Neka Harbour

Separate Port Development

ROYAL HASKONING

CONFIDENTIAL

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PREFACE

The present M.Sc. thesis forms the completion of my education at the Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department of Civil Engineering, Division Ports and Inland Waterways. The research has been performed by order of Royal Haskoning, division Maritime.

The study concerns a feasibility study for *separate* port development of Neka Harbour in Iran. Focus in the study is on the port planning of the waterside part of the port.

During the study a short visit was made to Iran. Neka Harbour was visited and meetings were held with representatives of NIOC. Many thanks go to Royal Haskoning for giving me this opportunity. In one week I learned a lot, as well from my supervisors Theun Elzinga and Wim Welvaarts as from the Iranian people.

Special thanks go to Wim Welvaarts, who was my supervisor at Royal Haskoning. I would also like to thank from the Rotterdam 1 office, Theun Elzinga, Jacco Valstar, Egbert van den Berg and Etienne Aalten, who were always willing to answer my questions.

Furthermore I would like to thank the graduation committee for their supervision and personal help in bringing this project to a favourable end. The committee consists of:

- Prof. ir. H. Ligteringen (Chief Supervisor, DUT)
- Ir. R. Groenveld (Supervisor, DUT)
- Ir. F.A.M. Soons (Supervisor, DUT)
- Ir. W.A.C. Welvaarts (Supervisor, Royal Haskoning)

The thesis consists of two report volumes:

Volume I: Neka Harbour – Separate Port Development
Volume II: Real Time and Fast Time Simulation – A Comparison Study

Roel de Bree
The Hague, December 2006

SUMMARY

Neka Harbour

Neka Harbour is located along the southern Caspian Sea Coast in the North of Iran (*refer Figure 0-1*). Originally the port was founded to facilitate the operations of the Marine Industrial Company (SADRA) – a shipyard. At present the National Iranian Oil Company (NIOC) possesses 3/4th of the port. Currently, some 75 ha dry area and approximately 35 ha protected wet area are in use to facilitate both SADRA, and the oil related activities of NIOC's sub-companies (OTC, KEPCO, NDC).

Figure 0-1: Location Neka Harbour

SWAP Deals Iran

The Caspian Coastal states located North of Iran, Kazakhstan, Azerbaijan and Turkmenistan, have a combined oil reserve of 30 billion barrels and 220 trillion cubic feet of gas reserves. Problem for these countries is the lack of direct access to international shipping routes. Iran made "SWAP" deals with these countries, i.e. substituting Caspian oil for Persian Gulf oil. Neka Harbour is an important factor in these deals, whereas under the SWAP arrangements the Caspian oil producers ship their product to Neka Harbour, where Caspian tankers discharge their cargo. The Caspian oil companies then receive an equivalent amount of crude from an Iranian port on the Persian Gulf.

Expansion Neka Harbour

The SWAP deals will ensure increasing throughputs for Neka Harbour. Both port users, NIOC and SADRA, have to expand their capacity. For this purpose a port planning study was performed by Royal Haskoning, based on a joint use of the port basin. SADRA and NIOC had selected Alternative 0 as their preferred Alternative (refer Figure 0-2).

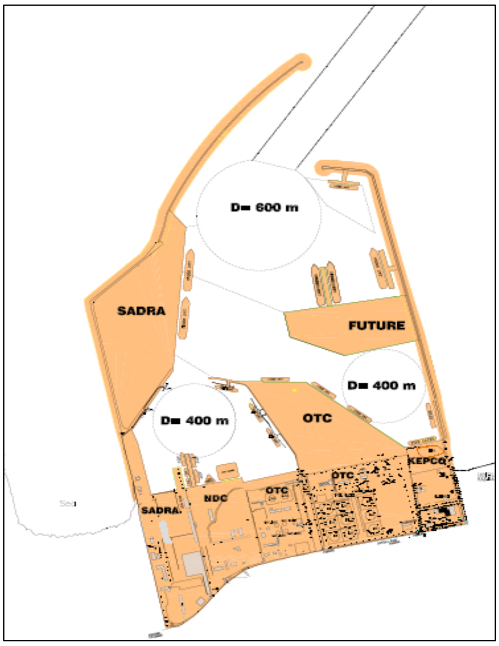

***Figure 0-2: Layout** Joint Port Development*

Recently, NIOC had decided that it might be opportune to split the port basin and approach channel for both users, i.e. a separate port development. In the present study the feasibility of such a *separate port development* for Neka Harbour has been researched. Focus in the study was on the port planning of the waterside part of the port.

During an exploration of the problem it was identified that:

- User Requirements for the separate port development are the same as the requirements which were valid for the joint port development. In addition requirements are stated on the physical split of the port
- Neka Harbour is positioned in an environment with relatively tranquil natural conditions with highest waves coming from N-NW direction
- Crude Oil is the key commodity for Neka Harbour. In 2014 a throughput of 1,000,000 barrels per day is expected
- The port has to be designed for tankers up to 70,000 DWT

Port Planning Exercise

A port planning exercise focusing on separate port development is performed. Four distinctive different Alternatives were developed (refer Annex XII). These Alternatives have been evaluated by means of a Multi Criteria Evaluation (MCE). In addition a Bill of Quantities (BoQ) of all alternatives was prepared for each alternatives. The conclusion was drawn that Alternative A and D are potentially feasible when considering a *separate port development*. Alternative A was chosen as the main subject for the remaining of the thesis. The layout of Alternative A is depicted in Figure 0-3.

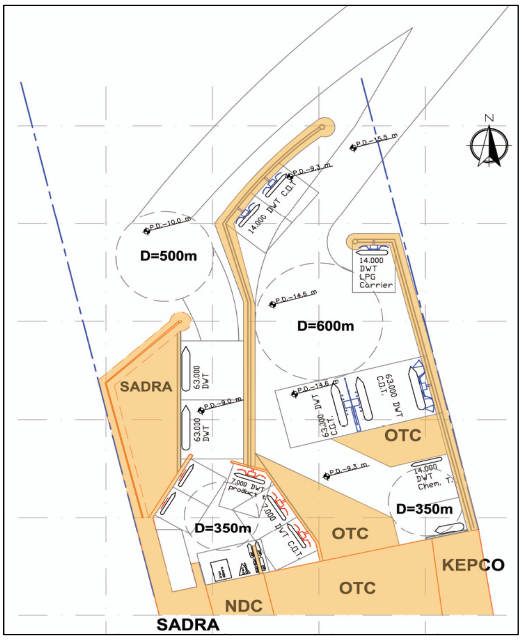

Figure 0-3: Layout Alternative A
Separate Port Development

In the evaluation of Alternative A, it was assessed that the wave agitation in the West Basin, and the accessibility of both basins could be critical. Hence it was decided to perform a wave tranquillity study and a ship manoeuvring simulation, in order to analyse whether Alternative A is acceptable.

Numerical Wave Modelling

The "Boussinesq Wave module" of Mike21 software was used for the wave study regarding the West Basin. Simulations were performed for irregular waves coming from N to NW directions. The design of the middle breakwater was varied in the modelling, i.e. a caisson type and a rubble mound type. The operational and limit state conditions were both analysed. It was assessed that if the middle breakwater is designed as a rubble mound type then the layout is acceptable. For this configuration the following is valid:

- *The West Basin is subjected to downtime for normal port operations, less than 3.15 % of time*
- *Vessels do not have to leave the West Basin for extreme conditions with a return period of less than ten years*

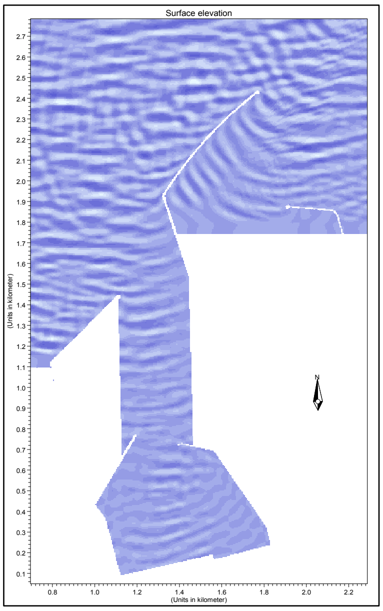

Figure 0-4: Wave Study

Navigational Study

A navigational study was performed using "Shipma 6.1 Fast Time Simulation" software. The design vessel for the West Basin was a 30% ballasted 63,000 DWT tanker. The design vessel for the East Basin was the same vessel but fully loaded. It was assessed that:

- *During normal natural conditions the West Basin can be accessed safely; these conditions are exceeded in 6% of the time*
- *During normal natural conditions the East Basin can be accessed safely; these conditions are exceeded in 3% of the time*

Conclusions

For all port processes in Neka Harbour the level of downtime was assessed and expressed in costs. It became clear that for the *separate port development* both the investment and yearly downtime costs are slightly higher compared to the *joint port development*. The current study did not focus on what the advantages of a separate port development are. The benefits should be clearly analysed before a decision can be made whether to perform a *separate* port development or a *joint* port development. Further it is strongly recommended to perform a risk assessment and a detailed economical analysis for both port developments, as it was not part of the current study.

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ABBREVIATIONS

SADRA	:	Iran Marine Industrial Co.
NIOC	:	National Iranian Oil Co.
NDC	:	National Drilling Co.
OTC	:	Oil Terminals Co.
KEPCO	:	Khazar Exploration & Production Co.
PSO	:	Ports & Shipping Organisation
NITC	:	National Iranian Tanker Co.
DWT	:	Dead Weight Tonnage
bpd	:	Barrels per day
tpa	:	Tonnes per annum
FPSO	:	Floating Production, Storage and Offloading Vessel
LPG	:	Liquid Petroleum Gas
LOA	:	Length Over All
RT-Simulation	:	Real Time Simulation
FT-Simulation	:	Fast Time Simulation

PART ONE: INTRODUCTION

1 INTRODUCTION

Neka Harbour is located along the southern Caspian Sea Coast in the North of Iran. Recently, the government of Iran made SWAP deals[1] with the countries bordering the East Coast of the Caspian Sea. These deals initiate increasing throughput figures for Neka Harbour in the coming years. Subsequently, the port has to be expanded in order to guarantee an efficient assimilation of the forecasts.

A master plan study for the expansion of Neka Harbour is currently being undertaken by the consultancy firm Royal Haskoning. This master plan focuses on a *joint port development* for both port users, i.e. SADRA (IRAN Marine Industrial Company) -a shipyard- and NIOC (National Iranian Oil Company). A 'port planning study report' was prepared for the same. This report includes a number of master plan layout Alternatives. The client of Royal Haskoning (SADRA and NIOC together) had selected Alternative E as their preferred Alternative. This layout can be found in Annex I.

Recently it was decided by NIOC that it might be opportune to separate the port development for both SADRA and NIOC. The current thesis assignment focuses on this *separate port development*, i.e. both parties require their own basin including a dedicated approach.

1.1 Problem Analysis

Originally Neka Harbour was founded to facilitate the shipyard company, SADRA. In later times the port was expanded to create facilities for the unloading of liquid products. Until recently the port consisted of 2 small Breakwaters with along the Eastern Breakwater three jetties. This configuration was sufficient considering the throughput figures.

As indicated in the introduction, throughput figures will increase heavily the coming years. Expansion of Neka Harbour is required for both port users. NIOC desires an expansion because of the increasing throughput figures. SADRA is the builder of the tankers which are aimed to transport the 'SWAP' related Crude Oil to Neka. To be able to construct and maintain these types of vessels, SADRA have to enlarge their constructing capacity.

Originally both port users agreed upon a *joint port development*. In co-operation they made a phased development plan and moreover they agreed upon a joint use of the waterside area of the port. At present, already an extension of the western Breakwater is performed. Alignment of this Breakwater is based on joint use of the basin.

As indicated in the first Section of this Chapter, NIOC has indicated that it might be opportune to carry out a *separate port development*. They might want to develop the port into two separated basins, one for SADRA and one for NIOC.

[1] SWAP deals comprise arrangements on substituting Caspian oil for Persian Gulf oil. Please also refer Section 2.1

This fact leads to the following problem definition:

> On political grounds it might be opportune to split Neka Harbour for both port users. However, it is not clear whether it is technically feasible.

It is emphasized that the study on *joint* port development still is actual and ongoing. The assignment for a study on *separate* port development has been contracted by NIOC to understudy the possibilities *for the occasion* that it is decided to expand the port independently from SADRA. But, whenever that *occasion* appears, SADRA will not be involved at all as an active player in NIOC its masterplan. For the layout of the port this means a physical split of the port into two basins with each having its dedicated approach.

NIOC has set out a number of requirements on how the expansion of the port should be. These requirements will certainly have an impact on the activities of the other port user.

1.2 Objectives

In the current thesis it will be studied if it is feasible for NIOC to perform a *separate port development*. Essential in this is not only to make a satisfying development for NIOC but also to develop a master plan which is acceptable to SADRA as well.

The following research questions will be a red line through the study:

1. What are the basic port user requirements
2. What are the additional port user requirements generated by the desire to separate the port expansion
3. Which port layouts are suitable for a separate port development
4. Does an acceptable masterplan on *separate* port development exist for:
    a. NIOC
    b. SADRA
    c. Both NIOC and SADRA

1.3 Scope

Focus in the study will be on the technical and planning aspects of the masterplan. No economical optimization is foreseen on the issue when to perform a joint or a separate port development. The study can be seen as a feasibility study for *separate* port development. It aims to be an overall study with detailed sub-studies on critical issues, wherever they appear.

A masterplan study on *joint* development is being undertaken at this moment. Focus in that study is both the land- and waterside facilities of the port. The present study focuses on the waterside part of the port, whereas only this part will differ greatly in design compared to the ‘joint development’ study.

1.4 Approach

Figure 1-1 describes the used approach in the study.

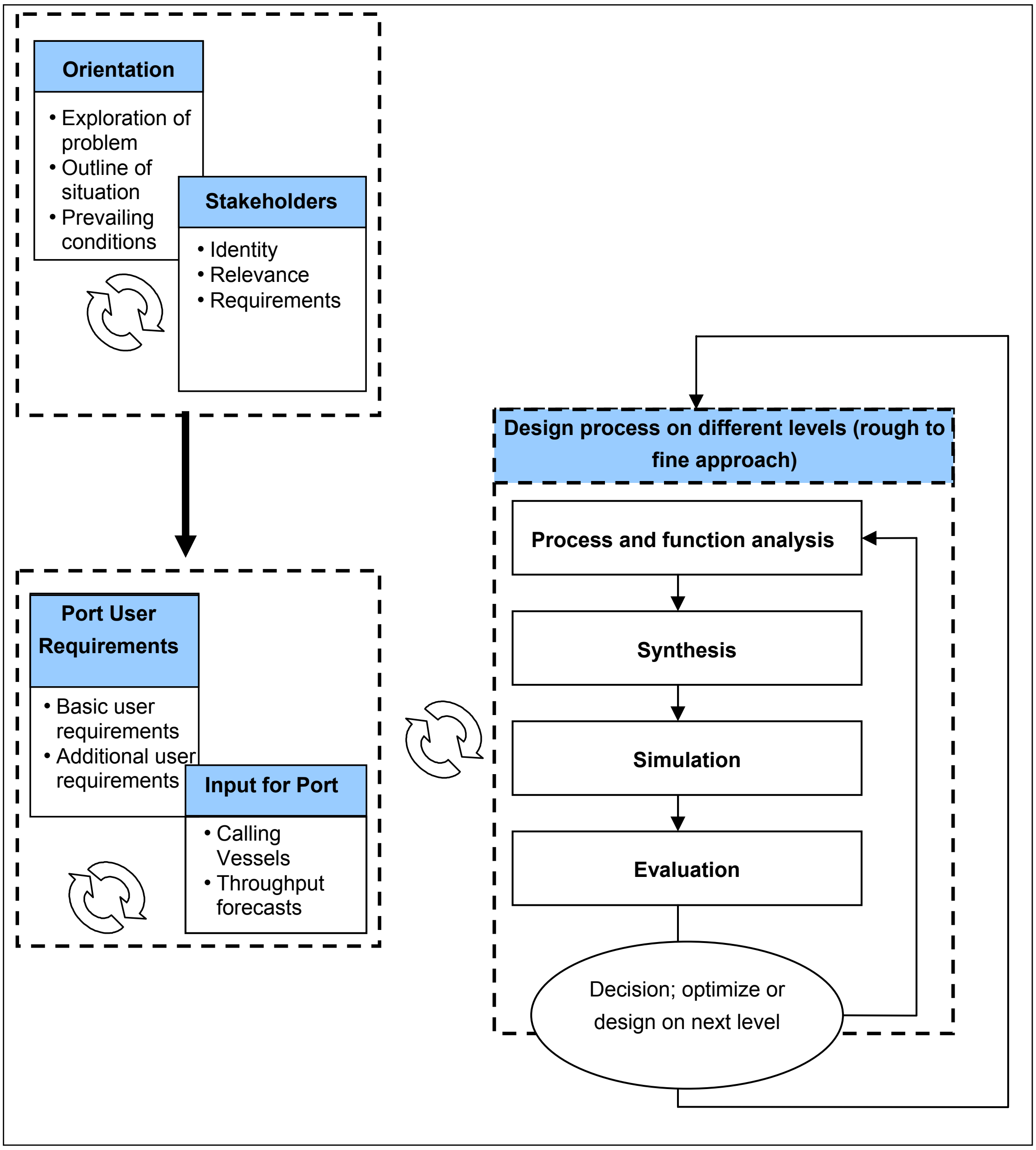


Figure 1-1: Approach in the Study

1.4.1 Orientation and Stakeholders

First the situation was explored. All available information and literature relevant to Neka Harbour has been reviewed. This orientation was a cyclic process in co-operation with the stakeholder analysis, i.e. by scrutinising relevant information, the stakeholders were identified and by analysing these stakeholders new sources and directions for relevant information were identified.

The basic conditions and requirements with which the port has to deal are identified in this part of the study.

1.4.2 Port User Requirements

Specific requirements made by the port users were defined from which port design parameters were derived. Number and type of vessels calling at Neka, and the throughput forecasts are the most important topics in this.

1.4.3 Design Process on Different Levels

The design has been carried out from rough to fine, i.e. from system level to sub system to component level (levels of decomposition). All according to the steps as depicted in Figure 1-1.

1.5 Report Structure

The report is split in six parts. Content of each part is discussed below.

1.5.1 Introduction

In Chapter 1 the problem is defined and the scope of the project has been determined. To depict the total study, all relevant information was explored. In Chapter 2 a summary is given on the available general information regarding Neka Harbour and its surroundings.

1.5.2 Data Gathering

Chapters 3 to 6 describe the data relevant for Neka Harbour. It comprises a stakeholder analysis, dimensioning of vessels calling at Neka, and throughput analysis.

1.5.3 Conceptual Design

In part three, the basis is set out for the port planning exercise. First a concept of the system is defined (Chapter 7). Secondly the system is split in various sub-systems. The landside sub-systems are discussed in Chapter 8. The waterside sub-systems are discussed in Chapter 9. Forthcoming all relevant components which have to be positioned in the port planning are dimensioned and analysed in Chapter 10.

1.5.4 Preliminary Synthesis and Evaluation

On basis of the design part, a port planning study is carried out in Chapter 11. Five distinctive different port lay outs are defined. A qualitative as well as a quantitative evaluation is performed on these Alternatives. The results can be found in Chapter 12.

1.5.5 Simulation and Refinement

Chapters 13 presents a wave tranquillity study performed. In Chapter 14 the navigational study on Alternative A is presented. Results of both simulations are analysed in Chapter 15. Possible refinements are analysed on their feasibility, the result is presented in Chapter 15 as well.

1.5.6 Conclusions and Recommendations

In this part the conclusions made during the study are summarised. Final conclusions will be drawn and recommendations for further study are presented.

2 NEKA HARBOUR

In this Chapter, any kind of information related to Neka Harbour will be discussed. First general information about the port and its surroundings will be discussed. Secondly the historical development of Neka Harbour will be treated. Thereafter an overview will be given on the present actual situation; what is currently operational, and which components are under construction. The Chapter will conclude with a discussion on the future prospects of the port.

2.1 General

Neka Harbour is situated at the Caspian Sea in the Northeast of Iran. The Harbour was originally founded as a home base for SADRA, but at present oil related activities are represented as well.

The oil and gas reserves of Iran itself are nearly all located in the southern part of the country. Neighbouring countries, Kazakhstan, Azerbaijan and Turkmenistan have a combined oil reserve of 30 billion barrels and 220 trillion cubic feet of gas reserves. Problem for these countries is the lack of direct access to international shipping routes. Different export routes are being developed to bring the vast amounts of oil and gas to the world market. One of these routes is established by means of SWAP deals between Iran and its neighbouring countries.

Neka Harbour is an important factor in these deals, whereas under the SWAP arrangements the Caspian oil producers ship their product to Neka Harbour, where Caspian tankers discharge their cargo. The Caspian oil companies then receive an equivalent amount of crude from an Iranian port on the Persian Gulf.

Figure 2-1: Iran, its surroundings and the location of Neka Harbour

2.2 History

Exact information on the historical development of Neka Harbour isn't available. Known is that in the 1970's the Shahid Salimi Power Plant, situated West of Neka Harbour, has been constructed. This can be considered as starting point of the developments in and around Neka Harbour. The Power Plant makes use of an intake and outlet system for cooling water. As a consequence of the construction, accretion occurred at the West side of the plant and erosion took place at the East side of the plant. Around 1990 a groyne at some 300 m West of the plant was constructed in an effort to stop the ongoing erosion.

At present the groyne is situated just West of the existing West Breakwater of Neka Harbour. The West Breakwater was constructed in the years 1994/1995, purpose of the Breakwater was to protect the shipyard complex of the Iran Marine Industrial Corporation (presently called SADRA) from incoming waves. In later times the West Breakwater was extended and the East Breakwater constructed to create protection and access to oil berths to be used by NIOC (National Iranian Oil Co.).

Figure 2-2: Birds view on Neka Harbour

2.3 Present Situation

2.3.1 Geographical

Neka Harbour is located in the North of Iran at the Southeast side of the Caspian Sea. Coordinates of the position of the harbour are 36.50˚ latitude and 53.16˚ longitude. Presently some 75 ha dry area and about 35 ha protected wet area is in use to facilitate the port operations. The shoreline of the surrounding coast is positioned at some 77˚ of North.

2.3.2 Organisation

Neka Harbour can be defined as a semi private service port model[2]. Two parties are related to Neka Harbour. One party is a private company (SADRA) involved in offshore, onshore, oil and gas, shipbuilding and repair as well as infrastructure civil projects. The other party is NIOC (National Iranian Oil Co.), a government owned company. More information on these companies can be found in Chapter 3.

Figure 2-3: Present Situation Neka Harbour

2.3.3 Port Operations

The Shipyard complex of SADRA is situated in the western part of the harbour and comprises some 17 ha land. The complex presently consists of a dry dock for 63,000 DWT vessel, Ship lift, construction area / berth for semi-submersibles, ship repair yard and additional facilities.

The remaining 58 ha land is used (or will be used in future) by NIOC related companies, all performing oil related business. The wet area is in joint use but arrangements are made on the possession of it. A map concerning the boundaries of available water area is included in Annex II.

On the East side, Neka port currently has existing facilities for the simultaneous berthing of three 5,000 – 7,000 DWT tankers. Each berth comprises of two unloading arms with a rated capacity of 800 m^3/hr each. The port also has facilities for blending of the imported crude oil, which is required as the oil is of four grades. Therefore OTC (Oil Terminal Company) possesses currently 9 tanks of which 6 are receiving tanks whilst the other three are used for blending. Nominal tank capacity is 28,000 m^3, which equals about 158,000 barrels.

[2] Private service port: the private port developer owns all the assets and operates all the services. [*Ref. 20*]

Present situation in Neka Harbour regarding the yearly throughput of the various liquids is given in Table 2-1.

Table 2-1: Present Throughput Figures (source: [*Ref. 11*])

Commodity	Yearly Throughput
Crude oil	28,835,000 barrels
Mazut[3]	239,000 tonnes
Gasoline / Diesel	239,000 tonnes

2.3.4 Port Expansion

At the moment there are a few components under construction. In the following the components will be discussed on their characteristics and the progress of construction.

Semi-Submersible
Although not a fixed part in the port, presently a large semi-submersible is under construction at the SADRA shipyard (refer Figure 2-5). The semi-submersible will be used for oil exploration at the Caspian Sea.

Dry Dock
SADRA is currently building a new dry dock for construction of 63,000 DWT tankers and future maintenance works on all types of vessels (refer Figure 2-4).

Extension West Breakwater
SADRA (as a contractor) has already started with the construction of the extension of the western Breakwater (refer Figure 2-6). The Breakwater was originally planned to extend perpendicular to the shore some 2,000 m into sea. According recent information this length would only be 1,500 m. SADRA has already constructed 1,120 m perpendicular to the coast and a curved section to the East of 400 m length. However, at this point SADRA was ordered by the PSO to stop the construction on ground of not having an approval for construction of the Breakwater.

New East Breakwater
SADRA is also constructing a new East Breakwater located some 700 m to the East of the existing East Breakwater (refer Figure 2-7). This Breakwater is planned to be of 1500 m length perpendicular to the shore.

New Pipeline
A new pipeline with capacity of pumping through 370,000 bpd to the hinterland is currently under construction.

[3] Mazut is a residue of Oil and is used as a fuel.

Figure 2-4: Dry Dock under construction

Figure 2-5: Semi Submersible under construction

Figure 2-6: Extension of the West Breakwater

Figure 2-7: Construction of East Breakwater

2.4 Economic Prospective

Iran's industrial infrastructure and population are located primarily in the northern part of the country. To meet the oil demand of this region, oil used to be pumped from the fields in the South to refineries and distribution centres in the North.

The "SWAP" arrangements between Iran and its neighbouring countries changed the situation. Since the moment of the "SWAP" deals Iran's northern refineries and distribution centres are served by Caspian Sea oil from the aforementioned countries. The oil is transferred via sea routes and direct pipelines. In turn, Iranian oil which was previously transferred from southern Iran to its northern refineries would instead be delivered to Iran's Persian Gulf oil terminal, Khargh Island, and sold in lieu of Caspian oil.

In the initial stage, the volumes of oil involved in the swap deals comprised some 50,000 barrels per day (bpd) being transferred by pipeline from Neka to Tehran refinery. Recently, an existing 300 km pipeline that earlier delivered oil products from Tehran refinery to the North Caspian region of Iran, has been upgraded and reversed. This caused an increase in capacity to some 120,000 bpd. In near future capacity will be increased to some 500,000 bpd by finalising the construction of a new pipeline with a capacity of 370,000 bpd.

At present the transport of crude oil towards Neka takes place with relatively small vessels (5,000 to 10,000 DWT). To meet the future demand, larger tankers (63,000 DWT) are being ordered. Some of these tankers will also be constructed in Neka Harbour. For this purpose and for future maintenance of the expanding tanker fleet in the Caspian Sea, a new dry-dock is under construction at Neka Harbour by SADRA construction company, who will also be the owner of the dry-dock.

PART TWO: DATA GATHERING AND ASSIMILATION

3 STAKEHOLDERS AND REQUIREMENTS

The two main users of NEKA Harbour are SADRA and NIOC (National Iranian Oil Company). Both parties differ considerably in performed activity. SADRA performs ship construction and maintenance in Neka Harbour. Activities of NIOC related with Neka Harbour are: exploration, production, blending and throughput of crude oil and natural gas.

Neka Power Plant is an important neighbour of Neka Harbour. This plant is located some 700 meters West of Neka Harbour and is mainly of importance as it uses sea water for cooling purposes. This process could possible be hampered by the expansion of Neka Harbour.

The mentioned stakeholders will be discussed in Section 3.1. An overview of all relevant identified stakeholders, including their interests and relation with Neka Harbour is given in Section 3.2. The requirements of all stakeholders are listed in Section 3.3.

3.1 Main Stakeholders

3.1.1 SADRA

SADRA is a private company mainly involved in shipbuilding and ship repairing, oil and gas, infrastructural projects and offshore installations and engineering. Emphasis is on the local Iranian market and on the Middle East and Asian markets. The company was founded in 1968 as a small repair yard in the city Bushehr, situated in the North West region of the Persian Gulf. Through the years, SADRA has established itself as a leading engineering and construction company doing different turn key projects. SADRA has its main office in Tehran and currently possesses two shipyards, one in Bushehr and one in the Caspian Sea at Neka.

3.1.2 NIOC

The National Iranian Oil Company was founded in 1948. Company’s core business is exploration, development, production, marketing and sales of crude oil and natural gas. NIOC's oil and gas in place reserves are 561.9 bn barrels and 41.14 trillion cubic meters, respectively which give it a unique status in the global energy supply. In fact, in recent years, NIOC has been invariably ranked as one of the biggest four global oil companies. Current NIOC production capacities include over 4 million barrels of crude oil and in excess of 300 million cubic meters of natural gas per day. On the export side, the company benefits from its modern extensive facilities on the three islands of Kharg, Lavan and Siri consisting of 17 jetties capable of berthing tankers of all sizes to lift and export its crude oil.

NIOC has been able to establish acceptable degrees of coordination within its organizational set up. In fact, NIOC's "Directors" act primarily in policy making and supervision while subsidiaries act as their executive arm in coordinating an array of operations such as exploration, drilling, production and delivery of crude oil and natural gas, for export and domestic consumption.

With respect to Neka Harbour this means that sub-companies of NIOC and related companies are established or will establish in Neka harbour. At this moment NIOC's sub-company OTC imports and blends crude oil in NEKA Harbour. Expansion of these activities is planned. Other sub-companies which are planned in Neka Harbour are the National Iranian Drilling Company (NDC) and the Khazar Oil Exploration and Production Company (KEPCO).

3.2 Facts

3.2.1 Overview

All identified stakeholders are given in the Table below. Summarised in the columns are their physical relation to Neka Harbour and the interest they have with respect to the Harbour.

Table 3-1: Overview Stakeholders

Stakeholder	Full name	Physical relation to Neka Harbour	Overall Interest
NIOC	National Iranian Oil Co.	Parent company of the oil related users of Neka Harbour	Coordinating Iranian oil activities
KEPCO	Khazar Exploration & Production Co.	Accommodations and facilities in port	Exploration and production of oil
NDC	National Drilling Co.	Accommodations and facilities in port	Operations and maintenance offshore drilling and exploration
OTC	Oil Terminals Co.	Accommodations and facilities in port	Receipt, storage and transit of crude oil and oil products
NITC	National Iranian Tanker co.	Shipping in port	Transports the crude oil from sites in Caspian Sea to Neka terminal
Future port users	No specs	Accommodation for future users in port	
PSO	Ports & Shipping Organisation	Accommodations and facilities in port	Responsible for the port traffic control
Marine services		Accommodations and facilities in port	Guarantee optimal use of port
SADRA	Iran Marine Industrial Co.	Accommodations and facilities in port (Physical separated with NIOC part)	Constructs and maintains vessel and marine structures for use in Caspian Sea
Surrounding users of the area	-	Direct neighbours	Unknown
Neka Power Plants		Neighbour at some 700 m West of Neka Harbour	Uses cooling water, recirculation
Amirabad port		Neighbour East of Neka Harbour	Port operations
Local government		-	Policy making and maintaining
National government		-	Policy making and maintaining
International mandatory treaties		-	Policy making and maintaining

3.2.2 Development Plan

The stakeholders made in co-operation a strategy on phased development. This plan was mostly applicable on joint development but gives a good framework for- and insight in- the new situation, regarding *separate port development*. Furthermore some requirements are linked to this plan. Time span of this phasing strategy is depicted below.

Table 3-2: Phasing

Phase	Operational at Date
0	Present
1	June 2009
2	February 2014

3.3 Port User Requirements

3.3.1 Basic User Requirements

During submission of the study on *separate port* development it was pointed out that user requirements for a *separate port* development remain as in the *joint development* study. All requirements are listed in Annex III, a split is given to requirements which are already assimilated in the existing situation and to requirements which have to be fulfilled in future.

3.3.2 Additional User Requirements

In the view of the new assignment (refer to Section 1.1), i.e. a separate port development for SADRA and NIOC, new requirements were received. As discussed before NIOC is the initiator of the new assignment and hence they are the composer of the new requirements. In the following, these requirements are referred to as *additional user requirements*. These requirements are all focussed on the situation of separated port development and in particularly on the physical separation itself. The following additional requirements were received:

- **[NIOC-1]** Eastern Breakwater of NIOC independent harbour to be identical to the Eastern Breakwater of the 'combined' SADRA – NIOC harbour as planned in the study on joint development
- **[NIOC-2]** Breakwater entrance configuration of NIOC's independent harbour to be identical to the entrance configuration of the 'combined' harbour
- **[NIOC-3]** The alignment of the western Breakwater of NIOC's independent harbour will run from the 'southern edge' of the physical model test area (at approx. N 4081500) Southward to the eastern Breakwater of the existing small port
- **[NIOC-4]** SADRA's 'new' (extended) Breakwater will be assumed to be 'as it currently is', in other words: no further future extensions of this Breakwater are foreseen within the framework of this new planning assignment

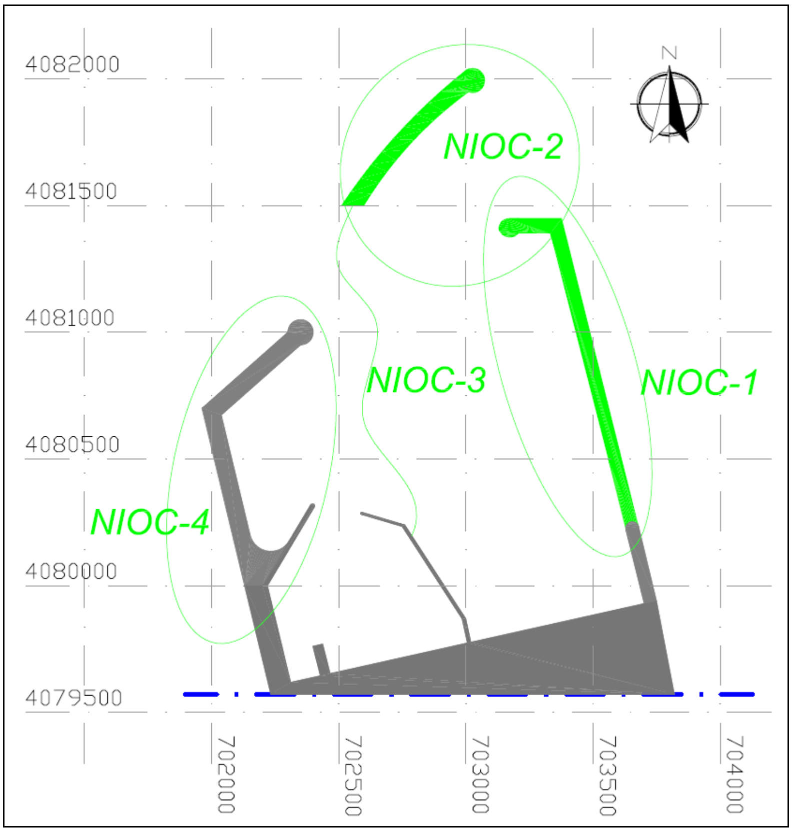


Figure 3-1: Additional Port Requirements

4 NATURAL CONDITIONS

All (potential) relevant natural conditions which are applicable on Neka Harbour are scrutinised. In this Chapter a summary is given of the same.

4.1 Geotechnical

No detailed information regarding the subsoil is available yet. Boreholes are planned to be taken. Known is already, that during construction of the newly extended western Breakwater by SADRA, a substantial settlement was reported. In any case, the incident demonstrates the possible presence of weak soils.

4.2 Water Levels

4.2.1 Project Datum

In 2005 a bathymetric survey was carried out. For this survey a Project Datum was defined. This Project Datum approximates to Mean Sea Level (MSL) at the time of the bathymetric survey and refers to the mean sea level of the Persian Gulf.

- $MSL_{Caspian\ Sea}$ = 0 m PD (Project Datum) = -26.4 m PGD (Persian Gulf Datum)

4.2.2 Mean Sea Level Changes

Contrary to other seas and oceans in the world, the average water level in the Caspian Sea shows to be rather unpredictable. Long term records indicate that the average level has varied considerably during the years. In Figure 4-1 the recorded variation form 1950 until 2002 is given. .

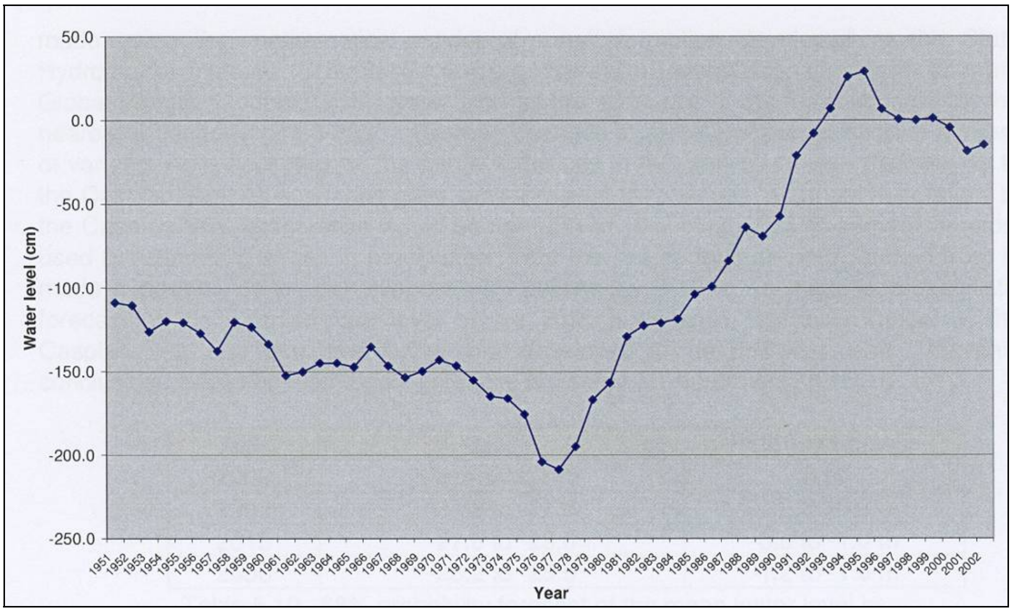


Figure 4-1: Variation of Caspian Sea Water Level, 1951 to 2002 (source: [*Ref. 12*])

In view of this observed variation in mean water level, many attempts have been undertaken in the past to predict the short and long term variation of water level. Scenarios regarding rising sea levels in the first half of the 21st century up to 6 to 10 m are predicted by some researchers, while others forecast it falling some 6 m.

The State Hydrological Institute (SHI, st. Petersburg, Russia) developed a dynamic stochastic model of the Caspian Sea level before 2030 in order to make a probabilistic forecast [*Ref. 12*]. The main conclusions based on the modelling results are summarised in Table 4-1.

Table 4-1: 68% probability forecast of the mean water level in the Caspian Sea in the years 2005 to 2030. Reference level is Persian Gulf Mean Sea Level (source: [*Ref. 12*])

Year	Level	Relative Change	Deviation with 95% Confidence Probability
2000	Approx. -26.4 m	0 m	
2005	-26.6 to -26.7 m	-0.2 to -0.3 m	± 0.75 m
2015	-27.0 to -27.4 m	-0.6 to -1.0 m	± 1.3 m
2030	-27.6 to -28.0 m	-1.2 to -1.6 m	± 1.6 m

4.2.3 Seasonal Variations

Because of the enclosed character of the Caspian Sea, appreciable tides are not present in the Caspian Sea. Though, due to the variation in river run-off, the water level does show monthly variation. River run-off is largest in summer and lowest in winter. Consequently the water level is highest in summer and lowest in winter. Observing the variations measured over a period of 50 year, it can be concluded that these variations are in the order of 15cm to 25cm increase/decrease to MSL [*Ref. 12*]. Maximum values, recorded during a measurement period of 50 years, are an increase of 0.268m and a decrease of 0.378 m.

4.2.4 Atmospheric Pressure Differences

Due to atmospheric pressure differences the water level in the Caspian Sea will vary. Extreme atmospheric values of about 990 hPa and 1046 hPa cause respectively a water level increase of about 0.25 m and a water lever reduction of 0.30m. Mean of the atmospheric pressure is 1016 hPa [*Ref. 12*].

4.2.5 Wind Set-up and Set-down

Wind set-up and set-down have been assessed at approximately 0.35m [*Ref. 12*].

4.2.6 Normal and Extreme Water Levels

The water levels as defined for the joint development of Neka Harbour are adopted in this study.

- Normal water levels: as described in Table 4-2
- Extreme water levels are derived by the summation of the following items (these items are considered to be independent):

Table 4-2: Extreme Water Levels (source: [*Ref. 12*])

	Max [m]	Min [m]	
Seasonal Variation	0.268	-0.278	
Atmospheric Pressure	0.25	-0.30	
Wind Set-up/down	0.35	-0.35	+
	0.9	**-0.9**	

- Normal minimum low water at MSL -0.5 m

4.3 Bathymetry

The Harbour of Neka is located in the Southeast corner of the Caspian Sea, bathymetry of the Caspian Sea itself including the location of Neka Harbour is given in Figure 4-2. The local bathymetry around Neka Harbour is sketched in the same Figure. It can be seen that the existing port is situated in relative shallow water. The Breakwaters of the original small port basin extend to some PD -3.5 m. The Port entrance of the planned port basin is approximately located at the PD -7.5 depth line, which is situated at some 2000 m offshore.

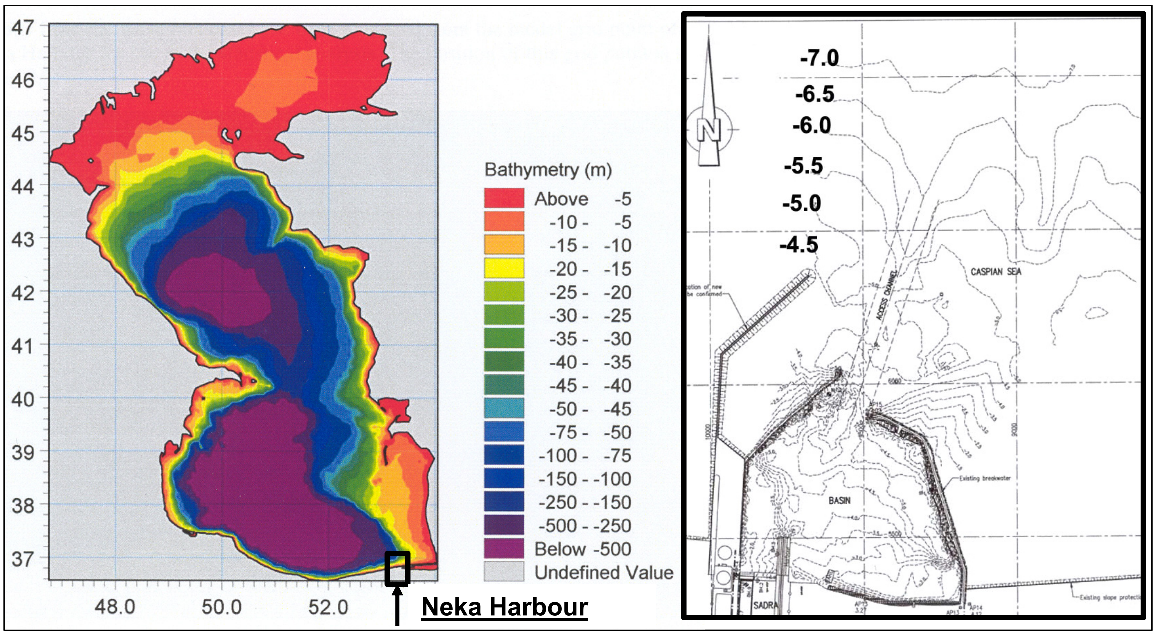


Figure 4-2: Bathymetry Caspian Sea and around Neka Harbour

4.4 Meteorology

In the Mazandaran province, where Neka Harbour is located, two opposite climates prevail. One is characterised by the plains at the vicinity of the sea and the other by the mountains in the elevated areas of the province. The plain climate has moderate weather, while the mountainous climate brings cold weather, snow and frost. In general, the climate of Mazandaran can be characterised as moderate and humid.

The winds blowing from the West are warm and bring rainfall and the winds blowing from the East and Northeast are cold and lead to snowfall. Average temperature in the hottest month of the year is about 27˚C and 25˚C in the coldest month. Generally, the eastern region has a dryer climate than the western sections. Usually, the temperature never exceeds 37˚C. Extreme temperatures observed in a period of 50 years are -7˚C and +42˚C.

4.4.1 Winds

Babolsar meteorological station[4] has recorded 38 years of wind data. This data is available on the website of the Iranian Meteorological Organisation. In Annex IV a print concerning the wind data is included. The print contains a typical one month record and the analysis of 38 years measurement.

In general, wind speeds are moderate (up to 5 m/s). Winds are mostly from SW to NW to NE and E with the strongest winds from the W-NW sector. Wind rose and the design wind for a return period of 100 years is given in Figure 4-3 and Table 4-3.

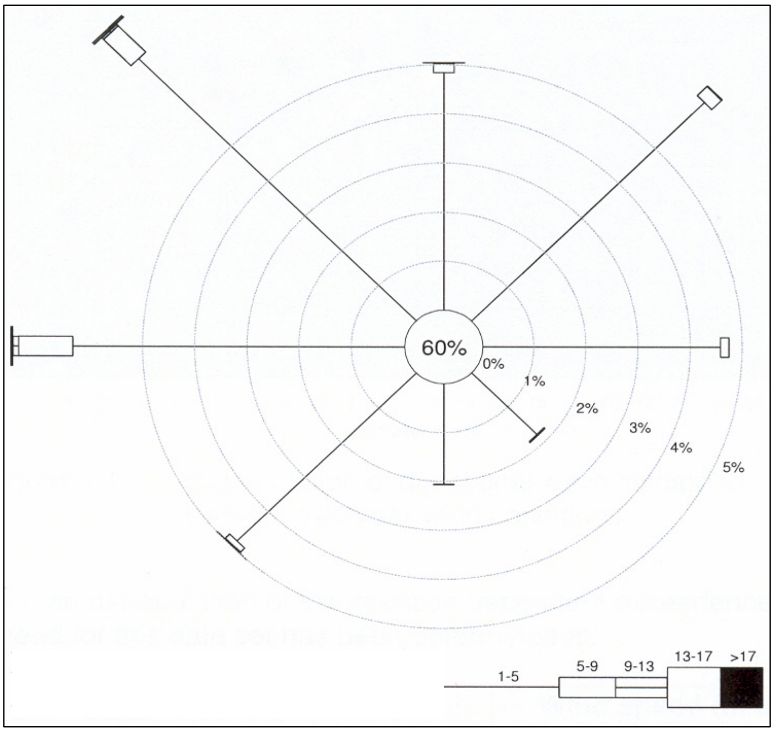


Figure 4-3: Wind Rose (source: [*Ref. 12*])

Table 4-3: Directional design wind speed, return period of 100 years (source: [*Ref. 12*])

Direction	Wind Speed (m/s)
N	16.4
NE	12.6
E	11.6
SE	9.7
S	11.9
SW	20.3
W	21.5
NW	22
All	24

[4] Babolsar Meteorological station is located some 50 km West of Neka Harbour

4.4.2 Visibility

In one year, the mean value of days with visibility less than 2 km is 22 days [*Ref. 19*].

4.4.3 Water Temperature

The water temperature of the region along the Iranian coast is highest compared to that of northern and Middle Caspian Sea. The temperature range in southern Caspian Sea is between 3.5˚C and 28˚C with an increase of 4˚C from West to East. Warming of the sea water in spring creates thermo clines between 30-40 m of depth, in the southern Caspian Sea, by winter it disappears [*Ref. 12*].

4.5 Wave Climate

4.5.1 Operational Wave Conditions

An indication of the operational wave conditions near Neka Harbour can be best derived from measurements carried out by Delft Hydraulics in 1991-1992 near Neka at a water depth of 13.5 m. In Annex V Tables are included showing the measurements. The annual wave rose is given in Figure 4-4.

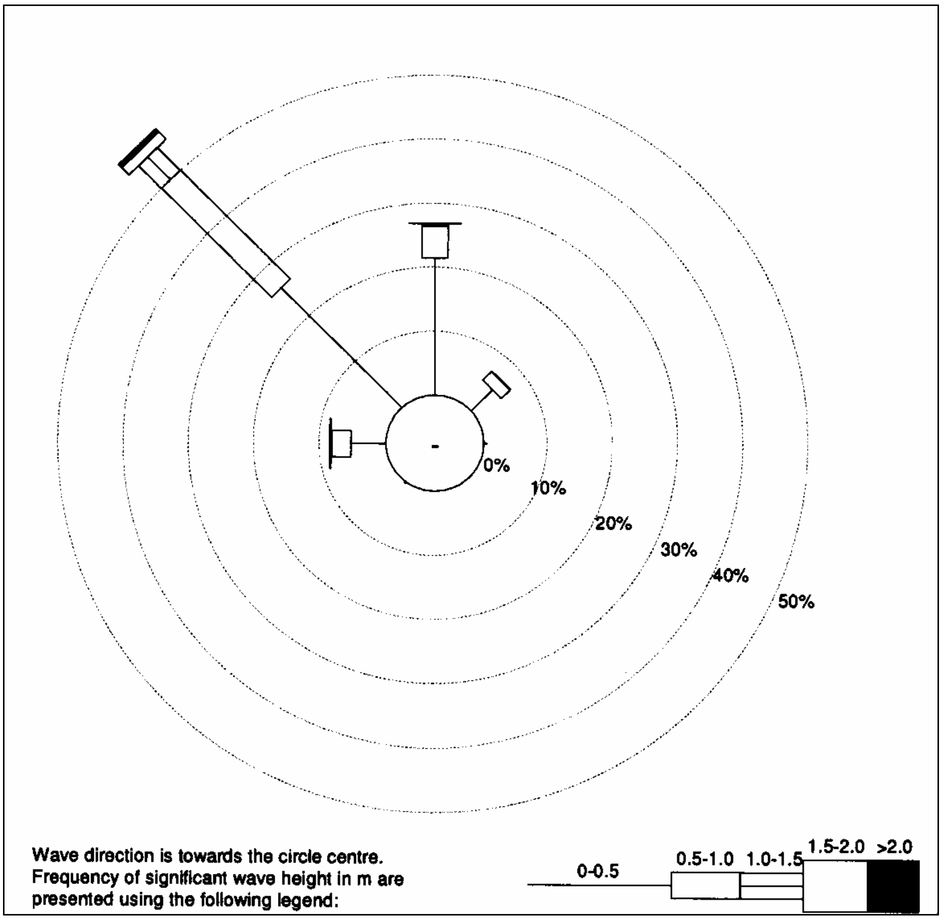


Figure 4-4: Annual Wave Rose (source: [*Ref. 12*])

4.5.2 Extreme Wave Conditions

Iranian National Center for Oceanography (INCO) and DHI (Danish Hydraulic Institute) have together for Ports and Shipping Organization, Iran (PSO), carried out a wave modelling hindcast project for the Caspian Sea covering the period January 1992 to August 2003. This hindcast has been carried out using DHI's MIKE 21 SW spectral wave model and covers the entire Caspian Sea. Results from the wave hindcast have been extracted from a model grid point offshore Neka Harbour at a depth of 67 m.

Results of a statistical analysis (including a direction analysis) of the hindcast using the weibull distribution can be found in Table 4-4.

Table 4-4: Results of Peak-Over-Threshold analysis using a Weibull distribution for significant wave heights, Hm0 (m), offshore Neka Harbour (depth: 67 m) (source: [*Ref. 10*])

Return period (years)	Hm0 (m) NW		Hm0 (m) N		Hm0 (m) NE	
	Central estimate	Standard deviation	Central estimate	Standard deviation	Central estimate	Standard deviation
50	5.78	0.54	4.74	0.44	3.06	0.29
100	6.11	0.63	5.01	0.52	3.24	0.33

Based on the results of the statistical analysis, the design wave conditions offshore Neka Harbour were determined as the central estimate plus one standard deviation. To determine the mean wave period, T_{02}, the following relationship is used.

Equation 1: $$T_{02} = 3.2 \cdot H_{m0}^{0.5}$$

The offshore design wave conditions are shown in Table 4-5.

Table 4-5: Extreme wave conditions offshore Neka Harbour (depth: 67 m (source: [*Ref. 10*])

Return period [yr]	NW H_s [m]	NW T_p/T_m [s]	N H_s [m]	N T_p/T_m [s]	NE H_s [m]	NE T_p/T_m [s]
50	6.32	8.8/8.2	5.18	8.0/7.5	3.35	6.8/6.4
100	6.74	8.8/8.2	5.53	8.0/7.5	3.75	6.8/6.4

DHI analysed the near shore extreme wave conditions by modelling wave transformation using MIKE 21 NSW. Results at 9 m water depth in front of the western Breakwater can be found in Table 4-6.

Table 4-6: Extreme wave conditions at 9 m depth, in front of western Breakwater (source: [*Ref. 10*])

Offshore wave direction	Return period [yr]	Hm0 [m]	Tp [s]	Local wave direction [°N]
NW	1	3.4	8.1	324
	10	4	9.4	327
	100	4.2	10.6	329
N	1	2.9	7.3	357
	10	3.8	8.5	355
	100	4.1	9.6	354

4.6 Currents and Sediments

4.6.1 Offshore Currents

In 1988-1989, a wave rider buoy was used just offshore Neka Harbour (water depth approximately 30 m). This buoy measured current speed and direction. The resulting current rose of these measurements can be found in Figure 4-5.

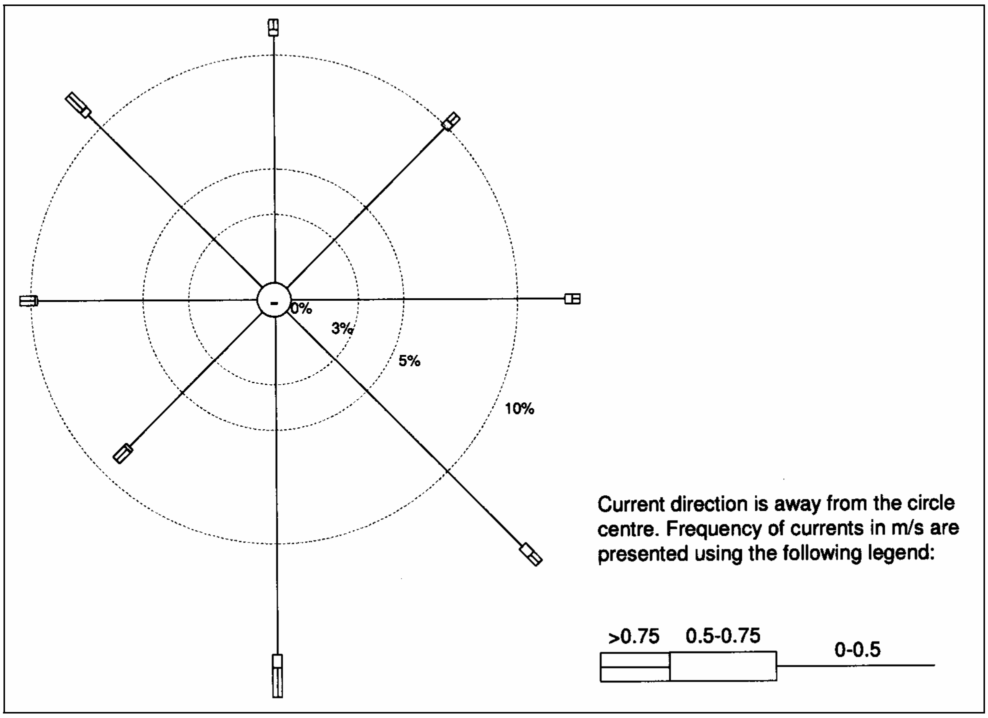


Figure 4-5: Current rose (source: [*Ref. 12*])

The current rose indicates that in general the currents are small in magnitude (less than 0.5 m/s) and running in all directions.

4.6.2 Nearshore Currents

DHI carried out a study to determine the typical current conditions at and around Neka Harbour. This study is performed with the flow model MIKE 21 FM. The flow profile is mostly depended on the wind. The simulations showed East – going currents for 180˚N-330˚N winds whereas 0˚N-150˚N winds result in West-going currents. Based on the wind statistics, discussed in Section 4.4.1, this means that the near-shore current is W-going approximately 1/3 of time and East going in 2/3 of the time.

4.6.3 Sediments

No information is available on the size or behaviour of sediment. Impression of the sediments may be obtained from the measurement of the nearby Amirabad port[5]. Review of the sieve curves indicate that the bottom sediments consist of silty sand. The median diameter of the sand is about D_{50} = 0.100 mm. Because the absence of a tide, river outflow, low value of wave set-up / set-down, and dependent on wind conditions, the amount of siltation is expected to be low.

[5] Amirabad is a harbour located some 8 km east of Neka Harbour

5 CALLING VESSELS AT NEKA HARBOUR

In the present Chapter the dimensions of the design vessels is discussed. In the requirements composed by the relevant parties is the fleet defined, mostly in categories of Dead Weight Tonnages. First these requirements will be stated. Due to its enclosed nature, the Caspian Sea is different than other seas worldwide. Especially the fact that the Caspian Sea is totally enclosed by land makes the Caspian Sea fleet different in dimensions than the world fleet. This will be discussed in Section 5.2. In Section 5.3 the design vessels calling at Neka Harbour are dimensioned.

5.1 Relevant Requirements

The requirements discussed in the following are made by the related parties [*Ref. 11*].

OTC

[OTC-1] Jetties capable of handling 5,000 DWT to 7,000 DWT tankers

[OTC-2] Crude oil fleet consists of:

i. 5,000 to 7,000 DWT tankers (maximum 300,000 BPD)
ii. 14,000 DWT tankers
iii. 63,000 to 70,000 DWT tankers

[OTC-3] Product tanker fleet consist of

iv. 5,000 to 7,000 DWT tankers

[OTC-4] One berth for chemical tankers of up to 14,000 DWT

[OTC-5] One berth for LPG carriers with design ship of up to 14,000 DWT

KEPCO

[KEPCO-1] Facilities for supporting services to maximum one unit as below:

i. FPSO unit, 12,760 DWT
ii. Pipe layer unit

NDC

[NDC-1] Provision of a berthing location for Iran Khazar jack up rig

[NDC-2] Provision for a berthing location for Iran Alborz Semi Submersible Drilling Unit

[NDC-3] Provision of 3 berthing locations for 3x 16,000 HP Anchor handling / towing support vessels (74.4mx16mx6.5m)

[NDC-4] Provision of 2 berthing locations for 2x 4,400 HP tug boats (33.5mx8.45mx4.13m)

SADRA

[SADRA-1] Existing fleet:

i. 1 Tug boat 1,400 HP
ii. 1 Tug boat 400 HP
iii. 1 Flat barge 36mx9.0mx2.70m
iv. 1 Flat barge 36mx12.0x2.80 (crane capacity 100 ton)

[SADRA-2] Dry dock with dimensions 250mx40mx11.8m, suitable for 63,000 DWT tankers

[SADRA-3] 2 berthing posts with 5m water depth and capacity for berthing 5,000 ton vessels

[SADRA-4] Capacity of the mentioned ship building factory is expected to be suitable for 70,000 ton ships (without goods and maximum 30% ballast) and berthing and (un)loading of maximum 7,000 DWT vessels

5.2 World Fleet and Caspian Sea fleet

The Caspian Sea is of different nature than the other seas worldwide. Especially the fact that it's a totally enclosed sea makes it special. Vessels shipping in the Caspian have no entrance to international shipping routes. The only link to the Azov Sea is through the lower Volga and Don rivers which are connected at Volgograd by the Volga-Don Canal. This Russian inland waterway of over 800 km can only be used by small river/sea vessels up to 5,000 GT (130m length, 3.4m draft). This is the main reason that vessels found in the Caspian Sea have different dimensions than the vessels found in the general world fleet.

In Annex VI Figures are given on general dimensions as they appear in the world fleet and as they appear in the Caspian Sea. The vessels in the Caspian Sea tend to be longer and of less depth. Furthermore the capacity of vessels representative in the Caspian is at present not exceeding 16,000 DWT.

5.3 Dimensioning Fleet

In this Section, the fleet will be dimensioned. First the vessels will be discussed; exact dimensioning is given in Section 5.3.6 Table 5-1. The dimensioning is based on the Figures given in Annex VI.

5.3.1 Tankers

All 7,000 DWT and 14,000 DWT tankers are at present operational in the Caspian Sea. Therefore the design dimensions of these vessels will be based on the typical Caspian Fleet. This fleet is for the different sizes of tankers given in the Tables in Annex VI.

The 63,000 DWT Tankers of these sizes are not yet operational in the Caspian Sea. Dimensions of this design vessel will be configured on the base of typical dimensions of this size of tankers as they prevail in the world fleet.

5.3.2 LPG Carriers

LPG carriers are not used yet on a regular basis in the Caspian Sea. Dimensions of the required 14,000 DWT carrier are based on the typical dimensions of this size of carriers as used worldwide.

5.3.3 Pipe Layer Barge

No details are known about the pipe layer barge. General dimensions of several pipe layer barges are given in Annex VI. A wide range of dimensions can be found there. The pipe layer barge is assigned to make use of the same basin like the FPSO, but not at the same moment. Dimensions of the FPSO will most likely be of the same order as the pipe layer barge.

5.3.4 FPSO

The FPSO (Floating Production, Storage and Offloading Vessel) which will be part of the Neka harbour fleet is a former 13,000 DWT oil tanker, customised into a FPSO. Dimensions as derived for a 13,000 DWT Crude Oil tankers can be used by considering the FPSO.

5.3.5 Tugboats

To be dimensioned tugboats are a tug of 400 HP and one of 1,400 HP. In Annex VI, a range of tugboats is given. On the base of this range the dimensions are determined. The dimensions can be found in Table 5-1.

5.3.6 Overview Design Vessels

Table 5-1: Dimensions Design Vessels

Commodity / Name	Vessel type	DWT	LOA [m]	Beam [m]	Draught [m]
Crude oil	Tanker	63,000	228	38	12.8
Crude oil	30% ballasted tanker	63,000	228	38	7.2
Crude oil	Tanker	14,000	150	17.5	8
Crude oil	Tanker	7,000	147	17.5	5.3
Petroleum etc.	Product Tanker	7,000	147	17.5	5.3
Chemicals	Chemical Tanker	14,000	150	17.5	8
LPG	LPG Carrier	14,000	150	23	10
Various		5,000	130	16	4
Iran Khazar	Jackup rig	-	56.9	53.3	4.7
Iran Alborz	Semi Submersible	-	98.6	78.8	7.2
	Anchor Handling Tug	16,000 HP	74.4	16	6.5
	Tug boat	4,400 HP	33.5	8.45	4.1
	Tug boat	1,400 HP	28	7.0	3.5
	Tug boat	400 HP	20	5.0	2.8
	Flat barge 1		36	9.0	2.7
	Flat barge 2		36	12.0	2.8
	Pipe layer barge		n.a.	n.a.	n.a.
	FPSO	12,760	150	17.5	8.0

6 LIQUID CARGO

Neka Harbour will mainly be a port for throughput of liquid bulk. In order to come to a correct dimensioning of the port, the throughput and the fleet mix will be analysed in this Chapter. In Section 6.1 a closer look will be taken to the throughput figures. In Section 6.2, the fleet mix which transports the liquid to the port will be analysed.

6.1 Throughput

The relevant stakeholders have stated the forecast they expect in requirements [OTC-8] to [OTC-12]. The Forecast is summarised in Table 6-1. For information on the phasing reference is made to Section 3.2.2.

Table 6-1: Forecast on Throughput Figures (source: [*Ref. 11*])

Commodity	Present	Phase 1	Phase 2
Crude Oil	79,000 bpd	500,000 bpd	1,000,000 bpd
Mazut	239,000 tpa	350,000 tpa	500,000 tpa
Gasoline	239,000 tpa	350,000 tpa	500,000 tpa
Chemical Products	0	n.a.	n.a.
LPG	0	n.a.	n.a.

6.2 Fleet Mix

In this Section the fleet is analysed. For each commodity the fleet mix will be determined and the number of berths will be assessed.

6.2.1 Vessels

In Chapter 5, the vessels' dimensions were already determined. Requirements [OTC-6] to [OTC-9] contain data on the fleet which transports the liquids to the unloading points.

Characteristics of the transporting fleet are summarised in the Table below.

Table 6-2: Characteristics of Liquid Bulk Tankers, calling at Neka (source: [*Ref. 11*])

Commodity	Vessel type	DWT	Average Parcel Size [tonnes]	Unload Capacity [tph]
Crude oil	Tanker	63,000-70,000	60,000	3,800
	Tanker	14,000	13,000	1,200
	Tanker	5,000-7,000	4,500	900
Mazut and Gasoline	Product Tanker	5,000-7,000	4,500	900
Chemicals	Chemical Tanker	14,000	4,500	900
LPG	LPG Carrier	14,000	4,500	900

6.2.2 Crude Oil

Forecast on the fleet mix was earlier discussed in the port planning report of Royal Haskoning. According to this discussion the following forecast was made, and adopted in this study. For explanation on the phasing, reference is made to Section 3.2.2:

Table 6-3: Fleet mix calling at Neka (source: [*Ref. 11*])

Crude Oil Tankers	% of total throughput to be transport by vessel	
	Phase 1	**Phase 2**
5,000 - 7,000 DWT	20	10
14,000 DWT	35	17.5
63,000 -70,000 DWT	45	72.5

In Annex VII a spreadsheet is included in which the required number of berths is calculated. It is noted that the category 5,000 – 7,000 DWT Tankers can berth as well at their own berth as at the 14,000 DWT tanker berths. Other possibilities of interchangeable berths do not exist. Results can be found in Table 6-4.

Table 6-4: No. of Crude Oil Berths

Crude Oil Tanker	No. of Berths	
	Phase 1	**Phase 2**
5,000 - 7,000 DWT	2	2
14,000 DWT	2	2
63,000 -70,000 DWT	1	3

6.2.3 Mazut and Gasoline / Diesel

The model in Annex VII is used to determine the possibilities of realising the throughput. For both only one unloading point is required. In the following Tables the results of the model are given.

Table 6-5: Required No. of Mazut Berths

	Phase 0	**Phase 1**	**Phase 2**
Throughput [tpa]	239,000	350,000	500,000
No. of berths	1	1	1
Utilization	0.07	0.08	0.11

Table 6-6: Required No. of Gasoline Berths

	Phase 0	**Phase 1**	**Phase 2**
Throughput [tpa]	79,000	350,000	500,000
No. of berths	1	1	1
Utilization	0.07	0.08	0.11

The utilization of the berths for both commodities Mazut and Gasoline are very low, furthermore the related vessels have matching dimensions. It is decided to apply one berth which serves both the Mazut and the Gasoline tankers.

6.2.4 Chemicals and LPG

No detailed forecasts on throughput of Chemical liquids and LPG are made available. Required future situation are for both one berth / unloading point for as well phase 1 as phase 2.

PART THREE: CONCEPTUAL DESIGN

Levels of Decomposition
The design will be carried out from rough to fine, i.e. from system level to sub system to component level (levels of decomposition).

Process and Function Analysis
A process analysis and forthcoming a function analysis has to be performed in order to depict the functioning characteristics of the port. This will be done for each system level, considered in the design process.

Synthesis
In this phase the concept/definition/design will be developed. Dimensions will be determined on base of guidelines and hand calculations. Key approach in the design cyclic is: from objective via function to design. This approach is sketched in the following figure:

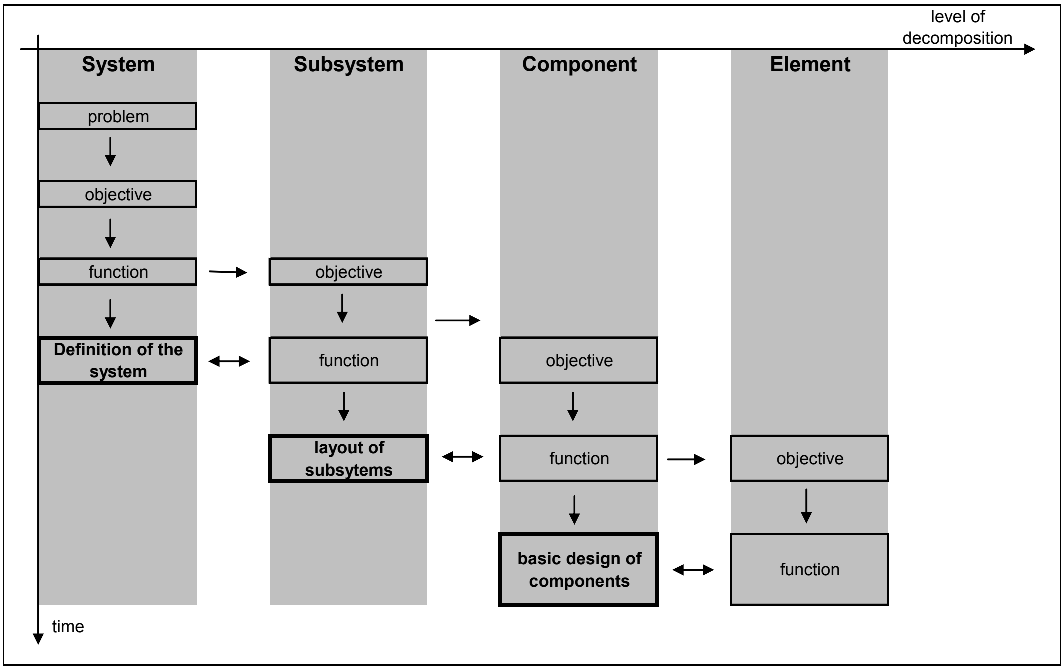


Figure: Design process, from rough to fine

7 SYSTEM DEFINITION

Central in the current study is the existing Neka Harbour and its expansion. The system is more elaborate than Neka Harbour alone. Also the areas which influence or are influenced by Neka Harbour has to be included in the system to be studied. In this Chapter the total system will be defined.

7.1 Process Analysis

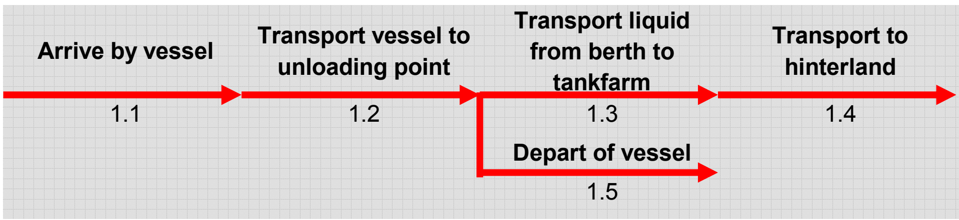
7.1.1 Definition

In a process analysis, a close look will be taken to the actions which occur or which should occur within the boundaries of the considered region. Processes are characterised by the fact that they consists out of several sequential activities, which can be placed in a flow diagram.

In the following, the processes of each stakeholder are scrutinised in order to depict the activities related to Neka Harbour.

7.1.2 Process OTC and NITC

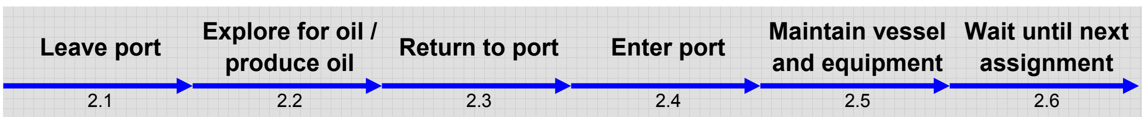
***P1**: Throughput of Liquid bulk*



This process has to be seen from the viewpoint of the liquid commodity itself. First the liquid arrives at Neka Harbour. This can be done by means of a pipeline or a certain vessel. When the liquid is transported by a vessel, it has to be transported to tranquil water in order to create the correct unloading conditions. The liquid will be transported to the tankfarm, there it will be stored for a certain time or blended with other commodities. Subsequently, the liquid will be transported to the hinterland. In Figure 7-1 the process is sketched in the system concept.

7.1.3 Process KEPCO

***P2**: Explore / Production of Oil*

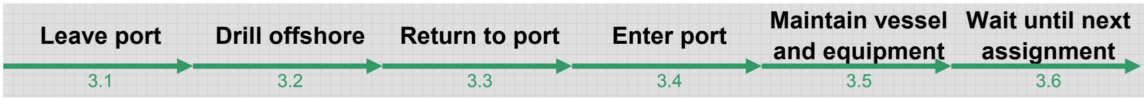


The main activity of KEPCO is mostly situated outside Neka Harbour, i.e. the exploration and production of oil is situated offshore in the Caspian Sea. Though, Neka Harbour is home base for the equipment and vessels of KEPCO.

The equipment is accommodated in Neka Harbour outside operational hours, and the repair and maintenance of the equipment will be partly carried out as well inside Neka Harbour.

7.1.4 Process NDC

***P3**: Offshore Drilling*



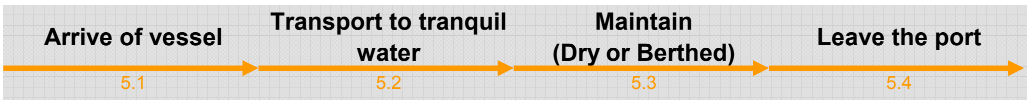
The activities of NDC match for a great part the activities of KEPCO. Difference between both is that NDC does the drilling work and KEPCO is responsible for overall management. However these activities take place outside Neka Harbour. The manoeuvring, accommodating and maintaining of the vessels and equipment within Neka Harbour are shown similar as in the process performed by KEPCO. Both processes are paste in the depicted concept of the system in Figure 7-1.

7.1.5 Processes SADRA

***P4**: Construction of Vessels*

SADRA its core business is the construction and maintenance of oil related vessels (tankers, semi submersibles, etc.) Construction starts on land, and will be fitting out on the vessel berthed along the quay. Therefore a facility is required to transport the vessel from land to water. This is carried out by a ship lift or a crane. When the construction of the berthed vessels is completed, the vessel has to leave the port to make place for new vessels.

***P5**: Maintenance of Vessels*



The Process 'maintenance of vessels' does not differ much from the construction process. Different is the two-way traffic, not only leaving the port via water but also arriving by waterway. It can be decided whether it's required to maintain or repair the vessel on the dry, or it's more advantageous to repair the vessel while berthed along the quay.

***P6**: Construction Components of Port*

Besides the role of port user, SADRA acts as a builder of Neka Harbour. For example, currently SADRA is involved in the construction of the Breakwaters.

7.1.6 Process Neka Power Plants

***P7**: Cooling Water Recirculation*

Neka Power Plants uses sea water to cool their power production process. The inlet is situated on the East side of the plant, just West of Neka Harbour. Consequently, the water temperature in front of the inlet could be influenced by the expansion of Neka Harbour (circulation might be hampered).

7.2 Function Analysis

In Table 7-1 the functions to be fulfilled by the system are stated. Result of the function analysis is the frame for the system. All sub functions indicate a subsystem within the system.

Objective of the study is to split the processes of NIOC and SADRA as much as possible, therefore distinction is made between vessels with liquid commodity transport purposes and vessels to be constructed / maintained.

Table 7-1: Function Analysis of the System

Main function of the system		
Throughput of	Oil and oil related commodities	
Sub functions		**Sub system**
Receive	vessels	*Approach area*
(un)load, berth and accommodate	Oil related vessels	*NIOC protected wet area*
Store and blend	Oil related commodities and facilities	*NIOC dry area*
Construct and maintain	Vessels	*SADRA dry area*
Berth and accommodate	Vessels to be maintained / finalised	*SADRA protected wet area*

7.3 System Concept

The system consists of the sub-systems derived in the function analysis above, but also boundary areas have to be added to border the system. These areas are especially of importance because of the conditions, processes and requirements they generate. The processes performed in Neka Harbour itself will be influenced by them.

In the following Section first a short summary will be given of the different sub-systems, thereafter the boundary areas will be defined and discussed.

By situating the sub-systems and boundaries in the existing situation a concept of the whole system is created. The conceptual layout of the system is given in the last Section of this Chapter.

7.3.1 Summary of Sub Systems

Approach Area
The approach area is the connection between deep water area and the protected port area. The approach area should make vessels able to ship safely and quick to the entrance of the port. If a particular vessel hasn't received permission to enter the port immediately, it should be able to wait in the vicinity of the port entrance. Special attention in the design of this subsystem has to be given to the fact that the entrance channel has to serve two different port entrances.

NIOC Protected Wet Area
This subsystem should create proper conditions for the berthing, unloading and accommodating of NIOC related vessels. At present a small basin exists, however expansion of this area is required to serve the forecasted cargo amounts. Protection of the area will be obtained by the Breakwaters, these will be considered as part of the subsystem.

NIOC Dry Area
The NIOC related companies are located in this subsystem. All have their own part of the area, on which they perform their activities. All locations are already assigned, planning and further analysing of this subsystem is not the aim of the present study.

SADRA Dry Area
The dry area on which SADRA performs her activities is located in the West of the port. Major part of the required facilities in this area is already constructed or under construction. Therefore planning and further analysing of this subsystem is not the aim of this study.

SADRA Protected Wet Area
In this subsystem the water related activities of SADRA take place.

7.3.2 Boundaries / Environment

The identified boundary areas including their relevance will be discussed in the following.

Offshore Region
The daily wave climate and the extreme wave conditions are generated by offshore weather conditions.

Surrounding Western and Eastern Coastal Area
The direct coastal area West of Neka harbour is of importance because the Neka Power Plants are located in this area. In both coastal areas the sediment flows and bathymetry is of importance, this influences the design of Neka Harbour.

Hinterland
At the hinterland, the surrounding users are located. All throughputs have to be transported to the hinterland.

7.3.3 Concept of the System

In the following Figures a concept of the system is sketched. All the identified processes and subsystems are stated in Figure 7-1.

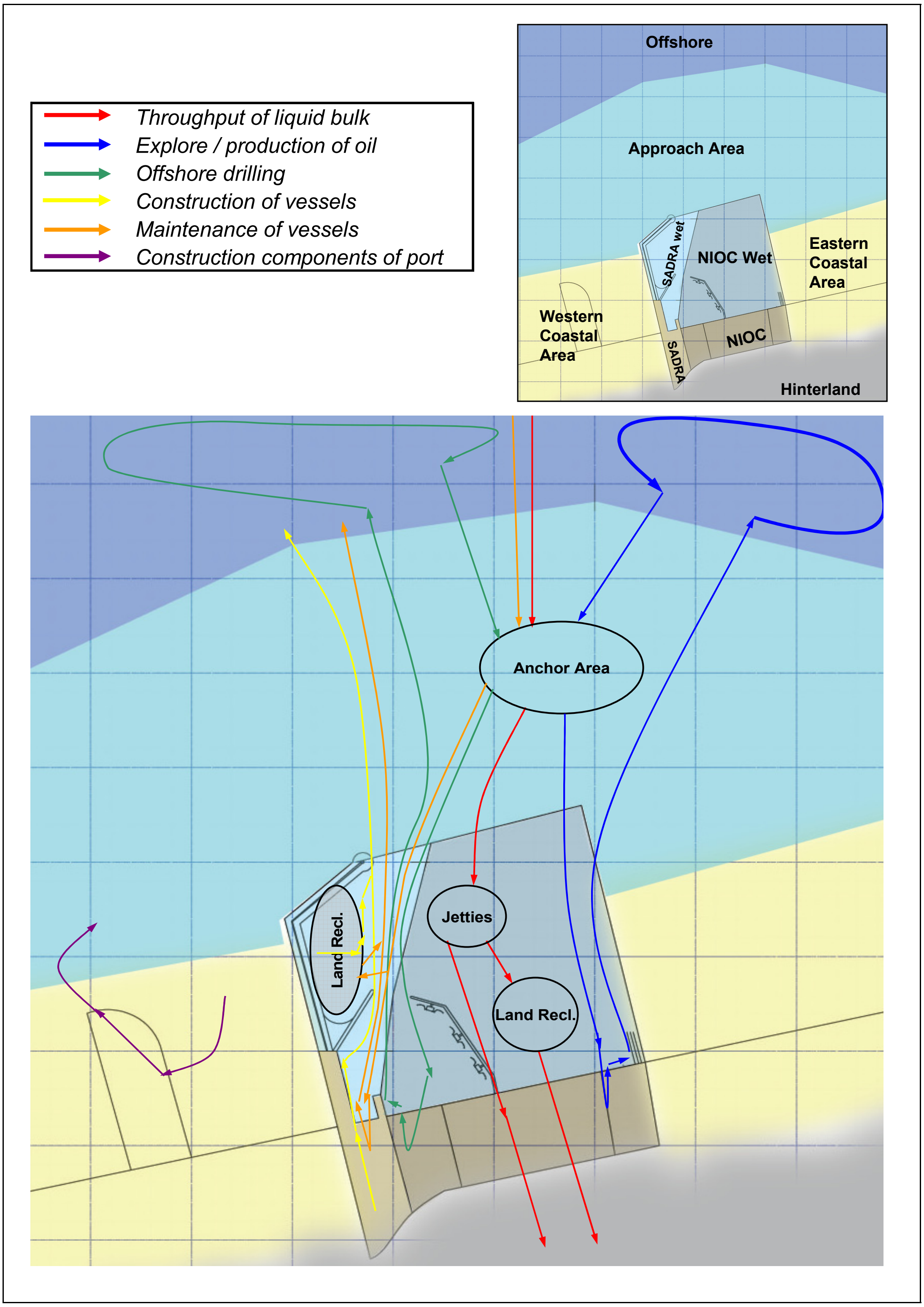


Figure 7-1: Concept of the System

8 LANDSIDE SUB-SYSTEMS

Focus in this study is not on the landside of the Neka Harbour (refer Section 1.3). Though to present a complete picture, the landside areas related to Neka Harbour will be discussed in the present Chapter. Per stakeholder a brief summary will be given on the size and use of their area in the port.

8.1 Surrounding Users

In the study on joint development, carried out by Royal Haskoning, the surrounding users were identified to establish whether additional port land could be acquired from these users. A map showing the land ownership is given in Annex II. From the investigation undertaken it is clear that the land area adjacent to the port area is not available for the port expansion. Therefore any additional land requirements for the expansion, needs to be reclaimed within the new port basin.

8.2 NIOC

In Figure 8-1 the landside area of NIOC is depicted. Each sub-company of NIOC has it own part, which is discussed below.

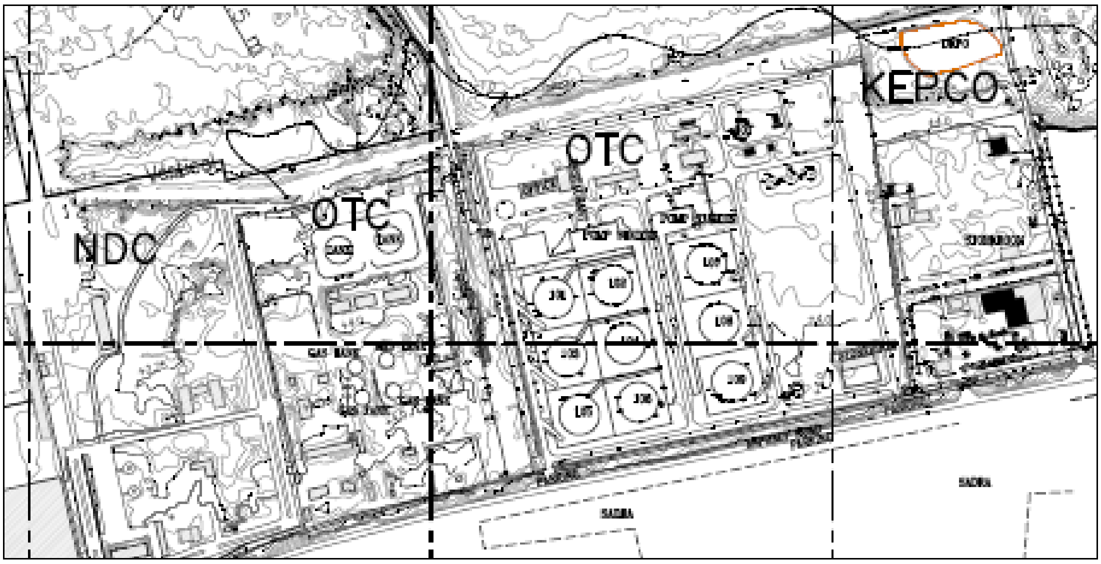


Figure 8-1: Landside Area NIOC

8.2.1 NDC

The NDC area has a surface of approximately 14.8 ha available. On this area the following elements will be placed according to requirement [NDC-9].

- Covered storage:
  - Machinery Spare Parts 60m x 30m = 1,800 m²
  - Chemical Materials 40m x 30m = 1,200 m²
  - Bulk Materials 10,000 m²
  - Refrigerated Storage 100 m²
- Open Storage for drilling pipes, risers, wellhead part 10,000 m²
- Two Fuel tanks with capacity of 5,000 m³ each
- Two fresh water tanks with a capacity of 1,000 m³ each

8.2.2 OTC

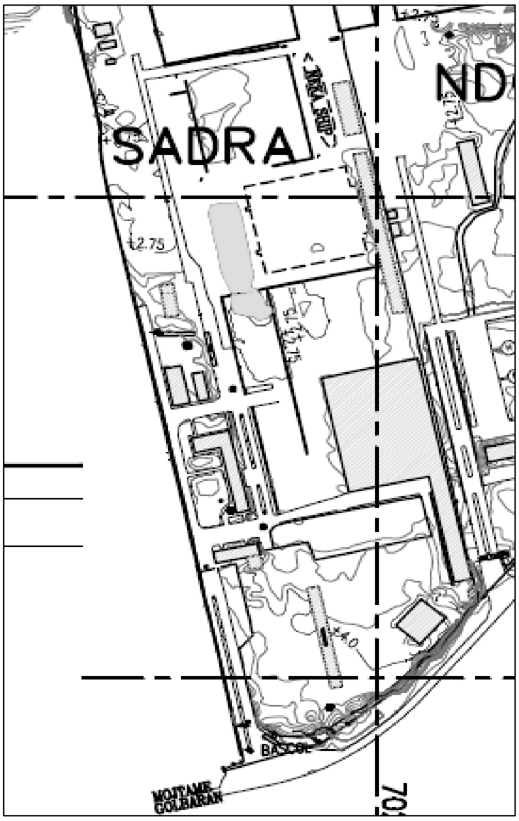
The OTC area consists of 36 ha land. In its area currently there are 6 storage tanks and 3 blending tanks located. Including the piping corridor they cover about 58,000 m². Furthermore some gas tanks, administration buildings and other facilities are positioned on the area. Remaining available land area will be used to locate more storage and blending tanks. This is further described in Annex XI.

