerable advantage of this second lock compared to the first is the fact that ships do not have to turn on the river.

Having in mind the lack of knowledge and detailed information the proposed riverside masterplan should only be considered as a first and rough indication. Although the final layout may be quite different, except the location of the jetties, it is expected that this part of the complete masterplan will not be a final constraint for the development of the port.

10.3 PORTSIDE MASTERPLAN

10.3.1 Introduction

The basin and the terminals are the basic elements of the portside masterplan. Within the available area, according to the existing masterplan, the basin and the terminals have to be arranged as convenient as possible. Many alternatives can be developed since there are several designs not only for the basin but for the arrangement of the terminals as well. Making different combinations increases the number of alternatives. To order the design procedure first the size and layout of the basin has been determined before the location of the respective terminals was established. Although these steps were taken separately the influence they have on each other has not been overlooked. This will appear from the criteria used to choose the best alternatives for the basin and the arrangement of the terminals around the basin. The next subsection will deal with the basin and in subsection 10.3.3 the position of the terminals will be discussed.

10.3.2 Size and shape of the basin

The dimensions and shape of the new basin dominate the layout of the port. An effort has to be made to decrease the area of the basin whilst its outline is kept as long as possible. The minimum required outline is equal to circa 8 km and the width is 300 m, see section 9.5. However, in connection with future expansion the maximum basin has to found, i.e. the basin with the longest possible outline. In fact manoeuvring- and berthing parts of the basin have their own most efficient shape, which makes the smallest demand upon area. The ship manoeuvres near the lock and the entrance to the basin legs demand a relatively large area, whilst the outline is of minor importance. Circular shapes combine their circumference with a maximum area. Reduction of the berthing area, under the condition of the prescribed width, results in the choice of a rectangular shape of the basin. The rectangle is the best approach of a line, which combines the longest outline with a minimum area.

Alternatives

Several alternatives for the shape of the basin are shown in the Figure 53. The size of the basin is limited by the border of the port area. Use of the clean industries zone would allow bigger dimensions of all the proposed basins and add one alternative basin shape. It appears from the Figure 53 that maintaining the destination of this zone eliminates the extra alternative and restricts the size of the basin in all the other alternatives.

Criteria

The criteria used to judge about the suitability of the alternatives can be divided into three main categories with a further subdivision of criteria, viz.:

- category 1 arrangement of the terminals around the basin

  - required waterfront available
  - possibility of opening up the terminal by road
  - possibility of opening up the terminal by railway
  - orientation towards prevailing wind direction

- category 2 convenience of ship manoeuvres

  - number of manoeuvring areas
  - size of the manoeuvring areas (determined by its orientation in regard of the basin legs)
  - orientation of the basin legs towards the prevailing wind direction

- category 3 use of the ground area in the port

  - violating reservations in the existing masterplan
  - possibilities for expansion of the basin in future
  - remaining pieces of ground area; size, shape, united or cut into bits

To select the best alternative a simple version of the score-table method will be used. Contrary to the usual procedure no specific weights have been attached to the categories of criteria and the criteria themselves, although a certain rankorder can be distinguished. One exception has to be made for the criterion about the required waterfront. If any of the alternatives does not meet the demand of the required waterfront it has to be rejected. The scores will be assessed by comparing the alternatives with each other, taking alternative 1 as a reference. The score of an alternative will be denoted by a plus- or minus sign if it is respectively better or worse. Plus-plus or minus-minus indicates much better or much worse whereas zero is used if there is no or hardly any difference.

alternatives	1	2	3	4	5
terminals					
required waterfront	0	0	-	-	exit
road connections	0	0	0	0	
railway connections	0	-	-	-	
orientation towards wind	0	-	--	-	
ship manoeuvres					
number of manoeuvring areas	0	--	--	--	
size of manoeuvring areas	0	-	-	-	
orientation towards wind	0	-	--	-	
Ground area					
reservations	0	+	+	+	
future expansions	0	+	-	-	
remaining area	0	+	+	-	

Based on the score-table alternative 1 will be chosen to develop the definitive layout of the port.

10.3.3 Arrangement of the terminals

To complete the layout of the portside masterplan the location of the terminals in the port has to be determined. The number and type of berths differs in 1989/90 and 1999/2000, moreover in the second target year 22 or 27 breakbulk berths are required. In total 38 to 43 berths have to be arranged around the basin. While developing the alternatives first the situation in 1999/2000 with 27 breakbulk berths and a container terminal depth of 550 m has been assessed. From this layout the map for 1989/90 and the layout for the alternative with 22 breakbulk berths in 1999/2000 are easily derived. The terminal layouts will be taken over from the previous chapter and, in principal, will not be changed. When the alternatives are drawn up it appears that some reservations in the present masterplan of Haldia cannot be remunerated. Figure 54 shows the present and the adjusted area available for port activities in the masterplan.

Alternatives

Finally two alternatives have been drawn up, see Figure 55 and 56, the descriptions follow below.

Alternative 1

Basic thought behind alternative 1 is maintaining the destination of all the present facilities, the resulting layouts are shown in Figure 55 A,B,C. In 1999/2000 the present coal terminal with 2 berths is extended with a coking coal berth at its southern side. Inbetween the existing coal and phosphate rock berth 2 extra berths are planned for handling fertilizer traffic. Two fertilizer berths are located at the jetty. At the western side of the first basin leg 3 container, 2 fertilizer and 2 breakbulk berths are planned successively from top to bottom. The second basin leg is completely surrounded by breakbulk berths, depending on the attained breakbulk berth productivity with either 27 or 22 berths. The only difference between the layout for 1989/90 and 1999/2000 is the location of 2 container and 5 fertilizer berths at the western side of the first basin leg, obviously the second basin leg will be surrounded by 22 breakbulk berths.

Alternative 2

This alternative is the result of strictly applying the berth group concept and maintaining the coal and fertilizer berths at their present location, which almost completely determines the layout of this alternative, see Figure 56 A,B,C. Locating the container berths as close to the lock as possible determines the position of the remaining breakbulk group. Unfortunately the container terminal layout based on a terminal depth of 550 m has to be adjusted to the shape of the corner in this part of the port, Figure 57 shows the result. The new layout of the container terminal keeps the southern side of the basin free from berths.

Criteria

During the production of the alternatives already some of the evaluation criteria were already taken into consideration. The following criteria will be used to judge about the suitability of the alternatives:

- possibilities for further extension
- flexibility
- utilisation of present facilities
- safety of ship manoeuvres
- environmental aspects

The possibilities for further extension can be examined for a separate berth, for the berth group or the port as a whole. There is a difference in the situation for 1989/90 and 1999/2000, however the years after 1999/2000 are of more interest to form an opinion about the development of the whole port. Owing to the decreasing dwelltime the required area for breakbulk terminals will diminish slightly towards 1999/2000. Since the length of the berth remains the same every berth will have some area in reserve. On berth group level and for the port as a whole there will be no space left in 1999/2000 if 27 breakbulk berths are required. In case 22 breakbulk berths are required there is of course more space available for further development of the port but the difference is not spectacular. The river bank might offer some opportunities for expansion of the port as long as the cargo can be handled at a jetty and the required

water depth is available.
The overall criterion of flexibility can be split up in:

- possibilities to phase the implementation of the masterplan.
- possibilities to react on developments regarding the dimensions of the vessels.
- possibilities to change the destination of a quay or terminal.

Considering the number of berths that has to be provided in 1989/90 it is not possible to phase the implementation of the masterplan. A fast building program has to be started and already it is possible to predict this program will not be finished before the first target year. In fact it should be concluded the developed masterplan cannot be implemented before 1989/90.

From 1989/90 to 1999/2000 the number of required berths behind the lock either decreases with 2 or increases with 3 berths. On the river bank a third oil jetty has to be provided in 1999/2000. It is possible to phase the implementation of the masterplan from 1989/90 to 1999/2000. The required flexibility regarding ship dimensions heavily depends on the depth of the approach channel and the dimensions of the present lock or the second lock built in future, see chapter 8. Flexibility has to be incorporated in the design of the quays which leads to bigger foundation depths than would be necessary at this moment. The united waterfront allows a reasonable spread in the shiplenght, i.e. a ship longer than the berth can occupy a part of the adjacent berth, assuming that this berth is free or used by a smaller ship. Existing facilities can be used while their function or destination remains the same or by adapting the facility for other purposes. The bearing capacity of the quay and the number of solid constructions at the terminal determine whether it will be easy to develop, for instance, a fertilizer terminal into a container terminal. To allow for these kind of changes the quay should be designed for the maximum load and structures on the terminal should allow easy dismantlement and reerection at another place. If the new facility requires more than the available area it will not be possible to change the destination of the existing facility.

Utilisation of present facilities and flexibility are related to each other. Use of facilities while their function or destination changes has been described as flexibility. This criterion is used regarding the use of facilities with an unchanged destination.

The safety of shipmanoeuvres at the river has been described in chapter 8. In the basin the safety criterion can be translated to the distance of a specific berth to the turning circle, and the number and size of ships using this berth. From safety point of view it is better to locate a berth closer to the turning circle if is used by many or large ships.

Dust and noise originating from a terminal can be a nuisance for the environment. To use this criterion the location of the township Haldia at the western side of the port and the location of, for instance, the fertilizer terminal are important.

To select the best alternative a score-table could be used. However, the number of criteria and alternatives is small, and the score of the alternatives on the respective criteria will not differ too much. Therefore only the advantages and disadvantages of the alternatives will be described before one of them is selected.

The advantage of alternative 1 is the fact that the western basin leg is completely reserved for breakbulk traffic. This allows the best opportunities to phase the implementation of the proposed masterplan in this part of the port.
The disadvantages of this alternative are the scattered fertilizer berths, the long distance of the container berths to the turning circle, and a slightly cramped situation of the container berths in respect of vessel traffic due to the jetty. During the implementation of this masterplan due attention has to be paid to the fertilizer berths that must be changed into container and breakbulk berths. The foundation depth of constructions in relation with the depth in the second basin leg also deserves special attention.

Obviously the advantage of alternative 2 is the flexibility of port operations due to application of the berth group concept. All the berth groups have their own area. The container berth group is located close to the turning circle.
A disadvantage of this alternative is the fact that the present container terminal has to be changed into a fertilizer terminal. During the implementation of this masterplan it has to be kept in mind that the breakbulk berths adjacent to the container terminal must be changed into container berths in future.

Comparison of the mentioned advantages and disadvantages results in selection of alternative 2 for the arrangement of terminals around the basin.

11. CONCLUSIONS AND RECOMMENDATIONS

Main conclusions:

1 - Untill 1999/2000 there is enough space available in the port area of Haldia for concentration of all the port activities of both Calcutta and Haldia.

2 - After 1999/2000 increases of the cargo throughput will be limited or impossible in Haldia if this port has indeed taken over Calcutta's cargo.
Increase of cargo throughput has to be realised by further expansion of the port and construction of new facilities, or an increase in the efficiency of the cargo handling process. Lack of port area will prevent the first solution while the second solution will result in a relatively small increase of the cargo throughput.

3 - Implementation of the developed masterplan for Haldia is impossible before 1989/90, therefore the port of Calcutta cannot be abandoned in the near future.
At this moment the port in Haldia is not sufficiently equipped to handle the total amount of forecasted cargo, especially in regard of the breakbulk cargo. Thus, for the time being, Calcutta has to remain in action. Immediate improvement of the cargo handling process in both ports would partially solve the implementation problem. It must be possible to provide the necessary facilities in Haldia before 1999/2000.

4 - It is possible that a third port has to be developed after 1999/2000.
Whether or not a third port will be necessary depends on the amount of cargo to be transported through the ports after 1999/2000 and the capacity of the ports in Calcutta and Haldia.

Subconclusions:

5 - The small and inefficient cargo throughput in Calcutta is caused by the low shift productivity during the transshipment of cargoes, frequent breakdown and lack of equipment, bad utilization of the storage facilities, and poor management of the whole cargo handling process.
- The efficiency of the port in Haldia is hampered, first of all, by the relatively undeveloped hinterland connections and, secondly, by the draught restrictions of the approach channel.

6 - The cargo forecast is highly influenced by economic developments and policies of the Indian Government, thus will need adjustment regularly in following years.

7 - In agreement with the growing amount of liquid- and dry bulk cargo, however, in spite of increasing containerisation the amount of breakbulk cargo will grow.

8 - It is possible to increase the shift productivity during the transshipment of cargo considerably to an acceptable level.
If the productivity per shift, and consequently per berth, is not increased the construction of more berths will be necessary. The latter will be prevented by the involved costs and lack of port area.

9 - On the total of required berths the majority will be necessary for breakbulk traffic.

10 - High uncertainty exists about the amount of maintenance dredging per annum if a 10.7- or 12.2 m draught channel to Haldia has to be provided.

11 - The lock in Haldia meets the needs in regard of its dimensions and capacity. Tugboat assistance will be necessary more frequently.

12 - Reduction of the dwelltime of breakbulk and container cargoes will decrease the required port area and storage facilities considerably.

Recommendations regarding the ports in Calcutta and Haldia:

1 - Increase the efficiency of transport through the ports. Top priority should be given to improvement of the cargo handling process. More specific an increase of the shift productivity during transshipment of cargoes and a considerable decrease of the dwelltime of cargoes in the port should be attained. For these matters the figures for 1999/2000 in the developed masterplan for Haldia can serve as a guideline. Due attention will have to paid to keep the transport of cargo to and from the hinterland in pace with the productivity in the port.

2 - Compare the elaborated port development scheme, which concentrates all the port activities in Haldia, with the scheme based on maintaining both ports in Calcutta and Haldia with a fixed distribution of tasks. It will be necessary to:

2.1 - develop a masterplan for the port of Calcutta and to determine the potential cargo throughput. In first instance the following should be taken as starting point:
- the locks and the quays will not be demolished to avoid exessive expenditures on civil works.
- a reasonable balance, in regard of costs and benefits, between reduction of maintenance dredging and enhancement of the available dept in

the river. As a consequence of the previous starting point the draught of the vessels will be limited to circa 7.7 m anyway.

- establishment of an efficient cargo handling process and matching hinterland transport capacity, see recommendation 1.

Under these conditions Calcutta will be turned into an efficient port specialised in the reception of small-, mainly breakbulk and container, vessels.

2.2 - adjust the masterplan which was developed for Haldia. Depending on the potential throughput of Calcutta the demand made upon area and the number of required facilities in Haldia reduces.

2.3 - use an evaluation method like the multi-criteria or cost-benefit analyses to decide which port development scheme should be chosen and implemented.

3 - Make an inventory of locations for a third port besides Calcutta and Haldia. This third port will be necessary assuming further increase of the amount of transported cargo after the year 2000 and knowing the limits to the capacity of the two ports after elaboration of their masterplans. The development of ports in India as a whole will have to be taken into consideration.

Recommendations regarding the developed masterplan for Haldia:

4 - Analyse the capacity of Haldia's road- and rail connections with its hinterland. If necessary the capacity has to be adjusted to the amount of cargo that will be transported in 1999/2000, making a reasonable provision for further expansion after this year.

5 - Put up a thorough research into the morphological processes in the estuary in order to make a more reliable estimate of the required maintenance dredging to be expected if a deeper draught channel will be constructed.

6 - Elaborate the riverside masterplan for Haldia paying due attention to the position of the through channel to Calcutta and the river jetties, the manoeuvring areas required for lock and jetty approaches, and the position of the anchorages.

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Appendix A

THE HISTORY OF THE PORT OF CALCUTTA

The following is a summary of historical events on three subjects regarding the development of the port in Calcutta. The first subject is the navigability of the river Hooghly, the second the development of cargo handling facilities and the third subject is the administrative control of the port. Besides the historical data some general remarks are made if necessary. The information used for this summary descended from [20].

Navigability of the river Hooghly

The importance of the river's navigability is a direct consequence of choosing the location of the port 140 kms landinward along the river. In the past trade settlements, which developed themselves to ports, were established as far landinward as possible to escape the threat of pirats, freebooters, and slave dealers. Calcutta suffered from these plagues untill the 18th century. Throughout the years the increasing dimensions of ships made the surviving ports change their landinward positions to locations closer to sea. However in this respect the port of Calcutta has its own typical history, which is indeed intertwined with the navigability of the river Hooghly.

before 1570 -several ports in Bengal were abandoned due to siltation of the river. In 1570 the village Hooghly, 165 kms up the river, had established itself as main port.

1668 -the Pilot Service increased its efficiency which resulted in less hazardous use of the river.

1690 -Job Charnock settled himself in Kalikata, nowadays Calcutta, 25 kms downstream of Hooghly on the eastside of the river.
The deep channel on the outside of the riverbend provided a safe mooring place.

1765 -directors of the East Indian Company request the Calcutta Council to make proper arrangements to survey the river every year at least once or even more often.

1768 -the Pilot Service was made more respectable.

1853 -report of the Hooghly Commission on the dangerous state of navigation on the river which is only possible for vessels with the smallest tonnages. Two members of the commission recommended to build an auxilary port at Matla because however slow or gradual the Hooghly would deteriorate. The third member was more optimistic imputing the temporarrily bad condition of some channels to annual variations.

1863 -the Secretary of State for India placed H. Leonard on special duty to investigate the immediate and prolonged suspension. Leonard concluded that the river must deteriorate and suggested river training works.

1869 -steam ships started to sail the sea. Due to the shorter route through the newly opened Suez Canal steam ships were arriving with a higher frequency in Calcutta.

1870 -Leonard's spurs at Moyapur were constructed.

1872 -Leonard's spurs were removed.

1872-1891 -due to natural causes the condition of the channels improved.

1891-1898 -high freshets caused deterioration. L.F. Vernon-Harcourt investigated the matter and came to the conclusion that only two river stretches showed progressive deterioration, the James and Mary reach and Moyapur reach. He proposed certain river training works and the use of a powerful suction dredger.

1899 -novel scheme for the improvement of the James and Mary reach.

1901-1913 -lighting of the river to permit night navigation between Sagar and Mud Point.

1924 -diminition of head water supply progressively silts up the upper portion of the river and extended downstream, this phenomenon shows itself in Calcutta.

1929 -design depth for the King George's dock (NS dock): 9.1 m.

1938 -7.9 m draught vessels can enter the port 291 days per year. Report of T.M. Oag who does not notice any indication for serious deteriorating conditions on the river.

1939 -complaints of the Calcutta Liners Conference towards the Commissioners (board CPT); it would be uneconomically to continue sending vessels to Calcutta that were capable of loading to 8.5 or 8.8 m draught when river conditions precluded their leaving at such draughts.
For the next 25 years the number of days that the port has been open to 26 ft draught vessels will continue to decline.

1947 -on behave of the Government of India the Ministry of Transport hands over the Pilot Service to the Calcutta Port Trust. All the branches of the marine service were now under the responsibility of the Commissioners which enabled a better coordination with accompanying higher efficiency. For instance, after removal of ship meeting restrictions at Falta it was possible to use the higher available sailing speeds for crossing bars before the water level dropped.
Proposal for the construction of a ship canal to by-pass the difficult stretch of the river between

Calcutta and Diamond Harbour rejected because of the high cost involved, and because of the fact that the controlling bars for the major portion of the river were situated below Diamond Harbour.

1948-1949 -Owing to World War II recruitment of pilots had been neglected, this occasionally resulted in extra waiting time of ships because there was not a pilot available.
The Indian Waterways Research Station in Poona constructs two river models for experiments. First attempt to find scientifically justified solutions.

1951-1956 -first Five Year Plan. Some river training works for improving the navigability. Farakka was chosen (1952) as the location for building a barrage because at this site the river banks had not changed for nearly 100 years and the river width was only 2.5 miles.

1956-1961 -river training works between Falta and Hooghly Point, and at the Balari bar. Purchase of about 9 dredgers, some of them to replace old equipment others for increased dredging. The latter owing to the river training works and to arrest shoaling at some estuarian bars.

1957 -bends in the river limit the size of ships to 161.5 m, 15 bars impose draught restrictions, allowing only 7.9 m for 196 days in a year, which causes severe bunching of ships. Increased severity and high frequency of bore tides.

1961-1966 -in the programme of 'maintenance and preservation' of the port were included the construction of an auxilary dock system at Haldia and a barrage in the Ganga river at Farakka. In the plans drawn up for Haldia the following is proposed:

acces for 9.1 m draught ships on all days in the year, 9.8 m draught on 258 days and 10.7 m draught on 39 days in the year.

The sea acces to Haldia involves crossing of three bars. By dredging these bars several meters a subsequent higher draught could be allowed on an increased number of days.
Cutting a new channel over the Balari bar and training works for improving the Balari channel.

1962 -the port authorities had to open an alternative route along the Rangafala channel because the old was narrow and undependable, it required heavy dredging.
New department for carrying out studies of the hydraulic mechanism of the river and the estuary.

1975-1979 -Fifht FYP. Estuarian dredging described and executed as a new item of work.

1975 -completion of the Farakka Barrage- and Feeder Canal system. From now on a sufficient and silt-free head water supply could be expected. For every extra depth of 0.3 m a continuous head water supply has to be maintained for 2 or 3 years.

1977 -in February the first merchant vessel enters Haldia dock.

1980- -Sixth FYP. Capital dredging on the shipping channel

1985 leading to Haldia dock and execution of river training works to improve the dredged channel.

1985 -draught Calcutta port 7.7 m in the dry season, 8.7 m during the monsoon.

1986 -completion of guidewall at Nayachara Island near Haldia, upto a length of 2800 m. Cross bars of 190 m length are also under construction. The nose of the island had to be protected as well as the western side. Considerable scour in the vicinity of the secondary channel southwest of the Auckland bar drawing the ebb discharge away from the bar.

Cargo handling facilities

Throughout the years the increasing amount of (valuable and breakable) cargo and the occurrence of cyclones have always supplied the impetus for development of better cargo handling facilities. The following historical data in the course of the Calcutta-port life time will illustrates this.

1690 -for occasional landing of cargoes the somewhat protected roadstead, with some anchorage places, at Calcutta was suitable enough. Ships at the moorings were discharged by their tackles working on handcraft and the aid of small river boats that took the cargo to the river bank. The cargo was either carried to shore on men's heads or rolled upon the planks from the boat, to the shore or vice versa. From the shore the cargo was transported by cards. Discharged cargoes had to pas the Customs Office whereas export cargoes were immediately loaded.

1734 -cyclone bursts upon Calcutta, great damage was done to shipping. Owing to this disaster Government provided better port faclities and improved the available accomodation.

1781 -an unsuccesful start was made with the construction of wet docks at the south end of the port. Unsuccesful because not all the required land could be purchased, thus the project was called of.

1807 -James and Robert Kyd took over the old repair docks constructed, in 1790, by the Government. They also started shipbuilding activities at Kidderpore, a name presumably derived from the family name Kyd.

1833 -the loss of the Company's (EIC) trading operations coupled with the introduction of steam ships led to the disuse of Diamond Harbour anchorage as a place of loading and discharging.

1842 -hurricane caused disastrous loss of life and property among the ships lying in the port. The appointed Committee recommended construction of docks at Akra or Kidderpore. Ultimately nothing came out of it.

1864 -severe cyclone swept over the port where 195 vessels were moored. Only 23 escaped without damage, the other 39, 97 and 36 ships were respectively slightly-, severely damaged and totally wrecked.

1869 -four screw-pile jetties with steam cranes and sheds were ready. Having discharged their cargoes at the jetties the vessels went down the river to the moorings to take on board their export cargoes. The chance on damage or pilferage of cargo were minimized.

1871 -birth of the Port Trust.
Replacement of steam cranes by hydraulic cranes that operated cheaper.

1872 -2 extra jetties were built, the first four were remodelled because the size and shape of ships visiting Calcutta changed rapidly due to the opening of the Suez Canal.

1882 -completion of the 7th and 8th jetty

1883 -first proposals for construction of wet docks at Kidderpore. Wet docks were taken into consideration owing to the existing tidal range that caused problems in keeping ships afloat, resulted in frequent adjustment of moorings, and hampered the loading and unloading process.

1886 -hitherto petroleum had been stored at Garden Reach at considerable risk to the shipping of the port in case of fire. Now the wharf at Budge Budge was opened.

1892 -Kidderpore dock 1 declared open for traffic. The developing export coal trade started the extensive use of the dock which was first boycotted by the merchants.

1892-1896 -the old jetties were reserved for import cargoes whereas export cargoes were loaded at Kidderpore dock 1.

1897 -large foodgrain imports caused by famine.

1902 -Kidderpore dock 2 completed.

1913 -17 general cargo berths, number 18 now under construction, and 10 coal berths in the Kidderpore docks.

1901-1914 -9th jetty berth was completed, the transit shed area was also extended. The petroleum wharf at Budge Budge was thoroughly remodelled and the storage capacity was increased. The inland vessel wharves were provided with 11 pontoon-gangway berths and sufficient shed capacity, mainly used for tea and jute.

1920-1926 -4 jetties were constructed at Garden Reach. Growing amount of cargo after the lean World War I years.

1928 opening of the King George's dock, berths 1, 2, 3, 4, and A.

1930-1931 -having escaped the first year of the world wide depression, which started in 1929, now a fall in the amount of cargo with 24% compared to the previous year. Therefore the anticipated extension of the King George's dock was delayed.

1940-1945 -World War II delayed the extension of King George's dock once more.
Although Calcutta was transformed into an important centre of manufacture, mobilisation and distribution of important items for the Allied Forces, the

tonnage handled in one year was on average lower than in any of the slump years.

1942-1943 japanese air raids on the city and the dock area.

1943 -some works that could be executed quickly included construction of 3 berths in the Kidderpore docks, 2 berths in King George's dock, 2 (army) passenger berths at Princep Ghat, 2 laying up berths, a heavy lift yard in King George's dock, a coal jetty, 3 flat-loading berths and 2 extra berths at Budge Budge.

1951-1956 -two general cargo and a mechanical ore berth were constructed. With the purchase and installation of a electrically operated 200 tonnes cantilever crane and development of a heavy lift yard berth no.1 at King George's dock was changed into a heavy lift berth.

1956-1961 -conversion of berth D, C, 5 into respectively a general cargo -, oil -, and mechanical ore berth. Improvement of berth 22 to 26 in Kidderpore dock.

1957 -in a report of the port's Director of Operations it could be read that the lay-out of the berths, particularly the Calcutta jetties and the Kidderpore docks, was such that very few ships of over 152.4 m length could be accomodated.

1959 -near the outfall of the river Haldi into the Hooghly an anchorage was set up. At the Haldia anchorage lightering or topping up operations on deep draught vessels were executed in the fair weather period from November to February. A fleet of about 60 lighters was mobilised. While the anchorage handles a rather modest amount of cargo, all foodgrain cargo, work on the Haldia dock complex was progressing.

1961-1966 -extension of one arm of the King George's dock. Extension of the Kidderpore docks was considered to be unwise because the available width was limited and too many ships would depend on one lock.

1970-1974 construction of a new dry dock in the King George's dock.

1973 (King george's dock renamed Netaji Subhas dock).

1977 in February the first merchant vessel enters Haldia dock.

The above scheme is not complete, e.g. not all the rises and falls in the handled amount of cargo were mentioned, nor were all the extensions like civil works, mechanical- and floating equipment mentioned.

Appendix B

PLANNING PROCEDURES FOR PORT DEVELOPMENT

The tables are published in [27]

Procedure for national ports master planning

The eight main tasks A1 to A8 are as follows:

1. Define national economic objectives in so far as they affect ports.
2. Define the financial responsibilities of the ports.
3. Define the planning responsibilities of the ports.
4. Prepare a broad national traffic survey.
5. Assign traffic to individual ports.
6. Prepare a preliminary investment plan.
7. Co-ordinate and obtain approval of individual port master plans.
8. Prepare and publish the national ports master plan.

Each of these tasks is described in more detail below.

Task A1. Define national economic objectives as they affect ports

1. Hold preliminary discussions with national economic planners.
2. Collate published reports, etc., and extract material relevant to maritime traffic and to the connected networks.
3. Summarize the broad impact of economic policies on port development in a draft policy paper.
4. Discuss draft with national economic planners.
5. Revise and circulate policy paper.

Task A2. Define financial responsibilties of ports

1. Review existing orders and legislation.
2. Obtain views of port authorities.
3. Spell out new policy in detail (e.g. common tariffs, required return on investment, funding).
4. Discuss proposal with higher authority.
5. Draft new orders or decrees.

Task A3. Define planning responsibilities of ports

1. Review existing planning responsibilities.
2. Analyse need for regional or other structure.
3. Consider methods of planning any new ports.
4. Consult with port authorities.
5. Propose new structure. Discuss with higher authority and revise as necessary.
6. Draft any new orders or legislation needed.

Task A4. Prepare a broad national traffic survey

Chapter III of Part one discusses this in detail.

Task A5. Assign traffic to individual ports

1. Prepare broad origin/destination diagrams for each principle cargo class.
2. Examine scope for concentration of cargoes in each region or at national level.
3. Construct several alternative feasible traffic assignments.
4. Roughly evaluate alternatives and prepare paper on most economic solutions.
5. Circulate paper to all departments/organizations concerned.
6. Draw up plan reconciling comments received and submit for approval.
7. Issue approved plan.

Task A6. Prepare a preliminary investment plan

1. Obtain port estimates of future productivity for each cargo-handling technique in question.
2. Compare traffic assigned to each port with its rough existing capacity for each class of traffic and cargo-handling technique.
3. Roughly estimate scale of additional facilities needed.
4. Roughly estimate investment implications.
5. Compare with Ministry of Finance targets or other constraints and report any divergence.
6. Revise figures as necessary.
7. Notify ports of figures to give framework for their master planning.

Task A7. Co-ordinate and obtain approval of individual port master plans

1. Tabulate traffic forecasts used by each port and check for inconsistencies and duplications.
2. Carry out broad economic comparison of any competing plans.
3. Carry out rough check of all capacity calculations.
4. Revise plans as required.
5. Calculate national port investment total.
6. Discuss long-term port investment requirements with Ministry of Finance and revise as necessary.
7. Visit ports to discuss final master plans.
8. Issue authorizations.

Task A8. Prepare and publish the national ports master plan

1. Assemble individual port master plans into a national plan.
2. Publish the master plan in a form which can be easily revised.

A diagram showing these tasks and how they are related to master planning is given in figure 2.

The 11 main tasks B1 to B11 are as follows:

1. Set up an ongoing traffic analysis (if this does not already exist).
2. Prepare a broad long-term traffic forecast.
3. Initiate any broad engineering surveys needed.
4. Analyse the port's role as laid down by the national authority.
5. Determine the long-term phased area requirements.
6. Determine the long-term water and channel requirements.
7. Assign traffic to major port zones.
8. Calculate the rough cost of each terminal/berth group in each phase.
9. Prepare the draft master plan and submit for national approval.
10. Revise and publish the port master plan and obtain local approval.
11. Install a control system for initiating a project at the right time.

Each of these tasks is described in more detail below.

Task B1. Set up an ongoing traffic analysis

The data required are shown in chapter III, "Traffic forecasting". The UNCTAD "Manual on a uniform system of port statistics and performance indicators"[a] contains a complete system for collecting the data both for planning and for operational purposes.

Task B2. Prepare a broad long-term traffic forecast

Strictly speaking, the ports cannot start forecasting until their role has been defined at national level, but there is a lot of preparatory work and simple projections which need not wait for this. At the master planning stage, forecasting is to be broad and long term only.

Task B3. Initiate any broad engineering surveys needed

The surveys that should be initiated for master planning are those which provide a broad picture on which major zone decisions can be based, plus those (like siltation studies) which are themselves of a long-term nature. The range of surveys which may be needed are described in chapter VII, "Civil engineering aspects."

Task B4. Analyse the port's role as laid down by the national authority

If the national plan has not been prepared, it may be necessary to analyse the port's role as seen locally and submit this as a proposal.

Task B5. Determine the long-term phased area requirements

For each of the traffic streams likely to result from the defined role of the port:

1. Review characteristics of each class of traffic (transport, storage, ship size and draught, pollution).
2. Review industrial development plans and possibilities in port area.
3. Calculate broad land area requirements for the range of feasible long-term cargo throughputs.
4. Estimate land area requirements for long-term industrial development within port limits.
5. Estimate land area requirements for ancillary land-use (housing, amenities) within port limits.
6. Tabulate the various area requirements phased according to each traffic alternative.

Task B6. Determine the long-term water and channel requirements

For each class of ship traffic, calculate the broad water area and depth requirements for the range of ship types and sizes expected in the long term.

Task B7. Assign traffic to major port zones

This task is discussed further in chapter V of this handbook. The following is a sequence of work which is appropriate at the master planning stage:

1. Examine environmental impact of each class of port activity (both independently and as they affect each other).
2. Survey existing water areas and approaches and compare different ways of deepening and extending these, including new land cuts.
3. Survey existing and available land areas and compare alternative ways of extending them, including reclamation.
4. Draw alternative zone configurations with corresponding communications corridors.
5. Broadly evaluate alternative phased configurations for transportation economy, capital cost and flexibility.
6. Prepare zoning plan for the preferred solution.
7. Draw outline charts of water depth for the chosen zoning configuration, corresponding to the successive phases of each alternative.

Task B8. Calculate the rough cost of each terminal/berth group

1. Identify likely terminal or berth group developments, in each zone within the zoning plan, for each future alternative.
2. Estimate the rough costs of each terminal development.
   N.B. Although it will be difficult to obtain such cost estimates, it is important to find any indicative figure, however rough. This is because without such figures it will be impossible to build up a long-term investment plan, which is essential to show whether the master plan is feasible.
3. Tabulate the results.

Task B9. Prepare the draft master plan and submit for national approval

The contents of a master plan should include:
(*a*) The long-term forecast and its rationale;
(*b*) The planning maps;
(*c*) The investment implications.

