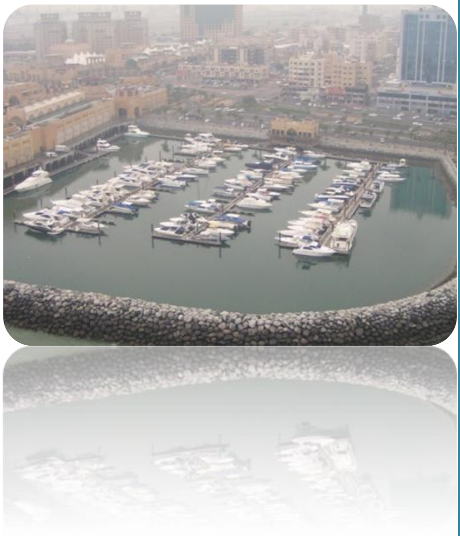
Masterplan Coastal Havens, "Nikas", Kuwait

Development of a master plan and layout for coastal havens on Kuwait coast

Master Thesis

J.C.S. Geerlings
Amersfoort, March 2010
Final report



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Delft University of Technology

Faculty of Civil Engineering and Geosciences

Hydraulic Engineering Section

Name student: J.C.S. Geerlings

Study number: 1180096

Graduation committee:

Prof. Ir. H. Ligteringen	TU Delft
Ir. M. de Jong	TU Delft / DHV
Ir. F.A.M. Soons	TU Delft

Preface

This document presents the report of my Master of Science thesis on “Master plan Coastal Havens, “Nikas”, in Kuwait”. This thesis completes my study Hydraulic Engineering, specialization Port and Waterways, at the faculty of Civil Engineering and Geosciences of the Delft University of Technology. The subject of this thesis was offered by DHV B.V. They provided me with the opportunity to work on this project at their main office in Amersfoort, The Netherlands.

This report is the result of a study into master plan development for the coastal havens in Kuwait and the functional layout of these havens.

I would like to thank my graduation committee members for their guidance, critical remarks and contribution during the process: Chariman prof. ir. H. Ligteringen, Ir. M. de Jong and Ir. F.A.M. Soons. I also would like to use this opportunity to express my gratitude to the employees of the department Ports and Waterways and the department of River and Coastal Development for their advice and assistance during my research project.

Jack Geerlings

March 2010, Amersfoort

Abstract

Currently there are 20,000 to 40,000 yachts in Kuwait. The majority of these yachts is stored on land because the number of berths in Kuwait is not sufficient to accommodate them all. Besides yachts, there are approximately 1,000 fishing vessels in Kuwait. The facilities for fishermen are not of sufficient quality. To overcome these problems, the Kuwaiti government initiated the development of a master plan for 9 coastal havens on Kuwait coast. Kuwait is located at the northeastern part of the Arabian Peninsula. It is bordering Saudi-Arabia and Iraq and lies on the northwestern shore of the Arabian Gulf. The emirate covers approximately 20,000 km^2 and has a population 3.5 million inhabitants.

The coastal havens need to facilitate fishing vessels, yachts, public transport vessels, vessels from the national authorities and incidentally vessels that take refuge in one of these coastal havens. The 9 proposed locations include 3 existing, but outdated coastal havens and 6 locations where very little or no maritime infrastructure is present. Additional to these proposed 9 locations, 5 other locations are considered. Furthermore, the current state of 11 marinas in Kuwait are considered during the formation of the master plan. The characteristics of the locations and the site specific advantages and disadvantages on various aspects are investigated.

Development of fishing and yachting industry

Besides the possible locations of the havens, the demand and need for these facilities is of course an important aspect. The yachting demand potential gives an indication of the expected development in demand of the yachting industry up to the year 2030. There already is a need for berths in Kuwait at the moment. In the future the demand will only increase due to the favorable economic situation of the indigenous population of Kuwait. The living standard of the national population enables this part of the Kuwaiti community to participate in yachting. The analysis is based on the development of the population and the economy and the part of the population that can afford a yacht in Kuwait. The development of the fishing industry and its fleet is based on the worldwide and Arabian developments of the industry. The worldwide trend for the fishing industry is not very optimistic. Depletion and overfishing of natures’ resources limits the development of this industry. This trend is, to a certain extent, also applicable to the industry in Kuwait.

Coastal water appraisal

In the master plan, boundary conditions applicable to the yachting and fishing industry need to be considered. The fishing grounds in Kuwait’s territorial waters are of interest for the fishing industry and the islands could be attractive sailing destinations for the

yachts. Other developments in Kuwait, such as new city development, also need to be taken into account to make the master plan successful and up to date. There are of course also aspects that lay down restrictions upon the development of these industries, such as the oil refining and exporting industry. These aspects are also incorporated in the master plan.

Master plan

The master plan accounts for 6750 berths in the year 2030, an increase of 4750 berths in 25 years, and a small increase in the number of fishing vessels in Kuwait. The master plan contains recommendations for the proposed development directions and functions that have to be allocated for all coastal haven locations. The geographical spread of the population and demand are also taken into account.

Generalized functional layout

The complexity of the concept of a coastal haven lays within the fact that it has to facilitate yachts, fishing vessels and somewhat larger vessels at the same time. The facility must be multipurpose to some extent, but other aspects must be kept separate in order to provide all users in their needs and meet their expectations. This has certain implications for the layout of the coastal haven. The main processes, functions and related facilities are translated into a generalized functional layout with a function interrelation matrix and the routing of the vessels through the coastal haven. From this analysis the conclusion can be made that combining certain functions brings along certain benefits.

Layout alternatives Al Syadeen

The design requirements and criteria are applied to one coastal haven location and are translated into three layout alternatives for the haven Al Syadeen. Al Syadeen is located along the Arabian Gulf coast at the mouth of the Kuwait Bay.

The layouts are evaluated with two hydraulic models. These models simulate the wave propagation from an offshore data point into the wave conditions within the coastal haven basins. The modeled wave conditions are those that occur only once during the life of the coastal haven. The layout has to be such that it can protect the vessels from these conditions. A extreme value analysis is applied to the purchased wave data to determine these conditions.

During the modeling it is concluded that the layout needs to be such that the basins are relatively closed off. The acceptable wave height within the coastal haven is very limited, because damage to the yachts and speedboats used for fishing is not acceptable in a coastal haven.

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Symbols

H_s	=	*Significant wave height [m]*
H_t	=	*Threshold wave height [m]*
T	=	*Wave period [s]*
U_{10}	=	*Wind speed at 10 above the surface / mean sea level [m/s]*
T_P	=	*Peak wave period [s]*
L	=	*Wave length [m]*
c	=	*Phase speed waves [m/s]*
k	=	*Wave number [m^{-1}]*
ω	=	*Radian frequency [rad/s]*
γ	=	*Peak enhancement parameter JONSWAP energy density spectrum [-]*
m	=	*Directional distributional parameter energy density spectrum [m]*
M	=	*Nautical mile (1,852 meter)*
g	=	*Gravitational constant (9,81) [m/s^2]*
d	=	*Water depth [m]*
B	=	*Beam [m]*
L_s	=	*Length ship [m]*
L_B	=	*Length berth [m]*
kn	=	*Knots (nautical mile per hour) [kn]*
D	=	*Draught [m]*
H_{cr}	=	*Critical wave height [m]*
P	=	*Probability of occurance [%)*
Q	=	*Probability of exceedance [%]*
α, β, γ	=	*Parameters Weibul/Gumbell distribution*
T_R	=	*Return period [year]*
λ	=	*Number of events per year [-]*
c_3, c_4	=	*Constant wave height period relation [-]*
θ_{naut}	=	*Origin direction of waves according nautical convention [degrees N]*
θ_{math}	=	*Heading direction of waves according Cartesian convention [degrees]*
W_{BM}	=	*Basic width [m]*
W_I	=	*Additional width [m]*
W_P	=	*Separation distance [m]*
W_B	=	*Bank clearance [m]*
R	=	*Reflectoin coefficient [%]*
α_I	=	*Angle between normal direction of boundary element and incoming wave [degrees]*
n	=	*Coordinate normal to the boundary pointing outward [degrees]*
α	=	*Slope angle breakwater slopes*
ξ	=	*Breaking parameter*
s_{op}	=	*wave steepness*
T_Z	=	*Zero crossing period [s]*

Abbreviations

CD	=	*Chart Datum*
E	=	*East*
ENE	=	*East-northeast*
ESE	=	*East-southeast*
FAO	=	*Food and Agriculture Organization of the United Nations*
GDP	=	*Gross Domestic Product*
IBI	=	*International Boat Industry*
IMF	=	*International Monetary Fund*
JONSWAP	=	*Joint North Sea Wave Project*
KPA	=	*Kuwait Port Authority*
LAT	=	*Lowest Astronomical Tide*
MHHW	=	*Mean Higher High Water*
MHLW	=	*Mean Higher Low Water*
MLLW	=	*Mean Lower Low Water*
MLHW	=	*Mean Lower High Water*
MOP	=	*Ministry of Planning*
MSL	=	*Mean Sea Level*
N	=	*North*
NE	=	*Northeast*
NNE	=	*North-northeast*
NNW	=	*North-northwest*
NW	=	*Northwest*
PACI	=	*Public Authority of Civil Information*
S	=	*South*
SE	=	*Southeast*
SSE	=	*South-southeast*
SW	=	*Southwest*

1 Introduction

1.1 Background

The Kuwaiti people have been connected to the sea since their old ancestors. The sea is still of vital importance to a large part of the inhabitants of Kuwait. But the maritime facilities for the part of the population that depends on fishing to make a living are not of good quality. Another aspect is the increasing popularity of yachting in Kuwait and the limited facilities present for the part of the population that would like to enjoy yachting in Kuwait.

Most marinas in Kuwait are managed by private companies and organizations, which operate locally. The existing coastal havens are managed by the governmental institution Kuwait Port Authority (KPA). In order to provide the yachting industry with network of destinations and the fishing industry with rational located facilities an integrated analysis needs to be made.

In a cabinet resolution from 2004, the cabinet of Kuwait decided that it is necessary to modernize the three existing coastal havens, and create new coastal havens along the coast of Kuwait. In 2005, the Ministry of Planning of the State of Kuwait sent an invitation to DHV to submit a proposal for "The development of current coastal havens "Nikas" and the establishment of new coastal havens "Nikas" on Kuwait coast". With this invitation for a master plan study, the Kuwaiti cabinet wants to set the first step into developing and establishing an integrated network of coastal havens along the Kuwait coastline. The three existing coastal havens should become part of an integrated network of coastal havens. To ensure a widespread integrated network the Ministry of Planning added 6 areas to the existing locations, in which a new coastal haven needs to be developed.

The development of a network of coastal havens is needed to incorporate concurrence position of the coastal havens with other coastal havens and marinas. In the network analysis the location of the fishing grounds, infrastructure, fish markets, development plans and other characteristics of the coastal waters of Kuwait should be taken into account. Next to this an integrated view is necessary to take care of the spatial variation in demand to the coastal haven from the users at the locations.

The analysis is mainly used for the definition of a yachting network. For these users, day trips but also multiple day trips are interesting and must be made possible. The local fishermen are mostly bound to a certain location and their fishing grounds are at a short distance away. The facilities for these users must be located within reach from their current location. For the yacht owners attractive destinations are needed, which yacht owners can visit with their yachts other than the clustered marinas in the Kuwait Bay. For yacht owners it is nice to be able to discover new places and not always see the same environment every time you go out on the water. When leaving the home port marina, the adjacent water area has no secrets left after some trips. If there are no other destinations to temporary berth your yacht the sailable area is limited. Moreover, most people enjoy yachting when a new destination is reached every night, with new exciting places to explore and to stroll around.

Attractive destinations for yachts should have the following characteristics.

- Within 1 to 4 hours navigation from other destinations or home ports
- Comfortable and safe berthing in the yachting season
- Attractive natural environment or attractive urban waterfront sites
- Provision of leisure activities such as museums, souvenir shops, bars, terraces and restaurants.

With the modernization of the existing coastal havens and construction of new ones, the government wants to facilitate fishing vessels, leisure crafts and other kinds of vessels, which enter the coastal haven in an emergency situation, with a protected berthing area. The development of coastal havens has to lead to better facilities to the people who depend on fishery for a living and to make further development of the yachting industry possible. Another goal of the development of the coastal havens is the development of the surrounding area. This plan fits in within the general vision of the government to diversify the sources of the country's national product.

1.2 Problem definition

Currently there are only few locations available for the non-commercial fishery sector; these locations do not have facilities of sufficient quality. Furthermore, the development of the yachting industry is hampered by the limited capacity, which is provided by the privately owned marinas. There is no master plan for an integrated network of coastal havens, able to facilitate leisure crafts and yachts, as well as private and commercial fishing ships, with the required facilities and which can serve as port of refuge for passenger service and public authority vessels.

1.3 Objective

The main objective of this thesis is to develop a master plan for the network of coastal havens that can reach up to the demands of its target user groups. Observations and findings for the existing and suggested locations for coastal haven development, boundary conditions and a development forecast for the fishery and yachting industry will be part of the development of this master plan.

Besides the master plan, the development of a generalized layout for the coastal havens and the application of this generalized functional layout to one location is part of this thesis. With the forecast of the fishing and yachting industry, routing of the yachts and fishing vessels within the coastal haven and other design criteria, layout alternatives are determined. Wave conditions in and outside the coastal haven are taken into account in the design. The most suitable layout is selected based on a multi criteria analysis and hydraulic modeling of the layout alternatives.

1.4 Structure of the report

This report consists of two phases. In the first phase the master plan is worked out, the second phase covers the generalized layout and the application of this concept to one coastal haven location. The report starts with general information about Kuwait in the second chapter. In the third chapter a detailed overview of the structure and approach is described.

The first phase, developing a master plan for the coastal havens, commences with the assessment of the current situation in Kuwait in chapter 4. The second part, chapter 5, deals with the development forecast of the target user groups, the users of the coastal havens. In the third part, chapter 6, the development of a master plan is described.

In the second phase is zoomed in to the level of one coastal haven. In chapter 7 the main functions of a coastal havens are determined based on an analyses of the functioning of a coastal haven (Appendix K). The main functions of a coastal haven are translated into a generalized functional layout. The generalized functional layout is subsequently applied to one of the coastal haven locations and this process is described in chapter 8. Several layout alternatives are generated in this chapter. These alternatives are evaluated with hydraulic models and an multi criteria evaluation in 9. The optimum layout that results from the evaluation methods is worked out in detail in chapter 10.

The report is concluded with conclusions in chapter 11 and the discussion and recommendations in chapter 12.

Amongst other things an extensive description of the economic, population and fishing industry development forecast are added in the appendices (Appendix I and Appendix J) The model set-up, input and output of the performed hydraulic modeling studies are also part of the appendices.

2 General information Kuwait

2.1 Kuwait

The State of Kuwait is a sovereign Arab emirate on the coast of the Arabian Gulf in the Middle East, enclosed by Saudi Arabia to the south and Iraq to the north and west. The border with Iraq is approximately 240 kilometer long and with Saudi Arabia 222 kilometer and a total length of 462 kilometer. Besides the borders with other countries, Kuwait borders the Arabian Gulf and Kuwait Bay over a length of 500 km. This includes the perimeter of the nine islands, which are also part of Kuwait.

figure 1: Position Kuwait in the world (en.wikipedia.org)

figure 2: Kuwait in the Middle East (en.wikipedia.org)

Kuwait has a population of 3.4 million people (2007) and has a surface area of 17,818 km². It is a constitutional monarchy with a parliamentary system of government and Kuwait City serves as its political and economic capital. A large part of the country constitutes of the relatively flat Arabian Desert. Vegetation and people can mostly be found along the coastline.

The current flag of Kuwait is used since the proclamation of independence from the United Kingdom in 1961. The flag and national emblem are shown and explained below.

The present emblem of Kuwait, which is used since 1963, is a falcon with outspread wings embracing a dhow, an artisanal sailing vessel, sailing on blue and white waves. It is a symbol of Kuwait’s maritime tradition.

(www.kuwait-info.com)

figure 3: National emblem of Kuwait

figure 4: Flag of Kuwait

Kuwait’s recorded history goes back to 1613. At that time it was one of the major centers for spice trading between India and Europe. In the 18th century, the people’s source of income was fishing and selling pearls. From 1930 on, this changed, because of the discovery of oil. Kuwait has approximately 7.5 % of the world’s proven oil reserve. Despite the changes that came along with the discovery of oil, the people still have a strong affection with the sea. This is shown for example by the large number of recreational vessels in the country. There are 30,000 registered leisure crafts, next to the public service crafts, fishing vessels and passenger vessels present in the existing harbors and marinas along the coast. A special type of ship is the dhow. Dhows, ships made from wood, are a distinct part of Kuwait's maritime fleet and dhow building is still practiced. The dhow is also part of the coat of arms of the country, as a symbol for the maritime tradition of the country, see figure 3.

2.2 Governorates

The country is divided into six governorates namely: Al Asimah (Al Kuwayt), Hawalli, Al Ahmadi, Al Jahra, Al Farwaniyah and Mubarak Al-Kabeer. Each is headed by a governor, a representative of the Emir.

Governorates	Capital	Area (km²)	Origin
Al Ahmadi	Al Ahmadi	5,120	1946 from Al Asimah
Al Asimah (Al Kuwayt)	Al Kuwait	200	original Governorate
Al Farwaniyah	Al Farwaniyah	190	1988 from Al Asimah
Al Jahra	Al Jahra	12,130	1979 from Al Asimah
Hawalli	Hawalli District	84	original Governorate
Mubarak Al-Kabeer	Mubarak Al-Kabeer	94	1999 from Hawalli

table 1: Overview governorates (en.wikipidia.org)

figure 5: Governorates Kuwait

In 1760 Kuwait covered 11 hectares, at the moment it has a surface area of 17,818 km^2 and contains 16 modern cities. Ninety percent of the population lives in the urbanized area (see figure 6). This is the area covered by Kuwait City and the coastal belt from the western edge of the Kuwait Bay at Al-Jahra, to Mina Abdulla in the South. The remainder of the county is very scarcely populated.

The major cities are the capital Kuwait City, Jahra, located 35 kilometers west of Kuwait City and and Ahmadi, located 40 kilometers south of the capital. The main residential and commercial areas are Salmiyah and Hawalli. The main industrial areas are around the two main ports. These are located in the Shuwaikh area, west of Kuwait City, and in the south around Shuaiba in the Al Ahmadi governorate.

figure 6: Urbanized area Kuwait (www.kuwait-info.com)

2.3 Kuwait City

The old city center of Kuwait City is located on the southern shore of the Kuwait Bay. The Kuwait Bay is a naturally sheltered location along the Arabian Gulf. Kuwait City developed in the 18th and 19th centuries as a trading city, relying on the income from the fishing and pearl banks in the Arabian Gulf as well as on the maritime cargo transport between Europe and India and Asia. Before the Suez Canel opened, Kuwait was a central maritime hub between these continents.

2.4 Historical background

The State of Kuwait was originally referred to as 'Qurain' (or Grane) in the early 17th century. This name is derived from the Arabic words 'Qarn' which means a high hill and 'Kout' meaning a fortress.

The history of Kuwait goes back to the moment Barrak Bin Ghuraif, Sheikh of the Bani Khalid tribe settled along the Kuwait Bay at the area that is now known as Kuwait City in

1672. The actual establishment of Kuwait was in 1711 with the arrival of the "Utub" tribe in the interior of the Arabian Peninsula, migrated to the area that is now Kuwait. They fled to this piece of land because of the drought at that time. The foundation of the autonomous sheikhdom of Kuwait is dated from 1756, when the settlers decided to appoint a Sheikh from the Sabah family.

Recent history

During the 19th century, Kuwait developed as a thriving, independent trading community. The Arabian Gulf has been an important waterway since ancient times, bringing the people who lived on its shores into contact with other civilizations. In the ancient times, the Gulf nations established trade connections with India; in the Middle Ages, they traveled as far as China; and in the modern era, they became involved with the European powers that sailed into the Indian Ocean and around Southeast Asia. In the twentieth century, the discovery of massive oil deposits in the Gulf made the area important for the modern world.

According to the CIA World Fact Book Kuwait has approximately 7.5% of the world's proven oil reserve. With this reserve, Kuwait holds the fifth position on the list of countries by proven reserves of oil after Saudi Arabia, Canada, Iran and Iraq and is ranked above the United Arab Emirates, Venezuela and Russia. Kuwait production holds a 10^{th} position worldwide with a production of 2,613,000 barrels per day. With its relatively small surface area and enormous oil wealth, Kuwait occupies a unique and unordinary position at the head of the Arabian Gulf, bordering Iraq and Iran.

From 1899 until 1961, Kuwait was a British protectorate. A succession of emirs of the Al Sabah ruled the country, but the handling of its foreign affairs was a British privilege. In exchange, the British guaranteed the security of the emirate. During the 1920s and 1930s, British protection became particularly important to hold back the Saudi encroachment. This encroachment resulted in a shared territory of 5675 km^2 by Kuwait and Saudi Arabia as a neutral zone until 1969, when a political boundary was agreed upon. Both countries equally share the revenues from oil production in the area. While the boundary with Saudi Arabia was defined by that time, the border with Iraq remained disputed.

Iraq repeatedly challenged the relations with Kuwait. However, because of the threat for the radical leadership of Iran, Kuwait aided Iraq during the Iran-Iraq War by permitting the transshipment of goods across its territory and by providing loans.

Kuwait responded to terrorist bombings and other violence inspired by Iran by intensifying its military cooperation with the Gulf Cooperation Council (GCC) and by strengthening its own military forces. Kuwait remained neutral and was reluctant to become involved with the great powers. Kuwait turned to the United States, the Soviet Union and Britain for naval protection of its tanker fleet after twenty-one ships were attacked in the gulf in the six months preceding.

With the end of the Iran-Iraq War in 1990, Iraqi-Kuwaiti relations began to deteriorate. On August 2, 1990, Iraq unexpectedly invaded and conquered the country. The main reason for this unexpected attack was the desire to control Kuwait's oil and wealth. The military benefit for Iraq was a greater frontage on the Arabian Gulf. On August 8 1990, Iraq announced the annexation of Kuwait, in spite of the condemnation from the United Nations, the major world powers, the Arab League, and the European Community.

On January 16-17 1991, a coalition of nations, acting under the authority of the United Nations and led by the United States and Saudi Arabia, began an air strike against Iraqi forces. Just before the ground war began on February 24, Iraqi troops set afire hundreds of Kuwait's oil wells, creating an enormous ecological disaster. By February 27 Kuwait was liberated from Iraqi control. As hundreds of thousands of Kuwaitis returned from foreign refuges to their homes in May of that year, the full extent of the damage created by the invasion, looting, and war became clear.

The invasion and occupation affected every aspect of Kuwaiti life. More than half the population fled during the war. Although most nationals returned during 1991, many non-nationals, notably the Palestinians, were not permitted to do so. The survival of the Iraqi regime in Baghdad spawned an ambient fear among the people of Kuwait that the events of 1990-1991 would someday be repeated.

After the war

During the retreat of the Iraqi army they damaged and set on fire 700 oil wells on Kuwait soil. It took a lot of effort and almost nine months to extinguish these fires and it took more than two years to reconstruct the infrastructure. In these two years Kuwait was able to reach the oil output they had before the invasion. Kuwait has largely recovered from the socio-economic, environmental, and public health effects of the Gulf War since. The country is largely depending on the income from oil exploration, but is trying to diversify it sources of income.

Besides the oil industry, the fishing industry was also seriously affected by the results of the war. Oil spillage into the Gulf deteriorated the marine life in the Kuwait Bay and Gulf. This had a huge impact, due to the fact that it is one of the most vibrant productive activities in the region after the production of oil. In addition to this degradation of an economic activity, many people living on the Gulf coast depend on fishing for a living. The oil spillage has disrupted the productiveness of the nursery grounds of shrimp and fish. The tourist industry was also affected by the war. Prior to the war Failaka Island was an island with facilities for tourist. During the war the tourist industry came to a hold and the island turned into a marina base.

2.5 Society

When the Utub tribe arrived in Kuwait there were already some other tribes living in the area. These tribes joined the Utub trading settlement. Other people got attracted by Kuwait's stability and in 1831 the population was about 4,000 people. Throughout the 19^{th} century a continuous immigration from Arabia, southern Mesopotamia, and Persia was taking place. As a result Kuwaiti culture is very diverse.

Although the most important social division in the country is between the indigenous population and foreigners, the indigenous population is internally divided as well. The first division that can be mentioned is based on religion. The majority of Kuwaiti nationals are Sunni Muslims; a minority is Shia. Kuwaiti can be divided into classes. Although the national population is generally well off because of the state's generous employment policies and social services for the indigenous people, there is also a division noticeable between the country's economic elite and the rest of the population.

The government invested the revenues from the oil exploration in the education of the indigenous people. The educated Kuwaitis began to replace the foreigners at the highest employment levels. The restrictions on female behavior in public and consequently on work force participation are not as strong as they are elsewhere in the Gulf.

The World Bank Development indicators, used to determine the development of a country compared to other countries in the world are given in table 2.

Indicator	
Annual population growth rate (%)	3.0
Life expectancy at birth (years)	78
Infant mortality rate (‰)	9
GDP per capita (PPP) US$	26 321

table 2: World Bank development indicators 2005 (unesco.org)

2.6 Natural resources

Kuwait's oil fields are located in the heart of the country and are connected by pipelines to the refineries and export facilities. These facilities are located in the area between Ahmadi and Shuaiba.

Kuwait has few natural resources other than oil. The gigantic natural harbor of Kuwait Bay, its fish stock in the Arabian Gulf and Kuwait Bay, and a few water supplies are others worth mentioning besides the oil reserves. Next to this natural gas is discovered in the Kuwait Bay in commercial quantities. The initial phase of production started at the end of 2007.

2.7 Maritime sector

At the moment Kuwait has two commercial ports, one industrial fishing port and several smaller harbors and marinas. The commercial ports, Shuwaikh port and Shuaiba port, deal with the international trade and are under supervision of the Kuwait Ports Authority (KPA). Shuaiba port is the large industrial area in the south of Kuwait with oil refineries and petrochemical industry. Shuaiba port consists of several part that are indicated as Al-Ahmadi, Shuaiba and Mina Abdullah on the hydrographical chart. Doha Port, the industrial fishing port, is located west of Kuwait City. The coastal havens and coastal slipways are also supervised by the KPA. Most of the marinas along the Kuwait coastline are managed by private companies and organizations.

A detailed location description of the location that are in the scope of this research project is made in section 4.2 Existing maritime infrastructure and location description.

3 Frame work and approach study

3.1 Introduction

In this chapter, the structure of the report and approach of the study is elaborated in detail. The two phases are indicated in figure 7. The content of the various parts is explained in this chapter.

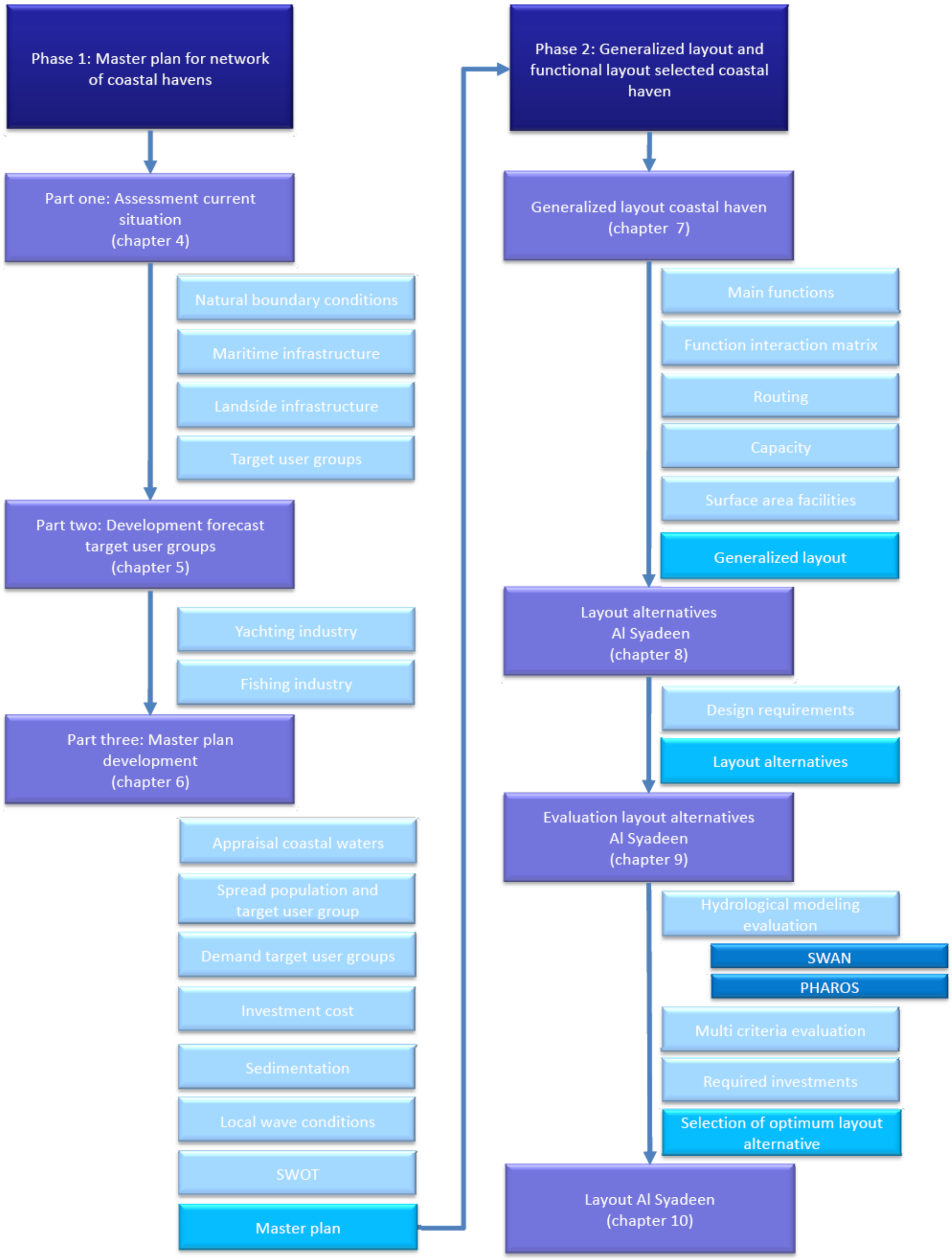


figure 7: Structure research project

3.1.1 First phase: Master plan for a network of coastal havens

3.1.1.1 Part one: Assessment current situation

In the first phase, the current situation in Kuwait is assessed. This is done by an overview of the existing maritime infrastructure in section 4.2. The existing coastal havens and assigned areas are described in detail. Next to that, an overview of the marinas and other interesting locations for coastal haven development is part of this section. Next to the maritime infrastructure, the landside infrastructure is also of importance. This is described in section 4.3. The natural boundary conditions are analyzed in 4.1. These are needed during the allocation of the coastal havens. The first part is concluded with an overview of the size and geographical spread of the target users groups in section 4.4.

3.1.1.2 Part two: Development forecast target user groups

The second part of the first phase contains a development forecast for the yachting sector in 5.3 and fishing sector in 5.4. These are based on economical, population and fishery sector background information. A overview of the approach and information input is given in the section methodology (5.2) at the beginning of this part.

This results in a forecast of the size and composition of the target user groups in the future, which will be used for the master plan development in the third part of the first phase in chapter 6. This analysis is made, based on the methodology applied during other project by DHV B.V. and its partners.

3.1.1.3 Part three: Master plan development

In the last part of this phase all information from the previous parts is used to set up a master plan for the network of the coastal havens. This is done based on an appraisal of the coastal waters, including the islands and the development plans, which can be found in section 6.2 and the geographical spread of the target user groups and their demand from the system in section 6.4 and 6.3 respectively. This results in the final product of this phase, a master plan for the network of coastal havens in section 6.7*.*

3.1.2 Second phase: Functional layout selected coastal haven

The main functions in a coastal haven determine the generalized functional layout, this aspect is treated in chapter 7. The generalized functional layout is able to facilitate the target user groups at the various locations. For the coastal haven of Al Syadeen several layout alternatives will be generated in chapter 8. The optimum layout is selected based on the results from the hydraulic modeling study and a multi criteria analysis in which the required investment costs are also considered, see chapter 9.

Phase one: Master plan coastal havens

4 Part one: Present situation

This chapter deals with the mapping of the current situation of the interesting aspects for developing a master plan. Next to the general information on the country, in chapter 2, specific information is needed to develop the master plan. This chapter discusses these aspects and starts with an overview of the natural boundary conditions; this is followed by an overview of the existing current maritime and landside infrastructure. This part is concludes with an assessment of the size and spread of the target user groups.

A detailed chart of the country and the locations of the coastal havens can be found in Appendix C as folding out map.

4.1 Natural boundary conditions

4.1.1 Geology

The relief of Kuwait is generally flat, with occasionally low hills and shallow depressions. The elevations range from sea level in the east to 290 meter at Al Shaqaya peak, in the western corner of the country. There are several ridges present in the country mainly running from north to south.

The land was formed in a recent geologic era. In the south, limestone rises in a long, north-oriented dome that lies beneath the surface. It is within and below this formation that the principal oil fields, Kuwait's most important natural resource, are located. In the west and north, layers of sand, gravel, silt, and clay overlie the limestone to a depth of more than 210 meters. The upper layers are part of the large sediment depositions done by a great wadi, dry riverbed, whose most recent channel was the Wadi al Batin, the broad shallow valley forming the western boundary of the country.

<u>Coastline</u>

Kuwait’s coastline length, including the perimeter of its islands, has been estimated at about 500 kilometer. It is mainly sandy and muddy with very few tidal inlets other than Kuwait Bay. The northern coast, in and around the bay, is bordered by extensive inter-tidal mudflats.

The southern coast along the Arabian Gulf mainly consists of sand deposits from the major rivers in the north. The bed of sand and silica deposits forms the transition between the desert inland and the relatively deep Arabian Gulf.

<u>Inter-tidal mudflats</u>

Inter-tidal mudflats can be found north of Bubiyan Island, along th the perimeter of the Kuwait Bay and around the tidal inlet at Khiran along the southern coast. The inter-tidal mudflats along the northern coast are created by the floodwaters of the Tigris and Euphrates Rivers. These rivers enter the northern end of the Gulf through the Shatt Al-Arab waterway, east of Bubiyan Island, and via the Khor al Subiyah, west of Bubiyan Island. Tidal currents and wave breaking make sediment transport into the Kuwait Bay possible.

Other sources of sediment are the inland deserts and the drained areas in the south of Iraq. Sediment is transported into the bay by the prevailing northwestern winds.

4.1.2 Bathymetry

The bathymetry is obtained from two admiralty charts. The hydrographic charts generally have a higher level of detail around the commercial ports. Most of the coastal haven locations are not within the area of interest for commercial shipping. The level of detail of the charts is therefore not sufficient to give a detailed overview of the water depths at some of the locations. The hydrographic charts are used as a first approach, because information with a higher level of detail is available.

Depths on hydrographic charts are indicated in meters and reduced to chart datum, which is approximately Lowest Astronomical Tide (LAT). Heights are in meters as well, underlined figures on inter-tidal mudflats and shoals are drying height above chart datum.

The Kuwait territorial water extends up to 25 – 30 m depth and can be divided in two areas: The shallow northern area, which is less than 5 m deep in most places with a muddy bed, and the relatively deep southern area, which has a bed of sand and silica deposits.

The charts are digitalized using AutoCAD. In Autocad the charts are translated into polylines and provided with an elevation compared to LAT. These polylines are then exported to a text file which can be interpolated by the program Surfer. The polylines are interpolated according a triangular linear interpolation with a grid cell size of 100 x 100 m.

Chart nr.	Chart name	Scale
1214	Khalij Al Kuwait	1:50,000
3773	Ra's Al Khafji to Jazirat Bubiyan	1:150,000

table 3: Admiralty Charts (Admiraty Chart 1214 (2002) and 3773 (2008))

The coastline, the line that represents the main land, is set at an elevation of 3.5 meter above lowest astronomical tide (LAT), equal to the mean higher high water (MHHW) in the Kuwait Bay. This is done because no height of the land is specified on the hydrographical charts. The result of this process are presented in figure 8.

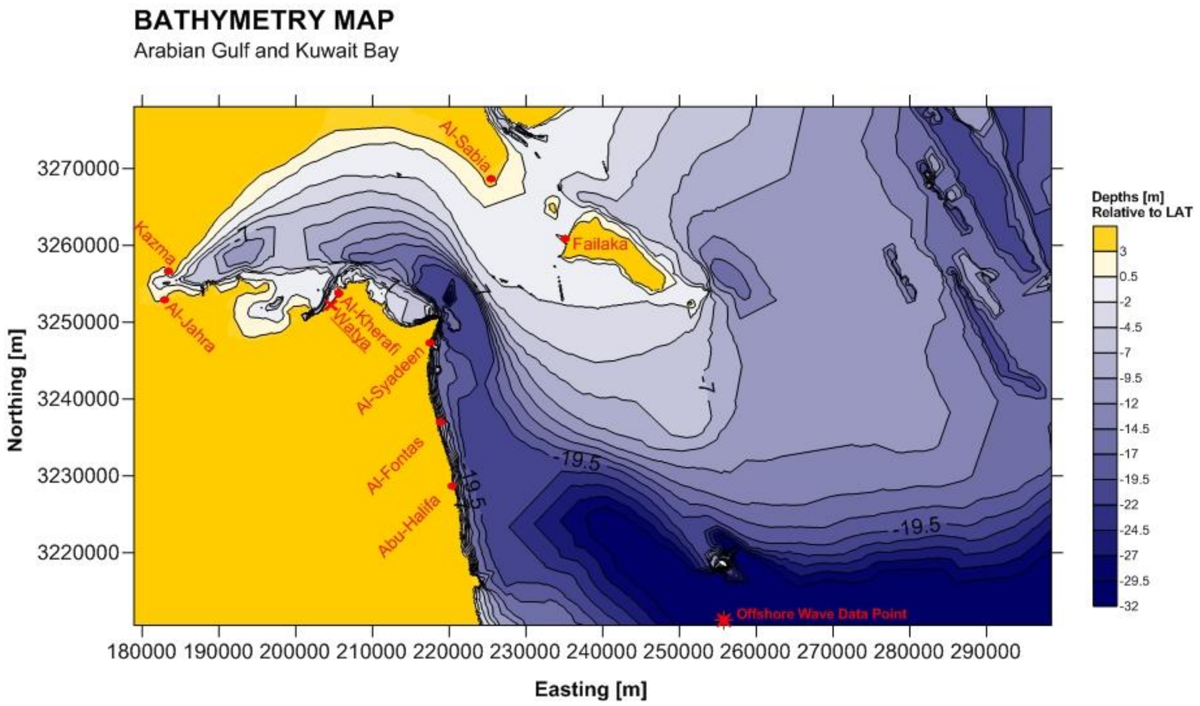


figure 8: Bathymetric map Arabian Gulf and Kuwait Bay including locations and offshore data point (Admiraty Chart 1214 (2002) and 3773 (2008))

4.1.3 Climatology

The climate of Kuwait is characterized by very hot, dry summers and cooler rainy winters. The average annual rainfall in Kuwait city is about 111 mm, but parts of the country receive as little as 23 mm and others as much as 206 mm yearly. Summer temperatures are extremely high, often exceeding 45°C during July and August. In winter, temperatures often rise to over 20°C during the day, but then fall rapidly at night when frosts are not uncommon, especially inland. The humidity is generally high and often exceeds 90%.

Temperature

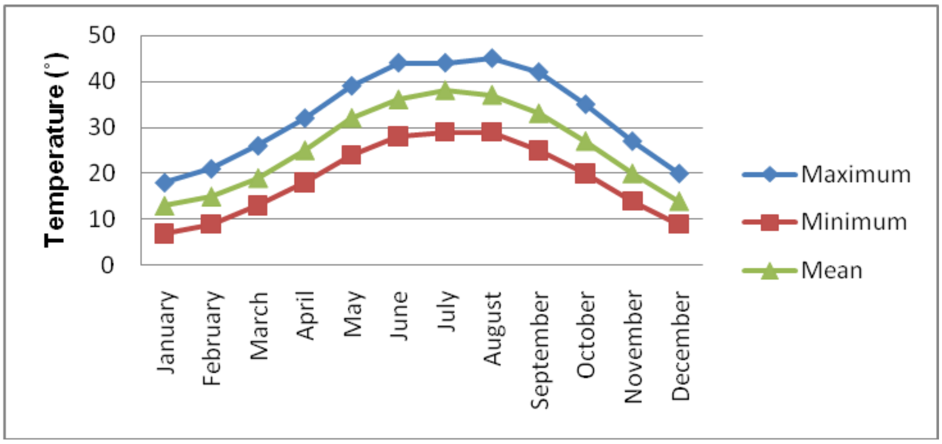


figure 9: Average temperature Kuwait International Airport 1961-1990 (theweathernetwork.com)

Precipitation

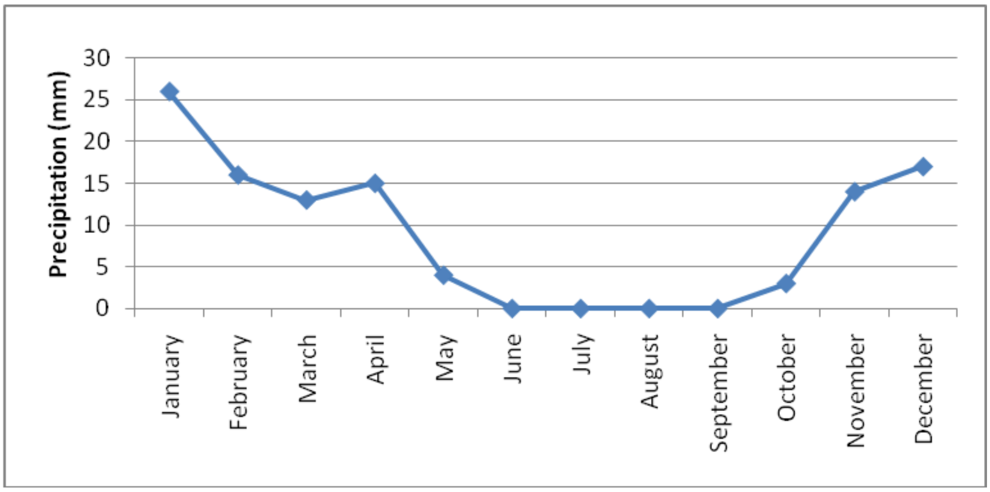


figure 10: Average precipitation Kuwait International Airport 1961-1990 (theweathernetwork.com)

Information on temperature and precipitation are averaged values over 1961 to 1990 for Kuwait International Airport. Source is The Weather Network (theweathernetwork.com). The measurements are taken at an altitude of 55 m at latitude 29°13'N and longitude 47°59'E. The temperatures along the coast is assumed to be more moderate due to the influence of the sea water temperature.

The fact that there is considerable variability in precipitation throughout the years, must be kept in mind. Some winter months may receive more rainfall than the mean yearly totals during thunderstorms.

4.1.4 Physical Oceanography

4.1.4.1 Wind and wave data

The wind and wave data are purchased from BMT ARGOSS. This company runs a global 3rd generation wave prediction model based on the WaveWatch III code. This model provides a hindcast as well as a forecast.

The model suite is forced by ice- and wind data provided by the National Center of Environmental Prediction (NCEP). Using this model, ARGOSS has produced a 16 year wave hindcast of directional wave spectra covering the years 1992-2007 with a time step of 3 hours. Worldwide satellite data, such as accurate observations of significant wave height (H_S) and wind speed (U_{10}) from several satellites and sensors, are used to calibrate hindcast significant wave height and wind speed.

The offshore data point, where wave and wind data are purchased, is located approximately 8 kilometer south of Kubbar Island in the Arabian Gulf (see figure 11) at a water depth of 22.5 meter. This location is such that wind and waves from the north could be affected by the island and the water depth around it. The waves are therefore assumed to be and underestimation of the wave height at this point.

Location	Offshore grid point
Latitude	29°00' N
Longitude	48°30' E
Water depth	22.5 m

table 4 Characteristics of selected grid point

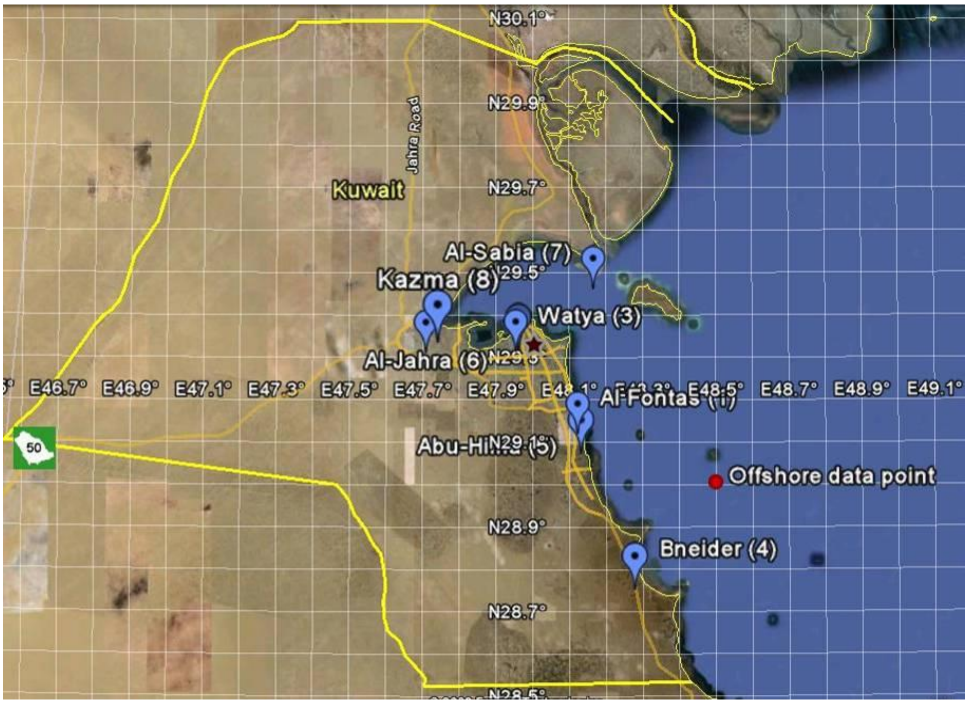


figure 11: Offshore data point [Google earth]

The purchased data from BMT ARGOSS consist of time series, a monthly distribution tables and scatter tables of wind speed, wave period, wave height and wave direction. From the time series the wind and wave rose in figure 13 and figure 14 are made. The scatter tables are used to select the scenarios to be modeled for the evaluation of the layout alternatives for the coastal haven of Al Syadeen in section 9.1.1.

4.1.4.1 Wind

Winds are generally from northwesterly direction at 10 to 15 knots over the northern half of the Gulf. These winds from the northwest are cool in winter and spring and hot in summer. Southeasterly winds, usually hot and damp, spring up between July and October; hot and dry south winds prevail in spring and early summer. The shamal, a northwesterly wind, causes dramatic sandstorms.

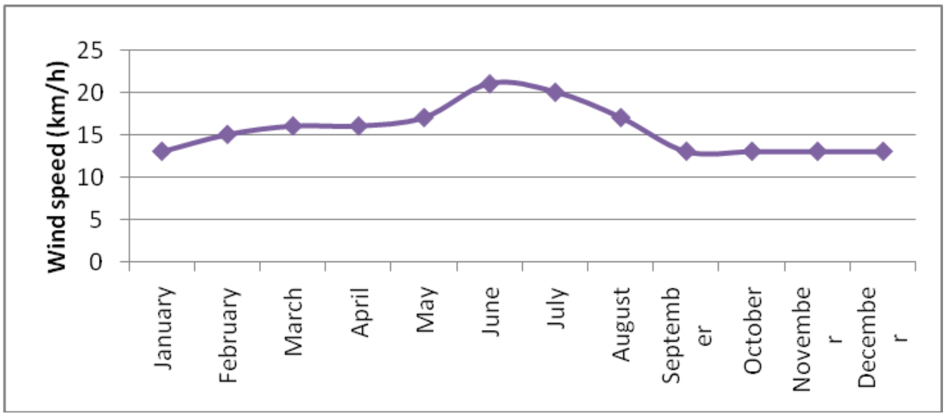
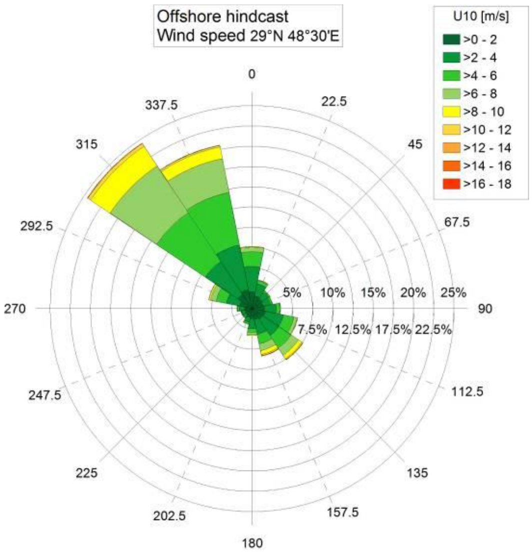


figure 12: Average wind speed Kuwait International Airport 1961-1990 (theweathernetwork.com)



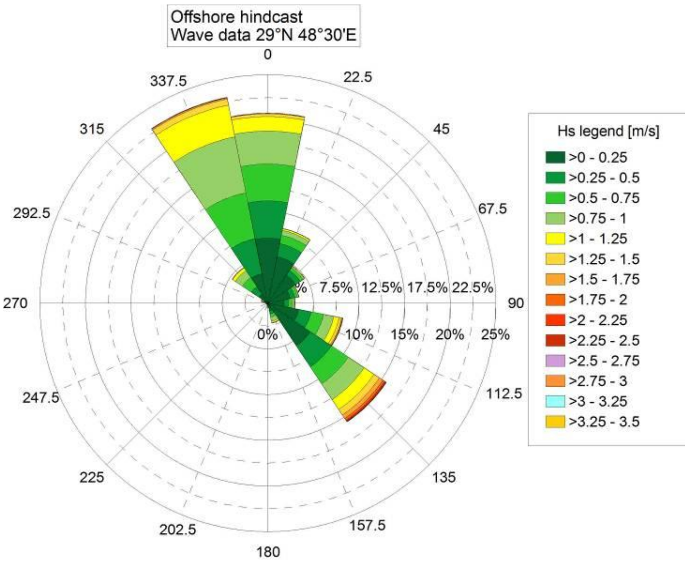


figure 13: Wind rose offshore wind data **figure 14: Wave rose offshore wave data**

4.1.4.2 Waves

The wave climate varies significantly from one location to another due to the variation in local bathymetric conditions. From an extreme wave height analysis (Neelamani, Al-Salem and Rakha, 2006) follows that significant wave heights are from southeasterly direction due to the long fetch length across the Arabian Gulf. The prevailing northwestern wind direction has no such fetch and this direction does not lead to a large wave height. Interesting wave directions for wind-wave generation are north-northwest via north to southeast for the coastal haven design in Kuwait as can be concluded from the wave rose in figure 14.

The significant wave heights in the Kuwaiti territorial waters, with a return period of 100 years, range from 2.5 meter at the northern end of the Arabian Gulf Coast to almost 4 meter in the south of Kuwait territorial waters. These waves are originating from southeastern direction. The significant wave height north of Failaka Island is much lower, due to the shelter of the island. A significant wave height with return period of 100 years of less than 2.0 meters is expected over there. The wave height at the mouth of the Kuwait Bay is in the extreme situation 2.5 up to 3.0 meters after which it reduces due to depth induced wave breaking. In figure 15 a result of the wave modeling study is presented. In this figure the extreme situation from southeastern direction is modeled. In figure 16 the maximum significant wave heights from the study (Neelamani, Al-Salem and Rakha, 2006) are presented, the figures show quite some resemblance.

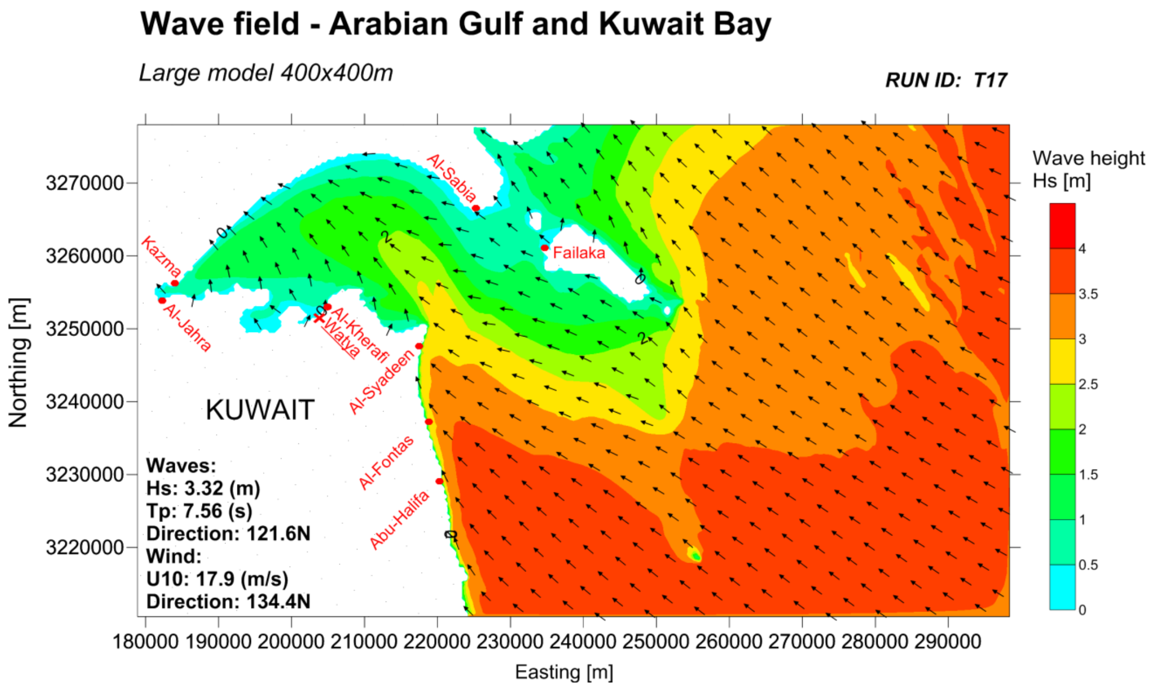


figure 15: Maximum significant wave height over 16 years modeled using SWAN

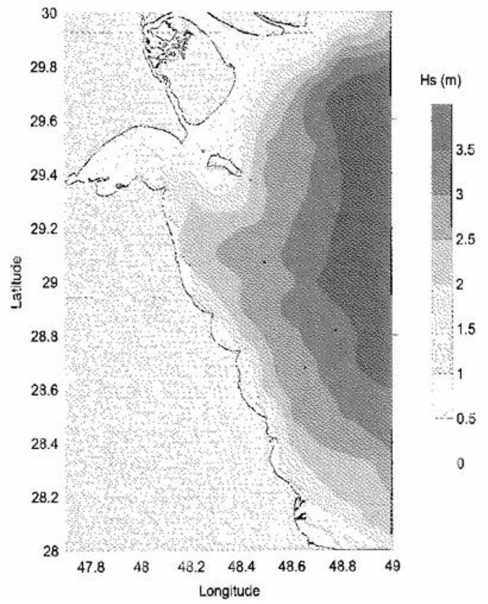


figure 16: Maximum significant wave height (Neelamani, 2006)

4.1.4.3 Tidal range

From the admiralty chart the information in table 5 on tidal levels is obtained. The tidal levels are given relative to Lowest Astronomical tide (LAT) or Chart Datum (CD).

Location	Lat. N	Long. E	Height in meter above datum			
			MHHW	MLHW	MHLW	MLLW
Ra's al Barshah (Subiyah)	29°33'	48°14'	3.4	2.9	1.8	0.8
Mina ad Dawhah (Doha Port)	29°23'	47°48'	3.5	2.9	1.6	0.7
Jazirat Awhah (Auhah Island)	29°22'	48°26'	2.8	2.3	1.5	0.7
Ash Shuwayk (Shuwaikh)	29°21'	47°55'	3.5	3.0	1.8	0.9
Jazirat Kubbar (Island)	29°04'	48°30'	2.3	1.9	1.4	0.6
Mina Al Ahmadi (Port)	29°04'	48°10'	2.7	2.2	1.5	0.5
Ra's al Qulay'ah (Failaka)	28°52'	48°17'	2.2	1.6	1.2	0.4

table 5: Tidal level information (Admiralty chart 1214 & 3773)

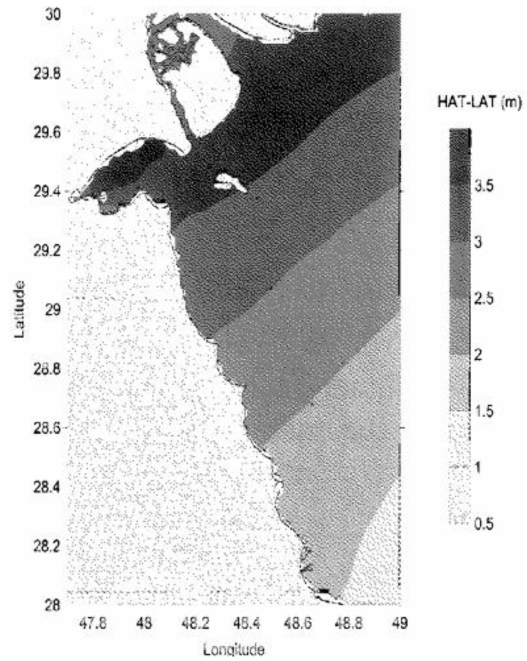


figure 17: Maximum tidal water level fluctuation for the upper part of Arabian Gulf (Rakha, 2007)

From this table it can be concluded that the tidal level is the largest in the north and decreases towards the south. Also in offshore direction the tidal level decreases. At Kubbar and Auhah Island the tidal level is 0.8 up to 1.2 m smaller than along the coast line at the same latitude. An article from the Kuwait Journal of Science and Engineering (Rakha, Al-Salem and Neelemani, 2007) gives the same image of the tidal levels in Kuwait territorial waters.

Around the border with Saudi-Arabia the tidal level is about 2.0 m. Around Al-Sabia and Doha port (located in the Kuwait Bay) the tidal level is between 3.5 – 4 m.

The tidal levels along the Arabian Gulf coast is in general smaller than along the Kuwait Bay coast. The figures from the hydrographic chart match with the observations in figure 17.

4.1.4.4 Currents

Although the incoming tide from the Arabian Sea through the Strait of Hormuz is semidiurnal, the tidal behavior in the Arabian Gulf is complex. As the tidal wave reflects back from the northwestern boundary, high water appears diurnally in some parts of the northern and southern areas of the Gulf.

The tidal currents in the Arabian Gulf have a general counter-clockwise circulation, because the water travels faster along the deeper Iranian side of the basin. At the northern end of the Gulf the tidal current turns southeasterly parallel to the Arabian coast. Finally, it turns northerly along the west side of the Omani Peninsula to join the fresh water origination from the Gulf of Oman. The Gulf of Oman is entering the Arabian Gulf through the Strait of Hormuz.

Tidal currents of 1 – 1.5 knots are expected along the entire Kuwait south coast but depend on the local bathymetry. The currents are generally smaller in magnitude in the Kuwait Bay, around 0.5 knots. Around the headland of Ras al Ardh higher speeds are observed (figure 18).

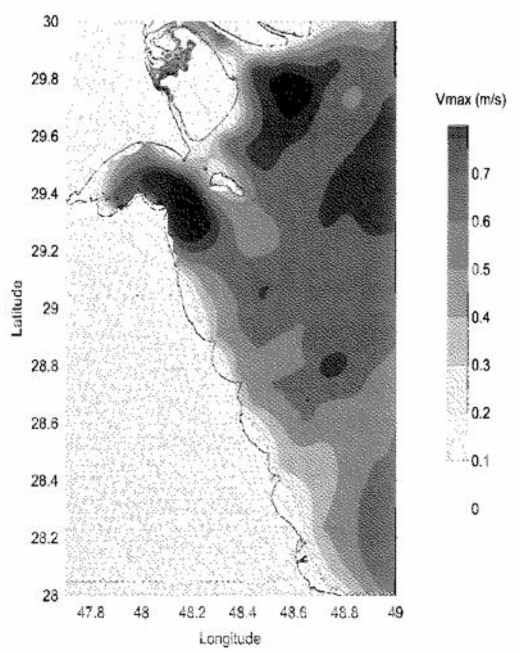


figure 18: Maximum tidal currents for the upper part of Arabian Gulf (Rakha, 2007)

4.1.4.5 Seawater

The water temperature of the Kuwait Bay varies from 12°C in January to 36°C in August, the published mean annual temperature of the Kuwait Bay surface water is 23.8°C. Salinities are generally high throughout most of the year, ranging from 38 to 42 part per thousand. Fresh water enters the Arabian Gulf through the Khor al Subiyah and Shatt Al-Arab.

The surface water temperature of the Arabian Gulf ranges from 21°C - 24°C throughout the years. In shallow areas larger ranges are observed.

4.2 Existing maritime infrastructure and location description

In this section an inventory of the current situation at the existing coastal havens, assigned areas for coastal haven development and other interesting areas is made. The infrastructure present at these sites and on a larger national scale is an essential aspect for the master plan development.

The existing sites are analyzed first, after that the assigned areas are described and finally other additional interesting locations are mentioned. Next to these locations, other maritime infrastructure, such as the commercial ports and marinas and a dhow harbor are part of this inventory. The target groups and the current users of the existing maritime infrastructure are assessed in section 4.4.

All sites are described based on admiralty charts, aerial photographs and available literature. The aerial photographs are used to assess the current layout or situation of the coastal haven locations. The existing infrastructure is indicated in these figures.

Limited or no maritime infrastructure is present at the assigned areas at this moment. Their specific locations in these areas are still to be determined and this analysis is used as first step in the allocation of these coastal havens.

To get an indication of the locations described in this section, maps are provided in the appendices. In table 6 an overview of the provided maps is given. The maps in the appendices can be folded out in order to support the description of the location.

Appendix	Contents
Appendix B	Map coastal havens (existing and assigned)
Appendix C	Map coastal havens all locations, islands, and commercial ports
Appendix D	Maps location coastal havens, additional locations, marinas and port in Kuwait
Appendix E	Maps locations coastal havens, additional locations, marinas and commercial port in Kuwait Bay

table 6: Overview supporting maps location description

4.2.1 Existing coastal havens

The locations of the existing coastal havens and assigned areas are indicated on the and figure 101 in Appendix B. The existing coastal havens of Al Syadeen, Al Fontas and the coastal haven opposite of the National Assembly, which is called Al Kherafi, are marked with red dots on the maps.

4.2.1.1 Al Syadeen

Location

The existing port of Al Syadeen is located in the Salmiyah district at the northeastern part of Kuwait City. This part of Kuwait City is part of the Hawalli governorate and is 10 kilometer to the southeast from the city center.

Layout

The location is connected to the landside infrastructure by a connection to Fifth Ring Road, which runs perpendicular to the coastline to the eastern part of Kuwait City. Four kilometers to east the ring road connects to the Fahaheel Expressway, which runs along the coast from north to south Kuwait.

The coastal haven itself consists of a fishing port section provided with sheltered inner basin bordered by two breakwaters. The breakwater that runs from north to south has a length of 200 meter. The other breakwater is physical barrier between the fishing port and the part that serves as a marina. It has a length of 300 meter, including the part running north of the marina terrain.

If the marina part, known as Al Bida Sea Club, is a private marina and therefore not part of the coastal haven.

figure 19: Current layout Al Syadeen (Google Earth; 2008)

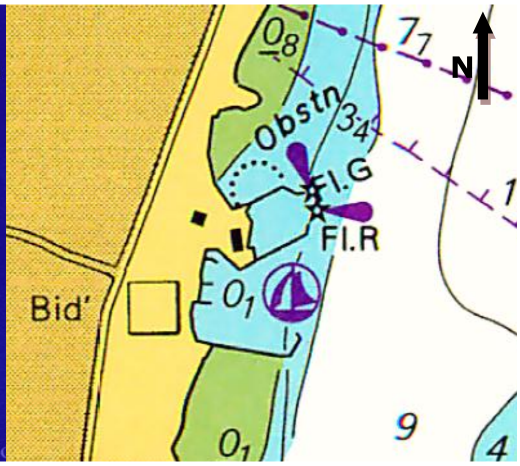


figure 20: Hydrographic chart Al Syadeen (Admiralty chart 1214; 2002)

Water depth

The chart is gives no detailed information about the location and not all the breakwaters are present on the chart. No update or other source could provide a better indication of the water depth at this location.

4.2.1.2 Al Fontas

Location

The existing coastal haven of Al Fontas is located in the Fintas district. This district is 30 kilometer south of Kuwait City.

Layout

At this location the fishing community is located between two rather wide breakwaters. The vessels are stored on land and a slipway is present to enter and leave the water. The function of the rather wide breakwaters is not clear. The length of these breakwaters is 500 meter, measured from the original coastline. The southern breakwater is somewhat shorter but its curvature leads to the length of 500 meter.

South of the fishing port a base for coastguard vessels is located. This coastguard port is located between its own breakwaters.

The coastal haven is connected to the landside infrastructure via a road running parallel to the coast, leading to the seventh ring road and to the Fahaheel Expressway. Furthermore a police station is located 500 m inland from the fishing port.

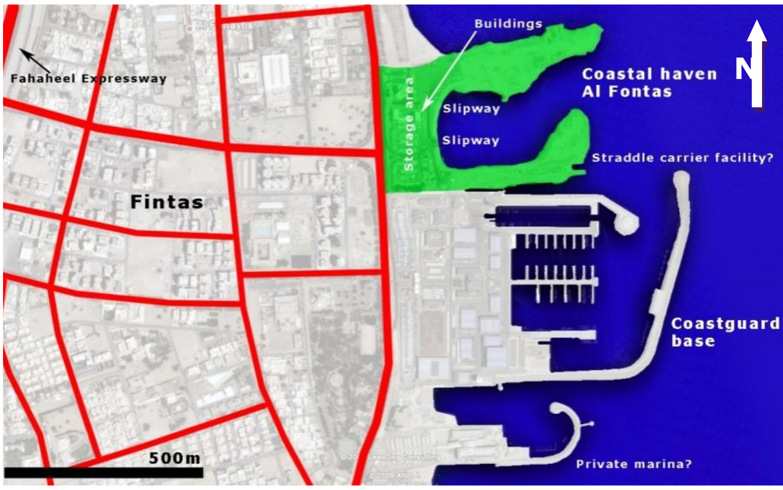


figure 21: Aerial photograph Al Fontas (Google Earth; 2008)

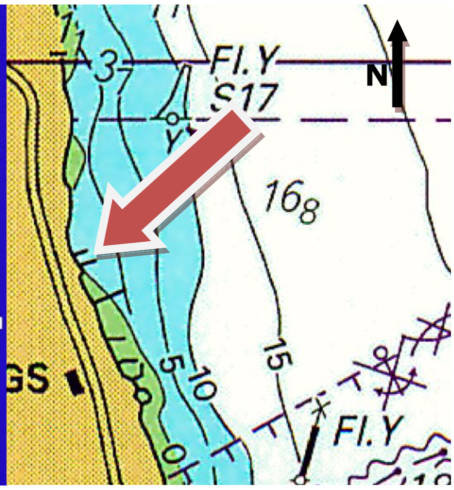


figure 22: Hydrographic chart Al Fontas (Admiralty chart 3773; 2008)

<u>Water depth</u>

The hydrographic chart on this part of Kuwait has different scale than the one of Kuwait City and Kuwait Bay. Admiralty chart 3773 has a scale of 1:150,000 and 1214 of 1:50,000. Based on chart 3773 only a rough indication of the water depth at the location of the coastal haven can be given. No clear distinction between the fishing port and the coastguard port can be made on this chart. We can only assume than entering this coastal haven is made possible by the breakwaters extending far enough to reach deeper water.

4.2.1.3 Al Kherafi (National Assembly)

This coastal haven is added to the two existing locations and the six areas assigned by the government in a later stage. The location is at the waterfront of the Qiblah district of Kuwait City.

<u>Location</u>

The location is close to the commercial area of Kuwait City. The coastal haven is located opposite of the National Assembly, National museum and has several governmental organizations, hotels and banks in its vicinity.

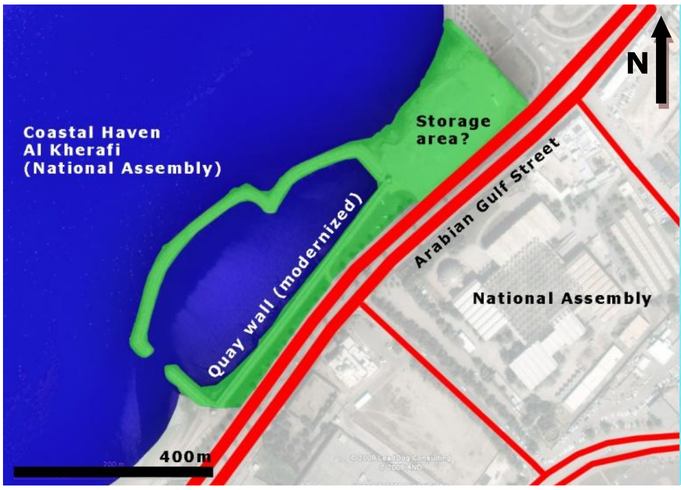


figure 23: Aerial photograph National Assembly (Google Earth; 2008)

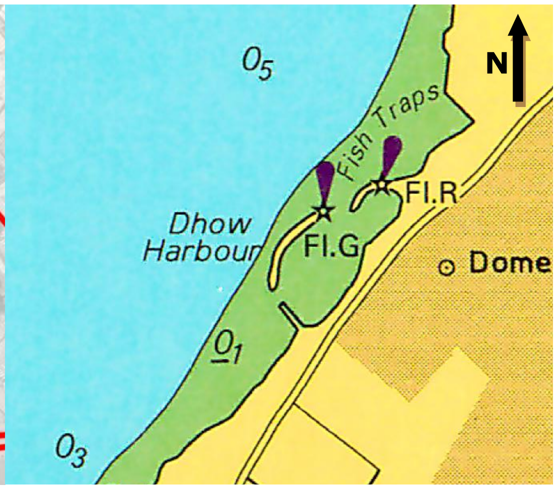


figure 24: Hydrographic chart National Assembly (Admiralty charts 1214; 2002)

Layout

This coastal haven consists of two breakwaters. The southern breakwater has a length of 55 meters and the northern 375 meter. A rough estimation of the surface area inside the coastal haven is 20,000 m^2 and the surface area of the terrain northeast of the coastal haven approximately 7,500 m^2 (135 x 55m). This is located along the Arabian Gulf Street. This street leads to the First Ring Road via the Soor Road.

figure 25: Top view coastal haven National Assembly (Panoramio.com)

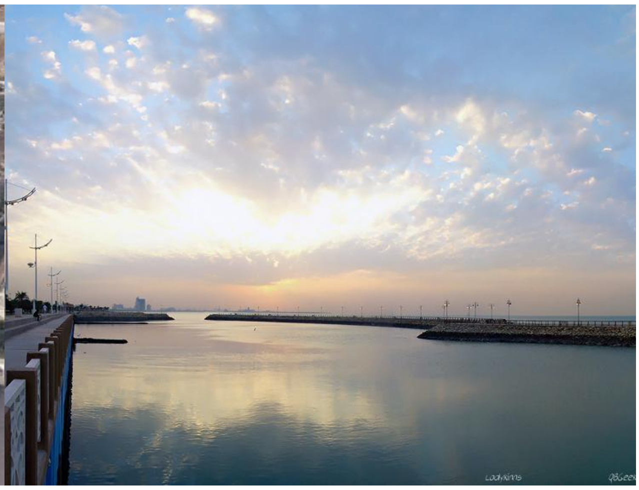


figure 26: View coastal haven National Assembly (Panoramio.com)

Water depth

This coastal haven is located in relatively shallow water of 0.1 meter above reference level Lowest Astronomical Tide (LAT). This coastal haven is thus not accessible under all tidal conditions. This might be better at the moment due to the recently done renovation of the coastal haven.

Remarks

On and figure 23 and figure 26 is showed that the current layout is improved compared to the layout in figure 24 and figure 25. A quay is constructed along the side parallel to the Arabian Gulf Street with a length of 270 meter. The breakwater is also upgraded to the current situation. There are no fishing vessels or other activities visible in this coastal haven on the most recent photographs (figure 23). Users might be shifted to the dhow harbor next to the Souk Sharq Mall, which is described in detail in the paragraph on this dhow harbor (section 4.2.3.3).