8.2.3 KEPCO

The KEPCO area amounts to 9.6 ha land. On this land facilities are located to support the services to the FPSO and pipe laying unit. Furthermore open air storage is positioned in the area. In front of the KEPCO area a quay wall of 150-200 m will be constructed.

8.3 SADRA

Figure 8-2: SADRA Landside Area



SADRA owns 16.75 ha of land at the West side of the port. The land is fully in use. The following elements can be found on the SADRA terrain.

- Dry dock with dimensions 250mx40mx11.8m, suitable for 63,000 DWT tankers
- 2 berthing posts with 5m waterdepth and capacity for berthing 5,000 ton vessels
- Syncrolift: 130mx25m, Nominal capacity of 3,259 ton
- Kroll tower crane with 240 ton capacity, maximum 80m acces radius perpendicular to the quay wall
- Construction area / berth for semi-submersibles
- Ship repair yard and dry berths located nearby the ship lift
- Work shops and open storage areas
- Admin building

9 WATERSIDE SUB-SYSTEMS

All waterside sub systems are analysed in this Chapter. Main goal in the analysis is to examine which components these sub systems comprise of. This is done by scrutinising all relevant functions of each subsystem, and thereafter dedicating a component to each identified function. All identified components are further elaborated in Chapter 10.

For a clarification for the choice on the waterside sub-systems reference is made to Chapter 7.

9.1 Approach Area

Purpose of the Approach Area is to realise safe transfer of vessels from offshore to either the NIOC basin or the SADRA basin (and vice versa). In Table 9-1 the function analysis of the Approach Area is presented.

Table 9-1: Function Analysis Approach Area

Main function approach area		
Receive	Vessels	
Sub functions		**Component**
Arrive of	Vessels	Approach / free area
Pass through of	Vessels from deepwater to port entrance	Approach channel
Accommodate	Vessels waiting for permission to enter port area	Anchor area

9.2 NIOC Waterside

Purpose of the NIOC Waterside is to allow safe transfer of cargo from vessel to shore and vice versa. In Table 9-2 the function analysis of the Approach Area is presented.

Table 9-2: Function Analysis NIOC Waterside

Main function NIOC waterside		
(Un)load	Oil related vessels	
Sub functions		**Component**
Protect	Wet area	Breakwaters
Facilitate	Entrance to protected wet area	Port entrance
Pass through of	Vessels from entrance to turning circle	Inner entrance channel
Enable	Vessels to turn	Turning circle
Accommodate	Crude oil tankers 63,000 DWT	Crude oil berth area 63,000 DWT
Accommodate	Crude oil tankers 14,000 DWT	Crude oil berth area 14,000 DWT
Accommodate	Crude oil tankers 7,000 DWT	Crude oil berth area 7,000 DWT
Accommodate	LPG carriers	LPG berth area
Accommodate	Chemical tankers	Chemical berth area
Accommodate	Import mazut and gasoline	Mazut/gasoline berth area
Accommodate	Drilling related vessels	NDC berth area
Accommodate	Offshore supply	KEPCO berth area
Accommodate	Supporting equipment	Supporting equipment basin
Accommodate	Vessels from unknown future users	Future users berth area
Transport	Liquids from berth to tank	Pipeline
Facilitate	Future expansion of dry land for OTC	Reclaimed area OTC
Facilitate	Future expansion of dry land for future users	Reclaimed area future users

9.3 SADRA Waterside

Purpose of the SADRA Waterside is to guarantee required conditions for berthed vessels to be finalised in construction or to be maintained. In Table 9-3 the function analysis of the Approach Area is presented.

Table 9-3: Function Analysis SADRA Waterside

Main function SADRA waterside		
Berth	Vessels (with construct and maintain purposes)	
Sub functions		**Component**
Protect	Wet area	Breakwaters
Enter	SADRA wet port area	Port entrance
Pass through	Vessels from entrance to turning circle	Entrance channel
Enable	Vessels to turn	Turning circle
Berth	5,000 – 7,000 DWT vessels	Berth area 5,000 - 7,000 DWT vessels
Berth	Vessels to be maintained / constructed (up to 63,000 DWT)	Berth area 63,000 DWT vessels
Transport	Vessels from land to water and v.v.	Waterside space for crane / lift
Accommodate	Supporting equipment	Supporting Eq. berth area
Facilitate	Future expansion of dry land	Reclaimed land

10 WATERSIDE COMPONENT ANALYSIS

All components identified in the previous Chapter will be analysed in the present Chapter. The relevant prevailing conditions, and forthcoming the possibilities in design of components will be discussed. Finally, a relation analysis is carried out for the components. The present Chapter is the basis for the port planning exercise, which is presented in Chapter 11.

10.1 Approach Area and Anchor Area

These components are not elaborated. When a port layout is chosen, a fulfilling approach area and anchor area can be designed.

10.2 Channels

10.2.1 General

A vessel should be able to arrive safely, enter and pass trough the port. The channels related to the port have to be designed in such a way that this is ensured. Key characteristics of the waterways are the width, depth and alignment. Design dimensions of these are mainly determined by the vessels which make use of the considered waterway in combination with the prevailing conditions which have influence on the navigation behaviour of the vessel. In the following Sections the design of the waterways related to Neka Harbour will be discussed. In Annex VIII the guidelines and used models regarding the channels are included.

10.2.2 Conditions

Environmental conditions have a major influence on the dimensions of the channels. Especially waves, winds and currents are of importance. These conditions are of a stochastic character, therefore close attention needs to be given to the choice of design conditions to which the channels will be designed. Design conditions can be defined as the maximum condition by which the related activity can still be performed in an acceptable way. By defining the design conditions, a certain level of downtime of the considered activity is introduced. However (financial) impact of downtime is not of the same magnitude for all processes.

In Section 7.1 all processes related to Neka Harbour are explored and identified. The design conditions for each of these activities have to be determined in order to be able to dimension the channels. Two characteristics of the performed process are especially of importance with respect to the (financial) impact of downtime

- intensity of performed process by considered vessel, i.e. in the situation of a vessel which enters and leaves the port only once a year it is a less poor situation to wait a day upon entering/leaving the port than in the situation when the intensity of the activity is more than once a day
- Total service time of considered vessel in port. The longer the *required* service time, the more acceptable is a longer waiting time due to downtime

Table 10-1 summarises the vessels, representative for a certain process. In the Table approx service time and intensity are indicated. On basis of this information, information stated in Chapter 4 (natural conditions) and according to the PIANC guidelines on navigation channels the design conditions are chosen. The resulting downtime caused by the configuration is given in the last column of the Table.

Table 10-1: Environmental Design Conditions for the Channels

Vessel	**Traffic**		**Limits Operational Conditions**				**Percentage of Time the Channel can not be used**
	Approx Service time [hrs]	*Intensity [calls/yr]*	*Wind [knots]*	*Waves [m]*	*Current [knots]*	*Visibility*	
C.O 63,000 DWT	21	640	<26	<1.5	<0.5	moderate	± 3 %
C.O. 14,000 DWT	15.6	714	<26	<1.5	<0.5	moderate	± 3 %
C.O. 7,000 DWT	9.5	1179	<26	<1.5	<0.5	moderate	± 3 %
LPG 14,000 DWT	n.a.	n.a.	<26	<1.5	<0.5	moderate	± 3 %
30% ballasted 63,000 DWT tanker	n.a.	n.a.	<10	<1.5	<0.5	Good	± 50 %
Iran Alborz	n.a.	n.a.	<10	<0.6	<0.2	Good	± 50%
FPSO	n.a.	n.a.	<10	<1.5	<0.5	Good	± 50 %

10.2.3 Design

The channels of Neka Harbour have to be dimensioned according to the design vessels and to the conditions as included in the previous Section. Distinction can be made to the approach channel which is located outside the Harbour, and the channels inside the harbour. Dimensions of the latter for both depth and width have to be designed less heavy because the Breakwaters reduce the currents and waves in the channels. Guidelines and a sheet containing the calculations on the channels are gathered in Annex VIII. For each design vessel, results are given in the following Table.

Table 10-2: Characteristics of Channel Dimensions according to the Design Vessels

Item	**63,000 DWT Crude Oil**	**14,000 DWT LPG**	**14,000 DWT Crude Oil**	**7,000 DWT Crude Oil**	**63,000 DWT 30% ballasted tanker**	**FPSO**	**Iran Alborz**
Outer entrance channel							
Width one way traffic [m]	215	130	100	100	150	70	205
Width two way traffic [m]	440	260	196	196	300	140	425
Required depth* [m]	15.5	12.7	10.7	8.0	9.9	10.7	9.9
Inner channel / basin							
Width one way traffic [m]	165	100	75	75	100	45	205
Width two way traffic [m]	390	230	175	175	250	120	425
Required depth* [m]	14.6	11.5	9.3	6.3	8.4	9.3	8.4

*To lowest water level

10.2.4 Alignment Approach Channel

The approach channel can either be orientated to the West or to the East. The length and volume to be dredged material will differ for both options (refer Annex VIII). The direction of the approach channel will have a major influence on the layout of the port.

10.3 Breakwaters

10.3.1 General

The alignment of the Breakwaters will have a major influence on the components located between the Breakwaters. The alignment should be configured in such a way that the Breakwater responds optimal to its main functions, i.e. blocking the waves and guiding the currents along the Harbour.

The aim of this study is not to design the Breakwaters in full detail. In the existing situation Breakwaters are already placed, these are to be extended in the new assignment. In this preliminary planning process the basic design of those existing Breakwaters will be used as well. Typical cross sections are included in Annex IX.

With respect to the respond to the prevailing conditions, the following facts need to be emphasized:

- N and NW are the most frequent wave directions with the highest waves
- Currents running 1/3 to the West and 2/3 to the East; net direction is to the East

Another issue of attention in this assignment is the possible physical split of the port. In this the Breakwaters play a key role, an extra Breakwater has to be added to realise the physical split. In the following, this Breakwater will be referred to as "*Middle Breakwater*".

10.3.2 Port Entrance

Between the Breakwaters a port entrance is required in order to let the vessel in and out the port. By the assignment of split basin, both the SADRA and the NIOC basin need a port entrance. The port entrances have to be configured in such a way that the wave agitation in the port is limited, the currents are guided along the port (not in the port), and the vessels can enter the port safely.

At the port entrance extra width has to be added at both sides of the entrance channel. This width is added because of the 'hard' Breakwaters on both sides. Space is needed because of safety reasons and realise a slope from bottom to Breakwater toe. An extra width of 50 m each side, is considered to be sufficient.

In Table 10-3 the required dimensions are given for the design vessels. Calculations on the port entrance can be found in Annex VIII.

Table 10-3: Required Dimensions of the Port Entrance according to the Design Vessels

Item	63,000 DWT Crude Oil	14,000 DWT LPG	14,000 DWT Crude Oil	7,000 DWT Crude Oil	63,000 DWT 30% ballasted tanker	FPSO	Iran Alborz
Port Entrance							
Width one-way [m]	315	230	200	200	250	170	245
Width two-way [m]	540	360	300	300	400	240	465
Depth [m]	15.5	12.7	10.7	8.0	9.9	10.7	9.9

10.4 Berths and Basins

10.4.1 General

Port basins should be given sufficient width for the safe towing in and towing out of the vessels, even whilst other berths are occupied.

All liquid bulk vessels have in common that they are unloaded via a central manifold midship, in contradiction to other cargo no heavy cranes are needed. Furthermore the design of the berth is different of character. The design of the berth can be either be of a jetty type (finger pier, T-jetty, etc.) or along a quay wall.

For safety reasons, liquid bulk berths should be separated from other port facilities, No other shipping should be allowed inside the oil basin. Furthermore, the mooring system has to be of such sturdiness that the vessel can, at all times, stay safely berthed, also when a storm is forecasted.

Safety guidelines are even more important considering LPG terminals. All other activity should be banned from the LPG basin. Liquid gas tankers can only sail with either full or empty cargo tanks, therefore the mooring system has to be of such sturdiness that the ship can, at all times, stay safely berthed, also when a storm is forecasted. Last but not least, in case of emergency the LPG carrier should be able to quick release.

Location of the crude oil berths can either be in open sea or inside the harbour. Both options are further elaborated in the following Sections.

The basins of NDC, KEPCO, SADRA and the supporting equipment have distinctive functions; these are discussed and dimensioned in the final three Sections of this section.

10.4.2 Design Liquid Berths and Basins

In Annex X guidelines are stated which are used to determine the dimensions of the berth basins to be located in Neka Harbour. An impression of the different berths can be found in this Annex as well. In Table 10-4 the results for the different design vessels are given.

Table 10-4: Required Dimensions of the Basins

Berth	63,000 DWT Crude Oil	14,000 DWT LPG	14,000 DWT Crude Oil	7,000 DWT Crude Oil	14,000 DWT Chemical product	7,000 DWT Mazut / Gasoline
Fingerpier (single)						
Length [m]	670	Not relev.*	435	435	Not relev.*	Not relev.*
Width [m]	300	Not relev.*	200	195	Not relev.*	Not relev.*
Jetty (single)						
Length [m]	300	200	200	200	200	200
Width [m]	290	215	190	190	190	190
Along Quay Wall (single)						
Length [m]	Not relev.**	Not relev.**	180	180	180	180
Width [m]	Not relev.**	Not relev.**	190	190	190	190

*Fingerpier is not applicable because only one berth is required
**Depth of the vessel is considerable, it is considered to be not economical to design a quay wall for this depth

10.4.3 Offshore Terminals

Advantage of offshore terminals is the considerable lower investment costs in relation with a jetty located in a port basin. The investment costs are mainly reduced as no dredging and Breakwaters construction is required. On the other hand the maintenance costs for offshore terminals are significantly higher than for Jetties. In general, offshore unloading may be economical in situations with small to moderate yearly throughputs, and vessels ranging from 5,000 to 60,000 DWT.

Offshore terminals can be either a fixed platform or a mooring buoy. The latter is more conventional. Only in areas where sea conditions are generally calm, the construction of fixed offshore terminals may be considered. Transportation of the liquid from unloading point to tankfarm can be by pipe trestles or by sub-marine pipelines.

SBM (Single Buoy Mooring) and MBM (Multiple Buoy Moorings)
The mooring system comprises Mooring Buoy(s) and Mooring Legs, where the buoys are generally moored to the seabed with chain legs and high holding power anchors or piles, depending on soil characteristics. A typical MBM includes 3 or 4 buoys and each buoy has a mooring assembly through the centre of the unit, terminating in a mooring eye on the bottom and padeyes on top for the fitting of quick release hooks.

The advantage of an SBM is that the ship always takes the most favourable position in relation to the combination of wind, current and waves.

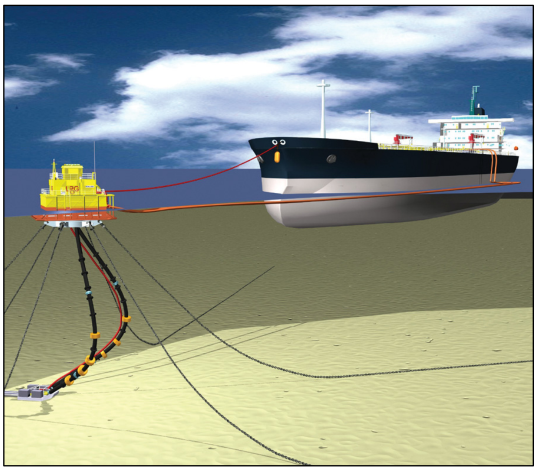


Figure 10-1: A SBM in Process

Overview

- Distance to the shore should be as short as possible
- Distance from buoy / platform to critical depth should be at least 3 times length of design vessel
- Critical depth is equal to critical depth in approach channel for the considered vessel

Table 10-5: Comparison Onshore – Offshore Unloading

	Jetty	Multiple Buoy Moorings	SBM's
Access from shore	direct	by sea	by sea
Number of hoses	1 - 8	1 - 4	1 - 3
Time between arrival and start of pumping	2 hours	5 hours	2 hours
Mooring possible with wind up to 40 knots and head waves of	1.0 -2.0 m	1.5 - 2.0 m	2.0 - 2.5 m
Oil unloading with wind up to 40 knots and head waves of	1.5 - 2.0 m	2.0 -2.5 m	3.0 - 4.5 m
Ship has to leave the berth with wind of 60 knots and waves higher than	-	2.0 - 3.0 m	3.5 - 5.0 m
Preference regarding ease of berthing and de-berthing	2	3	1
Possible tide effects	yes	no	no
Damage sensitive parts	fenders	buoy chains	hoses
Assistance during berthing and mooring	tugs and flats	flats, tugs desirable	flats
Assistance for the departure	tugs and flats	flats, tugs desirable	none

10.4.4 NDC Berth and Basin

In the NDC basin the following vessels are to be facilitated, specifications of the vessels are stated in Chapter 5:

- 3 X Anchor handling tugs
- 2 X smaller tugs
- Iran Khazar Jackup rig
- Iran Alborz semi submersible

Taking in account the design rules for a berth, the design as sketched in Figure 10-2 is of appliance.

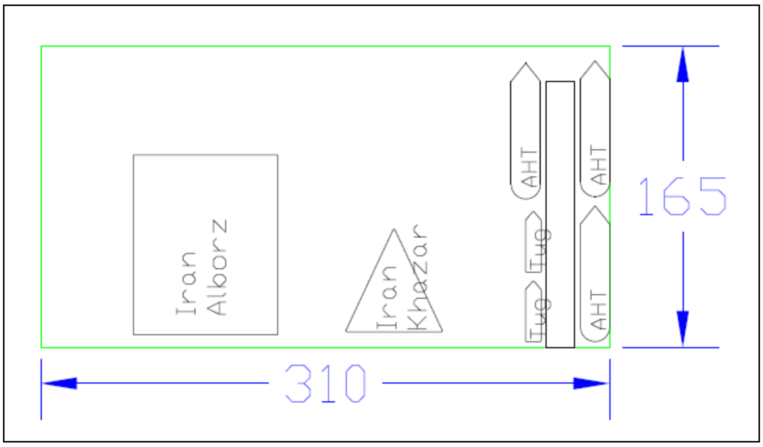


Figure 10-2: Required Dimension of the NDC Basin

10.4.5 KEPCO Berth and Basin

In the KEPCO basin either one of the following vessels at a time are to be facilitated, specifications of the vessels are stated in Chapter 5:

- Pipe layer
- FPSO

Taking in account the design rules for a general cargo berth, the design as sketched in Figure 10-3 is of appliance.

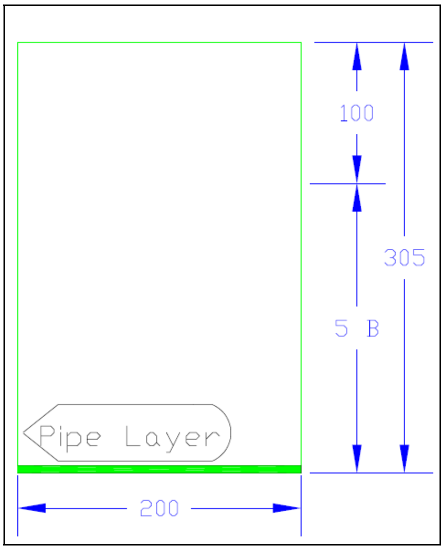


Figure 10-3: Required Dimension of the KEPCO Basin

10.4.6 SADRA

In the SADRA basin facilities are already available to berth the following:

- 1 Tug boat 1,400 HP
- 1 Tug boat 400 HP
- 1 Flat barge 36mx9.0mx2.70m
- 1 Flat barge 36mx12.0x2.80 (crane capacity 100 ton)
- 2 berthing posts with 5m water depth and capacity for berthing 5,000 ton vessels

To be placed in future situation:

- In front of basin possibility of berthing 63,000 DWT and 7,000 DWT vessels

The basin requires the same dimensions as NIOC's 63,000 DWT Crude Oil Tanker (refer Table 10-4).

10.4.7 Turning Basin

The entrance channel should end in a turning basin. In the case of Neka Harbour not enough space is available to facilitate the stopping distance (about 350 m) of the vessels within port boundaries. Consequently the tugs have to be tied up outside the port. As this can only be performed when waves are lower than 1.5 m, the port is not accessible during exceeding conditions, which is only the case in 2 to 3 % of the time.

Guidelines for turning basins are [*Ref.2*]:

- Diameter of the turning basin should be > 2 X L $_{design\ vessel}$.
- In exceptional cases, e.g. no tugs available, the turning basin should be > 3 L design vessel

Results are given in Table 10-6.

Table 10-6: Dimensioning of the Turning Basins

Item	63,000 DWT Crude Oil	14,000 DWT LPG	14,000 DWT Crude Oil	7,000 DWT Crude Oil	63,000 DWT 30% ballasted tanker	FPSO	Iran Alborz
Turning Circle (diameter)							
2 X L_{vessel} [m]	450	300	300	295	450	300	200
3 X L_{vessel} [m]	680	450	450	440	680	450	300

10.5 Land Reclamation

10.5.1 General

In the user requirements it is indicated that extra land is required to perform future activities. No possibilities exist to buy or obtain more landside area. Therefore the land has to be reclaimed from the sea. In the following Sections are the land requirements discussed per stakeholder. Furthermore the requirements per stakeholder are discussed.

10.5.2 OTC

OTC requires land to facilitate the increase of oil throughput. The oil has to be stored and blended. Calculations can be found in Annex XI. These calculations are based on the facilities as they are designed at present in Neka Harbour, and according to the throughput forecasts as discussed in Chapter 6. In Table 10-7 the results of the calculation are stated.

Table 10-7: Requirements on Land Reclamation OTC (source [*Ref 10*])

	Phase 1	Phase 2
Land area [ha]	8.4	27.7

10.5.3 Future Users

The data on land reclamation can be found in Table 10-8, they are drawn from requirement [FU-1] and [FU-2]. No details are known about the future users' activities. It is noted that these requirements are optional.

Table 10-8: Requirements on Land Reclamation Future Users

	Phase 1	Phase 2
Land area [ha]	20	35
Berth length [m]	400	700
Dept alongside [m]	-14.5	-14.5

10.5.4 SADRA

Requirements [SADRA-10 and 11] point clearly out the characteristics of SADRA's requirements on land reclamation, i.e. 26.5 ha with a quay of 700m in front. On the reclaimed land a shipyard will be built. SADRA has indicated that the position of the reclamation should be between both branches of the new and existing West Breakwaters.

10.6 Relation Analysis

In this Section a relation analysis, is performed in order to obtain insight in to which extent the components interact. The relation analysis has to be considered as a tool which helps by the configuration of the port layout Alternatives.

> ***Interaction Matrix***
> *First step in the relation analysis is to create an interaction matrix which compares all components to each other. By means of a number, the matrix indicates how strong the interaction is between two considered components.*

10.6.1 Interaction Matrix

The interaction matrix is given in Figure 10-4. In the first column the component is given, in the second column an abbreviation is dedicated. The examinations are based on the level on which characteristics of components – described in the previous Section – correspond. Frequent considered matching or contradictory characteristics are:

- Dimension of components (required depth, width, length, etc.)
- Related commodity
- Related company
- Safety guidelines
- Possibility of integration

Components		BW	PE	TC	CO	LPG	CH	MG	NDC	KEP	SE	FU	ROTC	BSA	RSA	LSA
Breakwaters	BW															
Port Entrance	PE	3														
Turning circle	TC	0	3													
Crude Oil berths	CO	3	4	4												
LPG berth	LPG	3	3	3	-											
Chemical berth	CH	2	2	2	0	-										
Mazut/gasoline berth	MG	2	2	2	0	-	1									
NDC basin and berth area	NDC	1	1	2	-	-	-	-								
KEPCO basin and berth area	KEP	1	1	2	-	-	-	-	2							
Supporting equipment basin	SE	0	2	1	1	1	1	1	0	0						
Future users basin and recl. area	FU	0	0	0	0	-	0	0	0	0	0					
Reclaimed area OTC	ROTC	3	0	0	3	3	3	3	0	0	0	2				
SADRA berths and basins	BSA	0	1	2	-	-	-	-	0	0	1	0	0			
Reclaimed area SADRA	RSA	3	0	0	0	0	0	0	0	0	0	0	0	4		
Landside area	LSA	3	-	-	2	2	2	2	4	4	3	2	3	0	4	

-	Negative relation
0	No relation
1	Weak relation
2	Moderate relation
3	Strong relation
4	Very strong relation

Figure 10-4: Relation Analysis

The most remarkable relations are discussed on the next page:

Level 4: Very Strong Relation

- **Crude oil basin 63,000 DWT – port entrance and turning circle**; shipping distance and manoeuvring actions of big vessels should be reduced inside the port boundaries, the 63,000 DWT Crude oil tanker is by far the largest vessel calling at Neka Harbour and therefore has a very strong relation with both the entrance channel and turning circle
- **Landside area – KEPCO basin**; The KEPCO area is situated at the landside part of the port. Equipment stored on this land has to be loaded and unloaded from the vessels berthed in the KEPCO basin. Considerable distance between storage and basin is not favourable. Furthermore KEPCO has stated that the basin should be in front of their land
- **Landside area –NDC basin**; same reasoning as above

Level - : Negative Relation

- **LPG – all other berths**; LPG handling has to be done with extreme caution, as LPG is highly flammable. Consequences of a possible emergency are substantial. Therefore no other terminals should be located in the LPG basin
- **Liquid bulk berths – NDC basin / KEPCO basin**; considering the safety guidelines on liquid bulk terminals, activities which are not related to liquid bulk should be expelled from liquid bulk basins

Other Remarkable Examinations

- **LPG basin – Port entrance / Entrance channel**; this interaction is examined with level 3; strong relation. The interaction is two fold; on one hand it is dangerous to place the LPG basin in the vicinity of the entrance channel because of the risk of wrong navigation of a vessel inside the channel with a crash as consequence, but on the other hand it’s extremely important that in case of a critical situation the LPG carrier can leave the port as quickly as possible, which indicates a strong relation. Furthermore long shipping distance of the LPG carrier inside the port boundary is undesirable, which also indicates a strong interaction
- **Breakwaters – all liquid bulk berths**; Jetties can be easily positioned alongside Breakwaters, especially bigger jetties. The inner slope of the Breakwater absorbs wave action which ensures a more tranquil situation than a liquid bulk berth in front of a vertical quay wall. Furthermore the Breakwaters are suitable to carry the pipelines to transport liquid bulk from berth to tank farm
- **Breakwaters** – **To be reclaimed land**; reclaimed land within port boundaries are suitable to connect to Breakwaters, in such a case the Breakwater protects one side of the land and the total quay length is decreased

Conclusions

The relation analysis gives insight in the way the components should be fit within the boundaries of the port. The following recommendations are made:

- Turning basin should be located at a central place
- Liquid basins and NDC + KEPCO basin should be separated
- LPG basins and all other basins should be separated
- The new to be reclaimed OTC area should have a central place according to all liquid berths
- The bigger the dimensions of a vessel, the better it is to locate its berth in the vicinity of the port entrance
- The supporting equipment basin, should be located near the port entrance and at a central place, but within tranquil environment

PART FOUR: SYNTHESIS AND EVALUATION

11 PRELIMINARY PORT PLANNING

Primary goal of port planning is to realise a well functioning, safe port which satisfies the user requirements. 5 distinctive different port layouts are developed in the present Chapter. A thorough evaluation in the next Chapter will point out the most potential out of the preliminary Alternatives. This layout will be refined after simulation of the most critical issues of the chosen Alternative.

In the previous Chapters a frame was built up for the expansion of Neka Harbour. First the overall situation was discussed. Thereafter, in Chapter 5 and 6 the input for Neka Harbour was analysed. For the throughput figures and characteristics of the calling fleet mix is referred to these Chapters.

In Chapter 7, 8 and 9 it is defined which areas are relevant for the study. First the total system to be studied was defined. Subsequently it was split in different subsystems. In the view of the current assignment it is merely required to design the waterside development into detail. In Chapter 10 all waterside components were defined and dimensioned; they form the basis for the present port planning.

The approach used in the port planning process is discussed in Section 11.1 and 11.2. The resulting port Alternatives are presented in Section 11.3 through 11.7. Layouts of all elaborated Alternatives are included in Annex XII.

11.1 Port Planning Consideration

The port planning performed in the present Chapter is *preliminary*; optimisation of the layouts take place in a later stage. Aim in the present process is to develop a wide range of Alternatives with each having their own identity. The considered range should cover all possible options. In this way a transparent and pragmatic decision making is ensured for identifying Alternative(s), judged to be potential for further elaboration (refer Section 11.1).

Alternatives should be all substantial divergent in order to reduce the total amount. For this effort primary variables are defined which outcome have a significant impact on the waterside port layout. Identified variables are bulleted below.

- **Integration of the Existing Land- and Waterside Port Situation**
  - Keep the present situation as it is (no or minor changes)
  - Restructure the existing situation (major changes)

- **Alignment Approach Channel**
  - Orientated to the West
  - Orientated to the East

- **Location of Liquid Product Berths**
  - Within port
  - Offshore

- **Port User Requirements** (refer Section 3.3)
  - Satisfying to the basic port user requirements
  - Satisfying to the basic *and* additional port user requirements

Alternatives are developed according to all possible combinations regarding the outcomes of the discussed primary variables. The Alternatives are compared to each other in an Alternative matrix, presented in Section 11.1.5. First the primary variables are discussed into more detail, presented in Section 11.1.1 through 11.1.4. At the end of each of these Sections a statement is established regarding the best configuration of the considered variable.

11.1.1 Integration of Existing Land- and Waterside Port Situation

For a comprehensive description of the existing situation reference is made to previous Sections (refer Section 2.3, Chapter 9 and Annex II).

With respect to the development of the port Alternatives it can be decided to configure the expansion of the port in such a way that no major changes are applied to the existing situation. Disadvantage is that the design of the expansion has to be connected to the existing situation. The other option is to (partly or totally) restructure the port. Two consequences are demolition of parts of the existing infrastructure, and temporary downtime for activities (both result in additional costs). Main advantage of a restructuring can be a more functional design.

For the expansion of Neka Harbour a more functional design can only be achieved if aside to demolition of the infrastructure, a reassignment of the landside area takes place. On basis of impressions gained during a visit this is assumed to be unfeasible. Therefore it is judged to be negative to accomplish major changes to the existing port layout.

11.1.2 Alignment Approach Channel

Direction of the Channel
In Chapter 10 the configuration of the approach channel has been discussed. Outcome of the analyses was that the approach channel can be either orientated to the East or to the West. Choice of direction for the approach channel is of a distinctive influence to the outline of the port.

Both options will need approximate the same length to reach the required depth line for safe navigation of the vessels, i.e. no substantial differences are expected in the amount of material to be dredged (refer Annex VIII). Though, the decisive wave direction is from N to NW and the net current is running to the East. For these reasons option one (approach to the East) seems to be better. In that situation the wave agitation and the rate of siltation in the basin are expected to be of less impact.

Split Approach
As a consequence of the preference of a split entrance for SADRA and NIOC, the approach channel should be branched before the entrance (refer Figure 11-1, next page). Another possibility could be that the approach channel runs in both directions. The latter is solution is doubtable. More dredging amounts are expected. And no clustering of navigation routes to the port is feasible. The split approach is judged to be double negative, as it has also the negative aspects of increased wave agitation and siltation.

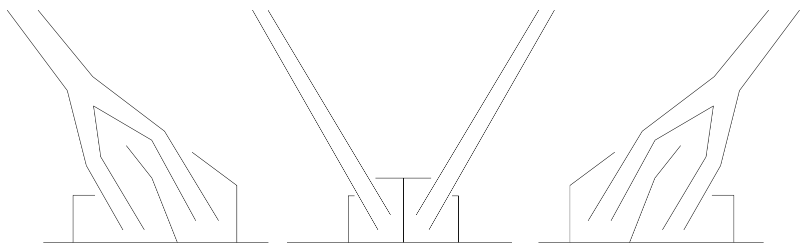


Figure 11-1: Alignment Approach Channel

11.1.3 Location of Liquid Product Berths

The unloading of the liquids can be performed either inside the port or by means of a facility offshore (refer Section 10.4.3). Both have strong and weak points as discussed in the Section. The parties involved indicated that the option of offshore unloading is not desirable, therefore this option is examined to be negative.

11.1.4 Port User Requirements

Earlier reference is made to the additional requirements of NIOC in the new assignment of *separated port development* (refer Section 3.3). These requirements can have negative influence on the performing of SADRA its processes. This justifies the consideration to explore besides port Alternatives which satisfy with the additional requirements, also explore Alternatives which to some extent do not satisfy with them.

The additional requirements [NIOC-1 to 4] (refer Section 3.3.2) indicate the preferences to physically split the basin and the entrance of the port for SADRA and NIOC activities (expelled NDC activities and the smaller liquid berths). As the present study is initiated in order to research the feasibility of a physical split of the port, for the current evaluation it is experienced to be negative when the additional requirements are neglected.

11.1.5 Alternative Matrix

In the Alternative matrix all possible combinations of the discussed variables are given. The combinations are judged by taking the sum of the examinations of the chosen value for each variable. The examination of the variables is given in brackets, with the following valuation:

- Double negative -2
- Negative: -1
- Not negative, not Positive: 0
- Positive: +1

Reasoning for the examination of the variables can be found in the previous Sections.

Example: The base case, Alternative 0, is described as follows: This Alternative comprises unloading of liquid inside the port (+1), approach channel orientated to the East (+1), no major change to the existing situation (+1) and no split basin and approach (-1). The examination is calculated by summing the independent examinations: +1 +1 +1 -1 = 2.

Table 11-1: Alternative Matrix

Unloading oil:	**Approach:** / **Basin:** / **Ex. situation:**	To East (+1) No Split (-1)	To East (+1) Split (+1)	To West (-1) No Split (-1)	To West (-1) Split (+1)	Both Ways (-2) Split (+1)
In port (+1)	No major change (+1)	**2** ***Alt. 0***	**4** ***Alt. A***	0	**2** ***Alt. B***	1
	Major change (-1)	0	**2** ***Alt. C***	-2	0	-1
Offshore (-1)	No major change (+1)	0	**2** ***Alt. D***	-2	0	-1
	Major change (-1)	-2	0	-4	-2	-3

Values in the matrix represent the score for the possible Alternatives. In the first row, first column results of the Alternative on *joint development* are given. As discussed before, this Alternative is worked out already by Royal Haskoning. This Alternative will function as the base case. A new Alternative should have the potential to be equal or better than the base case. If not, the base case would be preferred.

The base case, in the matrix referred to Alternative 0, is examined with the score 2. According to the explanation given above, potential Alternatives are the ones with a score of 2 or higher. In the following Sections these are introduced and elaborated.

11.2 Methodology Preliminary Port Planning Exercise

11.2.1 Boundaries

The port expansion has to be realised within the boundaries drawn by PSO[6]. Information on the alignment of the borderlines can be found in Annex II.

11.2.2 Design and Positioning of the Components

Requirements and forthcoming the components are assimilated according to analysis performed in Chapter 10. In this Chapter a relation analysis was carried out which resulted in guidelines for the positioning of the components. These guidelines are applied as much as possible during the port planning.

[6] One of the responsibilities of The Port Shipping Organisation (PSO) is "preparing and supervising the implementation of control and monitoring plans for the waters under the jurisdiction of the Islamic Republic of Iran" [*Ref. 23*]

The port users have indicated preferences on the location of some of the components. These are summarised below:

- Reclaimed area of SADRA to be placed between both branches of the old and new West Breakwaters
- The NDC berths and basin to be placed in front of their landside area
- The KEPCO berths and basin to be placed in front of their landside area

Preferences were made by NIOC on the design of the split of the port basin and port entrance. These have also been discussed in Chapter 3 and are summarised below:

- Eastern Breakwater to be identical as in Alternative on joint development
- Keep western Breakwater as it is in the existing situation, i.e. no extension
- Middle Breakwater has to be run from East Breakwater of the old small harbour to 'southern edge' of the physical model test area[7] (at approx. N 4081500) Southward to the eastern Breakwater of the existing small port
- Port entrance configuration to be identical as in Alternative on joint development

In Figure 3-1 these requirements are visualised.

11.2.3 Reduce Costs

In order to reduce the overall construction costs for the total project attention should be paid to the items which represent the major part of the costs. The following rules are followed to do so:

- Minimise Breakwater length
- Minimise length of the quay walls and revetments
- Minimise total amount of dredging volume

11.2.4 Evaluation

A Table is given in each of the following Section describing a port Alternative. It is summarising all components incorporated. An evaluation of the port Alternatives is carried out in Chapter 12. The weak and strong points of each Alternative are discussed there.

[7] Physical model is applied in the study on joint port development [*Ref. 10*]

11.3 Alternative 0 “Base Case”

Unloading in port, approach channel orientated to the East, no major change to the existing situation and ***no split basin and approach***

A3 Layout included in Annex I

This Alternative is the base case. It describes the chosen Alternative for *Joint Port Development.* SADRA and NIOC make use of the same approach and same basin.

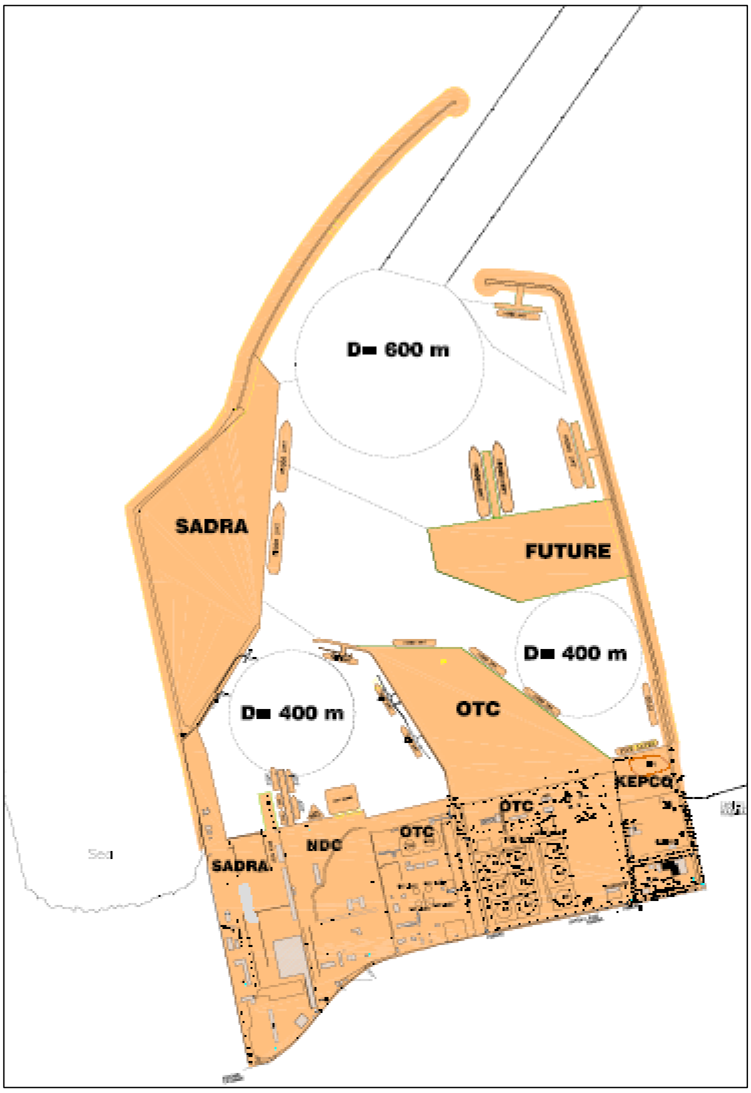


Table 11-2: Summary Alternative 0 (Base Case)

Sub System	Component	Remarks	Length [m]	Width [m]	Depth [m]*
Approach area	Approach Channel	Angle 35 CW with North line. Starts at a depth - 7.5m	6,285	200	15.50
NIOC wet	East Breakwater		1,550		
	Port Entrance			320	15.50
	Turning Basin 1	Diameter of 600 m			15.00
	Turning Basin 2	Diameter of 400 m			9.00
	Crude oil berth area 63,000 DWT	1 Jetty +1 fingerpier	620	280	15.00
	Crude oil berth area 14,000 DWT	2 berths along Quay wall	600		9.00
	Crude oil berth area 7,000 DWT	2 Jetties	400	200	6.50
	LPG berth area	Jetty	220	200	11.50
	Chemical berth area	Berth along quay wall	200		9.00
	Mazut/gasoline berth area	Jetty	200	190	6.50
	NDC berth area		280	180	8.40
	KEPCO berth area		250	200	9.30
	Reclaimed area OTC	26.5 ha			
	Reclaimed area future users	5 ha	0**		
SADRA wet	Breakwater		1250		
	Turning Basin 1		400		9.00
	Berth area 5,000 - 7,000 DWT vessels		350	180	5.00
	Berth area 63,000 DWT vessels	Quay Wall 1	500	300	9.00
	Berth area 63,000 DWT vessels	Quay Wall 2	200	300	14.50
	Waterside space for crane / lift		340	160	9.00
	Reclaimed land	26.5 ha			
	* to lowest waterlevel ** quay wall				

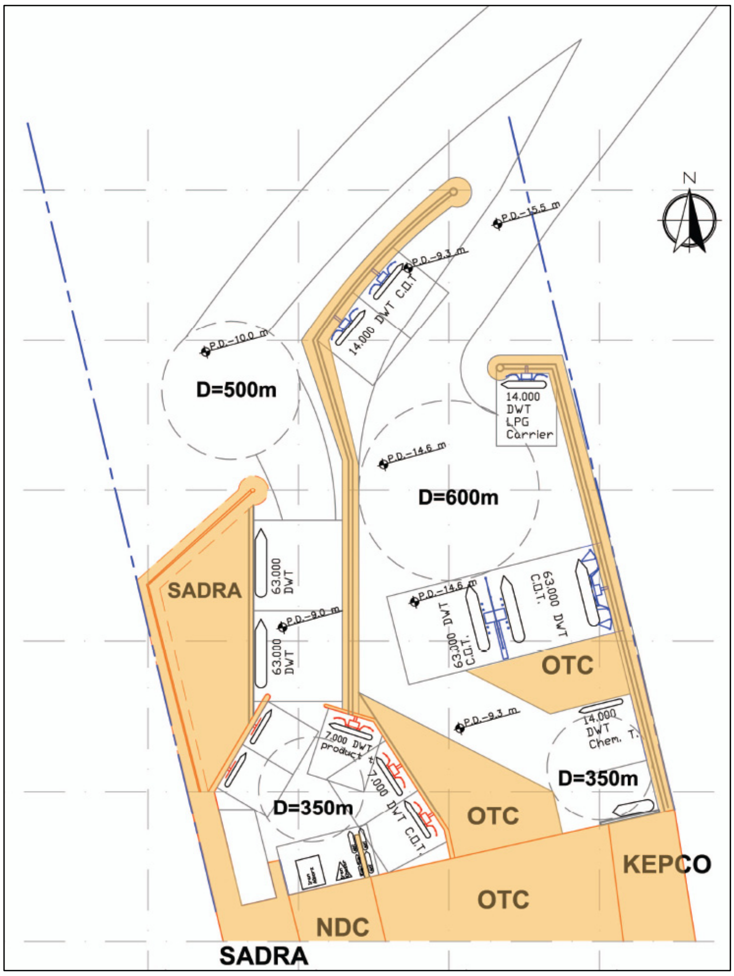
11.4 Alternative A

Unloading in port, approach channel orientated to the East, no major change to the existing situation and a separated basin and approach.

A3 Layout included in Annex XII

Description

The KEPCO basin and the NDC basins are both placed in front of their landside area. In the small existing port use is made of the current facilities, i.e. the crude oil and mazut/gasoline jetties along the existing Eastern Breakwater. Configuration of the Breakwaters according the additional user requirements limits the available space for the other berths. Therefore the 14,000 DWT Crude Oil tanker berths are placed at a somewhat hazardous location. A more detailed manoeuvring study should point out whether this is acceptable or not. The LPG berth is ideally placed. It is in a tranquil environment, but can leave the port quick when necessary. The large Crude Oil tankers are positioned near the reclaimed land, which is economical for quick storage. Furthermore, these berths are placed along the turning circle which enhances the manoeuvrability. The Chemical Tanker berth is realised by a quay wall along the reclaimed land. It is placed in front of the KEPCO berth such that it satisfies a similar required dredge depth. In the Southwest corner of the NIOC basin land reclamation is planned. The SADRA components are positioned according to the desires of SADRA. New land is reclaimed between the both branches of the western Breakwater with a quay wall capable for 63,000 to 70,000 DWT vessels in front of it.



This Alternative does fulfil completely the additional port user requirements, i.e. no extension of the West Breakwater, Middle Breakwater aligned according to the requirements and East Breakwater similar to the *joint development*.

Negative consequences of these choices are the following:

- Construction of a Middle Breakwater like this makes it impossible to realise the required size of the reclaimed area between both branches of the West Breakwater. This could be solved by orientating the middle Breakwater somewhat more to the East, though this would severely affect the already critical entrance situation of the NIOC basin
- Though the wave climate can be defined as mild (H_s < 1.5 m in 2 to 3 % of the time), problems can be expected regarding the wave tranquillity inside the SADRA basin. It should be considered to drop the *additional requirement* which describes not to extend the western Breakwater [NIOC-4]

In Table 11-3 the main dimensions of the Alternative are listed.

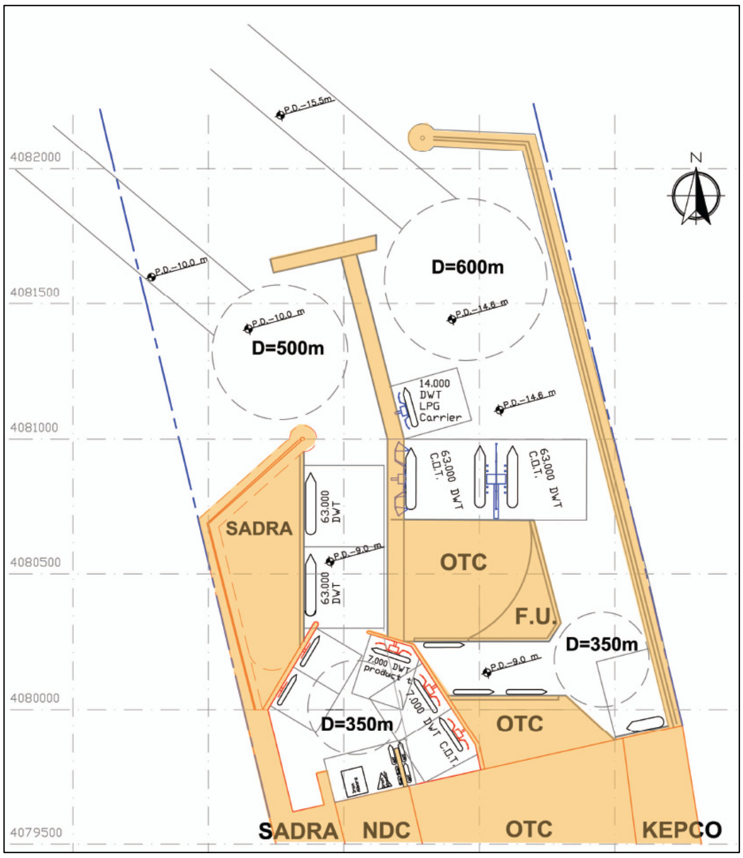
Table 11-3: Summary Alternative A

Sub System	Component	Remarks	Length [m]	Width [m]	Depth [m]*
Approach area	Approach Channel	Angle 35 CW with North line. Starts at a depth -7.5m	6,285	215	15.50
NIOC wet	Middle Breakwater		1,980		
	East Breakwater		1,550		
	Port Entrance			315	15.50
	Turning Basin 1	Diameter of 600 m			14.60
	Turning Basin 2	Diameter of 350 m			9.30
	Crude oil berth area 63,000 DWT	1 Jetty +1 fingerpier	700	300	14.60
	Crude oil berth area 14,000 DWT	2 Jetties	400	200	9.30
	Crude oil berth area 7,000 DWT	2 Jetties	400	200	6.30
	LPG berth area	Jetty	215	200	11.50
	Chemical berth area	Berth along quay wall	180	190	9.30
	Mazut/gasoline berth area	Jetty	200	190	6.30
	NDC berth area		310	165	8.40
	KEPCO berth area		305	205	9.30
	Reclaimed area OTC	26 ha			
	Reclaimed area future users	0 ha	0**		
SADRA wet	Breakwater		0		
	Port Entrance			250	10.00
	Approach branch	Starts at depth -7m	2,278	205	10.00
	Turning Basin 1		500		10.00
	Turning Basin 2		350		9.00
	Berth area 5,000 - 7,000 DWT vessels		350	180	5.00
	Berth area 63,000 DWT vessels	Quay Wall	700	300	9.00
	Waterside space for crane / lift		340	160	9.00
	Reclaimed land	20 ha			
	* to lowest waterlevel ** quay wall				

11.5 Alternative B

*Unloading in port, **approach channel orientated to the West**, no major change to the existing situation and a separated basin and approach.*

A3 Layout included in Annex XII



<u>Description</u>
Key issue in this Alternative is the western orientation of the approach channel. Main advantage of this feature is more space in the NIOC basin. Basic port user requirements can be almost completely fulfilled. This is not the case for the additional user requirements. Entrance configuration and eastern Breakwater are not according the requirements.

The LPG berth is located along the Middle Breakwater. The vessel can easily leave the port if so required. Land reclamation is foreseen along the Middle Breakwater. Along the reclamation area 63,000 DWT Crude Oil berths are planned. These berths are designed as a single jetty and one fingerpier. In the Southwest corner the 14,000 DWT Crude Oil berths and the chemical tanker berth are positioned. They are realized by a quay wall along the new land. The other liquid berths are located in the old small harbour. Use is made of the existing facilities. SADRA components are planned similar as in Alternative A.

In Table 11-4 the Alternative is summarised.

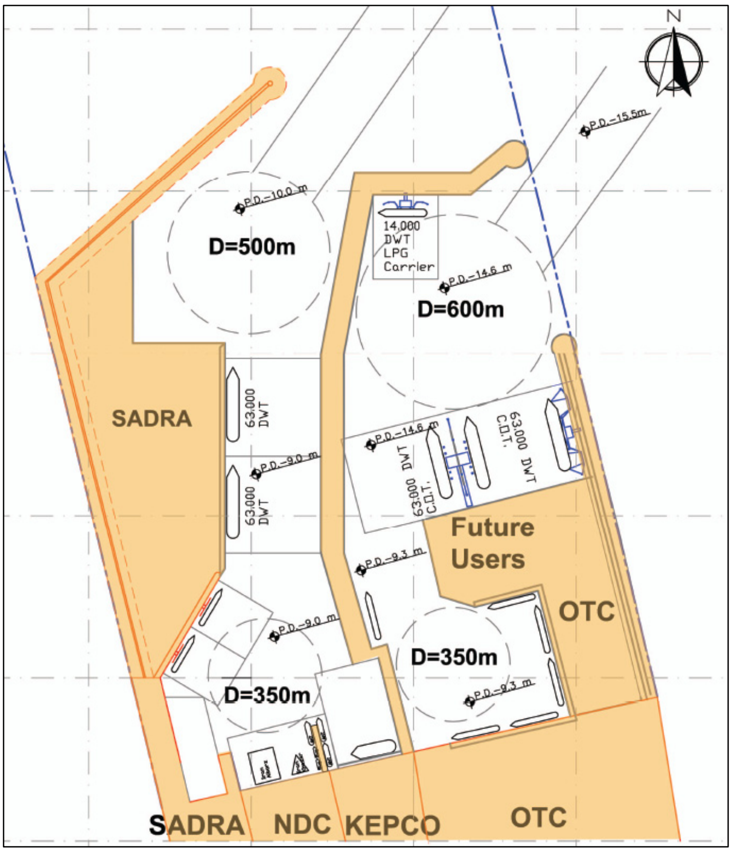
Table 11-4: Summary Alternative B

Sub System	Component	Remarks	Length [m]	Width [m]	Depth [m]*
Approach area	Approach Channel	Angle 35 CW with North line. Starts at a depth -8.0m	5,900	215	15.50
NIOC wet	Middle Breakwater		1,880		
	East Breakwater		2,450		
	Port entrance			315	15.50
	Turning Basin 1	Diameter of 600 m			14.60
	Turning Basin 2	Diameter of 350 m			9.30
	Crude oil berth area 63,000 DWT	1 Jetty +1 fingerpier	700	300	14.60
	Crude oil berth area 14,000 DWT	2 berths along quaywall	400	200	9.30
	Crude oil berth area 7,000 DWT	2 Jetties	400	200	9.30
	LPG berth area	Jetty	215	200	11.50
	Chemical berth area	Berth along quay wall	180	190	9.30
	Mazut/gasoline berth area	Jetty	200	190	9.30
	NDC berth area		310	165	8.40
	KEPCO berth area		305	205	9.30
	Reclaimed area OTC	26.4 ha			
	Reclaimed area future users	7.8 ha	700**		0.00
SADRA wet	Breakwater		0		
	Port Entrance			250	10.00
	Approach branch	Starts at depth -7m	2,280	205	10.00
	Turning Basin 1		500		10.00
	Turning Basin 2		350		9.30
	Berth area 5,000 - 7,000 DWT vessels		350	180	5.00
	Berth area 63,000 DWT vessels	Quay Wall	700	300	9.00
	Waterside space for crane / lift		340	160	9.00
	Reclaimed land	20 ha			
	* to lowest waterlevel ** quay wall				

11.6 Alternative C

*Unloading in port, approach channel orientated to the East, **major change to the existing situation allowed** and a separated basin and approach.*

A3 Layout included in Annex XII



Description

Key issue in Alternative C is the restructuring of the existing situation. The existing Eastern Breakwater and the jetties along it will be demolished. The land will be reassigned, i.e. KEPCO landside area is moved next to the NDC landside area. This action implies a proper split of the functions of the port, i.e. all liquid operations inside the NIOC basin and all other activities in the SADRA basin. In this way, the physical split is optimal.

The LPG berth is located in a tranquil environment and also ensures leaving the port quick and easy. The 63,000 DWT Crude oil berths are carried out similar as in Alternative A. All NIOC related land reclamation is placed in the Southeast corner of the NIOC basin. Along this land and in front of the OTC landside a quay wall is placed. Along this quay wall the other liquid berths are planned.

The additional user requirement [NIOC-4] regarding the West Breakwater is dropped. This Breakwater will be extended, by doing so the wave tranquility in the SADRA basin is minimised. Furthermore it enables the SADRA reclamation to be of the required amount.

In Table 11-5 the Alternative is summarised.

Table 11-5: Summary Alternative C

Sub System	Component	Remarks	Length [m]	Width [m]	Depth [m]*
Approach area	Approach Channel	Angle 35 CW with North line. Starts at a depth -7.0m	6,700	215	15.50
NIOC wet	Middle Breakwater		2,350		
	East Breakwater		1,100		
	Port Entrance			315	15.50
	Turning Basin 1	Diameter of 600 m			14.60
	Turning Basin 2	Diameter of 350 m			9.30
	Crude oil berth area 63,000 DWT	1 Jetty +1 fingerpier	700	300	14.60
	Crude oil berth area 14,000 DWT	2 berths along quaywall	400	200	9.30
	Crude oil berth area 7,000 DWT	2 berths along quaywall	400	200	9.30
	LPG berth area	Jetty	215	200	11.50
	Chemical berth area	Jetty	200	190	9.30
	Mazut/gasoline berth area	Berth along quay wall	180	190	9.30
	NDC berth area		310	165	8.40
	KEPCO berth area		305	205	9.00
	Reclaimed area OTC	26 ha			
	Reclaimed area future users	10 ha	0**		0.00
SADRA wet	Breakwater		1,650		
	Port Entrance			250	10.00
	Approach branch	Starts at depth -7.5m	2,500	205	10.00
	Turning Basin 1		500		10.00
	Turning Basin 2		350		9.00
	Berth area 5,000 - 7,000 DWT vessels		350	180	5.00
	Berth area 63,000 DWT vessels	Quay Wall	700	300	9.00
	Waterside space for crane / lift		340	160	9.00
	Reclaimed land	26.5 ha			
	* to lowest waterlevel ** quay wall				

11.7 Alternative D

Offshore unloading of liquid, *approach channel orientated to the East, no change to the existing situation allowed and a separated basin and approach.*

A3 Layout included in Annex XII

<u>Description</u>

Central in this Alternative is the use of offshore unloading points for all liquid commodities. By doing so, the port onshore has to be expanded in a less extensive way. Main advantage is the more spacious configuration of the port itself.

The SADRA components and the small existing harbour are designed similar as in Alternative A. In NIOC's waterside sub-system a land reclamation is placed with options for future users. The Alternative is flexible in terms of future expansion possibilities. The KEPCO basin is positioned in front of their lanside area.

In Table 11.5 the main dimensions of the Alternative are listed.

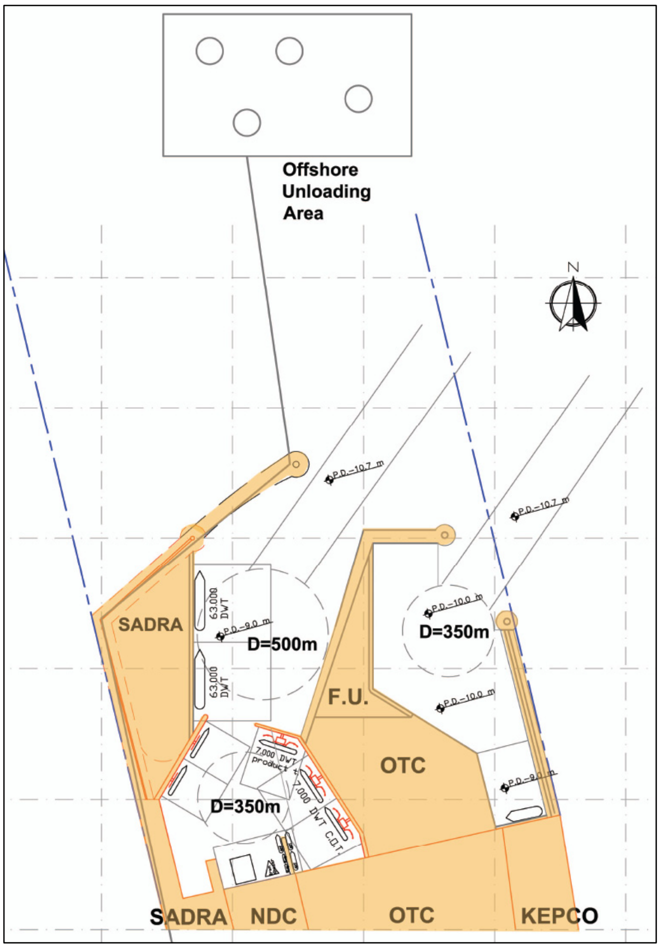


Table 11-6: Summary Alternative D

Sub System	Component	Remarks	Length [m]	Width [m]	Depth [m]*
Approach area	Approach Channel	Angle with nortline 35 CW, starts at depth -5 m	4,500	100	10.70
NIOC wet	Middle Breakwater		1200		
	East Breakwater		550		
	Port Entrance			200	10.70
	Turning Basin 1			350	10.00
	Crude oil berth area 63,000 DWT	Not in port, via SBM			17.30
	Crude oil berth area 14,000 DWT	Not in port, via SBM			12.50
	Crude oil berth area 7,000 DWT	2 Jetties	400	200	6.30
	LPG berth area	Not in port, via SBM			14.50
	Chemical berth area	Not in port, via SBM			12.50
	Mazut/gasoline berth area	Jetty	200	190	6.30
	NDC berth area		310	165	8.40
	KEPCO berth area		305	205	9.30
	Pipeline		8000		
	Reclaimed area OTC	26.4 ha			
	Reclaimed area future users	7.8 ha	700**		10.00
SADRA wet	Breakwater		500		
	Port Entrance			250	10.70
	Approach branch		3450	205	10.70
	Turning Basin 1		500		10.00
	Turning Basin 2		350		9.00
	Berth area 5,000 - 7,000 DWT vessels		350	180	9.00
	Berth area 63,000 DWT vessels	Quay Wall	700	300	9.00
	Waterside space for crane / lift		340	160	9.00
	Reclaimed land	20			
	* to lowest waterlevel ** quay wall				

12 EVALUATION

The Port Alternatives, as presented in the previous Section will be evaluated in this Chapter. The qualitative evaluation will be done by means of a Multi-Criteria-Evaluation (MCE). This evaluation gives insight in the weak and strong points of each Alternative. Costs are not represented in the evaluation; these are evaluated later by means of a Bill of Quantities (BoQ).

Based on the outcome of the MCA and evaluation of the BoQ Alternatives have been selected which have highest potential to become feasible.

12.1 Multi-Criteria-Evaluation

A Multi-Criteria-Evaluation (MCE) is an evaluation tool which makes use of qualitative criteria. In this case the MCE is performed in order to give insight in the decision problem and to eliminate inferior Alternatives.

The MCE comprises the following items:

- Criteria; different criteria are identified to be relevant in order to make a confident and unambiguous evaluation of the port Alternatives. These criteria are discussed in Section 12.1.2
- Effect Matrix; in the effect matrix the port Alternatives are examined on the various criteria
- Vision and Weights; the main stakeholders NIOC and SADRA have each their own opinion on how the port should be expanded. Both visions are assimilated in the evaluation. This is done by dedicating weight factors to each criterion according to both visions
- Score Table; in the score table the effect matrix is combined with the both visions. It is the result of the evaluation

12.1.1 Criteria

User Requirements

- <u>Basic User Requirements</u>; these requirements represent all requirements which are indicated by the port users in first stage, i.e. in the situation of *joint development* for SADRA and NIOC in Neka Harbour. These requirements are still valid in the present considered port development
- <u>Additional User Requirements</u>; in the present study, additional user requirements are indicated by NIOC. These requirements comprise a situation in which both port users have their own basin and approach. Fulfilling these requirements is considered to be positive

For more information on port user requirements reference is made to Chapter 3 and Annex III.

Environmental Impact

- Dredging / Fill ratio; the dredge and fill quantities should be balanced. By doing so the environment will not be harmed by depositing or lifting of material
- Cooling water Power Plant; the temperature of the cooling water of the neighbouring Neka Power Plants should not be influenced by Neka Harbour. In the study on joint development it was analysed what the possible influence of the Neka's port extension on the water temperature in front of the power plant's water intake could be. It was concluded that Neka Harbour hardly affects the temperature. In general it is presumed that the further the port's Breakwaters extend into the sea, the greater the port's influence is on the cooling water temperature
- Other; all possible environmental issues, not mentioned above, caused by the port extension should be minimised

Port Planning

- Positioning of Components; the components within the port should be positioned such that incompatible activities are separated and high risk components are isolated. For example oil related activities should be separated from shipyard activities and the LPG berth should be isolated because of the high risks involved with LPG
- Long Term Potential; future expansion is always hard to predict. However the port should be able to handle an eventual positive change of the forecast without major Breakwater modifications. Another considered issue is the uncertainty in sea level prediction (refer Section 4.2.2). It is positive if the Alternative can respond to fluctuations of the sea level
- Suitable for Phasing; it is not economical to realise the total port extension in once. The port should be built in such a way (in phases) that the capacity growth of the port follows the economic growth

Ship Manoeuvring

- Outer Approach; the approach channel should be aligned in such a way that it shows as little curvature as possible and it makes a small angle with the decisive wind and wave directions
- Entrance; the entrance of the port should be straight. A vessel should be able to enter in a safely. Furthermore space has to be available in case of incorrect navigation by the captain
- Inner Manoeuvring and Berthing; the basin should be designed in such a way that vessels are able to manoeuvre safely, and relatively quickly to their respective berth. Also the berthing process itself should be easy in particular when other berths are occupied

Operational Aspects

- Wave Tranquillity; to minimise harbour downtime, the wave conditions inside the harbour should be mild. Therefore the Breakwaters should be configured in such a way that the wave agitation inside the basin is restricted
- Rate of Siltation; harbour siltation should be minimised in order to reduce maintenance dredging. No tidal elevation is to be found in the Caspian Sea and furthermore currents induced by other forces are limited in and around Neka Harbour. It can be concluded that in general the rate of siltation will be low and consequently the variation between Alternatives will be low. Therefore this criterion will have a relatively minor importance factor

12.1.2 Effect Matrix

At the end of this Section the effect matrix is given. In the effect matrix all Alternatives are examined on the criteria discussed above. This examination is based on a range of 0 to 5. A '0' means the most negative examination possible. A 5 means the best examination possible. First a summary is given on how the Alternatives score on the various criteria.

Alternative 0

- User Requirements; the Alternative satisfies to all basic requirements. Though it does not satisfy any of the additional requirements, as it was originally developed for the *joint port development*
- Environmental Impact;
    - The Dredge / Fill ratio is assessed at 3.4
    - A study was carried out to assess the influence, conclusion was: hardly any effect [*Ref. 11*]
    - No other issues were identified
- Port Planning;
    - All berths are well spread. The LPG berth is isolated but the carrier can leave the port easily. With reference to the other Alternatives, this Alternative does not provide a physical break up between the shipyard activities and the crude oil basin, which is preferred in view of safety
    - 7 ha reclaimed land and a berthing area for possible future users is included in the design. If more capacity is required the Breakwaters have to be reconstructed
    - In the port planning report of Royal Haskoning it is shown that phased construction is very good possible
- Ship Manoeuvring;
    - The approach channel is straight. Disadvantage of the present alignment is that waves from Northwest impact the vessels almost perpendicular to the bow
    - SADRA and NIOC make use of the same port entrance. A Real Time Ship Manoeuvring Study for the port layout has been carried by Force Technology [*Ref. 9*]. Entrance of the vessels was found to be sometimes complicated but acceptable. The same counted for inner manoeuvring
- Operational Aspects;
    - SADRA and NIOC make use of the same basin. A wave Tranquillity Study for the port layout has been performed by DHI [*Ref. 14*]. Results indicated an acceptable situation
    - Hardly any rate of siltation was assessed for the port layout during an analysis carried out by Royal Haskoning [*Ref. 11*]

Alternative A

- User Requirements;
    - In this port layout it was not feasible to incorporate sufficient land reclamation between both branches of the West Breakwater as stated by requirement [SADRA-10]. All other requirements are satisfied
    - This Alternative satisfies all additional requirements as stated by NIOC

- Environmental Impact;
    - Dredge / Fill ratio is assessed at 4.7
    - This Alternative has almost the same port contour like Alternative 0, hence it gets the same score
    - No other issues were identified
- Port Planning;
    - All berths are wide distributed. The LPG berth is isolated but can leave the port easy. Furthermore a physical break is realised between the shipyard basin and the bigger oil berths which contributes to the safety aspects
    - No extra space is available if more capacity is required in future, then the Breakwaters have to be partly reconstructed
    - Phasing is very well possible. Similar to Alternative 0
- Ship Manoeuvring;
    - The approach channel is slightly curved. Waves coming from NW run cross on the approach channel (refer previous page). The port entrance is split for SADRA and NIOS basin, hence the approach channel has to be split as well, which has a negative influence
    - Entrance of the NIOC basin is complicated; access channel is bended and a hard obstacle is placed at the end (middle Breakwater).
    - Turning basin is positioned outside the Breakwaters. Due to the lack of manoeuvring area inside the basin, the bigger vessels have to be towed in backwards
    - Both basins are very compacted
- Operational Aspects;
    - Substantial wave penetration in the SADRA basin
    - Regarding the NIOC basin, the entrance and Breakwater configuration is almost similar to Alternative 0, hence the wave tranquillity in the basin is sufficient
    - No problems are expected concerning the rate of siltation

Alternative B

- User Requirements;
    - In this port layout it was not feasible to incorporate sufficient land reclamation between both branches of the West Breakwater as stated by requirement [SADRA-10]. All other requirements are satisfied
    - This Alternative fulfils the preference of a split basin and approach, Though it does not satisfies the *way* of separation as described in requirements [NIOC-1 to 4]; the East Breakwater is extended, entrance configuration does not match, alignment of middle Breakwater does not satisfy (refer Figure 3-1)
- Environmental Impact;
    - Dredge / Fill ratio is assessed at 5.3
    - Approach channel is orientated in front of Neka Power Plants, the channel itself and the vessel action will influence the cooling water temperature
    - No other issues were identified

- Port Planning;
  - Not all berths are well distributed. The LPG berth is not isolated, though the carrier can leave the port easy. A physical break is realised between the shipyard basin and the bigger oil berths which contributes to safety aspects
  - 7.8 ha reclaimed land and a berthing area for future users is included in the design. If more capacity is required the Breakwaters have to be reconstructed, however not as much as for Alternative 0, A and C
- Ship Manoeuvring;
  - The approach channel is straight. Approach channel is branched, which has a negative influence
  - Entrance of both the SADRA and NIOC basin is very complicated; directly behind the turning basins, in the leading line, the Breakwaters are placed
  - Both the SADRA and the NIOC basins are very compacted
- Operational Aspects;
  - Poor situation regarding the wave tranquillity, considerable wave agitation is to be expected for both basins
  - Regarding the NIOC basin, the entrance and Breakwater configuration is almost similar to Alternative 0, hence the wave tranquillity in the basin is sufficient
  - It is anticipated that sediment flows into both harbour basins

Alternative C

- User Requirements;
  - Not all basic requirements are satisfied; the land assignment is different to earlier agreed upon
  - This Alternative fulfils the preference of a split basin and approach, Though it does not satisfies the *way* of separation as described in requirements [NIOC-1 to 4]; the East Breakwater is designed to be shorter, entrance configuration does not match, alignment of middle Breakwater does not satisfy (refer Figure 3-1), western Breakwater is extended and partly demolished, and the small old Breakwater is demolished
- Environmental Impact;
  - Dredge / Fill ratio is assessed at 3.7
  - Western Breakwater is extended
  - No other issues were identified
- Port Planning;
  - Berths are widely distributed. The LPG berth is isolated and can leave the port easy. A physical break is realised between the shipyard basin and the bigger oil berths which contributes to the safety
  - 10 ha reclaimed land and a berthing area for future users is included in the design. if more capacity is required in future, then the Breakwaters have to be partly reconstructed, although to a lesser extent than in Alternative 0, and A

- Ship Manoeuvring;
  - The approach channel is straight. Waves coming from NW run cross on the approach channel. Approach channel is split, which has a negative influence
  - Entrance of the NIOC and SADRA entrance is complicated; a hard obstacle is placed at the end for both
  - Both the SADRA and the NIOC basins are very compacted
- Operational Aspects;
  - Acceptable situation for the SADRA basin and a positive situation for the NIOC basin is expected regarding the wave tranquillity
  - Due to the extension of the West Breakwater hardly any rate of siltation is to be expected

Alternative D

- User Requirements;
  - Does not fulfil the basic requirements, all unloading takes place offshore
  - Does split the basins and approaches, however not on the manner as required. Western Breakwater extended
- Environmental Impact;
  - Dredge / Fill ratio is assessed at 2.3
  - Alternative extent less far in sea than the others
  - Pipelines along considerable length at sea bottom. Leakages are possible, environment disturbed
- Port Planning;
  - All berths are excellent spread. A physical break is realised between the shipyard basin and the bigger oil berths
  - 7.8 ha reclaimed land and a large berthing area for undefined future users is included in the design. If more capacity is required only more offshore facilities has to be placed
  - Alternative is very suitable for phasing
- Ship Manoeuvring;
  - The approach channel is aligned without bends. Waves coming from NW run cross on the approach channel. Approach channel is branched, which has a negative influence
  - No problems expected by entrance of NIOC basin. Vessels to be finished in construction along the quay of SADRA have a more or less vulnerable position regarding the entrance configuration
- Operational Aspects;
  - No problems expected regarding the wave tranquillity

Table 12-1: Effect Matrix

Criteria	0	A	B	C	D
User Requirements					
Basic	5	4	4	5	0
Split basin	0	5	2	2	2
Environmental Impact					
Dredging / Fill ratio	3	2	1	3	5
Cooling water Power Plant	4	4	2	1	5
Other	5	5	5	5	1
Port Planning					
Positioning components	3	4	2	5	5
Long term potential	2	0	4	4	5
Suitable for phasing	4	4	2	4	5
Ship Manoeuvring					
Outer approach	4	1	4	3	5
Entrance SADRA basin	3	2	0	2	3
Entrance NIOC basin	3	1	0	2	4
Inner Manoeuvring and berthing	3	2	2	3	5
Operational Aspects					
Wave tranquillity SADRA basin	5	1	1	2	3
Wave tranquillity NIOC basin	5	5	1	5	3
Rate of siltation	5	4	2	5	3

12.1.3 Vision and Weights

Both NIOC and SADRA have different visions on the importance of the various criteria with respect to the evaluation of the Alternatives. For example, the port entrance of NIOC is considered as not important in the eyes of party SADRA whereas NIOC has a reverse opinion. Hence, for both visions a qualification of the importance of the different criteria is made.

For each vision 100 points are divided over the criteria. The more points are dedicated to a certain criterion, the more important the criterion is believed to be. In Table 12-2 the distribution of the points according to both visions is listed.

Table 12-2: Vision and Weights

Criteria	Visions	
	SADRA	*NIOC*
User Requirements	**16**	**30**
Basic	16	10
Split basin	0	20
Environmental Impact	**17**	**9**
Dredging / Fill ratio	3	3
Cooling water Power Plant	7	3
Other	7	3
Port Planning	**32**	**22**
Positioning components	12	8
Long term potential	10	8
Suitable for phasing	10	6
Ship Manoeuvring	**20**	**26**
Outer approach	5	6
Entrance SADRA basin	10	4
Entrance NIOC basin	0	8
Inner Manoeuvring and berthing	5	8
Operational Aspects	**15**	**13**
Wave tranquility SADRA basin	12	0
Wave tranquility NIOC basin	0	10
Rate of siltation	3	3

12.1.4 Score Table

The score table is the result of the MCE. For each vision, a score table is given. In the first column the criteria are given. In the second column the maximum score is stated. In the next column the score of each Alternative on the criteria is stated. This score is obtained by applying the effect matrix to the maximum points given in the first column.

Table 12-3 and 12-4 are the score tables matching with respectively the vision of SADRA and the vision of NIOC.

Table 12-3: Score Table SADRA

Criteria	max points	0	A	B	C	D	
User Requirements	**16**	**16**	**12.8**	**12.8**	**16**	**0**	
Basic	16	16	12.8	12.8	16	0	
Split basin	0	0	0	0	0	0	
Environmental Impact	**17**	**14.4**	**13.8**	**10.4**	**10.2**	**11.4**	
Dredging / Fill ratio	3	1.8	1.2	0.6	1.8	3	
Cooling water Power Plant	7	5.6	5.6	2.8	1.4	7	
Other	7	7	7	7	7	1.4	
Port Planning	**32**	**19.2**	**17.6**	**16.8**	**28**	**32**	
Positioning components	12	4.8	6.4	3.2	8	8	
Long term potential	10	4.8	0	9.6	9.6	12	
Suitable for phasing	10	4	4	2	4	5	
Ship Manoeuvring	**20**	**13**	**7**	**6**	**10**	**16**	
Outer approach	5	4	1	4	3	5	
Entrance SADRA basin	10	6	4	0	4	6	
Entrance NIOC basin	0	0	0	0	0	0	
Inner Manoeuvring and berthing	5	3	2	2	3	5	
Operational Aspects	**15**	**15**	**4.8**	**3.6**	**7.8**	**9**	
Wave tranquility SADRA basin	12	12	2.4	2.4	4.8	7.2	
Wave tranquility NIOC basin	0	0	0	0	0	0	
Rate of siltation	3	3	2.4	1.2	3	1.8	+
	100	**77.6**	**56.0**	**49.6**	**72.0**	**68.4**	

The score Table for SADRA points out Alternative 0 to be the best. The ship manoeuvring and wave tranquillity criteria are in this respect decisive. On base of the MCE the conclusion can be drawn that a *separate port development* is not positive for SADRA.

If one would only review the situation of separate port development, Alternative C seems to be the option to SADRA. This is mainly due the extension of the West Breakwater in this Alternative. The extension creates a situation which is very positive regarding the wave tranquillity and entrance manoeuvring in the SADRA basin. However this will heighten the costs. The additional costs need to be paid for by SADRA. In Section 12.2 the costs will be discussed into more detail, further conclusions are drawn there.

Table 12-4: Score Table NIOC

Criteria	max points	0	A	B	C	D
User Requirements	**30**	**10**	**28**	**16**	**18**	**8**
Basic	10	10	8	8	10	0
Split basin	20	0	20	8	8	8
Environmental Impact	**9**	**7.2**	**6.6**	**4.8**	**5.4**	**6.6**
Dredging / Fill ratio	3	1.8	1.2	0.6	1.8	3
Cooling water Power Plant	3	2.4	2.4	1.2	0.6	3
Other	3	3	3	3	3	0.6
Port Planning	**22**	**12.8**	**11.2**	**12**	**19.2**	**22**
Positioning components	8	4.8	6.4	3.2	8	8
Long term potential	8	3.2	0	6.4	6.4	8
Suitable for phasing	6	4.8	4.8	2.4	4.8	6
Ship Manoeuvring	**26**	**16.8**	**7.6**	**8**	**13.2**	**22.8**
Outer approach	6	4.8	1.2	4.8	3.6	6
Entrance SADRA basin	4	2.4	1.6	0	1.6	2.4
Entrance NIOC basin	8	4.8	1.6	0	3.2	6.4
Inner Manoeuvring and berthing	8	4.8	3.2	3.2	4.8	8
Operational Aspects	**13**	**13**	**12.4**	**3.2**	**13**	**7.8**
Wave tranquility SADRA basin	0	0	0	0	0	0
Wave tranquility NIOC basin	10	10	10	2	10	6
Rate of siltation	3	3	2.4	1.2	3	1.8 +
	100	**59.8**	**65.8**	**44**	**68.8**	**67.2**

The scores of Alternative A, C and D do all give the same order of value and are higher than the score of the base case, whereas Alternative B has a significant lower score.

12.1.5 Sensitivity Analysis

By performing a MCE it is common to carry out a sensitivity analysis on the score table. Aim of such an analysis is to prove that the outcome of the MCE is robust with respect to large variations in the weight factors of the criteria.

In the present MCE the two different visions (and so the variation in weight factors) of NIOC and SADRA are essential. The outcome of the MCE is proved to be different for each vision. According to the first lines in this Section, this implies that the MCE is not robust with respect to large variations in the weight factors. This is certainly the case; sensitivity of the whole study according to the two different visions of the main stakeholders is the key issue in this study. Therefore, in the current MCE, a sensitivity analysis is not useful and should miss its aim.

12.2 Bill of Quantities

In this Section a cost evaluation for each Alternative is presented. The Bill of Quantities including the used cost figures are incorporated in Annex XIII. The results of the cost estimate are merely used as a comparison tool. Costs calculated are indicative only.

The Bill of Quantities comprises the following cost items:

- Dredging
- Reclamation
- Costs for Jetties, Fingerpiers or Offshore Unloading Points
- Quay walls
- Pipe Lines

12.2.1 Comparison on Costs

The costs calculated in Annex XIII are translated to relative costs, in which the highest cost is represented by the number 100. In Table 12-5 the results are given for the both parties.

Table 12-5: Results out of Bill of Quantities

	0 (Base Case)	**A**	**B**	**C**	**D**
SADRA	99.4	33.4	33.9	100.0	61.4
NIOC	65.4	86.0	97.7	100.0	55.1

SADRA
Alternative 0 and C are by far the most expensive options for SADRA. In Annex XIII in Figure XIII-1 it can be seen that the main part of the costs is generated by the extension of the West Breakwater.

It is noted that extra costs are anticipated for Alternative C as the demolishing of existing constructions is not represented in the Bill of Quantities.

NIOC
Alternative C is also for NIOC the most expensive option. Least expensive is Alternative D, as the total Breakwater length and dredging volume is limited.

12.3 Conclusions and Abbreviations

In the present Chapter the MCE and BoQ are analysed together in order to assess the preferred port Alternative. First a summary of both is given. Thereafter conclusions are made. Recommendations on further study are performed at the end of the Chapter.

12.3.1 Summary MCE and Bill of Quantities

In this Section the costs and the values, represented by the score tables, will be considered together for all Alternatives. In Table 12-6 an overview is given for both visions.

In addition the item Value over Costs is included in the Table. This factor divides the score of the MCE by the costs found in the BoQ. It represents the total value per unit of cost and hence it is indicative for the relative rate of return the considered Alternative gives.

Table 12-6: Summary MCE and BoQ

Vision	Item	0 (base case)	A	B	C	D
SADRA	MCE	**77.6**	56	49.6	72	68.4
	BoQ	99.4	**33.4**	**33.9**	100	61.4
	VoC	0.78	**1.68**	1.46	0.72	1.11
NIOC	MCE	59.8	**65.8**	44	**68.8**	**67.2**
	BoQ	65.4	86	97.7	100	**55.1**
	VoC	0.91	0.77	0.45	0.69	**1.22**

Multi Criteria Evaluation
If the MCE alone would be decisive Alternative 0 should be the best Alternative for SADRA, whereas Alternative A, C, D satisfies NIOC's vision best. Only the performing of Alternative B is unambiguous; it has the lowest score according to both visions.

Bill of Quantities
If the choice for an Alternative would be based on its total costs then Alternative A or B should be the choice for SADRA. Alternative D has the lowest costs for NIOC. For both parties Alternative C causes the highest investments.

Value of Costs
The VoC is determined by combining value and costs. Alternative A scores the best on this item for SADRA closely followed by Alternative B. For NIOC Alternative D returns by far the most profit per unit cost.

12.3.2 Conclusions

NIOC and SADRA earlier agreed upon *joint port development (base case)*, in this perspective it can be remarked that an Alternative incorporating *separate port development* should return more value compared to the base case (or the investments should be considerably lower). In addition both parties have to agree upon the separated port development. Consequently an Alternative is only potential when it satisfies both SADRA and NIOC. For this reason in Table 12-7 an overall vision is given on the items as discussed in the previous Section. This vision is derived by summing the items for both parties.

Table 12-7: MCE and BoQ for Overall Vision

Vision	Item	0 (Base Case)	A	B	C	D
Total	MCE	137.4	121.8	93.6	**140.8**	135.6
	BoQ	164.8	**119.4**	**131.6**	200.0	**116.5**
	VoC	0.83	**1.02**	0.71	0.70	**1.16**

As the VoC combines the MCE and BoQ, this tool is used to assess which Alternatives should be potential. In Table 12-7 it can be seen that Alternative A en D score better on the VoC then the Base Case and hence are the potential Alternatives.

12.3.3 Abbreviations

According to the conclusions drawn above it is recommended to elaborate Alternatives A and D. For the present thesis it is not feasible to elaborate both. Alternative D is an offshore orientated project, whereas Alternative A comprises Coastal Engineering and Port Engineering aspects. Alternative A is chosen to be the subject for the remaining of the thesis, as it fits better with the educational background of the student.

In the following it is discussed what optimisation should be foreseen on Alternative A.

Alternative A did not score well on the wave tranquillity and ship manoeuvring with respect to the SADRA basin (refer Table 12-3 and Section 12.1.2). Simulations of these items are required to assess the limitations caused, and in addition to optimize the port layout.

The accessibility of the NIOC basin was found to be complex (refer Table 12-4 and Section 12.1.2). A ship manoeuvring simulation has to be carried out to assess whether the configuration is acceptable or not.

PART FIVE: SIMULATION AND REFINEMENT

13 WAVE TRANQUILITY SADRA BASIN

This Section presents the results of the numerical wave agitation modelling for the SADRA Basin.

13.1 Objective

The objective of the wave agitation task was to document the wave conditions in the SADRA basin for Alternative A and if required refine the breakwater alignment to ensure an acceptable downtime percentage.

13.2 Numerical Model

The wave agitation was studied using the Boussinesq Wave (BW) module of the mike21 software[8]. Mike21 BW can be applied to the study of wave dynamics in ports and coastal areas. It is a 2D time-domain model capable of reproducing the combined effects of most wave phenomena including refraction, shoaling, diffraction, partial reflection and transmission, non-linear wave-wave interaction, frequency dispersion, and directional dispersion.

The model requires the following input:

- A digitised bathymetry
- Basic model parameters describing the extent of the model area, the grid spacing of the computational model grid, the time step and the duration of the simulation
- Incident wave conditions described by flux series on the boundaries of the model area
- Porosities (‘reflection and transmission coefficients’) to describe the reflection and transmission characteristics for structures and natural obstructions (breakwaters, quay walls, cliffs, beaches, etc.) in the model area
- Description of so-called sponge layers, which are areas absorbing all wave energy propagating into the model area (e.g. from the boundaries of the model)

13.3 Model Set-up

13.3.1 Model Bathymetry

The bathymetry for the models was derived in the following way:

1. Drawings based on a recent local survey were received from Royal Haskoning
2. Schematised drawing was prepared based on drawings as described above
3. Drawings were digitised and imported in the Mike21 Model

In addition the layout as described in Annex XII, Alternative A was included in the model.

[8] A description on the set-up and working of the module can be requested on the website http://www.dhisoftware.com/mike21/download

Resulting harbour contour and bathymetry as applied during the simulations is presented in Figure 13-1. The light blue areas at the top of the domain, West of SADRA basin, in the NIOC basin and East of the port have been excluded in the simulation to reduce computational time. Waves are assumed absorbed (no reflection) when entering these areas. This is realised by creating a “sponge layer” at the boundaries of the discussed areas.