One way of organizing the preparation of the plan is as follows:

1. For each class of port activity, combine the successive stages of development in the alternative cases into a single framework independent of time.
2. Draw planning maps showing the proposed zoning and alternative development sequences within the framework.
3. Prepare order-of-magnitude investment cost figures for the development sequence of each activity.
4. For the time-scales both of a conservative and of a radical alternative, calculate the total investment implications over the period.
5. Assemble this material into a draft master plan, with a supporting commentary on assumptions and rationale.

Task B10. Revise and publish the agreed port master plan

This should be published in such a form that it can be easily revised and amended each year.

Task B11. Install a control system for initiating a project at the right time

It is essential to initiate a project feasibility study as soon as there is an indication that, by the time the development is complete, there will be enough traffic to justify it. Master planning is not complete until a routine is established for checking when projects should be initiated. The following procedure is one way of doing this:

On completion of the master plan

1. Identify each individual investment project within the plan over the next ten years.
2. For each of these projects, estimate the likely development time that will elapse between initiating project action and bringing the facilities on stream. This will include: the whole sequence of project planning; funding and time for decision-making; tendering; design and construction.

Every year

1. Bring the traffic forecast up to date, for each traffic class.
2. Estimate the future growth rate of traffic in that class, taking account of latest developments and customer requests.
3. At this growth rate, calculate the traffic level a number of years in advance of the date at which the project capacity is needed. This is the triggering level.
4. Activate the project if the triggering level has been reached.

[a] UNCTAD/SHIP/185/Rev.1.

The 18 main tasks C1 to C18 are as follows:

Task C1. Detailed traffic forecast

Revise master plan forecast and detailed figures for the economic life of the investment proposed.

Task C2. Survey of cargo-handling techniques

For each class of traffic that has been forecast, examine the alternative port-handling techniques and their impact on future productivity, bearing in mind the expected form of presentation of the cargo.

Task C3. Rough dimensions

Group together traffic classes with similar handling characteristics and, for each berth group or terminal, find the approximate level of additional facilities needed and make a rough estimate of their dimensions.

Task C4. Alternative locations

For the berth groups and terminals concerned, propose alternative water and land areas in locations that will not interfere with traffic in adjoining zones and that will provide safe berthing.

Task C5. Engineering surveys

For each location, carry out the engineering studies to quantify the main works required and adjust site locations where necessary to avoid excessive costs. Although engineering surveys should be carried out after task C4 and before task C6, in practice they may need to be continued for the whole period, providing more accurate results as the survey proceeds.

Task C6. Rough costs

Estimate the cost of constructing and equipping each of the facilities under consideration.

Task C7. Selection of promising options

Eliminate the less attractive alternative solutions, discuss conclusions with the decision authority and obtain agreement on a short list of alternatives to be further studied.

Task C8. Labour constraints

Consider the labour questions and manning problems which may arise with respect to each alternative technology in parallel with task C7.

Task C9. Preliminary design

For each alternative retained, design the layout of all facilities in sufficient detail to discover access, operating or storage problems.

Task C10. Operational planning

Prepare plans showing the equipment and operation of the new facilities, and the productivity targets.

Task C11. Capacity calculations

Calculate the alternative levels of facilities needed to accommodate the range of capacities and services that is feasible.

Task C12. Union consultation

Initiate consultation with trade unions on any new cargo-handling techniques proposed.

Task C13. Cost estimates

Refine the cost estimates for all works, equipment and services to produce a basis for the economic and financial analysis.

Task C14. Cost-benefit analysis

Analyse the economic case for each of the alternatives.

Task C15. Financial analysis

Analyse the financial viability of each option and review the available methods of achieving sound financing.

Task C16. Draft proposal

Consolidate all analyses and compare advantages and disadvantages of each option in a draft report.

Task C17. National and local approval

Discuss draft report with local and national authorities and obtain agreement on recommended solution.

Task C18. Final proposal

Formalize the agreed solutions in a report with the supporting analyses.

The main resources for a port project in a developing country are land, labour, and foreign exchange. The economic cost of each of these resources differs from the ordinary market prices, and is equal to what is called the 'opportunity cost' or 'shadow price'. The costs are equivalent to the highest valued benefit which is given up by using the resources for this project rather than for another project. It is not such a straightforward matter to determine the economic costs as compared to the fixation of the financial costs based on market prices. Land might have been used for building offices. Instead of using the purchase sum the value of the land, if it were released for building offices, which would have been higher, would be entered as the cost of the land. The opportunity cost of labour is very low when there is no alternative useful employment. In areas of high unemployment, irrespective of the wages which will be paid, the labour costs will be very small and may often be set at zero. Costs that have to be paid in foreign currency will have a higher shadow price since the exchange rates in developing countries are often fixed at arbitrary levels.

The economic benefits of port investment are the transport cost savings, the reduced turn around time of ships in port, the reduced period goods spend on ships and in port, the increased economic activity, and the increase of exports. The value of the benefits is often difficult to measure, especially in case of the increased economic activity and the increased exports.

Discounting and evaluation methods for both analyses

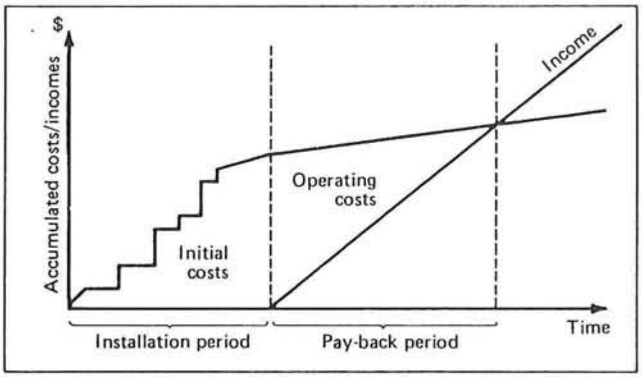
Characteristical for projects, consisting civil engineering works, are the high initial costs, whilst the benefits occur after delivery of the work during the period of utilisation. The life of the work directly influences the total benefits and the result of the evaluation method. Owing to the life of the work, including the construction period, costs and benefits have to be discounted, which indirectly influences the result of the evaluation method.

Discounting of costs and benefits is necessary because of the time preferrence of money and depreciation of money due to inflation. It is obvious that costs and benefits have to be compared at an equal time base. The nett monetary flow expected from the project is calculated and converted with the discount rate to the present value. For commercial profitability, in the financial analyses, the correct discount rate is the market rate of interest. However, for national economic profitability the appropriate discount rate is more difficult to define because of social factors.

Evaluation methods often used are the payback-, nett present value-, internal rate of return-, and benefit/cost ratio method.

The payback method literally means the number of years required to recover or pay back the initial investments. The basis of the payback calculation is shown in the Figure below:

The pay-back period approach



The nett present value method takes into account the time value of money. The discount rate specified must be used to discount all future cash flows to their present value. Summing these flows gives the nett present value of the investment. The criterion used in this method is to accept the project if the nett present value is greater than zero and otherwise to reject it.

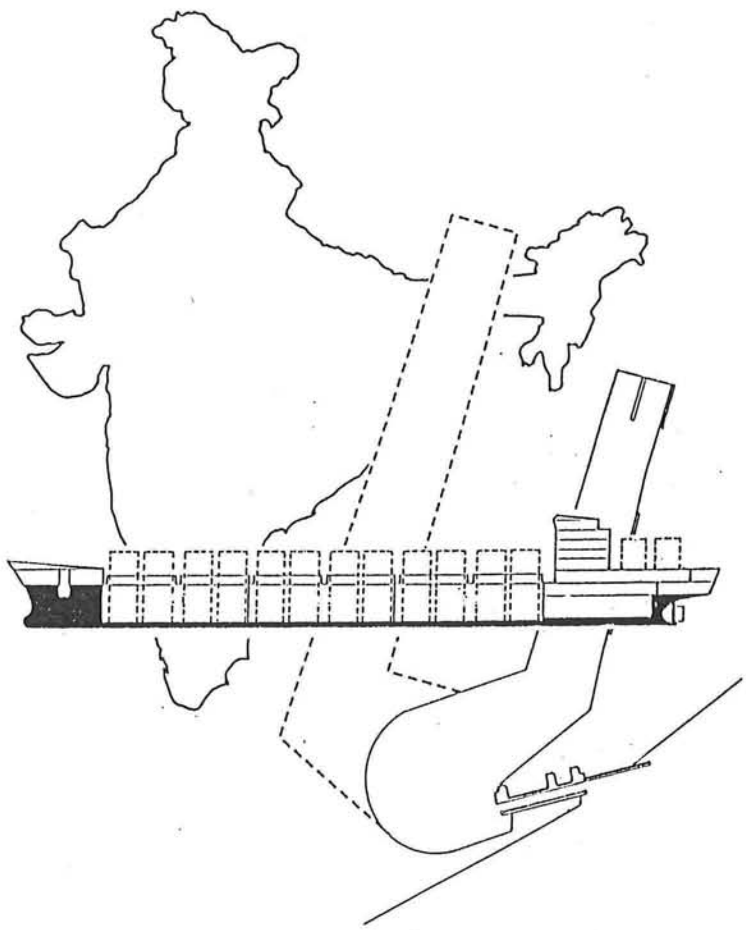
The internal rate of return method also takes the time value of money into account. The internal rate of return is the discount rate that gives a zero nett present value, in other words, the rate at which the present value of benefits equals the present value of the costs. If the internal rate of return of a project exceeds the required rate of return, or cut-off rate, the project is acceptable, otherwise it is not.

The nett present value method and internal rate of return method will give similar answers with respect to the acceptance and rejection of an investment proposal.

The benefit/cost ratio method uses the present value of benefits and the present value of costs and is obtained by dividing the benefits by the costs. A ratio greater than 1 implies that the project is acceptable, while a ratio less than 1 implies that the project is unacceptable.

PORT DEVELOPMENT in HALDIA

VOLUME 2



TU Delft

Technische Universiteit Delft

Faculteit der Civiele Techniek

PORT DEVELOPMENT IN HALDIA

Masterplan based on concentration of all the port activities presently taking place in Haldia and Calcutta

VOLUME 2 FIGURES AND TABLES

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May, 1988

Delft University of Technology

Civil Engineering Faculty

FIGURES AND TABLES

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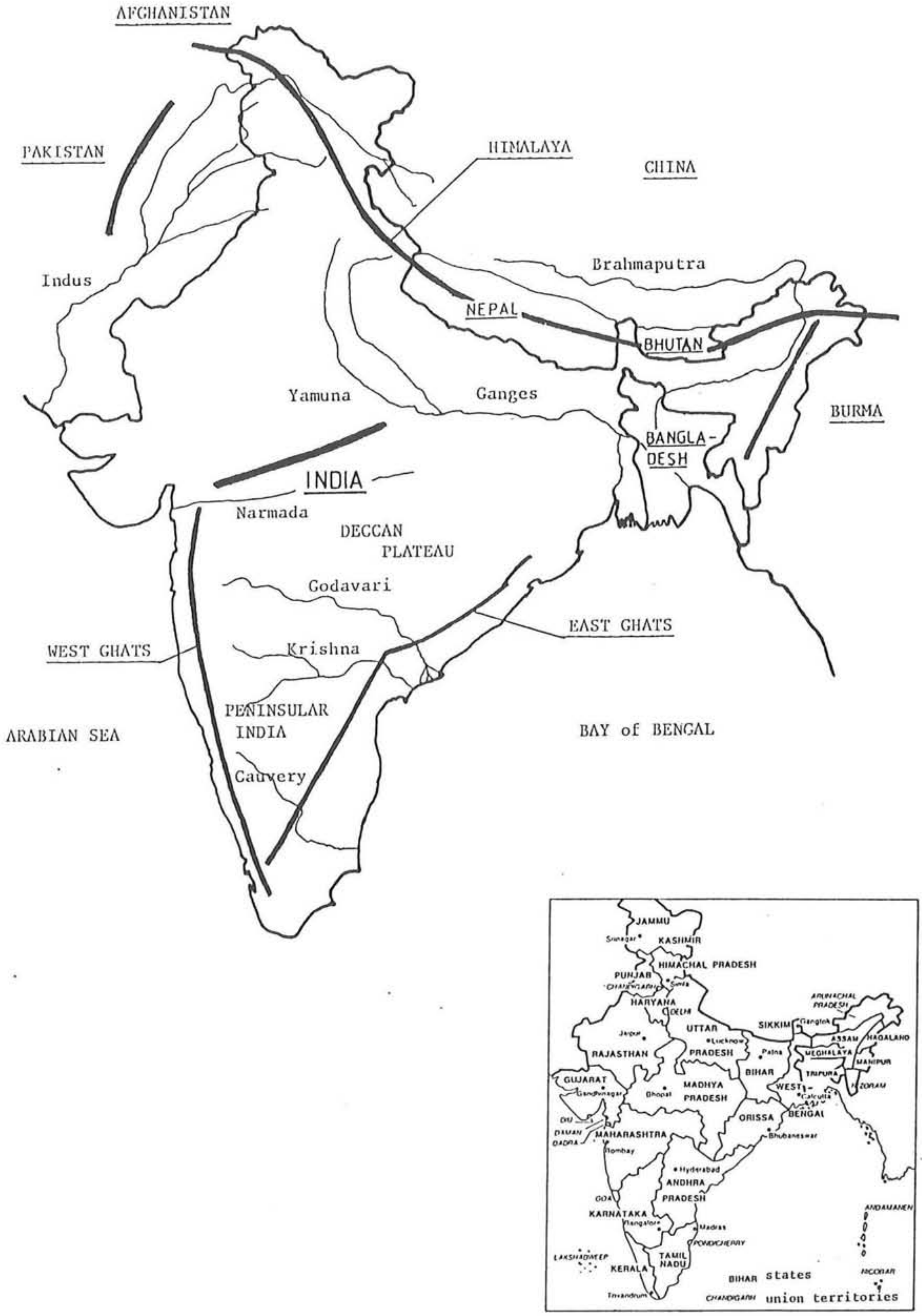


Figure 1: India, country borders, characteristical rivers and -areas

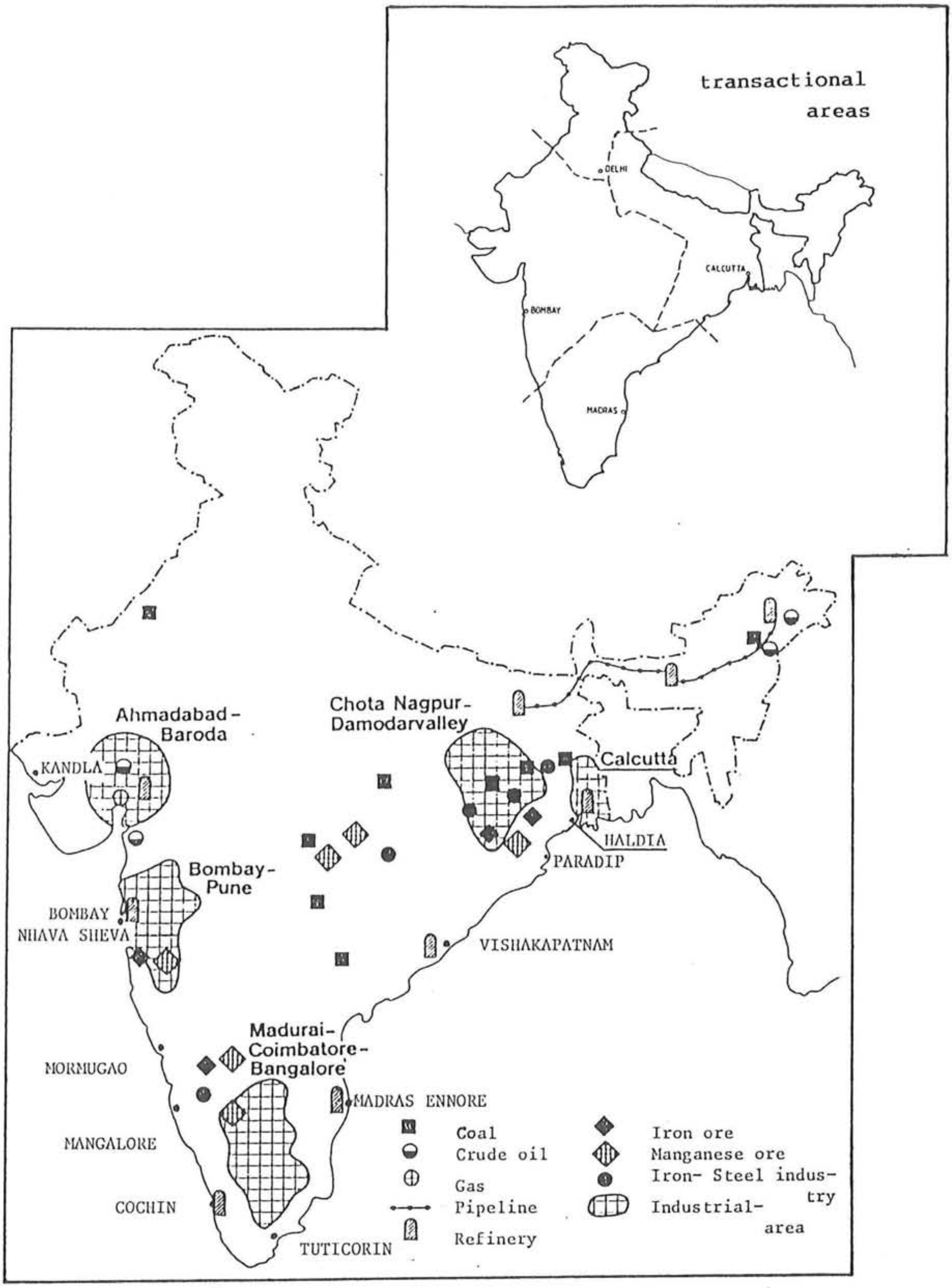


Figure 2: Location of ports, industrial- and transactional areas

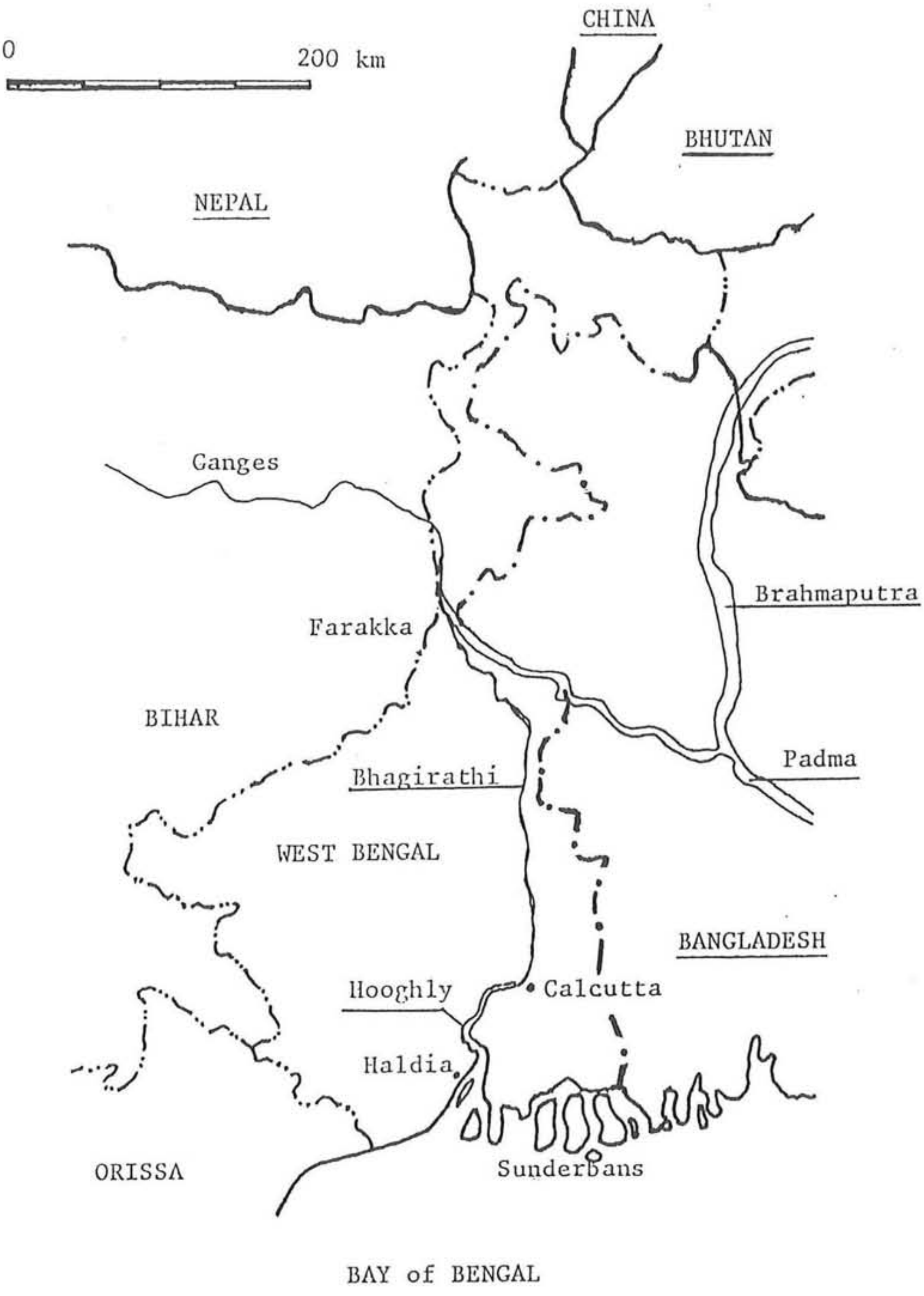


Figure 3: The state West-Bengal

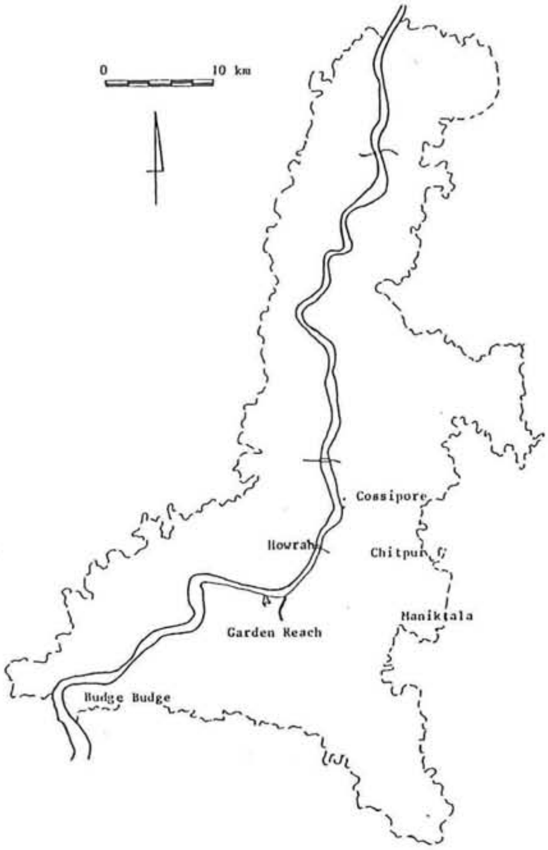


Figure 4: The metropolis Calcutta

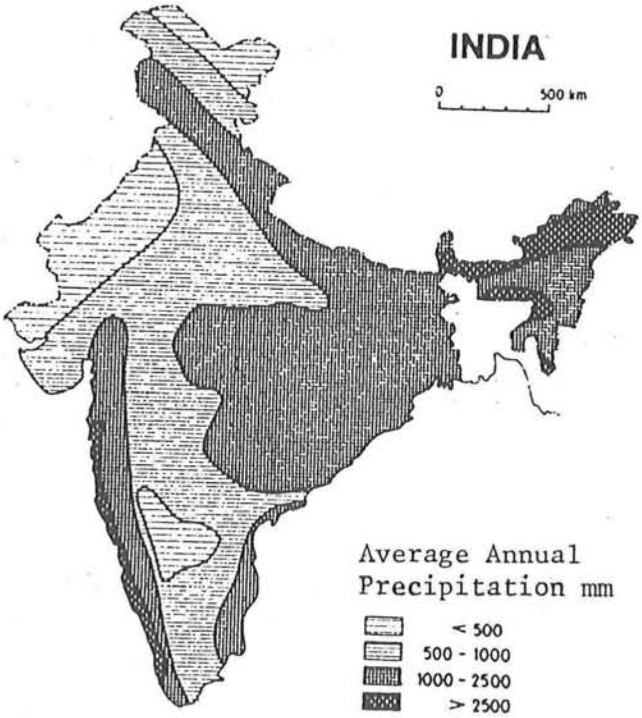


Figure 5: Distribution of precipitation in India

Table 1.

Temperatures, humidity and precipitation in India

	Average year temperatures C		Observated extreme temperatures C		Relative humidity %	Average yearly precipitation mm
	Max	Min	Max	Min		
1 Srinagar	20	7	37	-14	66	660
2 Delhi	32	18	46	-3	48,5	640
3 Ahmadabad	35	22	46	6	47	730
4 Trivandrum	29	24	38	16	76,5	1700
5 Calcutta	32	21	46	7	73	1530

Source: [21]

Table 2.

Population and its growth throughout the years

	15-8-1948	1951	1961	1971	1981	1991	2001
population	340	361	444	560	701	840	986
growth rate per annum	2,0%	2,1%	2,3%	2,3%	1,8%	1,6%	

Source: [17,18]

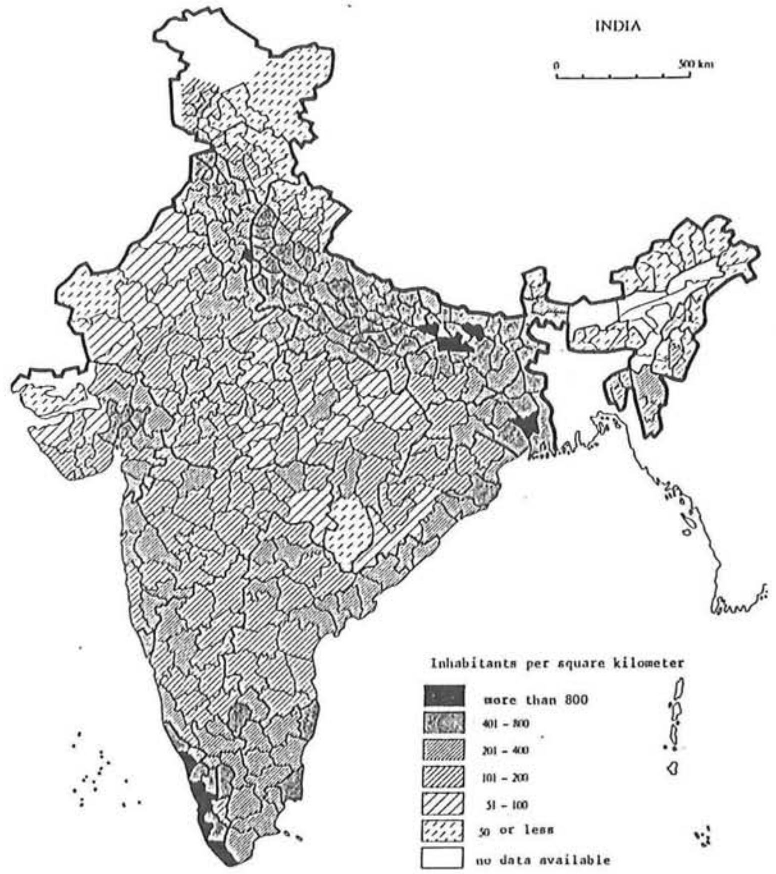


Figure 6: Density of population in India

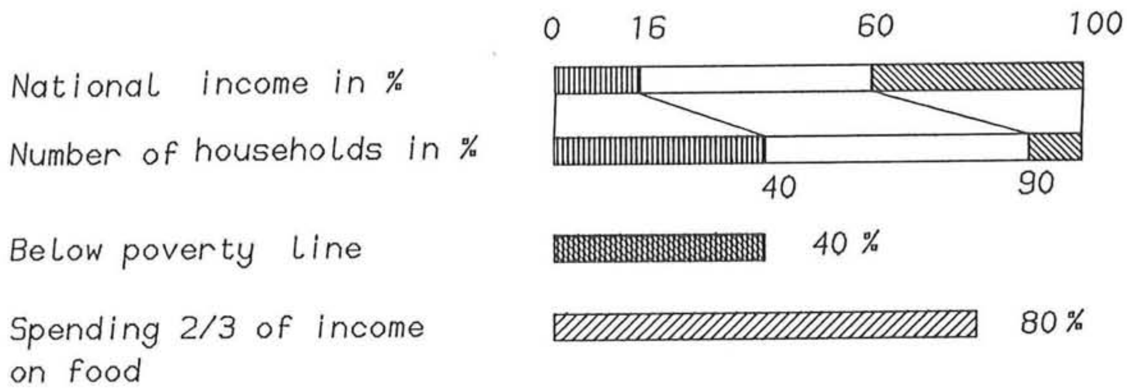


Figure 7: Distribution of National Income over the households

Table 3.

Gross Domestic Product per sector

in 1970/71 prices

Sector	1950/51 mld Rps	%	1975/76 mld Rps	%	1984/85 mld Rps	%
Agriculture	103.21	58.8	193.49	45.3	225.89	36.7
Mining	1.32	0.8	4.80	1.1	8.21	1.3
Industry	17.50	10.0	61.28	14.4	95.58	15.5
registered	9.55	5.4	38.72	9.1	64.61	10.5
not registered	7.95	4.6	22.56	5.3	30.97	5.0
Building industry	7.39	4.2	20.27	4.8	26.41	4.3
Energy	0.49	0.3	5.77	1.4	10.79	1.8
Trade	6.35	3.6	25.29	5.9	45.37	7.4
Transport	14.50	8.3	49.32	11.6	75.94	12.4
Banking	9.19	5.2	25.01	5.9	43.34	7.0
Government	4.75	2.7	22.38	5.2	55.76	9.1
Other services	10.66	6.1	19.01	4.5	27.44	4.5
Total	175.36	100.0	426.62	100.0	614.73	100.0

Table 4.

