Jamaica's new transshipment port

October 31, 2013

Pim van den Akker
Marloes Brands
Wieger Buijs
Louise Hamilton

Delft University of Technology

Delft Infrastructures & Mobility Initiative
Sustainable solutions from a multidisciplinary approach

Smith Warner International
Coastal Environment

Preface

This report is written as a part of the multidisciplinary project for the master program Civil Engineering of Delft University of Technology, the Netherlands. This project is the collaboration of two master students Hydraulic Engineering and two master students Transport & Planning. The project and research is performed under guidance of Smith Warner International Ltd. in Kingston, Jamaica and is made financial possible with the support of Waterbouwfonds, Delft Infrastructures & Mobility Initiative (DIMI), and Fonds Internationale Stages (FIS), all related to the Delft University of Technology.

We want to thank David Smith and Philip Warner of Smith Warner International Ltd. for providing this interesting project and for the possibility to accomplish this project at their office in Kingston. Furthermore we would like to thank the employees of SWIL for all their support. In particular we want to thank Jamel Banton for his guidance during the project, giving us a warm welcome, and showing us around in Jamaica.

Pim van den Akker
Marloes Brands
Wieger Buijs
Louise Hamilton

Kingston, Jamaica
October 31, 2013

Table of Contents

Summary

When the new locks of the Panama Canal are finished in 2015 Post Panamax vessels are able to sail through the Panama Canal. This will increase the container traffic intensity through the Caribbean. China Harbour Engineering Company (CHEC) wants to anticipate on this expansion of the Panama Canal by investing in a US$1.5 billion transshipment port in the Caribbean. Jamaica is an interesting location to realize this port, because of its ideal central position in the Caribbean and its location lies in the doorway of the Panama Canal. CHEC aims for the Goat Islands in Jamaica as their location for the new port. Normally the Jamaican government welcomes foreign investments of CHEC with open arms, but the Goat Islands are an environmentally protected area. Recently, this led to many complains by environmentalists.

The new port can only be successful if it has a good competitive position with respect to other ports. The new port in Jamaica is a location with high potency to accommodate the container vessels which have ports at the East Coast of North America as destination. To attract shipping companies to the new transshipment port in Jamaica the price and efficiency of the new port must be competitive with other ports. As the new port of Jamaica doesn't have a large hinterland and focusses mainly on transshipment, shipping companies are not bounded to Jamaica and can switch easily to other ports. The most competitive ports are Mariel (Cuba) and Freeport (the Bahamas).

This report proposes designs and alternative locations for the new port. To find the ideal location for a new port in Jamaica different potential areas are selected and studied. The first steps resulted in sixteen possible locations for the port. Two Multi Criteria Analyses (MCA's) resulted in a selection of four locations. Those possible locations for the new port are: the Goat Islands, Jackson Bay, Maccary Bay, and Little Bay. The best location is not found, because all the four locations are well-matched for their designed level of detail. Therefore the recommendation is made that all the four locations should be designed in a higher level of detail, so the decision makers can make well informed choices for the people of Jamaica. Because the media attention, the Jamaican government, and CHEC are more focusing on the Goat Islands than on the other locations, the location Goat Islands is designed further into detail.

For designing the port the total surface of the port of 12 km^2 is divided into port area for transshipment (4 km^2) and area for the use of industry (8 km^2). The transshipment area has a quay length of 3 kilometer, which provides enough berthing space to handle seven Post Panamax ships and one Panamax ship simultaneously. The maximum expected throughput of 7 million TEU per year is found. The transshipment area is also designed into further detail. Super Post Panamax ship-to-shore cranes, multi trailer systems and rail mounted gantry cranes are most suitable for the port. The hinterland connection is also designed. A road connection is needed and a railway connection is designed as an option. The industrial surface can be used for many different facilities. These facilities are the assembling of gantry cranes for the Americas and creating cement and steel for export purposes. These activities need quay length which is included in the design of the total layout. Also space is reserved for a manufacturing facility, a logistics center, a LNG power plant, and a major IT facility.

The extreme wave conditions for the new port are investigated to come up with the design loads. Extreme waves with a return period of 1/200 years give a surge level of 2.0 meter and wave heights of 4.0 meters at the port entrance. Behind the port is found a higher surge level of 2.5 meters. Next to the extreme conditions the downtime of the port due to waves is established. Tropical storms are not strong enough to cause downtime, because of the sheltered area of Portland Bight. Only during hurricanes the port is not operational.

The economical, social, and environmental impacts of the new port are described. For the new port the most favorable port model and a finance scheme are found. A private service port model with full concession in combination with a Build, Operate, and Transfer contract (BOT) is advised. The land will still be owned by the Jamaican government, but CHEC will fulfill both the functions of port authority and port operator. An environmental impact assessment has to be performed, because there are more issues besides the destruction of Little Goat Island, harming the fish sanctuary, and the impact on the total Portland Bight. Also these three issues should be investigated in detail.

A SWOT analysis is carried out to find the strengths, weaknesses, opportunities and threats. The main opportunity and threat is the change in expected throughput. To deal with this uncertainty an adaptive port planning is designed.

1 Introduction

This chapter illustrates the reason for the project, the aim of the project, and describes the structure of the report. These aspects give an introduction to the rest of the report.

1.1 Reason for the project

The reason for the project can be split up into different components. This section contains the background information, the description of the problem, and formulates the importance of the project.

1.1.1 Background information

In the end of August 2013 the people of Jamaica were shaken up by several news items about their beloved Goat Islands in the south of Jamaica. Rumors were going around about heavy investment of the Chinese to create a big port in Jamaica for transshipment purposes. The Minister of Land, Water, Environment and Climate and the Prime Minister of Jamaica met with the China Harbour Engineering Company (CHEC) during a visit in China to talk about this investment (Jamaica Gleaner, 2013a).

When the new locks of the Panama Canal are finished Post Panamax vessels are able to sail through the Panama Canal. This will increase the container traffic intensity through the Caribbean significantly (see appendix A, Background information). The Chinese (CHEC) want to anticipate on the expansion of the Panama Canal by investing around US$1.5 billion in building a transshipment port in the Caribbean (Jamaica Information Service, 2010).

Jamaica is an interesting location for this port because of its ideal central position in the Caribbean and it is nearby the Panama Canal. The scale of this project is quite intense, because the port area will be about 3,000 acres (12 km^2). The investment consists not only the developing and building of the container transshipment port, but also plans are made to create an industrial area (Jamaica Information Service, 2013c). During CHEC's first investigation at Jamaica the Goat Islands area (see Figure 1-1) was chosen as primary possible location for their port. The Goat Islands lie 20 kilometers west of the capital of Jamaica, Kingston.

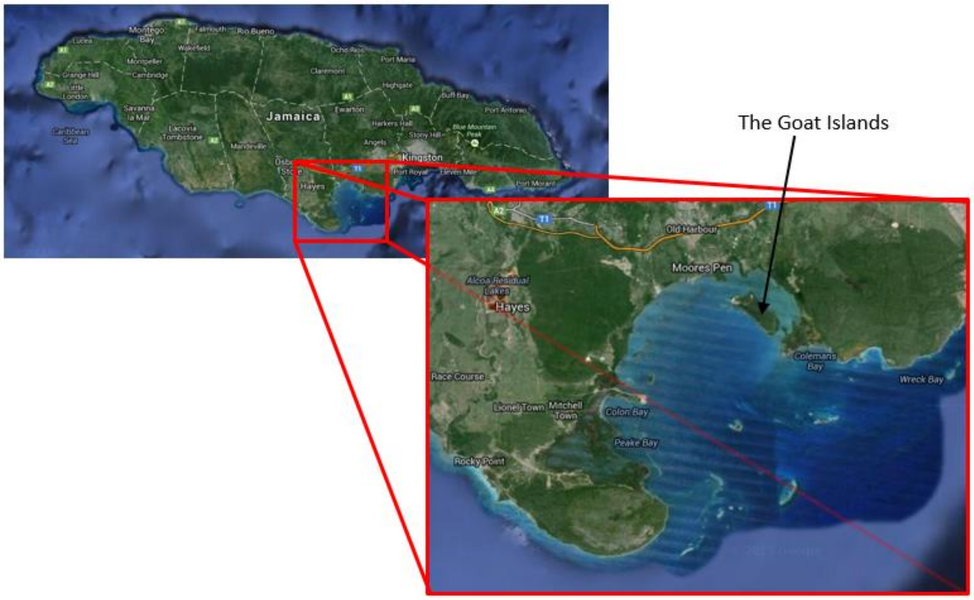


FIGURE 1-1: LOCATION OF INTEREST FOR CHINESE INVESTOR (CHEC)

1.1.2 Problem description

CHEC's aim for the Goat Islands gave a lot of tumult with local environmentalists because the Goat Islands are an environmentally protected area (Jamaica Observer, 2013). North of the Goat Islands lies a large fish sanctuary where juvenile fish can grow up, protected from bigger fish. Next to the environmental impact there are also voices complaining about '*selling their birthright for less than a mess of pottage'* (Espeut, 2013). For now, little is known about the benefits for the (local) Jamaicans. This makes them very skeptical about the new transshipment port.

However, extra economic activity will give the Jamaican economy a (necessary) boost. On one hand the Jamaican government normally welcomes foreign investments of CHEC with open arms (see appendix A, Background information), but on the other side the Goat Islands are an environmentally protected area. This raises big discussions amongst almost everyone in Jamaica and reaches to the highest level of the Jamaican politics (Jamaica Gleaner, 2013b).

1.1.3 Importance of the project

The balance between (environmental/social) costs and benefits is mainly political, but engineers can propose designs and alternatives for this port. By investigating stakeholders and looking at reference ports, designs can be made. By showing alternative locations, showing different lay-outs, summing up the strengths, weaknesses, threats, and opportunities, and investigating the (social, environmental, and economical) impact of the new port the decision makers can make well informed choices for the people of Jamaica. The challenge is to find solutions that are most beneficial for all concerned parties.

1.2 Aim of the project

The purpose of this report is to present the Jamaican government possible alternative locations instead of only focusing on the Goat Islands and present a good design for the new port. Together with analyses about competitiveness, other stakeholders, possible port models, impact of the new port for Jamaica, and impact on the existing port of Kingston this gives a clearer and wider view of the subject. The goal is to show the reader that the described problem description in the previous section is in fact an opportunity.

The main question which will be answered in this report is:
What is the best (economical/social/environmental) way, location, and design to develop a 12 km^2 new port in Jamaica?

1.2.1 Research method

Various methods of information gathering are done during this project. Literature studies were executed and site visits were carried out to gather on site information. During the time of the project different involved people were consulted: Dr. Hu and her colleague engineers of CHEC, several environmentalists, local fishermen, Dr. Robertson (former cabinet minister and senior director of the Port Authority of Kingston), and the engineers of Smith Warner International ltd.

1.2.2 Boundary conditions and principles

During the research of this project many assumptions are made. These assumptions are explained in their relevant chapters and their associated appendix. However, the most important boundary condition is that only Jamaica is investigated for possible locations and not any of the other Caribbean countries. These countries are seen as competitors. The most important principle that is used is that Jamaica will benefit from the port regardless of its location on the island. This means not building the port at all is not considered as an option in this report.

1.3 Structure of the report

Chapter 2 describes the specifications of the project. In this chapter the stakeholder analysis is carried out, competitors are defined, and design values are established. Chapter 3 continues with possibilities for the port location. The locations with the highest potential are selected and different basic layouts are sketched. In this chapter a reflection on the design values from chapter 2 is executed. A detailed design for one of the locations is found in chapter 4. Here, possibilities for the industrial area, the layout of the port, and the hinterland connection are treated. Deeper analyses of the waves and the subject adaptive port planning can also be found in this chapter. The final design of the port is stated in the end of chapter 4 and continues in chapter 5 by describing the impact of this port design. Finally, conclusions can be found in chapter 6 and recommendations in chapter 7.

2 Specifications

Before a design is made it is important to know different aspects of the port design. From the background information (appendix A, Background information) the first design requirements are known. It is important to analyze the stakeholders and the possible competitors of the new port. Without these analyses it is not clear which aspects are desired to be included in the design process. After these analyses the values for different design values, for instance depth of approach channel, can be determined.

2.1 Stakeholders

A stakeholder analysis is performed (see appendix B, Stakeholder analysis) to get an overview of the different stakeholders and their interest, power, and attitude. In the analysis there is a distinction made between different decision processes, which occur during the development of the new port. These are location choice processes, port design processes, and contract processes. The stakeholders can be divided into three groups which are presented below.

- **Jamaica**
  - Government of Jamaica
  - Port Authority of Jamaica
  - Environmental protection organizations
  - Jamaican press
  - Jamaican citizens

- **China**
  - China Harbour Engineering Company Ltd. (CHEC)
  - China Communications Construction Company Ltd. (CCCC) (Parent company CHEC)

- **Others**
  - Shipping companies
  - Other transshipment ports in the Caribbean

The most important stakeholders are the Government of Jamaica and CHEC. CHEC wants to make the investment and develop the port, but the Government of Jamaica needs to give permission. CCCC and the Port Authority of Jamaica are also important stakeholders, they should definitely be included in the decision making processes about the port location and port design. In these decision making processes it is important to consult the environmental protection organizations and the people of Jamaica.

For the port design processes it is useful to consult the shipping companies for their needs. Also the other transshipment ports in the Caribbean should be analyzed in the port design process to ensure a good position as a competitor for the new port. More about competitiveness will be discussed in the next section, 2.2.

In the contract processes the Government of Jamaica and CHEC should be included. If possible also the shipping companies can be included in this process. Also in these processes it is important to consult the Jamaican people. In all the processes the Jamaican press should be informed to keep the project as transparent as possible.

2.2 Competitiveness

The new port can only be successful if it has a good competitive position with respect to other ports. Therefore it is advised to include competitiveness in designing the details of the port. The competitiveness of the new port is described in appendix D, Competitiveness.

The new port in Jamaica is a location with high potency to accommodate the container vessels which have ports at the East Coast of North America (the middle and the north of North America) as destination. The most competitive ports are Mariel (Cuba) and Freeport (the Bahamas). The highest share of opportunities for the new port in Jamaica is the transshipment of containers with North America as destination. The amount of containers which has to be shipped to the East Coast of North America is by far the largest stream transiting the Panama Canal. The stream of containers going to the East Coast of North America is also assumed to be the key growth driver of the Panama Canal expansion. (Panama Canal Autorithy, 2006)

To attract shipping companies to the new transshipment port in Jamaica the price and efficiency of the new port must be competitive with other ports. This means the new port must not have a too long waiting time, must have suitable equipment and technology, and the dwell time of containers must be appropriate. It must be noted if these factors are not good enough to compete with other ports, shipping companies probably will switch to another port. As the new port does not have a large hinterland and focusses on transshipment, shipping companies are not bounded and can switch to other ports easily.

2.3 Design values

Based on reference ports (see appendix C, Reference ports) and a reference terminal (Euromax Terminal Rotterdam) the values for the different design parameters are established. This is done with different theories in appendix G, Design values. The total surface of the port of 12 km^2 is divided into different sections for wet and dry area and for transshipment and industry. At first it was assumed that 50% (6 km^2) of the port area is used for transshipment (wet and dry) and the other 50% is used for industry (wet and dry). Based on the design of the Maasvlakte 2 (part of the Port of Rotterdam, the Netherlands) it is assumed that the dry surface of the transshipment port is 50% of the total surface of the transshipment port. This dry surface is 3 km^2. With this known surface the maximum expected throughput and the average dwell time are estimated based on references ports and Ligteringen & Velsink (2012). After a sensitivity analysis is performed, the division of the surfaces is changed. This analysis will be explained in the next paragraph.
To determine the number of berths and the corresponding quay length, reference ports and the maximum expected throughput are used. Reference ports are used to estimate the number of berths with the knowledge of (Ligteringen & Velsink, 2012). Two different methods are used for calculating the quay length. The two different values for the quay length are used in the sensitivity analysis.

A sensitivity analysis is performed to investigate the difference in value for the total port design between a quay of 3 kilometer (according to the queuing theory) and a quay of 6 kilometer (according to reference ports and linear scaling). This is described in appendix K, Sensitivity analysis. This analysis is done by adapting the port design for different locations and a multi criteria analysis, this is explained in chapter 3.

Besides the above parameters the values for the dimensions of the approach channel are established. For the industrial part the distinction between dry and wet area is made. Also the number of berths and the quay length of the industrial part are determined. All the established values for the design parameters from appendix G, Design values, are shown in Table 2-1. After the sensitivity analysis some of the design values are changed, this is shown in the last column of Table 2-1.

Table 2-1: Overview design values for first design and sensitivity analysis

			First design	**After sensitivity analysis**
Surface port area	Transshipment port	Dry	3 km^2	
		Wet	3 km^2	1.5 km^2
	Industrial area	Dry	5 km^2	6.5 km^2
		Wet	1 km^2	
Approach channel	Width		500 m	
	Length in port		At least 500 m	
	Diameter turning circle		At least 732 m	
	Depth	Transshipment port	At least 18 m	
		Industrial area	At least 15 m	
Average dwell time			7.5 days	
Maximum expected throughput			Nearly 7 million TEU	
Number of berths	Transshipment port		15 berths	8 berths
	Industrial area		not determined	6 berths
Quay length	Transshipment port		6 km	3 km
	Industrial area		not determined	2 km

3 Port location

To determine the port location sixteen possible locations at Jamaica are investigated. A pre-selection is made of all the locations to come up with the five best locations. Those five locations are investigated further by making the port designs. A multi criteria analysis (MCA) is done to select the best locations for the development of the new port. A sensitivity analysis is performed to investigate to influence of the quay length on the costs and the total value of the designs.

3.1 Possible locations

To find the ideal location for a new port in Jamaica different potential areas are selected and studied. The selection of the potential areas is done by looking at various kinds of maps (road maps, bathymetry maps, contour maps, etc.) to indicate where on the island enough space is found to develop a port with a total area of 3,000 acres (12 km^2). This first step results in sixteen possible locations for the area of the port, see Figure 3-1. The names of the numbered places of Figure 3-1 are shown below the figure. Those areas are located at places where only small settlements or even none inhabitants are situated along the coast.

FIGURE 3-1: OVERVIEW OF ALL THE POSSIBLE LOCATIONS FOR A NEW PORT IN JAMAICA

(1) Portland Bight - Great Goat Island
(2) Portland Bight - Cockpit
(3) Portland Bight - Mitchell Town
(4) Jackson Bay
(5) Maccary Bay
(6) Long bay
(7) Alligator Pond – Calabash Bay
(8) Parottee
(9) Black River
(10) Crawford – West
(11) Belmont
(12) Savanna-la-Mar
(13) Little Bay
(14) Duncans
(15) Buff Bay
(16) Bowden Harbour

After a rough MCA, see appendix I, Site selection, a pre-selection is made of five locations. These locations are (in Figure 3-1) the Goat Islands (1), Jackson Bay (4), Maccary Bay (5), Savanna-la-Mar (12), and Little Bay (13). All five locations are further investigated.

3.2 The pre-selected five locations

Designs are made for the pre-selected locations (Goat Islands, Jackson Bay, Maccary Bay, Savanna-la-Mar, and Little Bay), see appendix J, Further investigation of five port locations. All the designs satisfy the first design criteria listed in chapter 2. The designs include a dredge and fill balance and a rough estimation of the costs for dredging, reclamation, and the costs for the breakwaters. The goal is to find the best possible location which satisfies the main question (stated in section 1.2) best. The five locations are explained in the next subsections. The total costs are found with indicators and only contains dredging, reclamation and breakwater costs.

3.2.1 The Goat Islands

For the Goat Islands five alternative designs are made. The most promising design is shown in Figure 3-2 and the key numbers are presented in Table 3-1. The other designs can be found in appendix J, Further investigation of five port locations.

TABLE 3-1: KEY NUMBERS OF THE PORT DESIGN AT THE GOAT ISLANDS

Key numbers

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.2	km^2
Wet area for transshipment	4.1	km^2
Dry area for industrial	5.3	km^2
Wet area for industrial	0.0	km^2

Lengths		
Quay length for transhipment	6.6	km
Quay length for industrial	5.5	km
Length approach channel	5.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	79.8	mln. m3
Total surplus material	51.8	mln. m3
Volume of breakwater	0.0	mln. m3

Total costs	**920**	**mln. U.S. Dollar**

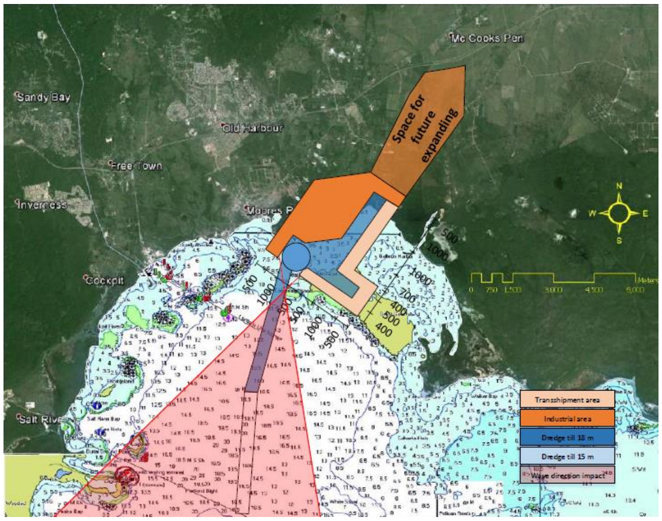


FIGURE 3-2: FIRST PORT DESIGN AT THE GOAT ISLANDS

The main advantages of this location are the natural sheltered area of the bay and the connection with the highway system of Jamaica. The main disadvantages of the location are the environmental area and the valuable nature and ecological systems.

3.2.2 Jackson Bay

The development of a port at Jackson Bay has good potential, because the area is abandoned. There is a lot of space for the port without really damaging the nature. It is in a shallow area, but close to deep water. This results in a short approach channel, but heavy breakwaters need to be designed for hurricane waves, see Figure 3-3. This increases the investment costs, see Table 3-2. Also some extra investment needs to be done for a good connection with the highway system of Jamaica.

TABLE 3-2: KEY NUMBERS OF THE PORT DESIGN AT JACKSON BAY

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	3.0	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	0.9	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.8	km
Length approach channel	4.0	km
Length of breakwater	7.0	km

Volumes		
Total amount of dredging	51.1	mln. m3
Total surplus material	25.7	mln. m3
Volume of breakwater	2.7	mln. m3

Total costs	**1,230**	**mln. U.S. Dollar**

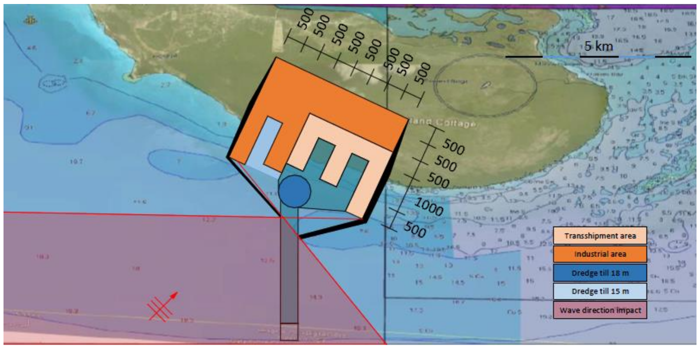


FIGURE 3-3: FIRST PORT DESIGN AT JACKSON BAY

3.2.3 Maccary Bay

In Figure 3-4 the port design of Maccary Bay is shown. The main advantage of this location is the very large available area and the land area is already some meters above sea level. The disadvantage of a port at Maccary Bay is the long approach channel which can be seen in (the costs in) Table 3-3.