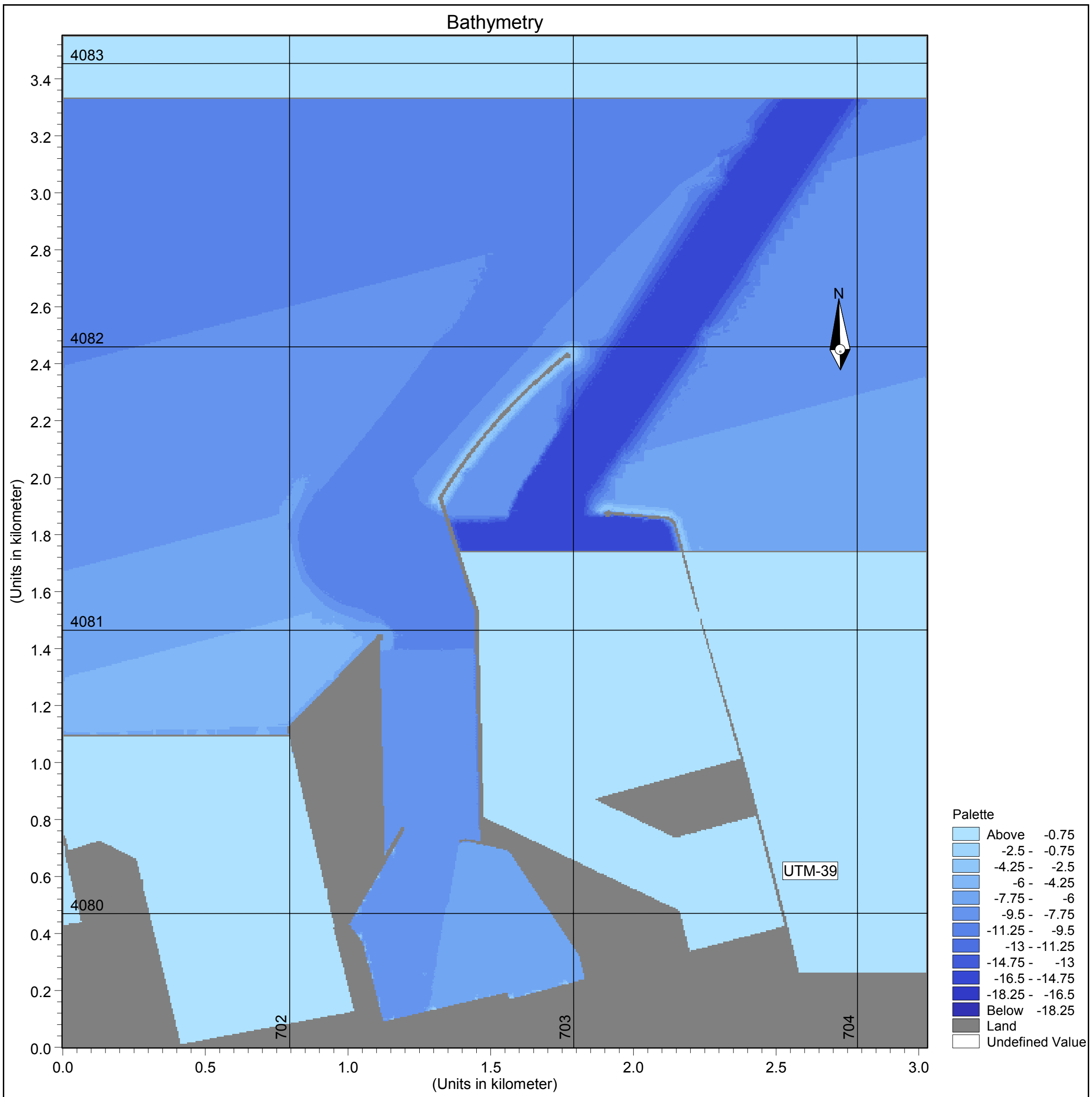


Figure 13-1: Bathymetry and Harbour Contour

13.3.2 Reflection Properties

Partial reflections from the harbour structures were included in the simulations by specifying the porosity values corresponding to the reflection characteristics of these structures.

The West and East Breakwaters are Rubble Mound Structures, their typical cross sections are included in Annex IX. For these structures a reflection of 30-40 percent was applied for the porosity layers at rock slopes.

The footprint of a rubble mound breakwater is substantially wider than the footprint of a caisson breakwater. Therefore the Middle Breakwater will be preferably designed as a Caisson Breakwater as such construction contributes in a positive way to the lack of space. It is recognised that this type of structures, i.e. vertical walls, have a considerable reflection (approx 98 percent). This could have negative effects on the wave tranquillity in the SADRA Basin. For this reason two Cases were simulated:

1. Middle Breakwater designed as Caisson Breakwater; reflection of 98 percent was included
2. Middle Breakwater designed as Rubble Mound Breakwater with a typical cross section like the Eastern Breakwater; reflection of 30-40 percent was included

Last part of the Middle Breakwater is highly exposed to the incoming waves and in addition is in front of the approach channel to the SADRA basin. This part will be designed as a Rubble Mound Breakwater with a typical cross section like the Western Breakwater. A reflection of 30-40 percent was applied for this part of the Middle Breakwater.

Figure 13-2 and 13-3 indicate the applied reflection properties for respectively Case 1 and Case 2.

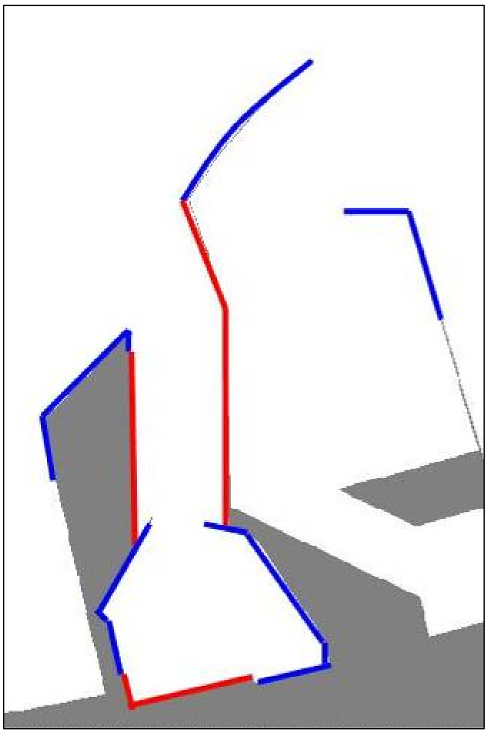


Figure 13-2: Case 1:
Blue: 30-40%. Red: 98%

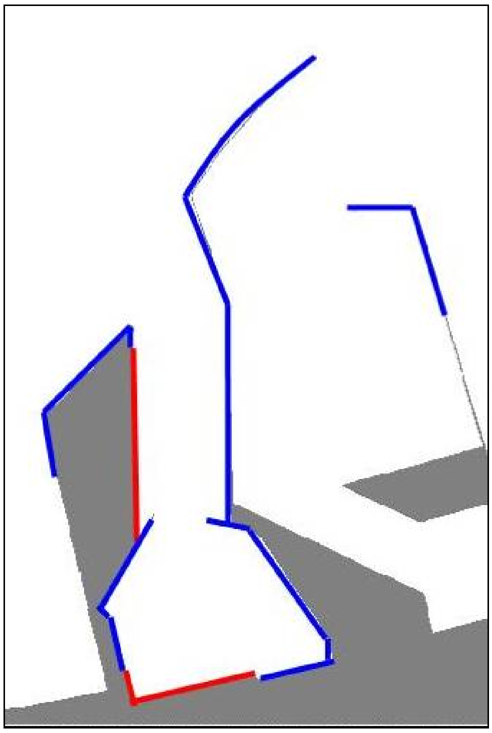


Figure 13-3: Case 2:
Blue: 30-40% Red: 98%

13.3.3 Incident Wave Generation

Irregular waves approaching the harbour from specified directions were simulated. Directional irregular waves conforming standard JONSWAP spectrum (γ=3.3) with corresponding wave height, wave period, and wave direction were used for defining the wave conditions at the boundary of the model. The directional spreading was taken as $\cos^8(\theta - \theta_{mean})$, where θ was the direction and θ_{mean} the mean wave direction. The directional spreading was confined within ±20º around θ_{mean}.

Simulations were made for waves with a T_p of 7 s. This type of wave is representative for waves during operational conditions (return period < 1 year) (refer Annex V).

For case 2 and directions 330º N and 360º N simulations were made for waves with T_p = 9 s. This type of waves is representative for waves during limit state conditions (return period > 1 year).

For both T_p = 7s and 9s wave periods represented in the spectrum less than 5 s were not solved in the model. The spectrum was rescaled to ensure that the total wave energy is conserved.

For the simulations, a wave height of 1 m was applied. It is noted that by using a boundary condition with 1 m significant wave height, the wave conditions determined inside the harbour can be viewed as Wave Disturbance Coefficients (WDC). Hence, if a different wave height (but with same wave direction and wave period) is used at the boundary, the corresponding wave heights inside the harbour are found by multiplying the boundary wave height and the wave agitation coefficients.

Wave breaking was not included in the modelling. This will not affect the results for the operational wave conditions, as wave breaking will only occur for waves higher than 3.5 m (minimal depth in front of harbour is 6.5 m). For limit state conditions wave breaking does occur in reality, hence applying the Wave Disturbance Coefficients presented in the following will lead to a conservative estimate for limit state conditions.

Simulations were carried out for the mean wave directions in the range 310º N - 360º N. The wave direction range is depicted in Figure 13-4.

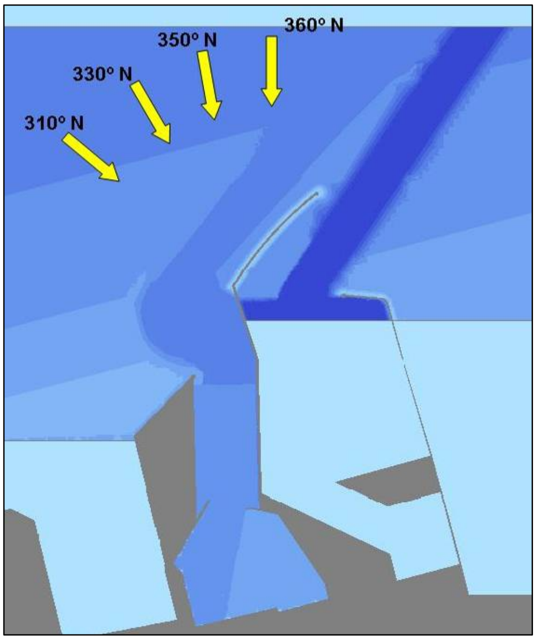


Figure 13-4: Modelled Wave Directions

13.3.4 Simulation Duration

To ensure fully developed wave patterns within the harbour, the duration of each simulation corresponded to 30 minutes, of which the last 15 minutes could be used for statistical analysis. The time step (Δt) applied in the simulations was 0.15 s. The model resolution (grid spacing) was 5 m.

13.4 Presentation of Results

13.4.1 Plots

The results for T_p = 7s are presented as follows:

- Figures 13-5 through 13-8 present the wave disturbance coefficients for the entire harbour area, with the Middle Breakwater designed as a caisson breakwater
- Figures 13-9 through 13-12 present the wave disturbance coefficients for the entire harbour area, with the Middle Breakwater designed as a Rubble Mound Breakwater. In Annex XIV the wave disturbance coefficients for the whole model are included in A4 scale
- Figures 13-14 through 13-17 and Tables 13-1 and 13-2 present the calculated wave disturbance coefficient at locations 4 through 17 as defined in Figure 13-13. The presented wave disturbance coefficient for these reference locations are mean values over areas of 25 m X 25 m. It is noted that locations 1 to 3 and 18 are included for calibration purposes (reference is made to Section 13.7)
- In Figures 13-18 through 13-21, examples of wave propagation patterns for the entire harbour area are presented in form of instantaneous surface elevations (snapshots) from the simulations of case 2. In Annex XIV the instantaneous surface elevations for the whole model are included in A4 scale

The results for T_p = 9s are presented as follows:

- Figures 13-22 and 13-23 present the wave disturbance coefficients for the entire harbour area, with the Middle Breakwater designed as a caisson breakwater
- In Figures 13-24 and 13-25, examples of wave propagation patterns for the entire harbour area are presented in form of instantaneous surface elevations (snapshots) from the simulations
- Figures 13-14 through 13-17 and Table 13-3 present the calculated wave disturbance coefficient at locations 4 through 17 as defined in Figure 13-13

13.5 Comments

13.5.1 Operational Conditions, Tp = 7s

The Rubble Mound design for the Middle Breakwater ensures considerable better results for the wave agitation inside the SADRA Basin. Especially for the wave directions 310º N and 330º N the wave disturbance coefficients are substantial lower:

- In the SADRA basin in front of the land reclamation WDC are up to 0.44 lower for the RM Breakwater
- In the existing small basin WDC are up to 0.36 lower for the RM Breakwater

Considering the results for the Rubble Mound Breakwater the following is assessed:

Wave Direction 310º N
No problems are to be expected for any of the berths; Highest Wave Disturbance Coefficient < 0.3 (at quay in front of land reclamation SADRA

Wave Direction 330º N
No problems are to be expected for any of the berths; Highest Wave Disturbance Coefficient < 0.36 (at quay in front of land reclamation SADRA

Wave Direction 350º N
- The Jetties for the 14,000 DWT Vessels is exposed; Wave Disturbance Coefficient < 0.5
- Quay in front of SADRA reclamation is exposed, Wave Disturbance Coefficient < 0.53
- Quay NDC is exposed: Wave Disturbance Coefficient < 0.42

Wave Direction 360º N
- The Jetties for the 14,000 DWT Vessels is exposed; Wave Disturbance Coefficient < 0.59
- Quay in front of SADRA reclamation is exposed, Wave Disturbance Coefficient < 0.53
- Quay NDC is exposed: Wave Disturbance Coefficient < 0.41

13.5.2 Limit State Conditions, Tp = 9s

Simulations are made for case 2 with directions 330º N and 360º N, as these were decisive in the case of T_p= 7 s.

Wave Direction 330º N
- Values of the Wave Disturbance Coefficients are in the same range as for the simulation with T_p = 7s

Wave Direction 360º N
- Values of the Wave Disturbance Coefficients are in the same range as for the simulation with T_p = 7s

Middle Breakwater Caisson

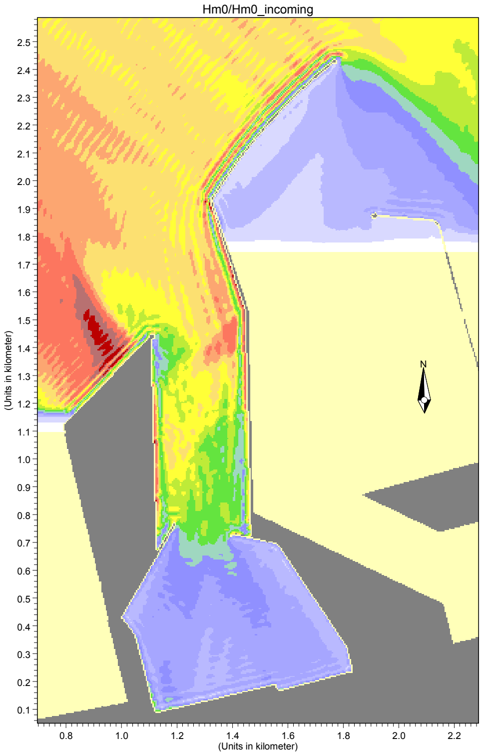


Figure 13-5: T_p = 7 s, MWD 310° N

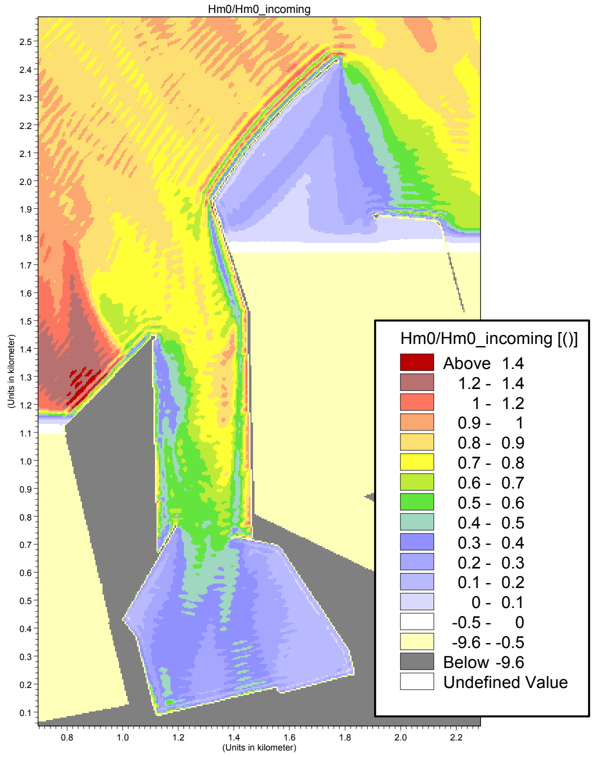


Figure 13-6: T_p = 7 s, MWD 330° N

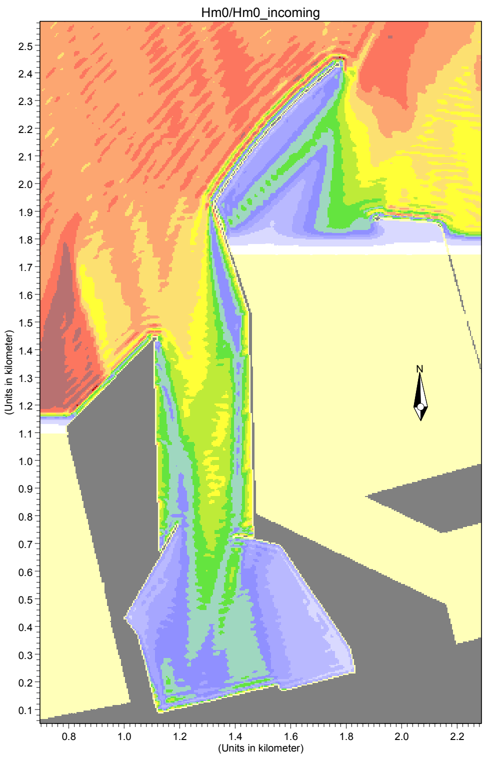


Figure 13-7: T_p = 7 s, MWD 350° N

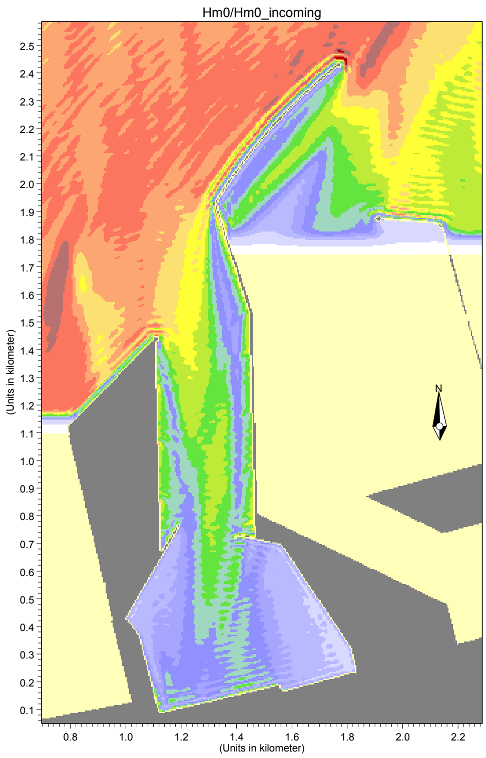


Figure 13-8: T_p = 7 s, MWD 360° N

Middle Breakwater: Rubble Mound

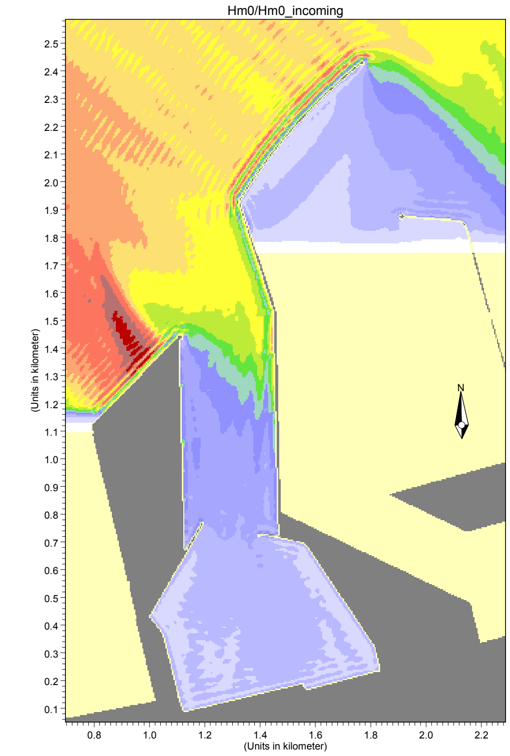


Figure 13-9: T_p = 7 s, MWD 310º N

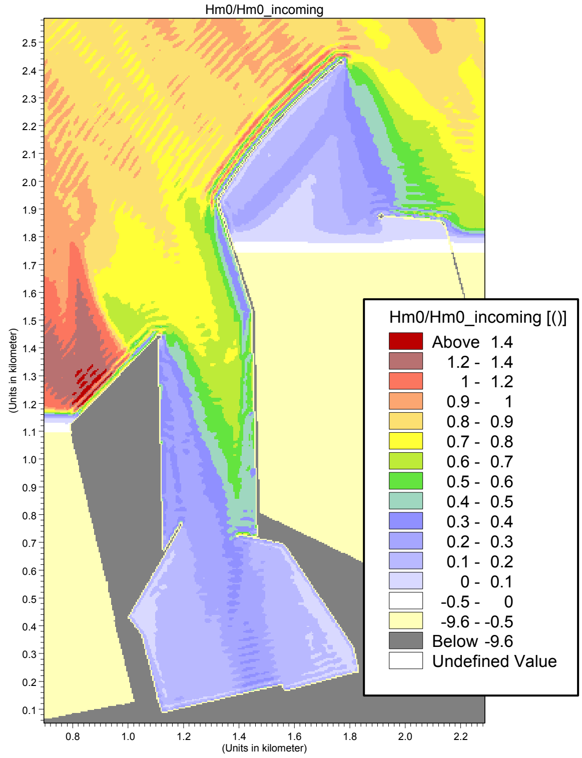


Figure 13-10: T_p = 7 s, MWD 330º N

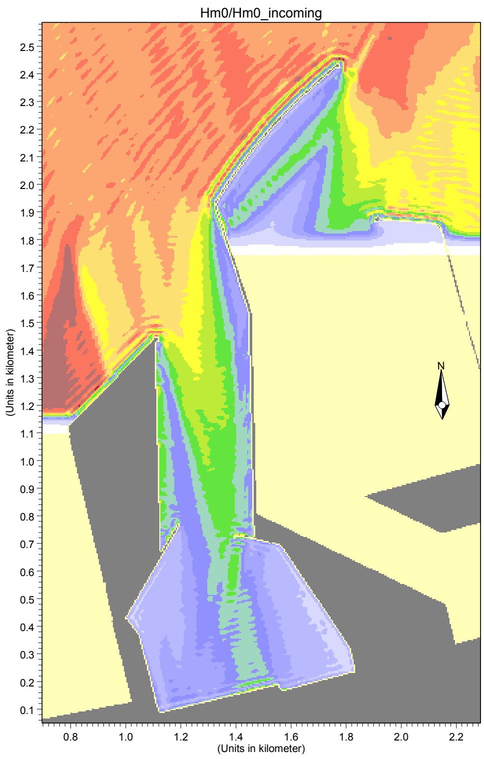


Figure 13-11: T_p = 7 s, MWD 350º N

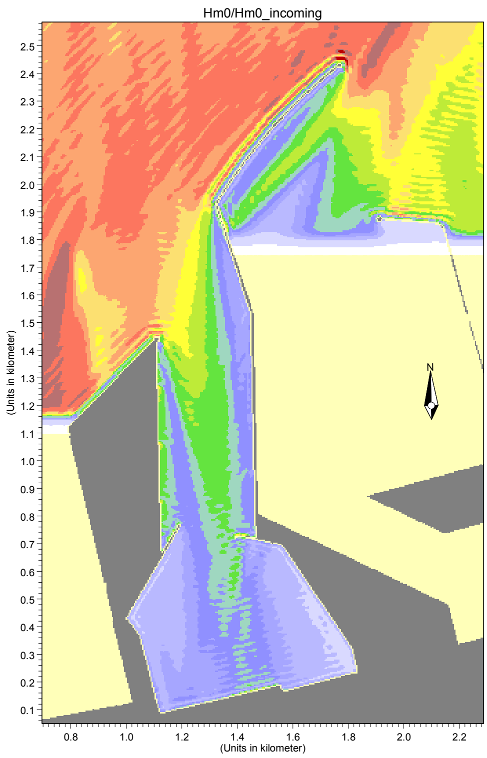


Figure 13-12: T_p = 7 s, MWD 360º N

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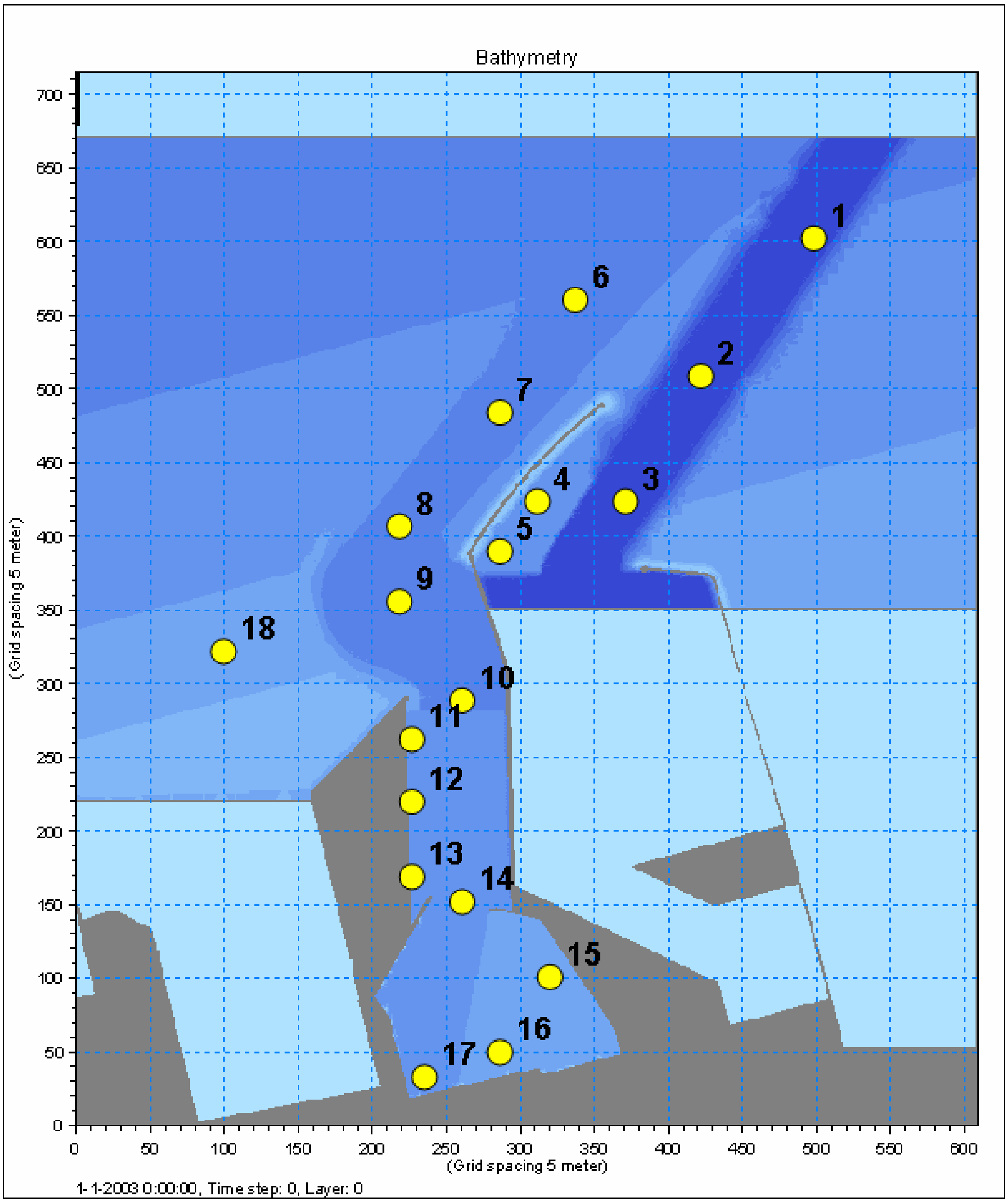


Figure 13-13: Reference Locations for Wave Output

Table 13-1: Tp = 7 s, Wave Disturbance Factors at Ref. Points for Caisson Middle Breakwater

Ref Location	310	330	350	360
4	0.09	0.14	0.34	0.49
5	0.15	0.22	0.50	0.58
6	0.86	0.93	0.94	0.96
7	0.84	0.92	1.03	1.03
8	0.85	0.85	0.99	1.01
9	0.84	0.80	0.88	0.97
10	0.84	0.79	0.68	0.59
11	0.58	0.45	0.57	0.57
12	0.73	0.42	0.49	0.48
13	0.52	0.44	0.53	0.52
14	0.57	0.50	0.62	0.6
15	0.21	0.18	0.13	0.13
16	0.20	0.37	0.46	0.44
17	0.35	0.43	0.51	0.42

Table 13-2: T_p = 7 s, Wave Disturbance Factors at Ref. Points for Rubble Mound Middle Breakwater

Ref Location	310	330	350	360
4	0.09	0.14	0.34	0.49
5	0.15	0.22	0.5	0.59
6	0.86	0.93	0.94	0.96
7	0.84	0.92	1.03	1.03
8	0.85	0.85	0.99	1.00
9	0.83	0.78	0.87	0.97
10	0.65	0.70	0.64	0.57
11	0.29	0.36	0.53	0.54
12	0.27	0.30	0.43	0.44
13	0.22	0.27	0.47	0.48
14	0.23	0.25	0.44	0.44
15	0.11	0.11	0.12	0.12
16	0.14	0.28	0.43	0.41
17	0.12	0.18	0.31	0.28

Ref Location	310	330
4	0.16	0.54
5	0.22	0.54
6	1.06	1.00
7	1.09	1.05
8	1.01	1.07
9	0.95	1.00
10	0.99	0.60
11	0.39	0.60
12	0.33	0.48
13	0.30	0.46
14	0.34	0.44
15	0.12	0.13
16	0.35	0.40
17	0.22	0.28

Table 13-3: T_p = 9 s, Wave Disturbance Factors at Ref. Points for Rubble Mound

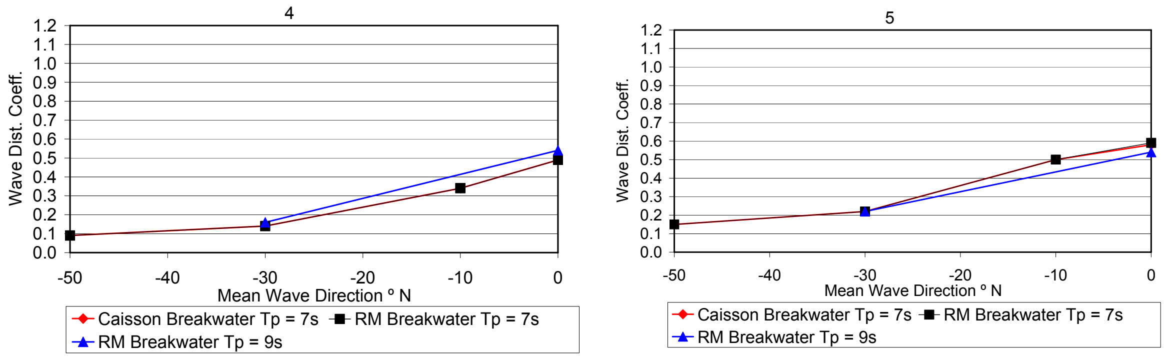


Figure 13-14: Ref 4 + 5: 14,000 DWT Crude Oil Jetties

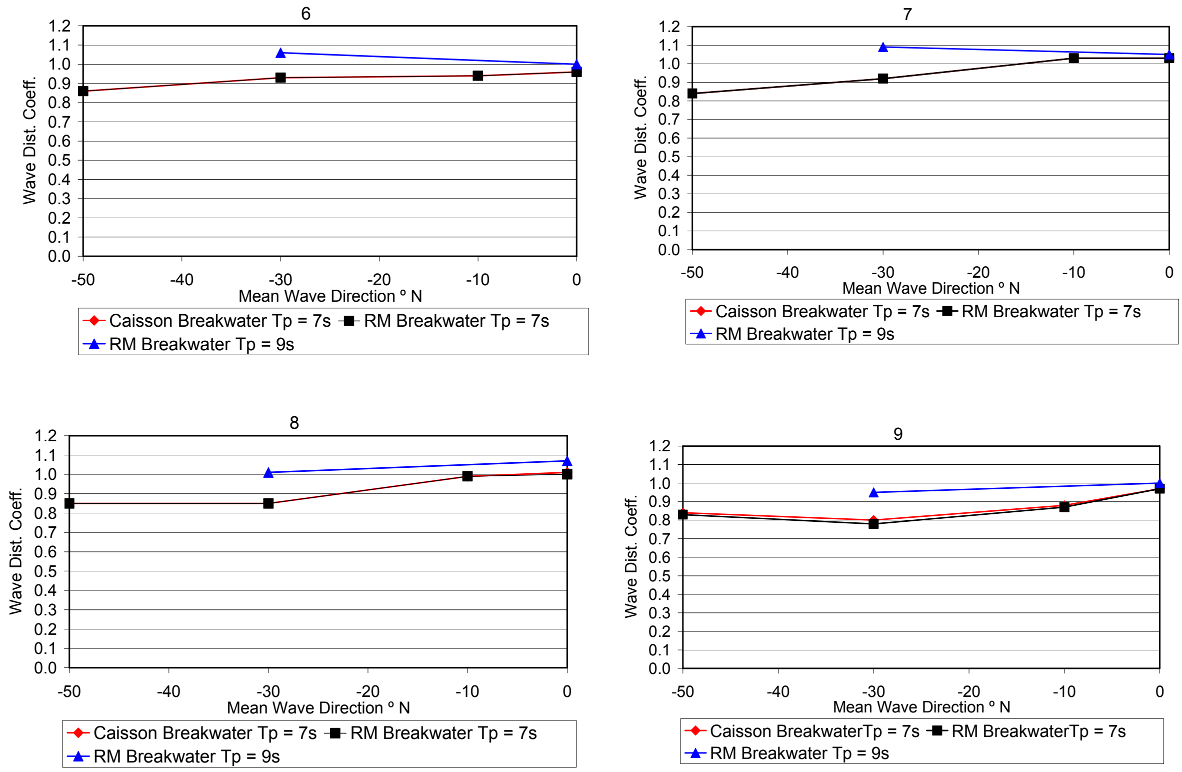


Figure 13-15: T_p = 7 s, Ref 6, 7, 8, and 9: Approach Channel SADRA Basin

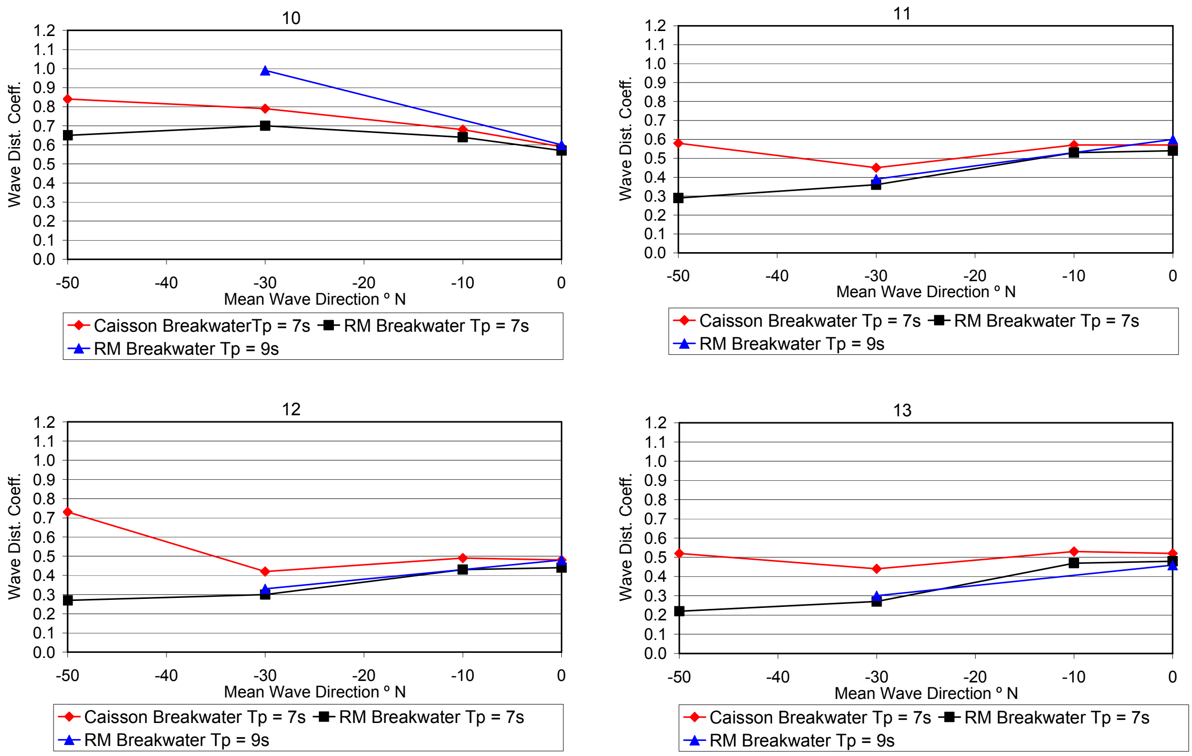


Figure 13-16: T_p = 7 s, Ref 10, 11, 12, and 13: SADRA Basin

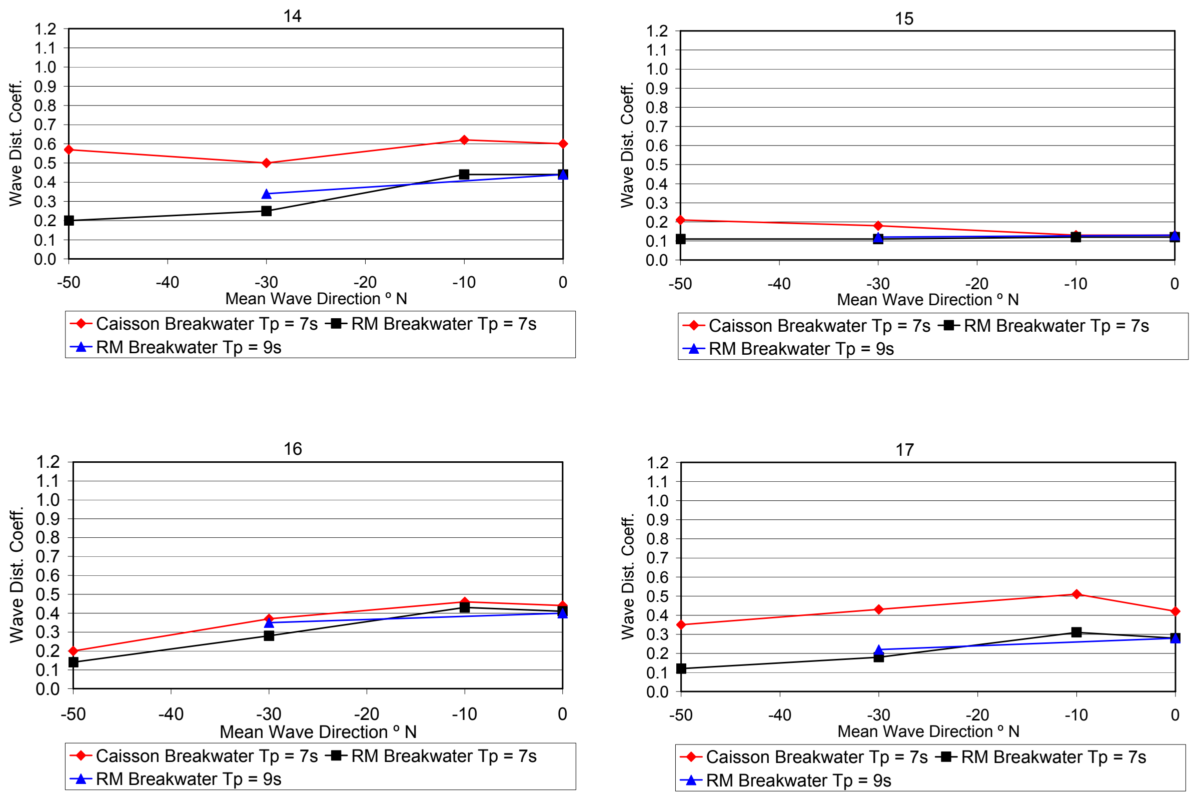


Figure 13-17: T_p = 7 s, Ref 14, 15, 16, and 17: Existing Small Basin

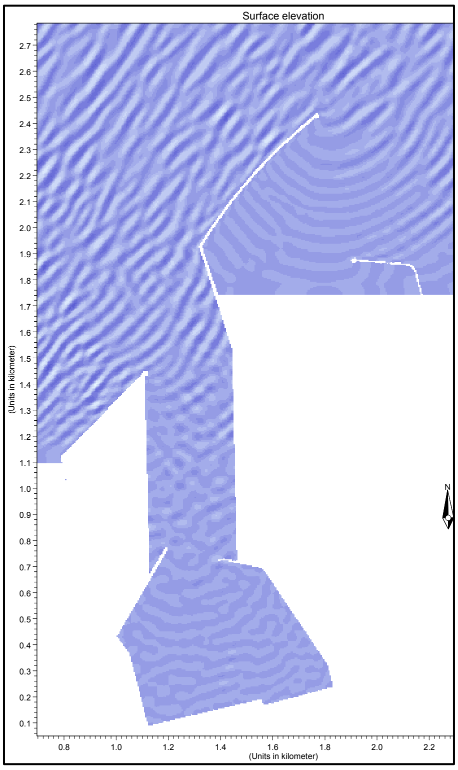


Figure 13-18: T_p = 7 s, Surf. Elev. 310° N

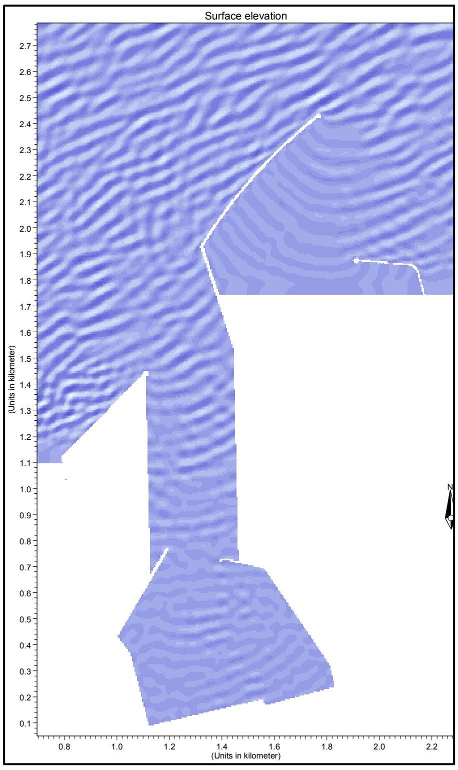


Figure 13-19: T_p = 7 s, Surf. Elev. 330° N

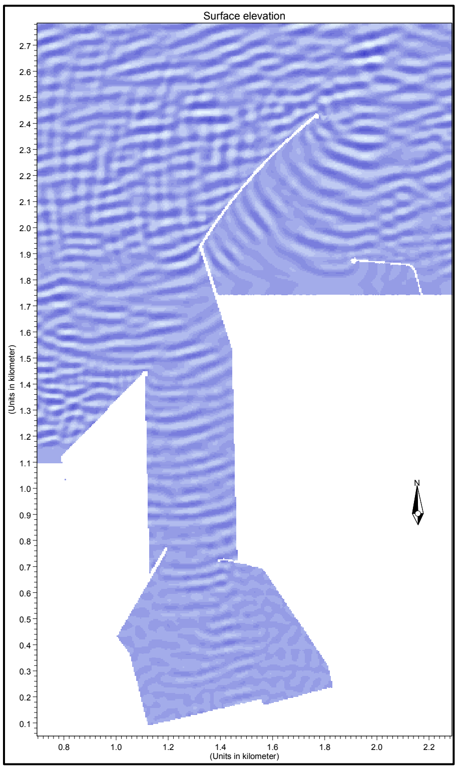


Figure 13-20: T_p = 7 s, Surf. Elev. 350° N

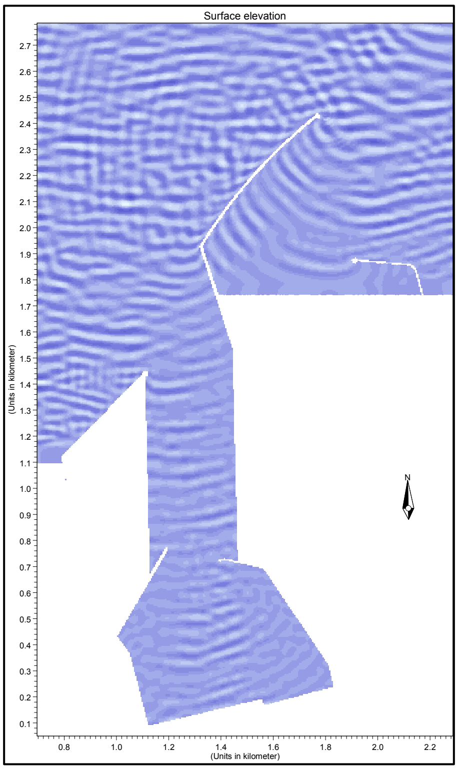


Figure 13-21: T_p = 7 s, Surf. Elev. 360° N

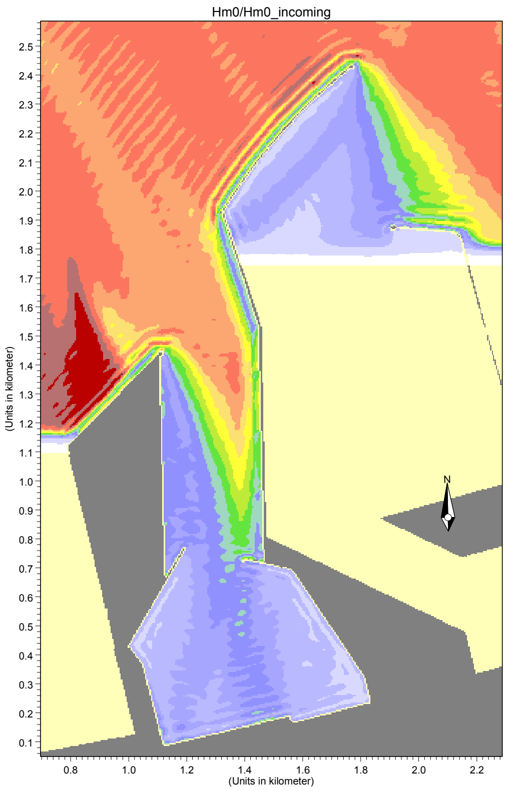


Figure 13-22: T_p = 9 s, MWD 330° N

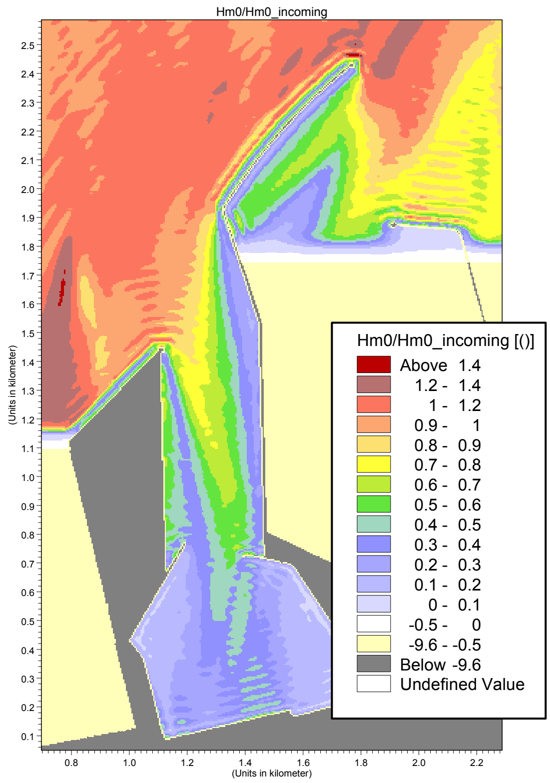


Figure 13-23: T_p = 9 s, MWD 360° N

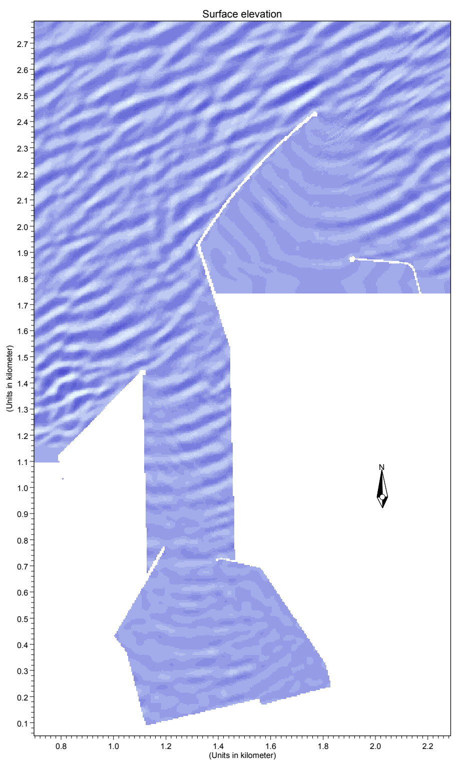


Figure 13-24: T_p = 9 s, Surf. Elev. 330° N

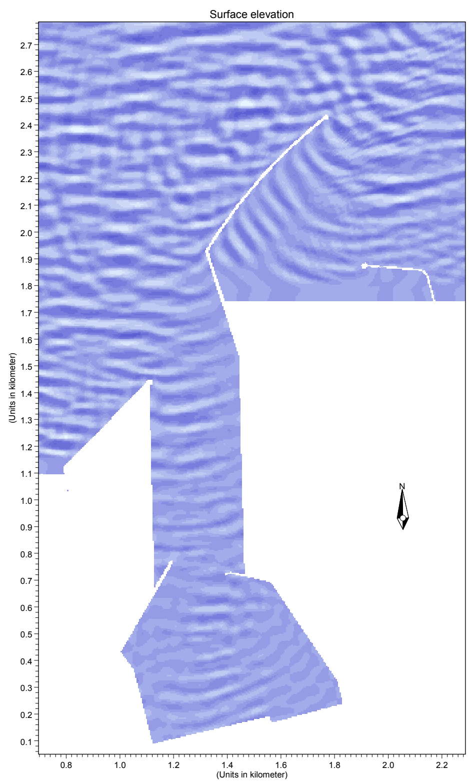


Figure 13-25: T_p = 9 s, Surf. Elev. 360° N

13.6 Preliminary Conclusions

13.6.1 Operational Conditions

Case 2, with the Middle Breakwater designed as a Rubble Mound Breakwater, gave the best results with respect to the wave tranquillity inside the SADRA basin. Differences regarding the wave tranquillity inside the SADRA Basin, found in the wave modelling are of such magnitude that the advantage of the Caisson Middle Breakwater, i.e. smaller footprint, is overruled. Therefore it is recommended to design the Middle Breakwater as a Rubble Mound type.

Both the NIOC basin and the SADRA basin were found to be exposed mostly for Northern waves. An Indication of operational downtime caused by agitation of Northern waves is given in Table 13-4. A more detailed analysis of the operational downtime of all port activities is carried out in Chapter 15.

Table 13-4: Indication of Downtime Levels caused by Northern Waves

Component	Operational Limiting Hm0 [m]	Max Wave Disturbance Coefficient	Acceptable Hm0 at Model Boundary [m]	Exceeded [%]
14,000 DWT Crude Oil Jetties	1.5	0.59	2.54	0.25
SADRA Quay	0.7	0.53	1.32	< 0.75
NDC Quay	0.5	0.41	1.22	0.75

From the results it can be concluded that minimal downtime is expected. In Chapter 15 minor adjustments to the port layout are discussed.

13.6.2 Limit State Conditions

In Table 13-5 it is presented which wave height a vessel experiences during conditions with a return period of 1 and 10 years when berthed alongside the quay / jetty.

Table 13-5: Indication of Limit State Conditions

Component	*Max WDC*	**RP 1 year**		**RP 10 years**	
		Wave height at Boundary [m]	*Hm0 at berth [m]*	*Wave height at Boundary [m]*	*Hm0 at berth [m]*
14,000 DWT Crude Oil Jetties	0.54	2.90	1.57	3.80	2.05
SADRA Quay	0.6	2.90	1.74	3.80	2.28
NDC Quay	0.4	2.90	1.16	3.80	1.52

In Table 13-5, it can be seen that a maximum wave height of 2.28 m can be expected once in ten years. This level of wave height should be no problem for a berthed vessel [*Ref. 5*], [*Ref. 16*]. Hence the vessel does not leave the port for conditions with a return period of ten years.

As the limit state conditions are acceptable inside the basin, no further analysis on this subject will be performed.

13.7 Calibration

Two sources were available and were used to verify the model:

1. Comparisons have been made with wave measurements inside the port in the physical breakwater stability model as was applied in the study on *joint port development* [*Ref. 14*]
2. Comparisons have been made with the wave tranquillity simulation as it is applied in the on *joint port development* by DHI. [*Ref. 14*]

Both sources are used to calibrate the present model used. The results are discussed in the first two Sections. In addition the simulation is analysed whether it responds like one should expected based on physical rules. This analysis is discussed in Section 13.7.3.

Results are interpreted to be satisfying if values correspond with less then 10 % deviation.

13.7.1 Physical Model

As in the physical model test only long-crested waves without directional spreading were applied, simulations were carried out for the same. Simulations were performed for wave directions 330º N and 352.5º N with respectively a T_p of 8.1 and 7.3 s. These periods are the one-year event for these directions. The one-year event was chosen as this was the test with the least wave-breaking (not represented in the present numerical model).

Data from the physical model for point 3 were available (refer Figure 13-13). Satisfying agreement for T_p = 8.1 s is found. For T_p = 7.3 s results deviate with more than 10% as can be seen in Table 13-6. For this T_p, the Wave Disturbance Coefficients in the area around point 3 are subjected to substantial differences, which will certainly influence the mean value found for point 3 (refer Figure 13-27).

Table 13-6: Measurements for Reference Location 3

T_p	Direction	WDC Physical Model	WDC Numerical Model
8.1	330	0.17	0.25
7.3	352.5	0.4	0.54

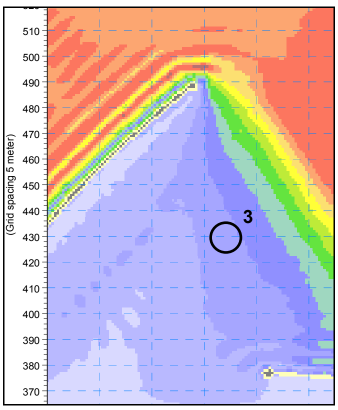
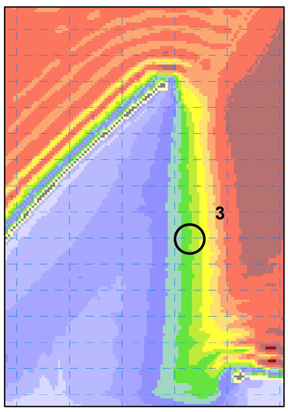


Figure 13-26: T_p = 8.1 s, WDC 330º N



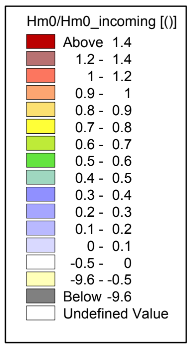


Figure 13-27: T_p = 7.3 s, WDC 352.5º N

13.7.2 DHI Results for Joint Port Development

Locations 1 to 3 as defined in Figure 13-13 will be used to verify the model. These locations were chosen for the calibration process for the following reasons:

- This part of the model is most similar for both port layouts as can be seen in Figure 13-28
- Data from the DHI modelling was available for these locations

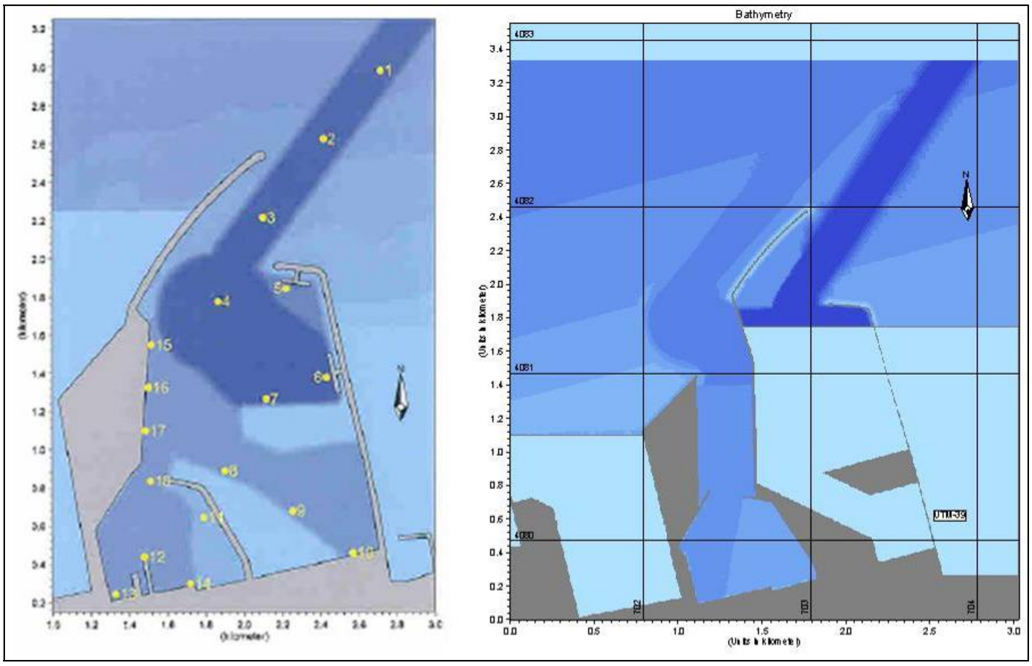


Figure 13-28: DHI Model and Present Model

In Table 13-7 wave disturbance factors are stated as were found in the simulation for joint port development carried out by DHI [add ref]. The results from the present numerical modelling at the discussed locations are presented in Figures 13-29 through 13-31. All the considered simulations are carried out for case 2 with T_p= 7s. It is noted that DHI did not carry out runs with a Mean Wave Direction of 310º N

Table 13-7: Wave Disturbance Factors according to mike21 Simulation of *joint port development*

Ref Location	330	350	360
1	1.04	1.11	0.92
2	1.01	1.08	1.04
3	0.25	0.74	0.87

As seen from the contour plots, the agreement with the DHI mike21 modelling is satisfactory for most of the considered points.

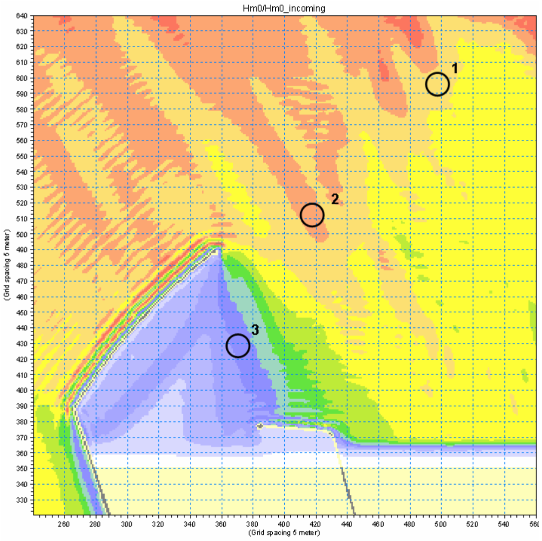


Figure 13-29: WDC for 330º N

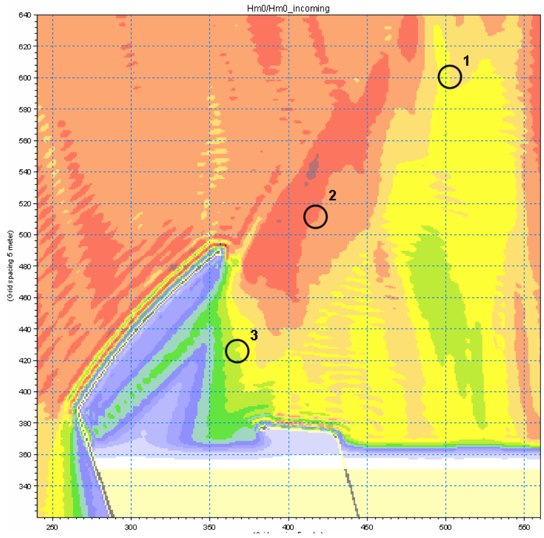


Figure 13-30: WDC for 350º N

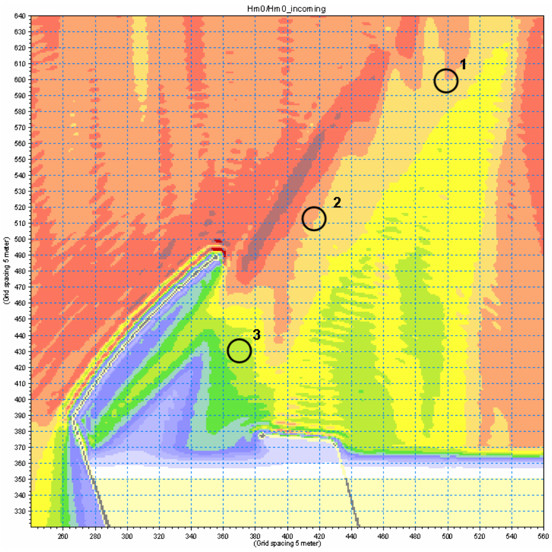
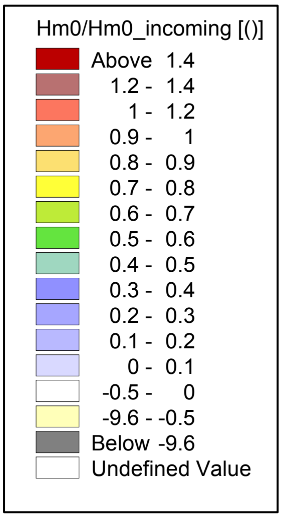


Figure 13-31: WDC for 360º N



13.7.3 Verification by Analysis of Physics

Wave Climate
360º N Waves are generated at the North boundary of the model (refer Figure 13-1). 310 / 330 / 350º N waves are generated at the upper boundary *and* West boundary of the model. In this way the domain of the model could be reduced to the present size, which ensured a considerable lower computational time. Disadvantage of this choice is an incorrect wave height for the waves generated at the left boundary, as these waves should already have been influenced by shoaling, refraction and bottom friction (Mike 21 does not allow one to vary the wave height along the wave generator).

In the Figures in Annex XIV it can be seen that this assumption results in a conservative approach as the waves generated at the West boundary are higher than waves generated at the North boundary. Though, the results are not influenced, as the decisive waves for the area of interest are coming from the North.

In the Figures in Annex XIV it can be seen that the directions are modelled correctly.

Results were shown for fully developed waves, which was the case after 25 minutes simulation. In Figure 13-32 this is shown for point 14 for waves coming from 310º N and 360º N.

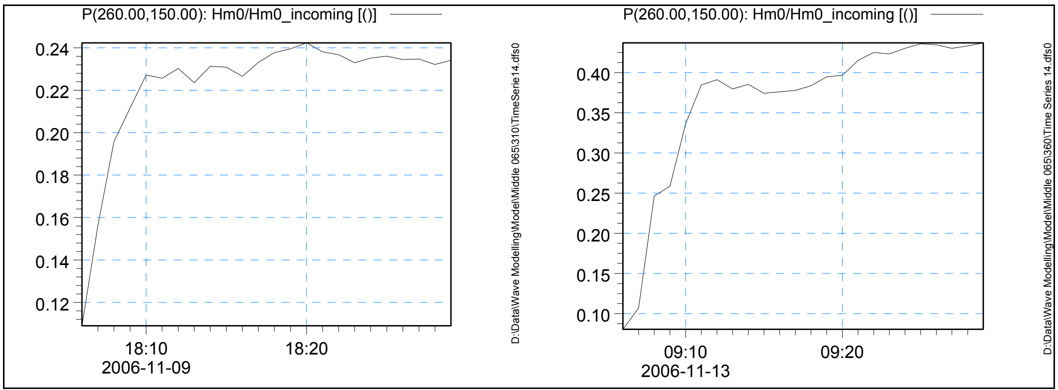


Figure 13-32: Time series WDC for 310º N (left) and 360º N (right)

Reflection
Reflection behaviour can be best seen in the case of 360º N Waves. In front of the Middle Breakwater a diamond pattern for the waves is identified caused by a reflection direction of approx 90º according to the incoming waves (refer Figure 13-21 and Annex XIV).

For 310º N Waves a standing wave is expected in front of the Middle Breakwater, as the waves are aligned perpendicular to the Breakwater. But, features of a considerable standing wave are not represented in Figures 13-10 and 13-18 however. This missing element will not influence the area of interest.

Porosity of the structure determines the amount of reflection it gives. In the simulation two cases were analysed with different porosity characteristics for the Middle Breakwater (refer Section 13.3.2). As expected, higher reflection is to be found for case 2 (porosity = 0.65) then for case 1 (99% reflection) (compare Figures 13-5 / 6 and 13-9 / 10).

Diffraction
The Figures in Annex XIV present diffraction patterns in the lee of the tip of the Middle Breakwater and in the entrance of the SADRA Basin as one should expect.

Shoaling and Refraction
In Table 13-8 a hand-calculation is given based on shoaling and refraction (bottom friction is neglected, which is also the case in the simulation). Analysed points are 6 and 18 (refer Figure 13-13) for waves coming from 310º N and 360º N. The deviations between hand-calculation and simulations do not exceed 10% which is satisfying.

Table 13-8: Shoaling and Refraction Hand-Calculation

		North Bound.	**West Bound.**	**310º N**		**360º N**	
				6	*C*	*6*	*C*
Hm0	[m]	1.00	1.00	1.00	1.00	1.00	1.00
Tp	[s]	7.00	7.00	7.00	7.00	7.00	7.00
h	[m]	10.30	8.90	15.50	6.80	15.50	6.80
Ks	[-]	1.00	1.00	0.99	1.03	0.99	1.02
Kr	[-]	1.00	1.00	1.05	0.93	1.00	1.00
Calculated WDC	[-]	1.00	1.00	1.04	0.95	0.99	1.02
Simulation WDC	[-]	1.00	1.00	0.96	1.04	0.96	1.06
Deviation	%			7.42	-9.36	3.17	-4.18

14 NAVIGATIONAL STUDY ALTERNATIVE A

14.1 Objective

Aim of the present study is to test the ship manoeuvring aspects of the SADRA Basin and the NIOC Basin for Alternative A (refer Section 11.4 and Annex XII).

The accessibility will be evaluated and the operational limits for the layout will be assessed.

14.2 Mathematical Model

14.2.1 Fast Time Simulator Shipma

The navigational study has been carried out with the Fast Time-Simulator Shipma. Shipma is a pc program for simulating the manoeuvring behaviour of ships, taking into account the following aspects [*Ref. 7*]:

- Ship's manoeuvring characteristics
- Kind of manoeuvre and desired track
- Rudder and engine actions
- Tug assistance
- Wind, waves and currents
- Shallow water
- Bank suction
- Rudder, engine and tugs are controlled by a combination of:
- A track keeping autopilot and tug controller
- Input data as defined by the user

The autopilot corresponds to deviations from the user-defined *desired* track and course angle. In the case of curved tracks and changes in the current profile, the autopilot will anticipate on these changes while taking into account user-defined sensitivity coefficients and anticipation lengths. The configurations of these coefficients and the anticipation length have both a major influence on the output of the simulation.

For a detailed description on the working and functioning of Shipma reference is made to Thesis Report Volume II, Chapter 4.

14.2.2 Comparison Study

Before the start of the navigational study of Alternative A, a comparison study concerning a Shipma-and a Real Time-Simulation both performed on a strongly related case (refer Thesis Report Volume II) had been carried out. Reason for the comparison was that Real Time Manoeuvring Simulations are generally believed to be more realistic than Fast Time Simulations, and only the latter was available for the present navigational study.

The comparison study aimed to:

1. Establish configurations for the sensitivity coefficients and anticipation lengths in the Shipma autopilot for which simulation returns the most realistic output (compared to RT-Simulation)
2. Assess to which extent the FT-Simulation is realistic compared to a RT-Simulation

The conclusion drawn in the comparison study and applicable on the present navigational study of Alternative A is presented in the textbox below. The comparison study is discussed in Thesis Report Volume II.

When using the configuration of the autopilot as found in the comparison study, the Shipma Fast Time Simulation returns realistic results. With Shipma the navigational safety and operational limits can be assessed. However, considering the results, use of the vessel its rudder and powerbursts have to be evaluated with care as both are functioning too efficiently.

14.3 Model Setup

14.3.1 Focus of the study

The study focuses on the following operations:

- Entrance of NIOC Turning Basin
- Entrance of SADRA Turning Basin

It is assumed that the entrance operation is acceptable when the Turning Basin can be reached safely, as from this point on the vessel is fully under tug control and at low speed.

The entrance operation can be split in two sub-operations:

1. Safe navigation through the Approach Channel to the Turning Basin
2. Reducing the vessel it speed from dead-slow to close to zero in the middle of the Turning Basin

Both operations were carried out with different configurations of the Shipma autopilot in order to derive realistic results (refer Thesis Report Volume II, Section 7.2.2).

14.3.2 Included Vessels

The entrance operation is carried out for the largest design vessels calling at the considered basins (refer Chapter 5). When operations are found to be safe for these vessels, operations will certainly be safe for the smaller vessels calling at the basin.

Comparable vessels to the design vessels as were available in Shipma and used in the present study are depicted in Table 14-1.

Table 14-1: Overview Used Vessels

Item	Unit	NIOC Basin		SADRA Basin	
		Design Vessel	*Used Vessel in Shipma*	Design Vessel	*Used Vessel in Shipma*
Dead Weight Tonnage	[dwt]	63,000	59,800	63,000	59,800
Loaded	[-]	Fully	Fully	30% Ballasted	30% Ballasted
LOA	[m]	228	225	228	225
Beam	[m]	38	32.2	38	32.2
Draught	[m]	12.8	12	7.2	7.0

14.3.3 Tugs

2 tugs of 44 tons bollard pull were available and used during the simulation.

14.3.4 Bathymetry

The bathymetry for the model was derived in the following way:

1. Drawings based on a recent local survey were received from Royal Haskoning
2. Schematised drawing was prepared based on drawings as described above
3. Drawings were digitised and imported in the Shipma Model

In addition the layout as described in Annex XII, Alternative A was included in the model. Resulting harbour contour and bathymetry as applied during the simulations is presented in Figure 14-1.

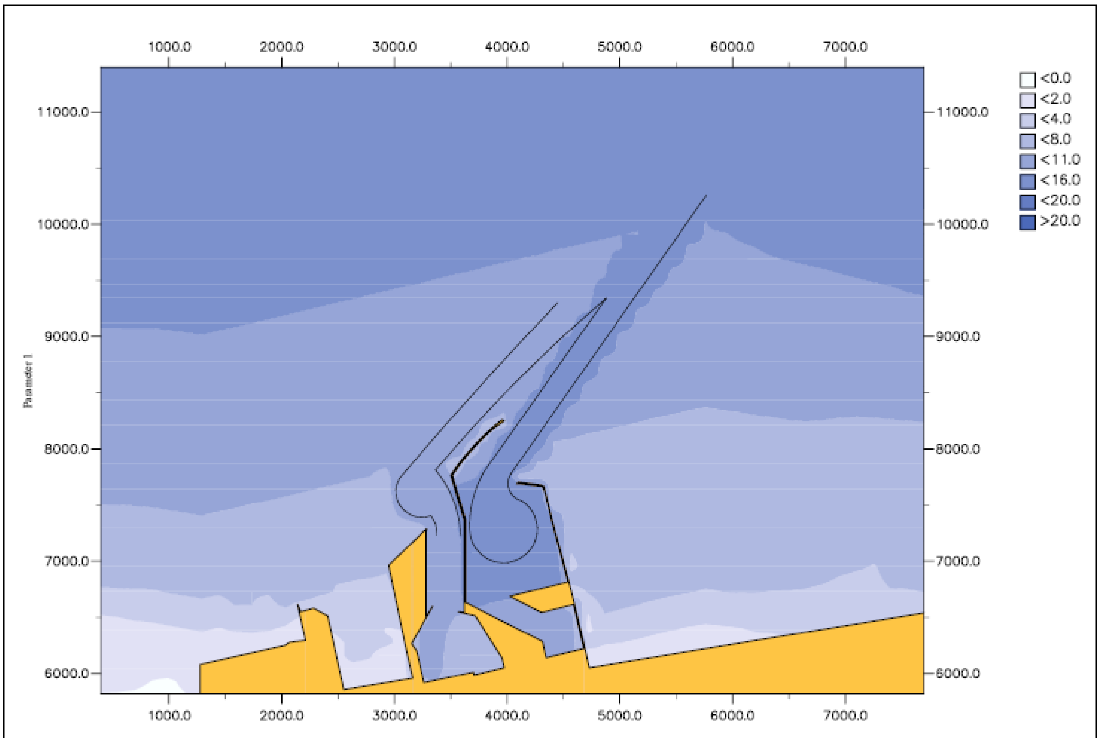


Figure 14-1: Bathymetry and Harbour Contour

14.3.5 Currents

The variation in current can be seen in Annex XV. Current is given as points in the mathematical model (speed and direction), and the simulator program will interpolate between these points. A factor of 1 corresponds to the current charts given in Annex XV, and is representative for an overall local current of approximately 0.6 m/s.

Current going E and W were prepared for the simulations. The current patterns and figures were received from DHI, who carried out a flow modelling task on Port Alternative 0 (refer Section 11.3). Pattern for current going West is expected to be the same for the new Alternative A. Pattern for current going East will be different for Alternative A, though no considerable differences are expected.

Currents with factor 1 are generated by winds of 15 m/s. Winds with direction 180º – 330º N result in east-going current, whereas winds with direction 0º -150º N result in a west-going current [*Ref. 14*]. Taking into account the wind distribution as included in Section 4.4.1, the current is going West in 1/3 of time and going East 2/3 of time.

Analysing the prevailing wind conditions (refer Section 4.4.1), the following can be concluded:

- West-going current with factor 1 or higher prevails approximately 0.1% of time
- East-going current with factor 1 or higher prevails approximately 0.2% of time

14.3.6 Waves

Wave data (height, direction and period) were modelled in Chapter 13. Results are included in the mathematical Shipma model. A factor of 1 corresponds to the wave charts given in Annex XV, and is representative for an overall local wave height of approximately 1 m. Waves from N and NW were prepared for the simulations.

14.3.7 Wind

Wind was set in the simulator as a uniform wind field. The wind parameters included are speed and direction.

14.3.8 Track and Autopilot

The desired tracks for entering the SADRA Turning Basin and entering the NIOC Turning Basin are both depicted in Figure 14-2 (blue line). Different sections during the track are shown as well. The aimed speed for each section is stated in Tables 14-2 and 14-3. The resulting autopilot files, in the form as they were used in the Shipma simulation are included in Annex XVI.

Alignment of the desired track and speed figures in the different sections are based on guidelines as described in Thesis Report Volume II, Chapter 5.3.

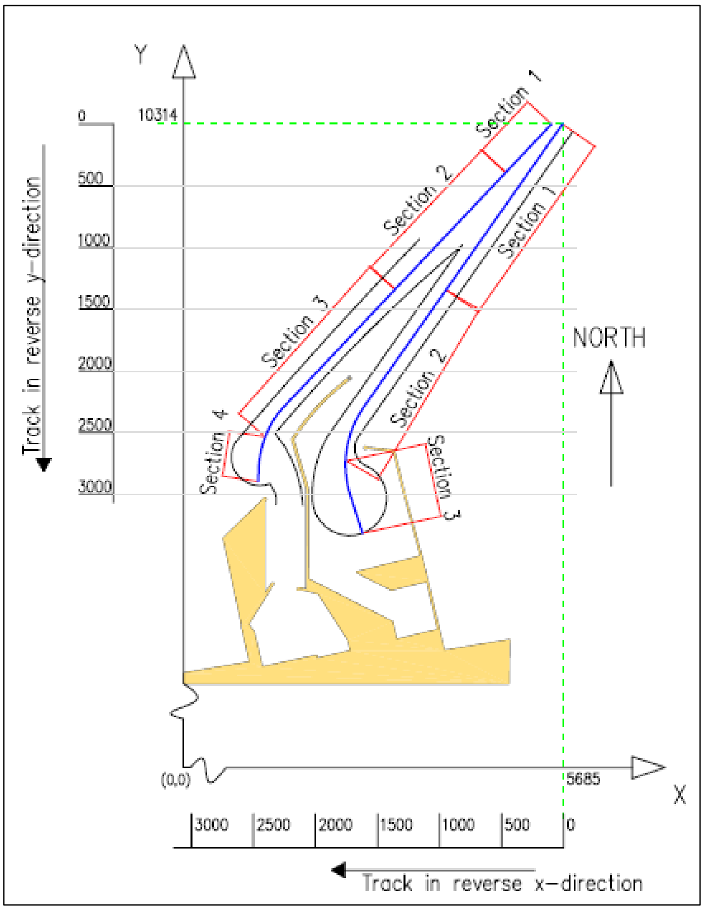


Figure 14-2: Desired Track and Sections

Table 14-2: Section Description Entrance SADRA Basin

Section	Aimed Propagation
1	1.1 [rev/s]
2	1.0 [rev/s]
3	0.7 [rev/s]
4	0 [m/s]

Table 14-3: Section Description Entrance NIOC Basin

Section	Aimed Propagation
1	1.1 [rev/s]
2	0.8 [rev/s]
3	0 [m/s]

14.4 Presentation of Results

The evaluation whether both basins are safe to enter, and the assessment of the limiting operational conditions will be performed by means of an evaluation of safety criteria. The criteria as defined in Thesis Report Volume II, Section 5.5 will be used for that purpose.

Runs performed to test the SADRA Basin are documented in Table 14-4 Runs performed to test the NIOC Basin are documented in Table 14-5. Combinations of the natural conditions are representative for the prevailing climate (refer Section 4.4 through 4.6).

Table 14-4: Runs SADRA Basin

Run No.	Wind		Current		Waves	
	Direction (from)	Speed [m/s]	Direction (to)	Factor	Direction (from)	Factor
1		0	0	0	0	0
2	NW	10	E	0.5	NW	1
3	NW	10	W	0.5	N	1
4	SE	10	E	0.5	NW	1
5	SE	10	W	0.5	N	1
6	SW	10	E	0.5	NW	1
7	SW	10	W	0.5	N	1
8	SE	6	E	0.5	NW	1
9	SE	6	W	0.5	N	1
10	NW	10	W	1	N	1
11	SW	10	E	1	NW	1

Table 14-5: Runs NIOC Basin

Run No.	Wind		Current		Waves	
	Direction (from)	Speed [m/s]	Direction (to)	Factor	Direction (from)	Factor
1		0	0	0	0	0
2	NW	14	E	1	NW	1
3	NW	14	W	1	N	1
4	SE	10	E	1	NW	1
5	SE	10	W	1	N	1
6	SW	10	E	1	NW	1
7	SW	10	W	1	N	1
8	NW	12	E	1	NW	1
9	NW	10	E	0.5	NW	1
10	SE	10	E	0.5	NW	1
11	SW	10	E	0.5	NW	1
12	Equal to run 1 but Rudder Use was limited to 50%					

In Annex XVII (SADRA) and Annex XVIII (NIOC) for each run, graphs are included concerning the following items along the track in *reverse Y-direction* (refer Figure 14-2).

- Overall Track
- Vessel Speed over the bottom
- Propeller Revolutions
- Transverse deviation of desired track
- Drift Angle
- Rudder Use

The results are presented as follows:

- In Figure 14-3 through 14-4 the overall track is presented for the SADRA Basin concerning run 9 and 11, which are representative for the limiting operational conditions

- In Figure 14-5 through 14-8 typical Figures concerning the stopping operation in the SADRA Turning Circle are shown

- In Figure 14-9 and 14-10 the overall track is presented for the NIOC Basin concerning run 3 and run 8, which are representative for the limiting operational conditions

- In Figure 14-11 through 14-14 typical Figures concerning the stopping operation in the NIOC Turning Circle are shown

14.5 Comments

In this Section the results from the Shipma Simulation are discussed. In Section 14.5.2 the runs performed to test the SADRA Basin are discussed. In Section 14.5.3 the runs related to the NIOC basin are discussed.

First the safety criteria which are used during the evaluation are presented. For a detailed description on the criteria, reference is made to Thesis Report Volume II, Section 5.5.

14.5.1 Safety Criteria

A run can be considered feasible (F), critical (C) or unacceptable (U) for each of the following criterion (adopted from “AVV Transport Research Centre”).

Sailing distance with a rudder angle > 20º
- 0 – 400 m F
- 400 – 550 m C
- > 550 m U

Drift Angle
- 0 – 15º F
- 15 – 20º C
- > 20º U

Sailing distance with a power burst
- 0 – 120 m F
- 120 – 240 m C
- > 240 m U

Deviation from desired track
A large deviation is considered undesirable as it may result in grounding of the ship. If the vessel tends to reach the boundaries of the access channel, the run is qualified as unsafe.

Speed in Turning Basin
The Speed of the vessels has to be close to zero when arriving in the middle of the Turning Circle.

Use of total power tug
- 0 – 70% F
- 70 – 90% C
- > 90% U

14.5.2 SADRA Runs

Entrance of the SADRA Basin by the 63,000 DWT Tankers will be minimised to a few times a year, as these vessels call at the port for maintenance purposes. The correct conditions can be awaited for entering or leaving the port. For this reason it is only necessary to analyse the operation during normal conditions.

In run 1 through 7 currents with maximum factor of 0.5, winds up to 10 m/s and waves up to 1 m height were included. Except run 4 and 5, the runs scored acceptable on the safety criteria (refer Thesis Report Volume II, Section 5.5).

In run 4 and 5, the SE wind orientated perpendicular to the vessel, in combination with a changing current pattern next to the West Breakwater, caused an unacceptable transverse deviation from the desired track. In both runs the vessel tends to ground at the East bank of the approach channel. In run 8 and 9 the SE wind was reduced to 6 m/s which had a positive effect on the manoeuvring behaviour. Run 8 was found to be acceptable, the maximum transverse deviation was reduced with approx 40 m. Run 9 remain critical, and is assessed as the limiting operational condition for SE winds.

In run 10 the current to the West was increased to a factor 1.0 and a NW wind of 10 m/s was included. The run was found to be unacceptable. The transverse deviation from the desired track was too large and the drift angle was at a critical height for a distance of 300 m.

In run 11 the current to the East was heightened to factor 1.0 and a SW wind of 10 m/s was included. The run scored acceptable on all safety criteria.

In all runs the stopping operation in the last part of the track was found to be acceptable. Typical manoeuvring behaviour during the operation is presented in Figures 14-5 through 14-8.

In Section 14.2.2 it was stated that the use of rudder and powerburst should be evaluated with care. In none of the runs a powerburst was used, and in none of the runs the use of rudder was considerable. Therefore no problems are expected based on the experiences gained in the comparison study.

Waves have a minor influence on the manoeuvring behaviour (refer Thesis Report Volume II, Section 6.3.11). Tug assistance is required for the entrance operation and the tugs used in the simulation can be operational up to a wave height of 1.5 m.

As can be concluded from the ship manoeuvring simulations, a vessel approach under the following conditions does not present any major complications:

- Currents to the West do not exceed factor 0.5 (overall current of 0.3 m/s)
- Currents to East do not exceed factor 1.0 (overall current of 0.3 m/s)
- Winds from E to S directions do not exceed 6 m/s
- Winds from SW to NE directions do not exceed 10 m/s
- Wave height does not exceed 1.5 m

14.5.3 NIOC Runs

Entrance of the NIOC Basin by 63,000 DWT Tankers will be on a common basis in future. Each hour downtime of the process will bring a considerable cost. For this reason the focus in the analysis will be on determining the limiting operational conditions.

In run 1 no natural conditions were included. The run scored acceptable on all safety criteria except on the use of the rudder. The rudder is used for a distance of 500 m with an angle of more than 20º. This indicates a critical situation.

In run 2 and 3 currents with factor 1.0 and a NW wind of 14 m/s were included. Run 3 scored acceptable on all safety criteria. Run 2 scored unacceptable on the use of the rudder. In the lee of the Western Breakwater the current pattern changed abruptly. The rudder was used to correct but also had to be used for turning the vessel to the middle of the breakwater. This resulted in use of the rudder with an angle of more than 20º for a distance of more than 600 m, which is unacceptable. In run 8 the same current and wave conditions were used, but the wind was decreased to 12 m/s, which had a positive effect on the results. However the run remain critical.

In run 4 and 5, currents with factor 1.0 and a SE wind of 10 m/s were included. Run 5 scored acceptable on all safety criteria. Run 4 scored critical on the use of the rudder. Use of the rudder with an angle of more than 20º was performed for a distance of approx 400 m. In run 10 the current decreased to factor 0.5, which had a positive effect on the results; the run scored acceptable on all criteria.

In run 6 and 7, currents with factor 1.0 and a SW wind of 10 m/s were included. Run 7 scored acceptable on all safety criteria. Run 6 scored critical on the use of the rudder. Use of the rudder with an angle of more than 20º was performed for a distance of approx 460 m. In run 11 the current decreased to factor 0.5, which had a positive effect on the results, however the run remain critical.

In Section 14.2.2 it was stated that the use of rudder and powerburst should be evaluated with care. In none of the runs a powerburst was used. The rudder is used considerable in most of the runs, caused by the bending track towards the middle of the Turning Circle. To test whether a critical situation is acceptable or not a run was carried out in which the rudder could only be used for max 50% during the complete track (max angle of 17.5º). Run 12 shows the results. This run scored acceptable on all criteria. This indicates that critical situations regarding the use of the rudder will not lead to unacceptable situations.

In all runs the stopping operation in the last part of the track was found to be acceptable. Typical manoeuvring behaviour during the operation is presented in Figures 14-11 through 14-14.

Waves have a minor influence on the manoeuvring behaviour (refer Thesis Report Volume II, Section 6.3.11). Tug assistance is required for the entrance operation and the tugs used in the simulation can be operational up to a wave height of 1.5 m.