Allotment of finances in Five Year Plans

Five Year Plan	1	2	3	annual plans	4	5	6	7
Transport and Communication	26.4	27.0	24.6		18.4	19.2		16.4
Industry and Minerals	2.8	20.1	20.1		18.5	22.3		12.5
Energy	7.6	9.7	14.6		17.8	16.2		30.5
Agriculture	14.8	11.7	12.7		16.9	13.2		12.7
Irrigation and Floodcontrol	22.2	9.2	7.8		7.4	7.3		9.4
Other	26.2	22.3	20.2		21.0	21.8		18.5
	100	100	100		100	100		100

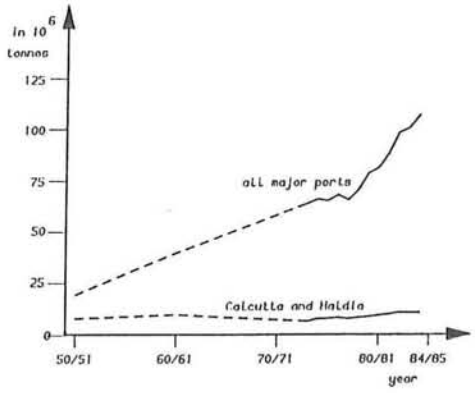


Figure 8: Cargo throughput in ports

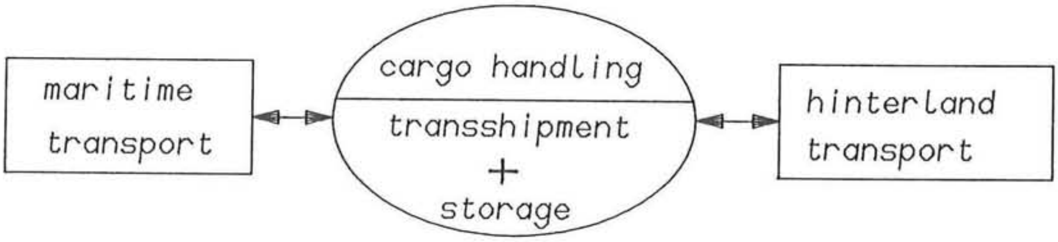


Figure 9: Division of port operations

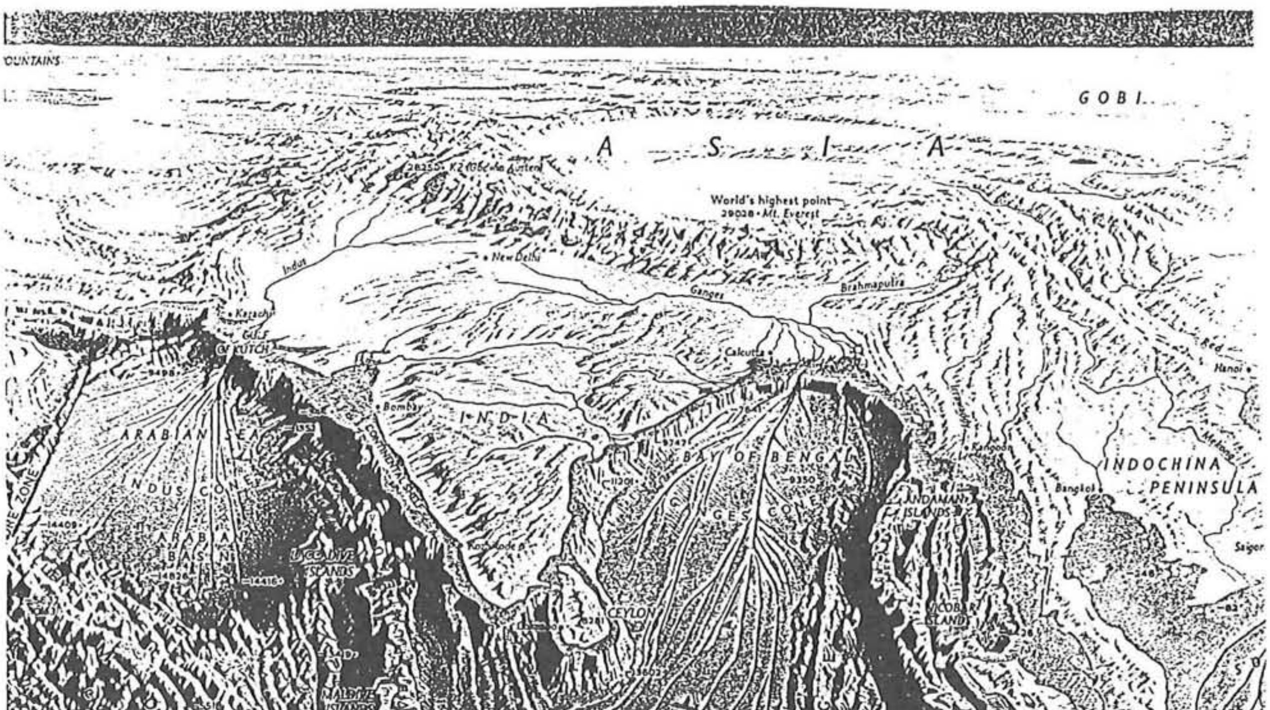


Figure 10: Ganges Cone, Indian and Asian continental plates

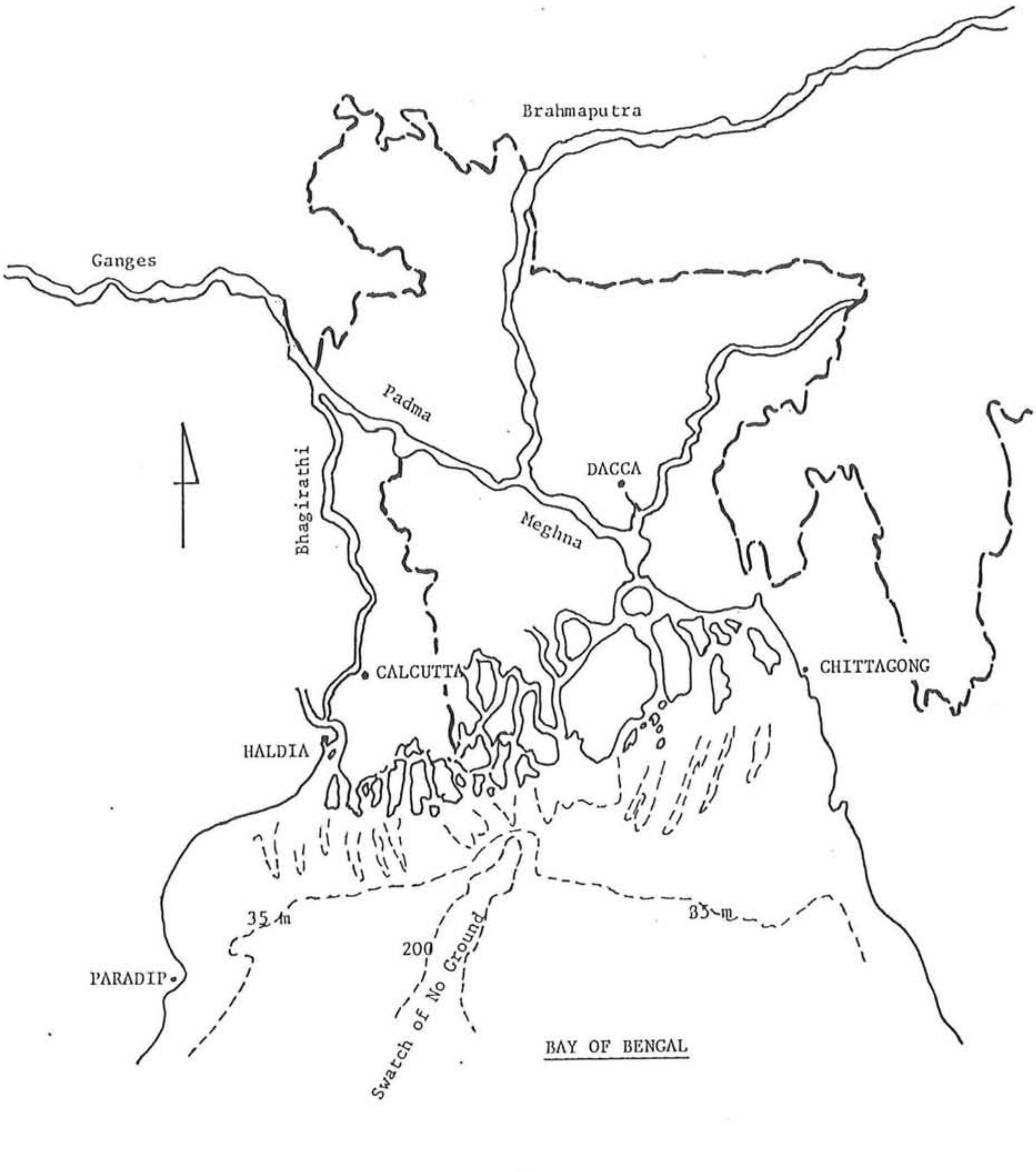


Figure 11: Ganges delta and the Bay of Bengal

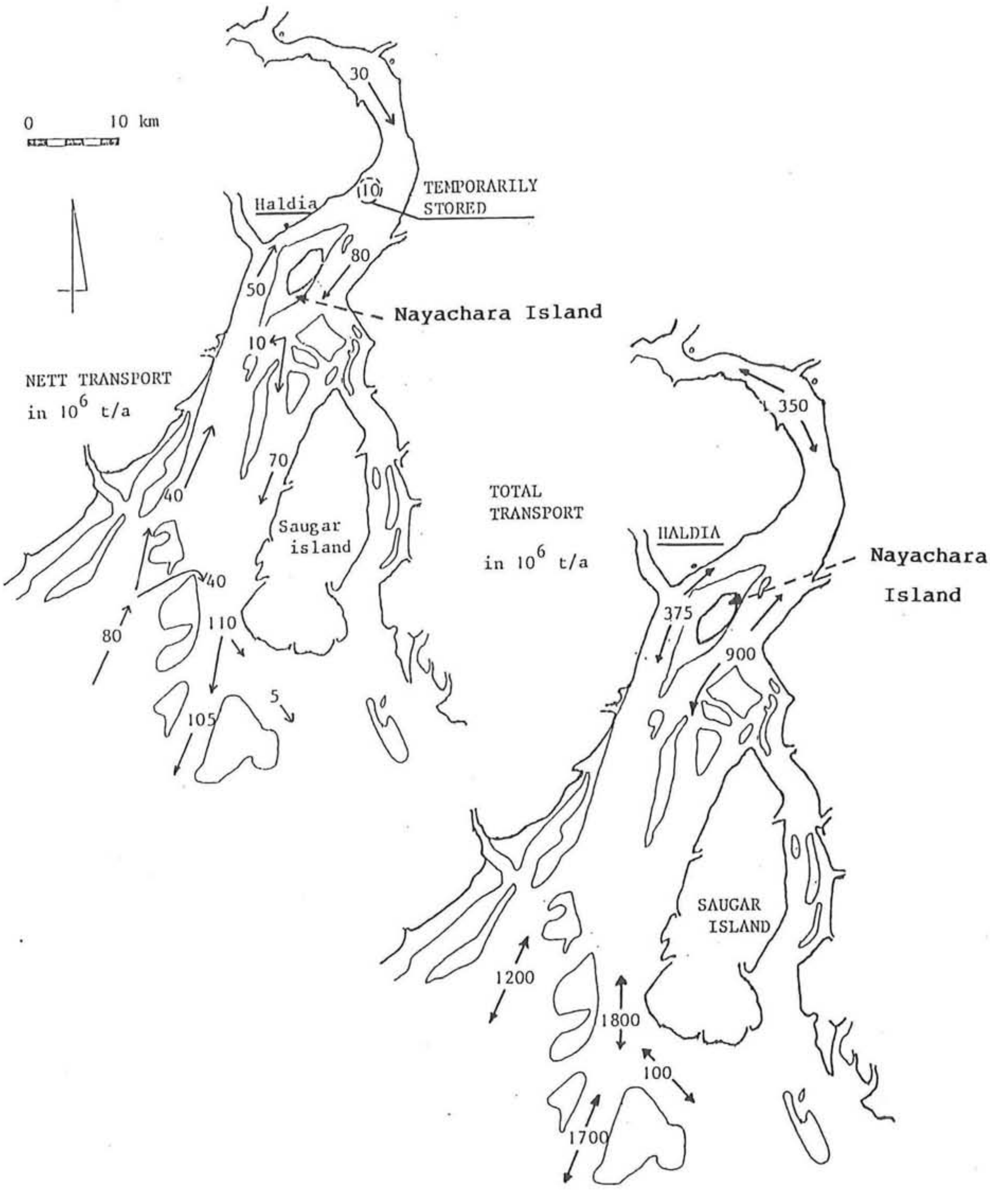
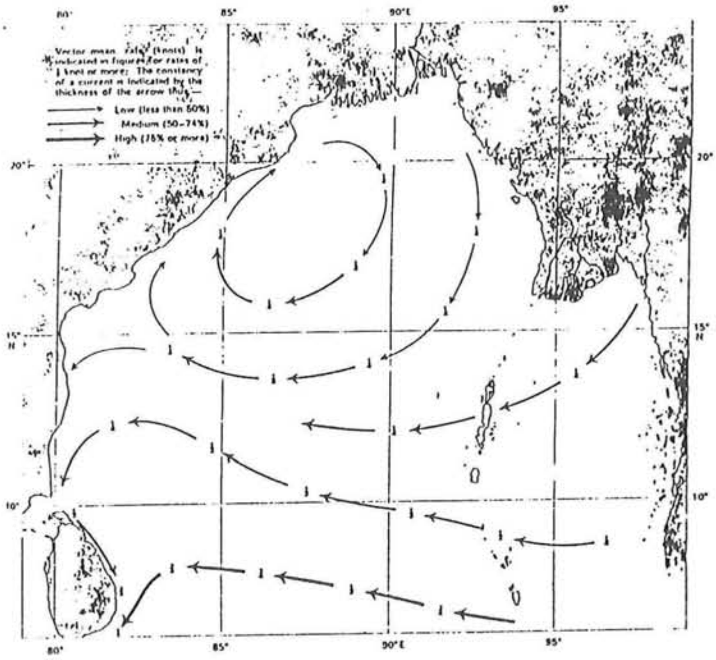
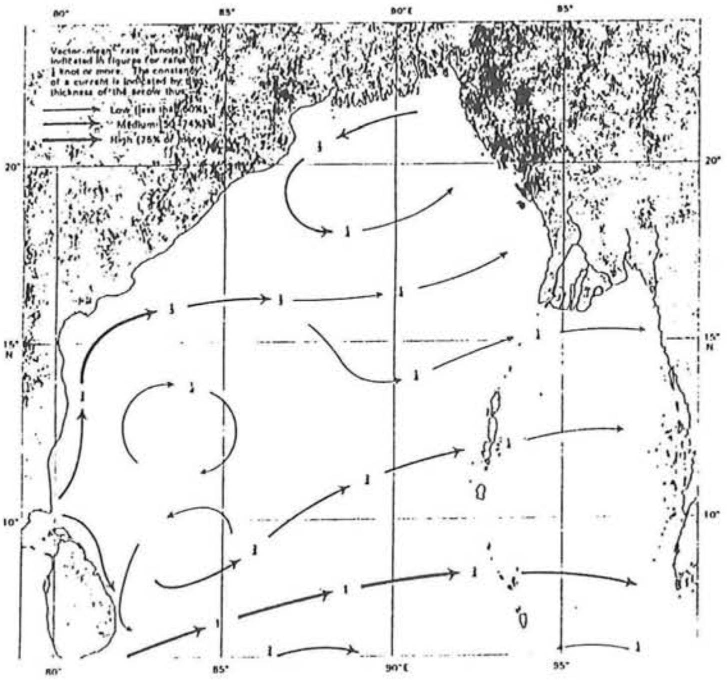


Figure 12: Nett- and Total transport of sediments



Vector-mean currents during January.



Vector-mean currents during July.

Figure 13: Currents in the Bay of Bengal

Boretide in the River Hooghly overturns a floating gangway

Boretide in the River Hooghly

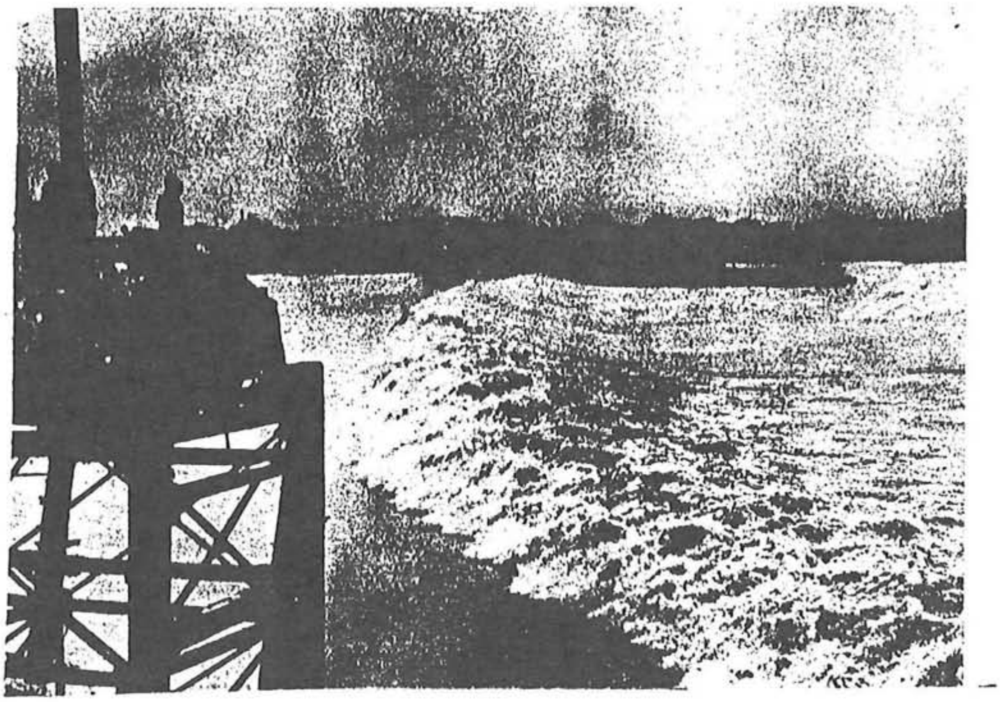


Figure 14: Bore tide in the river Hooghly

Table 5.

Windforce, description of circulation and windspeed

windforce Beaufort	description of circulation	windspeed km/hr
0 to 7	tropical depression	0 to 61
8 to 9	tropical storm	62 to 87
10 to 11	cyclonic storm	88 to 120
above 12	cyclone	above 120

Table 6.

Storms recorded in a recent 50-year period

Months	J	F	M	A	M	J	J	A	S	O	N	D	Total
Storms force 8 or more	4	1	6	14	21	24	23	16	22	32	39	20	222
Severe Storms force 10 or more	1	0	3	8	13	3	5	2	7	14	16	5	77

Table 7.

Wind, rain and temperatures data at Saugar Island

PLACE—SAGAR ISLAND. LAT. 21° 39′ N. LONG. 88° 03′ E. Height above Mean Sea Level—3 m
Climatic Table compiled from 28 to 30 Years' Observations, 1931 to 1960

Month	Average pressure at MSL 0800 ϕ	Temperature: Mean daily max.	Temperature: Mean daily min.	Temperature: Mean highest in each month	Temperature: Mean lowest in each month	Average humidity 0800	Average humidity 1700	Average Cloud cover 0800	Average Cloud cover 1700	Precipitation: Average fall	Precipitation: No. of days with 2·5 mm or more
	mb	°C	°C	°C	°C	%	%	Oktas		mm	
January	1016	25	16	28	12	79	63	1	1	14	1
February	1014	27	19	30	13	78	66	2	2	22	2
March	1011	30	24	34	18	75	73	3	2	21	2
April	1008	31	26	34	21	77	78	4	4	42	3
May	1004	32	27	33	22	79	79	5	5	128	6
June	1000	32	27	34	24	83	81	6	6	250	12
July	1000	30	27	32	24	86	83	6	6	409	17
August	1001	30	27	32	24	86	83	6	6	410	17
September	1005	30	27	32	24	84	82	6	6	329	14
October	1010	30	25	32	22	81	77	5	5	240	9
November	1014	28	20	30	17	76	68	2	3	35	2
December	1016	25	16	28	13	76	64	1	1	8	1
Means	1008	29	23	36*	11**	80	75	4	4	—	—
Totals	—	—	—	—	—	—	—	—	—	1908	86
Extreme Values	—	—	—	40†	7††	—	—	—	—	—	—
No. of years' observations	30										

Month	Wind direction 0800, percentage of observations from: N	NE	E	SE	S	SW	W	NW	Calm
January	39	34	4	2	2	5	2	9	3
February	24	19	5	2	9	18	7	12	4
March	11	7	2	2	17	43	9	7	2
April	2	2	1	2	30	55	6	2	0
May	1	2	3	6	36	48	2	1	1
June	2	4	5	9	30	40	7	2	1
July	3	6	7	9	20	42	9	4	0
August	5	7	7	10	19	37	9	4	2
September	7	11	9	13	21	24	7	5	3
October	25	25	7	5	18	11	6	11	2
November	44	31	5	1	0	2	2	15	0
December	49	31	2	1	1	2	1	12	1
Means	18	15	5	5	16	27	6	7	1
Totals	—	—	—	—	—	—	—	—	—
Extreme Values	—	—	—	—	—	—	—	—	—
No. of years' observations	28								

Month	Wind direction 1700, percentage of observations from: N	NE	E	SE	S	SW	W	NW	Calm	Mean wind speed 0800	Mean wind speed 1700	No. of days with gale	No. of days with fog	No. of days with thunder
										Knots		‡		
January	29	12	1	5	25	18	3	6	1	6	5	0	9	⊕
February	12	7	1	8	43	23	2	3	1	7	8	0	3	1
March	3	2	0	10	57	26	1	1	0	9	11	⊕	1	2
April	1	1	0	8	59	29	1	1	0	13	15	1	0	3
May	1	1	1	15	56	25	1	0	0	14	16	2	0	5
June	1	1	2	18	45	29	3	1	0	11	13	0	0	0
July	1	1	3	16	36	36	6	1	0	13	13	6	0	3
August	1	1	3	17	37	32	1	2	2	11	11	8	0	8
September	4	3	5	19	27	24	4	2	2	8	8	0	0	6
October	18	14	7	10	17	16	4	7	7	7	5	0	⊕	3
November	38	17	2	1	8	13	5	11	5	6	5	0	⊕	⊕
December	40	15	1	2	12	15	5	8	2	u	5	0	5	⊕
Means	12	6	2	11	36	24	3	4	2	9	10	—	—	—
Totals	—	—	—	—	—	—	—	—	—	—	—	4	19	34
Extreme Values	—	—	—	—	—	—	—	—	—	—	—	—	—	—
No. of years' observations	28									28	28	30		

*Mean of highest each year.
**Mean of lowest each year.

†Highest recorded temperature.
††Lowest recorded temperature.

⊕Rare.
‡Force 8 or more.
ϕAverage decrease of 3 mb by 1700.

Table 7.

Wind, rain and temperatures data at Calcutta

PLACE—CALCUTTA. LAT. 22° 32′ N. LONG. 88° 20′ E. Height above Mean Sea Level—6 m

Climatic Table compiled from 28 to 30 Years' Observations, 1931 to 1960

Month	Average pressure at MSL 0800 ϕ	Temperature: Mean daily max.	Temperature: Mean daily min.	Temperature: Mean highest in each month	Temperature: Mean lowest in each month	Average humidity: 0800	Average humidity: 1700	Average Cloud cover: 0800	Average Cloud cover: 1700	Precipitation: Average fall	Precipitation: No. of days with 2·5 mm or more
	mb	°C	°C	°C	°C	%	%	Oktas		mm	
January	1017	27	14	30	10	78	56	2	2	14	1
February	1014	29	17	34	12	75	48	2	2	24	2
March	1011	34	22	38	16	71	46	2	2	27	2
April	1008	36	25	40	21	71	56	3	3	43	3
May	1004	36	26	40	22	74	67	4	4	121	6
June	1000	34	27	38	24	80	77	6	6	259	12
July	999	32	26	35	24	84	82	7	7	301	17
August	1001	32	26	34	24	85	83	7	7	306	18
September	1005	32	26	35	24	84	82	6	6	290	14
October	1010	32	24	34	20	80	77	4	4	160	8
November	1014	29	18	32	15	74	67	2	2	35	1
December	1016	27	14	29	11	76	63	1	1	3	⊕
Means	1008	22	32	41*	10**	78	67	4	4	—	—
Totals	—	—	—	—	—	—	—	—	—	1583	84
Extreme Values	—	—	—	44†	7††	—	—	—	—	—	—
No. of years' observations											

Month	0800 N	0800 NE	0800 E	0800 SE	0800 S	0800 SW	0800 WW	0800 NW	0800 Calm	1700 N	1700 NE	1700 E	1700 SE	1700 SS	1700 SW	1700 W	1700 NW	1700 Calm	Mean wind speed 0800	Mean wind speed 1700	No. of days with gale	No. of days with fog	No. of days with thunder
																			Knots		†		
January	18	13	4	2	1	2	2	11	47	13	1	1	1	3	5	3	17	56	1	1	⊕	9	1
February	12	9	3	3	4	12	6	12	39	10	1	1	5	9	15	11	21	29	2	3	⊕	7	2
March	6	4	2	3	12	36	9	18	10	5	1	1	4	22	26	8	11	22	3	3	0	3	4
April	1	1	1	6	21	51	6	3	10	2	1	2	6	40	32	3	2	12	5	5	⊕	⊕	6
May	1	3	6	10	33	36	3	1	7	1	2	5	11	46	28	1	2	4	5	6	2	0	11
June	1	4	11	6	24	26	4	1	13	1	2	7	19	38	19	3	1	10	4	4	2	0	13
July	1	5	14	16	19	29	4	1	11	0	1	6	20	33	24	3	1	12	4	4	0	0	9
August	1	5	17	14	17	25	4	2	15	1	2	7	19	30	21	3	1	16	3	3	0	0	12
September	2	7	14	17	13	17	5	4	21	1	3	8	15	20	18	3	3	29	3	3	⊕	⊕	16
October	11	15	8	5	4	10	4	10	33	8	4	5	7	8	9	3	9	47	2	2	0	⊕	9
November	21	11	3	1	0	2	3	14	45	12	3	2	1	1	1	1	11	68	1	1	0	2	1
December	27	8	2	1	0	1	1	16	44	11	1	1	1	1	1	1	12	71	1	1	0	4	1
Means	9	7	7	8	12	21	4	7	25	5	2	4	9	21	16	4	8	31	3	3	—	—	—
Totals	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	26	85
Extreme Values	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
No. of years' observations																							

*Mean of highest each yerar.
**Mean of lowest each year.

†Highest recorded temperature.
††Lowest recorded temperature.

†Force 8 or more.
⊕Rare
ϕ Average decrease of 3 mb by 1700.

Table 8.

Vessels observed in Haldia and Calcutta in 1985/86

<u>Haldia</u>

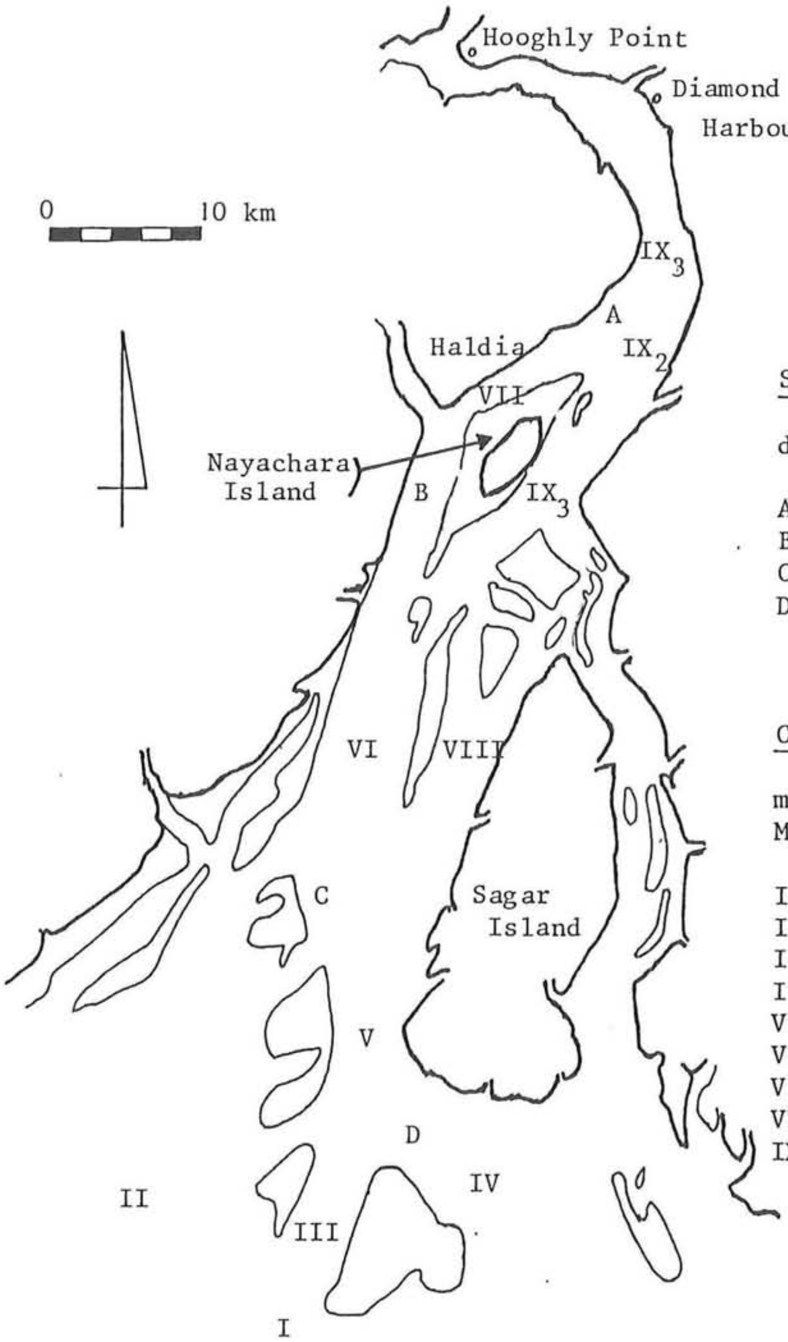
	DWT	LOA	B	D
Breakbulk				
Opatija Yugoslavia	11,869/ 15,142	148.01	20.65	8.999
Bulkcarrier				
General Segundo Filippines	34,541	180.02	28.45	10.891
Teleorman Romania	6,136/ 8,750	130.77	17.68	6.601/ 8.100

<u>Calcutta</u>

	DWT	LOA	B	D
Breakbulk				
Mupo North Korea	11,810	139.68	19.26	8.370
Container				
Calaber Germany	7,822 500 TEU	125.33	18.55	5.884
Bulkcarriers				
Sincere no. 5 Liberia, Morovia	17,567	153.04	22.26	8.992
Sunny Ocean Japan	18,611	152.53	22.89	9.170
Fortune Falcon Maldives	19,804	156.17	22.66	9.541

Other container vessels:

	DWT	LOA	B	D
largest feeder	13,193 846 TEU	146.5	22.23	8.08
smallest feeder	3.827 229 TEU	91.3	14.80	5.70



SANDBARS:

depth below MLWS in m

A - Balari bar		2.5
B - Jellingham bar		5.3
C - Auckland bar		4.0
D - Middleton Bar		6.1

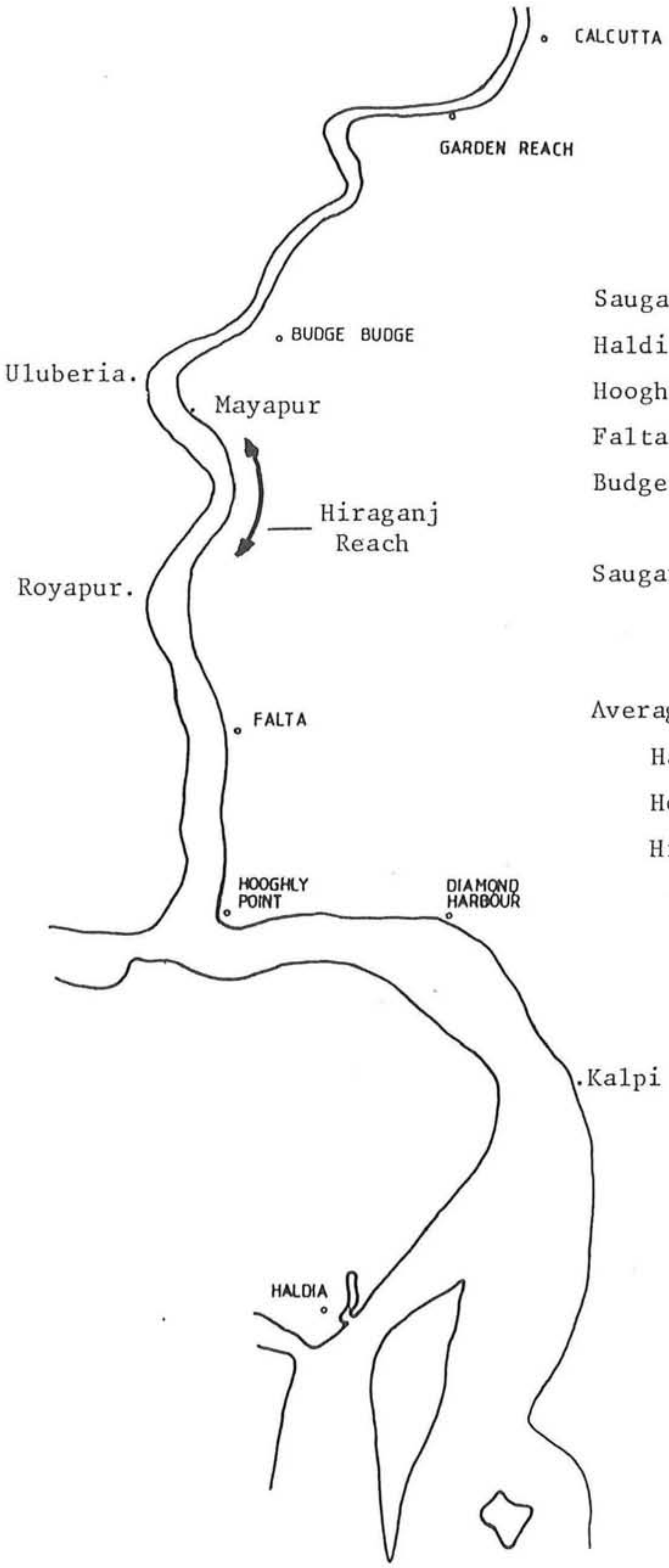
CHANNELS:

maximum depth below MLWS in m

I	- Eastern	
II	- Western	
III	- Beaumonts Gut	13.7
IV	- Gaspar	10.6
V	- Saugar Roads	20.4
VI	- Jellingham	8.5
VII	- Haldia	12.2
VIII	- Bedford	8.5
IX	- Rangafala -1	11.8
	-2	6.7
	-3	34.0

Source: (9)

Figure 15: Channels and sandbars in the estuary



Saugar Roads	- Haldia	40 km
Haldia	- Hooghly Point	43 km
Hooghly Point	- Falta	8 km
Falta	- Budge Budge	31 km
Budge Budge	- Calcutta Docks	23 km
		------ +
Saugar Roads	- Calcutta	145 km

Average width of channel:

Haldia channel 1000 m

Hooghly Point - Hiraganj 800 m

Hiraganj - Calcutta 400 m

Figure 16: Hooghly river between Haldia and Calcutta

Table 9.

Berth occupancy in Haldia and Calcutta in recent years

Calcutta

Sections/berths	Berth occupancy in percentage		
	1983/84	1984/85	1985/86
KP-dock			83.3
coal berths	75.6	62.4	39.8
other berths	73.9	70.7	-
NS-dock			
berth 1	53.9	77.7	88.7
berth 2, 3, 4, A, B	87.8	85.6	87.3
berth 5, D containers	54.3	68.9	77.2
berth C	38.0	29.7	41.8
Budge Budge jetties	9.3	41.3	42.2

Haldia

Sections/berths	Berth occupancy in percentage		
	1983/84	1984/85	1985/86
Bulk			
iron ore berth	36	41	47
coal berth	86	90	79
phosphate berth	45	72	75
General cargo/container berth	78	91	94
Oil jetty	62	63	75

Table 10.