TABLE 3-3: KEY NUMBERS OF THE PORT AT MACCARY BAY

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	2.6	km^2
Wet area for transshipment	2.8	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	1.2	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.6	km
Length approach channel	12.0	km
Length of breakwater	8.0	km

Volumes		
Total amount of dredging	101.9	mln. m3
Total surplus material	99.8	mln. m3
Volume of breakwater	1.6	mln. m3

Total costs	**1,060**	**mln. U.S. Dollar**

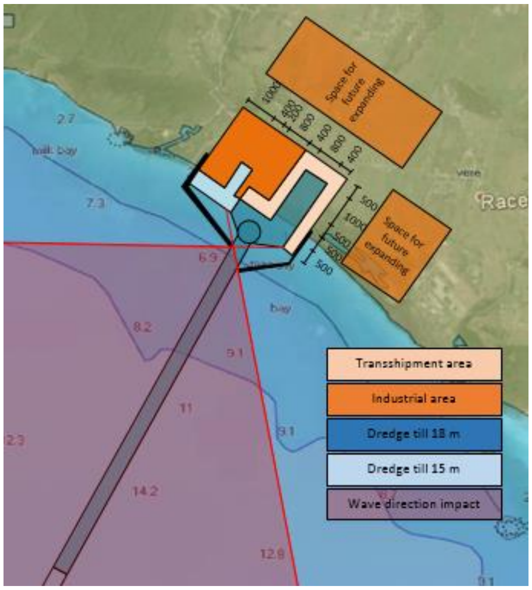


FIGURE 3-4: FIRST PORT DESIGN AT MACCARY BAY

3.2.4 Savanna-la-Mar

This location is just west of the city Savanna-la-Mar (a town in the west of Jamaica). The surrounding land area is large, flat, and not much living can be found over there. It is a very shallow bay and during hurricanes this area is naturally good protected against waves, because the waves will break in the shallow zone. Therefore the breakwater can be seen as an integrated revetment, see Figure 3-5. This advantage (shallow waters) is at the same time a disadvantage. A large amount of dredging is needed because of the shallow zone while the approach channel is not enormous, see Table 3-4 (resulting in a big surplus in dredged material).

TABLE 3-4: THE KEY NUMBERS OF THE PORT AT SAVANNA-LA-MAR

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	3.4	km^2
Wet area for transshipment	3.0	km^2
Dry area for industrial	4.7	km^2
Wet area for industrial	0.8	km^2

Lengths		
Quay length for transhipment	6.4	km
Quay length for industrial	2.9	km
Length approach channel	5.5	km
Length of breakwater	6.5	km

Volumes		
Total amount of dredging	96.4	mln. m3
Total surplus material	73.4	mln. m3
Volume of breakwater	0.8	mln. m3

Total costs	**1,150**	**mln. U.S. Dollar**

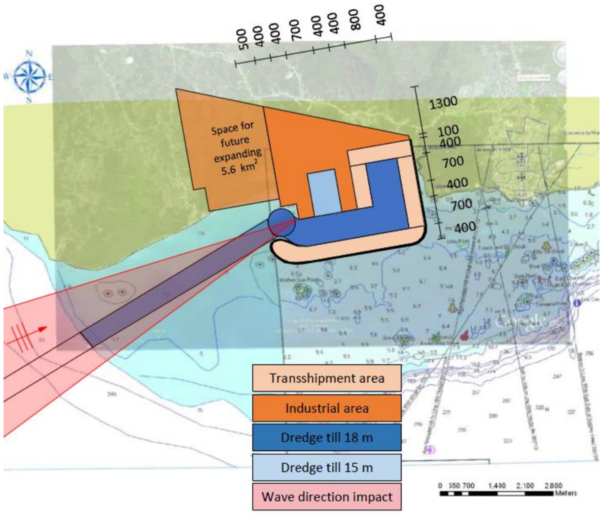


FIGURE 3-5: FIRST PORT DESIGN AT SAVANNA-LA-MAR

3.2.5 Little Bay

A little bit more to the west of the port design of Savanna-la-Mar is the location which is called Little Bay. The main advantage of this area with respect to the port design at Savanna-la-Mar is the short approach channel, see Figure 3-6. This results in less dredging, see Table 3-5. The other aspects are quite similar. There is space for expansion, but it is only possible to the east, so a breach in the port has to be made in case of expansion. The main disadvantage however is the distance to the highway system and Kingston, the biggest population of Jamaica.

TABLE 3-5: KEY NUMBERS OF THE PORT DESIGN AT LITTLE BAY

Key numbers

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.6	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.8	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	6.7	km
Quay length for industrial	2.0	km
Length approach channel	1.3	km
Length of breakwater	4.7	km

Volumes		
Total amount of dredging	63.8	mln. m3
Total surplus material	53.3	mln. m3
Volume of breakwater	0.6	mln. m3

Total costs	**720**	**mln. U.S. Dollar**

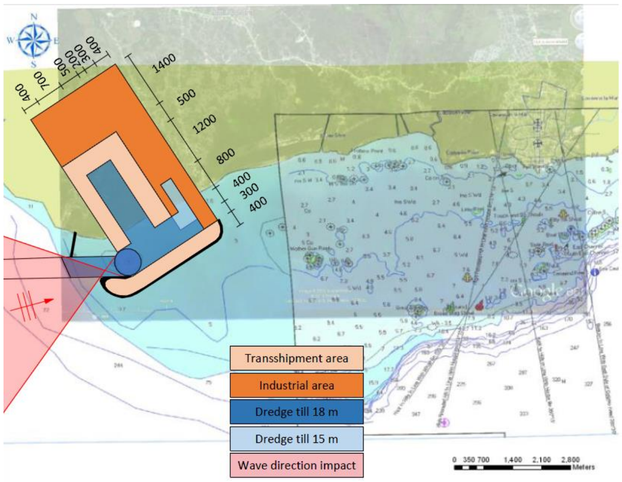


FIGURE 3-6: FIRST PORT DESIGN AT LITTLE BAY

3.3 Sensitivity analysis

The result of the MCA to select the best of the five locations is not sufficient to select the best possible location. This is further explained in appendix J, Further investigation of five port locations. From the five locations explained in the previous sections only Savanna-la-mar has a low score. The other four locations are well-matched. A small change in weights will change the scores and ranking of the four locations.

Next to this not all the costs are taken into account (building method and time, etc.). There are also uncertainties in the design values. Therefore a sensitivity analysis is made. This is only done for the best four locations; the Goat Islands, Jackson Bay, Maccary Bay, and Little Bay (so without Savanna-la-Mar).

The sensitivity analysis is found in appendix K, Sensitivity analysis. In this analysis the length of the quay is adapted. Reducing the required quay length of the transshipment port has a big influence on the design of the port. On the MCA score it does not make a big difference for all the four locations, but on the costs it does. Even up to 33% costs reduction (for dredging, reclamation, and the costs for the breakwater) can be accomplished when reducing the quay length from 6 kilometer to 3 kilometer.

In the rest of the report the port design is based on 3 kilometer quay length. This also effects the port area distribution, see Table 2-1.

3.4 Selecting the location for detailed design

Using the appendices I (Site selection), J (Further investigation of five port locations), and K (Sensitivity analysis), the conclusion can be made that there are four very good alternative locations for a new port. These locations are the Goat Islands, Jackson Bay, Maccary Bay, and Little Bay. All the locations are winners in different ways. The scores lie close to each other. This makes them very sensitive to the assumptions that are made.

To make a real comparison all the locations have to be designed to their final stage. A lot of aspects have to be established or designed in more detail.

- First of all, some of the design values have to be set, such as dry surface and aimed throughput.
- Also the design life time and the probability of failure have to be established. With those parameters the design return period of waves can be calculated. The wave and wind data have to be analyzed and the modeling of the waves near shore, the associated design wave height for the return period can be found. With these parameters the breakwaters and the port can be designed in more detail and a good estimation of the costs can be given.
- The designed breakwaters in the sensitivity analysis are too rough and also the price per cubic meter is the same everywhere, which is not true in reality.
- The sedimentation in the port and approach channel have to be simulated for the costs of maintenance dredging.
- A bathymetric survey with higher accuracy has to be done for establishing the real amount of dredging.
- The dredged material has to be investigated. Can the material be used for reclaiming?
- The currents have to be modeled to see if the approach channel doesn't lead to unnecessary downtime.
- For all the locations a timeframe of the building process should be made. A shorter building time is preferable, because of the finishing of the expansion of the Panama Canal in 2015.
- Also an Environmental Impact Assessment has to be made for every location. What is really the consequence of building and operating the port? Which environmental aspects are important? Where and how is the environment compensated in case of destroying some environmental areas?
- A Social Impact Assessment has to be made. Which part of Jamaica needs the economic boost the most? Which location is preferable for (the Government of) Jamaica?

Only after making a final and detailed design for all the four locations the involved parties can choose the best location.

Because of limited time for this project only one location will be investigated further. This further design is not a complete design including all the details described above. For example, bathymetric survey, currents, and sand quality cannot be checked in this project. It is recommended to investigate these in future studies.
The location Goat Islands looks the most interesting. It looks like media (and public opinion), government, and CHEC are more focusing on the Goat Islands than on the alternative locations. Although three very good alternatives are found, it would be a challenge to show all stakeholders that it is possible to use the Goat Islands for a port and keep the environment in mind. The Goat Islands design (see Figure 3-7) is chosen as design to be further investigated and designed.

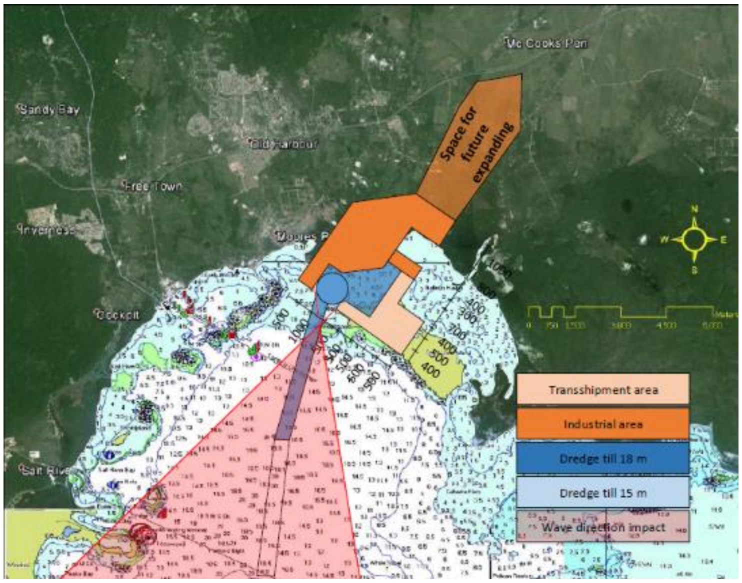


FIGURE 3-7: THE GOAT ISLANDS DESIGN WITH A 3 KILOMETER QUAY LENGTH

4 Port design

The port design consists of a transshipment part and an industrial part. First the facilities in the industrial part are listed. After that the layout of the new port (both parts) is shown. Two options for the hinterland connection are illustrated and adaptive port planning is applied to the port. Finally, a wave analysis is done for the new port.

4.1 Industrial facilities

To increase the value of the new port, 6.3 km^2 is reserved for industrial activities that are not directly related to the (container) transshipment port. The industrial area can be used for many different facilities. There are multiple news articles in which is stated which kind of facilities will be located in the industrial area of the new port (Jamaica Information Service, 2013a) (Jamaica Information Service, 2013b) (Jamaica Information Service, 2013c). Based on these news articles the division of the industrial area is made. More information can be found in appendix H, Industrial area.

At this moment the assembling of gantry cranes is done in China, but a large demand of gantry cranes is in the Americas. Therefore Jamaica is a good location for assembling the gantry cranes, because of the shorter distribution distance. This assembly plant will be located in the new port.

A cement plant and a steel fabrication plant will also be built in the industrial area. These facilities are used for export. The assembly plant, cement plant and steel fabrication plant all need two berths (650 meters of quay length). The total quay length for the industrial area is 2 kilometer, see Table 2-1.

To provide the new port with energy a power plant will be constructed. The power plant will use LNG, which is transported by LNG vessels. For the mooring of the LNG vessels a jetty is needed.

The ideal location for building a logistics center and manufacturing facilities is the industrial area which is close to the transshipment area. The logistics center could contain warehouses, freight forwarders and repair depots. Also a major IT facility will be built.

All the facilities have to be connected to the infrastructure for the transportation of cargo and employees. Therefore a part of the industrial area is reserved for related and supporting infrastructure.

4.2 Layout

A layout for the new port is made. This is divided in a layout for the industrial area and a layout for the transshipment area. In appendix L, Layout of the port, more detailed information about the layout of the new port is given.

4.2.1 Industrial area

The mentioned facilities for the industrial area in section 4.1 are placed in the new port, see Figure 4-1.

The location of the power plant is assigned first in the layout of the port, because the placement has a lot of constraints. The power plant is assumed to be a LNG power plant, which is hazardous liquid bulk. The power plant must be located at a place which is not close to the villages and factories. A jetty in a branch of the approach channel and a pipeline to the power plant is constructed. This is not visible in Figure 4-1. Taking all these constraints into account, the best location for the power plant is southeast of the transshipment area.

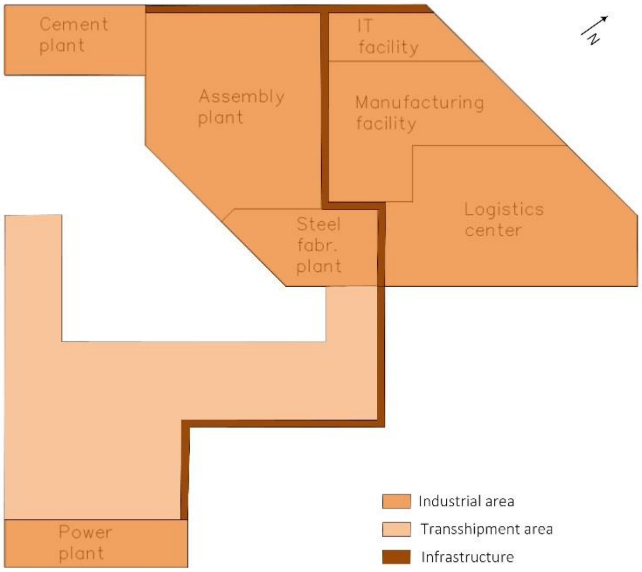


FIGURE 4-1: LAYOUT OF THE INDUSTRIAL AREA OF THE PORT

After the power plant the facilities which need quay length are placed, because they all need to be placed at the waterfront. These facilities are the cement plant, assembly plant and the steel fabrication plant.

The rest of the area is used for the IT facility, manufacturing facility and the logistics center. The related and supporting infrastructure connects all the facilities. As mentioned before the manufacturing facility and the logistics center are closer to the transshipment port than the IT facility.

4.2.2 Transshipment area

A layout for the transshipment area of the port is made. The transshipment area is divided in the storage yard, apron area, between storage yard and apron area and the other areas. This layout is shown in Figure 4-2.

Apron area

Super Post Panamax ship-to-shore cranes are used at the quay to load and unload the vessels. In case of future expansion for handling Super Post Panamax vessels, only dredging is needed and not replacement of the cranes. Next to that this cranes have a high capacity.

Five cranes are needed to (un)load a Post Panamax vessel and four cranes are needed to (un)load a Panamax vessel. If seven Post Panamax vessels and one Panamax vessels are simultaneously being (un)loaded the maximum number of cranes is needed. For this situation 39 cranes are needed in total. Each crane can handle 100 containers per hour. The maximum number of containers per hour that will be handled is equal to (39 * 100=) 3,900 containers per hour. It takes 24 hours to unload a Post Panamax vessel with 12,000 TEU. (Five cranes are used, which can handle 100 containers per hour per crane. 12,000 / (5*100) = 24.) It will take 12.5 hours to unload a Panamax vessel with 5,000 TEU.

Within the storage yard

Rail mounted gantry cranes are most suitable for stacking the containers in the new port. This system has a good space utilization, is reliable, has low maintenance requirements and auto-mation is possible. However, this system requires a high investment and is inflexible, but it is assumed that the cranes will be positioned appropriately for a long period and no flexibility in the apron area is necessary. (Ligteringen & Velsink, 2012)

The design of the storage yard is based on Terminal 2 at the port of Jebel Ali in Dubai. This terminal uses rail mounted gantry cranes, is able to handle Post Panamax vessels, and handles the same amount of TEU per squared kilometers compared to the expected throughput per squared kilometer of the new port. (DP World) (The National, 2013) (CSS Group, 2013)

The layout of the storage area of the new transshipment port will be based on the layout of the terminal at the port of Jebel Ali.

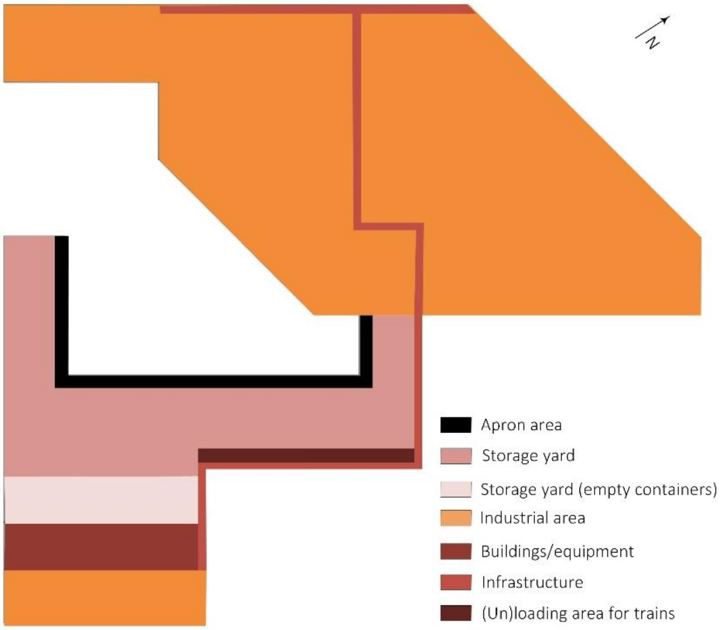


FIGURE 4-2: LAYOUT OF THE TRANSSHIPMENT PART OF THE PORT

The layout of the storage area is shown in Figure 4-3. There is space for stacking areas, the rails, an area for the picking up and putting down the containers and there is enough space for vehicles to pass. Between the stacking areas (at the short side) there is a two-way lane for transporting the containers. The rail mounted gantry cranes are able to serve different stacking areas, because the rails are extended between the stacking areas. In total 109 rail mounted gantry cranes are needed for the new port.

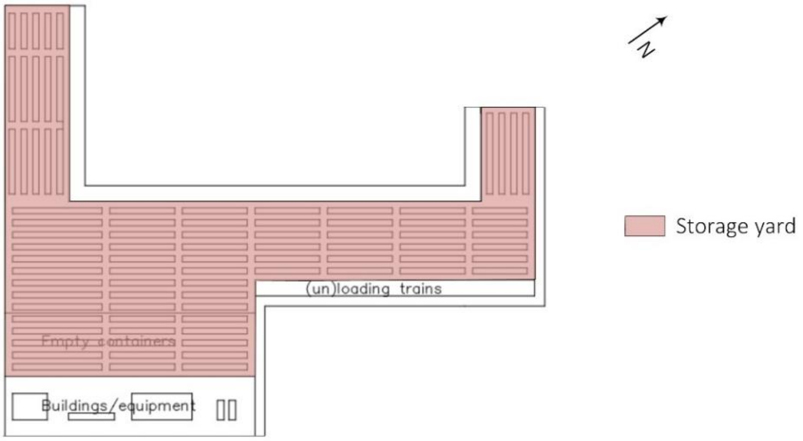


FIGURE 4-3: LAYOUT OF THE STORAGE YARD OF THE TRANSSHIPMENT AREA

It is assumed that 15% of the area consists of empty containers and therefore 15 empty containers handlers are needed.

The capacity of the storage area is approximately 317,000 containers. With an average stacking height of 5.25 containers (75% of the nominal stacking height) the number of stacked containers during full occupancy is equal to approximately 237,000 containers. However, the occupancy is normally around 70%, (the arrival of ships is not uniform distributed), so the average number of containers on the storage yard is approximately 166.000.

Between apron area and storage yard
At the port of Jebel Ali in Terminal 2 yard tractors with trailers are used for the transport of containers between the apron area and the storage yard. (DP World, n.d.) These can also be used in the new port. A low investment for the pavement is needed. The trailers have low maintenance costs and are simple and flexible in operation. However, a large number of them is needed, they have a low throughput capacity and are labor intensive. (Ligteringen & Velsink, 2012) It is also possible to use a multi trailer system. This is a yard tractor which pulls up to five trailers. These trailers stay in place while making a turn. By using a multi trailer system less drivers are needed, a high throughput capacity can be reached and the traffic peaks are easily absorbed, but they are less flexible in operation.

As mentioned before, a maximum of 3,900 containers per hour can be handled by the ship-to-shore cranes. One round trip with a multi-trailer system is assumed to take 26 minutes, so 12 containers can be handled per hour by one multi trailer system. In total 338 tractors and 1690 trailers are needed in the new port.

Other areas
10% of the area is reserved for buildings, equipment, and infrastructure. The road is designed through the industrial area of the port and enters the transshipment part at the northeast. The road is extended up to the power plant. There is also space for constructing a rail connection next to the road and there is space for an (un)loading area for the trains. This is further explained in the next section, 4.3.

4.3 Hinterland connection

The new port must be integrated with the current infrastructure of Jamaica. For the new port a good hinterland connection is necessary during the building phase and the operational phase.

The hinterland connection is needed for transporting people and goods from and to the new port. The main advantage of the location of the new port is the small distance from the port to the highway system of Jamaica. Furthermore this highway is in good condition, so can provide a fast connection to (for instance) Kingston. A road connection is needed for sure. It is not necessary to build a railway system right away. This strongly depends on the development of the total rail infrastructure and rail operations in the rest of Jamaica.

For the connection between the current network and the new port there are two options, see Figure 4-4. The first option is shorter and is lower in price, but the impact might be higher, because it is closer to settlements. The second option is more expensive due to its length, but the impact on the settlements is lower. Which of the option is favorable depends on the available budget and policy.