4.2.2 Assigned locations coastal havens

The government of Kuwait has assigned six locations for coastal haven development. In most cases nothing is present at these sites and is the name of the location often linked to a village, district, area or headland. The locations are described in the way it is done with the existing coastal havens. The geographic location of the coastal havens is provided in figure 101 in Appendix B, and a detailed map of the location within the Kuwait Bay figure 104 in Appendix E. The assigned locations are indicated with a purple dot on these maps.

4.2.2.1 Watya

Location

The assigned area Watya is located along the coast of the Wattiyah district. This district is the most westerly located part of the Central Kuwait City. At this location a slipway is already present. In the district several Christian churches and hotels are present. Next to that a hospital, bus station and a power station can be found in this district. The location is situated along the Arabian Gulf Street, this street connects to the First Ring Road via the Soor Road.

Layout

This location is not listed as a coastal haven, although there are several facilities at this location. Next to the slipway, an on land storage area protected against erosion is with a rubble mound armor layer are already present at this location. The breakwater with a length of 100 meter provides a sheltered area in front of the slipway.

Water depth

From the hydrographic chart it follows that the area around Watya has a drying height of 0.7 m above Chart Datum. These shallow areas are used for fish traps in the Kuwait Bay. This shallow strip runs along the coast from the Seif Harbor until Shuwaikh Port.

figure 27: Current layout Watya (Google Earth; 2008)

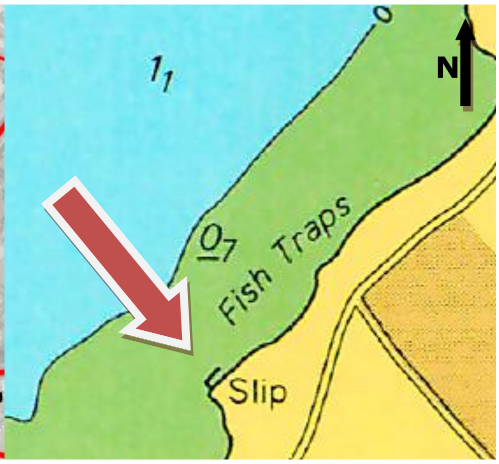


figure 28: Hydrographic chart Watya (Admiralty chart 1214; 2002)

4.2.2.2 Bneider

Location

There is not a lot of information available on this area. The town Bnedr lies in the middle of the parabolic shaped part of the coast. At the point where the curvature towards the east starts, lies the town of Bnedr.

Layout

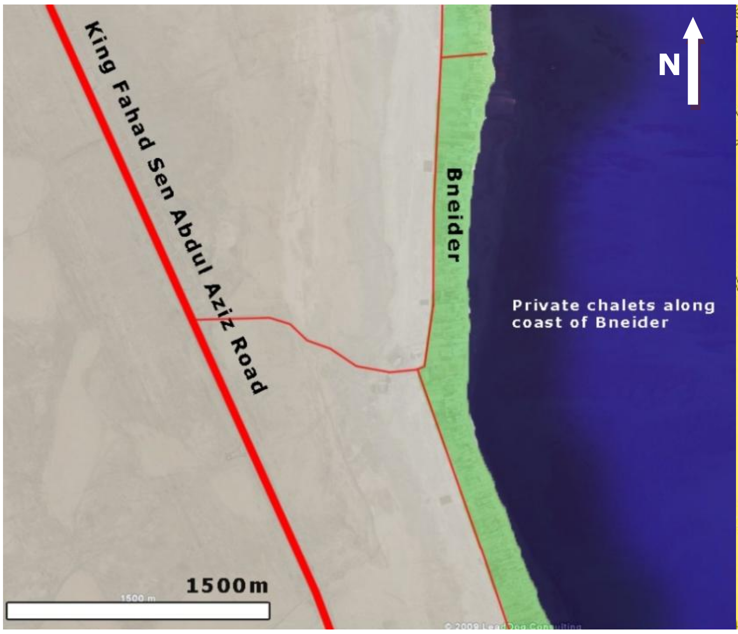


figure 29: Aerial photograph Bneider coast and breakwaters (Google Earth; 2006)

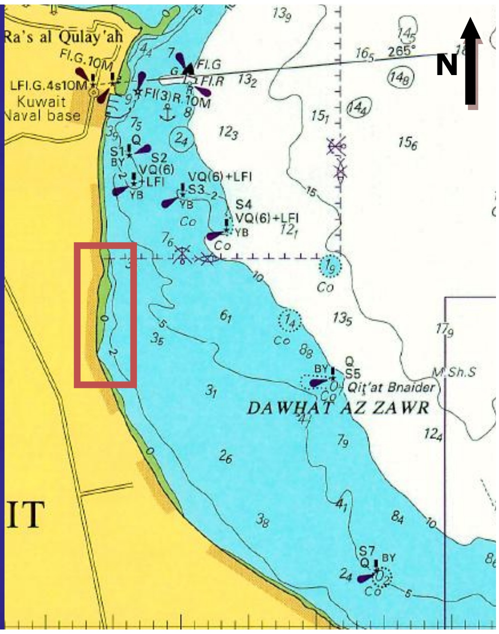


figure 30: Hydrographic chart Bneider coast (Admiralty chart 3773; 2008)

The area is known for its private chalets build in a string along the coastline. At this location breakwaters some breakwaters are present, these are assumed to be private and belong to the owners of the private chalets. Three miles offshore the shoal Qit'at Bnaider is visible on the hydrographic chart.

Bneider is connected to the King Fahed Ben Abdul Aziz Road. Taking the paved road for 2 kilometer westwards leads to this higher order highway. To the north of Bneider a Naval Base is situated. Around this naval base no anchoring or fishing is allowed.

Water depth

Parts of this coastal strip are very shallow and even above water at LAT, but at the location of Bneider there seems to be a location where the depth is in between 0 and 2 meters. Until the shoal of Qit'at Bnaider the depth ranges from 2 to 10 meters after this point the depth increases further.

4.2.2.3 Abu-Hilifa

Location

This assigned area is located north of the oil loading piers of the commercial port Shuaiba. East of the town of Abu Hilifa oil storage tanks are situated along the Fahaheel Expressway, which are part of the large oil processing and exporting area around Al Ahmadi and the port of Shuaiba.

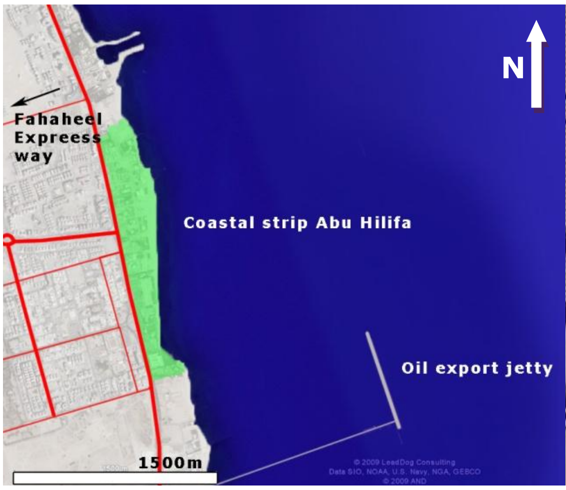


figure 31: Current situation Abu-Hilifa (Google Earth; 2008)

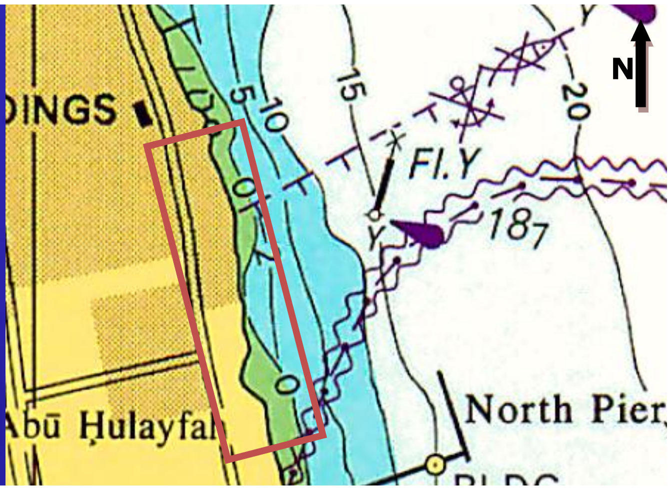


figure 32: Hydrographic chart Abu Hilifa (Admiralty chart 3773; 2008)

Layout

No fishing vessels or yachts can be spotted using Google Earth at this location. However, some small breakwaters are present along the coastline. These constructions are considered to belong to the buildings along the coastline. Most of these are part of private property along the coast and are not publicly accessible. Further north lays the existing coastal haven of Al Fontas. The distance between Al Fontas and the north pier is approximately 5.5 kilometer.

Water depth

On the part of the hydrographic chart in figure 32 the North Pier and breakwaters of the coastal haven at Al Fontas are visible. The area around the North Pier is a restricted area because the presence of the oil industry and pipelines on the bottom of the Gulf. In the coastal water around Abu Hilifa anchoring and fishing is prohibited. The depth profile is approximately the same as Bneider. Some parts of the coastal strip show a drying height (above water at LAT) other parts have a depth of 0 to 2 m.

4.2.2.4 Al Jahra

Location

The city of Al Jahra had a population of 28,000 people in 2005, according to the preliminary results of the population census. This city is located in the utmost westward end of the Kuwait Bay. Between the urbanized area and the Bay a strip of 1.5 kilometer wide is kept clear from buildings. The aerial photograph in figure 33 of Al Jahra represents the area around left outfall of the hydrographic chart in figure 34.

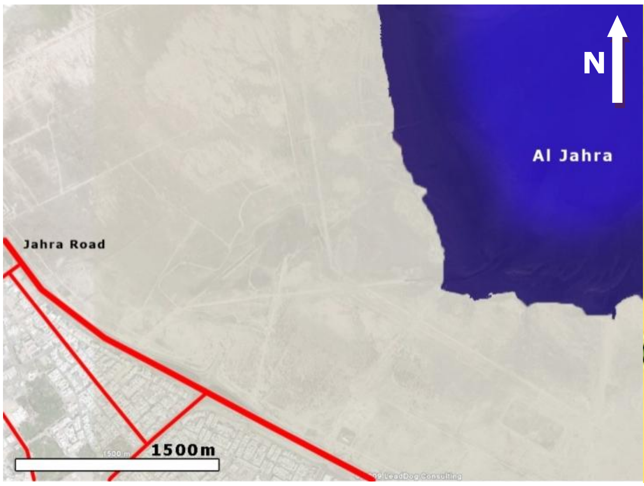


figure 33: Current situation Al-Jahra (Google Earth; 2006)

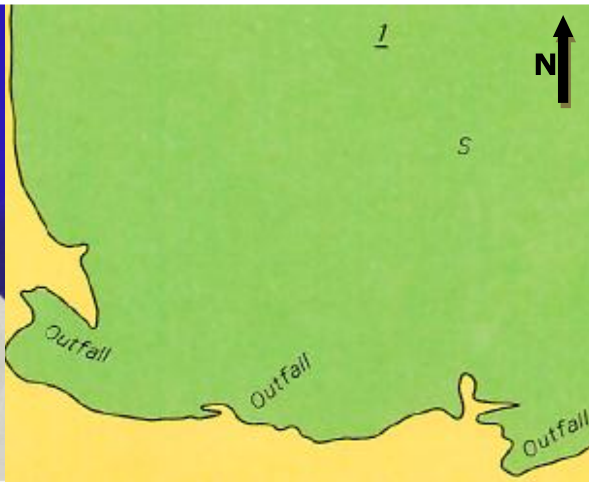


figure 34: Hydrographic chart Al-Jahra (Admiralty chart 1214; 2002)

Layout

No waterfront development is present here. Several roads from Kuwait City lead to Al Jahra, which is located 30 kilometer westward of Kuwait City. From Al Jahra the Jahra Road leads towards Iraq in northern direction.

Water depth

This part of the Kuwait Bay is very shallow and it is the area where several sewage outfalls discharge waste water. The shallow parts of the Kuwait Bay function as fishing grounds.

4.2.2.5 Al-Sabia

Location

This assigned area is the most northern located one. Close to Bubiyan Island and situated along the river outflow of the Khor as Subiyah in the Arabian Gulf. The name of this location is referring to this river and to the headland Ras as Subiyah. On the hydrographic chart it is called Ras al Himarah. Development plans for the City of Silk are planned in this area.

Layout

The current situation in this area exists of a power station with an outfall into the Kuwait Bay and two breakwaters at the water intake in the Khor as Subiyah. This river flows into the Gulf here. Whether the power station can be reached via the canal is not clear. It looks like an intake facility for cooling water or a facility for delivering raw materials for the power station. Shumaymah is a small village with vessels stored on land, lays six kilometers upstream the Khor Al Subiyah from the power station. It is situated on a land outcrop in the river. Further upstream houses are built on the riverbanks with direct access to the river.

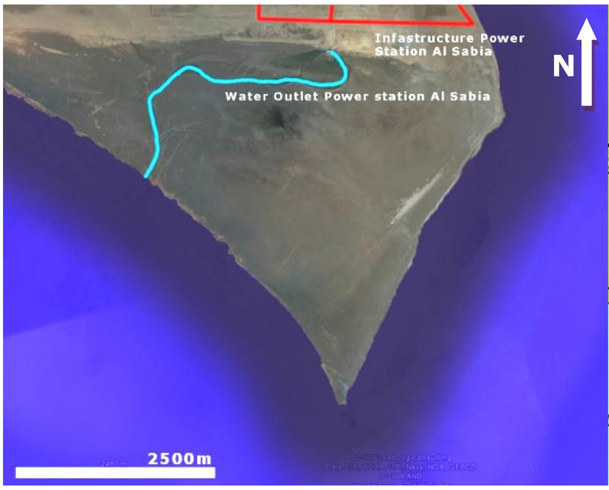


figure 35: Current situation Al-Sabia (Google Earth; 2005)

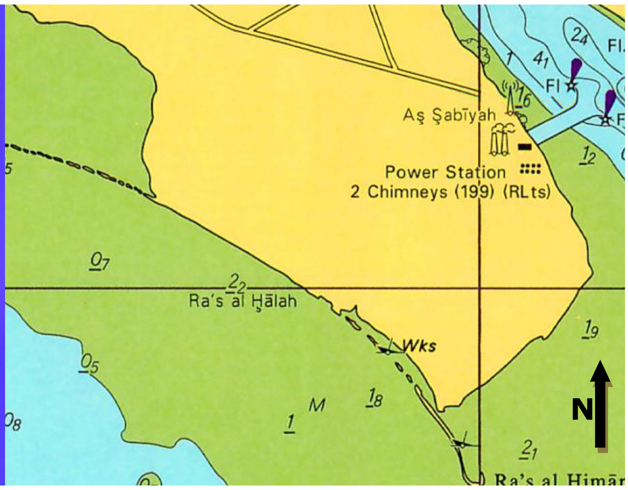


figure 36: Hydrographic chart Al Sabia (Admiralty chart 1214; 2002)

The power station is connected via paved road to a highway which bends toward the north over here leading to Iraq. In the other direction the highway leads to Al Jahra and runs along the Kuwait Bay. Another feature at this location is the connection to Bubiyan Island. The two kilometer long bridge over the Khor as Subiyah is the only connection between the mainland and the island. There is not a lot developed area on the island.

Water depth

The hydrographic map of this area shows the shallow coastal waters in the Kuwait Bay with a wide extension in the direction of Miskan and Falaika Island. The mudflats make navigation hard in this area. This part of the coastline is not accessible at all tidal conditions. On the riverside of the headland several channels are indicated on which navigation seems possible.

4.2.2.6 Kazma

Location

This assigned location is on the other side of the Kuwait Bay seen from Al Jahra. The distance between the two locations is approximately 5 kilometer. The name is related to the headland called Ras Kazimah.

Layout

Some fishing port infrastructure is present at this site. A breakwater of 100 meter and some shed with on land storage of vessels can be seen on figure 37 around the breakwater. Fish traps are located in the shallow coastal waters around Kazma.

Water depth

The water depth at this location is comparable to other sites in the Kuwait Bay. The entire perimeter of the Kuwait bay has wetlands and mudflats, that all are at or above LAT, except for the locations with dredged canals or outfalls of power plant or sewage.

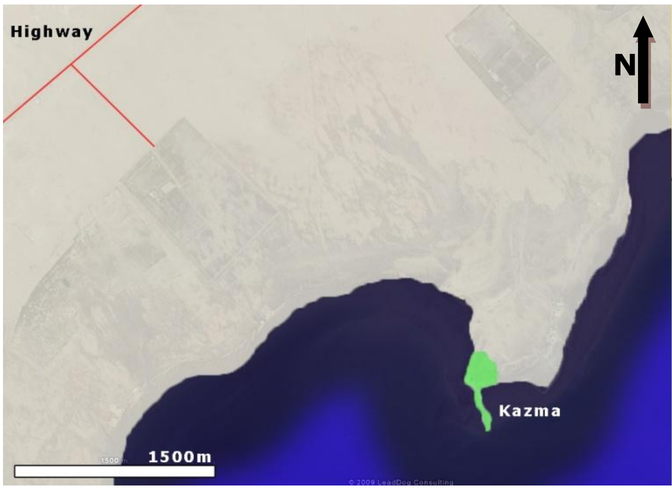


figure 37: Current situation Kazma (Google Earth; 2006)

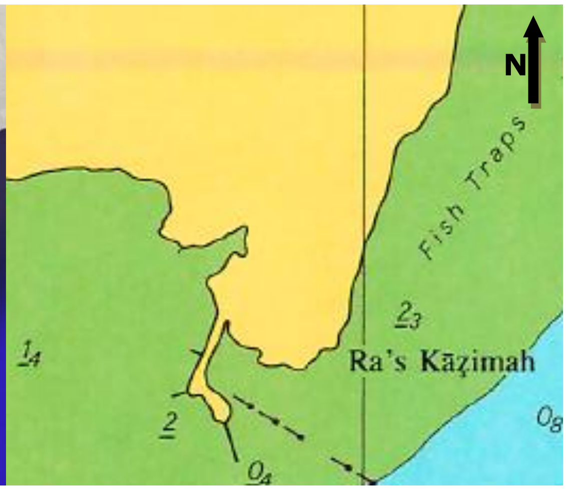


figure 38: Hydrographic chart Kazma (Admiralty chart 1214; 2002)

4.2.3 Additional locations

During the description of the existing and assigned locations other possible interesting locations were noticed. Some of these can be developed as coastal haven in the future;

others are only described in order to take into account in the development of the master plan. The description of additional locations is important for the analysis of destinations and the estimation of assessment between locations. In this way these locations can have an effect on the layout of the network of coastal havens. The additional locations are indicated on the map in figure 102 in Appendix C. For each location the relevance for coastal haven development is assessed.

4.2.3.1 Khiran

Location

Khiran is located 90 kilometers south of Kuwait City, close to the border with Saudi Arabia. South of Khiran marina, on the other side of the tidal creek, a facility for other vessels than yachts is already present. No information is available on the presence of a fishing community at this location. The marina part of this location is described in 4.2.4.11. This location is isolated from other locations or destinations, but is in open connection with the Arabian Gulf.

Layout

The entrance of the tidal creek is protected by a breakwater that block the sediment transport from north to south. The infrastructure is well developed and no maritime infrastructure is present south of this location. The area around the marina is under development at the moment. Possibilities for a coastal haven for this location will be limited to implement in the development plan for this location, since the area around the marina in Khiran is already under development and a new marina is already incorporated in this plan.

Water depth

The marina and port infrastructure can be reached through a marked channel, at sailing direction 305°N. The minimal depth indicated on the hydrographic chart is 3.7 m. The marina and port infrastructure seem well reachable.

Relevance for master plan

The infrastructure south of the marina a fishing port and port of refuge can be developed further to facilitate fishing vessels. This location is therefore taken into account, in the way it is now, with two separate parts on both sides of the entrance channel.

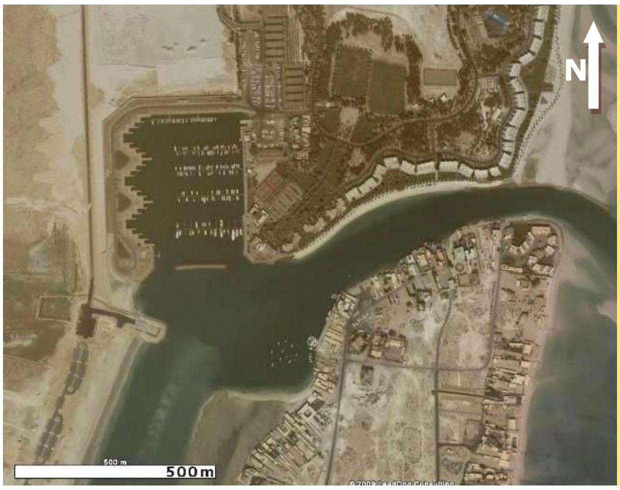


figure 39: Aerial photograph Khiran Pearl City (Google Earth; 2005)

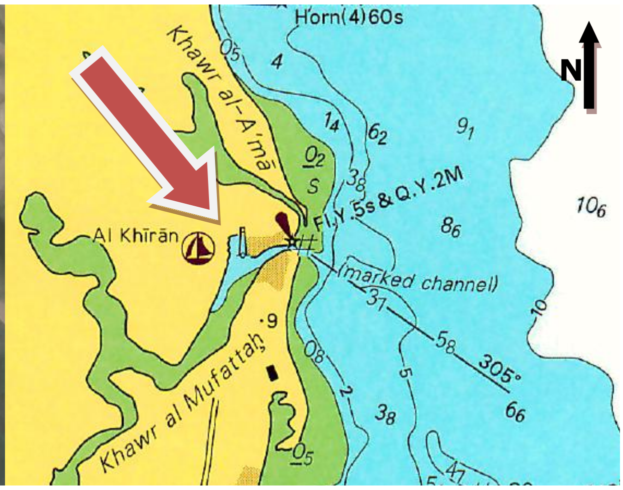


figure 40: Hydrographic chart Khiran Pearl City (Admiralty chart 3773; 2008)

4.2.3.2 Failaka harbor

Location

Failaka Island is located 11 nautical miles offshore to the northeast from Kuwait City. On the western end of the island two breakwaters are present. These structures are probably originating from the time that the island was a tourist destination before the Iraqi occupation.

Layout

The western side of the island is the most developed part of the island. A ferry landing facility is located at the southwestern end of the island, which connects the island with the mainland at Ras al Ardh and Marina Crescent. These locations on the mainland are both located east of the old city center Kuwait City on the most northeastern tip of the city. The island is left abandoned after the Iraqi invasion. There is still infrastructure present on the island from that time.

Water depth

The hydrographic chart indicates that the existing infrastructure is reaching until an area where a minimal water depth of about 0.8 meter is indicated.

Relevance for master plan

Failaka will be taken into account in the development of the master plan, since it seems an interesting destination for yachting and developments for the island are planned, for which maritime infrastructure will be an essential part.

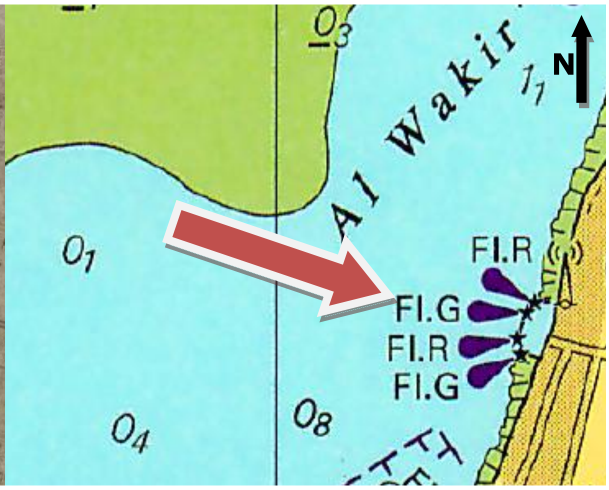


figure 41: Aerial photograph Failaka (Google Earth; 2004)

figure 42: Hydrographic chart Failaka (Admiralty chart 3773; 2008)

4.2.3.3 Dhow harbor Souk Sharq

The dhow harbor of Souk Sharq is used by the traditional wooden boats, known as the dhow. This ship is used for several purposes in the past, such as pearl fishing, fishing and transporting water from the island of Bubiyan to Kuwait City. Nowadays it is used for transporting small cargo and fishing.

Location

Dhow harbor Souk Sharq is located between the Seif Harbor and the fish market. Besides the Seif palace several ministries and the Grand Mosque are located in the vicinity of the dhow harbor.

Layout

The dhow harbor does not have any jetties where vessels can berth when they are not used. Two jetties with a combined length of 100 meter are visible in figure 44. Vessels can unload their catch over there. The catch is then transported and marketed on the fish market, located northeast of the dhow harbor. After unloading all vessels are berthed abreast somewhere in the harbor. Shelter is provided by two breakwaters with lengths of 225 and 75 meter. The rest of the

figure 43: Dhows and small speedboats at jetty in Dhow harbor Souk Sharq

perimeter of the coastal haven, 650 meter is constructed of the same material as the breakwater. The harbor is connected to the Arabian Gulf Street, which provides easy access to the First Ring Road.

figure 44: Aerial photograph dhow harbor and a part of Souk Sharq Marina (Google Earth; 2006)

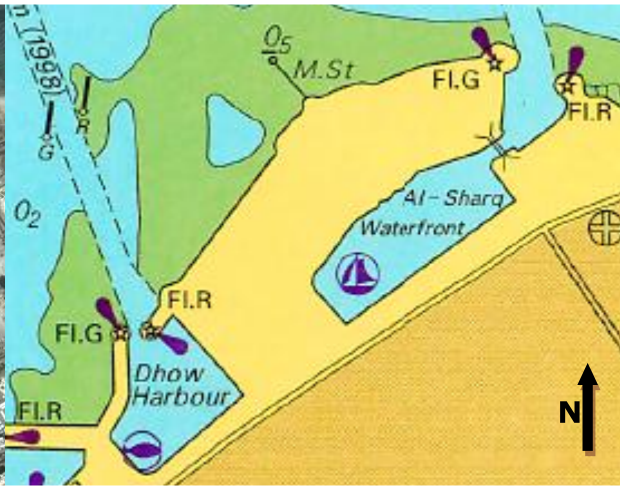


figure 45: Hydrographic chart Dhow harbor Souk Sharq (Admiralty chart 1214; 2002)

Water depth

From the hydrographic charts it follows that a canal with water depth of CD - 3.0 meter leads to this harbor. The other channels with the same dredged depth lead to the Seif harbor and the Souk Sharq marina. These are dredged in 1998 according to the chart. The current depth depends on the sedimentation of the canal and if it has been dredged recently. The canal leading to the Seif harbor is prohibited to enter.

Relevance for master plan

This harbor is currently functioning as fishing port for 110 dhows and approximately the same number of speedboats, which are used for fishing. Dhow Harbor Souk Sharq is expected to accommodate the dhows in the future and will not be one of the locations suitable for coastal haven development. This harbor will facilitate a specific target user group, the dhows. The restricted space at this location does not allow the development of a coastal haven. Competition with this location and the target user groups present at this location are taken into account during the development of the master plan.

4.2.3.4 Fahaheel waterfront (Al-Kout)

This waterfront development project consists of a marina and fishing port, buildings at the waterfront and a mall. Its name Al-Kout, refers to the old name of the country. This location is also of importance for the design of the network. At this existing location part of the target user groups yachts and fishing vessels is present. The marina and fishing community at this location should be incorporated in the network.

The assumption is made that the development of this location is part of a private project, and is therefore not subject to the authority of the Kuwait Port Authority (KPA).

figure 46: Aerial photograph Fahaheel (Google Earth; 2006)

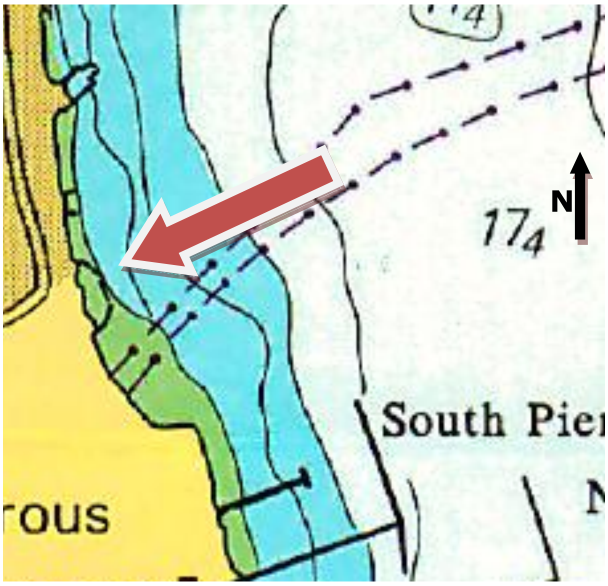


figure 47: Hydrographic chart Fahaheel (Admiralty chart 3773; 2008)

<u>Location</u>

Located 25 kilometer south of Kuwait City, this marina and fishing port is the most southern located fishing port. This waterfront development project is located along the coastline of the Fahaheel district. Fahaheel is located between the North and South Pier of the oil refineries of Mina Al Ahmadi.

<u>Layout</u>

The northern part of the port is a marina. According to project references it can hold up to 150 yachts. The 315 meter long northern breakwaters provides shelter to the vessels. The port can be entered via an opening in between the two breakwaters. The southern breakwater is significantly longer than the northern. The 700 meter long southern breakwater provides shelter to the fishing port.

The fishing port is separated from the marina by the Fahaheel waterfront, which is built on artificial land reclamation in between these two sections. Several berths can be used to more along these buildings. The fishing port has several piers to enable the fishermen to unload their catch. Fishing vessels use moorings somewhere else in the fishing port or on land storage via the slipway when they are not used. Piers for berthing these vessels separately are not present Marketing and distributing is done at the vegetable and fish market at the south western end of the fishing port. This location is connected to the Fahaheel Expressway, via secondary roads.

<u>Water depth</u>

The chart on this area is not in great detail. Fahaheel waterfront development project is located just north of the oil pipeline leading to the offshore loading locations. These are indicated by the dotted lines in figure 47. The entire marina and fishing port is located within an area at or above LAT.

Relevance for master plan

Fahaheel is considered as example of the way a coastal haven could look like. This location is well developed and assumed to be a private initiative. Therefore, it is not incorporated in the network of coastal havens, but competition with this location is taken into account. Further development of this location does not seem necessary. This location has to be kept in mind when developing the master plan, since this location provides yachts and fishing vessels with up to date facilities and could be a serious competition for coastal haven locations in its vicinity.

4.2.4 Marinas

The resorts, hotels and waterfront development projects along the Arabian Gulf and Kuwait Bay include a lot of marinas. At the moment there are already several marinas which facilitate the yachts in the country. The development projects, which are still in a design phase, also contain future plans for marinas. A total of 11 marinas are included in the location description in order to incorporate them in the development of the master plan.

The marinas are thus not described is the same level of detail (with the use of aerial photographs and the hydrographic chart) as the coastal haven locations. These 11 marinas, that are assumed to be publicly accessible, are listed below. Starting from the north working to the south, all marinas located along the coast, are briefly described. The exact location is presented in figure 103 in Appendix D and in detail for the Kuwait Bay in figure 104 in Appendix E.

Besides the locations that are listed as marinas or sea clubs, breakwaters with mooring facilities are visible along the coast. Most of these facilities are part of a resort or building that is expected to be a private property and only accessible by a very restrict part of the population.

4.2.4.1 Souk Sharq Mall Marina

This marina is the most inward located marina in the Kuwait Bay. It is one of the larger marinas located along the coastline of the Sharq district. Expected is that the facilities are at a relatively high level, because of the level of cultivation of the surrounding buildings and infrastructure. There is for example a mall next to the marina. Not a lot of on land storage possibilities are present in the marina. A large range in sizes of vessels use this marina. The marina is accessible through a dredged channel with a depth of 3 m, dredged in 1998.

4.2.4.2 Kuwait Marina

This marina is one of the five marinas along this stretch of coast of this part of Kuwait. The marina itself is located in the Bned Al Qar district of Kuwait City.

Not a lot of storage possibilities are visible from aerial photographs at this location. Most of the vessels in this marina have a length of about 10 m. The inner basin is protected from waves and made accessible by two breakwaters.

figure 48: Top view Al Sha'ab Sea Club (right) and Yacht Club marina (left)

4.2.4.3 Al Sha'ab Sea Club

Al Sha'ab Sea Club and Yacht Club Marina are located next to each other. A clear distinction is visible between the two marinas. Sha'a Sea Club is facilitated to receive the smaller vessels, say approximately 10 m and smaller. The sheltering and entrance is again provided by several breakwaters, as can be seen on figure 48. Again no large on land storage area is available.

4.2.4.4 Yacht Club Marina

Yacht club Marina is located east of Al Sha'ab Sea Club and is approximately 6 times larger than its neighbor. This marina has a small storage and repair area at the landside of the inner basin. More to the east are two slipways with a parking lot where vessels can be stored on land. Smaller vessels are stored over there. In the marina itself larger vessels are berthed. This marina has two entrances and exits through the breakwaters.

figure 49: Marina Crescent

4.2.4.5 Marina Crescent

This marina is again part of a waterfront. The marina is located behind the real estate that is developed on the artificially created land in front of the marina section. The name of the marina is referring to the beach in front of the buildings, that has the shape of a crescent. Facilities seem to be again at a relative high level, like the marina at the Souk Sharq mall. A landing facility for the high speed ferry to Failaka Island is present at this location as well. Storage of vessels at this location is done on the reserved area along the original coastline.

4.2.4.6 Ras al Ardh Sea Club

The sea club at the headland of Ras al Ardh, has also a landing facility for the ferry to Failaka Island. This marina is located on the headland between the Kuwait Bay and Arabian Gulf. The remaining marinas are located along the coast along the Arabian Gulf.

figure 50: Ras al Ardh Sea Club

Around this marina a lot of vessels are stored on land. The marina provides berths for several kinds of vessels; no specific target group can be defined. This marina is located in a large inner basin along the channel leading to the ferry landing area.

4.2.4.7 Kuwait Sea Club

Not a lot of vessels are visible at the location of the Kuwait Sea Club. This could be due to the moment when the aerial photograph was taken or the state of this marina. In this marina not a lot of berths are present. Large sheds are visible on the aerial photograph are visible, their function is not clear.

4.2.4.8 Al Bida Sea Club

The Al Bida Sea Club is the marina bordering the Al Syadeen fishery community at the northern edge. This marina doesn't seem occupied at the moment this aerial photograph was taken. The marina again between two large breakwaters has again several sheds at the landside of this marina.

Al Bida Sea Club is located between two breakwaters. The southern breakwater of this marina has a length of 400 meter, taking the part running along the terrain until the original coastline into account. This marina has jetties with capacity for approximately 50 vessels. The moorings are approximately 3 meters wide and 10 meter long, separated by finger piers of 1.5 meter wide. There are three moorings with a width of 7.5 meter and the same length of 10 meter. This marina will facilitate the larger yachts based on the size of the moorings.

4.2.4.9 Kuwait Airlines Club

This quite well occupied marina is located between two breakwaters, where the southern breakwater is stretching out much further into the Gulf. This could be related to the main wave or wind direction. No on land storage is present at this marina and it seems quite well occupied.

4.2.4.10 Al-Kout marina


figure 51: Al-Kout marina (Fahaheel)

Al-Kout marina is part of the Fahaheel waterfront in the Fahaheel district. Next to the marina, a mall, fishery port and fish and vegetable market are located at this site. This Kuwait International Boat Show is organized in this marina in 2007 and 2008 and will be held here again in 2009. Facilities and berthing piers have a relative high level of luxury compared with the other marinas. The situation at the recently developed marina shows resemblance with the Souk Sharq marina and Marina Crescent.

4.2.4.11 Khiran

This harbor is probably part of a large development plan in the Khiran area. Large artificial land reclamation and creek dredging is going on in this area. Several kinds of vessels are berthed and stored on land at this location. The marina seems to be recently developed as a part of the waterfront development project of Khiran Pearl City. More berths are expected to become available in front of the houses build along the two tidal creeks as part of the waterfront development project.

4.2.5 Commercial ports

Kuwait exports its oil and refined hydrocarbon products through the ports of Mina Ahmadi, Mina Abdullah, Mina Az-Zoor and Shuaiba. These ports are the main oil export terminals and load the oil tankers with the aid of offshore berths.

Next to these ports for oil exporting, Kuwait also has two commercial sea-ports, Shuwaikh and Shuaiba, for import and non-oil export. These ports handle bulk, containerized, refrigerated and general cargoes and they also have roll-on roll-off (Ro-Ro) facilities. A third commercial port in Doha is used by commercial fishing vessels, dhows and barges. The barges and dhows transport light cargo between ports enclosing the Arabian Gulf. The three main commercial ports, Doha, Shuwaikh and Shuaiba are described in this section. Their geographic location is indicated on the maps in figure 102 in Appendix C and in detail for the Kuwait Bay in figure 104 in Appendix E.

4.2.5.1 Doha port

Location

The Doha port and the greater Doha area spreads along 6.5 kilometer coastline located 15 kilometer west of Kuwait City along the Kuwait Bay. The Doha area can be reached from the Fifth and Sixth Ring Road via the Doha Spur Motorway, which bends towards the Doha Port from the ring roads.

figure 52: Aerial photograph Doha area (Google Earth; 2006)

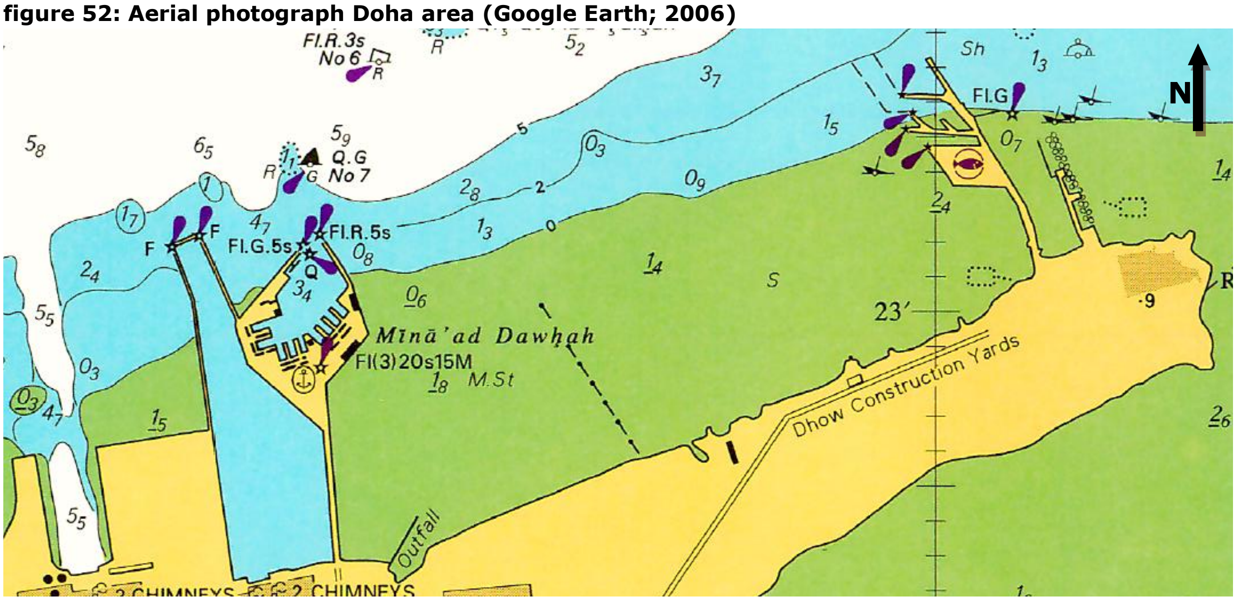


figure 53: Hydrographic chart Doha area (Admiralty chart 1214; 2002)

Layout

The first features at the west side of this area are the power stations cooling water intakes. Sedimentation of these cooling water intakes is prevented by breakwaters. Doha Port is an integral part of the eastern breakwater. This small coastal port has a depth of 3.4 meter. The port is used to berth commercial fishing vessels, dhows, barges and coastal vessels transporting goods between Gulf ports. Along the port basin there are 9 quays with a total length of 2600 meters.

The larger Doha area includes the village that was the centre of boat building in Kuwait, nowadays very few dhows are built. On the hydrographic chart in figure 53 this is made clear by the remark on the area between Doha Port and the port infrastructure at the eastern end of the map. Dhows land on the shallow shores to reach these construction yards. Storage and maintenance of dhows but also smaller and larger vessels can be done here. Shipyards in this area are equipped with slipways and protected berthing areas in front of the yard.

The infrastructure on the eastern end is not as modern as Doha Port and is known as Doha Harbor. Dhows and other vessels use the sheltered area located south of this harbor area to berth or put the vessels ashore.

Water depth

Almost the entire area between the breakwaters of the Doha area is an inter-tidal mudflat area. Only Doha Port and the most offshore quays of the eastern located harbor have as water depth left at low tide.

Relevance Doha harbor for master plan

There is no interesting waterfront for yachting and there are no facilities present at this location. This location is not mentioned as possible coastal haven location in the invitation from the Kuwaiti government. The fishing vessels present at this location are taken into account in the master plan, but this site is not considered to be not suitable for coastal haven development.

4.2.5.2 Shuwaikh Port

Shuwaikh Port is considered as the main commercial port in the country. It is located in the Kuwait Bay, west of Kuwait City. The vessels sail through a navigational channel, dredged in the Kuwait Bay, to reach the port. The length of the channel is about 8 kilometers and its depth is 8.5 meters at low tide.

The port has 21 berths of which 14 berths with 10 meters depth, four berths with a depth of 8.5 meters and three berths with 6.7 meters depth. Total length of all berths is 4055 meters. The Port can receive vessels of 7.5 meters draft at any tide condition and vessels of 9.5 meters draft at high water level.

4.2.5.3 Shuaiba Port

Shuaiba Port is located 45 kilometers south of Kuwait City. The port area extends from the southern part, Mina Abdulla, via Shuaiba port to the northern part Mina Ahmadi.

There are 20 berths at this port, which quays have a total length of 4068 meter. The depth of these berths range from 10 to 14 meter. Four of these berths are used for container Vessels. The berths for oil carriers have a depth of 16 meter.

There are two small vessel basins in the port. One basin has a depth of 4 meter and has three quay walls of respectively 100,200 and 175 meter length. The other basin has a depth of 6 meter and has four quays with respectively 211, 157, 287, 250 meter length.

4.2.6 Table with specifications and properties locations

Name	District	ID	Length breakwater (m)	Natural Shelter	Hinterland connection	Fish market
Coastal havens						
Existing						
Al Syadeen	Salmiyah/Rumaitzhiyah	2	200 N & 300 S	No	Fifth Ring Road/Fahaheel Express Way	?
Al Fontas	Fintas	1	2 X 500	No	Seventh Ring Road/Fahaheel Express Way	?
Al Kherafi (National Assembly)	Qiblah	9	55 S & 375 N	Other ports	Arabian Gulf Street/Soor Road/First Ring Road	Seif fish market
Assigned						
Watya	Wattiyah	3	100	Headland	Arabian Gulf Street/Soor Road/First Ring Road	Seif fish market
Bneider	Bneder	4		No	King Fahed Ben Abdul Aziz Road	
Abu-Hilifa	Abu-Hilifa	5		No	Fahaheel Expressway	
Al-Jahra	Al-Jahra	6		Kuwait Bay	Jahra Road	
Al-Sabia	Al Subayah	7		Headland	Highway	
Kazma	Kazimah	8	250	Headland/Kuwait Bay	Highway	?
Others						
Al-Kout	Fahaheel	10	315N & 700S	No	Fahaheel Express Way	Fahaheel fish market
Failaka Harbor	Failaka	11	3 x 250	No	Ferry to Ras al Ardh and Marina Crescent	-
Khiran	Khiran	12	not present	Inland	King Fahed Ben Abdul Aziz Road	-
Doha harbor	Doha Village	13	1200W & 600m	Kuwait Bay	Doha Spur Motorway/Jahra Road	
Dhow harbour Souk Sharq	Sharq	14	75 W & 225 E	No	Arabian Gulf Street	Souk Sharq Market

table 7: Locations characteristics

4.3 Landside infrastructure

4.3.1 General

Kuwait has a modern and well maintained transportation system. Kuwait has no railway infrastructure, and the main urban transport system is the highway system. Highway infrastructure is based on series of radial roads that fan out from the old city center of Kuwait City. These are bisected by transverse roads with leads to the radial system. The entire system suffered extensive damage in the Gulf War, but by 1993 repairs had brought most facilities back to their prewar conditions.

The current highway and local street network is over 5,000 kilometer in length of which about 350 km are expressways. The network contains more than 250 bridges. Expressways extend south and west from the city of Kuwait to neighboring cities. Paved highways link Kuwait with Iraq to the north and Saudi Arabia to the west and south. Despite the excellent network of roads in populated areas, traffic congestion is a growing problem. Plans to build a causeway across Kuwait Bay were delayed by the Iraqi invasion in 1990. This is one of the parts within the planned development of Silk City in the northern part of Kuwait.

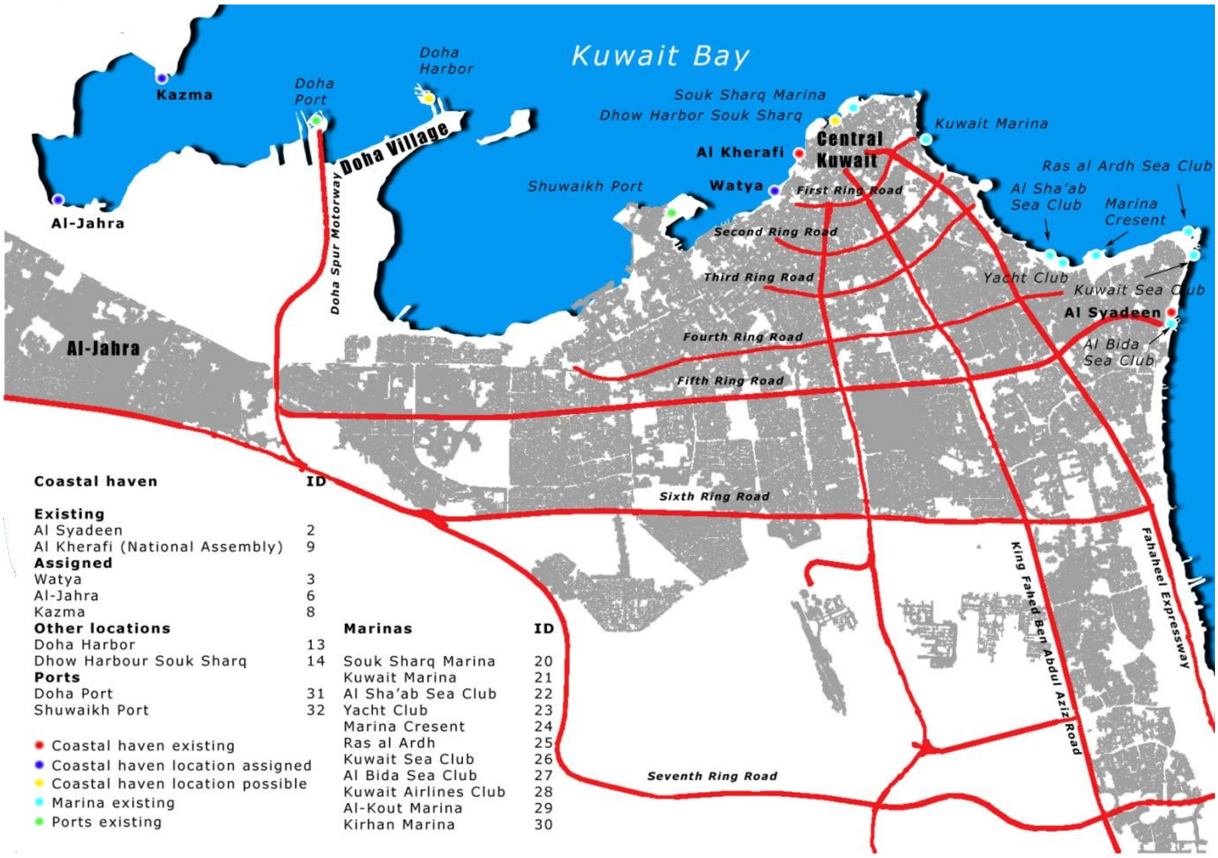


figure 54: Urbanization and highways around Kuwait Bay

Kuwait has one civilian airport, Kuwait International Airport, and is located in Farwaniya, about 16.5 kilometers south of the city centre of Kuwait City. Next to the civilian airport there are two military airports, one near Jahra, the other in the south of Kuwait.

An indication of the main highway infrastructure around Kuwait Bay and the urbanized areas can be found in figure 54.

4.3.2 Power supply

Kuwait has five electricity generation stations; these are located in Shuwaikh, Doha East, Doha West, Al-Zour, and Shuaiba South. These power stations can run on gas or oil. Energy requirements in Kuwait are relatively high because of the domestic needs as a result of the climate. The demand for energy is rising due to the continuous increase in the population and an expansion in industry. A new power station is being built in Subiya, plus an additional plant planned for Az-Zour. These should ensure that generating capacity can continuously comply with the growing demand.

4.4 Target user groups

4.4.1 Introduction

Target user groups are groups of users that are defined to make a distinction between users of the coastal haven. Private fishing vessels, yachts and the vessels that take refuge in the coastal haven are the main users of the coastal haven. The vessels that take refuge in a coastal haven exist of commercial fishing vessels, coastal passenger ships, barges and public authority vessels.

This estimation is done to get a clear picture of the number, size and geographical spread of the vessels present in Kuwait. This data is of importance for the forecast of the yachting industry and the master plan development. The coastal havens have to be designed for the vessels from the target user group, but also during the determination of the concurrence position and allocation of the coastal haven this information is of importance.

In this section the number of vessels and their location is assessed with the aid of aerial photographs. A visual estimation is made, because no extensive literature is available on this topic. The visual estimation is the best estimation that can be made with the data available at the moment. The used methodology is explained first, after which the results are presented. The results are analyzed and interesting aspects are mentioned before a conclusion is drawn from this data.

4.4.2 Methodology

The aerial photographs from Google Earth are used for this assessment. The resolution of the aerial photographs is sufficient to measure the size of the vessels and count them. The photographs are all recently taken, the oldest date from January 2006 and the most recent from June 2008. A measurement tool in the Google Earth program is used to determine the size of the vessels. The vessels present in the 11 marinas in Kuwait are used to assess the number, size and location of the yachts in Kuwait. The same is done for the fishing vessels. For this target user group, the existing coastal havens, other interesting locations, such as the dhow harbor and the fishing port of Fahaheel, are used. For the commercial fishing fleet the aerial photographs of the commercial ports are used. Besides these target groups the target group coastguard, naval vessels and barges are assessed to take into account as target user group for the port of refuge functions, as well as the barges present at all the locations.

At some locations vessels are stored on land in the vicinity of the marina or coastal haven. At the existing coastal havens the majority of the vessels is stored on land. Therefore a subdivision in vessels stored on land and present in the water is made. Next to this, a subdivision in vessel size is made. The following classes are defined during the assessment: smaller than 10 meter, between 10 and 15 meter, larger than 15 meter and larger than 20 meter for the yachts and 5-10 meter, 10-15 meter, larger than 15 meter and commercial fishing vessels for the fishing fleet. For the part of the fishing fleet present in the water, dhows and barges with a length between 15 and 60 meter has to be added, because these are only present in the water.

These classes are made based on the following arguments:

- The ability to distinguish them during the visual estimation
- Vessels larger than 10 meter are assumed to be not transportable on a trailer
- The observation that a majority of the fishing vessels is between 5 and 7.5 meter
- The international adaptation of the boat builders to this regulation

Not all vessels in Kuwait are measured with the tool in Google Earth. Only a small part of the vessels per location are measured to get an indication of the sizes present at that location. Based on the indication the number of vessels are counted and collected in a table to arrive at the total number of vessels. Besides the number of vessels, the moorings that are not used are also counted at each marina. With this data the capacity in the water per location and the current occupancy of the moorings in the marinas is determined.

In the International Boating Industry (IBI) magazine from 2007, is stated that the yachting fleet of Kuwait is build up out of 2,000 yachts present in marinas and 16,000 yachts stored by their owners on private property or at other locations than the coastal havens or marinas. In this article is also stated that the capacity is not sufficient at the moment. Waiting lists for moorings in marinas are common and yacht owners pay a relatively high fee to get a berth in a marina.

The current yachting fleet of Kuwait consists out of a large portion of speedboats with quite a lot of outboard engine power. The remainder of the yachting fleet consists out of larger yachts, which supply the owners with a more comfortable way of enjoying the coastal waters of Kuwait. For simplicity the word yachts is used as general term to refer to the entire yachting fleet in this report.

The remaining 16,000 yachts stored on land elsewhere are not estimated during this assessment. The accuracy of finding and counting these vessels is questionable and it would take too much time. The number of 16,000 vessels is therefore to be added up to the number of yachts determined in this assessment to arrive at the total number of yachts in Kuwait. All the fishing vessels are assumed to be present at the mentioned locations and no addition is used for this target user group.

4.4.3 Result yachts

The assessment is concluded with the results for the following aspects. A complete overview of the data originating from the visual fleet assessment for the yachting fleet can be found in table 9.

Total number of yachts

The total number of yachts present in the marinas is assessed at 2091. 531 yachts are stored on land and 1560 are berthed at moorings within the marinas. This figure shows a match with the data from the IBI article, which mentions a total number of 2000. If we add the 16,000, that are stored elsewhere, we end up with 18,000 yachts present in Kuwait in the period 2006 - 2008.

Capacity

Besides the yachts, the empty moorings in the marinas are also counted. This is done in order to determine the total capacity. The total capacity of the marinas is estimated at 1982 berths. This capacity is too small to facilitate the total number of 18,000 yachts in Kuwait. The marinas can only facilitate 11% of the yachts (2,000 out of 18,000) with a berth.

Occupancy

Not all berths are occupied in the visual assessment. The average occupancy of the berths in the aerial photographs is assessed at 79%. This means that approximately 1560 of the 1982 berths are occupied on the photographs. A distinction is made between the marinas along the Kuwait Bay coast, which have an average occupancy of 85%.

The Kuwait Sea Club and the Al Bida Sea Club, along the northern part of the Arabian Gulf coast, have a very low occupancy of 20%. However Kuwait Sea Club has only 10 moorings and from Al Bida Sea Club it is not clear if it is part of the coastal haven Al Syadeen or a private or public marina. The marinas in the south of Kuwait have occupancy of 65% - 75%. The marina of Fahaheel is recently developed but is quite well occupied already.

The occupancy is thus reasonable overall and high in the marinas in the Kuwait Bay. The capacity in the Kuwait Bay is thus almost fully used and additional marina facilities are especially preferable in this area.

Relatively high fees and the traveling distance between marinas and their home can be a restraint for yacht owners to moor their yacht in one of the marinas. By constructing the coastal haven with public funding an alternative comes available and the popularity of yachting and the proportion of yachts moored in marinas and coastal haven can increase. This effect is taken into account in the development forecast of the target user groups.

Yacht mix

The classes made during the assessment and the assessed number for each class result in the yacht mix in table 8. Due to the resolution and the fact that measuring every vessel in Kuwait would consume too much time, the classes in table 8 are specified.

Class	Number per class (visual fleet assessment)	Percentage per class (visual fleet assessment	Total per class	Percentage of total
< 10 (m)	976	47%	15376	85%
10 - 15 (m)	971	46%	2571	14%
> 15 (m)	132	6%	132	1%
> 20 (m)	12	1%	12	0%
Total	**2091**	**100%**	**18091**	**100%**

table 8: Yacht mix Kuwait visual assessment and total 2007

If the 16,000 yachts stored on land are also taken into account the yacht mix will change. IBI states that the majority of these yachts on trailers belong to the small outboard-powered boats sector up to 10.7 m (35ft). The class with yachts smaller than 10 meter and the class of yachts between 10 and 15 m will increase. A distribution over the classes

< 10 meter and 10 - 15 meter of 90% and 10% is assumed to account to these yachts in the yacht mix. If we recalculate the yacht mix with taking these 16,000 vessels in this way into account we end up with the last columns in table 8.

Motor yachts and sailing yachts

Next to the boat mix based on size a subdivision between motor yachts and sailing yachts is common to make. No data is available on this subdivision and very few images from the Kuwaiti marinas contain sailing vessels. However, in the design of the coastal havens the minority of sailing yachts must be incorporated to have sufficient water depth in the coastal haven and its entrance to receive sailing yachts.

Marina			Land			Water				Total	
District	Name	ID	<10 (m)	10-15 (m)	>15 (m)	<10 (m)	10-15 (m)	>15 (m)	>20 (m)	Occupancy	Capacity
Sharq	Souk Sharq	20	25	20		160	50	10		80%	275
Bneid Al Qar	Kuwait Marina	21	8	2			200	20		90%	244
Maidan Hawalli	Al Sha'ab Sea Club	22	8			155				80%	194
Maidan Hawalli	Yacht Club	23	80	25	4		250	40		90%	322
Maidan Hawalli	Marina Cresent	24	8	15	6	35	75	15	10	90%	150
Salmiyah	Ras al Ardh	25	100			150				80%	188
Salmiyah	Kuwait Sea Club	26				1	1			20%	10
Salmiyah	Al Bida Sea Club	27				6	3			20%	45
Manqaf/Fahaheel	Kuwait Airlines Club	28	No onland storage			115	25			75%	187
Fahaheel	Al-Kout marina	29	No onland storage			25	55	10	1	65%	140
Khiran	Kirhan	30		210	20	100	40	7	1	65%	228
Total			**229**	**272**	**30**	**747**	**699**	**102**	**12**		**1982**

Total	
<10 (m)	976
10-15 (m)	971
>15 (m)	132
>20 (m)	12
Total	**2091**
Capacity	**1982**

table 9: Results visual fleet assessment number of yachts (layout table)

4.4.4 Result fishing fleet and other vessels

Total number of vessels

For the fishing fleet and other vessels an overview with the number of vessels per location is given in table 10. The majority of the fishing vessels use the coastal havens of Al Syadeen and Al Fontas. At these locations all vessels are stored on land. Other used locations are the assigned coastal haven location of Watya and the dhow harbor next to the Souk Sharq Mall and the fishing port of Fahaheel and Khiran. The sport fishing speed boats stored at Watya are assumed to belong to the fishing fleet. No vessels are present at the coastal haven of Al Kherafi (National Assembly) on the aerial photographs and the visit done by the team.

In total 659 small fishing vessels (speedboats), 160 dhows and 90 commercial fishing are counted on the aerial photographs. Furthermore there are 25 barges counted and the number of public authority vessels is mentioned separate in table 10. A large part of the vessels out of the classes 5-10 m and 10-15 m is stored on land.

The small fishing vessels (speedboats) are a separate target user group and are counted in the existing coastal havens (Al Syadeen and Al Fontas) and other locations dedicated to fishing. A distinction between these vessels and the yachts (in marinas or on land near marinas) is thus possible to make based on aerial photographs.

Correspondence with literature

The figures in table 10 seem to correspond with the statistics obtained from the fishery country profile from 2001 from the Food and Agriculture Organization of the United Nations (FAO). The number of small fishing vessels (speedboats) is estimated at 748, the number of dhows at 153 and the number of commercial fishing trawlers at 35.

The number commercial fishing vessels deviates from the statistics. An explanation for the deviation is the presence of coastal cargo vessels in this class. The distinction between a coastal cargo vessel and commercial fishing vessel cannot be made on aerial photographs

Barges and coastal passenger ships

In the commercial fishing and industrial ports several barges and larger vessels are present. Only the barges with a size up to 60 m present in Doha Port are part of the assessment of the target user groups.

Vessels that could use a coastal haven as port of refuge are barges, coastal passenger ships, naval vessels and coast guard vessels. For the class coastal passenger ships only the ferry between Ras Al Ardh and Failaka and the fast ferry service between Marina

Crescent and Failaka Island are known. Approximately 4 vessels sail between these marinas and Failaka Island. Ferries are part of the class barges, since they represent a small share of the entire fleet.

4.4.1 Accuracy of the assessment

No vessels seem to be present along the coastline, except in the most northern part of Kuwait, along the river Khor as Subiyah. Only the vessels present at the locations mentioned in table 9 and table 10 are taken into account during this assessment.

Screening the entire coastline would consume a considerable amount of time and the distinction of land stored vessels and cars is hard to make on the aerial photographs of the more remote areas.

Kuwait is a well developed country and it has reasonably developed maritime infrastructure. Most of the yachts and vessels are assumed to be present in the marinas, existing coastal havens, private berths and commercial ports. The number of vessels and yachts berthed or landed at locations along the coast without any detected maritime infrastructure is expected to be limited and not significant for this analysis.

The resolution of the aerial photographs of the Arabian Gulf and Kuwait Bay is not good enough to assess the number of vessels sailing offshore is therefore not possible. Furthermore is there a large deviation in the origin dates of the photographs. Double counting or not counting vessels could be introduced in this way. This area is therefore not part of the visual assessment. The origin dates of the aerial photographs can be found in Appendix H.

This assessment is considered to be a reasonable and actual representation of the situation of the target user groups in the period between 2006 and 2008, since they show a correspondence with the literature on the various target user groups.

Coastal			Land				Water					
District	Name	ID	5-10 (m)	10-15	>15 (m)	Commercial fishing	5-10 (m)	10-15 (m)	>15 (m)	Dhows	Barges (15-60m)	Commercial fishing vessels
Existing												
Salmiyah	Al Syadeen	2	137	3	6	-	No vessels in water					
Fintas	Al Fontas	1	135	25	-	-	No vessels in water					
Qiblah	Al Kherafi (National	9	Not used				No vessels in water					
Assigned												
Wattiyah	Watya	3	88	-	-	-	-	-	-	-	-	-
Kazimah	Kazma	8	10	-	-	-	-	-	-	-	-	-
Others												
Fahaheel	Al-Kout	10	-	15	-	-		70		10		-
Failaka	Failaka Harbor	11	Not in use									
Khiran	Khiran	12	10	10	2	-	20	4	4	-	-	-
Doha Village	Doha harbor	13	-	-	-	-	-	-	-	40	15	-
Souk Sharq	Dhow harbour Souk	14	No onland storage				100	-	-	110		
Commercial												
Doha Village	Doha Port	31	-	-	-	10					5	60
Shuwaikh	Shuwaikh Port	32	No vessels in target user groups									
Shuaibah	Shuaibah Port	33	-	-	-	-	5	15	-	-	5	20
Total			**380**	**53**	**8**	**10**	**125**	**89**	**4**	**160**	**25**	**80**
Other												
Al Julay'ah	*Naval Base*	*34*					*15*	*7 of 55 (m); 8 of 40 (m); 1 of 90 (m) and 1 of 50 (m)*				
Fintas	*Coastguard Base*	*35*					*34*	*20 vessels (ranging from 20 to 50 m)*				

Total	
5-10 (m)	505
10-15 (m)	142
>15 (m)	12
Total	**659**
Dhows	160
Commercial fishing vessels	90
Barges (15-60m)	25

table 10: Results fishery fleet assessment

5 Part two: Development forecast

5.1 Introduction

The assessment of the size and location of the user groups considered in the previous part. From the target user groups assessment we proceed to their development. To develop a sustainable master plan, the fishing and yachting potential in Kuwait are assessed.

The assessment results in a forecast of the development of the fishing fleet and a potential yachting demand over a period of 23 years. These two target user groups are handled with a different approach since their development is based on different aspects. For the target user group that consists of the vessels that use the coastal haven as port of refuge no such forecast is made. This target user group is considered to keep approximately the same size in the future.

5.2 Methodology

To make an estimation of the potential yachting demand in Kuwait a methodology is applied to asses this potential from the economic development, population development, disposable income, affordability and adoption rates. **The adoption rate is defined as the number of vessels owned per 100 inhabitants or members of a user category.** A user category is subsequently defined as a part of the population or the entire population.

Besides the adoption rate and the user categories, the affordability is an aspect that is part of the analysis. The affordability analysis gives for each user category an indication of the share for that category that is able to afford yachting. The affordability is based on data of the disposable income, consumption priorities and patterns, ability of saving and the yachting cost in Kuwait. Since there is not enough data available to forecast the amount of people who are – economically spoken - able to buy and possess a yacht, this aspect will only be treated in general. Developments are analyzed and the trend in affordability for the entire population is given.

The entire forecast of the potential yachting demand can be found in Appendix I*. The scenarios, calculation and the conclusions, which are based on the information in the appendix, are taken up in the main report.*

For the fishing industry a different methodology is applied, since this industry has a different background. Statistics on the worldwide fishery development, employment in the fishery sector and the consumption of fish in Kuwait are used to determine the development of this sector.

The entire forecast of the fishing industry can be found in Appendix J. For this section are also only the scenarios, calculation and conclusions taken up in the main report.

5.2.1 Scenarios

In the methodology of this part of the project, several scenarios are adopted to assess the sensitivity of the forecast. The bandwidth of the development forecast is created by determining three development scenarios. The low, medium and high development scenario introduces the bandwidth of this analysis. The bandwidth is an indication of the sensitivity of the forecast and provides insight into the development uncertainties in the long term.

The medium forecast represents the most probable development trend. It is based on realistic parameter values in relation to the present situation. The medium scenario will therefore be used for further calculations. The high development trend assumes a positive bias of the average values, whereas the low scenario assumes a negative bias.

5.2.2 Overview methodology

An overview of the used methodologies for these two target user groups is given in figure 55. This overview is at the same time the structure of this part of the research project. Aim of this part is to end up with the number of yachts and fishing vessels present in Kuwait in 2030. The share and the size of the vessels that will use a marina or a coastal haven then is important input for the next part of the report, the development master plan of the network of coastal havens.

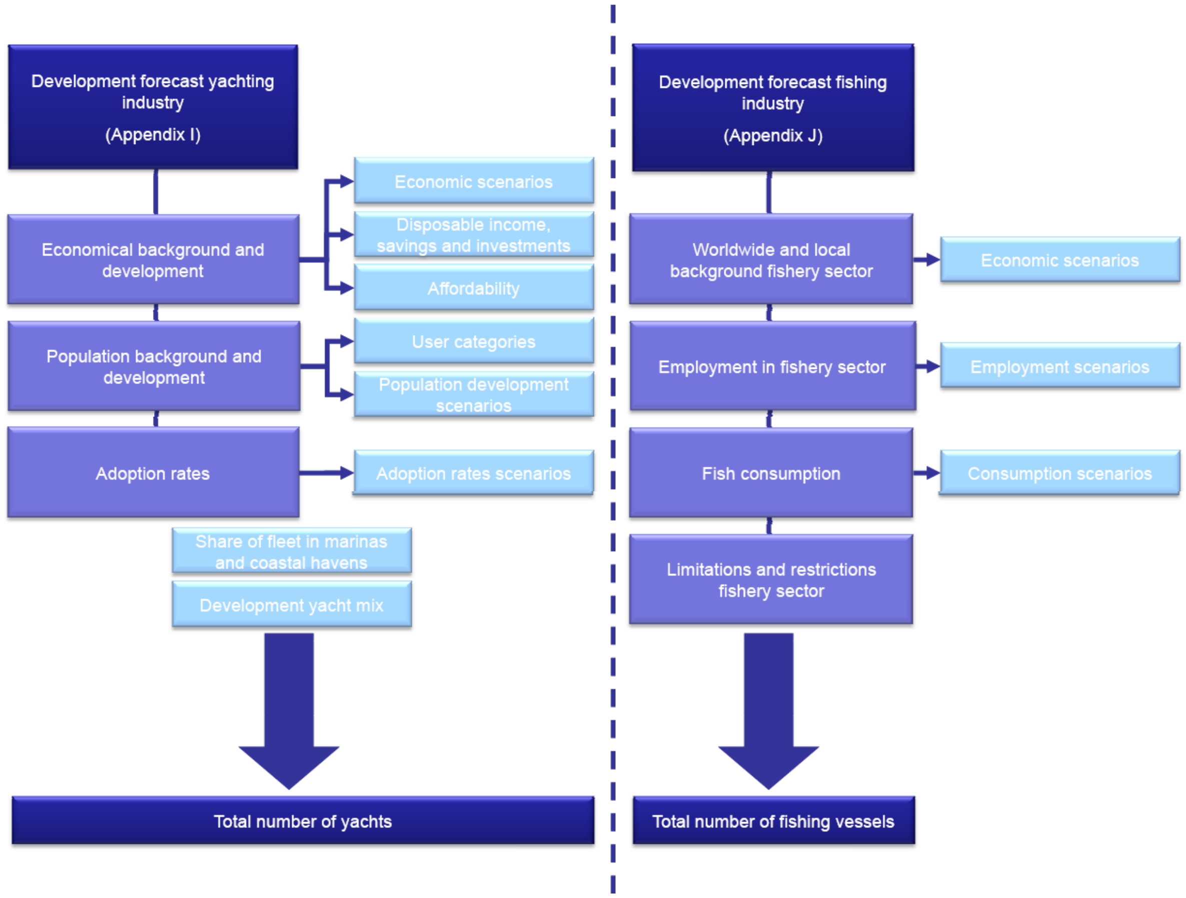


figure 55: Overview part 2: development forecast target user groups

5.3 Yachting industry

The yachting development scenarios are split up into the development scenarios for the economy, population and the adoption rate.

5.3.1 Economic scenarios

The economic scenarios only give an indication of the economic climate in Kuwait and create in this way boundary conditions for the development of the yachting industry. An economy that shows high growth rates stimulates development of the fishery and yachting industry, since the population is able to make investments. The determination of these scenarios is done based on statistics on the gross domestic product (GDP) and predictions of the International Monetary Fund (IMF, April 2006). This information can be found in section I.1.

<u>*High scenario*</u>

In the high scenario the GDP per capita stays highly ranked on the international ranking of countries. The growth rate of this figure is expected to stay at the same *rate as it was in the period 2001 – 2007, 6% per year. The relative wealth of the population stays relatively high in this scenario. High overall economic growth figures in the last decade also support this development scenario. The GDP of Kuwait has been increasing in the period 2001-2008 with an average growth rate of 5.2% per year according to the statistics from the CIA World Fact Book. In general this scenario is very favorable for the development of the yachting industry in Kuwait.*

Medium Scenario

The medium scenario will show more moderate GDP growth rate. Assuming that Kuwait will enforce its tourism potential, it is predicted that the economic growth will be still substantial in this scenario. The average development in this scenario is related to the average growth rate of the GDP per capita in the period 1991 – 2001 of 3.7% and to the predicted short term (until 2014) development of the Kuwaiti GDP per capita with 3.5%. This growth rate is predicted by the International Monetary Fund (IMF). Although this scenario is more moderate that the high scenario it is still favorable for the potential development of the yachting industry.

Low scenario

In the conservative low scenario it is assumed that the Kuwaiti economic growth falls back to the average growth rate of the world wide annual growth of the GDP per capita (PPP) of 2.1% (CIA World Fact Book over the period 1953-2001). This development is thus below the development of the last decades in Kuwait.

The conditions in the low scenario result in an economic climate where not a lot of development of the yachting industry is expected. The potential yachting demand and number of yacht owners is assumed to stagnate at its current number.

5.3.2 Population scenarios

The indigenous population and the western expatriates are indicated as main user categories for yachting industry in appendix I.3.3. In all scenarios it is assumed that the natural growth of the indigenous population stays at the averaged growth rate of the period 2000-2007. This growth rate was constant around the value of 3.25%. Keeping this growth rate constant has consequences for the share of the indigenous population in the several scenarios.

High scenario

In the high scenario a growth of the entire population is expected with the average growth rate of the period 2001 – 2007. In this scenario the entire population keeps on growing with a rate of 6% per year. The main source of growth is the expatriate *population that continuous to grow with a relatively high rate compared to the indigenous population. This rate is not as high as the rate in 2007 since the influx is expected to flatten off in the future.*

Medium Scenario

For the medium scenario a more moderate approach is adopted. It is assumed that the Kuwaiti population will grow in the same pace as the indigenous population in the coming years. In the medium scenario the average growth rate over the period 2001-2007 of the indigenous population serves as basis for the development of the entire population. The influx of expatriate population, the driving force behind the large growth rates, is expected to reduce more than in the high scenario. With a growth rate of 3.25% per year the proportionality between the indigenous and foreign part stays the same and the population will double within 20 years like has happened in the past 20 years.

Low scenario

In the conservative approach, the growth of the Kuwaiti population is linked to the expected worldwide population growth rate of 1.14% per year, determined by the United Nations. The population in Kuwait keeps on growing, since it has been for the entire history of the country, except the period when the country was under Iraqi occupation. The country's oil industry is expected to guarantee the favorable economic conditions for the expatriate population to stay in Kuwait.