Turn around time in Haldia and Calcutta in recent years

Calcutta

Kind of vessels	Turn around time in days			pre-berthing detention in days		
	83/84	84/85	85/86	83/84	84/85	85/86
Bulk						
Tanker	5.33	6.25	--	--	--	--
crude oil	--	6.13	4.19	0.3	0.34	0.02
oil products	--	6.78	5.15	0.9	0.33	0.05
Coal/salt	30.38	40.47	49.17	1.3	3.86	0.80
Fertilizer (finished)	15.30	23.94	27.85	0.3	1.47	4.83
Fertilizer (raw)	11.20	14.37	22.08	1.2	1.52	6.45
Foodgrain vessels	22.43	31.28	--	4.8	5.5	--
General cargo vessels	13.77	17.52	19.83	0.6	0.7	2.83
Containers	6.11	6.19	5.48	0	0.09	0.20
All combined	14.23	15.30	15.91	1.2	0.82	1.88

Haldia

Kind of vessels	Turn around time in days			pre-berthing detention in days		
	83/84	84/85	85/86	83/84	84/85	85/86
Bulk						
Tanker crude oil	2.60	2.53	2.73	0.5	0.34	0.56
oil products	3.90	4.07	3.67	1.5	1.32	0.89
Coking Coal	--	13.75	10.39	--	7.33	2.03
Colliers	11.94	12.97	6.44	6.8	7.32	1.33
Fertilizer (finished)	17.62	40.25	40.19	2.5	5.68	6.33
Fertilizer (raw)	20.53	23.34	45.01	1.5	7.28	14.90
General cargo vessels						
Sugar	--	--	--	--	1.25	8.28
Other	--	--	--	--	4.14	6.51
Containers	2.89	3.52	4.29	0.1	0.18	0.26
All combined	7.14	8.22	6.71	2.4	2.69	1.56

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Source: [2]

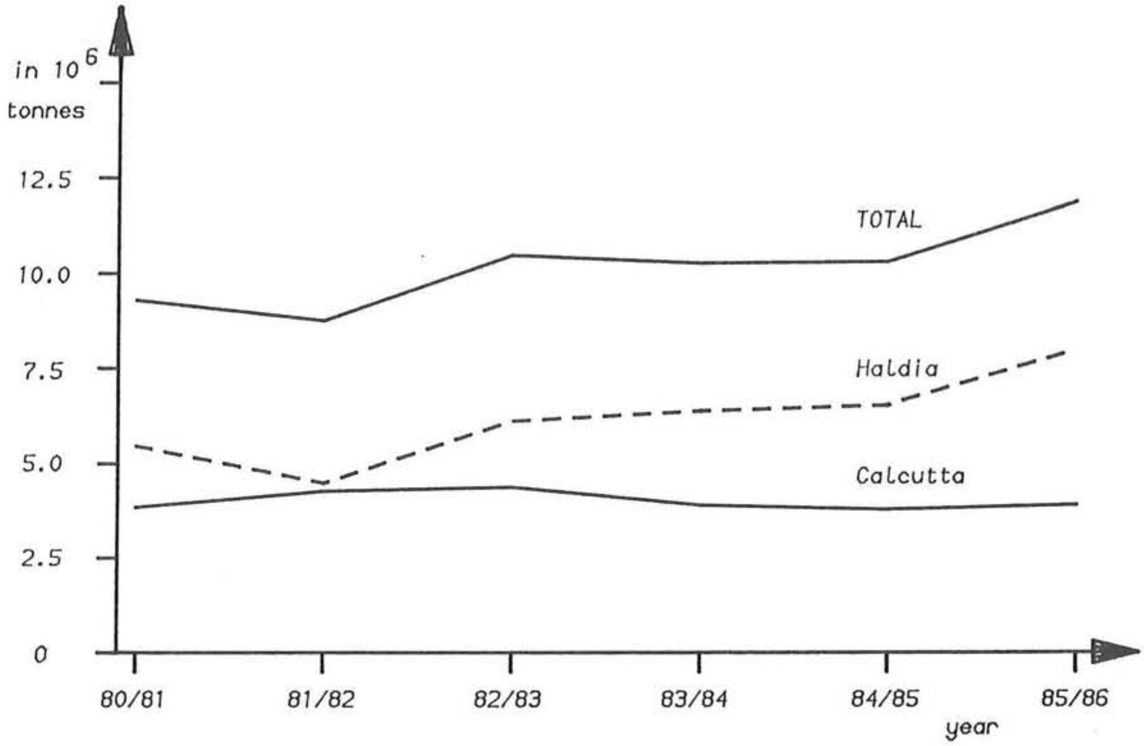

Figure 17: Cargo throughput in Haldia and in Calcutta

Table 11.

Productivity in the ports of Haldia and Calcutta

Calcutta

Traffic class	Commodity	Average output Tonnes/ hook/shift 1983/84	1984/85	1985/86	Average output Tonnes/ ship/day 1983/84	1984/85	1985/86	Highlights Tonnes/ ship/shift	Where	When shift
dry bulk	fertilizer finished product	81.3	66.6	64.7	819	680	602			
	fertilizer raw material rock phosphate	105.0	115.2	91.0	990	924	750	350	B NSD	1st 16-2-84
	foodgrain	93.1	93.6	0	881	723		442	23 KP	2nd 16-4-84
	sugar	110.3	154.9	93.5				360	23 KP	1st 16-2-84
	cement	127.6	116.3	124.4				305	25 KP	1st 16-2-84
	coal/salt				1213	630	474			
general cargo		66.0	69.8	69.3	610	627	523			
	import							475	1 NSD	1st 18-4-84
	export							337	1 KP	3rd 26-10-84
	steel							475	1 NSD	1st 4-11-84
liquid bulk					2310	3031	3365			
container		169.9	202.7							
	import							1215	D NSD	3rd 16-2-85
	export							1016	D NSD	3rd 15-1-85

Source: [2]

Table 11.

Productivity in the ports of Haldia and Calcutta

Haldia

Traffic class	Commodity	Average output Tonnes/ hook/shift 1983/84	1984/85	1985/86	Average output Tonnes/ ship/day 1983/84	1984/85	1985/86	Highlights Tonnes/ ship/shift	Where	When shift
	fertilizer finished	69	53	--						
	fertilizer raw	92	69	--						
bulk	coal				5808	4918	6173			
	fertilizer finished+raw	--	50.4	46.4	674	506	413			
bagged	fertilizer finished+raw	--	118.7	125.5	675	400	255	280		day 12-12-84
	coking coal	441	343	333	3192	3240	2443	598		night 16-3-85
general cargo		77	85							
	including containers		103.2	148.9						
	paper reels							148		day 17-4-84
	sugar	99	84	145.5				195		day 16-12-84
	cement	106	109	104				86		day 21-6-85
container		25 TEU	26 TEU					78 TEU		afternoon 19-4-84
liquid	POL, crude				26626	33811	25571			

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Source: [2]

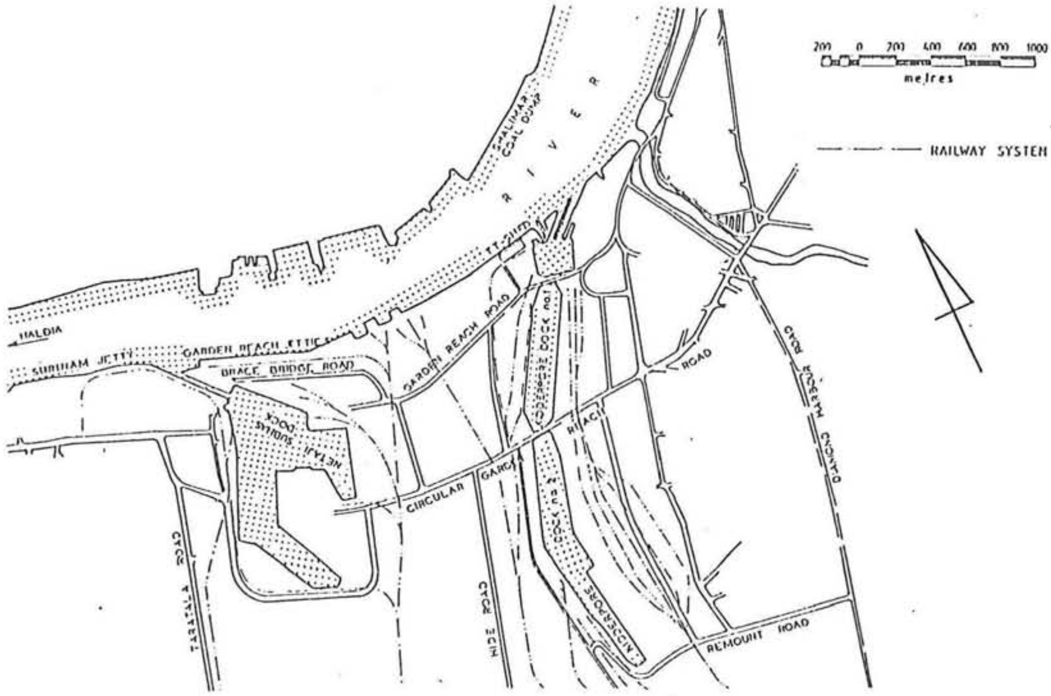


Figure 18: Survey of the whole port complex in Calcutta

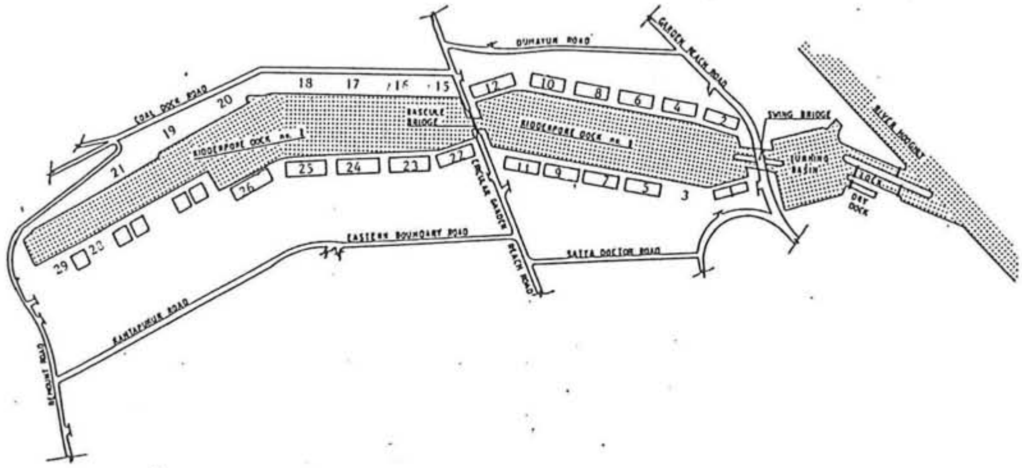


Figure 19: Lay-out Kidderpore Dock

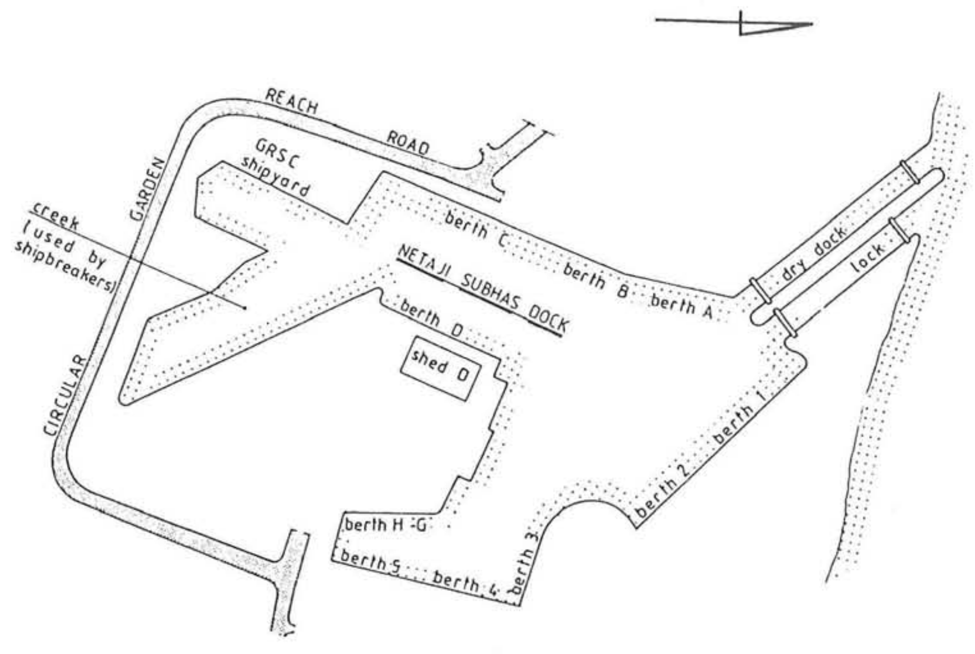


Figure 20: Lay-out Netaji Subhas Dock

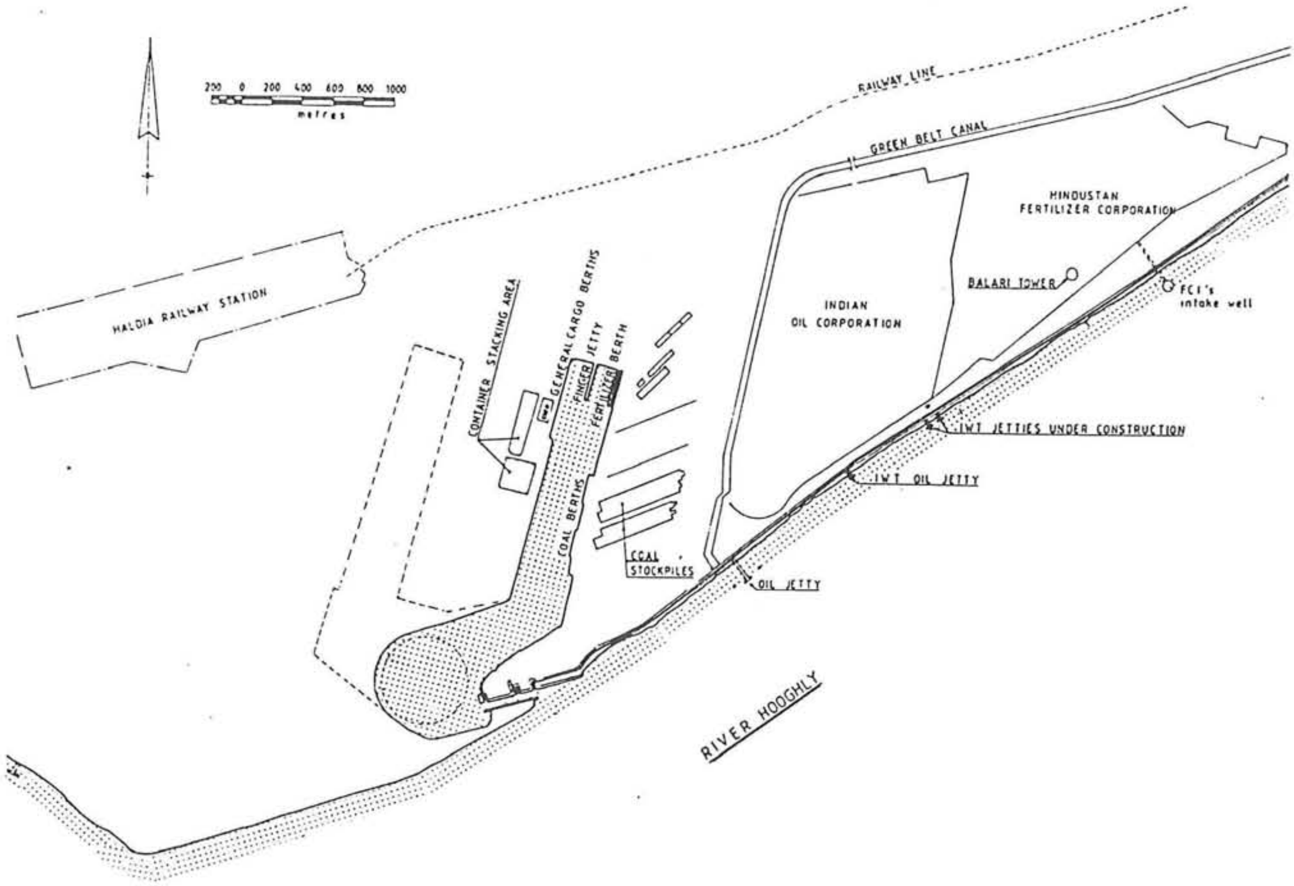


Figure 21: Lay-out dock complex in Haldia

Table 12.

Number and categories of CPT employees in recent years

Category employees	total strength as on		Calcutta		Haldia	
	1-1-83	1-1-84	1-1-83	1-1-84	1-1-83	1-1-84
class I	836	791	733	703	103	88
class II	225	256	156	155	99	101
class III	13,447	13,547	11,973	12,048	1,504	1,501
class IV	16,663	17,951	15,017	16,347	1,646	1,604
Total	31,231	32 545	27,879	29,235	3,352	3,294