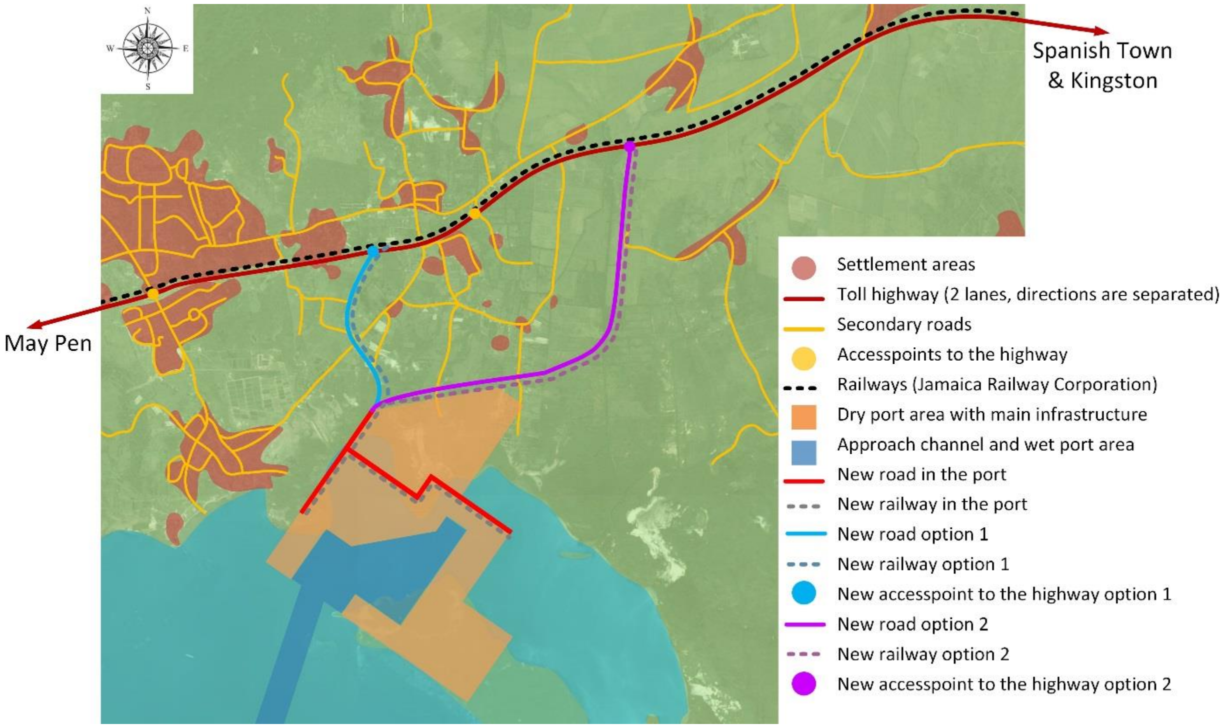


FIGURE 4-4: TWO OPTIONS FOR THE HINTERLAND CONNECTION

The hinterland connection is described in more detail in Appendix N, Hinterland connection.

4.4 Adaptive port planning

Because of uncertainties during the planning, design and operation phase it is possible that conditions change in the future. This causes the original plans to fail and this could result in a loss of cargo, loss of investment and loss of the competitive position of the port. To make plans which include this uncertainty it is possible to anticipate on the future developments and revise the master plan during the lifespan. This is called adaptive port planning. (Taneja, n.d.)

For the new port a basic plan is made. This basic plan includes facilities which will be constructed definitely. Next to that a set of pro-active actions is listed, which include the construction of facilities based on the future demand. This is shown in Figure 4-5. In appendix M, Adaptive port planning, more information can be found about the adaptive port planning.

The basic plan consists of a few facilities which will be constructed definitely, shown in Figure 4-5 with the dark red colors. It is advised that the dry area of the port (industrial and transshipment) must reclaimed in the first stage. The main infra-structure and the assembly plant has to be built completely. The assembly plant must be constructed, because cranes are needed for the transshipment area and it is assumed there is already enough external demand. Basically there are no

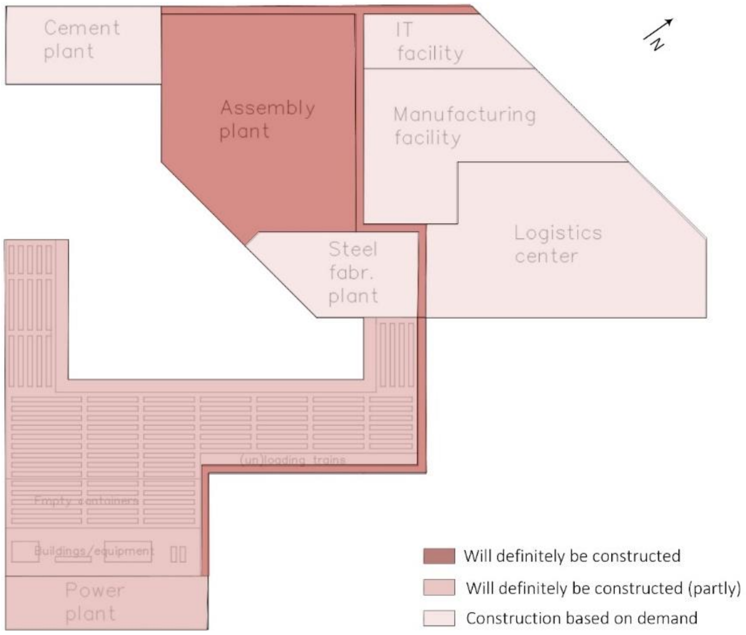


FIGURE 4-5: ADAPTIVE PORT PLANNING OF THE NEW PORT

big uncertainties for building these facilities. Also (a part of) the power plant, the assembly plant and (a part of) the transshipment area have to be constructed. A part of the power plant will be constructed definitely, because the new port definitely needs energy. A part of the transshipment area will be needed definitely, because in the beginning there will be vessels mooring at the port (if the competitive power is large enough, see appendix D, Competitiveness). A piece of the transshipment port will be built when there is enough demand, shown in Figure 4-6. One part is definitely constructed. When more surface is needed for transshipment the area could be extended more to the right in the figure and when even more surface is needed expansion is possible.

The set of pro-active actions consists of facilities which will be constructed when there is enough demand. These facilities are the cement plant, steel fabrication plant, IT facility, manufacturing facility and logistics center. These facilities are shown in Figure 4-5 with the light color.

Due to stepwise development of the port there will be an undeveloped area, which can be assigned to the facilities which have an increased demand and need more area. This can be repeated multiple times until the whole area is fully in use. By using this way of port planning the needed area per facility could be different in the future than expected. Parts of the facilities which are first built must be located at a wisely chosen location. The constructions which cannot be moved should be located at a place which do not block the adjacent parcels to expand.

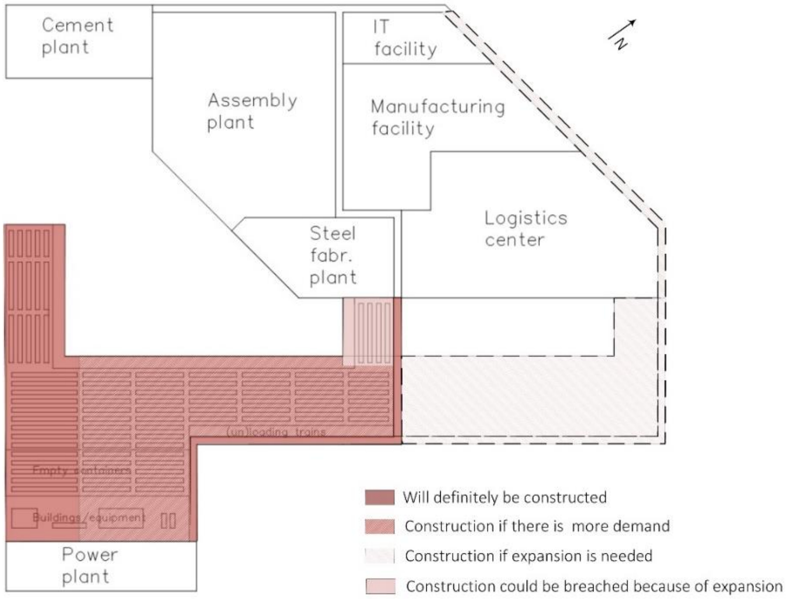


FIGURE 4-6: ADAPTIVE PORT PLANNING OF THE TRANSSHIPMENT AREA OF THE NEW PORT

4.5 Wave analysis

The extreme wave conditions for the new port are investigated to come up with the design loads. The return period is set to 1/200 years and the associated hurricane waves offshore are gathered from existing data with HURWave. The hurricanes wave are modeled near shore with MIKE 21 and the extreme waves at the port entrance are calculated, see Figure 4-7. This is described in more detail in appendix O, Wave analysis.

The extreme wave conditions with a return period of 1/200 years at the entrance of the port are:

• Surge level	2.0 meters
• Wave height	4.0 meters
• Wave period	4.5 seconds
• Wave and wind direction	From the south

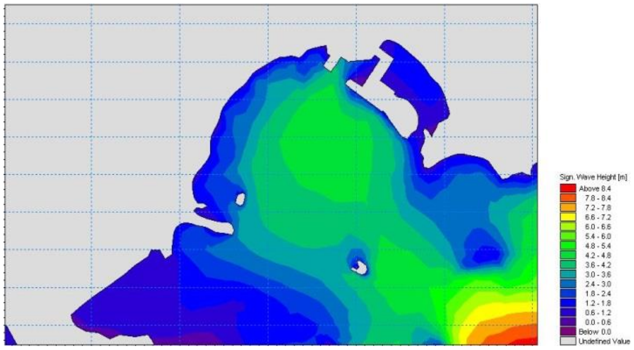


FIGURE 4-7: EXTREME WAVE HEIGHTS IN THE PORTLAND BIGHT AREA WITH A RETURN PERIOD OF 1/200 YEARS

The downtime of the port is established with existing data of node 10, see Figure 4-8. This data is based on 3 hour time series, recorded between July 1999 and November 2007. The hurricanes are filtered out of this data, because during the hurricanes the port is not operational. The hurricanes in this data are Iris (2001), Chantal (2001), Ivan (2004), Charley (2004), Emily (2005), and Dean (2007). For this data the highest values for the wind speeds and wave heights (exclusive hurricanes) is modeled near shore with MIKE 21. This modelling results in no exceedance of the maximum wave height (Hs) of 1.5 meters in the approach channel. If Hs > 1.5 meters, the tugboats cannot fasten to the containers vessels, so no approaching is possible. (Ligteringen & Velsink, 2012) Even during a tropical storm (like Claudette on July 9, 2003) the wave heights in the approach channel are lower than 1.5 meters. The Portland Bight Area (with coral and small islands) gives really sheltered area for the port and only during hurricanes there is downtime.

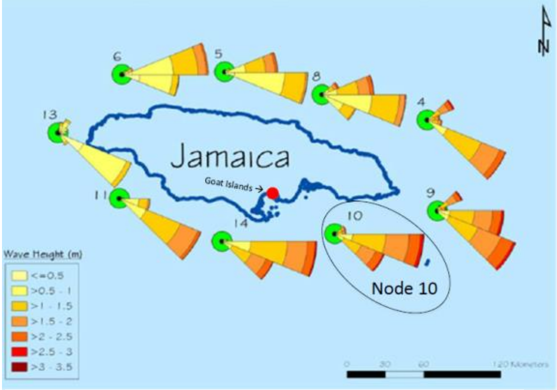


FIGURE 4-8: WAVE AND WIND DATA OFFSHORE IN NODE 10

Noticeable are the wave heights and the surge level behind the Goat Islands during hurricanes. The port blocks the water flow behind the Goat Islands which results in a big water set-up, see Figure 4-9. Because of the higher water level during hurricanes also the wave heights increase. This phenomenon has to be investigated for protection of the back of the port and for the influences on the fish sanctuary.

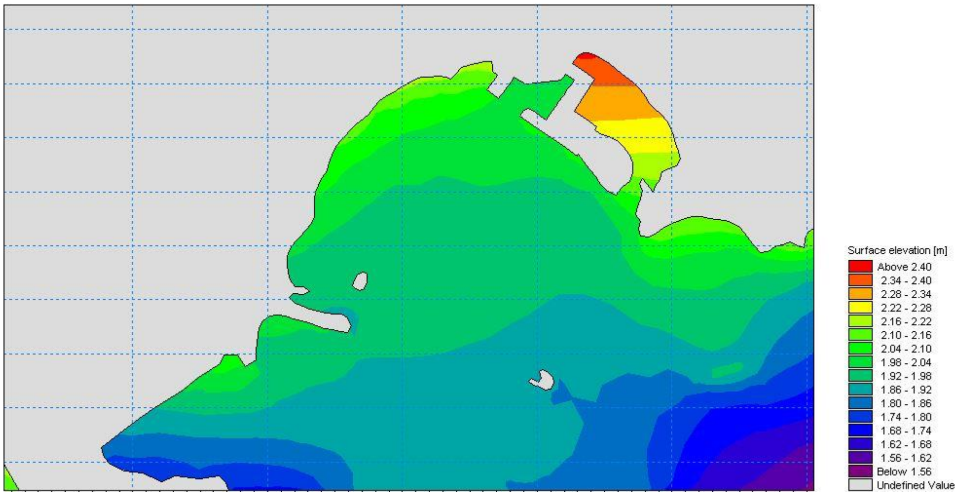


FIGURE 4-9: SURGE LEVEL IN THE PORTLAND BIGHT DURING A HURRICANE WITH A RETURN PERIOD OF 1/200 YEARS

5 Impact of the new port

The new port will have impact on certain issues. There are environmental aspects, but also economic and social impacts. These different impacts are discussed in this chapter. At the end other threats and opportunities are also described.

5.1 Economic and social impact

For the new port a private service port model with full concession is advised as described in appendix E, Port model and financing scheme. The land will still be owned by the Jamaican government, but CHEC will fulfill both the functions of port authority and port operator. The owning of the land by the Jamaican government is important, because in this way there is no risk CHEC could sell the land (this is a risk in case of a full privatization) and probably the government doesn't want to sell their land to CHEC anyway. (World Bank, n.d.)

A concession contract is often combined with a financing scheme, like a Build, Operate, and Transfer contract (BOT). With the BOT arrangement the government of Jamaica gives CHEC the responsibility for constructing, financing, operating and maintaining the port.
CHEC has the freedom to construct and operates the new port in the way they want it. CHEC is responsible for the financial risks and has to do all the investments. Therefore the investigation of the financial feasibility and the debt repayment capacity are very important. The contract with Jamaica is of great importance for CHEC, especially for the payments and the duration of the concession.
Jamaica doesn't have to invest in the new port and doesn't have to take care of the financial risks. The land of the port will be transferred to CHEC, but after the period of concession Jamaica gets the land back together with the port. At that point Jamaica can decide what to do with the port, for instance lease the port or grant a concession for a new management contract. The government of Jamaica will receive a base fixed fee and a variable fee in return for the land lease. This variable fee is based on the revenue or based on the cargo. This means that Jamaica have more benefits if the business in the port is going better. More information can be found in appendix E, Port model and financing scheme.

However, there are some indirect financial risks for the current port of Kingston. When there is a new port in Jamaica, the transshipment activities at the current port of Kingston will probably move to the new port, because of its (probably) better equipment, price or faster handling time. The port of Kingston has at this moment a high transshipment percentage of 85% of its total throughput (see appendix C, Reference ports). In case of a decrease of throughput in the current port of Kingston the surface has to be redeveloped, see appendix F, Redevelopment of the port of Kingston. There are different possibilities for the redevelopment of the port of Kingston. A few possibilities are the export of limestone, increasing the tourism in Kingston, deep sea fishing and container handling with a low value of time. There are more possibilities than the ones that are mentioned. It depends on the policy of the port authority what will happen with the current port of Kingston.

In appendix A, Background information, it is told that the construction of the new port possibly will employ 2.000 people and after construction 10.000 people will be employed. The Prime Minister of Jamaica has said that "it will be a non-negotiable requirement that the majority of these workers will be Jamaican nationals." (Jamaica Information Service, 2013a) The creation of these jobs will have a social and economic impact on Jamaica.

5.2 Environmental impact

The environmental impact can be divided in three different main impacts, as discussed in appendix P, SWOT Analysis. The first one is the destruction of Little Goat Island. This island is used for the land area of the port. The destruction of Little Goat Island can be compensated with new nature somewhere else.
Another impact involves the fish sanctuary behind Great Goat Island. The new port is designed next to this sanctuary. During the building phase the sanctuary will be harmed by for example constructing the sheet piles. There might be ways to minimize the disturbances of the sanctuary during construction, but this increases the investment. Also during operational phase the fish sanctuary will be harmed. The port blocks the north entrance of the fish sanctuary, so there is only a south entrance. This is a change of the current situation and maybe influences the habitat of the juvenile fish. Next to this the water level set up and the waves will be higher than nowadays, especially during hurricanes, this is shown in appendix O, Wave analysis. Maybe it is possible to relocate this sanctuary, but this is a difficult and expensive operation. If this can be done, the issue of the fish sanctuary becomes smaller.
The last impact is the environmental impact for the bay. The currents and waves will change in the rest of the bay, because of the port and the approach channel. The waves will propagate different due to the port and its approach channel. This impact should be further investigated, before measures can be stated. Also the landside

of the bay will change, especially the area where the port will be built. This impact should be investigated in more detail, before measures can be presented.
To get a good overview of the environmental impact an environmental impact assessment has to be performed.

5.3 Opportunities and threats

Besides the above mentioned positive and negative impacts of the new port, there are other opportunities and threats. These are mentioned in appendix P, SWOT Analysis.

Next to the economic boost there is another opportunity when the port is built. This is receiving a higher throughput than expected. A growth in throughput will be a direct opportunity for CHEC to make more profit. In case of a variable tariff (based on the throughput) in the land lease contract, a higher throughput will also be beneficial for Jamaica.
Causes for this opportunity can be being a good competitor or growth of the container flow through the Caribbean. The throughput can grow due to competitiveness by being better on (a) certain aspect(s) than the competitors. This can be achieved with a good strategy.
If the overall container flow in the Caribbean grows, the throughput of the port might also grow. The flow can grow due to an increase in economies such as Brazil or due to an increase in import of the US or due to an increase of trade in the Caribbean. Another reason for a growing container flow might be the construction of the Nicaragua Canal, see appendix A, Background Information. These factors cannot be influenced by measures. More about the competitiveness, container flow and the trade routes is described in appendix D, Competitiveness.

Where an increase of the throughput is an opportunity, a decline of the throughput is a threat. A decrease of the throughput leads to a decrease of the income. Also a lower throughput than expected is seen as decrease.
This threat can happen due to competitiveness or a decreasing container flow overall. If the competitors perform better on one or more aspects shipping companies might choose another port for their transshipment purposes. How competitors act is uncertain and might lead to lower income for the port. It is possible to react on the competitiveness to avoid a decreasing throughput. This can be done by a constant investigation in the strategies of the competitors.
A decreasing flow of containers through the Caribbean can also lead to a decline in throughput. This might happen if the economy of the USA decreases or if important trade routes shift. These factors cannot be influenced by Jamaica or CHEC with measures. The strategy that can be chosen to cope with uncertainties in the flow of containers through the Caribbean is adaptive port planning, as described in section 4.4 and appendix M, Adaptive port planning.

6 Conclusions

To answer the main question, stated in section 1.2, Aim of the project, the conclusion can be split up in three different parts. The conclusion is divided into the best location, the best design and the best way for developing the new port in Jamaica.

The following conclusions are made about the best location:

- There are four very good locations for the development of the new port in Jamaica. The following port locations all have high potential; the Goat Islands, Jackson Bay, Maccary Bay, and Little Bay. The best location is not found. This is because all the locations are well-matched for the designed level of detail.

- The location of the Goat Islands is selected for detailed design, because the Goat Islands are subject to much discussion in the media in Jamaica and CHEC aims for the Goat Islands.

The following conclusions are made about the best design:

- The total surface of the port of 12 km^2 is divided into different sections. For transshipment purposes a total surface of 4 km^2 is needed, of which 3 km^2 is needed for the dry area. To increase the value of the new port the other 8km^2 is designed for industrial activities.

- Using the queuing theory a needed quay length of 3 kilometer is determined. This gives berthing space to handle seven Post Panamax ships and one Panamax ship simultaneously. Therefore 39 super Post Panamax cranes are needed for (un)loading. The distribution to the storage area is done with a multi trailer system, which requires between 300 and 350 tractors.

- A maximum expected throughput of 7 million TEU per year can be reached with a dry surface of the transshipment area of 3km^2, more than 100 rail mounted gantry cranes for stacking, sufficient equipment (as described in the previous bullet point), and an expected dwell time of 7.5 days.

- Industrial activities at the port are the assembling of gantry cranes for the Americas and creating cement and steel for export purposes. These activities need quay length which is included in the design of the total layout. Also space is reserved for a manufacturing facility, a logistics center, and a major IT facility. To provide the new port with energy a LNG power plant will be constructed. A pipeline and a jetty are needed so the LNG ships can moor outside the port.

- Two options are designed for the hinterland connection between the new port and the current network, which include a road and a possible railway connection. Due to uncertainties a good advice is not made.

- Only during hurricanes there is downtime.

- The extreme wave heights at the port and behind the port are determined with a return period of 1/200 years. A surge level of 2 meters and a significant wave height of 4 meters are found at the entrance of the port.

- The construction of the designed port at the Goat Islands will have a big impact on the environment. Little Goat Island will be destroyed and the construction and operation of the port will probably harm the fish sanctuary. The port blocks the north entrance of the fish sanctuary and creates high water level setup during hurricanes.

The following conclusions are made about the best way to develop:

- The whole transshipment area must not be built all at once, but adaptive port planning is advised. The transshipment area should be built in stages to deal with uncertainties.

- For the industrial part adaptive port planning should also be used. The power plant has to be built definitely, but not directly for the full capacity. The assembly plant can directly be built for the full capacity because of the needed cranes for own purposes. The other facilities of the industrial port have to be built if there is enough demand.

- For the new port a private service port model with full concession is advised. The combination with a Build, Operate, and Transfer (BOT) contract is most suitable. With the BOT arrangement the government of Jamaica gives CHEC the responsibility for constructing, financing, operating and maintaining the port. CHEC leases the land and returns it to the government when the concession period ends.

- The new port has good opportunities for transshipping containers transiting the Panama Canal with the south of North America and the middle of North America as destination. However the shipping companies are not dependent on the port in Jamaica, because the port does not have a large hinterland and will be used for transshipment primary. This makes the port very sensible for sudden changes and its competitive power.

- Due to the new port of Jamaica the container throughput to the port of Kingston might drop. There are possibilities for redevelopment of the current port to cope with this possible loss.

7 Recommendations

After eight weeks of research still questions are left unanswered and some aspects are not completely investigated. The following recommendations are made:

- The four best possible locations are well-matched for the designed level of detail. Therefore all four alternatives should be investigated into further detail. As already described in section 3.3 extra technical studies need to be done. Also an in-depth social impact assessment and an environmental impact assessment should be executed. Only if these further analyses are done a well-informed decision can be made about the best location.

- The maximum expected throughput calculated in the first phases of the project depends on several assumptions. This throughput is an important factor for all the calculations and designs later in the report. The throughput should be estimated with more certainty so the subsequent values will also increase in accuracy.