5.3.3 Adoption rate scenarios

The current adoption rate is around 2 among the indigenous Kuwaiti population. This means that 2 out of 100 Kuwaiti nationals own a yacht at this moment in Kuwait. The development scenarios of the adoption rate, mentioned in the box below, are based on the adoption rate among the user categories. As a reference countries with a developed yachting industry are used. This results in the following development scenarios, which are used in the calculation for the potential yachting demand.

High scenario

In the high scenario the adoption rate is on the high end. The accompanying economic scenario is above the current expectation from the IMF and the number of vessels will increase with a larger rate than the number of members in the user categories do. The adoption rate will thus increase to such a value that we can speak of a fully developed yachting industry, if we look at the user categories indigenous and expatriate population. The Dutch adoption rate of 3 is taken as reference value *for the user category indigenous population. The user category western expatriates is assumed to reach an adoption rate of 2 yachts per 100 inhabitants. This is half of the averaged adoption rate from the countries of origin that is used as reference for this rate. Taking only a half of the reference rate is done to compensate for the limited time of stay of the expatriates in Kuwait.*

Medium scenario

In the medium scenario the adoption rate will be assessed as a more modest figure. The medium scenario economic assumes a moderate development as well. The user categories are assumed to be able to live in the same manner as they do now and the interest and involvement in yachting continues to develop. The adoption rate among the indigenous population is assumed to stay at 2 until 2030. For the expatriate population a moderate development is expected. In this case the adoption rate will develop a value of 1 yacht per 100 western expatriates in 2030, a quarter of the averaged value over the countries of origin of this user category.

Low scenario

In this conservative approach yachting will almost not gain any popularity. The economic scenario indicates development below the growth rate of the last two decades and investments in yachting are therefore not expected. The infrastructure for yachting stays the way as it is now and the sector cannot develop any further. The number of yachts in Kuwait in this scenarios will not increase, but the population continues to increase with the natural growth of the population. The adoption rate of the indigenous population will therefore reduce to a rate of approximately 0.85. The adoption of yachts among the western expatriates is expected not to develop at all in this scenario. Fewer investments lead to less work for western expatriates in Kuwait and that will have its effect on the yachting demand potential from this user category.

5.3.4 Results

The figures determined for the various scenarios result in the following forecast for the potential yachting demand.

				2005	2010	2015	2020	2025	2030
Population (x1,000,000)	High		6.00%	2.9	4.0	5.2	6.9	9.7	12.4
	Medium		3.25%	2.9	3.7	4.1	4.6	6.0	6.6
	Low		1.14%	2.9	3.5	3.4	3.4	4.2	4.0
Kuwaiti (x1,000,000)	Medium		3.25%	1.0	1.1	1.3	1.6	1.8	2.2
Adoption rate	Kuwaitis	High		1.92	2.00	2.25	2.50	2.75	3.00
		Medium		1.92	2.00	2.00	2.00	2.00	2.00
		Low		1.92	1.75	1.50	1.25	1.10	1.00
	Arabian expatriates			0	0	0	0	0	0
	South Asia expatriates			0	0	0	0	0	0
	Western expatriates	High		0	0.25	0.75	1.00	1.50	2.00
		Medium		0	0.00	0.25	0.50	0.75	1.00
		Low		0	0	0	0	0	0
Result (x1000)	Kuwaitis	High		18.0	22.8	30.2	39.3	50.7	65.0
		Medium		18.0	22.8	26.8	31.5	36.9	43.3
		Low		18.0	18.0	18.0	18.0	18.0	18.0
	Arabian expatriates			0	0	0	0	0	0
	South Asia expatriates			0	0	0	0	0	0
	Western expatriates	High		0	0.1	0.4	0.7	1.5	2.5
		Medium		0	0	0.1	0.2	0.5	0.7
		Low		0	0	0	0	0	0
Total (x1000)		High		18.0	22.9	30.5	40.0	52.2	67.4
		Medium		18.0	22.8	26.9	31.7	37.4	44.0
		Low		18.0	18.0	18.0	18.0	18.0	18.0

table 11: Development forecast yachting demand potential

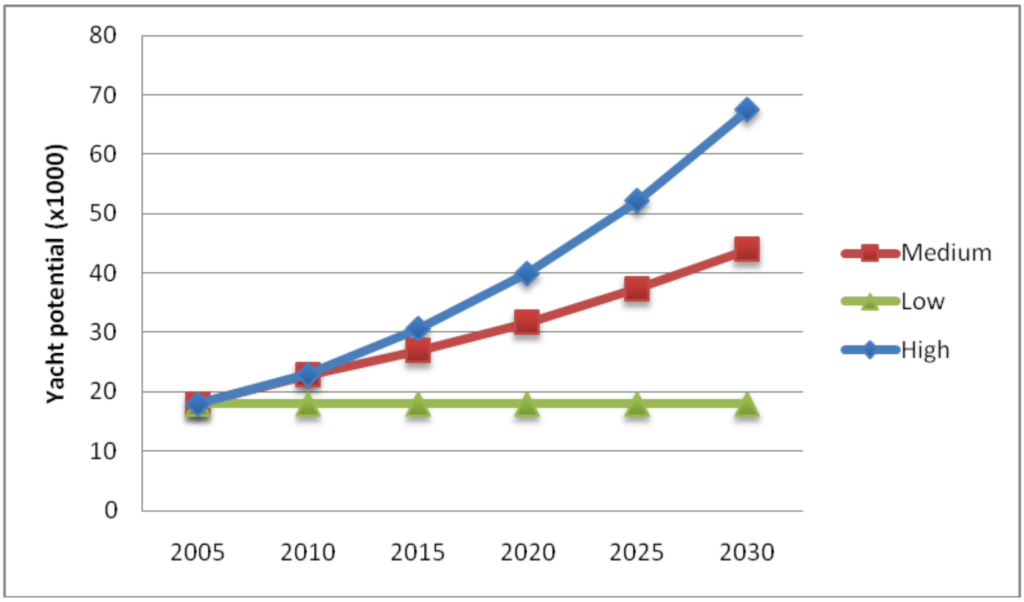


figure 56: Result yacht potential analysis

Share of yachts moored in marinas or coastal havens

An increase of the share of the vessels moored in marinas is expected to occur due to the realization of coastal havens. An increase of 9% (from 11% to 20%) is assumed to be possible for the high scenario, for the low scenario nothing changes and this rates stays at 11%. For the medium scenario the medium share of 15.5% (the average of 20 and 11%) is expected to be achievable. The construction of infrastructure cannot be developed in the same pace as the yachting demand potential develops. Up to 2010 the share of yachts in marinas and coastal havens is therefore tempered. The results are presented in table 12 and figure 57.

Scenario	Share	2005	2010	2015	2020	2025	2030
High	20,0%	2,0	3,6	5,4	8,0	10,4	13,5
Medium	15,5%	2,0	2,5	3,6	4,9	5,8	6,8
Low	11,0%	2,0	2,0	2,0	2,0	2,0	2,0

table 12: Share of yachts in marinas and coastal havens (x1000)

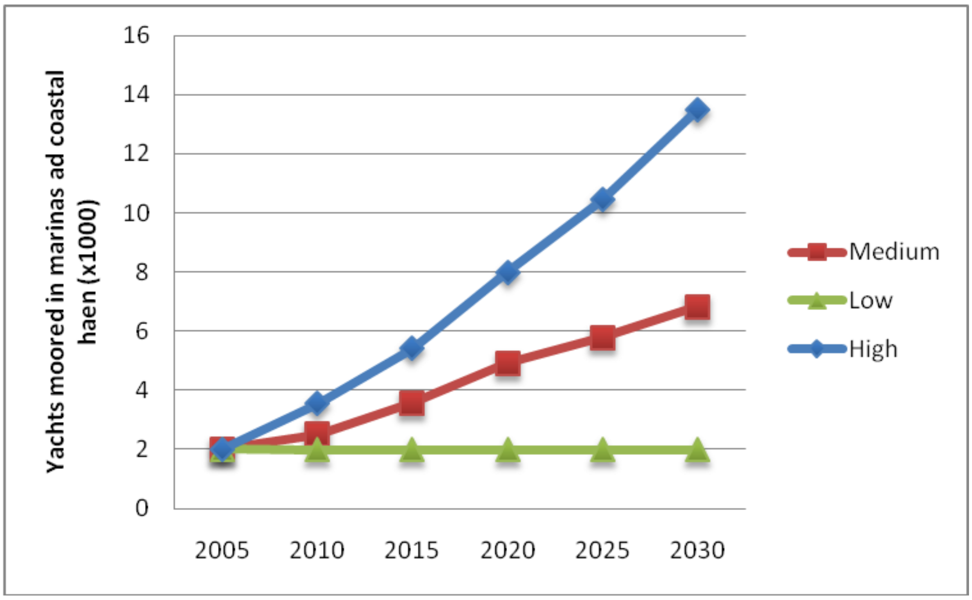


figure 57: Results share of yachts moored in marinas and coastal havens

Yacht mix

A change in the Kuwaiti boat mix is expected due to the construction of coastal havens. The large influx of smaller vessels, currently stored on land, and growth of the yachting industry in general in the medium and high scenario, result in a different yacht mix in 2030.

The yacht mix in marinas and coastal haven in 2030 is assumed to be represented by table 13. The calculation of the yacht mix in 2030 is made in appendix I.4.2.

Classes	Marinas (2007)	Total (2007)	Low 11%	Medium 15.5%	High 20%
< 10 (m)	47%	85%	47%	41%	39%
10 – 15 (m)	46%	14%	46%	51%	53%
10 - 15 (m)	6%	1%	6%	6%	5%
> 20 (m)	1%	0%	1%	2%	2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

table 13: Yacht mix scenarios 2030

5.4 Fishing industry

For the fishing vessels a different approach is used. In this forecast the worldwide and Kuwaiti development of the fishing industry, people employed in the fishing industry and the consumption of fish in Kuwait is taken into account. Next to this the limitations and regulations applicable to the fishing industry are part of the analysis.

5.4.1 Scenarios

All the background with indicators for the development of the fishing industry are mentioned in Appendix J. This information results in the following scenarios for the development of the fishing industry.

High scenario

For the high scenario, the growth rate is linked to the high potential of fish consumption and the growth of employees in the sector. The statistics on these aspects showed a larger growth than the captures. If we add the proposed investments by government to the sector by creating coastal havens, a high development scenario with a growth rate for the industry of 2% can be achieved.

Medium Scenario

The trend line for the statistics on the captures from 1950 until 2007 show an increase of 1% as well as the landing on Arab beaches for the period from 1990 until 1995 (both originating from FAO statistics). Therefore this growth rate will be set for the medium development scenario.

Low scenario

In the pessimistic scenario no growth or even a decrease of the sector is expected. Fishermen will not respond directly and with the same rate on the decline of the captures in the last decade. This results in a more modest rate for the development of the fishing industry that the averaged decline of captures over the last decade.

The statistics from the FAO on the last decade show a setback in captures, averaged over this period we arrive at a rate of -3%. The sector already showed years where a decrease was noticeable. If regulations are enforced more strictly and natural circumstances are further deteriorating, a development of the sector size with a rate of -1.5% is accounted for.

5.4.2 Results

The growth rates mentioned in the different scenarios above will be applied to the fishing fleet of Kuwait. Several restrictions, limitation and global circumstances limit the growth of the fishing industry. The known restrictions are assumed to limit the growth of the dhows and commercial fishing vessels in particular. Keeping the commercial fishing and dhow fleet at current levels, we end up with the forecast for the fishery fleet in table 14.

Scenario			2007	2010	2015	2020	2025	2030
High	2.0%	Dhows	160	160	160	160	160	160
		Commercial fishing vessels	90	90	90	90	90	90
		Total speed boats	659	699	772	852	941	1039
Medium	1%	Dhows	160	160	160	160	160	160
		Commercial fishing vessels	90	90	90	90	90	90
		Total speed boats	659	679	714	750	788	828
Low	-1.5%	Dhows	160	160	160	160	160	160
		Commercial fishing vessels	90	90	90	90	90	90
		Total speed boats	659	630	584	541	502	465

table 14: Development forecast fishing vessels

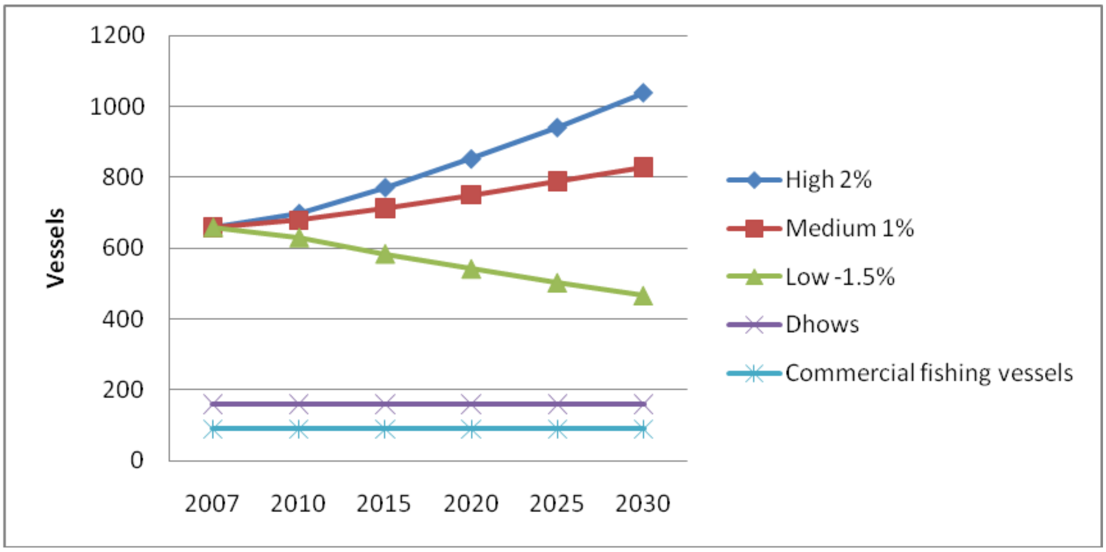


figure 58: Results fishing industry

5.5 Conclusions

- Not a lot of growth is expected for the fishery industry
- The increase in the number of vessels will be restricted
- Only the number of smaller speedboats will show a significant increase in the future.
- Significant restrictions exist for the fishing industry
- The high development scenarios results in a growth of the fishery sector with 380 speedboats, the medium in a growth of 170 speedboats and the low scenario result in a decrease of the fishing fleet with 200 speedboats over a period of 23 years.

6 Part three: Development master plan

6.1 Methodology

All locations, target user groups, landside and maritime infrastructure are described in detail in the first part of this phase (chapter 4). The development of the yachting and fishing industry are assessed in the second part (chapter 5).

In this third part the coastal water system, geographical spread of the target user groups demand from these groups towards the coastal havens is analyzed. This information a base of the master plan on.

A Strengths, Weaknesses, Opportunities and Treats (SWOT) analysis is used as a framework to assist in the development of the master plan. The analysis identifies and arranges the properties and qualities of the locations. With this information it is possible to make a comparison between the locations. Based on this comparison locations for coastal haven development are selected and functions are allocated.

The SWOT is based on the analysis of the locations (4.2), the development forecasts for the yachting and fishing industry (5) and a coastal water system appraisal, which is presented in this chapter. The difficulty in the analysis is the combination of aspects of interest for the yachting and for the fishing industry. Next to these aspects, an assessment of the locations where a port of refuge function is performed.

6.2 Appraisal coastal water system

For the analysis that will be done within the scope of this research project the current state of the maritime infrastructure is a key aspect. Various components of the coastal water system in Kuwait will be discussed in the following section.

The Arabian Gulf and the Kuwait Bay and the nine islands in the coastal waters of Kuwait are the main components of the coastal water system. The islands are considered as destinations for yachting and are in this way part of the network. Furthermore, there are several development projects planned and under construction that need to be considered during the development of the master plan. Fishing grounds, restrictions and limitations within the coastal water system are also considered in this section. All aspects mentioned in this section are input for the SWOT analysis and are therefore part of this chapter.

The restricted areas, limitations, development projects, islands and coastal haven locations are indicated on figure 105 and figure 106 in Appendix G and Appendix F. This is done to get an indication of the boundary conditions of the master plan in a spatial framework. This information is also part of the SWOT analysis.

6.2.1 Arabian Gulf

This inland sea of some 251,000 km² is connected to the Gulf of Oman in the east by the Strait of Hormuz. Its western end is marked by the major river delta of the Shatt al-Arab, which brings water from the Euphrates and Tigris into the Gulf. Its length is 990 kilometer, with Iran covering most of the northern coast and Saudi Arabia most of the southern coast. All the countries with a coastline on the Gulf are (clockwise, from the north): Iran, Oman, United Arab Emirates, Saudi Arabia, Qatar, Bahrain, Kuwait and Iraq in the northwest.

The gulf is about 56 kilometer wide at its narrowest, in the Strait of Hormuz. The water depth is on average 35 meters, but depths of more than 107 meter occur in some place. The gulf's water depth increases in the southeast direction.

6.2.2 Kuwait Bay

Kuwait Bay is a generously sized natural harbor and has always been a prime access point for trade entering and leaving the hinterland of northeast Arabia and Iraq. Before discovery of oil, it was the country's most valuable natural resource. One of the main commercial ports Shuwaikh and the commercial fishing port Doha Port are located along the shore of Kuwait Bay and its economic importance continues.

The bay is 18 kilometer wide, measured from Ras al Subiyah to Ras al Ardh, at the mouth and 40 kilometer long from the mouth to the most western end. The average water depth of the Kuwait Bay is approximately 5 meters, but almost the entire perimeter of the bay is covered by inter-tidal wetlands. The shallow areas provide a more moderate wave climate, but this brings along disadvantages with respect to navigation with it at the same time.

The location of the islands is indicated on figure 102 of Appendix C.

6.2.3 Islands

There are nine islands offshore of the Kuwait coast, namely Failaka, Bubiyan, Miskan, Warba, Auhha, Umm Al-Maradim, Umm Al-Naml, Kubbar and Qaruh. The largest of Kuwait's nine islands, Bubiyan, is an uninhabited, low-lying, muddy island near the border with Iraq. The other islands are sandy islands fringed with coral reefs. All except the large island of Failaka near Kuwait City are uninhabited except for police outpost and several support breeding colonies of sea-birds. A short description of the islands is given below. The geographical location of the islands is provided in figure 102 in Appendix C.

Failaka

Failaka is considered to be the most beautiful island. The island has some of the most significant archaeological sites in the Gulf, dating from the Bronze Age. Next to that evidence is found from Dilmun and Greek settlements. The Dilmun and Greek were both cultures that ruled over and had settlements in this region in the past. The island is located at the mouth of Kuwait Bay.

figure 59: Failaka Island (Panoramio.com)

It was considered a top tourist attraction with chalets and beach resorts before Iraqi invasion. Due to the island’s location close to the Iraqi coastal waters it was occupied by Iraqi forces and used a naval base during the occupation. The island is deserted since the Iraqi invasion.

The island is approximately 12 kilometers long and 6 kilometers wide. Shoals are present around the entire island, only the western end of the island is directly accessible from the water via a harbor or the ferry landing facilities. Both locations are equipped with breakwaters. On the photograph in figure 59 the ferry landing on the southwestern end of the island is visible.

Miskan and Auhah

figure 60: Miskan Island (Panoramio.com) **figure 61: Auhah Island (Panoramio.com)**

Miskan Island is a small, uninhabited island, 3.2 kilometer north of Failaka Island. It is about 1200 meter long and 800 meters wide. The distance between Miskan and the nearest part of Kuwait City is about 24 kilometers.

Auhah Island lies 4 kilometers southeast of Failaka Islands and has comparable properties as Miskan Island. Its size, 800 meter long and 540 meters wide, is somewhat smaller than Miskan.

The islands are links in a chain of islands along Kuwait's coastline from north to south. The water depth around the islands is limited and entrance is therefore restricted for larger vessels. There are no economic activities present on both islands. The island could be developed into a potential interesting destination for yacht owners.

Umm-Al-Namil

On Umm Al-Namil island, which is located northwest of Kuwait City in the Kuwait Bay, has a lot of archeological findings from the Islamic era and the Bronze Age. The island is 600 meter from the Kuwaiti mainland and lies between the Doha area and Shuwaikh Port.

figure 62: Mudflats at Bubiyan Island (Panoramio.com)

Bubiyan Island

Bubiyan Island covers an area of 863 km^2 and is connected to the mainland by a bridge from Al-Sabia. This bridge was destroyed during the Iraqi invasion and quickly rebuilt afterwards. This is done to ensure the Kuwaiti claim on the island. In the past fresh water was transported from the Shatt al-Arab waterway, near Bubiyan Island, by dhows to Kuwait. This was not necessary anymore after the first desalination plant along the Kuwait coastline was built. The island is now mainly used for camping.

figure 63: Kubbar Island (Panoramio.com)

Warbah Island

Warbah Island is at the most northern part of Kuwait. The island is composed of soft mud and silt. It has several tidal creeks and during high tide a large part of the island is flooded. The properties of this area are comparable to those of Bubiyan Island.

Kubbar

Kubbar Island is located roughly 30 kilometers east off the southern coast of Kuwait and 29 kilometer from Failaka. The island is nearly circular, with a diameter of 370 to 380 meters, corresponding to an area of about 11 hectares. It is sandy, with low coasts and sparsely vegetated. The island is inhabited by various forms of wildlife and is surrounded by coral reefs. Therefore it is a popular destination for scuba divers.

Quaruh

figure 64: Quaruh island (Panoramio.com)

The island received its name from the large amounts of petroleum sediments in the area, known as *Qar* in Arabic. It is the smallest of the nine islands, and is located at the largest distance from the Kuwaiti mainland. It is located 37.5 kilometers away from the mainland, and 17 kilometers away from Umm Al- Maradim. The island is roughly 275 meters long and 175 meters at its widest and has a surface area of about 3.5 hectare. The island was also the first part of Kuwait that was liberated from Iraq during the Gulf War.

Umm Al-Maradim

Umm Al-Maradim is the most southern located island of the nine islands. The island is approximately 1.500 meter long and 500 meter wide. It is located between Kuwaiti and Saudi territorial waters. The island is known to have deep waters surrounding it, in which large ships can safely anchor.

figure 65: Umm Al-Maradim (Panormio.com)

Conclusion

The chain of islands along the south coast of Kuwait is not a part of the maritime infrastructure at the moment. Most of them are not suitable for large development project like the ones planned on Failaka and Bubiyan Island. However, by developing facilities for yachts on these islands, they can become a more interesting destination for yacht owners. The popularity of yachting can increase due to these developments. The same holds for the islands around Failaka. By improving the infrastructure on the other islands, yachting is getting a positive impulse.

6.2.4 Development plans

In 2005 and 2006 development plans are made for the islands of Bubiyan and Failaka and the region named Al-Khiran in the south of Kuwait, close to the border with Saudi Arabia. The development plans are still in a planning phase at the moment of writing of this report. The development plans are briefly introduced in this paragraph.

The areas of the development plans are indicated in pink on figure 106 of Appendix G.

Madinat Al Hareer (City of Silk)

figure 66: Bubiyan Island and Al Sabia (www.civicarts.com)

The state's higher Committee for Urban planning and Major Projects is considering development of Bubiyan Island. In January 2004 the Kuwait Cabinet approved a project to build an international seaport on Bubiyan Island and a city on the mainland around the area that is known as Al Sabia. The city will provide housing for 700,000 people in the future.

The development plan, which is called Midinat al Hareer (Silk City), contains the construction of the world's largest tower and a causeway to Kuwait City. The causeway across the Kuwait Bay is connecting to the mainland somewhere between Shuwaikh port and the island of Umm-Al-Namil.

The construction of the port is expected to lead to a big increase in the volume of containers shipped through the northern Gulf region. The artist impression in figure 66 shows the city and the cause way with Kuwait Bay in the background.

Failaka Island

Another development plan concerns the transformation of Failaka Island into a tourist attraction again (figure 67). The island infrastructure is already based on tourism industry, but most of it was destroyed during the Iraqi invasion. The development plan includes a desalination station and electricity plant. A ferry connection with Ras al Ardh and one of the marinas in the Kuwait Bay on the mainland is already present.

figure 67: Masterplan Failaka (www.watg.com)

figure 68: Al Khiran Pearl City under construction (www.burohappold.com)

Al-Khiran (Pearl City)

Al Khiran Pearl City is a waterfront development project that covers an area of 6.4 million square meters. The city is located 85 kilometers south of Kuwait City. The area, currently under construction, will eventually be home to a population of around 100,000 people. In the project two tidal creeks around a marina and houses are created along the waterfront.

6.2.5 Fishing grounds

Fishing grounds are mainly located in the Kuwait Bay. Fishing is done with the traditional fixed fishing traps ("hadra") on the shallow parts of the Kuwait Bay. Recreational fishing is also common to do in the Kuwait Bay.

The shallow bay with inter-tidal mudflats is an important nursery ground for crustaceans. In the deeper parts of the western part of the Kuwait bay an area is meant for fish farms. Fish traps and fish stakes are indicated on the admiralty charts on the shores around the perimeter of the Kuwait Bay.

Next to fishing in Kuwait Bay is expected that the larger commercial fishing vessels operate on the Arabian Gulf. These fishermen and vessels are less bound to the Kuwaiti shores and sail further offshore. Fishing grounds are less well defined in this area and fishermen are assumed to sail on the Kuwaiti territorial part of the Arabian Gulf.

6.2.6 Restrictions and limitations

The restricted areas and limitations are indicated in red on the Admiralty charts in figure 105 and figure 106 of Appendix F and Appendix G.

Former mined areas

Around the Kuwaiti territorial waters are several former mined areas. The northern end of the Arabian Gulf and at the southern and eastern end of the territorial waters are areas marked as former mined areas on the hydrographic charts. Anchoring and fishing is not possible in these areas.

Areas around commercial port

Besides the former mined areas, the shipping lanes, leading to the commercial ports of Kuwait, impose restrictions to the yachting and fishing industry as well. The lanes are marked with buoys and fishing and anchoring is not allowed in most of these areas. This also holds for the anchoring areas, where vessels can wait before entering the commercial ports. Around these commercial ports is a lot of infrastructure present on the sea bottom, like for example pipelines, which lead to offshore loading facilities. Overall can be said that large areas with restrictions are indicated on the hydrographic chart around the port of Shuaiba, where most of the oil exporting industry is located.

The entrance channel to Shuwaikh Port also lays down its restrictions to other vessels sailing in this area.

Private beaches and marinas

Parts of the coastal strip are private property and are not available for coastal haven extension or development. Determining the possibilities at the location will be one of the main determining parameters in the final allocation of the coastal haven. But also the extension of the existing coastal havens can be hampered in this way.

Marinas are in general owned and managed by private parties. Creating the network of coastal havens in cooperation with these private parties seems not possible and the government has limited power to determine their development. Competition between the coastal havens and marinas should be taken into account.

Others

- The area around the Fibre Optic Gulf cable, on the sea bottom in the Arabian Gulf around Shuaiba Port, also brings along its restrictions for anchoring and fishing in this area. Anchoring and trawling are prohibited within 0.5 M of the cable.
- Restricted areas are also present around the naval and coastguard base along the south coast of Kuwait.
- Furthermore, the area around the ferry connection with Failaka is indicated as an area where no anchoring is allowed.

6.2.7 Conclusion appraisal coastal waster system

- Several restrictions limit the area available for yachting and fishing.

- The water depth in the Kuwait Bay and around the islands can be a limiting factor in developing coastal havens and interesting destinations.
- The islands are interesting destinations for yacht owners, but need to be provided with facilities in order to receive yachts.
- Various development projects are planned or under construction in Kuwait, which can result in a positive effect on the popularity of yachting. More destinations and capacity is created in this way.

6.3 Spread population and target user groups

6.3.1 Yachts

The existing marinas are clustered in the Kuwait Bay around the old city center (7 out of 11). The remainder is spread over a much larger coastal strip along Kuwait's south coast. To get an indication of the geographical spread of the facilities, the marinas and coastal havens are categorized by the governorate in which they are located. An overview of the governorates is provided in figure 5. To include the geographical spread of the target user groups, a population census from 2005 is used. This information also contains a distinction between the indigenous and non-Kuwaiti population per governorate. This makes an estimation of geographical spread of the yachting demand potential per governorate possible.

Based on the spread of the population and target user groups in table 15 it can be concluded that the waterfronts and marinas are mainly developed in the governorates of Hawalli, Al-Ahmadi and the capital Al-Kuwayt. Next to that is expected that the inhabitant of the governorate of Al-Farwaniya is also using these facilities, since this governorate is not bordering coastal water.

The governorates of Mubarak and Al-Jahra have a relatively large share of indigenous population, but no facilities are present along the coastline. A significant yachting demand potential is expected to be present in these governorates. This potential is able to stimulate the yachting industry development in these governorates and makes coastal haven development feasible.

The distribution of wealth of the population is not taken into account in this rough estimation of yachting demand potential per governorate. The proportionality of the indigenous and foreign population is used as a first indication for the feasibility of a marina function within a coastal haven.

		Kuwaitis [2005]	Non-Kuwaitis [2005]	Yachts	Berths
Al-Ahmadi	Marina/Coastal haven	183,831	210,030	609	555
Abu-Hilifa	Coastal haven				
Bneider	Coastal haven				
Kuwait Airlines Club	Marina			140	187
Al-Kout Marina	Marina			91	140
Khiran	Marina			378	228
Al-Farwaniya	*No coastline*	166,730	455,393		
Al-Jahra	-	97,669	174,704		
Kazma	Coastal haven				
Al Jahra	Coastal haven				
Al-Sabia	Coastal haven				
Capital (Al-Kuwayt)		137,508	123,505	495	519
Kuwait Marina	Marina			230	244
Souk Sharq	Marina			265	275
Watya	Coastal haven				
Souk Sharq	Dhow harbor				
Al-Kherafi	Coastal haven				
Bubiyan and Warbah	-	-	-		
Hawalli	-	157,069	330,445	988	909
Kuwait Sea Club	Marina			2	10
Al Bida Sea Club	Marina			9	45
Ras al Ardh	Marina			250	188
Al Sha'ab Sea Club	Marina			163	194
Marina Crescent	Marina			164	150
Al Syadeen	Coastal haven				
Yacht Club Marina	Marina			400	322
Mubarak		137,967	38,552		
Al Fontas	*Coastal haven*				
Total		**880,774**	**1,332,629**	**2091**	**1982**

table 15: Geographical spread population and target user group (PACI, 2005)

6.3.2 Fishing vessels

The current location and number of the fishing vessels is determined in the target user group analysis. The development forecast in Appendix J of this target user group resulted in the conclusion that the size of this target user group will not show large deviations in the future. The vessels are currently located at Doha Harbor, Dhow Harbor Souk Sharq, Al Syadeen, Al Fontas, Watya and Fahaheel.

The focus during the master plan development will be mainly on the location of the vessels than on the potential growth at specific locations of this target user group. Attracting vessels from other locations or a voluntary or a forced shift of vessels towards to another location is mentioned as an opportunity for certain locations to ensure a feasible fishing port function.

6.3.3 Other vessels

Barges and commercial fishing vessels are located in Doha Port, Doha Harbor and the Shuaiba Port. Ferries operate between Failaka Island and Ras al Ardh and Marina Crescent. The naval base is located in the south of Kuwait and the coastguard base is south of Al Fontas. Coastal havens around these locations or along the route of these vessels should take these vessels into account in the design in order be able to function as port of refuge.

6.4 Demand target user groups

In this section for each target user group an indication of their demand to the network of coastal havens is given.

The medium scenario is assumed to be the most likely development direction. The high and low scenarios give an indication of the bandwidth of the forecast. The design of the coastal havens is based on the medium scenario. Extension of the coastal haven is assumed to accommodate the extra users from the high scenario extension.

6.4.1 Yachting

Depending on the selected share of vessels that will be present in the coastal haven in 2030, the demand from the yachting industry is somewhere between 6,750 (medium scenario; 15.5% in marinas and coastal haven) and 13,500 yachts (high scenario; 20% in marinas and coastal havens). The number of yachts from the medium scenario is used as target number for the coastal haven master plan development.

Not known is if more marinas will be constructed within the next 20 years. Investments from the private sector in marina development can lead to capacity increase as well, this is not taken into account in the development of the master plan.

It can be concluded that there is a need for a large scale marina function within the coastal havens. If each of the 9 coastal haven are allocated with a capacity of 200 berths the coastal havens can accommodate a doubling of the number of berths in Kuwait. If we consider the required 6,750 berths in the medium scenario, an average capacity of 500 berths per coastal haven is required. The 2,000 already existing berths within the marinas are part of the 6,750 berths in Kuwait in 2030.

6.4.2 Fishing

The development of this target user group is characterized by the number of speedboats used for fishing. In the low scenario a decline to 465 speedboats and in the high scenario an increase towards 1,000 speedboats is expected. For the master plan the medium scenario is used, the values above indicate the bandwidth of the development. In the medium scenario 840 fishing speedboats are expected in 2030. The total demand from this target user group will in general consists of approximately 160 dhows, 90 commercial fishing vessels and the speedboats. For this target user group the quality and location of the facilities is more important than the increase of capacity.

6.4.3 Port of refuge

In certain coastal havens a facility for vessels that will use the coastal haven as port of refuge is required. The demand from this target user group is hard to determine in great detail. An additional facility in the functional layout is incorporated in the design for the coastal havens that are likely to receive vessels of this target user group. Especially coastal havens that are located close to the commercial ports or along the main sailing routes of this target user group need to supply this function.

6.5 Strengths and weaknesses locations

6.5.1 Introduction

In this section, strengths and weaknesses for all locations are listed. Strengths are described as those facets which are already there and will help making the project to a success. Weaknesses are qualities, which are a disadvantage for the planned development, but are possible to turn into strengths by the national authorities. In this way they can be and extra stimulant for starting the project.

The locations are treated in the same order as location description in 4.2. The division into the existing, assigned and additional locations is made again in this section. The information from the location description is also input for the SWOT analysis. After the strengths and weaknesses, the opportunities and threats are described in general for all locations in section 6.6, since most of them are applicable to all locations. If opportunities and threats are applicable to one location only it is mentioned in the SWOT of that location.

Prior to the SWOT analysis some aspects are treated, that are not part of the location description or the appraisal of the coastal waters. The required investments cost, maintenance and the local wave conditions are briefly discussed and taken into account in the SWOT analysis.

6.5.2 Additional aspects SWOT

<u>Investment cost</u>

This section deals with the main aspects determining the investment cost of a coastal haven. This is done in order to make a comparison on this aspect between the possible locations. The focus is on the objects that determine the majority of the investment costs and differ per location. The costs of the construction a breakwater and dredging an entrance channel are the object of interest.

Breakwater

A rough indication of the investment cost of a breakwater is done based on the approximated required length of the breakwaters. The surface areas of the coastal havens are comparable because they are all assumed to facilitate approximately 500 yachts. This criterion is thus of minor importance for the selection of the preferable locations.

The coastal havens need to have approximately 500 berths each. A rule of thumb in the design of marinas is that 70 up to 80 berths can be created on one hectare of water surface. The required surface area for 500 berths results in 62,500 up to 71,500 m^2. The fishing port function requires less surface area. Assumed we can use the same rule of thumb and 150 fishing speedboats are used, approximately 2 hectares are required. If we compare this with the existing marina basins in Kuwait:

- Failaka has a basin of 200 x 500 m (100,000 m^2) and a breakwater of 900 m.
- Fahaheel has a basin of 190 x 190 m (36,000 m^2) and a breakwater of 380 m.

For the coastal havens breakwaters of a total length of 900 up to 1,000 m will be required as well. For sites that have natural shelter less breakwater can be sufficient to provide enough protective berths. Besides the length, the water depth is an important factor if we want to estimate the construction cost of a breakwater. However all coastal haven are located on land with a comparable water depth. The characteristics are summarized in table 16.

Entrance channel

The length of the channel is different for each location, the width will be comparable. At some existing locations an entrance channel is already present. Other locations do not have any infrastructure yet and dredging a entrance channel is in those cases also part of the construction of the coastal haven. The characteristics for each location as summarized in table 16. The entrance channel length to be created is taken into account in the SWOT analysis.

<u>Maintenance</u>

Besides the costs for creating a coastal haven the yearly returning maintenance costs are important in order to determine if a location is suitable and feasible for coastal haven development. The maintenance of the entrance channel and breakwater are elaborated below. These elements of the coastal haven determine the major maintenance costs.

Other aspects, such as the landside facilities are not very different for the coastal haven locations and are therefore not taken into account in this analysis.

Maintenance dredging

Very little information is available on the coastal morphology in Kuwait. The direction of the littoral drift along the south coast of Kuwait can be defined by the prevailing wave direction. The waves are the driving force behind the littoral drift. The waves originate from southern and southeastern direction during the largest part of the year. Wave breaking in the surfzone of these waves induces the transport of sediment towards the north. This is supported by the fact that groyns along the coast show a northern directed littoral drift.

For the southern shore of the Kuwait Bay the littoral drift seems to be directed to the east. This is made up from the sand deposits behind the groins along the southern shore of the Kuwait Bay. The sand input in the Kuwait Bay is mainly originating from the river Khor Al Subiyah in the north and the desert. The wind from northwestern direction in combination with the desert sand turn the northwestern shore into another sediment source. The water in the Kuwait Bay has in general a high rate of suspended sediment. In the Kuwait Bay coastline the sediment transport direction is assumed to be counterclockwise along its shores.

The wave climate differs for the locations along the Arabian Gulf coast and the Kuwait Bay coast. Waves are in general higher for the locations along the Arabian Gulf and therefore the rate of sediment transport expected to be larger for those locations. Information on the indicative rate of sedimentation is part of table 16.

Maintenance breakwater

The maintenance of a breakwater is related to the investment cost, wave exposure, quality and size of the breakwater. Exposure to high waves can induce damage to the breakwater and could require more maintenance than less exposed location. The locations along the Arabian Gulf coast are assumed to need more maintenance than the coastal havens in the Kuwait Bay. A rule of thumb for the maintenance of a breakwater is 2 % of the initial investment cost per year and is in this way directly related to the dimensions of the required breakwater.

Existing locations				
Location	**Breakwater**	**Entrance channel**	**Investment cost**	**Sedimentation**
Al Syadeen	Existing but extension required	Existing, less than 2,000 meter	Average amount of investments cost	High sedimentation expected along the Arabian Gulf
Al Fontas	Existing but extension required	Existing, less than 2,000 meter	Average amount of investment cost	High sedimentation expected along the Arabian Gulf
Al Kherafi (National Assembly)	Existing but extension required	Less than 2,000 meter	Relatively little investment cost	Medium sedimentation expected along southern shore of the Kuwait Bay
Assigned locations				
Location	**Breakwater**	**Entrance channel**	**Investment cost**	**Sedimentation**
Watya	Existing but extension required	Less than 2,000 meter	Average amount of investments cost	Medium sedimentation expected along southern shore of the Kuwait Bay
Bneider	Nothing present	2,000 meter	More than average investment cost	High sedimentation expected along the Arabian Gulf
Abu-Hilifa	Nothing present	2,000 meter	More than average investment cost	High sedimentation expected along the Arabian Gulf
Al Jahra	Nothing present	4,000 meter	Relatively large investment cost	High sedimentation expected at the eastern end of the sediment rich Kuwait Bay
Al-Sabia	Nothing present	More than 4,000 meter	Relatively large investment cost	High sedimentation expected at the northern end of the Kuwait Bay (input from river, desert)
Kazma	Nothing present	2,000 meter	More than average investment cost	High sedimentation expected at the eastern end of the sediment rich Kuwait Bay

table 16: Overview location characteristics

Local wave conditions

The suitability for coastal haven development of a location is dependent on the local wave climate. Location with natural shelter are preferred above locations with severe wave action. The prevailing wind and wave direction in Kuwait are used to give a first indication of the expected local wave climate for each location. This in order to make a ranking of the locations possible.

The prevailing winds are from northwestern and southeastern direction (section 4.1.4.1 and 4.1.4.2). Storms are reported from southeastern direction. Al-Sabia is affected by the waves originating from the Arabian Gulf but not by wind waves generated by the northwestern wind.

For the coastal havens on the southern shore of the Kuwait Bay it is the other way around. Waves from the Arabian Gulf need to refract around the headlands and adapt their direction from SE to NW. Their effect with respect to downtime will be limited due to the wave height at the site. Energy dissipating refraction results in a large wave height reduction for the waves in the Kuwait Bay.

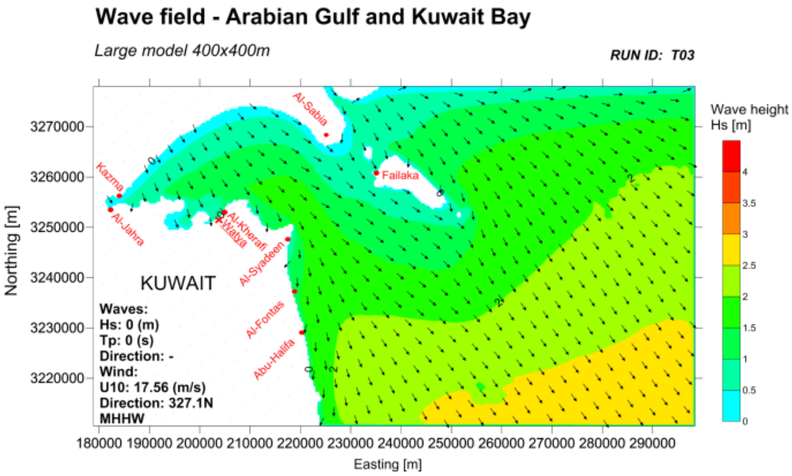


figure 69: Result wave height T03 (wind NNW)

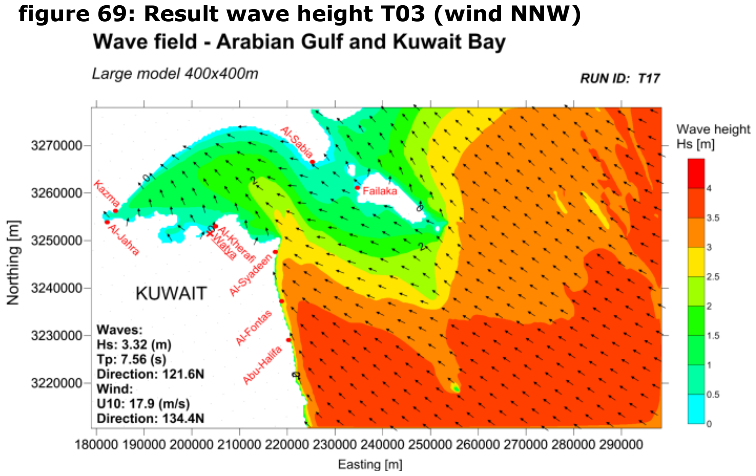


figure 70: Result wave height T17 (Wind & waves SSE)

The wind generated waves from northwestern direction have a fetch of approximately 20 kilometer over the Kuwait Bay and can affect the coastal haven of Watya and Al-Kherafi (National Assembly). Waves traveling towards these coastal havens have to cross the tidal wetlands north of Shuwaikh Port. These wetlands limit the wave height that is possible to reach the coastal havens. The relative importance of the two scenarios is tested during one of the runs with the hydraulic model Simulating WAves Nearshore (SWAN). More information about the hydraulic model can be found in section 9.1.3. The test runs concerning the effect of several interesting scenarios is further elaborated in Appendix M. The comparison between the scenarios wave from the southeast and wind from the northwest is done in more detail in appendix N.6.

The wave height plots in figure 69 and figure 70 show the results of these scenarios. From the output it can be concluded that the scenario with only wind from NW direction leads to the highest waves at the southern shore of the Kuwait Bay.

The locations further in the Kuwait Bay are even less affected by wave from the Arabian Gulf or local generated wind waves. Failaka and in smaller extent also Al-Sabia are located in the shelter of Failaka Island and experience also limited wave action.

The locations along the Arabian Gulf coastline are the most exposed and are therefore expected to have more requirements concerning the breakwaters that will have to provide the necessary shelter.

6.5.3 SWOT Existing locations

6.5.3.1 Al Syadeen

Strengths	Weaknesses
<u>General</u> • Close to Kuwait City • Connected to the landside infrastructure by Fifth Ring Road • Open sea is easily accessible • Well protected against waves by breakwaters • Located close along Arabian Gulf coast and close to Kuwait Bay <u>Fishing</u> • Reasonably developed fishing port function <u>Yachting</u> • Al Bida Sea Club present south of fishing community • Failaka, Kuwait Bay and several islands within sailable distance	<u>General</u> • Located south of area with restrictions • Limited space available for extension <u>Yachting</u> • Competition with Kuwait Marina (2M) and marinas in Kuwait Bay on marina function • Basin Al Bida Sea Club is relatively small and narrow to develop the marina function properly • Fishing port is located upwind of Al Bida Sea Club

6.5.3.2 Al Fontas

Strengths	Weaknesses
<u>General</u> • Connected to landside infrastructure, by Fahaheel Expressway • Located along coastal water that is free of restrictions • Easily connected to open sea • Space available on breakwaters • Large inner basin, not used at the moment • Well protected against wave by breakwaters <u>Fishing</u> • Reasonably developed fishing port function <u>Yachting</u> • Stepping stone between southern marinas, Al Syadeen and marinas in the Kuwait Bay.	<u>General</u> • Competition with Abu Halifa (2M), Fahaheel (6.5M) and Kuwait Airlines Club (5.5M) • 30 km south of Kuwait City <u>Yachting</u> • Limited number of offshore destinations the nearest is Failaka Island (17M) • No marina function developed

6.5.3.3 Al Kherafi (National Assembly)

Strengths	Weaknesses
<u>General</u> • Recently modernized breakwater and quay present • Sheltered from waves by breakwater and shallow Kuwait Bay • Close to commercial area Kuwait City • Located along Arabian Gulf Street • Less investments required • Attractive waterfront <u>Fishing</u> • Close to fish traps • Close to fish markets Souk Sharq and National Assembly. <u>Yachting</u> • Only one marina in this part of the Kuwait Bay (Souk Sharq Marina) • Centrally located in the Kuwait Bay, Al-Sabia (15M) and Kazma (12M)	<u>General</u> • Limited space in basin • Located near Shuwaikh Port channel • Limited expansion possibilities • No facilities present • Located in shallow part of the Kuwait Bay • Only in use as landing place for fishing vessels, not for berthing vessels • Competition with Watya (0.8M) and Dhow Harbor Souk Sharq (1M) for the fishing fleet and Souk Sharq Marina (1.5M) for the yachting industry

6.5.4 SWOT Assigned locations

Of the assigned locations is only in Watya some existing infrastructure present. The new locations have fewer restrictions than the existing ones, but require higher investments.

6.5.4.1 Watya

Strengths	Weaknesses
<u>General</u> • Maritime infrastructure present (slipway and a breakwater) • Easily connected to the landside infrastructure via the the Arabian Gulf Street and First Ring Road. • Centrally located in the Kuwait Bay, Kazma (11M) and Al-Sabia (15M) • Space available for expansion <u>Fishing</u> • Close to fish market of National Assembly and Souk Sharq Mall • Fish traps in its vicinity	<u>General</u> • Located near Shuwaikh Port channel • Located in shallow part of coastal water • Competition with Al Kherafi (National Assembly) (0.8M) and Dhow Harbor Souk Sharq (1.8M) <u>Yachting</u> • No interesting waterfront, compared to other locations near Kuwait City. • Watya is at the western end of the City centre.

6.5.4.2 Bneider

Strengths	Weaknesses
General • Connected to the landside infrastructure by King Fahed Ben Abdul Aziz Road • Easily connected to open sea • Smaller tidal range than northward located coastal havens Yachting • Stepping stone between Khiran and Fahaheel and marinas more northward.	General • No maritime infrastructure present at the moment • Naval base with its restrictions in the vicinity • Large sailing distance to other locations (16M) • No interesting waterfront development present • Investments required • Oil industry port Shuaiba act as barrier between Khiran and Bneider and the northward located marinas and coastal havens. • Competition with Khiran (16M) Yachting • Remote location, not a lot of destinations from here, Khiran (16M) • No target user group present along coastline at this location Fishing • No fishing industry present

6.5.4.3 Abu-Hilifa

Strengths	Weaknesses
General • Easily connected to the landside infrastructure • Easy accessible from the seaside as well	General • No target user groups present at this location • Competition with Al Fontas (2M), Kuwait Airlines Club (3.5M) and Fahaheel (4.5M) • No maritime infrastructure present • Close to oil industry in Mina al Ahmadi, and therefore a lot of commercial vessels in the surrounding area Yachting • No interesting offshore destinations within 20M present. (Kubbar Island is in between shipping lanes, not a good destination)

6.5.4.4 Al Jahra

Strengths	Weaknesses
General • Space available to develop a coastal haven on coastal strip of approximately 1.5 km wide. • Wave heights are expected to be low in the Kuwait Bay due to limited water depth • Small tidal current in Kuwait Bay (0.5 kn) • There are no coastal havens or marinas present this far into the Kuwait Bay at the moment, less competition. • Easy connection to Kuwait City (30km) and Iraq Fishing • Close to fishing grounds and fish farms in Kuwait Bay	General • No maritime infrastructure present • Large investments required for developing entrance channel to make coastal haven accessible in shallow area • Numerous outfalls along coastline • 2M to reach deeper water in Kuwait Bay • Competition with Kazma (3M) • Sedimentation of entrance channels Fishing • No fishing vessels present Yachting • Besides Kuwait City and possibly Kazma no other interesting destinations located in its vicinity.

6.5.4.5 Al-Sabia

For this location also the opportunities and threats are mentioned because there is a lot of uncertainty around the development this location.

Strengths	Weaknesses
General • Location where Arabian Gulf, Kuwait Bay and the and river Khor as Subiyah come together • Located along main route from Kuwait to Iraq (export) • Small tidal current in Kuwait Bay (0.5 kn) Fishing • Close to fishing grounds in Kuwait Bay Yachting • Diverse sailing area (open sea, bay, river) • Close to Failaka Island (8.5M), Miskan and Auhah and marinas in Kuwait City (11M) • Close to nature of Bubiyan Island	General • No maritime infrastructure present yet • Large investments required • The need for a long entrance channel to keep the coastal haven accessible under all tidal conditions. • Not a lot of buildings in its vicinity, except upstream the Khor as Subiyah • Close to the former mined area in the northern part of the Arabian Gulf near Iraq and Iran. • Close to power station • No interesting waterfront present • Water quality due to river outflow Fishing • No fish markets near, totally dependent on local markets and export.
Opportunities	**Threats**
• Attract fishermen from along the river Khor as Subiyah • Increasing yachting potential due to development project City of Silk on the area around Ras as Subiyah and Bubiyan. • Connection to Kuwait in the future via Causeway straight to the south	• Close to politically unstable countries Iraq and Iran. • Environmental constraints for development project City of Silk

6.5.4.6 Kazma

Strengths	Weaknesses
<u>General</u> • Natural shelter provided by outcrop • Breakwater structure present • Less investments required • Located along road from Al-Jahra to Iraq. • Low wave heights the Kuwait Bay due to limited water depth • Distance to deeper water (1M) • Small tidal current in Kuwait Bay (0.5 kn) • There are no coastal havens or marinas present this far into the Kuwait Bay at the moment <u>Fishing</u> • Close to fishing grounds and fish farms in Kuwait Bay <u>Yachting</u> • Sailing in a straight line towards Kuwait City possible.	• The need for long breakwaters to keep the coastal haven accessible under all tidal conditions. • Not a lot of buildings in its vicinity • Besides Kuwait City not a lot of sailing destinations from here. • Distance to open sea • Large investments required

6.5.5 SWOT Additional locations

6.5.5.1 Failaka

Strengths	Weaknesses
<u>General</u> • Already breakwaters present • Ferry connection to island • Development plan for tourism industry • Centrally located between Al-Sabia (8.5M) and Ras al Ardh (11M) • Close to open sea <u>Fishing</u> • Close to fishing grounds in Kuwait Bay <u>Yachting</u> • Interesting destination for yachting industry in the future	<u>General</u> • Outflow of Khor al Subiyah • Shoals around the island, only western end accessible under all tidal conditions • Restricted area to the south due to pipelines and ferry <u>Fishing</u> • Target user group not present • No fish market <u>Yachting</u> • Currently no interesting waterfront
Opportunities	**Threats**
• Development of Failaka Island as tourism destination	

6.5.5.2 Khiran

Strengths	Weaknesses
<u>General</u> • Already breakwater/entrance channel present • Natural shelter within tidal creeks • Waterfront under development • Open sea easily accessible <u>Fishing</u> • Offshore fishing locations easily reachable <u>Yachting</u> • Interesting destination for yachting industry in the future • Potential target user group from development plan	<u>General</u> • Remote location • Restricted area to the south due to pipelines and ferry <u>Fishing</u> • Target user group not present • No fish market <u>Yachting</u> • Not a lot of sailing destinations

6.6 Opportunities and threats network

Opportunities and threats are not changeable by the power of authorities and will have a negative influence on the master plan implementation. The opportunities and threats are treated in general and are applicable for the entire network in most cases.

Besides the general opportunities and threats for the network of coastal havens, such as the demand from the target user groups and the restrictions and limitations mentioned in section 6.2.6 and 6.3 respectively, the following aspect are mentioned.

6.6.1 Opportunities

- The majority of the assigned locations, 5 out of 6, are totally new locations where nothing is present. These are green field projects and have fewer restrictions than the existing and additional locations. The assigned locations can be designed and developed in the way the authority wants and their success is less hampered by constraints from its surroundings. Higher initial investments are required however.

6.6.2 Threats

- The water depth in combination with the tidal range in the Kuwait Bay must be mentioned as main threat for the success of the coastal haven in the Kuwait Bay. The averaged depth and especially the depth at the western end are such that this will determine the design and costs of the development of Kazma, Al-Sabia, and Al-Jahra.
- The assigned locations have no interesting waterfronts at the moment. Their waterfronts are underdeveloped and need to be developed in order to provide yacht owners in particular with interesting destinations to visit. The same holds for the islands. Basic facilities are needed on the majority of the islands to attract yacht

owners. The popularity of yachting and its development depend on these aspects. This cannot be changed by the government, but investments from the private sector are also required to increase the popularity of yachting.

6.7 Result SWOT analysis

The location description (4.2), coastal water appraisal, information on investment and maintenance costs, an indication of the local wave condition and the listing of the strengths and weaknesses (6.5) result in several interesting aspects and considerations. A comparative assessment is made on certain aspects between the locations. The results are summarized in table 17. Based on this summary the development direction for the sites is determined.

After the summary of the SWOT analysis some remarks and comparisons between locations are mentioned as argumentation for choices made. The existing and assigned locations are treated separately. Besides this separation, a separation is made between the coastal havens along the Kuwait Bay coast and the Arabian Gulf coast, since the natural boundary conditions along these two parts of the Kuwaiti coastline differ considerably.

Locations / **Criteria**	Landside infrastructure	Access to open sea	Restrictions and limitations		Target user group fishing vessels	Fishing grounds and markets		Yachting demand potential	Sailing destinations	Waterfront attractiveness		Competition	Local wave conditions	Sedimentation		Investment cost	Natural shelter	Breakwaters	Current state facilities	Expansion possibilities
Al Syadeen	++	+	-		++	+		+	++	+		-	-	+		++	-	+	+	-
Al Fontas	+	+	+		++	+		+	+	+		-	-	+		+	-	+	+	-
Al Kherafi	+	o	-		+	+		+	+	++		-	o	-		+	+	+	+	-
Watya	++	o	-		+	+		+	+	+		-	o	-		o	+	-	-	+
Bneider	+	++	-		-	++		+	+	-		+	-	+		-	--	o	o	+
Abu-Hilifa	++	++	--		-	-		+	-	+		-	-	+		-	-	o	o	+
Al-Jahra	+	--	--		-	+		++	--	-		+	o	--		--	+	-	o	++
Al-Sabia	-	o	-		+	o		++	+	--		+	o	-		-	+	-	o	++
Kazma	-	--	-		+	++		-	o	--		+	+	-		-	++	+	o	++
Failaka	-	+	-		--	-		+	++	0		+	+	+		+	-	+	-	+
Khiran	+	+	-		-	-		+	+	+		+	+	+		+	++	o	+	+

table 17: Summary SWOT analysis

The scores in table 17 are translated to a total score, a score for the yachting and fishing aspect for each location. By adding all the marks for each coastal haven location a final decision can be made. The criteria that are assumed to give a representation of the location suitability for yachting and fishing are combined separately. This is done in order to make the allocation of these functions over the locations possible. The development directions are listed in table 19.

The score "++" is weighted with 2 point, "+" with 1 point, "o" with 0 point, "-" with -1 point and "--" with -2 points. This weighing and summation results in the scores in table 18.

Locations	Total		Fishing		Yachting		Port of Refuge
Al Syadeen	10		3		4		Yes
Al Fontas	9		3		3		Yes
Al Kherafi	7		2		4		No
Watya	4		2		3		No
Bneider	3		1		1		Yes
Abu-Hilifa	-1		-3		1		Yes
Al-Jahra	-5		0		-1		No
Al-Sabia	1		1		1		Yes
Kazma	1		3		-3		No
Failaka	3		-3		3		Yes
Khiran	10		-2		3		Yes

table 18: Results SWOT

Conclusions

- In general it can be said that the existing coastal havens score best. This can be explained by their current state and the need for smaller investments.
- 5 out of the 7 remaining locations score positive in this analysis.
- Al-Jahra has a large negative score and Abu-Hilifa has a small negative score.
- All existing coastal haven are advised to develop a marina and fishing port function within the coastal haven.
- All coastal haven locations that will be developed should have a marina function in order to live up to the demand, although this is not concluded from the results in table 18. Kazma and Al-Jahra score both negative on the for yachting interesting aspects.
- For the assigned locations Watya, Al-Sabia and Kazma are advised to be developed with a marina and fishing port function, Bneider and Abu-Hilifa only with a marina function.
- The additional locations Failaka and Khiran are advised to be developed with a marina function.

- From the results it is advised that the coastal haven of Al-Jahra should not be developed. This location is located in the vicinity of another assigned location Kazma, which has a better score in this evaluation is selected to be developed within the master plan. A detailed consideration and motivation is presented in the next section.
- The additional locations of Failaka and Khiran show both a positive score in this analysis. Khiran's score especially since the current state of that location is comparable to the existing coastal haven in Kuwait. This location has the most natural shelter of all locations (tidal creeks) and is very interesting for a marina function. Failaka has also a very large potential since the infrastructure is already present, but is not abandoned since the Iraqi invasion. This location is interesting keeping the master plan for the entire island in mind.

6.8 Discussion results SWOT analysis

The folding out map (figure 101) in Appendix B can be used to get an indication of the location described below.

Locations along Kuwait Bay coastline

Consideration Kazma - Al-Jahra

A selection of one of these two locations seems evident if we look at the results of the SWOT in the previous section. Of these two, Kazma can best be developed as coastal haven with the fishing port function as main function. When designing the coastal haven of Kazma, the yachting section demand potential from the city Al-Jahra must be taken into account. The coastal strip of Al-Jahra contains a lot of outfalls of domestic sewerage and other waste water from the town of Al-Jahra and Kuwait. Furthermore, the inter-tidal wetlands make it even more difficult to reach than Kazma.

The coastline of Al-Jahra is not selected to develop a coastal haven. Kazma is suggested to facilitate the fishing industry and the yachting demand potential from Al-Jahra. The willingness to use the marina function in Kazma will be determining the feasibility of the marina function in Kazma. The marina function of this location will have a target user group and the total investments will be less than the situation in which both location are developed.

Al-Sabia

Development of a coastal haven that has all functions seems necessary at this location if we look at the opportunities and development plans for this location. At the moment the yachting demand potential is very small at this remote location, but the development plan for the City of Silk (Madinat Al Hareer) can change this. Fishermen living upstream the Khor al Subiyah are expected to use the fishing port function in time.

The marina function might be a facility for passer-by users in the beginning, but if the City of Silk (Madinat Al Hareer) becomes reality it an become a homeport of yacht owners. With its central location between the Kuwait Bay, the Arabian Gulf and the Khor al Subiyah and Failaka Island within reach it is expected that this coastal haven has a large potential in the future. The port of refuge function is also required for this location.

Watya

This coastal haven can be best developed for yachting and small fishing vessels. The main target user group is the current number of vessels together with the small speedboats used for fishing now present in the Dhow Harbor near Souk Sharq and the boat owners from the city centre of Kuwait City and the Wattiyah district. The facilities at Watya must improve in order to guarantee that the shift of the fishing vessels to Watya will become a success. The coastal haven does not need to have a port of refuge function since it is located close to the commercial port of Shuwaikh.

Al Kherafi (National Assembly)

For this location is decided to focus on the marina function. This location has an interesting waterfront consisting of the National Assembly and National Museum. Limited space is available at this location. A combination of functions does not seem feasible. By facilitating this location with all marina facilities, a coastal haven at an exclusive and exceptional position can be realized. The coastal haven does not need to have a port of refuge function since it is located close to the commercial port of Shuwaikh.

Along Arabian Gulf coast

Al Syadeen

Further development of this location is advised. Modernized and additional facilities for the fishing industry and a more infrastructure like piers and moorings must be realized in order to compete with the marinas. Al Syadeen can benefit from the yachting demand potential present in Kuwait City in the northern part Arabian Gulf coast of Kuwait. The breakwaters of this location are of good quality and further development of a full service coastal haven is the next step.

Al Fontas

Further development of the fishing port function by increasing facility qualities around the coastal haven is required. The available space on the breakwaters can be used for this purpose. Dependent on the geographical spread of the yachting demand potential on the hinterland of Al Fontas a marina function can be developed as well. Preferably located north of the fishing port since the prevailing winds come from northwestern direction and the coastguard base is located directly south of the existing coastal haven.

Abu-Hilifa

Only a marina function would be feasible at this location. The target user group fishing vessels is not present at this location. The yachting demand potential present in the governorate should become the main target user group. If not enough potential is present on the hinterland of this coastal haven, only the marina function of Al Fontas might be feasible.

If a full service coastal haven is developed at this location, it would lead to the situation that there are three full service coastal havens within 6.5 nautical mile distance. It must be mentioned however than the North Pier of Shuwaikh port acts as physical barrier between Fahaheel and Kuwait Marina south and Al Fontas and Abu Hilifa north of the pier.

Bneider

If we look at the strengths and weaknesses, there are more weaknesses than strengths mentioned for this location. However, in order to make the marina of Khiran part of the network of marinas, the development of a coastal haven with a marina function in Bneider is necessary. In this way the distance of 30 nautical miles between Khiran and Fahaheel is split up in two trips of approximately 15 nautical miles. The coastal haven will be a sort of stepping stone between the two locations.

The target user group fishing vessels is also not present at this location. The naval base is within 5 nautical miles from Bneider, so the port of refuge function should be a part of the design.

Additional locations

Failaka

This coastal haven can at first best be equipped with a only a passer-by marina function, since no target user groups are present here. If the island is turned into a destination for tourists it can for instance start as marina for yacht chartering. Its location at the eastern end of the Kuwait Bay and centrally between Ras Al Ardh and Al-Sabia, make it a suitable destination for day tours from the marinas in Kuwait City.

Khiran

From this location to the border with Saudi Arabia a lot of buildings along the shorelines are present. Development of coastal haven with a fishing port and port of refuge function could be possible on the other side of the tidal creek. Since this section is 500 meter removed from the marina, certain facilities can be used by all target user groups at one location. The port of refuge function at this sheltered location is recommended if the entrance of the tidal creek allows it and not a lot of additional measures need to be taken.

6.9 Conclusions master plan

6.9.1 Allocation function

Based on the consideration above the following sites are selected and the functions according table 19 are advised to develop at the locations.

Existing locations		
Location	**Function**	**Target user group**
Al Syadeen	Marina/fishing port/port of refuge	Yachts and fishing vessels <15 m
Al Fontas	Marina/fishing port/port of refuge	Yachts and fishing vessels <15 m
Al Kherafi	Marina	Yachts *(exclusive)*
Assigned locations		
Watya	Marina and fishing port	Yachts and small speedboats used for fishing
Bneider	Marina/*port of refuge*	Yachts and *naval vessels*
Abu-Hilifa	Marina/*port of refuge*	Yachts and *commercial fishing vessels*
Al Jahra	None, do not develop	-
Al-Sabia	Marina/fishing port/port of refuge	All
Kazma	Marina and fishing port	Yachts and fishing vessels
Additional locations		
Failaka	Marina function	Yachts (passer-by) / tourism industry
Khiran (Pearl City)	Marina function	Yachts and fishing vessels

table 19: Location selection and allocation of functions

6.9.2 Allocation berths

The demand of 6.750 berths in 2030 is allocated to the coastal havens in table 20. To facilitate the increase all coastal haven locations that are assigned to develop a marina function will have to accommodate 500 yachts or more in order to facilitate the expected number of yachts.

	Fishing		**Yachting**
	Dhows	**Speedboats**	
Al Syadeen		190	700
Al Fontas		200	700
Al Kherafi (National Assembly)			350
Watya		260	600
Bneider		65	500
Abu-Hilifa			600
~~Al Jahra~~	—	-	-

Al-Sabia*			500
Kazma*	40	15	200
Failaka*	-	-	600
Dhow Harbor Souk Sharq	110		0
Fahaheel	10	125	(in marinas)
Marinas			2000
Total	**160**	**840**	**6750**

table 20: Capacity per location

At Al-Kherafi (National Assembly) the space is limited and this location is therefore expected to facilitate less yachts. The development of the coastal haven of Al-Sabia, Failaka and Kazma must be done in the same pace of the developments around these locations. These locations are indicated with a "*" in table 20.

6.9.3 Conclusions

- The existing coastal haven locations need to be modernized.
- Of the assigned locations all locations need to be developed except Al-Jahra.
- Of the additional locations Failaka and Khiran should develop en enhance the marina function.
- Of the coastal haven locations all locations should be equipped with a marina function in order to live up to the potential yachting demand.
- Not all coastal havens need a port of refuge function.

Phase 2: Generalized functional layout

Approach phase two

The first chapter of this phase describes the definition of the generalized layout of the coastal haven. The generalized layout is based on the theoretical background on the functioning of a coastal haven, which can be found in Appendix K. There, the main processes, functions and facilities are described in detail.

Chapter 7 starts with the advantages of combining several functions in one coastal haven (7.2) and a representation of the main functions (7.3). The functions for each target user group (7.4), a function interaction matrix (7.5) and the facilities related to these functions (7.6) are also presented in this chapter. These two concepts make the translation to the generalized functional layout of a coastal haven possible. Based the routing of vessels in a coastal haven (7.6) and the earlier determined capacity (7.8) the spatial claim of the facilities is determined in section 7.9. The final product of this chapter is the generalized layout in section 7.10.

The generalized functional layout is translated in a functional layout of the coastal haven of Al Syadeen. For the layout of Al Syadeen, all objects are dimensioned based on the situation of Al Syadeen, determined in the design requirements and criteria (section 8.2 and Appendix L). These design requirements are incorporated in the layout alternatives created in section 8.3.

The alternatives are evaluated with a combination of a hydraulic modeling study and a multi criteria evaluation in chapter 9. Final product of this phase are drawings of the layout of the coastal haven of Al Syadeen in chapter 10.

The entire structure of the report is again represented in figure 71 on the next page.

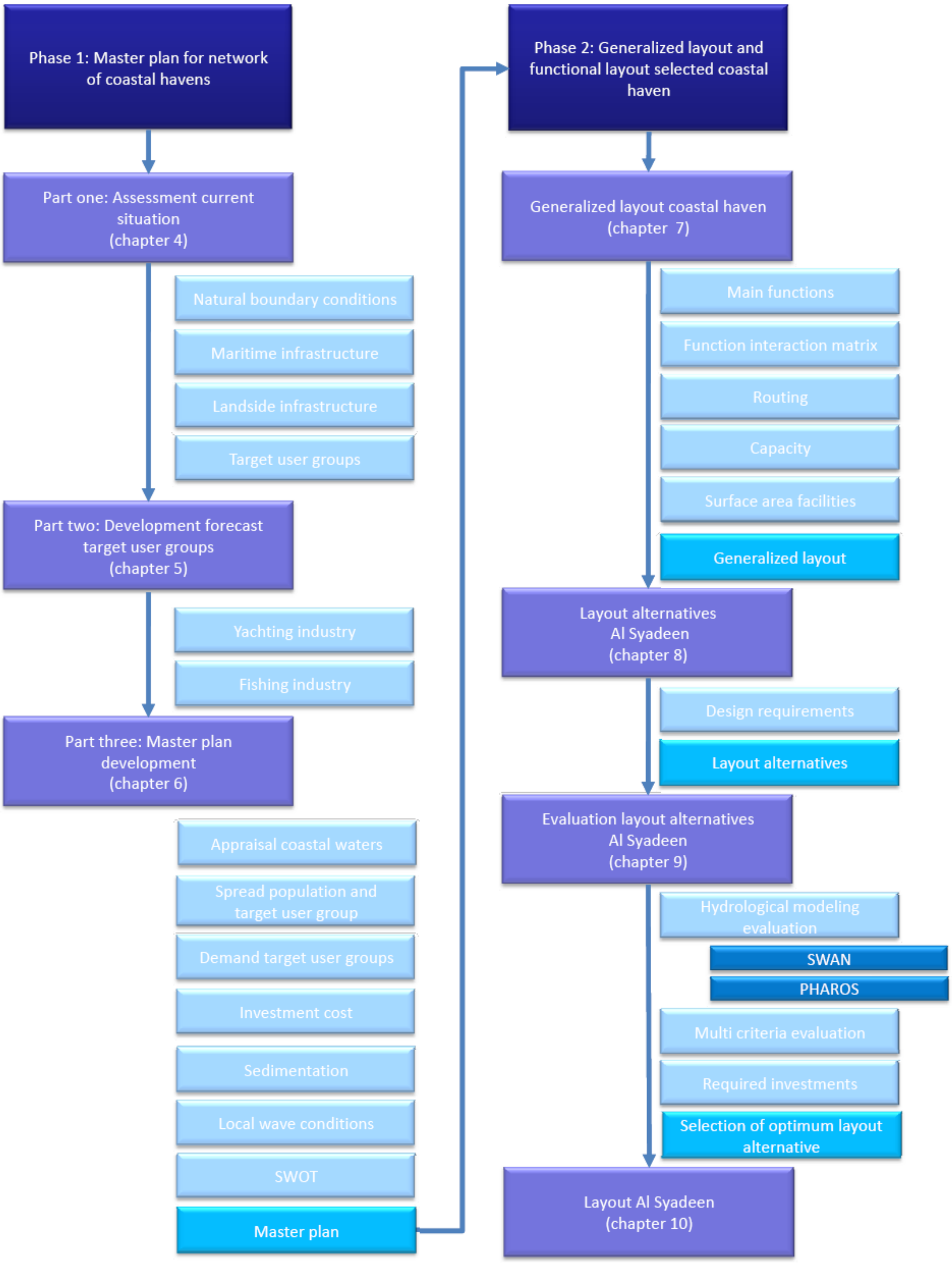


figure 71: Structure research project

7 Generalized functional layout coastal haven

7.1 Introduction

Since most marinas in Kuwait are owned by commercial companies and organizations and meant for yachts, they may not want to adapt their infrastructure and facilities to receive fishing and other types of vessels. Furthermore, since they already run low on capacity, adapting for the fishing industry is not necessary for the marinas. To overcome the capacity problem and to create more facilities for leisure crafts and fishing vessels, the government introduced a specific type of harbor: the coastal haven.

A coastal haven has to be able to facilitate leisure crafts and yachts, as well as private and commercial fishing ships, with the required facilities. The haven can additionally function as port of refuge for passenger transport vessels and vessels from public authorities. The coastal havens will be financed by the government and managed by Kuwait Port Authority (KPA), which is a governmental organization.

In the generalized functional layout, the orientation of the facilities is determined based on the routing of the different target user groups through the coastal haven. An indication of the shape and the required surface area for the facilities can be establishing at this stage of the design.

For a location specific layout the boundary conditions at that site need to be taken into account. Next to that, the distribution of the target user groups over the locations has its effect on the layout of the coastal haven. If and how the locations need to be developed is of importance in this step.

7.2 Advantages of combining functions in a coastal haven

By investing in this type of infrastructure, the fishery sector is supported by facilities which are lacking at the moment. By combining facilities for yachting and fishing vessels in a coastal haven, more people can benefit from the offered facilities and services at a location. A larger group of users also means that more facilities become feasible within a coastal haven. This is beneficial for the users, for whom a full-service coastal haven is at their disposal.