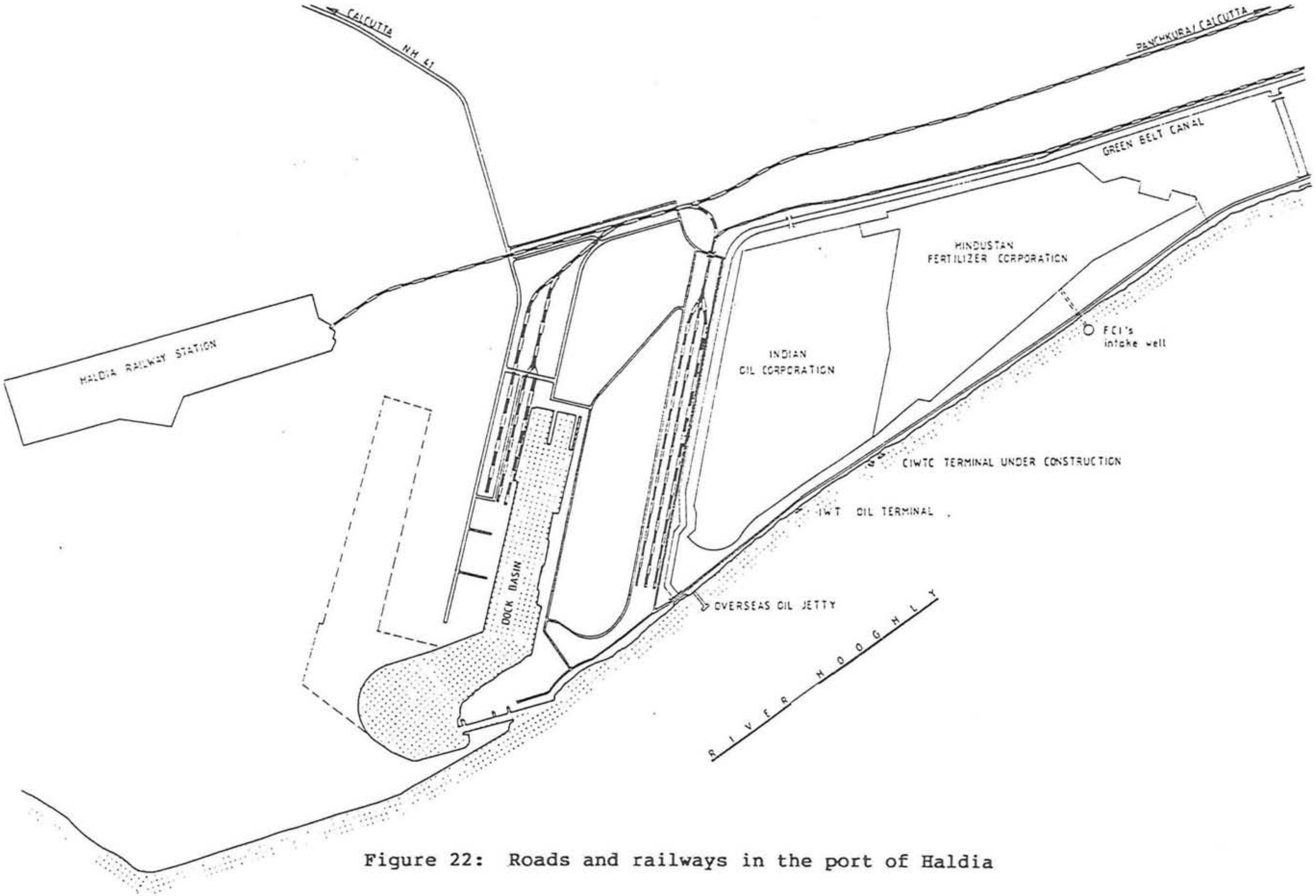


Figure 22: Roads and railways in the port of Haldia

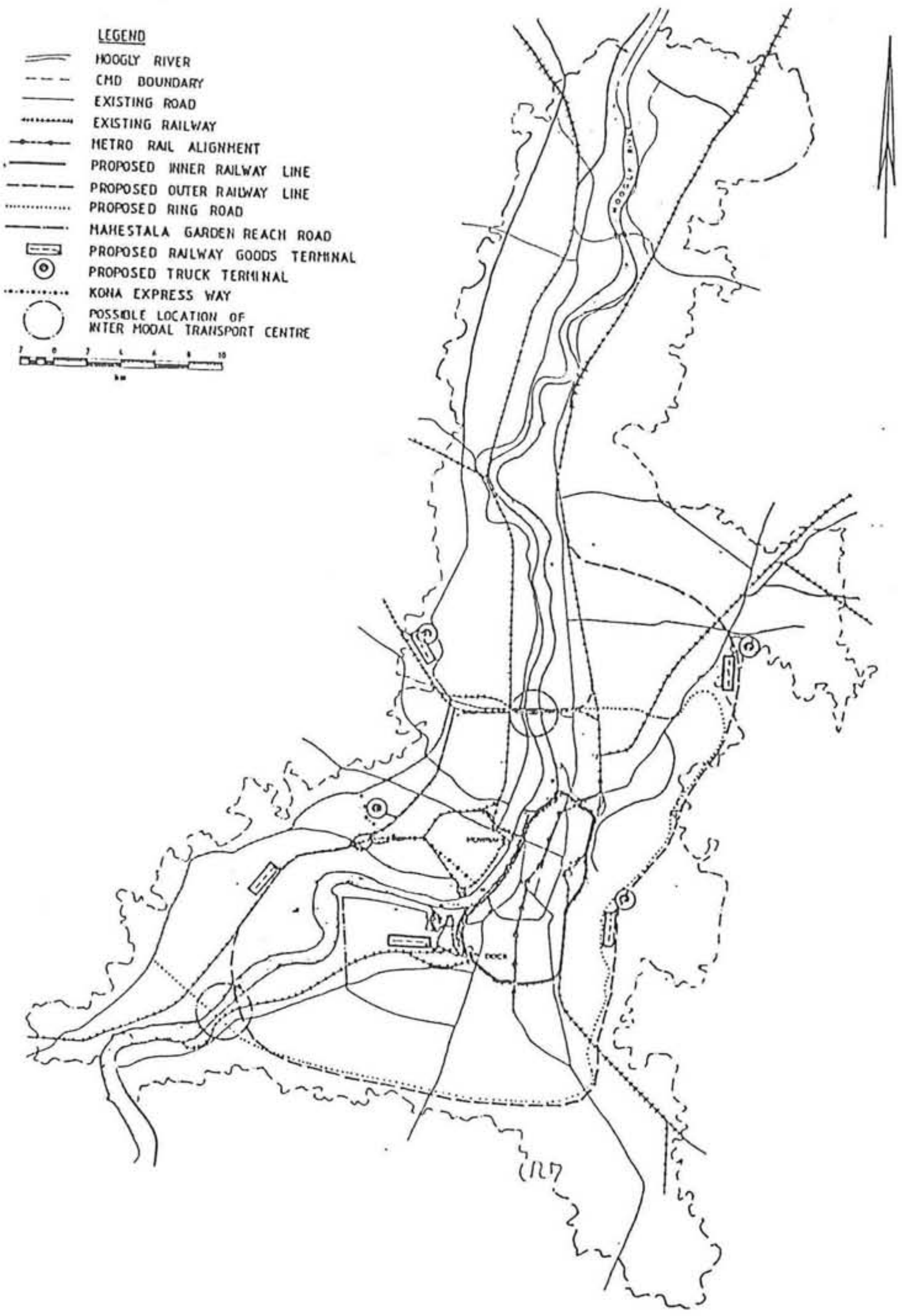


Figure 23: Infrastructure proposed by the CMDA

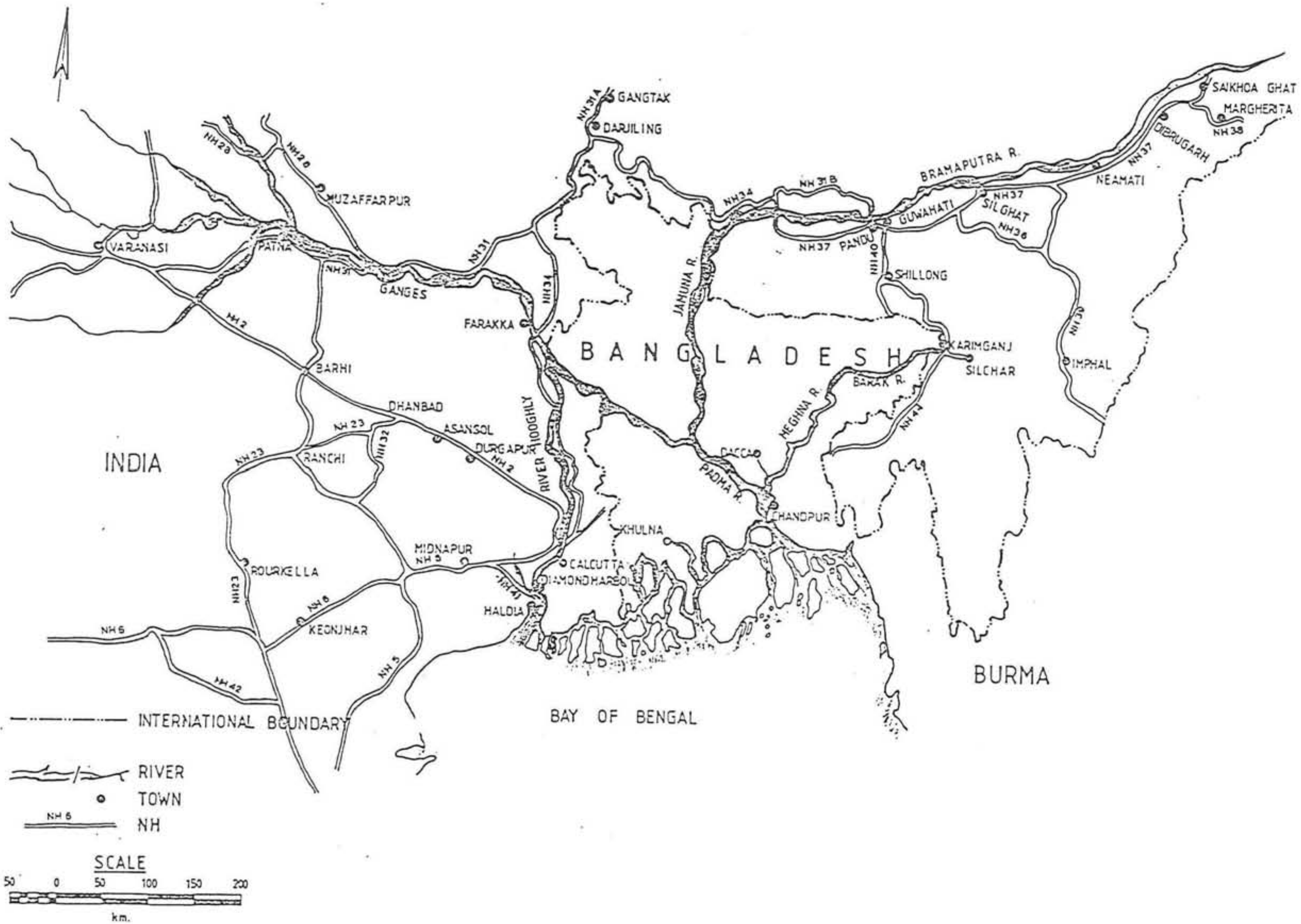


Figure 24: National Highway system in northeastern India

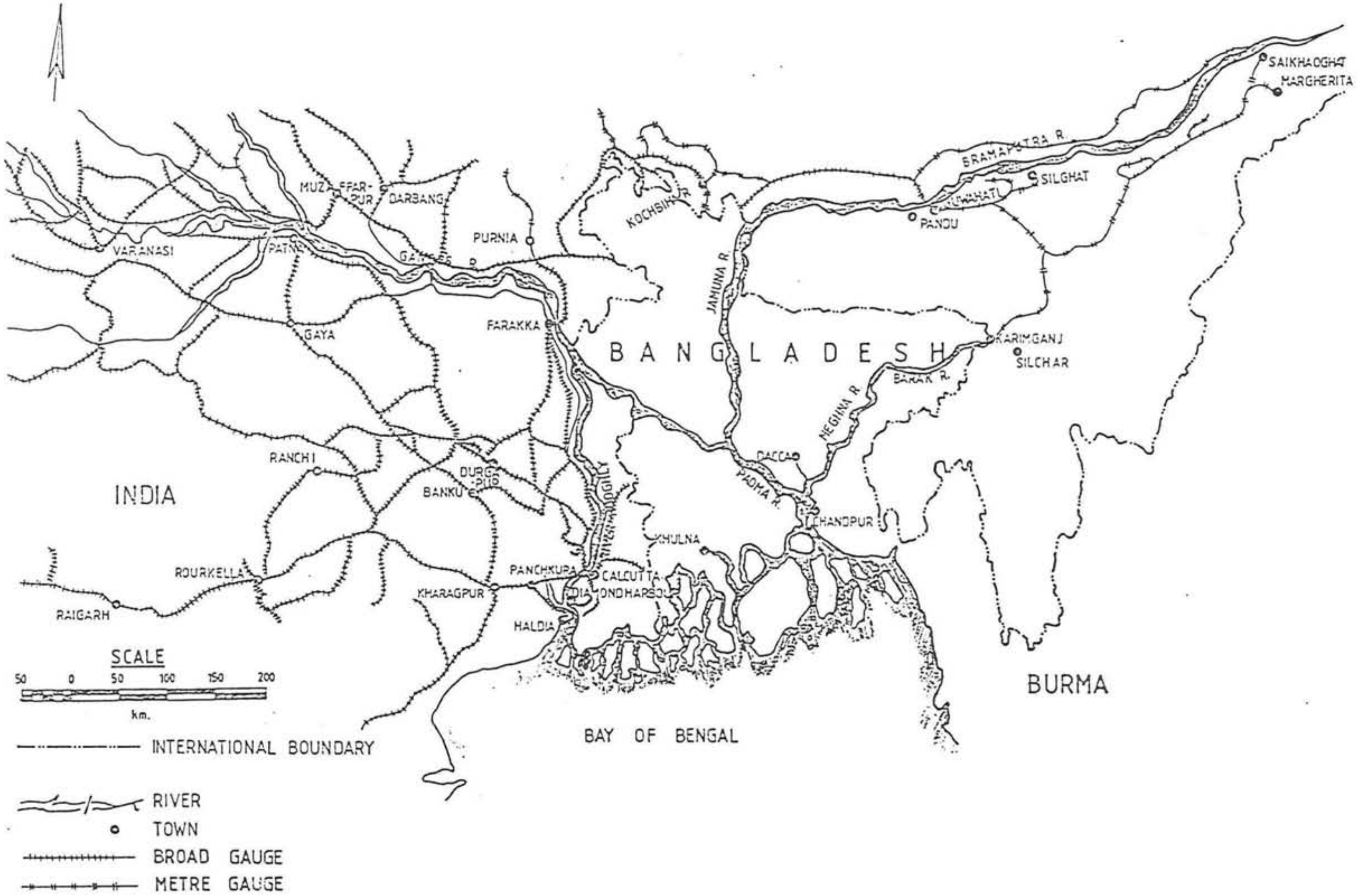


Figure 25: Railway system in northeastern India

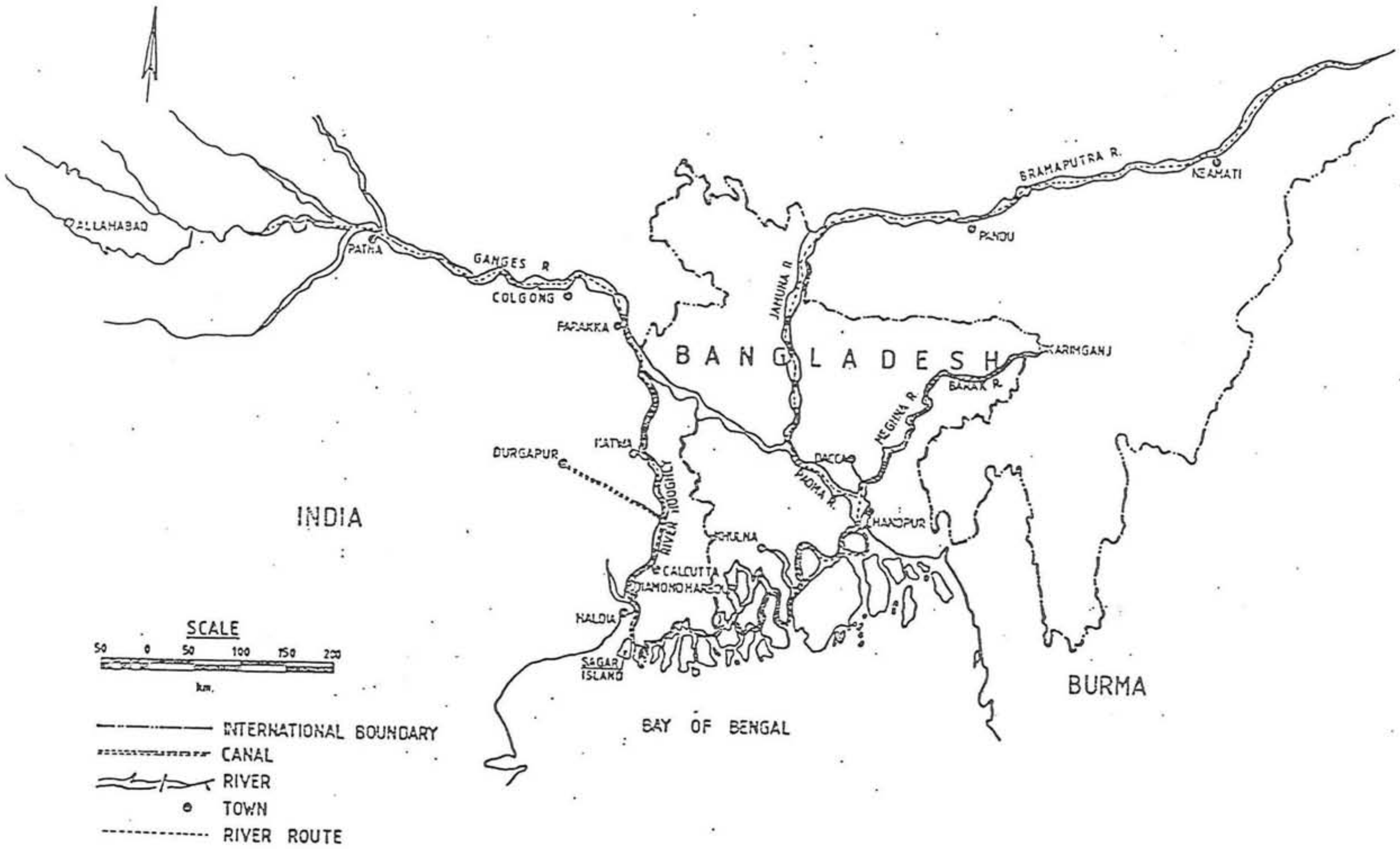


Figure 26: Inland waterways in northeastern India

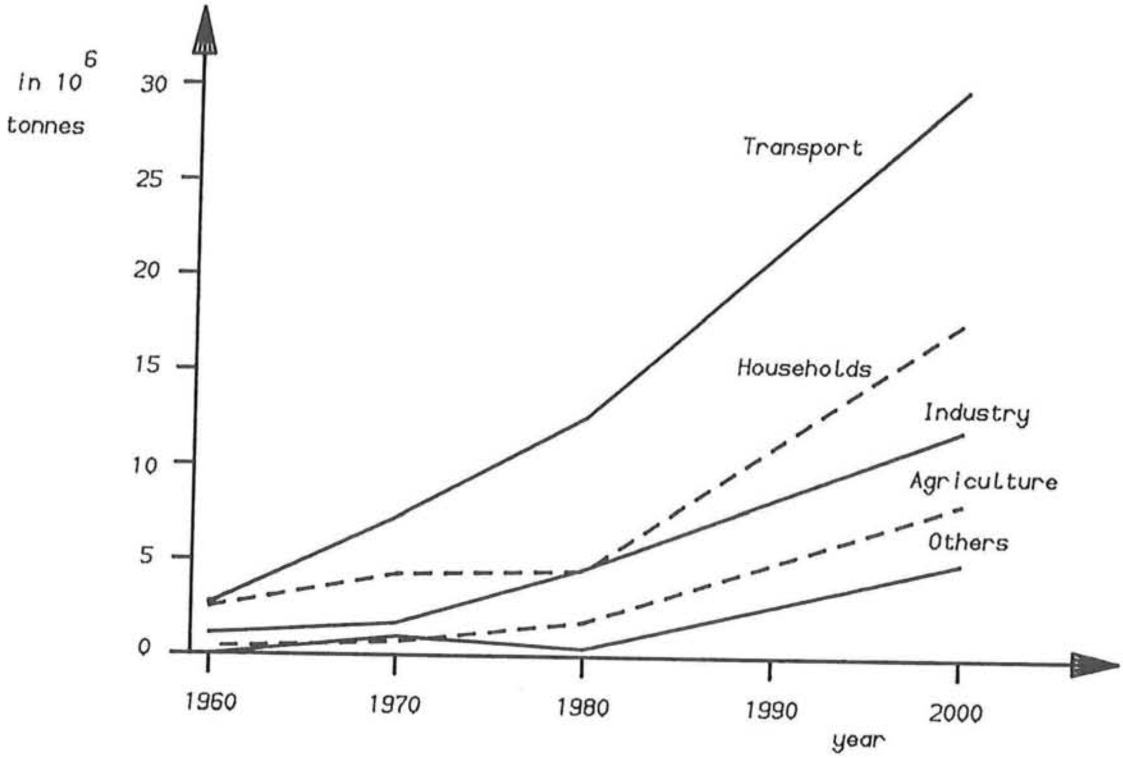


Figure 27: Oil distribution over several sectors of Indian society

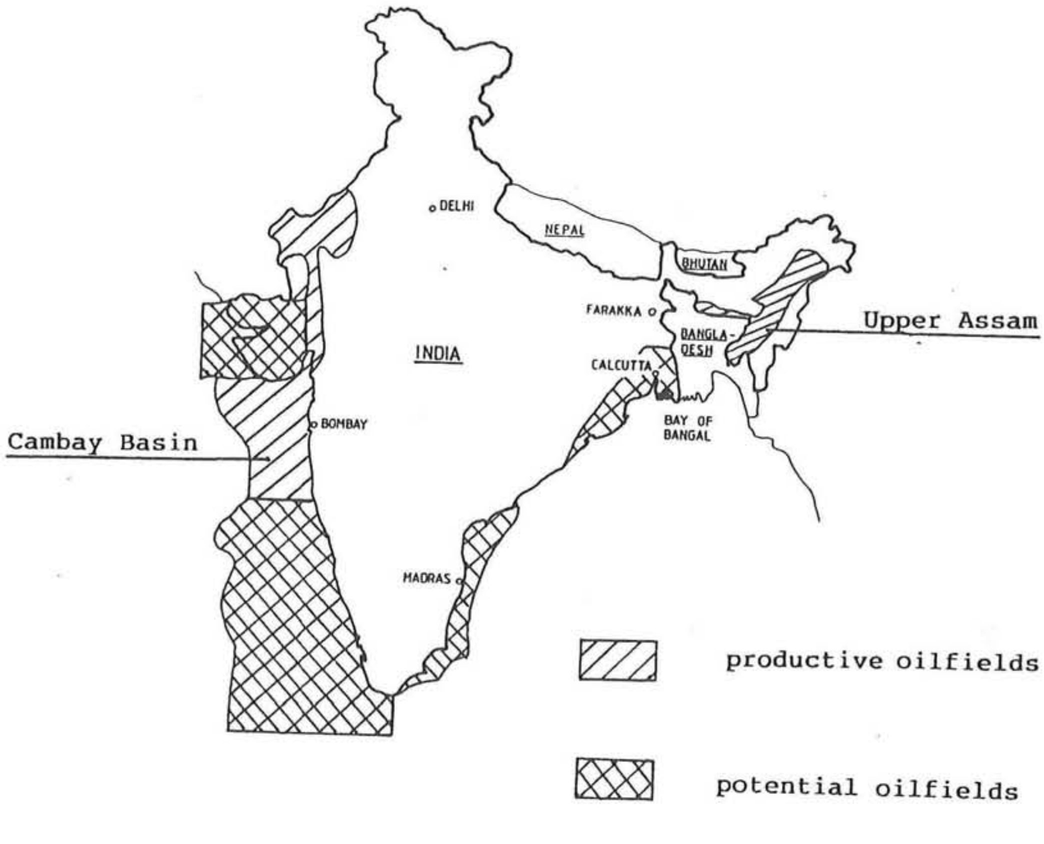


Figure 28: Location of productive and potential oilfields

Table 13.

Domestic production, import and export of POL

Performance of POL handling in ports.

Year in 10**6 Tonnes/annum	80/81	81/82	82/83	83/84	84/85	89/90	1999/2000
Domestic Production							
crude oil	10.5	16.2	21.1	26.0	29.0	34.5	40-50
refinery products	25.8	30.1	33.2	35.3	35.6	45.3	55-74
1 Total	36.3	46.3	54.3	61.3	64.6	79.8	95-124 A
2 Import	23.5	19.4	17.4	14.8	13.3	21.1	44-54
3 Export	-	0.1	0.8	1.5	0.9		
4 POL handled at major ports	33.6	34.2	46.3	47.5	49.7	67.4	96-122 C
Domestically produced oil that is handled in ports 5 figure= line4 - line2	10.1	14.8	28.9	32.7	36.4	46.3	52-68 B
6 figure= line1/line5 *100% average is 55%	28	32	53	53	56	58	

Source: Esin, 7th FYP.

Figures underlined and characterised by A are determined as follows:

growth rates in %	84/85-89/90	90/91-1999/2000
crude oil	3.6	1.5 - 3.7
refinery products	4.9	2.0 - 5.0 a

Assume that in the 2nd period the growth rate for refinery products will be again 4.9/3.6 times higher than the one for crude oil, this yields 2.0-5.0

Figures underlined and characterised by B are determined as follows:
- the average percentage of line 6 has been used to compute the missing figure for 1999/2000 in line 5

Figures underlined and characterised by C are determined as follows:
- addition of the values in line 2 and line 5

Table 14.

Growth rates of POL transport in Haldia

%	84/85-89/90	90/91-1999/2000
POL in major ports	6.2	3.8 - 6.1
Haldia and Calcutta	9.4	3.8 - 6.1

Table 15.

Import export ratio of POL

year	import	export	total	import	export
10**3	t	t	t	%	%
1983/84	4,015	739	4,754	84	16
1984/85	4,383	709	5,092	86	14
1985/86	5,235	824	6,059	86	14
			average	85	15

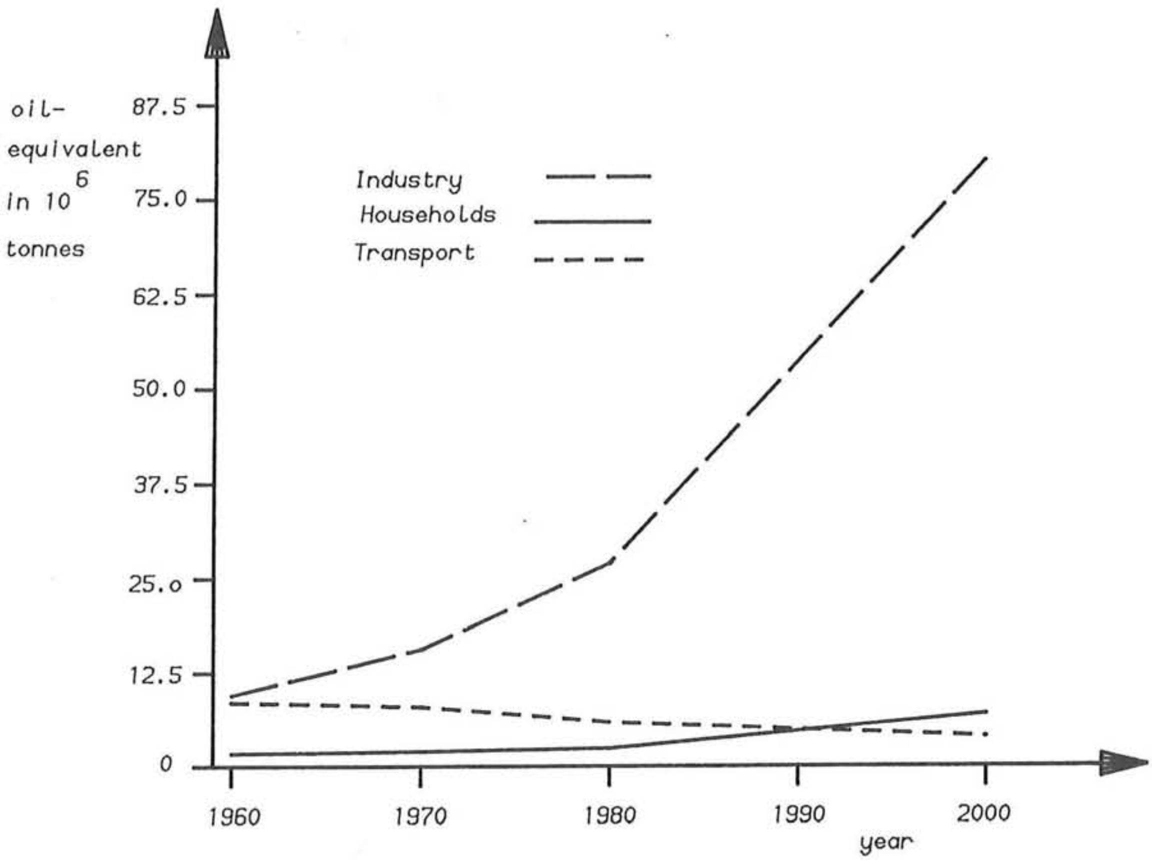


Figure 29: Coal distribution over several sectors of Indian society

Table 16.

Coal production in India and coal traffic in ports

Year 10**6 Tonnes/annum	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85		89/90		1999/2000
Domestic coal production	99.68	101.04	100.97	101.95	103.95	114.01	124.23	130.50	138.12	147.70		226		417
growth rates 7th FYP plan periods											8.9		6.3	
Coal traffic at major ports					2.05	2.40	2.81	3.28	3.84	4.49		10.55		
growth rate											18.3			
Coal at Calcutta	0.9	0.8	1.0	0.8	0.7	0.87	1.38	2.19	1.95	1.708				

Table 17.

Import export ratio coal

year 10**3 t	import t	export t	total t	import %	export %
1983/84	62	1,885	1,947	3	97
1984/85	46	1,662	1,708	3	97
1985/86	470	1,849	2,319	20	80
			average	9	91

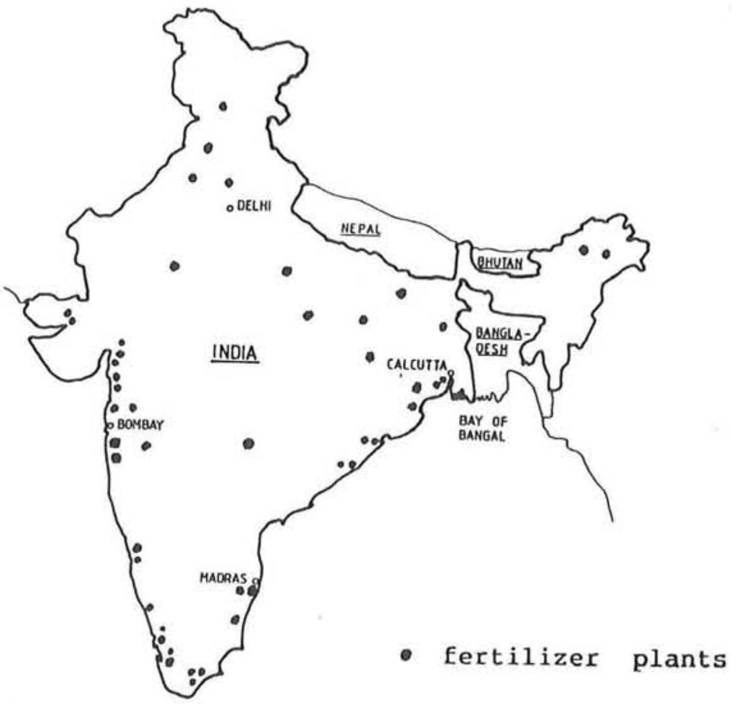


Figure 30 : Location of fertilizer plants in India

Table 18.

Domestic production and import traffic of fertilizer

Year	70/71	71/72	72/73	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85		89/90		1999/2000
In 10**3 Tonnes/annum																			
1 Domestic production	1059	1230	1386	1383	1512	1855	2380	2670	2940	2983	3005	4093	4404	4533	5181	11.8	8750	5.8	15580
2 Import	629	997	1197	1244	1602	1556	1051	1521	1987	2005	2759	2041	1132	1355	3624	6.6	5000		
TOTAL 1+2	1688	2227	2583	2627	3114	3411	3431	4191	4927	4988	5764	6134	5536	5888	8805		13750		
3 Handled in H&C	100	200	400	400	500	400	400	400	700	400	675	550	346	401	798		1375 ----		1960-2613 ---------
4 import *100% / H&C	16	20	34	32	31	26	38	26	35	20	24	27	31	30	22	average line 4 = 27.5			
5 import *100% / domestic	37	45	46	47	51	46	31	36	40	40	48	33	20	23	41		36		

The underlined figure for 1989/90 in line 3 has been calculated with the help of the average in line 4

An rectilineairly decreasing growth rate, from 6.60 in 1990/91 to 0.66 in 1999/2000, results in a factor of 1.42. Multiplying 1375 with 1.42 yields 1960.

An annual growth rate of 6.60 in the period from 1989/90 to 1999/2000 combined with the starting value of 1375 results in 2613.

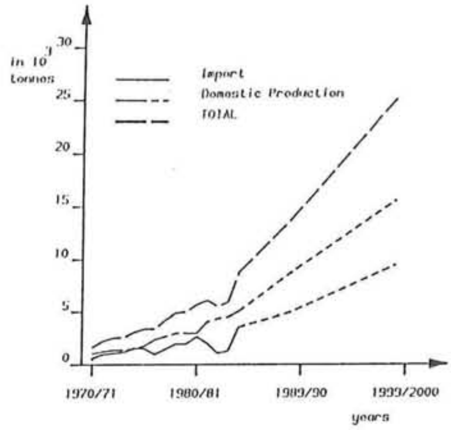


Figure 31: Domestic production and import of fertilizer

Table 19.

Ratio unloaded finished fertilizer to phosphate rock

	1983/84		1984/85		1985/86		average
	t	%	t	%	t	%	%
Finished fertilizer	207	52	560	70	471	61	69
Phosphate rock	194	48	238	30	300	39	31

Table 20.

Domestic production ,import and export of iron, steel and machinery in India and performance in Haldia

Year	79/80	84/85	89/90	94/95	1999/2000
In 10**6 Tonnes/annum					
Domestic demand			13.86	17.76	22
Domestic production	6.90	8.77	12.65	16.30	21
- growth rate in %		7.6	5.2		
Import	1.90	1.99	1.59	1.36*	1*
- growth rate in %		-4.4			
Export		0.15	0.38		
- growth rate in %		20			
Total import + export		2.14	1.97		
Handled in Haldia and Calcutta	0.60	0.395			

* without export

Table 21.

Forecast calculation iron, steel and machinery

for different growth rates.

in 10**6 Tonnes/annum	1979/80	1984/85	1989/90	1999/2000 5%	1999/2000 10%
import	1,90	1,99	1,59	1,61	1,99
export	n.a.	0,15	0,38	0,61	0,99
	+	+	+	+	+
total import and export	1,90	2,14	1,97	2,22	2,98
20% of total	0,38	0,43	0,39	0,44	0,60
transported in Haldia and Calcutta	0,60	0,40			

n.a. = not available

Table 22.

Import export ratio iron, steel and machineries

	year	import t	export t	total t	import %	export %
Iron & Steel	1983/84	6,651	2,458	9,109	73	27
	1984/85	6,925	1,773	8,698	80	20
	1985/86	33,190	7,326	40,516	82	18
				average	78	22

Table 23.

Jute production, export and handled quantities

Year	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85		89/90
Domestic production in 10**3 t/a	1382	1049	1064	1278	1287	1499	1433	1469	1507	1291	1390	1436		1625
-growth rate in %													3.5	
Export in 10**3 t/a	563	589	522	457	521	330	722	661	430	330	300	290		270
Export *100% / Production	41	56	49	36	40	22	50	45	29	26	22	20		17
Handled in Haldia and Calcutta in 10**3 t/a	700	600	700	500	600	400	600	571	560	357	205	292		

Source: [5,17,18]

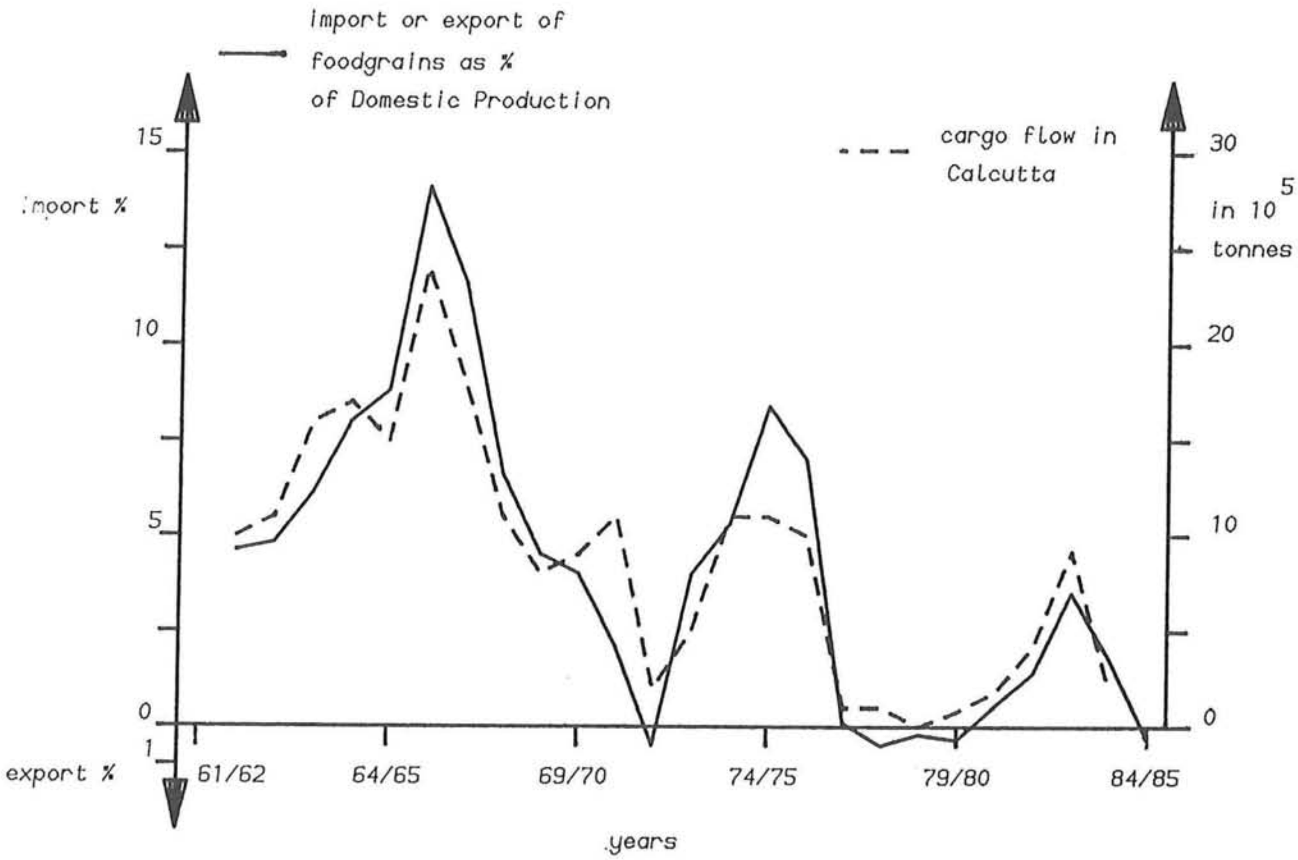


Figure 32: Import of foodgrains as a percentage of domestic production

Table 24.

Domestic tea production, export and cargoflow

Year	73/74	74/75	75/76	76/77	77/78	78/79	79/80	80/81	81/82	82/83	83/84	84/85		89/90
Domestic production in 10**3 t/a	454	471	468	530	533	515	520	571	561	565	585	645		766
- growth rate per annum in %													3.5	
- target								585	610	640	670	705		766
- % achievement average = 91.3%								97.6	92.0	88.3	87.3	91.5		
Export in 10**3 Tonnes/annum	192	230	212	244	224	172	204	229	214	195	198	216		
- % Dom. Prod. average 80/81- 84/85 = 36%	42	49	45	46	42	34	39	40	38	35	34	33		
Handled in Haldia and Calcutta in 10**3 t/a	100	200	200	200	200	100	200	152	160	133	135	153		195
- % of export average 80/81- 84/85 = 70%	52	87	94	82	89	58	98	66	75	68	68	71		
- % of Dom. Prod. average 80/81- 84/85 = 25.4%								27	29	24	23	24		

0.36 * 0.7 = 0.252

Table 25.

Import export ratio of "All Other Cargo"

year	import	export	total	import	export
	t	t	t	%	%
1983/84	72,968	73,168	146,136	50	50
1984/85	108,645	135,756	244,401	44	56
1985/86	169,090	180,677	349,767	48	52
			average	47	53

Table 26.

Preliminary cargo-forecast

in 10**3 tonnes/annum	1984/85	1989/90	1999/2000
1 POL	5,092	6,880	11,580-14,420
2 Coal	1,708	3,520	6,500-19,000
3 Fertilizer	0,798	1,375	1,960- 2,613
4 Iron & Steel, Machinery	0,395	0,390	0,440- 0,600
5 Gunnies	0,292	0,270	0,381
6 Foodgrains	0,204	-	-
7 Tea	0,153	0,176-0,195	0,212- 0,235
8 All other Cargo	1,882	2,830	6,400
	-----+	-----------+	-----------+
Total	10,524	16,541-16,560	27,473-43,649

Table 27.

Preliminary cargo-forecast compared to CPT-forecast

in 10**3 Tonnes/annum	1984/85	CPT	1989/90	CPT	1999/2000	CPT
1 POL	5,10	5,19	7,98	7,37	11,58-14,42	11,57
2 Coal	1,71	1,71	3,52	3,30	6,50-19,00	4,20
3 Fertilizer	0,80	0,79	1,38	0,52	1,96- 2,61	0,90
4 Iron & Steel, Machinery	0,40	0,49	0,39	0,64	0,44- 0,60	0,99
5 Gunnies	0,29	0,28	0,27	0,40	0,38	0,40
6 Foodgrains	0,20	0,19	-	0,20	-	0,20
7 Tea	0,15	0,15	0,18-0,20	0,25	0,21-0,24	0,32
8 All other Cargo	1,88	1,73	2,83	2,68	6,40	4,59
	-----+	-----+	-----------+	-----+	----------+	-----+
Total	10,52	10,53	16,54-16,56	15,54	27,47-43,65	23,17

Table 28.

Final cargo-forecast

in 10**3 Tonnes/annum	1984/85	CPT	1989/90	CPT	1999/2000	CPT
1 POL	5,10	-	7,98	-	11,58-14,42	-
2 Coal	1,71	-	3,52	-	-	4,20
3 Fertilizer	0,80	-	1,38	-	1,96- 2,61	-
4 Iron & Steel, Machinery	0,40	-	0,39	-	0,44- 0,60	-
5 Gunnies	0,29	-	0,27	-	0,38	-
6 Foodgrains	0,20	-	0	-	0	-
7 Tea	0,15	-	0,18-0,20	-	0,21-0,24	-
8 All other Cargo	1,88	-	2,83	-	6,40	-
	-----+		-----------+		----------------+	
Total	10,52		16,54-16,56		25,17-28,95	

- means this figure is not used in favour of other forecast figure

Table 29.

World seaborne containerised traffic growth

from 1970 to 1981 in 10**6 tonnes/annum.

Year	Volume	Index
1970	47.3	100
1971	58.9	124
1972	77.0	163
1973	108.2	229
1974	123.7	262
1975	127.3	269
1976	158.1	334
1977	182.3	385
1978	214.7	454
1979	235.1	497
1980	255.5	540
1981	275.3	582

Table 30.

Container throughput in Indian ports

1000 TEU's	77/78	78/79	79/80	80/81	83/84
Bombay	13.6	38.9	77.8	101.3	136.3
Haldia/Calcutta	0.7	1.9	4.5	15.5	32.6
Cochin	2.2	4.3	13.8	20.7	32.5
Madras		1.3	4.4	9.4	28.1
Kandla					2.8
Mormugao			0.1	--	--
Mangalore		0.1	0.1	0.4	--
Tuticorin				9.3	--

-- means figure not available

Table 31.

Containerisation degrees per commodity in 3 recent years

A = Total tonnage transported in Haldia and Calcutta
B = Tonnage transported in containers
C = (B/A)*100% , the containerisation degree

A, B in '000 T C in %	1983/84			1984/85			1985/86			AVERAGE OF C
	A	B	C	A	B	C	A	B	C	
Tea	135	53	39.3	153	48	31.4	169	37	21.9	30.9
Gunnies	205	28	13.7	292	24	8.2	292	34	11.6	11.3
Iron & Steel	65	8	12.3	91	6	6.6	102	29	28.7	1.2
Machinery	320	1	0.3	395	3	0.8	421	11	2.6	15.9
All Other Cargo	1993	146	7.3	1790	244	13.6	1992	350	17.6	12.8
Total	2718	236	8.7	2721	325	11.9	2976	461	15.5	

Table 32.

Course of the containerisation degree

from 1984/85 to 2004/2005

in %	average set in 1984/85	1989/90	1999/2000	2004/2005
Tea	30.9	48.2	82.7	100
Gunnies	11.3	27.2	59.1	75
Iron & Steel	1.2	5.9	15.3	20
Machineries	15.9	24.4	41.5	50
All Other Cargo	12.8	22.1	40.7	50

Table 33.

Containerised cargo in 1989/90 and 1999/2000

A = amount of cargo in target year, see table ....
B = containerisation degree, see table ....
C = A*B = amount of containerised cargo

in '000 Tonnes	1989/90 A	B	C	1999/2000 A	B	C
Tea	176-195	48.2	84.8-94.0	212-235	82.7	175.3-194.3
Gunnies	270	27.2	73.4	381	59.1	225.2
Iron & steel, Machineries	390	5.9-24.4	23.0-95.2	440-600	15.3-41.5	67.3-249.0
All Other Cargo	2830	22.1	625.4	6400	40.7	2604.8
	3,666-3,685		806.6-888.0	7,433-7,616		3,072.6-3,273.3

Table 34.

Average tonnage/TEU

	Import Tonnes	loaded TEU's	Tonnes/ TEU	Export Tonnes	loaded TEU's	Tonnes/ TEU
1980/81	53,149	4,454	11.9	84,649	6,102	13.8
1981/82	62,179	5,091	12.2	124,605	11,096	11.2
1982/83	65,839	5,292	12.4	165,502	15,014	11.0
1983/84	79,619	6,317	12.6	156,304	13,400	11.7
1984/85	115,578	8,940	12.9	209,422	17,098	12.2
		average	12.4		average	12.0

Table 35.

Percentage of empty containers

	Import				Export			
TEU's	Total	Loaded	Empty	%	Total	Loaded	Empty	%
80/81	8,116	4,454	3,662	82	7,352	6,102	1,250	20
81/82	15,087	5,091	9,996	196	12,865	11,096	1,769	16
82/83	15,607	5,292	10,395	196	17,697	15,014	2,683	18
83/84	16,283	6,317	9,966	158	16,359	13,400	2,959	22
84/85	19,342	8,940	10,402	116	19,555	17,098	2,457	14

average 18 %

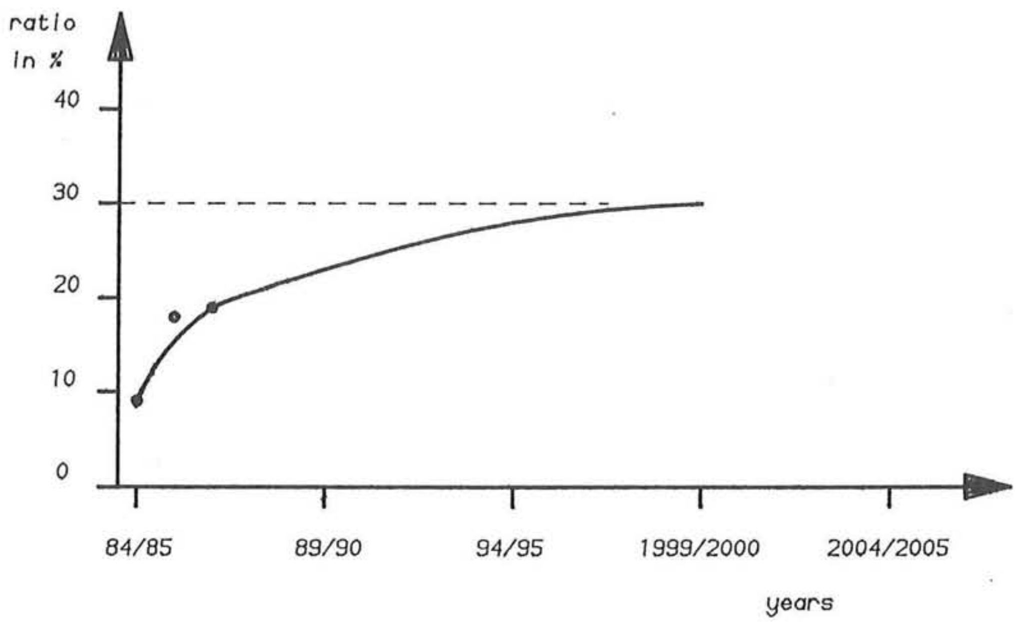


Figure 33 : Ratio 20 to 40 feet containers in future

Table 36.

Number of containers in 1989/90

Tonnage in '000	Import	Export	Total
Tea	0	84.8-94.0	84.8-94.0
Gunnies	0	73.4	73.4
Iron & Steel, Machineries	17.9-74.3	5.1-20.9	23.0-95.2
All Other Cargo	239.9	331.5	625.4
	----------- +	----------- +	
Total	311.8-368.2	494.8-519.8	
Tonnage/TEU	12.4	12.0	
Number of loaded TEU,s	25,145-29,694	41,233-43,317	
Percentage empty export TEU's		18 %	
Number of empty export TEU's		7,422- 7.797	
Total import and export TEU's	48,655-51,114	48,655-51,114	
Number of empty import TEU's	23,510-21,420		

Total number of TEU's 97,310 - 102,228

Table 37.