As can be concluded from the ship manoeuvring simulations, a vessel approach under the following conditions does not present any major complications:

- Currents do not exceed factor 1.0 (overall current of 0.3 m/s)
- Winds from W to N directions do not exceed 12 m/s
- Winds from E to S directions do not exceed 10 m/s
- Wave height does not exceed 1.5 m

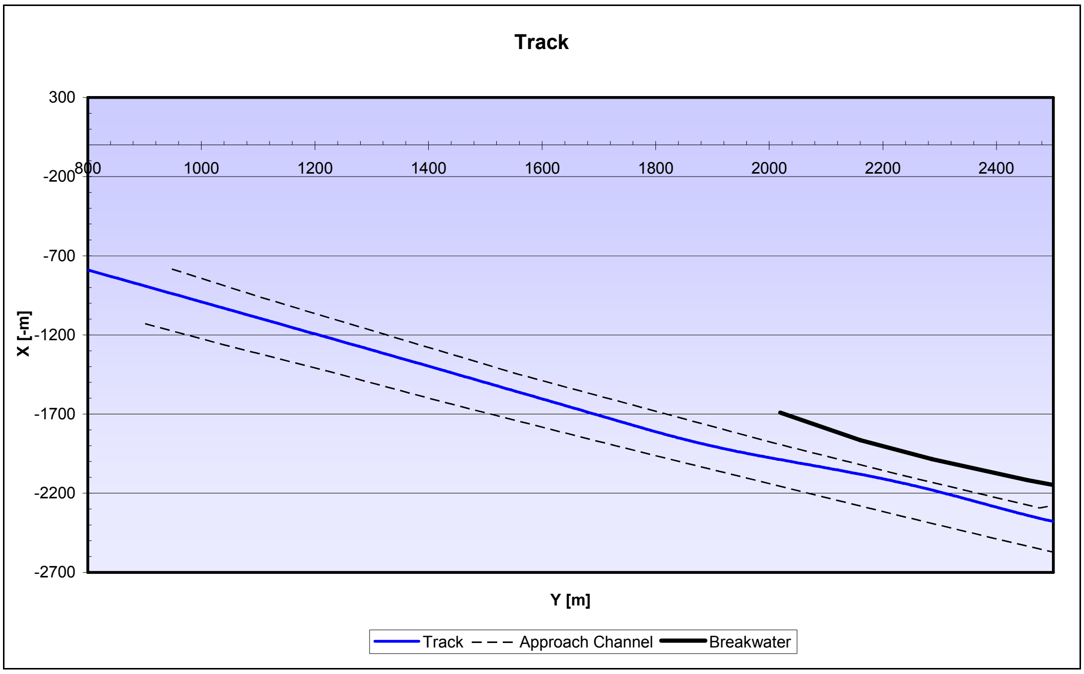


Figure 14-3: SADRA Basin, Run 9

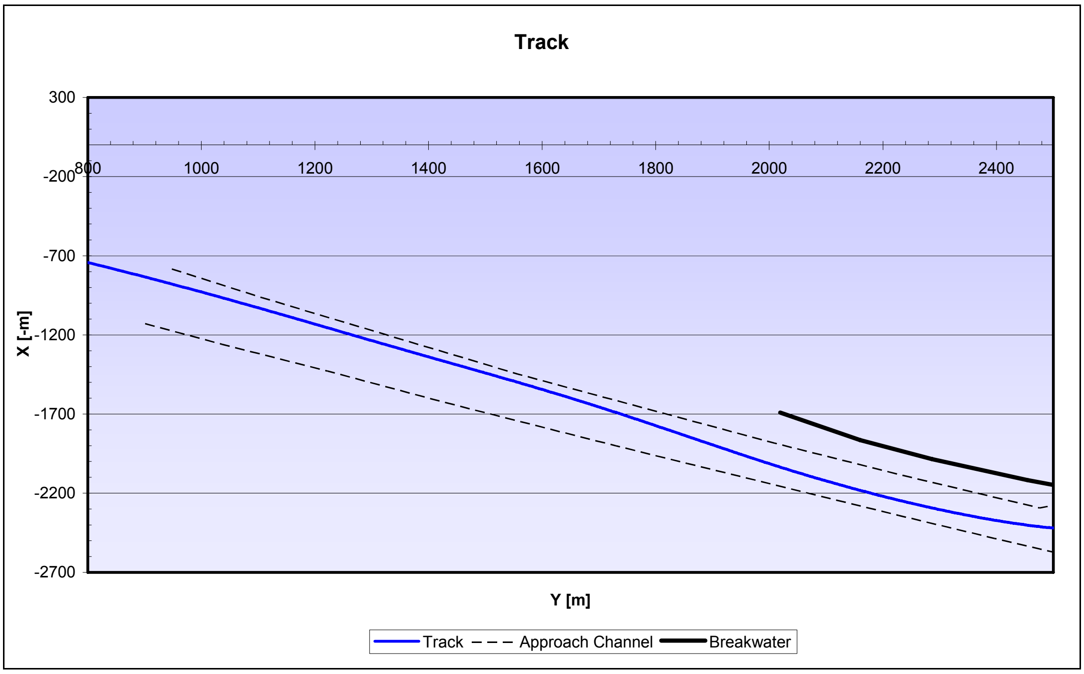


Figure 14-4: SADRA Basin, Run 11

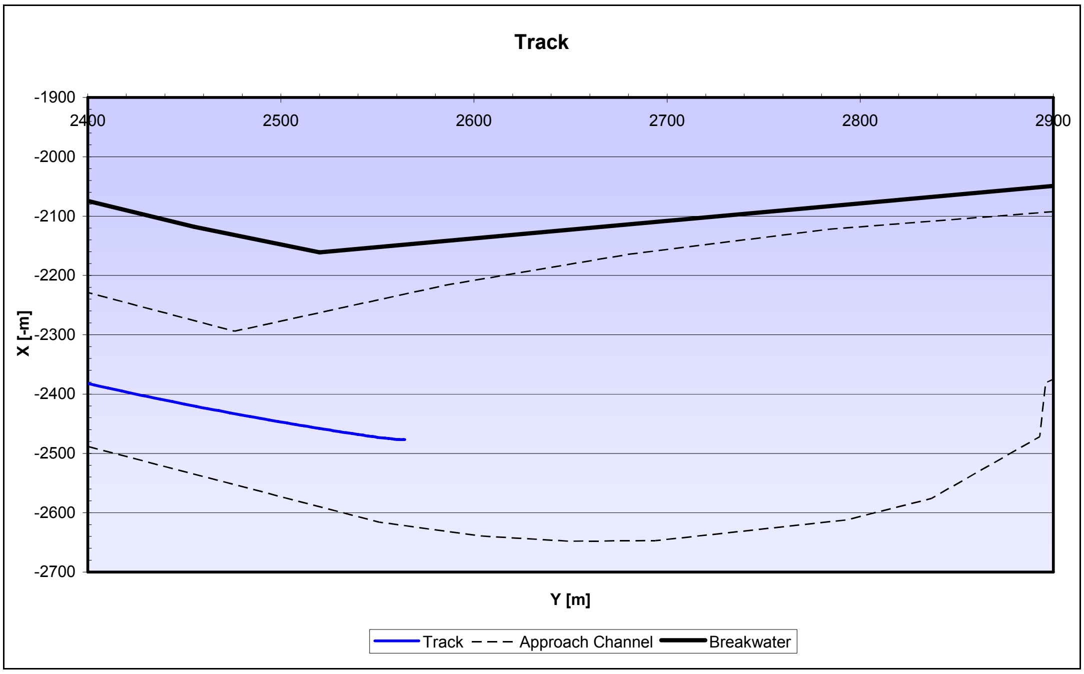


Figure 14-5: Typical Stopping Operation SADRA Basin

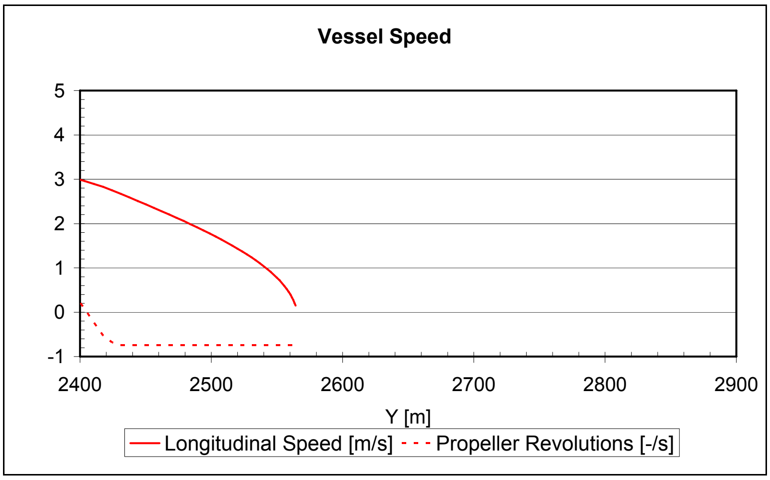


Figure 14-6: Typical Vessel Speed and Engine Use SADRA Basin

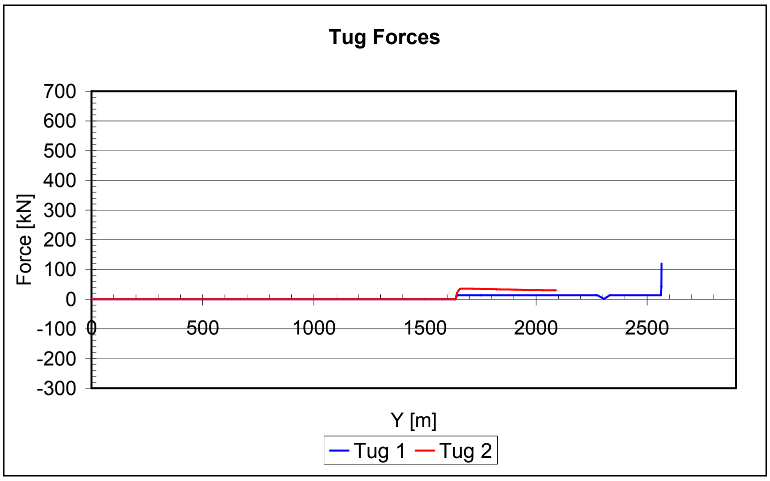


Figure 14-7: Typical Tug Forces during Stopping Operation SADRA Basin

Figure 14-8: Typical Tug Force Directions during Stopping Operation SADRA Basin

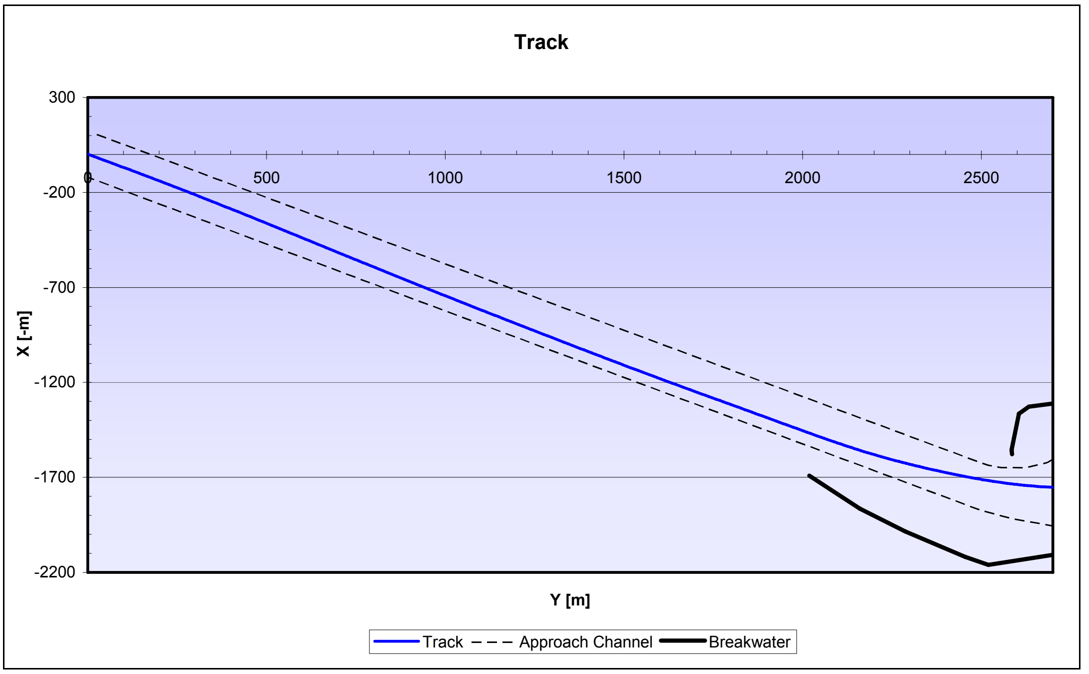


Figure 14-9: NIOC Basin: Run 3

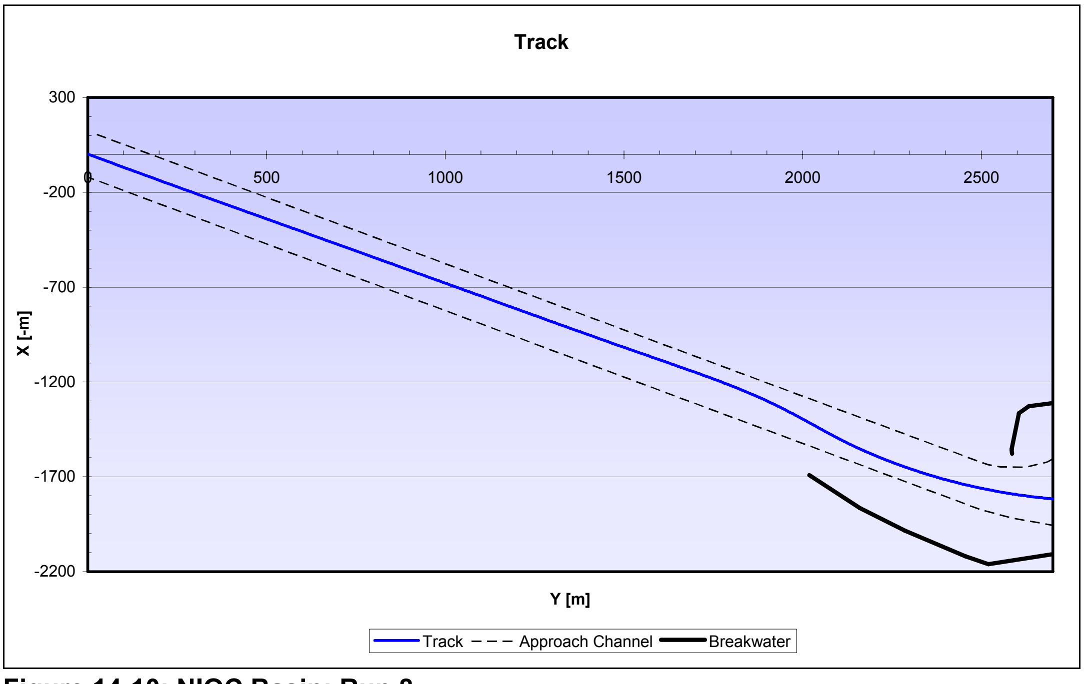


Figure 14-10: NIOC Basin: Run 8

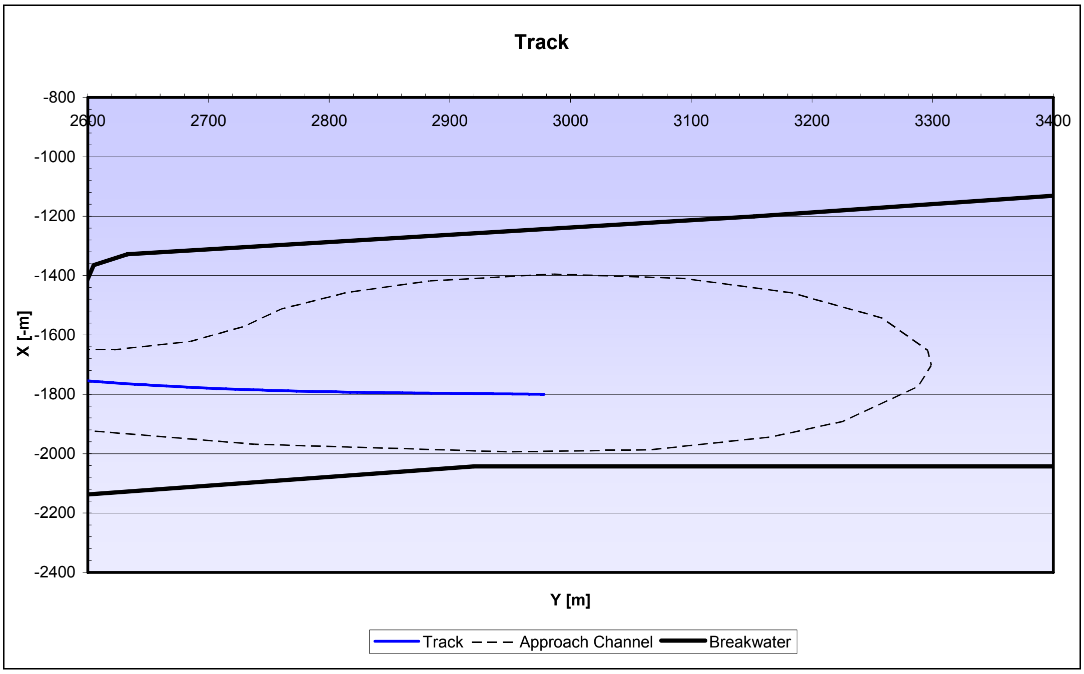


Figure 14-11: Typical Stopping Operation NIOC Basin

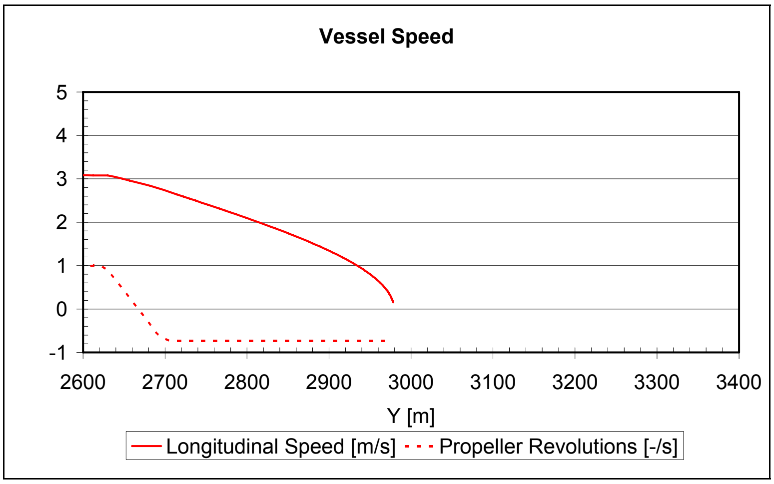


Figure 14-12: Typical Vessel Speed and Engine Use NIOC Basin

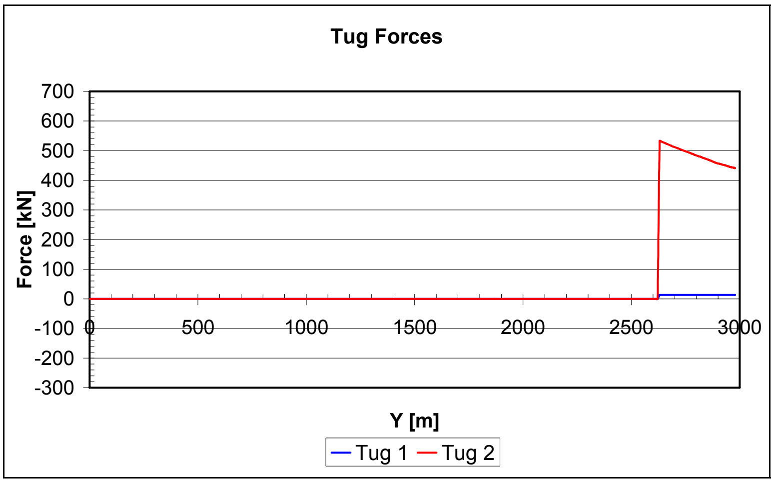


Figure 14-13: Typical Tug Forces during Stopping Operation NIOC Basin

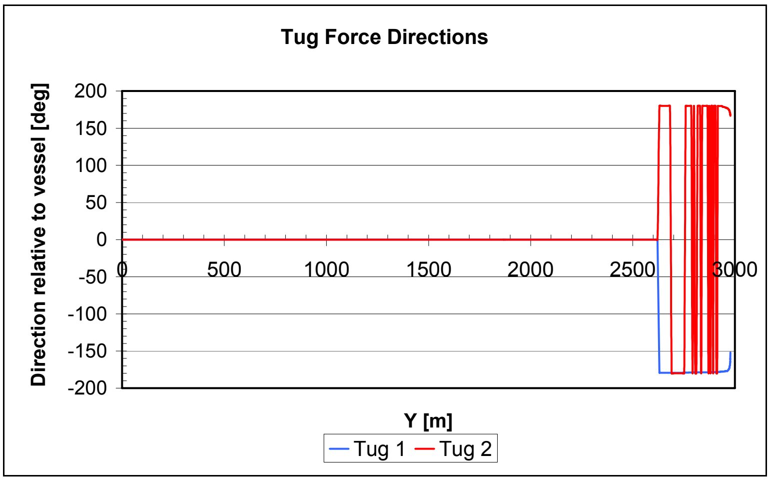


Figure 14-14: Typical Tug Force Directions during Stopping Operation NIOC Basin

14.6 Preliminary Conclusions

The Ship Manoeuvring Simulation performed, showed that during normal conditions the entrance operation can be carried out safely.

Indication of downtime level for reaching the SADRA Basin by the Design Vessel is assessed in Table 14-6, it is emphasised that the total downtime is a conservative upper limit as current, waves and wind are interdependent.

Table 14-6: Operational Conditions SADRA Basin

Item	Direction	Rule	Exceeded [%]
Current	To West	< factor 1	0.1
	To East	< factor 0.5	2.5
Wind	E – S	< 6 m/s	0.3
	SW – NE	< 10 m/s	0.2
Waves	All	< 1.5 m	2.5 - 3
Total			**± 6**

The Design Vessel for the SADRA Basin has to enter or leave the berth only few times a year. Subsequently the downtime levels for the SADRA Basin are acceptable.

Indication of downtime level for reaching the NIOC Basin by the Design Vessel is assessed in Table 14-7:

Table 14-7: Operational Conditions NIOC Basin

	Direction	Rule	Exceeded [%]
Current	all	< factor 1.0	0.3
Wind	W – N	< 12 m/s	0.1
	E –S	< 10 m/s	0.1
Waves	All	< 1.5 m	2.5 - 3
Total			**± 3**

The figures show minimal downtime for the Design Vessel of the NIOC Basin.

Other vessels than the Design Vessel are not simulated. Most of these vessels are considerable smaller than the Design Vessel.

All 14,000 DWT and 7,000 DWT vessels should be able to enter the port without assistance of tugs. Hence the entrance operation for these vessels can be performed for waves higher than 1.5 m. It is assumed that downtime for these vessels will be < 1% of time.

Conditions during transport of the floating objects related to the NDC quay have to be very calm. As these objects are hard to manoeuvre, exact downtime of these objects can not be assessed in the present study.

In Chapter 15 a more detailed analysis on the downtime for all port activities is given.

15 REFINEMENT OF PORT ALTERNATIVE A

In this Chapter, the downtime of the port activities for Alternative A will be analysed. Based on the level of downtime, an assessment will be made how to further optimise the configuration of Alternative A to ensure a minimal downtime inside the port basin.

Costs in this Chapter will be expressed in US Dollars, as world oil prices and world charter prices are so to.

15.1 Port Processes

For a detailed description on all processes represented in Neka Harbour, reference is made to Section 7.1. All processes related to NIOC and SADRA can be schematised as presented in Figure 15-1.

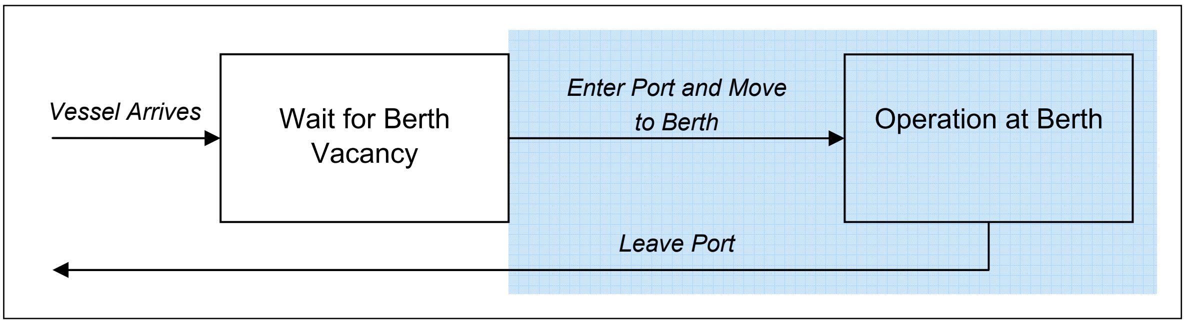


Figure 15-1: Process Structure from Viewpoint of the Vessel

All operations positioned in the blue square will be incorporated in the present downtime and cost assessment. If either the berth is not accessible or operations at the berth are halted, downtime of the process is experienced.

Level of berth utilisation was assigned by the relevant parties. Hence, the waiting time for a vessel subjected to berth occupation is considered as "been accepted", and subsequently is not incorporated in the present downtime assessment.

Remaining causes and downtime levels of the processes are discussed below:

- **Access Channel to the berth is occupied**
  Focus in the present study was not on the performance of the port's traffic system. For detailed insight in this aspect, for example a HARBOURSIM simulation could be performed. However with 5 vessels a day calling at the NIOC Basin and 4 vessels a day calling at the SADRA Basin (refer Annex VII), no problems are foreseen regarding this issue.

- **Limiting conditions for a safe entrance / depart of the port are exceeded**
  In Chapter 14 a manoeuvring simulation has been carried out. The conclusion was drawn that safe access to the berths was not possible in approximately 3% of the time for the 63,000 DWT tankers, and 1% for the smaller tankers (refer Section 14.6). The vessels calling at the SADRA quay will not be able to enter the port in approximately 6% of the time.

- **Limiting conditions for operations at the berth are exceeded**
  In Chapter 13 a wave tranquillity study was carried out for the SADRA Basin. For the NIOC Basin results from the wave tranquillity study on Alternative 0, performed by DHI, are available [*Ref. 14*]. Table 15-1 summarises all results derived. In the first column the considered component is stated (for description and overview on the components, reference is made to Section 11.4). The second column presents the maximum Wave Disturbance Coefficients (WDC) at the location of the considered component, found in the wave modelling. In the third column the maximum wave height is indicated for which the operation at the berth can still be performed [*Ref. 5*]. In the fourth column the wave height - and the % of the time this wave is exceeded - at the boundary of the wave tranquillity model (depth 10.3 m) is presented, for which the maximum operational wave height at the considered berth is generated. In the last column the resulting total downtime for each berth is indicated.

Table 15-1: Operational Downtime at Berth

Component	Max WDC			Max Hm0 at Berth	NW		N		NE		Total
	NW	*N*	*NE*		H_{m0}	*% Exc.*	H_{m0}	*% Exc.*	H_{m0}	*% Exc.*	*% Exc.*
63,000 DWT Crude Oil Jetty	0.14	0.32	0.07	**1.50**	10.7	0.00	4.7	0.00	21.4	0.00	**0.00**
63,000 DWT Crude Oil Fingerpier	0.07	0.27	0.07	**1.50**	21.4	0.00	5.6	0.00	21.4	0.00	**0.00**
14,000 DWT Crude Oil Jetties	0.22	0.59	0.35	**1.50**	6.8	0.00	2.5	0.05	4.3	0.00	**0.05**
LPG Jetty	0.13	0.28	0.09	**1.00**	7.7	0.00	3.6	0.00	11.1	0.00	**0.00**
Chemical Tanker Jetty	0.10	0.15	0.07	**1.00**	10.0	0.00	6.7	0.00	14.3	0.00	**0.00**
Product Tanker Jetty	0.11	0.13	0.10	**1.00**	9.1	0.00	7.7	0.00	10.0	0.00	**0.00**
5-7,000 DWT Jetties	0.11	0.13	0.10	**1.00**	9.1	0.00	7.7	0.00	10.0	0.00	**0.00**
KEPCO Quay	0.10	0.26	0.07	**0.50**	5.0	0.00	1.9	0.11	7.1	0.00	**0.11**
NDC Quay	0.28	0.43	0.10	**0.50**	1.8	1.00	1.2	0.55	5.0	0.00	**1.55**
SADRA Quay Wall Berth 1	0.33	0.49	0.10	**0.50**	1.5	2.20	1.0	0.95	5.0	0.00	**3.15**
SADRA Quay Wall Berth 2	0.29	0.46	0.10	**0.50**	1.7	1.15	1.1	0.75	5.0	0.00	**1.90**
Ship Lift	0.18	0.31	0.10	**0.50**	2.8	0.20	1.6	0.20	5.0	0.00	**0.40**

15.2 Downtime Costs

The period that either the berth or the access channel can not be operational while it should be in use, leads to additional costs.

Equation 2 presents the yearly costs for downtime of the access channel. Equation 3 presents the yearly costs for downtime of the berth.

Equation 2: Yearly Downtime Costs Berthing Place

- $C_{downtime\_berth} = D_{berth} \times U_{berth} \times C_{downtime\_process} \times T_{year}$

Equation 3: Yearly Downtime Costs Access Channel

- $C_{downtime\_acces\_channel} = D_{ac} \times U_{ac} \times C_{downtime\_process} \times T_{year}$

In Which:

- D_{berth} : % Downtime of Berth [%]
- U_{berth} : Utilisation of Berth [-]
- $C_{downtime\_process}$: Downtime costs port process [$]
- T_{year} : Operational hours in one year [hrs]
- D_{ac} : % Downtime of the Access Channel [%]
- U_{ac} : Utilisation of the Access Channel [-]

Height of the downtime costs for one of the port processes depends on the performed activities during the process. The costs are discussed below:

Downtime costs for unloading of liquid commodities consist of:

- **Vessel Costs**
  When the transport of the liquid by vessel is delayed by downtime of the port, the costs of the vessel and its crew are ongoing. Figures 15-2 presents charter prices for an 80,000 MT Aframax during 2002 -2004. An estimate for the year 2006 regarding the vessels calling at Neka Harbour is based on Figure 15-2, and presented in Table 15-2.

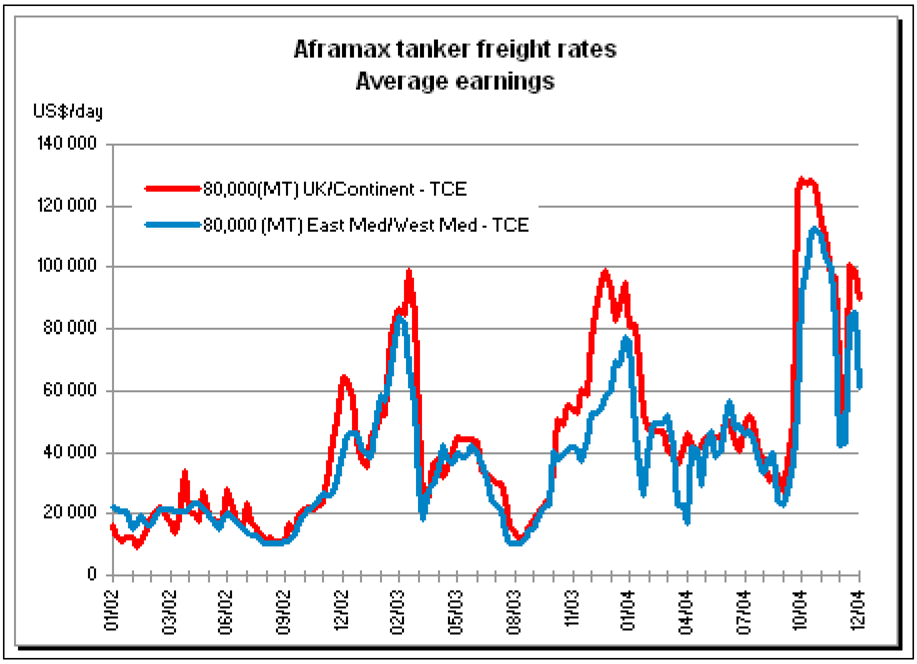


Figure 15-2: Charter Prices Aframax Tanker

Table 15-2: Estimated Charter Prices Tankers Neka Harbour

Vessel	Charter Price [$ / day]
63,000 DWT Crude Oil Tanker	35,000
14,000 DWT Crude Oil Tanker	15,000
7,000 DWT Crude Oil Tanker	10,000
14,000 LPG Carrier	20,000
14,000 DWT Chemical Tanker	15,000
7,000 DWT Product Tanker	10,000

- **Less Revenue Liquid Bulk**
  If no downtime was to be experienced a higher total volume of liquid cargo could be transferred.

  By swapping Iranian oil for Caspian oil, a *profit* per barrel of swapped crude oil is made. The amount of profit depends amongst others on the price of oil on the world market, costs of other transport alternatives of Caspian oil to the world market, capacity of the Oil Refineries in the North of Iran, rate of oil production in the Caspian and consumption of oil in Iran, etc.

  The amount of the missed revenues depends on the profit that could have been made on that throughput volume. An in-depth study is required to assess a correct estimate of the profit per barrel oil, transferred through Neka Harbour.

Table 15-3 presents the yearly costs for the downtime in unloading of liquids for Neka Harbour. In the calculation no profit on the throughput of oil is assimilated as no funded estimate could be made of the same. Depending on the height of this profit, yearly downtime costs could be considerably higher.

It is noted that for this case the downtime costs at the berth will not be included in the total costs. Downtime wave conditions at the berth are only prevailing if limiting wave conditions for the access channel are already exceeded for some time. Subsequently the berth was already inaccessible (for a longer period than the total unloading time of the vessel). Hence, costs for downtime of the process were already calculated in the access channel downtime costs calculation. The total downtime costs amount to **$ 173,800.**

A Spreadsheet containing the full calculation is included in Annex XIX.

Table 15-3: Downtime Costs Unloading Liquids

Component	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]
63,000 DWT Crude Oil Jetty	0.00	0.40	0	3.00	0.10	37,392
63,000 DWT Crude Oil Fingerpier	0.00	0.80	0	3.00	0.20	74,783
14,000 DWT Crude Oil Jetties	0.05	0.92	2,416	1.00	0.34	17,850
5-7,000 DWT Crude Oil Jetties	0.00	0.70	0	1.00	0.56	19,650
LPG Jetty	0.00	0.50	0	1.00	0.17	11,900
Chemical Tanker Jetty	0.00	0.50	0	1.00	0.17	8,925
Product Tanker Jetty	0.00	0.24	0	1.00	0.09	3,300
Total / year			**$ 2,416**			**$ 173,800**

Downtime costs for the processes related to construction / maintenance of vessels consist of:

- **Construction equipment and labour**
  If construction or maintenance work will be congested for a certain period, labour and equipment costs (rent or depreciation) are ongoing. Height of costs is totally dependent on the equipment and labour involved, and on the possibility of applying the labour and equipment on other work (flexibility). An in depth study is required for a correct estimate of the costs / hour.

In order to derive insight in the order of magnitude of the costs, a calculation was carried out for an averaged downtime cost of $ 1,000 / hour. For this estimate, Table 15-4 presents the yearly downtime costs for the construction and maintenance processes in Neka Harbour.

A Spreadsheet containing the full calculation is included in Annex XIX.

For this type of process the total yearly costs consist of the downtime costs at the berth and the downtime costs for the access channel together, i.e. $ 259,980 + $ 28,770 = **$ 294,300.**

Table 15-4: Downtime Costs Construction and Maintenance Processes

Component	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]
KEPCO Quay	0.11	0.3	2,772	40	0.0047	16,000
NDC Quay	1.55	0.1	13,020	40	0.0024	8,000
SADRA Quay Wall Berth 1	3.15	0.5	132,300	6	0.0038	1,920
SADRA Quay Wall Berth 2	1.9	0.7	111,720	6	0.0048	2,400
Ship Lift	0.4	0.05	1,680	6	0.00898	4,500
Total / year			**$ 261,492**			**$ 32,820**

15.3 Adjustments to the Waterside Port Layout

In this Section possible adjustments to the waterside port layout of Alternative A are discussed. Each adjustment will be analysed on the Net Present Value (NPV) of the additional costs and revenues it generates, calculated at the moment that the port starts fully operating.

The present cost assessment concerns a strong schematisation of reality. Though it will gain important insight required for the assessment of the feasibility of potential adjustments.

In the calculation, the following costs are considered:

- The Investment (I) required for the adjustment, which is assumed to be paid at the moment that the port starts fully operating. It is assumed that the investment is financed with own capital (no loans)
- The additional yearly Running Costs (C) the adjustment brings. These costs are assumed to arise at the end of each year
- Additional yearly Revenues (R), which consist of the reduction in downtime costs ensured by the adjustment of the port configuration. The Revenues are assumed to become available at the end of each year

A lifetime (T) of 30 years will be assumed for the present configuration of the port. Calculation will be based on a Net Present Value approach. For this calculation a discount rate (i) of 10% is used, which is commonly applied for these types of projects [*Ref. 8*]

Used equation for the calculation is presented below:

Equation 4: Net Present Value

- $$NPV = -I + \sum_{t-0}^{T} \frac{R_t - C_t}{(1+i)^t} > 0$$

15.3.1 Increase Capacity Tugboats

For the 63,000 DWT vessels calling at the NIOC basin, 3% downtime for use of the access channel is experienced. The downtime is mainly caused by the operational wave height limit in which the tugs (44 tons bollard pull) can still operate, namely 1.5 m. If 90 tons bollard pull tugboats would be used in stead, downtime of the approach channel can be reduced to 1% for the 63,000 DWT Tankers. Downtime levels for the smaller tankers will remain the same.

90 tons bollard pull tugboats have a considerable higher investment cost than 44 tons tugboats, i.e. $15,000,000 in stead of $ 5,000,000[9]. Two tugboats are required which lead to an *additional* investment of $ 20,000,000. The additional running costs of these tugboats are assumed to be $ 500.000 per year.

Table 15-5 presents the NPV. Charter prices for 2006 were used, which represent a conservative value, as charter prices are expected to rise. A profit of $ 2.70 per swapped barrel of crude oil was used for the NPV. The conclusion can be drawn that an increase of the tugboats should be incorporated, if a profit of $2.70 per barrel of crude oil can be realised.

A Spreadsheet containing the full calculation is included in Annex XIX.

Table 15-5: NPV Increasing Tugboat Capacity

Investment at t =0 [$]	Additional Running Cost [$/year]	Additional Revenue [$/year]	NPV [$]
20,000,000	500,000	2,656,861	**332,548**

SADRA requires own tugboats. A reduction of the downtime costs for the SADRA processes concerning an upgrade of the tugboats is not feasible, as costs caused by downtime of the access channel are minimal (refer Table 15-4).

15.3.2 Extension or Detached West Breakwater

The SADRA basin can be better protected against N and NW waves by either extending the West Breakwater or positioning a detached breakwater in front of the turning basin, outside the port. The latter should incorporate the lowest investment costs. It was estimated that the required length of the breakwater should be some 400m in order to reduce the downtime to almost nil.

Estimated cost of a breakwater in about 8m water depth is some 35,000 EUR / m (refer Annex XIII), which equals approximately $ 42,000 / m[10].

[9] Prices of the tugboats were estimated based on second hand prices available, and on a private database of tugboat prices from a senior port consultant
[10] An exchange rate Euro / US$ of 1.2 was used in the analysis

Table 15-6 presents the NPV if the averaged downtime costs for the “construction / maintenance” process would be $ 6900,- / hour. For this order of downtime cost the NPV turns out to be positive. The conclusion can be drawn that a detached breakwater should be incorporated, if the average downtime costs for the construction and maintenance processes in the SADRA quay will exceed $ 6900,- / hour, which is very unlikely.

A Spreadsheet containing the full calculation is included in Annex XIX.

Table 15-6: NPV Detached Breakwater

Investment at t =0 [$]	Additional Running Cost [$/year]	Additional Revenue [$/year]	NPV [$]
16,800,000	0	1,804,295	**208,933**

15.3.3 Reduction of size to be Reclaimed Land SADRA

If the reclaimed land area of SADRA should be reduced, a better protection of the SADRA quay is possible, as then it is in the lee of the West Breakwater. Further analysis is required on both the operational costs of a reduction of the SADRA land reclamation and on the downtime costs, in order to assess whether this adjustment is economically feasible.

PART SIX: CONCLUSIONS AND RECOMMENDATIONS

16 CONCLUSIONS AND RECOMMENDATIONS

In this study the feasibility of a *separate port development* for Neka Harbour was analysed. Focus in the study was on the port planning of the waterside part of the port.

In this Chapter conclusions made during the study are summarised and a final assessment on the feasibility of a separate port development for Neka Harbour is presented.

In the second Paragraph recommendations are stated concerning the port development of Neka Harbour.

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16.1 Conclusions

The conclusions drawn in the following will be discussed using the same sequence as in the main report.

16.1.1 Data Gathering and Assimilation

Part II of the study consisted of data gathering and assimilation. Key aspects related to Neka Harbour are stated below.

1. *Neka Harbour and its expansion are subjected to three important stakeholders*

   - National Iranian Oil Co. (NIOC); Initiator of the present study. This company coordinates all oil activities related with Neka Harbour
   - SADRA. A shipyard company, located in Neka Harbour. It will construct a.o. the 63,000 DWT which will be used to import crude oil from the Caspian to Neka.
   - Neka Power Plants. Direct Neighbour of Neka Harbour. Expansion of Neka Harbour could influence the temperature of the water, which the plant uses for cooling purposes

2. *User requirements made by the initiator of the study have a major impact on the waterside port layout*

   - User requirements which were made for the joint port development have to be applied on the separate port development as well
   - Additional requirements were made which describe the alignment of the physical split of the port basin
   - Incorporating all these requirements requires more space than is presently available

3. *Neka Harbour is positioned in an environment with tranquil natural conditions*

   - Wave conditions with a H_{m0} = 2.0 m, and a T_p = 7 s are exceeded only 0.9 % of time
   - In general currents are less than 0.5 m/s.
   - Winds do hardly exceed a speed of 12 m/s
   - Appreciable tides are not present

4. *With a throughput of 1,000,000 barrels per day (in the year 2014) Crude Oil is the key commodity for Neka Harbour (all import). In addition, Neka Harbour is the home base for floating equipment (semi-submersible, anchor handling tugs, FPSO) related to oil exploration and production*

5. *Sizes of the vessels calling at Neka Harbour are relatively small, dimensions deviate to some extent with the general dimensions of the "world fleet"*

   Fleet mix calling at Neka Harbour can be categorised to the Design Vessels as indicated in Table 16-1.

Table 16-1: Design Vessels

Size	Length Over All	Beam	Draught	No. of Berths
63,000 DWT Tankers	228	38	12.8	3
14,000 DWT Tankers	150	17.5	8	3
14,000 DWT LPG Carriers	150	23	10	1
7,000 DWT Tankers	147	17.5	5.3	3

16.1.2 Conceptual Design

In part III of the study components to be fit in the waterside layout of the port were identified and dimensioned. The key components are discussed below.

1. *Approach Channel for the NIOC Basin has to be dredged up to a depth of 15.5 m below lowest sea level. Approach Channel for the SADRA basin has to be dredged up to a depth of 10 m*

2. *Both the SADRA and NIOC Basin require a Turning Basin with a diameter of 500 to 600 m*

3. *Port Entrance of the NIOC basin requires a minimal width of 315 m. Port Entrance of the SADRA basin requires a minimal width of 250 m*

4. *Typical cross sections of the Breakwaters as designed for the joint port development can be applied in the separate port development as well*

5. *Land Reclamation required for NIOC amounts to 27.7 ha. SADRA indicated that they require 26.5 ha additional land, however due to lack of space only 20 ha reclaimed land is feasible*

16.1.3 Synthesis and Evaluation

In the port planning exercise four different Alternatives were developed. The layouts are included in Annex XII. These Alternatives were evaluated by means of a Multi Criteria Evaluation (MCE). In addition a Bill of Quantities (BoQ) of all alternatives was prepared and compared with one and other. The port alternative which was designed for the joint port development was included in the evaluation and served as a base case. The MCE and BoQ were used to make a Value over Cost estimate (VoC).

1. *Based on the preliminary port planning exercise Alternatives A and D are feasible Alternatives concerning a separate port development*

   Opposing to Alternatives C and D, Alternatives A and D scored better on the VoC than the base case. Hence these Alternatives can be considered as potentially feasible for the separate port development. Both Alternatives should be further elaborated to make a final assessment on their feasibility. For the present thesis, Alternative A was chosen as the main subject of the remaining of the thesis as it fits best with the educational background of the student.

16.1.4 Simulation and Refinement

In the evaluation of Alternative A, it was assessed that the wave tranquillity in the SADRA Basin, and the accessibility of both the SADRA and NIOC basin could be critical. Hence it was decided to perform a wave tranquillity study and a ship manoeuvring simulation, in order to analyse whether Alternative A is acceptable.

The “Boussinesq Wave module” of Mike21 software was used for the wave tranquillity study. It was assessed that:

1. *If in Alternative A the Middle Breakwater is designed as a Rubble Mound Breakwater, then the port layout is acceptable with respect to the wave tranquillity in the SADRA Basin*

   - The SADRA basin is subjected to downtime for the port operations for less than 3.15 % of time
   - Vessels do not have to leave the port for extreme conditions with a return period of less than ten years.

A navigational study was performed using “Shipma 6.1 Fast Time Simulation” software. It was assessed that:

2. *During normal natural conditions the SADRA Basin can be accessed safely; operational conditions are indicated in Table 16-2*

Table 16-2: Operational Conditions SADRA Basin

Item	Direction	Rule	Exceeded [%]
Current	To West	< factor 1.0	0.1
	To East	< factor 0.5	2.5
Wind	E – S	< 6 m/s	0.3
	SW – NE	< 10 m/s	0.2
Waves	All	< 1.5 m	2.5 - 3
Total			**± 6**

3. *During normal natural conditions the NIOC Basin can be accessed safely; operational conditions are indicated in Table 16-3*

Table 16-3: Operational Conditions NIOC Basin

	Direction	Rule	Exceeded [%]
Current	all	< factor 1.0	0.3
Wind	W – N	< 12 m/s	0.1
	E –S	< 10 m/s	0.1
Waves	All	< 1.5 m	2.5 - 3
Total			**± 3**

An assessment of the additional costs and revenues for minor adjustments to the port configuration of Alternative A was performed by means of a Net Present Value approach. Using a lifetime of 30 years and a discount rate of 10%, the main conclusions are:

4. *If the capacity of the tugboats for the NIOC Basin will be increased from 44 tons to 90 tons BP, then downtime levels for unloading the 63,000 DWT Crude Oil Tankers can be reduced. An average profit on the throughput of at least $ 2.70 per barrel crude oil is required make the investment feasible*

5. *Extension of the West Breakwater or a detached Breakwater in front of the SADRA Basin could reduce the downtime levels for the SADRA Basin. However the investment for both types of Breakwaters is much higher than the revenues it creates*

6. *If the reclaimed land area of SADRA could be reduced, a better protection of the SADRA quay is possible. Further analysis is required on both the operational costs of a reduction of the SADRA land reclamation and on the downtime costs, in order to assess whether this adjustment is feasible*

16.1.5 Final Conclusions

Study Objective
The study showed that a separate port development is feasible for Neka Harbour. Preliminary Alternatives A and D, both included in Annex XII, are suitable configurations as was concluded in the evaluation discussed in Chapter 12.

Alternative A
A detailed study of Alternative A proved that the critical points (wave agitation in the SADRA basin and ship manoeuvring regarding both basins) are acceptable and less critical than expected.

In Chapter 15 possible refinements to the preliminary Alternative A were analysed. It could not be assessed which of the refinements - increased capacity tugboats, extension West Breakwater and reduction of reclaimed land SADRA - should be applied, as a detailed study is required to make a correct estimate of the downtime costs.

Increasing the capacity of the tugboats will, in addition to the benefits caused by a reduction in downtime, also contribute to the safety. Ship manoeuvring remains complicated. More powerful tugboats could reduce the risks of collisions. Again further study is required to assess the exact benefits.

Alternative D
No further study was applied on the preliminary Alternative D. Hence Alternative A and D can not be compared.

Separate or Joint Development
The current study did not focus on what the advantages of a separate port development are. The benefits should be clearly analysed before a decision can be made whether to perform a separate port development or a joint port development.

In Table 16-4, both types of development are compared on costs, which consist of construction and downtime costs. It can be seen that both the investment costs and the averaged yearly downtime costs are higher for Alternative A (refer Annex XII and XIX)[11].

Table 16-4: Costs Alternatives 0 and A

Alternative	Construction Costs	Yearly Downtime Costs
0 (joint development)	EUR 303,093,352	EUR 419,450
A (separate development)	EUR 324,109,397	EUR 588,161
Difference	EUR -21,016,045	EUR -168,711

In this cost assessment no costs for risks are involved. For Alternative A, risks are on one hand reduced by isolating the basin with large liquid tankers from the SADRA Basin. On the other hand risks are increased by a more complicated ship manoeuvring. A risk assessment should be performed to analyse the costs and benefits.

Phased expansion of the port will be more complicated for Alternative A than 0. Hence, for this aspect more costs are to be expected for Alternative A.

Other point of attention is the flexibility of the port to changes in the forecasts. Alternative A is designed for just one forecast scenario. A low scenario will not cause problems, a high scenario will. In Alternative A no space was available to reserve for additional land and berths, whereas in Alternative 0 approximately 5 ha additional land including berths could be included for future use.

[11] For the calculation no profit on the throughput of oil, and a downtime cost for construction / maintenance operation of $1000 / hour were used. Exchange rate Euro / US Dollar was approximately 1.2 at time of writing

16.2 Recommendations

The following is recommended:

1. *Identify all benefits for a separate port development compared to a joint port development*

   This study researched the feasibility of a separate port development. The conclusion was drawn that such a development is feasible. If an analysis will be performed concerning the additional benefits of a separate port compared to a port in joint use, then, based on the results of this study, a decision can be made which development should be applied.

2. *Perform a Risk Assessment on both the chosen alternatives for joint and separate port development*

   In the cost calculation, risks of unwanted events were not incorporated. Though risks can lead to high costs, i.e. the averaged cost of risk equals to the probability of the risk event multiplied with the costs of that event. Risk is an important aspect for Neka Harbour as large volumes of flammable liquids are involved. The risk assessment could play a decisive role in the choice for a joint or a separate port development.

3. *Carry out a Financial and Economical Analysis for all port processes*

   If a financial and economical analysis is performed on the port processes and related aspects, a better estimate of the costs and revenues of the port can be made.

4. *Develop a Phasing Strategy for Alternative A*

   This study did develop Alternatives for the final phase of the port. Only a brief qualitative consideration is given to the possibilities of phasing. A phasing strategy should be developed to ensure a financially feasible port development.

5. *Ship Manoeuvring Study with the smaller vessels*

   In the manoeuvring simulation performed for the current study only a 63,000 DWT Tanker was included. It was assumed that if the used tankers did not experience problems the smaller vessels should not either. A manoeuvring simulation should be performed to confirm the assumption.

6. *Make Basic Designs for all components*

   Basic Designs have to be developed for all components of the port. After this phase a more accurate cost estimate of the construction of the port expansion can be made.

   Especially the design of the Middle Breakwater needs attention. In this study it was indicated that this breakwater should be of the Rubble Mound type. It has to be studied if other possibilities can be applied. These possibilities should have the same reflection properties, but have a smaller footprint.

7. *Elaborate Alternative D*

   In Chapter 12 it was already stated that Alternative D is a potential Alternative for separate port development. Further elaboration of the Alternative is required to assess if this Alternative is really feasible, and to see analyse how it compares to Alternative A.

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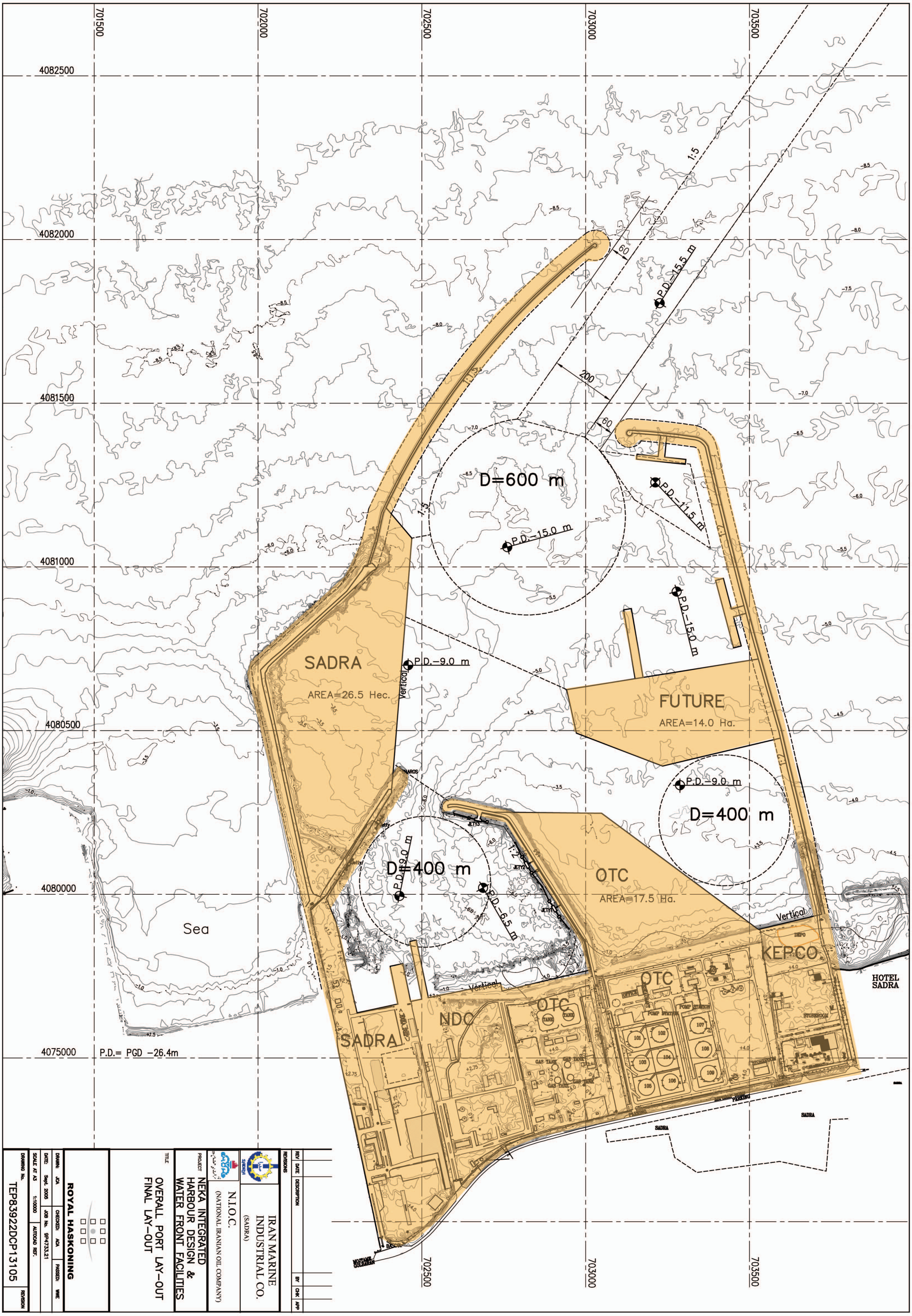
ANNEXES

Annex I
Layout Joint Port Development



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702000
702500
703000
703500
4082500
4082000
4081500
4081000
4080500
4080000
4075000
1:5
60
200
P.D.-15.5 m
D=600 m
P.D.-15.0 m
P.D.-11.5 m
P.D.-15.0 m
P.D.-9.0 m
SADRA
AREA=26.5 Hec.
Vertical
FUTURE
AREA=14.0 Ha.
P.D.-9.0 m
D=400 m
D=400 m
P.D.-9.0 m
P.D.-6.5 m
OTC
AREA=17.5 Ha.
Vertical
KEPCO
HOTEL SADRA
Sea
Vertical
OTC
OTC
NDC
SADRA
P.D.= PGD -26.4m
REV
DATE
DESCRIPTION
BY
CHK
APP
REVISIONS
IRAN MARINE INDUSTRIAL CO.
(SADRA)
N.I.O.C.
(NATIONAL IRANIAN OIL COMPANY)
PROJECT
NEKA INTEGRATED HARBOUR DESIGN & WATER FRONT FACILITIES
TITLE
OVERALL PORT LAY-OUT
FINAL LAY-OUT
ROYAL HASKONING
DRAWN: JOA
CHECKED: ADA
PASSED: WWE
DATE: Sept. 2005
JOB No. 9P4733.21
SCALE AT A3 1:10000
AUTOCAD REF.
DRAWING No. TEP83922DCP13105
REVISION

Delft University of Technology

ROYAL HASKONING

Annex II
Land and Water Ownership

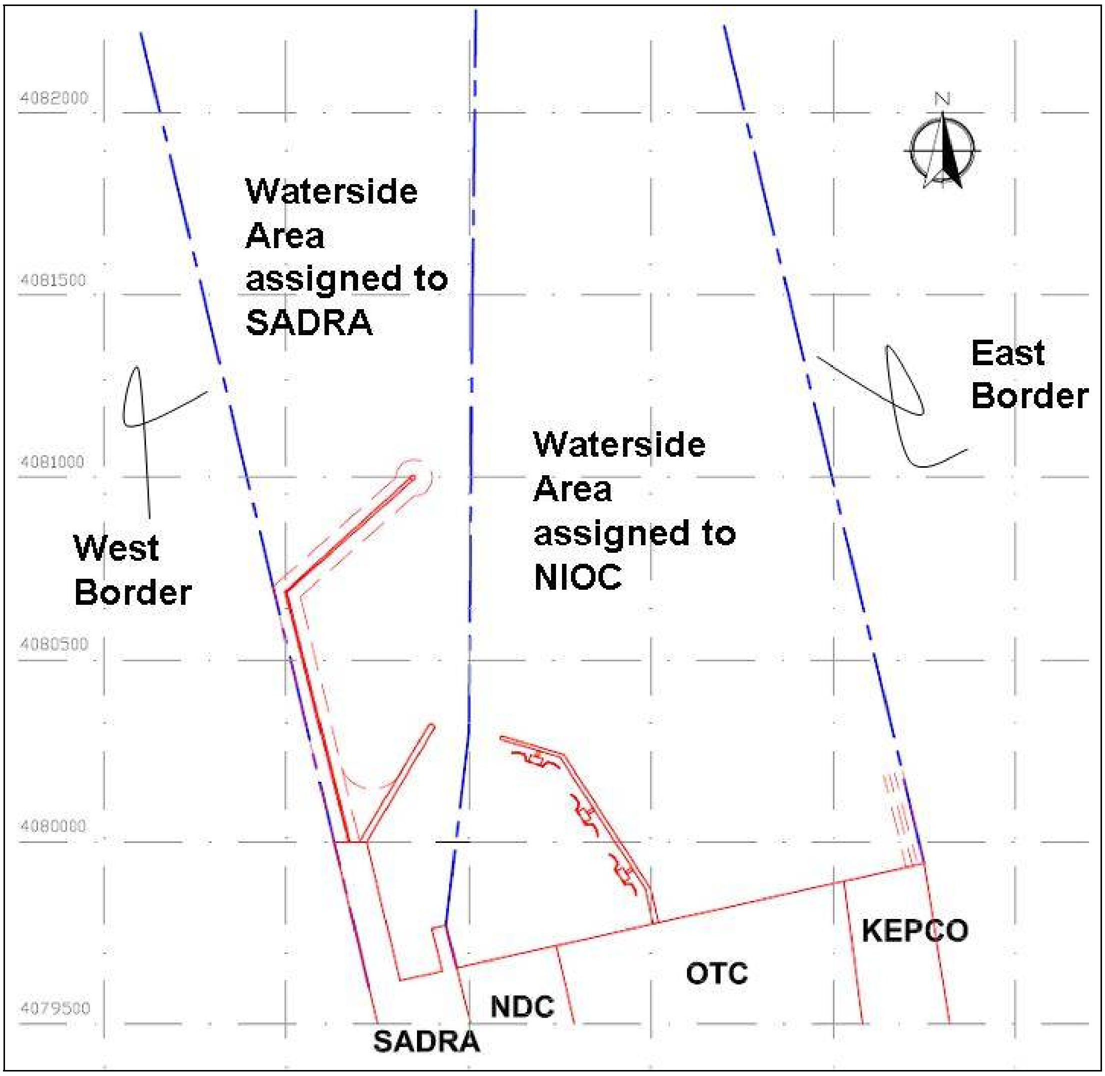
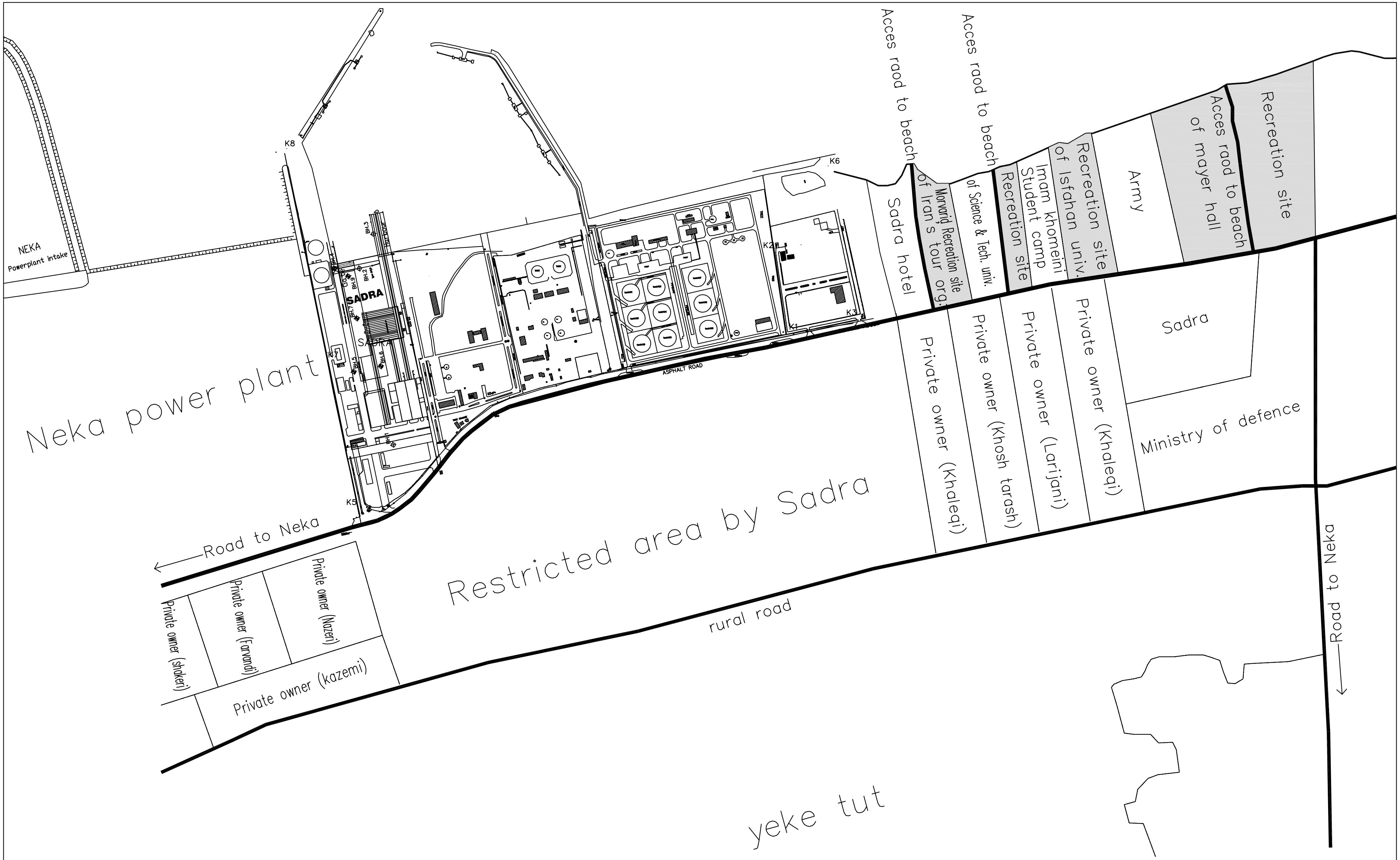


Figure II-1: Existing Situation (red) Including Waterside Borderlines (blue)



خاک بافت
مهندسین مشاور
KHAK BAFT CONSULTING ENGINEERS

TITEL:	NEKA INEGRATED PORT ALTERNATIVE V-1-1
Scale : 1:10000	UNIT: METRIC

Annex III
Port User Requirements

NIOC

Future

[NIOC-1] Eastern Breakwater of NIOC independent harbour to be identical to the Eastern Breakwater of the 'combined' SADRA – NIOC harbour as planned in the study on joint development

[NIOC-2] Breakwater entrance configuration of NIOC's independent harbour to be identical to the entrance configuration of the 'combined' harbour

[NIOC-3] The alignment of the Western Breakwater of NIOC's independent harbour will run from the 'southern edge' of the physical model test area (at approx. N 4081500) Southward to the eastern Breakwater of the existing small port

[NIOC-4] SADRA's 'new' (extended) Breakwater will be assumed to be 'as it currently is', in other words: no further future extensions of this Breakwater are foreseen within the framework of this new planning assignment

KEPCO

Future

[KEPCO-1] Facilities for supporting services to maximum one unit as below:

iii. FPSO unit, 12,760 DWT
iv. Pipe layer unit

[KEPCO-2] Quay wall of 150-200m length, 50 m adequate for heavy loads (10 tonnes/m²) and 100-150m for normal loads (5 tonnes/m²)

[KEPCO-3] Open storage area

[KEPCO-4] All water related components located in front of their land

OTC

Existing

[OTC-1] Jetties capable of handling 5,000 DWT to 7,000 DWT tankers

[OTC-2] Pipeline corridors between the jetties and storage tanks

[OTC-3] Tank farm comprising 9 tanks of 28,000m³ capacity and other facilties

[OTC-4] Utilities for waste water treatment, fire fighting, etc.

[OTC-5] Admin building and offices

Future

[OTC-6] Crude oil fleet consists of:

i. 5,000 to 7,000 DWT tankers (maximum 300,000 BPD)
ii. 14,000 DWT tankers
iii. 63,000 to 70,000 DWT tankers

[OTC-7] Product tanker fleet consist of

iv. 5,000 to 7,000 DWT tankers

[OTC-8] One berth for chemical tankers of up to 14,000 DWT

[OTC-9] One berth for LPG carriers with design ship of up to 14,000 DWT

[OTC-10] Throughput figures crude oil:

v. Phase 1, 500,000 BPD
vi. Phase 2, 1,000,000 BPD

[OTC-11] Throughput figures Mazut and Gasoline (phase 1 – phase 2):

vii. Mazut: 350,000 - 500,000 tonnes/year
viii. Gasoline: 350,000 – 500,000 tonnes/year

[OTC-12] Berth vacancy of 35 to 40 percent wherever appropriate

[OTC-13] Dwell time of 7 days should be incorporated

[OTC-14] Ratio blending tanks / storage tanks is judged on 0.25

NDC

Future

[NDC-1] Provision of a berthing location for Iran Khazar jack up rig

[NDC-2] Provision for a berthing location for Iran Alborz Semi Submersible Drilling Unit

[NDC-3] Provision of 3 berthing locations for 3x 16,000 HP Anchor handling / towing support vessels (74.4mx16mx6.5m)

[NDC-4] Provision of 2 berthing locations for 2x 4,400 HP tug boats (33.5mx8.45mx4.13m)

[NDC-5] Provision of supporting facilities for the above mentioned rigs and vessels as below:

I. Machinery spare parts covered store (30mx60m)
II. Chemical material covered store (30mx40m)
III. 10,000m² open air storage for drilling pipes, risers and wellhead part
IV. 10,000m² covered store for bulk material such as cement, barite, bentonite etc.
V. 100m² covered store for refrigerated commodities
VI. Fuel tanks with the total capacity of 2x5,000 m³ for supporting the above mentioned rigs and vessels
VII. Fresh water tanks with the total capacity of 2x2,000m³ for supporting the above mentioned rigs and vessels

[NDC-6] All berths in front of their land

NITC

Future

[NITC-1] 3 Berthing facilities for loading and unloading of three 63,000 DWT oil tankers. The berths are to be designed, constructed and outfitted to OCIMF, ISGOTT, Marpol and International Association of Port and Harbors construction standards.

[NITC-2] Exit channel from basin to deep sea shall be in the location of -15 m water depth

[NITC-3] The basin and connecting channel related to the 63,000 DWT tankers, are to be dredged to -15m depth

[NITC-4] Turning circle diameter, inside the basin is to be minimum 600m for the 63,000 DWT tankers

Future users

Optional requirements:

[FU-1] Phase 1: 20 ha land and 400m quay length

[FU-2] Phase 2: 35 ha land and 700m quay length

PSO

[PSO-1] Port control tower which has a good view on all port operations

Marine services

[MS-1] Mooring berths for tugs, mooring launches and pilot boat
[MS-2] Port reception facilities
[MS-3] Fuel supply tanks and bunkering vessel

SADRA

Existing

[SADRA-1] Existing fleet:
- i. 1 Tug boat 1,400 HP
- ii. 1 Tug boat 400 HP
- iii. 1 Flat barge 36mx9.0mx2.70m
- iv. 1 Flat barge 36mx12.0x2.80 (crane capacity 100 ton)

[SADRA-2] Dry dock with dimensions 250mx40mx11.8m, suitable for 63,000 DWT tankers
[SADRA-3] 2 berthing posts with 5m waterdepth and capacity for berthing 5,000 ton vessels
[SADRA-4] Syncrolift: 130mx25m, Nominal capacity of 3,259 ton
[SADRA-5] Kroll tower crane with 240 ton capacity, maximum 80m acces radius perpendicular to the quay wall
[SADRA-6] Construction area / berth for semi-submersibles
[SADRA-7] Ship repair yard and dry berths located nearby the ship lift
[SADRA-8] Work shops and open storage areas
[SADRA-9] Admin building

Future

[SADRA-10] Reclamation of the area between new West branches of new and old Breakwater as a ship building yard, 26.5 ha
[SADRA-11] Constructing a quay wall for berthing purpose and ship completion during construction beside the basin. Minimum length quay wall is 700m
[SADRA-12] Capacity of the mentioned ship building factory is expected to be suitable for 70,000 ton ships (without goods and maximum 30% ballast) and berthing and (un)loading of maximum 7,000 DWT vessels
[SADRA-13] Capacity of crane which will be used in the new yard will be announced later

NEKA Power Plant

[PP-1] Rate of cooling water intake of the existing power plant is 57 m^3/s
[PP-2] Rate of cooling water intake of the new power plant is 22 m^3/s
[PP-3] The anticipated start of operation of the new power plant will be in two years time

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Annex IV
Wind Data

Table 3.1 a typical recorded data in Babolsar synoptic station

ISLAMIC REPUBLIC OF IRAN
METEOROLOGICAL ORGANIZATION (IRIMO)

STATION BABOLSAR
LATITUDE 36 43 N
LONGITUDE 52 39 E

DATA PROCESSING CENTER

MONTH JANUARY YEAR 1997
HOURLY DDFF AND MAX WIND AND GUSTY WIND IN KNOT

HOUR	00 GMT.		03 GMT.		06 GMT.		09 GMT.		12 GMT.		15 GMT.		18 GMT.		21 GMT.	
DAY	DD	FF	DD	FF	DD	FF	DD	FF	DD	FF	DD	FF	DD	FF	DD	FF
1	0	0	0	0	0	0	60	3	40	5	0	0	0	0	0	0
2	0	0	0	0	0	0	70	5	60	7	100	3	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	90	1	60	1	60	1
4	0	0	70	1	70	1	60	3	60	3	40	5	90	3	0	0
5	0	0	0	0	0	0	40	3	40	5	0	0	0	0	0	0
6	0	0	0	0	150	5	90	3	270	5	0	0	90	3	100	3
7	210	3	240	5	270	7	270	5	300	3	310	5	290	7	270	5
8	60	5	70	5	120	5	90	3	30	3	100	1	110	3	120	1
9	0	0	0	0	110	5	70	5	50	7	0	0	0	0	0	0
10	0	0	0	0	0	0	270	5	180	5	60	1	270	19	250	9
11	250	9	270	9	0	0	0	0	0	0	20	1	0	0	0	0
12	0	0	0	0	110	1	20	9	40	11	90	3	0	0	0	0
13	0	0	0	0	0	0	340	3	30	3	270	7	0	0	180	3
14	150	3	100	3	90	7	40	3	80	7	60	5	100	1	50	5
15	60	3	0	0	0	0	30	3	0	0	0	0	290	7	210	3
16	200	3	210	1	270	19	270	19	270	19	240	11	210	3	270	3
17	0	0	210	3	210	3	240	7	300	5	0	0	30	3	0	0
18	0	0	0	0	180	5	0	0	350	9	60	19	100	7	30	7
19	90	7	90	3	0	0	30	3	60	5	60	3	210	3	0	0
20	210	3	190	3	200	3	290	5	330	3	0	0	0	0	0	0
21	0	0	0	0	180	3	300	3	310	3	0	0	0	0	0	0
22	0	0	0	0	210	3	230	5	260	7	360	3	280	5	250	5
23	0	0	90	7	90	5	90	3	90	3	90	3	90	5	0	0
24	0	0	180	1	90	5	50	7	60	9	0	0	0	0	0	0
25	0	0	0	0	0	0	50	5	70	5	0	0	0	0	0	0
26	0	0	0	0	360	3	360	7	70	9	0	0	250	7	270	19
27	350	3	0	0	0	0	0	0	0	0	150	5	160	1	140	3
28	50	7	110	7	110	5	240	9	300	19	270	19	320	9	20	5
29	180	3	0	0	70	3	50	15	100	11	0	0	0	0	0	0
30	0	0	0	0	0	0	320	7	40	7	0	0	0	0	0	0
31	0	0	0	0	240	1	270	13	250	11	310	13	260	11	320	9

Table 3.2 the analysed recorded data of 38 years

	Calm(<1)	1-3	3-5	5-7	7-9	9-11	11-13	13-15	15-17	17-19	>19(m/s)
N	59.049%	3.383%	1.437%	0.167%	0.029%	0.013%	0.004%	0.002%	0.000%	0.000%	0.000%
NE		4.342%	1.952%	0.252%	0.025%	0.009%	0.000%	0.000%	0.000%	0.000%	0.000%
E		3.335%	1.216%	0.151%	0.013%	0.001%	0.000%	0.000%	0.000%	0.000%	0.001%
SE		1.444%	0.323%	0.026%	0.002%	0.001%	0.000%	0.000%	0.000%	0.000%	0.000%
S		1.864%	0.186%	0.013%	0.003%	0.002%	0.000%	0.000%	0.000%	0.000%	0.000%
SW		4.137%	0.738%	0.109%	0.016%	0.004%	0.006%	0.004%	0.000%	0.000%	0.002%
W		3.917%	2.428%	0.856%	0.187%	0.082%	0.032%	0.017%	0.003%	0.000%	0.002%
NW		4.591%	2.913%	0.582%	0.077%	0.034%	0.013%	0.005%	0.002%	0.001%	0.001%

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Annex V
Wave Data

Table V-1: Extreme directional offshore wave characteristics at 67m depth (source: [*Ref. 10*]

Return period [yr]	NW H_s [m]	NW T_p/T_m [s]	N H_s [m]	N T_p/T_m [s]	NE H_s [m]	NE T_p/T_m [s]
50	6.32	8.8/8.2	5.18	8.0/7.5	3.75	6.8/6.4
100	6.74	8.8/8.2	5.53	8.0/7.5	4	6.8/6.4

Table V-2: Extreme offshore wave characteristics at 67m depth, (source: [*Ref. 10*]

wave direction	Return period [yr]	Hm0 [m]	Tp [s]
NW	1	3.9	8.1
	10	5.3	9.4
	100	6.7	10.6
N	1	3.2	7.3
	10	4.4	8.5
	100	5.5	9.6

Table V-3: Extreme wave conditions in front of Neka at 9m depth, (source: [*Ref. 10*]

Offshore wave direction	Return period [yr]	Hm0 [m]	Tp [s]	Local wave direction [˚N]
NW	1	3.4	8.1	324
	10	4	9.4	327
	100	4.2	10.6	329
N	1	2.9	7.3	357
	10	3.8	8.5	355
	100	4.1	9.6	354

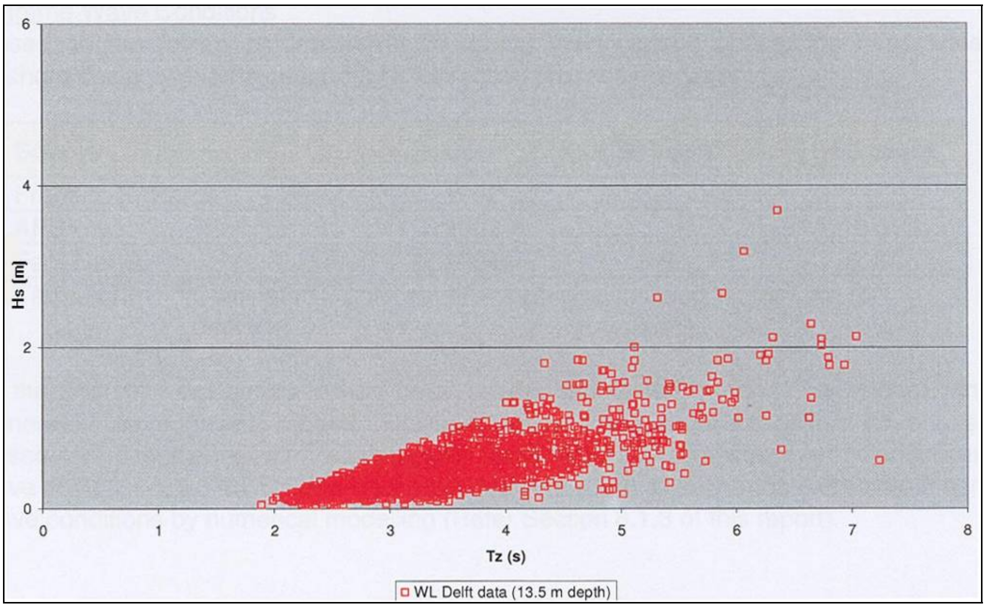


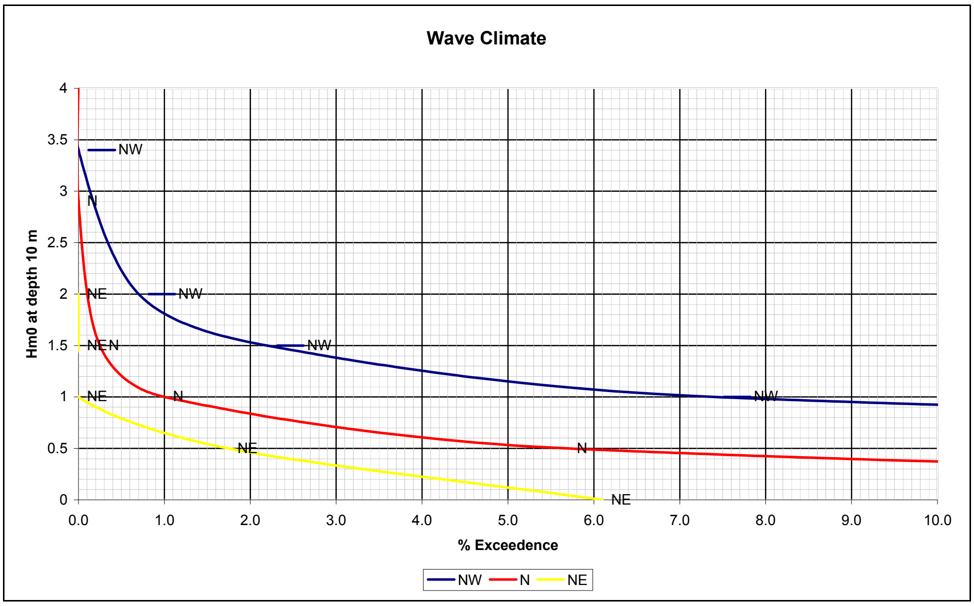
Figure V-1: Recorded waves H_s - T_z by Delft Hydraulics, water depth approximately 13.5 m

Table V-4: H_s exceeded (depth 13.5m), (source: [*Ref. 12*])

H_s [m]	T_p [s]	Percentage of time H_s is exceeded (%)
0.2	3.0	98
0.4	4.0	73
0.6	4.0	43
0.8	4.5	23
1.0	4.5	12
1.2	5.0	7
1.4	5.0	4
1.6	5.0	2
1.8	5.5	1

Table V-5: H_s direction distribution (depth 13.5m)

H_s [m]	W (%)	NW (%)	N (%)	NE (%)	Total (%)
0-0.5	5.20	26.30	21.45	4.35	57
0.5-1.0	3.10	24.10	4.70	1.75	34
1.0-1.5	0.20	5.20	0.75	0.00	6
1.5-2.0	0.25	1.50	0.25	0.00	2
>2.0	0.20	0.70	0.00	0.00	0.9
Total	8.95	57.80	27.15	6.10	+



Annex VI
Dimensioning of Calling Vessels

Delft University of Technology

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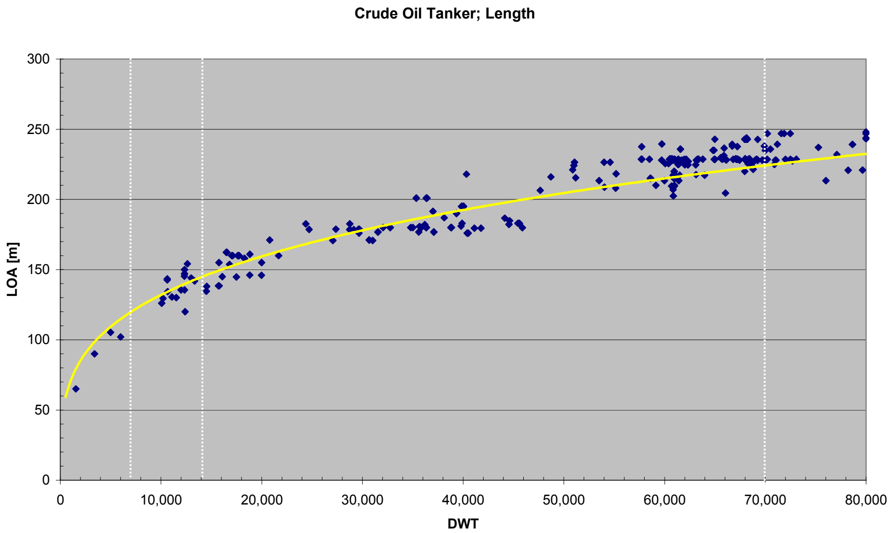
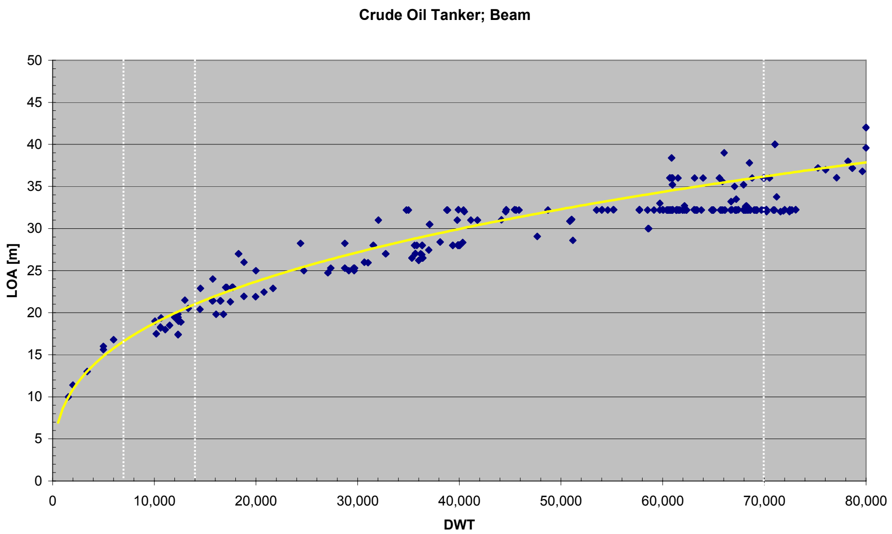
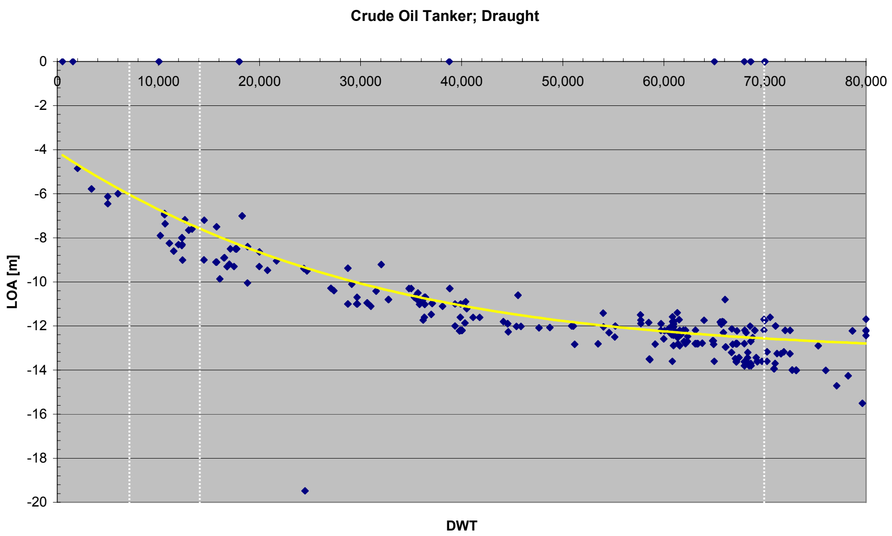
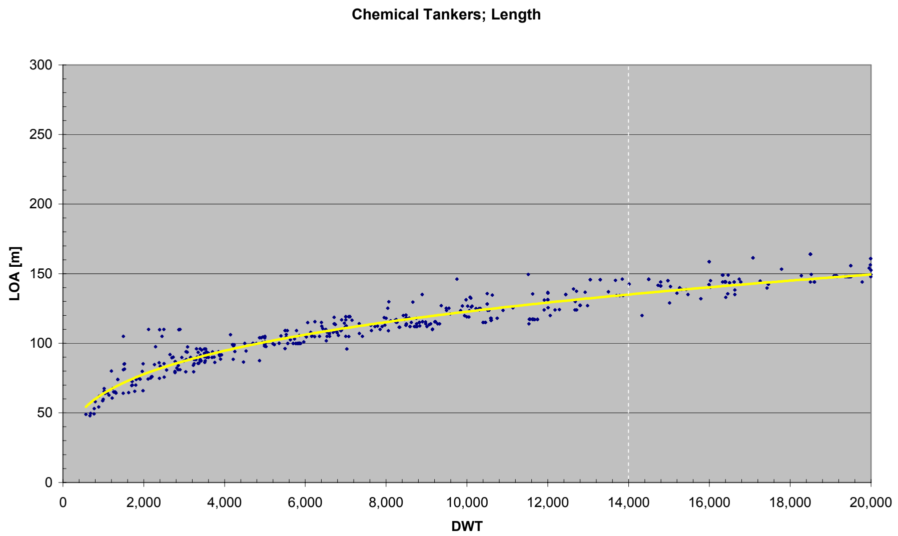
World fleet Crude Oil Tankers