Benefits and added value are also generated by activities inside the coastal haven. Activity in and around a coastal haven attracts more economic activities. The coastal haven can become a interesting place for the establishment of new shops and restaurants. Combining several functions at the same place makes it a pleasant place to spend your time. People from the land side and sea side will be attracted by the sights, shops, restaurants and activities in the coastal haven and will contribute to the value of the waterfront of the district.

Constructing the coastal havens has another effect, which will affect even a larger group. The development of the havens will provide yacht owners with berths at lower fees, because the havens are publicly funded. This has an influence on the fees in the whole of Kuwait. Another effect for all yacht owners is the fact that the development of the coastal havens will result in yachting destinations at interesting waterfronts along the entire Kuwaiti coastline.

7.3 Main functions

Below, the main functions of a coastal haven are listed in order to make a comprehensive generalized functional layout. A spatial representation of the main functions gives a first indication of the spatial outlook of the coastal haven.

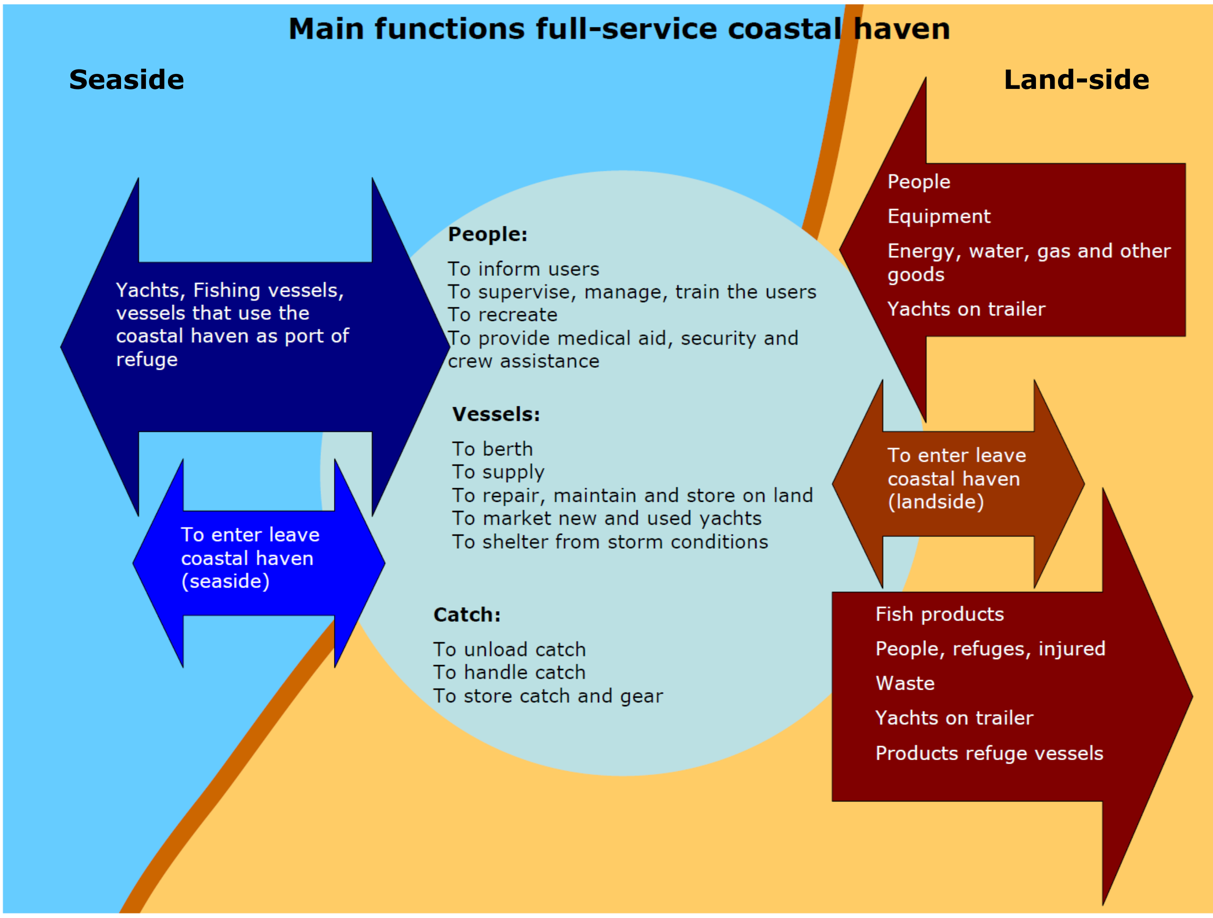


figure 72: Overview main functions coastal haven

Facilities are linked to the main functions of the coastal haven. In figure 72, these main functions are spatially positioned in and around the coastal haven. From this information we can proceed towards the routing of yachts, fishing vessels and vessels that take refuge in the coastal haven.

7.4 Functions per target user group

To provide the processes and functions above with the required infrastructure, a translation into facilities is made for all functions and processes above. As mentioned earlier, the functions that a coastal haven will have to fulfill in the network are the base of the facilities that need to be placed in a coastal haven. The facilities that need to be incorporated in the functional layout are depending on the geographical spread of the target groups and allocation of functions in the master plan.

It can be concluded that a coastal haven is built up out of several aspects derived from the three main functions of a coastal haven. The three main functions are to provide services that can be expected from a marina, fishing port and port of refuge. These functions are interrelated if all target groups are present in a coastal haven and the coastal haven is to be developed as a full-service coastal haven.

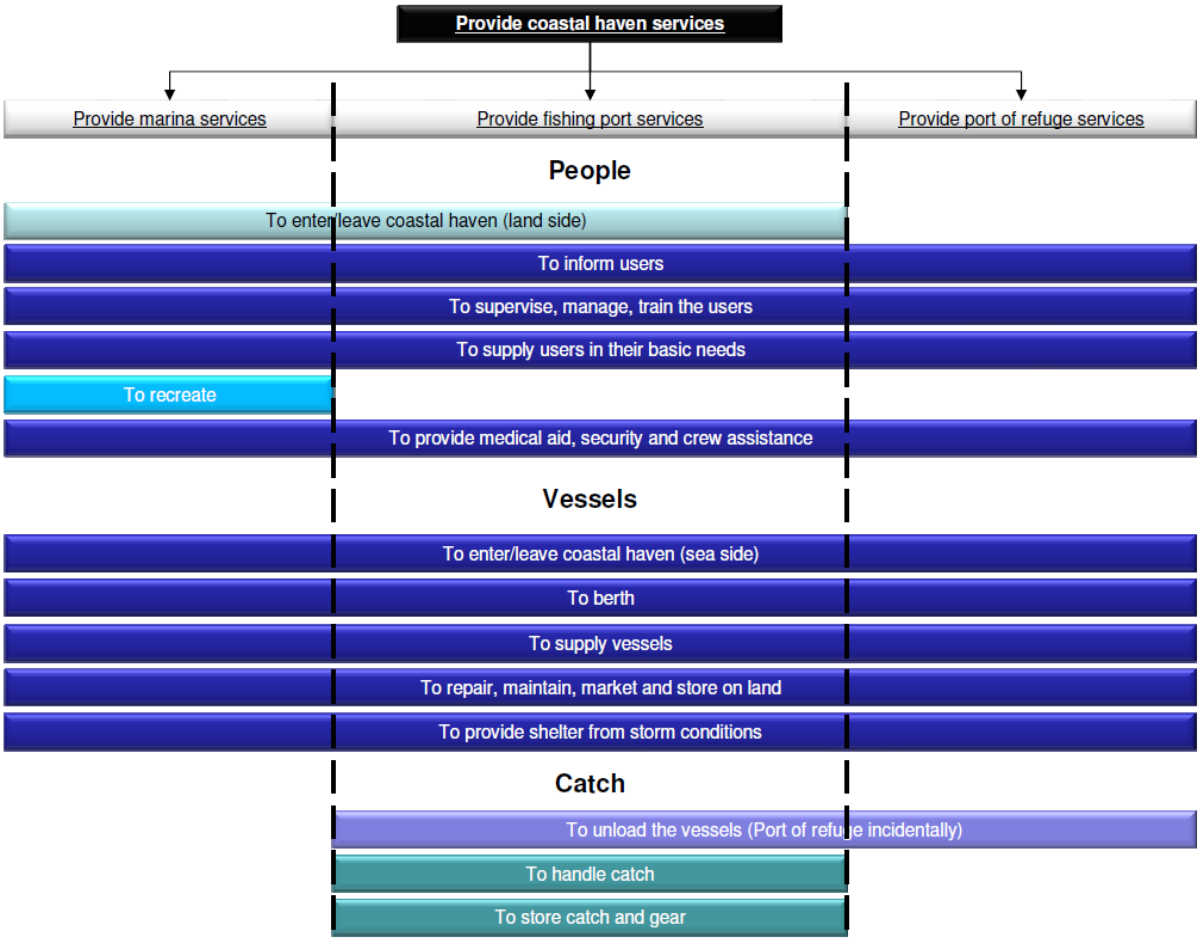


figure 73: Main function analysis coastal haven

7.5 Function interaction matrix

The main functions are now listed in a matrix and the degree of interaction is indicated by a mark. Two points are rewarded if a strong relation between the two functions is applicable, 1 point is rewarded if a relation is present but it is not as strong as in the previous case and no points are given if no relation is present or the functions must be kept separate. The results are shown in the matrix in table 21.

In general, the functions related to the handling of the catch and the gear of the fishing vessels are separate functions bound to the fishing vessels. The entering and leaving, refueling and maintaining of the vessels and protecting them against storm conditions is a function that can be combined for the three groups.

Mooring of the vessels needs to be done separately with moorings adapted to the various vessel and yacht sizes in the target user groups. Separation of moorings is also needed because of the difference between the users of the yachts and the fishermen. Yacht owners and fishermen have a different background, are present in a coastal haven for different reasons and therefore have different needs.

A third reason for the separation of moorings are the waves that are induced by ships sailing in the coastal haven. The allowable wave height at the berths of yacht is 30 centimeters or less. Larger fishing vessels induce ship waves that can make staying on a yacht at a berth unpleasant. Separation of berths and additional measures are therefore advisable.

The supply of basic needs and information can partly be combined, but yacht owners demand higher standards and have other preferences, so these functions will have to be partly separated as well.

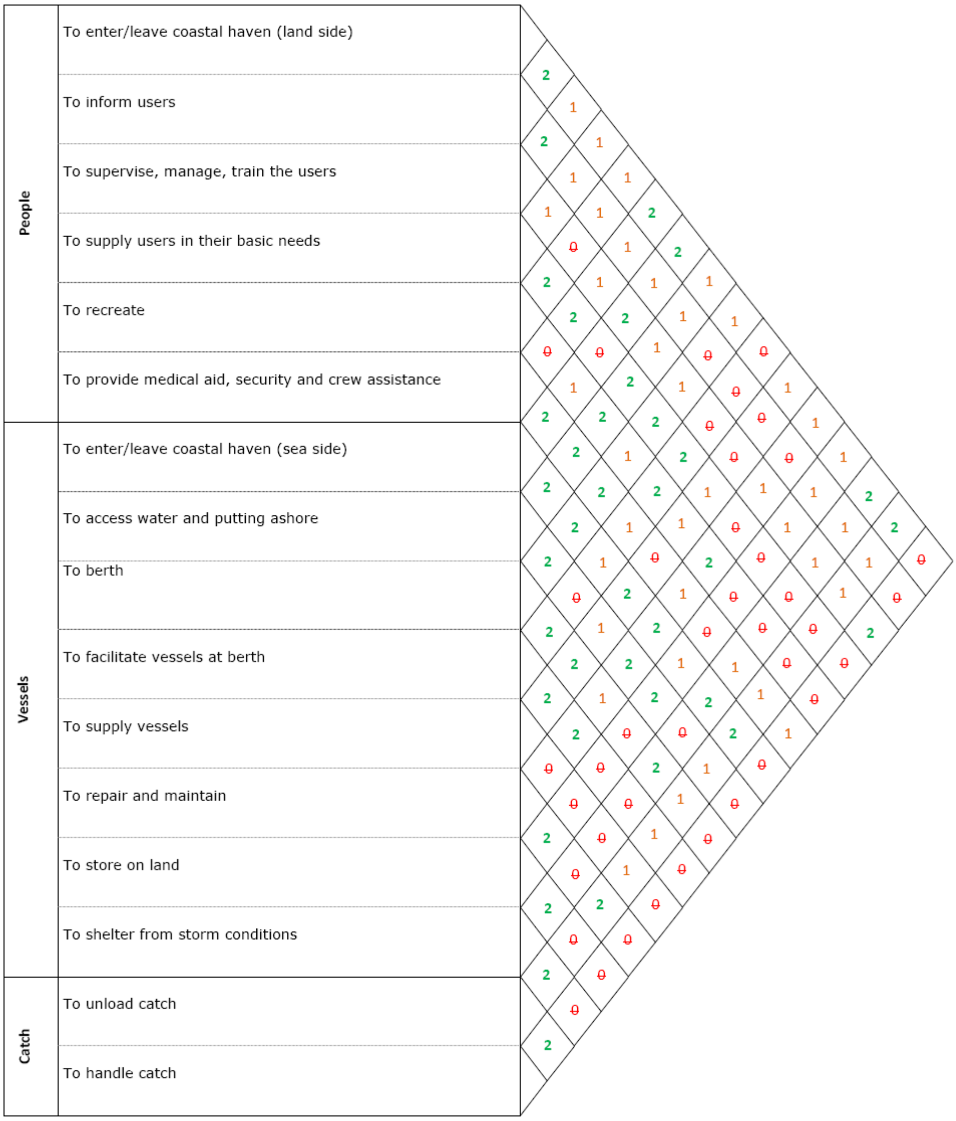


table 21: Function interaction matrix

7.6 Facilities per target user group

All possible facilities are gathered in table 26. In this table the facilities are linked to the main functions and to the target user groups. The table is added at the end of this chapter together with the generalized functional layout.

7.7 Routing target user groups

The routing of vessels and yachts is essential in the generalized functional layout of the coastal havens. The vessels and yachts enter the coastal haven and address facilities in a certain order. Fishing vessels have a different routing and require different facilities as is shown in the previous paragraphs. The people that enter the coastal haven from the landside and the vessels that enter from the seaside have been split up, since they run trough different routes. This also applies to the catch of the fishing vessels.

7.7.1 Marina section

<table>
<tr>
<td><u>Yachts</u>
• Entering
• Accessing water
• Putting ashore
• Berthing
• Facilitating moored yachts
  ○ Electricity
  ○ Water
  ○ Cooking gas
• Refueling
• Pumping out waste water
• Repairing
• Maintaining
• Watching
• Supervising
• Storing on land</td>
<td><u>People</u>
• Arriving
• Parking
• Informing
• Recreating
• Facilitating
  ○ Visitors
  ○ Residents
• Leaving</td>
</tr>
</table>

table 22: Routing marina

7.7.2 Fishing port section

<table>
<tr>
<td><u>Fishing vessels and gear</u>
• Entering
• Berthing
• Unloading catches
• Cleaning
• Repairing and maintaining
  ○ Vessels
  ○ Nets
  ○ Other fishing gear
• Fuelling
• Supplying
• Mooring
• Storing
  ○ Vessels
  ○ Spare parts ships
  ○ Maintenance equipment
  ○ Nets/ other fishing gear
• Leaving</td>
<td><u>Catches</u>
• Cleaning
• Sorting
• Packaging
• Weighing
• Storing
  ○ Iced (chilled)
  ○ Alive
• Marketing
• Distributing</td>
<td><u>People</u>
• Arriving
• Parking
• Gathering
• Discussing
• Working
• Training
• Managing
• Leaving</td>
</tr>
</table>

table 23: Routing fishing port

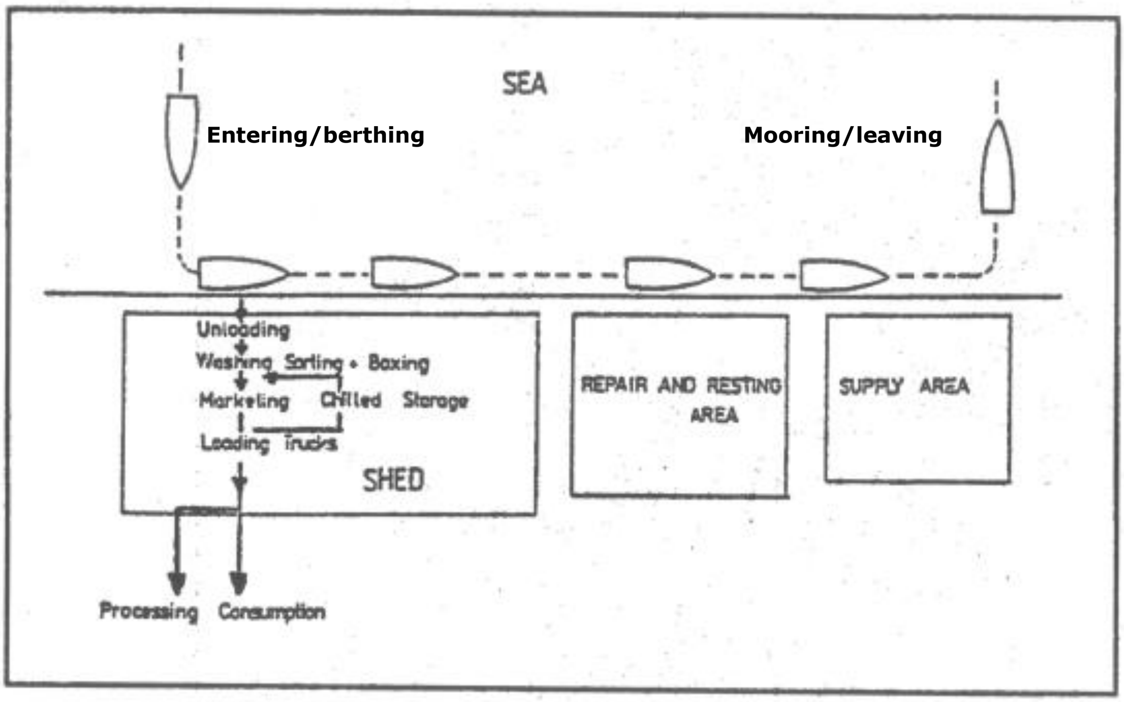


figure 74: Routing fishing vessels and catch (Ligteringen, 2000)

7.7.3 Port of refuge section

- Entering in bad weather conditions or other cases of emergency
- Sheltering
- Berthing in bad weather
- Incidental loading/unloading
- Emergency repairing
- Boarding of berthing and entering assistance from coastguard, tugs or other vessels
- Crew assistance, medical aid services
- Leaving

table 24: Routing port of refuge

7.8 Capacity

With the development forecast in section 6.4.1 a rough estimation of the number of berths per coastal haven is made. According to the master plan each haven should haven approximately 500 berths. This number is used for the dimensioning of the main facilities.

The target user group "fishing vessels" is present in the existing coastal havens with 100 to 200 speedboats used for fishing. On average, 150 speedboats used for fishing are counted. This figure together with the 500 yachts mentioned above, is used as required capacity for the generalized functional layout of the coastal haven. Depending on the spread over the coastal havens these figures can differ.

7.9 Required surface area facilities

The facilities are connected to the main functions from the appendix on the functioning of a coastal haven (Appendix K). This is done in table 26 at the end of this chapter. Each facility is linked to a function of the coastal haven and a target user group in this way.

In table 25, an assessment of the required surface area for each facility is made. It is based on the capacity determined in the previous section. The required surface areas are based on several references and references projects in which guidelines and rules of thumb concerning required areas for the facilities are described. The following references can be mentioned (Ligteringen, 2000), (Thoresen, 2003), (Australian Standard, 2001), (U.S. Army Corps of Engineers, 2009) and reference projects provided by DHV B.V..

Facility	Guideline	Surface area
Harbor master office		100 m^2
Recreational facilities		700 m^2
Slipway	1:7 extend 1.5 up to 2.0 meter under water level	500 m^2
Gantry crante for haul-out sevices	15x20 m	300 m^2
Parking lots marina users	0.5 number of berths Cars: 2.5 x 5.0 m	3125 m^2
Supply area	20 x 5 m	100 m^2
Fishing port administration building	crew 4-20 men	350 m^2
Workshop	15 x 10 m	150 m^2
Central toilet building	<150 m from berth	90 m^2
Daycare centre	50 x 70 m	360 m^2
Cold storage	20 x 20 m	400 m^2
Net storage	12 x 10 m	120 m^2
Power station	4 x 4 m	16 m^2
Fish market	20 x 10 m^2	200 m^2
Fuel depot	4 x 4 m	16 m^2
Net mending	30 x 15 m	450 m^2
Handling sheds	30 x 15 m	450 m^2
Parking lot fishing port users	Cars+trailers: 11 x 3.0 m	5,000 m^2
Parking lot trucks	Truck: 14 x 4 m	600 m^2
Sceptic tank	10 x 10 m	100 m^2
Waste water treatment	10 x 10 m	100 m^2
Supermarket	20 x 10 m	200 m^2
Laundry services	7.5 x 10m	75 m^2
Ship shop	10 x 10 m	100 m^2
Yachting berths	70-80 yachts per hectare	70,000 m^2
Fishing port berths	70-80 speedboats per hectare	20,000 m^2
Port of refuge berths	3 berths for vessels of 35 meter + 15% space Width 7 - 10 meter	1,000 m^2
Storage yachts	125-150 per hectare	9,000 m^2

Dry storage	35 m^2 per yacht	1,000 m^2
Storage fishing vessels	125-150 per hectare	4,500 m^2
Roads	20% of the total surface area land	6,115 m^2

Wet surface area marina section	70,000 m^2	76%
Dry surface area marina section	21,000 m^2	24%
Total surface area marina section	91,000 m^2	
Wet surface area fishing port section	20,000 m^2	56%
Dry surface area fishing port section	15,500 m^2	44%
Total surface area fishing port section	35,500 m^2	
Wet surface area port of refuge section	1,000 m^2	
Total wet surface area	91,000 m^2	70%
Total dry surface area	36,500 m^2	30%
Total surface area	127,500 m^2	

table 25: spatial claim facilities generalized functional layout

Remarks

For the on land storage in Kuwait it is assumed that most of the yachts will stay in the water during the season. The winter in Kuwait is mild, the lowest temperatures are around 10 degrees Celsius, so storing on land during the winter is not necessary for all vessels. It is assumed that the maximum storage situation is represented by the case that, 25% of the yachts and 50% of the fishing speedboats in a coastal haven would want to use the on-land storage. Furthermore, it is assumed that 85% of the yachts is stored outside and 15 % of the yachts in a storehouse. It is possible to store 125 to 175 vessels with an average length of approximately 9 meter on one hectare. This is done without any space between the yachts. For yachts of approximately 12 meter, 80 to 100 vessels fit on one hectare.

7.10 Generalized functional layout

As final product of this stage of the design, the facilities, buildings and surface areas are planned spatially. The mutual relations, routings of the users and the guidelines from reference projects and literature on the specific types of harbors are taken into account. This results in a first indication of the generalized functional layout, which is worked out in detail for the selected location in the next chapter.

The drawing including the surface areas can be found in figure 75. To make a distinction between the facilities required by all target users groups or one specific target user group, colors are used.

Functions / Target user group	Marina	Fishing port	Port of refuge	General	Remarks
People					
To enter/leave coastal haven (land side)	Car and truck parking lot Hinterland connection Truck loading area/facility				Truck facilities bounded to the fishing industry
To inform users	Fax and office services Posted coastal haven rules Weather information bulletin Message board Telephone / TV connection				Additional information for target user group yachting. Recreational information for example
To supervise, manage, train the users	Harbor masters office Concierge services				
		Fishing village centre Fishermen's cooperative office			
To supply users in their basic needs	Ample sanitary facilities Supermarket				Separation of target user groups advised
	Restaurants, cafeterias and cafes Gantry crane for haul-out services Laundry service	Canteen, rest rooms Daycare			
To recreate	Recreation or lounge area Yacht club Picnic area Swimming pool Gymnasium/spa/fitness Golf course Library Historical sights				
To provide medical aid, security and crew assistance	Rescue center Police post Fire station Medical aid service				
Yachts and vessels					
To enter/leave coastal haven (seaside)	Safely accessible entrance channel under all conditions Turning basin Adequate water depth				
Access water and putting ashore	Slipway Gantry crane				
Berth	Secure tie up system		Separate mooring facility with secure tie up system	Passer-by berth-holder berths	Separation of berths for different target user groups.
Facilitate vessels at their berth	Fresh water supply network Electricity supply network Sewage pomp out network Trash collection bins Power station				Pumping waste water out at berth? Additional luxury facilities for this target user group
To supply vessels	Gas station and storage tank for fuel and cooking gas Sewage pomp out station Fresh water supply Waste oil and chemical disposal containers Septic tank Trash collection bins			Separate location in the coastal haven, reachable for all target user groups	Pumping waste water at the berth?
To repair and maintain	Gantry crane for haul-out services Rigging shop Ship shop / part and equipments Engine services Mobile floating marine workshop Spare part storage				
	Sail maker	Net mending			
To store on land	Storage area Sheds for dry storage Dinghy storage area/rack				
To market new and used yachts	Yacht broker				
To shelter from storm conditions	Protective berths Adequate spending area for waves penetrating the coastal haven				Separation of berths required between target user groups Wave energy spending area of ship induced waves from fishing vessels
Catch					
To unload		Unloading facility	To unload (incidentally)		Kind of facility to be determined
To handle catch (clean, sort, package, weigh, store, market and distribute)		Ice factory Handling sheds Sewage			
To store		Cold warehouses Ice storehouses (freezer storehouses) Live fish-tanks and transport vehicles Fishing gear warehouse Fishing gear drying area			

table 26: Functions and facilities coastal haven

(yellow = all target user groups; orange = yachts; green = yachts & fishing vessels; blue = fishing vessels; red = port of refuge)

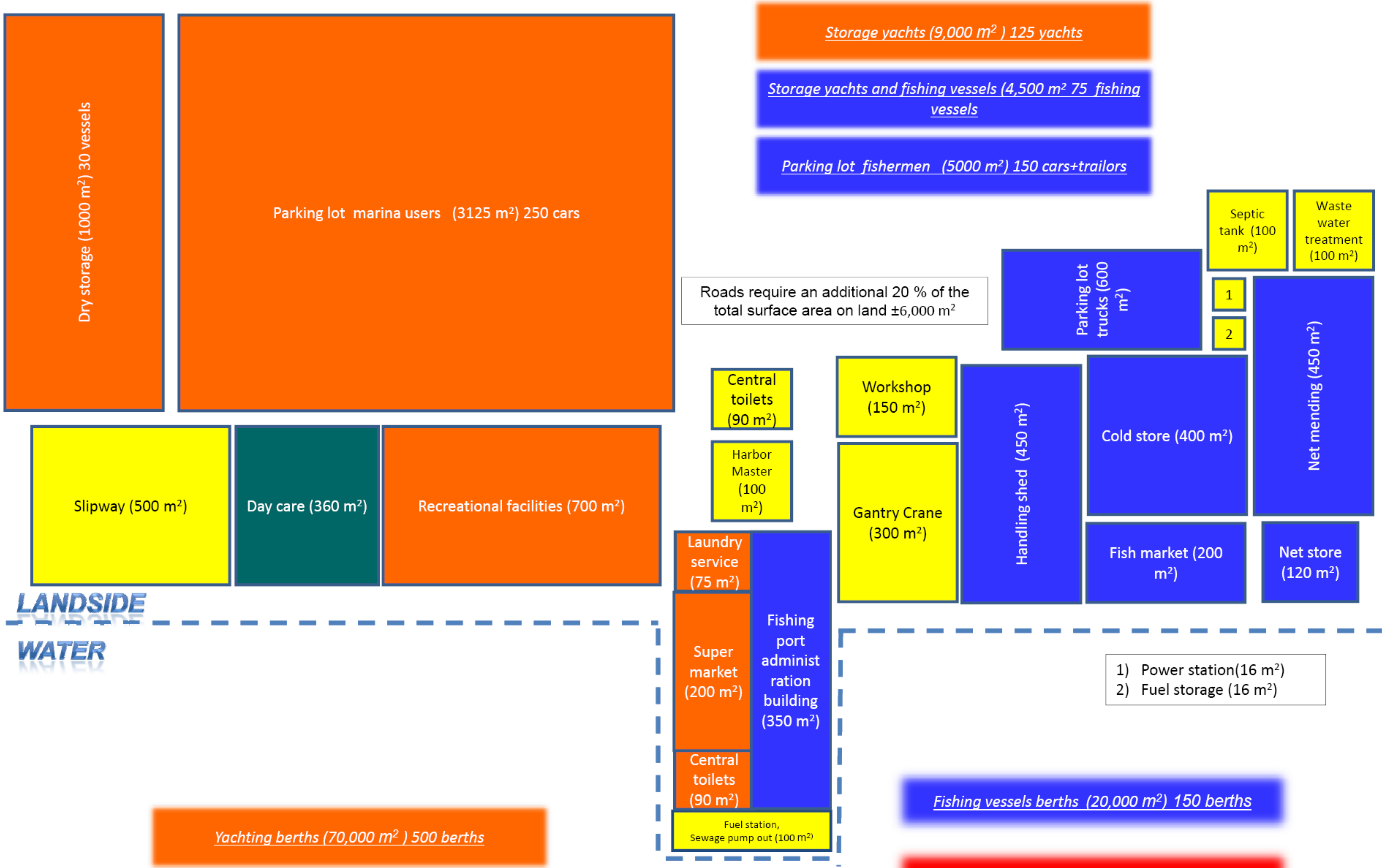


figure 75:Generalized functional layout coastal haven

(yellow = all target user groups; orange = yachts; green = yachts & fishing vessels; blue = fishing vessels; red = port of refuge)

8 Layout alternatives Al Syadeen

8.1 Introduction

In the previous chapters, the generalized functional layout was made, based on the theoretical background on the functioning of a coastal haven. This generalized layout is applicable for all coastal havens that are designed for all target user groups (a full-service coastal haven). In this paragraph this generalized layout is applied to the coastal haven of Al Syadeen.

Al Syadeen

The coastal haven of Al Syadeen was selected in order to make a layout for a full-service coastal haven. This location has to provide all target user groups with the required facilities according to the master plan and it is located along the Arabian Gulf coast. This location is therefore subject to higher waves than the coastal havens in the Kuwait Bay. Modeling and designing the layout of this coastal haven is therefore more interesting than the other locations.

Structure

In section 8.2 the location specific design conditions are determined and layout alternatives are presented in section 8.3.

8.2 Layout design criteria

During the creation of the layout alternatives, the aspects listed below are taken into account. The way in which these aspects are incorporated in the design is treated in this section.

- Layout design criteria summary
- Prevailing wind and wave direction
- Prevailing sediment transport direction
- Entrance to deeper water
- No wave breaking at entrance of the coastal haven
- Required capacity
- Surface area facilities

8.2.1 Layout design criteria summary

The design criteria for the coastal haven are determined in Appendix L and are summarized in table 27.

Aspect	Design requirement
Water depth -Marina section -Fishing port section -Entrance/turning basin/port of refuge	 d = 5 m d = 5 m d = 6 m
Approach channel width	120 m
Inner channel Turning circle	105 m 105 m
Interior channel (yachting)	43.75 m
Fairways (yachting) Berth length and width Finger piers	Dependent on yacht size see table 28
Quay length fishing section	L_B = 100 m
Berth length port of refuge	L_B = 120 m
Quay length supply area	L_B = 40 m

table 27: Summery design criteria coastal haven Al-Syadeen

8.2.2 Prevailing wind and wave direction

The wind and wave data at the offshore data location is presented in section 4.1 The wave and wind rose are inserted again in this section in combination with an aerial photograph of Al Syadeen. The wave and wind direction of interest are analyzed in section 9.1.1.

8.2.3 Prevailing sediment transport direction

As discussed within the chapter on the natural boundary condition (4.1), the sediments transport along the Arabian Gulf coast is expected to be from the south to the north due to the prevailing wind and wave direction. This part of the coast is only subject to waves from the S, SE and ESE direction and this induces a sediment transport towards the north. This is also concluded from the shape of the beaches along this part of the coast. The sediment transport direction must be considered during the determination of the breakwater configuration. Since the prevailing wave propagation direction and sediment transport direction are approximately equal, this aspect is almost automatically taken Lay-out alternatieven Al Syadeeninto account.

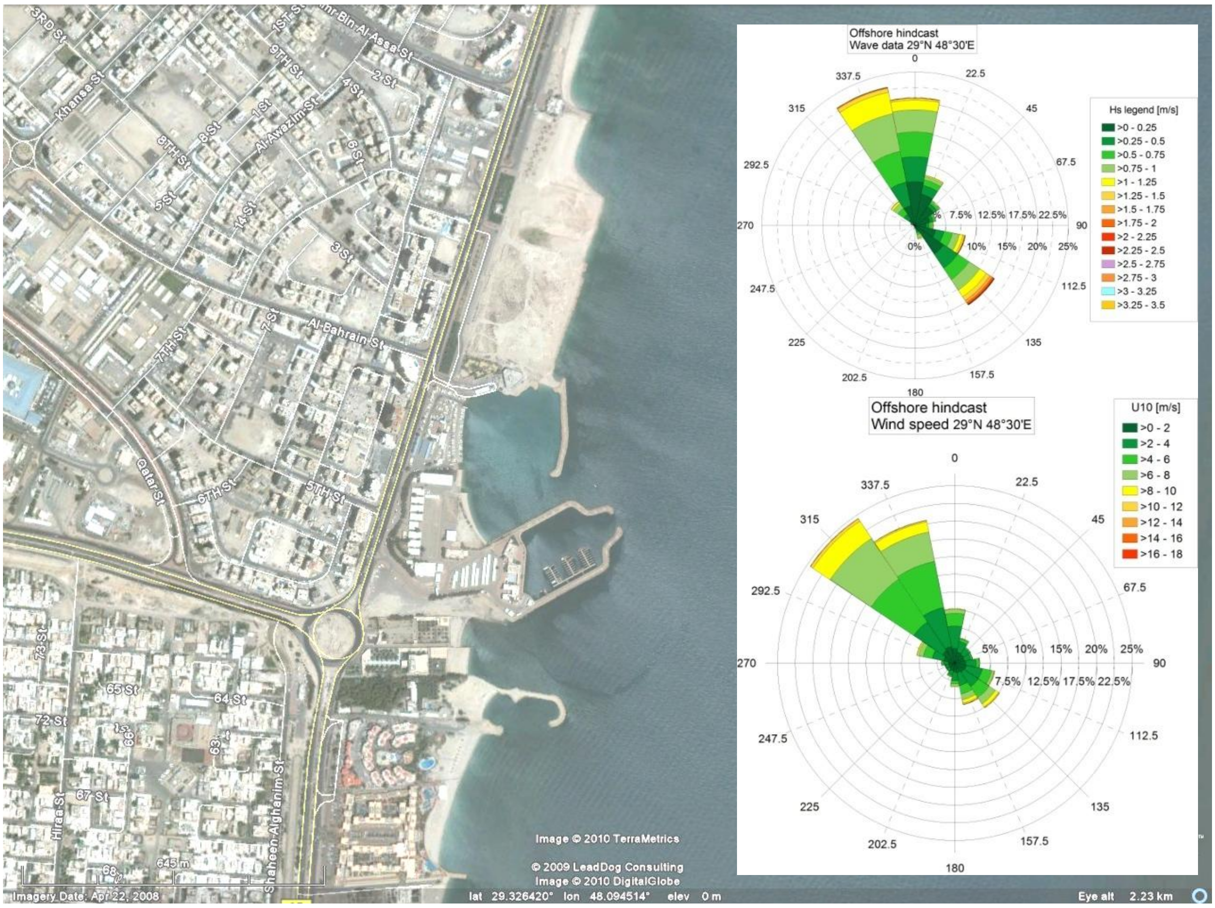


figure 76: Al Syadeen (Google Earth; 2008) and offshore hindcast data (BMT Argoss; 2009)

8.2.4 Entrance to deeper water

The breakwaters should extend towards deeper water in order to limit the length of the entrance channel. The rate of sedimentation of the entrance channel and the amount of sediment deposited in the coastal haven also decrease if this criterion is taken into account. Building the breakwaters further into the sea will limit the amount of sediment transportation along the coastal haven. Sand is transported within the surf zone, where the waves dissipate their energy. By extending the breakwaters further into the sea than the surf zone, these phenomena will play a minor role.

8.2.5 Breaking waves at the entrance

As mentioned earlier, breaking of waves at the entrance of the haven is not desirable. The waves break at a wave height (H_s) over water depth (d) ratio of approximately 0.8. The maximum occurring wave for the output point of Al Syadeen is 3.61 m. The depth d has to be larger than 3.61 m / 0.8 = 4.51m. The breakwaters should extend to a minimum water depth of 4.5 m in order to enable entering the coastal haven outside of the breaker zone.

8.2.6 Required capacity

The master plan anticipates for a demand increase up to 6.750 berths in 2030. These need to be facilitated by the marinas and coastal havens in 2030. The coastal haven of Al Syadeen is expected to facilitate 700 yacht berths within the master plan (section 6.9.2). Besides the yacht berths, the coastal haven has to facilitate approximately 200 speedboats used for fishing. Additional to these more or less known target user groups, vessels can take refuge in the coastal haven. A special facility for this purpose needs to be taken into account in the design of the coastal haven.

8.2.7 Yacht mix

A required capacity of 700 yachts is obtained from the yachting demand potential in the master plan. If we use apply this figure to the earlier determined yacht mix this result in the berth size distribution in table 28. In this figure the berth width, fairway widths and finger pier lengths for each berths length.

Berth length (m)	Berths width (m)		Fairway width (m)		Finger pier length (m)	Berths
	Single berth	Double berth	Min.	Preferred		
8	4.4	7.8	12	14	>6.4	200
10	5	9	15	17.5	>8.0	200
12.5	5.5	10	18.75	21.88	>10	150
15	6	11	22.5	26.25	>12	100
17.5	6.35	11.7	26.25	30.63	>14	25
20	6.7	12.9	30	35	>16	15
25	8	14.5	37.5	43.75	>20	10

table 28: Berth length, berth width, fairway width and number of berths Al Syadeen

8.2.8 Surface area facilities

The spatial requirements for the main facilities determined in the generalized layout are based on a coastal haven of 700 marina berths and approximately 200 fishing vessel berths. The spatial requirements for the marine section are adjusted to the required capacity for Al Syadeen in the table below.

Facility	Guideline	Surface area
Harbor master office		100 m^2
Recreational facilities		700 m^2
Slipway	1:7 extend 1.5 up to 2.0 meter under water level	500 m^2
Gantry crante for houl-out sevices	15x20 m (2)	600 m^2
Parking lots marina users	0.5 number of berths Cars: 2.5 x 5.0 m	4375 m^2
Supply area	40 x 15 m	600 m^2
Fishing port administration building	crew 4-20 men	350 m^2

Workshop	15 x 10 m	200 m^2
Central toilet building	<150 m from berth	120 m^2
Daycare centre	50 x 70 m	360 m^2
Cold storage	20 x 20 m	400 m^2
Net storage	12 x 10 m	120 m^2
Power station	4 x 4 m	16 m^2
Fish market	20 x 10 m^2	200 m^2
Fuel depot	4 x 4 m	16 m^2
Net mending	30 x 15 m	450 m^2
Handling sheds	30 x 15 m	450 m^2
Parking lot fishing port users	Cars+trailers: 11 x 3.0 m	6,250 m^2
Parking lot trucks	Truck: 14 x 4 m	600 m^2
Sceptic tank	10 x 10 m	100 m^2
Waste water treatment	10 x 10 m	100 m^2
Supermarket	20 x 15 m	300 m^2
Laundry services	15 x 10m	150 m^2
Ship shop	15 x 10 m	150 m^2
Yachting berths	70-80 yachts per hectare	100,000 m^2
Fishing port berths	70-80 speedboats per	25,000 m^2
Port of refuge berths	3 berths for vessels of 35 meter + 15% space Width 7 - 10 meter	1,000 m^2
Storage yachts	125-150 per hectare	11,000 m^2
Dry storage	35 m^2 per yacht	1,250 m^2
Storage fishing vessels	125-150 per hectare	6,000 m^2
Roads	20% of the total surface area land	7,500 m^2
Wet surface area	126,000 m^2	73%
Dry surface area	45,000 m^2	27%
Total surface area	171,000 m^2	

table 29: Surface area facilities layout Al Syadeen

The surface areas above are specified to be the minimum of surface area for this amount of users. The amount of storage area, where yachts can be stored on trailers could be increased if there is sufficient demand for it. There is a large number of yachts in Kuwait that is not stored in the vicinity of a marina or coastal haven. People might want to store their yacht in the vicinity of the marina or coastal haven if this facility is available, instead of storing it near their house or on an inland parking area. The yachts are usually stored on a trailer. An additional (secured) parking area dimensioned for cars with trailers is sufficient for this extra service.

8.3 Alternatives

Based on the design criteria determined above several alternatives are developed. The layout consists of the breakwater configuration and the spatial planning of the facilities and their surface area. During the development of the layout alternatives is mainly focused on the breakwater configuration. The land-side layout do not differ a lot and are therefore not treated in detail in this chapter. The results of designing the land-side part of the coastal haven can be found in chapter 10 and the appendices. The layout alternatives are mainly developed from the viewpoint of suitable protection alternatives for the vessels berthed in the coastal haven. This is done in order to model these layouts with wave models, to evaluate their effectiveness in protecting the inner basin from high waves.

Layout A is used as a test layout during the hydraulic modeling. Subsequently Layout B, C and D were defined.

8.3.1 Layout B

This layout is the basic configuration of the breakwaters with the southern breakwater extended far to the north in order to create overlap with the northern breakwater. Entering is possible through the entrance channel, which runs from north to south.

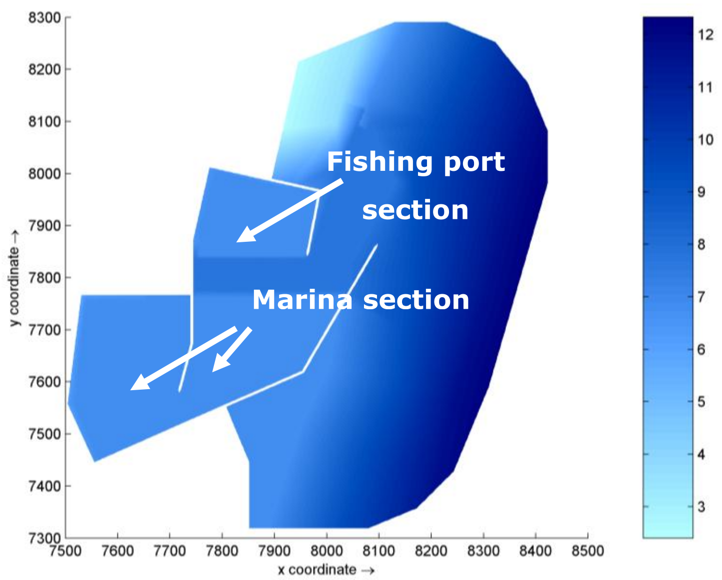


figure 77: Layout and water depth alternative B

8.3.2 Layout C

This layout is mainly determined in order to block the waves from the SE direction. This layout is more open than the previous one. The coastal haven is more open and entering can be done from the east. Compared to layout B, the northern breakwater has an additional part protecting the fishing port section.

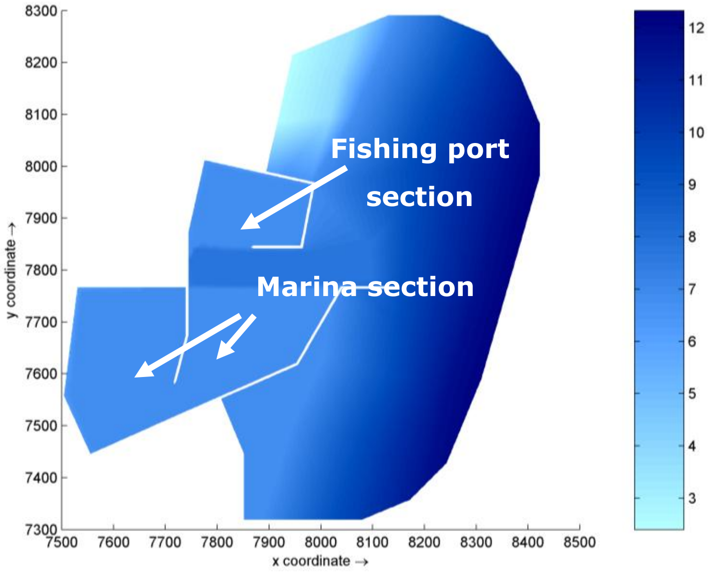


figure 78: Layout and water depth alternative C

8.3.3 Layout D

This layout is the layout which is completely closed off and also has an entrance channel, which runs from north to south.

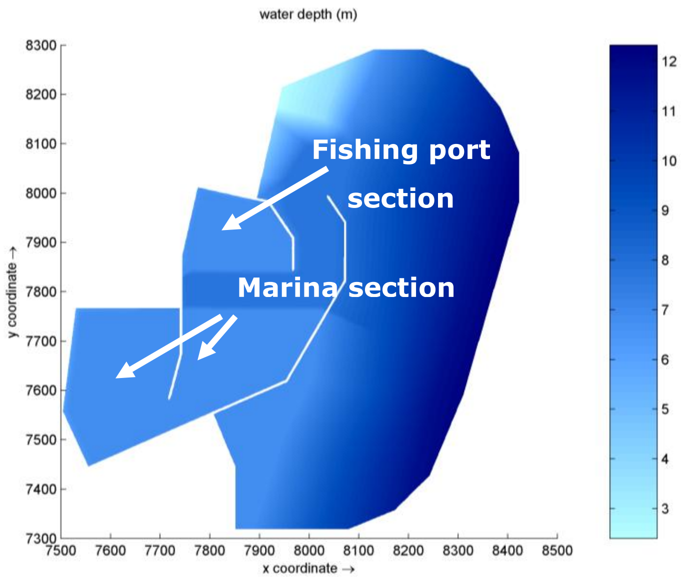


figure 79: Layout and water depth alternative D

9 Evaluation alternatives

In this chapter, the optimal layout is determined with the aid of a hydraulic modeling study and a multi criteria evaluation. The main criterion in the hydraulic modeling evaluation is the degree of protection against wave heights above a critical value. After the evaluation with the hydraulic model the layouts will be evaluated on other criteria with a multi criteria evaluation in section 9.2.

9.1 Hydraulic modeling evaluation

The coastal haven functions as a port of refuge during storm conditions and has to provide safe berthing conditions at all time. Therefore it needs to provide shelter and the wave conditions in the haven need to stay below certain critical values. Wave conditions above these critical values lead to damage to the vessels and are therefore not allowed. The type and size of vessels that use the coastal haven determine the critical wave height above which the coastal haven does not fulfill its function any longer.

The layout of the coastal haven needs to be such that it provides protection against the critical wave height that will occur during its economic lifetime. The economic lifetime of the coastal haven is assumed to be 50 years. Although breakwaters in general have a lifetime of about 100 years, an economic lifetime of a marina or small craft harbor is commonly taken at 50 years, which is used as return period of the wave conditions.

Detailed information about the wave climate at the coastal haven of Al Syadeen is not available. Therefore, a wave study has been carried out to determine the wave conditions at this location. Since local wave data is not available, offshore wave and wind data is purchased. This offshore wave and wind data is translated to nearshore conditions with the use of a wave propagation model. This model calculates the local wave climate, just outside the coastal haven. A second model is used to determine the wave penetration into the coastal haven. The study is carried out using the numerical wave models SWAN (Simulating Waves Nearshore provided by Delft University of Technology) and PHAROS (Program for HARbor Oscillations provided by Deltares). The study also comprises an analysis of the relevant wave scenarios.

The work method is to compute the wave field from the boundaries of the SWAN model to the coastal haven location. At the coastal haven, several output points are defined where SWAN will produce output. This output is used to determine the boundary conditions of the PHAROS model. This model is used to model the diffraction, reflection and oscillations within the coastal haven basin. PHAROS was used, because SWAN is not suitable for this purpose. PHAROS is specially developed to make diffraction and reflection calculations within harbor basins.

Prior to the modeling of wave propagation to the coastal haven of Al Syadeen, a sensitivity analysis for the SWAN model is performed. Results from these runs are used in the determination of the model parameters. The sensitivity analysis can be found in Appendix N.

The relevant scenarios to be modeled are determined in 9.1.1. Subsequently, the critical wave heights are determined in 9.1.2. The first step in the testing of the layout alternatives is done with the SWAN model. Section 9.1.3 contains an introduction to SWAN, the model set-up, input and the output. The motivation behind the choices made for the model parameters is discussed in Appendix M. With the results of the SWAN model, the hydraulic modeling is continued with the PHAROS model. The introduction to PHAROS, the model set-up, input and the output are reported in section 9.1.4. For this model, the motivation behind the model parameters can found in Appendix M.

The final aim of this modeling study is to compare several layouts based on their ability to protect the vessels berthed in the coastal haven from the wave conditions that occur once during the lifetime of the coastal haven.

9.1.1 Scenario's to be modeled Al Syadeen

In this section, an analysis is made of the data set and the modeled scenarios are determined. The data presented is originating from the offshore data point, presented earlier in section 4.1. The wave propagation direction, wave height, wave period and wind speed in combination with the return period will be treated subsequently.

9.1.1.1 Propagation directions

Several aspects play a role in the selection of relevant wave scenarios for the coastal haven of Al Syadeen. The assumption is made that wind and wave directions are correlated. This is motivated with figure 80. The wave height and the wind speed show a clear correlation. This does not say anything about direction correlation. The Arabian Gulf is a relatively small sea and wave generation is assumed to be correlated to local wind conditions.

More on the correlation between wind wave generation and wind direction can be found in appendix N.3.

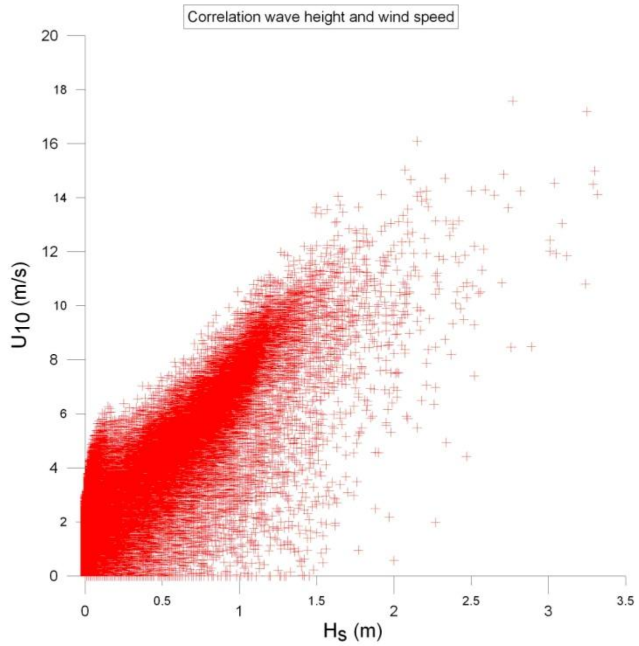


figure 80: Correlation significant wave height (H_s) and wind speed (U_{10}) offshore data point

This assumption eliminates more than half of the wave directions, because directions that are not likely to propagate towards the coastal haven of Al Syadeen are eliminated from the analysis. The directions of interest are presented in table 30. The directional sectors indicated in grey comprise the highest waves and the majority of the waves.

H_s	Wave direction (˚N)							Total
	45	67.5	90	112.5	135	157.5	180	
1.5-2				0.141	0.655			0.796
1-1.5				0.833	1.917	0.195		3.153
0-1	0.471	0.386	0.596	2.409	4.093	0.78	0.129	10.267
Total	**0.471**	**0.386**	**0.596**	**3.383**	**6.665**	**0.975**	**0.129**	**14.216**

table 30: Probability of occurrence (%) relevant directions offshore data point for Al Syadeen

In order to reduce the amount of input data and computational time for the hydraulic models, these four wave propagation directions are selected. This decision is based on the probability of occurrence of these conditions and the fact that the 90, 112.5, 135, 157.5 ˚N comprise the highest waves of all directional sectors in table 30.

9.1.1.2 Design wave height

In this paragraph the design wave height for the directions selected in the previous one is determined. In order to arrive at the extreme wave height for the hydraulic models, an extrapolation method is used. The layout of the coastal haven must be able to protect the vessels against waves from the relevant directions with a return period of 50 years. A least square regression analysis is used to determine the design wave height (Kamphuis, 2000).

The design wave height is determined from the probability of occurrence with the use of a Weibull distribution. The design wave height is also calculated with a Gumbel distribution, but these values do not differ a lot from each other.

Threshold

For calculation for the waves from 112.5 °N and 135 °N, a threshold wave height (H_t) of 1.0 meter is used. This is done to rule out the smaller values. These smaller values need to be ruled out in order to guarantee independence of the events. The threshold value of 1.0 meter is arbitrarily introduced as is done in another research project on the wave climate on the Arabian Gulf (Neelamani, 2006).

No threshold is applied to the waves from 90 °N (E) and 157.5 °N (SSE. These directional sectors do not comprise a lot of high waves and using a threshold would rule out too much data.

Weibull

$$P = 1 - \exp\left(-\left(-\frac{H-\gamma}{\beta}\right)^{\alpha}\right)$$

$$Y = -\ln\left(\ln\frac{1}{Q}\right)^{1/\alpha} = W; X = H; A = \frac{1}{\beta}; B = -\frac{\gamma}{\beta}$$

$$H_{T_R} = \gamma + \beta\left(\ln\frac{1}{Q}\right)^{1/\alpha} = \gamma + \beta\left(\ln\{\ln \lambda T_R\}\right)^{1/\alpha}$$

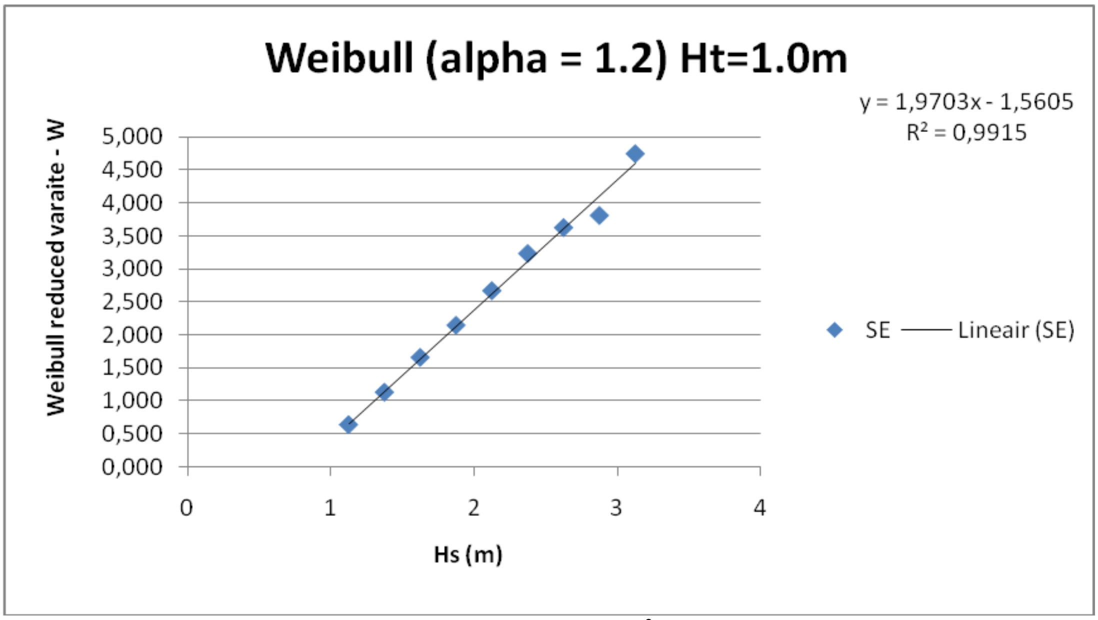


figure 81: Weibull distribution for waves from SE 135°N (A=1.97 and B=-1.56)

		Return period				
Direction	Parameter	10	20	50	100	200
E	H_S (m)	1.66	1.81	2.01	2.15	2.29
	T_P (s)	5.13	5.34	5.60	5.79	5.96
ESE	H_S (m)	2.96	3.29	3.75	4.10	4.47
	T_P (s)	6.73	7.07	7.52	7.85	8.16
SE	H_S (m)	3.27	3.48	3.76	3.96	4.16
	T_P (s)	7.05	7.26	7.53	7.72	7.90
SSE	H_S (m)	1.66	1.79	1.96	2.08	2.21
	T_P (s)	5.13	5.31	5.54	5.71	5.86

table 31: Wave and wave conditions with return period offshore data point

9.1.1.3 Wave period

The wave periods provided in table 31 are determined with a relation between wave height and wave period (Kamphuis, 2000).

$$T = c_3 H_S^{c_4}$$

T = Wave period (s)

c_3, c_4 = constants (-)

H_S = Significant wave height (m)

The coefficients for Dubai, retrieved from the literature and provided in table 32, are used to determine the wave period for the design wave heights in table 31.

It is possible to determine the constants by plotting the wave period against the wave height for the offshore data set. A power type trend line will give the parameters of this relation. This is done in figure 82 and result in c_3=4.12 and c_4=0.46. These constants match with the constants provided in the literature for Dubai (table 32) and are a characterization of the relation between the wave height and period in the Arabian Gulf.

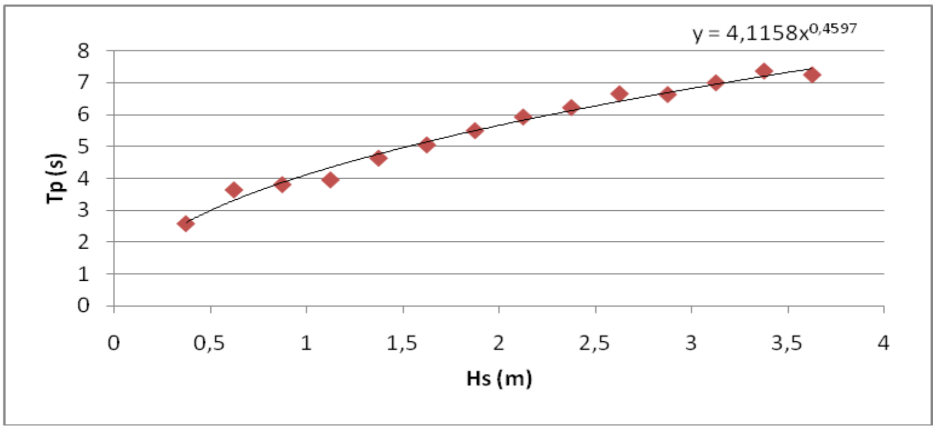


figure 82: Relation wave height and period

Location	C3	C4
North Sea	3.94	0.38
Dubai	4.04	0.47
Israel	6.96	0.28

table 32: Wave period and height relation (Kamphuis, 2000)

<u>Wind conditions</u>

Each model scenario requires a wave height and direction, wave period and wind speed and direction. The wave height and period are determined above. The wind speed is determined with a extreme value method using a Gumbel distribution.

$$P = \exp\left(-\exp\left(-\frac{H-\gamma}{\beta}\right)\right)$$

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G; X = H; A = \frac{1}{\beta}; B = -\frac{\gamma}{\beta}$$

$$H_{T_R} = \gamma - \beta\left(\ln\frac{1}{P}\right) = \gamma - \beta\left(\ln\left\{\ln\frac{\lambda T_R}{\lambda T_R - 1}\right\}\right)$$

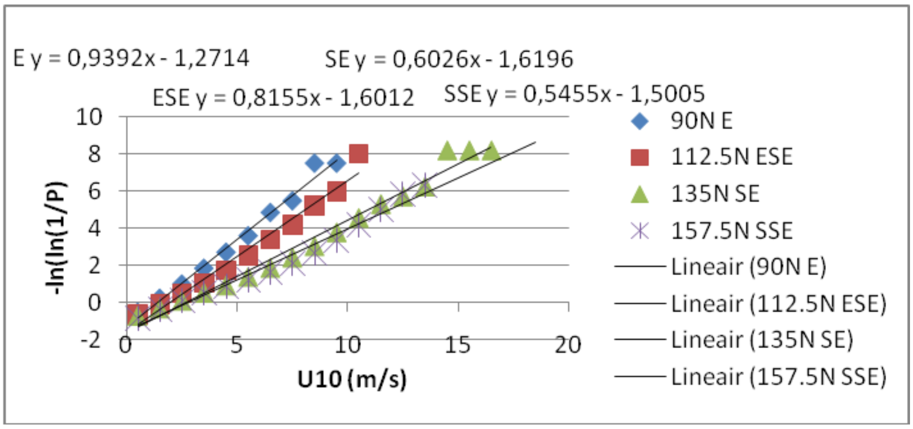


figure 83: Gumbel distribution and trend line wind speed per sector

Direction	Parameter	Return period				
		10	20	50	100	200
E	U_{10}	10.48	11.42	12.66	13.60	14.54
ESE	U_{10}	15.86	17.22	19.02	20.38	21.74
SE	U_{10}	22.45	24.31	26.78	28.64	30.50
SSE	U_{10}	22.29	24.20	26.72	28.63	30.53

table 33: Wind speeds return period according Gumbel distribution (m/s)

9.1.2 Critical wave height

In the design of a marina it is necessary to take measures to limit the height of the waves, which can affect the vessels berthed in the marina. This limitation is necessary to ensure that the marina is a safe haven for the berthing and protection of vessels. This also holds for a coastal haven, which has this function not only for yachts, but also for the fishing vessels and other vessels that take refuge.

The coastal haven of Al Syadeen is sited at an exposed location, where the largest wave heights will occur during strong winds on the Arabian Gulf. For this reason, the wave height has to be limited by breakwaters for this location. Design standards for small craft harbors and fishing ports are used to determine the critical wave heights. The critical wave height is used as criterion for the design of the breakwaters. The design of the breakwaters must reduce the wave height to a value below the critical wave height.

The determination of the critical wave height is performed based on several references. The Australian standard (Australian Standard, 2001), the Port designers handbook (Thoresen, 2003) and lecture notes from the Delft University of Technology (Ligteringen, 2001) are used to determine a critical wave height for each target user group.

Yachts

The critical wave height for this target user group is presented in table 34.

Direction and peak period of design harbor wave	Significant wave height (H_s)	
	Wave event exceed once in 50 years	Wave event exceeded once a year
Head seas less than 2s	Conditions not likely to occur during this event	Less than 0.3 m wave height
Head seas greater than 2s	Less than 0.6 m wave height	Less than 0.3 m wave height
Oblique seas greater than 2s	Less than 0.4 m	Less than 0.3 m wave height
Beam seas less than 2s	Conditions no likely to occur during this event	Less than 0.3 m wave height
Beam seas greater than 2s	Less than 0.25 m wave height	Less than 0.15 m wave height

table 34: Criteria wave climate in small craft harbors (Australian Standard, 2001)

Since the focus is on the wave events that occurs onece during the lifetime of the coastal haven, the second column of table 34 is used. This allows a larger wave, but a less frequent event. For yachts, a wave height that is exceeded only once during a period of 50 years is 0.60 m, if we assume that most the yachts are berthed in a way that they are subject to head seas. This has an impact on the layout and berthing arrangement of the coastal haven. Above this value serious damage is to be expected. The value of **0.60 m** is thus normative for the yachts and speedboats in the marina section of the coastal haven.

Fishing vessels

If we consider the conditions of importance for fishing vessels the conditions at which the vessels can stay berthed are of importance. Since the target user group "fishing vessels" exists of more or less the same vessels as the yachts, this target user group is also subject to the design criteria for small craft berthing facilities. The same significant wave height and return period as the marina section of the coastal haven is therefore selected. Damage will also occur to speedboats used for fishing when waves with a height of more than **0.6 m** will enter the berthing basin.

Vessels that take refuge

The vessels that take refuge in the coastal haven will be berthed closer to the entrance if their length exceeds 25 m. The damage criterion is also applicable to these vessels. The wave height above which damage is likely to occur is somewhat larger. A significant wave height (H_s) of **0.75 m** is used as normative value for the wave event for this target user group with a return period of 50 years. If smaller vessels take refuge in the coastal haven, they need to berth in the marina or fishing port berthing area.

Target user group	H_{cr} (wave event exceeded one in 50 years)
Speedboats and yachts	0.60 m
Fishing vessels (speedboats)	0.60 m
Fishing vessels (dhows)	0.75 m
Vessels that take refuge 25-35 m	0.75 m

table 35: Berthing limiting wave height

Entering limitation

High waves at the entrance are not desirable, since entering the coastal haven with waves higher than a certain value can lead to dangerous situations. Vessels cannot enter the coastal haven under all conditions. High waves at the entrance of the coastal haven will in general not lead to the rejection of a layout alternative. Entering the coastal haven in situations with high waves is simply not allowed any longer. An indication of wave heights limiting the entrance of the coastal haven is provided in table 36.

Target user group	Entering limiting wave height (m)
Speedboats and yachts	1.0 – 1.5
Fishing speedboats and vessels	1.0 – 1.5
Vessels that take refuge (dhows, barges and fishing vessels <35m)	1.5 – 2.0

table 36: Entrance limiting wave height

Port designer's handbook (Thoresen, 2003)

It is very difficult to predict the acceptable movements for the different types of ships. It can be done with varying degrees of accuracy and reliability by mathematical models and analytical methods, but the most reliable method of predicting a ship's response under wave action is to build and test in a physical model. Recommendations to acceptable movements are given in this part.

Waves can be exposed to waves by a head, quartering or beam sea. Waves with short periods will more or less only affect small ships while long-period waves will affect more or less all ships. In harbors, for fishing boats or small ships, the shorter periodic waves (less than about 6 – 8s) normally determine the berthing and acceptable movement conditions for the ship.

Waves are assumed to be representative for vessels at their berth. Wind and currents are assumed not to lead to the design conditions. These forcing are thus assumed not to lead to design conditions for the layout of the coastal haven.

Maximum significant wave heights

Ships at berth	H_s (m) at berth
Marinas	0.15
Fishing boats	0.40
Passenger ship	0.70
General cargo (<30,000 dwt)	0.70

Limiting criteria for ship movements under working conditions:

- Fishing boats 25 – 60 meter ± 0.3 m heave
- Limiting criteria for ship movement under safe mooring conditions
- Fishing boats 25 – 60 meter ± 0.5 m heave
- Coasters 60-120 m ± 0.75 m heave

9.1.3 SWAN

9.1.3.1 Introduction SWAN

The SWAN model is a very well-validated third-generation wave model which computes random, short-crested wind-generated waves in coastal regions and inland waters. The model predicts a 2D wave field at beforehand specified grid points. SWAN accounts for the following physics:

- Wave propagation in time and space
- Shoaling
- Refraction due to current and depth
- Frequency shifting due to currents and non-stationary depth
- Wave generation by wind
- Triad and quadruplet wave interactions
- White capping, bottom friction, and depth induced breaking
- Wave induced setup
- Propagation from laboratory up to global scales
- Transmission through and reflection from obstacles.

Diffraction, currents and individual waves are not modeled with SWAN. In this study the latest release of SWAN was used: Version 40.72AB. Diffraction can be included in this version. However the simulation of diffraction is not yet considered sufficiently reliable, especially for long waves. Diffraction is therefore not included in the SWAN computations, which will produce results outside of the port area (where diffraction is not of importance).

9.1.3.2 Model set-up

Grid

To obtain accurate model results at the locations and to prevent unnecessary long computations, a complex nested model could be set up. Setting up such a model and computing the wave propagation with the use of a nested model is a laborious exercise. In order to spend relatively not too much time modeling with SWAN, no nested model is made.

Instead of the nested model, one model with a rather large modeled area of 67.5 x 120 km is set up to calculate the wave propagation towards all coastal havens. The model was chosen to be this size because the offshore data point and the entire Kuwait Bay needs to be included. The model boundary is put further east in order to include the shallow northern and more shallow part of the Arabian Gulf into the model as well (see figure 84). Waves from northeastern and eastern direction can be calculated due to this inclusion.

Bathymetry

The bathymetry was digitized in a grid with a cell size of 100 x 100 meter, but during the first runs of the SWAN model the resolution of the computational grid is reduced from 100 meter to 400 meter in order to reduce the computational time. The bathymetry is treated in 4.1.2 as a part of the natural boundary conditions and is presented again in figure 84.

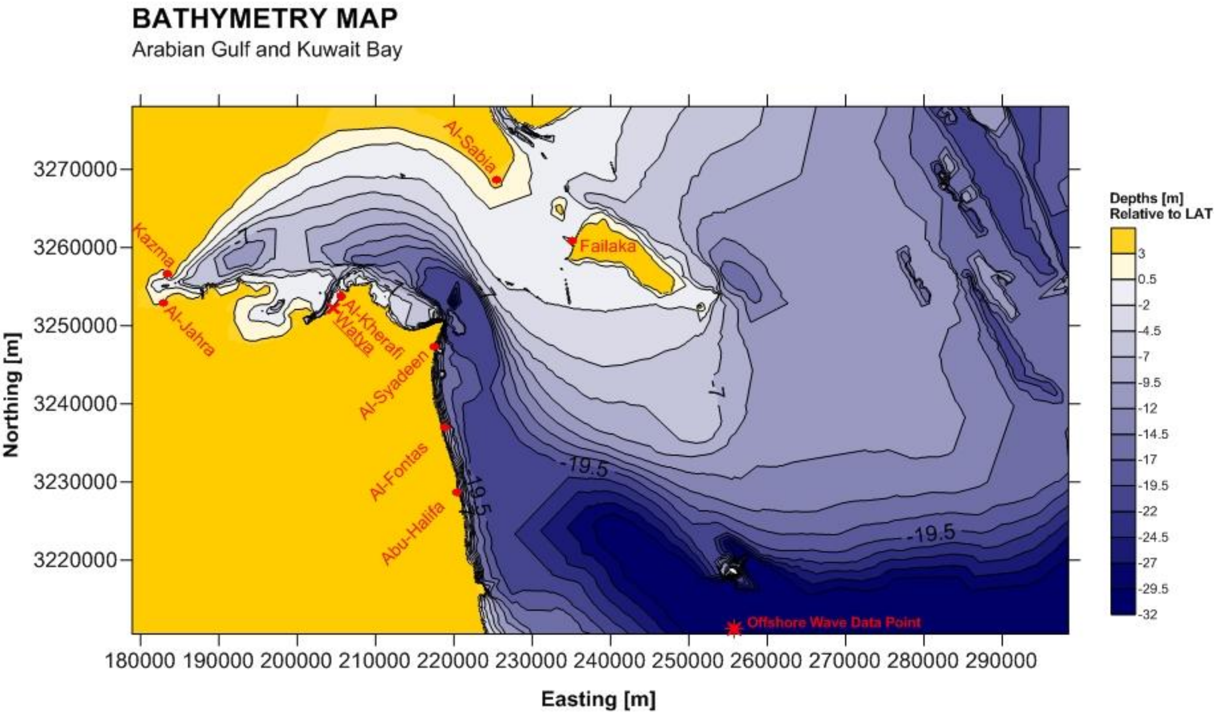


figure 84: Bathymetry modeled area including locations and offshore data point (Admiraty Chart 1214 (2002) and 3773 (2008))

Model parameters

A detailed description of the determination of the model parameters can be found in Appendix M. The main parameters are listed in table 37. During the sensitivity analysis, these parameters are altered to investigate their effect on the output of the model.

The motivation behind the model parameters can be found in Appendix M.

Parameter	Value	Remarks
Mode	Stationary 2D	
Water level	+1.75 m	Mean Sea Level (MSL)
Coordinates	Cartesian	Universal Transverse Mercator
Spectrum	JONSWAP	Default with gamma = 3.3
Directional spreading	21.9 degrees	Wind waves, large directional
GEN3	Yes	Indicates SWAN to use the third-

BREA	Yes	Breaking is taken into account
FRIC	Yes	Uses the (default) JONSWAP description
TRIAD	No	Triad wave-wave interaction

table 37: Model parameters for SWAN model

9.1.3.3 Input SWAN

The wind and wave conditions in the previous paragraphs (9.1.1) lead to the scenarios in table 38 to be modeled with SWAN.

Run ID	H_S (m)	T_P (s)	Dir (° N)	U_{10} (m/s)	Directional spreading (°)
S01	2.01	5.6	90	12.66	22.9
S02	3.75	7.52	112.5	19.02	22.9
S03	3.76	7.53	135	26.77	22.9
S04	1.96	5.54	157.5	26.71	22.9

table 38: Scanrios SWAN Al Syadeen retun period 50 years

9.1.3.4 Output location SWAN Al Syadeen

The output of SWAN is generated at the wave entrance boundary of the PHAROS model. This point is indicated in figure 85. The location of the SWAN output point of Al Syadeen is located at UTM coordinates easting 3247717 m and northing 218350 m. The water depth at this location is 12.40 m.