- The sensitivity analysis shows that a quay wall of 3 or 6 kilometer differs a lot in the costs of the port. Before a final port design can be made a deeper analysis on expected throughput, dwell time, number of berths and quay length should be carried out.

- For now, the design of the industrial area is based only on three news articles. To concretize these made assumptions CHEC should be consulted for their goals with the industrial area.

- The wave analysis in this report is far from complete. Only wave heights, water level set-up, wave and wind directions, and wave periods are investigated. However, some other impacts should also be investigated like the influence of the black river behind the port. Also some investigation should be done about the currents and sedimentation in approach channel. The sedimentation and the resonance waves in the port should be included in a detailed wave analysis. Also the found results should be validated by downing calibration to model. Risks and investments should be established with higher accuracy so the optimal investment solution can be found.

- As the port is very sensible to changes in the market, the market should be analyzed intensively and continuously. Although some flexibility in the port is accounted for in the design (adaptive port planning) container forecasts are roughly estimated.

- The economic aspects of the port are analyzed only on a minimal level of detail. This aspect should be investigated in much more detail.

- The effects of the new port on the current port of Kingston are unknown and are not investigated in this project. These effects should be found as soon as possible, because redevelopment of the current port is possibly needed.

References

CSS Group. (2013, 09). *Making Of Container Terminal 2 At Jebel Ali Port*. Retrieved 10 16, 2013, from Lighthouse: http://www.cssgroupsite.com/lighthouse/making-of-container-terminal-2-at-jebel-ali-port/

DP World. (n.d.). *Jebel Ali Port – Dubai's gateway to the world.* Retrieved 10 25, 2013, from Port technology: http://www.porttechnology.org/images/uploads/technical_papers/PT41-14.pdf

DP World. (n.d.). *Facilities and service*. Retrieved 10 25, 2013, from DP World: http://www.dpworld.ae/en/content.aspx?P=fxP7qHof%2FgsE0giJLkwR2A%3D%3D&mid=CW8SJWcj%2BhX1sqCpgEZqDA%3D%3D

Espeut, P. (2013, 08 23). *Selling Our Birthright*. Retrieved 09 10, 2013, from Jamaica Gleaner: http://jamaica-gleaner.com/gleaner/20130823/cleisure/cleisure3.html

Jamaica Gleaner. (2013a, 08 22). *Hub Sights New Home: Gov't Puts China's Preferred Logistic Site At Top Of List*. Retrieved 09 13, 2013, from Jamaica Gleaner: http://jamaica-gleaner.com/gleaner/20130822/lead/lead1.html

Jamaica Gleaner. (2013b, 08 23). *JET Butts Hub Plan: Environment Lobby Says Goat Islands Development Would Betray Pact With Gov't*. Retrieved 09 10, 2013, from Jamaica Gleaner: http://jamaica-gleaner.com/gleaner/20130823/lead/lead1.html

Jamaica Information Service. (2010, 08 23). *Mike Henry breaks ground for Palisadoes coastline rehab*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/114-transport-works/25078-trans_works-mike-henry-breaks-ground-for-palisadoes-coastline-rehab

Jamaica Information Service. (2013a, 05 01). *CHEC to invest US$1.5 billion in transshipment port*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/122-parliament/33743-chec-to-invest-us15-billion-in-transshipment-port

Jamaica Information Service. (2013b, 05 08). *Local contractors to benefit from MIDP*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/list/33800

Jamaica Information Service. (2013c, 09 11). *Prime Minister's Statement on the official trip to China*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/list/34998

Jamaica Observer. (2013, 08 22). *Gov't admits Goat Islands under 'serious consideration' for trans-shipment hub*. (J. Richardson, Editor) Retrieved 09 10, 2013, from Jamaica Observer: http://www.jamaicaobserver.com/news/Gov-t-admits-Goat-Islands-under--serious-consideration--for-trans-shipment-hub_14922802

Ligteringen, H., & Velsink, H. (2012). *Ports and Terminals.* Delft: VSSD.

Panama Canal Autorithy. (2006). *Proposal for the Expansion of the Panama Canal.*

Taneja, P. (n.d.). Flexible ports/terminals. *Lecture slides CIE5306 Ports & Waterways 2*. TU Delft.

The National. (2013, 06 27). *DP World's Terminal 2 expansion finished at Jebel Ali*. Retrieved 10 16, 2013, from The national: http://www.thenational.ae/business/industry-insights/shipping/dp-worlds-terminal-2-expansion-finished-at-jebel-ali

World Bank. (n.d.). *World Bank port reform tool kit; Module 3: Alternative port management structures and ownership models.* Retrieved 10 04, 2013, from http://rru.worldbank.org/Documents/Toolkits/ports_fulltoolkit.pdf

Appendix A Background information

To provide more information concerning the project background information is gathered. This is done using different news articles and reports. The first chapter of this appendix is about the contact between China and Jamaica, with at the end a summary about the details from the media about the new port. After that a chapter about the Panama Canal is included, which also looks at the expansion of the Panama Canal. At the end there is a chapter concerning a possible canal through Nicaragua.

1 Contact China and Jamaica

For a good overview and understanding the aim of the transshipment hub project this chapter will present the contact between China and Jamaica about previous projects. First the different Chinese players will be given, followed by an overview of recent building projects in Jamaica in which the Chinese were involved. The news items per date will form the next section. At the end of this chapter a summary with regard to the transshipment port project will be given. This background information will also be used for the stakeholder analysis.

1.1 Different Chinese players

Several parties from China are involved in the different projects in Jamaica. For a good overview the different Chinese players are given below, with a short description.

China Harbour Engineering Company Ltd.
This engineering company is an international contractor and a subsidiary of China Communications Construction Company Ltd. China Harbour Engineering Company Ltd. (CHEC) is a specialist "in basic infrastructure construction, such as Marine Engineering, Dredging and Reclamation, Road and Bridge, Railways, Airports, Complete Plant, and other works". CHEC works with different service contracts, such as Design & Build and Build, Operate & Transfer.
(China Harbour Engineering Company Ltd., 2009)

China Communications Construction Company Ltd.
This company offers a lot of different construction works; "port, terminal, road, bridge, railway, tunnel, civil work design and construction, capital dredging and reclamation dredging, container crane, heavy marine machinery, large steel structure and road machinery manufacturing, and international project contracting, import and export trading services". China Communications Construction Company Ltd. (CCCC) is the second largest dredging company (in terms of capacity) of the world.
(China Communications Construction Company Ltd., 2008)

Government of China
The government of China helps to mediate the contact between the CHEC (and CCCC) and the government of Jamaica.

Chinese banks
There are two banks involved in the project in Jamaica. These are the Export-Import Bank of China (Eximbank) and China Development Bank.

1.2 Different projects

This section contains an overview of the different projects and contracts between China and Jamaica. Per project the start, duration, the contract sum and the financial agreement are given.

TABLE A-1: OVERVIEW OF PROJECTS IN JAMAICA WHERE CHINA IS INVOLVED

Project name	**Start**	**Duration**	**Contract sum**	**Paid by whom and kind of agreement**	**Reference**
Jamaica Airport Road project	Feb. 2010	Unknown	US$400 million	Loan from CHEC	(China Harbour Engineering Company Ltd., 2010)
North-South link of Highway 2000	Jan. 2013	36 months	US$601 million	US$457 million loan of China Development Bank and US$144 million equity investment CHEC and right to operate toll for 50 years	(Jamaica Information Service, 2013a) (Ministry of Transport, Works & Housing, 2013) (China Harbour Engineering Company Ltd., 2012)
Mount Rosser bypass Linstead – Moneague	Jan. 2013	14 months	US$120 million	Investment of CHEC and right to operate toll for 50 years	(Ministry of Transport, Works & Housing, 2013)
Jamaica Major Infrastructure Development (formerly Jamaica Development Infrastructure Programme)	Oct. 2010	5 years	US$350 million	US$300 million loan from China Eximbank and US$50 million Government of Jamaica	(Jamaica Information Service, 2013a)

1.3 News per date

In this section the contact between China and Jamaica is put in chronological order. This information comes from Jamaican newspapers, the information website of the Government of Jamaica and press releases from China Harbour Engineering Company.

February 2nd, 2010

The Minister of Transport of Jamaica signed an agreement with China Harbour Engineering Company (CHEC) on technology exchange cooperation, initial cooperation about expressways of Jamaica and financing cooperation. Since May 2009 China and Jamaica had a contract for the Jamaica Airport Road project and a US$400 million-loan agreement on Jamaica Development Infrastructure Programme (JDIP). These contracts will produce significant social and economic benefits in Jamaica.

(China Harbour Engineering Company Ltd., 2010)

April 20th, 2010

With the islands wide road repair project, JDIP, 6,700 new jobs are expected for Jamaicans. CHEC will carry out the road and infrastructure works. The loan is lent by the Export-Import Bank of China (Eximbank) with an interest rate of three per cent.

(Jamaica Information Service, 2010a)

August 23rd, 2010
Palisadoes Shoreline Rehabilitation and Protection Project is undertaken by CHEC and is scheduled for completion within 18 months. This project is part of the Jamaica Development Infrastructure Programme. The aim of the project is rehabilitating the Palisadoes coastline and improving the roadway which connects Port Royal to Kingston. The China Eximbank gives Jamaica a US$65 million loan for this project. Recreational and other facilities will be developed along the roadway, besides that the project will prevent erosion of the shoreline.
(Jamaica Information Service, 2010b) (Caribbean Trakker, 2011)

September 24th, 2010
The Chinese Ambassador has assured that his Government has no hidden agenda in partnering with the Government of Jamaica on JDIP. The Ambassador noted that CHEC "has maintained a keen sense of social responsibility alongside business expansion in terms of creating the greatest value for its clients, establishing win-win cooperation, carrying out technology transfer and fulfilling both commercial and social responsibilities". The Chinese engineers will give the local engineers knowledge and expertise on design and construction of roads.
(Jamaica Information Service, 2010c)

Minister Daryl Vaz, responsible for Information, Telecommunication and Special Projects, said: "We want to thank the Government of China for supporting the Jamaica Development Infrastructure Programme (JDIP) and note that China's interest in our country's development is not limited to mere brick and water but has spanned support through scholarships, technical assistance programmes, investments in the agriculture sector and even in my own portfolio, the provision of technological networking solutions to the telecoms industry".
(Jamaica Information Service, 2010d)

January 10th, 2011
The government wants to upgrade the economic activity in the Caymanas, called the Caymanas Economic Zone project. This project involves 1,000 acres. In this project this area will transform in factories and warehouses for the ICT industry, the services industry, manufacturing and agro-processing. The Minister of Industry, Investment and Commerce of Jamaica announced that it has discussions at the highest level with CHEC.
(Jamaica Information Service, 2011a)

April 28th, 2011
JDIP will start in 2010, with CHEC as the contractor. The local companies will be subcontractors in the majority of the labor. The National Works Agency is implementing the JDIP and expects close to 7,000 jobs will be created for Jamaicans.
(Jamaica Information Service, 2011b)

February 27th, 2012
The Westmoreland Bridge Project is opened. This is one of the key projects for repair and reconstruction of the national road network of Jamaica undertaken by CHEC. This project will make travelling easier and will encourage the economic development of Saint Mary Parish.
(China Harbour Engineering Company Ltd., 2012)

December 5th and 6th 2012
CHEC announced that it will spend US$610 million on the North-South Link of Highway 2000 between Caymanas (St. Catherine) and Ocho Rios (St. Ann). Besides this capital injection CHEC will reimburse US$120 million for the Mount Rosser Bypass.
(Jamaica Gleaner, 2012) (Jamaica Information Service, 2012)

April 9th, 2013
The four-year project, being jointly funded by the Government and China Eximbank, is scheduled for completion in March 2016. Formerly this project was known by JDIP, now it is called Major Infrastructure Development Programme (MIDP).
(Jamaica Information Service, 2013b)

May 1st, 2013
CHEC and China Construction and Communications Company (CCCC) announced a direct investment in the development of a transshipment port in Jamaica of US$1.2 billion to US$1.5 billion. The port area "will consist of transshipment facilities, a logistic center, industrial plants, a cement plant and perhaps a power plant" according to the Prime Minister in the House of Representatives on April 30. This development will result in employment for 2,000 construction workers and over 10,000 permanent jobs. "It will be a non-negotiable requirement that the majority of these workers will be Jamaican nationals," the Prime Minister told the House.
To allow all the relevant studies for this development, including the environmental assessments, the extension of the Memorandum of Understanding (MOU) will run for another year. This MOU was signed in half 2012 by the Port Authority of Jamaica and CHEC to explore the feasibility of establishing a new transshipment port at Fort Augusta. Since the signing of the MOU CHEC indicated that Fort Augusta is not big enough.
(Jamaica Information Service, 2013c)

May 8th, 2013
There are rumors about a potential contract with CHEC. This agreement is scheduled to end in 2016 and will cover the rehabilitation of 430 kilometers of prioritized roads, upgrading or reconstruction of 27 critical bridges, retaining walls and other protective works, and complete subprojects started under the JDIP. The Minister of Transport, Works and Housing announced that a total value of US$130 million is reserved for allocated projects for local contractors. The remaining US$220 million of this contract is for major projects, with the responsibility of CHEC. CHEC will utilize Jamaica sub-contractors for these projects. The total amount of the US$350 million contract will be a loan of US$300 million of the China Ex-Im Bank and a contribution of approximately US$50 million from the Government of Jamaica.
(Jamaica Information Service, 2013d)

Besides this agreement an article is found about another contract with CHEC. CHEC wants to invest US$1.5 billion in a major transshipment and logistics center in Jamaica. The project description is extent to the establishment of a transshipment port, the construction of various manufacturing facilities, the development of a major IT facility, the development of a cement plant and the possible development of a power plant to provide electricity to the industrial complex. The project will be a direct investment of CHEC and China Construction and Communication Company (CCCC). The new site must be in excess of 6,000 acres (24 km^2). The Minister of Transport, Works and Housing says that the government will ensure that all the required environmental impact assessments are carried out.
(Jamaica Information Service, 2013e)

August 22nd, 2013
The Jamaican minister with responsibility for land and environment told CCCC that the Goat Islands will be considered to be the location for the new port area. The minister said that the new port area will require 3,000 acres (12 km^2) and an appropriate location.
(Jamaica Gleaner, 2013)

August 23rd, 2013

The Premier of China's State Council and the Jamaica's Prime Minister singed on 21st August a contract about Jamaica's MIDP and a loan agreement of US$3.5 billion. This project will mainly consist of upgrading and replacement of the road network and infrastructure of Jamaica. The news article stated about CHEC "is currently focused on business development in Jamaica as well as the successful implementation of the MIDP project. This will further enhance the future of the company's (red. CHEC's) market position and influence within Jamaica and even within the entire region, thus providing strong support for the company (red. CHEC) to further open up to the Latin American Marker".

(China Harbour Engineering Company Ltd., 2013)

September 10th, 2013

In the Statement by Minister of Transport, Works and Housing on Goat Islands is written that the Cabinet approved on April 21 2013 an Addendum of one year on the existing MOU between the Port Authority and CHEC to allow CHEC to undertake the necessary feasibility studies. These studies will include technical, financial and environment factors. By the end of April 2014 "a decision will be made as to whether to proceed to a conclusive agreement, providing that all social, developmental and environment issues have been addressed and the requisite regulatory permits are in place". During the assessments the Port Authority will remain a constant dialogue with CHEC. In this contact CHEC announced that there first choice for the location of the port area is Goat Islands. This port area will connect to the north to the mainland of Jamaica.

The Minister of Transport, Works and Housing states the objectives of the feasibility study, these are:

- "Determining the geographic boundaries of the Portland Bight Protected Area
- Conducting archival research on the historical use of the area.
- Identifying applicable international and national environmental policies, legislation, regulations and standards for the area.
- Identifying the biologically sensitive features of the marine and terrestrial environment.
- Determining the location of rare, threatened and endangered species and their spatial distribution in the Portland Bight and Ridge Area and the Goat Islands.
- Identifying the boundaries of fish sanctuaries."

(Government of Jamaica, 2013)

September 11th, 2013

In the Statement of the Prime Minister on the official trip to China various aspects around the transshipment port are mentioned. Together with the Chairman and President of the CCCC a discussion was held about the port area with the related and supporting infrastructure, an assembly plant and a steel fabrication plant. The president of China Development Bank (CDB) announced the importance of Jamaica as a trading partner. The government of China offered 40 scholarships to Jamaican health students in each of the next three years. Jamaica offers 10 scholarships to Chinese athletes. At the end of the Statement of the Prime Minister the next sentence about the projects between Jamaica and China: "In relation to all of the identified projects, stakeholder consultation will begin shortly to ensure that there is full understanding of the scale, scope, benefits and implications of what is contemplated, and that the interests of the people of Jamaica are protected at all stages of project and programme development."

(Jamaica Information Service, 2013a)

September 12th, 2013

The Minister of Transport, Works and Housing has instructed the Port Authority to continue its assessment and monitoring of Goat Islands and the greater Portland Bight protected area.

(Jamaica Information Service, 2013f)

1.4 Summary about the new port area

CHEC wants to build a new port area in Jamaica. Together with CCCC they will invest US$1.2 to US$1.5 billion. Their first choice location is Goat Island. The port area should be about 3,000 acres (12 km^2). The project consists not only of developing and building a transshipment port but also the related and supporting infrastructure, assembly plant and steel fabrication plant (Jamaica Information Service, 2013a). In return for this port Jamaica will expect about 10,000 jobs after the port is build and 2,000 jobs during building. Those new jobs will give the Jamaican economy a (necessary) boost.

2 Panama Canal expansion project

The Panama Canal is a canal (for ships) with a length of approximately 80 kilometers, which connects the Atlantic Ocean (via the Caribbean Sea) to the Pacific Ocean. At each end there are locks to lift the ships up to the level of the Gatun Lake. The Panama Canal serves more than 144 maritime routes connecting 160 countries and reaching 1,700 ports in the world. (Panama Canal Authority, 2013) An overview of the location of the Panama Canal is shown in Figure A-1.

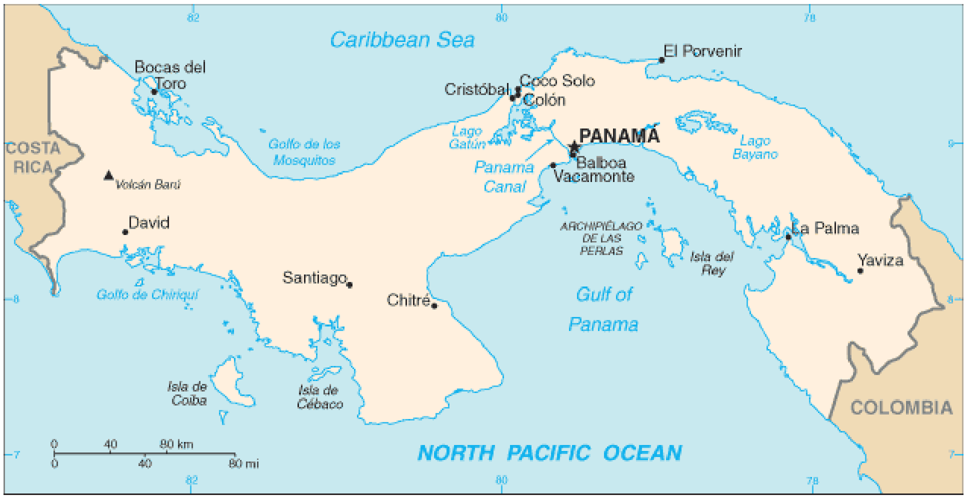


Figure A-1: The location of the Panama Canal (Central Intelligence Agency, n.d.)

There are some competitive trading routes with the Panama Canal trading route. These will be discussed. The Panama Canal will be expanded, because then it could handle larger ships and the capacity of the canal will be enlarged. The expansion project will be explained and afterwards the expected throughput is given.

2.1 Competitiveness

There are other routes that compete with the Panama Canal route for the transportation of cargo. The two main competition routes are the U.S. intermodal system route and the Suez Canal route, shown in Figure A-2.

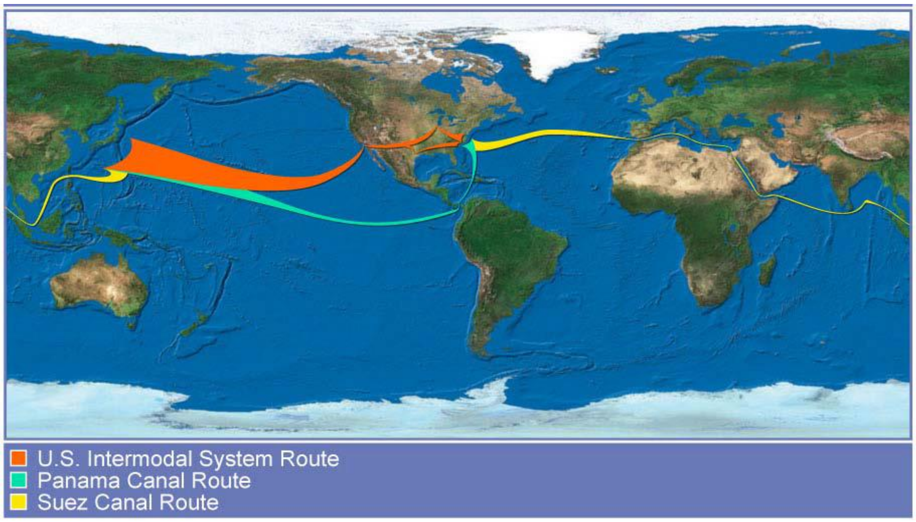


Figure A-2: Main competitors of the Panama Canal route (Panama Canal Autorithy, 2006)

2.2 U.S. intermodal system route

The U.S. intermodal system route runs partially on land from the West Coast to the East Coast of the United States and is a competitor for the transportation between Northeast Asia and the East Coast of the United States. In 2005, 38% used the Panama Canal route, 61% used the U.S. intermodal system route and 1% the Suez Canal route. The advantage at this moment of the intermodal route is that it can handle the Post-Panamax ships and it has a shorter navigation time (18.3 days compared to 21.6 days of the Panama Canal). The advantages of the Panama Canal are the less costly and more reliable transportation of cargo. Because of the growth of the trade between the U.S. and Asia, the routes on land are becoming more congested, which affects the reliability. Also the higher pollution, which could cause higher taxes can have an influence of the price of the intermodal route. (Panama Canal Autorithy, 2006)

2.3 Suez Canal route

The Suez Canal route could compete with the Panama Canal for the transportation between Northeast Asia and the East Coast of the U.S. The Suez Canal route has longer sailing times than the Panama Canal route. When the intermodal system route is influenced by more congestion and higher costs and the Panama Canal has got a too low capacity the Suez Canal route becomes an attractive alternative. The advantage of the Suez Canal is the possibility to handle Post-Panamax vessels. The Suez Canal route will only be an attractive alternative if the capacity of the Panama Canal is too low. With an expansion of the Canal the advantages of the Panama Canal route compared to the Suez Canal route will stay larger. (Panama Canal Autorithy, 2006)

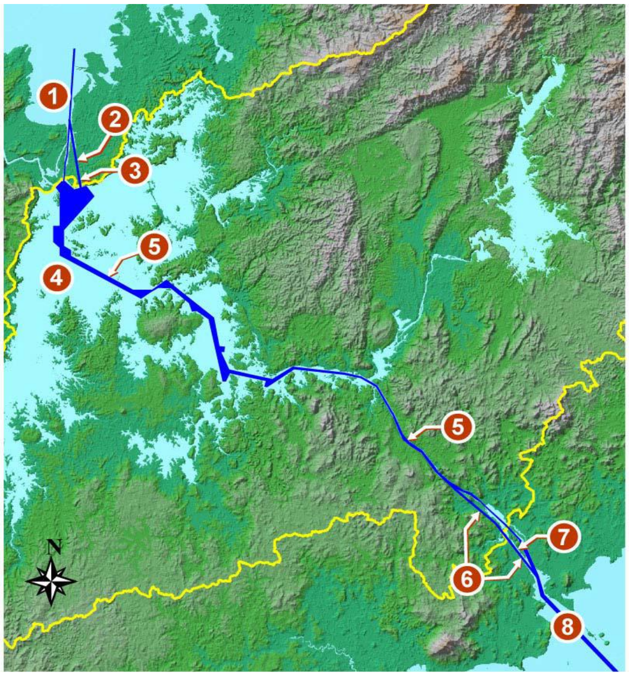
2.4 Expansion project

Since 2007 the expansion of the Panama Canal is started and is expected to be completed in 2015. This project consists of multiple components:

- "construction of a lock facility at the Atlantic side and a lock facility at the Pacific side
- excavation of the new access channels to the new locks and the widening of existing navigation channels
- deepening of the navigation channels and the elevation of Gatun's Lake's maximum operating level"

(Panama Canal Autorithy, 2006)

An overview of the project is shown in Figure A-3.