Number of containers in 1999/2000

Tonnage in '000	Import	Export	Total
Tea	0	175.3- 194.3	175.0-194.3
Gunnies	0	225.2	225.2
Iron & Steel, Machineries	52.5- 194.2	14.8- 54.8	67.3-149.0
All Other Cargo	1224.3	1380.5	2604.8
	------------- +	------------- +	
Total	1276.8-1418.5	1795.8-1854.8	
Tonnage/TEU	12.4	12.0	
Number of loaded TEU,s	102,968-114,395	149,650-154,567	
Percentage empty export TEU's		18 %	
Number of empty export TEU's		26,937- 27,822	
Total import and export TEU's	176,587-182,389	176,587-182,389	
Number of empty import TEU's	73,619- 67,994		

Total number of TEU's 353,174 - 364,778

Table 38.

Resulting packing-forecast for 1989/90

in 10**3 T/a	Total	Discharging	Loading
Liquid bulk			
POL	7,980	6,783	1,197
Dry bulk			
Coal	3,520	317	3,203
Fertilizer	1,375	1,375	0
Breakbulk			
Iron & Steel Machinery	295- 367	230- 286	65- 81
Gunnies	197	0	197
Tea	91- 101	0	91- 101
All Other Cargo	2,205	1,036	1,169
Total	2,788-2,870		
Containers			
in TEU's	97,310-102,228	48,655-51,114	48,655-51,114
in boxes	79,114-83,112	39,557-41,556	39,557-41,556

Table 39.

Resulting packing-forecast for 1999/2000

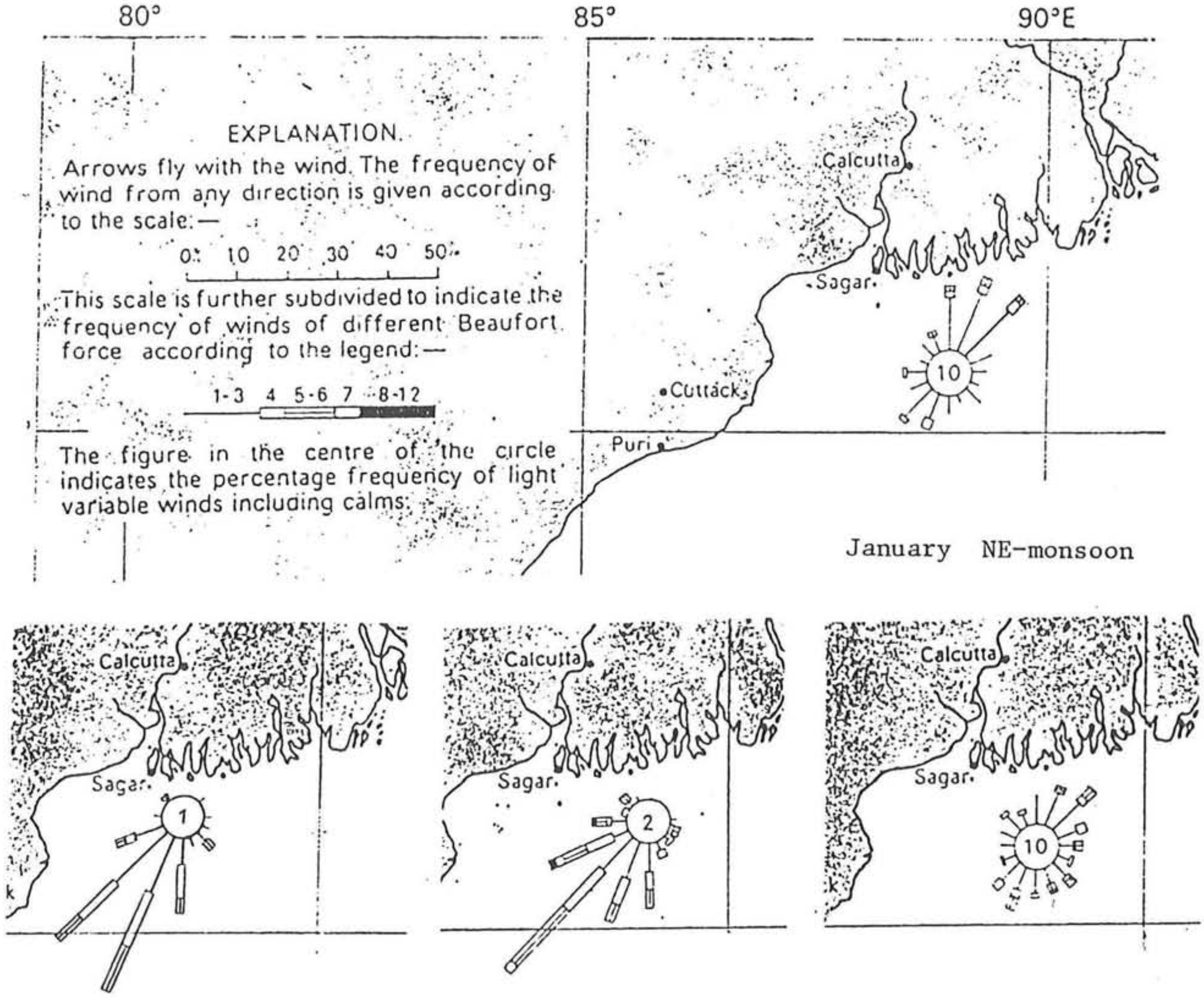
in 10**3 T/a	Total	Discharging	Loading
Liquid bulk			
POL	11,580-14,420	9,840-12,260	1,740-2,160
Dry bulk			
Coal	4,200	378	3,822
Fertilizer	1,960- 2,613	1,960- 2,613	0
Breakbulk			
Iron & Steel Machinery	351- 373	274- 291	77- 82
Gunnies	156	0	156
Tea	37- 41	0	37- 41
All Other Cargo	3,795	1,784	2,011
Total	4,339- 4,365		
Containers			
in TEU's	353,174-364,778	176,587-182,389	176,587-182,389
in boxes	271,672-280,598	135,836-140,299	135,836-140,299

Table 40.

Strikes and incidents at Haldia

	1983/84	1984/85	1985/86
Incidents	-	4	6
Strikes; no. of lost mandays			
- Port originated	1,868	2,014	2,147
- State related	0	24,777	3,599
		------ +	----- +
Total		26,791	5,746

Workforce Haldia approximately 3,300 dock-workers



January NE-monsoon

April SW-monsoon

July SW-monsoon

October

Source: (8)

Figure 34: Wind arrows for the Bay of Bengal

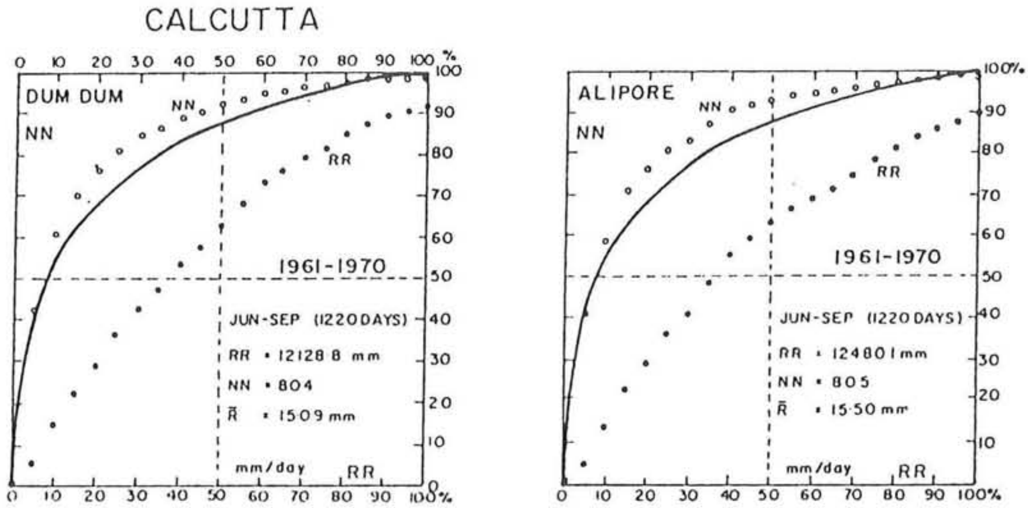


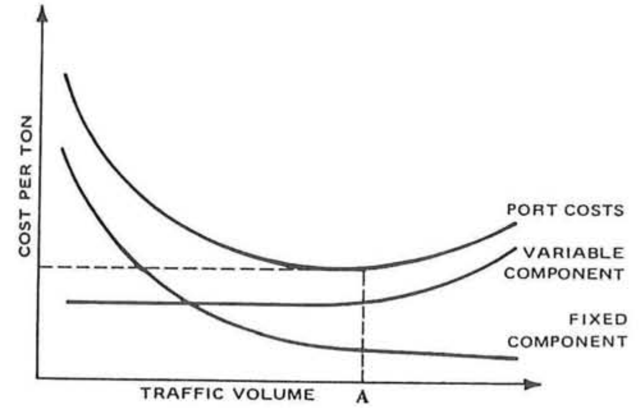
Figure 35: Number of rainy days versus cumulative rainfall

Table 41.

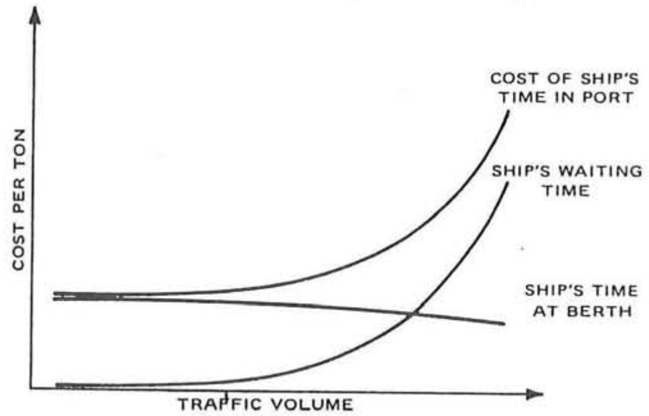
Average number of commission days per annum

	Breakbulk	Dry Bulk		Liquid Bulk	Containers
Lost days			Fertilizer	Other	
Local holidays	3	3	3	3	3
Strikes	5	5	5	5	5
Wind	–	–	6	6	6
Rain	45	64	–	–	–
Maintenance dredging	1	1	1	1	1
	--- +	--- +	-- +	-- +	-- +
Total	54	73	15	15	15
Average number commission days per year	311	292	350	350	350

Figure 36: Variation of port costs with increasing traffic



Variation of the cost of ship's time in port with increasing traffic



Variation of total costs in port with increasing traffic

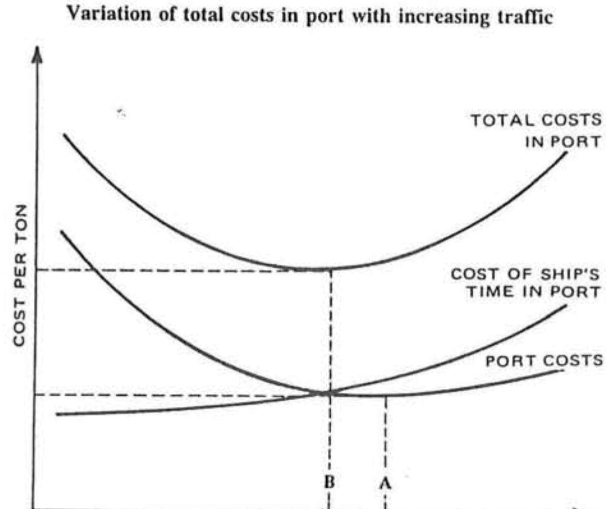


Table 42.

Berth-productivity and number of berths

p	expressed in	Tonnes/shift or Boxes/shift
w	expressed in	days/annum
BOF	expressed in	%
Berth-productivity	expressed in	10**3 Tonnes/annum or 10**3 Boxes/annnum
Maximum forecasted cargo	expressed in	10**3 Tonnes/annum or 10**3 Boxes/annnum

1989/90	p	w	BOF	B	Maximum forecasted cargo	no. of berths
liquid bulk	9,000	350	0.50	4,725	7,980	2
dry bulk:						
coal	3,900	350	0.50	2,048	3,203	2
coking coal	1,200	350	0.40	504	317	1
finished fertilizer	250	292	0.70	153	839	6
rock phosphate	250	292	0.70	153	536	4
breakbulk	200	311	0.70	131	2,870	22
containers	80	350	0.50	42	83	2

1999/2000	p	w	BOF	B	Maximum forecasted cargo	no. of berths
liquid bulk	9,000	350	0.55	5,698	14,420	3
dry bulk:						
coal	4,700	350	0.50	2,468	3,822	2
coking coal	1,500	350	0.40	630	378	1
finished fertilizer	800	292	0.70	490	1,594	4
rock phosphate	800	292	0.70	490	1,019	3
breakbulk	250	311	0.70	163	4,365	27
	310	311	0.70	204	4,365	22
containers	200	350	0.55	116	281	3

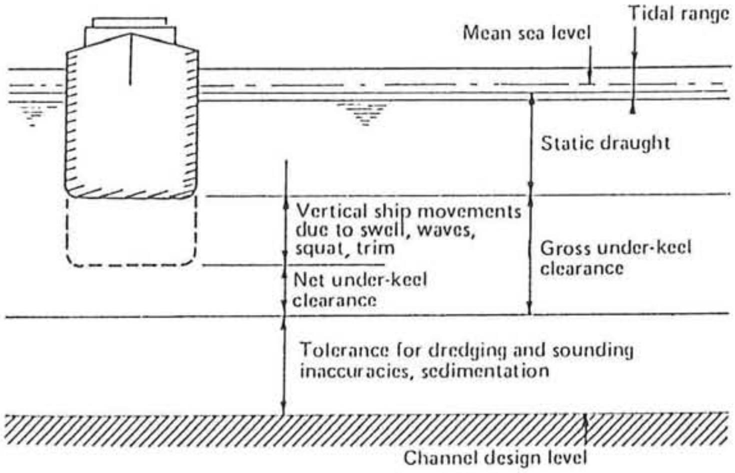


Figure 37: Contributions to underkeel clearance

Tuck-Tailor's formula to compute squat for unrestricted water widths reads as follows:

$$Z_v = \frac{F_{nh}^2}{\sqrt{1 - F_{nh}^2}} \cdot \frac{\nabla}{L_{pp}^2} \cdot C$$

in which:

Z_v	= maximum squat	(m)
F_{nh}	= Froude depth number (is $V_s / \sqrt{gh}$)	
V_s	= ship's speed, is 6 m/s	
g	= acceleration of gravity, is 9.81 m/s^2	
h	= average water depth, is 9 m	
∇	= displacement of the ship	(m^3)
L_{pp}	= length between the perpendiculars of the ship	(m)
C	= constant, equal to 1.5	

	∇	L_{pp}	Z_v
	m^3	m	m
tanker	105,000	280	1.10
container vessel	35,000	198	0.70

C has been determined for different shiptypes at the Delft Hydraulics Laboratory. The value of C varies between 1.5 and 2.0 for the ship's bow.

Figure 38: Computation of squat

The theory of extrema for stochastic processes provides the following expression to compute the probability of touching the channel bottom during one channel transit:

$$P_r(A > 0) = 1 - \exp\left[-\frac{T_p}{T_m} \cdot \exp^{\left(-\frac{KC^2}{2m_o}\right)} \right]$$

with:

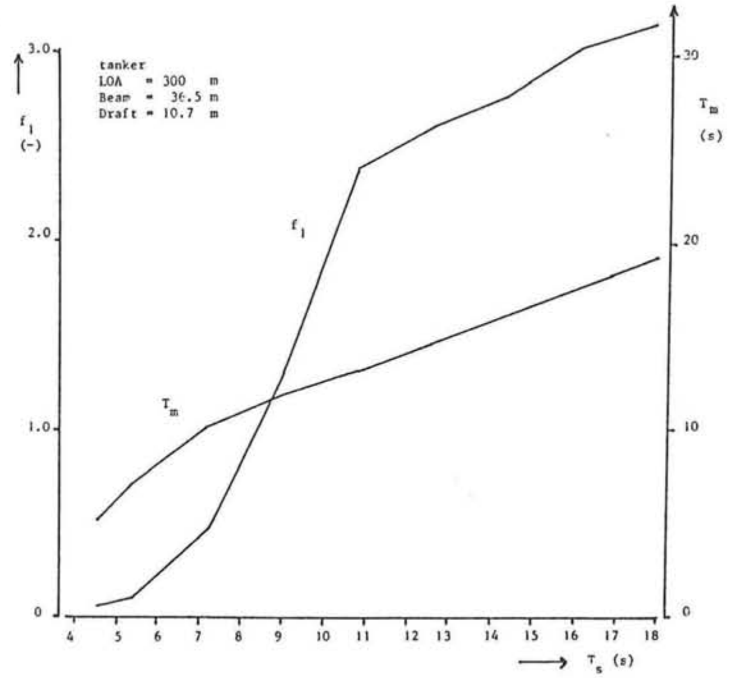
A	= number of bottom touches	
T_p	= duration of channel transit , 7500 s	(s)
KC	= keel clearance, equal to water depth minus ship's draught and minus squat	(m)
T_m	= average period of ship response	(s)
	= $(m_2/m_o)^{\frac{1}{2}}$	
m_o	= zeroth spectral moment of ship's response	(m^2)
m_2	= second spectral moment of ship's response	$(m^2 s^2)$
m_o	= $f_1^{\,2} \cdot (H_s/4)^2$	
f_1	= R_s/H_s = ratio between significant ship response amplitude R_s and significant wave height H_s	

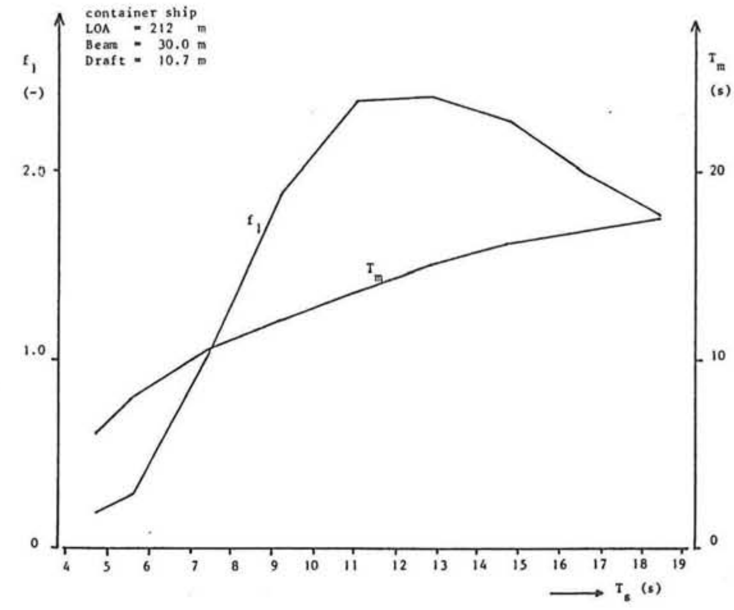
Using the Jonswap spectrum to represent the ship response the Delft Hydraulic Laboratory found the relation between T_m, f_1, and the wave period T_s for several shiptypes. To apply the test results on the design vessels Froude's scale law has been used. See the graphs for tanker and container ship, found for a point on the foresholder of the vessel.

With the prescribed criterion $P_r(A > 0) = 0.01$ at maximum, the known values of T_s and H_s, first f_1 and T_m are determined, followed by the required keel clearance KC.

Required KC in m	outer estuary maximum	average	inner estuary
tanker	2.36	0.15	0.19
container ship	3.83	0.36	0.38

Figure 39: Computation of wave respons





Outer estuary:

maximum conditions H_s = 2.5 m T_s = 8 s

average conditions H_s = 1.5 m T_s = 5 s

Inner estuary:

H_s = 0.8 m T_s = 6 s

Figure 39: Computation of wave respons

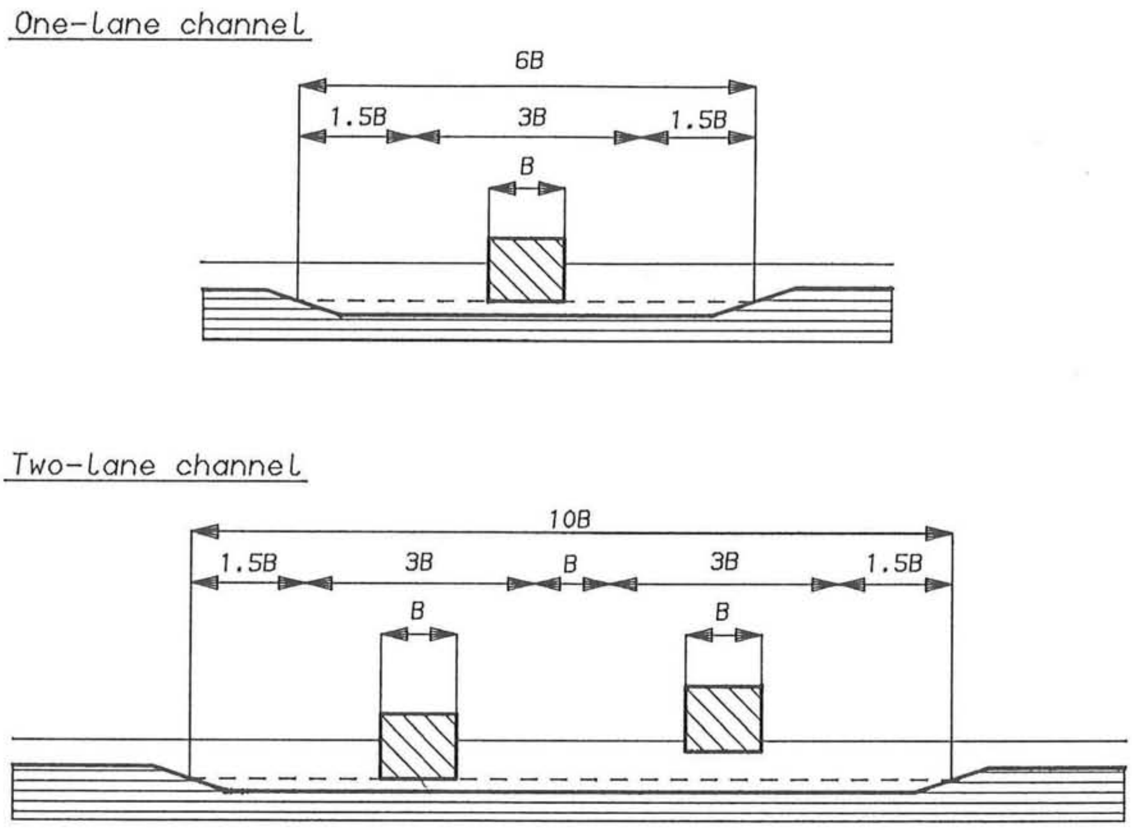


Figure 40: Width of the channel

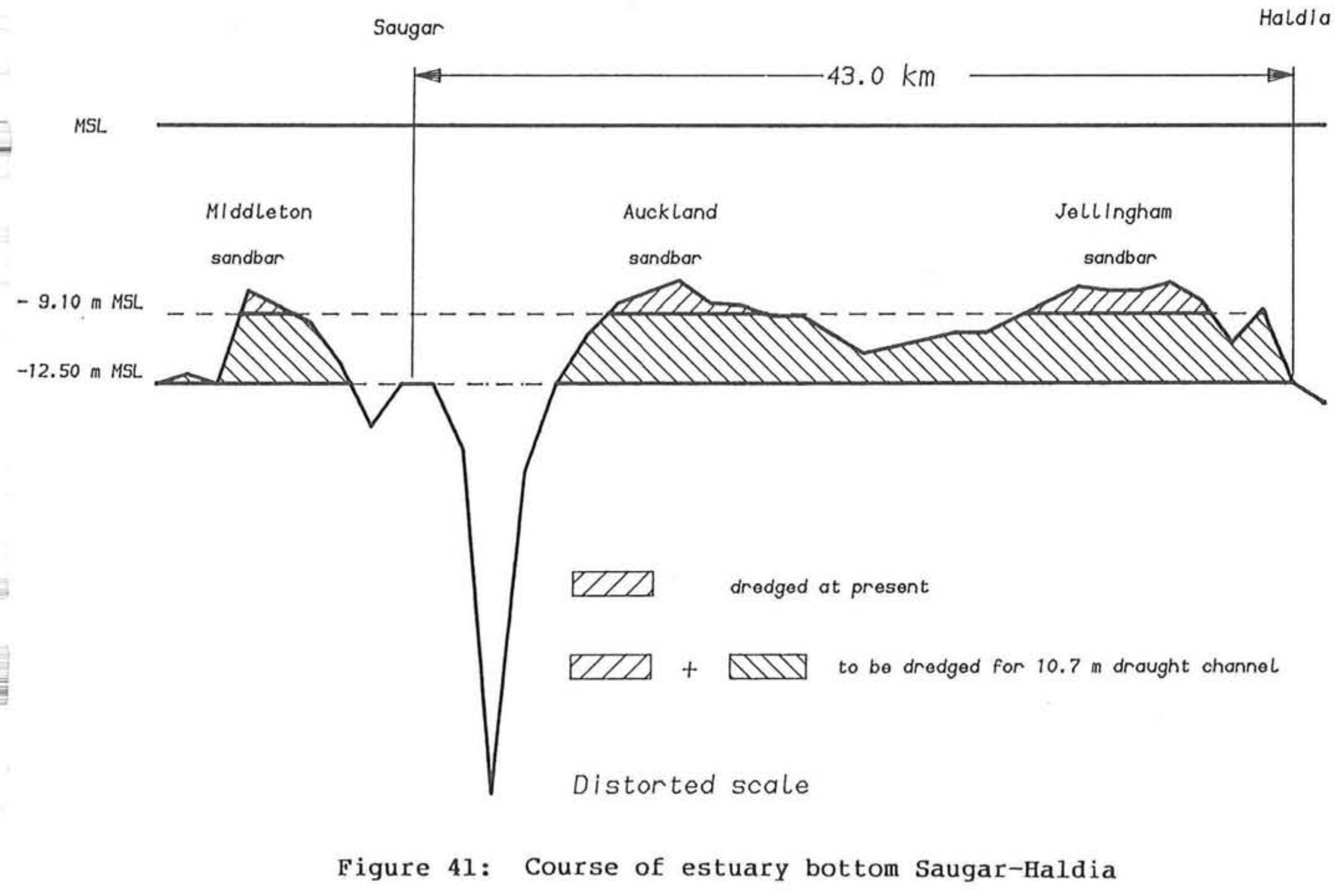
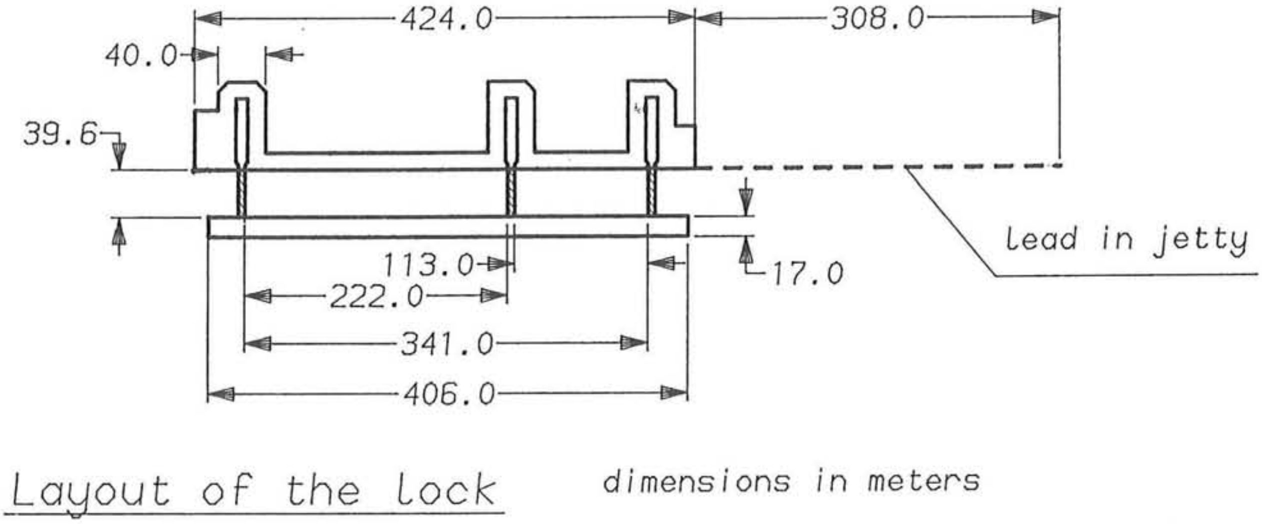


Figure 41: Course of estuary bottom Saugar-Haldia



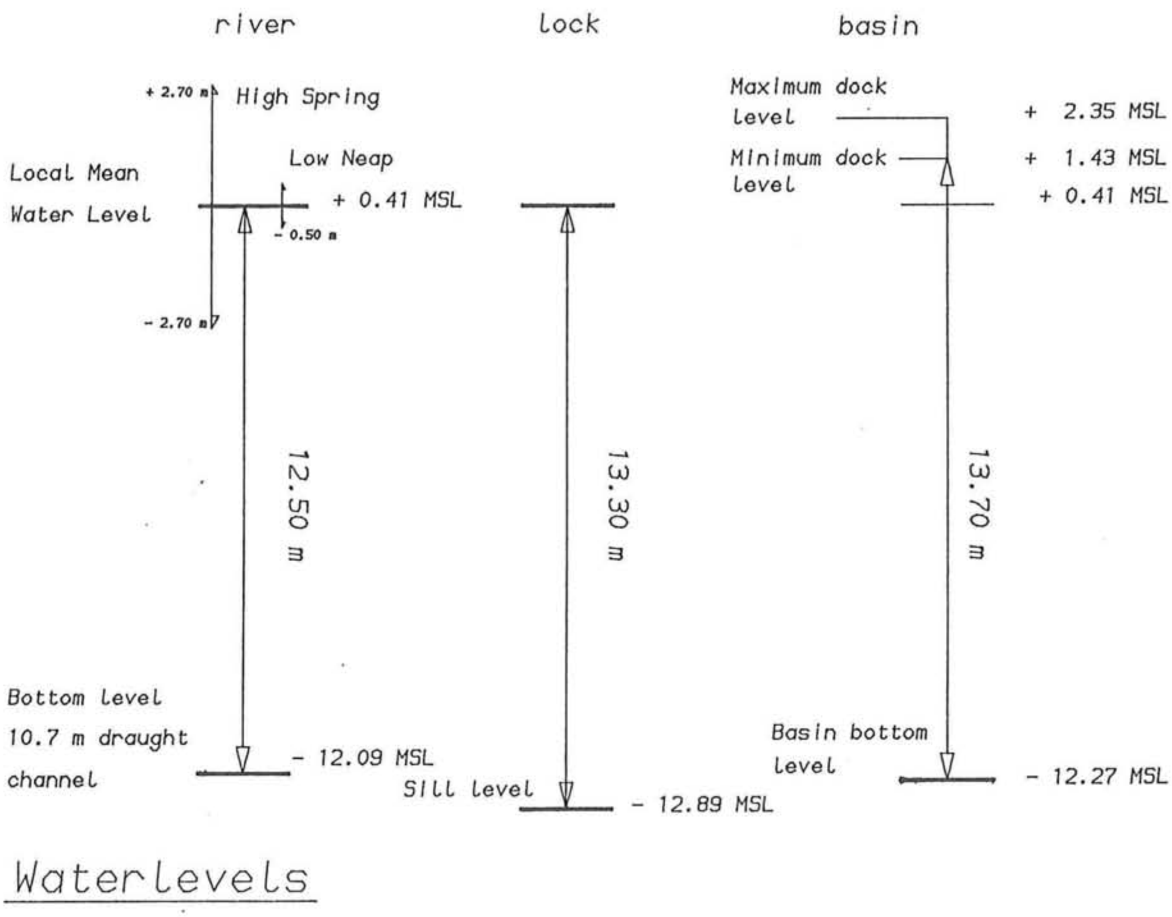


Figure 42: Layout of the lock, waterlevels

Table 43.

Ship-forecast 1989/90

1989/90	DWT	TEU	LOA	B	D	cargo share %	in 10**3 tonnes or TEU's	% in or out ship	no. of ships	loading or unloading time in days
Dry bulk										
Coal	25,000		190	25.5	10.7	100	3,520	100	141	2.14
Coking coal										6.94
Fertilizer	15,000		165	21.5	9.5	100	1,375	100	92	20.00
Breakbulk	7,500		135	16.0	7.5	50	1,435	25	765	3.13
	15,000		165	21.5	9.5	50	1,435	25	382	6.25
Container	7,000	316	143	19,0	6.5	30	31.2	90	110	0.96
	10,000	530	159	23.5	8.0	40	41.6	70	112	1.26
	25,000	1380	212	30.0	10.7	30	31.2	30	75	1.40
Subtotal									1677	
Liquid bulk	10,000		125	18.0	8.0	50	3,990	100	399	0.25
	85,000		300	36.5	10.7	50	3,990	100	47	2.36
Total									2123	

Intensity lock = (1677 * 2)/365 = 9 ships/day
Intensity channel = (2123 * 2)/365 = 12 ships/day

Table 44.

Ship-forecast 1999/2000

1999/2000	DWT	TEU	LOA	B	D	cargo share %	in 10**3 tonnes or TEU's	% in or out ship	no. of ships	loading or unloading time in days
Dry bulk										
Coal	25,000		190	25.5	10.7	100	4,200	100	168	1.77
Coking coal										5.56
Fertilizer	15,000		165	21.5	9.5	50	1,307	100	87	6.25
	25,000		190	25.5	10.5	50	1,307	100	52	10.42
Breakbulk	15,000		165	21.5	9.5	100	4,365	25	1164	4.03
Container	10,000	530	159	23.5	8.0	50	180	80	425	0.54
	25,000	1380	212	30.0	10.7	50	180	50	261	0.88
Subtotal									2157	
Liquid bulk	10,000		125	18.0	8.0	15	2,163	100	216	0.25
	85,000		300	36.5	10.7	85	12,257	100	144	2.36
Total									2517	

Intensity lock = (2157 * 2)/365 = 12 ships/day
Intensity channel = (2517 * 2)/365 = 14 ships/day

Table 45.