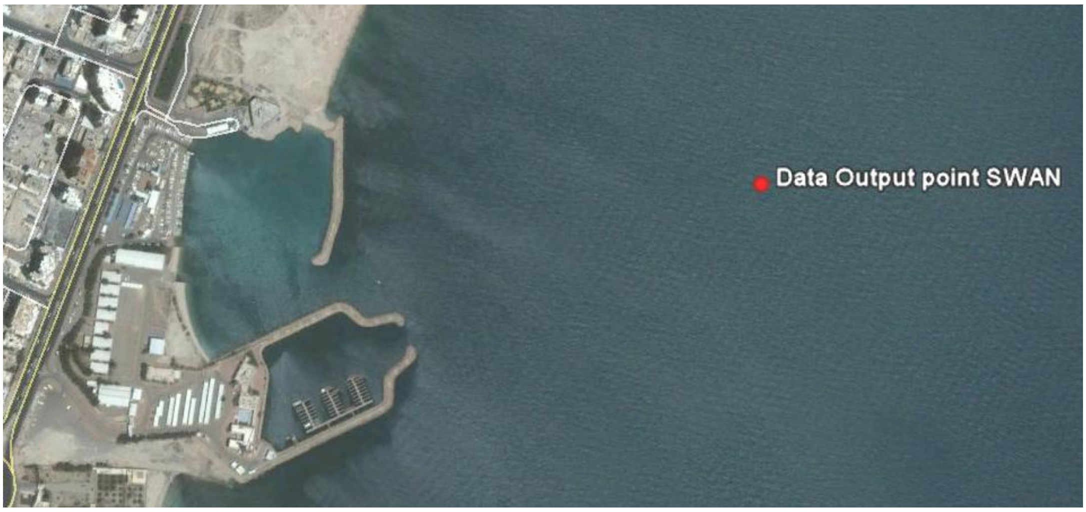
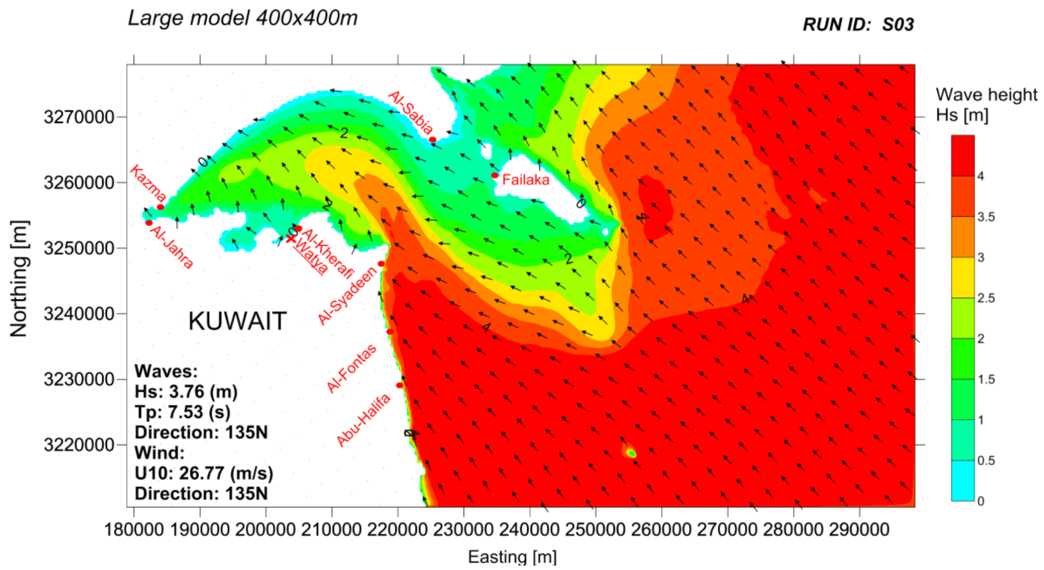


figure 85: Output point SWAN Al Syadeen (Google Earth)

Run ID	H_S (m)	T_P (s)	Dir (°N)	Directional spreading (°)
S01	1.51	5.88	122.68	22.38
S02	2.76	7.74	131.38	21.40
S03	3.61	8.47	139.25	23.38
S04	3.36	7.06	150.53	26.52

table 39: Output SWAN Al Syadeen (x=218350; y=3247717, d=12.397m)

The scenarios to be modeled with PHAROS are obtained from the SWAN output. The wave conditions with a return period of 50 years from ESE (135°N) and SE (157.5°N) direction show the highest waves. To include a third direction, the S02 direction is also taken into account. The PHAROS input is explained in detail in 9.1.4.3.



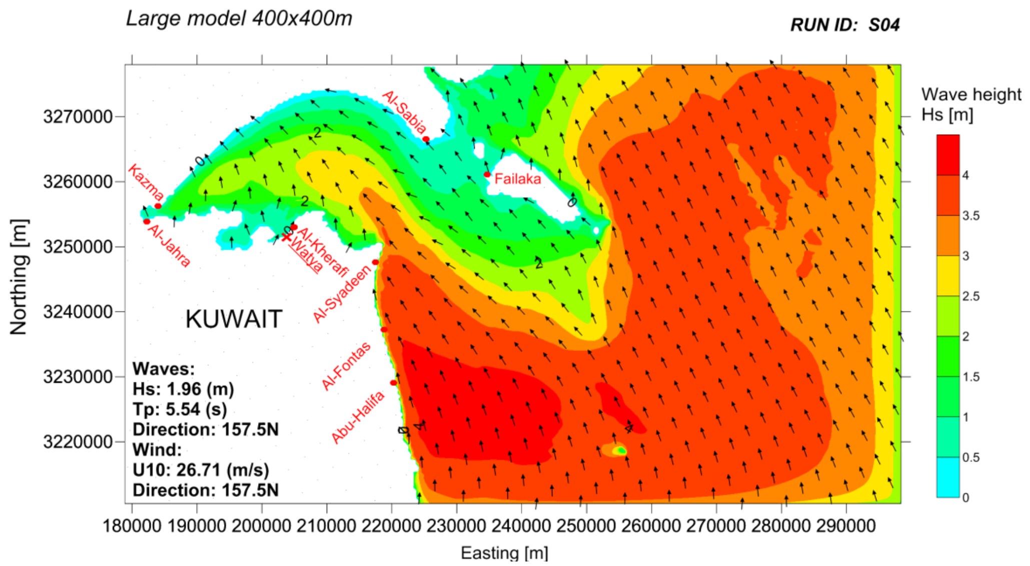


figure 86: Output SWAN run S03 and S04

9.1.4 PHAROS

9.1.4.1 Introduction to PHAROS

PHAROS is an integrated system for modeling wave penetration into harbours and around coastal structures. PHAROS is an acronym for Program for HARbour Oscillations. The program solves the mild-slope equation and includes the representation of:

- refraction over an irregular depth profile;
- wave diffraction around structures;
- reflection or partial reflection by structures;
- transmission or partial transmission over (or through) structures;
- dissipation by wave breaking;
- dissipation by bottom friction;
- propagation over an ambient current;
- directional spreading;
- spectral energy distribution.

In the PHAROS model formulations, the following main assumptions are made:

- the fluid is ideal, which means that it is considered to be incompressible and that viscosity or turbulence effects have to be taken into account.
- The fluid motion is irrotational, which allows for the use of a potential-flow formulation.
- The formulation can be linearised, implying the assumption of small wave steepness.

The linearity assumption allows the wave motion to be described as a sum of harmonic (regular) wave components that can be calculated independently.

9.1.4.2 Model set-up

Bathymetry

The bathymetry is obtained from the Admiralty Charts and is the same as the one used for the SWAN model. The water depth in the coastal haven basin and entrance channel are added to the bathymetry from the admiralty charts in order include the future water depth within the coastal haven in the model. The bathymetry for each alternative is presented in figure 77, figure 78 and figure 79 in paragraph 8.3.

Computational grid requirements

PHAROS has some requirements for the computational grid. The bottom cannot have a too large slope. This is because of the fact that PHAROS solves the mild-slope equation and the bathymetry has to fulfill the mild-slope conditions.

The quality of the computational grid can be tested within the application that generates the computation grid. The mild-slope condition and the wave length versus grid cell size criterion are tested within this application. The grid fulfills the mild-slope condition up to a wave period of 10 seconds. This wave period is larger than the expected wave period during the modeling of the coastal haven layout. Besides the mild-slope condition the computational grid has to fulfill the element size versus wavelength conditions. In this check the smallest expected wave period is used (7 seconds). The generated computational grids fulfill these requirements for the computations that are made.

Besides this check, a check of the relation between the minimum and maximum surface area of a grid cell is important. The largest surface area should not be more than one or two orders larger than the smallest.

The entrance parameters should be applied to a boundary at an uniform water depth, where waves from all modeled directions can enter the domain. Corners of 90 degrees in the entrance should be limited, because this introduces diffraction at these points, which will introduce boundary effects. For these reasons the boundary is chosen to be in the shape of half a circle.

Parameter	Grid B	Grid C	Grid D
Wave period for grid generation	5.5	5.5	5.5
N (points per wave length)	8	8	8
Minimum surface area element	0.85	0.55	0.54
Maximum surface area element	14.97	13.84	13.95
Number of nodes	60803	61262	59886
Number of elements	120332	121938	118459
Volume	$3.56725*10^6$	$3.55252*10^6$	$3.61874*10^6$
Area	549024	548560	548674

table 40: Parameters grid generation

Model parameters

A detailed description of the determination of the model and input parameters can be found Appendix Q. The main aspects are summarized in table 41. The most important aspect in the PHAROS model set-up is the definition of the reflection coefficients and the angle for which this coefficient holds and the directional spreading for the modeled wave directions. These aspects are subsequently described in section Q.5 and Q.6.

Parameter	Value	Remarks
Mode	Directional spreading	
Water level	+1.75 m	Mean Sea Level (MSL)
Coordinates	Cartesian (shifted)	Universal Transverse Mercator
Spectrum	JONSWAP	Default with gamma = 3.3
Directional spreading	m = 4 and 5	Wind waves, large directional spreading
Wave breaking	Yes	γ_s=0.8, γ_d=0.14
Uniform bed level	No	Bathymetry is used for the bed level
Bottom friction	No	Bottom friction is neglected
Entrance losses	No	Entrance losses are neglected
Wave-current interaction	No	Not possible yet in PHAROS

table 41: Model parameters for SWAN model

9.1.4.3 Input Pharos

Scenarios

Some simplifications are applied to the input for PHAROS. The propagation directions are set to the mean of the directional sectors of 22.5 in order to simplify the input. The SWAN runs S03, waves from the SE (135 °N) and S04 , waves from the SSE (157.5 °N) result in this way to run1 and run2 for PHAROS respectively. Run3 is added to these two scenarios in order to include waves from the ESE (112.5 °N). The wave height of S02 with a propagation direction of 112.5°N is used for this purpose and is set at a propagation direction of 112.5°N. This is in between the SWAN output for run S01 and S02. An overview of the runs is given in table 42. These runs in combination with the three layout alternatives lead to the case administration in table 43.

Run ID	Hs (m)	Tp (s)	Dir (°N)	Directional spreading power m
Run1	3.61	8.47	135	5
Run2	3.36	7.06	157.5	4
Run3	2.76	7.74	112.5	5

table 42: Input PHAROS entrance boundary element

Directional spreading

To include directional spreading in PHAROS, the degree of directional spreading has to be given in the power m and not in degrees (for SWAN both ways of defining are possible). Besides this power, several sub directions for each main direction have to be indicated to create a directional distribution of the wave energy. This is done with 4 sub directions for each main direction. Waves from 112.5°N is modeled with sub directions 67.5, 90, 135 and 157.5°N, waves from 135°N with 90, 112.5, 157.5 and 180°N and waves from 157.5°N with 112.5, 135, 180 and 205.5°N.

The directional spreading for run1 and run3 is kept at m=5 or 22.9°, for run2 it is changed to m=4 in order to increase directional spreading from the output of SWAN in a right way.

More information on the directional spreading parameters can be found in appendix Q.5.

Project	Description	Grids	Description	Runs	Description
Al Syadeen	Coastal haven of Al Syadeen, Nikas, Kuwait	Layout B	Layout alternative coastal haven B	Run1	Waves from 135°N, H_s=3.61m, T=8.47s, m=5
				Run2	Waves from 157.5°N, H_s=3.36m, T=7.06s, m=4
				Run3	Waves from 112.5°N, H_s=7.74m, T=7.74s, m=5
		Layout C	Layout alternative coastal haven C	Run1	Waves from 135°N, H_s=3.61m, T=8.47s, m=5
				Run2	Waves from 157.5°N, H_s=3.36m, T=7.06s, m=4
				Run3	Waves from 112.5°N, H_s=7.74m, T=7.74s, m=5
		Layout D	Layout alternative coastal haven D	Run1	Waves from 135°N, H_s=3.61m, T=8.47s, m=5
				Run2	Waves from 157.5°N, H_s=3.36m, T=7.06s, m=4
				Run3	Waves from 112.5°N, H_s=7.74m, T=7.74s, m=5

table 43: Case administration PHAROS

Reflection and transmission

The layout alternatives are split up into boundary elements during the set-up of the model. For all these elements, 20 to 25 for each of the three layouts, a reflection coefficient and a wave approach angle, measured from the normal of that boundary element, needs to be specified in order to model the reflection.

The quays are assumed to have a reflection coefficient of 100%, for the other boundary elements a value is determined based on three equations for reflection. The entire determination can be found in Appendix Q.6. The overview of reflection coefficients and wave approach angle can be found in Appendix R.

Transmission is not included in the model. The breakwaters are assumed to be designed is such a way, that they prevent transmission through and over the structure.

9.1.4.4 Output Pharos

The PHAROS output module provides figures of the weighted mean wave height in m for the three main directions for each layout (9 figures in total, see Appendix S). PHAROS averages the output of the main and sub directions over the directional distribution determined in the input (see Appendix Q.5).

For every layout, a figure below shows the results for the scenarios with waves from main direction 112.5°N. This main wave direction leads to the highest waves within all three coastal haven layout alternatives. Based on these figures conclusions are drawn in the next section.

A white layer is included in the scale to indicate locations with wave heights of 0.6 meter. This is the critical wave height for the yachts and speedboats used for fishing.

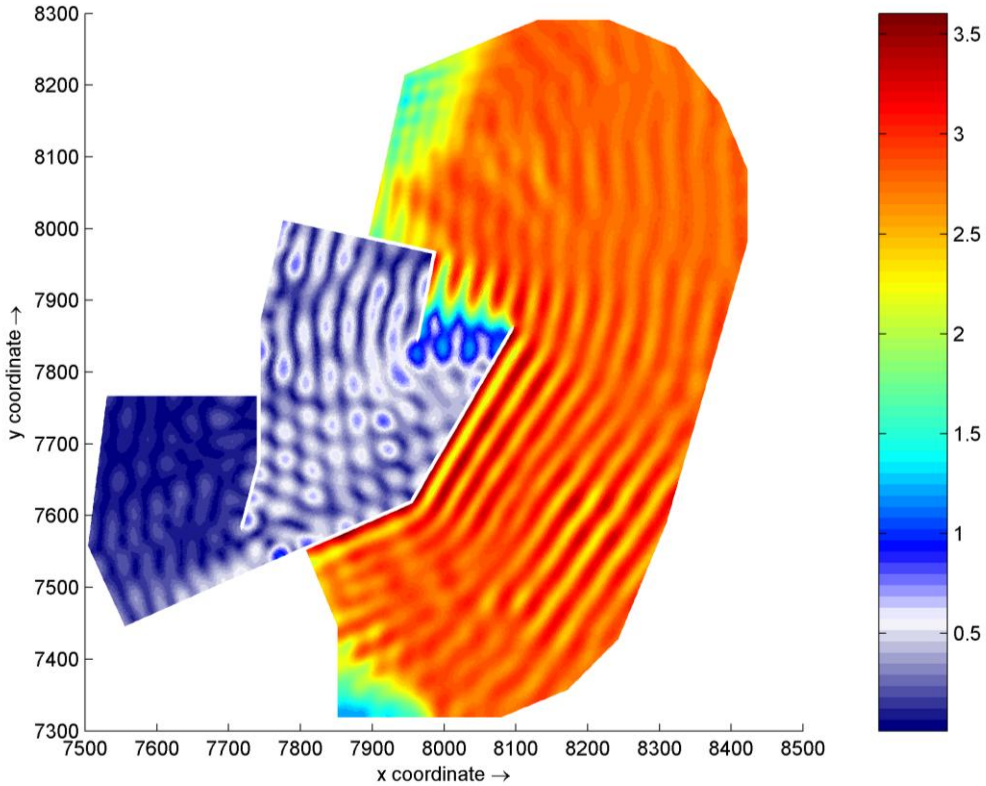


figure 87: Weighted mean wave height layout B, waves from 112.5°N

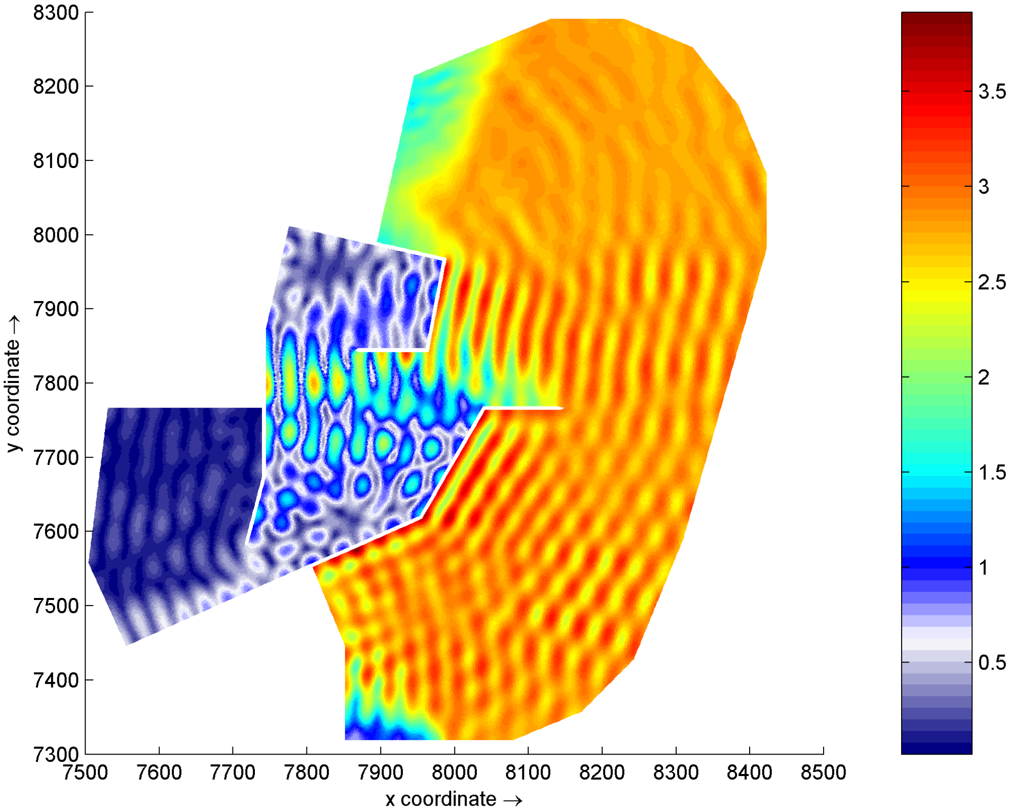


figure 88: Weighted mean wave height layout C, waves from 112.5˚N

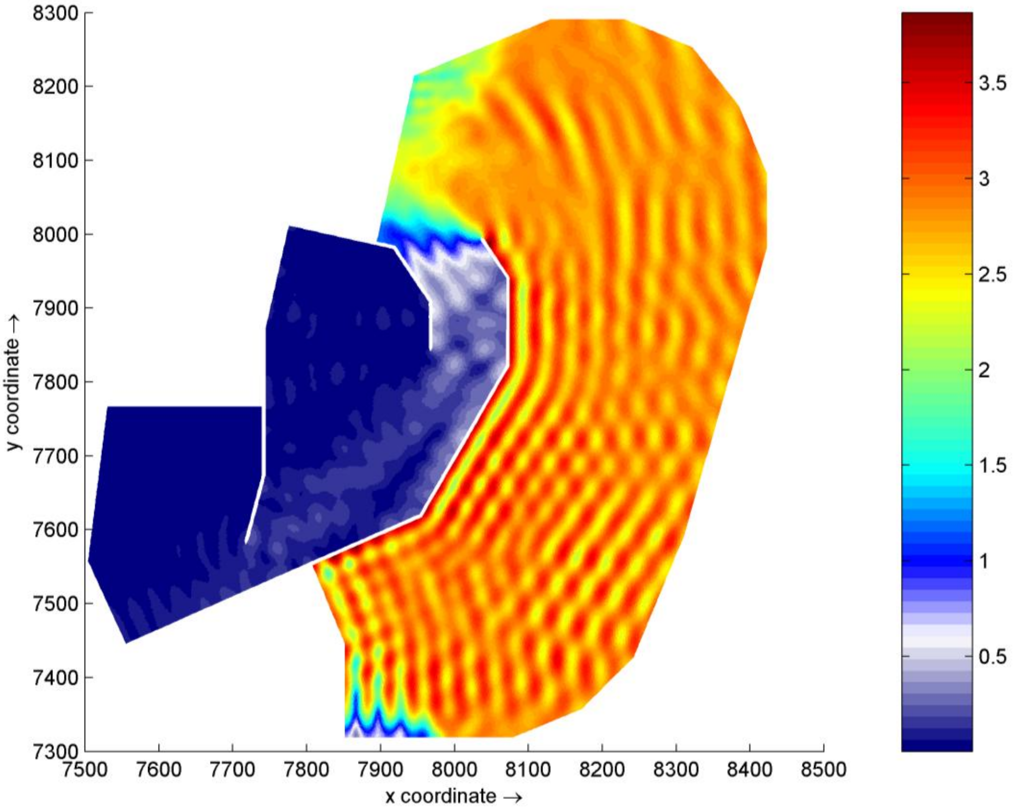


figure 89: Weighted mean wave height layout D, waves from 112.5˚N

9.1.5 Discussion output hydraulic modeling

General

For all layouts, the waves from ESE direction lead to the wave pattern with the highest waves within the coastal haven. A total of 3.3% (Argoss, 2009) of the waves originate from this direction, and this scenario is thus likely to occur during the lifetime of the coastal haven.

If we look at the sub directions (67.5, 90, 135, 157.5 °N) modeled for the main direction ESE, it can be concluded that waves from 67.5°N are responsible for the highest waves within the layout alternatives. This direction to a certain extend determines the result that is represented by the weighted mean wave height.

Layout B (figure 87)

Waves from 112.5°N lead to a complex diffraction and reflection pattern within the coastal haven basins of layout B. The highest waves are visible at the entrance and along the southern boundary corner of the existing basin. At some points of the diffraction and reflection pattern, the wave height exceeds the critical value of 0.6 m.

With an optimization of the configuration and length of the southern breakwater, the wave heights within the coastal haven can be reduced. By lengthening it in northward direction the blockage of waves from ESE direction will be increased and the wave heights in the back of the coastal haven are expected to reduce.

Layout C (figure 88)

For layout C the waves run easily into the coastal haven from the eastern direction. This wave penetration leads to an unallowable wave height along the quays and in the marina section for the larger yachts. Waves of 2 to 2.5 m will lead to extensive damage to the vessels and pontoons berthed in the coastal haven during these storm conditions.

The fishing port however seems to be moderately sheltered by the additional landward directed breakwater. Wave heights above the critical value of 0.6 m are however still visible.

The configuration of the northern breakwater needs to be optimized further and additional measures for the southern part of the coastal haven need to be taken in order to create a layout that can provide the required shelter as well.

It must be said that this layout is the more open alternative and the wave height in the central part of the coastal haven will in general be higher compared to the other alternatives. The port of refuge area, located in the central part of the coastal haven, will have limited shelter in this alternative.

Layout D (figure 89)

The completely closed off alternative, layout D, shows no severe diffraction and reflection pattern within the coastal haven basins. Wave heights approaching the critical value are visible at the entrance of the coastal haven and a diffraction pattern with this wave height runs towards the south. This breakwater configuration will provide the most shelter of all the layouts during the prevailing wave conditions.

9.1.6 Conclusions hydraulic modeling evaluation

- The coastal haven maritime infrastructure requires a very closed off basin in order to reduce the wave height below the critical value. The breakwaters should have a large overlap in order to limit the wave penetration into the basin.
- Waves from 112.5°N in combination with the assumed amount of directional spreading result in the normative conditions for all three layout alternatives.
- Layout B is able to provide shelter up to a wave height of approximately 1.0 m within the basin and 1.25 m at the entrance. Layout optimization is needed in order to provide full shelter under once in 50 years conditions.
- Sub direction 67.5 °N of main direction 112.5°N result in the highest waves in layout B.
- Layout C is too much of an open layout; additional measures are required to reduce the wave height in the berthing area of the coastal haven.
- Sub direction 90°N of main direction 135°N is the direction that induces the highest waves in layout C. Reflection against the quays within the coastal haven results in high waves in the central part of the coastal haven.
- Layout D is able to provide full shelter for all occurring and normative wave conditions.
- Sub direction 67.5°N of main direction 112.5°N is the direction that induces the highest waves in layout D

9.1.7 Effect of reduced directional spreading

Adjustments

It can be concluded that the sub directions (especially 67.5°N) have a large influence on the results. These sub directions are introduced to model directional spreading. The effect of a reduced number of sub directions is looked further into in this additional section.

In the previous sections the layout alternatives were modeled with four sub directions for each main direction. This was done in combination with a directional distributional parameter m of 4 and 5 (see table 42).

The results for this section are based on a model with directional spread that is modeled with the same values for parameter m, but the number of sub directions is reduced to two. In this way, the directional distribution reduces from the one in figure 90 to the one in figure 91 (the modeled directions are indicated with red lines). Side effect of reducing the number of sub directions is that the 2 sub directions will have approximately the same weight as the main direction in the weighted mean wave height. This is indicated in the top right corner of the two figures.

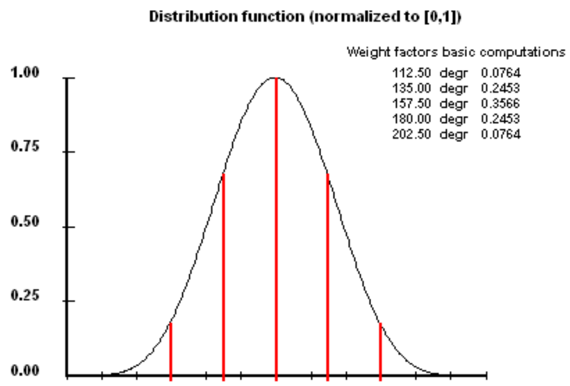


figure 90: Directional distribution 4 sub directions for main direction 112.5°N

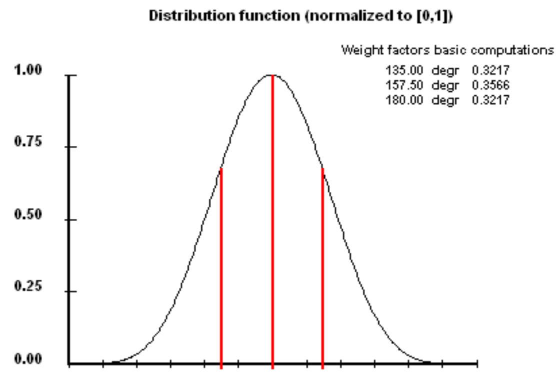


figure 91: Directional distribution 2 sub directions for main directions 112.5°N

Results

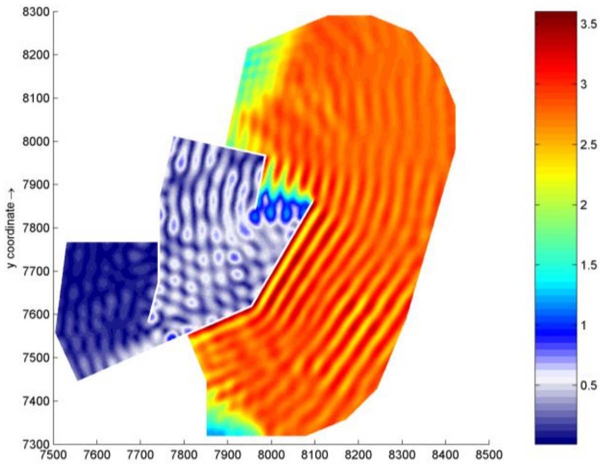


figure 92: Weighted mean wave height distribution 4 sub directions layout B main direction 112.5°N

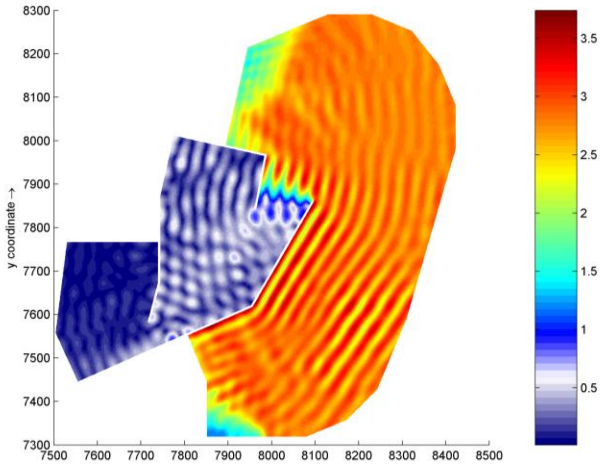


figure 93: Weighted mean wave height distribution 2 sub directions layout B main direction 112.5°N

From the figures above it can be concluded that reducing the directional spreading to two sub directions, 22.5 degrees towards the north and south of the main direction, leads to a reduction of the wave heights in the weighted mean wave height. For layout B the difference is visible between figure 92 and figure 93. There are still points within layout where the critical wave heights of 0.6 m is exceeded, but at much less locations compared to the results from the modeling with 5 sub directions.

For layout C the effect of the adjustments is also visible, but wave heights are still above the critical value. The results for layout D do not show a significant deviation.

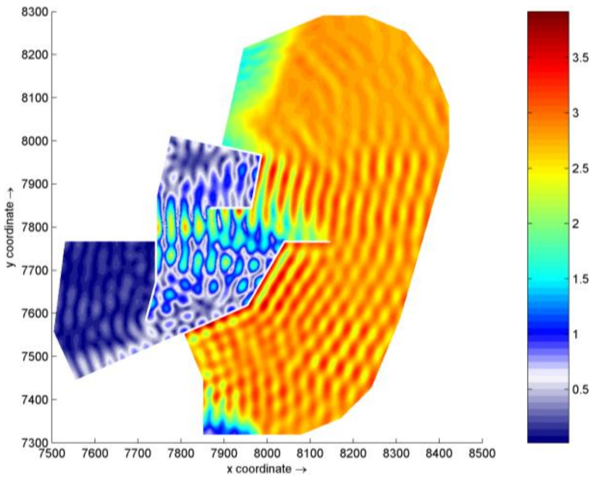


figure 94: Weighted mean wave height distribution 4 sub directions layout C main direction 112.5˚N

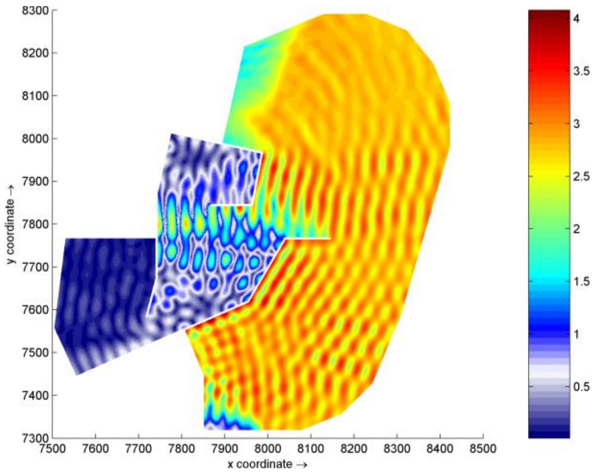


figure 95: Weighted mean wave height distribution 2 sub directions layout C main direction 112.5˚N

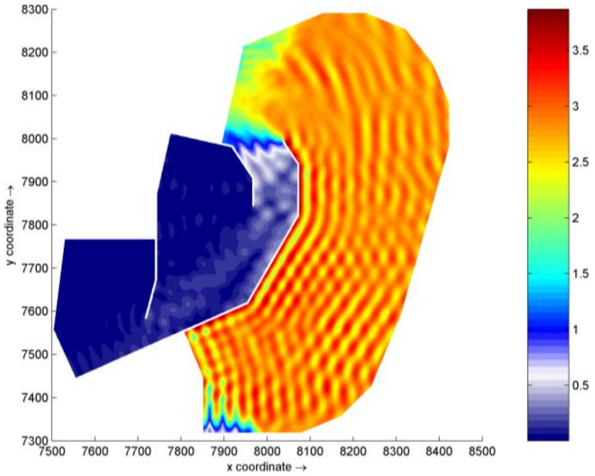


figure 96: Weighted mean wave height distribution 4 sub directions layout D main direction 112.5˚N

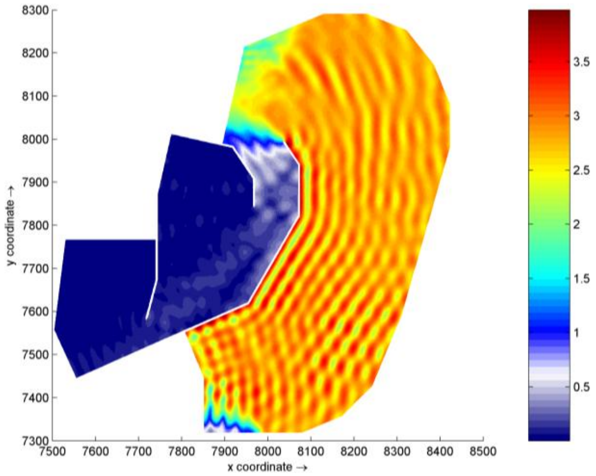


figure 97: Weighted mean wave height distribution 2 sub directions layout D main direction 112.5˚N

The purchased data set does not contain information about the directional spreading. Settings for this effect are based on default settings and advised settings by experts. Assumptions are made in order to take this into account during the modeling. Research into this aspect is therefore recommended in order to model this in a correct way. This will result in hydraulic models that are able to represent the real situation better.

9.2 Multi criteria evaluation

9.2.1 Introduction

To make a comparison between the layout alternatives, a Multi Criteria Evaluation (MCE) is applied. This is a decision making tool is particularly applicable to cases where a single criterion approach, such as a cost-benefit analysis, is not enough.

The multi criteria evaluation will be used to assess the alternatives by a number of weighted criteria (1 is not important, 5 is very important). The different alternatives are scored (where 1 point is the minimum score and 5 points is the maximum score) for each criterion, which will be multiplied by the weighing factor of the criterion. The results are summed up to get a total score for each solution. This way, a better alternative gets a higher score.

The criteria used for the evaluation are described in the next section (9.2.2). The weighing of these criteria is described in 9.2.1. The score of the alternatives and the result of the MCE can be found in 9.2.4.

The alternatives differ not only in the way they offer protection against storm conditions and their score on criteria, but also in required investments. The breakwater length, the depth at which it has to be constructed and the required volume to be dredged are some of the main components when creating the coastal haven. Other main components are the quays and land-side infrastructure. Since these components do not differ significantly between the alternatives these are not treated in detail. The main components are thus the distinctive components resulting in alternatives investment costs. These are taken into account in the alternative comparison on the aspect of required investment costs. An assessment of these investments is done in 9.2.4.

This chapter is concluded with the preferable alternative selection. This is done based on the hydraulic modeling result, MCE results and the investments costs comparison.

9.2.2 Criteria

The criteria on which the alternatives are evaluated are explained in this section. The allocation of the landside facilities does not differ a lot between the layout alternatives, since the focus during this research project was on the breakwater configuration and the modeling of these configuration. No criterion on this aspect is therefore part of the evaluation, since the alternatives will not score differently. Different land-side facilities layouts are possible to investigated, but this is beyond the scope of this research project.

Nautical accessibility

The ease to enter the coastal haven during normal conditions is evaluated with this criterion. The coastal haven is located along the Arabian Gulf coast. Vessels will approach the coastal haven mostly from the east. The focus during the score on this criterion will be on the complexity of the route that the vessels have to sail to enter the coastal haven.

Nautical safety

This criterion focuses on entering safely during once per 50 years conditions. The angle between the entrance and the prevailing wind and wave direction is an important motivation behind the ranking. Beam waves can result in vessels ending up at one of the breakwater heads and this can result in extensive damage. Furthermore, wave breaking and the wave height at the entrance are taken into account in scoring on this criterion.

Nautical maneuverability

The space to maneuver within the coastal haven basins is another criterion that evaluates the nautical quality of the alternatives. The possibility to separate the target user groups by dedicated inner channels is also part of the score on this criterion.

Extension possibilities

The area around the coastal haven available for future extension is the most important aspect of this criterion. The required measures to make an extension possible and the reusability of existing infrastructure as a part of a future extension are also considered.

Sedimentation

The expected relative degree of sedimentation at the entrance and in the basins of the alternatives is evaluated with this criterion. For each alternative the water depth where the breakwaters ends is looked into. The blockage of the long shore transport will not be the same for the alternatives.

Environmental impact

The spatial claim of the layout alternatives is expressed with the environmental impact criterion. A high spatial claim influences the score on this criterion in a negative way. Other aspects considered within this criterion are the degree to which the area around the coastal haven will be subject to changes due to the degree of sediment blockage. Large breakwaters extending far into the sea create an artificial gradient in the natural environmental conditions. A large interruption of the natural coast will lead to a lower score on this criterion.

9.2.1 Weighing of criteria

For all criteria, a weighing factor is determined. The most important criteria are given a high weighing and the less important criteria a low weighing factor. This weighing factor, in combination with the score of the alterative on the criteria, results in a final score for each layout.

The nautical accessibility and safety are both very important criteria and are therefore provided with the highest weighing factor (5). The accessibility of the layout and the safety during storm conditions to a large extend determine the suitability of the breakwater configuration. The nautical maneuverability is important for the vessels that are already in the coastal haven. It is not one of the main functions of the coastal haven and gets therefore the weighing factor 2.

The extension possibilities are of interest on the long run. This is not the most important criterion for the evaluation of the current layout alternatives, which are already an extension of the current situation, and are therefore given a weighing factor of 1.

The environmental impact is becoming a more important criterion and this criterion gets a weighing factor of 4. The functionality of the coastal haven is, besides the nautical accessibility and safety, the most important criterion during the evaluation of the layout alternatives. This criterion is therefore also provided with a weighing factor of 5.

The sedimentation of the coastal haven has a strong relation with the maintenance costs of the coastal haven. A high degree of sedimentation results in high maintenance costs. This influences the feasibility of the coastal haven. This aspect is important, but not a lot of information is available on this aspect. It is therefore given a weight of 3 in the evaluation. More research into this topic is required.

9.2.2 Scoring of alternatives on criteria

Nautical accessibility

If the route that the yachts and vessels have to sail to enter the coastal haven are compared, layout C scores best. Entering this layout from the south however is more complicated due to the breakwater that is extending into deeper water towards the east, therefore this layout scores 4 points. The entrance to layout B is more complicated since it is only accessible from a northwestern direction and scores 3 points for this reason. Layout D is the most complex to enter. The completely closed off layout is only accessible from northern direction and requires a more complicated route for vessels approaching from the east. This layout scores 2 points for this reason.

Nautical safety

If we consider the nautical safety layout C scores the least number of points. This layout showed high waves at the entrance and inner channel during the hydraulic modeling and scores therefore only 1 point on this criterion, although entering is possible with aft seas. Layout B and D show better conditions at the entrance of the coastal haven. Layout B shows shows wave conditions above the critical wave height at the inner channel, and D does not. Entering layout B and D has to be done with beam and head seas the majority of the situation and are therefore scored with 3 and 4 points respectively.

Nautical maneuverability

The separation of the yachts and vessels in the entrance channel is most easily in the layout with a somewhat larger inner channel. Both target user groups have more time to adapt their course along inner channel. Layout B and D scored for these reason 4 point and C 2 points. In this layout the yachts have to enter the marina section almost immediately after entering the coastal haven.

Extension possibilities

All three layouts are bounded by the Al-Bida at the southern end. The entrance channels of layout B and D claim the northern part of the land around the coastal haven. Extension of these layout alternatives is only possible towards the west, into deeper water. This is not preferable, since breakwaters at deeper water requires significant investments. The extension of layout D is the most complex one due to the entrance channel and this alternatives scores therefore 1 point. Layout B has more land space available for extension and this layout scores therefore 2 points. Layout C leaves the land area north of the coastal haven untouched. This land in combination with the breakwater configuration creates a score of 4 points on this criterion for this alternative.

Sedimentation

The breakwater configuration is not only based on the degree to which they provide the required shelter against waves but also on the degree they protect the inner basin against sedimentation. Layout C is the most open layout and sediment that transport along the southern breakwater can easily enter the coastal haven basins. Although the breakwater extend into deeper water compared to the other layouts, the score of this layout on this criterion is 2. The sediment transport in northern direction is expected to have more difficulties entering layout C and even more in case of layout D and these alternatives are therefore scored with 3 and 4 points respectively.

Environmental impact

The spatial claim of the entire layout, including the entrance channel area and breakwater is the largest in case of layout D. This layout needs all the area north of the coastal haven to make the entrance from a northern direction possible. Besides this aspect all layouts from an obstruction for the long shore sediment transport, layout C the largest, because this layouts extends the furthest into the Arabian Gulf. Layout B requires less surface area for its entrance channel, but still influence the area north of the coastal haven. Layout B scores 2 points on the environmental impact criterion. The entrance channel of layout C in east-west direction and claims in this way the least surface area, it forms on the other hand the largest sediment blocker of the three layout alternatives and scores therefore 3 points.

9.2.3 Result MCE

Evaluation criteria	Weighing	Layout B	Layout C	Layout D
Nautical accessibility	5	3	4	2
Nautical Safety	5	3	1	4
Nautical maneuverability	2	4	2	4
Extension possibilities	1	2	4	1
Sedimentation	5	3	2	4
Environment impact	3	2	3	1
Total score		**61**	**54**	**62**

table 44: Scoring table MCE

9.2.4 Investment cost comparison

As mentioned earlier, the investments concerning the construction of the breakwaters and the dredging works are the main aspects to consider. The berthing infrastructure and the land-side facilities are comparable for the three alternatives and therefore not further quantified.

A rough estimation of the required investments for each alternative is made. This estimation is based on key figures for dredging works and breakwater construction.

<u>Dredging works</u>

For the dredging works, 5 €/m^3 is used to determine the investments cost. This figure is based on the assumption that the material to be dredged is sand and is based on Dutch prices. The price per m^3 depends, besides the type of material that has to be dredged, on the type of equipment, the amount to be dredged and the situation.

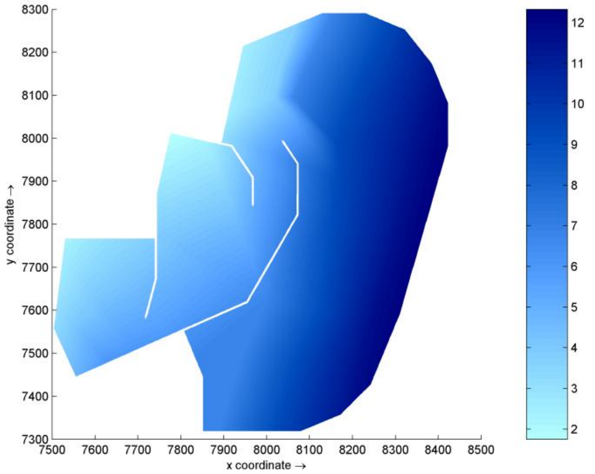


figure 98: Water depth reference situation

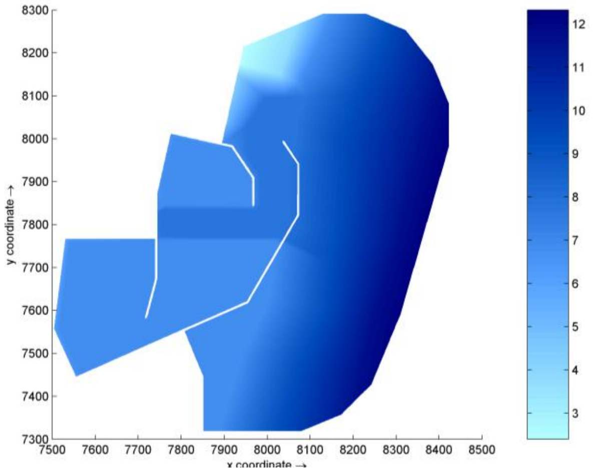


figure 99: Water depth layout D

The amount of material that has to be dredged for each alternative is based on the computational grids from PHAROS. A basic bathymetry (figure 98), without the user-defined bathymetry for each coastal haven basin is used as reference volume. The volume difference between the volume for each layout alternative (figure 99) and the reference volume is used to determine the volume that has to be dredged for each alternative. This is a not very exact approach, since the depth lines from the admiralty chart are a very rough indication of the bathymetry, but it is used for this first rough estimation.

	Layout B	Layout C	Layout D
Volume computational grid (m^3)	3,567,250	3,552,520	3,618,740
Reference volume (m^3)	3,100,620	3,100,620	3,100,620
Volume to be dredged (m^3)	466,630	451,900	518,120
Investments costs dredging (€)	2,333,150	2,259,500	2,590,600

table 45: Investment costs dredging works

Breakwater

The breakwaters are assumed to be of the rubble mound type without any additional concrete crown wall element. The minimal width of the rubble mound at the crown is 5 m to allow land-based construction. A design wave height of 3.5 m at high water CD+3.5 m is taken as design condition. These figures combined up with a wave run-up addition of 10% results in a crest level at CD + 7.5 m.

The key figures for the breakwater are based on Dutch prices for construction material and installation. A rough estimation is made of the core material and the armor layers including a heavy toe structure. The assumed slope of 1:2 for the breakwater slope for the previous phase is used in the estimation. Per running meter breakwater at 5 m water depth (LAT) a price of € 20,000 is used. For a breakwater at 6 m water depth (LAT) the investment costs are estimated somewhat higher at € 22,000 per running meter.

A design of the breakwater is required in order to give a detailed and more exact indication of the investments for the breakwaters. It is, amongst others, dependent on the availability of construction material, design requirements, allowable overtopping, maximum amount of overtopping and the design heights of the breakwater structure and the function located directly behind the breakwater structure.

	Breakwater length/investments		
Water depth (LAT)	**Layout B**	**Layout C**	**Layout D**
6m (m)	745	745	650
5m (m)	115	215	395
Investment costs	**€ 17,430,000**	**€ 19,630,000**	**€ 21,690,000**

table 46: Investment costs breakwater construction

<u>Investment costs main components per alternative</u>

	Layout B	Layout C	Layout D
Investment costs dredging	€ 2,333,150	€ 2,259,500	€ 2,590,600
Investment costs breakwaters	€ 17,430,000	€ 19,630,000	€ 21,690,000
Total	**€ 19,763,150**	**€ 21,889,500**	**€ 24,280,600**

table 47: Total investment layout alternatives

9.2.5 Ratio MCE value and investment cost

In order to combine the results of the multi criteria evaluation and the required investments, the ratio between these two figures is determined. This ratio represents the effectiveness of the investments in relation to the created value according the score in the MCE. With the ratio and the results from the hydraulic modeling it is possible to conclude this chapter with the selection of the preferable layout alternative.

	Layout B	Layout C	Layout D
Points scored MCE	61	52	62
Investments costs (10^6)	19.8	21.9	24.3
Value – investment ratio ((MCE point/ €*10^6)	**3.08**	**2.37**	**2.55**

table 48: Total investment layout alternatives

9.3 Selection optimum layout

In general, layout C is too open and this results in a low score in the MCE and still requires considerable investments, since considerable breakwater length is required in order to construct this coastal haven layout.

A relatively closed layout alternative is thus preferable. Layout B and D comply to this design requirement. From the hydraulic modeling study it can be concluded that layout D is the only layout that is able to provide the required shelter. Layout B is expected to be able to provide the required shelter as well if this layout is optimized.

Layout D is also the optimum layout according the value from the multi criteria evaluation. However, if we look at the value – investment cost ratio in section 9.2.5 layout B is the optimum layout. The value in relation to the investment cost scored are the largest for this layout. Layout B needs to be optimized to provide sufficient shelter in order to meet the design criteria. This will lead to higher investment costs for this layout alternative. The required additional investment cost for optimization are expected not to exceed the difference in investments between layout B and D (€ 4.2 milion) and layout B is therefore selected as most optimum layout. Additionally can be mentioned that layout B is easier to construct (more straight parts). The result from MCE is taken as final result and layout B is expected to be able to give the required protection with slight additional investment costs.

10 Layout Al Syadeen

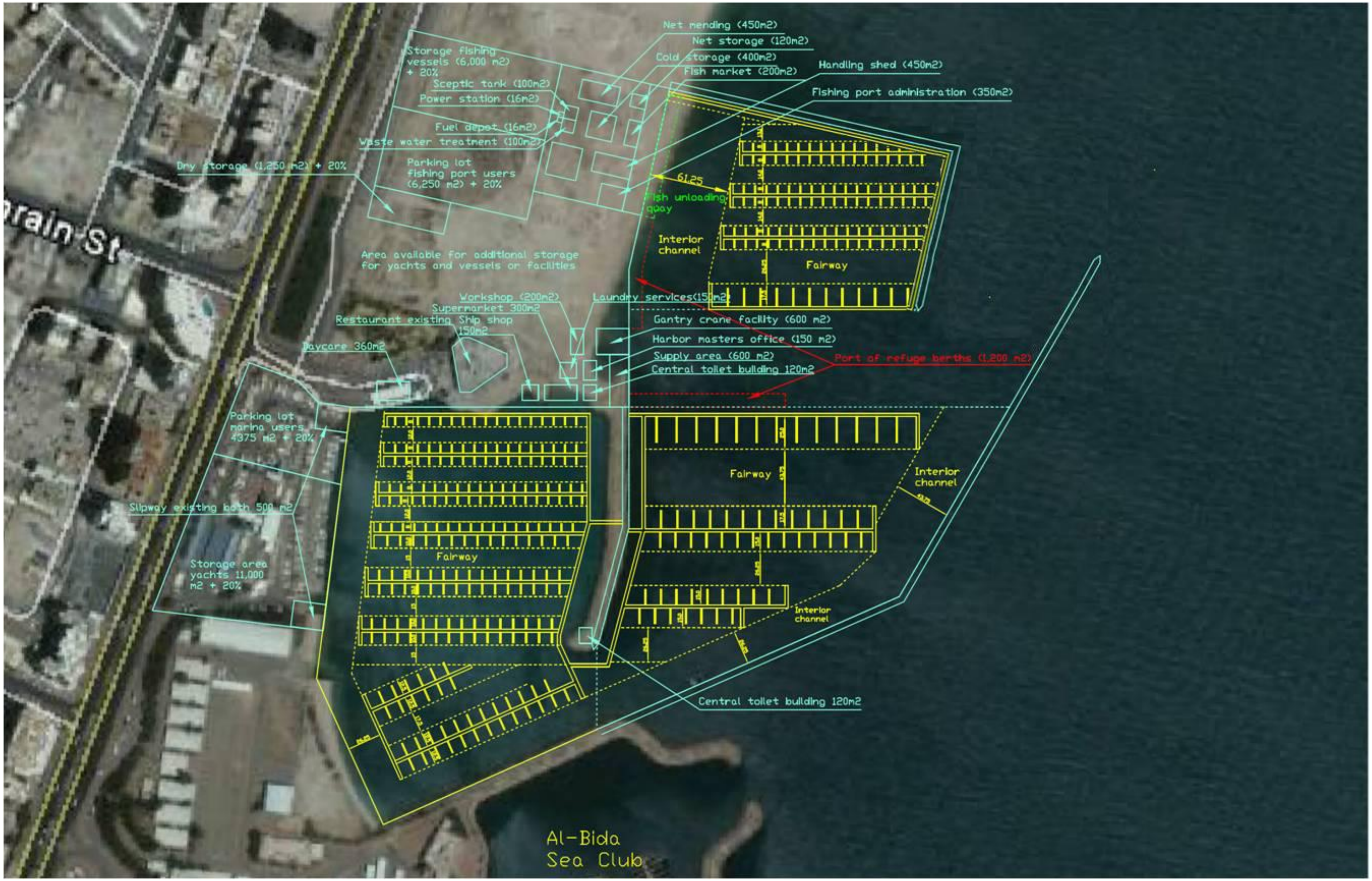


figure 100: Final layout Al Syadeen

11 Conclusions

Locations

- Three of the 9 indicated locations by the Kuwait Government are existing coastal havens. One of the 6 remaining locations has limited maritime infrastructure, at the 5 other locations very little or no maritime infrastructure is present and the potential success of a coastal haven at those sites is closely linked to the development that will be deployed there.

Target user groups

- There are approximately 2,000 yacht berths in Kuwait, all fully occupied. Furhtermore, there are 16,000 “dry berths” or yachts stored in backyards and parking lots.
- The number of vessels moored in and stored in the area around the marinas is assessed at 2,100 yachts.
- In the existing coastal havens a total of 660 speedboats used for fishing are counted and in Kuwait are approximately 160 fishing dhows are present.

Development forecast scenarios

- Not a lot of growth is expected for the fishery industry. A small increase in the number of fishing vessels is accounted for in the master plan. The existing restrictions for the fishing industry are one of the factors that limit the development possibilities.
- The population is expected to keep increasing until 2030. Together with the favorable economical climate and the reasonably developed yachting industry this resulted in a master plan in which more than a tripling of the number of required wet berths is taken into account.
- The yachting industry in Kuwait is reasonably developed. The user category or owners of yachts are the indigenous population of Kuwait.

Appraisal coastal waters

- By developing facilities for yachts on the islands in the Kuwaiti territorial waters, the islands can become a more interesting destination for yacht owners. By improving the infrastructure on the other islands, yachting will get a positive impulse.
- Various development projects are planned or under construction in Kuwait, which can result in a positive effect on the popularity of yachting. More destinations demand and capacity is created in this way.

Master plan

- In general, the existing coastal havens are the locations for which further development and modernization is preferred in the master plan. The locations that are located far into the Kuwait Bay do not have enough potential to be developed as full-service coastal havens. For one of these locations no development is recommended at all. For two of the additional investigated locations, a modest marina function is recommended.
- All locations for which development is recommended are allocated with marina function. This is also done in order to live up to the high yachting demand potential that is currently present in Kuwait and will probably only increase in the future.

Generalized layout

It can be concluded that a coastal haven is built up out of several elements from the three main functions of a coastal haven: to provide services that can be expected from a marina, a fishing port and a port of refuge. These functions are interrelated if all target groups are present in a coastal haven and the coastal haven is to be developed as a full-service coastal haven. From this analysis it is concluded that certain facilities and functions can be combined and others need to be strictly separated. Facilities related to the fishing industry need to be separated as well as the moorings. Supply facilities, if adapted to the various types of vessels can for example be combined in one facility.

Hydraulic modeling study

- The extreme wave heights that are expected to be of interest for the modeling of the layout of Al Syadeen, originate from the south-southeast, southeast and east-southeast direction. These waves are generated on the approximately 900 km long Arabian Gulf. The design wave height (H_S) for these directions is 2.75 to 3.75 meter at the offshore data point.
- The layout must be relatively closed off to provided enough shelter during design conditions. A large entrance channel width in combination with the modeled directional spread requires a layout in which an entrance with large overlapping length of breakwaters at the entrance is required.
- From the results of the hydraulic modeling it is concluded that the directional spreading modeled in the applied PHAROS model has a significant influence on the results.

Layout Syadeen

From the results of the hydraulic modeling study and multi criteria evalution, it is concluded that the alternative with the least breakwater length is the most optimum alternative if it is optimized to provide sufficient shelter.

12 Discussion and recommendations

12.1 Discussion

Several decisions made and sources used during this research project, might deserve a more careful consideration. It is therefore advised to reassess the following aspects and consider their importance the final result.

Development of yachting demand potential

The yachting demand potential analysis in this research project is based on information retrieved from the internet and technical literature that was available worldwide. Information from the Kuwaiti authorities was not part of this analysis, some information became available during the project, but this was after the phase that the master plan was made and is therefore not included. More research on the aspects that play a role in this analysis could lead to a better estimation of the yachting demand potential development in Kuwait and explain the large difference between the amount of wet and dry storage in the country.

Fishing industry development

The development analysis of the fishing industry was largely based on the international statistics and data from the Middle East. To give a better indication of the development of this industry, more recent and more localized statistics need to be included.

Hydraulic models

<u>Bathymetry</u>

The bathymetry was obtained from two admiralty charts and was manually digitized. This information was interpolated with the use of various computer programs. During this research project, this was the most up to data available, but it did not have a very high resolution. The reliability of this bathymetry has a large influence on the outcome of the hydraulic models and the estimation of the investment costs.

<u>Modeling grid SWAN</u>

To give more detailed information on the output points of the hydraulic models, a more detailed SWAN model should be set up. This should be done in combination with more detailed and recent bathymetry. The SWAN model can be set-up with the use of a nested model. This was not done during this research project because the bathymetry was not of sufficient quality and setting-up a nested model was too time consuming.

The suggested nested grids for the SWAN model are:

- Course grids of Arabian Gulf, resolution 400x400 m

- Medium grid Kuwait Bay, resolution 100x100 m
- Fine grid Coastal Haven, resolution 25x25 m

Calibration hydraulic model

The quality of the numerical model and the determination of several properties of the model, depend on the reliability of the available data. The limited amount of bathymetric data made it hard to create a reliable model. The model was not calibrated with an offshore wave buoy. Verification and calibration of the hydraulic was not part of this research project, the reliability of the model output was thus not determined.

Directional spreading

From the results from the hydraulic model PHAROS, it was concluded that the modeled directional spreading is an important model parameter. The directional spreading in the model was however based on assumptions; further research into this topic could result in a more reliable hydraulic model.

Discussion information obtained from the mission to Kuwait

A master plan is already outdated before it is finished, due to developments on the way. In December, I got the opportunity to visit Kuwait for the DHV project. Then I found out that my interpretation of some aspects was corresponding with reality quite well. Some aspects were different than I concluded from the literature study though. Some aspects may have an impact on the outline of the master plan and are therefore treated below. This information is not included in the master plan of this master thesis.

Regulations for fishing industry

There already were strict regulations and restrictions for the fishing industry in Kuwait. The latest information is that fishing is no longer allowed in the Kuwait Bay. This has a serious impact on the function of the coastal havens in the Kuwait Bay.

Indication of locations corresponding with the reality

For some of the locations, the destination and the ownership was not yet clear during my research project. For some locations, this became clear during my visit. The exact ownership and development direction is still disputable though. The client's wishes became clear during visit. This information was not available during the development of this master plan and is therefore not incorporated.

The desires of yachts owners, fishermen, public authorities and passenger transport companies also need to be taken into account when this information becomes available.

Berth prices in Kuwait

During an interview with marina managers of the existing marinas in Kuwait, it was concluded that prices for a berth are extremely high in Kuwait. This is also an indication for the need for additional berths in Kuwait.

12.2 Recommendations

Several improvements to the analyses and to collection of additional data could improve the results of this research project. Recommendations on these improvements are listed below.

Natural boundary conditions

Geotechnical data

To be able to make a detailed assessment of the construction costs and suitability of a location, more information on the soil characteristics is required. Geotechnical data was not available during this research project. This aspect does have a large influence on the investment cost to construct a coastal haven. The foundation of the breakwater and the quay cannot be constructed without this data. The type of soil for a large part determines the costs of dredging.

Sedimentation

Information on sedimentation rates and directions was not available. Collecting more information on this topic is advised. This information should be used to determine the degree of sedimentation and to adapt the breakwater orientation to this phenomenon.

Bathymetry

As stated before, the bathymetry has a big influence on the outcome of this research project. With a more detailed and recently measured bathymetry, the representativeness of the hydraulic models and investment cost analysis would increase. The interaction between the bottom and the waves is an important aspect in the hydraulic models. Furthermore, the bathymetry is used to determine the volumes to be dredged to create the coastal haven basins and the entrance channels.

Yachting demand potential analysis

More detail and greater representativeness in this analysis can be achieved when detailed statistics on the Kuwaiti yachts ownership are part of the analysis. Available data on the yacht licenses, yacht sizes, yacht ownership, disposable income, cost to own a yacht in Kuwait, waiting lists and fees for berths in Kuwait and the income distribution in Kuwait are aspects that need to be investigated and included.

Information on the development of new marinas and the geographical spread of the yachts and yacht owners is also not part of this analysis in the current master plan. This is interesting and essential information for the master plan though.

Fishing industry development analysis

The location of the fishing grounds in Kuwait are only roughly indicated. To adapt the master plan to this target user group, more information on the fishing grounds, fishing methods and sailing distances should be incorporated.

Hydraulic modeling study

Calibrating hydraulic models

It is advised to use wave buoy data to verify the output and reliability of the hydraulic models. This data could also be used to improve the models. The output of the models is now compared to hand calculations and figures provided in literature, but calibration with a wave buoy is preferred.

Shift offshore data point to the east

The offshore data point is located at 22.5 m water depth. This is relatively shallow water. It is preferable to move this location to deeper water and at the same time move the boundary of the modeled area to deeper water.

Directional spreading

The influence of the directional spreading on the hydraulic models is not yet fully investigated. Reducing the directional spreading in PHAROS leads to less wave penetration in the coastal haven basins. The effect of reducing the directional spread was investigated during this research project. More theoretical background on this phenomenon should be obtained to have a better understating of this phenomenon.

Layout Al Syadeen

To ensure the preferred width of the fairways within the marina section of the basins need to be increased. Due to the shape of the existing basins at Al Syadeen it is hard to fit in enough berths with the preferred fairway widths.