1) Deepening and widening of the Atlantic entrance channel
2) New approach channel for the Atlantic Post-Panamax locks
3) Atlantic Post-Panamax locks with 3 water saving basins per lock chamber
4) Raise the maximum Gatun lake operating water level
5) Widening and deepening of the navigation channel of the Gatun lake and the Culebra Cut
6) New approach channel for the Pacific Post-Panamax locks
7) Pacific Post-Panamax locks with 3 water saving basins per lock chamber
8) Deepening and widening of the Pacific entrance channel

FIGURE A-3: COMPONENTS OF THE THIRD SET OF LOCKS PROJECT (PANAMA CANAL AUTORITHY, 2006)

At this moment the largest vessel which can use the Panama Canal is the Panamax vessel. With the expansion of the Panama Canal it is possible to permit Post-Panamax vessels through the Panama Canal. Panamax vessels have a draft of 12 meters and can handle 5,000 TEU. Post-Panamax vessels have a draft of 15.2 meter and can handle 12,000 TEU. (Panama Canal Autorithy, 2006)

2.5 Expected throughput Panama Canal

The expected flow of the containers through the Panama Canal can be calculated, using the expectations of the Panama Canal Authority. They expect an annual growth between 2005 and 2025 of containerized cargo of 5.6%. (Panama Canal Autorithy, 2006) Since half 2005 the Panama Canal Authority uses a new billing structure, which includes TEU. In the annual report of 2005 is only the transported amount of TEU given for May 2005 till September 2005. (Canal de Panamá, 2006) This is not a complete year, so the throughput of 2006 will be used to calculate the expected container flow through the Panama Canal. The flow of containers of 2006 through the Panama Canal was 11.4 million TEU. (Canal de Panamá, 2007) The expected container flow through the Panama Canal in 2025 will be (11.4 million * 1,056^19 =) 32.1 million TEU.

Because the larger Post-Panamax vessels could use the Canal after expansion the containerized cargo segment will be one of the most important growth factors. Higher cargo volumes will be moved with less transits and less water utilization. The containerized cargo between Northeast Asia and the East Coast of the United States is the most important route. This route is also expected to be the key growth driver of the Canal. (Panama Canal Autorithy, 2006)

3 Nicaragua Canal

For more than 150 years there is an idea to build a canal through Nicaragua, but eventually in June 2013 Nicaragua gave a Chinese company a 100-year concession to build and operate a canal between the Pacific and the Caribbean, the Nicaragua Canal. The geographical position of this canal is shown in Figure A-4.

FIGURE A-4: THE GEOGRAPHICAL POSITION OF THE NICARAGUA CANAL (TORONTO STAR NEWSPAPER, 2013)

This $40 billion project will be a rival to the Panama Canal and will be 22 meters deep and 286 kilometers long. These dimensions will allow mega-container ships, which are double the size of the containers that can pass the Panama Canal after expansion. The government expects the construction would take ten years and the first ships will pass after six years. The company that has the concession is HK Nicaragua Canal Development Investment. (HKND Group). (The Guardian, 2013) (The Wall Street Journal, 2013)

3.1 HKND Group

HKND Group sees opportunities in investing in the Nicaragua Canal because of three fundamental trends:

1. “Global maritime trade is expected to continue to grow, especially between Asia and the Americas
2. Drive for efficiencies will continue to spur investment in ever larger containerships that exceed the dimensions of the expanded Panama Canal.
3. The Americas are expected to remain a vital supplier of commodities, particularly energy, to meet Asia’s growing demand.”

Because of the growing trade between Asia and the Americas and the larger becoming containerships the construction of a second canal would be meaningful. The trends in the larger becoming containerships alone would already give the construction of the Nicaragua Canal potential market. (HKND Group, 2013)

3.2 Uncertainty of the project

The route of the Nicaragua Canal will cross the freshwater expanse of Lake Nicaragua. This lake is already heavily polluted with sewage and could be damaged even more because of the project. There are also doubts on Mr. Wang, president of HKND Group, since he hasn’t done any huge infrastructure projects before and this canal project contains much challenges. There are more doubts about the project, such as the way the concession was approved in the Congress. It violates up to 41 articles of the Nicaraguan Constitution. Also a transportation expert, Jean Paul Rodrigue, thinks the project is economically irresponsible and that there is no demand for it. (The Telegraph, 2013) (IBTimes, 2013)

4 References

Canal de Panamá. (2006). *Annual report 2005.* Retrieved 10 01, 2013, from http://www.pancanal.com/common/general/reports/informe-anual-2005.pdf

Canal de Panamá. (2007). *Annual report 2006.* Retrieved 10 01, 2013, from http://www.pancanal.com/eng/general/reporte-anual/annual-report-2006.pdf

Caribbean Trakker. (2011, 09 19). *Palisadoes Shoreline Protection and Rehabilitation Works*. Retrieved 09 19, 2013, from Caribbean Trakker: http://www.caribbeantrakker.com/2011/09/palisadoes-shoreline-protection-and-rehabilitation-works/#.UjsyuNLmOqo

Central Intelligence Agency. (n.d.). *The World Factbook*. Retrieved 10 11, 2013, from Central Intelligence Agency: https://www.cia.gov/library/publications/the-world-factbook/geos/pm.html

China Communications Construction Company Ltd. (2008). *About Company - Introduction*. Retrieved 09 17, 2013, from China Communications Construction Company Ltd.: http://en.ccccltd.cn/aboutcompany/introduction/

China Harbour Engineering Company Ltd. (2009). *About CHEC - Corporate Overview*. Retrieved 09 17, 2013, from China Harbour Engineering Company Ltd.: http://www.chec.bj.cn/tabid/67/Default.aspx

China Harbour Engineering Company Ltd. (2010, 02 23). *CHEC President met with the Minister of Transportation of Jamaica*. Retrieved 09 13, 2013, from China Harbour Engineering Company Ltd.: http://www.chec.bj.cn/zg/tabid/81/InfoID/2716/Default.aspx

China Harbour Engineering Company Ltd. (2012). *Highway 2000 North-South Link*. Retrieved 09 19, 2013, from Latin America & The Caribbean: http://www.checlatin.com/index.php/layout/project_details/highway_2000_north_south_link/jamaica%7C

China Harbour Engineering Company Ltd. (2012, 03 05). *Official start of main project for repair and reconstruction of national road network of Jamaica*. Retrieved 09 13, 2013, from China Harbour Engineering Company Ltd.: http://www.chec.bj.cn/zg/tabid/81/InfoID/3215/Default.aspx

China Harbour Engineering Company Ltd. (2013, 08 23). *Jamaica MIDP Project loan agreement signed*. Retrieved 09 13, 2013, from China Harbour Engineering Company Ltd.: http://www.chec.bj.cn/zg/tabid/81/InfoID/4401/Default.aspx

Government of Jamaica. (2013, 09 10). *Statement to Parliament: The proposed Chinese investment in the Portland Bight protected area.* (M. Dr. the Hon. Omar Davies, Ed.) Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/docs/Statement%20GOAT%20ISLAND%20BY%20HM%20DAVIES.pdf

HKND Group. (2013). Retrieved 09 16, 2013, from http://hknd-group.com/trends-in-global-shipping-trade-demand-a-new-canal/

IBTimes. (2013, 08 14). Retrieved 09 16, 2013, from http://www.ibtimes.com/nicaraguas-canal-project-might-be-unconstitutional-president-daniel-ortegas-dream-nonviable-1383907

Jamaica Gleaner. (2012, 12 05). *China Harbour to Spend US$610m for North-South Highway.* (L. Barrett, Editor) Retrieved 09 13, 2013, from Jamaica Gleaner: http://jamaica-gleaner.com/latest/article.php?id=41556

Jamaica Gleaner. (2013, 08 22). *Hub Sights New Home: Gov't Puts China's Preferred Logistic Site At Top Of List*. Retrieved 09 13, 2013, from Jamaica Gleaner: http://jamaica-gleaner.com/gleaner/20130822/lead/lead1.html

Jamaica Information Service. (2010a, 08 20). *Islandwide road project to provide 6,700 jobs*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/114-transport-works/25064-trans_works-islandwide-road-project-to-provide-6-7-jobs

Jamaica Information Service. (2010b, 08 23). *Mike Henry breaks ground for Palisadoes coastline rehab*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/114-transport-works/25078-trans_works-mike-henry-breaks-ground-for-palisadoes-coastline-rehab

Jamaica Information Service. (2010c, 09 24). *China has no hidden agenda on JDIP Project - Ambassador Jinghua*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/114-transport-works/25386-trans_works-china-has-no-hidden-agenda-on-jdip-project-ambassador-jinghua

Jamaica Information Service. (2010d, 09 24). *Engineers will contribute even more after Chine Harbour Conference - Minister Vaz*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/opm-news/25398-officePM-engineers-will-contribute-even-more-after-china-harbour-conference-min

Jamaica Information Service. (2011a, 01 10). *Blue chip companies interesed in Caymanas Economic Zone*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/107-industry-investment-commerce/26450-blue-chip-companies-interested-in-caymanas-economic-zone

Jamaica Information Service. (2011b, 04 28). *Works Minister says JDIP is the most transparent programme*. Retrieved 04 28, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/114-transport-works/27553-works-minister-says-jdip-is-the-most-transparent-programme

Jamaica Information Service. (2012, 12 06). *Work on Mount Rosser Bypass Resumes January*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/146-transport-works-housing/32474-work-on-mount-rosser-bypass-resumes-january

Jamaica Information Service. (2013a, 09 11). *Prime Minister's Statement on the official trip to China*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/list/34998

Jamaica Information Service. (2013b, 04 09). *$2.5 billion allocated to Major Infrastructure Programme*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/146-transport-works-housing/33499-25-billion-allocated-to-major-infrastructure-programme

Jamaica Information Service. (2013c, 05 01). *CHEC to invest US$1.5 billion in transshipment port*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/122-parliament/33743-chec-to-invest-us15-billion-in-transshipment-port

Jamaica Information Service. (2013d, 05 08). *Local contractors to benefit from MIDP*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/list/33800

Jamaica Information Service. (2013e, 05 08). *CHEC to invest US$1.5 billion in port and other facilities*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/leads-122/33799

Jamaica Information Service. (2013f, 09 12). *Port Authority will continue Goat Islands Assessment - Dr. Davies*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/leads/35008

Ministry of Transport, Works & Housing. (2013, 01 07). *Segment 2 of North-South link re-started*. Retrieved 09 19, 2013, from Ministry of Transport, Works & Housing - News: http://www.mtw.gov.jm/NewsPage/2012/Segment%202%20of%20North-South%20link%20re-started.aspx

Panama Canal Authority. (2013, 02 22). *This is the Canal*. Retrieved 10 11, 2013, from Panama Canal Authority: https://www.pancanal.com/eng/acp/asi-es-el-canal.html

Panama Canal Autorithy. (2006). *Proposal for the Expansion of the Panama Canal.*

The Guardian. (2013, 06 06). Retrieved 09 16, 2013, from http://www.theguardian.com/world/2013/jun/06/nicaragua-china-panama-canal

The Telegraph. (2013, 07 30). Retrieved 09 16, 2013, from http://www.telegraph.co.uk/news/worldnews/asia/china/10212169/Chinese-entrepreneur-reveals-route-for-Nicaraguan-canal.html

The Wall Street Journal. (2013, 06 13). Retrieved 09 16, 2013, from http://online.wsj.com/article/SB10001424127887323734304578543432234604100.html?mod=WSJ_hpp_MIDDLENexttoWhatsNewsTop

Toronto Star Newspaper. (2013, 09 02). *Nicaragua, China bet $40 billion on a canal to rival Panama.* Retrieved 09 16, 2013, from Toronto Star Newspaper: http://www.thestar.com/news/world/2013/09/02/nicaragua_china_bet_40_billion_on_a_canal_to_rival_panama.html

Appendix B Stakeholder analysis

To investigate what the power and attitude is of different interested parties and to identify these a stakeholder analysis can be performed. In this analysis first the different stakeholders will be divided into classes. The next chapter will show per stakeholder their involvement, interest, power and attitude in a table. With this information graphs are made, which will be used to identify the different stakeholders. With this identification an advice will be given on how to handle each of the stakeholders. This advice will be presented in the stakeholder table for a good overview.

1 Different stakeholders

Like in many projects there are many different stakeholders. The stakeholders for this project can be classified in different groups. Those groups and stakeholders are named below.

Jamaica:

- Government of Jamaica
- Port Authority of Jamaica
- Environmental protection organizations
- Jamaican press
- Jamaican people

China:

- China Harbour Engineering Company Ltd. (CHEC)
- China Communications Construction Company Ltd. (CCCC)

In appendix A, Background information, the government of China and the Chinese bank are also mentioned as players in China. The government of China is mentioned is news articles but their role is mainly to be intermediary. The banks of China are providing the loan but they don’t have (direct) interest in this project.

Others:

- Shipping companies
- Other transshipment ports in the Caribbean

2 Stakeholder table

To create Table B-1 information from the appendix A, Background information, is used. When another source of information is used a footnote in the table is placed. The last column is filled for a good overview. Chapter 3, Identification importance of stakeholders and chapter 4, Advice per stakeholder are used for this column.

TABLE B-1: STAKEHOLDER TABLE WITH INVOLVEMENT, INTEREST, INFLUENCE/POWER, ATTITUDE AND ADVICE PER STAKEHOLDER

	Involvement	**Interest**	**Influence/power**	**Attitude**	***How to handle this stakeholder***
Government of Jamaica (GoJ)	The GoJ has a contract with CHEC to investigate the options of a new port (including a transshipment part and an industrial part) in Jamaica. The GoJ also has other contracts with CHEC which involves loan for upgrading roads.	The interest of GoJ is **very high**. This new port will create jobs for the Jamaican people during and after the building process. The port also will give the economy a boost. When the port is built it will be built in Jamaica and maybe in an environmental protected area.	The influence and power of GoJ is **very high**, because eventually they will decide where and if there will be a new port.	The GoJ has a **positive** attitude towards the new port. Basically the port will be beneficial for the economy and the employment of the country. On the other hand the environmental impact can be an issue.	*This stakeholder is very important and needed for a successful project. Involvement in location choice and design of the port and in contracts is necessary.*
Port Authority of Jamaica (PA)	The mission of PA is be "developers and regulators of the world class facilities and services that ensure the sustainable growth of Jamaica's maritime industry and maximum satisfaction of all stakeholders." [1]	If a new port will be built, a lot will change for PA. The port can even be a direct concurrent to the port of Kingston and possibly lower their throughput and activities. The interest of PA is **high**.	The PA can influence the project, because they are involved in the project. Their power is limited since they are not a big player. Therefore the power of the PA is **medium**.	A new port in Jamaica can be a competitor for PA, but it can also create new opportunities. The attitude of PA is **neutral**.	*The PA should be involved and consulted in the decision making processes regarding the port design and the activities, to make sure the PA will not be negative influenced by the development of the new port.*

---

[1] (The Port Authority of Jamaica, 2006)

	Involvement	**Interest**	**Influence/power**	**Attitude**	***How to handle this stakeholder***
Environmental protection organizations	Their goal is to protect the environment for negative changes.	The interest of the environmental protection organizations is **high** because the location choice is very important for the possible damage to the environment.	There will be an Environmental Impact Assessment with an advice, to which the GoJ should read, but the decision of the GoJ is not bounded to it. The influence of environmental protection organizations is **medium**	The attitude of the environmental protection organizations can be slightly positive or negative. This depends on the chosen location. Their attitude is **negative** towards the original location for the port, Goat Island.	*The attitude of the environmentalists can change to neutral when the alternative location will be less harm for the environment. Their environmental impact assessment should be consult in decision making processes for the location choice and design of the port.*
Jamaican press	The press will publish studies and opinions about the project. This can influence the point of view of the Jamaican people.	For the press the interest in the outcome is **very low**, only the facts matter. Their goal is to inform people.	Their influence is **high** because they decide which news to tell. This can influence the opinion of the people of Jamaica and therewith possibly the statement of the government.	The press is supposed to have a **neutral** attitude about the news they publish and tell both sides of the story.	*This stakeholder should be informed regularly about decisions and in designs for the new port (and the current port).*

	Involvement	**Interest**	**Influence/power**	**Attitude**	***How to handle this stakeholder***
Jamaican people	During and after the building of the new ports there will be jobs created for the Jamaican people. The economy is expected to grow due to the new port.	For the people of Jamaica it is very important that there will be more jobs available in their country because of the high unemployment. Also a growing economy will be beneficial for the Jamaican people. Their interest is **high**.	The influence of the people of Jamaica is quite low. They don't have the power to change the plan or prevent the development of the port. That's the government's decision, which can be influenced by the people, but there is no direct influence possible. Their (direct) power is **low**.	The Jamaican people have a **neutral** attitude. The port will create jobs and gives the economy a boost, but can harm the environment.	*It is important to listen to the opinions of the Jamaican people, because the decision will have an indirect impact on them. Their opinions should be consulted in the decision making processes.*
China Harbour Engineering Company Ltd. (CHEC)	CHEC wants to invest in the new port and will probably be responsible for building infrastructure and possible plants, dredging and manage the service contract.	The interest of CHEC is **very high**. The port will be their direct investment, and most likely they will get money in return when the port is ready and they are operating it.	The power of CHEC is **very high**, because they are the investors and without investors there won't be a port.	CHEC has a **positive** attitude towards the new port, otherwise they won't invest in the plan.	*This stakeholder is very important. CHEC should be included and consulted in the decisions and discussion about location and design of the port. They should also be included in the contract processes.*
China Communications Construction Company Ltd. (CCCC)	CCCC also will do a direct investment in the new port. They will probably be responsible for building the port.	The interest of CCCC is **high,** but not very high like CHEC because they will probably not manage the service contract.	CCCC has **very high** power, because they also invest in the port.	CCCC has a **positive** attitude towards the new port, otherwise they won't invest in the plan.	*Like CHEC this stakeholder is very important. CCCC should be included and consulted in the decisions and discussion about location and design of the port.*

	Involvement	**Interest**	**Influence/power**	**Attitude**	***How to handle this stakeholder***
Shipping companies	These companies decide where to transship their containers. The costs are very important for these companies.	Their interest is **medium.** The shipping companies do have interest in the new port, because it might be a port they want to use. When there won't be a port, they will ship the goods via another route or the same they used to do.	The companies don't have direct power on the new port, but they will be the users of the port. Probably the port service contract will be from the Chinese, so the Chinese shipping companies might prefer this port. The Chinese do a lot of shipping, so it can be assumed that there will be a big market for this port. The influence of the shipping companies is **medium**.	Building this new port will cause more competiveness in the Caribbean. This probably will cause lower costs for transshipment or extra services. The attitude will be **positive** for the shipping companies.	*It is important the meet their needs, especially with respect to the terminal and port design. Their interest can be increased through involvement in the design process. This stakeholder should also be included in the contract process.*
Other transshipment ports in the Caribbean	The transshipment ports are competitors of the new port.	The interest of the other transshipment ports is **high**, because a new port will influence the competitiveness in the Caribbean.	The other transshipment ports have no power to change the plans about the new port, but they can influence the competitive position in the Caribbean by adapting their own ports. Their power is therefore **medium**.	A new port will mean more competition. This will cause a **negative** attitude for the other transshipment ports in the Caribbean.	*The other ports can be used or consulted in the design process of the port, especially for variables which involve competitiveness.*

3 Identification importance of stakeholders

With the table from chapter 2, Stakeholder table, different graphs can be drawn. The stakeholders in the group Jamaica are represented by the colors green and yellow. The Chinese stakeholders are blue and the other stakeholders have a purple color. The first graph will plot the interest and power of every stakeholder. This graph is shown in Figure B-1.