Data liquid bulk terminal

POL	1989/90	1999/2000
Cargo forecast, in 1000 T/a	7,980	14,420
Berth-commission days/annum	350	350
Berth occupancy factor	0.50	0.55
Berth productivity, in 1000 T/a	4,725	5,198
Number of required berths	2	3
Ship characteristics		
10,000 DWT 125 LOA	50%	15%
85,000 DWT 300 LOA	50%	85%
Annual number of ships	446	360

Table 46.

Data coal terminal

	1989/90	1999/2000
Cargo forecast, in 10**3 T/a	3,203	3,822
Berth-commission days/annum	350	350
Berth occupancy factor	0.50	0.50
Berth productivity, in 1000 T/a	2,048	2,468
Number of required berths	2	2
Ship characteristics	25,000 DWT	190 LOA
Annual number of ships	128	153

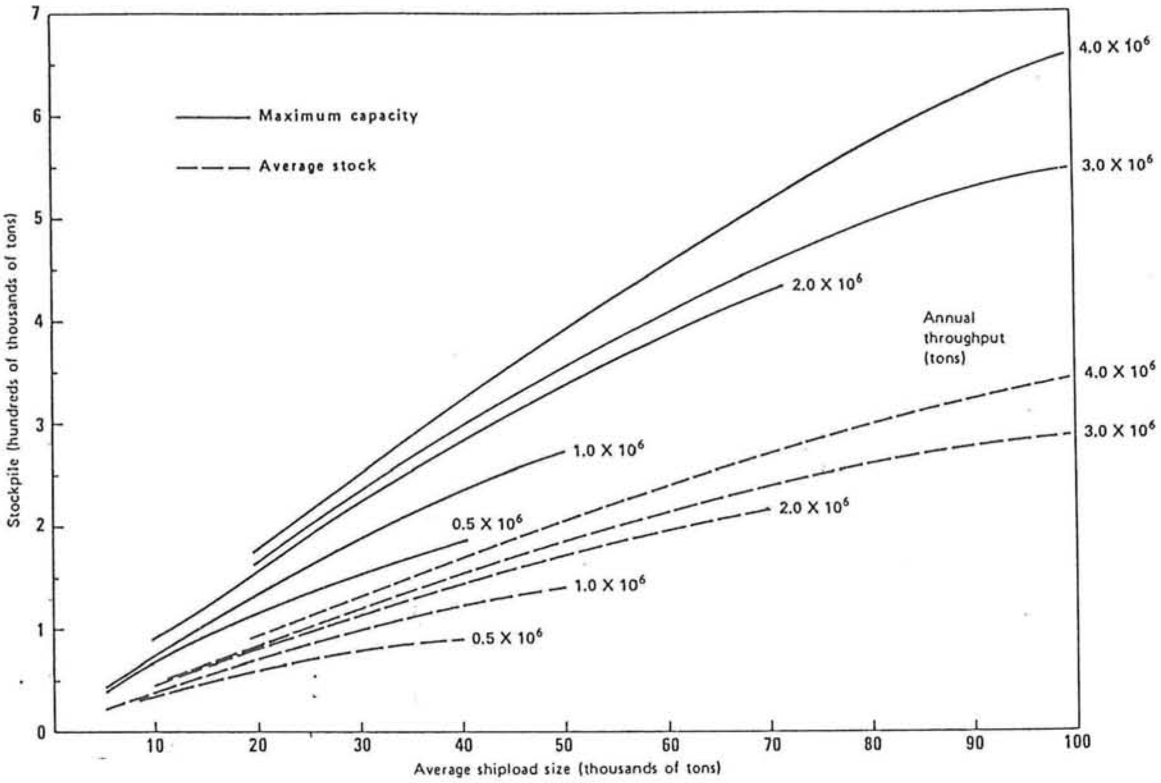


Figure 43: Dimensions of stockpiles versus throughput and shipload

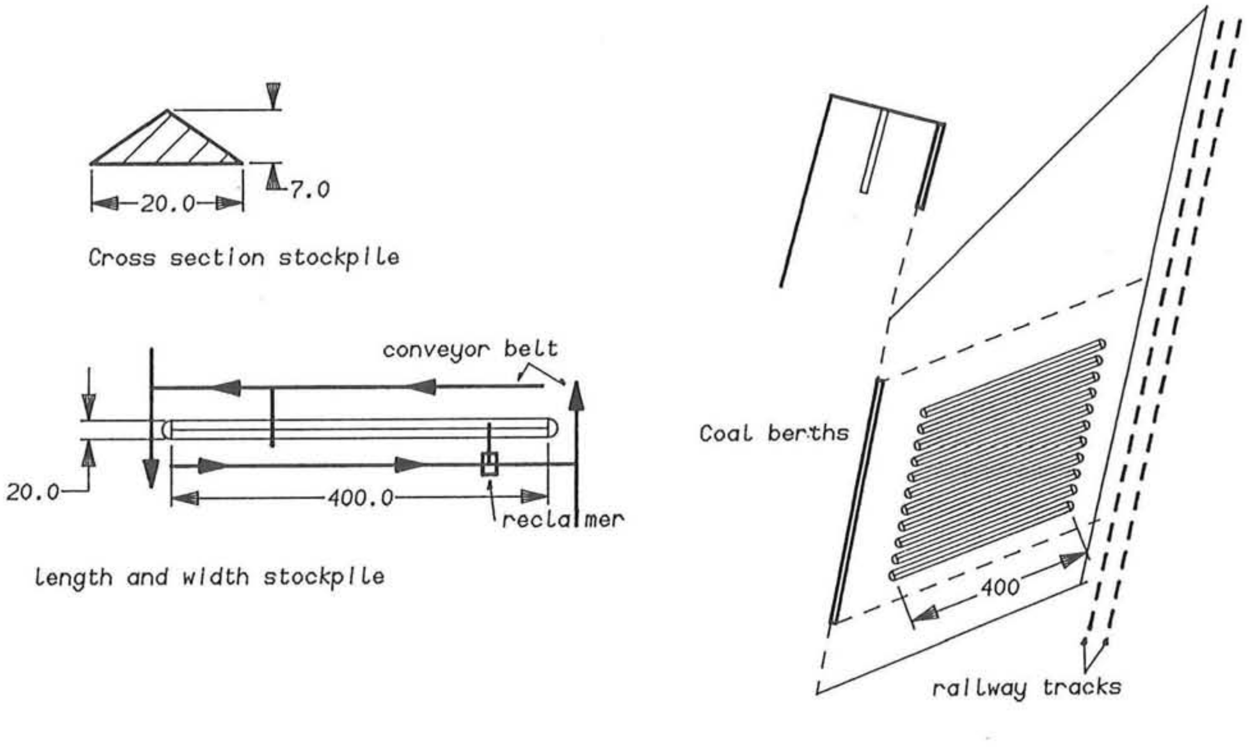


Figure 44: Layout coal stockpile

Table 47.

Data coking coal terminal

Coking coal	1989/90	1999/2000
Cargo forecast, in 10**3 T/a	317	378
Berth-commission days/annum	350	350
Berth occupancy factor	0.40	0.40
Berth productivity, in 1000 T/a	504	630
Number of required berths	1	1
Ship characteristics	25,000 DWT	190 LOA
Annual number of ships	13	15

Table 48.

Data finished fertilizer terminal

Finished fertilizer	1989/90	1999/2000
Cargo forecast, in 10**3 T/a	839	1,594
Berth-commission days/annum	292	292
Berth occupancy factor	0.70	0.70
Berth productivity, in 1000 T/a	153	490
Number of required berths	6	4
Ship characteristics		
15,000 DWT 165 LOA	100%	50%
25,000 DWT 190 LOA	-	50%
Annual number of ships	56	85

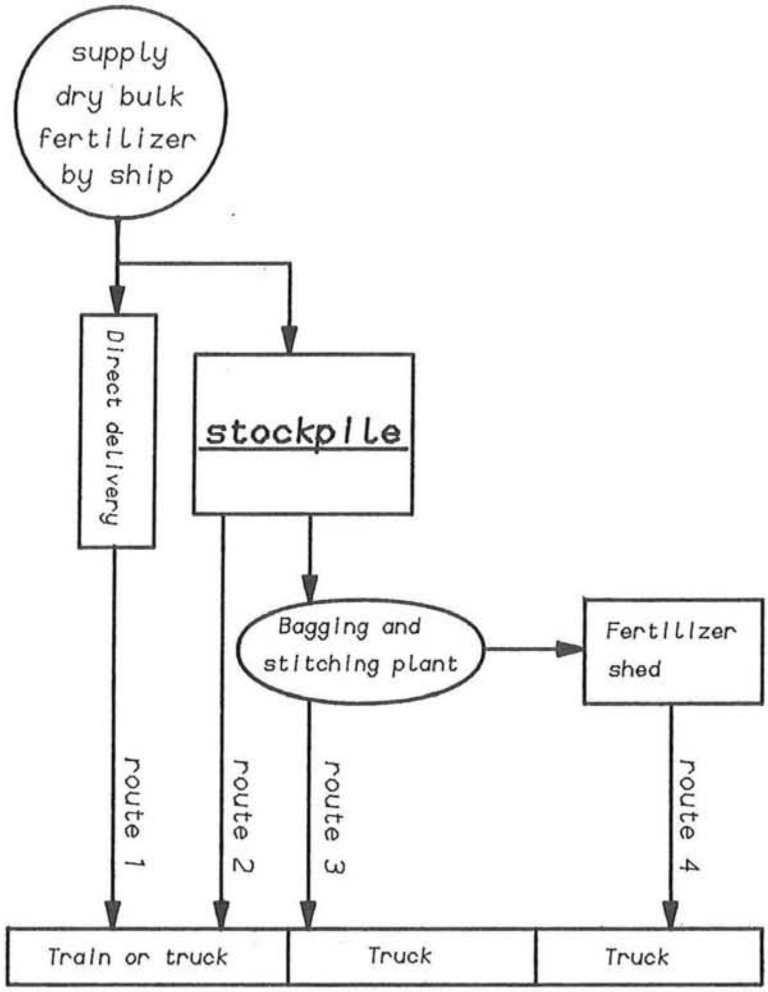


Figure 45: Transport routes of fertilizer through terminal

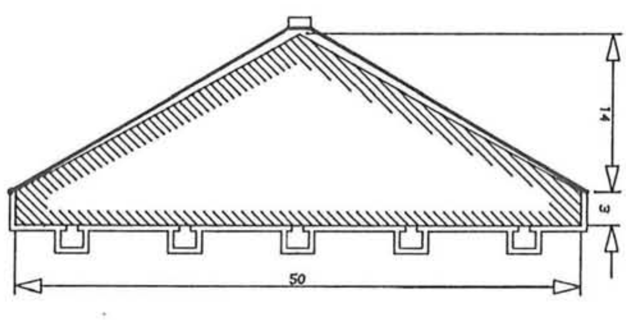


Figure 46: Cross-section dry bulk fertilizer shed

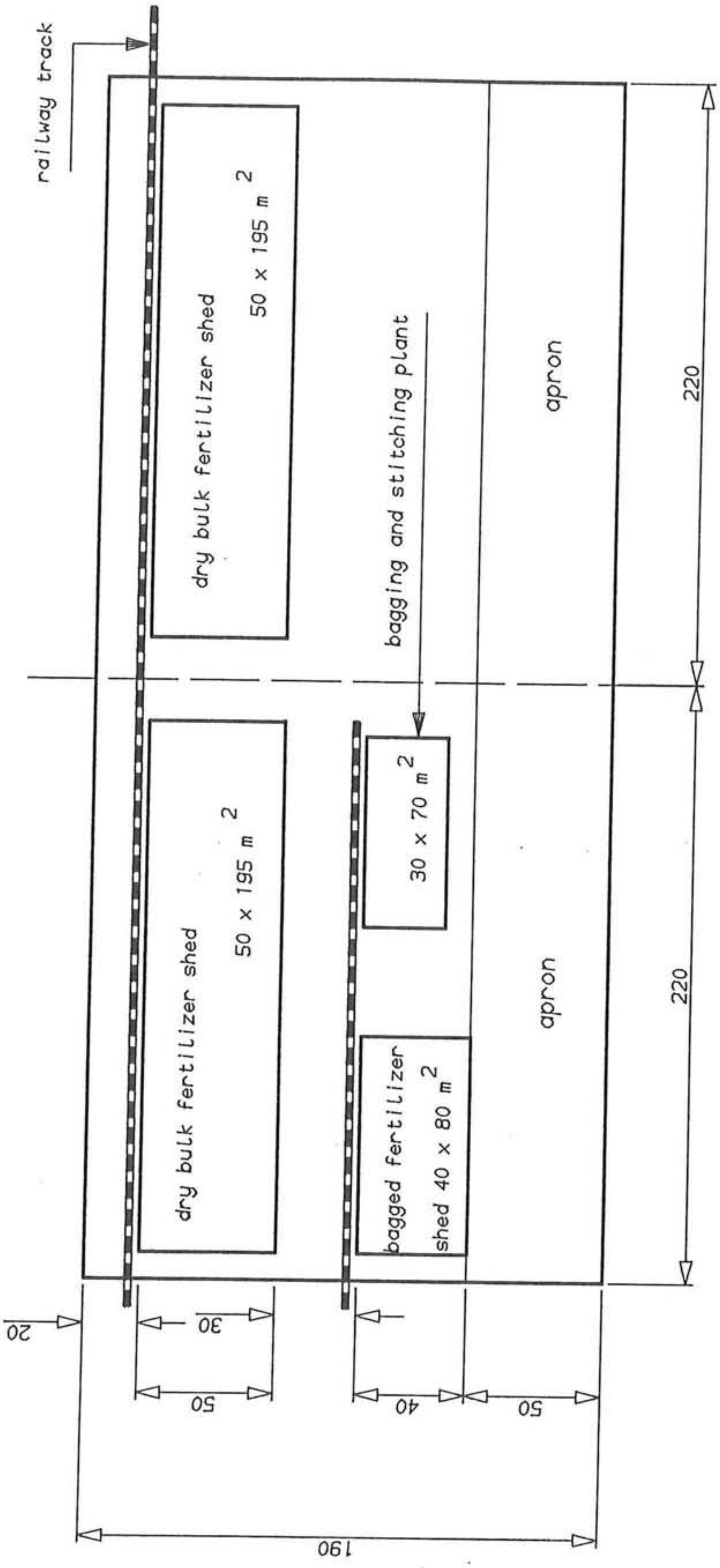


Figure 47: Layout fertilizer terminal

Table 49.

Data phosphate rock terminal

	1989/90	1999/2000
Cargo forecast, in 10**3 T/a	536	1,019
Berth-commission days/annum	292	292
Berth occupancy factor	0.70	0.70
Berth productivity, in 1000 T/a	153	490
Number of required berths	4	3
Ship characteristics		
15,000 DWT 165 LOA	100%	50%
25,000 DWT 190 LOA	-	50%
Annual number of ships	36	54

Table 50.

Data breakbulk terminal

	1989/90	1999/2000
Cargo forecast, in 10**3 T/a	2,870	4,365
Berth-commission days/annum	311	311
Berth occupancy factor	0.70	0.70
Berth productivity, in 1000 T/a	131	163
Number of required berths	22	27
Berth productivity, in 1000 T/a	131	202
Number of required berths	22	22
Ship characteristics		
7,500 DWT 125 LOA	50%	100%
15,000 DWT 165 LOA	50%	-
Annual number of ships	1148	1164

Berth length correction factor for break-bulk general cargo terminal planning

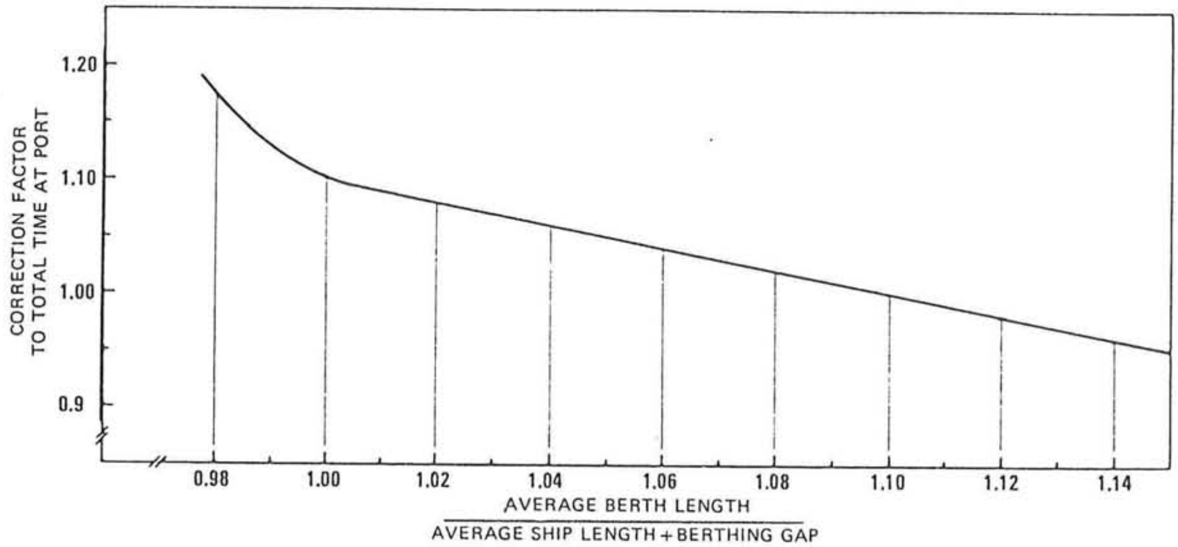


Figure 48: Berth length correction factor

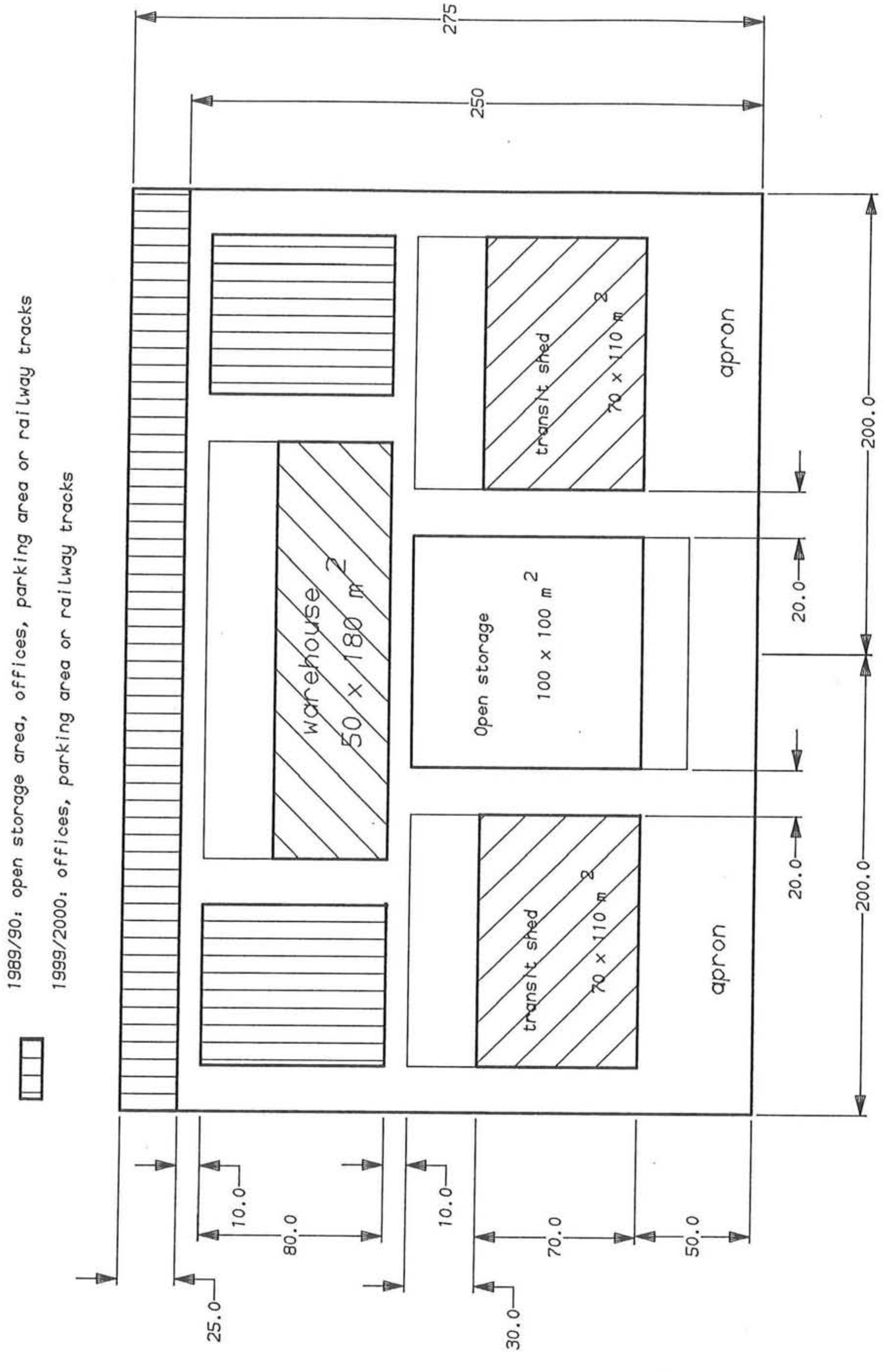


Figure 49: Layout breakbulk terminal

Table 51.

Data container terminal

	1989/90	1999/2000
No. of forecasted import TEU's	30,000	114,000
No. of forecasted export TEU's	43,000	155,000
No. of forecasted empty TEU's	31,000	101,000
No. of Boxes	81,000	276,000
Berth-commission days/annum	350	350
Berth occupancy factor	0.50	0.55
Berth productivity, in boxes/annum	42,000	115,500
Number of required berths	2	3

Ship characteristics 1989/90

7,000 DWT	316 TEU	143 LOA	30%
10,000 DWT	500 TEU	159 LOA	40%
25,000 DWT	1380 TEU	212 LOA	30%

Ship characteristics 1999/2000

10,000 DWT	500 TEU	159 LOA	50%
25,000 DWT	1380 TEU	212 LOA	50%

	1989/90	1999/2000
Average ship length	170	186
Annual number of ships	292	694

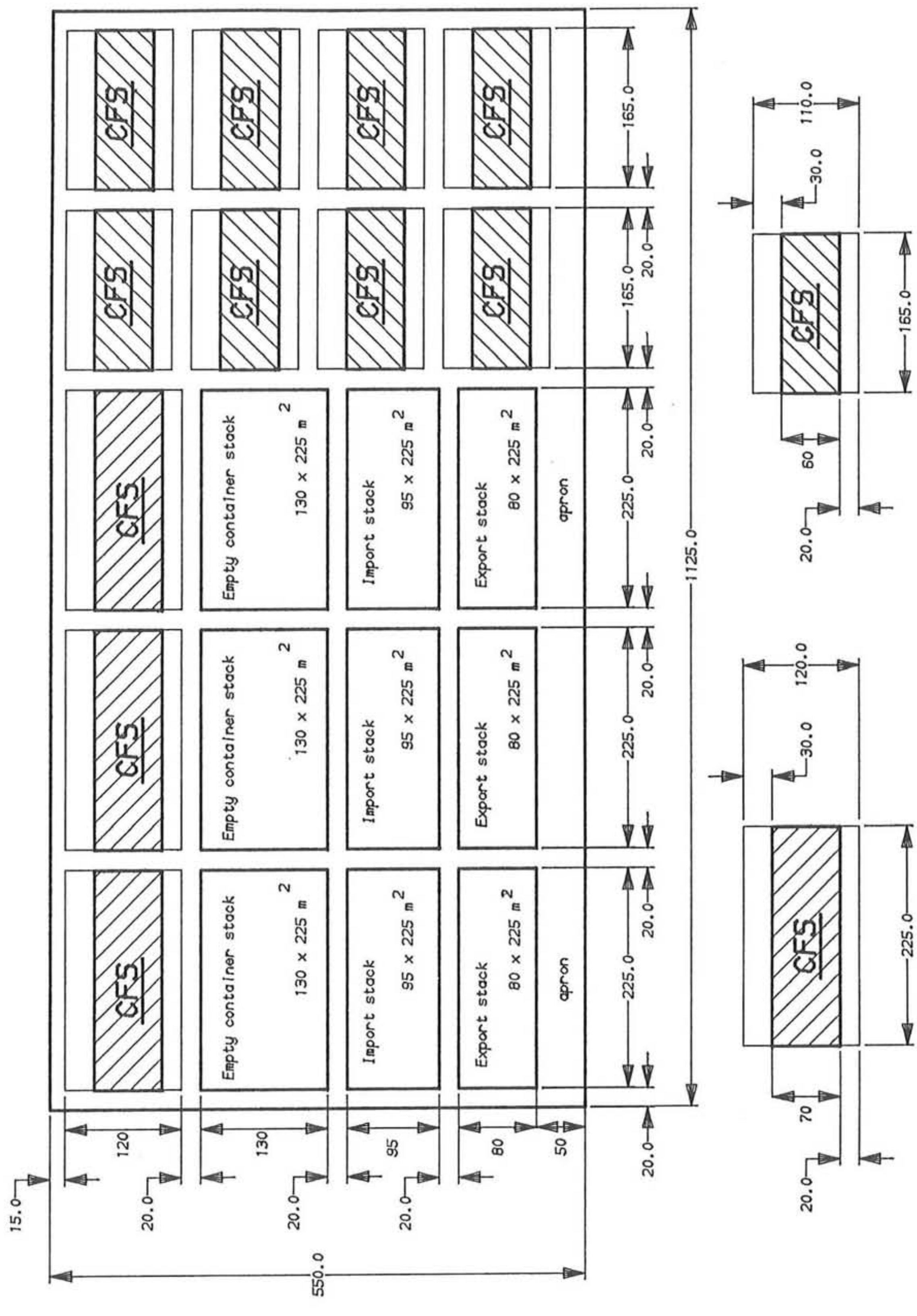
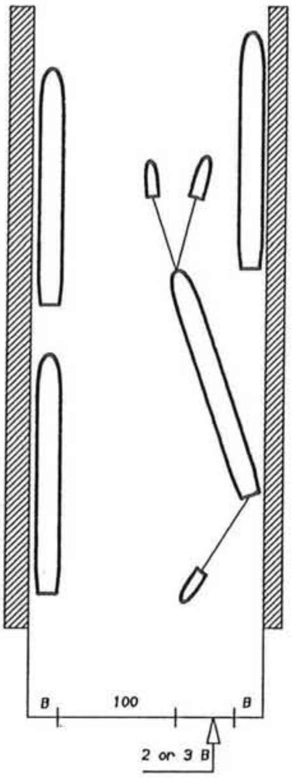
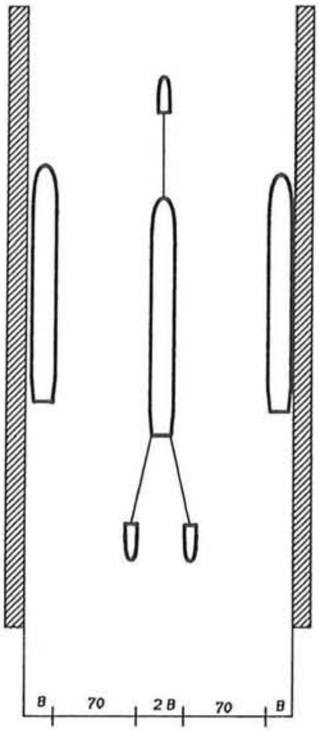