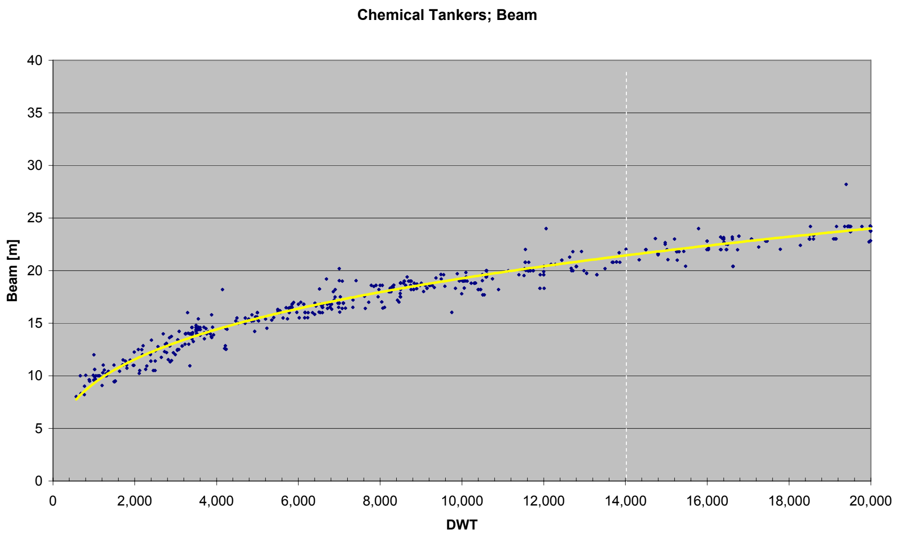


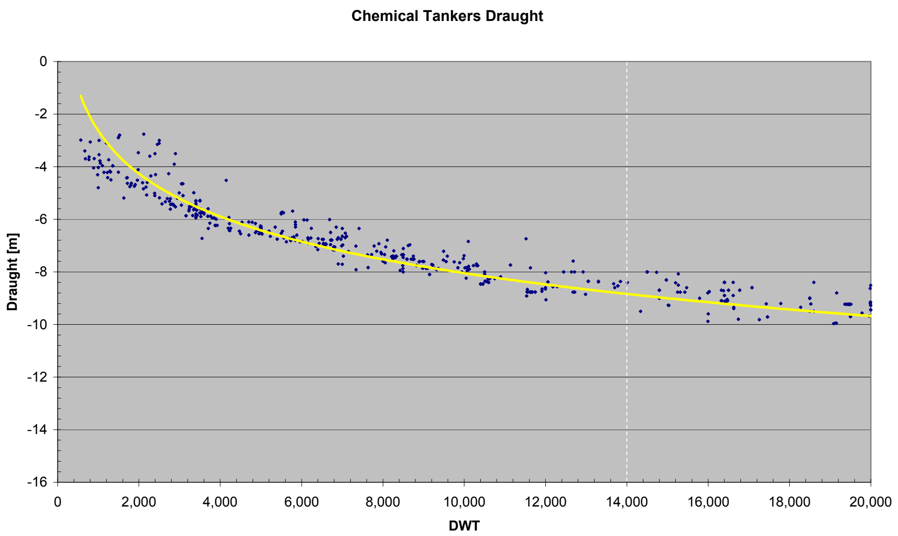




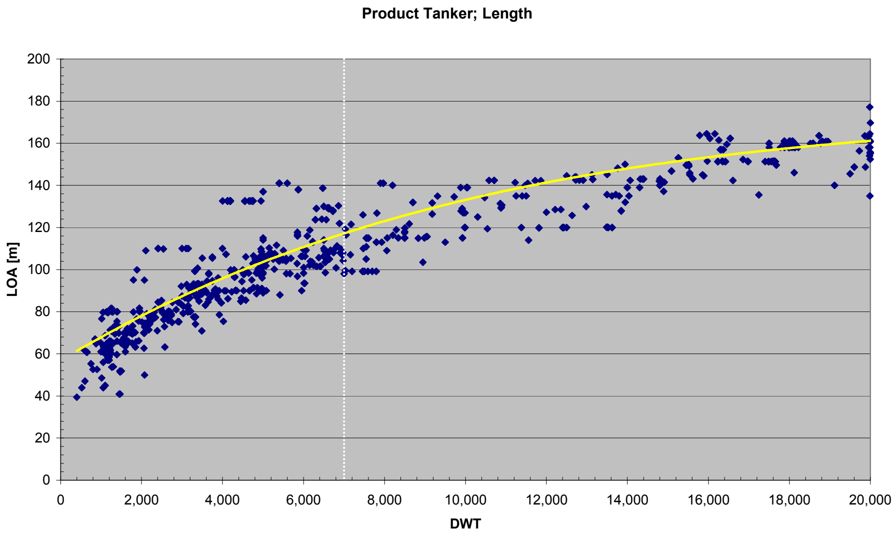
World fleet Chemical Tankers

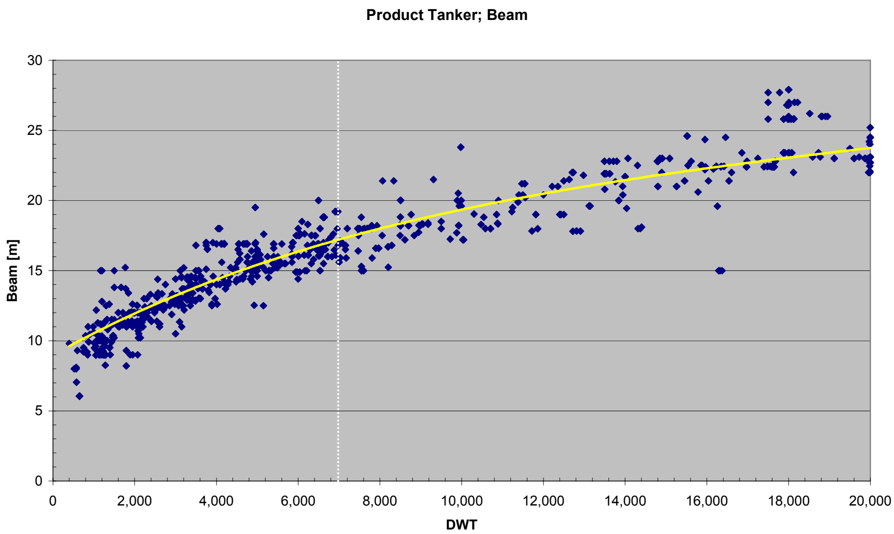


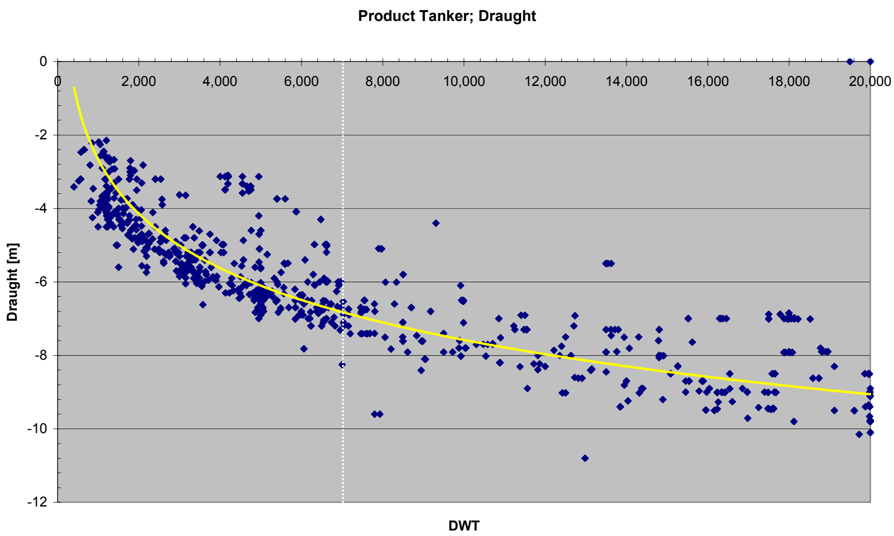




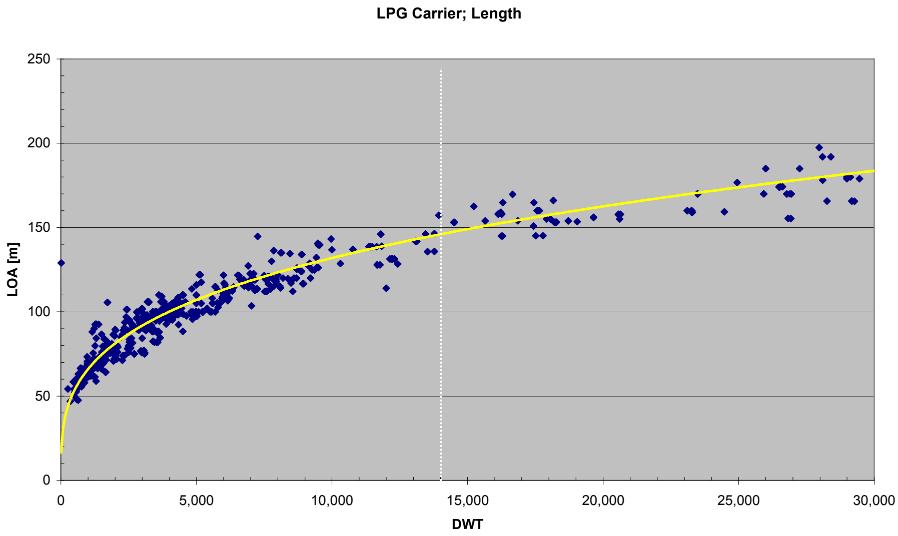
World fleet Product Tankers

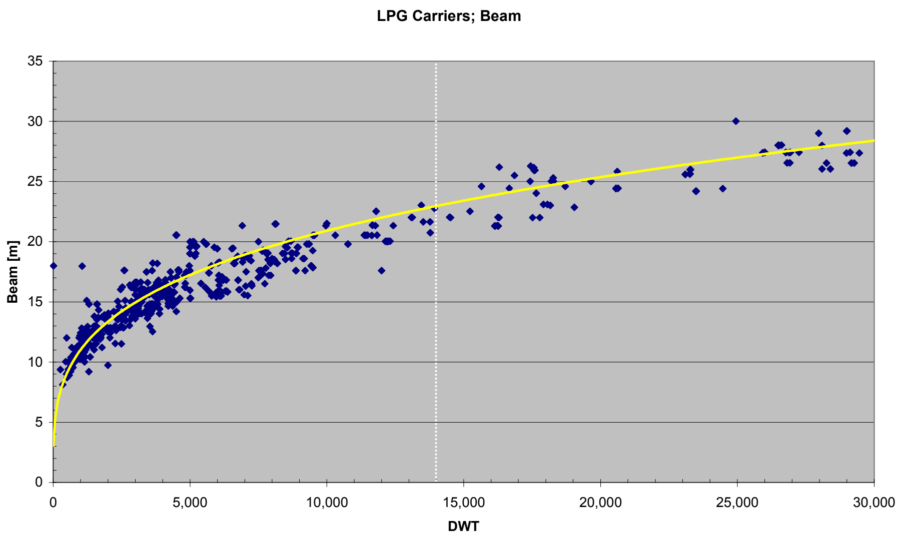


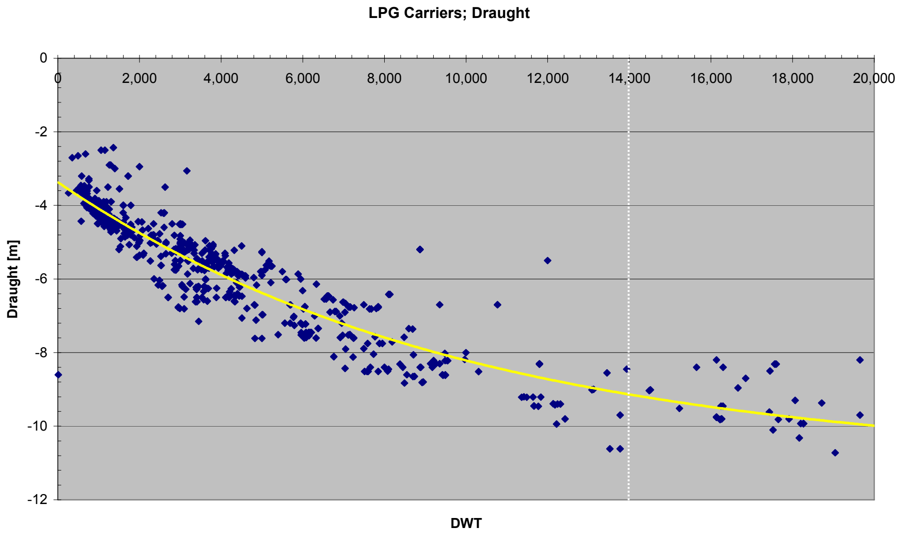




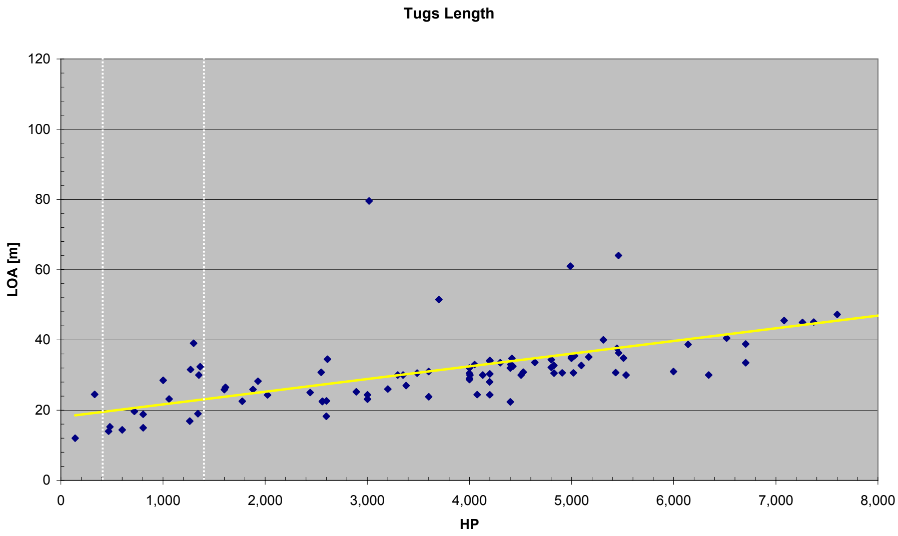
World fleet LPG Carriers

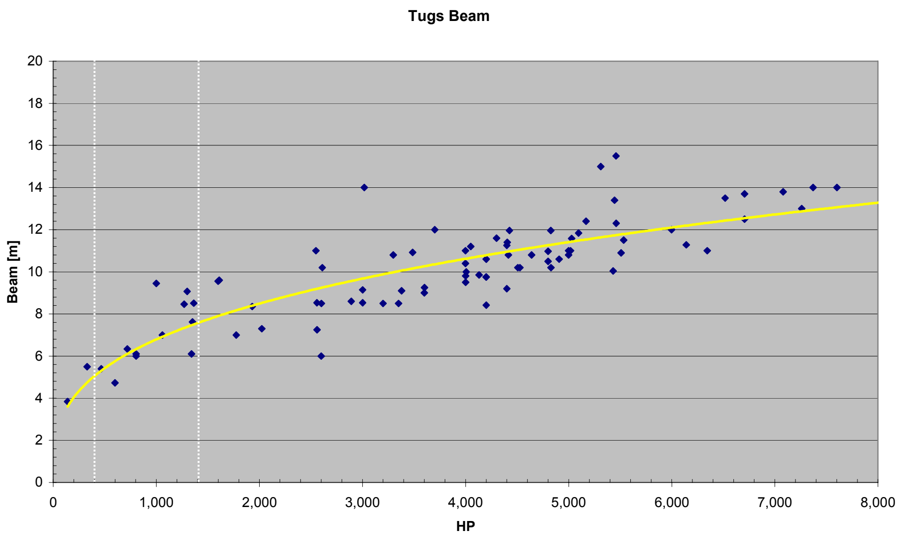


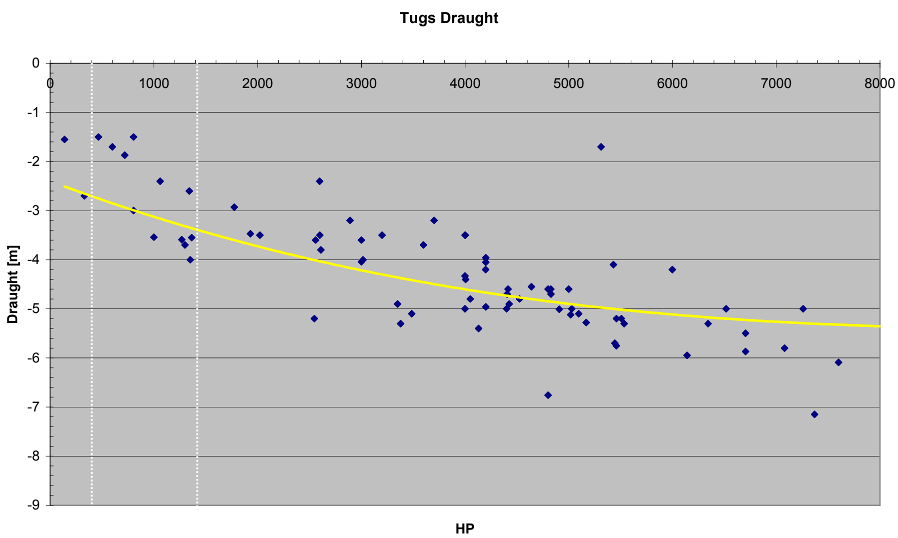




Gathered fleet Tugs

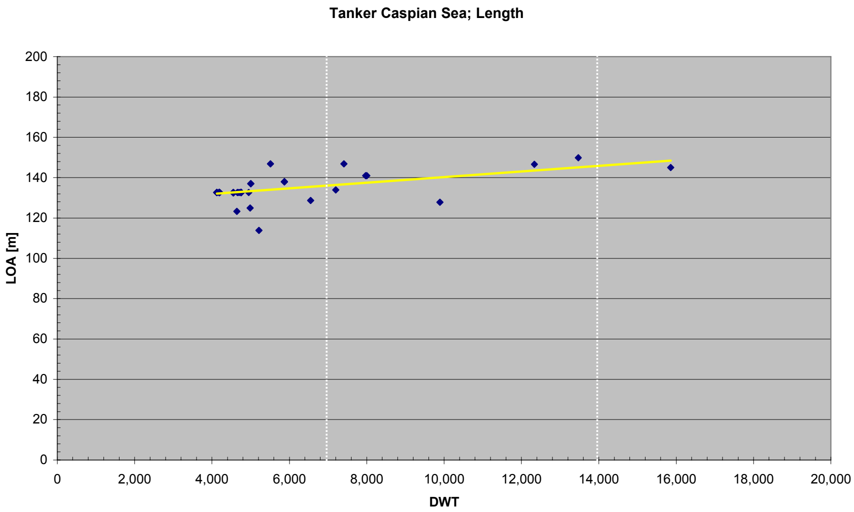


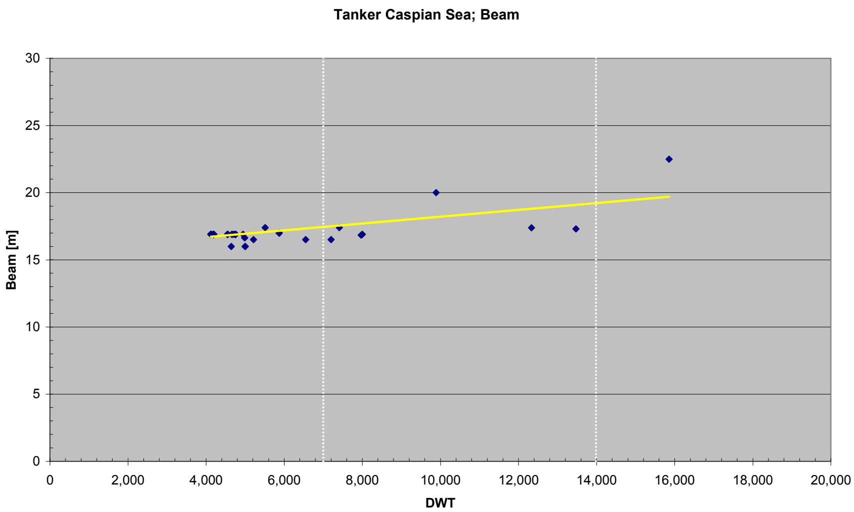




Caspian Sea fleet Tankers

Sources used: http://www.volgotanker.com, http://www.vympel.ru, http://www.caspar.baku.az/, Russian register: http://www.rs-head.spb.ru/





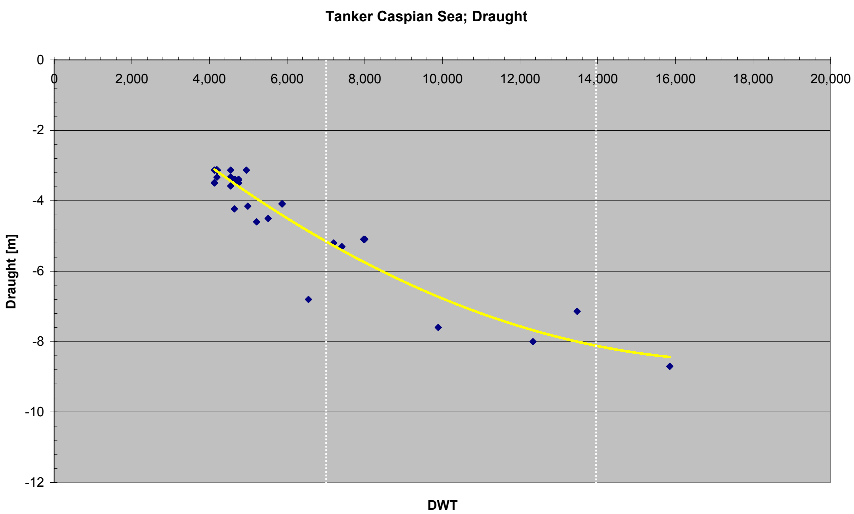


Table VI-1: Overview Pipe Layers

Company	Vessel name	Type	Operational Area	Length [m]	Beam [m]	Draught [m]	Max. Pipelaying depth [m]
Subsea7	Kommandor 3000	MSV	Brazil	118	21	4.9	1,000
Halliburton Subsea	SubSea Viking	MSV	Worldwide	106	21	5.9	620
Stolt Offshore	Discovery	MSV	Worldwide	119	19	6.5	
Subsea7	Toisa Perseus	MSV	Northsea	113	22	6.75	3,000
Global Industries Ltd.	DLB 264	Pipe-Lay	SE Asia	124	43	7.75	465
Stolt Offshore	Polaris	Pipe-Lay	West Africa	137	39	9	2,000
Stolt Offshore	Seaway Falcon	Pipe-Lay	Worldwide	153	21		1,000
Halliburton Subsea	SCV Balder	Laybarge	Worldwide	156	25		>300
Stolt Offshore	LB 200	Laybarge	Northsea	167	58		600
Allseas Engineering	Lorelay	Laybarge	Worldwide	182	26		1,645
Allseas Engineering	Sollitaire	Laybarge	Worldwide	299	40		Unlimited

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Annex VII
No. of Required Berths

	Unit	Present	Phase 1	Phase 2
Crude oil				
Average Daily Throughput	[bpd]	79,000	500,000	1,000,000
Average Yearly Throughput	[tpa]	3,771,460	23,870,000	47,740,000
Operational hrs, one year	[hrs]	8400	8400	8400
Vessel characteristics				
Dead Weight Tonnage	[dwt]	63,000	63,000	63,000
Parcel Size	[tonnes]	60,000	60,000	60,000
Unload Capacity	[tph]	3,800	3,800	3,800
Scenario				
Part of Total Throughput	[%]	0	45	72.5
Average Yearly Throughput	[tpa]	0	10,741,500	34,611,500
Service time				
Berthing	[hrs]	2	2	2
Unloading	[hrs]	15.79	15.79	15.79
Deberthing	[hrs]	2	2	2
Efficiency factor	[-]	0.95	0.95	0.95
Total (average)	[hrs]	20.83	20.83	20.83
Average service rate μ	[-/hrs]	0.05	0.05	0.05
Arrival				
Minimum arrival rate	[-/hrs]	0	0.021	0.069
Correction factor for not 100% filled ships	[-]	0.9	0.9	0.9
Corrected arrival rate λ	[-/hrs]	0.000	0.024	0.076
Calls per Year	[-/Year]	0	199	641
No. Of berths				
ρ	[-]	0.00	0.49	1.59
No of berths	[-]	0	1	3
Utilisation (< 0.65)	[-]	#DIV/0!	0.49	0.53
Waiting Time				
In units of Service Time	[-]		0.39	0.07
Total Average Service Time	[hrs]		20.83	20.83
Total Average Waiting Time	[hrs]		8.12	1.46

	Unit	Present	Phase 1	Phase 2
Crude oil				
Average Daily Throughput	[bpd]	79,000	500,000	1,000,000
Average Yearly Throughput	[tpa]	3,771,460	23,870,000	47,740,000
Operational hrs, one year	[hrs]	8400	8400	8400
Vessel characteristics				
Dead Weight Tonnage	[dwt]	14,000	14,000	14,000
Parcel Size	[tonnes]	13,000	13,000	13,000
Unload Capacity	[tph]	1,200	1,200	1,200
Scenario				
Part of Total Throughput	[%]	0	35	17.5
Average Yearly Throughput	[tpa]	0	8,354,500	8,354,500
Service time				
Berthing	[hrs]	2	2	2
Unloading	[hrs]	10.83	10.83	10.83
Deberthing	[hrs]	2	2	2
Efficiency factor	[-]	0.95	0.95	0.95
Total (average)	[hrs]	15.61	15.61	15.61
Average service rate μ	[-/hrs]	0.06	0.06	0.06
Arrival				
Minimum arrival rate	[-/hrs]	0	0.077	0.077
Correction factor for not 100% filled ships	[-]	0.9	0.9	0.9
Corrected arrival rate λ	[-/hrs]	0.000	0.085	0.085
Calls per Year	[-/Year]	0	714	714
No. Of berths				
ρ	[-]	0.00	1.33	1.33
No of berths	[-]	0	2	2
Utilisation (< 0.65)	[-]	#DIV/0!	0.66	0.66
Waiting Time				
In units of Service Time	[-]		0.35	0.35
Total Average Service Time	[hrs]		15.61	15.61
Total Average Waiting Time	[hrs]		5.46	5.46

	Unit	Present	Phase 1	Phase 2
Crude oil				
Average Daily Throughput	[bpd]	79,000	500,000	1,000,000
Average Yearly Throughput	[tpa]	3,771,460	23,870,000	47,740,000
Operational hrs, one year	[hrs]	8400	8400	8400
Vessel characteristics				
Dead Weight Tonnage	[dwt]	5,000 - 7,000	5,000 - 7,000	5,000 - 7,000
Parcel Size	[tonnes]	4,500	4,500	4,500
Unload Capacity	[tph]	900	900	900
Scenario				
Part of Total Throughput	[%]	100	20	10
Average Yearly Throughput	[tpa]	3771460	4,774,000	4,774,000
Service time				
Berthing	[hrs]	2	2	2
Unloading	[hrs]	5.00	5.00	5.00
Deberthing	[hrs]	2	2	2
Efficiency factor	[-]	0.95	0.95	0.95
Total (average)	[hrs]	9.47	9.47	9.47
Average service rate μ	[-/hrs]	0.11	0.11	0.11
Arrival				
Minimum arrival rate	[-/hrs]	0.099774074	0.126	0.126
Correction factor for not 100% filled ships	[-]	0.9	0.9	0.9
Corrected arrival rate λ	[-/hrs]	0.111	0.140	0.140
Calls per Year	[-/Year]	931	1179	1179
No. Of berths				
ρ	[-]	1.05	1.33	1.33
No of berths	[-]	2	2	2
Utilisation (< 0.65)	[-]	0.53	0.66	0.66
Waiting Time				
In units of Service Time	[-]	0.15	0.11	0.11
Total Average Service Time	[hrs]	9.47	9.47	9.47
Total Average Waiting Time	[hrs]	1.42	1.04	1.04

	Unit	Present	Phase 1	Phase 2
Gasoline				
Average Daily Throughput	[bpd]	*	*	*
Average Yearly Throughput	[tpa]	239,000	280,000	400,000
Operational hrs, one year	[hrs]	8400	8400	8400
Vessel characteristics				
Dead Weight Tonnage	[dwt]	5,000 - 7,000	5,000 - 7,000	5,000 - 7,000
Parcel Size	[tonnes]	4,500	4,500	4,500
Unload Capacity	[tph]	900	900	900
Scenario				
Part of Total Throughput	[%]	100	100	100
Average Yearly Throughput	[tpa]	239,000	280,000	400,000
Service time				
Berthing	[hrs]	2	2	2
Unloading	[hrs]	5.00	5.00	5.00
Deberthing	[hrs]	2	2	2
Efficiency factor	[-]	0.95	0.95	0.95
Total (average)	[hrs]	9.47	9.47	9.47
Average service rate μ	[-/hrs]	0.11	0.11	0.11
Arrival				
Minimum arrival rate	[-/hrs]	0.006	0.007	0.011
Correction factor for not 100% filled ships	[-]	0.9	0.9	0.9
Corrected arrival rate λ	[-/hrs]	0.007	0.008	0.012
Calls per Year	[-/Year]	59	69	99
No. Of berths				
ρ	[-]	0.07	0.08	0.11
No of berths	[-]	1	1	1
Utilisation (< 0.65)	[-]	0.07	0.08	0.11
Waiting Time				
In units of Service Time	[-]	0.012	0.016	0.02
Total Average Service Time	[hrs]	9.47	9.47	9.47
Total Average Waiting Time	[hrs]	0.11	0.15	0.19

	Unit	Present	Phase 1	Phase 2
Mazut				
Average Daily Throughput	[bpd]	*	*	*
Average Yearly Throughput	[tpa]	79,000	280,000	400,000
Operational hrs, one year	[hrs]	8400	8400	8400
Vessel characteristics				
Dead Weight Tonnage	[dwt]	5,000 - 7,000	5,000 - 7,000	5,000 - 7,000
Parcel Size	[tonnes]	4,500	4,500	4,500
Unload Capacity	[tph]	900	900	900
Scenario				
Part of Total Throughput	[%]	100	100	100
Average Yearly Throughput	[tpa]	79,000	280,000	400,000
Service time				
Berthing	[hrs]	2	2	2
Unloading	[hrs]	5.00	5.00	5.00
Deberthing	[hrs]	2	2	2
Efficiency factor	[-]	0.95	0.95	0.95
Total (average)	[hrs]	9.47	9.47	9.47
Average service rate μ	[-/hrs]	0.11	0.11	0.11
Arrival				
Minimum arrival rate	[-/hrs]	0.002	0.007	0.011
Correction factor for not 100% filled ships	[-]	0.9	0.9	0.9
Corrected arrival rate λ	[-/hrs]	0.002	0.008	0.012
Calls per Year	[-/Year]	20	69	99
No. Of berths				
ρ	[-]	0.02	0.08	0.11
No of berths	[-]	1	1	1
Utilisation (< 0.65)	[-]	0.02	0.08	0.11
Waiting Time				
In units of Service Time	[-]	0.012	0.016	0.02
Total Average Service Time	[hrs]	9.47	9.47	9.47
Total Average Waiting Time	[hrs]	0.11	0.15	0.19

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Annex VIII
Guidelines and Model: Channels, Port Entrances and Turning Basins

Channels General

Width
The width will be determined following the PIANC guidelines for entrance channels [*Ref. 4*]

Equation 5: Width one-way-channel

- $W = W_{BM} + \sum W_i + 2W_B$

Equation 6: Width two-way-channel:

- $W = 2(W_{BM} + \sum W_i + W_B) + W_p$

The order of magnitude for the width its components, according to the prevailing conditions are given in the following Table:

Table VIII-1: Width components approach channel

Width component	Condition	Width
W_{bm}		
Basic width	1.25D<d<1.5D	1.6B
	d<1.25D	1.7B
W_i		
Prevailing cross-winds	15-33 kn	0.4B
	33-48 kn	0.8B
Prevailing cross-current	0.2 - 0.5 kn	0.2B
	0.5 - 1.5 kn	0.7B
	1.5 - 2.0 kn	1.0B
Prevailing long current	1.5 - 3 kn	0.1B
	>3 kn	0.2B
Prevailing wave height	(added) 0.6-1 m	0.5B
	1 - 3 m	1.0B
	>3 m	2.2B
Aids to navigation	VTS	0
	good	0.1B
Seabed characteristics	soft	0.1B
	hard	0.2B
Cargo hazard	medium	0.5B
	high	1.0B
W_p		
Separation distance	speed 8 - 12 kn	1.6B
	speed 5 - 8 kn	1.2B
W_B		
Bank clearance	sloping edge	0.5B
	steep, hard embankment	1.0B

At the port entrance extra width has to be added at both sides of the entrance channel. An extra width of 50 m each side, is considered to be sufficient.

Depth

The required depth of a channel, located outside the Breakwaters can be determined with the following formula:

Equation 7: Depth unprotected navigation channel [*Ref. 2*]

- $d_{channel} = D_{vessel} - R + s_{\max} + r + m + td$

In which:
  - d = channel depth, below reference level
  - D = draught design vessel
  - T = Tidal elevation above reference level, below which no entrance is allowed
  - s_{max} = maximum sinkage due to squat and trim
  - r = vertical motion due to wave response
  - m = remaining safety margin or net underkeel clearance
  - td = dredging tolerance

The required depth of a channel inside the port is estimated with the following guideline.

Equation 8: Depth protected navigation channel [*Ref. 2*]

- $d_{channel} = 1.1 \cdot D_{vessel}$

On the following page a model is included, concerning the dimensioning the channels for each relevant design vessel.

	value / codition	unit	(*B)	value / condition	unit	(*B)	value / condition	unit	(*B)	value / condition	unit	(*B)	value / condition	unit	(*B)	value / condition	unit	(*B)	value / condition	unit	(*B)
Design Vessel	**70,000 DWT**			**14,000 DWT**			**5,000 DWT**			**14,000 DWT**			**70.000 DWT**								
	CO tanker			**CO tanker**			**CO tanker**			**LPG carier**			**30% ballasted**			**Iran Alborz**			**FPSO**		
Length	228	m		150	m		147	m		150	m		228	m		98.6	m		150	m	
Beam	38	m		17.5	m		17.5	m		23	m		38	m		78.8	m		17.5	m	
Draught	12.8	m		8	m		5.3	m		10	m		7.2	m		7.2	m		8	m	
Width Approach Channel																					
Wi																					
Wind																					
Direction	NW			NW			NW			NW			NW			NW			NW		
Exceedenxe %	0.10%			0.10%			0.10%			0.10%			3.00%			3%			3.00%		
Speed	26	knots	0.4	26	knots	0.4	26	knots	0.4	26	knots	0.4	10	knots	0	10	knots	0	10	knots	0
Currents																					
Cross	0.2-0.5	knots	0.2	0.2-0.5	knots	0.2	0.2-0.5	knots	0.2	0.2-0.5	knots	0.2	0.2-0.5	knots	0.2	<0.2	knots	0	0.2-0.5	knots	0.2
Along	0.2-0.5	knots	0.1	0.2-0.5	knots	0.1	0.2-0.5	knots	0.1	0.2-0.5	knots	0.1	0.2-0.5	knots	0.1	<0.2	knots	0	0.2-0.5	knots	0.1
Waves																					
Exceedence %	1%			1%			1%			1%			12%			43%			12%		
Height	1.8	m	1	1.8	m	1	1.8	m	1	1.8	m	1	1.5	m	1	0.6	m	0	1.5	m	1
Other																					
Aids to navigation	VTS		0	VTS		0	VTS		0	VTS		0	VTS		0	VTS		0	VTS		0
Cargohazard	High		1	High		1	High		1	High		1	Low		0	Low		0	Low		0
Seabed	soft		0.1	soft		0.1	soft		0.1	soft		0.1	soft		0.1	soft		0.1	soft		0.1
visibility	moderate		0.2	moderate		0.2	moderate		0.2	moderate		0.2	good		0	good		0	good		0
Wp																					
Allowed speed in channel	5-8kn		1.2	5-8kn		1.2	5-8kn		1.2	5-8kn		1.2	5-8kn		1.2	5-8kn		1.2	5-8kn		1.2
Wb																					
Bank clearance	sloping edge		0.5	sloping edge		0.5	sloping edge		0.5	sloping edge		0.5	sloping edge		0.5	sloping edge		0.5	sloping edge		0.5
Wbm																					
Depth channel	15	m		15	m		15	m		15	m		15	m		15	m		15	m	
Draught vessel	12.8	m		8	m		5.3	m		10	m		7.2	m		7.2	m		8	m	
ratio	1.17		1.7	1.88		1.5	2.83		1.5	1.50		1.6	2.08		1.5	2.08		1.5	1.88		1.5
summarised																					
Wbm	64.6	m		26.25	m		26.25	m		36.8	m		57	m		118.2	m		26.25	m	
Wi	114	m		52.5	m		52.5	m		69	m		53.2	m		7.88	m		24.5	m	
Wp	45.6	m		21	m		21	m		27.6	m		45.6	m		94.56	m		21	m	
Wb	19	m		8.75	m		8.75	m		11.5	m		19	m		39.4	m		8.75	m	
Width outer channel																					
One way channel	216.6	m		96.25	m		96.25	m		128.8	m		148.2	m		204.88	m		68.25	m	
Two way cannel	440.8	m		196	m		196	m		262.2	m		304	m		425.52	m		140	m	
Width inner channel																					
One way channel	167.2	m		73.5	m		73.5	m		98.9	m		98.8	m		204.88	m		45.5	m	
Two way cannel	391.4	m		173.25	m		173.25	m		232.3	m		254.6	m		425.52	m		117.25	m	
Depth inner channel	14.58	m		9.3	m		6.33	m		11.5	m		8.42	m		8.42	m		9.3	m	
dredge tolerance	0.5	m		0.5	m		0.5	m		0.5	m		0.5	m		0.5	m		0.5	m	
Depth Entrance Channel																					
d	12.8	m		8	m		5.3	m		10	m		7.2	m		7.2	m		8	m	
T	0	m		0	m		0	m		0	m		0	m		0	m		0	m	
S max	0.5	m		0.5	m		0.5	m		0.5	m		0.5	m		0.5	m		0.5	m	
hs	1.5	m		1.5	m		1.5	m		1.5	m		1.5	m		1.5	m		1.5	m	
r	1	m		1	m		1	m		1	m		1	m		1	m		1	m	
m	0.7	m		0.7	m		0.7	m		0.7	m		0.7	m		0.7	m		0.7	m	
Dredge tolerance	0.5	m		0.5	m		0.5	m		0.5	m		0.5	m		0.5	m		0.5	m	
Depth	15.5	m		10.7	m		8	m		12.7	m		9.9	m		9.9	m		10.7	m	
Width Port Entrance																					
Marge at sides	50	m		50	m		50	m		50	m		50	m		20	m		50	m	
Total required width one-way	316.6	m		196.25	m		196.25	m		228.8	m		248.2	m		244.88	m		168.25	m	
Total required width two-way	540.8	m		296	m		296	m		362.2	m		404	m		465.52	m		240	m	
Turning Basin																					
Diameter (2*L)	456	m		300	m		294	m		300	m		456	m		197.2	m		300	m	
Diameter (3*L)	684	m		450	m		441	m		450	m		684	m		295.8	m		450	m	

Approach channel

Alignment
The following guidelines are used: [*Ref. 4*]

- Shortest possible length taking into account wave, wind and current conditions
- Minimise cross-currents; currents run in all directions, and are low in magnitude (General < 0.5 m/s)
- Minimise cross wind; wind is low in magnitude (97% below 5 m/s). Winds mostly blow from SW to E. (see Section 4.4.1)
- Small angle with dominant wave direction; the waves mostly come from NW to N direction (85 %). Wave heights are generally low (97 % of time below 1.5 m). (see Section 4.5)
- Minimise number of bends
- Avoid bends close to port entrance
- Avoid hard soil and rock, these introduce high dredging costs

According to these points two Alternatives are possible. The synthesis of both is sketched in the following Figure.

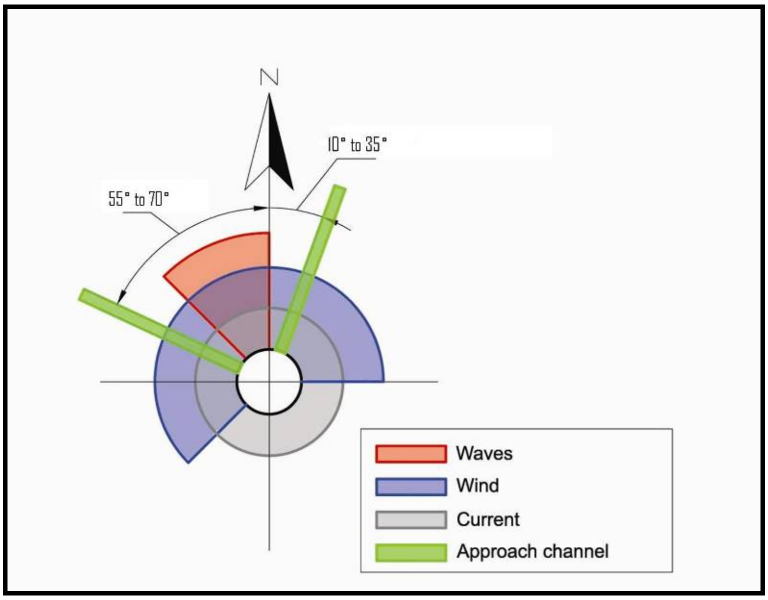


Figure VIII-1: Possible directions approach channel

Cross Section
In Figure VIII-2 the cross section of an approach channel is sketched.

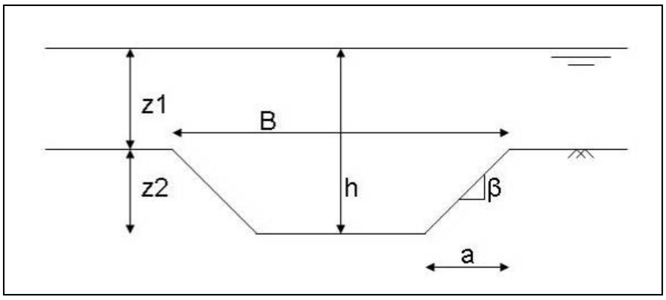


Figure VIII-2: Cross Section Approach Channel

Used Parameters

- h = Minimal required water depth to lowest water level
- z_1 = Depth to be dredged
- z_2 = Local water depth to lowest water level
- B = Required width of the channel
- a = Extra width required for stable bottom
- β = Angle of internal friction

Equation 9: Surface to be dredged approach channel

- $A = z_1 \times B + a \times z_1 = z_1 \times (B + \frac{z_1}{\beta})$

Length and volume

The approach channel has to be extended to the depth line which matches the required depth for safe navigating of the design vessel. In the next Figure depth profile is given for the bottom around Neka Harbour. In the Figure a West line is drawn which is representative for a line perpendicular to the coast just West of Neka Harbour. The same yields for the East line.

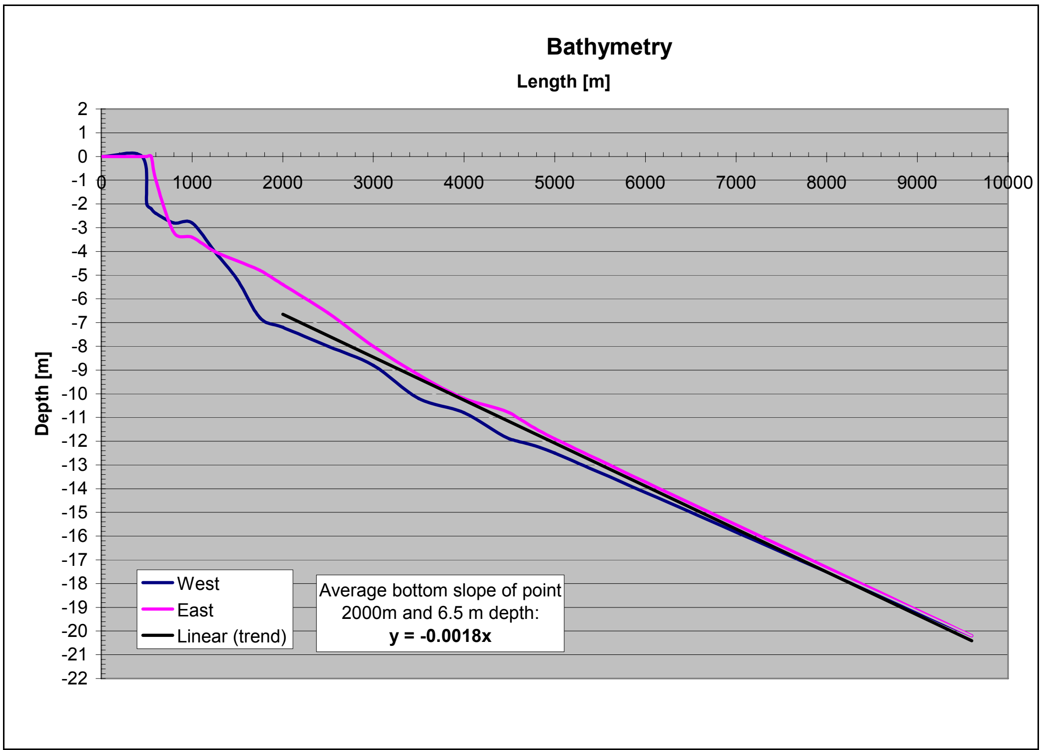


Figure VIII-3: Bottom Profile in front of Neka Harbour

Equation 10: Length Approach Channel

- $L_{approach\_channel} = (X_{end} - X_{begin}) \times \phi_{approach}$

In which:

Equation 11: Starting Point Approach Channel

- $X_{begin} = 2000 + \dfrac{(z_{2\_begin} - 6.5)}{0.0018}$ z_2>6.5, otherwise not applicable

Equation 12: End Point Approach Channel

- $X_{end} = 2000 + \dfrac{(h - 6.5)}{0.0018}$ z_2>6.5, otherwise not applicable

These equations can be used to determine the total amount of material to be dredged:

Equation 13: Total Volume to be Dredged for Approach Channel

- $V_{approach\_channel} = L_{approach\_channel} \times (0.5 \times z_1 \times B + 2 \times \dfrac{1}{3} \times z_1 \times a)$

On the following page a model is included concerning the length and dredging volume of the approach channel for each relevant design vessel.

Alternative 0
Approach to east

Angle approach with Normal to coastline:	45 =	0.79	rad	0.71	cos	1 rad =	57.30
Angle of internal friction	24 =	0.42	rad	0.45	tan		

Vessel	h [m]+B35	B [m]	z2 [m]	cos φ	tan β	z1 begin [m]	a [m]	X begin	X end	L [m]	V [m³]
70,000 DWT	15.5	215	7.5	0.71	0.45	8	17.97	2556	7000	6285	6007713
14,000 DWT	10.7	100	7.5	0.71	0.45	3.2	7.19	2556	4333	2514	440811
FPSO	10.7	68	7.5	0.71	0.45	3.2	7.19	2556	4333	2514	312086
70,000 ballasted	9.9	150	7.5	0.71	0.45	2.4	5.39	2556	3889	1886	355673
Iran Alborz	9.9	205	7.5	0.71	0.45	2.4	5.39	2556	3889	1886	480123
7,000 DWT	8	100	7.5	0.71	0.45	0.5	1.12	2556	2833	393	9968

Alternative A
Approach to east

Angle approach with Normal to coastline:	45 =	0.79	rad	0.71	cos	1 rad =	57.30
Angle of internal friction	24 =	0.42	rad	0.45	tan		

Vessel	h [m]+B35	B [m]	z2 [m]	cos φ	tan β	z1 begin [m]	a [m]	X begin	X end	L [m]	V [m³]
70,000 DWT	15.5	215	7.5	0.71	0.45	8	17.97	2556	7000	6285	6007713
14,000 DWT	10.7	100	7.5	0.71	0.45	3.2	7.19	2556	4333	2514	440811
FPSO	10.7	68	7.5	0.71	0.45	3.2	7.19	2556	4333	2514	312086
70,000 ballasted	9.9	150	7	0.71	0.45	2.9	6.51	2278	3889	2278	524253
Iran Alborz	9.9	205	7	0.71	0.45	2.9	6.51	2278	3889	2278	705960
7,000 DWT	8	100	7	0.71	0.45	1	2.25	2278	2833	786	40460

Alternative B
Approach to west

Angle approach with Normal to coastline:	45 =	0.79	rad	0.71	cos	1 rad =	57.30
Angle of internal friction	24 =	0.42	rad	0.45	tan		

Vessel	h [m]+B35	B [m]	z2 [m]	cos φ	tan β	z1 begin [m]	a [m]	X begin	X end	L [m]	V [m³]
70,000 DWT	15.5	215	8	0.71	0.45	7.5	16.85	2833	7000	5893	5247133
14,000 DWT	10.7	100	8	0.71	0.45	2.7	6.06	2833	4333	2121	309532
FPSO	10.7	68	8	0.71	0.45	2.7	6.06	2833	4333	2121	217891
70,000 ballasted	9.9	150	7	0.71	0.45	2.9	6.51	2278	3889	2278	524253
Iran Alborz	9.9	205	7	0.71	0.45	2.9	6.51	2278	3889	2278	705960
7,000 DWT	8	100	7	0.71	0.45	1	2.25	2278	2833	786	40460

Alternative C
Approach to east

Angle approach with Normal to coastline:	45 =	0.79	rad	0.71	cos	1 rad =	57.30
Angle of internal friction	24 =	0.42	rad	0.45	tan		

Vessel	h [m]+B35	B [m]	z2 [m]	cos φ	tan β	z1 begin [m]	a [m]	X begin	X end	L [m]	V [m³]
70,000 DWT	15.5	215	7	0.71	0.45	8.5	19.09	2278	7000	6678	6824639
14,000 DWT	10.7	100	7	0.71	0.45	3.7	8.31	2278	4333	2907	597378
FPSO	10.7	68	7.5	0.71	0.45	3.2	7.19	2556	4333	2514	312086
70,000 ballasted	9.9	150	7.5	0.71	0.45	2.4	5.39	2556	3889	1886	355673
Iran Alborz	9.9	205	7.5	0.71	0.45	2.4	5.39	2556	3889	1886	480123
7,000 DWT	8	100	7	0.71	0.45	1	2.25	2278	2833	786	40460

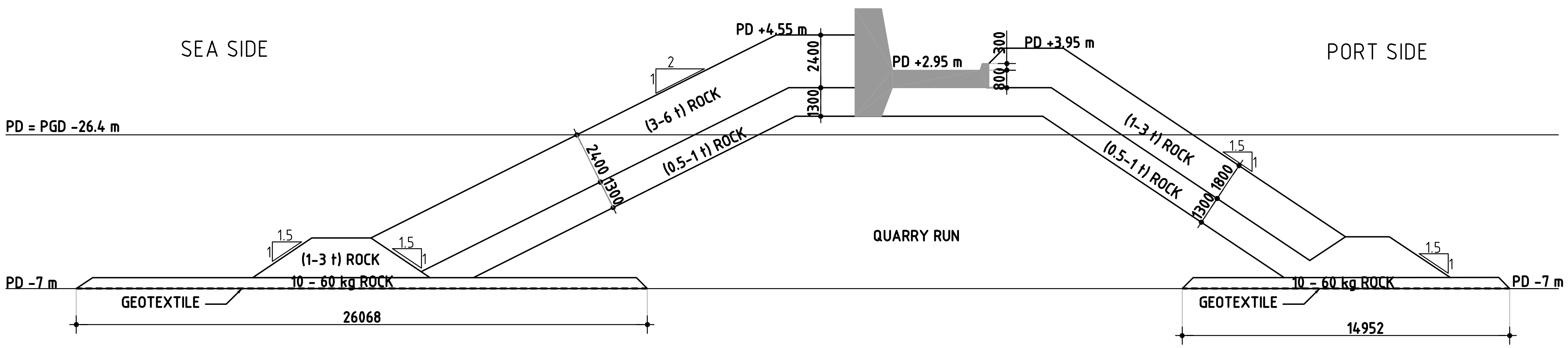
Alternative D
Approach to east

Angle approach with Normal to coastline:	45 =	0.79	rad	0.71	cos	1 rad =	57.30
Angle of internal friction	24 =	0.42	rad	0.45	tan		

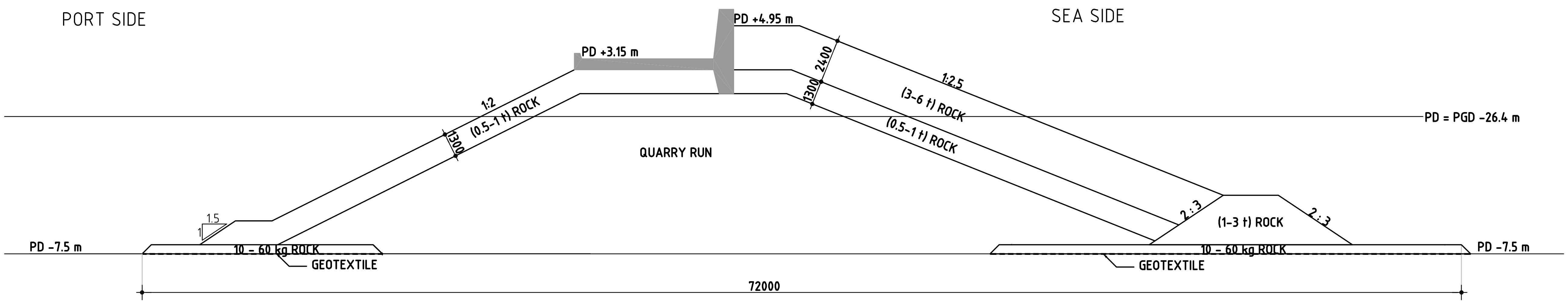
Vessel	h [m]+B35	B [m]	z2 [m]	cos φ	tan β	z1 begin [m]	a [m]	X begin	X end	L [m]	V [m³]
70,000 DWT	15.5	215	NA	0.71	0.45	#VALUE!	#VALUE!	#VALUE!	7000	#VALUE!	#VALUE!
14,000 DWT	10.7	100	5	0.71	0.45	5.7	12.80	1167	4333	4478	1494174
FPSO	10.7	68	5	0.71	0.45	5.7	12.80	1167	4333	4478	1085749
70,000 ballasted	9.9	150	5.5	0.71	0.45	4.4	9.88	1444	3889	3457	1241002
Iran Alborz	9.9	205	5.5	0.71	0.45	4.4	9.88	1444	3889	3457	1659295
7,000 DWT	8	100	5.5	0.71	0.45	2.5	5.62	1444	2833	1964	263903

Annex IX
Typical Cross Section Breakwaters

Typical Cross Section West Breakwater



Typical Cross Section East Breakwater



REV	DATE	DESCRIPTION	BY	CHK	APP

REVISIONS

IRAN MARINE INDUSTRIAL CO. (SADRA)

N.I.O.C. (NATIONAL IRANIAN OIL COMPANY)

PROJECT: NEKA INTEGRATED HARBOUR DESIGN & WATER FRONT FACILITIES

TITLE: TYPICAL CROSS SECTION WEST– AND EAST BREAKWATER

ROYAL HASKONING

DRAWN: JCA	CHECKED: ACA	PASSED: WWE
DATE: Sept. 2005	JOB No. 9P4733.21	
SCALE AT A3 1:250	AUTOCAD REF.	

DRAWING No. TEP83922DCP13106 | REVISION

Delft University of Technology

ROYAL HASKONING

Annex X
Guidelines Berths

General

Guidelines for determining the basin area are in general: [*Ref. 2*]

- For general cargo vessels: width of the basin should be 4 to 5B +100m
- For big tankers, the desirable basin width –also for two sided use of the basin- is 4 to 6B +100m
- Lower values apply for wind favourable conditions, higher values to frequent and strong cross-winds.
- The berth itself should be aligned within about 30˚ of the prevailing wind direction. Currents alongside the berth should be limited to 3 kn and perpendicular to the berth, no more than 0.75 kn.
- Centre to centre in a line: Length longest ship + 1 x width of largest ship + 2 x 15 m

Liquid berths

Liquid berths can be designed either as a jetty or a fingerpier. Typical designs of a (multiple) jetty can be found in Figure X-1. Typical design of a (multiple) fingerpier can be found in Figure X-2

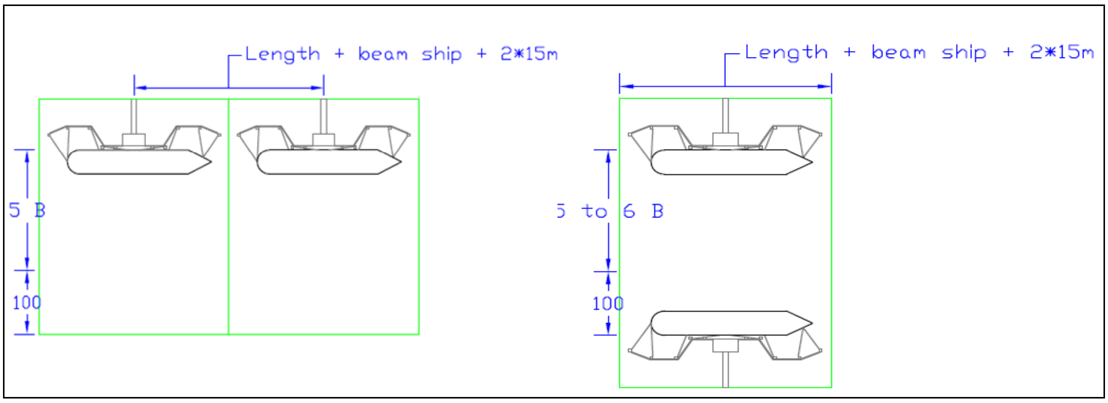


Figure X-1: Typical Design Jetty

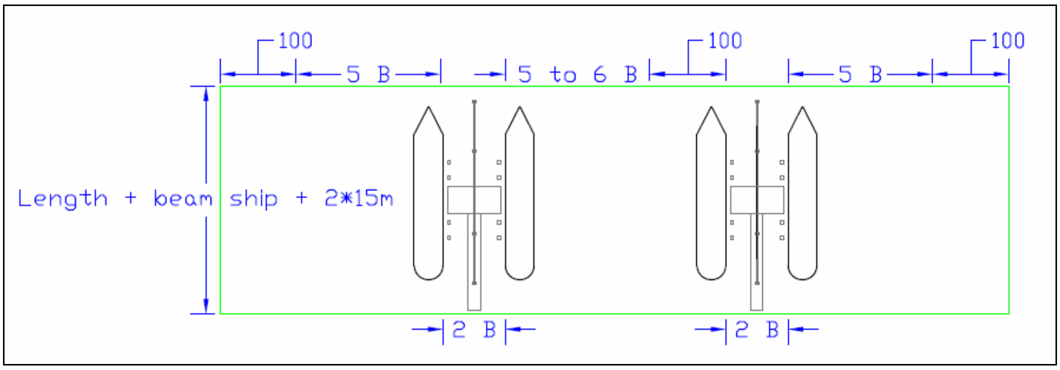


Figure X-2: Typical Design Fingerpier

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Annex XI
Model Land Reclamation

Used parameters

- Throughput according to Figures discussed in Chapter 6
- Average dwell time amounts, according to requirement [OTC-13], 7 days
- 1 barrel is equal to 0.16 m³
- Occupancy factor is estimated on 0.9
- Ratio blending / storage is assessed on 0.25 (Requirement [OTC-14])
- Required area per tank holds 6,444 m²: existing situation: 58,000 m² for 9 tanks, average per tank = 58,000/9=6,444m²
- Available land in existing situation meant for liquid storage and blending is judged on 11 ha

Used rule

Equation 14

$$O_{tanks} = 1.25 * (\frac{C_d * t_d * O_{1\_tank}}{V_{tank} * m})$$

In which:
- C_d = daily Throughput
- t_d = dwell time
- V_{tank} = storage capacity of 1 tank
- m = occupancy factor
- O_{tanks} = total required area for the tanks

Used Spreadsheet

	Unit	Phase 1	Phase 2
Throughput			
Daily throughput	[bpd]	500,000	1,000,000
Daily throughput	[m³/d]	80,000	160,000
Dwell time	[days]	7	7
Minimum required capacity	[m³]	560,000	1,120,000
Characteristics tank farm			
Present storage capacity per tank	[m³]	28,000	28,000
Occupancy factor	[-]	0.87	0.87
Required No. Of storage tanks	[-]	23	46
Blending tanks			
Ratio blending/storage tanks	[-]	0.25	0.25
No. Of blending tanks	[-]	6	12
Land use			
Required area per tank incl. safety requirements etc.	[m²]	6,444	6,444
Total No. Of tanks		29	58
Efficiency factor	[-]	1	1
Total required area	[ha]	18.69	37.38
Extra required land			
Available OTC area	[ha]	11	11
		7.69	26.38
Required m² new tank farm	**[ha]**	**7.7**	**26.4**

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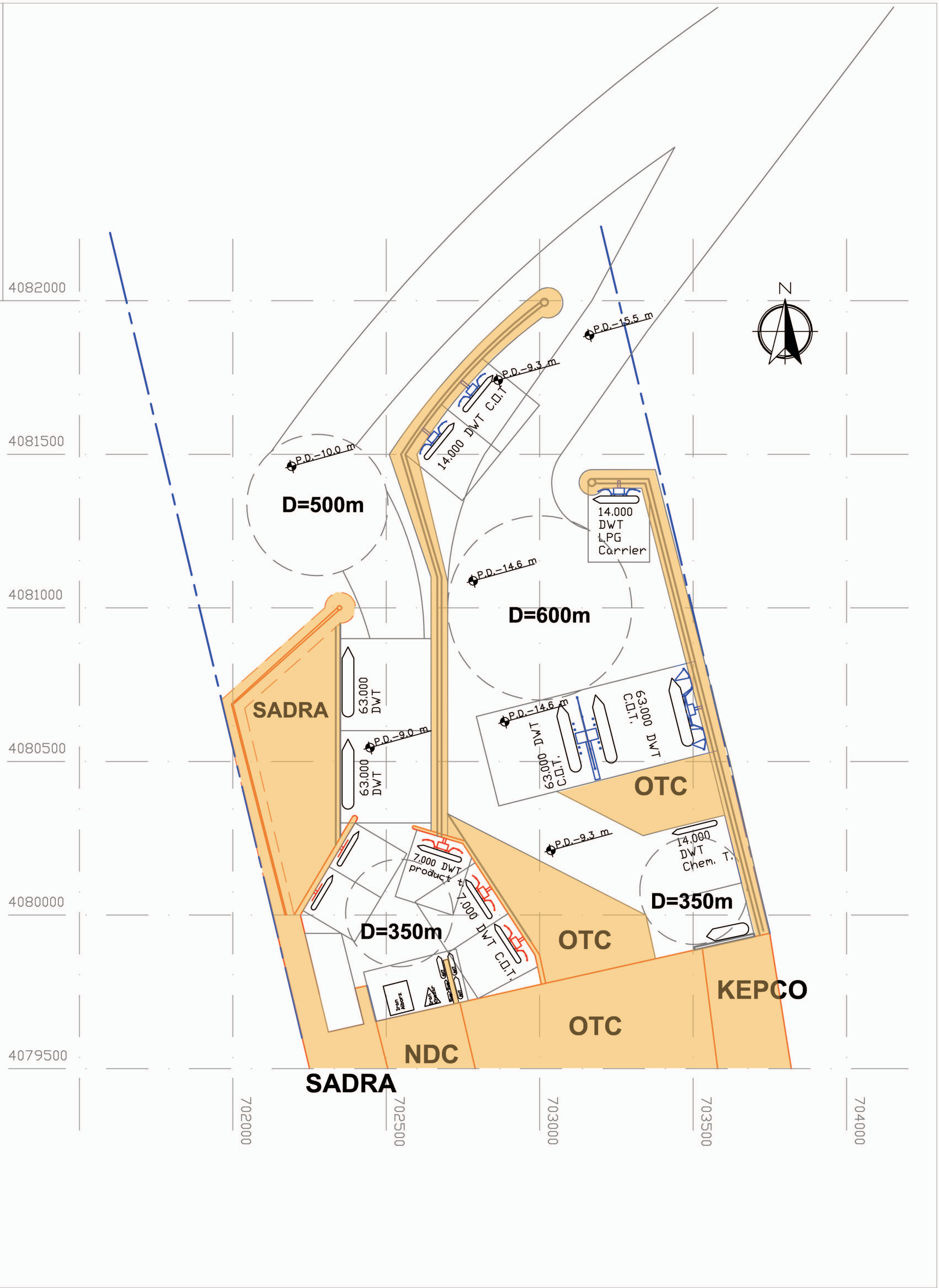
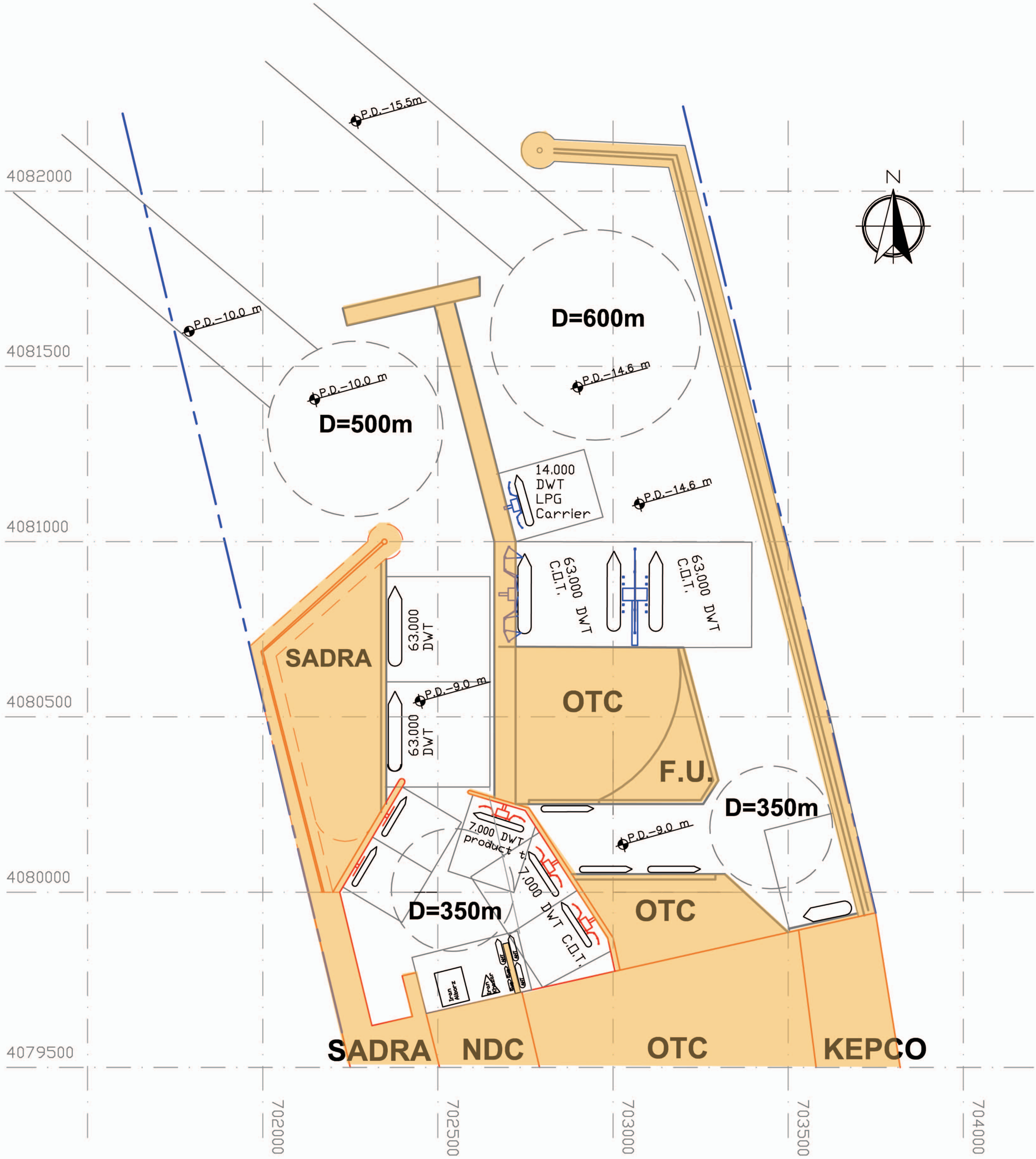
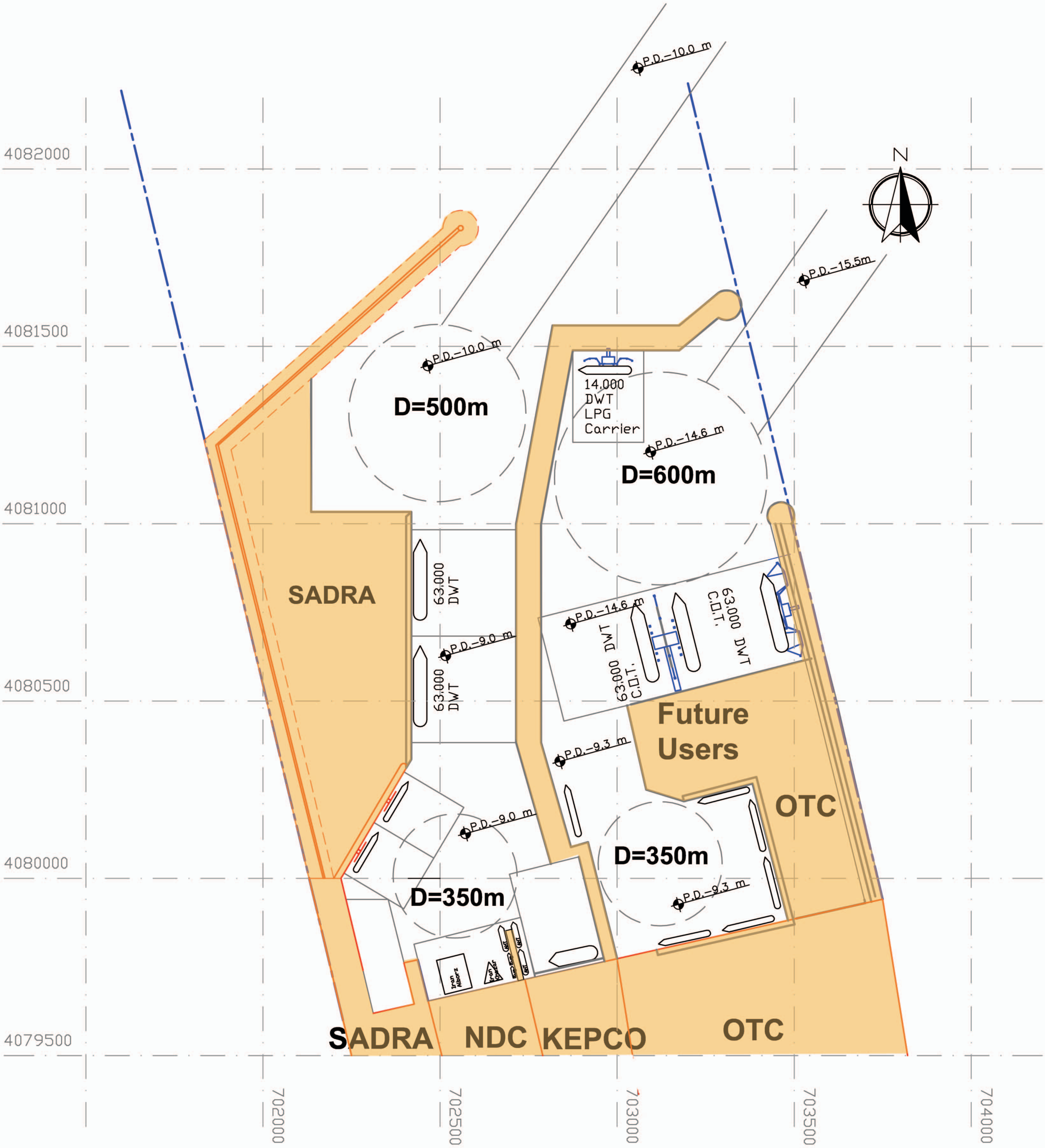
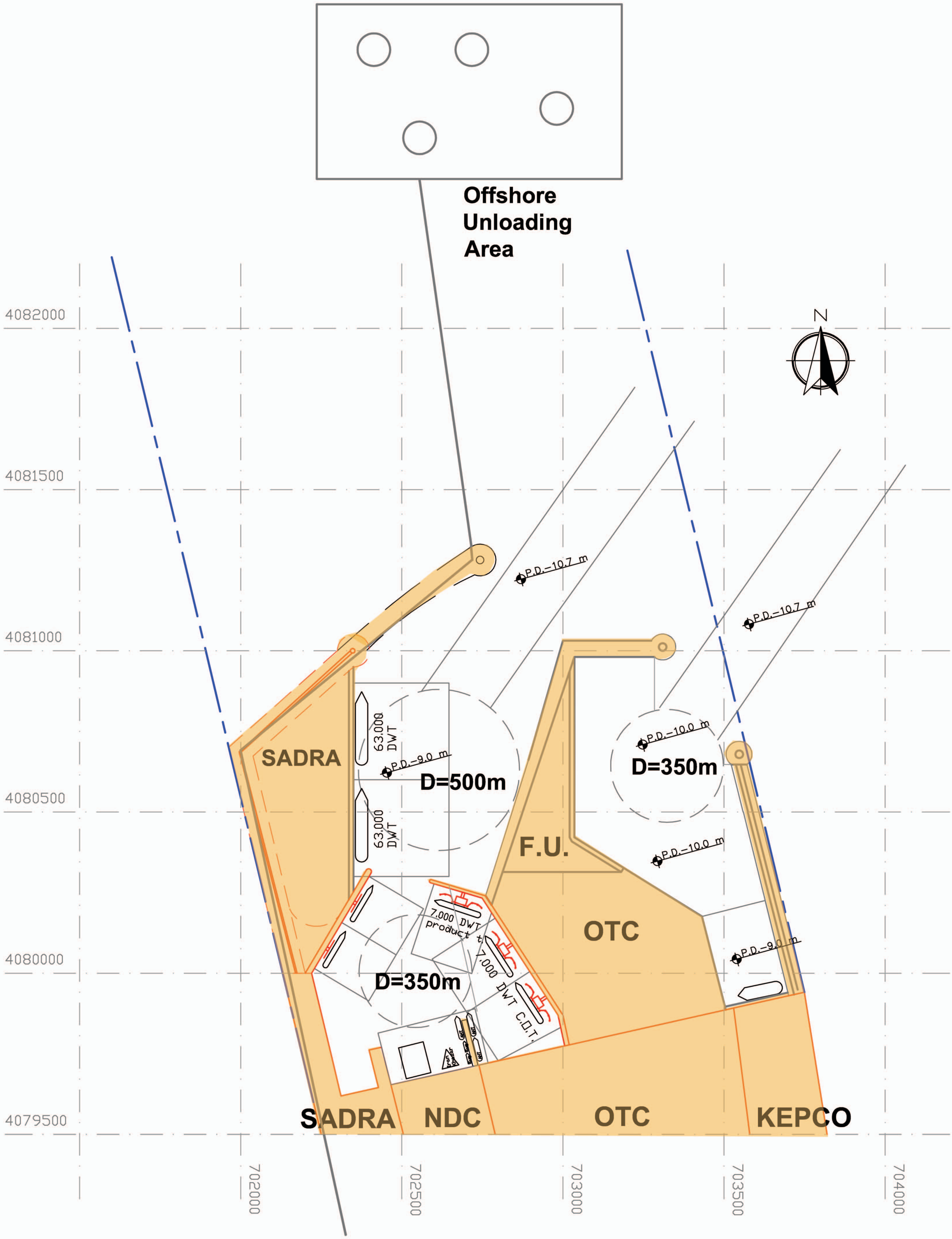
Annex XII
Preliminary Port Layouts


4082000
4081500
4081000
4080500
4080000
4079500
702000
702500
703000
703500
704000
N
P.D.-10.0 m
D=500m
P.D.-9.3 m
14,000 DWT C.O.T
P.D.-15.5 m
14,000 DWT LPG Carrier
P.D.-14.6 m
D=600m
SADRA
63,000 DWT
P.D.-9.0 m
63,000 DWT
P.D.-14.6 m
63,000 DWT C.O.T.
63,000 DWT C.O.T.
OTC
P.D.-9.3 m
14,000 DWT Chem. T.
7,000 DWT product t
7,000 DWT C.O.T.
D=350m
D=350m
OTC
KEPCO
OTC
NDC
SADRA



4082000
4081500
4081000
4080500
4080000
4079500
702000
702500
703000
703500
704000
N
P.D.-15.5m
P.D.-10.0 m
P.D.-10.0 m
D=500m
D=600m
P.D.-14.6 m
14.000
DWT
LPG
Carrier
P.D.-14.6 m
63.000 DWT
C.O.T.
63.000 DWT
C.O.T.
63.000
DWT
63.000
DWT
SADRA
P.D.-9.0 m
OTC
F.U.
D=350m
P.D.-9.0 m
7.000 DWT
product
7.000 DWT C.O.T.
D=350m
OTC
SADRA
NDC
OTC
KEPCO


4082000
4081500
4081000
4080500
4080000
4079500
702000
702500
703000
703500
704000
N
P.D.-10.0 m
P.D.-10.0 m
D=500m
P.D.-15.5m
14,000
DWT
LPG
Carrier
P.D.-14.6 m
D=600m
SADRA
63,000
DWT
P.D.-9.0 m
63,000
DWT
P.D.-14.6 m
63,000
C.O.T.
DWT
63,000 DWT
C.O.T.
Future
Users
P.D.-9.3 m
OTC
P.D.-9.0 m
D=350m
D=350m
P.D.-9.3 m
SADRA
NDC
KEPCO
OTC



Offshore Unloading Area
N
4082000
4081500
4081000
4080500
4080000
4079500
702000
702500
703000
703500
704000
P.D.-10.7 m
P.D.-10.7 m
P.D.-10.0 m
P.D.-10.0 m
P.D.-9.0 m
P.D.-9.0 m
SADRA
63,000 DWT
63,000 DWT
D=500m
D=350m
D=350m
F.U.
OTC
7,000 DWT product t.
7,000 DWT C.O.T.
SADRA
NDC
OTC
KEPCO

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Annex XIII
Bill of Quantities

In the present Annex the calculation on the Bill of Quantities is performed. First the cost items are stated in Table XIII-1. Thereafter a short explanation is given on the responsibilities of the costs. In Table XIII-2 to XIII-5 the BoQ's for each Alternative are listed. Finally the cost distribution for both SADRA and NIOC is stated in respectively Figure XIII-1 and Figure XIII-2.

Cost Figure

Table XIII-1: Cost Items

Item	Costs	Unit	Reference
Dredging	EUR 4	[m³]	RH
Reclamation	EUR 3	[m³]	RH
Revetments			
depth 9 m	EUR 10,400	[m]	RH
depth 14.5m	EUR 21,500	[m]	RH
Jetties			
NDC	EUR 50,000	[m]	RH
Depth 9.3	EUR 12,000,000	[-]	estimated
Depth 14.5m	EUR 15,000,000	[-]	RH
Fingerpiers			
Depth 9.3	EUR 22,800,000	[-]	RH
Depth 14.5m	EUR 28,500,000	[-]	RH
Quays			
Depth 8m	EUR 19,000	[m]	RH
Depth 9m	EUR 20,000	[m]	RH
Depth 10m	EUR 21,000	[m]	RH
Depth 11m	EUR 25,000	[m]	RH
Depth 14m	EUR 30,000	[m]	RH
SBM			
63,000 DWT	EUR 15,000,000	[-]	Benchmarked with confidential case
14,000 DWT	EUR 15,000,000	[-]	Benchmarked with confidential case
LPG	EUR 17,000,000	[-]	Benchmarked with confidential case
Pipelines	EUR 1,780	[m]	Benchmarked with confidential case

Cost Responsibilities

In the study of joint development, carried out by Royal Haskoning, was agreed upon the following cost share facts between SADRA and NIOC:

- Deepening old harbour: 50% SADRA, 50% NIOC
- SADRA basin / NIOC approach: 50% SADRA, 50% NIOC
- Turning circle: 50% SADRA, 50% NIOC

These facts are adopted and likewise applied in this study.