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Maps

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Programs

Google Earth

Surfer & Grapher, Golden Software

SWAN, Delft University of Technology

PHAROS, Deltares

14 Appendices

Appendix A. Kuwait economic figures

GDP in billion US$	149.1	in 2008 US$	2008 estimate
GDP in billion US$	137.4	in 2008 US$	2007
GDP in billion US$	131.2	in 2008 US$	2006
GDP in billion US$	159.7	official exch. rate	2008 estimate
GDP - real growth rate	8.50%		2008 estimate
	4.70%		2007 estimate
	6.30%		2006 estimate
GDP - per capita (PPP)	57,400	in 2008 US$	2008 estimate
GDP - per capita (PPP)	54,800	in 2008 US$	2007 estimate
GDP - per capita (PPP)	54,300	in 2008 US$	2006 estimate
GDP - compositoion by sector	Agricultur e	0.30%	2008 estimate
	Industy	52.20%	2008 estimate
	Services	47.50%	2008 estimate
Unemployment rate	2.20%		2004 estimate
Investments	18.40%	of GDP	2008 estimate
Budget			
Revenues in billion US$	113.3		2008 estimate
Expenditures in billion US$	63.55		2008 estimate
Public dept	7.20%	of GDP	2008 estimate
Inflation rate (consumer price index)		11.70%	2008 estimate
Central bank discount rate		6.25%	31 december
Commercial bank prime lending rate		8.54%	31 december
Stock of money in billion US$		15.12	31 december
Stock of quasi money in billion US$		55.20	31 december
Stock of domestic credit in billion US$		78.25	31 december
Industrial productional growth rate		8%	2008 estimate
Current account balance in billion US$		65.21	2008 estimate
Export in billion free on board (f.o.b.) US$		95.46	2008 estimate
Import in billion free on board (f.o.b.) US$		26.54	2008 estimate
Export partners	Japan 19.9%, South Korea 17%, Taiwan 11.2%, Singapore 9.9%, US 8.4%, Netherlands 4.8%, China 4.4%		2007
Import partners	US 12.7%, Japan 8.5%, Germany 7.3%, China 6.8%, South Korea 6.6%, Saudi Arabia 6.2%, Italy 5.8%, UK 4.6%		2007

table 49: Kuwait economic figures (CIA The World Fact book; 2009)

Appendix B. Map coastal havens (existing and assigned)

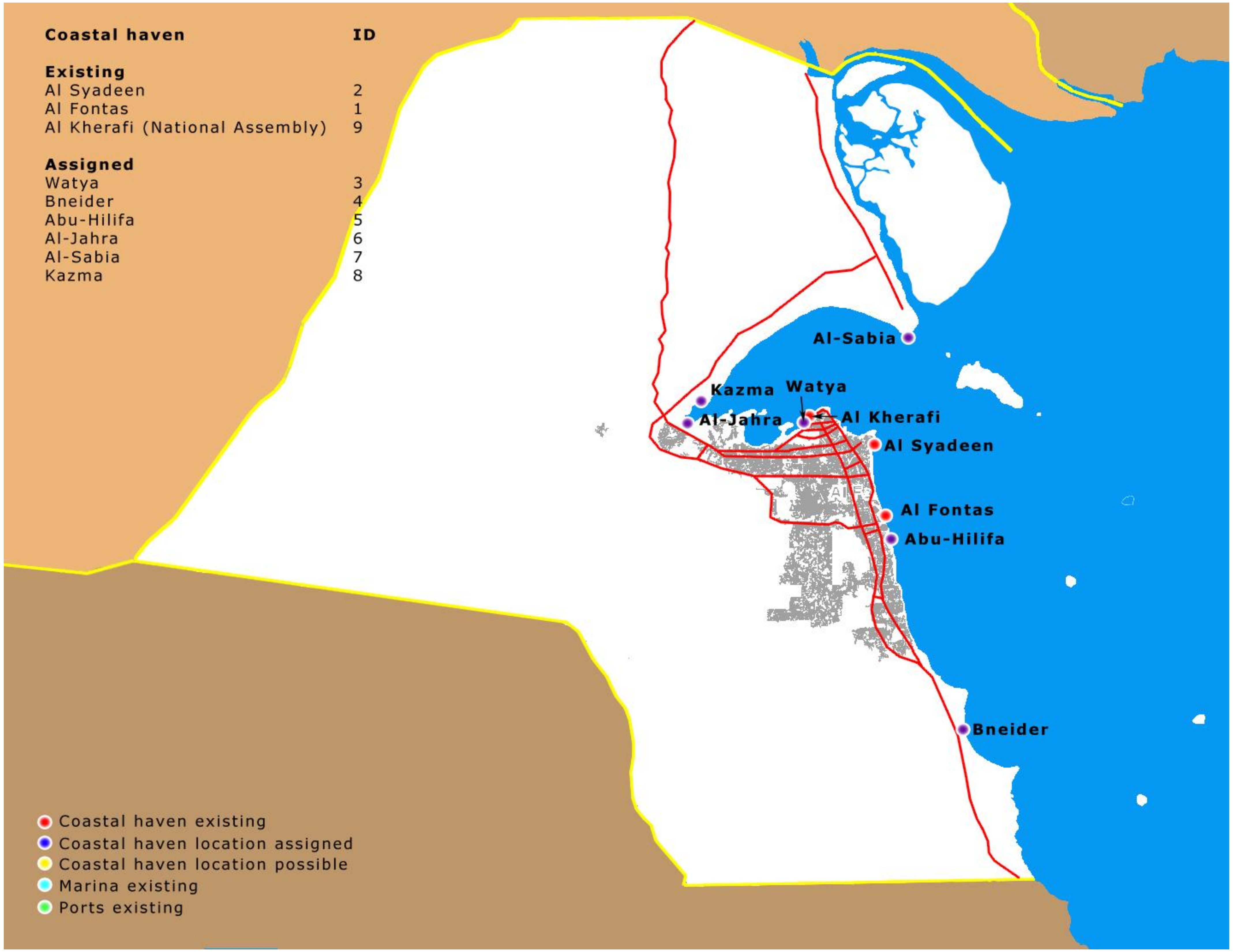

figure 101: Locations coastal havens

Appendix C. Map coastal havens all locations, islands, and commercial ports

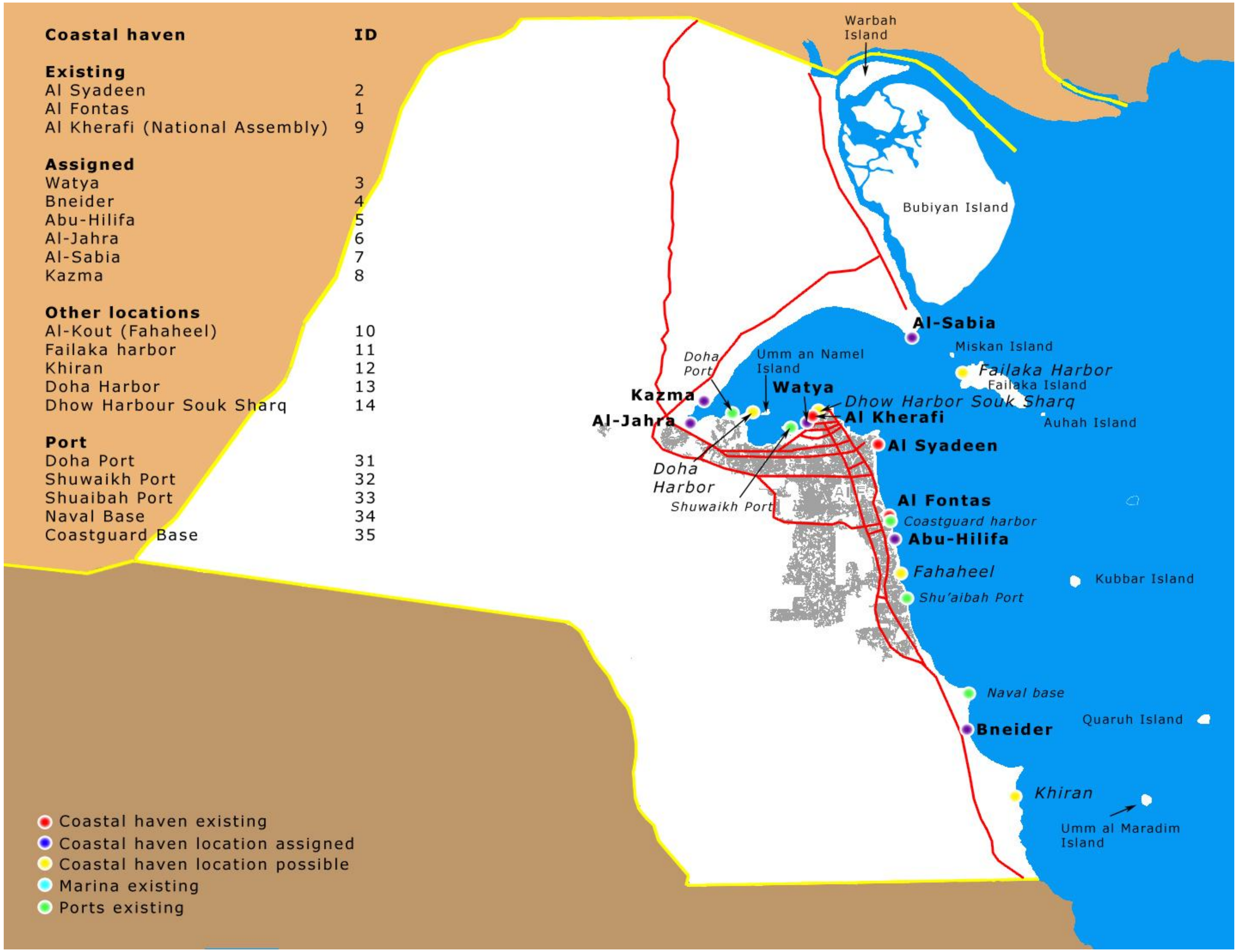

figure 102: All coastal haven locations coastal havens additional locations, islands and commercial ports

Appendix D. Maps location coastal havens, additional locations, marinas and port in Kuwait

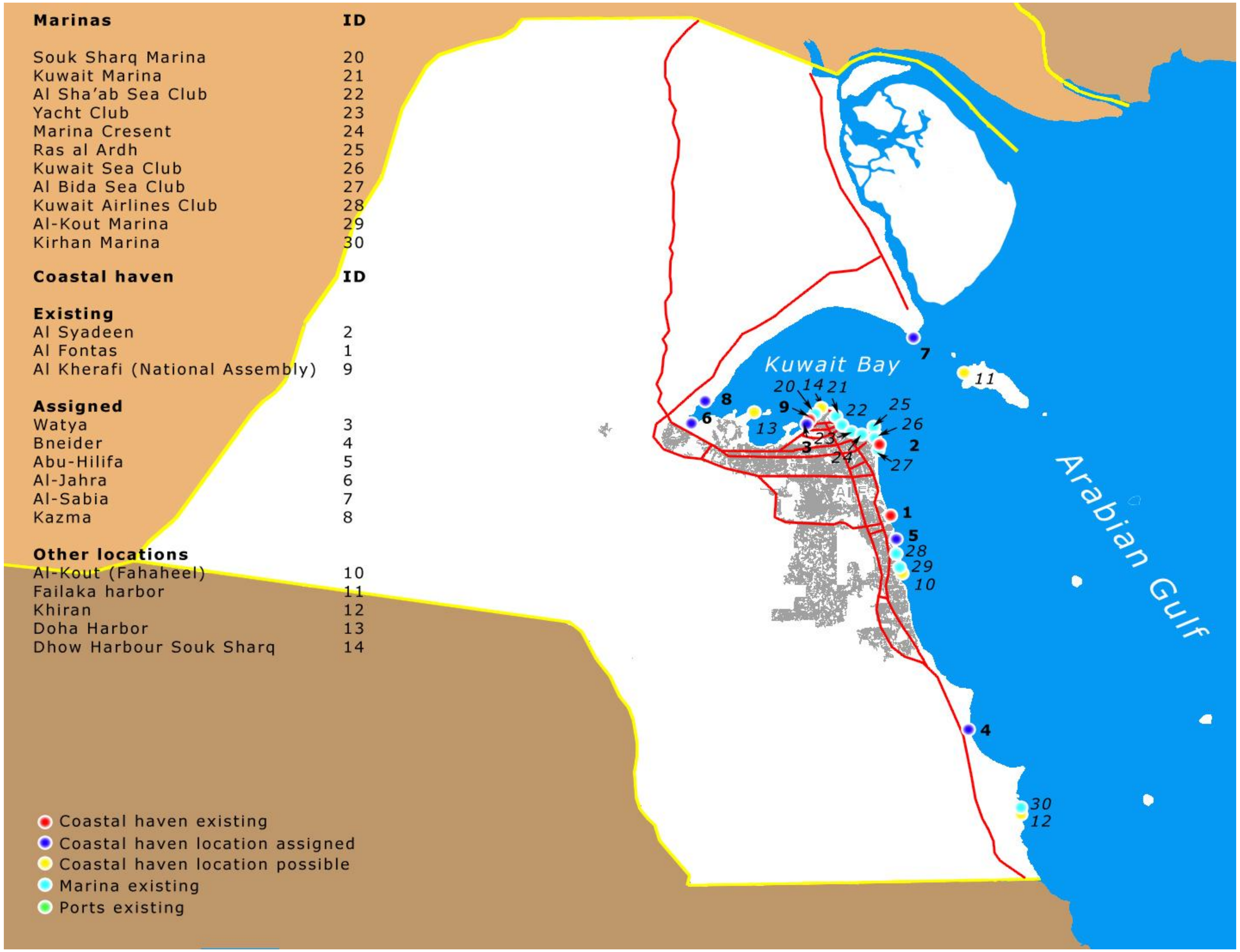

figure 103: Map location coastal haven existing, assigned and additional and marinas

Appendix E. Maps locations coastal havens, additional locations, marinas and commercial port in Kuwait Bay

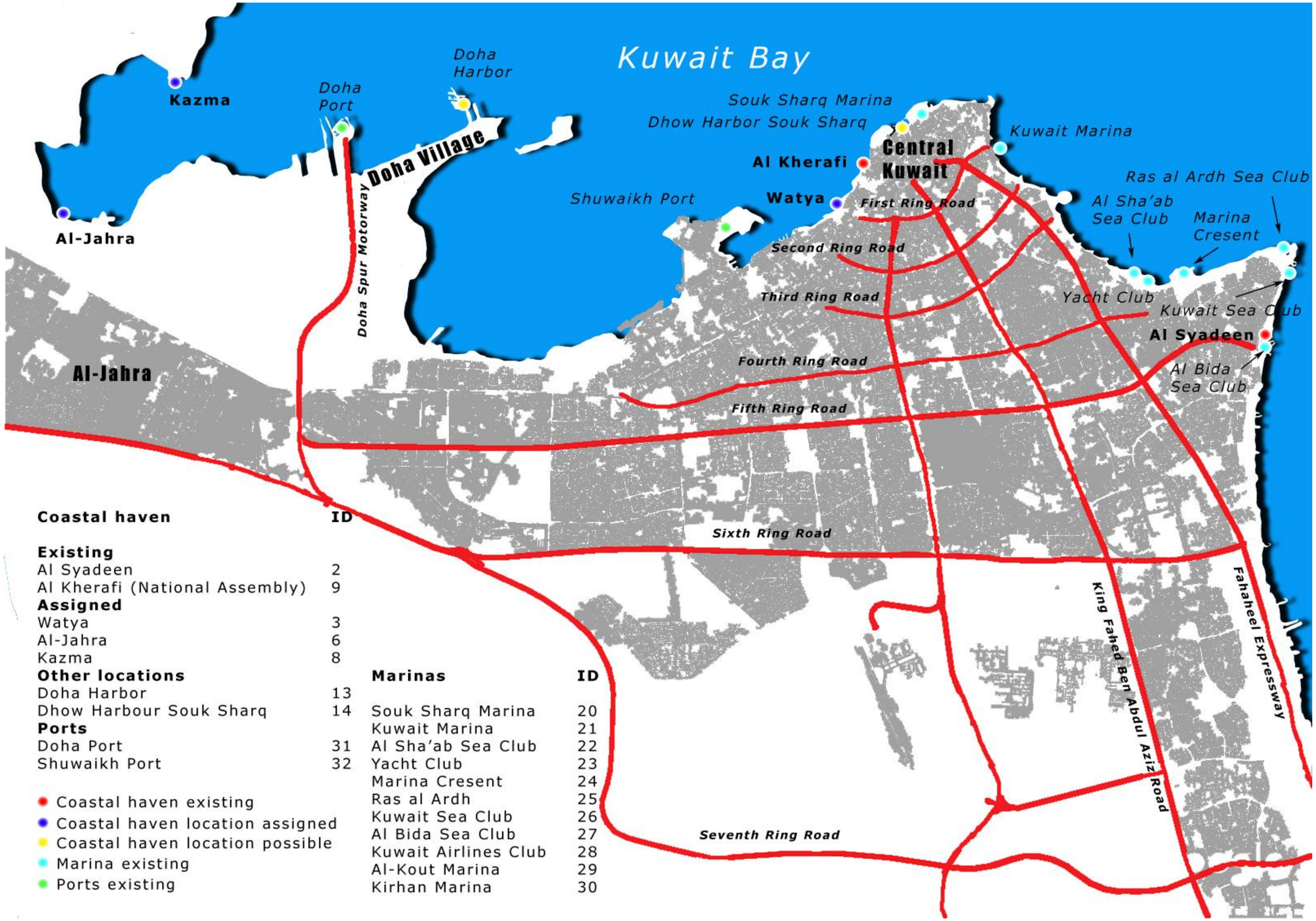

figure 104: Location of coastal havens, marinas and port in Kuwait Bay

Appendix F.Restricted areas admiralty chart 1214

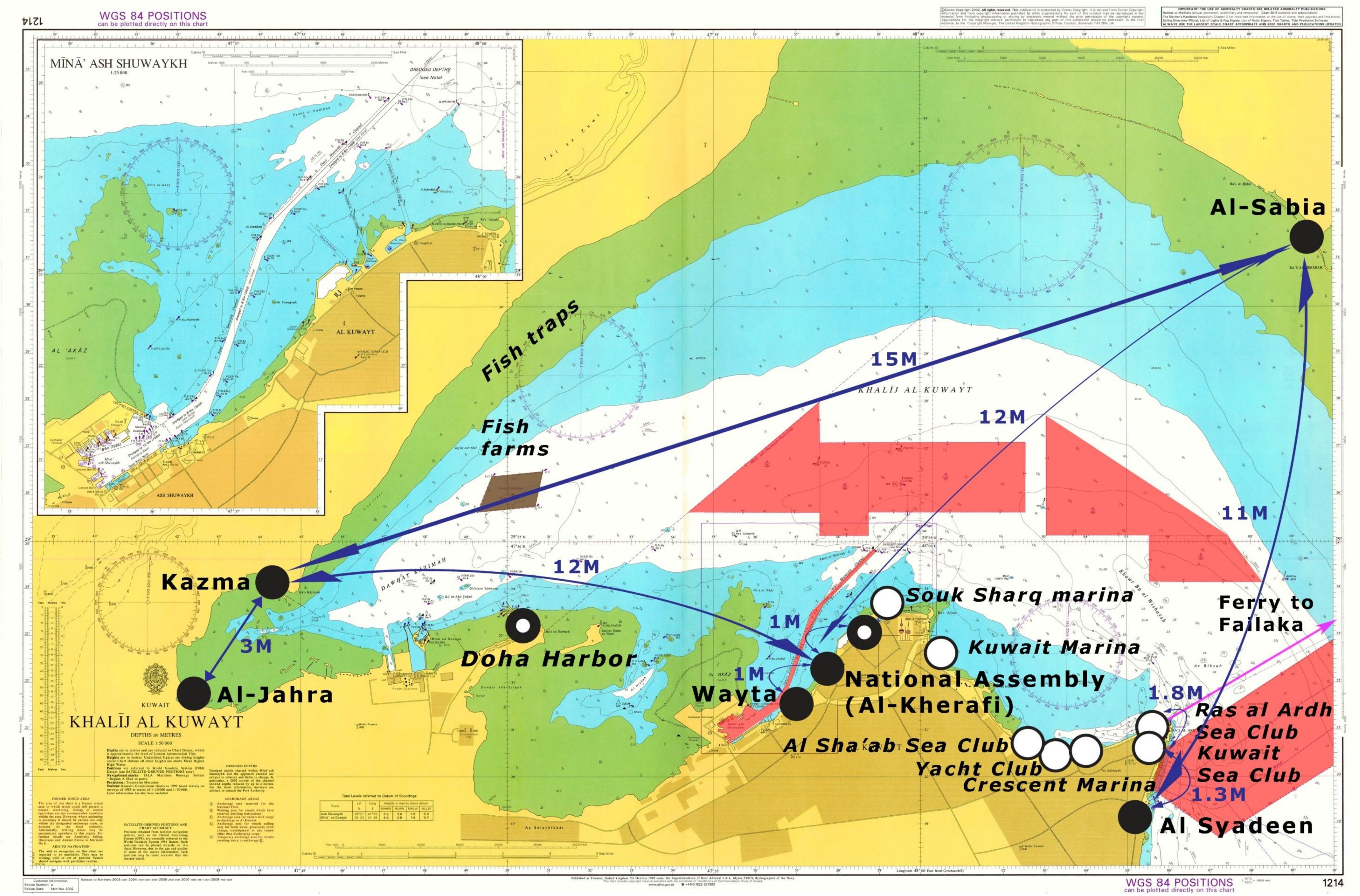

figure 105: Restricted areas admiralty chart 1214

Appendix G. Restricted areas admiralty chart 3773

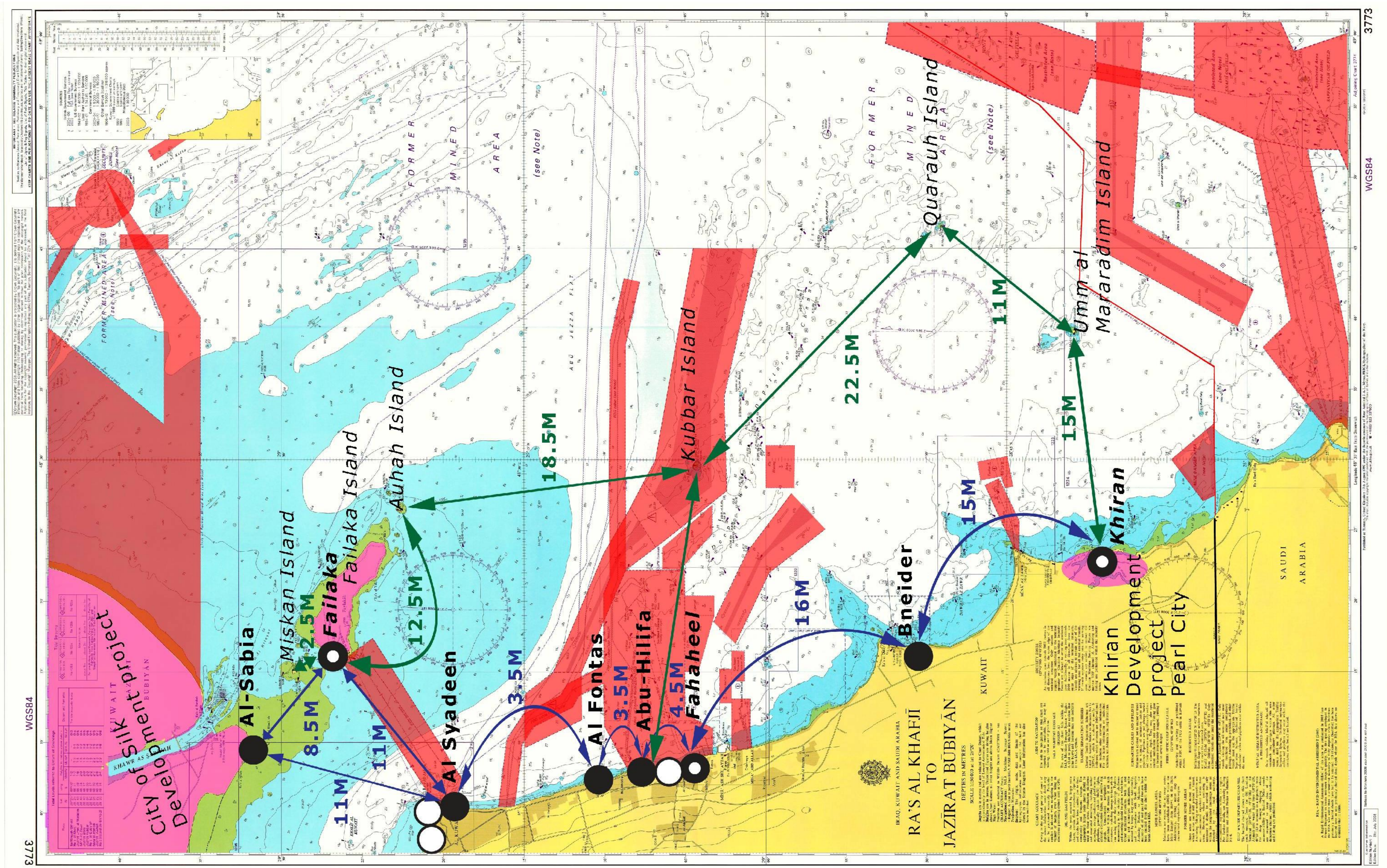

figure 106: Restricted areas admiralty chart 3773

Appendix H. Origin dates aerial photographs

Name	ID	Date of aerial photograph
Al Syadeen	2	04/22/2008
Al Fontas	1	04/22/2008
Al Kherafi (National Assembly)	9	06/28/2008
Watya	3	06/28/2008
Bneider	4	20/03/2006
Abu-Hilifa	5	04/22/2008
Al-Jahra	6	01/30/2006
Al-Sabia	7	01/04/2005
Kazma	8	01/30/2006
Fahaheel waterfront (Al-Kout)	10	01/30/2006
Failaka Harbor	11	08/13/2004
Khiran	12	10/22/2005
Doha harbor	13	01/30/2006
Dhow harbour Souk Sharq	14	01/30/2006
Souk Sharq Marina	20	01/30/2006
Kuwait Marina	21	06/28/2008
Al Sha’ab Sea Club	22	04/22/2008
Yacht Club	23	04/22/2008
Marina Cresent	24	04/22/2008
Ras al Ardh Marina	25	04/22/2008
Kuwait Sea Club	26	04/22/2008
Al Bida Sea Club	27	04/22/2008
Kuwait Airlines Club	28	01/30/2006
Al-Kout Marina	29	
Kirhan Marina	30	10/22/2005
Doha Port	31	01/30/2006
Shuwaikh Port	32	01/30/2006
Shuaibah Port	33	3/20/2006
Naval Base	34	3/20/2006
Coastguard Base	35	3/20/2006

table 50: Data aerial photographs used in target group analysis [Google Earth]

Appendix I. Development forecast yachting industry

I.1 Economic background and development scenarios

In this appendix the background information and development of the Kuwaiti economy is analyzed. With this data it is possible to assign various development scenarios. These scenarios are not provided with a final growth rate for the economy since this is not used in the calculation of the potential yachting demand. The scenarios will give an indication for the possibility of further development of the yachting industry in the country.

We start with general information on the Kuwaiti economy, than economic indicators of interest are treated. From there on the development of the economy is analyzed. With all the summarized information it is possible to determine economic development scenarios, as final goal of this section.

I.1.1 General

The economy of Kuwait and the Middle East is for a large part driven by the oil market. The production of crude oil and refined products accounts for nearly 50% of the GDP and 90% of the country's export. The country aims at diversifying the sources of the GDP. This is desirable in order to be less dependent on oil export. But with its large oil reserves, Kuwait's oil industry will determine the development of the country for quite some time.

Since the discovery of oil in Kuwait in 1938, the development of the petroleum industry in the years after World War II and the start of oil-export in 1948, the oil industry has dominated the economy of the country. Local production of crude oil, gas and refined products accounts for nearly half of Gross Domestic Product (GDP) and more than 90% of exports. All companies involved in oil, natural gas and petrochemicals production are state owned. Kuwait's oil reserve, which is estimated at 7.5% of the world's proven oil reserve, resulted in the present state of Kuwait and the prosperity of its population. Kuwait has invested a lot of its oil revenues in social services, including health and education (giving it one of the most literate populations in the region), in infrastructure, and marginally in local industry other than the oil industry.

Kuwait also has substantial overseas investments, both privately and publicly owned, which also provide substantial income. These foreign investments are mostly in the United States and include a variety of holdings. Income from these investments ensured that Kuwait sustained during the Iraqi occupation and the subsequent period when oil exports ceased. Kuwait's proven, recoverable oil reserves are thought to be enough to sustain the pre-invasion levels of production for more than 150 years.

Besides the country's dependence on oil export, the country is dependent on the import of its required goods and services. There are only few trade barriers that hinder import and export.

The economy is divided into four main sectors; the dominant public sector of government institutions and state-owned oil companies, the private sector controlled mainly by local merchant families, a joint sector in which business enterprises are owned by a mix of public and private interests, and the consumer cooperative sector, which includes the local companies owned by Kuwaitis.

I.1.2 Economic indicators

Real GDP

As a consequence of the large oil industry and the rising oil prices worldwide Kuwait's economy developed remarkably well the past decades. In table 51 an overview of development of the GDP is given. The growth rate of the GDP that is larger than the GDP per capita, with a growth of the economy of 8.5 % in 2008. For short term prognosis a growth rate of 6.5% seems reasonable. This growth rate is equal to the long term average from 1995 to 2008, but also to the average over the years 2006, 2007 and 2008.

GDP in billion US$	149.1	in 2008 US$	2008 estimate
GDP in billion US$	137.4	in 2008 US$	2007
GDP in billion US$	131.2	in 2008 US$	2006
GDP in billion US$	159.7	official exchange rate	2008 estimate
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	6.30%		2006 estimate
GDP - per capita (PPP)	57,400	in 2008 US$	2008 estimate
GDP - per capita (PPP)	54,800	in 2008 US$	2007 estimate
GDP - per capita (PPP)	54,300	in 2008 US$	2006 estimate

table 51: Economic figures (CIA World Fact Book)

GDP (PPP) per capita

The common figure to represent the economic situation and growth of a country is the gross domestic product per capita (GDP per capita). The GDP per capita is used as an indicator for the standard of living. The ranking of Kuwait on the list with countries listed by their GDP per capita gives a good indication of standard of living. The countries are listed by the real GDP per capita based on the based purchasing power parity (GDP (PPP) per capita) with the international dollar as unity. The international dollar is a hypothetical unity of currency, which is based on average prices of commodities and the purchasing power at a given point in time.

With the 4th position, with a value of Intl. $ 57,400, on the list from the International Monetary Fund from 2008, the conclusion can be drawn that Kuwait has a relatively high standard of living. As a comparison the Netherlands is ranked on the 13th position, with a value of Intl. $ 40,300, on this list. Position and figures are based on the 2008 estimates from the Central Intelligence Agency (CIA).

The position on the list does not give any information of the distribution of income over the population. This has to be kept in mind, especially if we look at the composition of the population in Kuwait. The majority of the population is non-Kuwaiti, and works in the private sector. In this sector the wages are in general lower than the public sector that employs the majority of the indigenous population. The composition of the population is further elaborated in the appendix on the population (I.2).

GDP per capita change rate

The prediction made by the International Monetary fund (IMF, April 2009) shows that the economies in the Middle East including Kuwait recover from 2009 on. The average real GDP change from 1991 until 2001 is 3.5 up to 4%, after which it increases in the period 2002 until 2007 to approximately 6%. During and after the crisis the real GDP growth rate falls back to 3.5% again. It seems justified to assume a GDP per capita growth of 3.5% for short term prognosis (5 years) until to 2014, like the IMF predictions.

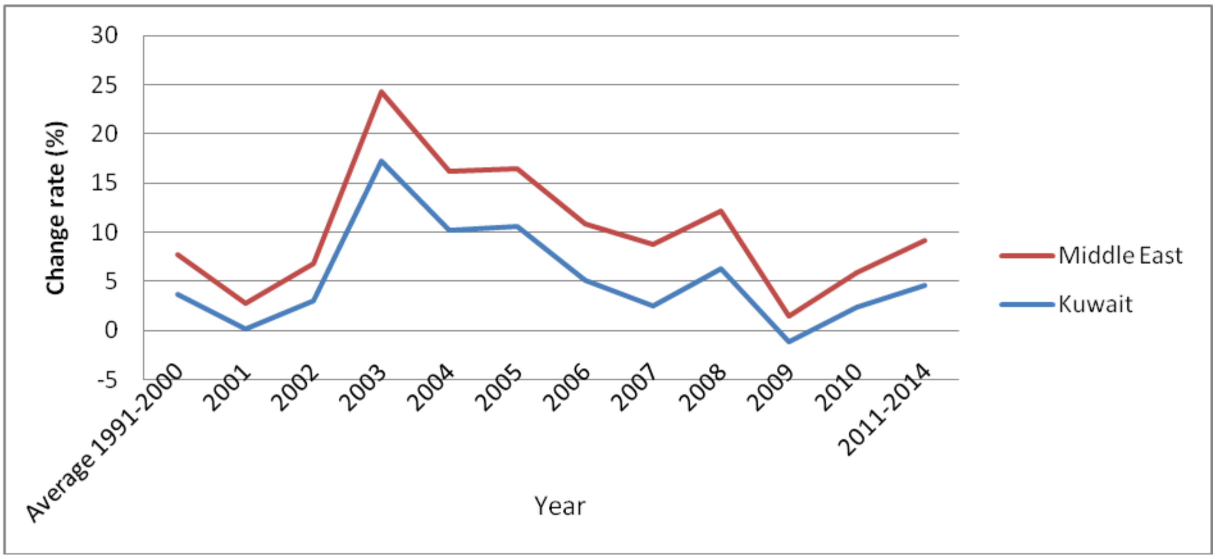

figure 107: GDP per capita growth figure per year (IMF, April 2009)

The GDP per capita of Kuwait showed an average growth of 3.7% from 1991 until 2000. In 2000 almost no growth is visible. From 2001 until 2005 the GDP per capita keeps growing with a rate of 5% or more a year. In 2006 the growth rate decreases to 2.5% per year. In 2007 a larger increase is noticed before the results of the world wide crisis become visible by a decrease of the GDP per capita by 1.1%. This is a mild decrease, since other countries in the world suffered under a larger decrease. Generally speaking the change of the Kuwait real GDP fluctuates around the change of the average real GDP change of the entire Middle East.

Tourist expenditures

As mentioned earlier Kuwait wants to diversify its sources of income. The tourist industry is one of the industries that Kuwait wants to expand within its borders. Like other countries along the Arabian Gulf, Kuwait is developing waterfront projects including real estate and marinas. The plan for Failaka Island is an example of project development for the tourist industry. Other examples are The Green Island, Souk Sharq Mall in Kuwait City and the Khiran Beach project in the south of Kuwait. The market seems to respond well to these efforts and developments.

figure 108: Green Island (Panoramio.com)

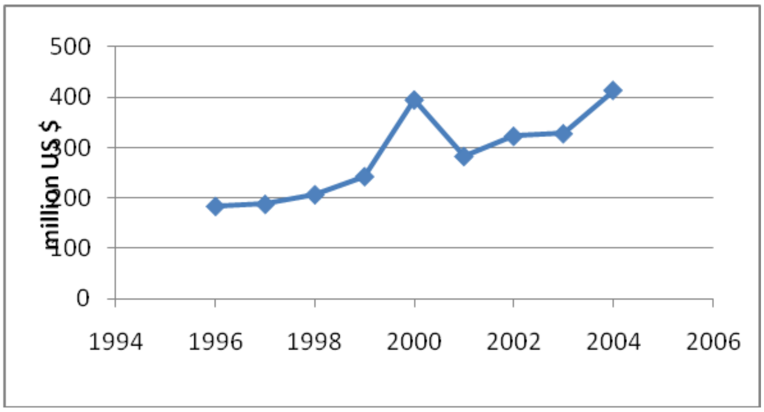

figure 109: Tourist expenditures (PACI, 2004)

The tourist expenditures in the country show a growth in the period between 2000 and 2005. The tourism sector in Kuwait shows an average increase of 12.5% per year over the period in figure 109. The potential for yachting demand will experience a positive effect from the increasing receipts from international tourists. Yacht charters and brokers for example can benefit from this development. A contribution to the yachting potential demand is therefore hard to determine, but like other influences this gives a positive contribution to the potential yachting demand.

I.1.3 Economic development scenarios

The number of prospective buyers of yachts is related to the economical climate in the country. The figures on the GDP and tourism show an increase. The prospect seems favorable, if we look at the predicted increase of the GDP per capita until 2014 projected by the International Monetary Fund. Based on the information in the previous section the scenarios in the following are assigned.

High scenario

In the high scenario the GDP per capita stays highly ranked on the internal ranking of countries. The growth rate of this figure is expected to stay at the same rate as it was in the period 2001 - 2007 of 6% per year. The relative wealth of the population stays relatively high in this scenario. High overall economic growth figures in the last decade also support this development scenario. The GDP of Kuwait has been increasing in the period 2001-2008 with an average growth rate of 5.2% per year according to the statistics from the CIA World Fact Book. In general is this scenario very favorable for the development of the yachting industry in Kuwait.

Medium Scenario

The medium scenario will show more moderate GDP growth rate. Assuming that Kuwait will enforce its tourism potential, it is predicted that the economic growth will be substantial as well in this scenario. For the average development in this scenario is referred to the average growth rate of the GDP per capita in the period 1991 – 2001 of 3.7% and to the predicted short term (until 2014) development of the Kuwaiti GDP per capita with 3.5%. This growth rate is predicted by the International Monetary Fund (IMF). Although this scenario is more moderate that the high scenario it is still favorable for the potential development of the yachting industry.

Low scenario

In the conservative low scenario is assumed that the Kuwaiti economical growth falls back to the average growth rate of the world wide annual growth of the GDP per capita (PPP) of 2.1% (CIA World Fact Book over the period 1953-2001). This development is thus below the scenario is below the development of the last decades in Kuwait.

The conditions in the low scenario result in an economical climate where not a lot of development of the yachting industry is expected. The potential yachting demand and number of yacht owners is assumed to stagnate at its current rate.

I.2 Population background and development scenarios

I.2.1 Introduction

In this section the background and development of the population is analyzed. With this information it is possible to assess various user categories (I.3.3). The selection of user categories is done based on the part of the population that has affection with yachting or has a specific background that leads to selecting them as a separate user category.

Information on the population development is one of the input parameters of the calculation of the development forecast of the target user groups. The growth of the entire population can for example result into an increasing group that is able to afford yachting. Next to that this analysis is indirectly linked to the target user group fishing vessels. Population development influences the consumption of fish as we will see in section J.2.5.

We start with general background information on the Kuwaiti population. The clear division in the population between the indigenous and the foreign part is essential to consider and this is discussed in section I.2.4 and I.2.5. The general information is used to determine the various user categories and the development scenarios of the population in section I.2.8.

I.2.2 General

The majority of the Kuwaiti population lives in and around the coastal capital, Kuwait City. A smaller proportion of the population inhabits the nearby cities of Al Jahra, Ahmadi and small desert and coastal towns. Before the Gulf War, the several islands in the Arabian Gulf, Failaka for example, were also inhabited.

A large part of the population of Kuwait consists of foreign workers. This part of the population grew steadily after the Second World War. The government development programs and the rise of the oil revenues after the export started in 1948 were the driving factors behind this increase.

In 1970 a master plan for urbanization and metropolitan expansion was made. This plan is covering the country as a whole and is used as reference for infrastructural development of the country. This plan is based on projected urban growth and projected population increase from 853,000 to 2 million. The population growth was beyond this expectation due to the influx of foreign laborers. In 1996 a third master plan for Kuwait was made and gave an estimation of 3.5 million inhabitants in 2015. This figure is already reached in the year 2007 according to the Public Authority of Civil Information (PACI) of the Ministry of Planning.

According to the statistics from the PACI, the population of Kuwait was 3,399,637 in December 2007. 1,054,598 (31%) of the population is Kuwaiti and 2,345,039 (69%) of the population are originally from a foreign country.

The women of the indigenous population outnumber the male population. In the foreign population it is the other way around. Almost two third of the expatriate population is male.

Total population	3,399,637	
Kuwaitis	1,054,598	31.8%
Expatriates	2,345,039	68.2%
Gender	male:female	
Overall	3:2	
Kuwaitis	0.97:1	
Expatriates	2:1	

table 52: Population Kuwait 2007 (PACI, 2007)

I.2.3 Labor force

About 95% of all employed indigenous Kuwaitis work for the government, most of them work in the public administration, defense, and the service sector. They enjoy a relatively high salaries compared to the private sector.

About one-fifth of all jobs are in construction and the trade, manufacturing, transportation and communication, finance, and agriculture sector. All these sectors together employ a larger part of the population than the oil sector. In the private sectors, Kuwait remains heavily dependent on foreign labor, although after the invasion, the government regulated foreign labor more forcefully to fulfill its goal of reducing this dependence. The government also implemented certain measures to employ a larger part the of the indigenous population in the private sector. Statistics of the population and work force from 2007 are given in table 53.

	Male	Female	Total
Kuwaitis	182,558	141,746	324,304
Expats	1,384,182	384,023	1,768,205

table 53: Labor force Kuwait 2007 (PACI, 2007)

The wealthiest Kuwaitis are members either of the ruling family or of what was once a powerful and still distinct merchant class. Many of these are descendants of the Bani Utub, the original central Arabian tribe that settled in Kuwait in the eighteenth century. The economic elite is largely Sunni. However, some Shia families and individual Shia are also wealthy. There are no important ethnic divisions: the national population is overwhelmingly Arab. Despite the internal divisions, the national population is also characterized by a strong sense of national identity. This national sense has been deeply reinforced by the Iraqi occupation.

I.2.4 Indigenous population

Native Kuwaiti, who comprised about 25% of the population of Kuwait before the Iraqi invasion, now make up 31 % of the country's total population. A large proportion of the Kuwaiti population is young, about 60% being under 21 years old, see figure 110. Large families are encouraged in Kuwait. The statistics state that there are about 95,000 Kuwaiti families, forming 44% of the total number of families in Kuwait. The average size of a Kuwaiti family is 8.2 members.

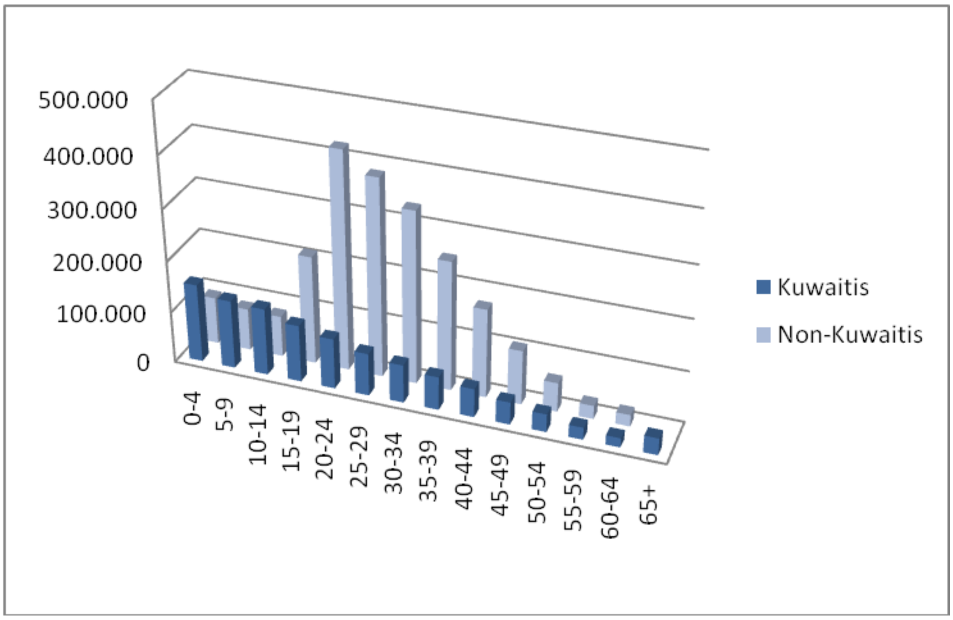

figure 110: Age groups (PACI, 2007)

I.2.5 Foreign population

The population of 2007 is for 69 % non-Kuwaiti. The foreign population differs a lot from the indigenous population if we look at the age groups in figure 110. The foreign population is mainly contributing to the labor force in the private sector. Therefore most of the foreign population falls in the age groups from 20 to 55 years. The largest age group is the 30-35 years, with a total number of 400,000.

The foreign population does not enjoy the economic and political rights of the indigenous population. Non-citizens can neither vote, nor run for a position in the National Assembly. They cannot form their own unions; although they can join Kuwaiti unions, they are prohibited from voting or running for union offices. Acquiring Kuwaiti citizenship is very difficult, and the number of naturalized citizens is low.

If we look at the origin of the foreign population in 2007 in figure 111, we can conclude that the Asian community is the largest. In 2007 more than 580,000 Indian nationals lived in Kuwait making them the single largest expatriate community. The rest of the foreign population mainly consists of Egyptians, Bangladeshi, Pakistani, Filipino and Sri

Lankan residents. A small group of expatriates from North America, Great-Britain and other so called western countries is present in Kuwait.

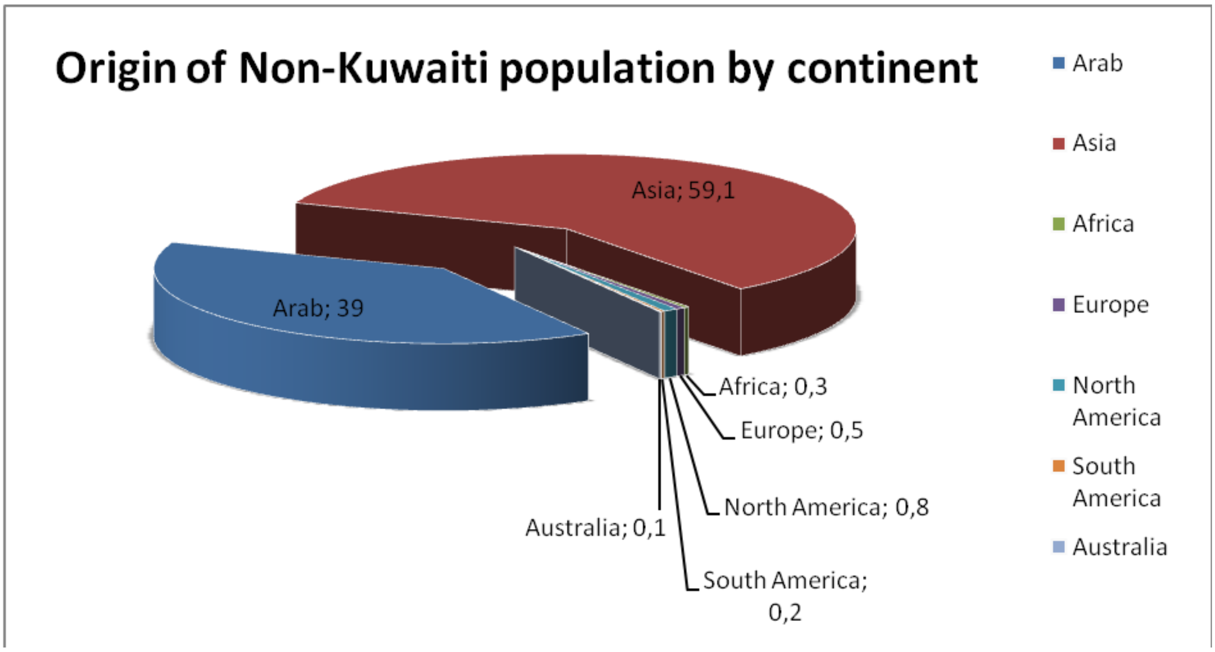

figure 111: Origin of Non-Kuwaiti population by continent (PACI, 2007)

I.2.6 Population development

The statistics that are used for the population development and forecast are obtained from report made by Ministry of Planning, Central Statistical Office of the Public Authority of Civil Information Authority (PACI) in 2005 and 2007. This information is collected in a report by the International Monetary Fund (IMF). This detailed set of data gives a good insight in the development of the population. Interesting aspects from these statistics are mentioned below and these will be used in the development of the target user groups later on.

Year	Female	Male	Kuwaiti	Non-Kuwaiti	Total	% Kuwaiti	Population growth		
							Non-Kuwaiti	Kuwaiti	Total
2000	874.6	1342.6	841.8	1375.5	2217.3	38%			
2001	919.5	1389.6	870.3	1438.8	2309.1	38%	5%	3%	4%
2002	956.7	1463.2	898.3	1521.6	2419.9	37%	6%	3%	5%
2003	991.6	1555.1	927.7	1619.0	2546.7	36%	6%	3%	5%
2004	1018.3	1626.5	942.9	1701.9	2644.8	36%	5%	2%	4%
2005	1075.5	1791.4	973.3	1893.6	2866.9	34%	11%	3%	8%
2006	1130.4	1921.5	1008.1	2043.8	3051.8	33%	8%	4%	6%
2007	1267.7	2131.9	1054.6	2345.0	3399.6	31%	15%	5%	11%

table 54: Overview statistics (PACI, 1995,2004,2005,2007)

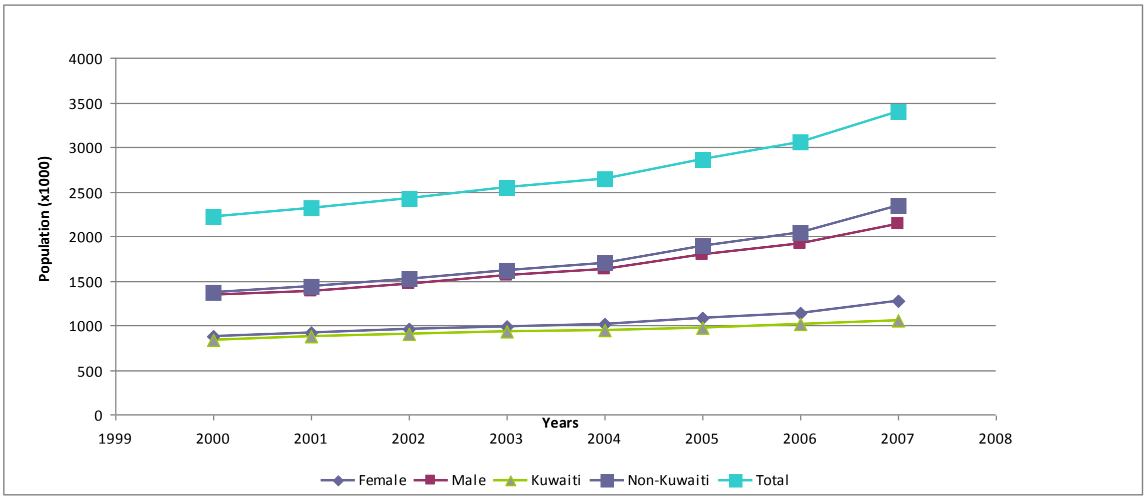

figure 112: Population development (PACI , 1995,2004,2005,2007)

In general the population of Kuwait has always been growing, if we ignore the setback during the Iraqi occupation. Since 2000 the population is growing with an average rate of about 4.5 %, with an increase up to 8% in 2006 and 2007. This growth is for a large part induced by the influx or foreign labor forces. The Kuwaiti population shows a constant growth of about 3.5% with a drawback in 2004 in which the growth was 1.5%. The non-Kuwaiti group is growing with a larger rate than the indigenous population due to the earlier mentioned large influx. This rate is 5.5% from 2000 until 2005 and increases to 11.5% in 2006 and 2007.

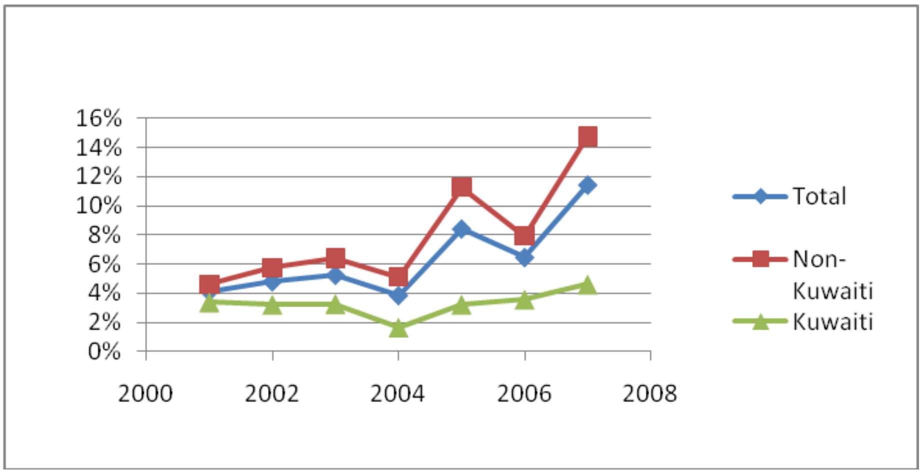

figure 113: Growth rate population (PACI , 1995,2004,2005,2007)

I.2.7 Population development scenarios

In all scenarios is assumed that the natural growth of the indigenous population stays at the averaged level of the period 2000-2007. This growth rate was reasonably constant around the value of 3.25% as is showed in figure 113. Keeping this growth rate constant has consequences for the share of the indigenous population in the several scenarios.

<u>High scenario</u>

In the high scenario a growth of the entire population is expected with the average growth rate of the period 2001 – 2007. In this scenario the entire population keeps on growing with a rate of 6% per year. The main source of growth is the expatriate population that continuous to grow with a relatively high rate compared to the indigenous population. This rate is not as high as the rate in 2007 since the influx is expected to flatten off in the future.

<u>Medium Scenario</u>

For the medium scenario a modest approach is adopted. It is assumed that the Kuwaiti population will grow in the same pace as the indigenous population in the coming years. In the medium scenario the average growth rate over the period 2001-2007 of the indigenous population serves as basis for the development of the entire population. The influx of expatriate population, the driving force behind the large growth rates, is expected to reduce more than in the high scenario. With a growth rate of 3.25% per year the proportionality between the indigenous and foreign part stays the same and the population will double within 20 years like has happened in the past 20 years.

<u>Low scenario</u>

In the conservative approach, the growth of the Kuwaiti population is linked to the world wide population expected growth rate of 1.14% per year, determined by the United Nations. The population in Kuwait keeps on growing, since it has been for the entire history of the country, except the period when the country was under Iraqi occupation. The country’s oil industry is expected to guarantee the favorable economical conditions for the expatriate population to stay in Kuwait.

I.2.8 Population development forecast

Statistics on the population from 2005 from the PACI serve as a starting point for the forecast. Statistics from 2006 and 2007 are also available but these years show a much larger increase compared to the trend of the period 2000-2007. 2005 is the last year that fits well in the trend of the data and will therefore be used as starting point of the development forecast.

In 2005 the population was about 2.9 million. The size of the expatriate population was 1.9 million (66% of the population). The development forecast in table 55 is another part of the input for the potential yachting demand calculation.

			2005	2010	2015	2020	2025	2030
Total	High	6.00%	2866.9	4049.0	5156.0	6870.7	9703.6	12356.7
	Medium	3.25%	2866.9	3742.0	4069.8	4631.9	6045.7	6575.4
	Low	1.14%	2866.9	3517.2	3379.6	3398.3	4169.1	4006.0
Kuwaiti		3.25%	973.3	1142.1	1340.1	1572.5	1845.2	2165.2

table 55: Population development forecast

The high development scenario leads to a population in 2030 that is 3.5 times larger than the size of 2007. The share of the indigenous shrinks to 20% in this scenario. In the medium scenario the growth rates of the entire population is equal to the one of the indigenous population and the share of the indigenous population stays at 30%. The share of the indigenous population increases to 50% in the low scenario. Since the natural growth of the indigenous population is assumed to stay at a rate that is much larger than the 1.14% per year in this scenario.

I.3 Assessment adoption rate and development scenarios

I.3.1 Introduction

Every country has its own yachting characteristics, these can be expressed with adoption rates. It is an indicator for the popularity of yachting in a nation, region or city. As such the adoption rate influences the forecast of yachting in a network to a larger extent. The adoption rate depends on various factors such as economic development, climate and seasons, coastline length and the type of water systems. It is the parameter that indicates the number of yachts per 100 inhabitants or members of a user category.

The adoption rates of countries around the world, shown in table 56, are good indicators for the popularity and development of the yachting industry around the world. They will be used as a reference for the adoption rate development scenarios in Kuwait.

Country	Estimated nr. of boats in use	Population (millions)	Boats per 100 inhabitants (adoption rate)
Europe			
Denmark	366000	5.5	6.7
Finland	737000	5.3	13.9
France	600000	60.2	1.0
Germany	800000	84	1.0
Italy	880000*	58.1	1.5
Norway	700000*	4.5	15.6
Spain	240000	40.1	0.6
Sweden	1200000*	9.1	13.3
The Netherlands	250000/500000*	16.3	1.5/3.0
United Kingdom	560000	60.1	0.9
Oceania			
Australia	550000	17.9	3.1

New Zealand	300000	3.6	8.3
North Amercia			
Canada	2200000	32.8	6.7
USA	17000000*	296	5.7
Africa			
South Africa	28000	44.2	0.06
Asia			
China	-	1,360	0
Japan	421000	127.4	0.3
Turkey	35500	6.7	0.6
Middle East			
Kuwait	18000	3.4	0.5
UAE	3000 (estimated total)	4.9	0.06

table 56: Adoption rates in the world (*including canoes, kayaks etc.) (IBI, 2007)

It is noted that the table includes accounts of small watercraft such as canoes and jet skis in the instance of the USA, Canada and come of the Scandinavian countries, all of which have a relatively high adoption rate. Many inhabitants need a private boat for transportation reasons. Therefore the adoption rates of these countries do not reflect only the desire to own a yacht, but also the need to own a yacht or boat for transportation. The adoption rate figures used for this project do not include small personal watercrafts needed for that purpose.

Furthermore should be noted that the assessment of the adoption rates is not based on a scientific approach, but on empirical judgment using related studies and the data from IBI.

I.3.2 Current adoption rate

In an article from IBI from 2007, a rate of 1 yacht per 52 Kuwaitis is given. The same article states that there are 18,000 registered leisure boats in Kuwait, with some 2,000 in marine berths. If we translate the figure of 1 boat for every 52 Kuwaitis to an adoption rate, we end up with an adoption rate of 1.92 per 100 indigenous inhabitants. The rate of 1 yacht per 52 Kuwaiti in combination with the total of 18,000 yachts also gives an indication of the size of the user category. The size of the target group can be determined by multiplying 52 with 18,000. This results in 936,000, which is approximately the size of the indigenous population, one of the user categories, in 2007. More on the user categories can be found in section I.3.3. If we take the entire population as user category of the yachting industry, 3.4 million in 2007, we arrive at an adoption rate of 0.5.

Kuwait has thus a reasonably developed yachting industry compared to the United Arab Emirates (UAE) and reaches an adoption rate that is comparable to Turkey (0.6), Spain (0.6), Germany (1) and France (1).

I.3.3 User categories

The adoption rate for the entire population deviates from the rate for only the indigenous population, as the calculation in the previous paragraph shows. To make a more accurate assessment of the yachting demand potential for coastal havens Kuwait, it is important to make a distinction in user categories. Selection of these target groups will be done based on cultural background and awareness of and attraction to yachting. For each user category an adoption rate must be assessed and a development of this rate will be determined in the development scenarios at the end of this paragraph.

The composition of the population is important because not the entire population is financially able to participate in yachting. To make this distinction, statistics from the census of 2005 from the Ministry of Planning, Public Authority of Civil Information are used.

User category: Indigenous population

The proportion of the indigenous population is smaller than the expatriate population. The last decade this proportion has been decreasing from 38% to 31%, although the annual natural growth of the indigenous population is constant at approximately 3.25%. The phenomenon of a decreasing proportion of Kuwaitis is not expected to continue in the future, because the influx of the foreign labor force is expected to flatten off. From the IBI article is derived that the indigenous population is the main user category involved in yachting in Kuwait. The development of this user category is therefore the main source for the yachting demand potential. In 2007 the adoption rate of this user category was about 2 yachts per 100 inhabitants.

User category: South East Asian and Arabian expatriates

This user category is by far the largest in Kuwait. The people originating from other Arab and South East Asian countries are mainly living and working in Kuwait to earn and save money for a better life than they had in their home countries. The probability that this user categroy gets involved or interested in yachting is considered to be low. They will not be taken into account any further. For their adoption rate a value 0 will be used. An overview of the composition of the foreign population is given in table 57. A graphical representation is provided in figure 111.

Continent of origin	Number	%
Arab	893,483	39
Asia	1,353,973	59.1
Africa	8,261	0.3
Europe	11,893	0.5
North America	18,878	0.8
South America	1,581	0.2
Australia	1,469	0.1
Total	**2,289,538**	**100**

table 57: Origin of Non-Kuwaiti population by continent (PACI, 2007)

User category: Western expatriates

The figures in table 57 show that this user category is a small group of the Kuwaiti inhabitants. They often work for a limited period in Kuwait. They are involved in project development and service-related industries. They are familiar with yachting and other leisure activities from their home country. Their adoption rate will therefore be related to their home countries. If we calculate the proportional adoption rate over the countries of origin of the expatriate population we end up with an adoption rate of 4 yachts per 100 inhabitants.

Since most people in this target group are in Kuwait for work and a limited period of time, their adoption rate will deviate from the rate in their home country. A somewhat lower value is assumed to be presentable for the western expatriated inhabitants. Expected is that this part of the population and their interest in yachting will increase in the future. This expectation is deduced from the trend in the Middle East and is further elaborated in section I.2.6. More tourist facilities are planned and developed in this area. This attracts western tourists, in the project development stage but also as a tourist.

The number of western expatriates in 2007 according to the PACI is 33,000 and they are originating from Western countries in Europe, South America, North America and Australia. This group is 1.6% of the expatriate population and 1.0% of the entire population. Since this group has a relatively high adoption rate from their origin this group is taken into account in the potential yachting demand analysis. The current adoption rate is assumed to be 0, since nothing about yacht ownership by the expatriate population. This user category is a group of inhabitant that has a potential and adoption rates will be determined in the next section.

I.3.4 Adoption rate development scenarios

Refereren aan Nederland, als er niks gebeurd qua ontwikkeling in Kuwait, dan kan de adoption rate ook dalen. Baseren op bestaand aantal schepen met een kleine ontwikkeling en de toename van de bevolking in Kuwait. 6 is en relatief hoog getal als optimum valua. De hele voorspelling hangt af van deze getallen. Manier van afleiden van waarden en klimaat voor ontwikkeling vam yachting industry, goed relateren aan informatie en voorspelde ontwikkelingen.

The yachting demand potential is thus for a large part based on estimated adoption rates.

High scenario

In the high scenario the adoption rate is on its highest end. The accompanying economic scenario is above the current expectation from the IMF and the number of vessels will increase with a larger rate than the number of members in the user categories do. The adoption rate will thus increase to such a value that we can speak of a fully developed yachting industry, if we look at the user categories indigenous and expatriate population. The Dutch adoption rate of 3 from is taken as reference value for the user category indigenous population. The user category western expatriates is assumed to reach an adoption rate of 2 yachts per 100 inhabitants. This is half of the averaged adoption rate from the countries of origin that is used as reference for this rate. Taking only a half of the reference rate is done to compensate for the limited time of stay of the expatriates in Kuwait.

Medium scenario

In the medium scenario the adoption rate will be assessed as a more modest figure. The medium scenario economic assumes a moderate development as well. The user categories are assumed to be able to live in the same manner as they do now and the interest and involvement in yachting continues to develop. The adoption rate among the indigenous population is assumed to stay the same until 2030. For the expatriate population a moderate development is expected. In this case the adoption rate will develop a value of 1 yacht per 100 western expatriates in 2030, a quarter of the averaged value over the countries of origin of this user category.

Low scenario

In this conservative approach yachting will almost not gain more popularity. The economical scenario indicates development below the growth rate of the last two decades and investments in yachting are therefore not expected. The infrastructure for yachting stays the way as it is now and the sector cannot develop any further. The adoption rate of the indigenous population will therefore draw back to a rate of approximately 0.85, due to the natural growth of the population. The adoption of yachts among the western expatriates is expected not to develop at all in this scenario. Fewer investments lead to less work for western expatriates in Kuwait and that will have its effect on the yachting demand potential form this user category.

I.3.5 Disposable income, savings and investments

Not a lot of data is available on the disposable income of the population of Kuwait. Known is that the disposable income and savings have been rising in the period from 2001 until 2005 (figure 114). The statistics show an average annual increase of 10%. Savings in this period, public and private combined, increase even with a larger rate. Due to the oil export, investments are high. Combined with the high standard of living, based on the GDP per capita, all the above mentioned aspects results in a economic situation that corresponds with a relatively high potential for yachting from certain user categories of the population.

The article from International Boat Industry (IBI) confirms this observation by stating that the Gulf area has a big market for luxury goods. Investments in the region are high at all times and people have a relatively high disposable income. It is therefore assumed that the user categories Kuwaiti population and Western Expatriates have a disposable income, which enables them to purchase luxury goods like yachts. This market will increase if the right facilities are provided. This is at the same a mentioned weakness in the article. Stated is that there is a shortage of berths and services and support structures are in its infancy.

In Kuwait there are already marinas present with good facilities, but at the same time only 11% (2,000 of the total of 18,000) of the yachts can be moored in a marina, due to the limited capacity. Not all marinas are at the same service level, there is space for development and improvement.

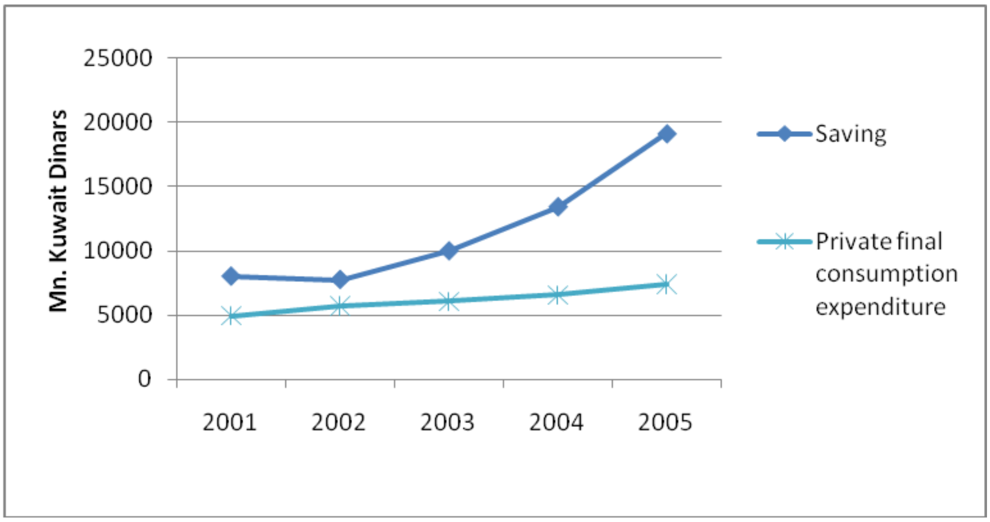

figure 114: Saving and private consumption expenditures (PACI, 2005)

I.3.6 Affordability analysis

The affordability provides an indication of the share of the Kuwaiti inhabitants that potentially is able to buy a yacht. This analysis is based on the disposable income distribution, consuming expenditures and the average costs that are coming along with the ownership of a yacht. Together with the adoption rate this will conclude the yachting demand potential. People that are not able to buy a yacht are not accounted for in the demand potential calculations. In developed yachting countries, normally the situation is that the affordability factor is 1 for the entire population, meaning that the entire user category can be considered as potential buyers and user of yachts.

In the case of Kuwait, unfortunately there is little information available that enables a distinction within a user category based on affordability. For this reason, a detailed assessment of the affordability and buyer potential cannot be made. Instead of a detailed assessment some general remarks can be made concerning the affordability of the various user categories.

Indigenous population

Kuwait is a country with one of the highest GDP per capita figures in the world. The population, especially the indigenous population, has all public services at hand. The majority of the indigenous population is employed by the government and earns a relatively high salary. Like the GDP per capita the disposable income is expected to be among the highest in the world. The adoption rate among this user category has a value of 2, which indicates that yachting is reasonably developed among this user category. Affordability of this target group therefore is assumed to be 1 like in other countries where the yachting industry is well developed.

South East Asian and Arabian expatriates

The foreign labor force, mainly consisting of Arab and South East Asian immigrants, are considered to be unable to afford yachts and other luxury goods. They are living in this country searching for a better life with the accompanying salaries, which they save until returning to their home country or send home to the family that they left behind. Their adoption is assumed to be 0 and stay that way in the adoption rate development scenarios. The affordability of this user category is also assumed to be 0, indicating that members of this user category are not potential users or buyers of yachts.

Western expatriates

The disposable income and the affordability of the western expatriates are assumed to be comparable to that of the indigenous population. The western expatriates are assumed to be able to buy and use yachts in their home countries if we look at their countries of origin. Therefore they are assumed to be able to afford yachts in Kuwait as well. In their home country of most western expatriates the yachting industry is well developed and an affordability of 1 is common there as well.

Conclusion

The conclusion for the affordability is that the user categories indigenous population and western expatriates have an affordability of 1. These entire user categories will thus be taken into account in the calculation for the yachting demand potential. For the South East Asian and Arabian expatriates affordability is set to 0. like is done with the adoption rate and will therefore not be taken into account any further.

I.4 Yachting demand potential

In this section, the calculation of the yachting demand potential is made with all the parameter and aspects earlier determined. From the population development scenarios and user categories result two user categories of interest. These are specified separately in the calculation. The indigenous population is assumed to increase with the natural growth as is explained in section I.2.7. The number of western expatriates in Kuwait is highly depended on the development of the economy and the prospects in project development and the service-related industries. Predictions for these prospects are hard to make. The number of western expatriates is therefore related to the development scenarios of the entire population. The current size, 1% of the entire population, is held constant in the calculation for all scenarios.

The calculation results in the total number of vessels present in Kuwait in a high, medium and low scenario. This number is the total of vessels present in and around marinas and stored elsewhere on trailers. This calculation does not include the results for the boat mix and separation of the number of yachts present in marinas. These aspects are treated in the next section (I.4.1).

			2005	2010	2015	2020	2025	2030
Population (x1,000,000)	High	6.00%	2.9	4.0	5.2	6.9	9.7	12.4
	Medium	3.25%	2.9	3.7	4.1	4.6	6.0	6.6
	Low	1.14%	2.9	3.5	3.4	3.4	4.2	4.0
Kuwaiti (x1,000,000)	Medium	3.25%	1.0	1.1	1.3	1.6	1.8	2.2
Adoption rate	Kuwaitis	High	1.92	2.00	2.25	2.50	2.75	3.00
		Medium	1.92	2.00	2.00	2.00	2.00	2.00
		Low	1.92	1.75	1.50	1.25	1.10	1.00
	Arabian expatriates		0	0	0	0	0	0
	South Asia expatriates		0	0	0	0	0	0
	Western expatriates	High	0	0.25	0.75	1.00	1.50	2.00
		Medium	0	0.00	0.25	0.50	0.75	1.00
		Low	0	0	0	0	0	0
Result (x1000)	Kuwaitis	High	18.0	22.8	30.2	39.3	50.7	65.0
		Medium	18.0	22.8	26.8	31.5	36.9	43.3
		Low	18.0	18.0	18.0	18.0	18.0	18.0
	Arabian expatriates		0	0	0	0	0	0

	South Asia expatriates		0	0	0	0	0	0
	Western expatriates	High	0	0.1	0.4	0.7	1.5	2.5
		Medium	0	0	0.1	0.2	0.5	0.7
		Low	0	0	0	0	0	0
Total (x1000)		High	18.0	22.9	30.5	40.0	52.2	67.4
		Medium	18.0	22.8	26.9	31.7	37.4	44.0
		Low	18.0	18.0	18.0	18.0	18.0	18.0

table 58: Yachting demand potential

I.4.1 Share of vessels moored in marinas or coastal havens

Currently the number of moorings is limiting the development of the yachting industry. Most marinas in Kuwait are privately owned. The marinas are thus not subject to governmental power or control. Prices for a berth rise due to the high demand in Kuwait. Furthermore, the marinas will only operate locally and investments are done for one location, not for an entire network. Coastal havens, on the contrary, are public property and are managed by the Kuwait Port Authority (KPA). To stimulate the yachting industry, the government wants to create an interesting network of possible moorings and facilitate the fishermen at the same time. The construction of marinas on some locations does not lead to the creation of a network with suitable facilities at specific locations. The development of a network of coastal havens is thus preferred above locally operating marinas. By developing coastal havens with good facilities and upgrading the facilities in the existing coastal havens and marinas the prices for users will drop and the potential number of users will increase. .

The current situation, assessed in chapter 4.4, is such that 2,091 of the total 18,000 (11%) use moorings or the storage areas in and around marinas. This share is relatively low compared to other countries with a reasonably developed yachting industry. If new infrastructure is developed for the yachting industry, people will decide to moor their yachts in marinas if moorings are available and affordable, and the share of vessels berthed in marinas will increase. If no or to little moorings become available, yacht owners will continue to transport their vessels on trailers and are restricted to smaller vessels.

Results

An increase of 9% (from 11% to 20%) is assumed to be possible for the high scenario, for the low scenario nothing changes and this rates stays at 11%. For the medium scenario the medium share of 15.5% (the average of 20 and 11%) is expected to be achievable. This is amongst other things dependent on the price for a mooring or storage and the development of the mooring capacity in Kuwait. In the low scenario for the adoption rate development is assumed that no investments will be done in the yachting industry, the capacity and rate of moored yachts in marinas are therefore expected to stay the same.

The two proportions of 11 and 20% indicate a bandwidth of the total number of vessels moored in marinas or coastal havens. For the years 2005 and 2010 no values are provided, since developing the yachting industry in such a short period is not possible. The first developments become effective from the year 2015 on.

Scenario	Share	2005	2010	2015	2020	2025	2030
High	20,0%	2,0	3,6	5,4	8,0	10,4	13,5
Medium	15,5%	2,0	2,5	3,6	4,9	5,8	6,8
Low	11,0%	2,0	2,0	2,0	2,0	2,0	2,0

table 59: Share of yachts in marinas and coastal havens (x1000)

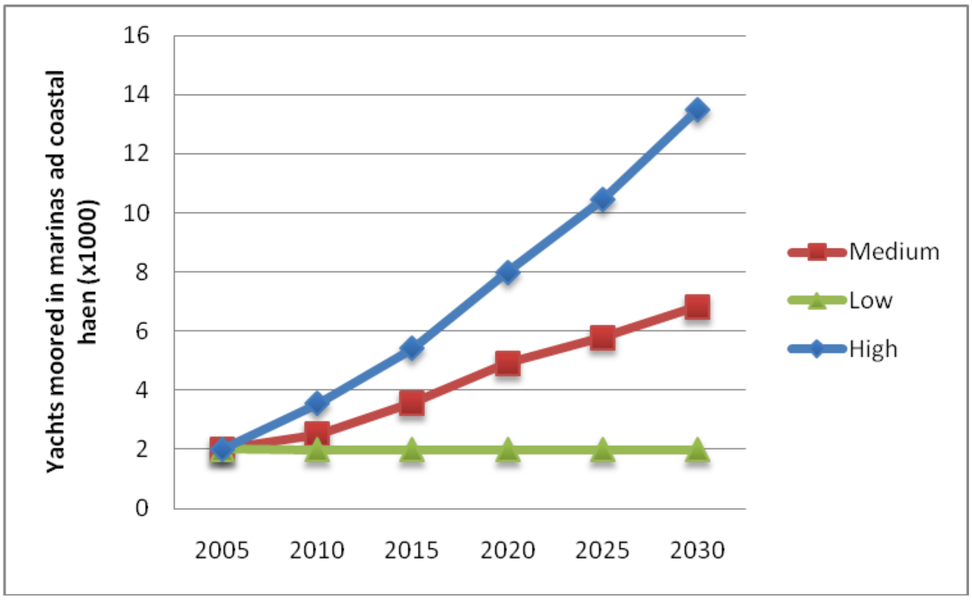

figure 115: Results share of yachts moored in marinas and coastal havens

I.4.2 Yacht mix development

People all over the world in general have a tendency to buy larger yachts. The expected development of the yacht mix in Kuwait is in the direction of the larger vessel classes of the yacht mix as well. This is based on the adoption rate development scenario, which indicates an increasing capacity in marinas and coastal havens for yachts. If the restriction of the limited capacity is solved, the share of people that transports their yacht to and from the slipway is expected to decrease and become users of this additional capacity. More yacht owners can use moorings in marinas. Buyers of a yacht can decide buy larger vessels, since it becomes possible to moor their yacht in a marina or coastal haven. This will result in an increasing share of the large vessels classes, next to the larger share of moored vessels. Furthermore, is expected that the existing waiting lists and the premium culture to obtain a mooring will disappear.

The current yacht mix in Kuwait from section 4.4.3 (again presented in table 61) and the yacht mix of the several references (table 60) serve as basis for the Kuwaiti yacht mix development. The translation of the classes in table 60 to the classes from the visual fleet assessment is made in the last column of table 61.

Yacht mix class	The Netherlands	Modern Seaside Marina	Existing UAE
< 6 (m)	12%	0%	3%
6 - 8 (m)	30%	5%	29%
8 -10 (m)	37%	25%	23%
10 - 12 (m)	13%	42%	22%
12 - 14 (m)	6%	19%	11%
14 - 20 (m)	2%	9%	10%
> 20 (m)	0%	0%	0%
Total	**100%**	**100%**	**100%**

table 60: Yacht mix references

The references figures are a characterization of the moored yachts in marinas. The yachts mix is therefore only applied to the share of vessels moored in a marinas or coastal haven and not to the yachts located elsewhere.

Yachts mix class	Marinas Kuwait (2007)	Share Kuwait (2007)	Total (2007)	The Netherland	Modern Seaside Marina	Existing UAE
<10 (m)	976	47%	85%	79%	30%	55%
10 - 15 (m)	971	46%	14%	19%	61%	33%
> 15 (m)	132	6%	1%	2%	9%	10%
> 20 (m)	12	1%	0%	0%	0%	0%
Total	**2091**	**100%**	**100%**	**100%**	**100%**	**100%**

table 61: Yacht mix visual fleet assessment, total and development

Two developments are considered in the development of the yacht mix towards 2030. The first aspects is the increase of the share of yacht using marinas as described in the previous section. The increase of 4.5 and 9% for the medium and high scenario is added up to the yacht mix in 2007 according the earlier mentioned distribution of 90% smaller than 10 meter and 10% in the class of yachts between 10 and 15 meter. The additional number of yachts in Kuwait due to the development of the yachting industry in the 11% scenario is assumed to be only originating from new vessels bought according to the modern sea side marina. Assumed is thus that none of the 16,000 vessels, currently stored on land are moored in a marina or coastal haven in these scenarios.

Another aspect is the growth of the yachting fleet. This is added up to the current yacht mix for the 11% and 20% development scenario using the yacht mix of a modern seaside marina as reference.

The yacht mix of a modern seaside marina is selected because the marinas and coastal havens in Kuwait are all located along coastal waters. Therefore is expected that the yacht mix of a fully developed Kuwaiti yachting industry will show a lot of resemblance with the situation in modern seaside marinas.

The yacht mix of the modern seaside marina shows the expected shift towards the larger vessels, but a contribution from the class larger than 20 meters lacks. The yacht mix from a modern seaside marina is adopted for the growth of the yachting industry with a correction for the last two classes. The class larger than 15 meter is reduced to 6% and the class larger than 20 meter is set at 3%. This is in line with the observations and development trends of the world wide yachting industry.

The assumptions for the yacht mix result in the figures in table 62 for the medium and high scenario. For the low scenario no figures are calculated, because no changes are expected in this scenario as a result of the lack of investments.

Classes	Marinas (2007)	Total (2007)	Low 11%	Medium 15.5%	High 20%
< 10 (m)	47%	85%	47%	41%	40%
10 – 15 (m)	46%	14%	46%	52%	53%
> 15 (m)	6%	1%	6%	5%	5%
> 20 (m)	1%	0%	1%	2%	2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

table 62: Yacht mix development and scenarios results relative

The average of the medium scenarios is expected to be representative for the development direction of the Kuwait yacht mix best. It is added in the outer right column of table 62, others are given to give an indication of the bandwidth.

In absolute sense the figures in table 63 are obtained. These are used in the next phase to determine the spread of the yachts over the marinas and coastal havens.

Yacht mix class	Low scenario	Medium scenario	High scenario
<10 (m)	976	2792	5400
10 - 15 (m)	971	3541	7155
> 15 (m)	132	341	675
> 20 (m)	12	136	270
Total	**2091**	**6810**	**13500**

table 63: Yacht mix development and scenarios results absolute

I.5 Conclusions

- The indigenous population of Kuwait and the western expatriates are the main user categories of the yachting industry.
- A large share of the yachts in Kuwait is stored on land and the majority of the marinas have a high occupancy. Especially near Kuwait City is a need for more capacity, without the projected yachting demand potential.
- The demand potential is assessed according to a medium, high and low scenario. The medium scenario, in which the adoption rate and the natural growth of the indigenous population are kept constant, leads to an increase of the yachting demand potential with a factor two to four, depending on the share of vessels moored in marinas and coastal havens. This development is almost entirely driven by the natural growth of the indigenous population.
- The high scenario projects logically a larger growth with a factor 3 to 6, also depending on the share of vessels moored in marinas and coastal havens. This determines the range from no development (low scenario) to 6 times the current situation.
- The share of vessels moored in marinas and coastal havens is expected to increase in the medium and high scenario from 11 to 15.5 and 20%.
- The yachting mix is expected to shift to larger vessels in the medium and high scenario.

Appendix J. Development forecast fishery industry

J.1 Introduction

The methodology used in the previous appendix cannot be applied to the fishery sector. The number of vessels in the fishery sector is not linked to a disposable income or a certain user category. To give an indication of the development of the fishery sector, statistics obtained from the worldwide development prognosis of the fishery industry and the development of the industry in the Middle East and Kuwait are used. These statistics will be treated after the background a historical development of the fishery industry is treated. Next the statistics on the fishing industry, the employment in the fishery sector and the consumption of fish are taken into account to assess the development scenarios for the fishery sector. Finally development scenarios are used to determine the number of fishing vessels in 2030. The restrictions with respect to fishing on shrimps are used in this determination.

J.2 Fishery sector background

Fishing was a leading industry in the history of Kuwait. Fishing was in that time done with the ancient and native dhow vessel. Shrimp was one of the few commodities besides oil that Kuwait continued to export after World War II. Shrimp production, however, was diminished the 1991 War.

Fifty years ago, Kuwait was self sufficient in marine food supply. Despite the 20 fold increase of the population, the fishing industry currently provides 50% of the country’s seafood demand. This does not go without any sustainability issues like the depletion of stocks due to over fishing and the pollution of the breeding grounds by increased sediment due to marsh-draining in southern Iraq.