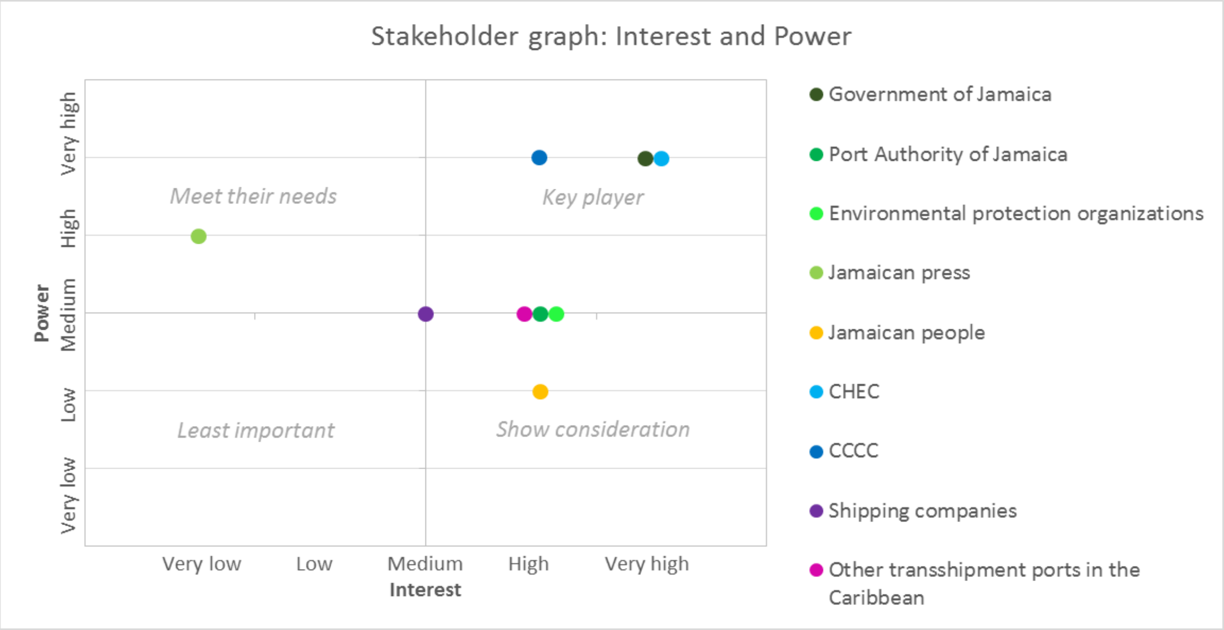


FIGURE B-1: STAKEHOLDER GRAPH OF INTEREST AND POWER PER STAKEHOLDER WITH AREAS OF IMPORTANCE

In Figure B-1 four areas of importance are shown in the graph. The first one is the upper left part of the graph. The stakeholders in this part can be placed under "meet their needs". The lower left part are the "least important" stakeholders. The "key player" stakeholders can be found in the upper right part of the graph. The last part, lower right part, will contain the stakeholders of the category "show consideration". Six of the nine stakeholders lie exact in one of these four parts of the graph, the other three stakeholders lie on the boundaries. The last three stakeholders should be placed in one of the four parts by investigating them a little more.
(Morphy, 2013)

The shipping companies lie exactly in the middle of the four parts in Figure B-1. They definitely do not belong in the "least important" part. Due to their limited power and limited interest they cannot be a "key player". It is good to keep them informed and listen to their needs. At the end their power can be very high, because they are the clients and will pay for the services. "Meet their needs" will be a good part for the shipping companies.
With the same power but higher interest three stakeholders lie on the boundary between "key player" and "show consideration". The first stakeholder is the group of the other transshipment ports in the Caribbean. This stakeholder is not a "key player". The other ports have an indirect influence on the port by influencing the choice of shipping companies. A competitiveness research will be necessary. That's why this stakeholder fits the best in the part "show consideration".
The second stakeholder on this boundary is the Port Authority of Jamaica. This stakeholder belongs to the group "key player", because the impact of the new port can have a big influence on the Port Authority of Jamaica. A negative impact on this stakeholder might lead to a negative influence on the economy and number of available jobs in Jamaica. Therefore this stakeholder is important and can placed in the group "key player".
The third stakeholder on this boundary between "key player" and "show consideration" is the group of the environmental protection organizations. Those organizations will be especially important for the location decision.

Since their power is limited, this stakeholder is not really a “key player”. The best part for this stakeholder is “show consideration”.

A new graph of the stakeholders and their power and interest can be made. This is shown in Figure B-2.

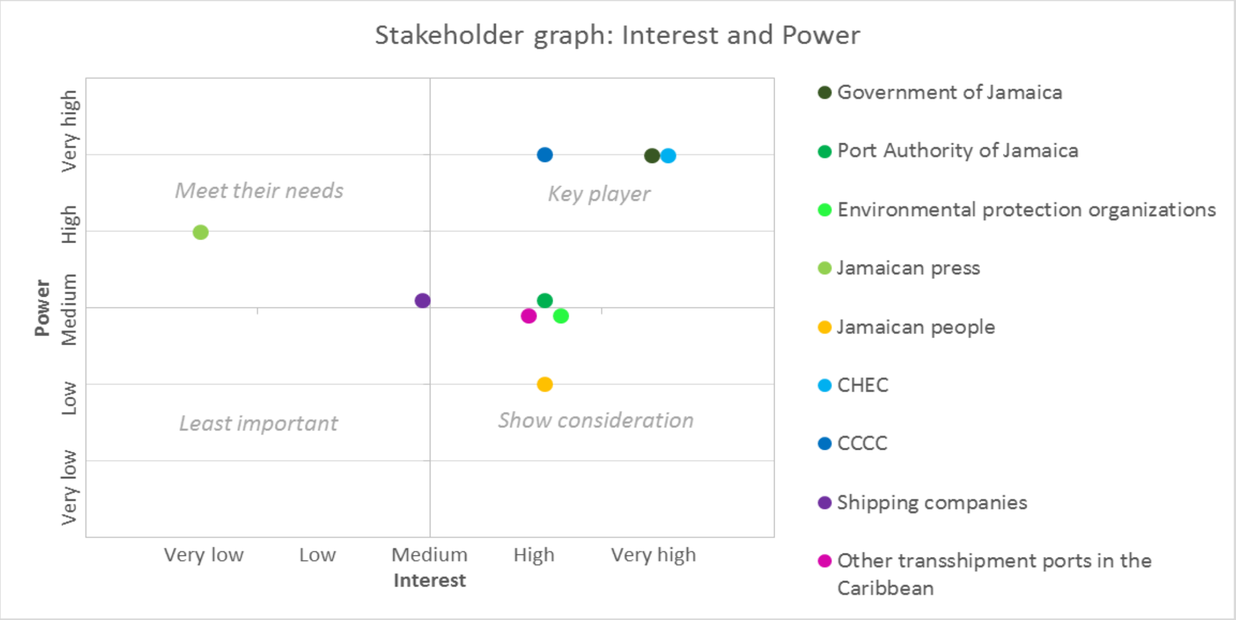


FIGURE B-2: RENEWED STAKEHOLDER GRAPH OF INTEREST AND POWER PER STAKEHOLDER

In Figure B-2 all the stakeholders are assigned to one of the four groups. This division is used in chapter 4 to give a general advice for handling the different stakeholders groups. To give a more complete advice per stakeholder the attitude of the stakeholders will be included in the analysis. The relation between attitude and the power per stakeholder is shown in Figure B-3. For this figure the original level of power is used as is shown in Figure B-1.

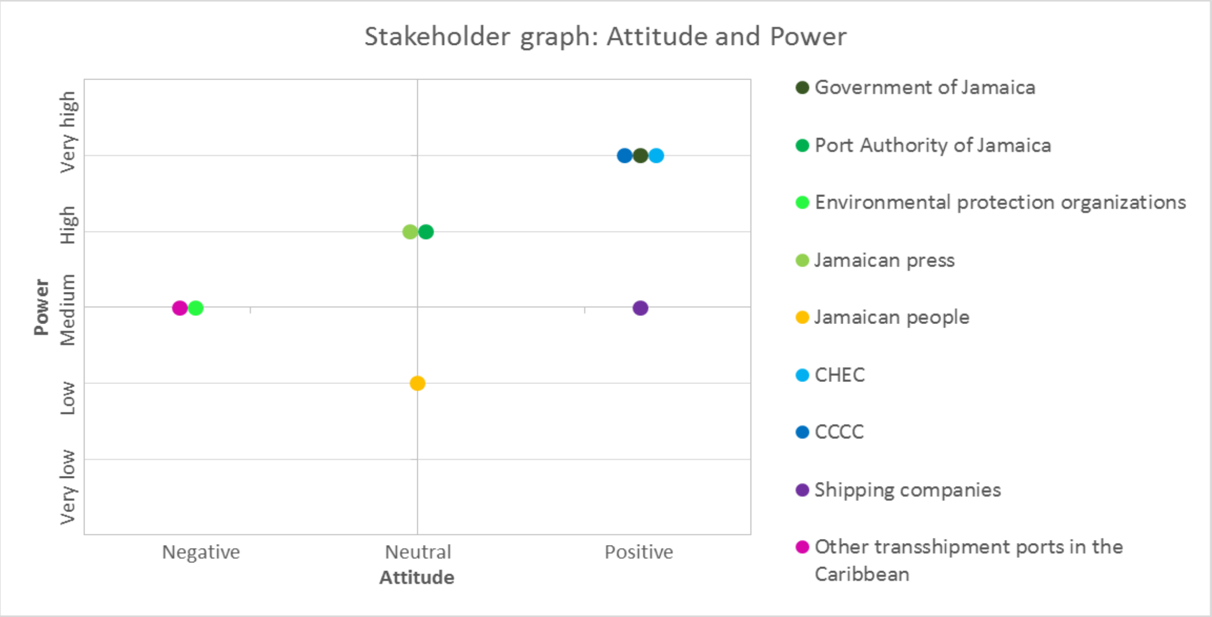


FIGURE B-3: STAKEHOLDER GRAPH OF ATTITUDE AND POWER PER STAKEHOLDER

Using Figure B-3 the stakeholders can be divided into groups based on their attitude. Other transshipment ports in the Caribbean and the environmental protection organizations will be in the group with a negative attitude. The group with a neutral attitude consists of the Port Authority of Jamaica, the Jamaican press and the Jamaican people. The last group, with a positive attitude are the government of Jamaica, CHEC, CCCC and the shipping companies.

4 Advice per stakeholder

The stakeholders can be divided into three of the four groups mentioned in chapter 3 Identification importance of stakeholders. Per group a general advice how to handle these stakeholders can be given. (Morphy, 2013) Based on these advices per group and Figure B-3 an advice per stakeholder can be given. This advice will be summarized in the last column of Table B-1 in chapter 2, Stakeholder table.

Key players

The general advice for these stakeholders is to focus on this group. They have to be involved in the decision making of the project. For a good relation and for information they have to be engaged and consulted regularly. The key players and their advice are shown below:

- **Government of Jamaica**
  The government of Jamaica is the stakeholder which will give permission to CHEC and CCCC to invest in a port and the government will also decide what the location of the new port will be. The government is willing to participate with the plan of a new port, because the development can be good for the country's economy, so their attitude is positive. This stakeholder is very important, without this stakeholder the project cannot be realized. The government should be included in all the decisions regarding to location choice and design of the port. They should also be involved in the contracts with regard to the new port.

- **Port Authority of Jamaica**
  This stakeholder is not as important as the previous stakeholder. This stakeholder should be involved and consulted in the decision making processes, because a wrong decision can have a negative impact on the current port and its port authority. The new port might be a competitor of the current port and can lead to less throughput. By involving and consulting this stakeholder in decisions and designing activities, it is possible to design other activities for the current port to cope with the decrease of throughput. When this is properly done the attitude of this stakeholder will not change from neutral to negative.

- **CHEC**
  CHEC is the main investor of the project and has a positive attitude. They want to create a new port, which eventually will be beneficial for them. Without this stakeholder there is no investor for the port, so there won't be a port. It is important to include this stakeholder in the decision making processes and to offer them a location and design which can be beneficial. This stakeholder should also be included in the contract process because they will operate the port.

- **CCCC**
  This stakeholder is almost as important as CHEC. They will also invest in the port and have a positive attitude. The big difference between CCCC and CHEC is that CHEC will be the port operator and CCCC will be mainly involved in the building process. CCCC also wants their investment to be beneficial, but they have more concerns in developing the port than in operating. Therefore they should be included in decisions about the location and design will be suitable for them.

Show consideration

The advice for this group is to use their interest through involvement in low risk areas. It is important to keep them involved or consult them within their interest area. These stakeholders can potential be a supporter or ambassador of the project. The stakeholders in the group "show consideration" and their advice are shown below:

- **Environmental protection organizations**
  The environmental protection organizations will (let) preform an environmental impact assessment. This assessment will give an advice to the government and should therefore be consulted. If their advice will be followed the environmental protection organizations' attitude might change from negative to neutral. Their attitude probably won't change to positive because the new green field port will destroy some of Jamaica's nature.
- **Jamaican people**
  The attitude of the Jamaican people is neutral, because their country's economy might benefit from the new port, but the environment might be harmed. It is important to know what the attitude of the Jamaican people is, because the new port might indirectly influence the Jamaican people. Their opinions should be heard and included in decision making processes.

- **Other transshipment ports in the Caribbean**
  This stakeholder is especially important for the success of the port when developed. The competiveness of the new port depends on chosen variables during the design. During the design it is important to be aware of the other transshipment ports in the Caribbean. The other ports can be used or consulted in the design process of the port. The attitude of this other ports is negative because of the possible competiveness.

Meet their needs

The general advice for this group is to engage and consult them within their interest area. Also it can be useful to increase their level of interest, so they become key players.

- **Jamaican press**
  The Jamaican press should be informed about the new port and the decision making processes. The goal of the press is to provide the people with information. By providing the wrong and/or negative information the attitude of the Jamaican people can change. It is important to make sure the information in the media is correct, this can be done by informing the press regularly. There is no need to change this stakeholder into a key player. It is not favorable to get the press very involved, because this can harm their impartiality.

- **Shipping companies**
  It can really be beneficial to change a few of the shipping companies from "meet their needs" to "key players". By involving shipping companies in the decisions and design processes their needs can really be met. This can be done by increasing their interest through involvement in the terminal and port design process. Their attitude will be in general positive because more competitiveness might lead to lower prices. The shipping companies should also be included in the contract process.

These advises can be summarized in Table B-2. In this table the actions per stakeholder per different process in the development of the port is shown.

TABLE B-2: SUMMARY OF ACTION PER STAKEHOLDER FOR DIFFERENT PROCESSES IN THE DEVELOPMENT OF THE NEW PORT

	Location choice processes	*Port design processes*	*Contract processes*
Government of Jamaica	Include	Include	Include
Port Authority of Jamaica	Include	Include	-
Environmental protection organizations	Consult	Consult	-
Jamaican press	Inform	Inform	Inform
Jamaican people	Consult	Consult	Consult
China Harbour Enginneering Company Ltd. (CHEC)	Include	Include	Include
Chine Communications Construction Company Ltd. (CCCC)	Include	Include	-
Shipping Companies	-	Include if possible, otherwise consult	Include if possible, otherwise consult
Other transshipment ports in the Caribbean	-	Consult	-

5 References

Morphy, T. (2013). *How to analyse stakeholders*. Retrieved 09 17, 2013, from Stakeholder Analysis: http://www.stakeholdermap.com/stakeholder-analysis.html

The Port Authority of Jamaica. (2006). *About us*. Retrieved 09 17, 2013, from The Port Authority of Jamaica: http://www.portjam.com/nmCMS.php?p=aboutus

Appendix C Reference ports

The goal of this list of reference ports is to investigate certain relationships between different port characteristics. These relationships are the relation between throughput and dry surface, the relation between throughput and quay length and the relation between dry surface and quay length. Also the throughput per square kilometer is calculated. In different parts of this project reference ports are used. Reference ports are used in the appendix G, Design values. The Euromax Terminal Rotterdam used in appendix G, Design Values, is no part of the reference ports because this is a terminal, not a port.

1 Throughput and transshipment

The annual throughput and the percentage of transshipment for the reference ports is given in Table C-1. Also the resource of the information is included in the table. The last column of Table C-1 contains the calculated amount of transshipment in TEU.

The reference ports differ in annual throughput. The port with the smallest annual throughput (less than 0.2 million TEU) is Point Lisas in Trinidad and Tobago. The port of Shanghai in China has the largest annual throughput (31.7 million TEU). The reference ports also differ in transshipment percentage (the amount of container transshipment as percentage of the total container throughput). The port with the smallest transshipment percentage (23%) is the port of Antwerp in Belgium. The largest transshipment percentage (99%) is found for the port of Salalah in Oman, Freeport in the Bahamas and Tanger-Med in Morocco. The current port of Jamaica in Kingston has an annual throughput of 1.8 million TEU and a transshipment percentage of 85%.

Table C-1: Overview of throughput per year, transshipment percentage and calculated transshipment per year for the reference ports

Port, city and country	Throughput per year (TEU)	Year of data resource	Resource	Transshipment percentage (%)	Year of data resource	Resource	Transshipment per year (TEU)
Aden, Yemen	180,185	2011	(Port of Aden, 2012)	88%	2008	(Rodrigue, 2013)	158,563
Algeciras, Spain	3,602,631	2011	(Containerisation International, 2012)	96%	2008	(Rodrigue, 2013)	3,458,526
Antwerp, Belgium	8,664,243	2011	(Containerisation International, 2012)	23%	2004	(Heymann, 2006)	1,992,776
Balboa, Panama	3,232,265	2011	(Containerisation International, 2012)	95%	2008	(Rodrigue, 2013)	3,070,652
Busan, South Korea	16,184,706	2011	(Containerisation International, 2012)	42%	2004	(Heymann, 2006)	6,797,577
Cartagena, Colombia	1,853,342	2011	(ECLAC, 2012)	67%	2011	(Puerto De Cartagena, 2013)	1,241,739
Colombo, Sri Lanka	4,262,887	2011	(Containerisation International, 2012)	75%	2008	(Rodrigue, 2013)	3,197,165
Constantza, Romania	662,796	2011	(Constantza Port, 2013)	75%	2008	(Rodrigue, 2013)	497,097
Damietta, Egypt	1,205,036	2011	(Containerisation International, 2012)	81%	2008	(Rodrigue, 2013)	976,079
Dubai, UAE	13,000,000	2011	(Containerisation International, 2012)	50%	2004	(Heymann, 2006)	6,500,000
Freeport, Bahamas	1,116,272	2011	(Containerisation International, 2012)	99%	2008	(Rodrigue, 2013)	1,105,109
Gioia Tauro, Italy	2,304,982	2011	(Containerisation International, 2012)	95%	2008	(Rodrigue, 2013)	2,189,733
Hamburg, Germany	9,021,800	2011	(Containerisation International, 2012)	33%	2004	(Heymann, 2006)	2,977,194
Hong Kong, China	24,384,000	2011	(Containerisation International, 2012)	30%	2004	(Heymann, 2006)	7,315,200
Kaohsiung, Taiwan	9,636,289	2011	(Containerisation International, 2012)	52%	2004	(Heymann, 2006)	5,010,870
Khor Fakkan (Sharjah), UAE	3,229,929	2011	(Containerisation International, 2012)	89%	2008	(Rodrigue, 2013)	2,874,637
Kingston, Jamaica	1,848,231	2011	(Containerisation International, 2012)	85%	2008	(Rodrigue, 2013)	1,570,996
Klang, Malaysia	9,603,926	2011	(Containerisation International, 2012)	63%	2011	(Port Klang, 2013)	6,050,473
Maasvlakte 2, the Netherlands	17,000,000	expected	(Port of Rotterdam, n.d. a)				
Manzanillo, Panama	1,899,802	2011	(Containerisation International, 2012)	83%	2008	(Rodrigue, 2013)	1,576,836
Marsaxlokk, Malta	2,360,489	2011	(Containerisation International, 2012)	96%	2008	(Rodrigue, 2013)	2,266,069
Point Lisas, Trinidad	170,581	2011	(ECLAC, 2012)	60%	2008	(Isik, 2012)	102,349
Port Said, Egypt	981,824	2010/ 2011	(Port Said Container & Cargo Handling Co., 2012)	73%	2010/ 2011	(Port Said Container & Cargo Handling Co., 2012)	716,732

Port, city and country	Throughput per year (TEU)	Year of data resource	Resource	Transshipment percentage (%)	Year of data resource	Resource	Transshipment per year (TEU)
Rio Haina & Caucedo, Dom. Rep.	1,313,159	2011	(ECLAC, 2012)	50%	2008	(Isik, 2012)	656,580
Rotterdam, the Netherlands	11,876,921	2011	(Containerisation International, 2012)	40%	2004	(Heymann, 2006)	4,750,768
Salalah, Oman	3,200,700	2011	(Containerisation International, 2012)	99%	2008	(Rodrigue, 2013)	3,168,693
Shanghai, China	31,700,000	2011	(Containerisation International, 2012)	43%	2004	(Heymann, 2006)	13,631,000
Singapore, Singapore	29,937,700	2011	(Containerisation International, 2012)	85%	2010?	(PSA Singapore, 2010a)	25,447,045
Tanger-Med, Morocco	2,070,000	2011	(Containerisation International, 2012)	99%	2008	(Rodrigue, 2013)	2,049,300
Tanjung Pelepas, Malaysia	5,617,562	2011	(Containerisation International, 2012)	96%	2008	(Rodrigue, 2013)	5,392,860
Taranto, Italy	604,404	2011	(Taranto Port Authority, 2012)	85%	2008	(Rodrigue, 2013)	513,743

2 Throughput and design characteristics

To investigate the relation between throughput and dry surface, between throughput and quay length and between dry surface and quay length the reference ports are used. The reference ports with the data about their annual throughput, dry surface and quay length are given in Table C-2. The empty cells indicate that no data is found. The resources of the data are included in the table as well. The last column of the table contains calculated values for the throughput per square kilometer of dry surface. The investigated relations will be discussed after Table C-2.

TABLE C-2: OVERVIEW OF THROUGHPUT PER YEAR, DRY SURFACE FOR CONTAINER HANDLING, QUAY LENGTH AND CALCULATED THROUGHPUT PER SQUARED KILOMETER FOR THE REFERENCE PORTS

Port, city and country	**Throughput per year from Table C-1 (TEU)**	**Dry surface for container handling (ha)**	**Quay length (km)**	**Resource**	**Throughput per km^2 (TEU/km^2)**
Aden, Yemen	180,185	42	0.7	(Aden Container Terminal, 2010a) (Port of Aden, 2010)	429,012
Algeciras, Spain	3,602,631		4.3	(Autoridad Portuaría de la Bahía de Algeciras, 2012)	
Antwerp, Belgium	8,664,243				
Balboa, Panama	3,232,265	182	2.3	(Panama Ports Company, n.d.)	2,486,358
Busan, South Korea	16,184,706				
Cartagena, Colombia	1,853,342				
Colombo, Sri Lanka	4,262,887	47	1.9	(Sri Lanka Ports Authority, n.d. a) (Sri Lanka Ports Authority, n.d. b)	9,064,187
Constanza, Romania	662,796				
Damietta, Egypt	1,205,036				
Dubai, UAE	13,000,000				
Freeport, Bahamas	1,116,272	49	1.5	(Freeport Container Port, 2013)	2,278,106
Gioia Tauro, Italy	2,304,982	155	3.4	(Gioia Tauro Port Authority, n.d.)	1,487,085
Hamburg, Germany	9,021,800	420	7.6	(Port of Hamburg, n.d.)	2,148,048
Hong Kong, China	24,384,000	279	7.7	(Hong Kong Port Development Council, 2010)	8,739,785
Kaohsiung, Taiwan	9,636,289				
Khor Fakkan, UAE (Sharjah)	3,229,929	70	2.0	(Sharjah Ports Authority, 2011)	4,614,184
Kingston, Jamaica	1,848,231	194	2.3	(The Port Authority of Jamaica, 2006)	952,696
Klang, Malaysia	9,603,926	147	6.7	(Port Klang Authority, 2011)	6,515,516
Maasvlakte 2, the Netherlands	17,000,000	600		(Port of Rotterdam, n.d. b)	2,833,333
Manzanillo, Panama	1,899,802	52	1.2	(Manzanillo International Terminal, 2013)	3,653,465
Marsaxlokk, Malta	2,360,489	34	2.6	(Malta Freeport, 2010a) (Malta Freeport, 2010b)	6,942,615
Point Lisas, Trinidad	170,581				1,748,652
Port Said, Egypt	981,824	44	0.9	(Maritime Transport Sector, 2013a) (Maritime Transport Sector, 2013b)	2,044,913

Port, city and country	**Throughput per year from Table C-1 (TEU)**	**Dry surface for container handling (ha)**	**Quay length (km)**	**Resource**	**Throughput per km² (TEU/km²)**
Rio Haina+Caucedo, Dom. Rep	1,313,159	75	3.8	(Autoridad Portuaria Dominicana, 2013) (DP World Caucedo, 2010)	1,750,879
Rotterdam, Netherlands	11,876,921	828	16.4	(Port of Rotterdam, 2012)	1,434,411
Salalah, Oman	3,200,700	77	2.0	(Salalah Port Services Co. , 2007)	4,183,922
Shanghai, China	31,700,000				
Singapore, Singapore	29,937,700	752	20.1	(PSA Singapore, 2010b)	3,981,077
Tanger-Med, Morocco	2,070,000	80	1.6	(APM Terminals Tangier S.A., n.d.) (Eurogate Tanger S.A., 2013)	2,587,500
Tanjung Pelepas, Malaysia	5,617,562	180	4.3	(Pelabuhan Tanjung Pelepas Sdn Bhd, n.d.)	3,120,868
Taranto, Italy	604,404	110	1.5	(Autorità Portuale Taranto, 2012)	549,458

2.1 Relation between throughput and dry surface

The relationship between the throughput and the dry surface of the reference ports is shown is plotted in a graph. This is shown in Figure C-1.