Table XIII-2: BoQ Alternative 0

Item	Owner	Location	Quantity [m^3]	Unit [-]	Rate [Euro]	Sub-total [Euro]	Total [Euro]
Dredging	SADRA	50% SADRA/NDC old harbour	630,000	m^3	4	2,520,000	8,420,000
		50% SADRA Basin+NDC/OTC approach	967,500	m^3	4	3,870,000	
		50% Turning Circle	507,500	m^3	4	2,030,000	
					4		
	NIOC	50% SADRA/NDC old harbour	630,000	m^3	4	2,520,000	55,190,852
		50% SADRA Basin+NDC/OTC approach	967,500	m^3	4	3,870,000	
		50% Turning Circle	507,500	m^3	4	2,030,000	
		Extra Deepening turning circle OTC	1,875,000	m^4	4	7,500,000	
		Deepening approach channel	6,007,713	m^4	4	24,030,852	
		Kepco basin	780,000	m^3	4	3,120,000	
		OTC basin	3,030,000	m^3	4	12,120,000	
Reclamation	SADRA	Future Area	2,145,000	m^3	3	6,435,000	6,435,000
	NIOC	Area OTC	1,487,500	m^3	3	4,462,500	7,522,500
		Area Future Users	1,020,000	m^4	3	3,060,000	
Revetment	SADRA	Revetment SADRA area (bottom -8.5)	150	m	10,400	1,560,000	1,560,000
	NIOC	Revetment OTC area (bottom -8.5)	850	m	10,400	8,840,000	28,465,000
		Revetment Future OTC area (bottom -8.5)	750	m	10,400	7,800,000	
		Revetment Future OTC area (bottom -14.5)	550	m	21,500	11,825,000	
Fingerpier/Jetty	NIOC	NDC jetty (bottom -8.5)	180	m	50,000	9,000,000	67,500,000
		Jetty LPG (bottom -14.5 m)	1	[-]	15,000,000	15,000,000	
		Jetty 70000 DWT tanker (bottom -14.5)	1	[-]	15,000,000	15,000,000	
		Fingerpier 70000 DWT tanker (bottom -14.5)	1	[-]	28,500,000	28,500,000	
Breakwaters	SADRA	West Breakwater (0-5 m depth)	0	m	25000	0	43,750,000
		West Breakwater (5-10 m depth)	1250	m	35000	43,750,000	
	NIOC	East Breakwater (0-5 m depth)	700	m	25000	17,500,000	47,250,000
		East Breakwater (5-10 m depth)	850	m	35000	29,750,000	
Quays	SADRA	SADRA quay -9.0 m	500	m	20000	10,000,000	16,000,000
		SADRA quay -14.5 m	200	m	30000	6,000,000	
	NIOC	NDC quay -9 m	250	m	20,000	5,000,000	21,000,000
		KEPCO quay -9 m	200	m	20,000	4,000,000	
		OTC quay -9 m	600	m	20,000	12,000,000	

NIOC	**226,928,352**
SADRA	**76,165,000**
	303,093,352

Table XIII-3: BoQ Alternative A

Item	Owner	Location	Quantity [m^3]	Unit [-]	Rate [Euro]	Sub-total [Euro]	Total [Euro]
Dredging	**SADRA**	50% SADRA/NDC old harbour	624,000	m^3	4	2,496,000	6,766,017
		50% SADRA Basin+NDC/OTC approach	420,000	m^3	4	1,680,000	
		50% Deepening turning circle SADRA basin	294,524	m^4	4	1,178,097	
		50% Deepening branch approach SADRA basin	352,980	m^5	4	1,411,920	
	NIOC	50% SADRA/NDC old harbour	624,000	m^3	4	2,496,000	61,490,880
		50% SADRA Basin+NDC/OTC approach	420,000	m^3	4	1,680,000	
		50% Deepening turning circle SADRA basin	294,524	m^4	4	1,178,097	
		50% Deepening branch approach SADRA basin	352,980	m^5	4	1,411,920	
		Deepening approach channel	6,007,713	m^4	4	24,030,852	
		Kepco basin	472,064	m^3	4	1,888,255	
		OTC basin	7,201,439	m^3	4	28,805,756	
Reclamation	**SADRA**	Future Area	1,600,000	m^3	3	4,800,000	4,800,000
	NIOC	Area OTC	1,997,500	m^3	3	5,992,500	5,992,500
Revetment	**SADRA**			m		0	0
	NIOC	Revetment OTC area (bottom -9.3)	1,450	m	10,400	15,080,000	21,960,000
		Revetment Future OTC area (bottom -14.6)	320	m	21,500	6,880,000	
Fingerpier/Jetty/SBM	**NIOC**	NDC jetty (bottom -8.5)	160	m	50,000	8,000,000	90,500,000
		Jetty LPG (bottom -14.5 m)	1	[-]	15,000,000	15,000,000	
		Jetty 14000 DWT tanker (bottom -9.3)	2	[-]	12,000,000	24,000,000	
		Jetty 70000 DWT tanker (bottom -14.5)	1	[-]	15,000,000	15,000,000	
		Fingerpier 70000 DWT tanker (bottom -14.5)	1	[-]	28,500,000	28,500,000	
Breakwaters	**SADRA**	West breakwater	0	m	25000	0	0
	NIOC	East Breakwater (0-5 m depth)	700	m	25000	17,500,000	106,250,000
		East Breakwater (5-10 m depth)	850	m	35000	29,750,000	
		Middle breakwater (0-5 m depth)	750	m	25000	18,750,000	
		Middle breakwater (5-10 m depth)	1150	m	35000	40,250,000	
Quays	**SADRA**	SADRA quay -9.0 m	700	m	20000	14,000,000	14,000,000
	NIOC	NDC quay -8.4 m	250	m	19,000	4,750,000	12,350,000
		KEPCO quay -9.3 m	200	m	20,000	4,000,000	
		OTC quay -9.3 m	180	m	20,000	3,600,000	

NIOC	**298,543,380**
SADRA	**25,566,017**
	324,109,397

Table XIII-4: BoQ Alternative B

Item	Owner	Location	Quantity [m^3]	Unit [-]	Rate [Euro]	Sub-total [Euro]	Total [Euro]
Dredging	**SADRA**	50% SADRA/NDC old harbour	624,000	m^3	4	2,496,000	7,158,716
		50% SADRA Basin+NDC/OTC approach	420,000	m^3	4	1,680,000	
		50% Turning Circle basin SADRA	392,699	m^3	4	1,570,796	
		50% Deepening branch approach SADRA	352,980	m^4	4	1,411,920	
					4		
	NIOC	50% SADRA/NDC old harbour	624,000	m^3	4	2,496,000	79,542,976
		50% SADRA Basin+NDC/OTC approach	420,000	m^3	4	1,680,000	
		Turning Circle	2,325,564	m^3	4	9,302,256	
		Deepening approach channel	5,247,133	m^4	4	20,988,532	
		50% Deepening branch approach SADRA	352,980	m^4	4	1,411,920	
		50% Turning Circle basin SADRA	392,699	m^3	4	1,570,796	
		OTC basin	10,523,368	m^3	4	42,093,472	
Reclamation	**SADRA**	Future Area	1,600,000	m^3	3	4,800,000	4,800,000
	NIOC	Area OTC	1,920,000	m^3	3	5,760,000	7,515,000
		Area Future Users	585,000	m^4	3	1,755,000	
Revetment	**SADRA**			m	10,400	0	0
	NIOC	Revetment OTC area (bottom -9.3)	200	m	10,400	2,080,000	2,080,000
Fingerpier/Jetty	**NIOC**	NDC jetty (bottom -8.5)	180	m	50,000	9,000,000	67,500,000
		Jetty LPG (bottom -14.5 m)	1	[-]	15,000,000	15,000,000	
		Jetty 70000 DWT tanker (bottom -14.5)	1	[-]	15,000,000	15,000,000	
		Fingerpier 70000 DWT tanker (bottom -14.5)	1	[-]	28,500,000	28,500,000	
Breakwaters	**SADRA**	West Breakwater (0-5 m depth)	0	m	25000	0	0
		West Breakwater (5-10 m depth)	0	m	35000	0	
	NIOC	East Breakwater (0-5 m depth)	700	m	25000	17,500,000	144,550,000
		East Breakwater (5-10 m depth)	1750	m	35000	61,250,000	
		Middle Breakwater (0-5 m depth)	880	m	35000	30,800,000	
		Middle Breakwater (5-10 m depth)	1000	m	35000	35,000,000	
Quays	**SADRA**	SADRA quay -9.0 m	700	m	20000	14,000,000	14,000,000
	NIOC	NDC quay -8.4 m	250	m	19,000	4,750,000	37,850,000
		KEPCO quay -9.3 m	200	m	20,000	4,000,000	
		OTC quay -9.3 m	580	m	20,000	11,600,000	
		Future users -9.3m	350	m	20,000	7,000,000	
		Future users -14.6m	350	m	30,000	10,500,000	

NIOC	**339,037,976**
SADRA	**25,958,716**
	364,996,693

Table XIII-5: BoQ Alternative C

Item	Owner	Location	Quantity [m³]	Unit [-]	Rate [Euro]	Sub-total [Euro]	Total [Euro]
Dredging	SADRA	50% SADRA/NDC old harbour	755,250	m^3	4	3,021,000	6,895,968
		50% SADRA Basin+NDC/OTC approach	420,000	m^3	4	1,680,000	
		50% Turning Circle SADRA basin	392,699	m^3	4	1,570,796	
		50 %Deepening branch approach SADRA basin	156,043	m^4	4	624,172	
	NIOC	50% SADRA/NDC old harbour	755,250	m^3	4	3,021,000	66,873,428
		50% SADRA Basin+NDC/OTC approach	420,000	m^3	4	1,680,000	
		50% Turning Circle SADRA basin	392,699	m^3	4	1,570,796	
		Deepening approach channel	6,824,639	m^4	4	27,298,556	
		50 %Deepening branch approach SADRA basin	156,043	m^4	4	624,172	
		OTC basin	8,169,726	m^3	4	32,678,904	
Reclamation	SADRA	Future Area	2,080,000	m^3	3	6,240,000	6,240,000
	NIOC	Area OTC	1,848,000	m^3	3	5,544,000	8,544,000
		Area Future Users	1,000,000	m^4	3	3,000,000	
Revetment	SADRA			m	10,400	0	0
	NIOC	Revetment OTC area (bottom -9.3)	200	m	10,400	2,080,000	21,185,000
		Revetment Future OTC area (bottom -10) (SADRA bas	700	m	10,400	7,280,000	
		Revetment OTC area (bottom -14.5)	550	m	21,500	11,825,000	
Fingerpier/Jetty	NIOC	NDC jetty (bottom -8.5)	180	m	50,000	9,000,000	79,500,000
		Jetty LPG (bottom -14.5 m)	1	[-]	15,000,000	15,000,000	
		Jetty Chemical tanker (-9.3)	1	[-]	12,000,000	12,000,000	
		Jetty 70000 DWT tanker (bottom -14.5)	1	[-]	15,000,000	15,000,000	
		Fingerpier 70000 DWT tanker (bottom -14.5)	1	[-]	28,500,000	28,500,000	
Breakwaters	SADRA	West Breakwater (0-5 m depth)		m	25000	20,625,000	49,500,000
		50% West Breakwater (5-10 m depth)	825	m	35000	28,875,000	
	NIOC	East Breakwater (0-5 m depth)	700	m	25000	17,500,000	142,625,000
		East Breakwater (5-10 m depth)	400	m	35000	14,000,000	
		Middle Breakwater (0-5 m depth)	1250	m	35000	43,750,000	
		Middle Breakwater (5-10 m depth)	1100	m	35000	38,500,000	
		50% West Breakwater (5-10 m depth)	825	m	35000	28,875,000	
Quays	SADRA	SADRA quay -9.0 m	700	m	20000	14,000,000	14,000,000
	NIOC	NDC quay -8.4 m	250	m	19,000	4,750,000	28,350,000
		KEPCO quay -9.3 m	200	m	20,000	4,000,000	
		OTC quay -9.3 m	980	m	20,000	19,600,000	

NIOC	**347,077,428**
SADRA	**76,635,968**
	423,713,397

Table XIII-6: BoQ Alternative D

Phase 2

Item	Owner	Location	Quantity [m^3]	Unit [-]	Rate [Euro]	Sub-total [Euro]	Total [Euro]
Dredging	**SADRA**	50% SADRA/NDC old harbour	624,000	m^3	4	2,496,000	10,745,386
		50% SADRA Basin+NDC/OTC approach	1,232,699	m^3	4	4,930,796	
		50% Deepening branch approach SADRA basin	829,648	m^4	4	3,318,590	
					4		
	NIOC	50% SADRA/NDC old harbour	624,000	m^3	4	2,496,000	26,353,037
		50% SADRA Basin+NDC/OTC approach	1,232,699	m^3	4	4,930,796	
		Deepening approach channel	1,494,174	m^4	4	5,976,696	
		50% Deepening branch approach SADRA basin	829,648	m^5	4	3,318,590	
		Kepco basin	472,064	m^3	4	1,888,255	
		OTC and Future Users basin	1,935,675	m^3	4	7,742,700	
Reclamation	**SADRA**	Future Area	1,600,000	m^3	3	4,800,000	4,800,000
	NIOC	Area OTC	1,800,500	m^3	3	5,401,500	7,390,500
		Area Future Users	663,000	m^4	3	1,989,000	
Revetment	**SADRA**			m	10,400	0	0
	NIOC	Revetment OTC area (bottom -9.3)	600	m	10,400	6,240,000	6,240,000
ingerpier/Jetty / SB	**NIOC**	NDC jetty (bottom -8.5)	180	m	50,000	9,000,000	116,000,000
		SBM LPG (bottom -14.5m)	1	[-]	17,000,000	17,000,000	
		SBM 14,000 DWT tanker (bottom 12.5)	3	[-]	15,000,000	45,000,000	
		SBM 70000 DWT tanker (bottom -17.3)	3	[-]	15,000,000	45,000,000	
Pipelines	**NIOC**	Pipelines	30,500	m	1,778	54,222,222	54,222,222
Breakwaters	**SADRA**	West Breakwater (0-5 m depth)	0	m	25000	0	17,500,000
		West Breakwater (5-10 m depth)	500	m	35000	17,500,000	
	NIOC	East Breakwater (0-5 m depth)	550	m	25000	13,750,000	13,750,000
Quays	**SADRA**	SADRA quay -9.0 m	700	m	20000	14,000,000	14,000,000
	NIOC	NDC quay -8.4 m	250	m	19,000	4,750,000	21,350,000
		KEPCO quay -9.3 m	200	m	20,000	4,000,000	
		Future users quay -10.0 m	600	m	21,000	12,600,000	

NIOC	**191,083,537**
SADRA	**47,045,386**

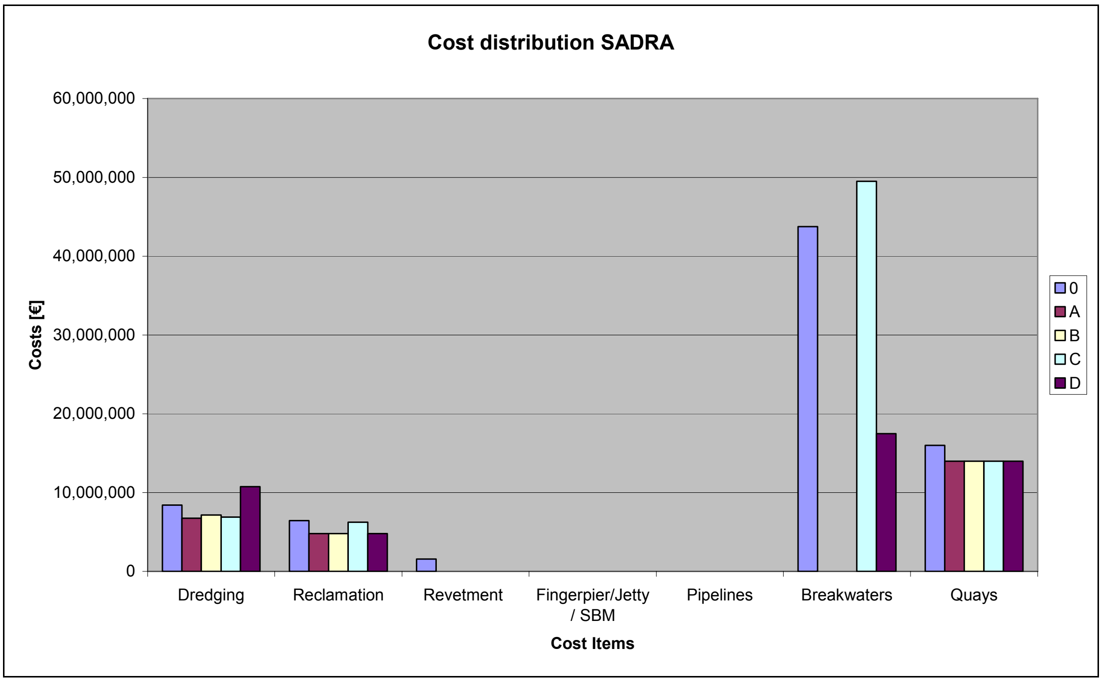

Figure XIII-1: Cost Distribution SADRA

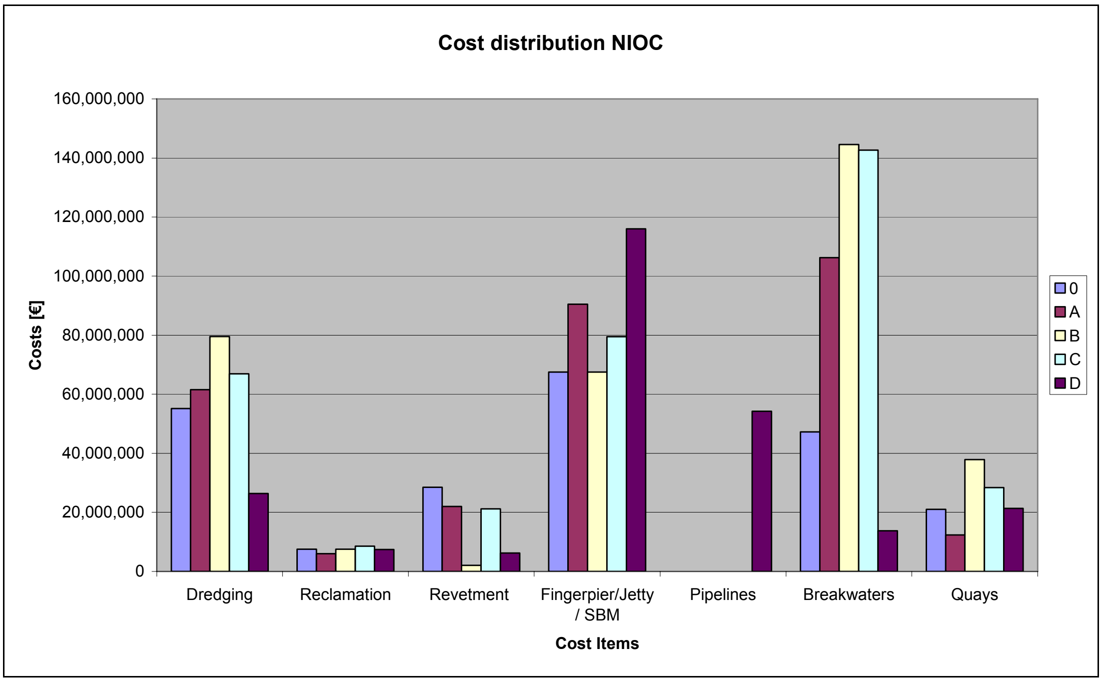

Figure XIII-2: Cost Distribution NIOC

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Annex XIV
Results of the Wave Agitation Task

TU Delft
Delft University of Technology

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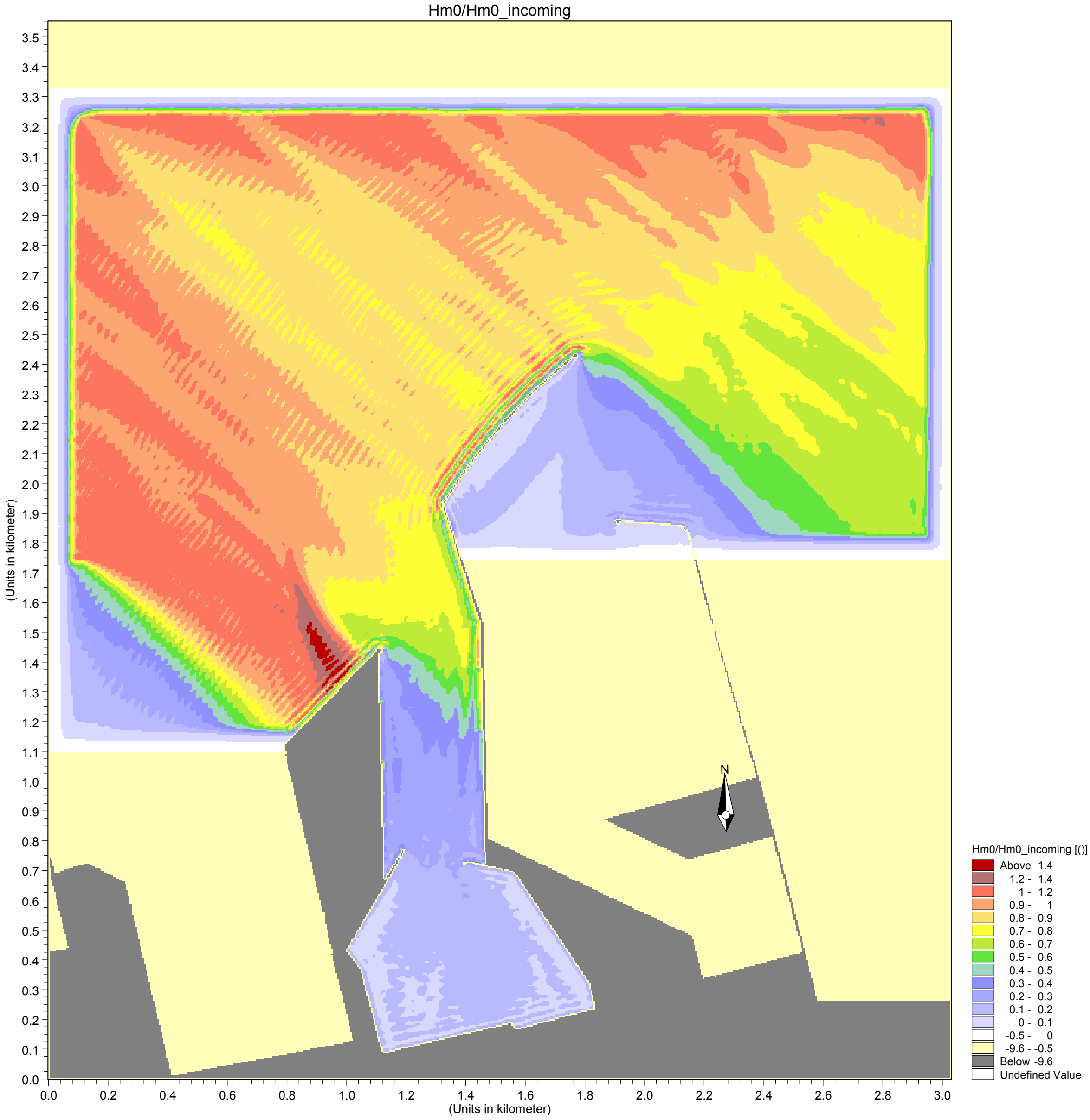
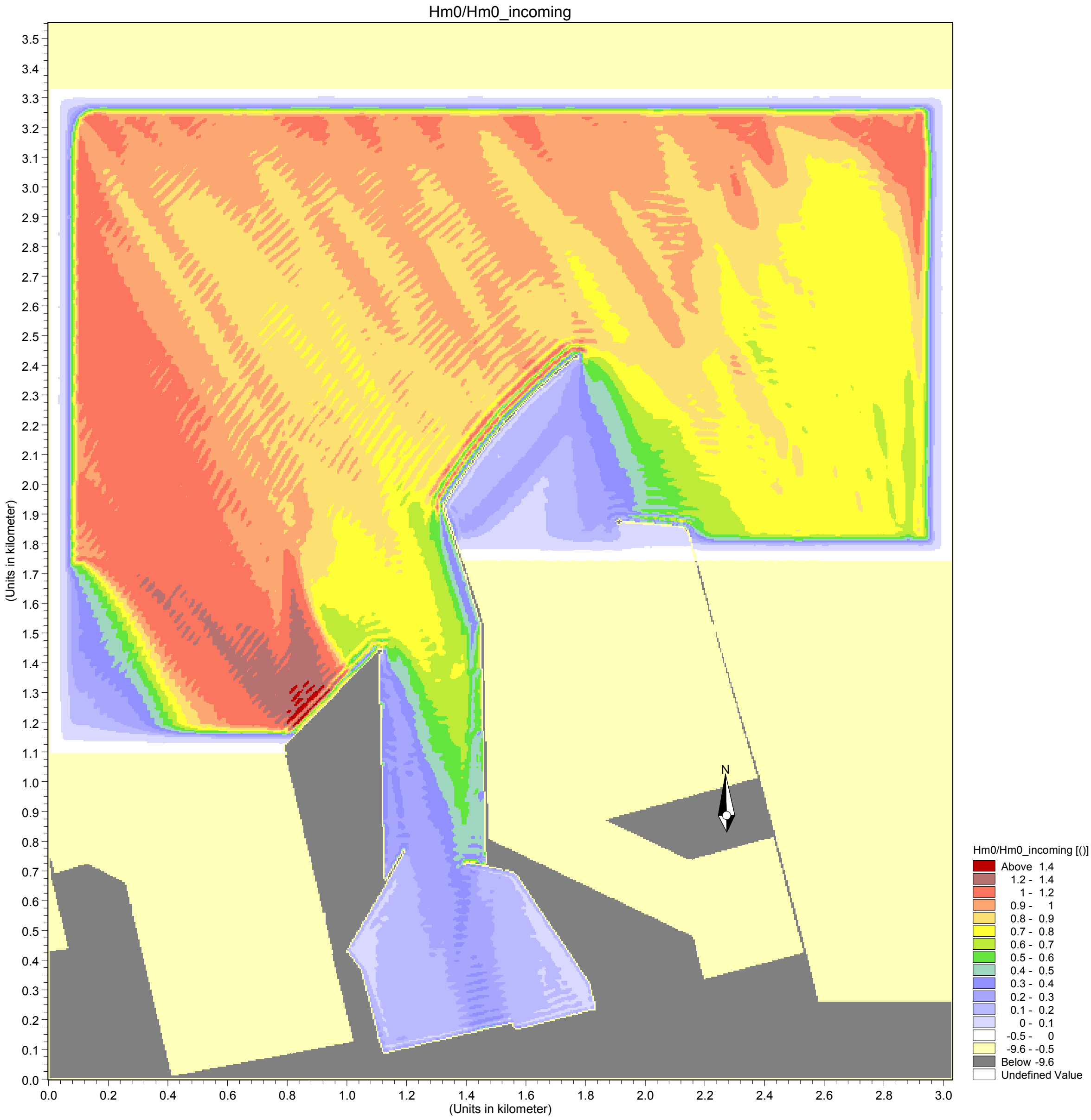
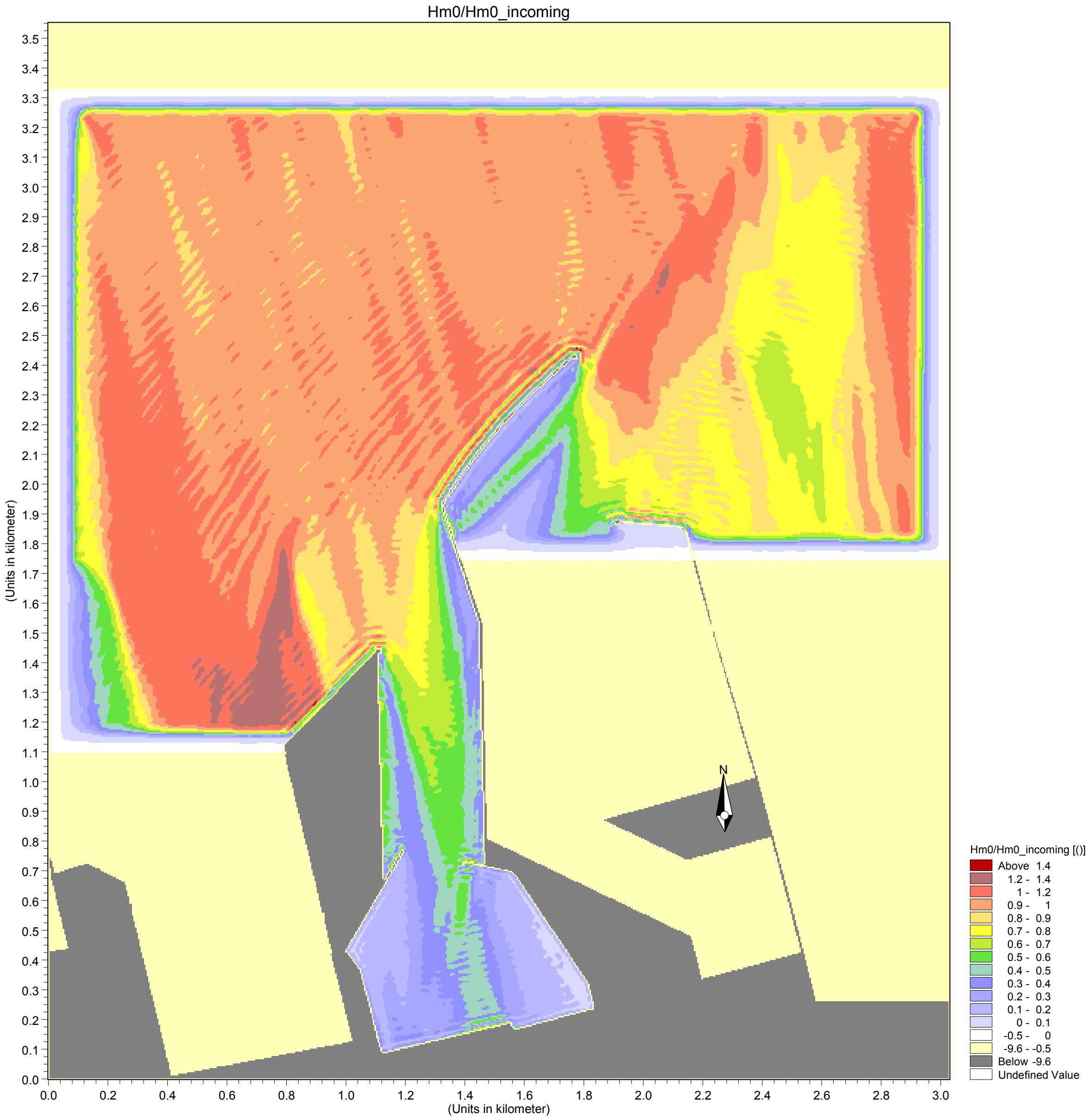


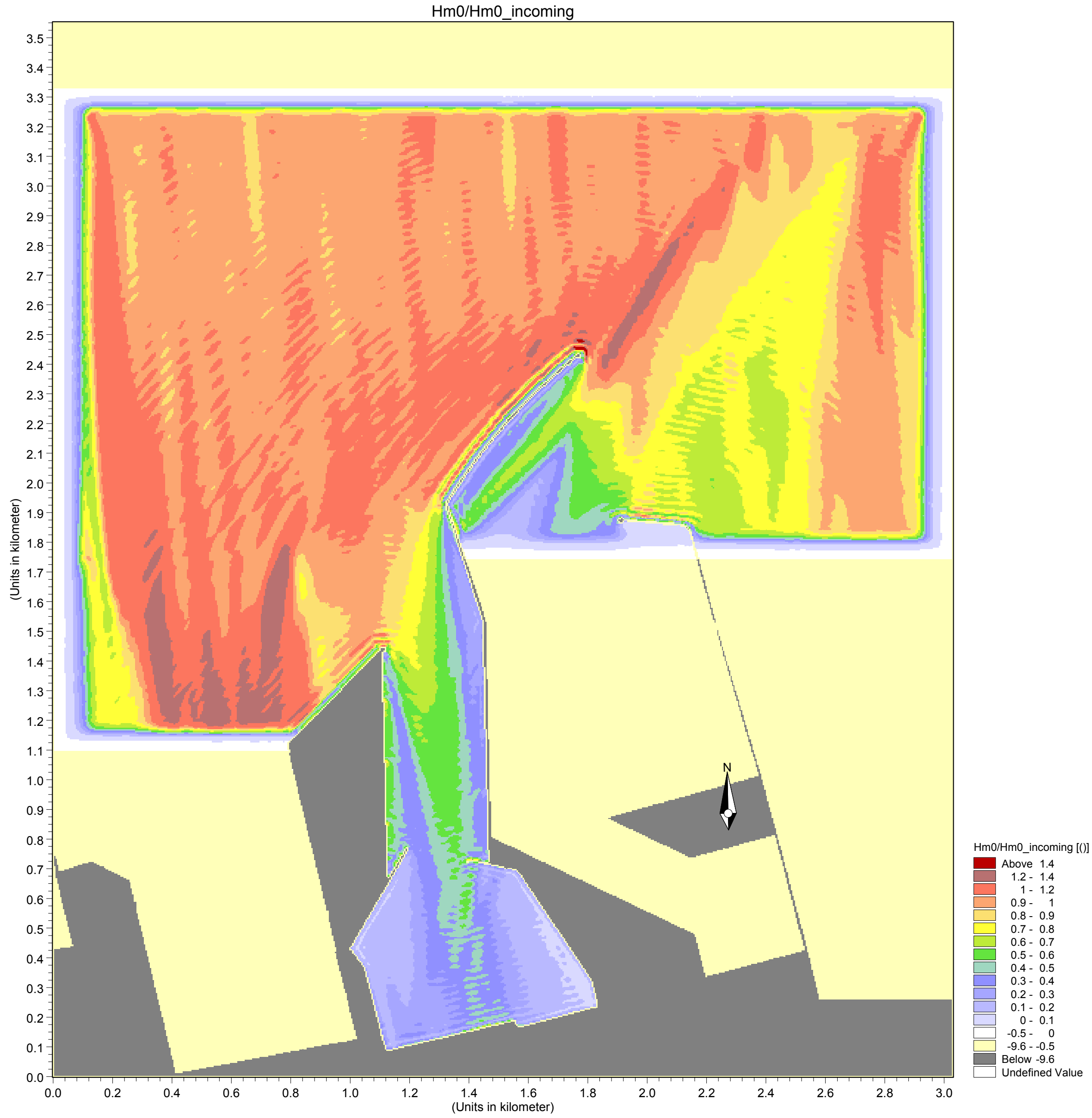
Wave Disturbance Coefficients for Direction 310º N



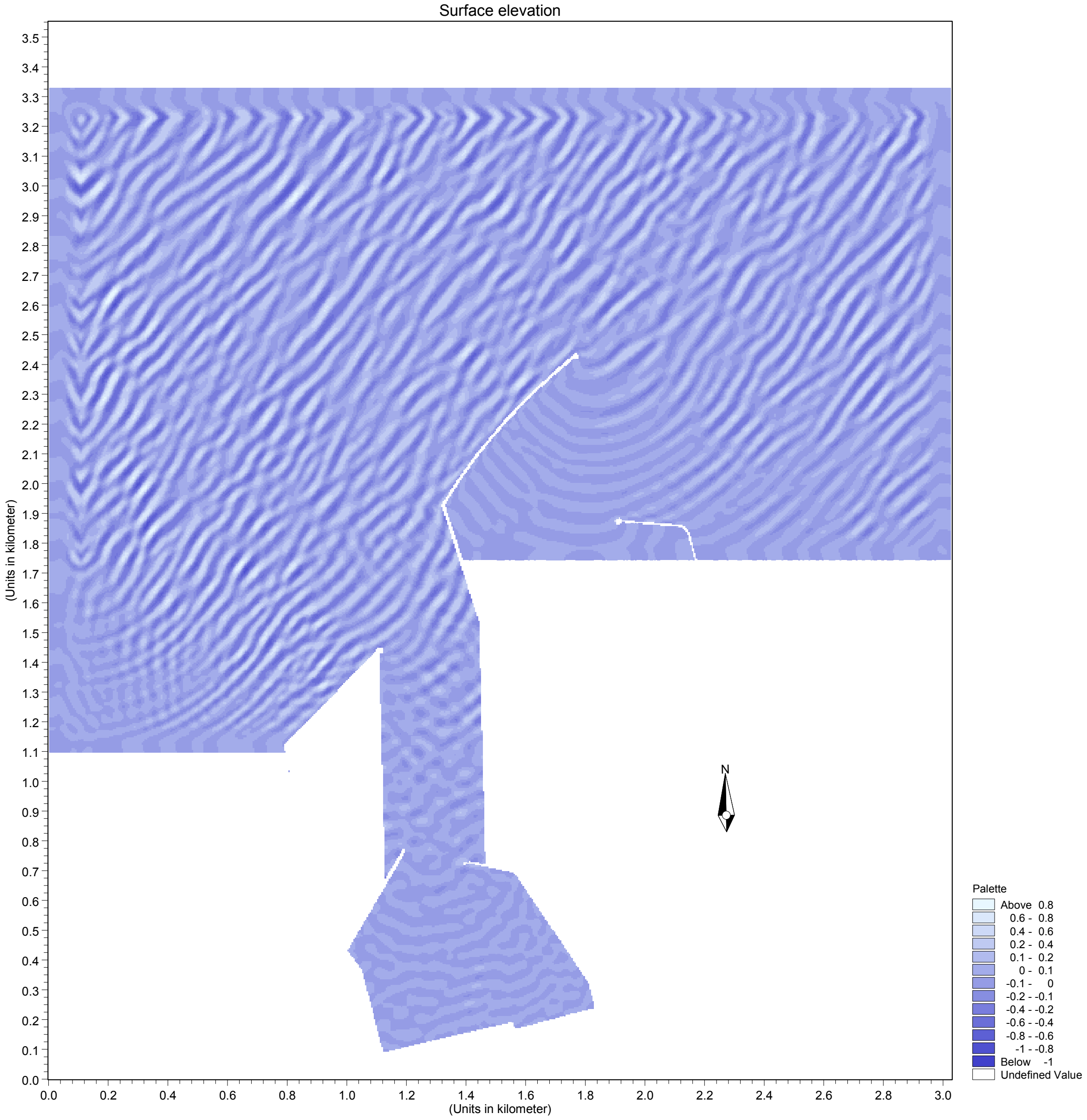
Wave Disturbance Coefficients for Direction 330º N



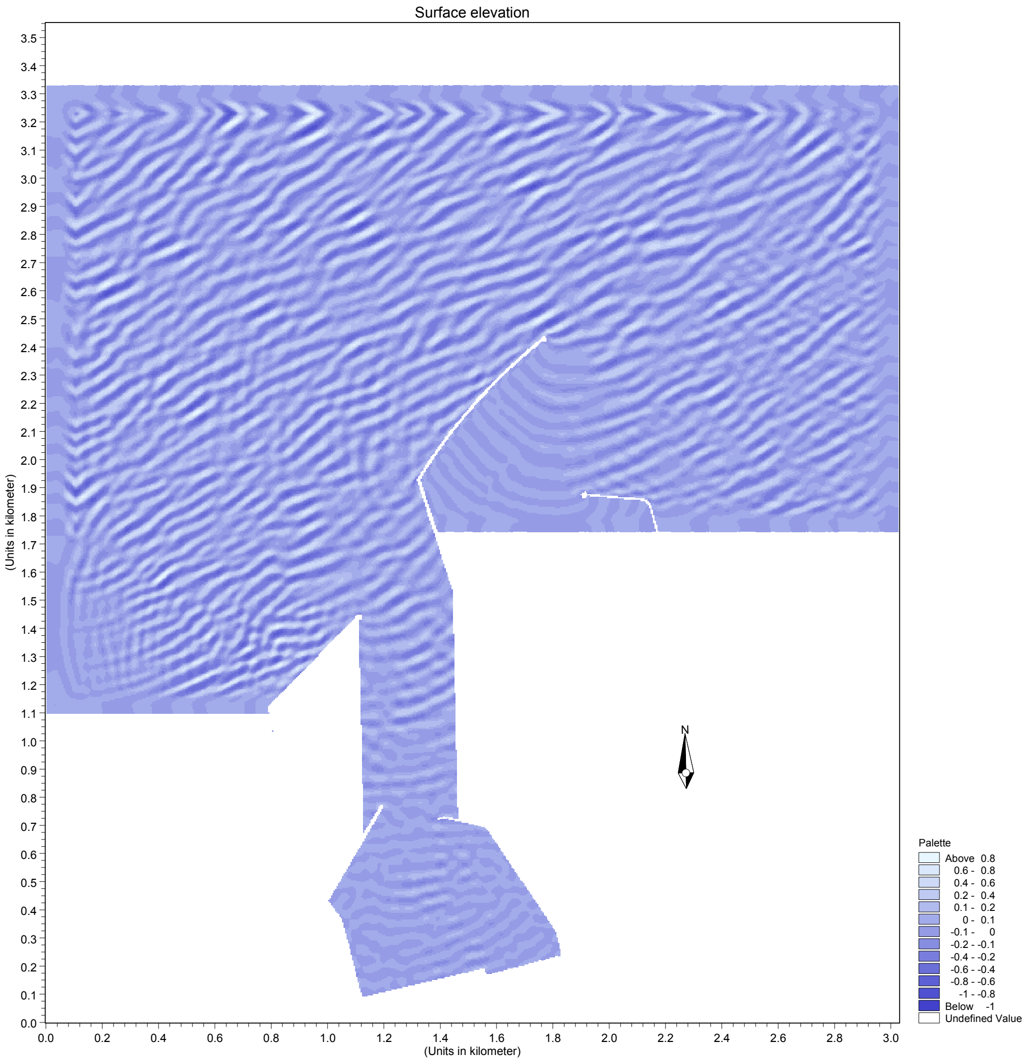
Wave Disturbance Coefficients for Direction 350º N



Wave Disturbance Coefficients for Direction 360º N



Instantaneous Surface Elevation 310º N



Instantaneous Surface Elevation 330º N

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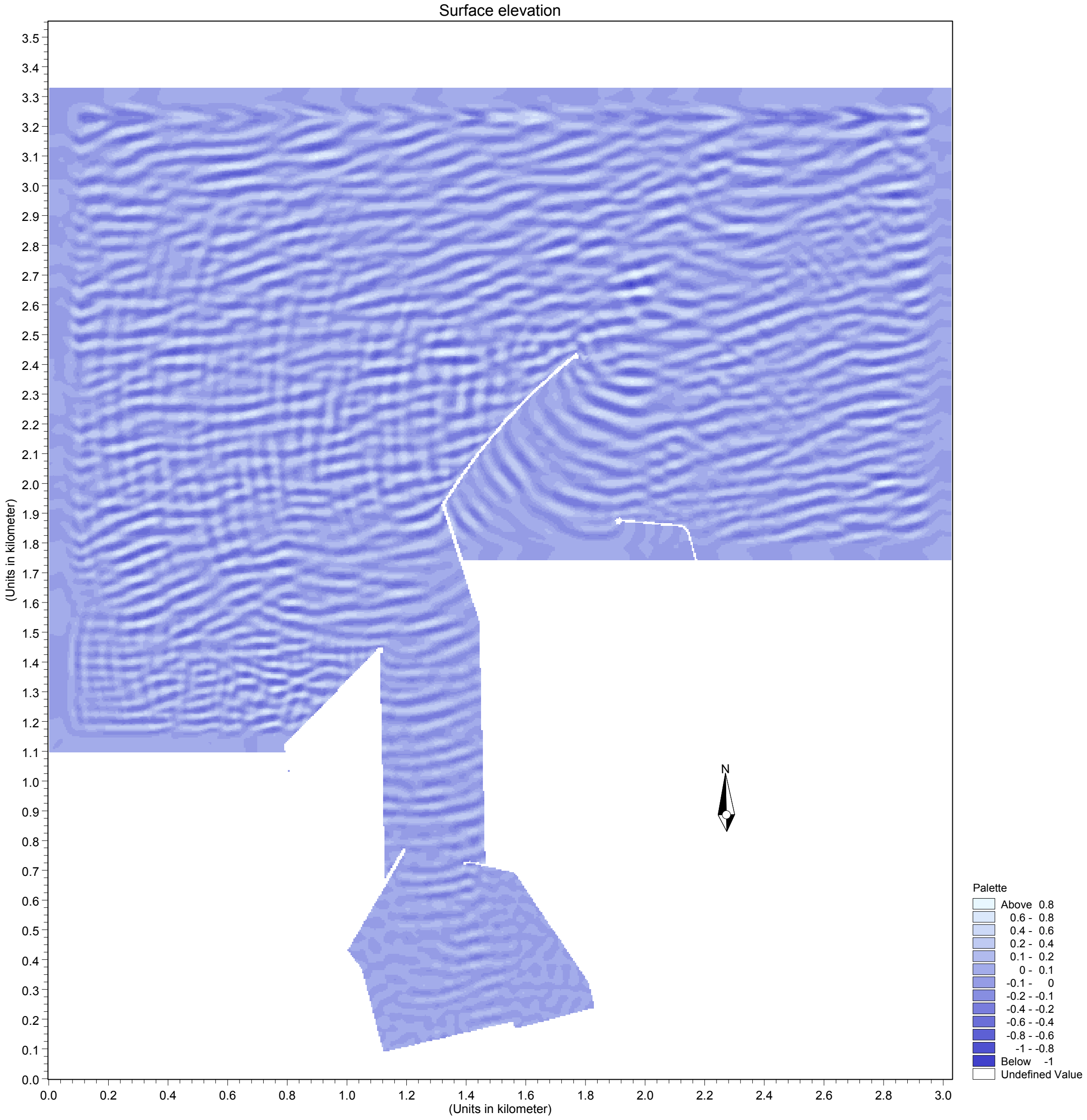
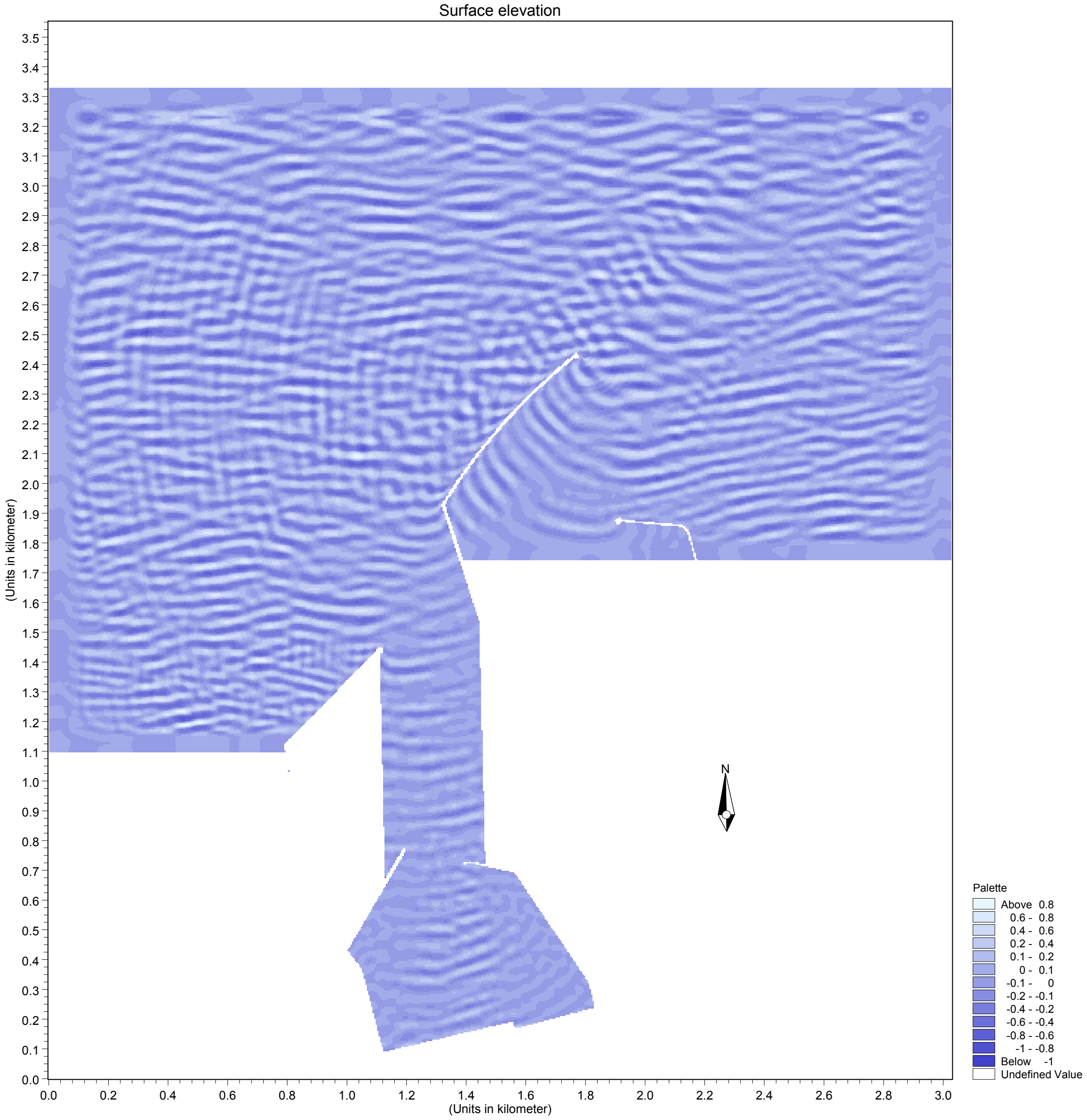


Instantaneous Surface Elevation 350º N



Instantaneous Surface Elevation 360º N

Annex XV
Current and Wave Patterns Used in the Shipma Simulation

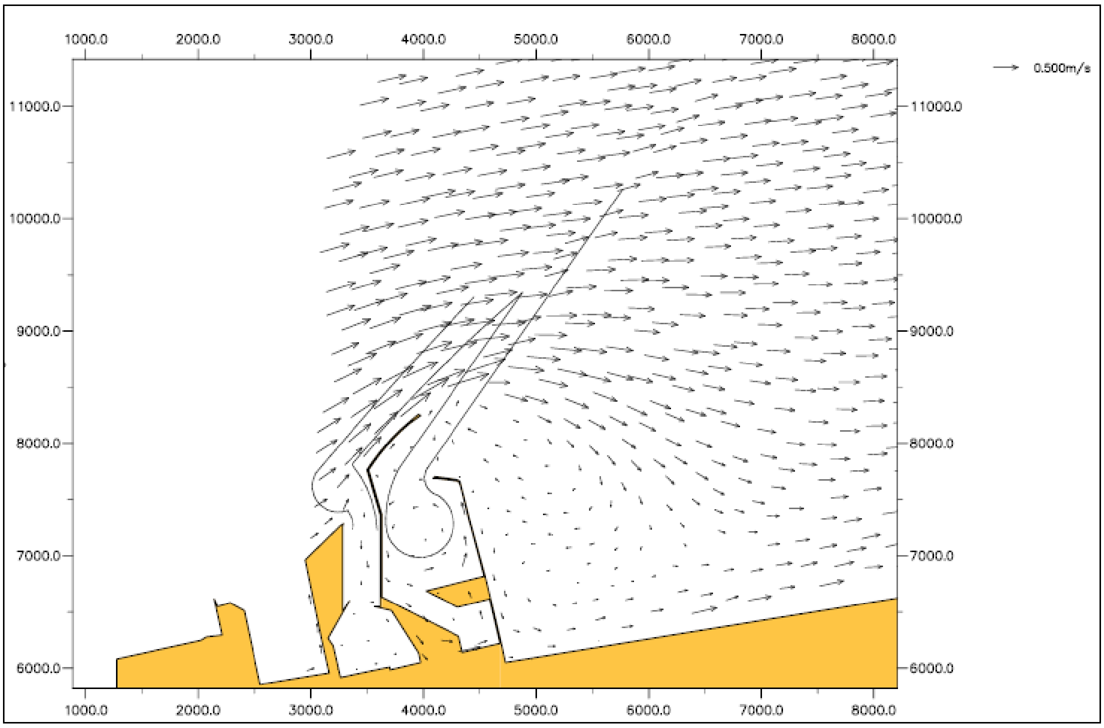


Figure XV-1: Current to the East with Factor 1

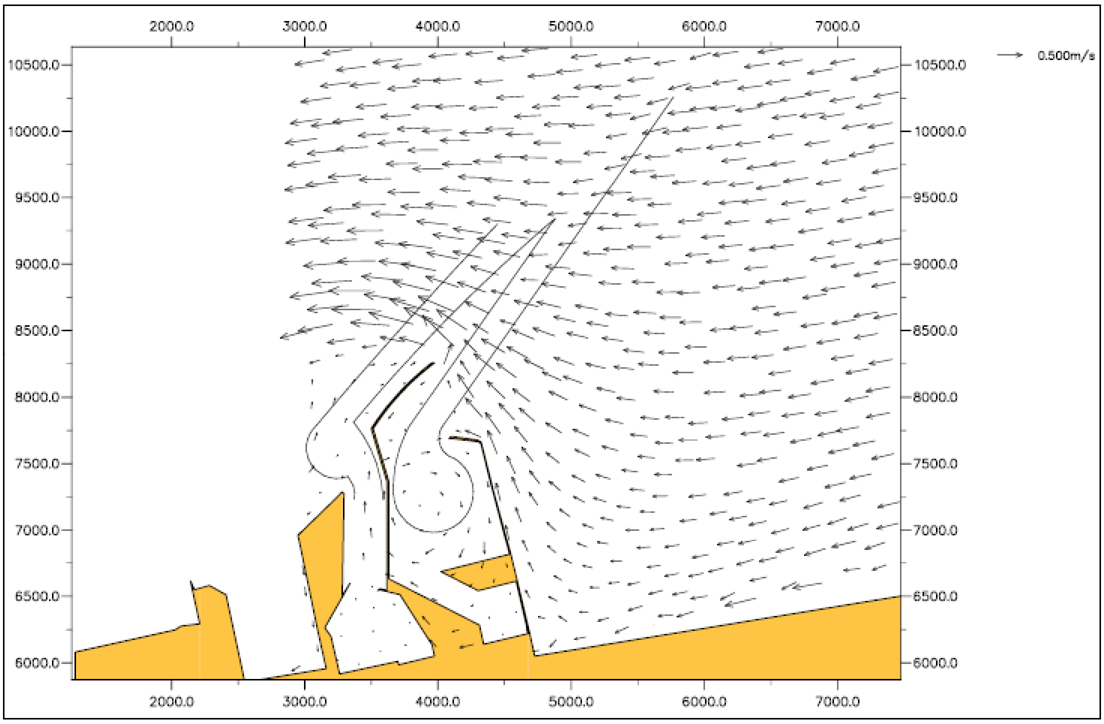


Figure XV-1: Current to the West with Factor 1

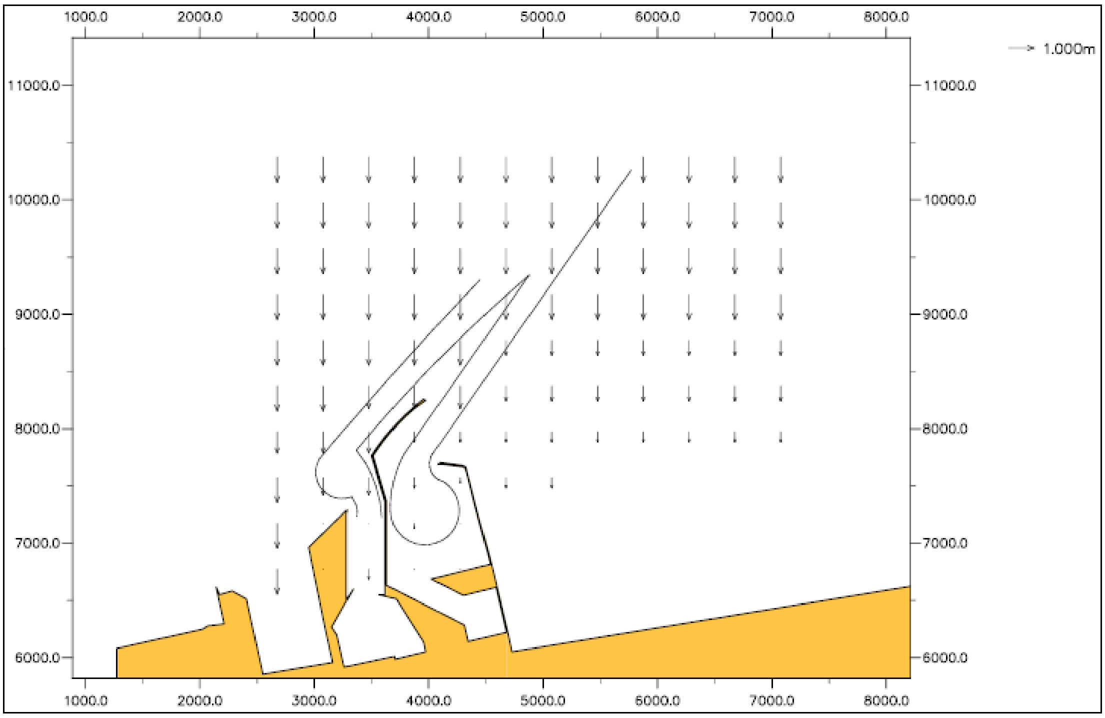


Figure XV-3: Waves from North with Factor 1

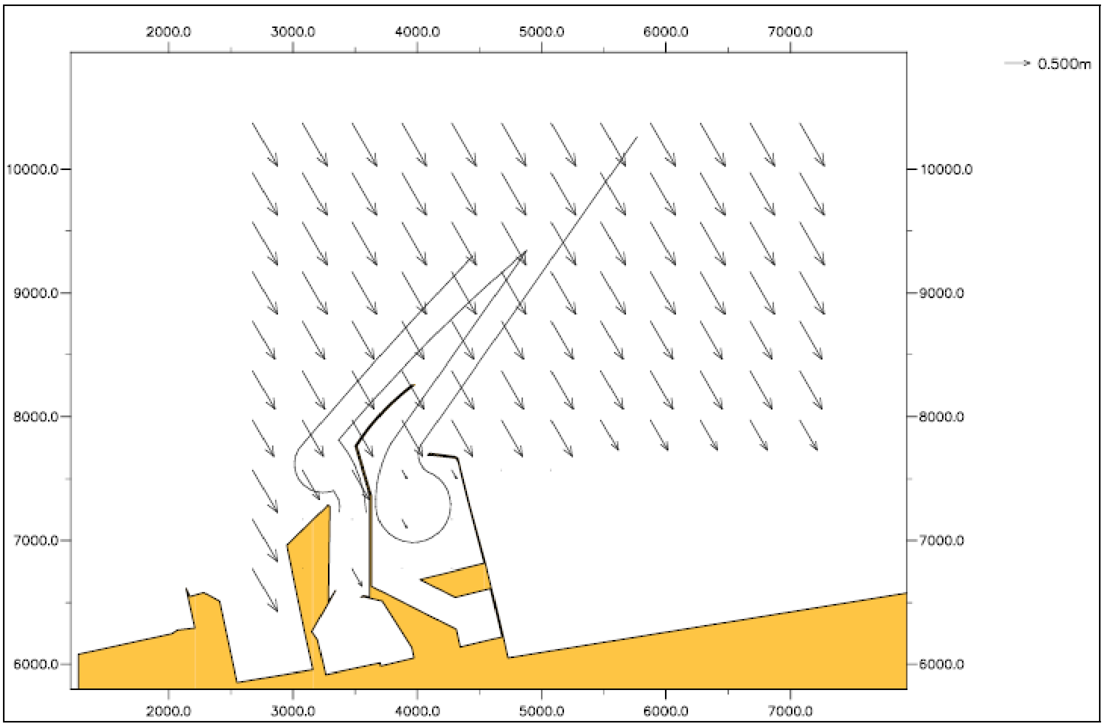


Figure XV-4: Waves from Northwest with Factor 1

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ROYAL HASKONING

Annex XVI
Autopilot Files Shipma

```
*************************************************************************
**       GENERAL INPUT DATA AND DESCRIPTION OF DESIRED MANOEUVRE        *
*************************************************************************
**                                                                      *
** FILE      : TBStopMiddle Guidelines.man                              *
** PROJECT   : Neka Harbour; separated port development                 *
** COMMENT   : Comparison Study                                         *
**                                                                      *
**                                                                      *
********************************* RH Rotterdam  ******** AUG 2006      **
**
**  Record 1 : Identification
**  Record 1a: Title                             Maximum = 70 characters
Neka Harbour, comparison Real Time - Fast Time Simulations
**
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 1b: Project identification            Maximum =  8 characters
Thesis RdeBree
**
**======================================================================
**
**  Record 2 : Composite Track
**  Record 2a:
**       Number of waypoints                                 Minimum = 3
3
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 2b: Track co-ordinates and trackradius                    [m]
**       Total number of co-ordinate pairs                  Minimum = 3
**       Specify the co-ordinates in the direction the ship sails
5685      10314      0.0
3852      7691       800.0
4046      6988       0.0
**
**======================================================================
**
**  Record 3 : Initial values
**  Record 3a:   0 = Equilibrium values calculated by SHIPMA
**               1 = Values specified by the user
0
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 3b: Initial values for the calculation. (if record 4a = 0)
**       x co-ordinate (in SHIPMA co-ordinate system)                [m]
**       y co-ordinate (in SHIPMA co-ordinate system)                [m]
**       Propeller revolutions                                     [1/s]
**   x       y      n
5685      10314     1.2
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 3c: Values specified by the user.     (if record 4a = 1)
**        X co-ordinate¦                                             [m]
**        Y co-ordinate¦ (in SHIPMA co-ordinate system)              [m]
**        Course angle ¦                                           [deg]
**        Rudder angle.                                            [deg]
**        Propeller revolutions.                                   [1/s]
**        Longitudinal velocity.                                   [m/s]
**        Transverse velocity.                                     [m/s]
**        Rate of turn.                                          [deg/s]
**   x     y    psi    d     n     u     v     r
**   0.    0.    0.    0.    0.    0.    0.    0.
**
**======================================================================
**
**  Record 4: Time-step.                                             [s]
**       Maximum number of time-steps.      Minimum = 2              [-]
3.0     5000
**
**======================================================================
**
**  Record 5: Stop criteria
```

```
**  Record 5a: Minimum forward speed for terminating the run        [m/s]
**       (value -99 means the criterium is not used)
0.1
**
**  Record 5b: Distance travelled relative to the start of the track  [m]
**       (negative value means the criterium is not used)
-6200
**
**  Record 5c: Maximum course deviation                              [deg]
**       (value 0.0 means the criterium is not used)
0.0
**
**  Record 5d: Minimum Under Keel Clearance                            [m]
**       (negative value means the criterium is not used)
-0.5
**
**=========================================================================
**
**  Record 6 Manoeuvre definition
**       The manoeuvre is defined along the specified track. More then
**       one manoeuvre section can be distinguished.
**                 For propeller revolution control.
**  Record 6a: Number of manoeuvre sections.        Minimum = 1      [-]
3
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**
**  Record 6b: Choice of velocity control
**       0 = Velocity defined by propeller revolutions [1/s]
**       1 = Velocity in [m/s]
0
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 6c: Manoeuvring description:
**  Start section [m] | Offset Course [deg] | RPS or Velocity | Pilotid
          0.0                0.0                   1.1             1
       1600.0                0.0                   0.8             2
       3200.0                0.0                  -0.9             3
**
**=========================================================================
**
**  Record 7: Kind of manoeuvre/Specification of the autopilot(s)
**       1 = Track keeping.    (specify record 7.1)
**       2 = Turning circle.   (specify record 7.2)
**       3 = Zig-zag.          (specify record 7.3)
1
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 7.1: Autopilot(s) for track keeping          (if record 7 = 1)
**  Record 8.1a: Number of Autopilots (Nauto)     (Maximum=15)       [-]
4
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 8.1b: Autopilotsettings (Nauto times)
**  Autopilot id
1
**  Choice Manoeuvring Devices
**  Rudder | Powerburst | Propeller | Thrusters | Tugs          [0-100%]
     100        0          100           0       0
**  Anticipation Length expressed in ship's length.                  [-]
1.5
**  Autopilot Coeff's X-dir (1)                                      [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                      [-]
1.0  0.05  0.1  0.05  0.05
**  Autopilot Coeff's N-dir (5)                                      [-]
1.0  0.05  0.1  0.05  0.05
**
**  Autopilot id
2
**  Choice Manoeuvring Devices
**  Rudder | Powerburst | Propeller | Thrusters | Tugs          [0-100%]
```

```
     100         100           100         0       0
**  Anticipation Length expressed in ship's length.                        [-]
1.0
**  Autopilot Coeff's X-dir (1)                                            [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                            [-]
1.0  0.05  0.1  0.05  0.05
**  Autopilot Coeff's N-dir (5)                                            [-]
1.0  0.05  0.1  0.05  0.05
**
**  Autopilot id
3
**  Choice Manoeuvring Devices
**  Rudder | Powerburst | Propeller | Thrusters | Tugs          [0-100%]
     100         100          50          100       100
**  Anticipation Length expressed in ship's length.                        [-]
0.7
**  Autopilot Coeff's X-dir (1)                                            [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                            [-]
1.0  0.05  0.1  0.05  0.05
**  Autopilot Coeff's N-dir (5)                                            [-]
1.0  0.05  0.1  0.05  0.05
**
**  Autopilot id
4
**  Choice Manoeuvring Devices
**  Rudder | Powerburst | Propeller | Thrusters | Tugs          [0-100%]
     100         50          30           100       100
**  Anticipation Length expressed in ship's length.                        [-]
0.5
**  Autopilot Coeff's X-dir (1)                                            [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                            [-]
1.0  0.1  0.4  0.075  0.075
**  Autopilot Coeff's N-dir (5)                                            [-]
1.0  0.1  0.2  0.075  0.075
**
**
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**
**  Record 7.2: Turning circle manoeuvre.        (if record 7 = 2)
**       Start time of manoeuvre.                                          [s]
**       Rudder angle. *)                                                [deg]
**       Desired turn angle to return rudder.                            [deg]
**0.  -20.    360.
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 7.3: Zig-zag manoeuvre.               (if record 7 = 3)
**       Start time of manoeuvre.                                          [s]
**       Rudder angle. *)                                                [deg]
**       Execute angle.                                                  [deg]
**0.    20.    20.
**  *) Value must be less or equal to the maximum value in the .SHP file
**
**===========================================================================
**  Record 8: Tug info
**
**  Bollard Definition:
**                 1
**             <--/\-->
**        8 --> /  \ <-- 2
**             |    |
**             |    |
**        7 -->|    |<-- 3
**             |    |
**             |    |
**        6 -->|    |<-- 4
**            <--\__/-->
```

```
**                  5
**
**     Tugtype definition: (Conventional=1, ASD=2, Voith-Schneider=3)
**     Assisting Mode    : (Pull=1, Push=2)
**     Bollard pull                                                     [N]
**
** Boll-id  Tugtype  Assisting-Mode  Bollard-Pull
     1        3            1             44E4
     2        1            1              0E4
     3        1            1              0E4
     4        1            1              0E4
     5        3            1             44E4
     6        1            1              0E4
     7        1            1              0E4
     8        1            1              0E4
**========================================================================
```

```
*************************************************************************
**       GENERAL INPUT DATA AND DESCRIPTION OF DESIRED MANOEUVRE       *
*************************************************************************
**                                                                      *
** FILE      : TBStopMiddle Guidelines.man                              *
** PROJECT   : Neka Harbour; separated port development                 *
** COMMENT   : Comparison Study                                         *
**                                                                      *
**                                                                      *
********************************* RH Rotterdam  ******** AUG 2006      **
**
**  Record 1 : Identification
**  Record 1a: Title                              Maximum = 70 characters
Neka Harbour, comparison Real Time - Fast Time Simulations
**
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 1b: Project identification             Maximum =  8 characters
Thesis RdeBree
**
**======================================================================
**
**  Record 2 : Composite Track
**  Record 2a:
**       Number of waypoints                                  Minimum = 3
3
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 2b: Track co-ordinates and trackradius                     [m]
**       Total number of co-ordinate pairs                   Minimum = 3
**       Specify the co-ordinates in the direction the ship sails
6992      11637      0.0
3246      7825       800
3224      7415       0.0
**
**======================================================================
**
**  Record 3 : Initial values
**  Record 3a:   0 = Equilibrium values calculated by SHIPMA
**               1 = Values specified by the user
0
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 3b: Initial values for the calculation. (if record 4a = 0)
**       x co-ordinate (in SHIPMA co-ordinate system)                 [m]
**       y co-ordinate (in SHIPMA co-ordinate system)                 [m]
**       Propeller revolutions                                      [1/s]
**   x       y       n
6992      11637     1.1
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 3c: Values specified by the user.     (if record 4a = 1)
**        X co-ordinate¦                                              [m]
**        Y co-ordinate¦ (in SHIPMA co-ordinate system)               [m]
**        Course angle ¦                                            [deg]
**        Rudder angle.                                             [deg]
**        Propeller revolutions.                                    [1/s]
**        Longitudinal velocity.                                    [m/s]
**        Transverse velocity.                                      [m/s]
**        Rate of turn.                                           [deg/s]
**   x     y    psi    d     n     u     v     r
**   0.    0.    0.    0.    0.    0.    0.    0.
**
**======================================================================
**
**  Record 4: Time-step.                                              [s]
**       Maximum number of time-steps.      Minimum = 2               [-]
3.0     5000
**
**======================================================================
**
**  Record 5: Stop criteria
```

```
**  Record 5a: Minimum forward speed for terminating the run        [m/s]
**       (value -99 means the criterium is not used)
0.1
**
**  Record 5b: Distance travelled relative to the start of the track  [m]
**       (negative value means the criterium is not used)
-6200
**
**  Record 5c: Maximum course deviation                             [deg]
**       (value 0.0 means the criterium is not used)
0.0
**
**  Record 5d: Minimum Under Keel Clearance                           [m]
**       (negative value means the criterium is not used)
-0.5
**
**=====================================================================
**
**  Record 6 Manoeuvre definition
**       The manoeuvre is defined along the specified track. More then
**       one manoeuvre section can be distinguished.
**                 For propeller revolution control.
**  Record 6a: Number of manoeuvre sections.        Minimum = 1      [-]
4
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**
**  Record 6b: Choice of velocity control
**       0 = Velocity defined by propeller revolutions [1/s]
**       1 = Velocity in [m/s]
0
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 6c: Manoeuvring description:
**  Start section [m] | Offset Course [deg] | RPS or Velocity | Pilotid
        0.0                  0.0                  1.1            1
       2350.0                0.0                  1.0            1
       3650.0                0.0                  0.7            2
       5250.0                0.0                 -0.9            3
**
**=====================================================================
**
**  Record 7: Kind of manoeuvre/Specification of the autopilot(s)
**       1 = Track keeping.    (specify record 7.1)
**       2 = Turning circle.   (specify record 7.2)
**       3 = Zig-zag.          (specify record 7.3)
1
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 7.1: Autopilot(s) for track keeping          (if record 7 = 1)
**  Record 8.1a: Number of Autopilots (Nauto)     (Maximum=15)       [-]
4
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 8.1b: Autopilotsettings (Nauto times)
**  Autopilot id
1
**  Choice Manoeuvring Devices
**  Rudder | Powerburst | Propeller | Thrusters | Tugs          [0-100%]
     100        0          100           0       0
**  Anticipation Length expressed in ship's length.                  [-]
1.0
**  Autopilot Coeff's X-dir (1)                                      [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                      [-]
1.0  0.05  0.1  0.05  0.05
**  Autopilot Coeff's N-dir (5)                                      [-]
1.0  0.05  0.1  0.05  0.05
**
**  Autopilot id
2
**  Choice Manoeuvring Devices
```

```
**  Rudder | Powerburst | Propeller | Thrusters | Tugs           [0-100%]
     100        100           100          0       0
**  Anticipation Length expressed in ship's length.                   [-]
0.7
**  Autopilot Coeff's X-dir (1)                                       [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                       [-]
1.0  0.05  0.1  0.05  0.05
**  Autopilot Coeff's N-dir (5)                                       [-]
1.0  0.05  0.1  0.05  0.05
**
**  Autopilot id
3
**  Choice Manoeuvring Devices
**  Rudder | Powerburst | Propeller | Thrusters | Tugs           [0-100%]
     100        100           50          100       100
**  Anticipation Length expressed in ship's length.                   [-]
0.5
**  Autopilot Coeff's X-dir (1)                                       [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                       [-]
1.0  0.05  0.1  0.05  0.05
**  Autopilot Coeff's N-dir (5)                                       [-]
1.0  0.05  0.1  0.05  0.05
**
**  Autopilot id
4
**  Choice Manoeuvring Devices
**  Rudder | Powerburst | Propeller | Thrusters | Tugs           [0-100%]
     100        50           30           100       100
**  Anticipation Length expressed in ship's length.                   [-]
0.5
**  Autopilot Coeff's X-dir (1)                                       [-]
1.0
**  Autopilot Coeff's Y-dir (5)                                       [-]
1.0  0.1  0.4  0.075  0.075
**  Autopilot Coeff's N-dir (5)                                       [-]
1.0  0.1  0.2  0.075  0.075
**
**
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**
**  Record 7.2: Turning circle manoeuvre.        (if record 7 = 2)
**       Start time of manoeuvre.                                     [s]
**       Rudder angle. *)                                           [deg]
**       Desired turn angle to return rudder.                       [deg]
**0.  -20.    360.
**- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
**  Record 7.3: Zig-zag manoeuvre.               (if record 7 = 3)
**       Start time of manoeuvre.                                     [s]
**       Rudder angle. *)                                           [deg]
**       Execute angle.                                             [deg]
**0.    20.    20.
**  *) Value must be less or equal to the maximum value in the .SHP file
**
**=========================================================================
**  Record 8: Tug info
**
**  Bollard Definition:
**                 1
**             <--/\-->
**        8 --> /  \ <-- 2
**             |    |
**             |    |
**        7 -->|    |<-- 3
**             |    |
**             |    |
**        6 -->|    |<-- 4
```

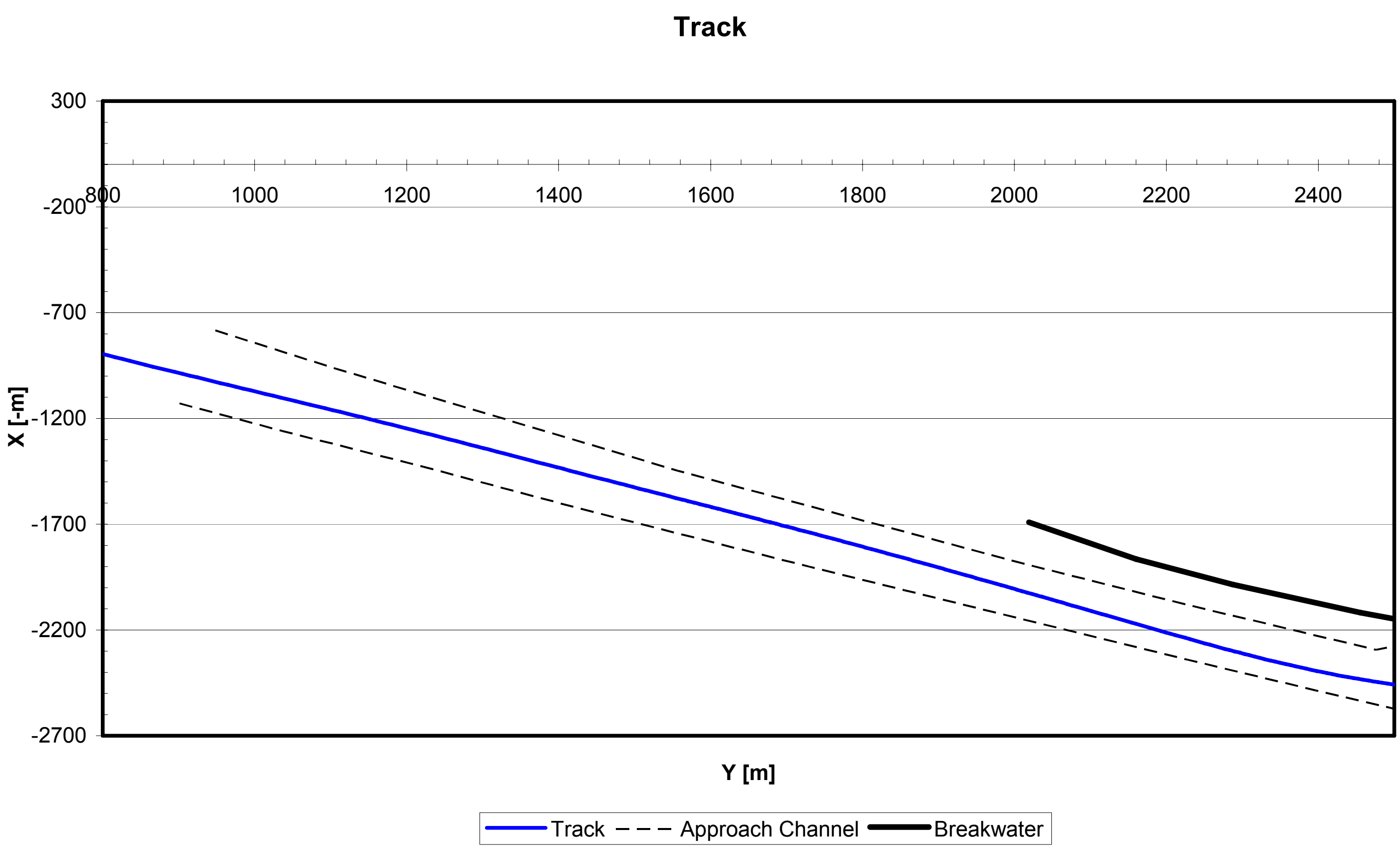
```
**              <--\__/-->
**                  5
**
**     Tugtype definition: (Conventional=1, ASD=2, Voith-Schneider=3)
**     Assisting Mode    : (Pull=1, Push=2)
**     Bollard pull                                                   [N]
**
** Boll-id  Tugtype  Assisting-Mode  Bollard-Pull
     1        3           1            44E4
     2        1           1             0E4
     3        1           1             0E4
     4        1           1             0E4
     5        3           1            44E4
     6        1           1             0E4
     7        1           1             0E4
     8        1           1             0E4
**=======================================================================
```

Delft University of Technology

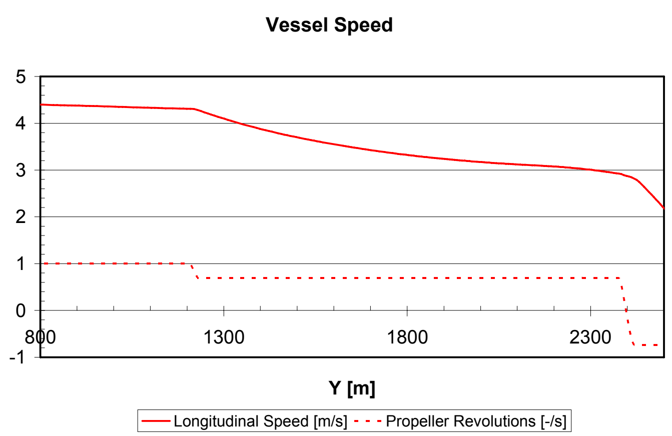
ROYAL HASKONING

Annex XVII
Shipma Runs SADRA Basin

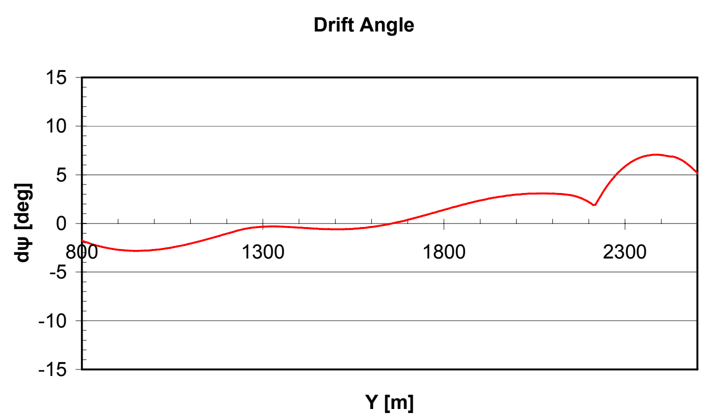
SADRA Run 1



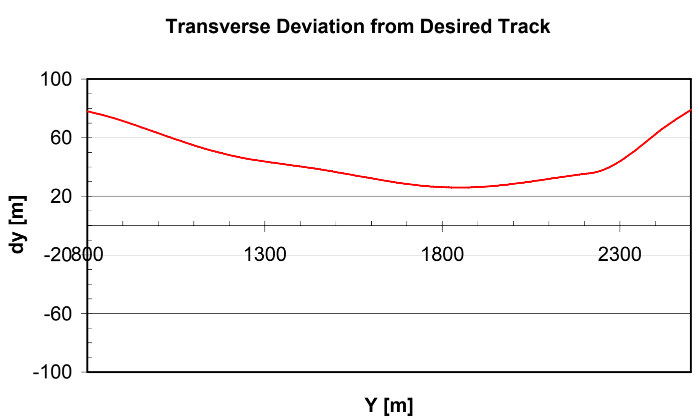
Track
300
-200
-700
-1200
-1700
-2200
-2700
800
1000
1200
1400
1600
1800
2000
2200
2400
X [-m]
Y [m]
Track
Approach Channel
Breakwater



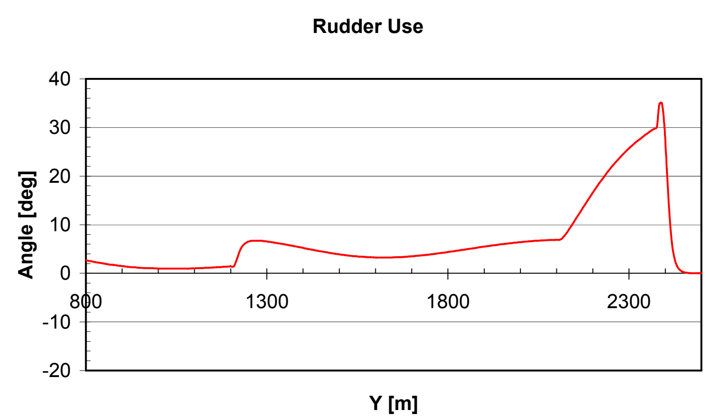
Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
800
1300
1800
2300
dψ [deg]
Y [m]

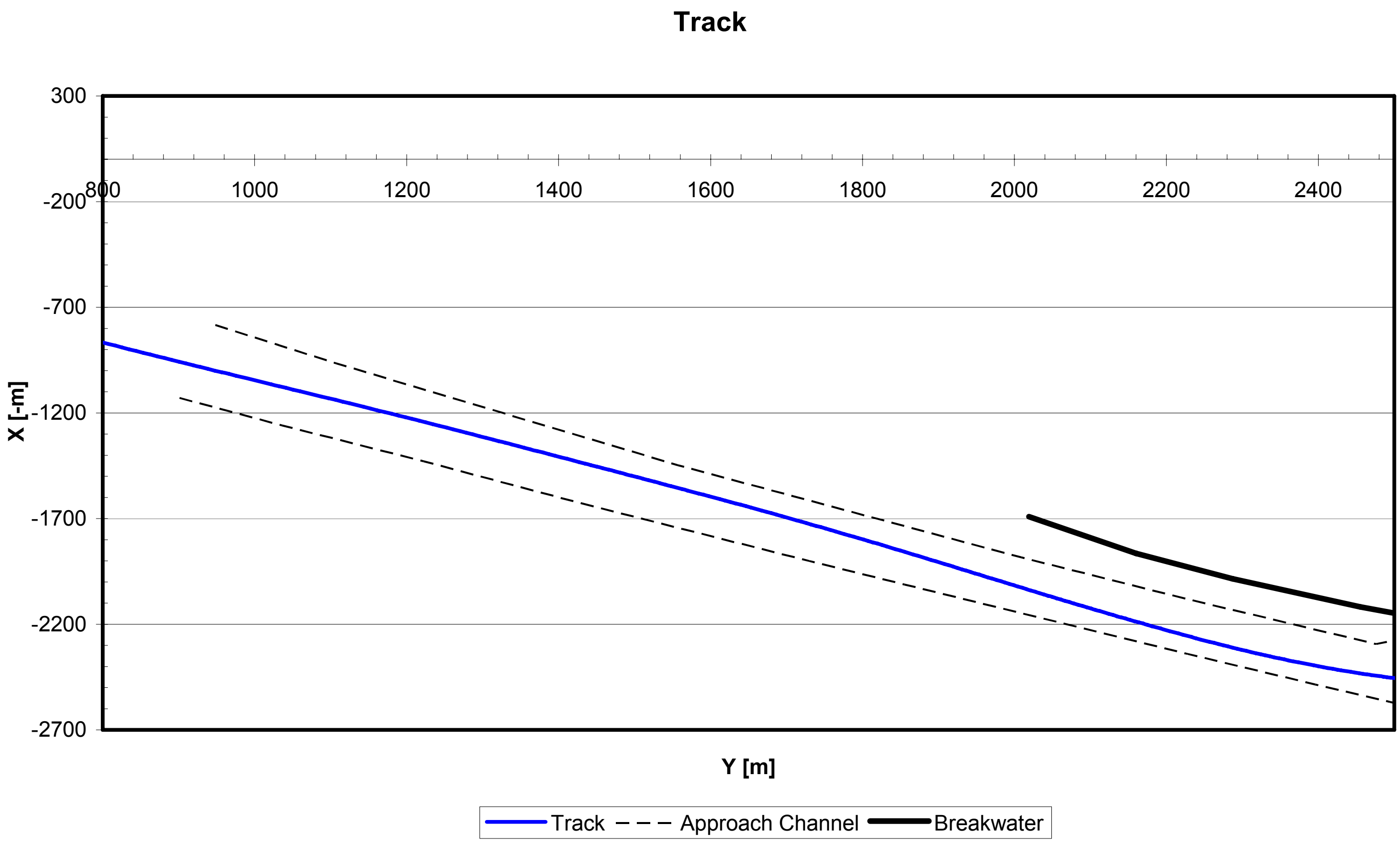


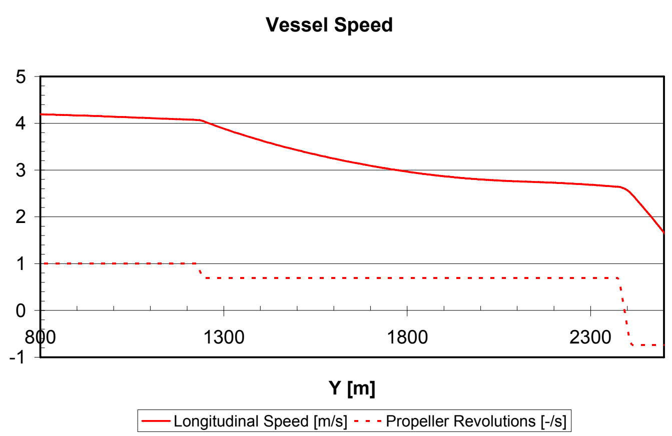
Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
800
1300
1800
2300
dy [m]
Y [m]

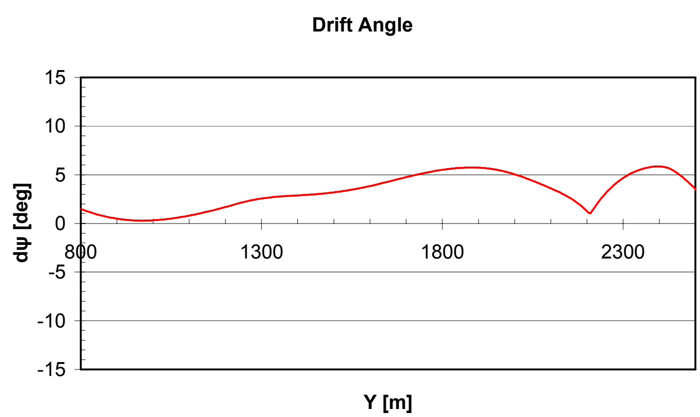


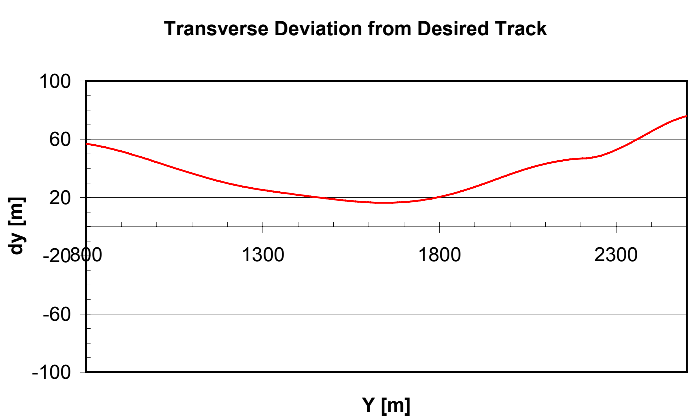
Rudder Use
40
30
20
10
0
-10
-20
800
1300
1800
2300
Angle [deg]
Y [m]

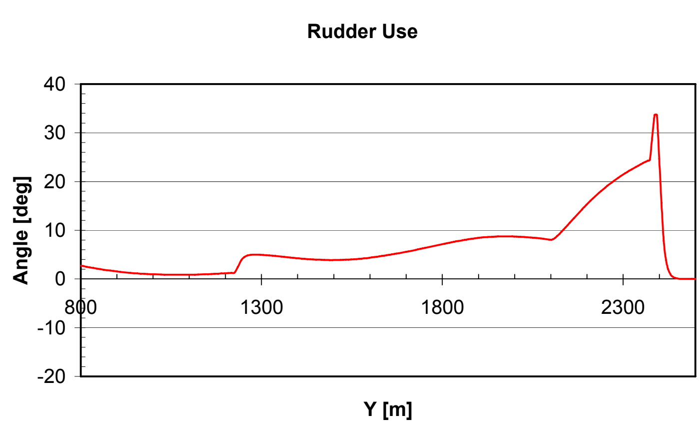
SADRA Run 2


Track
300
-200
-700
-1200
-1700
-2200
-2700
800
1000
1200
1400
1600
1800
2000
2200
2400
X [-m]
Y [m]
Track
Approach Channel
Breakwater


Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]