The economic success of Kuwait’s fisheries is due to the market demand, which is thus partially met by local production and import. In comparison to the oil industry, the contribution of the fishing industry to Kuwait’s gross national product is very small. In addition to commercial food production, the fisheries resources also support recreational fishing.

J.2.1 Worldwide development

In history, big increases were measured in the world wide catch production. In the 1950s and 1960s, world marine and inland capture fisheries production increased on average by 6 percent per year. During the 1970s and 1980s, the average rate of increase declined to 2 percent per year, falling to almost zero in the 1990s. This leveling off of the total catch follows the general trend of most of the world's fishing areas, which have apparently reached their maximum potential for capture fisheries production, with the majority of stocks being fully exploited. So the world marine catch totals continue to flatten off following the general trend of most major fishing areas of the world were fisheries have evolved from a developing to a more mature phase. When known traditional fish stocks and fisheries are taken into account, the total marine catches from most of the main fishing areas in the Atlantic Ocean and some in the Pacific Ocean seem to have reached their maximum potential years ago. Therefore, substantial total catch increases from these areas are unlikely. In contrast, growth in aquaculture production has shown the opposite tendency.

J.2.2 Present status of Arab fisheries

The coastal waters around the Arabian Peninsula, consisting of the Red Sea, the North Arabian Sea, several gulfs and the northern parts of the Indian Ocean, do not have the same productivity. The Red Sea is considered of poor productivity. The fisheries of the Arabian Gulf and Gulf of Oman are modest in their production. Some areas, especially in the Gulf of Oman and the north Arabian Sea, could withstand further exploitation. Only the shrimp resources are highly exploited in this region. The Gulf of Aden is considered a fish-rich area and is underexploited.

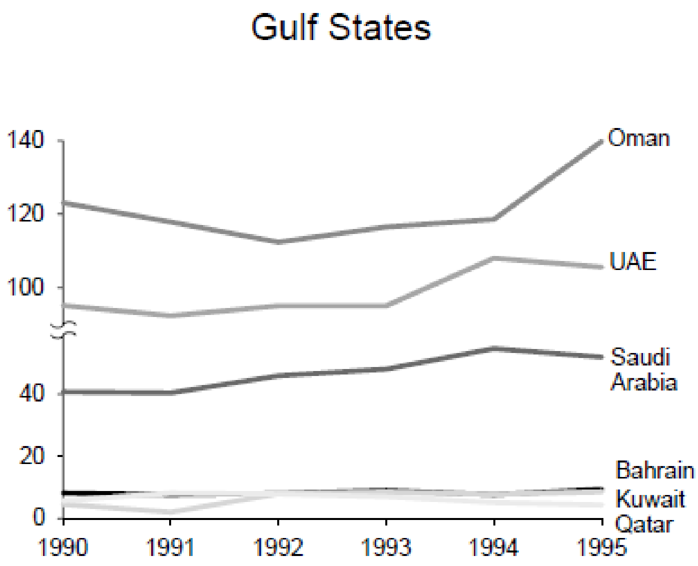

figure 116: Marine fish production (x1000MT) (FAO, 1995, 2001, 2003)

Statistics from the Food and Agriculture Organization of the United Nations (FAO) on fisheries in the Arab world show an averaged growth of landings over the period 1990-1995 of 1.1%. This growth is visible in the graph in figure 116 on fish production originating from marine wild life in the Gulf States.

J.2.3 Present status of Kuwaiti fisheries

The development of fishing capacity in Kuwait has taken place mostly in the large-scale (industrial) sector. Since the international development assistance, the main objective of fisheries development projects has been to increase fishing efficiency through motorizing boats, improving gear, and in harbor development and other infrastructure facilities.

At the same time, large numbers of small-scale fishermen have had no access to that assistance, finding it increasingly difficult to survive in an overexploited environment. The local fishermen play a minor role in the total fishery production. Most of their catch is sold on local market to the communities living in the area. The local fishermen may not be significant compared to the total fishery production, but they are for the community related to this small scale fishing industry. A family in Kuwait consists on average out of 8 members. In some situation these rather large families depend on the income brought in by the man of the family, who earns his money as fishermen.

The development of the captures in Kuwait is given in figure 117. This graph is very capricious especially during the time the country was under Iraqi occupation. The last decade also shows a deviation from the inserted trend line. This trend line shows a growth rate of the captures of 1% per year.

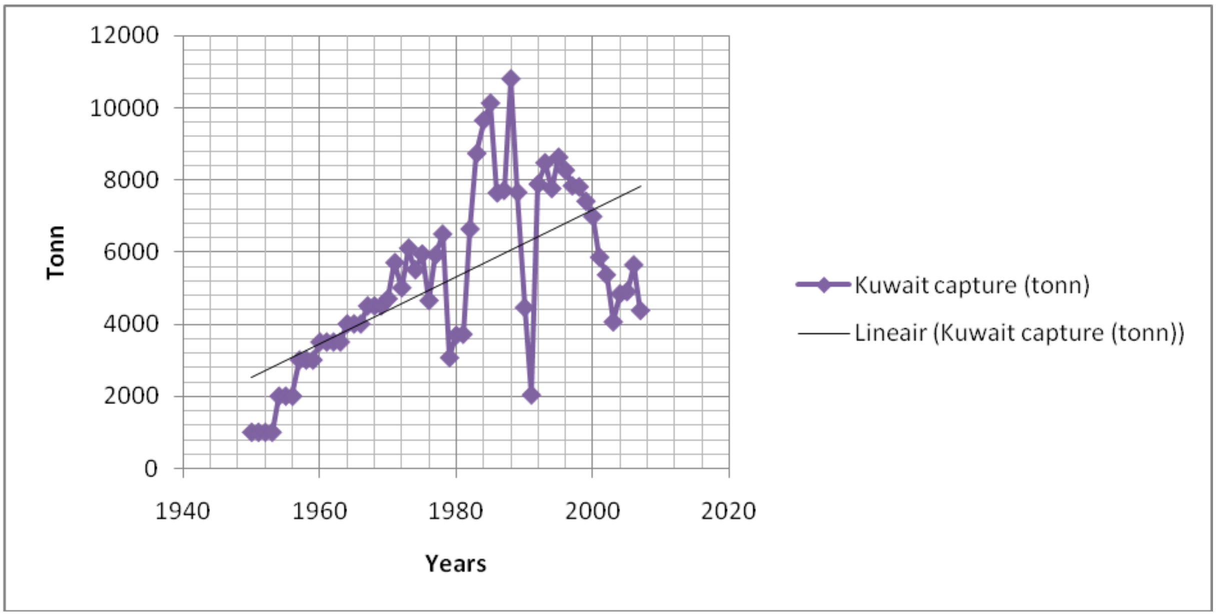

figure 117: Marina fish capture Kuwait including trendline (FAO)

J.2.4 Employment in the fishery industry

The number of employees active in the sector is specified in the statistics from the Ministry of Planning, the Public Authority for Civil Information (PACI). The number of employees active in this sector shows a growth of 10% between 2001 and 2003, in 2004 a growth of 22%, after 2004 the curve flattens and the grow rate becomes approximately 7.5%. Averaged over 5 years a growth rate of 12.5% is reached. In 2001 20,100 employees where active in the fishery sector and that number grew to 30,000 in 2005 (see figure 118).

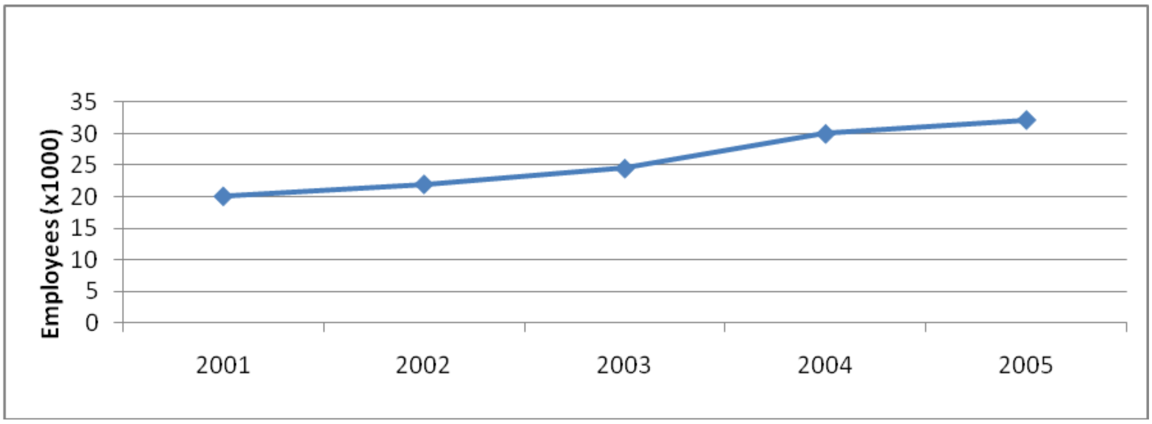

figure 118: Employees active in the fishery sector (PACI , 1995,2004,2005,2007)

J.2.5 Fish consumption

The average fish consumption per capita in the Arab world in 1995 was about 6.6 kg per year, compared with the world average of about 13 kg per year. Per capita fish consumption among the Arab countries is highest in the United Arab Emirates (51.1 kg/y) followed by Oman (36.7 kg/y) Bahrain (16.93 kg/y) Mauritania (16.6 kg/y) Qatar (16.5 kg/y) and Morocco (15.4 kg/y). All other Arab states are well below the international average. This is mainly due to low production levels in relation to a large population. Although Kuwait net imported fish product in the period 1990-1995, see figure 119, to satisfy the population's needs, the consumption is still far below the worldwide average. Fish consumption has a potential to increase further, also if we take the cultural relation of the Kuwaiti population with the sea and its resources into account. If we take the further growth of the population into account, fish consumption is expected to increase in the future.

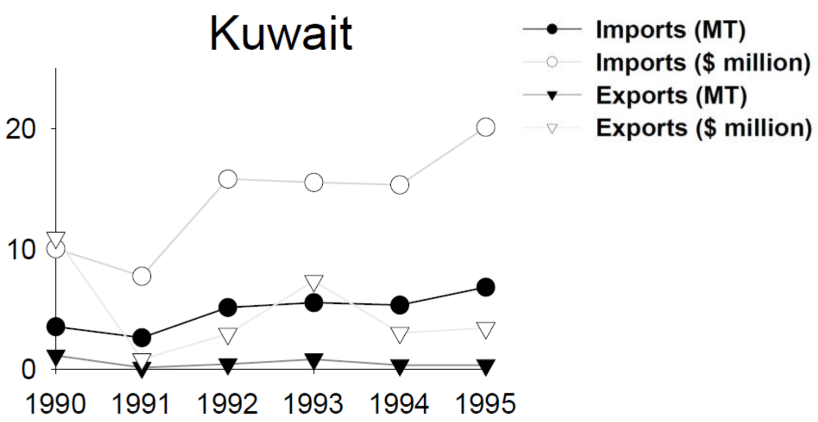

figure 119: Imports and exports of fish and fishery products (FAO, 1997)

J.2.6 Fisheries restrictions

The shrimp and finfish resources off the coast of Kuwait are already intensively exploited. The shrimp production could be increased by reduction of fishing activities and prevention of illegal fishing in the shrimp nursery in the Kuwait Bay. The draining of marshes in the northern part of the Arabian Gulf and a reduced outflow from the waterways of Iraq also influences the development of the resources in a negative way.

The shellfish production sector is bound by rules that limit the number of vessels, according to the country profile of Kuwait made by the FAO from 2001. This profile states that the number of commercial fishing vessels is limited to 35 trawlers and 33 dhows provided with engines.

The finfish fleet is not limited by a certain number of vessels, but suffers from rules prohibiting certain vessels to fish in the Kuwait Bay and further than 3 nautical miles offshore. The catch of finfish species in Kuwait and adjacent countries is in decline. Overexploitation may be the cause of this decline. There is no adequate enforcement of the regulations mentioned above, this results in illegal fishing.

J.2.7 Kuwaiti fishery sector statistics

The development of the fishery sector is limited by several aspects However statistics from 2001 to 2005 show a relatively large increase of the contribution to the Gross Domestic Product (GDP) by the agriculture and fishery sector, see figure 120, a large growth of this sector is not expected. This curve seems to flatten off in the years 2004 and 2005. The same trend was visible for the statistics on employees active in the fishery sector in figure 118.

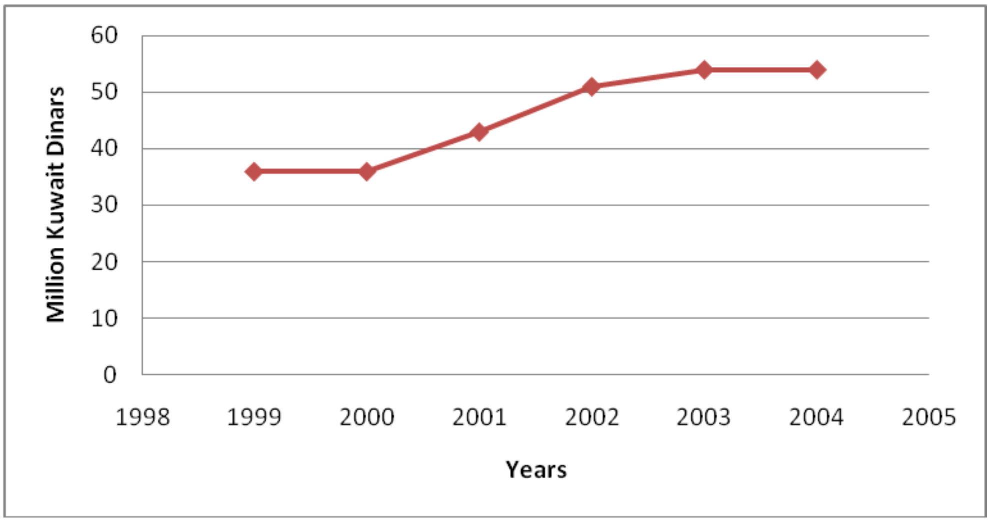

figure 120: Contribution of agriculture and fisheries sector to GDP (PACI, 1995,2004,2005,2007)

J.3 Fishery industry scenarios

The worldwide development and the more regional overview of the fishery sector show a very modest growth over the last years. All over the world the exploitation of the seas is pushed to its maximum and a large growth of the catch is not expected. Restrictions and regulations are imposed by governmental authorities to protect the resources from overexploitation.

The situation in Kuwait is comparable to the worldwide situation; overexploitation and regulations are already mentioned in country reports from the FAO in 2001. On the other hand import and consumption of fish show an increase in the period from 2001 and 2005, but these increases are also related to the continuing growth of the population. The consumption of fish has a development potential, since it is below the world wide average. If this growth is realized, the demand for fish cannot be met by captures alone, since the capture of fish could not follow the demand in the past. Beside the increased captures it has to be met by the import of fish or increased production of the aquaculture sector.

The following parameter values will be used in the three development scenarios:

High scenario

For the high scenario, the growth rate is linked to the high potential of fish consumption and the growth of employees in the sector. The statistics on these aspects showed a larger growth than the captures. With the proposed investments by government to the sector by creating coastal havens in mind, a high development scenario with a growth rate for the industry of 2% is assumed to be achievable.

Medium Scenario

The trend line for the statistics on the captures from 1950 until 2007 show an increase of 1% as well as the landing on Arab beaches for the period from 1990 until 1995 (both originating from FAO statistics). Therefore this growth rate will be set for the medium development scenario.

Low scenario

In the pessimistic scenario no growth or even a decrease of the sector is expected. Fishermen will not respond to the investments into the sector. The statistics from the FAO on the last decade show a setback in captures, averaged over this period we arrive at a rate of -3%. The sector already showed years where a decrease was noticeable. A more modest rate for the development of the fishing industry is used than the averaged decline of captures over the last decade.

If regulations are enforced more strictly and natural circumstances are further deteriorating, a development of the sector size with a rate of -1.5% is expected to become reality.

J.4 Fishery fleet forecast

The growth rates mentioned in the different scenarios below will be applied to the fishing fleet of Kuwait, taking the restrictions into account. One other restriction besides the ones laid down on the commercial fishing fleet is the fact that no or very few new dhows are built in Kuwait. This part of the fishing fleet will not show an increase in the future. The dhows still fulfill a useful contribution to the fishing industry but the development of the fishing fleet is mainly caused by the smaller speedboats, therefore the rates are applied to these vessels. Keeping the commercial fishing and dhow fleet at current levels, we end up with the forecast for the fishery fleet in table 65, which is based on the numbers in table 64 from the target user group analysis in chapter 4.4.

Speedboats			Dhows	Commercial fishing vessels	Barges (15-60m)
5-10 (m)	10-15 (m)	>15 (m)			
505	142	12	160	90	25

table 64: Number of vessels in target user group fishing vessels from visual estimation

Scenario			2007	2010	2015	2020	2025	2030
High	2.0%	Dhows	160	160	160	160	160	160
		Commercial fishing vessels	90	90	90	90	90	90
		Total speed boats	659	699	772	852	941	1039
Medium	1%	Dhows	160	160	160	160	160	160
		Commercial fishing vessels	90	90	90	90	90	90
		Total speed boats	659	679	714	750	788	828
Low	-1.5%	Dhows	160	160	160	160	160	160
		Commercial fishing vessels	90	90	90	90	90	90
		Total speed boats	659	630	584	541	502	465

table 65: Forecast fishery fleet

J.5 Conclusions

- Not a lot of growth is expected for the fishery industry
- The increase in the number of vessels will be restricted
- Only the number of smaller speedboats will show a significant increase in the future.
- Significant restrictions exist for the fishing industry
- The high development scenarios results in a growth of the fishery sector with 250 vessels, the medium in a growth of 100 speedboats and the low scenario result in a decrease of the fishing fleet with 150 vessels over a period of approximately 20 years.

Appendix K. Functioning of a coastal haven

K.1 Introduction

The processes, functions and facilities are described per target user group in this appendix. The interrelations and overlap of these aspects are mapped and discussed after the assessment. A conclusion on the processes, functions and facilities that can be combined and need to be separated in a coastal haven is the aimed result of this appendix.

The processes, functions and facilities are listed by the group that induces them. An overlap of processes in a marina, fishing port and port of refuge is expected, since the basic needs from these target user groups show a similarity. Mapping this overlap is one of the objectives of this appendix. This is done by monitoring the interrelations and combining the functions in one figure.

Next to the overlap, there are processes that belong to a specific target user group or need to be allocated at a separate location. This leads to additional functions and facilities bounded to one of the three groups.

K.2 Methodology

Common processes in a fishing port, marina and a port of refuge are used as a starting point for the formulation of functions that a coastal haven will have to fulfill.

These functions can be materialized by translating functions into facilities. The interrelations between the functions are important in the functional layout of a coastal haven.

The main focus of the master plan and functional layout of coastal havens will be on the target user groups under normal conditions. If auxiliary facilities are needed these will be taken into account to be able to serve as port of refuge in extreme conditions. The need for auxiliary facilities is one of the aspects that results from this analysis.

K.3 Processes

In this paragraph all the processes that occur in a marina, fishing port or port of refuge are elaborated.

K.3.1 Marina

People
- Arriving
- Parking
- Informing

- Recreating
- Facilitating
    - Visitors
    - Residential people
- Leaving

<u>Yachts</u>

- Entering
- Accessing water
- Putting ashore
- Berthing
- Facilitating moored yachts
    - Electricity
    - Water
    - Cooking gas
- Refueling
- Pumping out waste water
- Repairing
- Maintaining
- Watching
- Supervising
- Storing on land
- Leaving

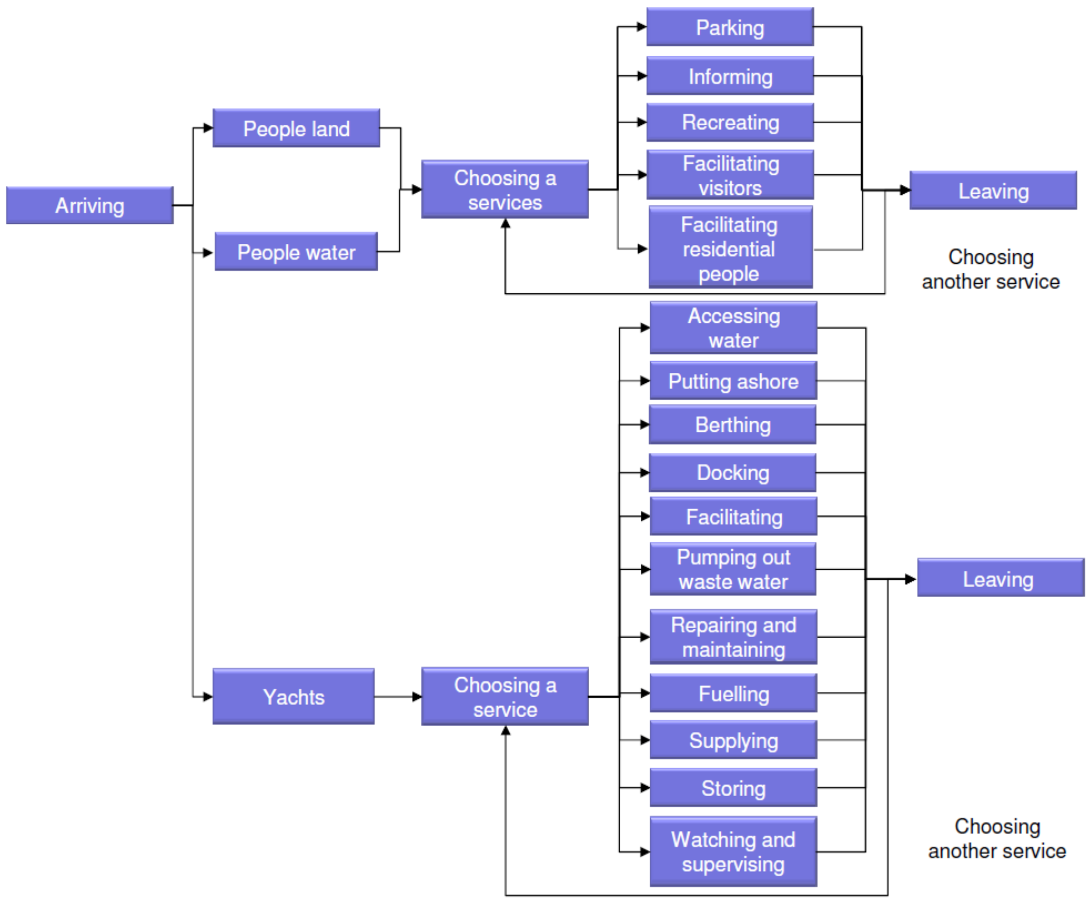

figure 121: Processes marina in flow chart

K.3.2 Fishing ports

The kind of fishing port that needs to be constructed depends on its users. The design and incorporated characteristics, processes and functions of a fishing port are related to its target user group. Corresponding characteristics, processes and functions that will occur are taken from the literature on the design of fishing ports.

Off-loading techniques

The handling technique depends on several factors such as the type of fish, vessel size and the total expected catch to handle. The used technique determines the dock equipment and the on land facilities.

The used catching methods in Kuwait are gillnets, traps, anglers and fish farming in Kuwait Bay. A manual off-loading method or a bucket and a winch are common to use in combination with these small to medium sized fishing vessels and catching techniques. Fish come to shore with or without ice, loose or in boxes. A bucket and winch (dock-based crane consisting of a boom and a winch) can be used to bring the buckets ashore. When the fish are boxed onboard the bucket is replaced with boxes, containers or pallets.

Catching method	Process on board	Species	Off-loading method
Anglers	None, icing, boxing, bleeding	Pelagic, demersal,	Manual, bucket and winch
Gillnet	Icing, boxing, bleeding	Benthic, demersal,	Manual, bucket and winch
Traps/farms	None, icing	Benthic, demersal	Manual, cage/bucket and winch, cranes

table 66: Catching method, species caught and off-loading method (PIANC WG18, 1998)

Handling techniques

The handling refers to the actions needed to get the fish from the operations required to get the fish from the dock to the consumer. Routine operations after off-loading are previews (the prospective buyers examine the quality of fish lots), cleaning (cutting off the head, trail, and gills, and gutting and bleeding), grading (the fish are classified according to size and species), weighing, packing (usually styrofoam packing with ice), and auctioning. Another option is the loading of a truck with fish and shipping it to distant markets. Some operation can be done at the dockside (preview, weighing, auctioning other are than performed at the remote facility.

Marketing practices

Marketing practices refer to the commercial process: fish sale, processing, packaging, distribution and promotion. This process starts usually at the dockside or in an adjacent auction hall. Prospective buyers inspect the fish and make offers in accord with quality. The new owner could be a wholesaler, a retailer or even the final consumer. The fish arriving at the coastal haven is expected to be sold to a general public market, restaurant chain or to the final consumer.

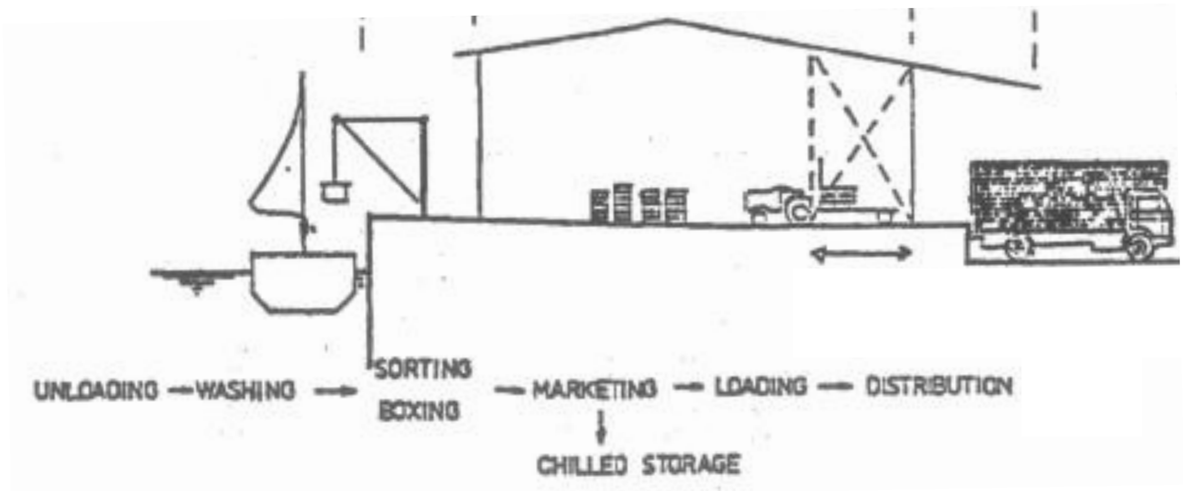

figure 122: Catch marketing processing principles (Ligteringen, 2000)

A fishing port can be designed for local fishermen, who use their small and simple vessels with or without motor to catch fish at a day trip away up to the large ships that sail for 7 months a year on the ocean.

Fishing port management model

The management model of a fishing port can be described by three types of management models. The port management model is strongly related to the ownership of the port infra- and supra-structure, and to the related responsibilities for the maintenance and the operation of the port itself. The type of management models are:

- Service port
- Tool port
- Landlord port

<u>Service port system</u>

In the case of the coastal haven in Kuwait, the service port system is applicable. The national government owns and maintains the port infrastructure, superstructure and equipment, and also operates the port. Day-to-day management and operations are entrusted to the Kuwait Port Authority.

<u>Tool port system</u>

The tool port system is similar to the service port system except that the Port Authority is not involved with the port operations. This is carried out or contracted to the fisherman or the fish buyer. Many of the smaller fishing port provided by governments for small-scale fisherman in developing countries operate under this system. In Kuwait the Port Authority carries out the coastal haven management of the existing locations. This management system is therefore not applicable.

Landlord port system

The landlord port system is the type of management structure in which the Port Administration only administers the port infrastructure, leaving all fish handling operations to private enterprises. The Port Administration develops, owns and maintains the infrastructure, but leases individual to private companies, which provide their own equipment and labor. This management system is also not applicable to the coastal havens in Kuwait, because the Kuwait Port Authority administers more than only the port infrastructure.

Processes

The target user group fishing vessels consists mainly of the local fishermen, who use their own fishing vessels and are bounded to a certain location and their fishing grounds are a short distance away. The larger commercial fishing vessels, which are owned by companies, use the commercial fishing port of Doha and Shuaiba.

To create an effective fishing port, the fishing vessels need a ramp and berthing quay, together with matching facilities for handling of the catch. Facilities for maintenance and repair increase the value of a fishing port.

Processes in fishing port are given below, categorized by the inducing group.

People

- Arriving
- Parking
- Gathering
- Discussing
- Working
- Training
- Managing
- Leaving

Catches

- Cleaning
- Sorting
- Packaging
- Weighing
- Storing
  - Iced (chilled)
  - Alive
- Marketing
- Distributing

Fishing vessels and gear

- Entering
- Berthing
- Unloading catches
- Cleaning
- Repairing and maintaining
    - Vessels
    - Nets
    - Other fishing gear
- Fuelling
- Supplying
- Mooring
- Storing
    - Vessels
    - Nets
    - Spare parts ships
    - Maintenance equipment
    - Other fishing gear
- Leaving

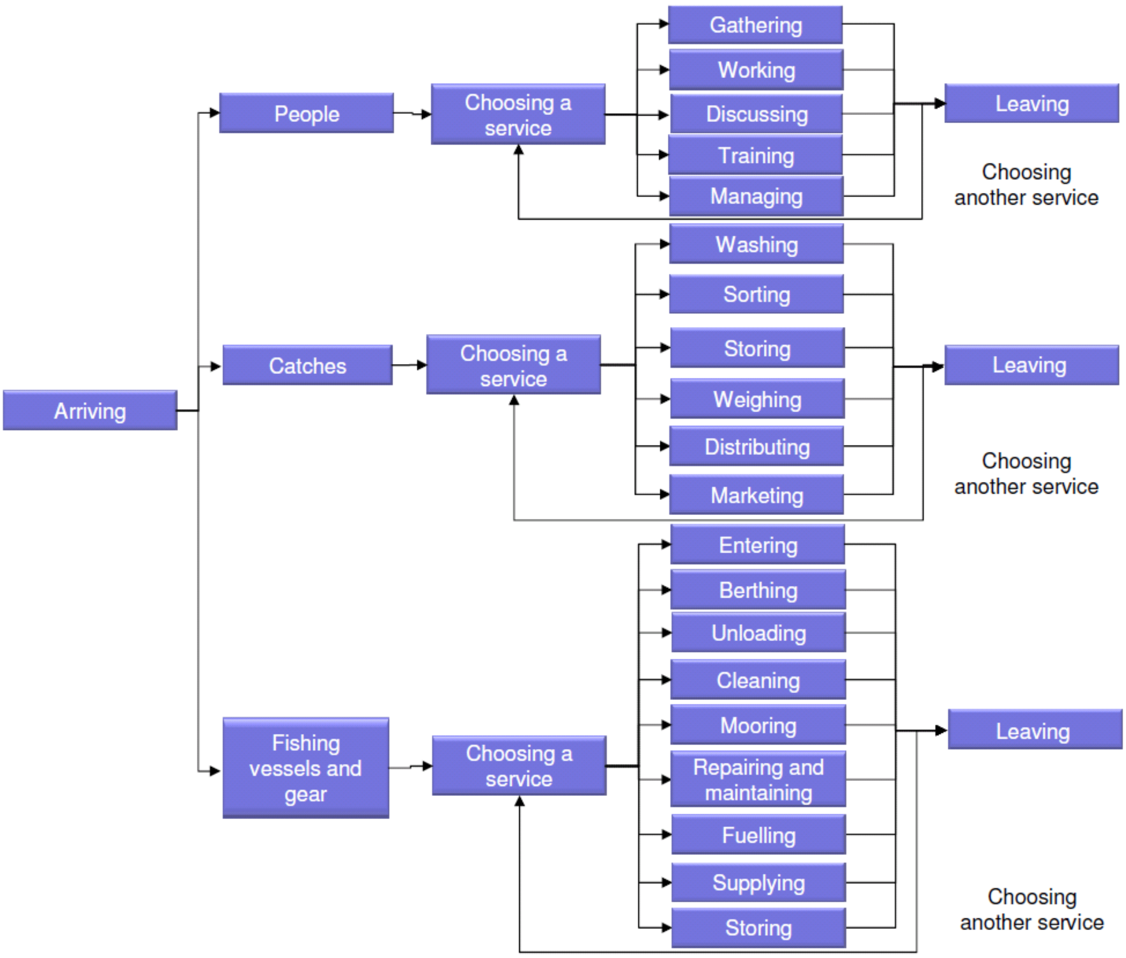

figure 123: Processes fishing port in flow chart

K.3.3 Port of refuge

- Entering in bad weather conditions or other cases of emergency
- Sheltering
- Berthing in bad weather
- Incidental loading/unloading

- Emergency repairing
- Boarding of berthing and entering assistance from coastguard, tugs or other vessels
- Crew assistance, medical aid services
- Leaving

Depending on the duration of stay in a coastal haven and the kind of vessel reference is made to the processes in a marina or fishing port.

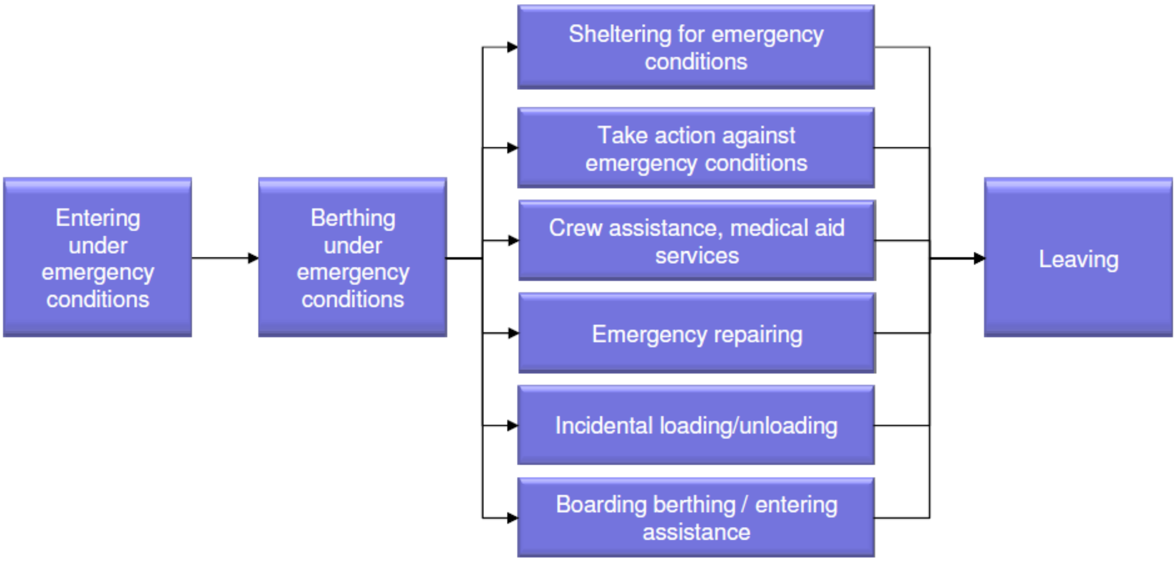

figure 124: Processes for a port of refuge in a flow chart

K.4 Functions

Processes are translated into functions. Functions can be seen as services that provide possibilities that enable the processes. A function is said to be the realization of a process. A function fulfills a certain demand of the target user groups. It provides opportunities to, or creates boundaries for a certain process. The functions are formulated in this way for a marina, fishing port and port of refuge in the following sections.

K.4.1 Marinas

Main function of the marina is to provide yachts with services that are expected from a marina.

- To park cars
- To inform users
- To recreate
- To facilitate visitors
- To facilitate residential people
- To access the water
- To enter the marina
- To put vessels ashore
- To berth the vessels
- To dock the vessels

- To facilitate the vessels
- To refuel the vessels
- To pump wastewater out of the vessels
- To supply the vessels
- To store the vessels
- To watch and supervise the vessels
- To leave the marina

K.4.2 Fishing port

Main function of the coastal is to provide commercial and private fishing vessels with services that are expected from a fishing port.

- To enter the port
- To gather the fishermen
- To discuss with fishermen
- To processes the fishermen
- To train the fishermen
- To inform the fishermen
- To clean the catch
- To sort the catch
- To package the catch
- To weigh the catch
- To distribute catch
- To market the catch
- To enter the port
- To berth the vessels
- To moor the vessels
- To repair and maintain the vessels and gear
- To clean the vessels and gear
- To refuel the vessels
- To supply the vessels
- To store the vessels
- To unload the vessels
- To leave the port

K.4.3 Port of refuge

There are few processes in a port of refuge. The main process is the safekeeping of the vessels using the coastal haven as a port of refuge. Processes deduced from this are given below.

Main function of the coastal haven is to provide users of a coastal haven in extreme conditions with services that are expected from a port of refuge.

- To protect the vessels
- To access the port in storm conditions
- To berth in storm conditions
- To load/unload the vessels incidentally
- To repair the vessels in case of emergency
- To board berthing/entering assistance from coastguard, tugs or other vessels
- To supply medical aid and crew assistance
- To leave the port

Depending on the time of stay in a coastal haven and the kind of vessel reference is made to the processes in a marina or fishing port.

K.5 Interrelations functions

Most of the functions needed to function as a port of refuge are also incorporated in the design of coastal haven that will facilitate yachts and fishing vessels. Facilities are present, but need to be dimensioned for vessels that will use the coastal haven as a port of refuge.

In this analysis all the functions are combined in one scheme. This results in 4 categories. Functions are divided into clusters that are needed for a marina, fishing ports and a port of refuge (general functions), the combination of fishing port and marina, only a fishing port and only a marina. In figure 73 an overview of the functions is given and their overlap is made visible.

<u>General functions for coastal havens are:</u>
- to enter/leave coastal haven (sea side)
- to repair, maintain vessels and yachts
- to supply vessels and yachts
- to provide medical aid, security and crew assistance
- to inform users
- to berth vessels and yachts
- to shelter from storm conditions
- to supervise, manage and train the users

<u>To fishing ports and marinas bounded functions are:</u>
- to store vessels and yachts on land
- to enter/leave coastal haven (land side)

<u>To fishing ports bounded functions are:</u>
- to handle (clean, sort, package, weigh, market and distribute) the catch
- to store catch and gear

<u>To fishing port and port of refuge bounded functions are:</u>
- to unload the vessels

<u>To marinas bounded functions are:</u>
- to recreate
- to market new and used yachts

K.6 Facilities

To provide the processes and functions above with the required infrastructure a translation into facilities is made for all functions and processes above. All the possible facilities are gathered in table 26 after section 7.10. In this table is also indicated for which kind of main functions these facilities are applicable.

As earlier mentioned, the functions that a coastal haven in the network will have to fulfill are the base of the facilities that need to be placed in a coastal haven. The facilities that need to be incorporated in the functional layout are depending on the geographical spread of the target groups and allocation of functions in the master plan.

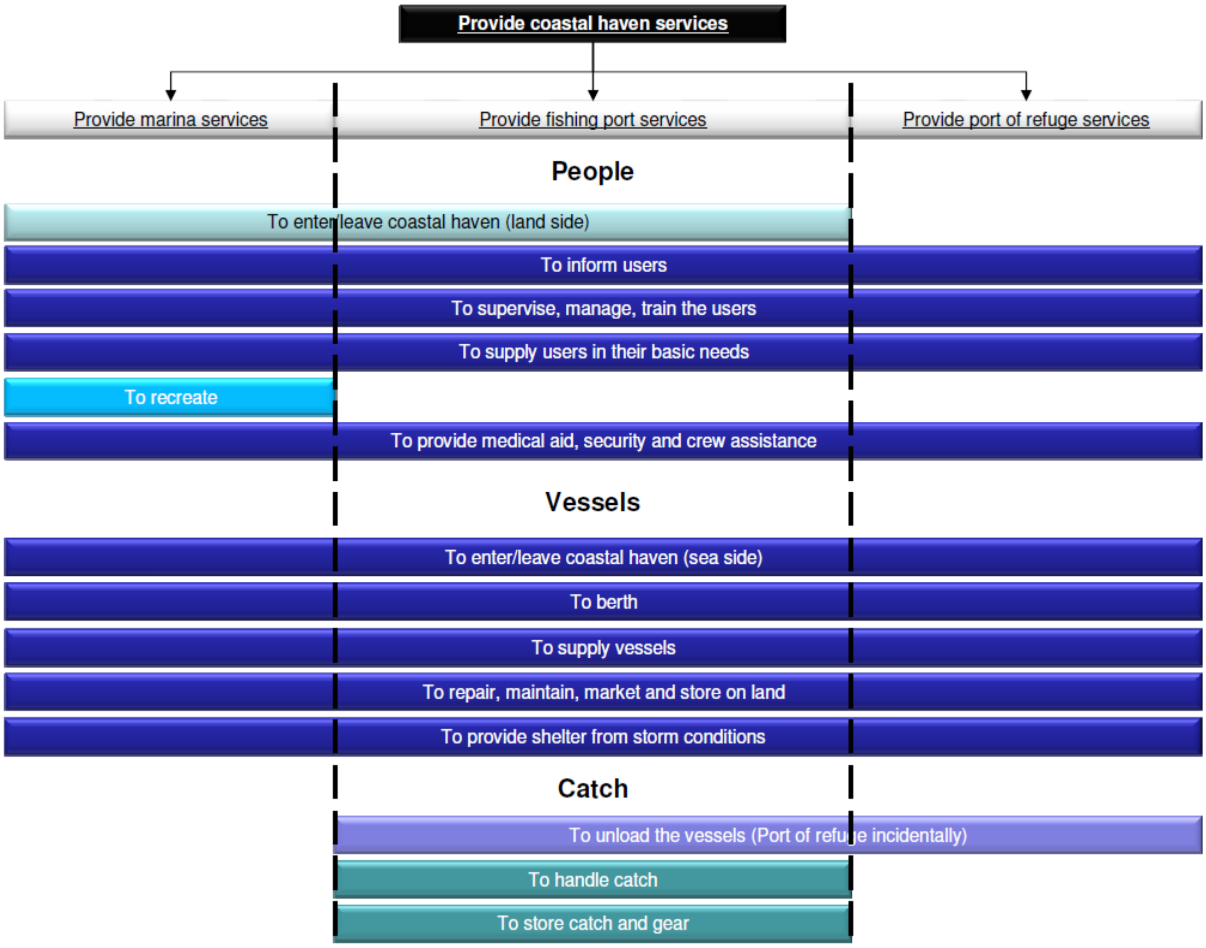

figure 125: Main function analysis coastal haven

K.7 Conclusion

It can be concluded that a coastal haven is built up out of several aspects from the three main functions of a coastal haven. The three main functions are to provide services that can be expected from a marina, fishing port and port of refuge. These functions are interrelated if all target groups are present in a coastal haven and the coastal haven is to be developed as a full-service coastal haven.

In general can be said that the functions related to the handling of the catch and the gear of the fishing vessels are separate functions bounded to the fishing vessels. The entering and leaving, refueling, maintaining and protecting against storm conditions of the vessels is a function that can be combined for the three groups. Mooring of the vessels needs to be done separate with moorings adapted to the various vessel and yacht sizes in the target user groups. Separation of moorings is also needed because of the difference between the users of the yachts and the fishermen. Yacht owners and fishermen originate from a different part of the society and are present in a coastal haven for different reasons.

A third reason for the separation of moorings are the waves that are induced by ships entering the coastal haven. The allowable wave height at the berths of yacht is 30 centimeters or less. Larger fishing vessels induce ship waves that make stay on a yacht at a berth unpleasant. Separation of berths and additional measures are therefore advisable.

The supply of basic needs and information can partly be combined, but yacht owners demand higher standards and have other preferences, so these functions will have to be separated partly as well.

Appendix L. Design criteria and requirements

L.1 Design criteria coastal haven

- A sailing yacht of 25 meter length and draught related to this ship length must be able to enter and berth in the marina section of coastal haven.
- The port of refuge function is for dhows, commercial fishing vessels and other vessels of 35 meter or less in length.
- Quay length for fishing vessels to unload their catch based on 8 to 10 vessels at the same time. This assumption is made, because no information is available about the amount of catch that passes a the coastal haven.
- All fishing speedboats are assumed to be berthed in the water. If berths are provided, storage space on land will also be available.
- Vessels that use the coastal haven as port of refuge use berths along a quay at the inner basin of the coastal haven. The quay must have sufficient length to berth 3 design vessels along.

L.2 Design vessels

The design vessels determine for a large part the layout and dimensions of the coastal haven. In this section the design vessel for each target user group of the coastal haven is determined.

L.2.1 Yachts

The yachts and speedboats in Kuwait range from small speedboats of 8 meter up to large yachts of 25 meters. Almost no sailing yachts are present in Kuwait. However sailing yacht are normative for the required water depth in marinas due to their draught. An overview of the relation between lengths and draught is given in table 67.

Boat length [m]	Vessel draught [m]		
	Speed boats	Motor yachts	Sailing yachts
8	0.9	1.5	1.50
10	1.0	1.8	2.25
12	1.0	2.0	2.50
15	1.2	2.5	3.25
20	1.5	2.9	3.75
25	**1.8**	**3.0**	**4.00**

table 67: Typical vessel draughts (Australian Standard, 2001)

The relation of the boat length and boat beam is given in table 68. This information is required in order to make an arrangement of berths for the functional layout.

Boat length [m]	Boat beam [m]		Boat length [m]	Boat beam [m]
6	2.8		17	5.3
7	3.1		18	5.4
8	3.4		19	5.5
9	3.7		20	5.7
10	4		21	5.8
11	4.3		22	5.9
12	4.4		23	6
13	4.6		24	6.3
14	4.8		**25**	**6.5**
15	5		30	7.5
16	5.2		35	8.7

table 68: Vessel length and beam relation (Australian Standard, 2001)

L.2.2 Fishing vessels

For the fishing vessel two distinct groups can be indicated: the speedboats up to 10 meter, and the dhows. The draught of the speedboats can be found in table 67. The dhows however are normative for the water depth in the fishing port section. The dhows can have a length of 15 up to 35 meter. The corresponding draught and beam are obtained from figure 126.

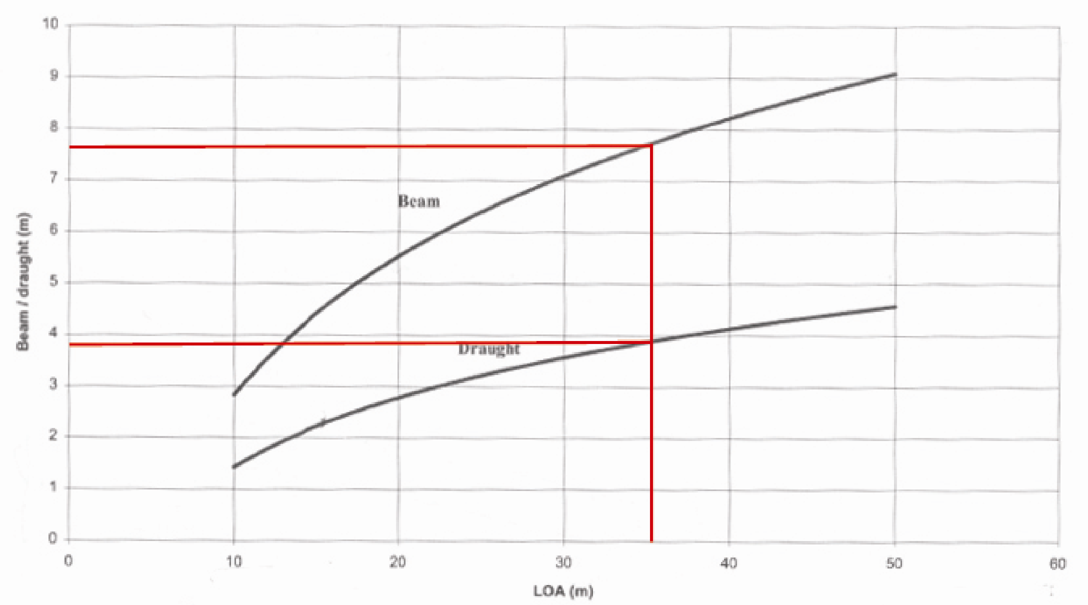

figure 126: Draught and beam fishing vessels (Ligteringen, 2000)

The beam of the maximum expected fishing vessel in the coastal haven is determined at 7.5 m and the draught at 4 m. These are values that are also applicable to the commercial fishing vessels or barges up to 36 m.

If these values are used to calculate the gross tonnage of the vessels a value that corresponds with the literature on dhows is obtained.

Dhow and related historical vessels

The dhow is a combined description of the artinenal fishing vessels in Kuwait. Some types are descripted below.

One of the Arab world's most common sailing vessels is the Sambuq. This vessel has a loading capacity that varies from 20 to 150 tons. In the past, the Sambuq was used for diving to collect pearls but now it is used for carrying cargo and transporting passengers.

One of the smallest and oldest traditional dhows in the emirates is the Shasha, a small oar-driven fishing boat made entirely of date palm sticks. Another early vessel was the Huri, often made of Mango wood. The Baghlah is a square-stern, lateen rigged 200-300 ton vessel used mainly for cargo transport. It is now rare as it is being replaced by the curved-stern Boom.

A variation of the Boom is the Breik. Another common dhow is the smaller Sambuq, usually around 40-60 feet in length. It was originally used for pearling and now mostly for fishing.

The Batil is a long fast dhow used in peace time for fishing, but designed as a high-speed attack vessel. This is the dhow that effectively defended Arab trading in the Gulf, and prompted the British to burn Ras Al Khaimah to the ground in 1809. A variation of the Batil is still used for racing.

L.2.3 Vessels that take refuge in the coastal haven

For this target user group, a vessel of 35 meter with corresponding depths and beam, is taken as representative. Barges, dhows and commercial fishing vessels of this size are present in Kuwait. This is the largest expected vessel that will use the entrance channel, turning circle, pass through the opening in the breakwater and moor at the dedicated berths. Vessel larger than 35 meters are expected to take refuge in the commercial ports of Shuaiba, Shuwaikh and Doha.

L.3 Water depth requirements

The required water depth for the different components and sections of the coastal haven are determined below. The reference level for the water depth is Chart Datum (CD), corresponding with Lowest Astronomical Tide (LAT).

<u>Entrance channel</u>

The water depth of approach channels depends on a number of factors:

- Draught of the design vessels
- Wave climate outside the coastal haven basin
- Nature of the bed material
- Likely rate of siltation of the entrance channel
- Future extension of the coastal haven
- Construction considerations

To account for all these factors the following additions are applied to the draught of the design vessel.

- A minimum of half the significant wave height for vessel movements resulting from wind-generated waves and boat wake.
- An appropriate allowance where significant siltation is likely to occur or where it is preferred to reduce the frequency of maintenance dredging. Since no information is available on the local siltation rate and the desired frequency of maintenance dredging, another approach is used. A minimum under keel clearance of 300 millimeter or 10 % of the design vessel draught, whichever is greater in case of soft soil. In case of hard material a minimum of 500 mm is to be used.

The design vessel for the entrance channel is the fishing vessel (dhow or commercial fishing vessel) with length 35 m, draught 4 m and beam 7.5 m. The maximum significant wave height obtained from the 13 year time series is 3.32 m. The vessels are not allowed to enter the coastal haven at situations in which the wave height exceed 1.5 – 2.0 m. The amplitude is half of the wave height thus 0.75 – 1 m. The area around Al Syadeen is characterized by sandy beaches. This leads to the assumption of a soft soil. The under keel clearance is determined at 0.4 m (10% of 4 m). This results in a required water depth 5.15 – 5.4 m. A value of 6 meter is used in order to include some additional depth in order to be able to have some sedimentation.

This matches with the design rule of 1.5 times the draught of the design vessel for locations that are subject to waves of 1 m or higher. This rule of thumb can be used for a preliminary assessment of the channel depth.

Turning basin/first section behind breakwaters

The water depth in this section of the coastal haven should be equal to the depth in the entrance channel.

Marina section

The marina section of the coastal haven is sheltered by the breakwaters, which results in less wave action in this section. The required depth can therefore be reduced to the draught of a sailing yacht of 25 m, 4 m, added with the remaining significant wave (H_s=0.6 m) and 10 % of the draught of the design vessel. This results in a required water depth of 5 m. For this section a water depth of 5 m is used.

Fishing port section

Inside the fishing port section the water depth is also less than in the entrance channel, since this section is less subject to wave action. The maximum significant wave height for fishing vessel is assessed at 0.6 meter. The required water depth is therefore also set at 5 m. An over depth can be required if less maintenance to this section of the coastal haven is desirable.

L.4 Nautical conditions

Number of lanes

The entrance channel of the coastal haven is designed with a 2 lane entrance channel. In this way the several target user groups can safely enter and leave the coastal time under normal and storm conditions. Separation of target user groups during entering and leaving the coastal haven is desirable. With a 2 lane channel the safety is expected to increase.

Approach channel width

A moving vessel makes a sinusoidal track and in this way covers a basic width of about 1.5 times the ships beam. Next to this wind, waves, currents and lack of visibility require additional width. Next to this several additional margins are needed. For a straight, two lane channel the total width is expressed by the formula below for a 2 lane channel for 2 dhows, barges or commercial fishing vessel with dimensions (L x B x D) 35.0 x 7.5 x 4.0 m.

$$W = 2\left(W_{BM} + \sum W_I + W_B\right) + W_P$$

With the components from table 69 the advised width of entrance channel width results in 8.8B. This is equal to 66 meter.

An overall minimum value for the channel width indicated in literature (Ligteringen, 2000) would be about 30 m to 40 m, applicable to small indigenous vessels and favorable nautical conditions. However, usually widths for two-way traffic vary from 90 to 100 m. For an outer channel for two-way traffic, as a rule of thumb, the minimum is about 10 times the beam of the maximum size vessels. For the design of the layout alternatives a width of 100 m is taken into account.

Width components	Condition	Width (m)
Basic width	d<1.25 D	1.6 B
Additional width		
-prevailing cross winds	15-33 kn	0.4 B
-prevailing long current	1.5 – 3 kn	0.1 B
-prevailing wave height	1-3 meter	1.0 B
-aids to navigation	Good	0.1 B
-seabed characteristics	Soft	0.1 B
Separation distance (W_P)	5-8 kn	1.2 B
Bank clearance (W_B)	Sloping edge	0.5 B

table 69: Channel width components (Ligteringen, 2000)

Alignment approach channel

The following requirements apply to the alignment of the approach channel:

- The shortest possible length taking into account wave, wind and current conditions
- Minimize the cross-current and cross-wind
- Small angle with dominant wave direction
- Minimize number of bends and avoid bends close to the entrance

The orientation of the approach channel should preferably be in line with the dominant wave direction. This should be done in order to have waves coming in "aft" of the vessel instead of "quartering" or "beam". At the same time the configuration should limit wave penetration. These two requirements lead to a small angle between wave direction and the axis of the approach channel.

Inner channel and turning circle

In the coastal haven basin, space is required to receive vessels and to turn. The turning basin and space behind the breakwater should be in the order of 1.5 times the length of the design vessel. This results in a diameter of the turning circle of 52.5 m. Width inner channel is equal to the outer channel. The additions for currents and waves are in theory not needed for the inner channel.

L.5 Berthing arrangement requirements

L.5.1 Marina section

The Australian Standard is used as guideline for inner channel width, fairway width, berth width and length for single and double berths, finger pier width and length and the gangway width. A typical layout looks like the one in figure 127.

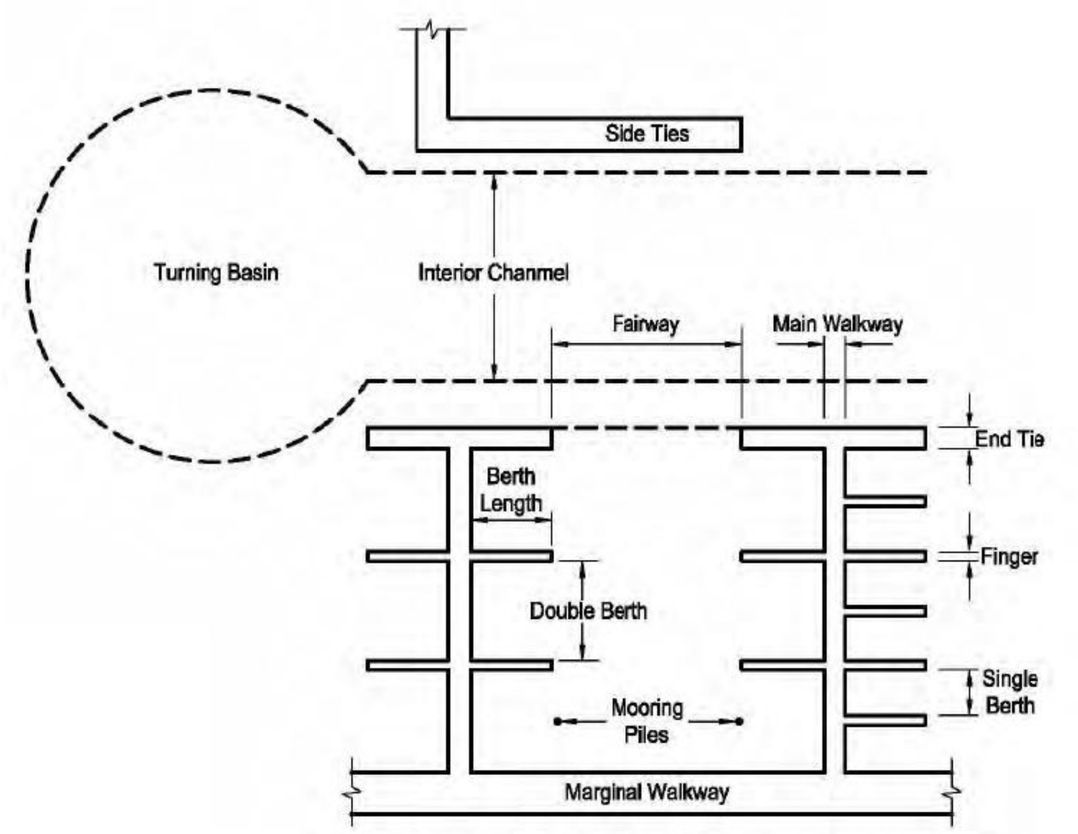

figure 127: Typical berthing arrangement (U.S. Army Corps of Engineers, 2009)

Interior channel

The interior channel of the marina is not greatly influenced by the wind, waves and currents. Its dimensions are therefore mostly based on the size, number and type of vessels and the frequency of usage.

- Minimum width inner channel: 37.5 m (20 m or 1.5 L_s)
- Preferred width inner channel: 43.75 m (25 m or 1.75L_s)

Fairways

For the fairways the overall length of the longest yacht using that fairways need to be considered. Berths for size classes are in general separated within a marina. The fairways within a marina can therefore differ. The design rules are as follows:

- Minimum width: 1.5 L_s m.
- Preferred width: 1.75 L_s m.

Berths

The number of berths in each size class and the length and width of the berths are determined according the yacht mix and marinas used as reference. For each class the fair way width is determined as well. The information on the vessel beam and length relation that is used for this calculation can be found in table 68.

The berth width is calculated with the following expressions:

- Double berths: 2 times the design maximum beam + 1 m up to 20 m long vessels and 1.5 for vessels above 25 m in length.
- Single berths: design vessel beam + 1 m up to 20 m long vessels and 1.5 m for vessels above 24 m in length.
- No berths are assigned or designed for multi hull vessels. These vessels can use the end ties.

Berth length (m)	Berths width (m)		Fairway width (m)		Finger pier length (m)	Berths
	Single berth	Double berth	Min.	Preferred		
8	4.4	7.8	12	14	>6.4	200
10	5	9	15	17.5	>8.0	200
12.5	5.5	10	18.75	21.88	>10	150
15	6	11	22.5	26.25	>12	100
17.5	6.35	11.7	26.25	30.63	>14	25
20	6.7	12.9	30	35	>16	15
25	8	14.5	37.5	43.75	>20	10

table 70: Berth length, berth width, fairway width and number of berths

Walkways

Walkways should not be less than 1.5 m wide. Consideration should be given to the need of trolleys passing each other and access in emergencies. The minimum width of walkways should be:

- 1.8 m for walkways of more than 100 m in length or,
- 2.4 m for walkways of more than 200 m in length.

Finger piers

The finger piers between the berths should support safe pedestrian use and loading and unloading of the vessels. The length of the finger piers should not be less than 0.8 L_s and can have an uniform width of 0.9 m, or can be tapered to a minimum of 0.6 m.

Gangway

The gangway ensures pedestrian access between the shore and the floating structure that provides the berths. The gangway width is dependent on the number of berths along walkway. In table 71 an overview of the requirements is given.

Number of berths	Width (m)
Up to 2	0.7
Greater than 2, up to 10	0.9
Greater than 10, up to 60	1.2
Greater than 60, up to 120	1.5
Greater than 120	1.8

table 71: Clear gangway width (Australian Standard, 2001)

L.5.2 Fishing port section

Interior channel

The design of the interior channel in this part of the coastal haven is based on a 20 m long fishing vessel. Longer vessels are not expected in the fishing port section.

- Minimum width inner channel: 30 m (20 m or 1.5 L_s)
- Preferred width inner channel: 35 m (25 m or 1.75L_s)

Fairways and berths

The fishing vessels in Al Syadeen are currently all speedboats between 5 and 20 meter, with a spread over the size classes according table 72. The same guidelines are used to design the fairways and berths for the fishing vessels as for the yachts since they have comparable dimensions. The results are listed in table 73.

Incidentally a dhow with a length of 30 -35 m also wants to use the fishing port facilities. This vessels has to pass the inner channel to the fish unloading quay. These aspects also need to be designed for this purpose. The width of the inner channel has minimum of 1.5 times L_S and a preferred width of 1.75 L_S, so between 56.25 and 61.25 meter.

Fishing vessel size class	Number of vessels (2007)	Number of vessels (2030)
5-10 (m)	137	175
10-15 (m)	3	5
> 15 (m)	6	10
Total	**143**	**190**

table 72: Fishing vessels mix Al Syadeen

Berth length (m)	Berths width (m)		Fairway width (m)		Number of berths
	Single berth	Double berth	Minimum	Preferred	
8	4.4	7.8	12	14	175
10	5	9	15	17.5	5
17.5	6.35	11.7	26.25	30.63	10
35	9	16.5	52.5	61.25	?

table 73: Berth length, berth width, fairway width and number of berths

L.5.3 Required quay length

Several quays are required in the coastal haven. In this section, guidelines are applied to the situation of Al Syadeen to determine the layout requirements for the quay length.

Fishing port section

The quay in the fishing port is meant for unloading the catch from the fishing vessels. The vessels are assumed not to arrive all at the same time. For the length of the quay is referred to the ones present in Fahaheel (75 m) and the Dhow harbor of Souk Sharq (100 m).

A loading and unloading quay of 100 meter is suggested for Al Syadeen. The width of the quay apron is based on the fact that the unloading is done manually, with or without help of ships gear. As first approximation a quay apron width of 1.5 up to 4.0 m is used. The level of the quay should not be too high in order to make manual unloading possible most of the time.

Berthing of dhows in the commercial port of Doha is done along quay and jetties of approximately 5 meter above CD. This quay height is also used for the coastal havens. Provisions in or along the quay should be made to manual unload at low water or make a floating walkway with a gangway for unloading only, like is done in Fahaheel and Dhow Harbor Souk Sharq.

Port of refuge section

This function is expected to provide a sheltered emergency berth for 3 design vessels at the same time. To make this quay a suitable berthing area for as much vessels as possible, the vessels should be berthed parallel to the quay. If more vessels seek shelter in the coastal haven the vessels can berthed abreast.

The length of the quay is based on the following guideline for parallel berthing:

$$L_B = \text{Berth length} = 1.15 \cdot L_S$$
$$L_S = \text{Ship length} = 35(m)$$
$$L_B = 40(m)$$
$$\text{Number of berhts} = 3$$
$$\text{Quaylenght} = 3 \cdot L_s = 120(m)$$

Fuelling, water and waste-water pump out station

The quay length of this facility is based on the situation that one design vessel wants to use this facility. In addition a provision must be made for the smaller speedboats to use this facility. The difference in required height of the quay for a 35 m long vessel and a 8 m long speed boats is too large.

$$L_B = \text{Berth length} = 1.15 \cdot L_S$$
$$L_S = \text{Ship length} = 35(m)$$
$$L_B = 40(m)$$

A facility with this length can be used by several smaller yachts or fishing vessels at the same time.

Appendix M. SWAN model parameters

M.1 Wind and wave data

The purchased data offshore of Kuwait is assumed to be representative for the northern, eastern and southern boundary of the model. The data is transferred to the northern boundary with 67.5 km and to the east with 42.5 km. This is done in order to model waves from the east in a right way. If the eastern boundary would be taken at the easting of the data point, waves from the east are imposed on a shallow part of the Arabian Gulf. The effect of waves propagating over this shallow part is not modeled in a right way.

By translating the data north the fetch decreases since there is a limited length of the Arabian Gulf remaining towards the north. On the other hand the offshore data point is located south of Kubbar Island and these two effects are assumed to level each other. The waves from northern directions are therefore being thought as representative for the model boundaries.

M.2 Wave propagation direction

The wave height information is given as a probability of occurrence in sectors of 22.5°. During the test runs these sectors are not used. During the test runs several interesting scenarios are selected from the time series. The accompanying wave propagation direction is found in the time series.

During the determination of the relevant conditions for the selected coastal haven the directions from the sectors are used. The wave direction is these cases set as the average of the range of the sector. For example, the sector 0° - 22.5° is modeled with a wave propagation direction of 11.25°.

M.3 Wave height

The wave height at the offshore data point is given as probability of occurrence per year and per month in bins of 0.25 meter per sector of 22.5°. In total 46688 measurements are included in the time series. Each measurement is thus 0.00241% of the total number.

The significant wave height is one of the input parameters for the SWAN model. Together with the wave period and the kind of spectrum this determines the wave climate that is imposed on the model boundaries.

In the downtime analysis the wave height is set to be the higher end of a bin size in the data series. Since we are interested in the exceedance rate of a certain value the higher end of for example the wave class 1.5 up to 2.0 meter is selected as significant wave height for the model.

M.4 Wind speed

The wind data is used to calculate the wind generated waves in the vicinity of the coastal haven. This data is obtained offshore. Measurements of local wind conditions will deviate from the offshore data due to the influence of relief of the land. However the offshore data set is assumed to be representative for the wind in the entire country and used as boundary condition for the entire model.

The wind speed is found in accordance with the exceedence rate of the waves. The wind speed in the same sector with approximately the same exceedence rate is used in the SWAN model. In the case the exceedence rate is in between two bins the upper boundary of the upper bin is used as input for the model.

M.5 Wind direction

The wind and wave direction are assumed to be correlated. In case of the wind generated waves this is by definition correct, but in the case of swell waves this needs a more detailed motivation.

The swell waves generated at the southern end of the Arabian Gulf during wind from south eastern direction travel reach Kuwait territorial within the same time scale as the storm duration. Since the Arabian Gulf is a relative small open water basin of approximately 900 by 60 kilometer, the swell wave and wind direction are assumed to be correlated. This is justified by the thought that the swell waves reach Kuwait within the same time scale as the storm duration according the calculation below. This is different than a location that can receive swell wave from the other side of the ocean and wind wave from a totally different direction at the same time.

$$\omega^2 = gk\tanh\left(kd\right)$$
$$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right)$$
$$g = 9.81(m/s^2); T = 7(s); d = 22.5(m)$$
$$L = 73,09(m)$$
$$L = cT \rightarrow c = \frac{L}{T}$$
$$c = \pm 10(m/s)$$

For a swell wave of 7 seconds at a water depth of 22.5 m (equal to that of the offshore data point) the wave travels over 900 kilometers in about 25 hours. Parts of the Arabian

Gulf are deeper than the selected depth this will result in a higher wave speed, but the selected characteristic values give a good first indication and justify this assumption.

M.6 Wave period

The wave period in the data set is given as scatter table per wave directional sector. This scatter table is an indication of the correlation of the wave period (with a bin size of 1 second) and the wave height (with a bin size of 0.25 m). The wave period is determined by a weighted mean, taking the probability of occurrence of the specific wave height and period into account. After selecting the wave height in a certain directional sector the accompanying wave period is to be determined according the principle above.

M.7 Currents

In the hydraulic modeling no currents are taken into account. The model is used to model only wind and waves. Information on the tidal currents can be obtained from the hydrographical charts but are not considered in the hydraulic model. The river Khor Al Subiyah in the north crosses the northern boundary of the model. This river is closed off in the model, by manually adapting the bathymetry. This is done in order to prevent waves entering the model from the river.

M.8 Water level

In the model the Mean Sea Level (MSL) is set a half times the difference between LAT and MHHW in the Kuwait Bay. The locations of Subiyah in the north, Doha port and Shuwaikh Port all give approximately the same tidal range of 3.5 meter. Mean sea level is determined at 1.75 meter above LAT (Chart Datum).

In the test runs, some tests are performed with a varying water level. During the downtime analysis MSL is used as water level for the modeling, since this in the average water level during normal conditions. Furthermore no set-up of the water level, sea level rise or storm surge water level is taken into account.

M.9 Spectrum

One of the required input parameters for the SWAN model is the type of spectrum according which the waves are imposed on the model boundaries. The results from many studies confirm that the JONSWAP spectrum is the most used among engineers. Although the fetch taken into account for this spectrum is rather limited and no transition is made for this to a fully developed sea state this spectrum suits well for engineering purposes. The spectrum should theoretically not be applied to swell waves.

The peak period, significant wave height and gamma value of the JONSWAP spectrum determine the wave conditions for the model. The gamma value is a peak enhancement parameter that enhances the energy at the peak frequency. For a standard JONSWAP spectrum this value is set to be 0.33.

For the model a JONSWAP spectrum is assumed to be applicable and the standard gamma value of 0.33 is applied in all models. Some verification of these assumptions is done in the test runs (see appendix N.8).

M.10 Directional spreading

In SWAN it is necessary to define an angle that indicates the directional spreading of the waves imposed at the boundaries. Swell waves are longer waves and have a more regular character. Their directional spreading is less due to their long crested character. Wind waves are in general more irregular and short crested. The value for directional spreading is kept constant at a value that is matching with a mix of swell waves and wind waves of 22.5°.

During the first test runs a directional spreading of 15°, later on a switch to 22.5° is made in order to use a better representation of wind waves.

Besides the directional spreading, the way the model needs to make the spectral/directional computation needs to be specified. This influences the time required for a computation. The range of frequencies that needs to be taken into account and the number of steps in which this range is to split up has to be specified. These settings are also not adjusted during the calculation and chosen is a frequency band of 0.03 up to 1.0 Hz with 46 steps. The range is stretched out to 2.0 Hz later on to get a view of the entire spectrum with the one dimensional spectral output from SWAN. The number of steps is kept identical.

The CIRCLE function within SWAN sets the way in which the directional calculation has to be made. The range of 360° can be split up in part, which SWAN needs to consider. Chosen is that the arc of 360° needs to be calculated in 60 part, thus steps of 6°.

M.11 Output points

For all coastal haven locations a output point is defined. In the table below and overview of these point is provided. The points are all defined at some distance offshore in order to use this point for the next model and to have some water depth left at the output locations.

Besides the coastal haven location within the grid of the model also two offshore locations are determined. This is done in order to compare the input information on the boundaries with the output at almost the same depth within the model.

Nr	Location	Location description	Easting (m)	Northing (m)
1	Al Fontas (1)	500 meter to the E	220820	3230304
2	Al Syadeen (2)	500 meter to the E	218250	3247717
3	Watya (3)	750 meter to the NW	203914	3252716
4	Abu-Hilifa (5)	500 meter to the E	221604	3225848
5	Al-Jahra (6)	3500meter to the NE	182599	3254982
6	Al-Sabia (7)	3500meter to the SW	222928	3265701
7	Kazma (8)	1500 meter to the SW	184945	3255564
8	Al-Kherafi (9)	1000 meter to the NW	204496	3253830
9	Failaka	2000 meter to the E	233330	3260482
10	Offshore 1	East of Kubbar Island	260758	3216778
11	Offshore 2	West of Kubbar Island	241241	3222264

table 74: Output locations SWAN

The water depth as output of the model is checked with the admiralty charts in order to determine if the model set-up is done correctly. The interpolated water depths are all reasonable representatives of the water depths indicated on the admiralty charts.