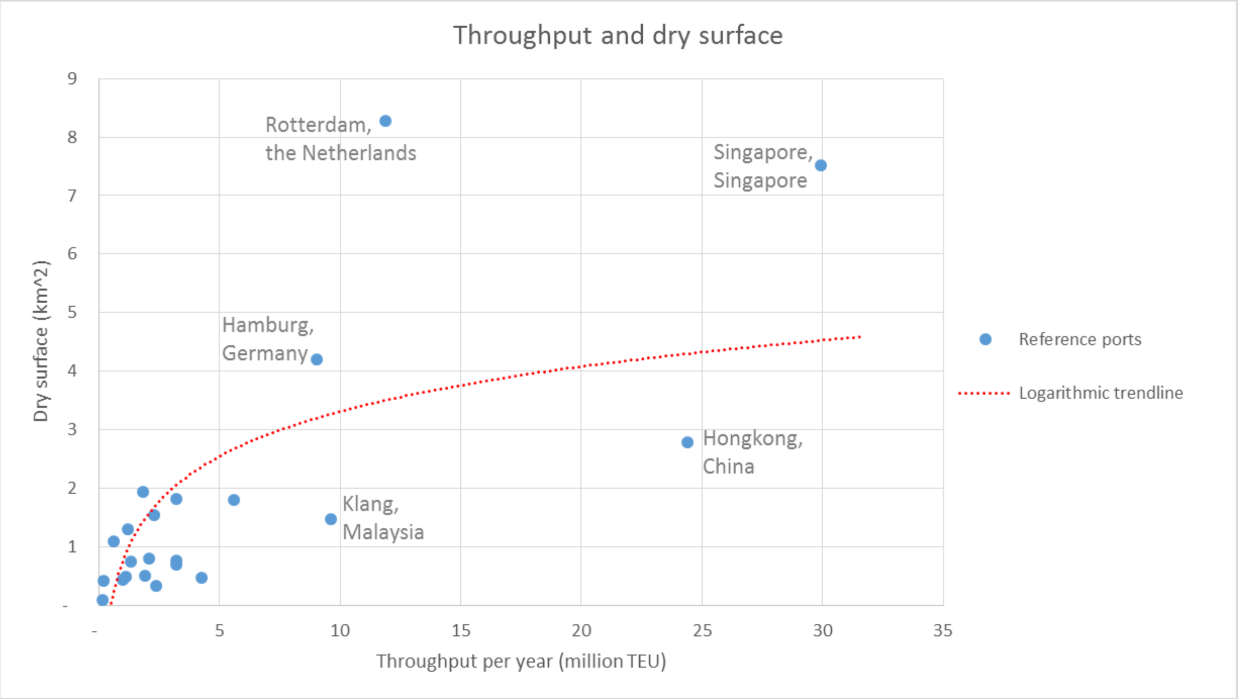


FIGURE C-1: GRAPH OF THE RELATIONSHIP BETWEEN THROUGHPUT AND DRY SURFACE

In Figure C-1a logarithmic trendlines is drawn to show the relation between the throughput and the dry surface. By drawing a logarithmic trendline instead of a linear trendline scale effects are taken into account. The five biggest ports (in throughput) are not lying close to the logarithmic trendline. Also the number of big ports is relatively small compared to the number of smaller ports. Therefore the bigger ports determine the curve of the logarithmic trendline. It cannot be said that this logarithmic trendline shows the actual relation between the throughput and dry surface. This is because of the limited number of reference ports, especially the bigger ports, and because of the dry surface of a port determines the capacity, not the throughput. The throughput is depending on more than the dry surface, but the dry surface will determine the capacity, so the maximum throughput.

2.2 Relation between throughput and quay length

The relationship between the throughput and the quay length of the reference ports is shown and plotted in a graph. This is shown in Figure C-2.

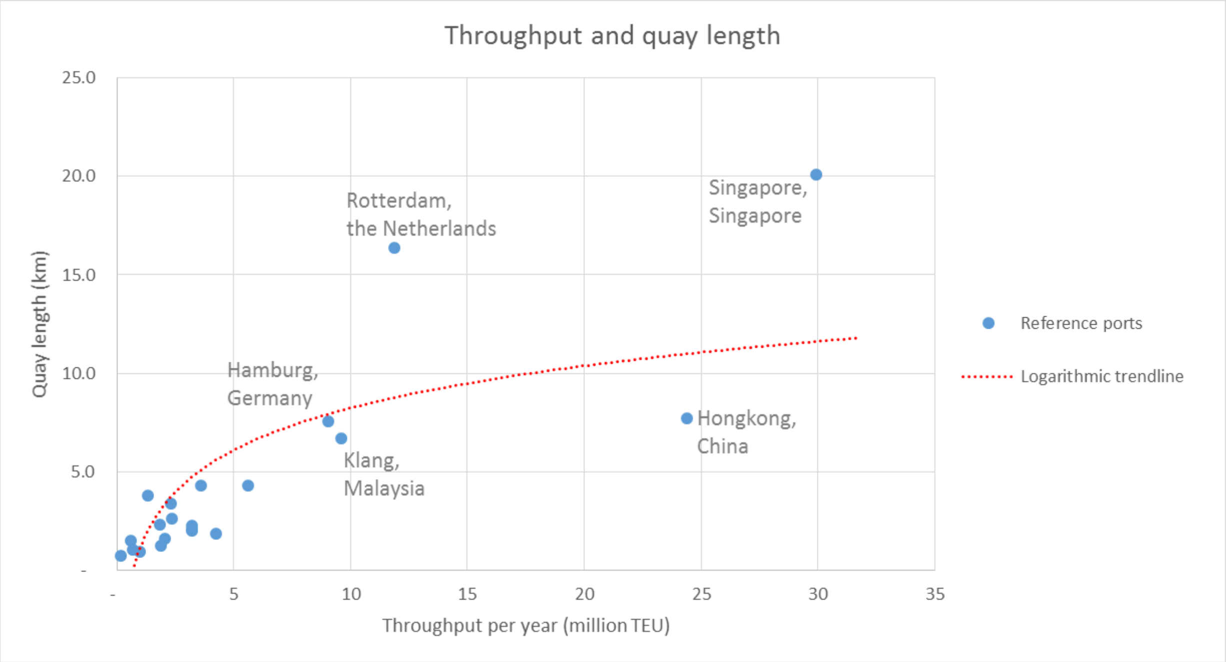


FIGURE C-2: GRAPH OF THE RELATIONSHIP BETWEEN THROUGHPUT AND QUAY LENGTH

In Figure C-2 a logarithmic trendline is drawn to show the relation between the throughput and the quay length. By drawing a logarithmic trendline instead of a linear trendline scale effects are taken into account. Three of the five biggest ports (in throughput) have certain distance to the logarithmic trendline. These three ports determine the curve of the logarithmic trendline. Because of this and the limited number of reference ports it cannot be said that this trendline can be used to show the relation between the throughput and the quay length. Moreover the quay length itself does not determine the throughput, also the equipment on the quay and the dry surface are of influence.

2.3 Relation between dry surface and quay length

The relationship between the dry surface and the quay length of the reference ports is shown and plotted in a graph. This is shown in Figure C-3.

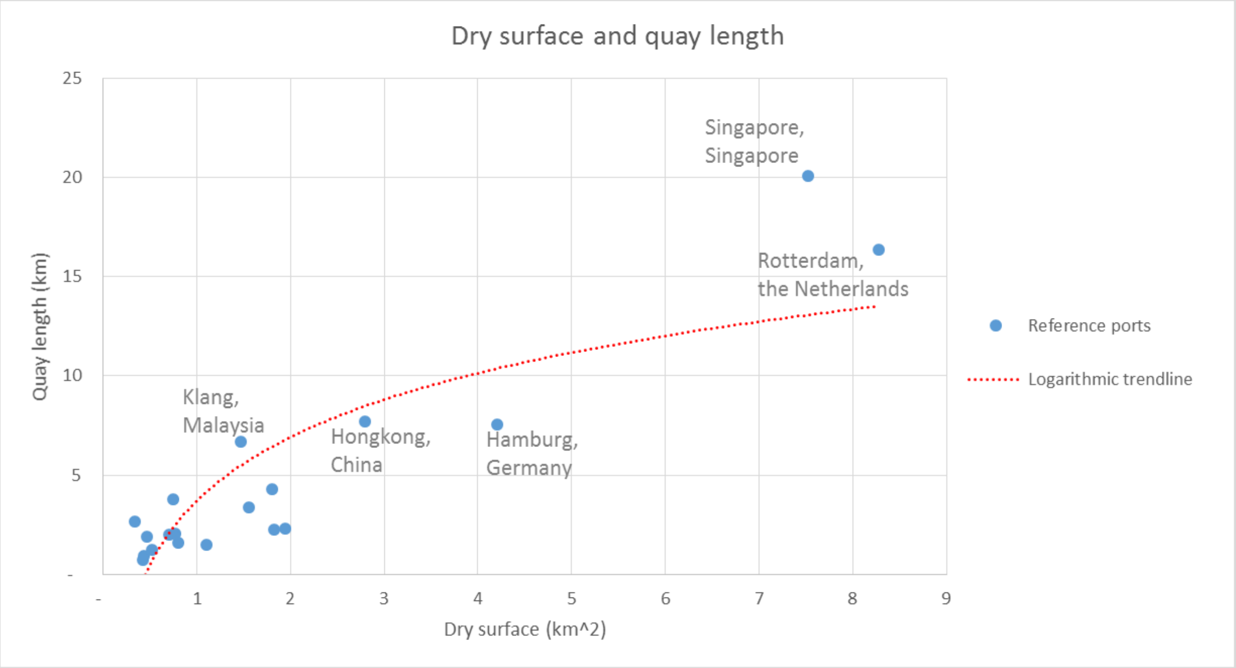


FIGURE C-3: GRAPH OF THE RELATIONSHIP BETWEEN DRY SURFACE AND QUAY LENGTH

In Figure C-3 a trendline is drawn to show the relation between the dry surface and the quay length. By drawing a logarithmic trendline instead of a linear trendline scale effects are taken into account. In this figure a lot of ports don't lie close to the trendline. Also in this graph the bigger ports determine the curve of the trendline. It is not realistic to say that this line represents the relation between the dry surface and the quay length, because the number of data points is limited. Besides that the relation between the dry surface and quay length is also determined by the design of the port, which is not included in this analysis.

2.4 Throughput per square kilometer

There are big differences in the reference ports when the throughput per square kilometer is taken into consideration. The smallest throughput per square kilometer (0.4 million TEU/km^2) belongs to the port Aden in Yemen. This port has a very small throughput (less than 0.2 million TEU per year) and a relative large dry surface (42 ha). It can be concluded that the available surface is not used very efficiently. The port with the largest throughput per square kilometer (9 million TEU/km^2) is port Colombo in Sri Lanka. This port has an annual throughput of 4.3 million TEU and a surface of 47 ha. This surface has almost the same size as the dry surface of the port Aden. Port Colombo uses their surface in a far more efficient way. This is probably because of the used equipment. This difference can be explained properly if the occupation rate of the port is known. With the occupation rate it can be stated that for a port with a low throughput per square kilometer if the port is inefficient designed (if the occupation is high) or if the demand of containers is far below the capacity (if the occupation is low).

To show the relation between the throughput and the throughput per square kilometer a graph is made, this is shown in Figure C-4.

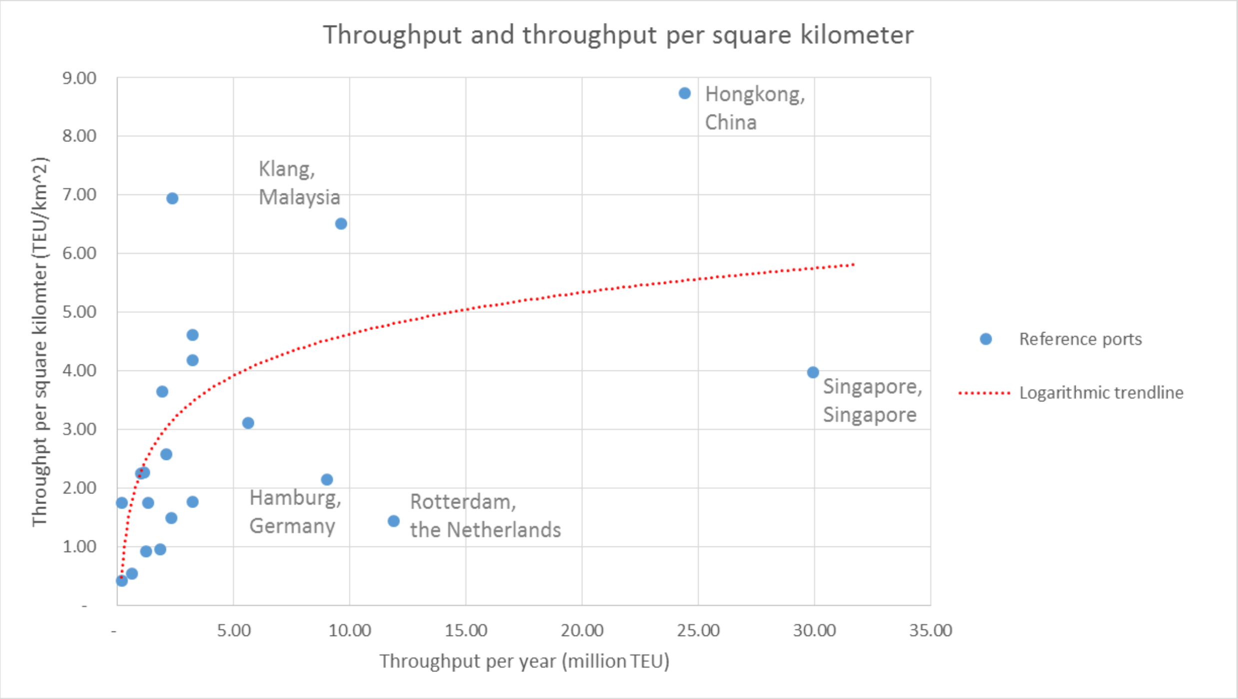


FIGURE C-4: GRAPH OF THE RELATIONSHIP BETWEEN THROUGHPUT AND THROUGHPUT PER SQUARE KILOMETER

The smallest port (in throughput) of the reference ports, Point Lisas in Trinidad and Tobago, has a throughput per square kilometer of 1.7 million TEU/km^2. The biggest port (in throughput) with a known dry surface, Singapore, has a throughput per square kilometer of 4.0 million TEU/km^2. But the second biggest port (in throughput) with a known dry surface, Hong Kong in China, has a throughput per square kilometer of 8.7 million TEU/km^2. In Figure C-4 can be seen that there is hardly no relation between the throughput and the throughput per square kilometer. Also in this graph a logarithmic trendline is drawn. This trendline cannot be used for the relation between the throughput and the throughput per square kilometer, because of the limited amount of data.

3 Conclusion

The relations of the previous chapters are more complex in reality than shown in the graphs. Also the number of the reference ports, especially the bigger ports is too limited to draw realistic trendlines. Another argument is the throughput is the realized number of handled containers, not the real capacity of the port. Therefore it is hard to make a conclusion about the mentioned relationships, because the realized throughput depends on more factors than the capacity. To investigate the relations more reference ports are needed and more information is needed per port, for instance capacity, equipment and dwell time.

4 References

Aden Container Terminal. (2010a). Retrieved 09 25, 2013, from Port of Aden: http://www.portofaden.net/ACT.aspx

APM Terminals Tangier S.A. (n.d.). *APM Terminals Tangier.* Retrieved 09 25, 2013, from APM Terminals: http://www.apmterminals.com/uploadedFiles/Tangier%20Brochure_English.pdf

Autoridad Portuaría de la Bahía de Algeciras. (2012, 12). *Resumen Acumulado*. Retrieved 09 25, 2013, from Puerto Bahía de Algeciras: http://webserver.apba.es/pls/portal/docs/PAGE/APBA_DOCUMENTACION/APBA_PAGE_DOCUMENTACION_ESTADISTICAS/DICIEMBRE%202012.PDF

Autoridad Portuaria Dominicana. (2013). *Rio Haina*. Retrieved 09 25, 2013, from Autoridad Portuaria Dominicana: http://www.apordom.gov.do/rio-haina.html

Autorità Portuale Taranto. (2012). *Container Terminal.* Retrieved 09 25, 2013, from Taranto Port Authority: http://www.port.taranto.it/en/the-port/berths/container-terminal.html

Constantza Port. (2013). *Overview - Port Statistics - General Statistics 2004-2012.* Retrieved 09 25, 2013, from Portul Constantza: http://www.portofconstantza.com/apmc/portal/static.do?package_id=st_generale&x=load

Containerisation International. (2012). *Top 100 Container Ports 2012.* Retrieved 09 24, 2013, from Containerisation International: http://europe.nxtbook.com/nxteu/informa/ci_top100ports2012/index.php?startid=60#/68

DP World Caucedo. (2010). *Infrastructure*. Retrieved 09 25, 2013, from Zona Franca Multimodal Caucedo: http://www.caucedo.com/infrastructure.php

ECLAC. (2012). Port container traffic in Latin America and the Caribbean 2011. *FAL Bulletin, Number 3*(307). Retrieved 09 25, 2013

Eurogate Tanger S.A. (2013). *Eurogate Tanger.* Retrieved 09 25, 2013, from Eurogate Tanger: http://www.eurogate-tanger.com/live/tanger_site/show.php3?id=1&nodeid=1&_language=en

Freeport Container Port. (2013). *Introduction.* Retrieved 09 25, 2013, from Freeport Container Port: http://freeportcontainerport.com/freeport-container-port

Gioia Tauro Port Authority. (n.d.). *Info - Tecnhical Data*. Retrieved 09 25, 2013, from Porto di Gioia Tauro: http://www.portodigioiatauro.it/info.php?id=5

Heymann, E. (2006, 04 25). *Container shippinh.* (H.-J. Frank, Ed.) Retrieved 09 24, 2013, from Deutsche Bank Research: http://www.dbresearch.com/PROD/DBR_INTERNET_EN-PROD/PROD0000000000198081/Container+shipping%3A+Overcapacity+inevitable+despite+increasing+demand.pdf

Hong Kong Port Development Council. (2010). *Hong Kong Port Facilities - Container Terminals*. Retrieved 09 25, 2013, from Hong Kong Port Development Council: http://www.pdc.gov.hk/eng/facilities/container.htm

Isik, G. (2012). *Logistics Connectivity in the Caribbean: Current Challenges and Future Prospects.* The World Bank, Kingston, Jamaica.

Malta Freeport. (2010a). *Terminal One.* Retrieved 09 25, 2013, from Malta Freeport: http://www.maltafreeport.com.mt/content.aspx?id=107941

Malta Freeport. (2010b). *Terminal Two.* Retrieved 09 25, 2013, from Matla Freeport: http://www.maltafreeport.com.mt/content.aspx?id=111332

Manzanillo International Terminal. (2013). *Operations - Operational Data.* Retrieved 09 25, 2013, from Manzanillo International Terminal: http://www2.mitpan.com/en/Operations/OperationalData/tabid/235/Default.aspx

Maritime Transport Sector. (2013a). *Ports - Commercial Ports - Port Said Port.* Retrieved 09 25, 2013, from Maritime Transport Sector: http://www.mts.gov.eg/articles/default/view/id/159/lang/en/Port+Said+port

Maritime Transport Sector. (2013b). *Ports - Commerical Ports - Port Said Port - Berths.* Retrieved 09 25, 2013, from Maritime Transport Sector: http://www.mts.gov.eg/articles/default/view/id/161/lang/en/Berths

Panama Ports Company. (n.d.). *Port Facilities - Port of Balboa - Facilities.* Retrieved 09 25, 2013, from Panama Ports Company: http://www.ppc.com.pa/pdf/facilidadesbalboa.pdf

Pelabuhan Tanjung Pelepas Sdn Bhd. (n.d.). *Services - Container Terminal.* Retrieved 09 25, 2013, from Port of Tanjung Pelepas: http://www.ptp.com.my/container2.html

Port Klang. (2013, 07 09). *Port Klang Statistics.* Retrieved 09 25, 2013, from Port Klang: http://www.pka.gov.my/index.php/en/component/content/article/44-about-us/127-port-klang-statistics.html

Port Klang Authority. (2011). *Port Facilities.* Retrieved 09 25, 2013, from Port Klang Authority: http://www.pka.gov.my/index.php/en/about-us-/port-klang-authority-/port-facilities-.html

Port of Aden. (2010). *Ma'alla Multipurpose and Container Terminal.* Retrieved 09 25, 2013, from Port of Aden: http://www.portofaden.net/MaallaTerminal.aspx

Port of Aden. (2012). *Statistics.* Retrieved 09 25, 2013, from Port of Aden: http://www.portofaden.net/Statistics.aspx

Port of Hamburg. (n.d.). *Container terminals.* Retrieved 09 25, 2013, from Port of Hamburg: http://www.hafen-hamburg.de/en/overview/containerterminals

Port of Rotterdam. (2012). *Haveninfrastructuur.* Retrieved 09 25, 2013, from Port of Rotterdam: http://www.portofrotterdam.com/en/Business/rotterdam-bio-port/Documents/Haveninfrastructuur.pdf

Port of Rotterdam. (n.d. a). *FAQ, Facts and figures.* Retrieved 09 25, 2013, from Maasvlakte 2: https://www.maasvlakte2.com/en/generic/faq/category/159/

Port of Rotterdam. (n.d. b). *Master Plan for business activity.* Retrieved 09 25, 2013, from Maasvlakte 2: https://www.maasvlakte2.com/en/index/show/id/595/Master+Plan+for+business+activity

Port Said Container & Cargo Handling Co. (2012). *Statistic from 2000 to 2011.* Retrieved 09 25, 2013, from Port Said Container & Cargo Handling Co.: http://test.pscchc.com/getpagesta.aspx?pid=12304&seqid=1

PSA Singapore. (2010a). *Our Core Business - Transhipment.* Retrieved 09 25, 2013, from Singapore PSA: http://www.singaporepsa.com/transhipment.php

PSA Singapore. (2010b). *Our Portfolio - Terminals.* Retrieved 09 25, 2013, from PSA Singapore: http://www.singaporepsa.com/terminal.php

Puerto De Cartagena. (2013). *SPRC/Contecar - Movimiento de carga contenerizada.* Retrieved 09 25, 2013, from Puerto De Cartagena: http://cisne.puertocartagena.com/opadmco.nsf/vstRefLinkDoc/46EBDD5910BBB784052573D0006BABAC

Rodrigue, J.-P. (2013). *Ports with the Highest Transshipment Incidence, 2008*. Retrieved 09 25, 2013, from The Geography of Transport Systems: http://people.hofstra.edu/geotrans/eng/ch4en/conc4en/majoroffshorehubs.html

Salalah Port Services Co. . (2007). *Operations*. Retrieved 09 25, 2013, from Port of Salalah: http://www.salalahport.com/organisation.aspx?id=7865

Sharjah Ports Authority. (2011). *Khor Fakkan*. Retrieved 09 25, 2013, from Sharjah Ports Authority: http://www.sharjahports.gov.ae/Docs.Viewer/6d4a1880-d2d8-407c-a9c9-ec9e8693a1b6/default.aspx

Sri Lanka Ports Authority. (n.d. a). *Java Container Terminal*. Retrieved 09 25, 2013, from Sri Lanka Ports Authority: http://www.slpa.lk/Jaya_container_terminal.asp?chk=6

Sri Lanka Ports Authority. (n.d. b). *Unity Container Terminal*. Retrieved 09 25, 2013, from Sri Lanka Ports Authority: http://www.slpa.lk/unity_container_terminal.asp?chk=6

Taranto Port Authority. (2012). *Data and statisitcs - Data per year*. Retrieved 09 25, 2013, from Taranto Port Authority: http://www.port.taranto.it/en/data-and-statistics/data-per-year.html

The Port Authority of Jamaica. (2006). *Major Ports*. Retrieved 09 25, 2013, from The Port Authority of Jamaica: http://www.portjam.com/nmCMS.php?p=ports

Appendix D Competitiveness

The surrounding ports of the new transshipment port in Jamaica have an influence on the market power of the new transshipment port. The competitiveness of the new port of Jamaica with the surrounding ports will be determined. First the current throughput and transshipment in the Caribbean will be given. After that the factors which influence the competitive power of other ports and the key growth drivers of the Panama Canal expansion will be explained. The competitiveness of other ports will be discussed for different origins and destinations and finally the opportunities for the new port in Jamaica will be discussed.