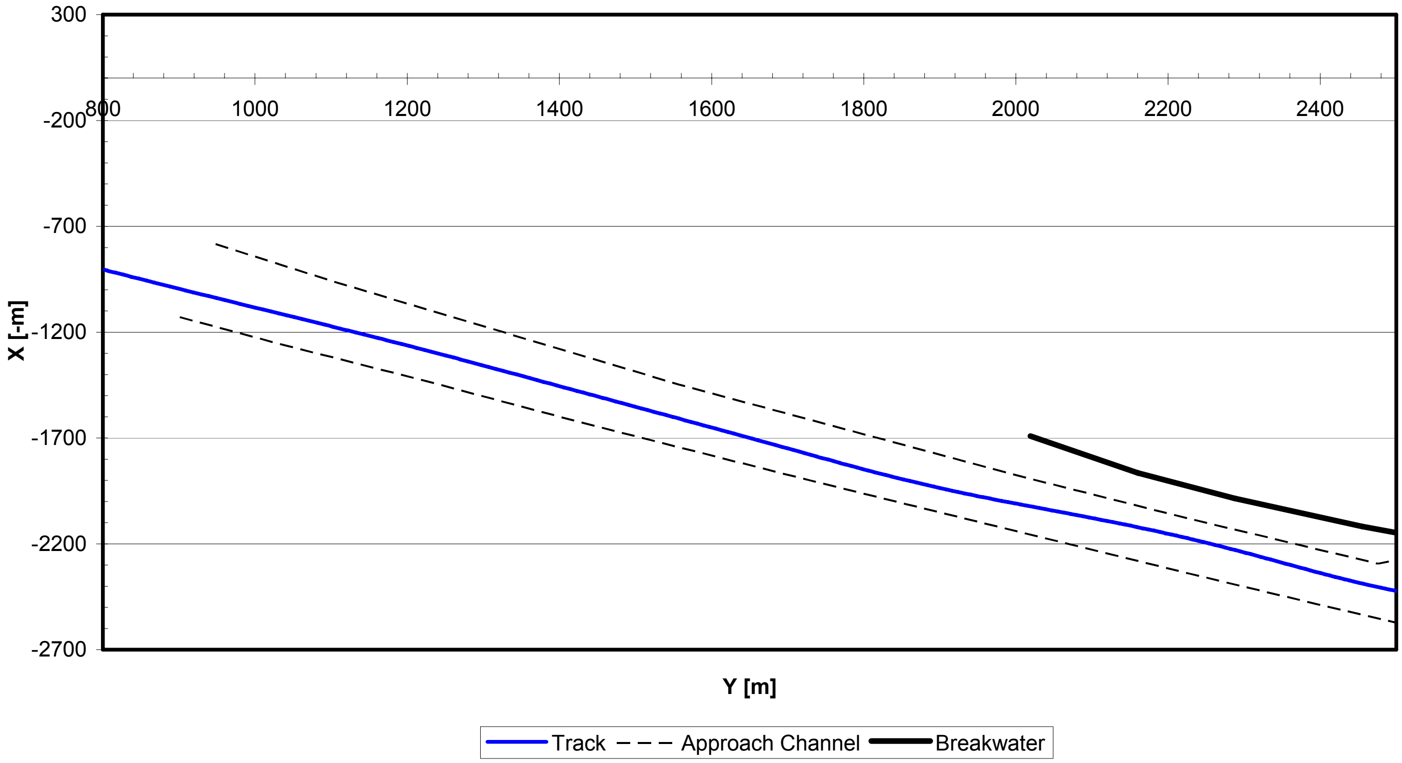

Drift Angle
15
10
5
0
-5
-10
-15
800
1300
1800
2300
dψ [deg]
Y [m]


Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
800
1300
1800
2300
dy [m]
Y [m]

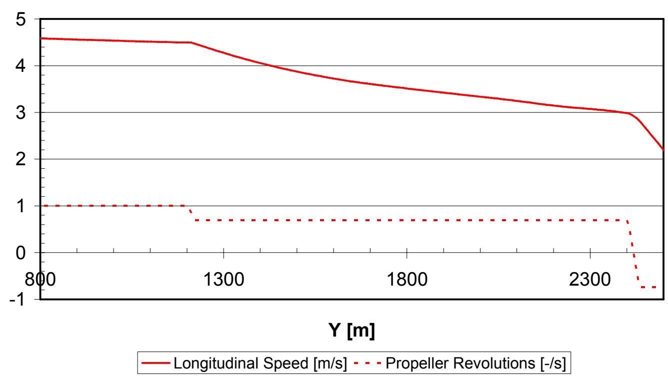

Rudder Use
40
30
20
10
0
-10
-20
800
1300
1800
2300
Angle [deg]
Y [m]

SADRA Run 3

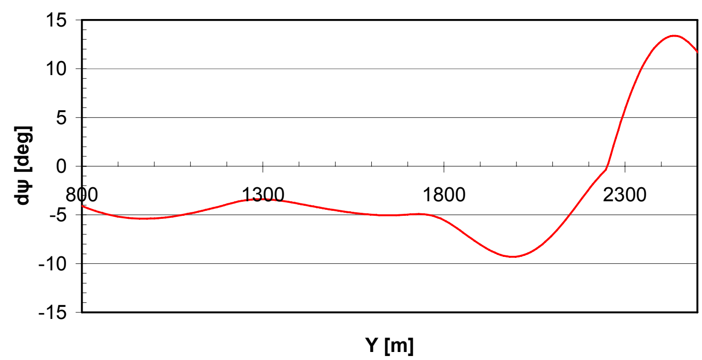
Track



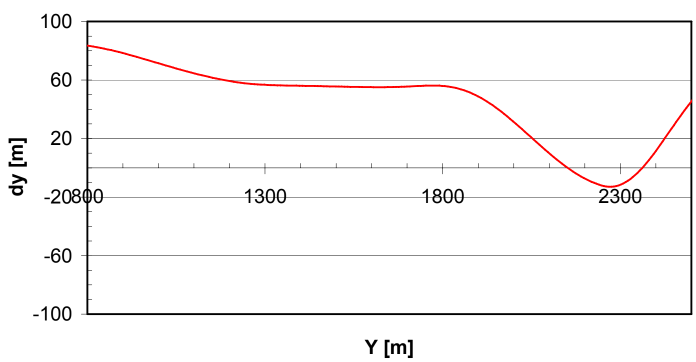
Vessel Speed



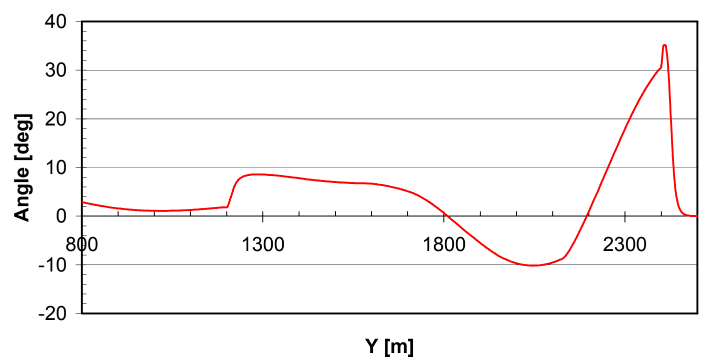
Drift Angle



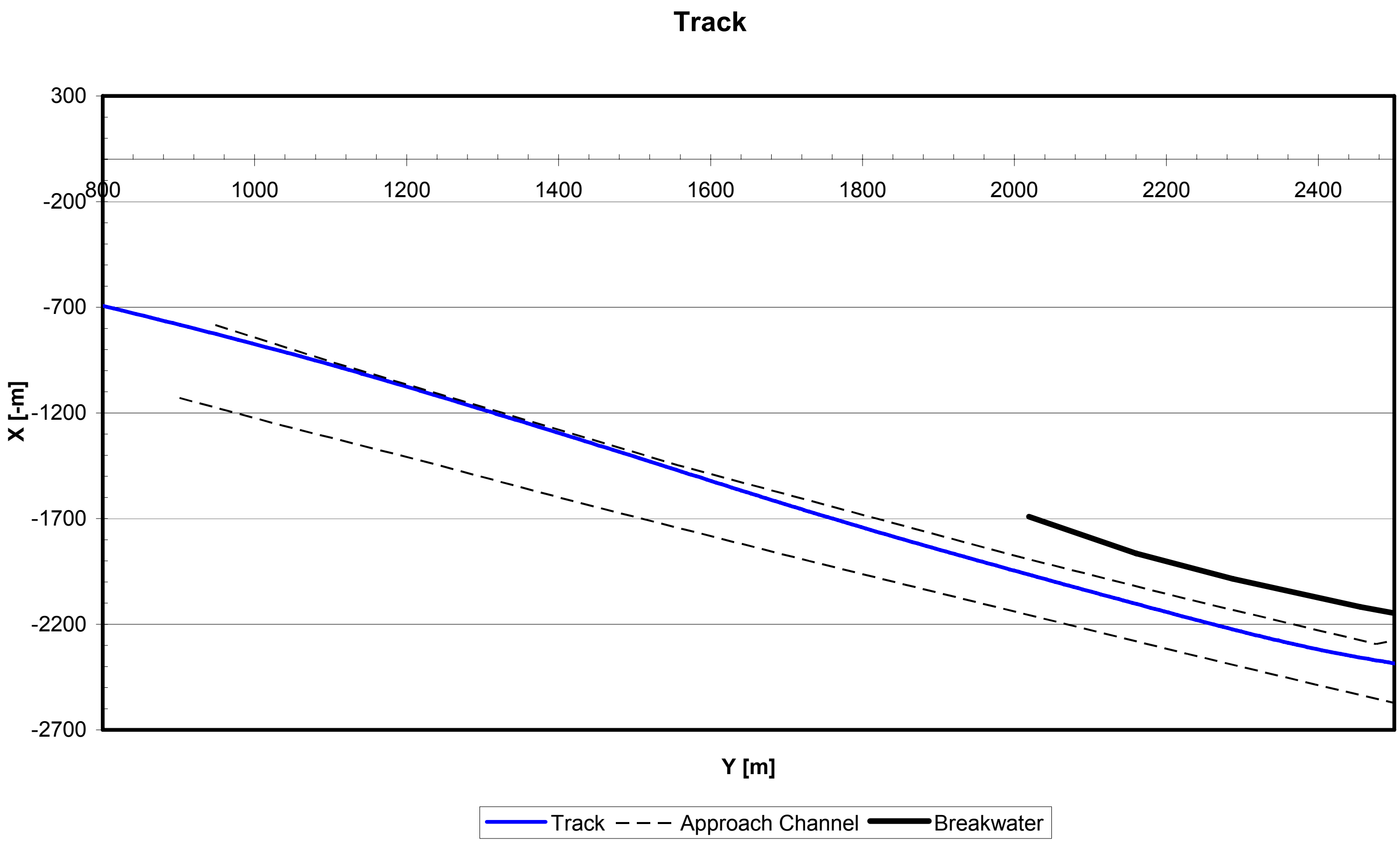
Transverse Deviation from Desired Track



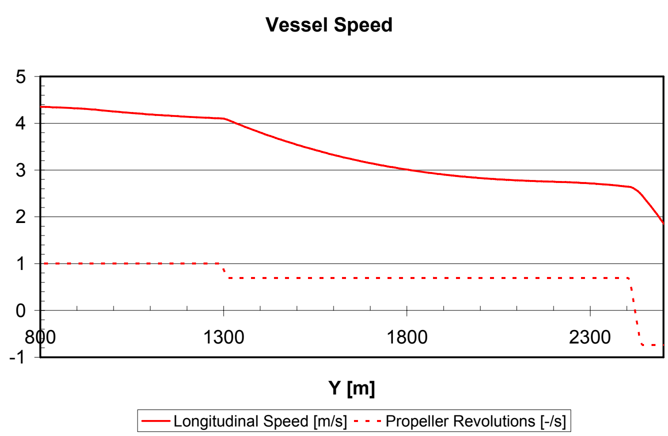
Rudder Use



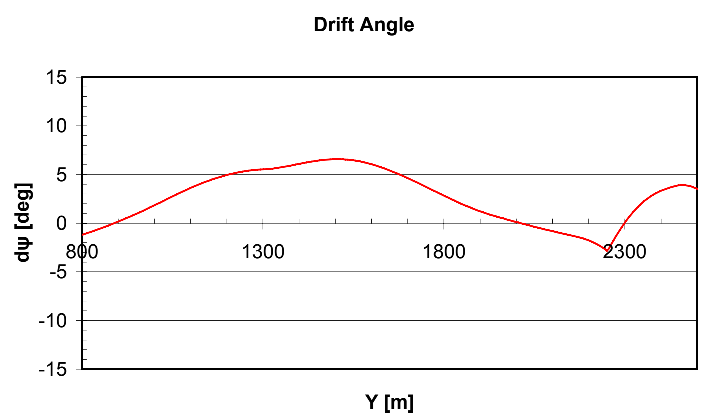
SADRA Run 4



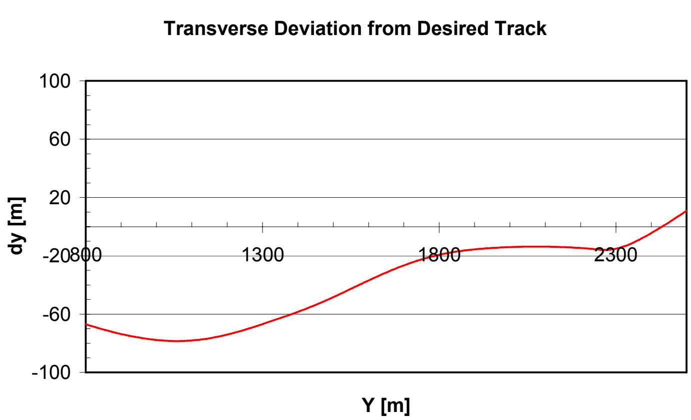
Track
300
-200
-700
-1200
-1700
-2200
-2700
800
1000
1200
1400
1600
1800
2000
2200
2400
X [-m]
Y [m]
Track
Approach Channel
Breakwater



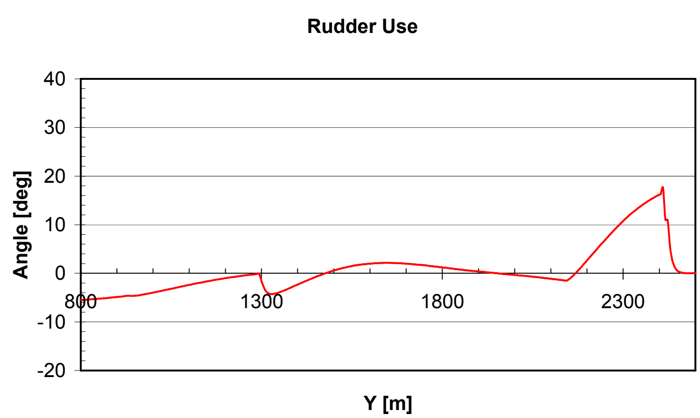
Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
800
1300
1800
2300
dψ [deg]
Y [m]

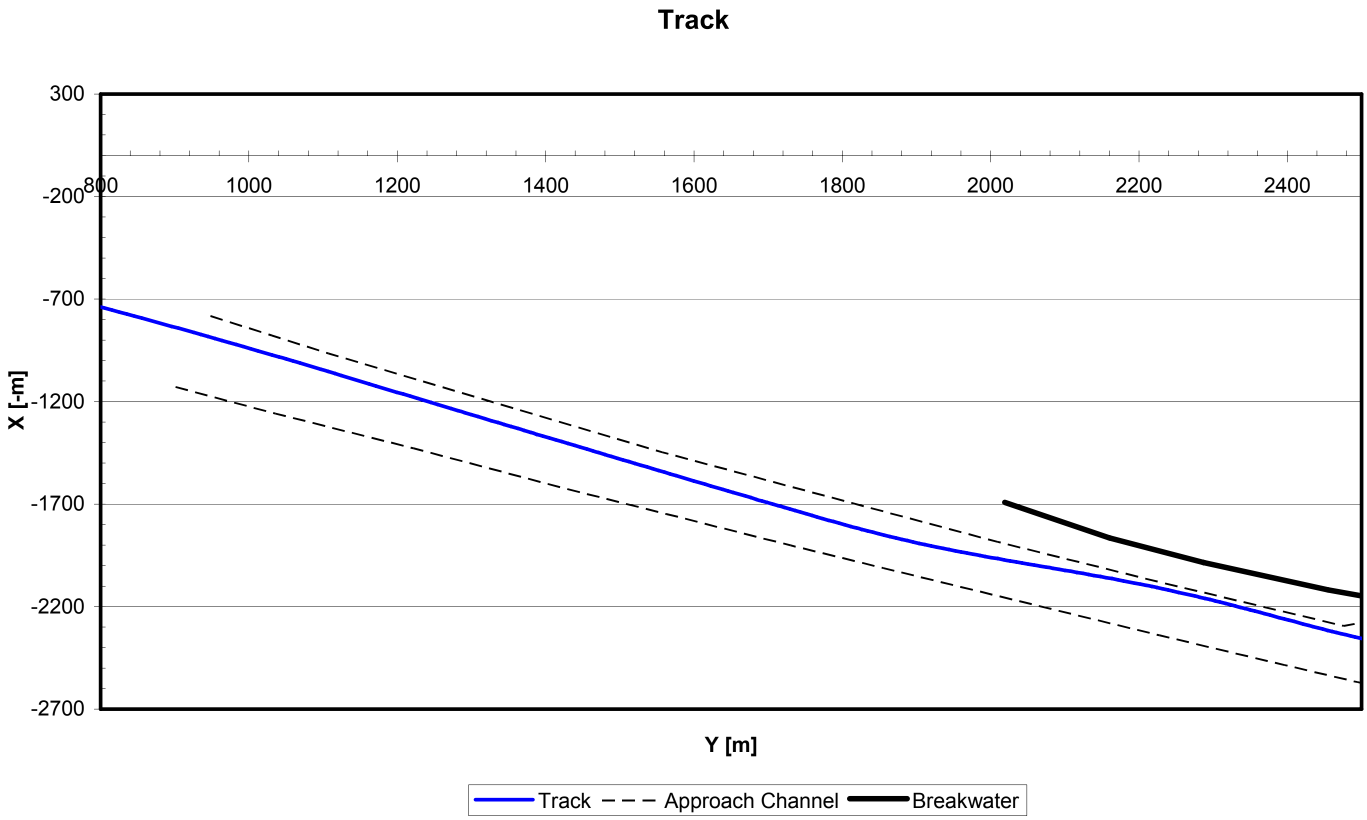


Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
800
1300
1800
2300
dy [m]
Y [m]

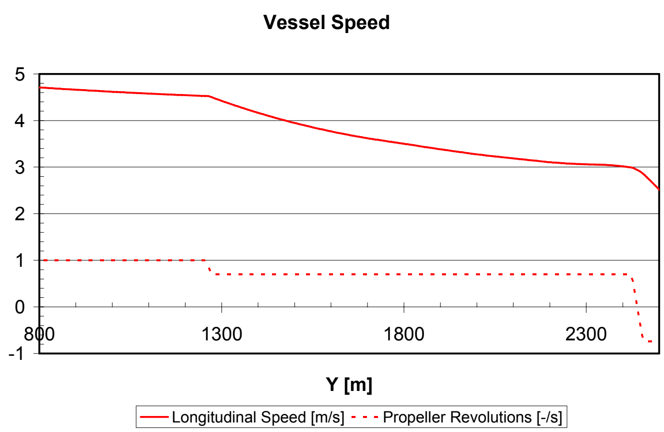


Rudder Use
40
30
20
10
0
-10
-20
800
1300
1800
2300
Angle [deg]
Y [m]

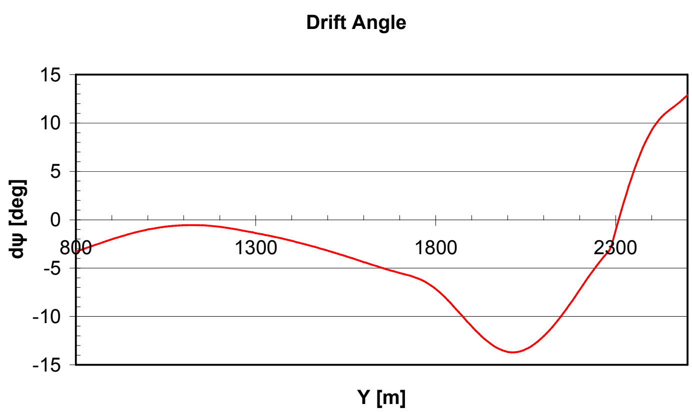
SADRA Run 5



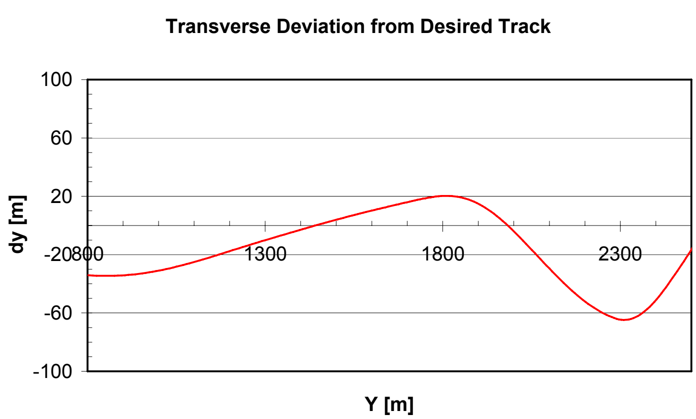
Track
300
-200
-700
-1200
-1700
-2200
-2700
X [-m]
800
1000
1200
1400
1600
1800
2000
2200
2400
Y [m]
Track
Approach Channel
Breakwater



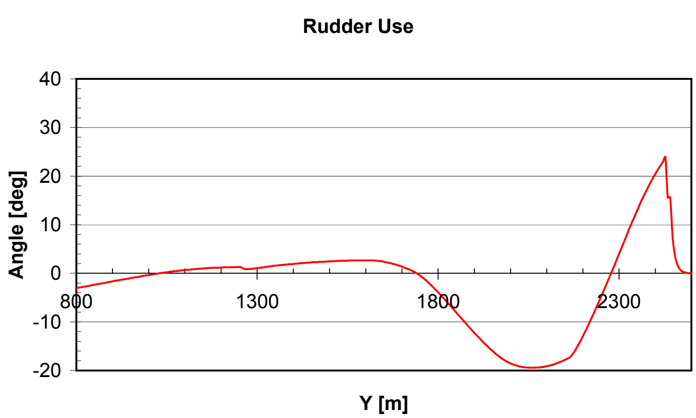
Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
dψ [deg]
800
1300
1800
2300
Y [m]

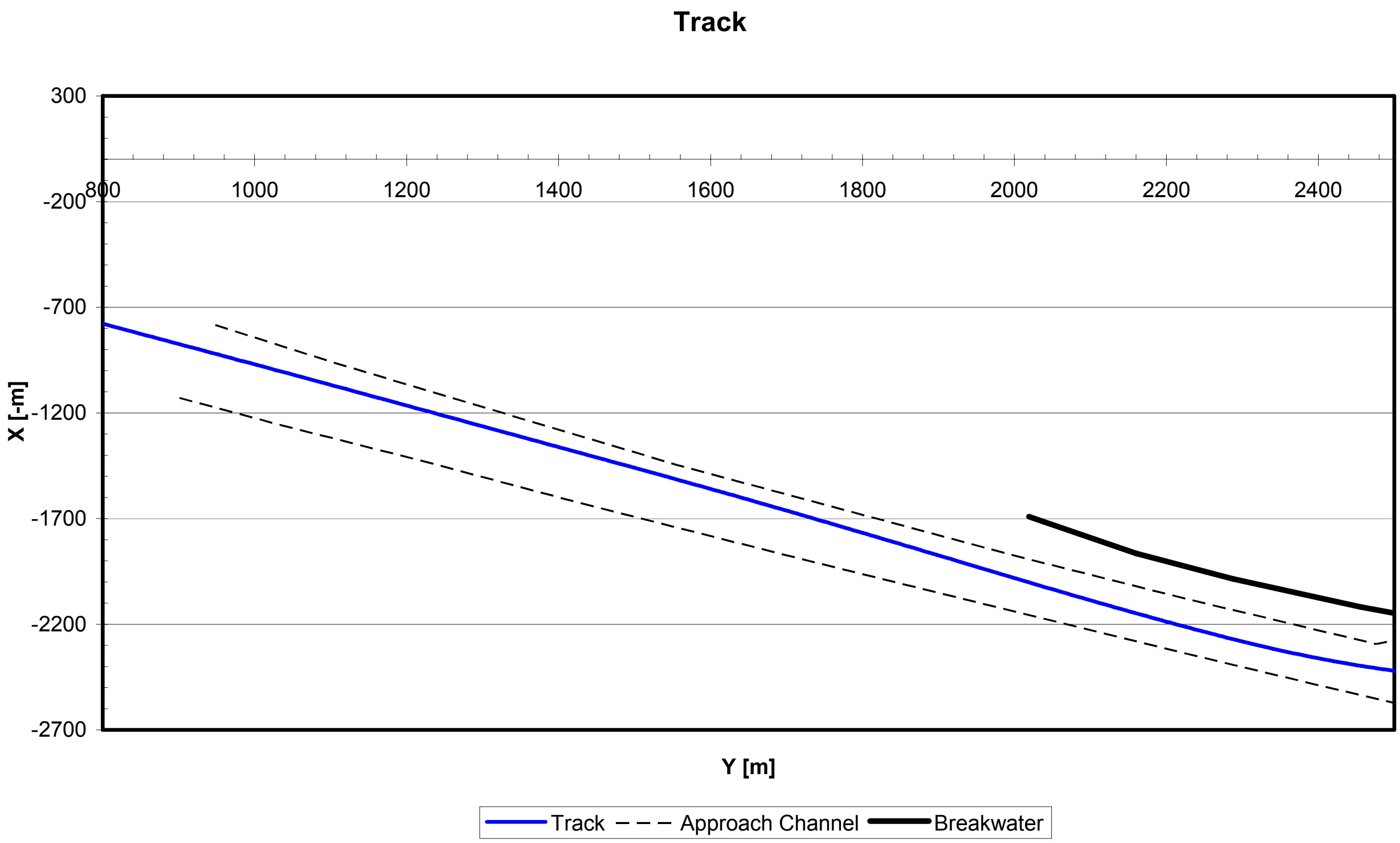


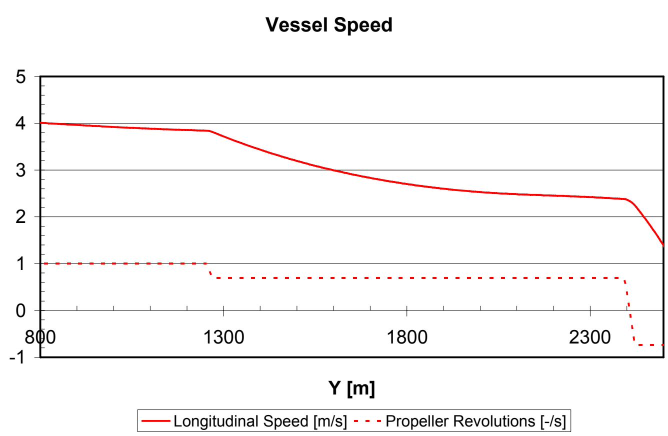
Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
dy [m]
800
1300
1800
2300
Y [m]

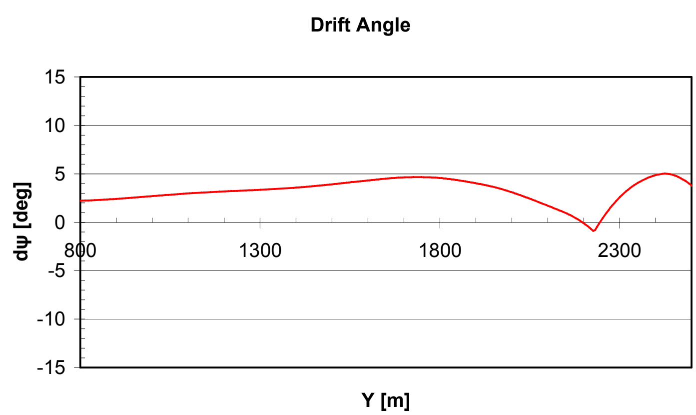


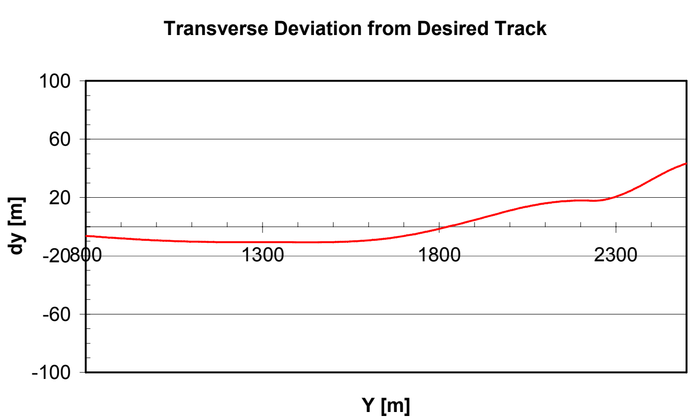
Rudder Use
40
30
20
10
0
-10
-20
Angle [deg]
800
1300
1800
2300
Y [m]

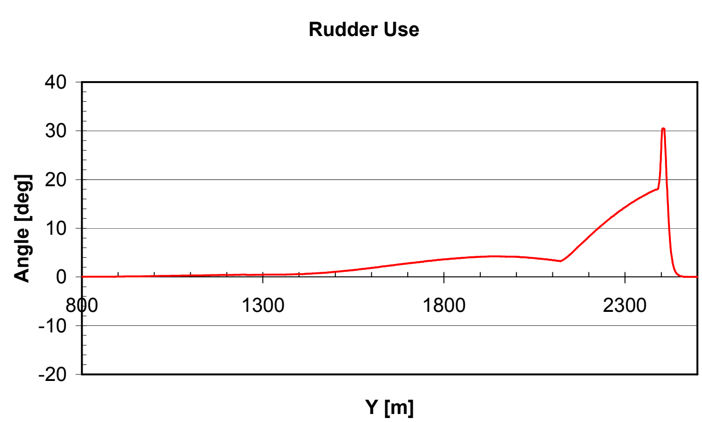
SADRA Run 6


Track
300
-200
-700
-1200
-1700
-2200
-2700
X [-m]
800
1000
1200
1400
1600
1800
2000
2200
2400
Y [m]
Track
Approach Channel
Breakwater

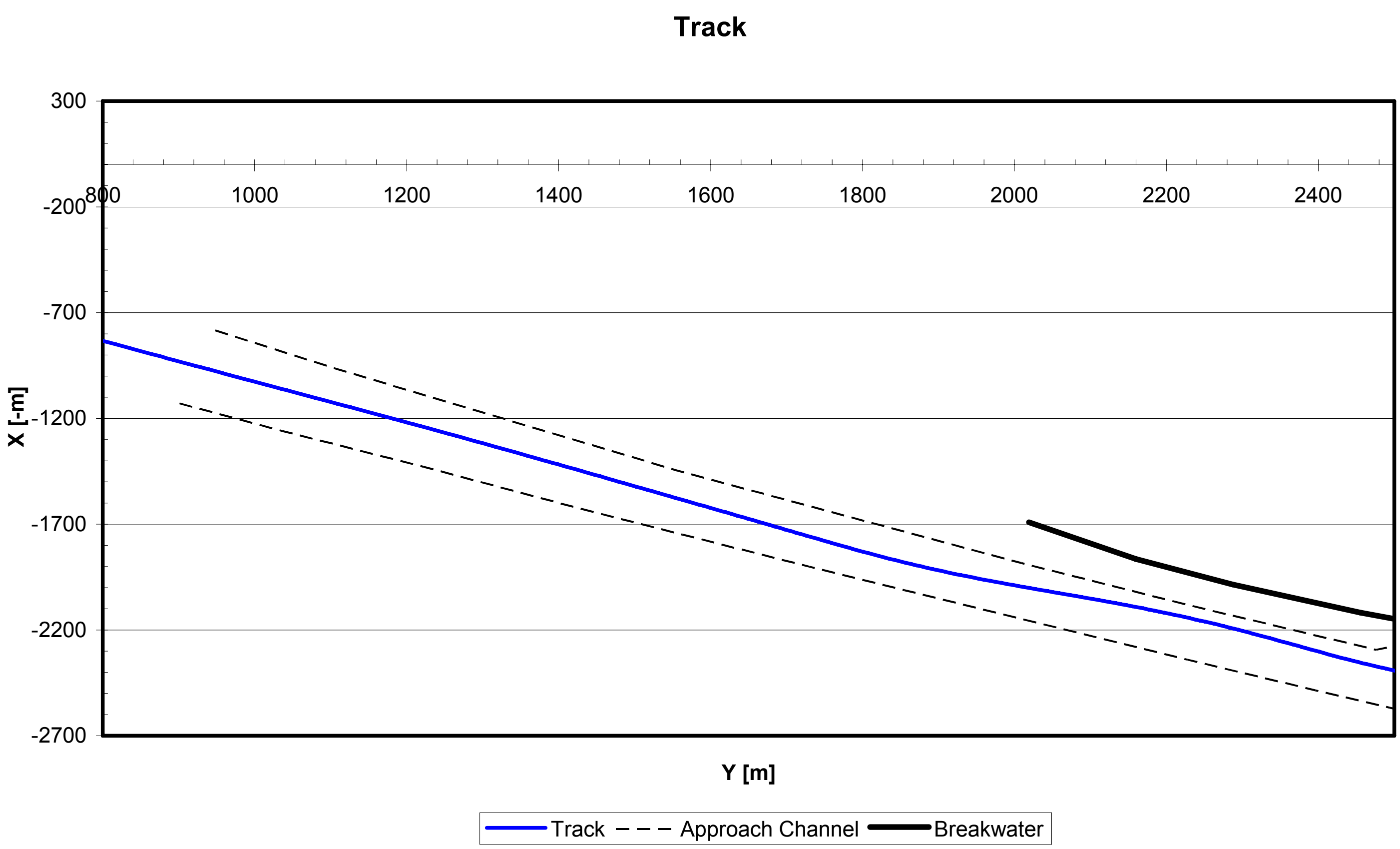

Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]


Drift Angle
15
10
5
0
-5
-10
-15
dψ [deg]
800
1300
1800
2300
Y [m]

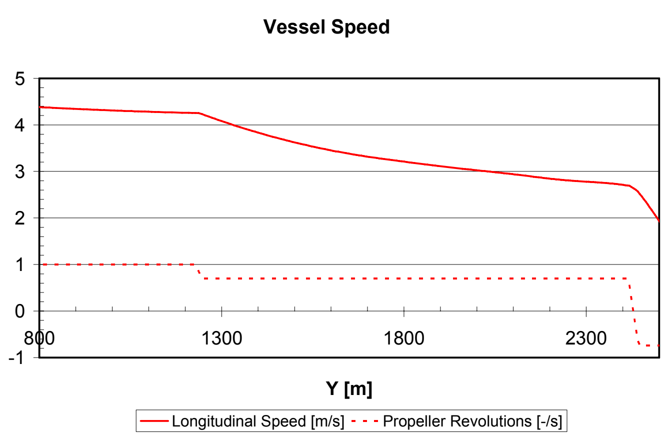

Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
dy [m]
800
1300
1800
2300
Y [m]


Rudder Use
40
30
20
10
0
-10
-20
Angle [deg]
800
1300
1800
2300
Y [m]

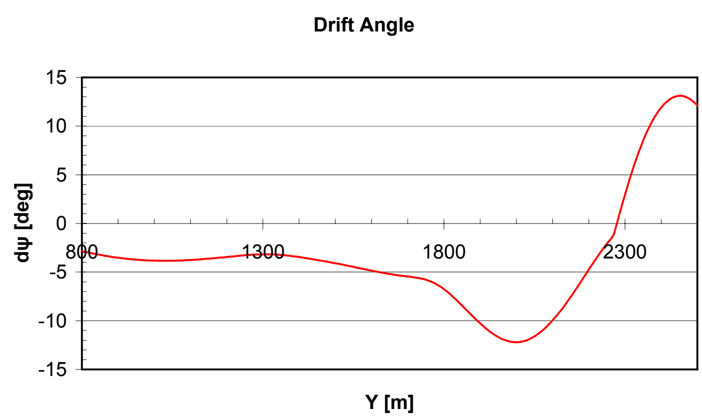
SADRA Run 7



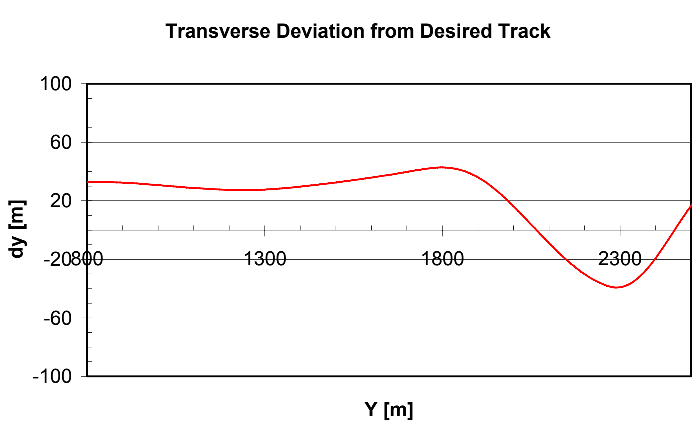
Track
300
-200
-700
-1200
-1700
-2200
-2700
X [-m]
800
1000
1200
1400
1600
1800
2000
2200
2400
Y [m]
Track
Approach Channel
Breakwater



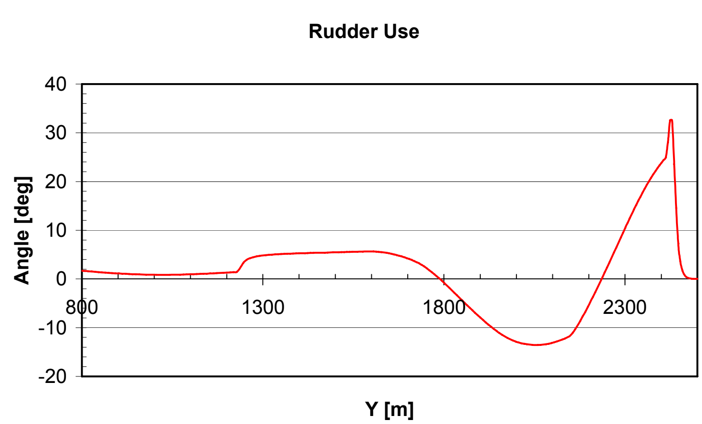
Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
dψ [deg]
800
1300
1800
2300
Y [m]



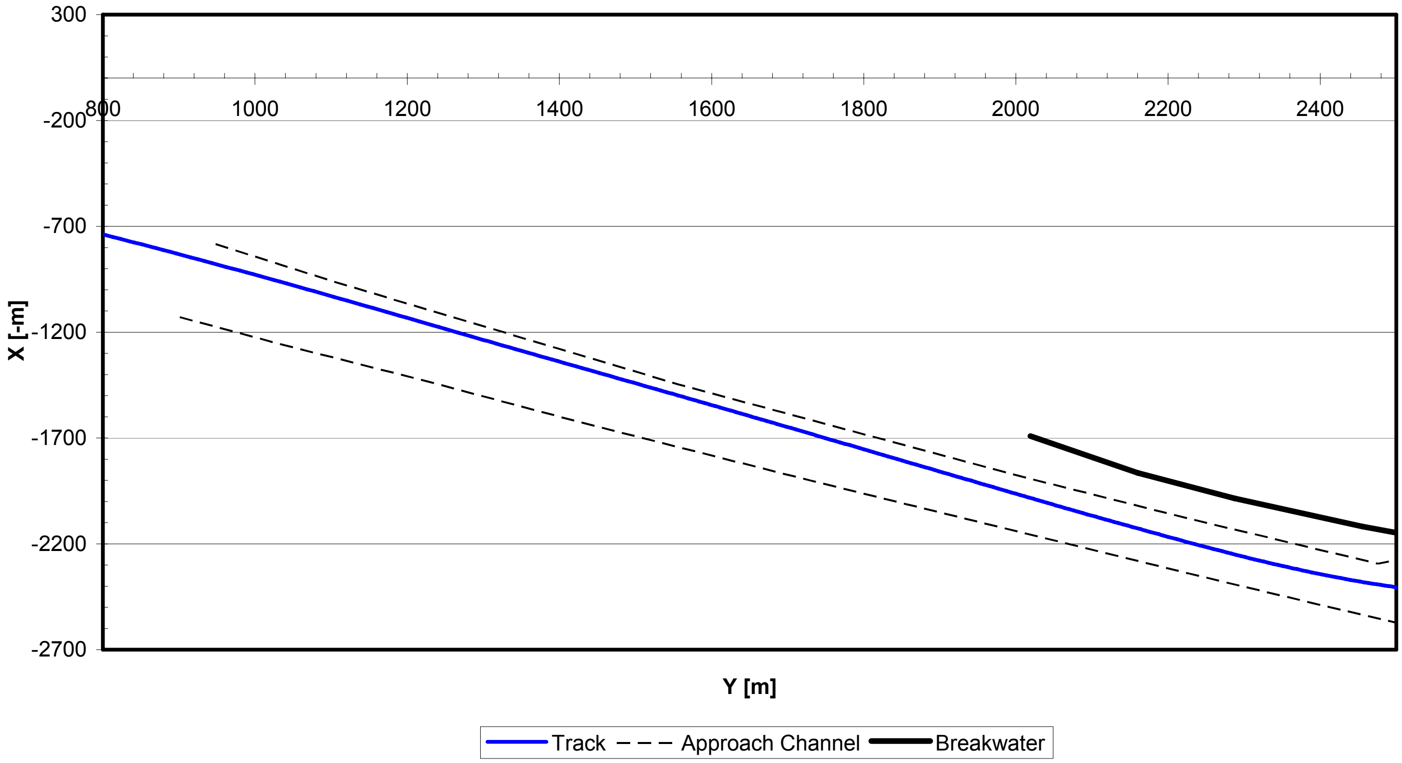
Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
dy [m]
800
1300
1800
2300
Y [m]



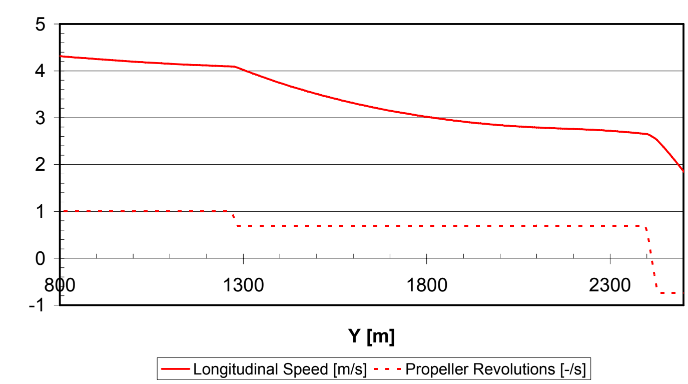
Rudder Use
40
30
20
10
0
-10
-20
Angle [deg]
800
1300
1800
2300
Y [m]

SADRA Run 8

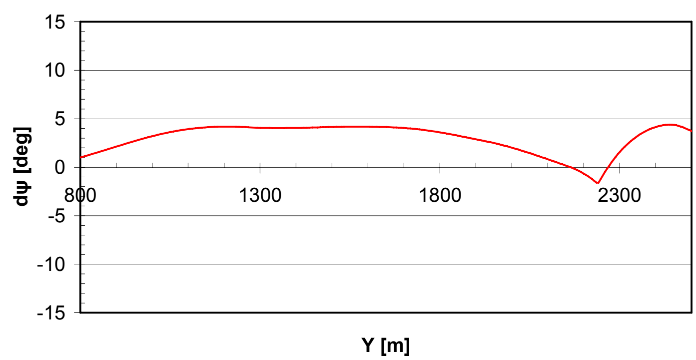
Track



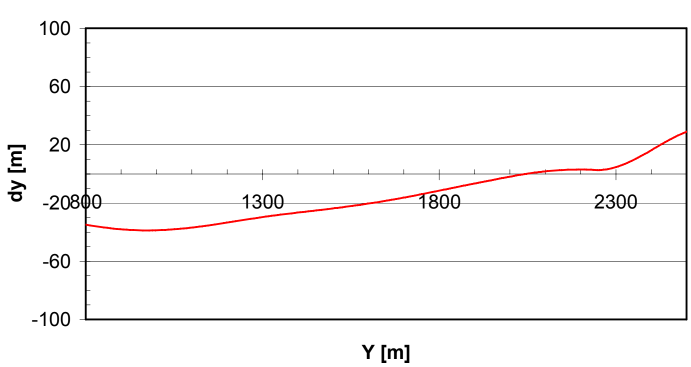
Vessel Speed



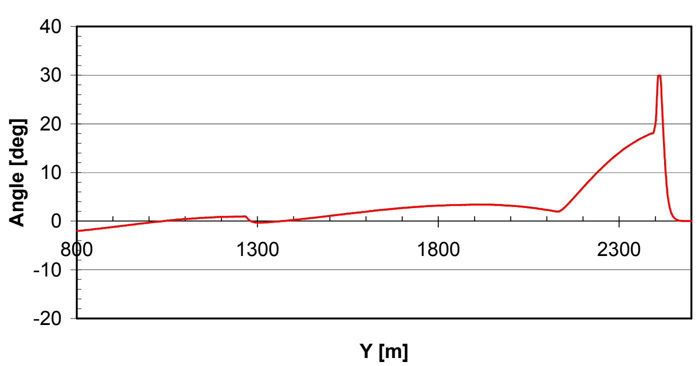
Drift Angle



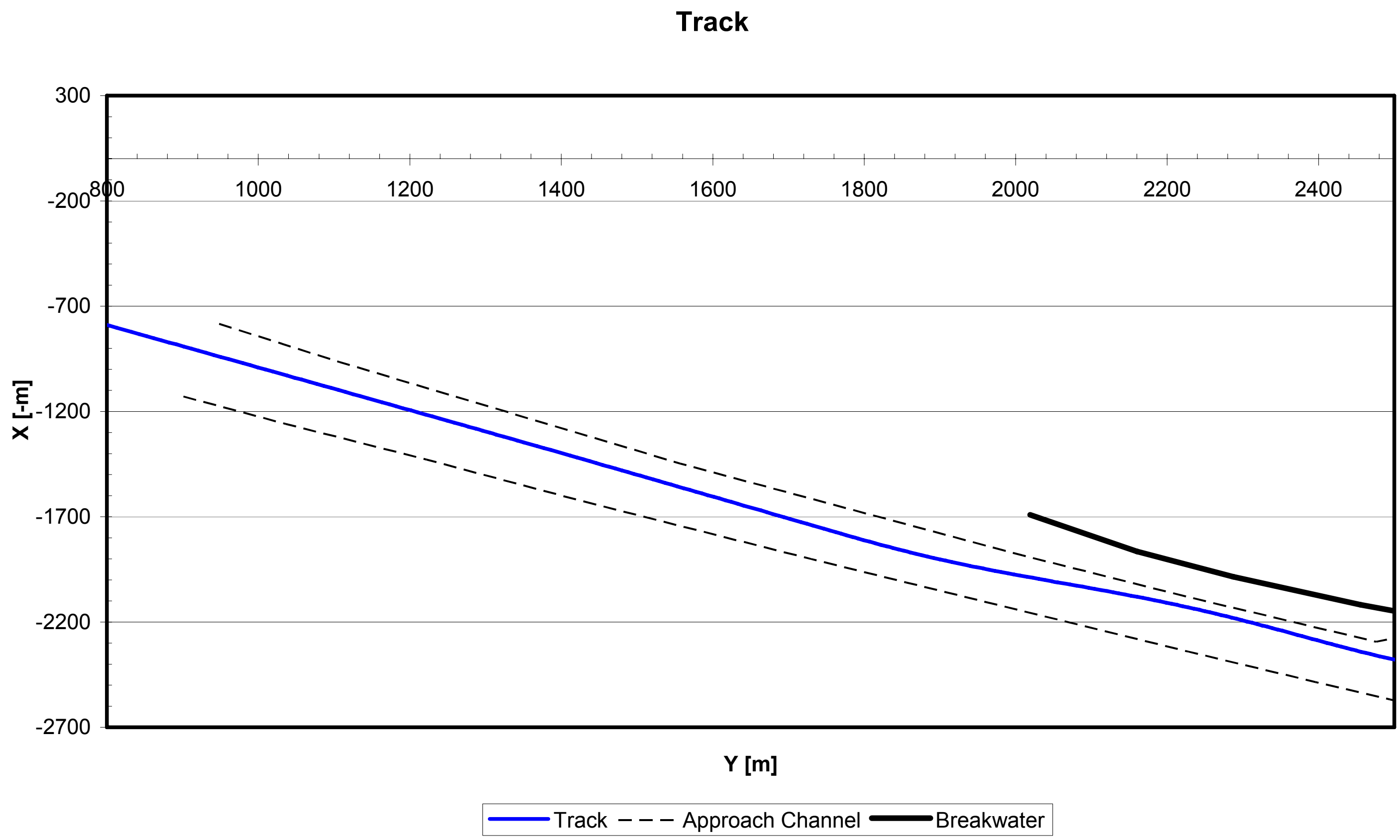
Transverse Deviation from Desired Track

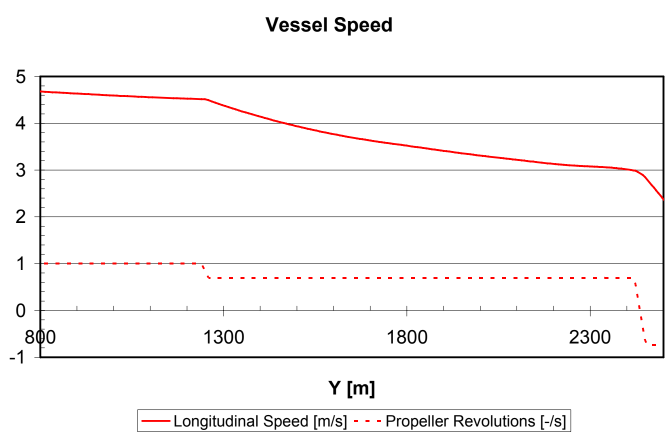


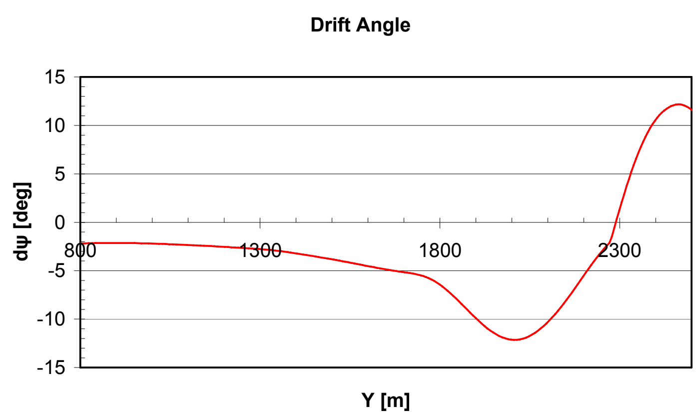
Rudder Use

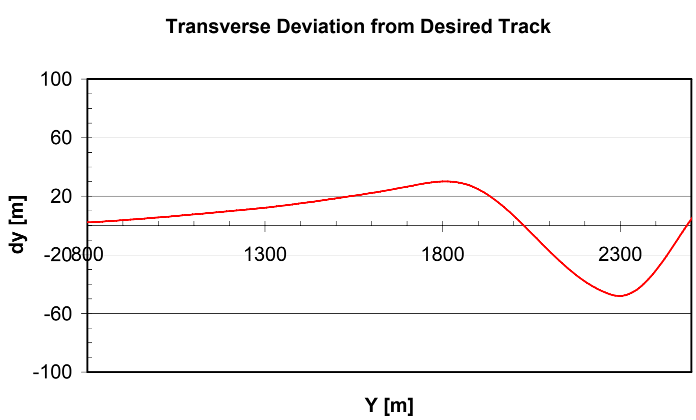


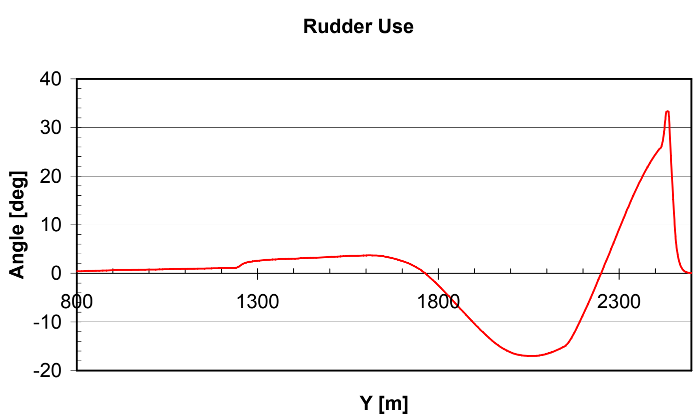
SADRA Run 9


Track
300
-200
-700
-1200
-1700
-2200
-2700
800
1000
1200
1400
1600
1800
2000
2200
2400
X [-m]
Y [m]
Track
Approach Channel
Breakwater

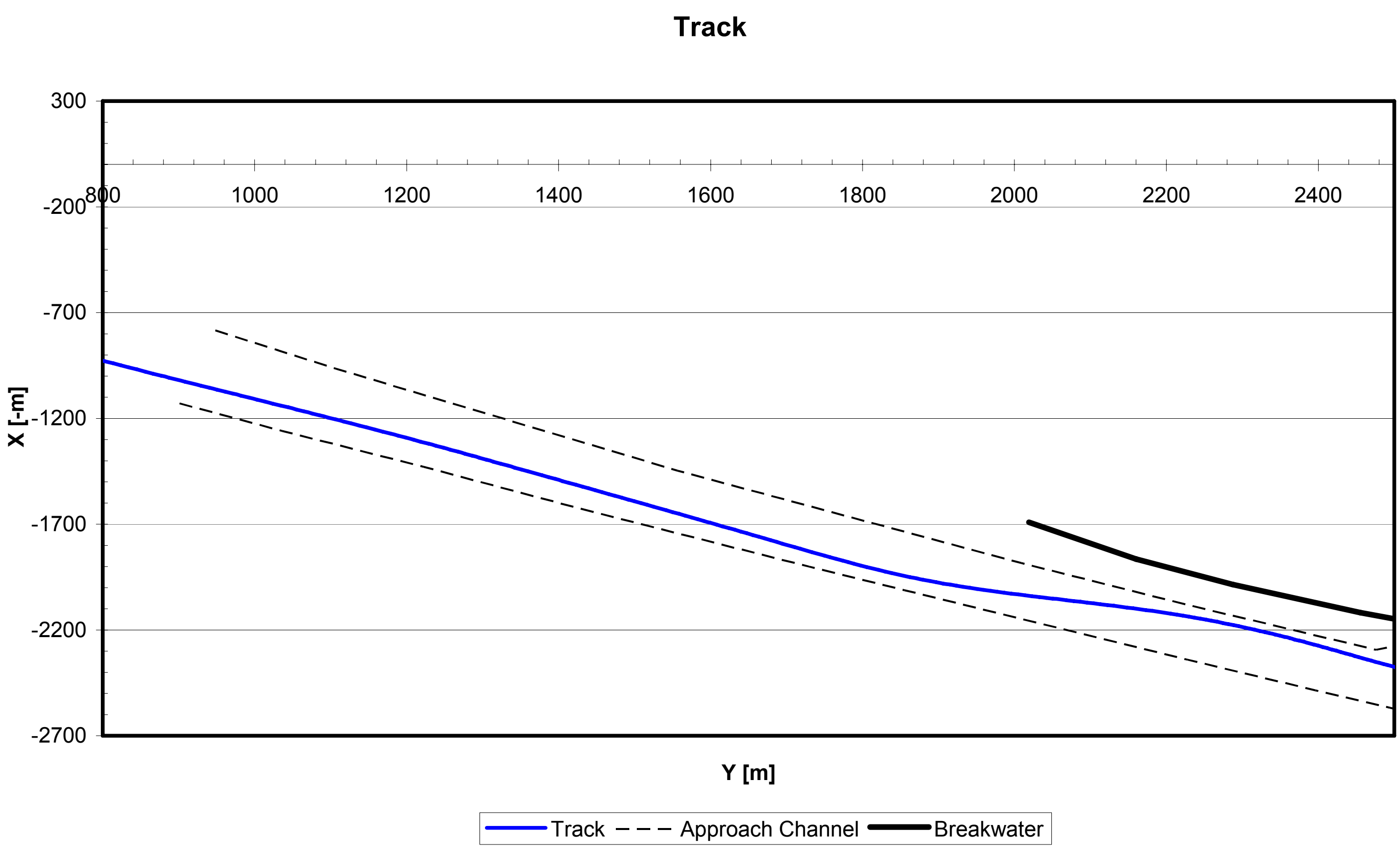

Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]

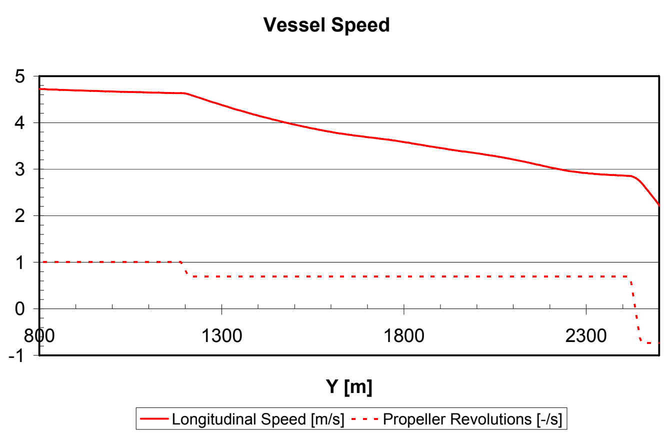

Drift Angle
15
10
5
0
-5
-10
-15
800
1300
1800
2300
dψ [deg]
Y [m]

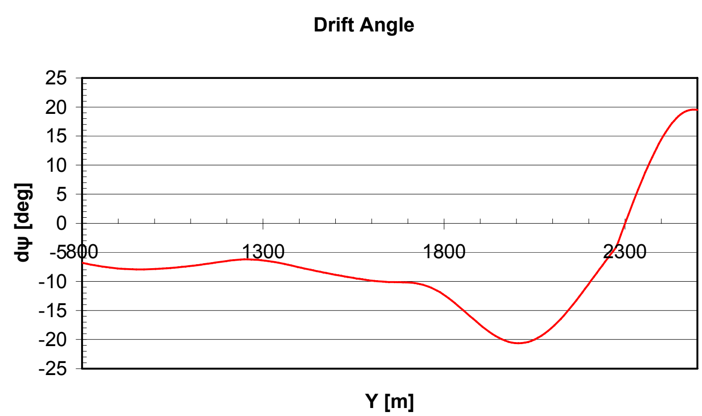

Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
800
1300
1800
2300
dy [m]
Y [m]

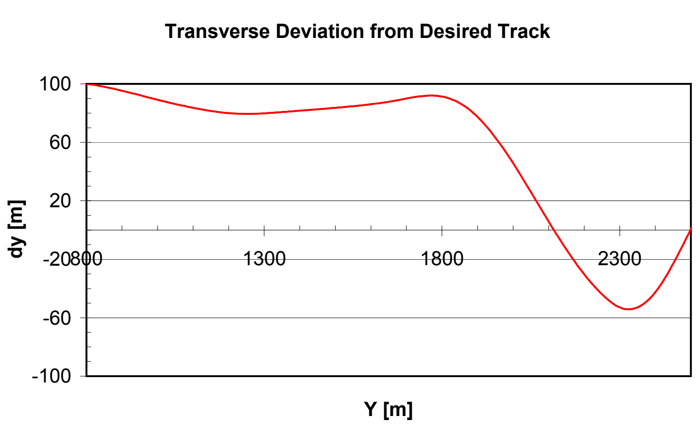

Rudder Use
40
30
20
10
0
-10
-20
800
1300
1800
2300
Angle [deg]
Y [m]

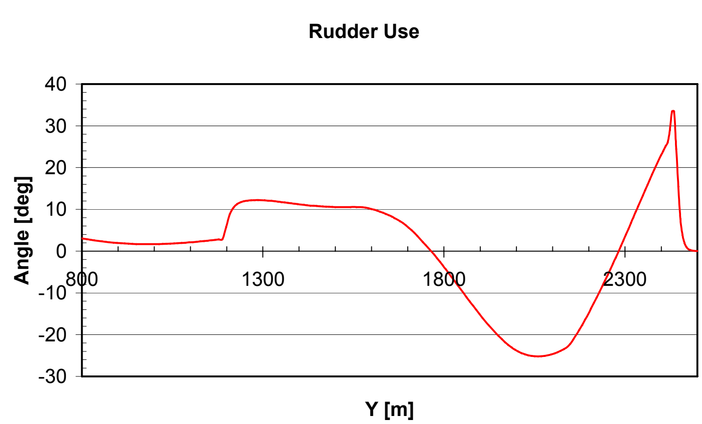
SADRA Run 10


Track
300
-200
-700
-1200
-1700
-2200
-2700
800
1000
1200
1400
1600
1800
2000
2200
2400
X [-m]
Y [m]
Track
Approach Channel
Breakwater

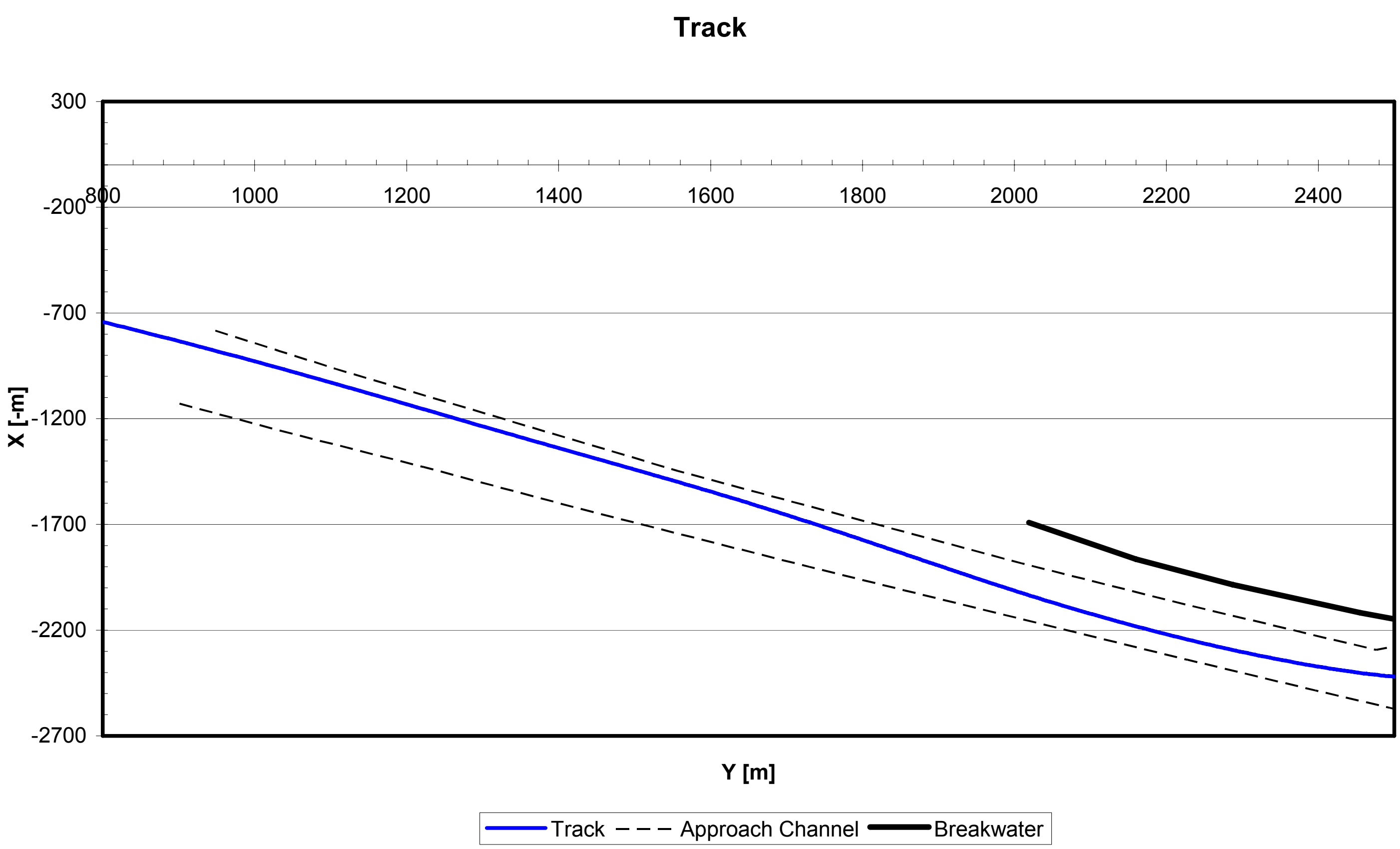

Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]

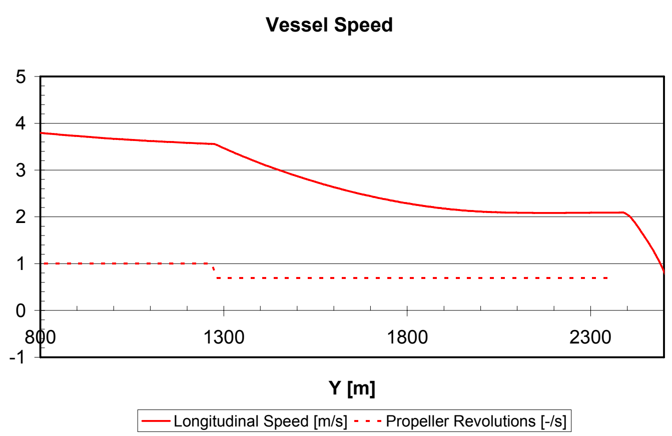

Drift Angle
25
20
15
10
5
0
-5
-10
-15
-20
-25
800
1300
1800
2300
dψ [deg]
Y [m]

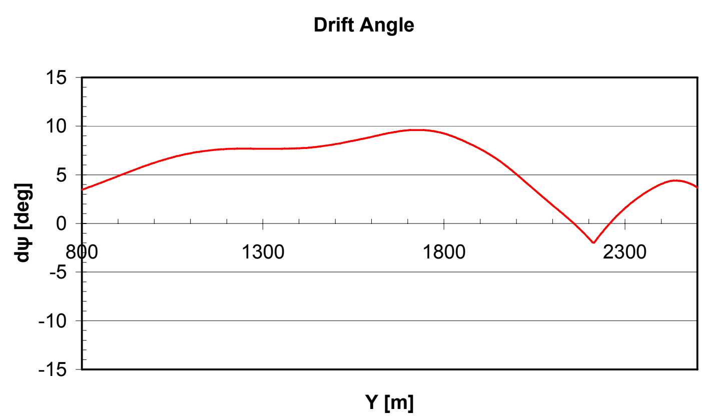

Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
800
1300
1800
2300
dy [m]
Y [m]

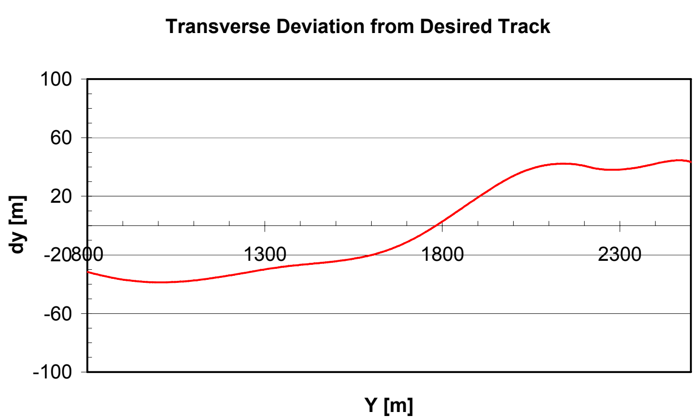

Rudder Use
40
30
20
10
0
-10
-20
-30
800
1300
1800
2300
Angle [deg]
Y [m]

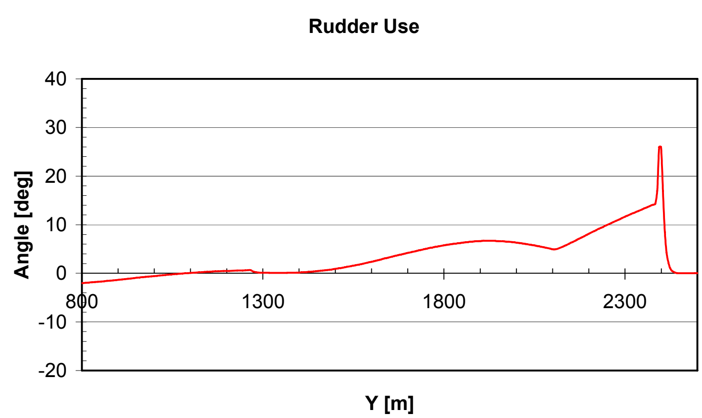
SADRA Run 11


Track
300
-200
-700
-1200
-1700
-2200
-2700
X [-m]
800
1000
1200
1400
1600
1800
2000
2200
2400
Y [m]
Track
Approach Channel
Breakwater


Vessel Speed
5
4
3
2
1
0
-1
800
1300
1800
2300
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]


Drift Angle
15
10
5
0
-5
-10
-15
dψ [deg]
800
1300
1800
2300
Y [m]


Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
dy [m]
800
1300
1800
2300
Y [m]

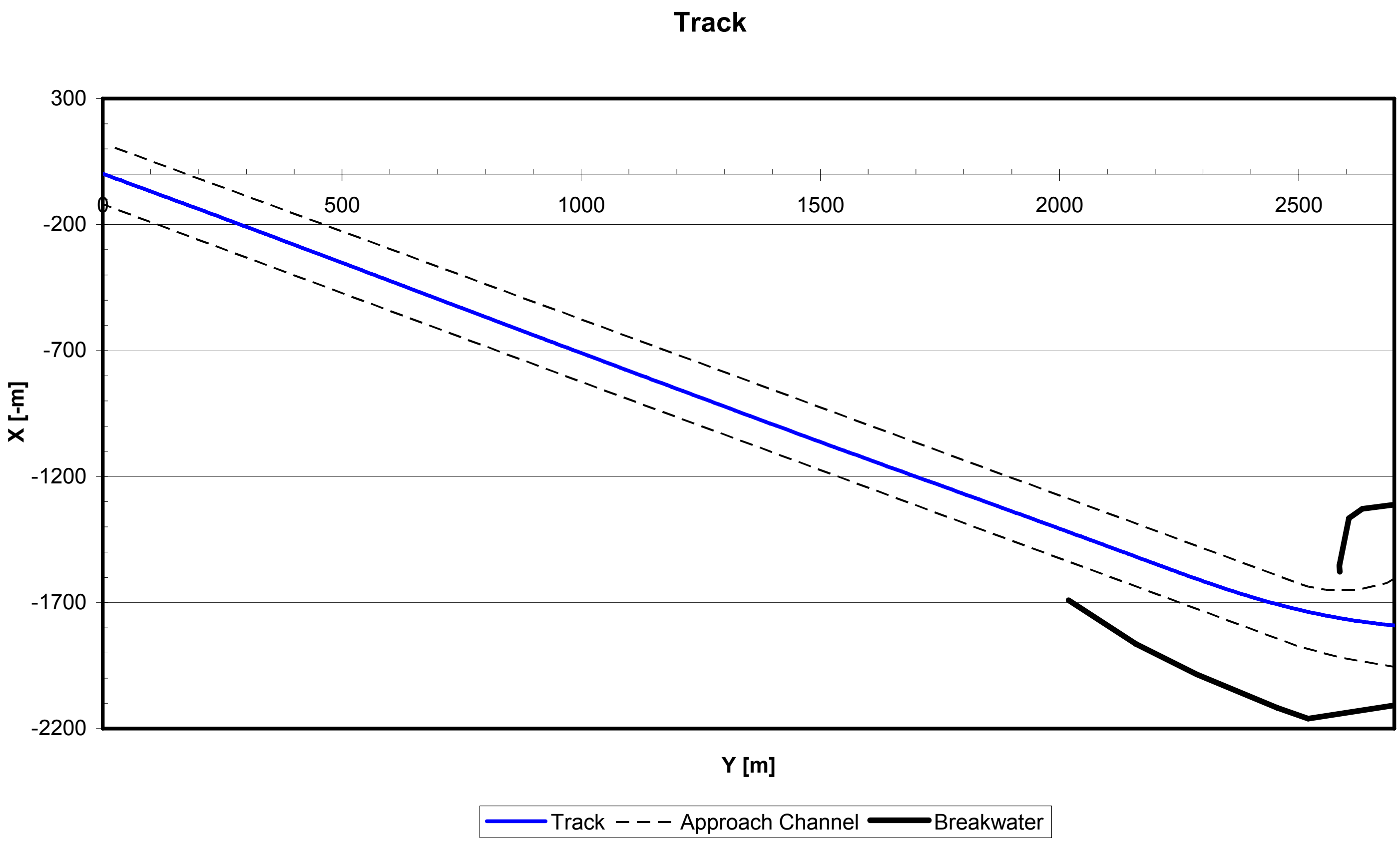

Rudder Use
40
30
20
10
0
-10
-20
Angle [deg]
800
1300
1800
2300
Y [m]

Delft University of Technology

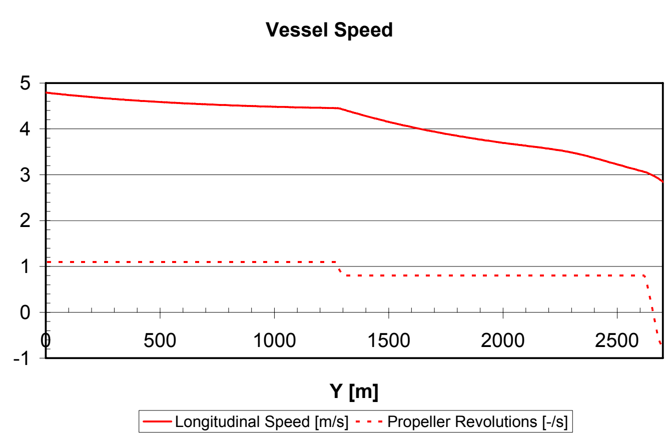
ROYAL HASKONING

Annex XVIII
Shipma Runs NIOC Basin

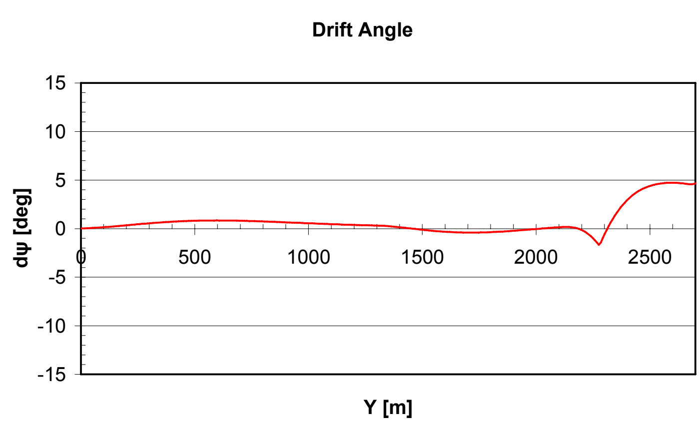
NIOC Run 1



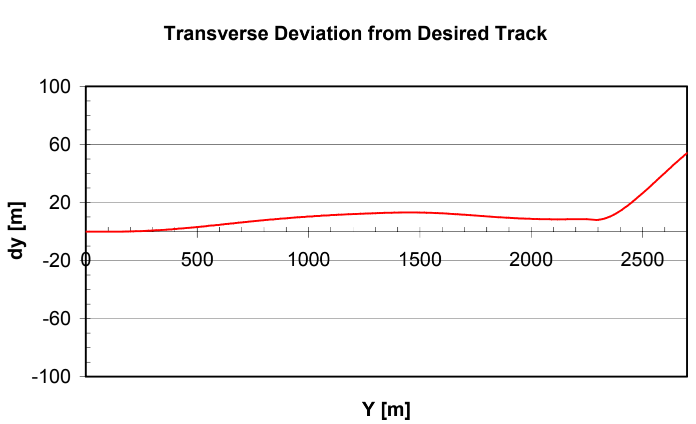
Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater



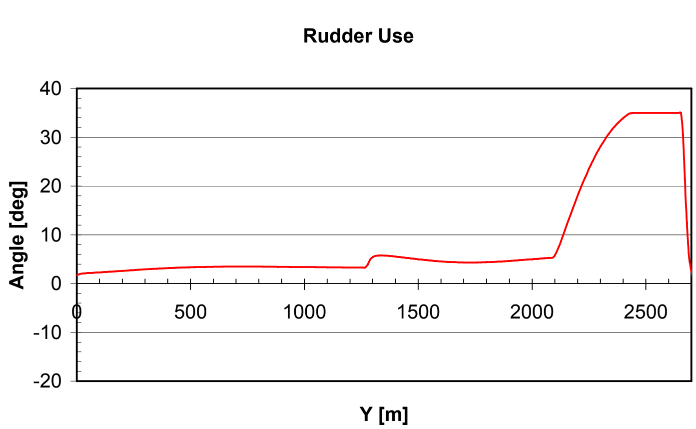
Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]

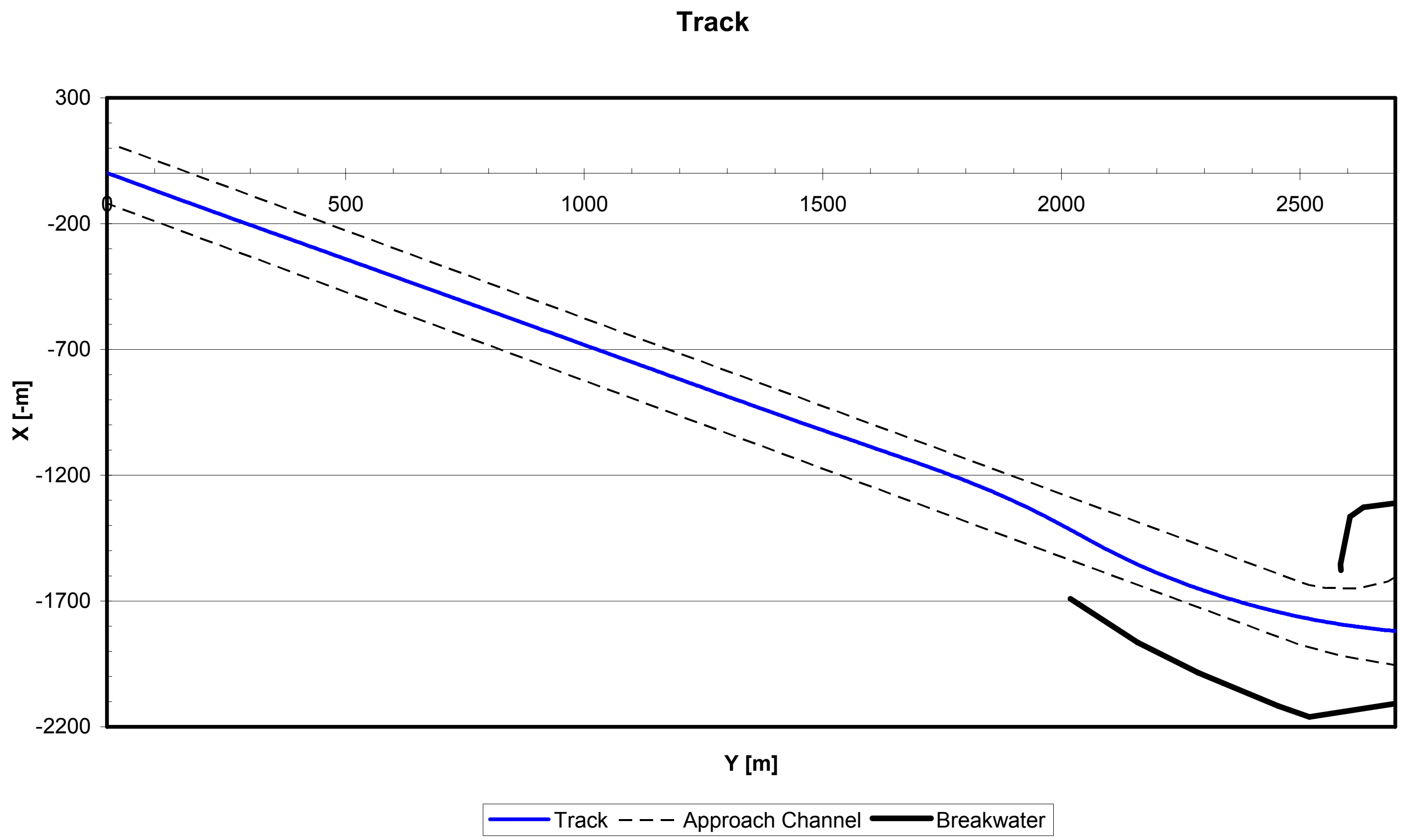


Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]

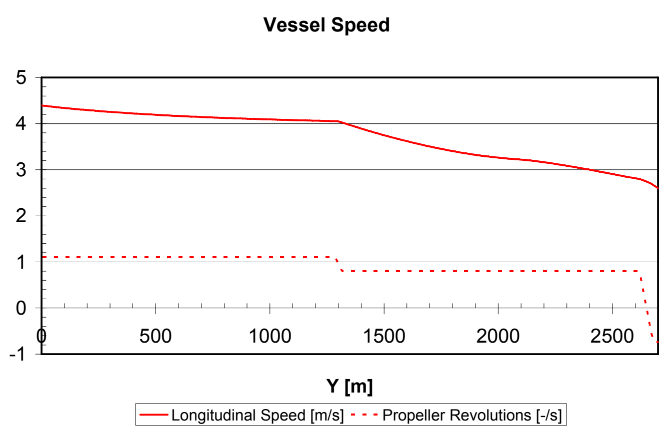


Rudder Use
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

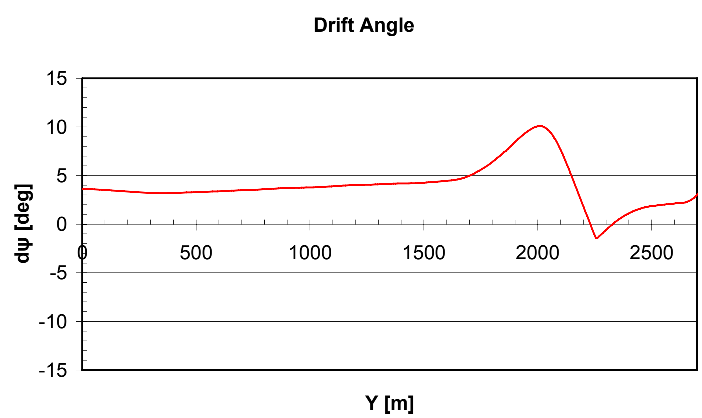
NIOC Run 2



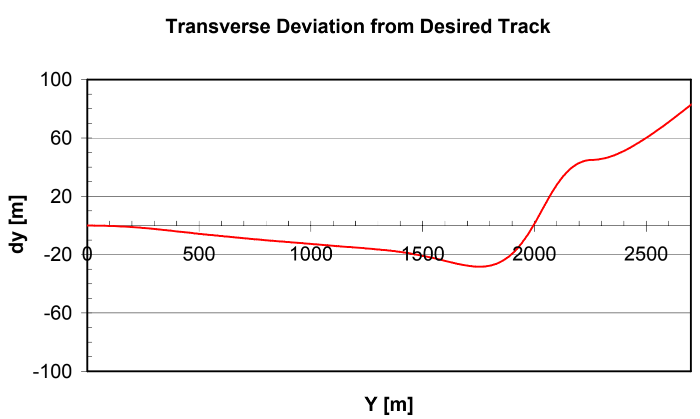
Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater



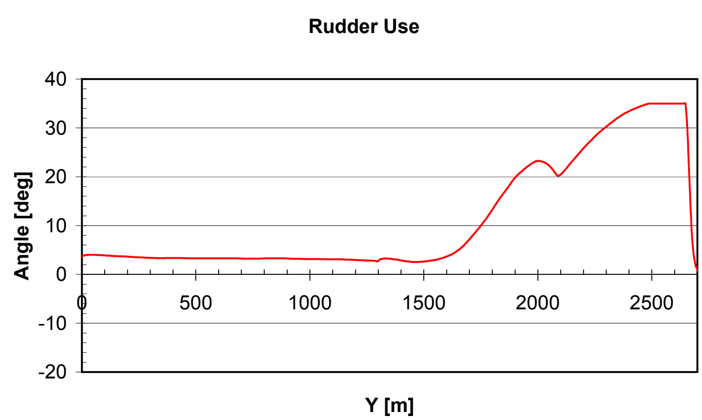
Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]