Nr.	Location	Water depth compared to MSL (m)	Water depth compared to LAT
1	Al Fontas (1)	8.19	6.44
2	Al Syadeen (2)	11.35	9.60
3	Watya (3)	6.82	5.07
4	Abu-Hilifa (5)	6.80	5.05
5	Al-Jahra (6)	3.05	1.30
6	Al-Sabia (7)	1.71	-0.04
7	Kazma (8)	3.88	2.13
8	Al-Kherafi (9)	4.27	2.52
9	Failaka	2.24	0.49
10	Offshore 1	31.75	30.00
11	Offshore 2	31.75	30.00

table 75: Water depth output model

Appendix N. Sensitivity analysis SWAN

In order to determine the relative importance of the wind waves or the swell waves several test runs are made. In this way an indication of the behavior and response of the hydrological system can be obtained and used a basic knowledge for the location specific modeling study. Another interesting aspect to test is the influence of certain parameters.

Runs with only wind or waves, at MSL or MHHW, different wave periods are selected to determine their influence on the waves in the vicinity of the coastal haven locations. In the table 76 the several scenarios, with parameter values are listed. In the next paragraph the results of the test runs will be discussed and compared.

Run	Gridsize (m)	Description	Hs (m)	Tp (s)	Dir (°)	Wind (m/s)	Dir (°)	Water level
T01	200m	Waves and wind extreme SE	3.5	7.05	135	17.5	135	MSL
T02	400m	Waves and wind extreme SE	3.5	7.05	135	17.5	135	MSL
T03	400m	Only extreme wind NNW	0	0	0	17.6	327.1	MSL
T04	400m	Waves from NNW, no wind	2.77	5.77	339.3	0	0	MSL
T05	400m	Waves from N, no wind	2.21	5.06	356.6	0	0	MHHW
T06	400m	Waves and wind extreme SE + diffraction	3.32	7.56	121.6	17.9	134.4	MHHW
T07	400m	Waves from NNW + wind	2.77	5.77	339.3	17.6	327.1	MSL
T08	400m	Waves from N + wind	2.21	5.06	356.6	14.3	339.4	MSL
T09	400m	Waves from E, no wind	2.05	5.82	100.9	0	0	MSL
T10	400m	Waves from E + wind	2.05	5.82	100.9	8.5	112.4	MSL
T11	400m	Waves from N + wind	2.21	5.06	356.6	14.5	339.4	MHHW
T12	400m	Waves from N, no wind	2.21	5.06	356.6	14.5	339.4	MSL
T13	400m	Waves and wind extreme SE	3.32	7.56	121.6	17.9	134.4	MHHW
T14	400m	Waves and wind extreme SE; small Tp	3.32	3.5	121.6	17.9	134.4	MHHW
T15	400m	Waves and wind extreme SE; large Tp	3.32	15	121.6	17.9	134.4	MHHW
T16	400m	Waves and wind extreme SE	3.32	7.56	121.6	17.9	134.4	MHHW
T17	400m	Waves and wind extreme SE	3.32	7.56	121.6	17.9	134.4	MSL
T25	400m	Same as T05, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T28	400m	Same as T08, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T31	400m	Same as T11, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T32	400m	Same as T12, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T33	400m	Same as T13, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T34	400m	Same as T14, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T35	400m	Same as T15, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T36	400m	Same as T16, directional spreading 22.5 degrees en frequency range from 0.03 tot 2 Hz in 46 steps						
T38	400m	large model Hs max only (DSPR =22.5)	3.32	7.56	121.6	0	0	MSL
T39	400m	large model Hs max only (DSPR =22.5)	3.32	7.56	121.6	0	0	MHHW

table 76: Test scenarios modeled

N.1 Sensitivity swell waves or wind waves Kuwait Bay

The coastal haven locations along the Arabian Gulf coast are logically most sensitive for wind and waves originating from the Arabian Gulf. The directional sector of interest for the locations of Al Syadeen, Al Fontas, Abu-Hilifa and Bneidr are roughly N, via E until S.

For the locations in the Kuwait Bay it is beforehand not clear if the maximum wind speeds from N and NNW direction or the extreme wave and wind speeds from SE direction is the most important scenario. To get an indication of the relative importance of these scenarios they are computed during the test runs.

Runs that are selected for this purpose are run T03, T10 and T16, the input parameters are given in table 77.

Run	Gridsize [m]	Description	Hs [m]	Tp [s]	Dir [°]	Wind [m/s]	Dir [°]	Water level
T03	400m	Only extreme wind NNW	0	0	0	17.58	327.1	MSL
T10	400m	Waves from E + wind	2.05	5.82	100.9	8.54	112.4	MSL
T16	400m	Waves and wind extreme SE	3.32	7.56	121.6	17.9	134.4	MSL

table 77: Sensitivity wind or swell waves

For the locations along the south coast of the Kuwait Bay the wind from the NNW direction is lead to the highest significant wave in front of the coastal haven. For all the other locations the extreme wind and wave from the SE direction leads to the highest waves.

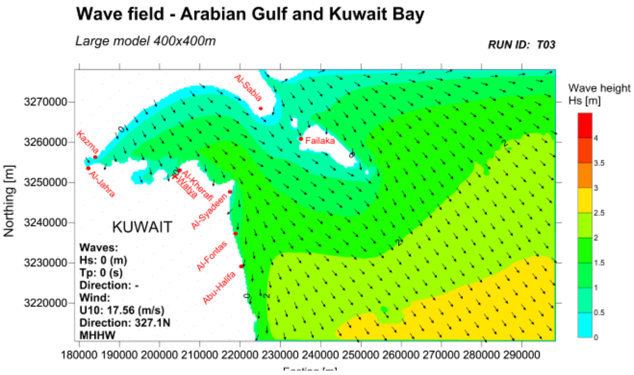

figure 128: Result H_s T03

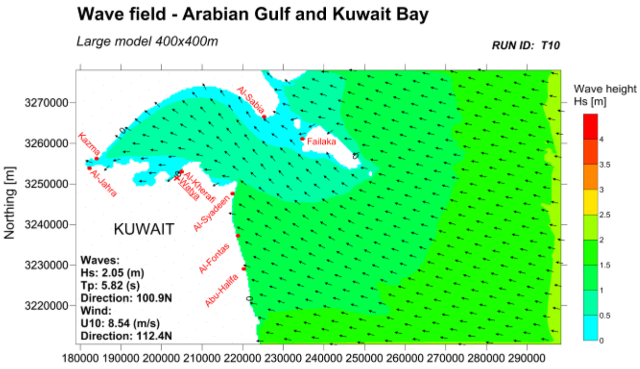

figure 129: Result H_s T10

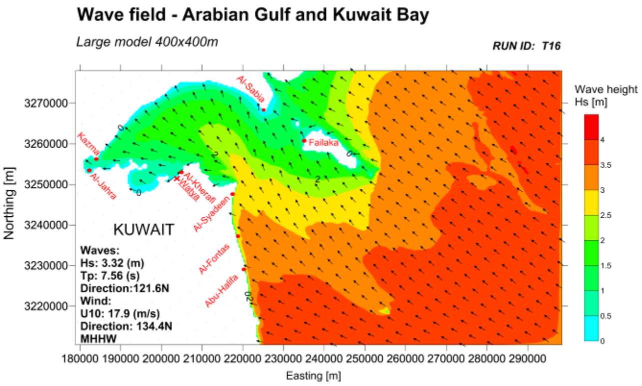

figure 130: Result H_s T16

Location	T03		T10		T16	
	H_s [m]	Dir [°]	H_s [m]	Dir [°]	H_s [m	Dir [°]
Al Fontas (1)	1,27	17	1,22	106	**2,9**	113
Al Syadeen (2)	0,64	17	1,02	120	**2,7**	129
Watya (3)	**0,88**	337	0,23	46	0,5	56
Abu-Hilifa (5)	1,34	17	1,23	100	**2,8**	108
Al-Jahra (6)	0,40	328	0,30	91	**0,6**	111
Al-Sabia (7)	0,56	301	0,32	139	**1,1**	162
Kazma (8)	0,47	323	0,44	86	**0,9**	101
Al-Kherafi (9)	**0,95**	333	0,29	54	0,6	60
Failaka	0,63	320	0,35	143	**1,2**	169

table 78: Result per location T03, T10 and T16

N.2 Gridsize

Intended was to run the model with a 100 meter grid, this would lead too much computational time. Therefore the grid size is scaled up to 200 meters in the first run after which was concluded that scaling up to a 400 meter grid size was necessary in order to reduce computational time to an acceptable level. There is no notable difference in results from run T01 and T02 and in all computation a 400 meter grid will be used (see figure 131 and figure 132).

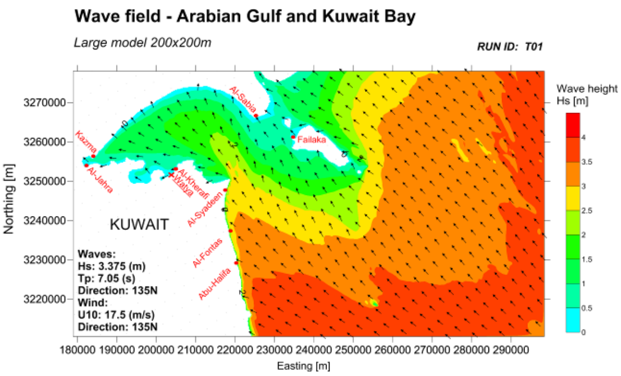

figure 131: Result H_s T01 (200 m grid)

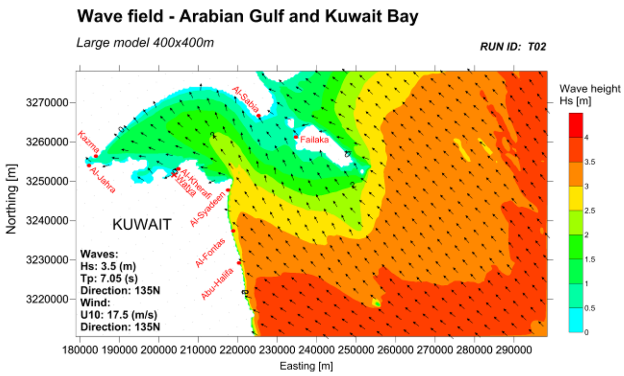

figure 132: Result H_s T02 (400 m grid)

N.3 Wave and wind from same direction

From the direction with the highest waves (121.6 degrees from the north), waves with a wave height of 3.32 meter accompanied by a wind speed of 17.9 m/s from 134.4 degrees from the north are imposed on the boundaries of the model. These are the maxima from the normal conditions retrieved from a dataset of 13 years. These maximum waves are wind waves (sea state) and therefore correlated to the wind direction as can be seen in figure 133. The yellow marks in this figure present the wind waves. A clear correlation is visible with the wind direction, on the other axes of the figure. The red and blue cloud of marks are largely overlapping and represent respectively the total data set and swell wave data set, less or no correlation is present in these data sets.

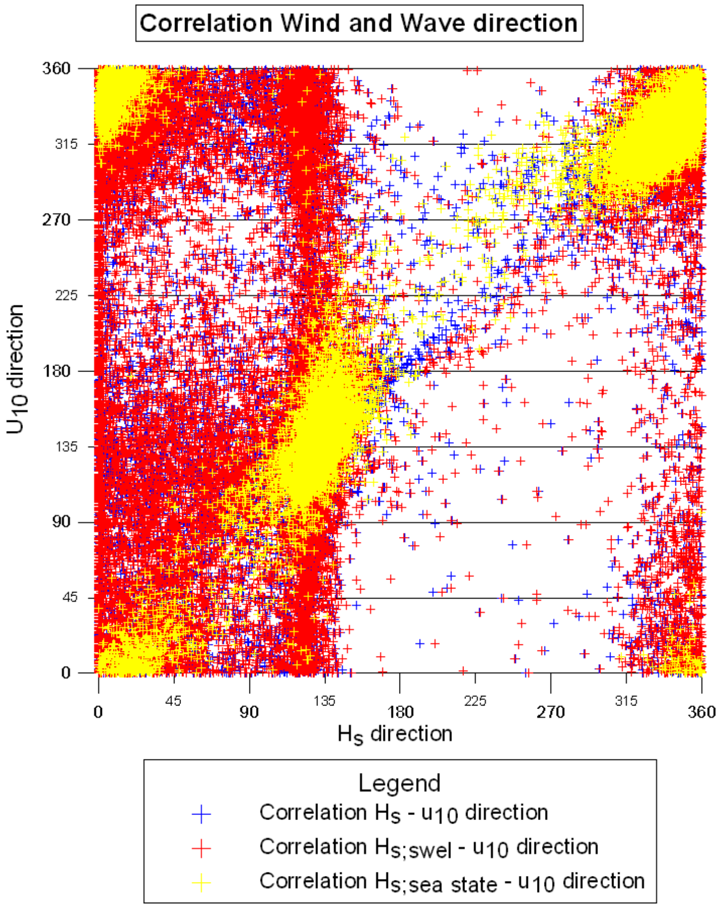

figure 133: Correlation wind and wave direction

In the following figures several situation are looked upon in order to find out more about the effect of the wind.

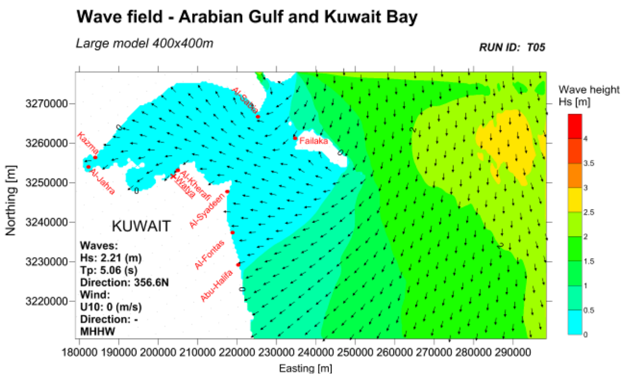

figure 134: Result H_s T05 (without wind)

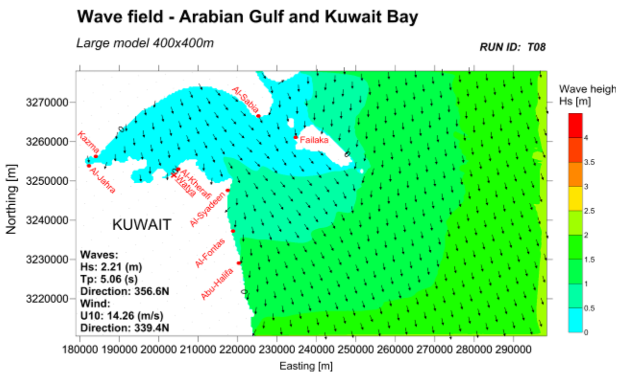

figure 135: Result H_s T08 (with wind)

In figure 134and figure 135 above, waves without and with wind is modeled. In the situation without wind the wave curve into the Kuwait Bay between the headland of Subiyah and Failaka Island and around Failaka Island. The waves refracting into the Kuwait Bay lose a lot of energy and the wave climate in the Bay is very mild in this case.

No wave growth is visible in the left figure, except at the eastern boundary, but this is expected to be the result effects induced by the boundary conditions. At the eastern boundary the wave height increase to 2.8 meter without any force present driving it.

In the right figure wind forcing from approximately the same direction as the waves is present. In this situation the waves continue propagating towards the south and wave growth is present due to the wind forcing.

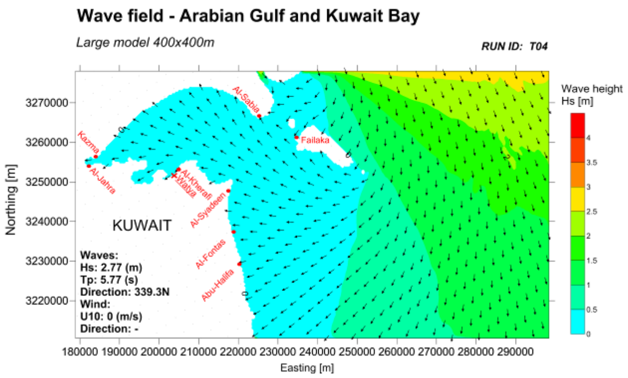

figure 136: Result H_s T04 (without wind)

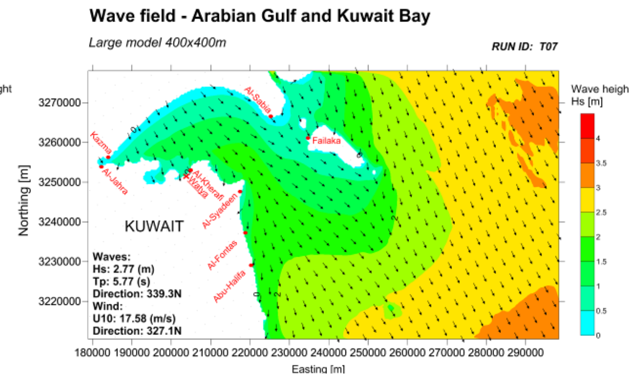

figure 137: Result H_s T07 (with wind)

In figure 136 and figure 137 the situation of only waves and waves combined with wind from NNW direction is modeled. The same effects are visible in figure 136 are visible as were described for figure 134. At the northern boundary waves start breaking almost immediately and the waves refract into the shallow Kuwait Bay again. In figure 137 higher wind speeds than the case above are present and even more wave growth up to 3 meter occurs with the boundaries of the model. The shelter provided by Failaka Island and the mild climate, this time with higher waves than in the case above are visible in the right figure.

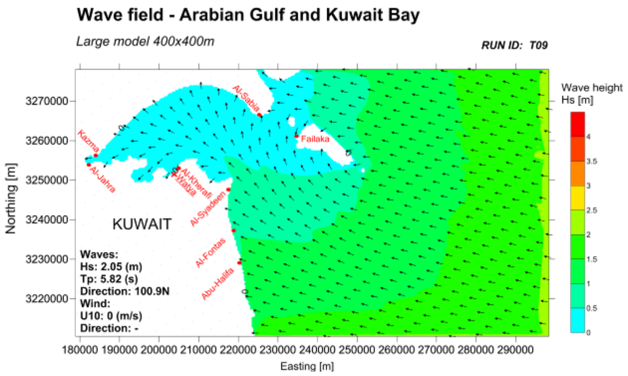

figure 138: Result H_s T09 (without wind)

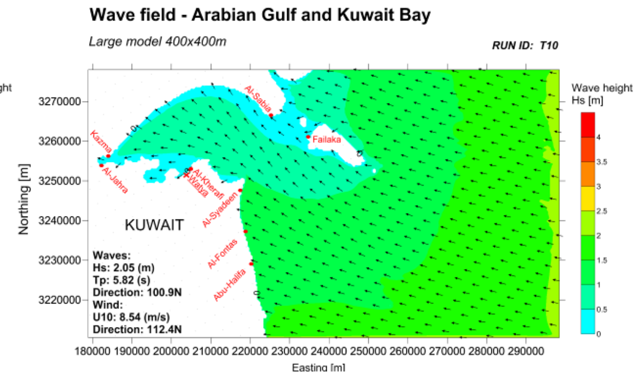

figure 139: Result H_s T10 (with wind)

In figure 138 and figure 139 the occurred extreme wave condition from the E direction is modeled without and with wind from approximately the same direction from the data series. In both figures the waves imposed on the eastern boundary start breaking at a short distance from the boundary. The same boundary conditions results in higher waves along the southern boundary of the model. The wave height reduces towards the Kuwait

Bay. In de right figure the refraction towards the shores of the Kuwait Bay is clearly larger than in the left figure. The wind in the situation of figure 139 result in higher waves in the Kuwait Bay. The waves refract less and a plume of waves between 0.5 and 1 meter reach the western shore of the Kuwait Bay.

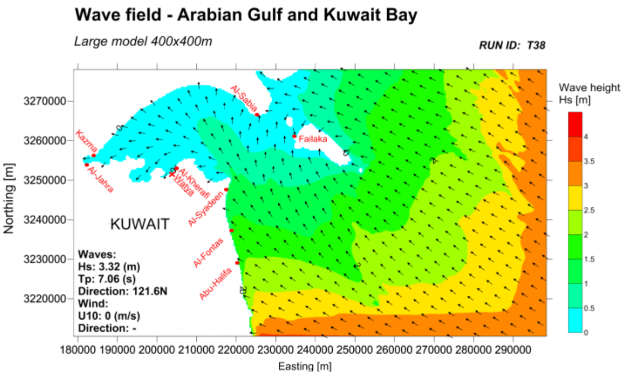

figure 140: Result H_s T38 (without wind)

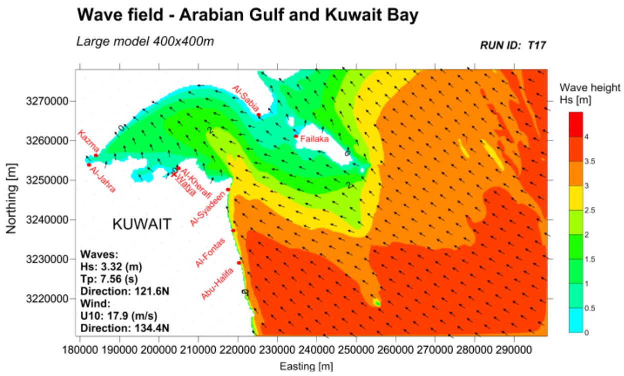

figure 141: Result H_s T17 (with wind)

In figure 140 and figure 141 the extreme wave condition from the data set is modeled without and with the occurring wind conditions. In the situation without wind the waves start breaking at a short distance from the boundaries due to the decreasing depth. There is almost no wave height left in the Kuwait Bay. Only at the deeper trough a wave height between 0.5 and 1 meter is left. On the left picture the influence of the wind is clearly visible. This winds speed is one of the extremes from the data set and it results in wave height of 3.5 up to 4 meters offshore. The wave height in the Kuwait Bay increases due to the wind and wind waves to 1.5 to 2 meters.

N.4 Water level

The test with respect to this aspect is mainly to see what effect the change of the water level from MSL to MHHW has on the waves that reach the coastal haven. Another interesting aspect are the waves that cannot enter the Kuwait Bay from the north between Subiyah headland and Failaka Island. If the water level is set to MHHW (chart datum +3.5 meter) can these waves from the North penetrate into the Kuwait Bay. This is tested in the comparison between figure 142 and figure 143.

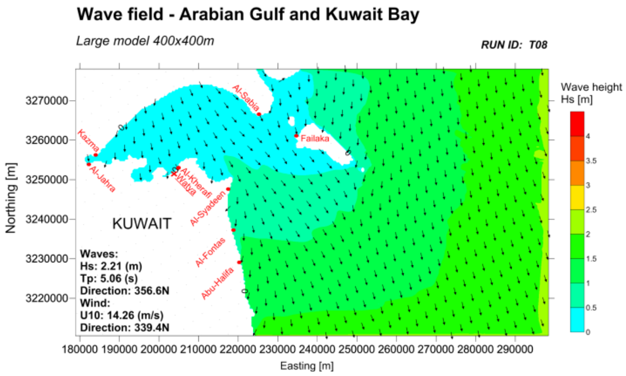

figure 142: Result wave height T08 (MSL)

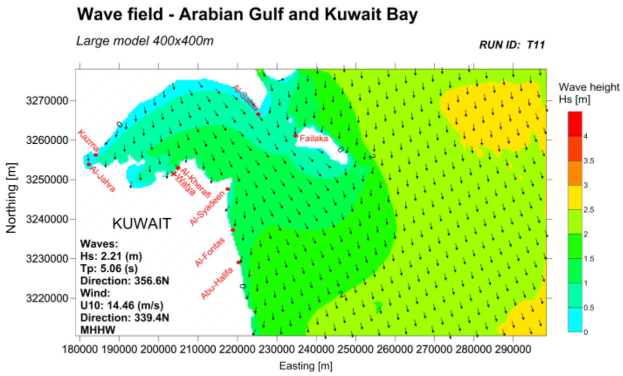

figure 143: Result wave height T11 (MHHW)

The difference between the two figures above are indicating that wind generated wave are faster generated at MHHW. Higher waves are also penetrating into the Kuwait Bay. The difference in wave height is not very large but ranges from almost 0 to 0.4 meters. The largest difference is the wind wave generation that reaches up to 2.5 -3.0 meter high waves at the SE end boundary of the model.

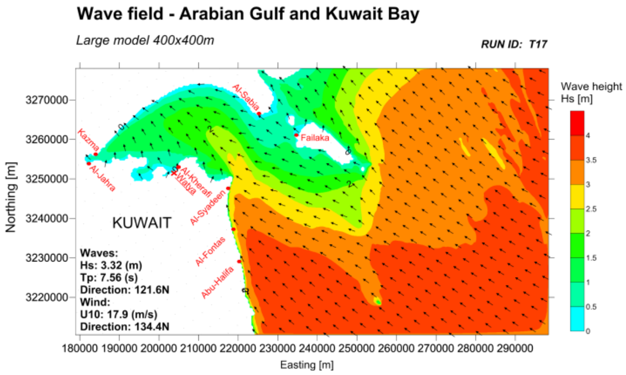

figure 144: Result H_s T17 (MSL)

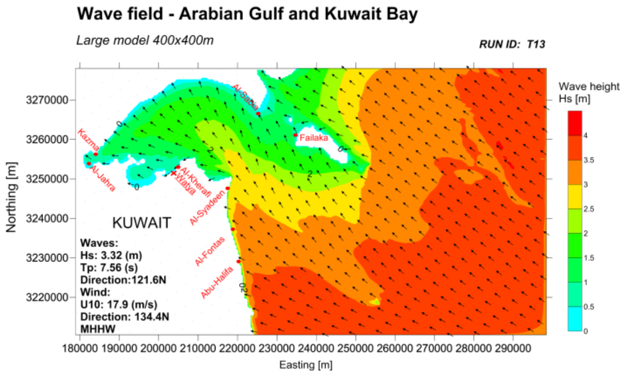

figure 145: Result H_s T13 (MHHW)

On the wave height graphs in figure 144 and figure 145 a difference of the wave height in the northeastern corner is clearly visible. In general the waves at the coastal haven locations are all slightly higher. Wave can penetrate further due to the increase water depth at MHHW compared to MSL.

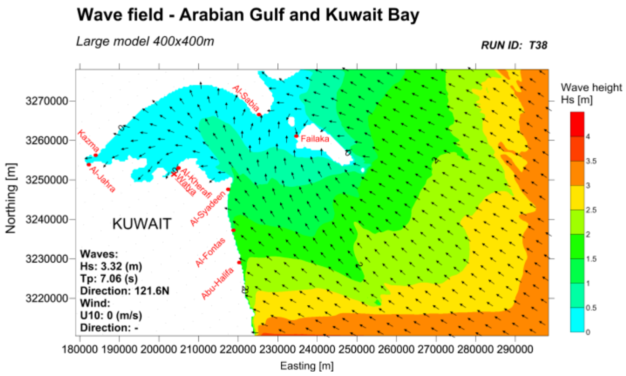

figure 146: Result H_s T38 (MSL)

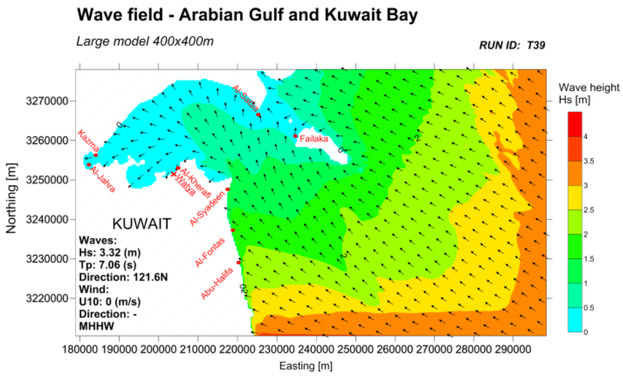

figure 147: Result H_s T39 (MHHW)

In both situation in figure 146 and figure 147 wave breaking is visible along the boundaries of the model. The higher water level in the left figure does not have a significant effect on the wave height figures above. From the output data it can be concluded that the wave height at those point is slightly higher, up to 0.2 meter, at all locations. This has no significant influence on the wave height.

N.5 Period

Several periods are modeled in order to get an indication of the effect of the several peak periods.

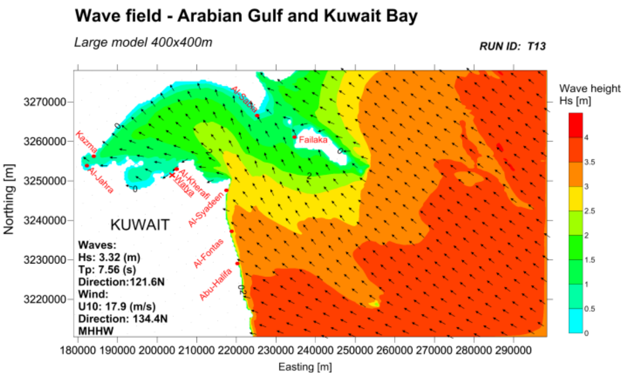

figure 148: Result H_s T13 (T_p=7.06 [s])

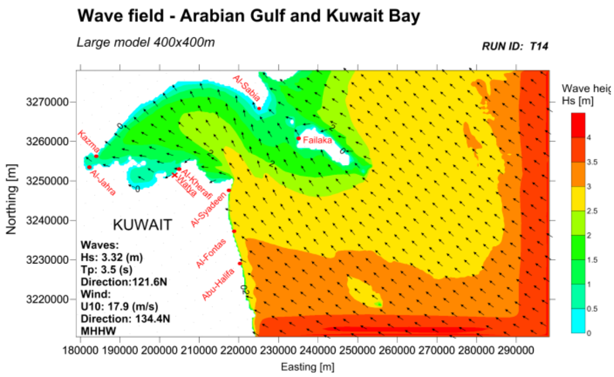

figure 149: Result H_s T14 (T_p=3.5 [s])

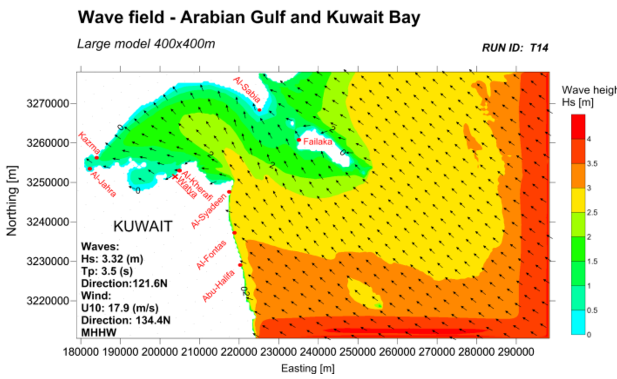

figure 150: Result H_s T15 (T_p= 15 [s])

Location	T14	T13	T15
	Hs (m)	Hs (m)	Hs (m)
Al Fontas (1)	2,65	2,93	**3,24**
Al Syadeen	2,68	2,70	**2,79**
Watya (3)	**0,69**	0,53	0,57
Abu-Hilifa (5)	2,51	2,84	**3,23**
Al-Jahra (6)	**0,75**	0,69	0,71
Al-Sabia (7)	1,18	1,17	1,18
Kazma (8)	**0,99**	0,91	0,94
Al-Kherafi (9)	**0,86**	0,69	0,74
Failaka	1,27	1,23	1,28

table 79: Result per location T14, T13 and T15

Longer waves, with a larger wave period are able to curve more easily around headland and are thus less hindered by the obstacles along the coast than waves with a smaller period. However, the longer waves are more sensitive to shallower water. They "feel" the bottom earlier than the shorter waves. In the figure 149 and figure 150 this can be noticed by the eastern and southern boundary. There the wave height is already reducing due to limited water depth. This is not the case in figure 148 (T_p=3.5 (s)). For the wave height at the location this results in higher waves for the locations along the Arabian Gulf with the larger wave periods and higher waves for the locations in the Kuwait Bay in the case of the smaller wave periods.

N.6 Only wind

If only wind is taken into account this situation can be compared with the extreme case of wind and waves from the southeast. It is interesting to see which case is normative for the locations on the southern shore of the Kuwait Bay with a significant fetch for wind wave generation. Watya, for example is such a location. This location has a fetch of approximately 20 kilometer across the bay in NNW direction. A wind speed of 17.56 (m/s) from 327° results in a wave height of 0.88 meter at a water depth 6.82 at the coastal haven of Watya. At the same location the wave height in scenario T07, with extreme waves and wind from the SE, is 0.10 meter. Wind from the NNW is for these locations thus normative for the design. Adding waves from the NNW to scenario T03, does not lead to higher waves for Watya.

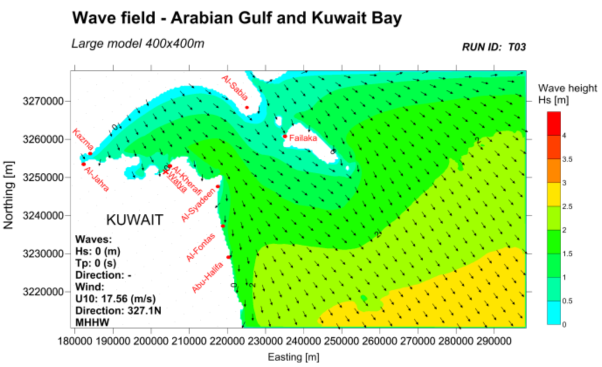

figure 151: Result H_s T03 (wind NNW)

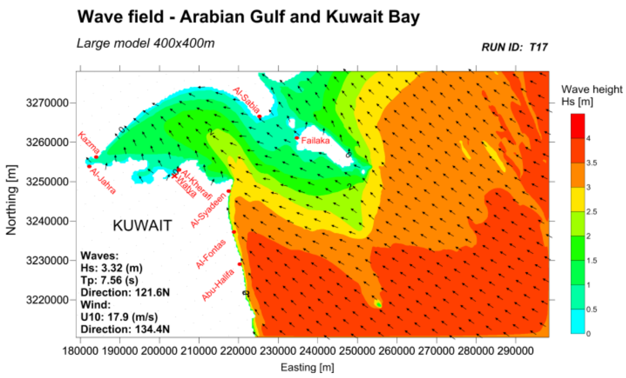

figure 152: Result H_s T17 (Extreme SE)

The output at Watya is compared to the analytical approach of wind wave generation according Bretschneider.

This equation holds for intermediate and shallow water with a constant depth. For the Kuwait Bay this is not the case, but this is used as first approximation and corresponds quite well with the result from the SWAN model.

N.7 Directional spreading

Changing the directional spreading of the waves on the boundaries from 15° to 22.5° changes the output of the locations insignificantly. The wind waves are relatively important for wave conditions at the locations. Changing the directional spreading from 15° to 22.5° seems therefore justified.

N.8 Frequency spectrum

The physical processes that add or withdraw wave energy to or from the wave field are wind input, whitecapping, bottom friction, depth-induced wave breaking, obstacle transmission, nonlinear wave-wave interaction (quadruplets and triads) and wave-induced set-up. The processes that are used in the model are wind input, whitecapping, quadruplets wave-wave interaction and depth-induced breaking. No extensive research is performed to the relative influence of the modeled processes is. The default values of the model coefficients are used for the modeling.

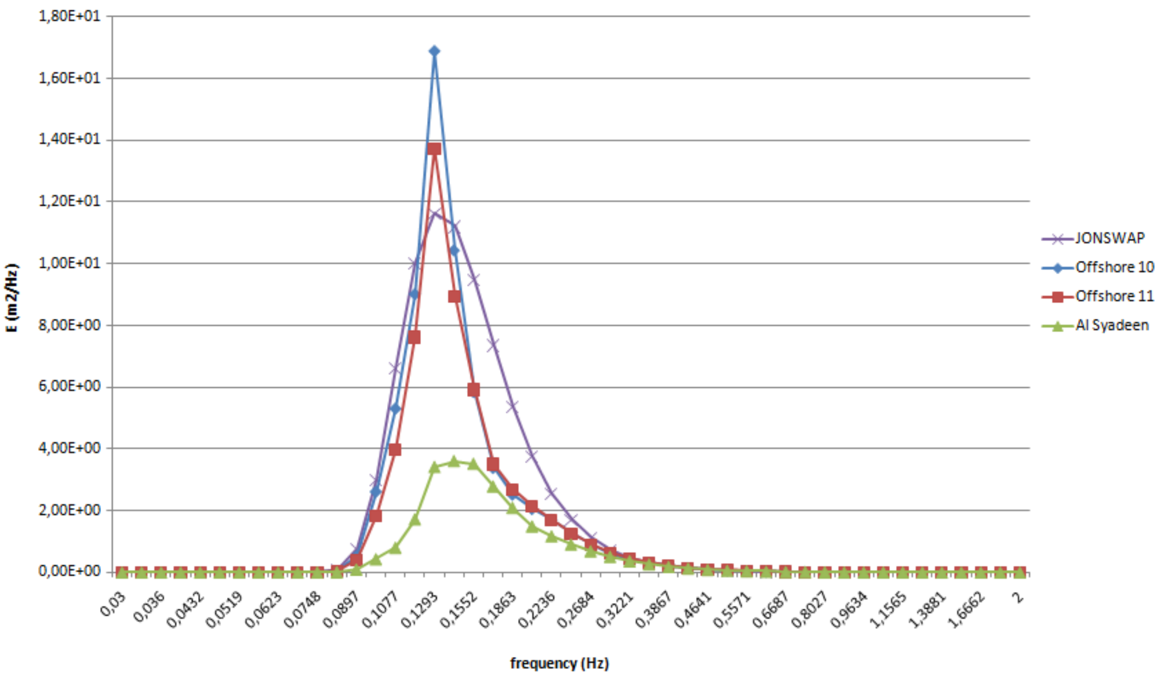

figure 153: 1D-spectrum scenario T16

Run	Gridsize	H_S	T_P	Dir	Wind	Dir	Water level
T16	400m	3,32	7,56	121,6	17,9	134,4	MSL

table 80: Properties scenario T16

The effect of the physical processes is presented in figure 153. The reduction of the surface area under the spectrum from offshore 10 and 11 to Al Syadeen is the result of these processes. The net loss of energy result in reduction of the wave height from offshore to near shore.

The JONSWAP spectrum is also plotted in this graph. This spectrum is calculated according the standard values from literature and the SWAN modeling manual. White capping result in a higher energy density at the peak frequency and more energy in the high-frequency tail of the spectrum. Wind input results in a reduced energy density in the intermediate frequencies.

$$E_{JONSWAP}(f) = \alpha g^2 (2\pi)^{-4} f^{-5} \exp\left[-\frac{5}{4}\left(\frac{f}{f_{peak}}\right)^{-4}\right] \gamma^{\exp\left[-\frac{1}{2}\left(\frac{f/f_{peak}}{\sigma}\right)^2\right]}$$

$$\gamma = 3.3$$

$$\sigma_a = 0.07 \text{ for } f \le f_{peak}$$

$$\sigma_b = 0.09 \text{ for } f \le f_{peak}$$

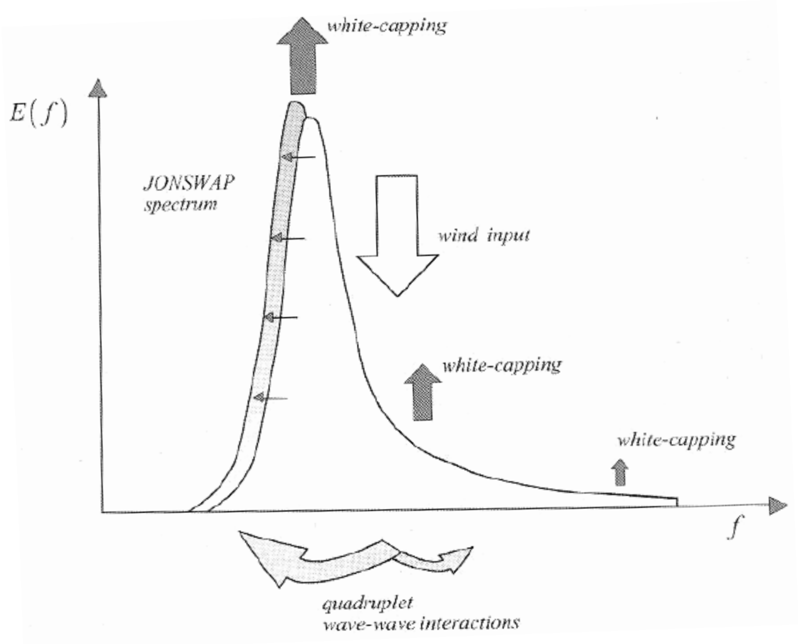

figure 154: The flow of energy trough the JONSWAP spectrum (Holthuijsen, 2007)

Appendix O. Input and output sensitivity runs

Run ID	H_s (m)	T_p (s)	Dir (°)	Prob. of occurrence (%)	Prob. of exceedance (%)	u10 (m/s)	H_s (m) Al Syadeen	Dir (°)	T_p (s)
G01	1,5	4,5	315	0,38	0,02	14	0,41	3	2,69
G02	1,5	5,5	337,5	4,1	0,2	13	0,52	24	3,14
G03	1,5	4,56	360	1,83	0,08	8	0,37	33	2,91
G04	1,5	5,36	22,5	0,21	0	9	0,57	45	3,14
G05	1,5	5,32	45	0,08	0,01	9	0,73	71	3,39
G06	1,5	6,54	67,5	0,05	0	8	0,78	96	3,66
G07	1,5	6,35	90	0,1	0,01	9	1,02	111	4,26
G08	1,5	6,11	112,5	0,83	0,17	8	0,99	124	5,77
G09	1,5	5,28	135	1,92	0,89	8	0,99	134	5,35
G10	1,5	5	157,5	0,2	0,02	14	1,74	139	5,77
G11	1,5	5	180	0,01	0	12	1,31	147	5,35
G12	1,5	6,5	202,5	0,01	0	10	0,85	154	4,59
G13	1,5	4,5	225	0	0	10	0,56	166	3,94
G14	1,5	7	292,5	0,01	0	12	0,24	281	1,71
G15	1,5	2,66	270	0,05	0,01	13	0,31	242	1,99
G21	1	3,45	315	2,02	0,4	11	0,3	3	2,31
G22	1	3,27	337,5	10,74	4,3	7	0,25	17	1,99
G23	1	3,69	360	7,28	1,91	5	0,22	31	2,14
G24	1	3,97	22,5	1,4	0,21	6	0,34	44	2,5
G25	1	4,32	45	0,47	0,08	6	0,43	69	2,69
G26	1	4,87	67,5	0,39	0,06	6	0,53	94	3,14
G27	1	4,68	90	0,6	0,11	6	0,6	110	3,65
G28	1	4,89	112,5	2,41	1	5	0,62	126	3,58
G29	1	4,29	135	4,09	2,8	5	0,61	135	4,59
G30	1	3,75588	157,5	0,78	0,21	10	1,11	140	4,59
G31	1	3,75	180	0,13	0,01	10	0,97	148	4,59
G32	1	3,63	202,5	0,05	0,01	9	0,67	158	3,94
G33	1	3,66	225	0,07	0	10	0,53	169	3,39
G34	1	3,76	270	0,09	0,01	9	0,2	235	1,71

Appendix P. SWAN file

An example of a random SWAN file used to model wave and wind conditions in Kuwait is given below.

```
$***************************** HEADING*********************************
PROJECT  'Nikas'  'G21'                                                  '
$ Downtime sectors, MSL, wind same direction, probability of exceedance
$
$***************************** MODEL INPUT *****************************

SET LEVEL 1.75 $ Mean Sea Level
SET NAUTICAL
MODE STATionary TWODimensional

CGRID REG  178894 3210512 0 119500 67500 298 168 CIRCLE 60 0.03 1.00 46

$ Nader bekijken van spectrale verdeling, richtingen, flow, fhihg, msc, msd achter circel

INP  BOTTOM REG 178894 3210512 0 1195 675 100 100 exception 999

READ BOTTOM -1. 'bathy_arabiangulf.grd' IDLA 1 6 FREE

WIND  VEL= 11 DIR= 315

BOUN SHAPE JONSWAP PEAK DSPR DEGR

BOUN SIDE S  CONST  PAR &
      1.  3.45     315      22.5
BOUN SIDE N  CONST  PAR &
      1.  3.45     315      22.5
BOUN SIDE E  CONST  PAR &
      1.  3.45     315      22.5
GEN3
 BREAK CON       1.00    0.73
 FRIC JON      0.0670
 LIM  10 1

 NUM DIR cdd=   0.50 SIGIM css=   0.50
 $
 NUM ACCUR       0.020    0.020    0.020   99   25

 $***************************** OUTPUT REQUEST *************************

QUANTity Per short='Tm-1,0' power=0.

POINTS 'SITES' FILE 'output.loc'

TABLE 'SITES' HEAD 'G21.tab' XP YP DEP HSIGN RTP PER TM01 DIR WLEN DSPR WIND

block 'COMPGRID'  noheader 'G21-Hs.dat' HS
block 'COMPGRID'  noheader 'G21-dir.dat' DIR
block 'COMPGRID'  noheader 'G21-Tp.dat' PER
block 'COMPGRID'  noheader 'G21-DEP.dat' DEP

SPECout 'SITES' SPEC1D ABS 'G21-spec.dat'

COMPUTE
STOP
```

Appendix Q. PHAROS model parameters

This appendix describes the model parameters that are used to set-up the PHAROS model. Each paragraph treats one model parameters and the motivation and theory behind the model parameter.

Q.1 Wave direction

PHAROS uses a rectangular (Cartesian) x-y axis coordinate system. In such a system all direction are based on the mathematical convention. This means that the direction to which the wave is going is measured anti-clockwise from the x-axis. Direction according the Nautical convention the direction is indicated as the direction from which the wave is coming clockwise starting from the North.

$$\theta_{math} = 270^{\circ} - \theta_{naut}, \ \theta_{math} = 270^{\circ} - \theta_{naut}$$

Nautical direction (θ_{naut})	Mathematical direction (θ_{math})
90	180
112.5	157.5
135	135
157.5	112.5

table 81: Transition nautical direction to mathematical direction

Q.2 Water level

The water level has to be defined in m in respect to the reference level. The water depths in the bathymetry are given in m in respect to LAT. The water level during the modeling is set to mean sea level. This result in an input value for the water level of 1.75 m, which is the same as in the SWAN model.

Q.3 Coordinates

The use of standard UTM coordinates can lead to convergence problems due to numerical accuracy within PHAROS. Coordinates with more than 5 digits before the decimal point are translated to an area closer to the origin of the coordinate system for this purpose.

The transition is done according:

$$\text{Easting (m) } x_{PHAROS} = x_{SWAN} - 210{,}000$$
$$\text{Northing (m) } y_{PHAROS} = y_{SWAN} - 3{,}240{,}000$$

Q.4 Spectrum

The standard spectrum within PHAROS is a JONSWAP spectrum with parameter γ with standard value of 3.3. This is thus kept the same as within the SWAN model.

Q.5 Directional spreading

Q.5.1 Theory

The article “Diffraction diagrams for directional random waves” (Goda, 1978) states that directional spreading has a larger influence on the diffraction than the frequency spectrum has. Furthermore is stated that diffraction diagrams with random waves instead of monochromatic waves lead to higher diffraction coefficients in the area behind the breakwaters. This is important for the model parameters of the SWAN model, in which the waves in the diffract around the breakwater heads en reflect against the quays and breakwaters.

Q.5.2 SWAN

Within SWAN directional spreading is defined according a cosine power relation. For the SWAN model the amount of directional spreading is indicated with an angle for the one-sided directional spreading. From the sensitivity analysis it is concluded that a directional spreading of 22.9° is to be used for the hydrological modeling within SWAN. This value corresponds with wind waves. A large amount of directional spreading is applicable to these type of waves.

Q.5.3 PHAROS

In PHAROS the directional spreading has to be indicated with the parameter m. The one-sided directional spread of 22.9 corresponds with a value for the power m of 5, see table 82.

$$D(\theta) = A(\cos\theta)^m$$

The SWAN output (table 39 in section 9.1.3.4) shows a directional spreading that is approximately the same as the input (table 38 in section 9.1.3.3) and can thus be used in the same way within PHAROS. Run S04, however, shows a directional spreading that increased significantly and a m of 4 is more applicable.

Besides the parameter m, several wave propagation directions need to be specified for each run. This must be done in order to introduce the directional spreading over the directions according the directional distribution (see above) indicated with the parameter m or with the one sides directional spreading in degrees. This needs to be done in order to simulate wind waves instead of monochromatic waves.

For each direction, 4 directional components are defined besides the main propagation direction, each at multiples of 22.5 degrees from the main direction. Entering several directional components for each wave direction leads to more data input. For each main and sub direction reflection coefficients and approach angles need to be defined within PHAROS.

The imposed main and sub direction in combination with the degree of directional spreading according parameter m lead to the distribution function in figure 155 for each of the three modeled main wave propagation directions.

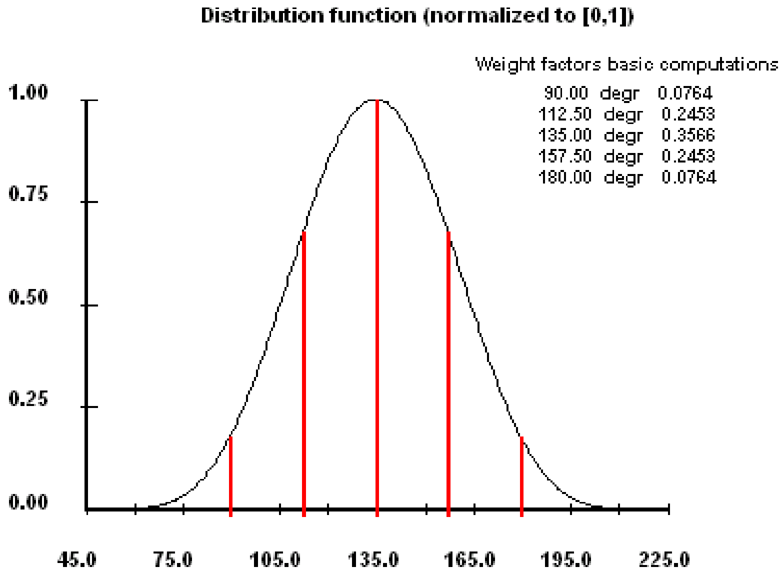

figure 155: Directional spreading for main direction SE 135°N

m	degrees
1	37.5
2	31.5
3	27.6
4	24.9
5	22.9
6	21.2
7	19.9
8	17.9

table 82: Relation direction spreading in degrees and parameter m

Q.6 Reflection coefficients boundaries

Q.6.1 Theory

Reflection against a boundary depend on a number of parameters, for example wave height, wave period, slope, height, porosity of the structure.

The reflection used in the PHAROS model is a 1st order partially reflecting type. 2nd order is also possible, but this is not used in the model set-up. The reflection is given as relation between the reflected wave height and the incoming wave height. Besides the reflection coefficient for each boundary element an expected main direction of waves approaching the boundary with respect to the normal at the boundary in degrees must be provided.

The reflection is based on the Sommerfeld condition:

$$\left(-ik\frac{1-R}{1+R}\cos\alpha_1+\frac{\delta}{\delta n}\right)\phi=0$$

With k the local wave number, R the reflection coefficient, α_1 an angle to be specified by the user (relative to the normal direction of the considered boundary), and n the coordinate normal to the boundary pointing outward.

This result in a reflection R for waves at angles $\theta \pm \alpha_1$, where θ is the 'actual' direction, according the solution inside the domain. For wave directions more normal to the boundary than the wave angle specified by the user, the actual reflection coefficient is larger than the specified one; it is smaller otherwise.

Q.6.2 Determination reflection

The reflection is determined based on the three equation below. Several assumptions are made in order to determine the reflection of the boundary elements. From the outcome of the three equations below an average value is determined and used for the modeling.

Postma

$$K_r = 0.71P^{-0.082}\cot\alpha^{-0.62}s_{op}^{-0.46}$$

Van der Meer

$$0.07\sqrt{\cot\alpha\xi_z}$$

$$\xi_z=\frac{1}{3\sqrt{s_{oz}}}$$

$$s_{oz}=\frac{2\pi\cdot H_s}{g\cdot T_z^2}$$

$$T_z=\frac{T_p}{1.29}$$

Seelig and Ahrens

$$\xi_p=\frac{1}{\cot\alpha\sqrt{s_{op}}}$$

$$s_{op}=\frac{2\pi\cdot H_s}{g\cdot T_p^2}$$

$$R_s=\frac{\xi_p^2}{\left(5.5+\xi_p^2\right)}$$

$$R_s=\frac{\xi_p^2}{\left(5.5+\xi_p^2\right)}$$

Q.6.3 Assumptions reflection

<u>Assumption porosity</u>

Literature (d'Angremond, 2001) indicates porosity levels between 35% and 40% for quarry stone placed in thin layers. A wider gradation of the stone sizes, may lead to a lower porosity. In the determination of the reflection coefficient a porosity of 40% is used.

<u>Assumption slope angle</u>

For the slope of the breakwater a generally accepted value is used. The slope of the breakwater is assumed to be 1:2. This leads to a *cot* α of 2 in the equations.

Assumptions for boundary elements

- As earlier mentioned the quays are assumed to have a reflection of 100%.
- The boundary element such as the sea boundary at the northern and southern boundary of the model, the beach in the north and the area around the Al Bida Sea Club (not of interest) are given a reflection of 0%. The determination of the wave approach angle for these boundary elements is important because the reflection alters if the wave approach angle deviates from the indicated wave approach angle.
- The elements of the inner basin are only approached by indirect waves due to reflection and diffraction and the wave approach angle is also determined in this way.
- Existing quay remains within the inner basin of the coastal havens. Slipways and other details, which influence the reflection, are not separately modeled and are defined within boundary.
- The northern boundary of the existing inner basin is assumed to stay in its existing form with rubble mound layers.

Q.7 Physical processes input parameters

Several physical processes can be included in the modeling. The paragraph below explain if the processes are included in the modeling and which parameters are used.

Q.7.1 Uniform bed level

This option is not used since it overwrites the bathymetry that is user-defined. The indicated entrance channel is removed in this way and that is not desirable.

Q.7.2 Bottom friction

This option is also not used during the computations. The default value of the Jonsson option, indicated by the Nikuradse roughness height K_N is used for the computation. This value is equal to the mean diameter of the grains or mean height of the variation in bottom level. No modification are done, due to a lack of information on this subject.

Q.7.3 Entrance losses

This phenomenon is only relevant for very long wave periods, almost current-like phenomena and thus only applicable for seiching computations. The use of this option requires expert-user insight into the required settings. For general application of PHAROS, i.e. describing wave periods corresponding to sea and swell waves, it is therefore not recommended to use this feature.

Q.7.4 Wave breaking

This option is used during the modeling. Three parameters have to be defined to describe wave breaking influences.

- α: adjustable constant in the energy loss formulation, the default value of $\alpha = 1$ is used.
- γ_d: coefficient of breaking in deep water, based on the maximum wave steepness (see equation below), the default value of $\gamma_d = 0.14$ is used.
- γ_s: coefficient for breaking in shallow water, based on the maximum ratio between wave height and water depth, the default value of $\gamma_s = 0.8$ *is used.*

$$\gamma_d = H / L = 0.14$$
$$\gamma_s = H / h = 0.80$$

Q.7.5 Wave current interaction

This physical process is not yet operational in the present version of PHAROS and also not used in the SWAN model. Currents are not taken into account during the hydrological study.

Appendix R. Input Pharos

nr	Name	R_run1	R_run2	R_run3	dir 1	dir 2	dir 3	dir 4	dir 5	dir 6	dir 7
					202.5	180	157.5	135	112.5	90	67.5
1	Beach	0	0	0	35.2	12.7	9.8	32.3	45.3	45.3	45.3
2	BW_N_1	25	20	25	54.8	77.3	79.8	79.8	79.8	79.8	79.8
3	BW_N_2	25	20	25	34.5	12.0	11.0	11.0	11.0	11.0	11.0
4	BW_N_3	25	20	25	79.7	79.7	79.7	79.7	79.7	79.7	79.7
5	BW_N_4	25	20	25	44.7	44.7	44.7	44.7	44.7	44.7	44.7
6	Quay_N	100	100	100	16.3	16.3	16.3	16.3	16.3	16.3	16.3
7	Quay_S	100	100	100	16.0	16.0	16.0	16.0	16.0	16.0	16.0
8	BW_Inner_1	55	45	50	28.0	28.0	28.0	28.0	28.0	28.0	28.0
9	BW_Inner_2	55	45	50	51.2	51.2	51.2	51.2	51.2	51.2	51.2
10	BW_Inner_3	55	45	50	79.3	79.3	79.3	79.3	79.3	79.3	79.3
11	BW_Inner_4	55	45	50	66.0	66.0	66.0	66.0	66.0	66.0	66.0
13	Inner_Basin_1	55	45	50	45.0	45.0	45.0	45.0	45.0	45.0	45.0
14	Inner_Basin_2	100	100	100	37.9	37.9	37.9	37.9	37.9	37.9	37.9
15	Inner_Basin_3	55	45	50	14.4	14.4	14.4	14.4	14.4	14.4	14.4
16	Inner_Basin_4	55	45	50	76.8	76.8	76.8	76.8	76.8	76.8	76.8
17	BW_S_1	55	45	50	79.3	79.3	79.3	79.3	79.3	79.3	79.3
18	BW_S_2	25	20	25	52.2	29.7	7.2	15.3	37.8	60.3	79.3
19	BW_S_3	25	20	25	79.3	66.3	43.8	21.3	1.2	23.7	46.2
20	Al_Bida	0	0	0	11.8	10.7	33.2	55.7	78.2	78.2	78.2
21	Boundary_S	0	0	0	64.5	80.0	67.5	45.0	22.5	0.0	22.5

	Hs	T	Wave breaking	Main direction	Bottom friction
run1	3.61	8.47	Yes (g_sh = 0.8, g_off=0.14)	135N/135	No
run2	3.36	7.06	Yes (g_sh = 0.8, g_off=0.14)	157.5N/112.5	No
run3	2.76	7.74	Yes (g_sh = 0.8, g_off=0.14)	112.5N/157.5	No

table 83: Reflection coefficients and wave approach angles layout B

nr	Names	R_run1	R_run2	R_run3	dir1	dir2	dir3	dir4	dir5	dir6	dir7
					202.5	180	157.5	135	112.5	90	67.5
1	Beach	0	0	0	35.2	12.7	9.8	32.3	45.3	45.3	45.3
2	BW_N_1	25	20	25	54.8	77.3	79.8	79.8	79.8	79.8	79.8
3	BW_N_2	25	20	25	34.5	12.0	10.5	33.0	28.0	28.0	28.0
4	BW_N_3	45	40	45	79.4	79.4	73.4	73.4	73.4	73.4	73.4
5	BW_N_4	55	45	50	79.5	79.5	79.5	79.5	79.5	79.5	79.5
6	BW_N_5	55	45	50	35.9	35.9	35.9	35.9	35.9	35.9	35.9
7	BW_N_6	55	45	50	40.7	40.7	40.7	40.7	40.7	40.7	40.7
8	Quay_N	100	100	100	30.3	30.3	30.3	30.3	30.3	30.3	30.3
9	Quay_S	100	100	100	11.0	0.0	11.0	11.0	11.0	11.0	11.0
10	BW_Inner_1	55	45	50	22.5	11.0	11.0	11.0	11.0	11.0	11.0
11	BW_Inner_2	55	45	50	38.7	38.7	38.7	38.7	38.7	38.7	38.7
13	BW_Inner_3	55	45	50	79.3	79.3	79.3	79.3	79.3	79.3	79.3
14	BW_Inner_4	55	45	50	66.0	66.0	66.0	66.0	66.0	66.0	66.0
15	Inner_Basin_1	55	45	50	45.0	45.0	45.0	45.0	45.0	45.0	45.0
16	Inner_Basin_2	100	100	100	37.9	37.9	37.9	37.9	37.9	37.9	37.9
17	Inner_Basin_3	55	45	50	14.4	14.4	14.4	14.4	14.4	14.4	14.4
18	Inner_Basin_4	45	45	50	76.8	76.8	76.8	76.8	76.8	76.8	76.8
19	BW_S_1	25	45	50	79.2	79.2	79.2	79.2	79.2	79.2	79.2
20	BW_S_2	50	40	45	66.2	79.7	79.7	79.7	79.7	79.7	79.7
21	BW_S_3	25	20	25	79.7	79.7	66.2	43.7	21.2	1.3	23.8
22	BW_S_4	25	20	25	52.7	30.2	7.7	14.8	37.3	59.8	79.8
23	BW_S_5	25	20	25	79.3	66.3	43.8	21.3	1.2	23.7	43.7
24	Al_Bida	0	0	0	11.8	10.7	33.2	55.7	78.2	78.2	78.2
26	Boundary_S	0	0	0	67.5	90.0	67.5	45.0	22.5	0.0	22.5

	Hs	T	Wave breaking	Main direction	Bottom friction
run1	3.61	8.47	Yes (g_sh = 0.8, g_off=0.14)	135N/135	No
run2	3.36	7.06	Yes (g_sh = 0.8, g_off=0.14)	157.5N/112.5	No
run3	2.76	7.74	Yes (g_sh = 0.8, g_off=0.14)	112.5N/157.5	No

table 84: Reflection coefficients and wave approach angles layout C

nr	Name	R_run1	R_run2	R_run3	dir1	dir2	dir3	dir4	dir5	dir6	dir7
					202.5	180	157.5	135	112.5	90	67.5
1	Beach	0	0	0	35.2	12.7	9.8	32.3	32.3	32.3	32.3
2	BW_N_1	25	20	25	54.8	75.3	75.3	75.3	75.3	75.3	75.3
3	BW_N_2	25	20	25	11.4	11.4	11.4	11.4	11.4	11.4	11.4
4	BW_N_3	50	40	45	32.8	32.8	32.8	32.8	32.8	32.8	32.8
5	BW_N_4	55	45	50	79.9	79.9	79.9	79.9	79.9	79.9	79.9
6	BW_N_5	55	45	50	70.1	70.1	70.1	70.1	70.1	70.1	70.1
7	BW_N_6	55	45	50	50.7	50.7	50.7	50.7	50.7	50.7	50.7
8	Quay_N	100	100	100	18.3	18.3	18.3	18.3	18.3	18.3	18.3
9	Quay_S	100	100	100	18.0	18.0	18.0	18.0	18.0	18.0	18.0
10	BW_Inner_1	55	45	50	31.0	31.0	31.0	31.0	31.0	31.0	31.0
11	BW_Inner_2	55	45	50	58.2	58.2	58.2	58.2	58.2	58.2	58.2
12	BW_Inner_3	55	45	50	79.3	79.3	79.3	79.3	79.3	79.3	79.3
13	BW_Inner_4	55	45	50	66.0	66.0	66.0	66.0	66.0	66.0	66.0
14	Inner_Basin_1	55	45	50	45.0	45.0	45.0	45.0	45.0	45.0	45.0
15	Inner_Basin_2	100	100	100	37.9	37.9	37.9	37.9	37.9	37.9	37.9
16	Inner_Basin_3	55	45	50	14.4	14.4	14.4	14.4	14.4	14.4	14.4
17	Inner_Basin_4	55	45	50	47.8	47.8	47.8	47.8	47.8	47.8	47.8
18	BW_S_1	55	45	50	64.8	64.8	64.8	64.8	64.8	64.8	64.8
19	BW_S_2	50	40	45	79.1	79.1	79.1	79.1	79.1	79.1	79.1
20	BW_S_3	25	20	25	79.8	79.8	79.8	79.8	79.8	79.8	79.8
21	BW_S_4	25	20	25	13.1	35.6	58.1	79.9	79.9	79.9	79.9
22	BW_S_5	25	20	25	22.6	0.1	22.4	44.9	67.4	79.9	79.9
23	BW_S_6	25	20	25	52.6	30.1	7.6	14.9	37.4	59.9	79.9
24	BW_S_7	25	20	25	79.3	66.3	43.8	21.3	1.2	23.7	46.2
25	Al_Bida	0	0	0	88.8	66.3	43.8	21.3	1.2	1.2	1.2
26	Boundary_S	0	0	0	17.1	5.4	27.9	50.4	72.9	84.6	62.1

	Hs	T	Wave breaking	Main direction	Bottom friction
run1	3.61	8.47	Yes (g_sh = 0.8, g_off=0.14)	135N/135	No
run2	3.36	7.06	Yes (g_sh = 0.8, g_off=0.14)	157.5N/112.5	No
run3	2.76	7.74	Yes (g_sh = 0.8, g_off=0.14)	112.5N/157.5	No

table 85: Reflection coefficients and wave approach angles layout D

Appendix S. Output PHAROS

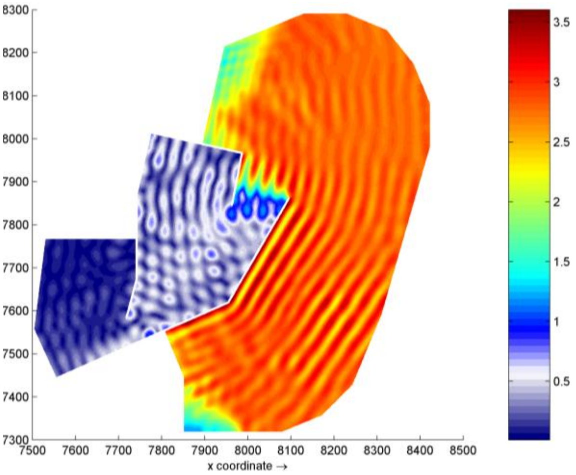

figure 156: Result PHAROS layout B waves from 112.5˚N

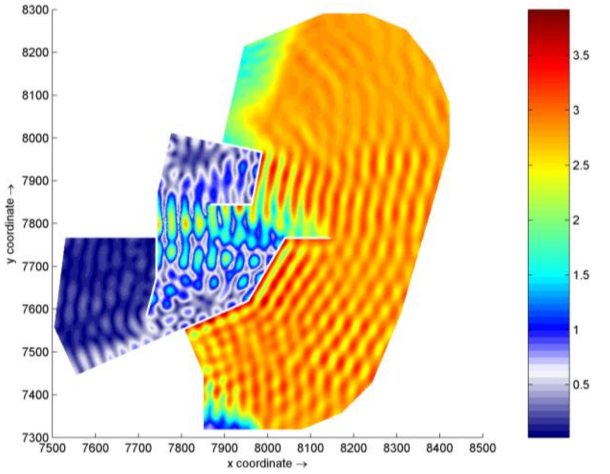

figure 157: Result PHAROS layout C waves from 112.5˚N

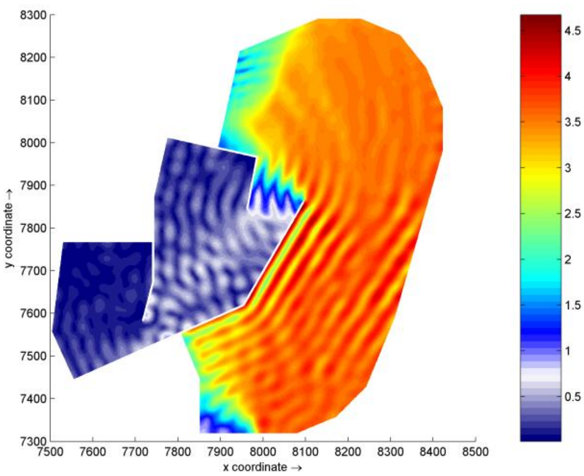

figure 158: Result PHAROS layout B waves from 135˚N

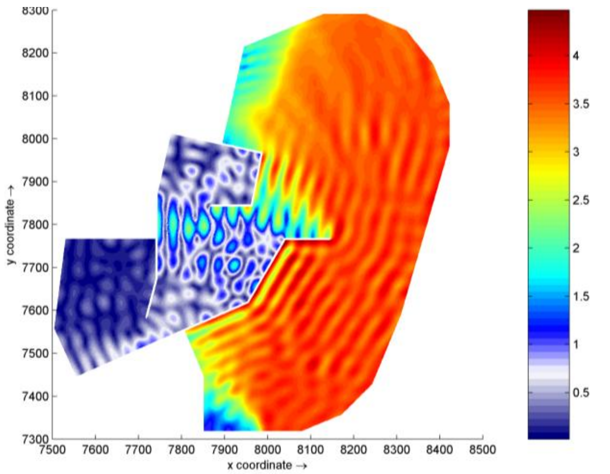

figure 159: Result PHAROS layout C waves from 135˚N

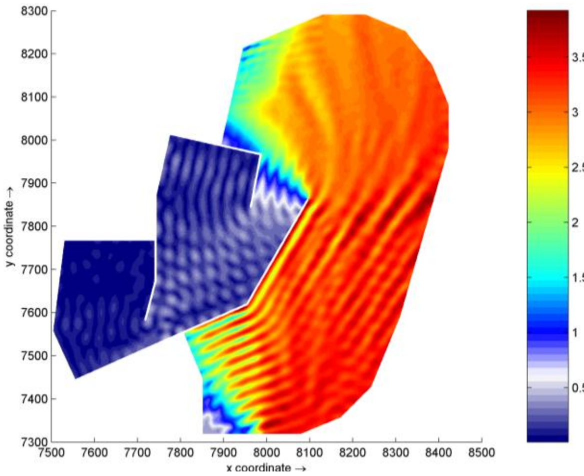

figure 160: Result PHAROS layout B waves from 157.5.5˚N

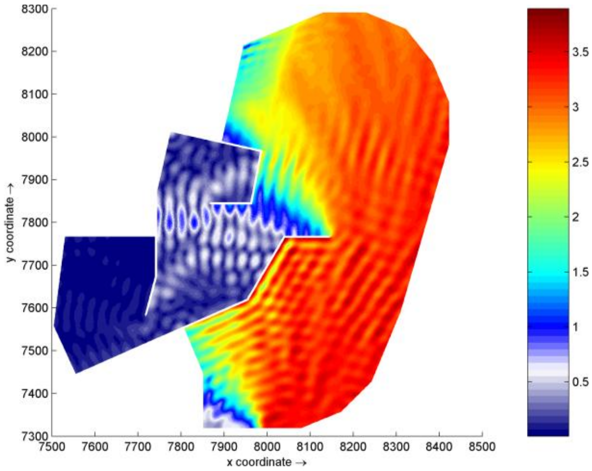

figure 161: Result PHAROS layout C waves from 157.5˚N

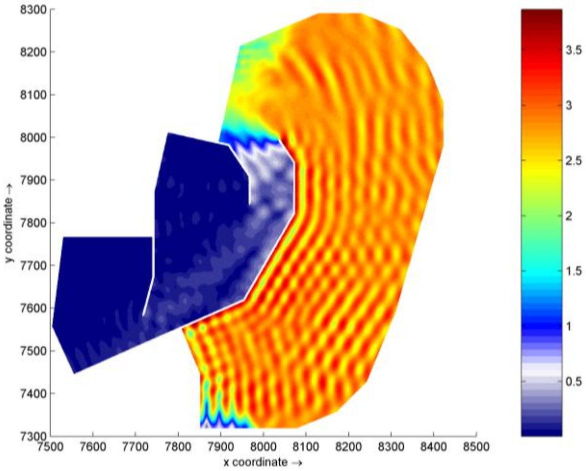

figure 162: Result PHAROS layout D waves from 112.5˚N

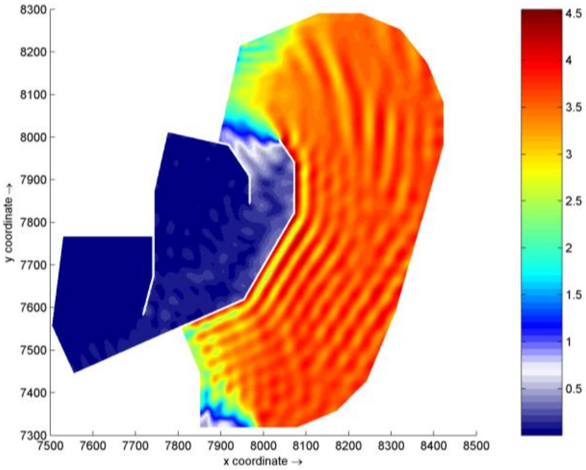

figure 163: Result PHAROS layout D waves from 135˚N

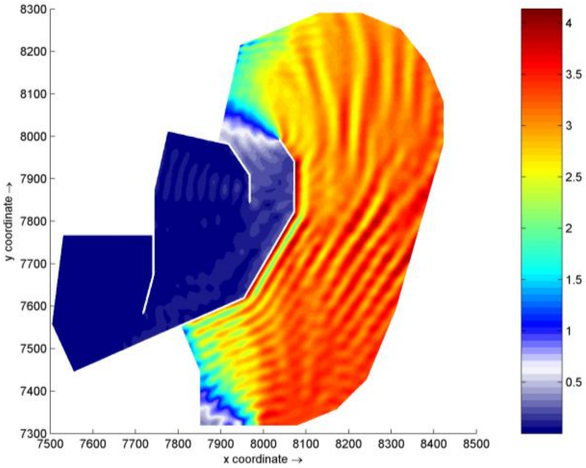

figure 164: Result PHAROS layout D waves from 157.5.5˚N