Figure 50: Preliminary layout container terminal

Short basin

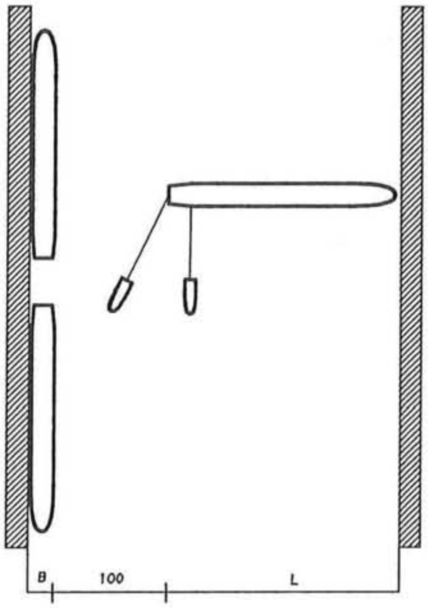


deberthing



sailing backwards

Long basin



turning the vessel

Figure 51: Situations determining the width of the basin

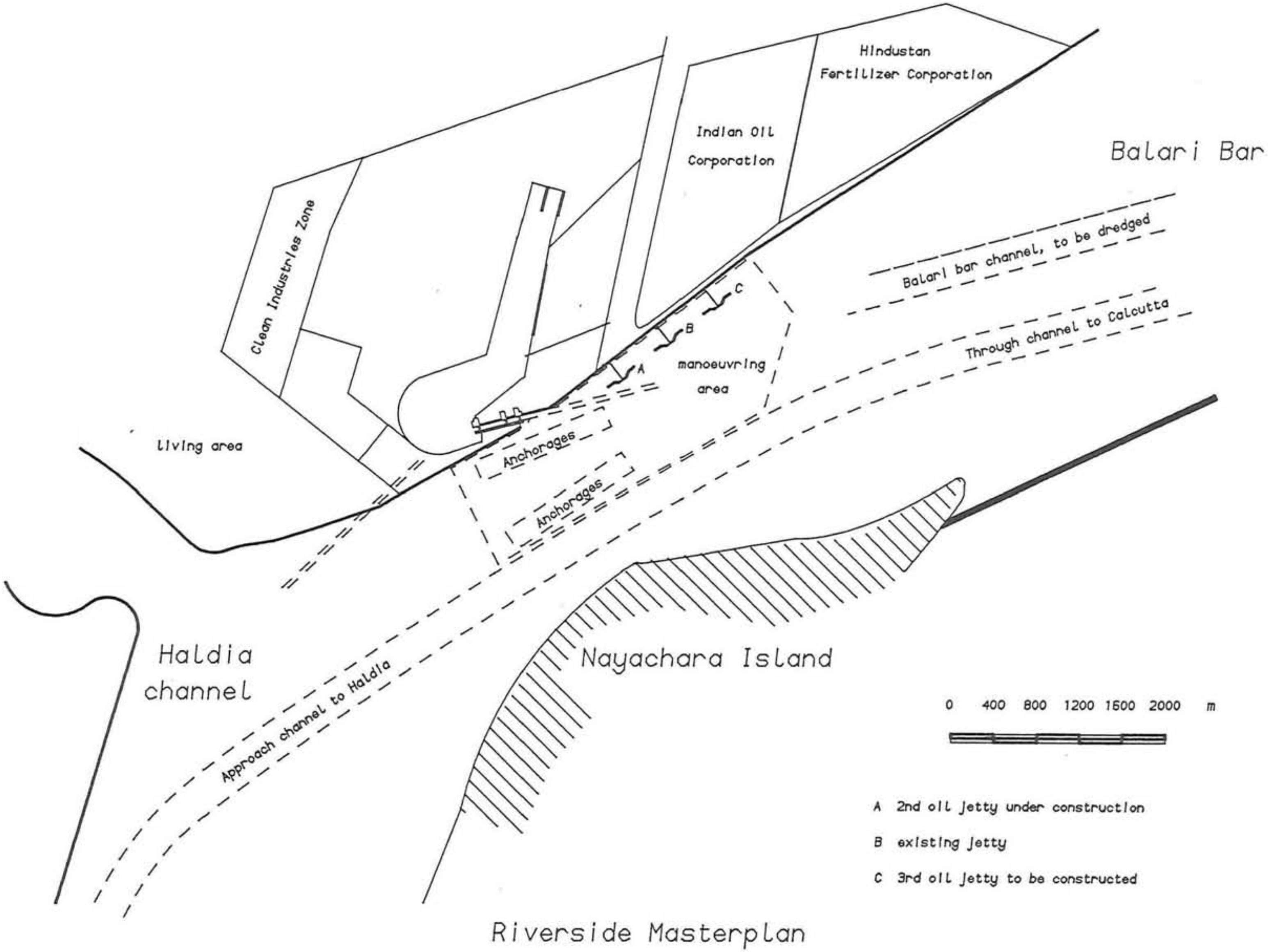


Figure 52: Riverside masterplan

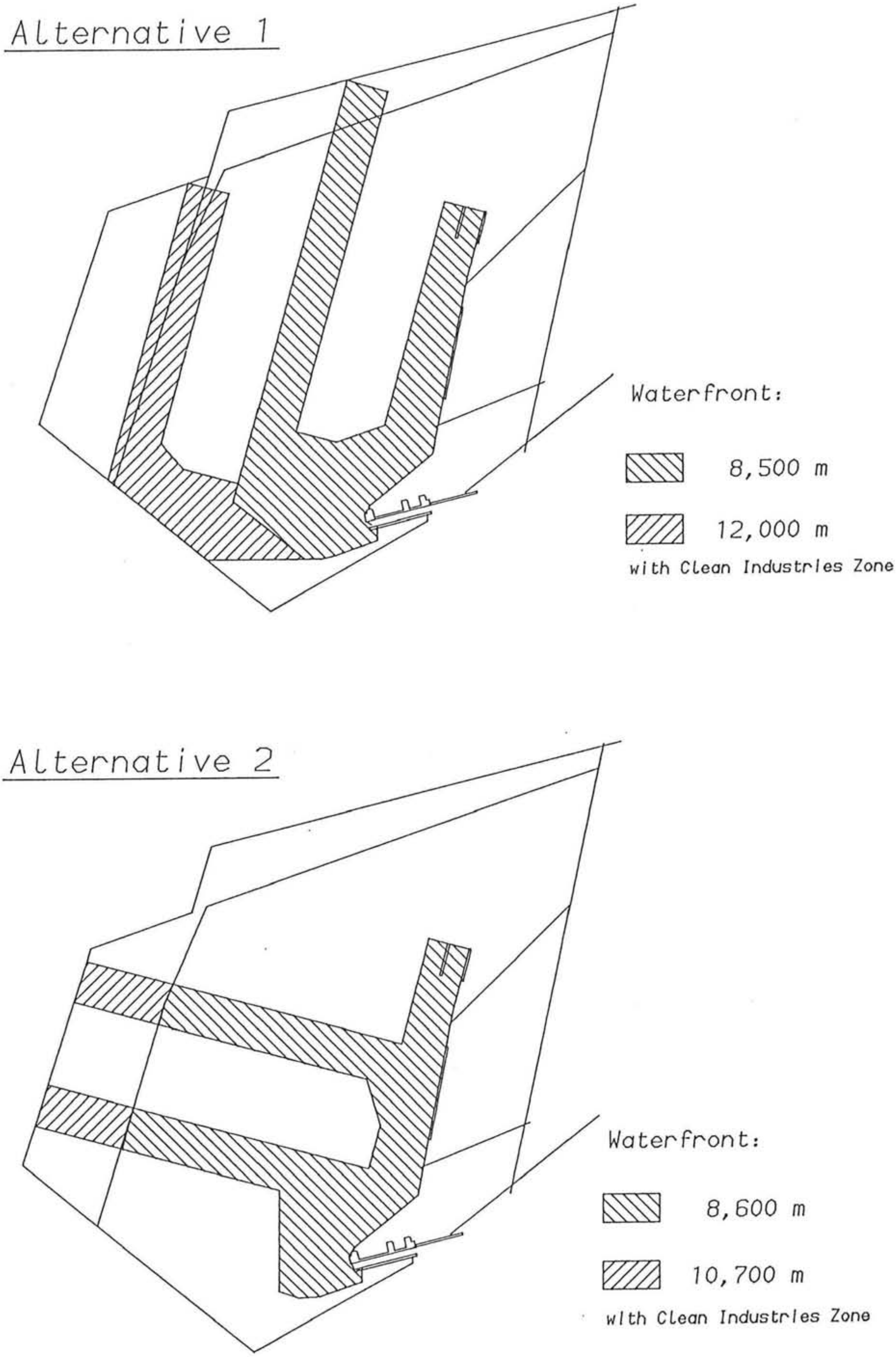
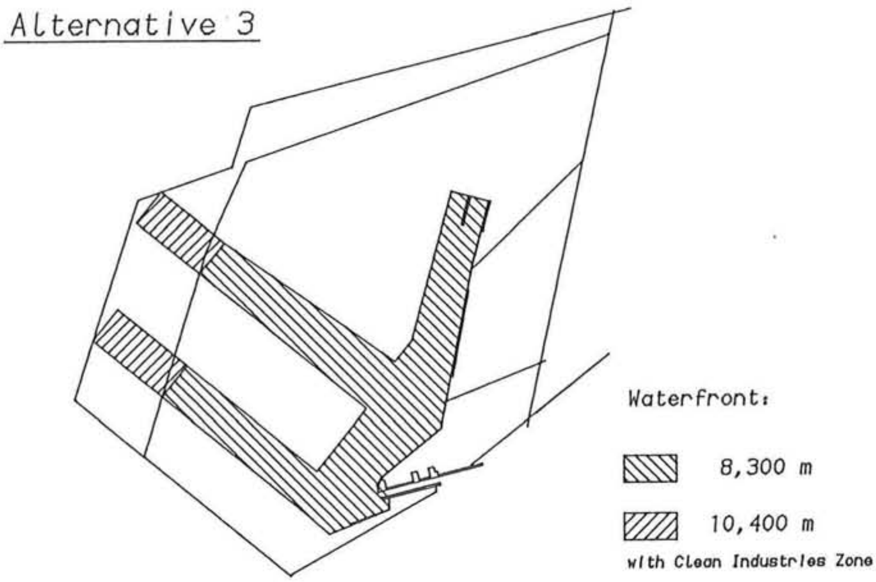
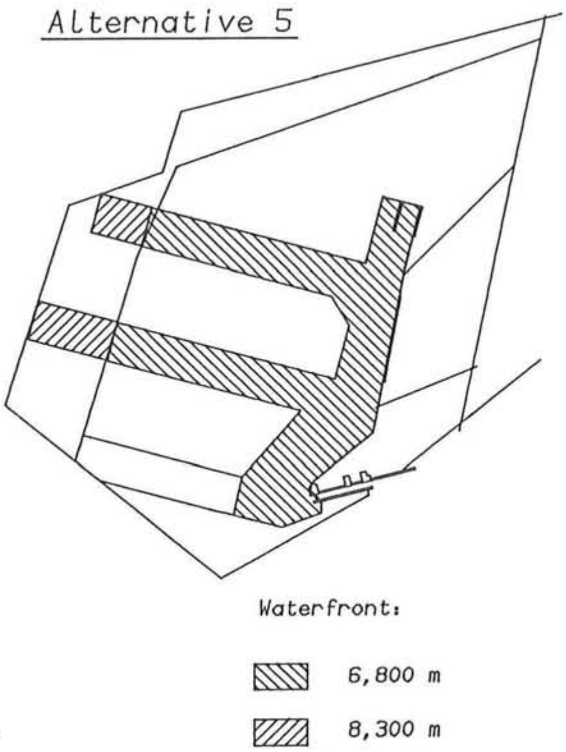


Figure 53: Alternatives for the layout of the basin





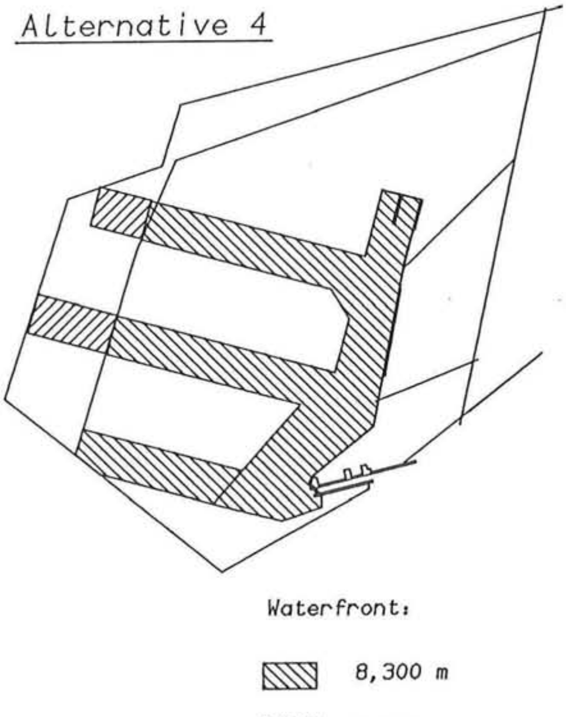
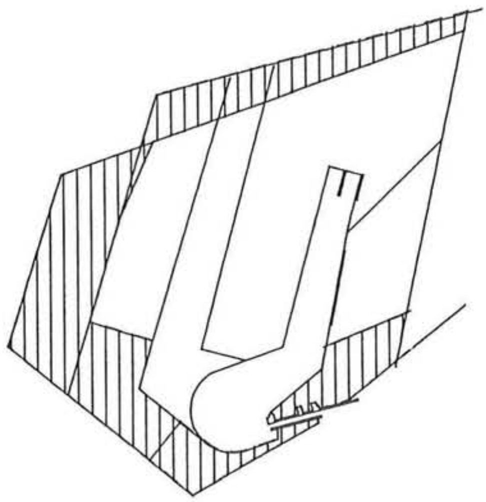
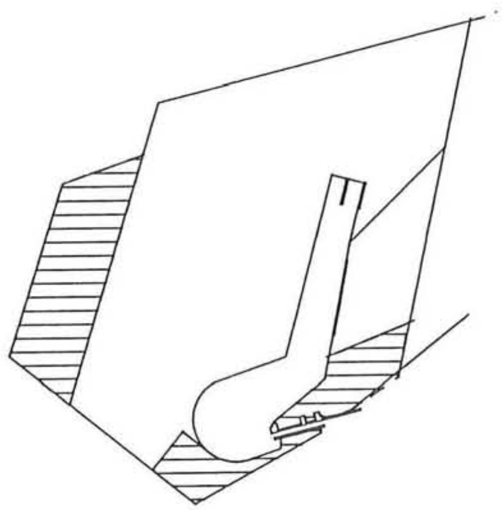


Figure 53: Alternatives for the layout of the basin



reservations in current masterplan
for other than port purposes



not used for preparation
port layout

Figure 54: Extension of reserved port area in existing masterplan

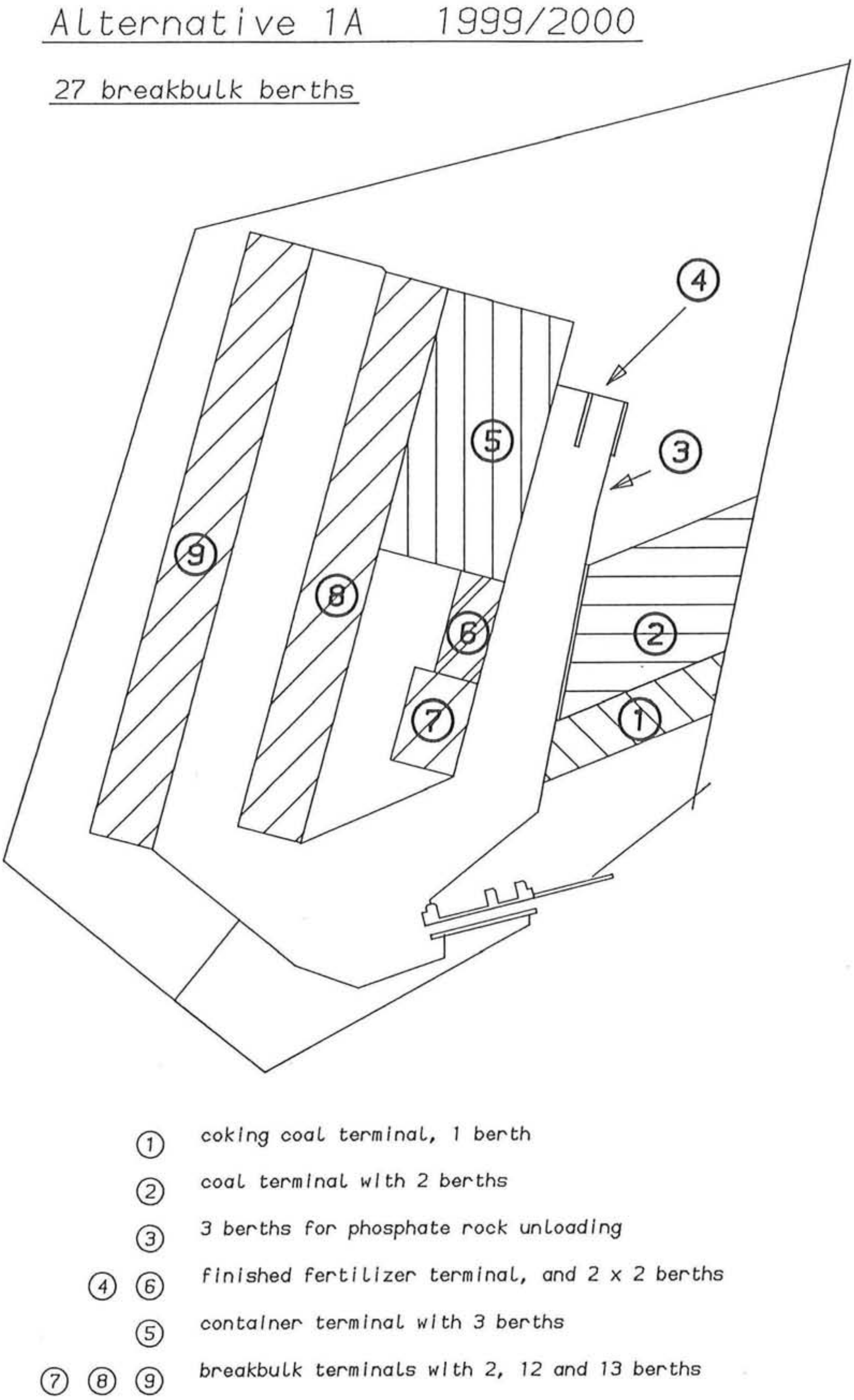
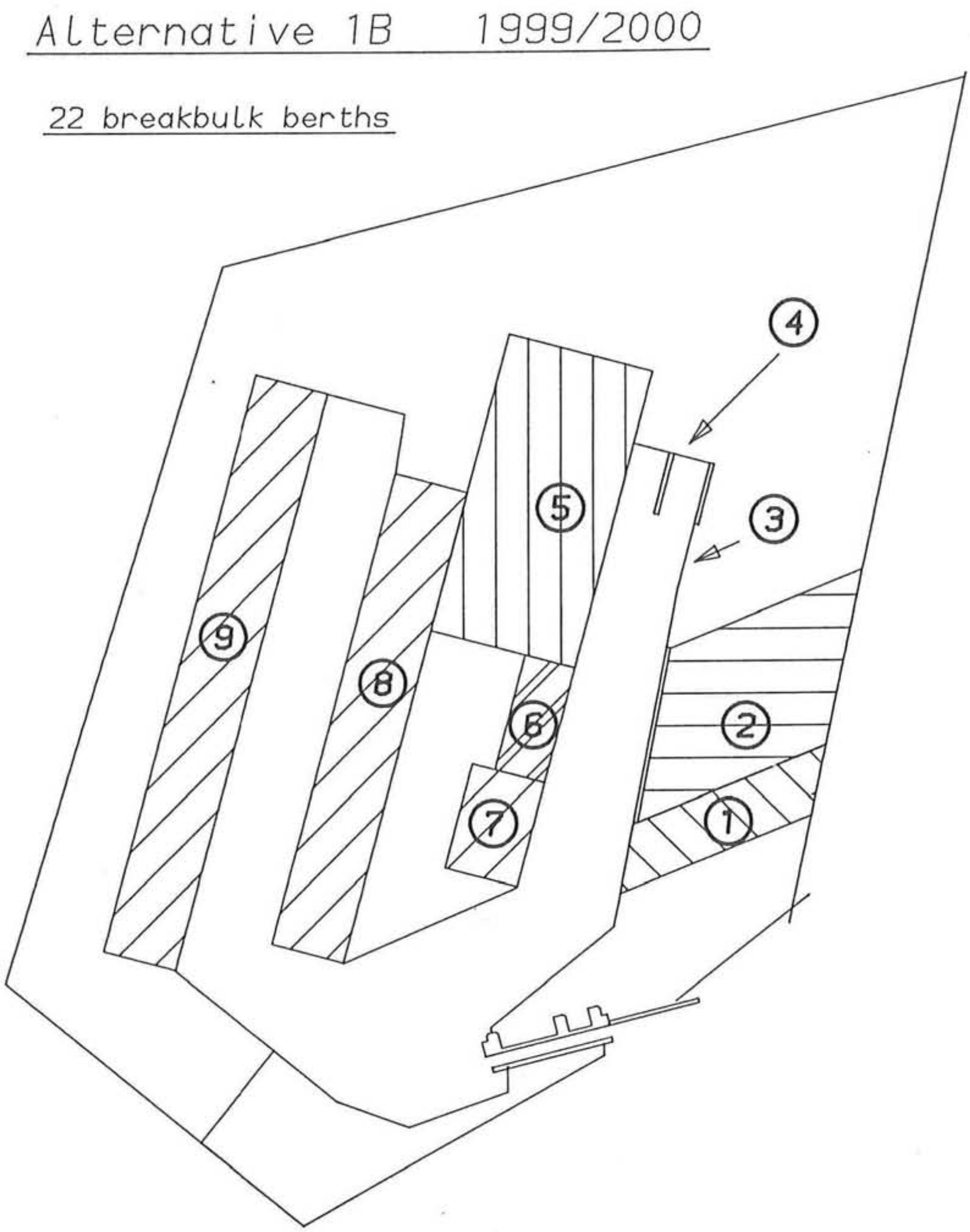


Figure 55: Alternative 1 for the arrangement of the terminals



① coking coal terminal, 1 berth

② coal terminal with 2 berths

③ 3 berths for phosphate rock unloading

④ ⑥ finished fertilizer terminals, and 2 x 2 berths

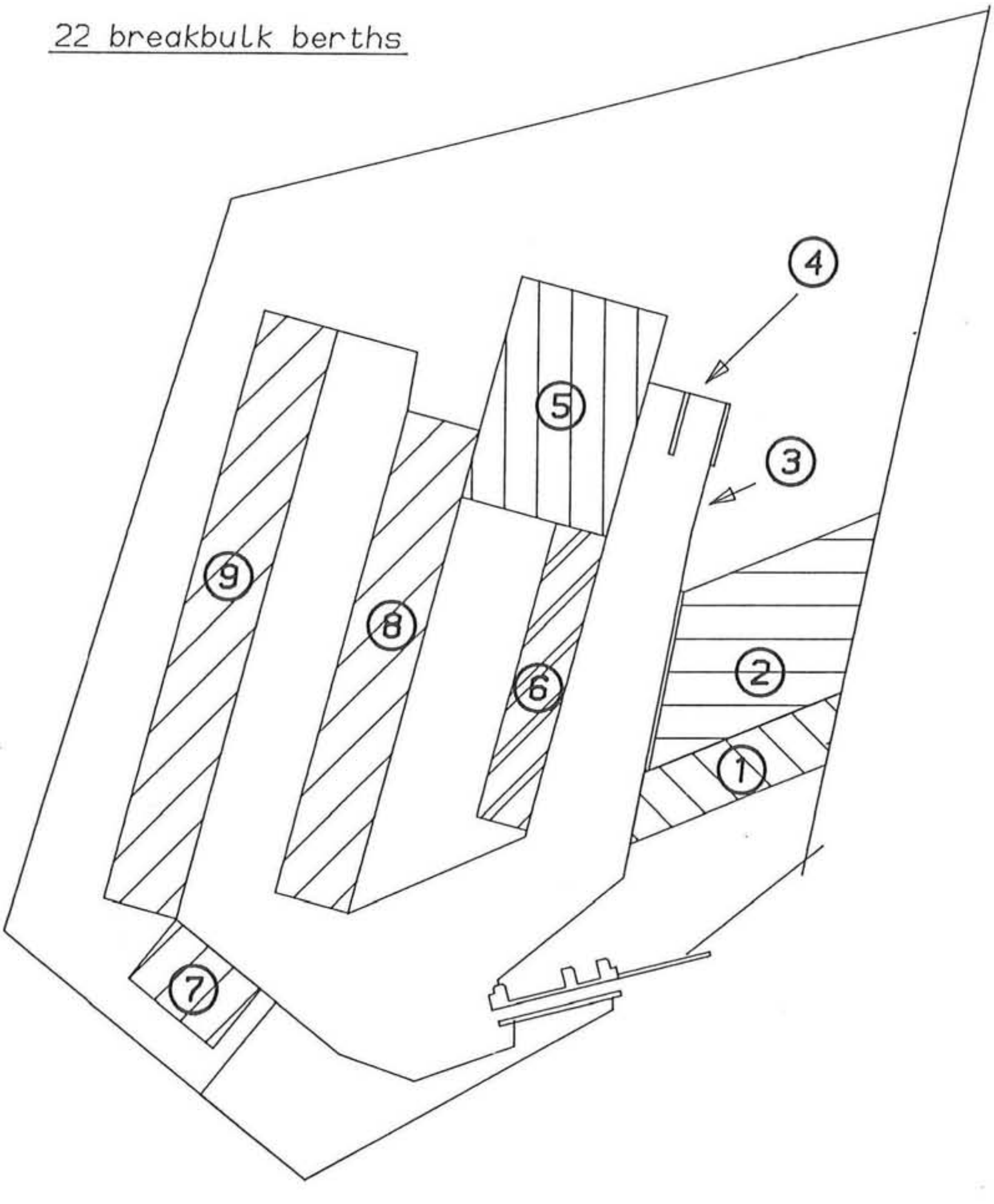
⑤ container terminal with 3 berths

⑦ ⑧ ⑨ breakbulk terminals with 2, 9 and 11 berths

Figure 55: Alternative 1 for the arrangement of the terminals

Alternative 1C 1989/1990

22 breakbulk berths



(1) coking coal terminal, 1 berth

(2) coal terminal with 2 berths

(3) 3 berths for phosphate rock unloading

(4) 1 finished fertilizer- and 1 phosphate rock unloading berth

(6) finished fertilizer terminal with 5 berths

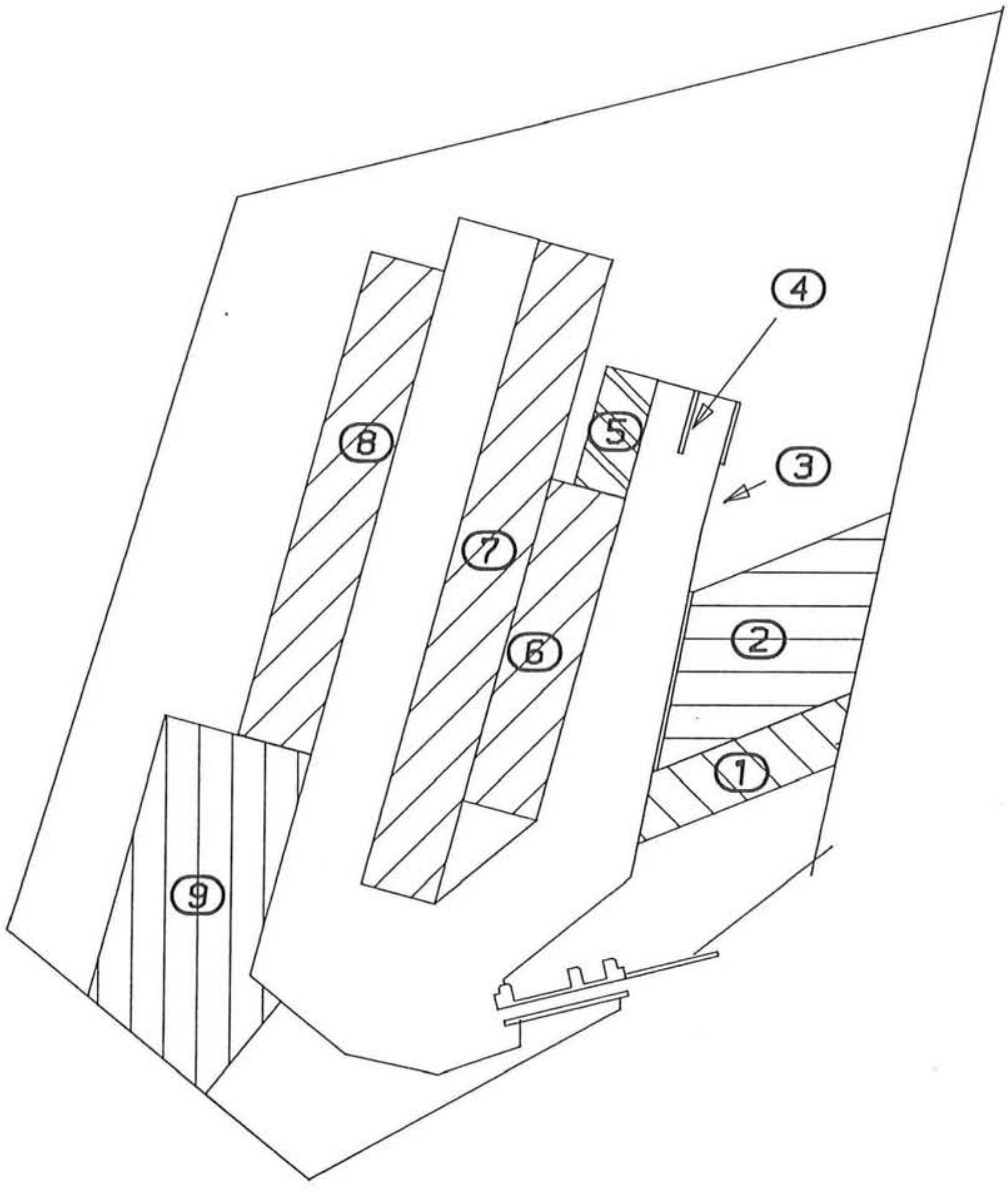
(5) container terminal with 2 berths

(7) (8) (9) breakbulk terminals with 2, 9 and 11 berths

Figure 55: Alternative 1 for arrangement of terminals

Alternative 2A 1999/2000

27 breakbulk berths



(1) coking coal terminal, 1 berth

(2) coal terminal with 2 berths

(3) 3 berths for phosphate rock unloading

(4) (5) finished fertilizer terminal, and 2 x 2 berths

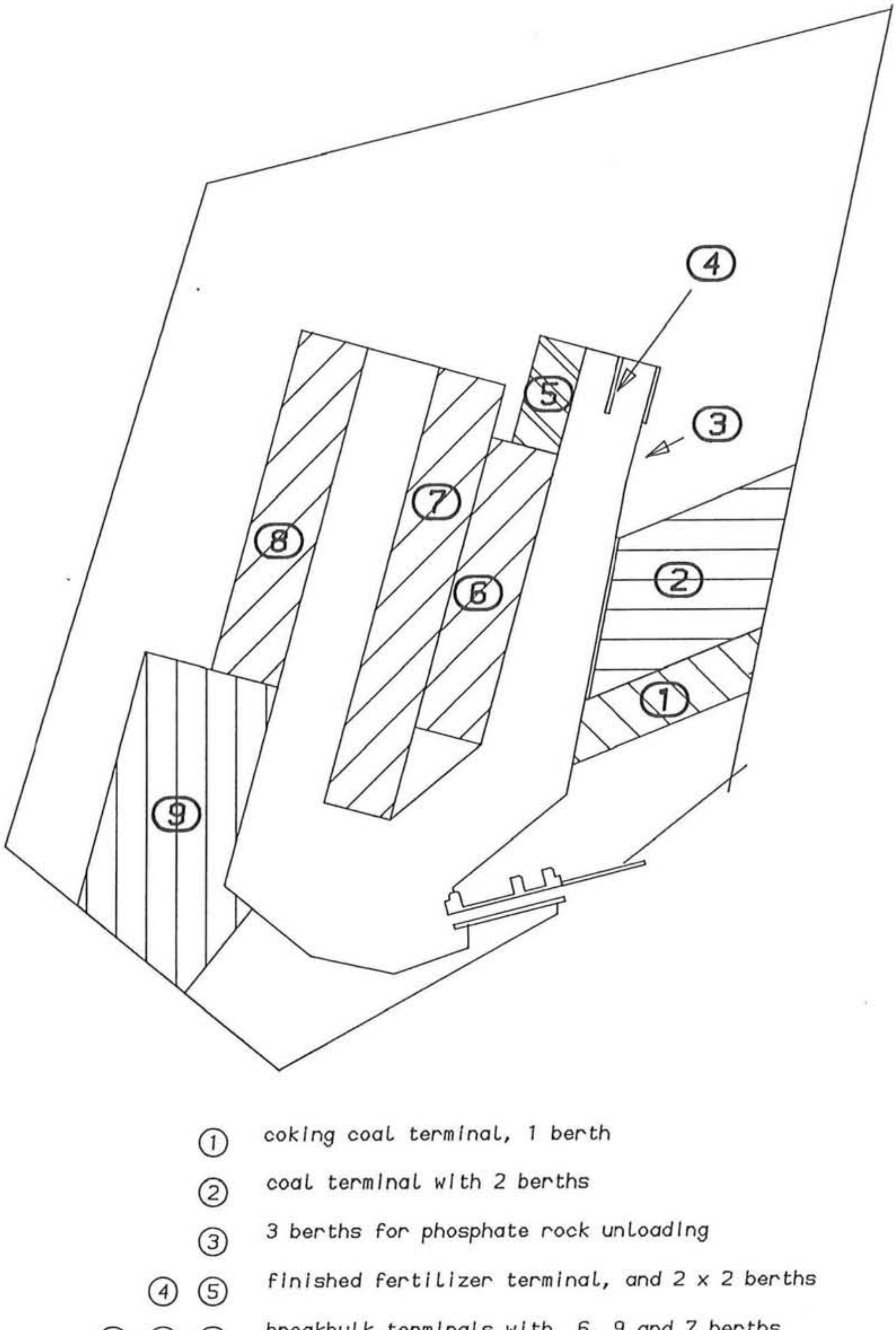
(6) (7) (8) breakbulk terminals with 6, 12 and 9 berths

(9) container terminal with 3 berths

Figure 56: Alternative 2 for the arrangement of the terminals

Alternative 2B   1999/2000

22 breakbulk berths



① coking coal terminal, 1 berth

② coal terminal with 2 berths

③ 3 berths for phosphate rock unloading

④ ⑤ finished fertilizer terminal, and 2 x 2 berths

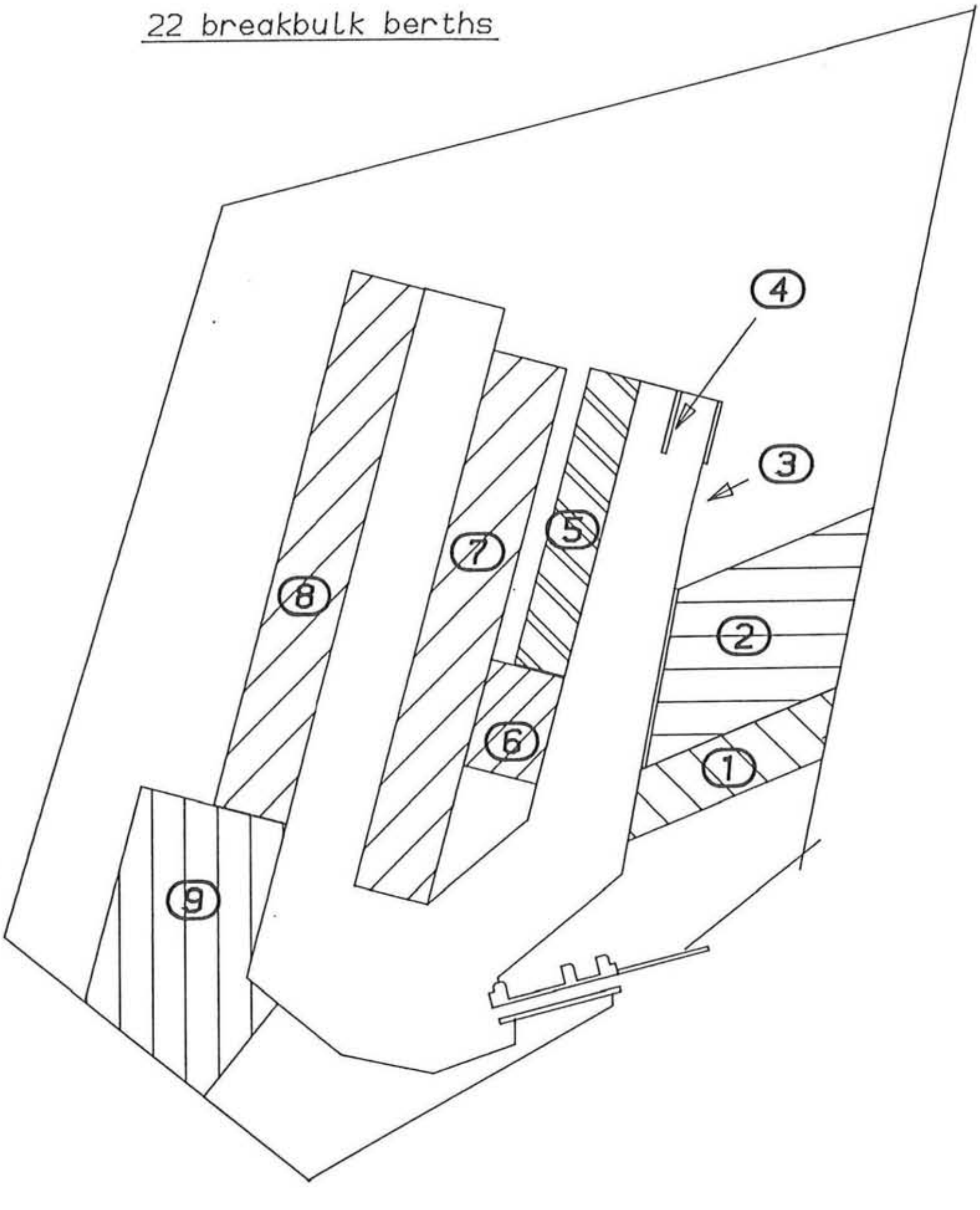
⑥ ⑦ ⑧ breakbulk terminals with 6, 9 and 7 berths

⑨ container terminal with 3 berths

Figure 56: Alternative 2 for the arrangement of the terminals

Alternative 2C 1989/1990

22 breakbulk berths



(1) coking coal terminal, 1 berth

(2) coal terminal with 2 berths

(3) 3 berths for phosphate rock unloading

(4) 1 finished fertilizer- and 1 phosphate rock unloading berth

(5) finished fertilizer terminal with 5 berths

(6) (7) (8) breakbulk terminals with 2, 10 and 10 berths

(9) container terminal with 2 berths

Figure 56: Alternative 2 for arrangement of terminals

Figure 57: Final layout container terminal