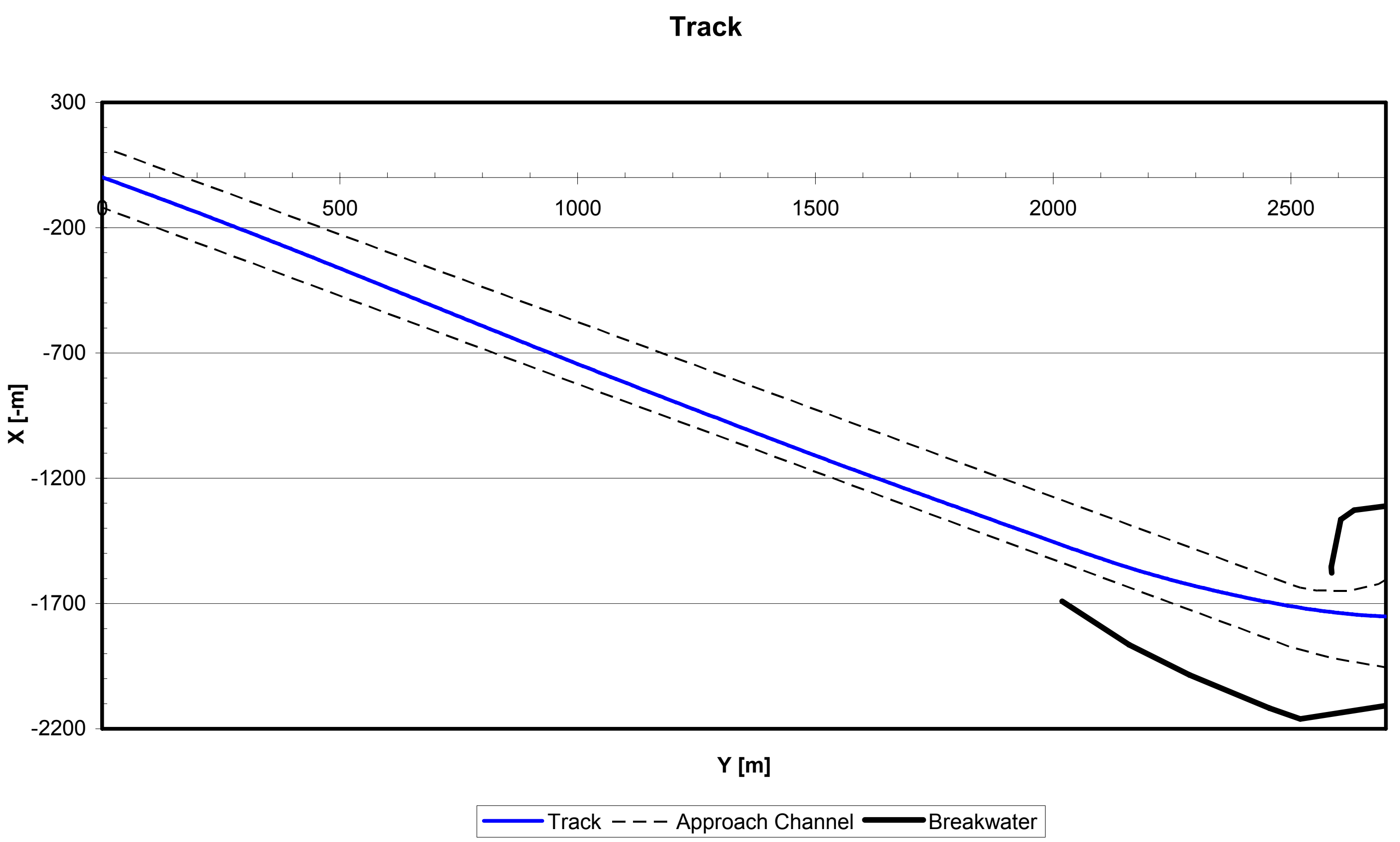


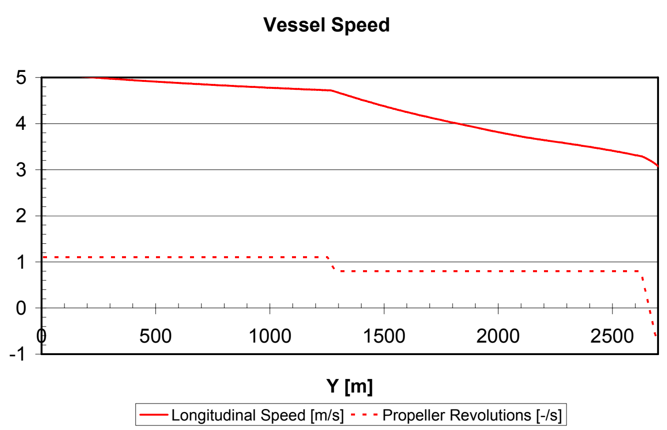
Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]

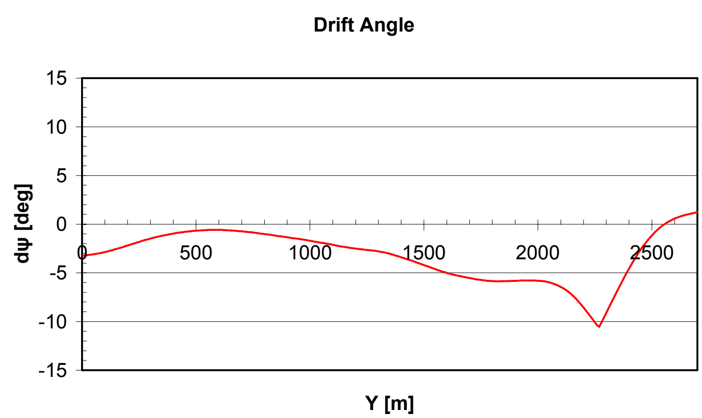


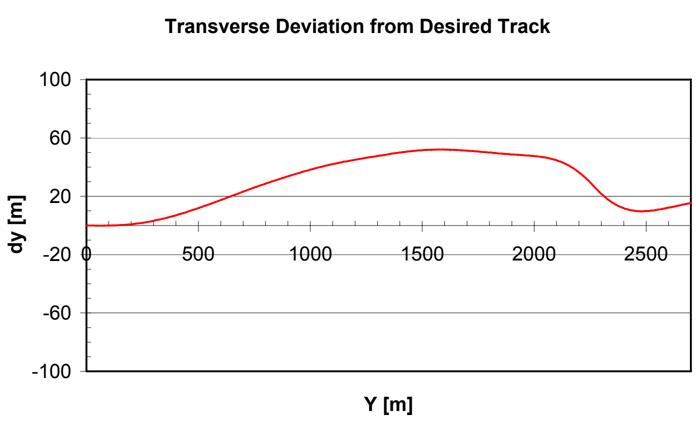
Rudder Use
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

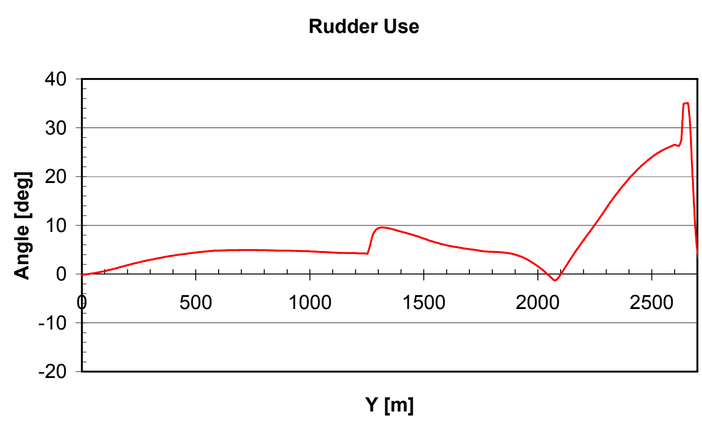
NIOC Run 3


Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater

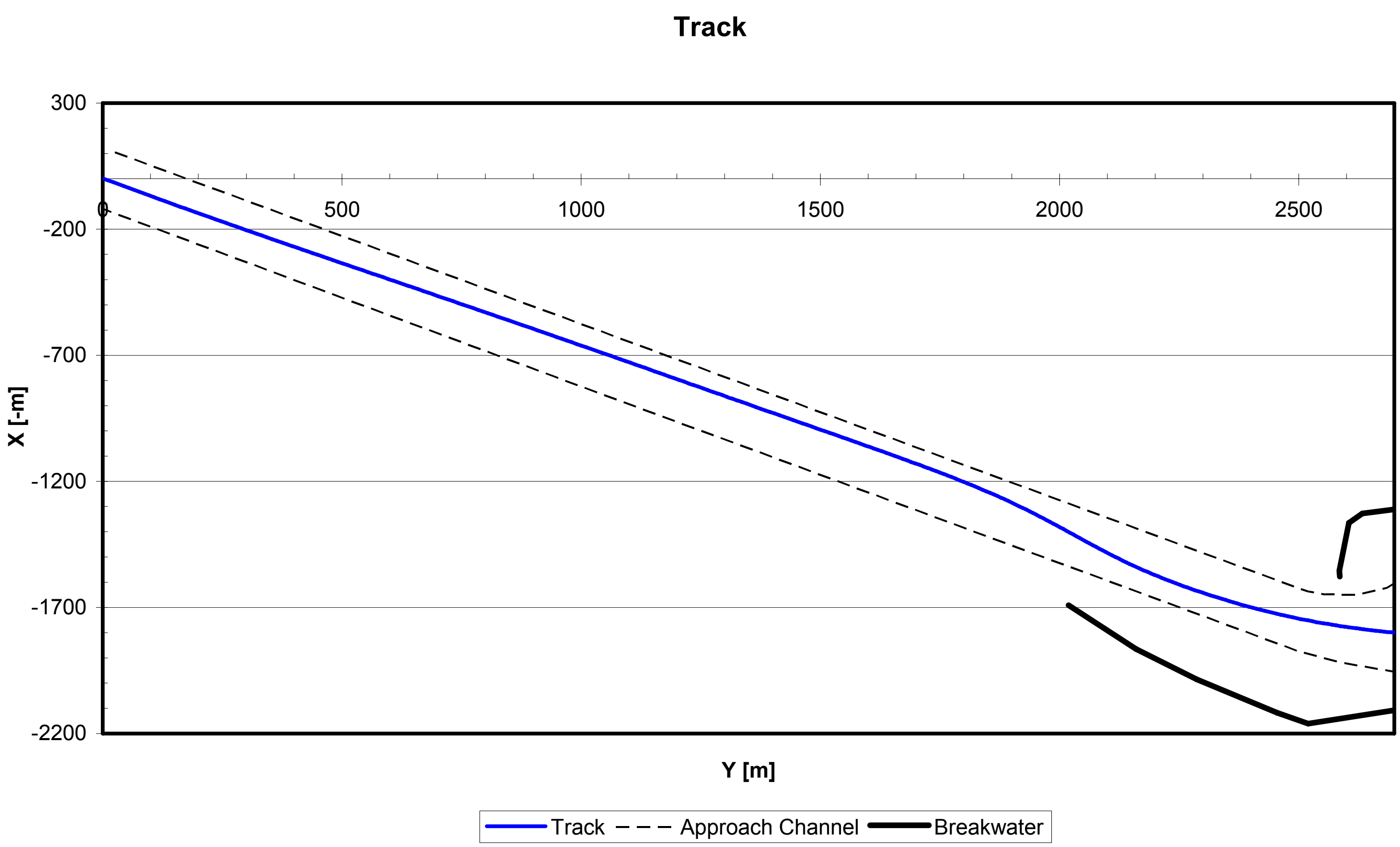

Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]


Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]

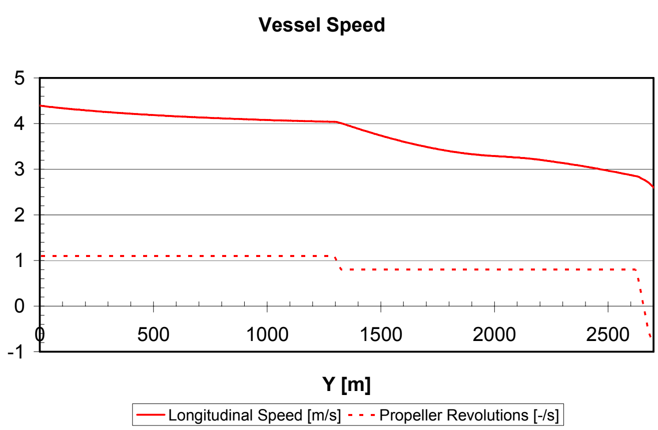

Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]


Rudder Use
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

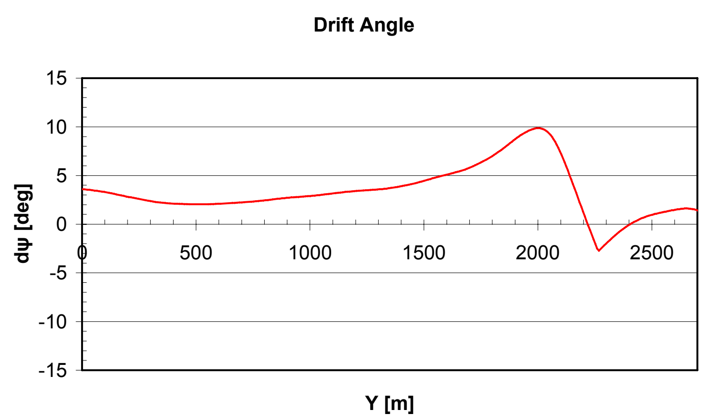
NIOC Run 4



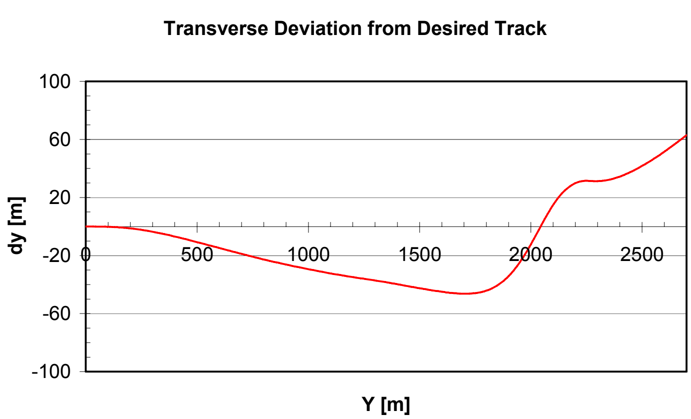
Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater



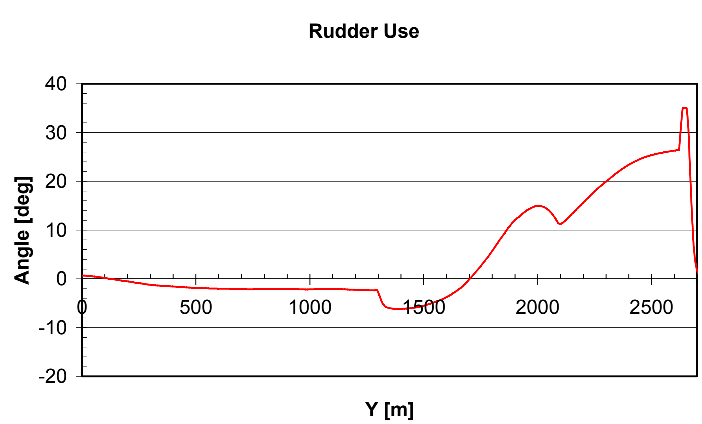
Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]

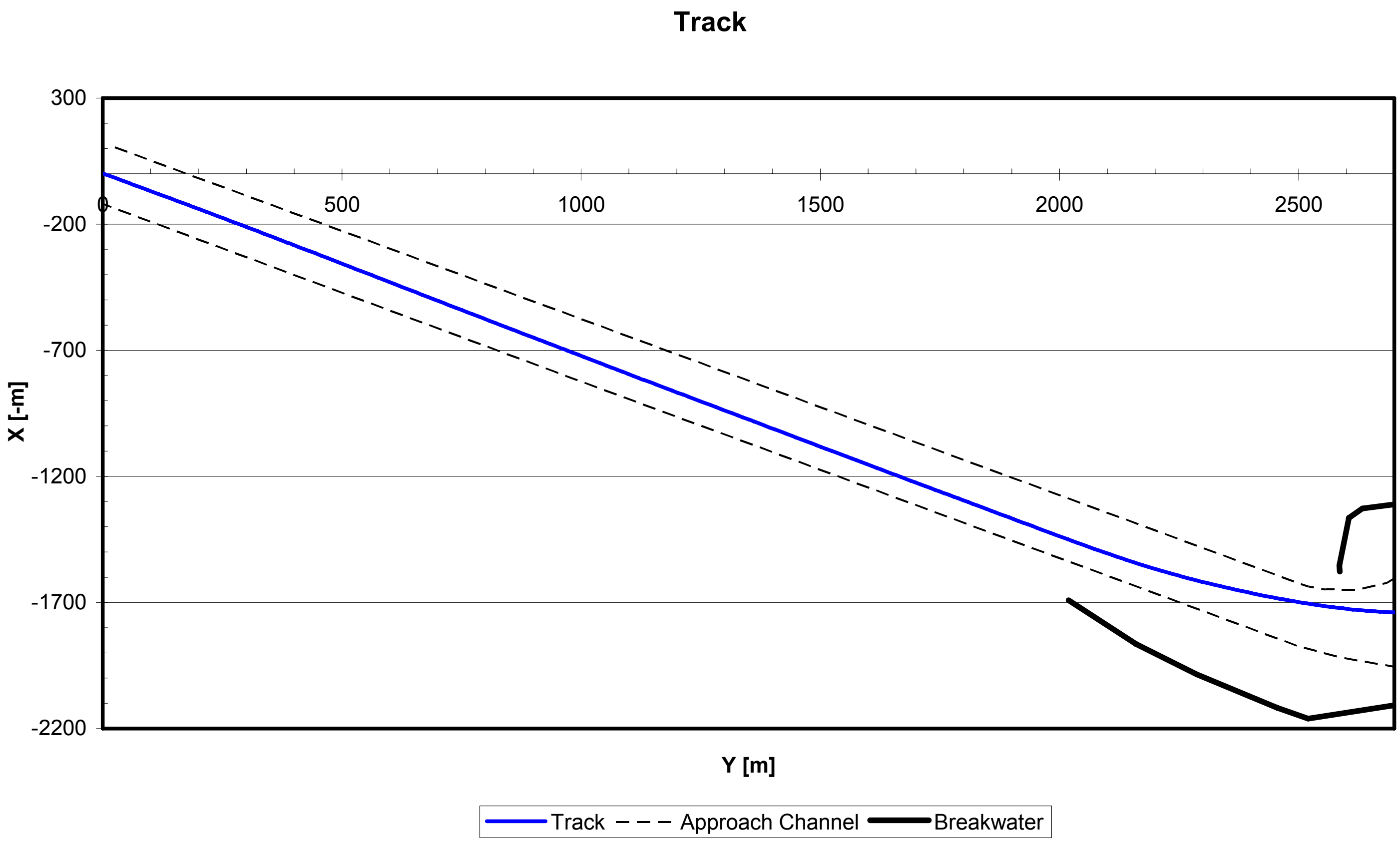


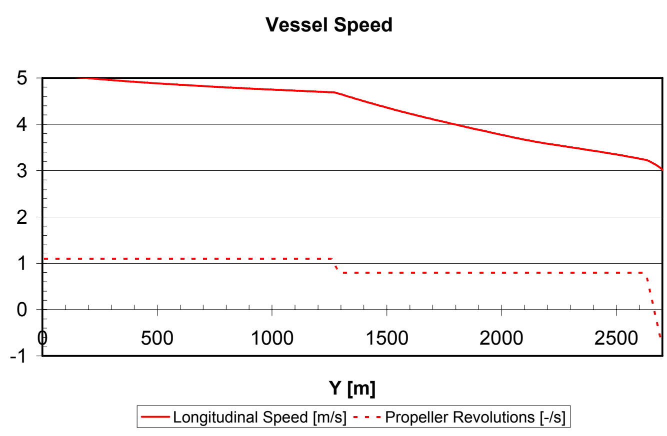
Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]

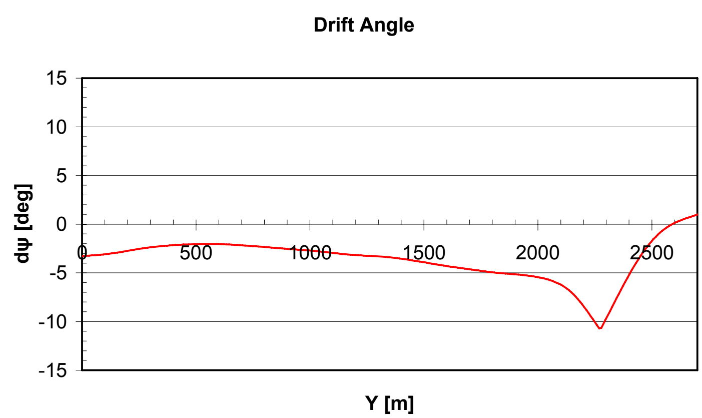


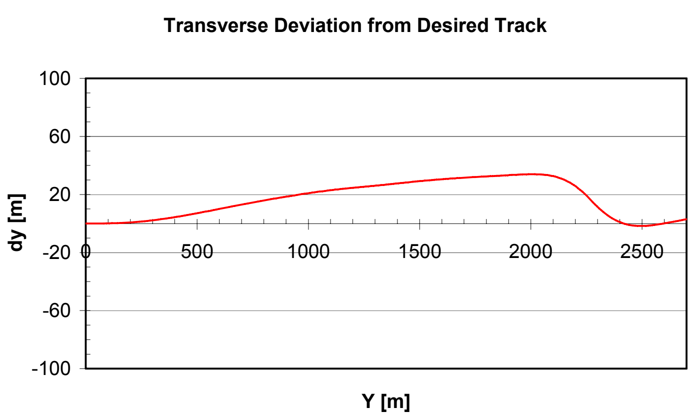
Rudder Use
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

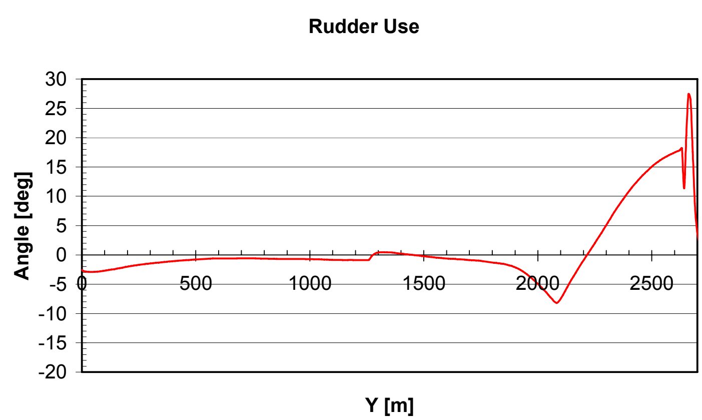
NIOC Run 5


Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater

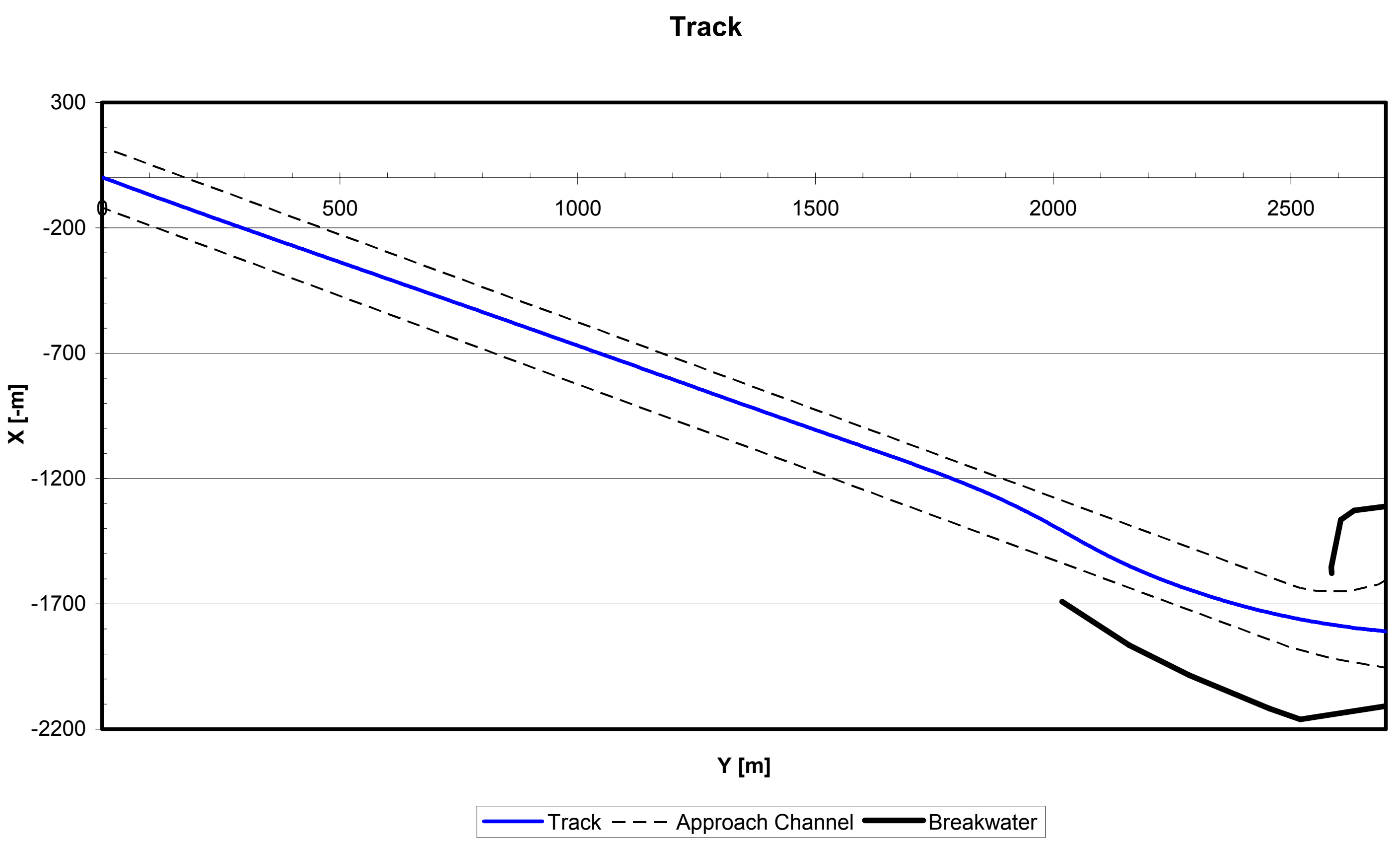

Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]


Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]

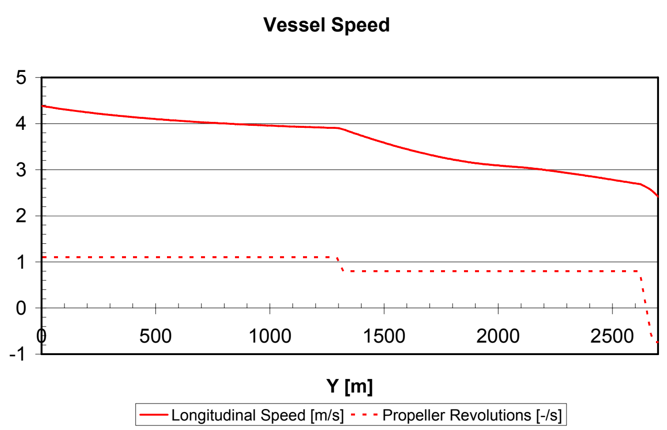

Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]


Rudder Use
30
25
20
15
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

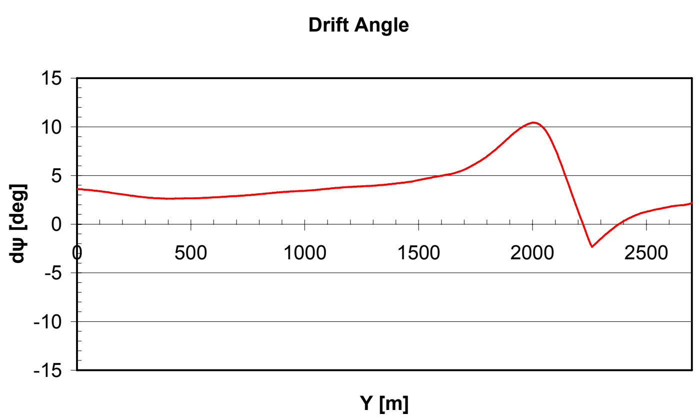
NIOC Run 6



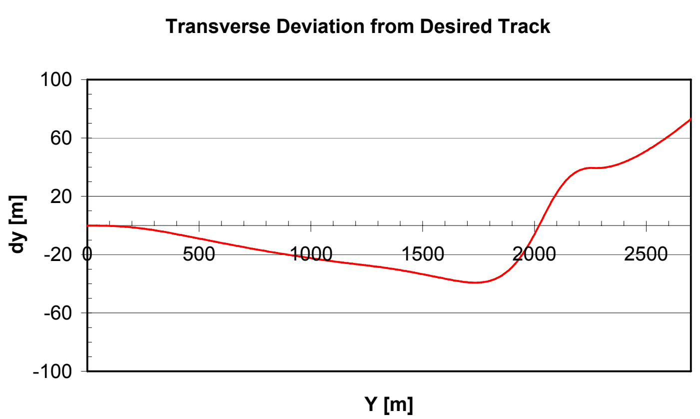
Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater



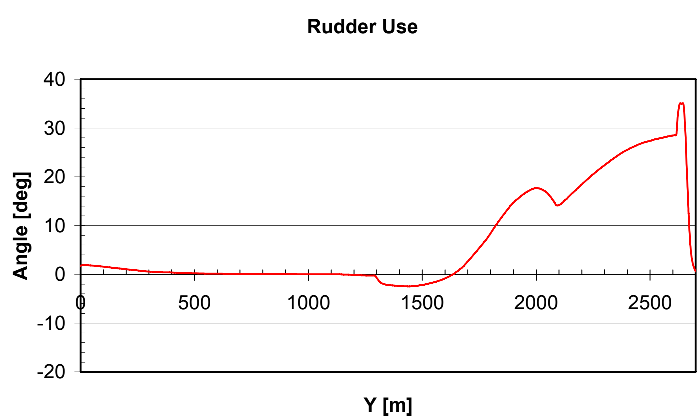
Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]

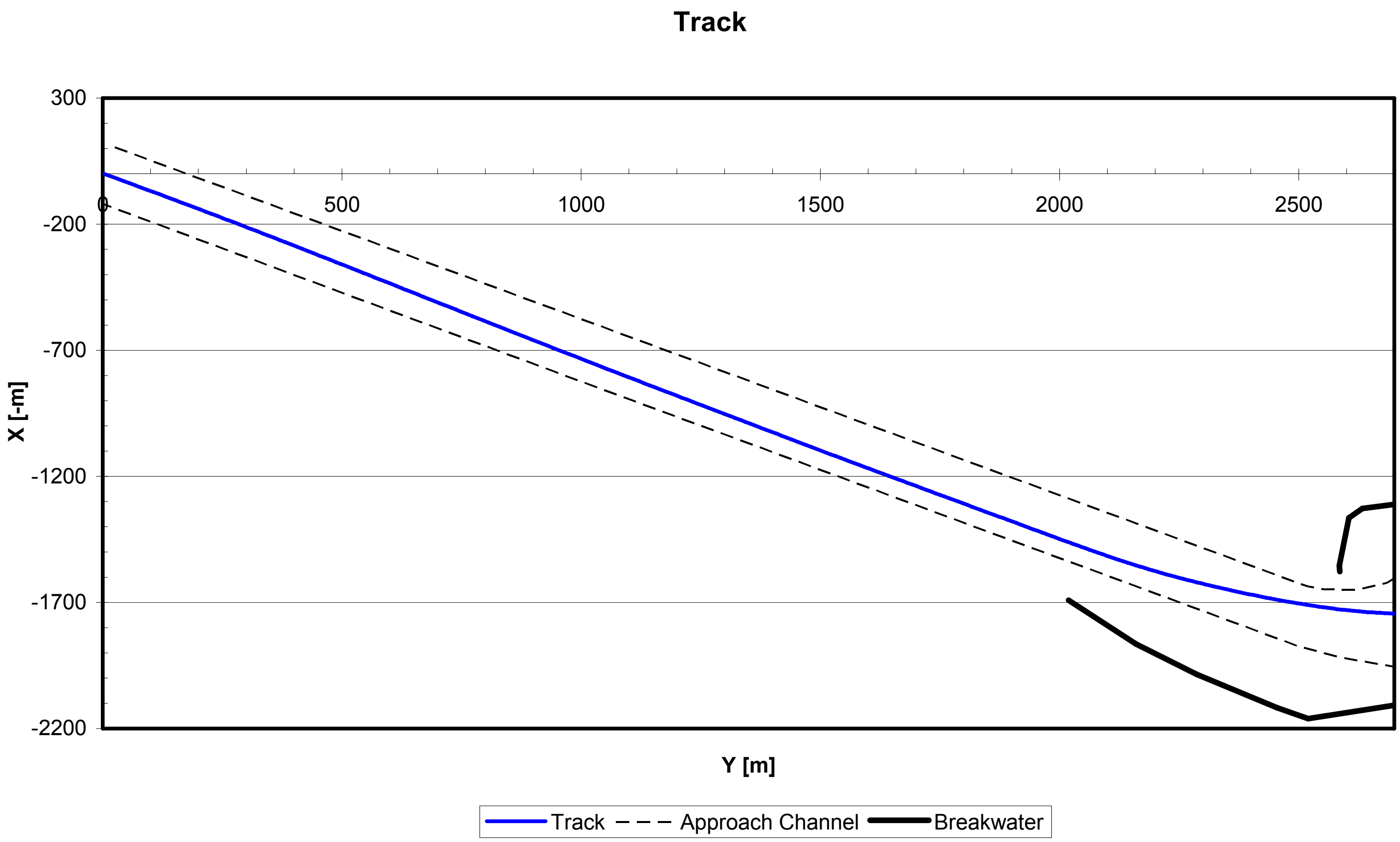


Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]

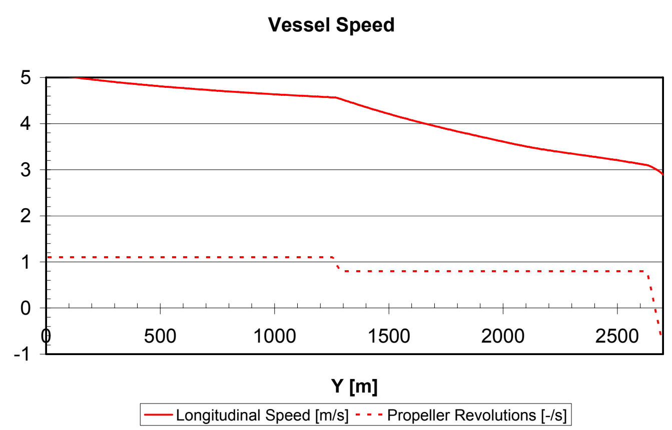


Rudder Use
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

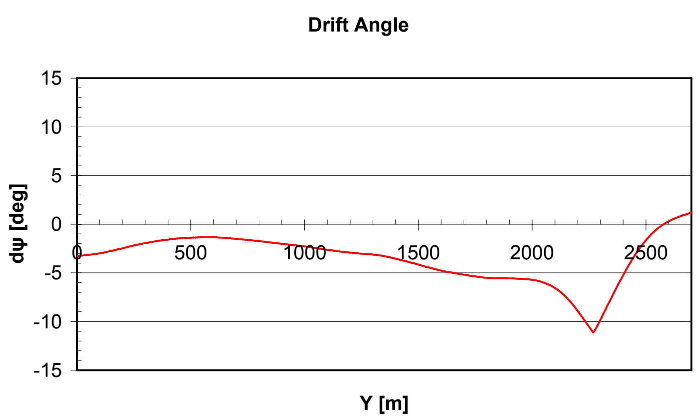
NIOC Run 7



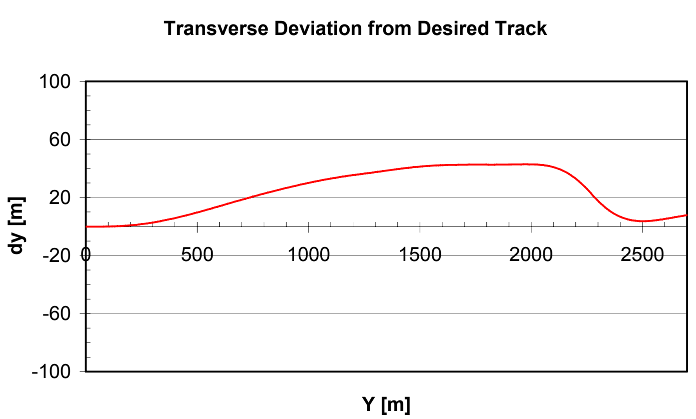
Track
300
-200
-700
-1200
-1700
-2200
X [-m]
0
500
1000
1500
2000
2500
Y [m]
Track
Approach Channel
Breakwater



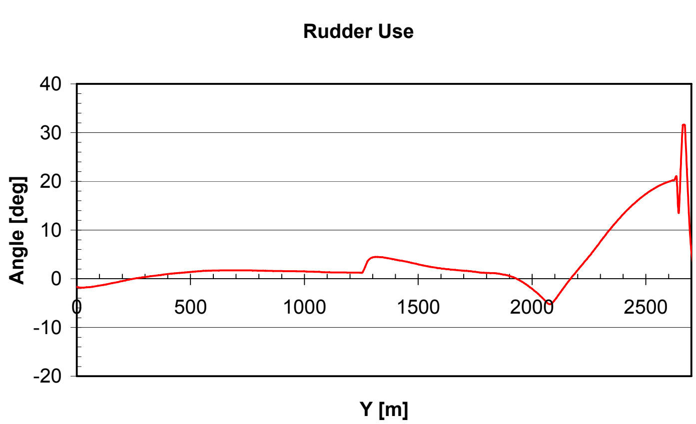
Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
dψ [deg]
0
500
1000
1500
2000
2500
Y [m]

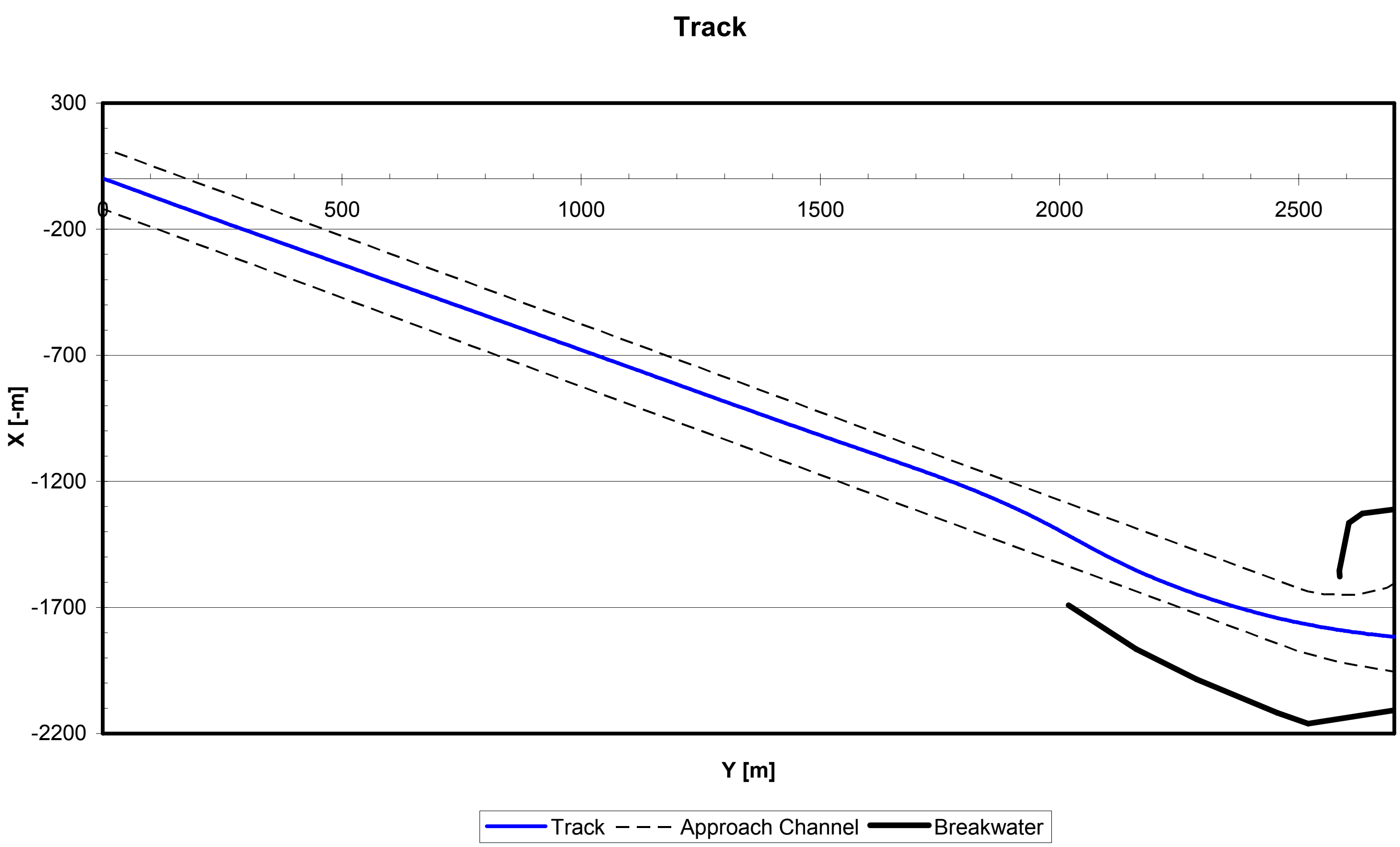


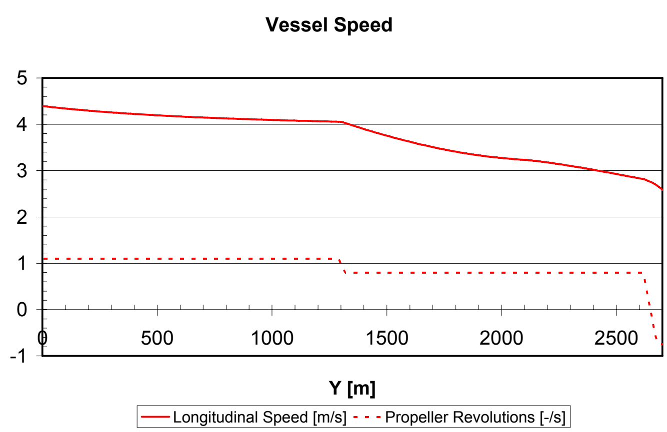
Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
dy [m]
0
500
1000
1500
2000
2500
Y [m]

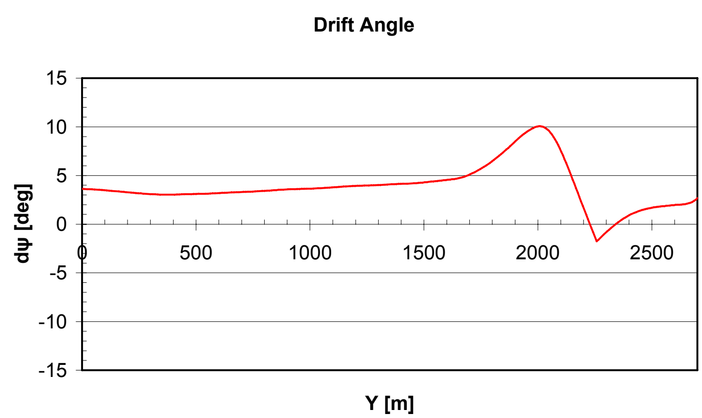


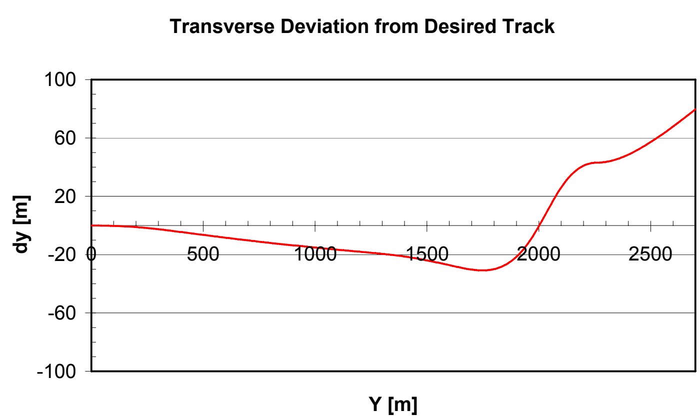
Rudder Use
40
30
20
10
0
-10
-20
Angle [deg]
0
500
1000
1500
2000
2500
Y [m]

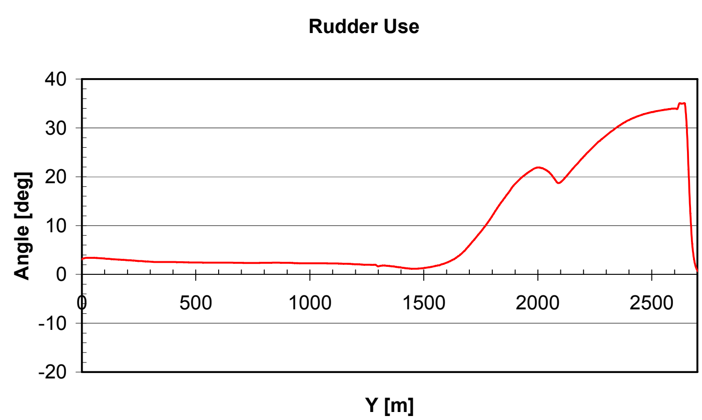
NIOC Run 8


Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater


Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]

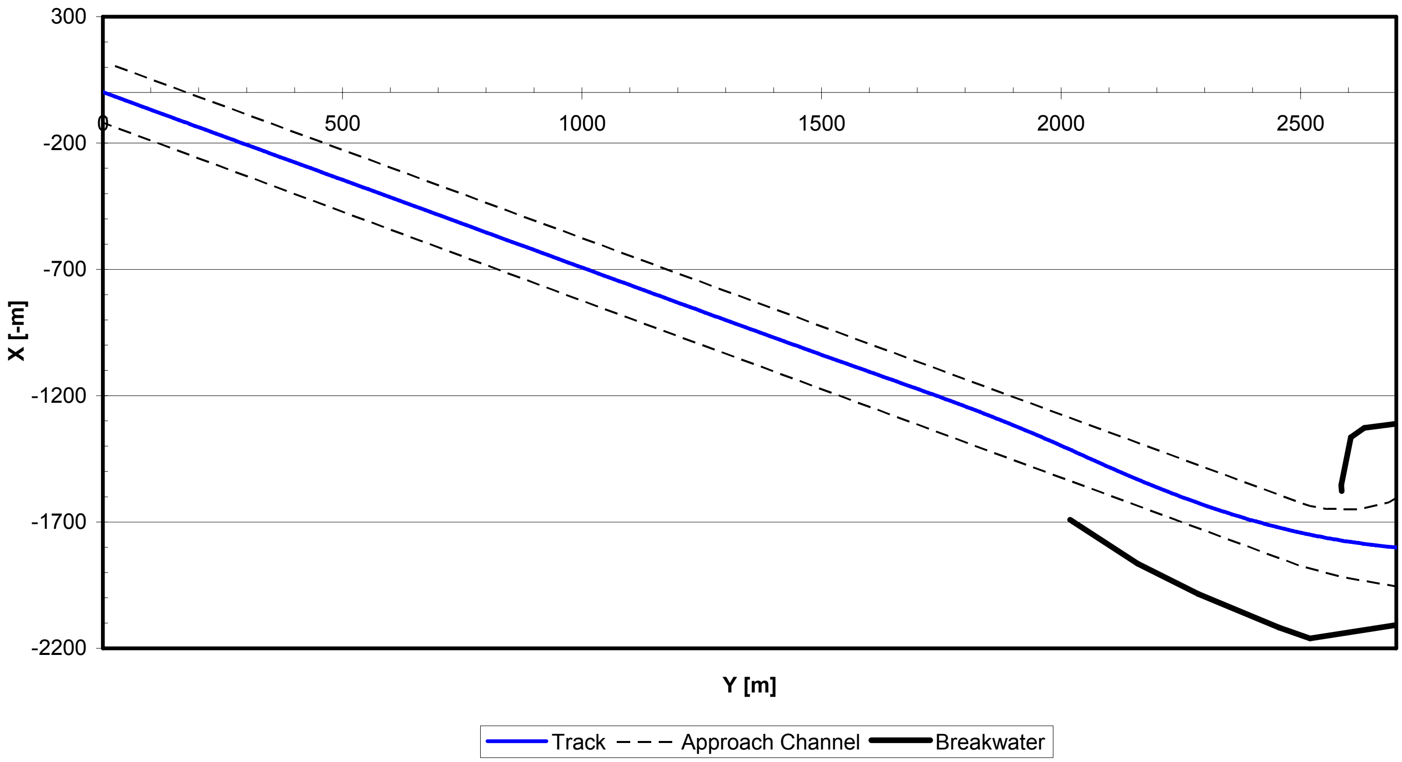

Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]


Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]

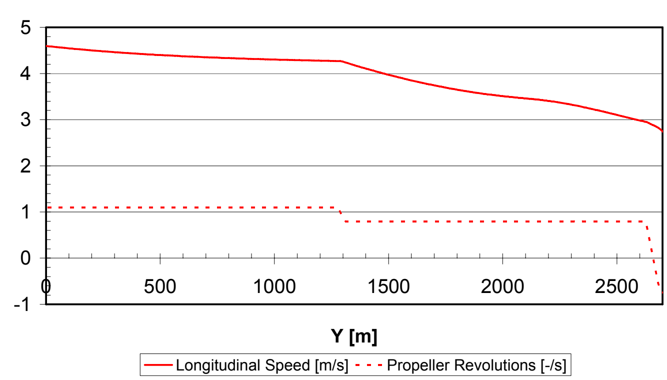

Rudder Use
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

NIOC Run 9

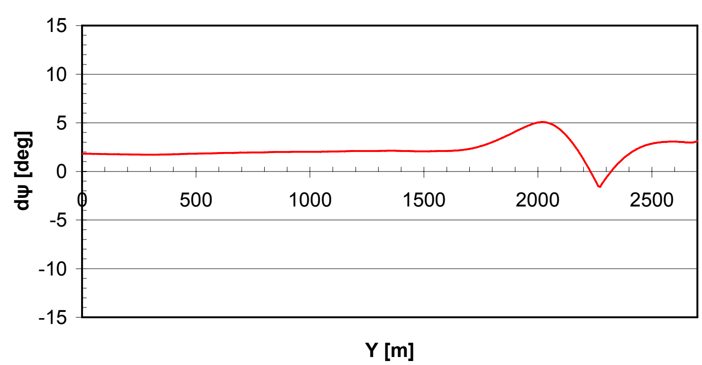
Track



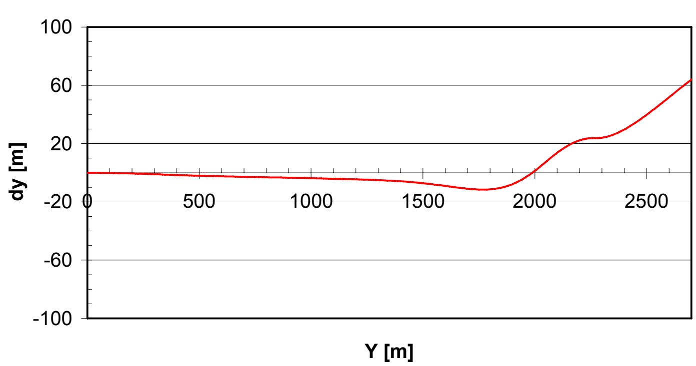
Vessel Speed



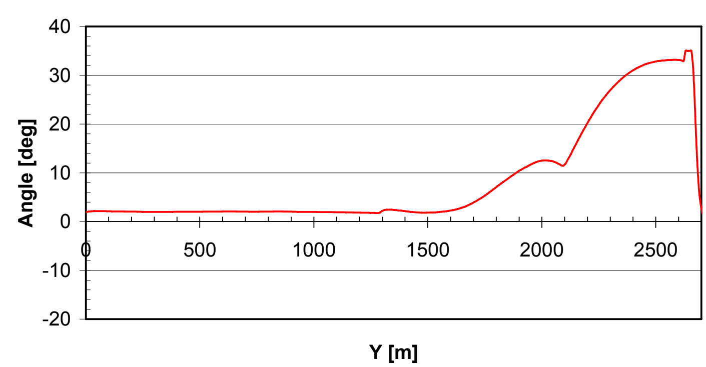
Drift Angle



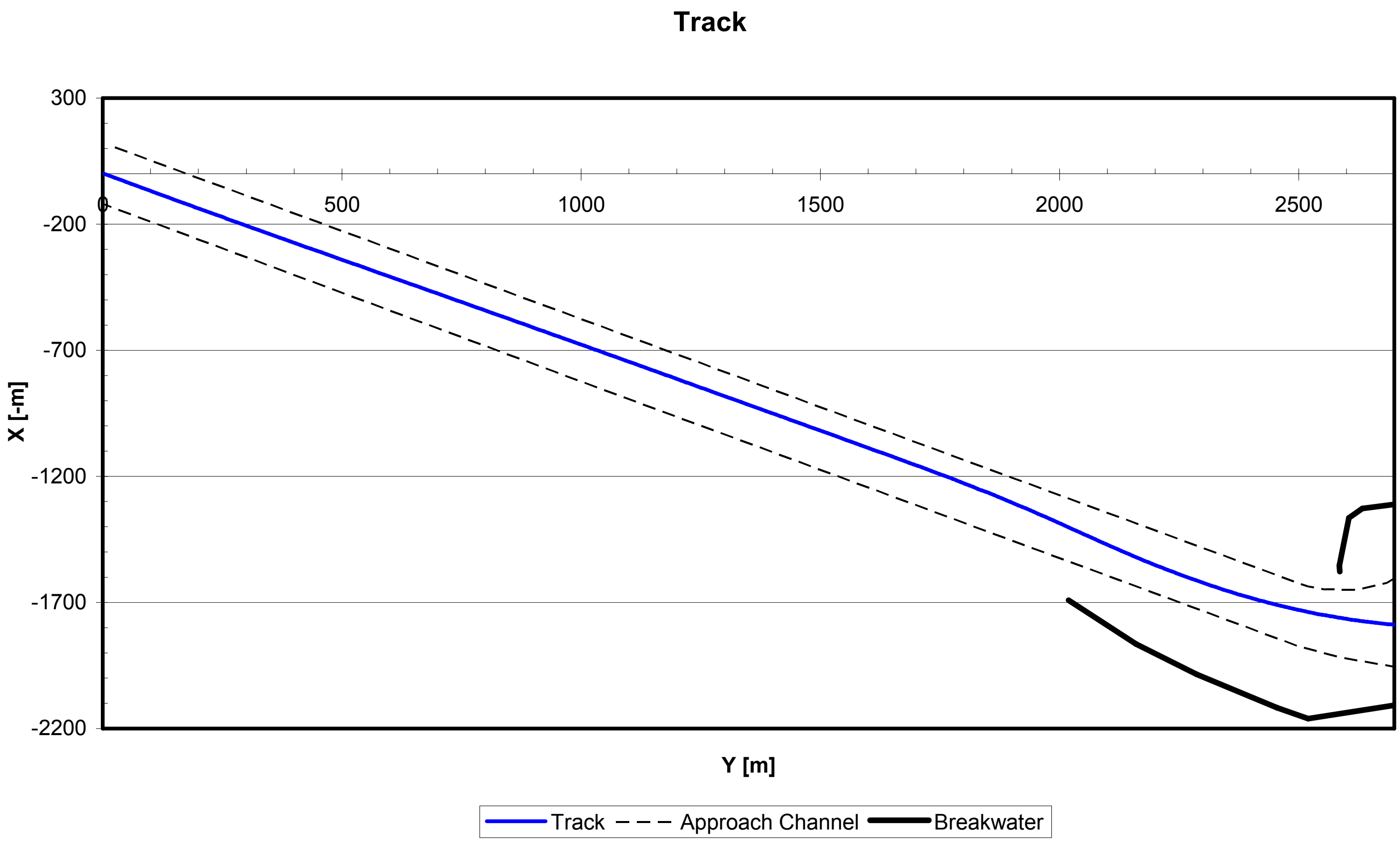
Transverse Deviation from Desired Track

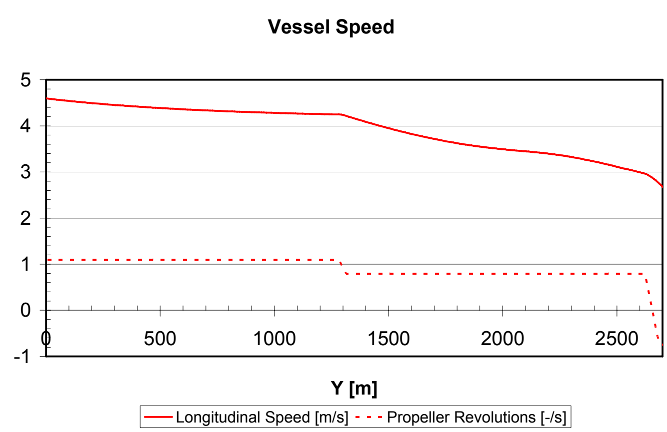


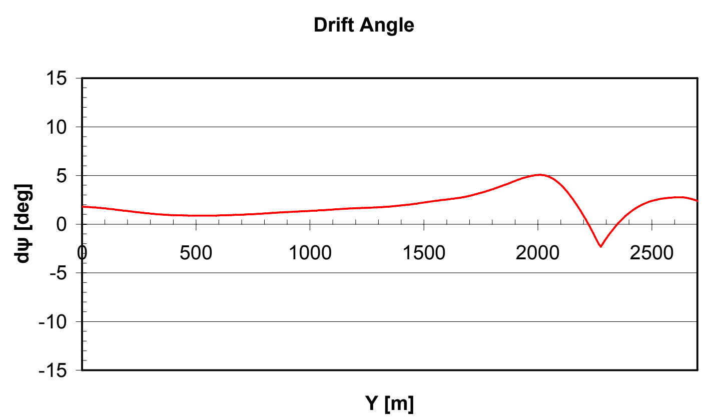
Rudder Use

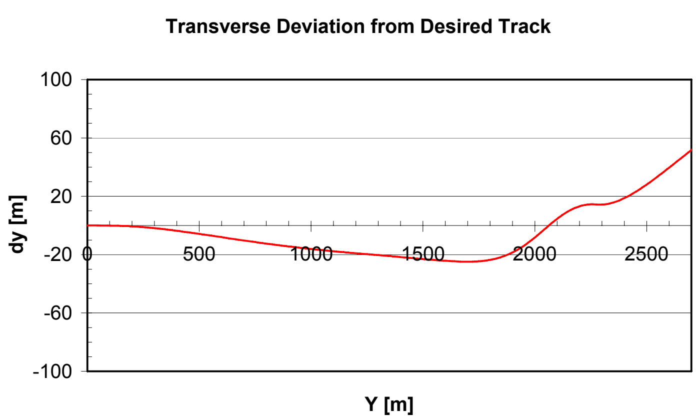


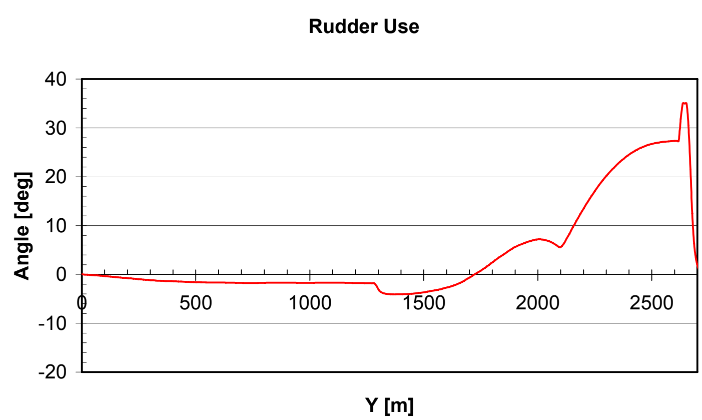
NIOC Run 10


Track
300
-200
-700
-1200
-1700
-2200
X [-m]
0
500
1000
1500
2000
2500
Y [m]
Track
Approach Channel
Breakwater

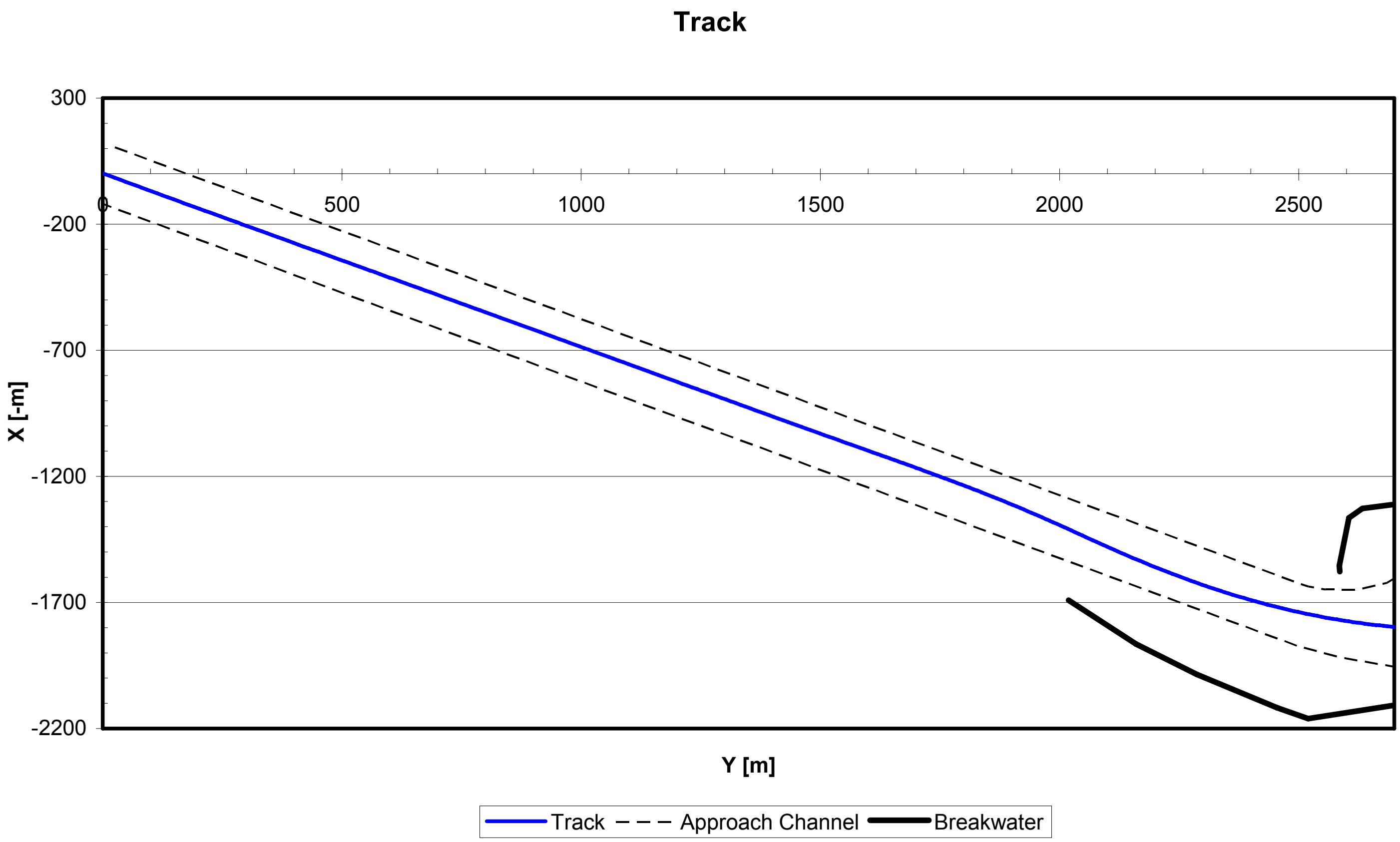

Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]


Drift Angle
15
10
5
0
-5
-10
-15
dψ [deg]
0
500
1000
1500
2000
2500
Y [m]

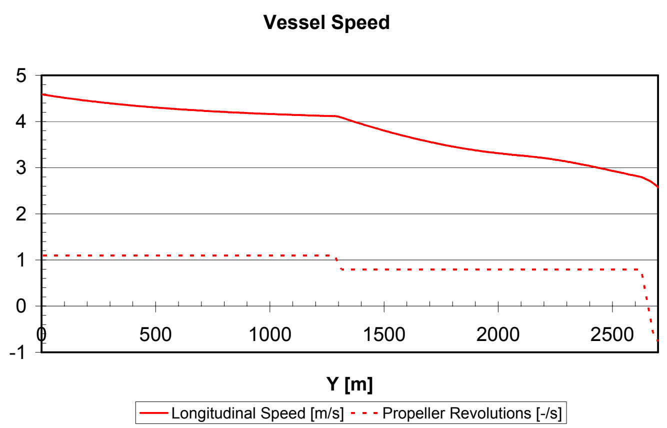

Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
dy [m]
0
500
1000
1500
2000
2500
Y [m]


Rudder Use
40
30
20
10
0
-10
-20
Angle [deg]
0
500
1000
1500
2000
2500
Y [m]

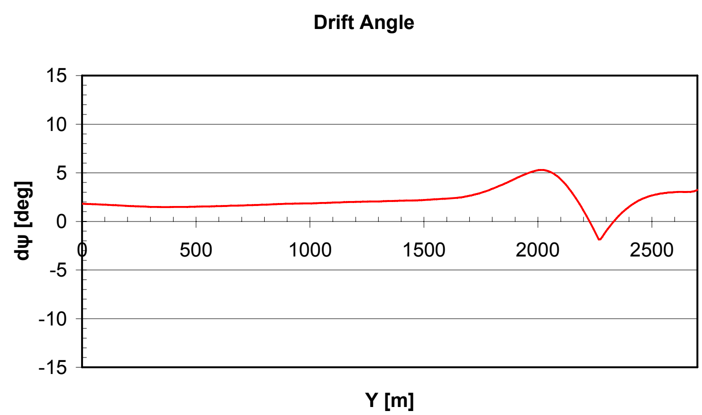
NIOC Run 11



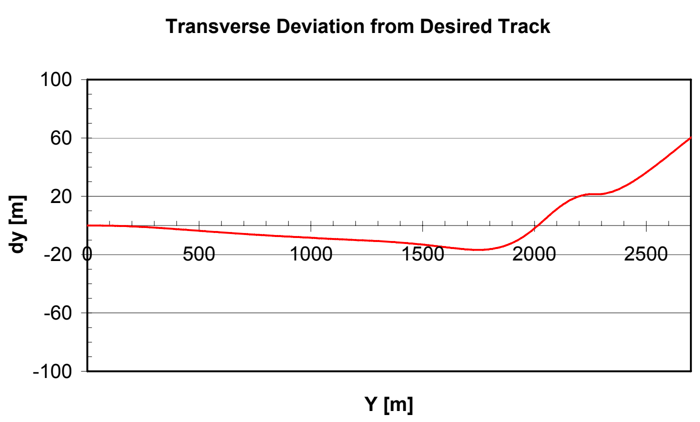
Track
300
-200
-700
-1200
-1700
-2200
X [-m]
0
500
1000
1500
2000
2500
Y [m]
Track
Approach Channel
Breakwater



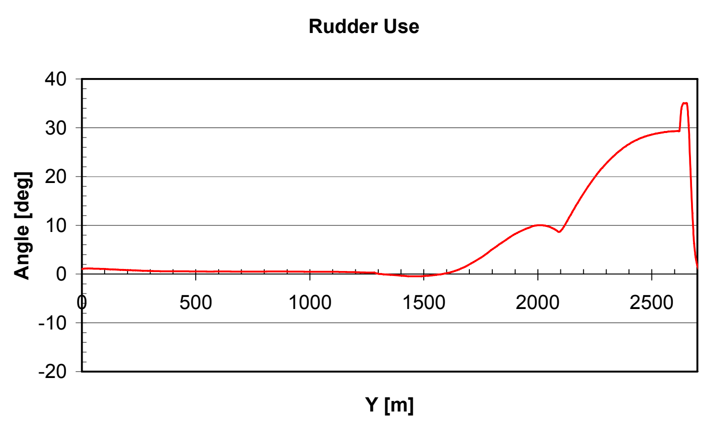
Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
dψ [deg]
0
500
1000
1500
2000
2500
Y [m]

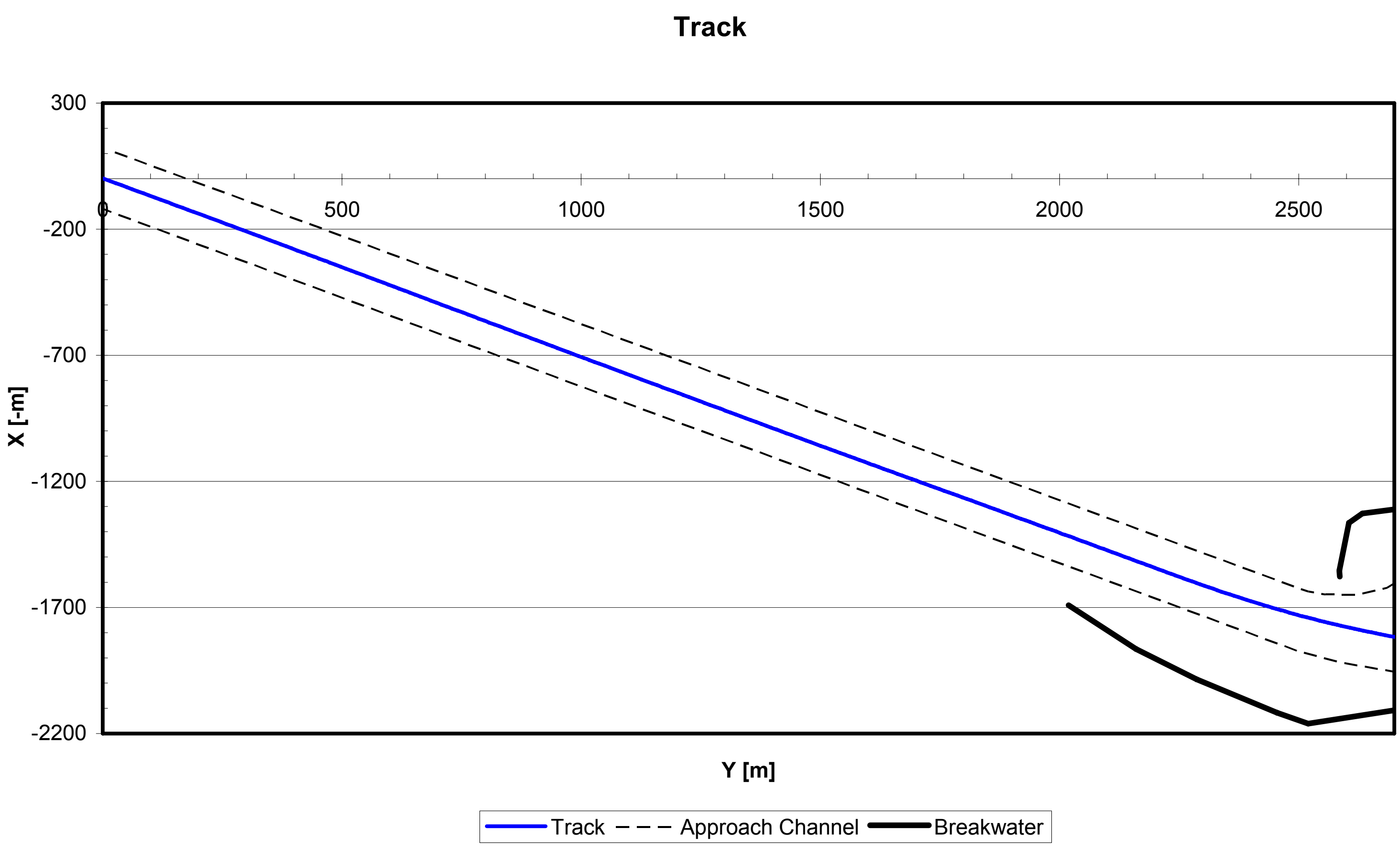


Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
dy [m]
0
500
1000
1500
2000
2500
Y [m]

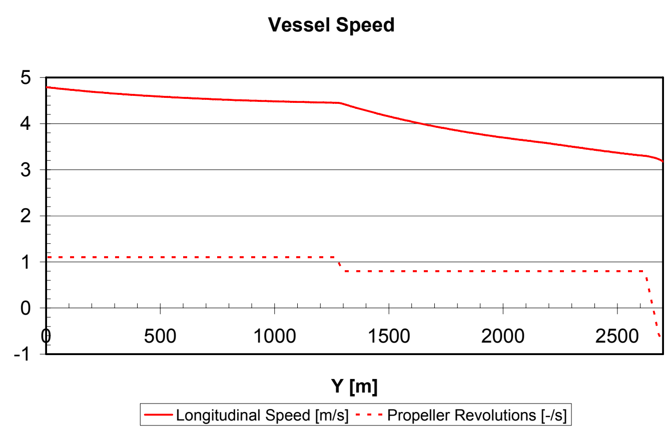


Rudder Use
40
30
20
10
0
-10
-20
Angle [deg]
0
500
1000
1500
2000
2500
Y [m]

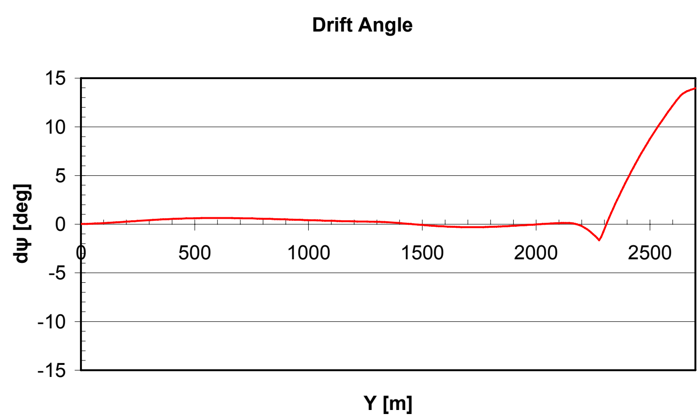
NIOC Run 12



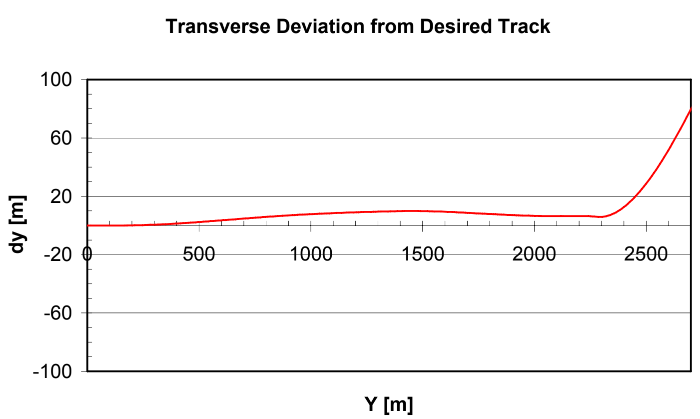
Track
300
-200
-700
-1200
-1700
-2200
0
500
1000
1500
2000
2500
X [-m]
Y [m]
Track
Approach Channel
Breakwater



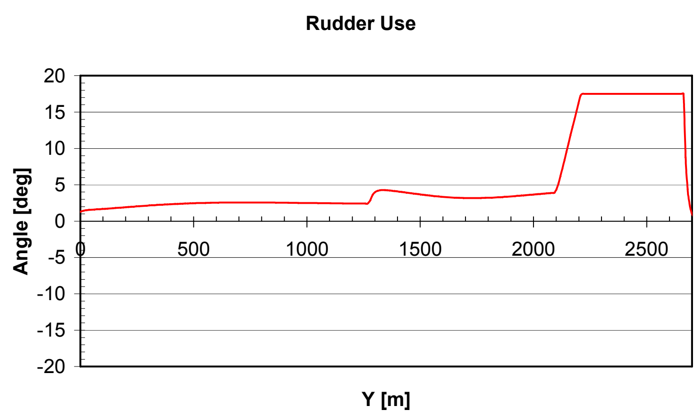
Vessel Speed
5
4
3
2
1
0
-1
0
500
1000
1500
2000
2500
Y [m]
Longitudinal Speed [m/s]
Propeller Revolutions [-/s]



Drift Angle
15
10
5
0
-5
-10
-15
0
500
1000
1500
2000
2500
dψ [deg]
Y [m]



Transverse Deviation from Desired Track
100
60
20
-20
-60
-100
0
500
1000
1500
2000
2500
dy [m]
Y [m]



Rudder Use
20
15
10
5
0
-5
-10
-15
-20
0
500
1000
1500
2000
2500
Angle [deg]
Y [m]

Delft University of Technology

ROYAL HASKONING

Annex XIX
Cost Assessment Alternative A

Alternative A: Preliminary Configuration

Unloading Processes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Unloading Time [hrs]	Unload Capacity [t/hr]	Vessel and Crew Costs [$/hr]	Profit Commodity [$/t]	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]
63,000 DWT Crude Oil Jetty	8400	214	4	15.79	3800	1458	0	0.00	0.40	0	3.00	0.10	37,392
63,000 DWT Crude Oil Fingerpier	8400	427	4	15.79	3800	1458	0	0.00	0.80	0	3.00	0.20	74,783
14,000 DWT Crude Oil Jetties	8400	714	4	10.83	1200	625	0	0.05	0.92	2,416	1.00	0.34	17,850
5-7,000 DWT Crude Oil Jetties	8400	1179	4	5.00	900	417	0	0.00	0.70	0	1.00	0.56	19,650
LPG Jetty	8400	n.a.	4	10.83	1200	833	0	0.00	0.50	0	1.00	0.17	11,900
Chemical Tanker Jetty	8400	n.a.	4	10.83	1200	625	0	0.00	0.50	0	1.00	0.17	8,925
Product Tanker Jetty	8400	198	4	10.00	900	417	0	0.00	0.24	0	1.00	0.09	3,300
										2,416			**173,800**

Processes with Construction / Maintenace Purposes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Constr. Costs [$/hr]	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]	
KEPCO Quay	8400	10	4	1000	0.11	0.3	2,772	40	0.004761905	16,000	
NDC Quay	8400	5	4	1000	1.55	0.1	13,020	40	0.002380952	8,000	
SADRA Quay Wall Berth 1	8400	8	4	1000	3.15	0.5	132,300	6	0.003809524	1,920	
SADRA Quay Wall Berth 2	8400	10	4	1000	1.9	0.7	111,720	6	0.004761905	2,400	
Ship Lift	8400	25	3	1000	0.4	0.05	1,680	6	0.008928571	4,500	
							261,492			32,820	**294,312**

Alternative A: Upgrading Tugboats

Unloading Processes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Unloading Time [hrs]	Unload Capacity [t/hr]	Vessel and Crew Costs [$/hr]	Profit Commodity [$/t]	Δ Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Δ Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]
63,000 DWT Crude Oil Jetty	8400	214	4	15.79	3800	1458	20	0.00	0.40	0	2.00	0.10	541,343
63,000 DWT Crude Oil Fingerpier	8400	427	4	15.79	3800	1458	20	0.00	0.80	0	2.00	0.20	2,115,518
14,000 DWT Crude Oil Jetties	8400	714	4	10.83	1200	625	20	0.00	0.92	0	0.00	0.34	0
5-7,000 DWT Crude Oil Jetties	8400	1179	4	5.00	900	417	20	0.00	0.70	0	0.00	0.56	0
LPG Jetty	8400	n.a.	4	10.83	1200	833	0	0.00	0.50	0	0.00	0.17	0
Chemical Tanker Jetty	8400	n.a.	4	10.83	1200	625	0	0.00	0.50	0	0.00	0.17	0
Product Tanker Jetty	8400	198	4	10.00	900	417	0	0.00	0.24	0	0.00	0.09	0
										0			**2,656,861**

Alternative A: Include Detached Breakwater

Processes with Construction / Maintenace Purposes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Constr. Costs [$/hr]	Δ Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Δ Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]	
KEPCO Quay	8400	10	4	6900	0.11	0.3	19,127	0	0.004761905	0	
NDC Quay	8400	5	4	6900	1.55	0.1	89,838	0	0.002380952	0	
SADRA Quay Wall Berth 1	8400	8	4	6900	3.15	0.5	912,870	0	0.003809524	0	
SADRA Quay Wall Berth 2	8400	10	4	6900	1.9	0.7	770,868	0	0.004761905	0	
Ship Lift	8400	25	3	6900	0.4	0.05	11,592	0	0.008928571	0	
							1,804,295			0	**1,804,295**

Alternative A: Upgrading Tugboats

Used Parameters

T	30
i	10

t	Investment [$]	Additional Running Cost [$/year]	Additional Revenue [$/year]	Discount Factor	Total [$/year]	NPV [$]
0	20,000,000	0	0	1.00	-20,000,000	**332,548**
1	0	500,000	2,656,861	1.10	1,960,783	
2	0	500,000	2,656,861	1.21	1,782,530	
3	0	500,000	2,656,861	1.33	1,620,482	
4	0	500,000	2,656,861	1.46	1,473,165	
5	0	500,000	2,656,861	1.61	1,339,241	
6	0	500,000	2,656,861	1.77	1,217,492	
7	0	500,000	2,656,861	1.95	1,106,811	
8	0	500,000	2,656,861	2.14	1,006,192	
9	0	500,000	2,656,861	2.36	914,720	
10	0	500,000	2,656,861	2.59	831,563	
11	0	500,000	2,656,861	2.85	755,967	
12	0	500,000	2,656,861	3.14	687,243	
13	0	500,000	2,656,861	3.45	624,766	
14	0	500,000	2,656,861	3.80	567,969	
15	0	500,000	2,656,861	4.18	516,335	
16	0	500,000	2,656,861	4.59	469,396	
17	0	500,000	2,656,861	5.05	426,724	
18	0	500,000	2,656,861	5.56	387,930	
19	0	500,000	2,656,861	6.12	352,664	
20	0	500,000	2,656,861	6.73	320,604	
21	0	500,000	2,656,861	7.40	291,458	
22	0	500,000	2,656,861	8.14	264,962	
23	0	500,000	2,656,861	8.95	240,874	
24	0	500,000	2,656,861	9.85	218,977	
25	0	500,000	2,656,861	10.83	199,070	
26	0	500,000	2,656,861	11.92	180,972	
27	0	500,000	2,656,861	13.11	164,520	
28	0	500,000	2,656,861	14.42	149,564	
29	0	500,000	2,656,861	15.86	135,967	
30	0	500,000	2,656,861	17.45	123,607	

Alternative A: Include Detached Breakwater

Used Parameters

T	30
i	10

t	Investment [$]	Additional Running Cost [$/year]	Additional Revenue [$/year]	Discount Factor	Total [$/year]	NPV [$]
0	16,800,000	0	0	1.00	-16,800,000	**208,933**
1	0	0	1,804,295	1.10	1,640,268	
2	0	0	1,804,295	1.21	1,491,153	
3	0	0	1,804,295	1.33	1,355,593	
4	0	0	1,804,295	1.46	1,232,358	
5	0	0	1,804,295	1.61	1,120,325	
6	0	0	1,804,295	1.77	1,018,477	
7	0	0	1,804,295	1.95	925,889	
8	0	0	1,804,295	2.14	841,717	
9	0	0	1,804,295	2.36	765,197	
10	0	0	1,804,295	2.59	695,634	
11	0	0	1,804,295	2.85	632,394	
12	0	0	1,804,295	3.14	574,904	
13	0	0	1,804,295	3.45	522,640	
14	0	0	1,804,295	3.80	475,127	
15	0	0	1,804,295	4.18	431,934	
16	0	0	1,804,295	4.59	392,667	
17	0	0	1,804,295	5.05	356,970	
18	0	0	1,804,295	5.56	324,518	
19	0	0	1,804,295	6.12	295,017	
20	0	0	1,804,295	6.73	268,197	
21	0	0	1,804,295	7.40	243,815	
22	0	0	1,804,295	8.14	221,650	
23	0	0	1,804,295	8.95	201,500	
24	0	0	1,804,295	9.85	183,182	
25	0	0	1,804,295	10.83	166,529	
26	0	0	1,804,295	11.92	151,390	
27	0	0	1,804,295	13.11	137,627	
28	0	0	1,804,295	14.42	125,116	
29	0	0	1,804,295	15.86	113,742	
30	0	0	1,804,295	17.45	103,402	

Alternative 0

Unloading Processes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Unloading Time [hrs]	Unload Capacity [t/hr]	Vessel and Crew Costs [$/hr]	Profit Commodity [$/t]	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]	
63,000 DWT Crude Oil Jetty	8400	214	4	15.79	3800	1458	0	0.00	0.40	0	3.00	0.10	37,392	
63,000 DWT Crude Oil Fingerpier	8400	427	4	15.79	3800	1458	0	0.00	0.80	0	3.00	0.20	74,783	
14,000 DWT Crude Oil Jetties	8400	714	4	10.83	1200	625	0	0.00	0.92	0	1.00	0.34	17,850	
5-7,000 DWT Crude Oil Jetties	8400	1179	4	5.00	900	417	0	0.00	0.70	0	1.00	0.56	19,650	
LPG Jetty	8400	n.a.	4	10.83	1200	833	0	0.00	0.50	0	1.00	0.17	11,900	
Chemical Tanker Jetty	8400	n.a.	4	10.83	1200	625	0	0.00	0.50	0	1.00	0.17	8,925	
Product Tanker Jetty	8400	198	4	10.00	900	417	0	0.00	0.24	0	1.00	0.09	3,300	
										0			173,800	**173,800**

Processes with Construction / Maintenace Purposes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Constr. Costs [$/hr]	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]
KEPCO Quay	8400	10	4	1000	0.10	0.3	2,520	40.00	0.004761905	16,000
NDC Quay	8400	5	4	1000	0.05	0.1	420	40.00	0.002380952	8,000
SADRA Quay Wall Berth 1	8400	8	4	1000	1.60	0.5	67,200	6.00	0.003809524	1,920
SADRA Quay Wall Berth 2	8400	10	4	1000	1.00	0.7	58,800	6.00	0.004761905	2,400
Ship Lift	8400	25	3	1000	0.00	0.05	0	6.00	0.008928571	4,500
							128,940			32,820

161,760

$ 335,560

Alternative 0

Unloading Processes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Unloading Time [hrs]	Unload Capacity [t/hr]	Vessel and Crew Costs [$/hr]	Profit Commodity [$/t]	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]	
63,000 DWT Crude Oil Jetty	8400	214	4	15.79	3800	1458	0	0.00	0.40	0	3.00	0.10	37,392	
63,000 DWT Crude Oil Fingerpier	8400	427	4	15.79	3800	1458	0	0.00	0.80	0	3.00	0.20	74,783	
14,000 DWT Crude Oil Jetties	8400	714	4	10.83	1200	625	0	0.05	0.92	2,416	1.00	0.34	17,850	
5-7,000 DWT Crude Oil Jetties	8400	1179	4	5.00	900	417	0	0.00	0.70	0	1.00	0.56	19,650	
LPG Jetty	8400	n.a.	4	10.83	1200	833	0	0.00	0.50	0	1.00	0.17	11,900	
Chemical Tanker Jetty	8400	n.a.	4	10.83	1200	625	0	0.00	0.50	0	1.00	0.17	8,925	
Product Tanker Jetty	8400	198	4	10.00	900	417	0	0.00	0.24	0	1.00	0.09	3,300	
										2,416			**173,800**	**176,216**

Processes with Construction / Maintenace Purposes

Component	Operational hours / year	Calls / year	Entrance + Departure Time [hrs]	Constr. Costs [$/hr]	Downtime at berth [%]	Utilisation berth [-]	Downtime Costs Berth [$]	Downtime A Ch [%]	Utilisation A Ch [-]	Downtime Costs A Ch [$]
KEPCO Quay	8400	10	4	1000	0.11	0.3	2,772	40	0.004761905	16,000
NDC Quay	8400	5	4	1000	1.55	0.1	13,020	40	0.002380952	8,000
SADRA Quay Wall Berth 1	8400	8	4	1000	3.15	0.5	132,300	6	0.003809524	1,920
SADRA Quay Wall Berth 2	8400	10	4	1000	1.90	0.7	111,720	6	0.004761905	2,400
Ship Lift	8400	25	3	1000	0.40	0.05	1,680	6	0.008928571	4,500
							261,492			32,820

294,312

$ 470,528