1 Current situation

First the current trade routes will be listed, separated in global trade routes and trade routes in the Caribbean. Then the current transshipment in the Caribbean and the throughput of the surrounding ports will be discussed.

1.1 Current global trade routes

The global shipping routes of 2007 are shown in Figure D-1. These routes show the busiest areas in the world, like the Panama Canal (indicated with the white circle).

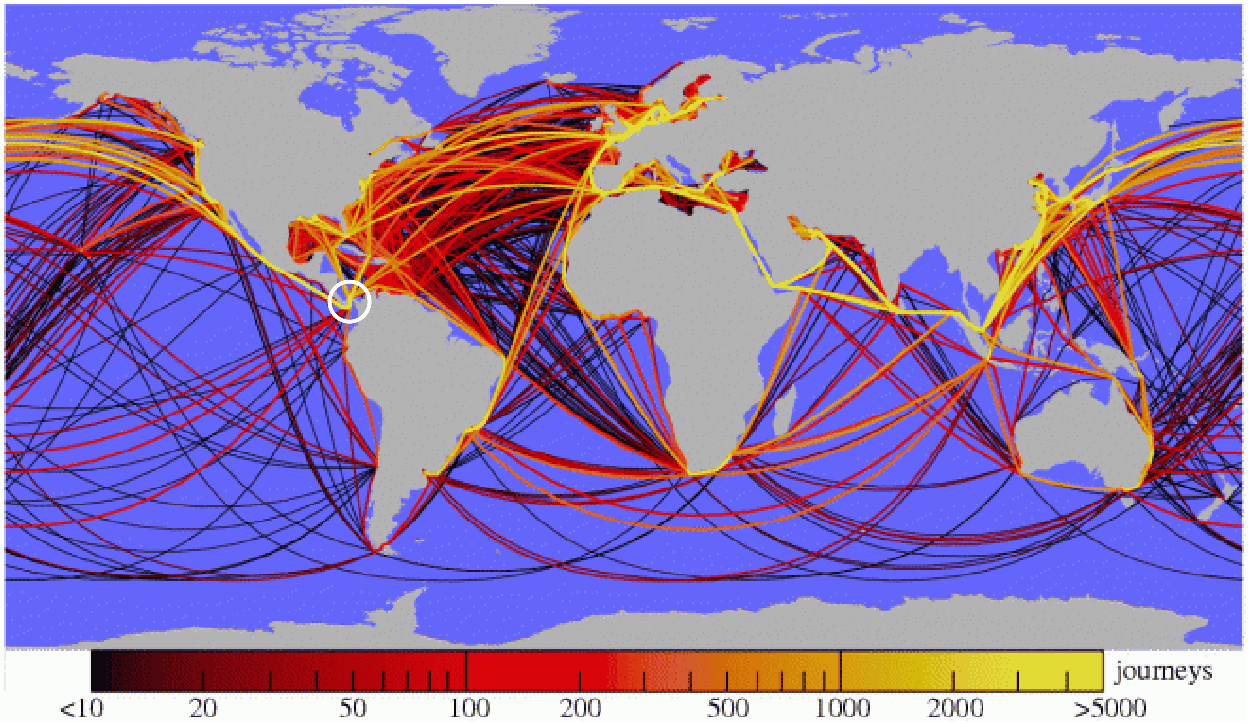


FIGURE D-1: GLOBAL SHIPPING ROUTES IN 2007 (KALUZA, KOLZSCH, GASTNER, & BLASIUS, 2010)

The top global shipping trade routes of 2012 are given in Table D-1. West Bound means that the main shipping route between the two areas takes place to the west. For East Bound, North Bound and South Bound this holds for the same way, but then in their given direction. The routes which probably are transiting the Panama Canal are Asia – North America and Asia – East Coast South America. These two routes have bold letters in Table D-1. It is assumed that the largest part of the trade route North America – East Coast South America will be transported from the East Coast of North America.

Table D-1: Top global shipping trade routes of containers in 2012 in TEU (World Shipping Council, 2013)

No.	Route	West Bound	East Bound	North Bound	South Bound	Total
1	**Asia – North America**	**7,529,000**	**14,421,000**			**21,950,.000**
2	Asia – North Europe	8,959,000	4,406,000			13,365,000
3	Asia – Mediterranean	4,371,000	1,875,000			6,246,000
4	North Europe – North America	2,632,000	1,250,446			4,637,000
5	Asia – Middle East	2,802,151	1,250,446			4,052,597
6	Australia – Far East			1,072,016	1,851,263	2,923,279
7	**Asia – East Coast South America**			**550,000**	**1,399,000**	**1,949,000**
8	North Europe/Mediterranean – East Coast South America			824,000	841,000	1,665,000
9	North America – East Coast South America			667,000	574,000	1,241,000

The global transport volume of containers in 2012 is equal to 125 million TEU. (Hapag Lloyd, 2013) This means the Asia – North America route consists of 12% of the global container shipping volume and the Asia – East Coast South America consists of 4% of the global container shipping volume.

1.2 Current trade routes in the Caribbean

The trade routes, number of vessels, total capacity and the average vessel size of 2009 are shown in Table D-2. Far East (East Asia and Southeast Asia) to Europe and Far East to US West Coast are the two major global trade routes. Their average vessel size are respectively 7,000 TEU per vessel and 5,000 TEU per vessel. At this moment the Panama Canal is able to handle vessels up to about 5,000 TEU. This means that a part of the vessels from the Far East to Europe is taking another route.

The average vessel size of the Intra Caribbean is the lowest of all (see Table D-2). This is caused by the lower export than import in the Caribbean and the containers will be returned empty. It is uneconomical to use much larger vessels, because of the imbalances in trade. Most of the time these smaller vessels have high fuel consumption and high maintenance costs, which causes that the transport costs of the Intra Caribbean are high. (Gozde, 2012)

Table D-2: Trade routes, number of vessels, total capacity and average size of vessel serving the Caribbean (Gozde, 2012)

No.	Trade Routes	No. of vessels	Total capacity (TEU)	Average Size of Vessel (TEU)
1	Far East to Europe	330	2,234,943	7,000
2	Far East to US West Coast	358	1,828,366	5,000
3	Caribbean/Central America to South America	121	204,448	1,700
4	Caribbean /Central America to North America West Coast	64	240,217	3,800
5	Caribbean/Central America to North America Gulf	58	110,282	1,900
6	Caribbean /Central America to South America (West Coast)	58	129,764	1,000
7	Caribbean/Central America to South America (East Coast)	56	132,298	2,400
8	Caribbean to Europe	54	84,040	1,600
9	Intra Caribbean to Central America	25	17,212	700
10	Caribbean to Mediterranean	21	30,090	1,500
11	South Africa to Caribbean/Central America	7	19.503	2.700
12	Australia to Caribbean/Central America	6	12.622	2.300
13	Caribbean/Central America to North/South Pacific	6	13.622	2.300

There are 476 vessels (the sum of no. 3 till 13 in Table D-2) which serve the Caribbean with a total capacity of 994,098 TEU. Over 90% of these vessels are being transshipped at a larger port. (Gozde, 2012)

1.3 Current transshipment in the Caribbean

The ports in the Caribbean are located within the east-west trading routes between Asia, America, Europe and the Middle East. These ports are also located within the north-south trading routes between North and South America and South America and Europe. The Caribbean ports could use of this beneficial geographical position to transship the cargo.

There are some large differences between Caribbean transshipment and transshipment in other parts of the world. The transshipment ports in the Caribbean have minimal export and serve very long feeders. The cabotage bypass trade and trans-Panama Canal make the shipment activities more complex. The market conditions could change rapidly and unexpected. The transshipment in the Caribbean is almost fully intramodal, because these ports haven't got a large hinterland. Investments in transshipment ports are very risky, because the transshipment activities could easily be moved to a competing port (with a higher efficiency or lower rates). This also causes different logistics management in the Caribbean than in other parts in the world. (Frankel, 2002)

Most of the transshipment in the Caribbean takes place in the so called "Caribbean transshipment triangle". This triangle is shown in Figure D-2. There are at least six ports lying in the triangle which are competing for the transshipment activities.

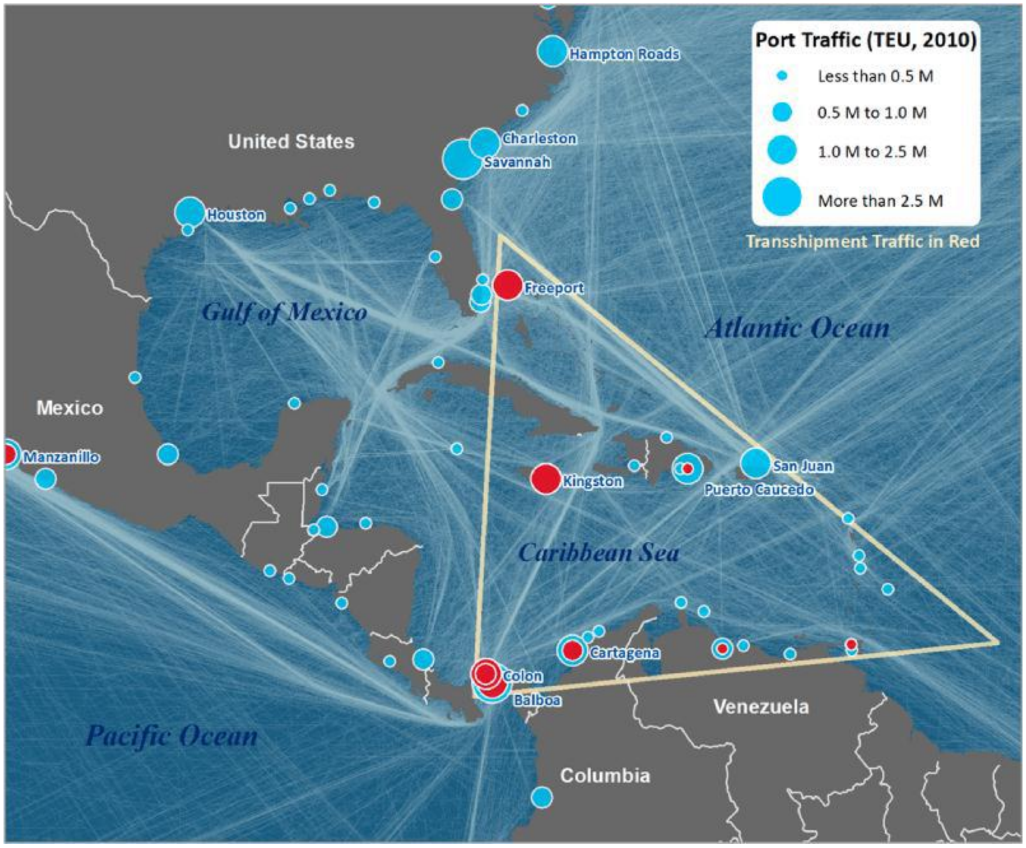


FIGURE D-2: "CARIBBEAN TRANSSHIPMENT TRIANGLE" (GOZDE, 2012)

In 91% of the cases the transshipment in the Caribbean takes place in the larger ports in Panama (Colon), Jamaica (Kingston), Bahamas (Freeport), Dominican Republic (Rio Haina/Caucedo), Colombia (Cartagena) and Trinidad and

Tobago (Port of Spain/Point Lisas). The distribution of transshipment in the Caribbean over these ports is shown in Figure D-3. The other 9% of transshipment in the Caribbean takes place in smaller ports which share also is included in Table D-3.

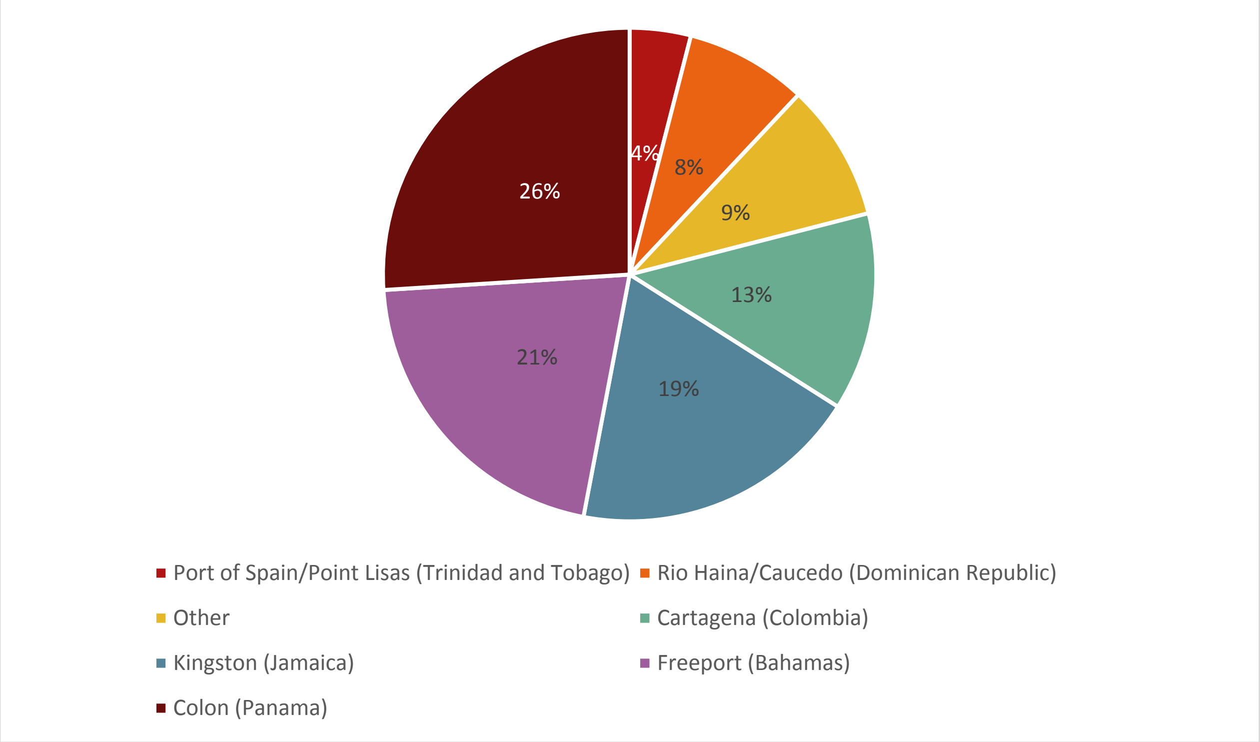


FIGURE D-3: PERCENTAGE OF TRANSSHIPMENT PER PORT IN THE CARIBBEAN (GOZDE, 2012)

The transshipment percentage of the total throughput of the ports named in Figure D-3 is shown in Figure D-4. Freeport's activities are almost entirely transshipment. Colon and Kingston have also a high percentage of transshipment.

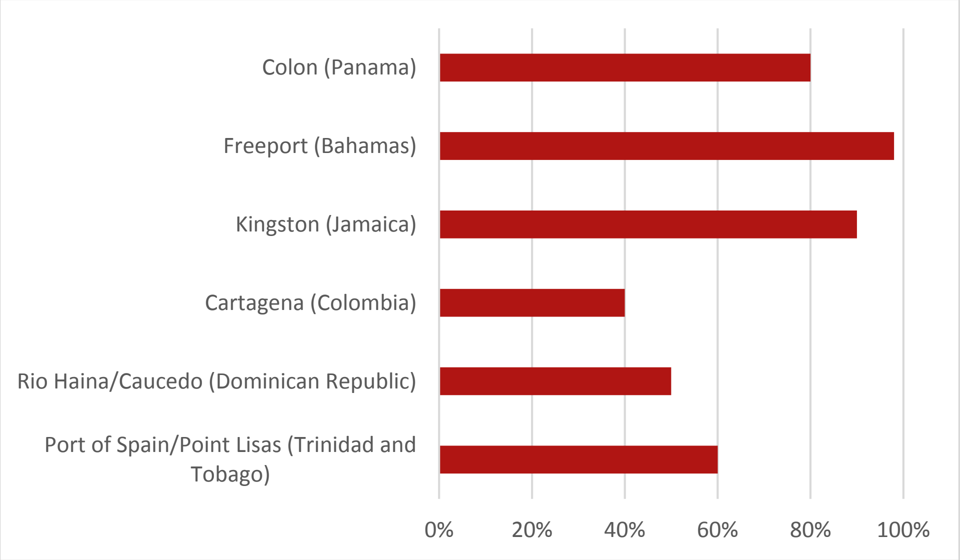


FIGURE D-4: TRANSSHIPMENT PERCENTAGE OF TOTAL THROUGHPUT OF THE PORTS FROM FIGURE D-3 IN THE CARIBBEAN (GOZDE, 2012)

It is visible in Table D-3 that the port of Kingston ships 19% of the total transshipment in the Caribbean. Figure D-4 shows that the port of Kingston does 85% transshipment. This can also be read for the other ports.

1.4 Throughput of surrounding ports

The throughput of the surrounding ports in 2011 is used to give an indication of the current situation in and around the Caribbean. In Table D-3 a list of the surrounding ports with their corresponding throughput is shown. Only the ports with a throughput higher than 600,000 TEU in 2011 are taken into account.

TABLE D-3: THROUGHPUT OF THE SURROUNDING PORTS IN 2011 (AMERICAN ASSOCIATION OF PORT AUTHORITIES, 2012) (ECONOMIC COMMISSION FOR LATIN AMERICA AND THE CARIBBEAN, 2012)

Port (country)	**Throughput in TEU in 2011**
North America	
New York/New Jersey (U.S.A.)	5,503,485
Savannah (U.S.A.)	2,944,678
Virginia (U.S.A.)	1,918,029
Houston (U.S.A.)	1,866,450
Charleston (U.S.A.)	1,381,352
Miami (U.S.A.)	906,607
Jacksonville (U.S.A.)	899,258
Everglades (U.S.A.)	880,999
Baltimore (U.S.A.)	631,804
Caribbean, Central America and South America	
Colon (Panama)	3,371,714
Balboa (Panama)	3,232,265
Manzanillo (Panama)	1,899,802
Cartagena (Colombia)	1,853,342
Kingston (Jamaica)	1,756,832
San Juan (Puerto Rico)	1,484,595
Freeport (Bahamas)	1,116,272
Caucedo (Dominican Republic)	960,000
Limon Moin (Costa Rica)	901,330
Veracruz (Mexico)	732,538
Puerto Cabello (Venezuela)	721,500

The throughput of the surrounding ports is used to make a distinction between small and large ports. It is assumed that only large ports, here defined as ports with a throughput higher than 600,000 TEU per year, could have competitive power.

2 Factors which influence the competitive power

The competitive strength of ports compared to each other depends on different factors. The factors which influence the competitive power of other ports are in this case:

- Ability to handle Post-Panamax vessels
- Geographical position of the ports
- Price and efficiency of the ports

2.1 Ability to handle Post-Panamax vessels

After the expansion of the Panama Canal Post-Panamax vessels are able to sail through the canal. At this moment not every port is able to handle these vessels. Some ports are therefore expanding their port or deepening their port. There are even plans for constructing new ports. Some ports can't handle the Post-Panamax vessels and don't have plans to do so (or the plans are yet unknown). For each of the surrounding ports, which are the same ports as mentioned in Table D-4, their ability to handle Post-Panamax vessels is summed. The surrounding ports are separated in North America and the Caribbean, Central America and South America.

North America

The port of Baltimore and port of Virginia in Norfolk are already expanded and they can handle the Post-Panamax vessels. (NPR, 2013)

In July 2013 the Obama administration announced that the expansion and modernization of the port of Savannah, New York and New Jersey, Charleston, Jacksonville and Miami will be expedited. In 2014 the Port Authority of New York and New Jersey expects to be able to handle the Post-Panamax ships by deepening its harbor. However, the deck of the Bayonne Bridge has to be raised before the Post-Panamax ships are able to reach the terminals.
The deepening of the port of Savannah is expected to be finished in the second half of 2016. (Miami Herald Americas, 2012)

The port of Miami is expanding and expects to be ready in late 2014 or early 2015. The completion of the expansion of Port Everglades is expected to be ready in 2016. (Progressive Railroading, 2013)

The port of Charleston is at this moment only deep enough to handle Post-Panamax ships at high tide. The deepening of the port is a candidate for federal funding. When the funding is approved, the deepening project could be finished 2019. (Examiner.com, 2013)

For the deepening of the port of Jacksonville a length of more or less 21 kilometers has to be dredged, which brings a lot of costs ($733 million) and the St. Johns River will be (environmentally) harmed. It isn't clear if there is enough funding and support. When the river will be deepened to 14.3 meters it will be ready in 2021, but this is not enough to handle the Post-Panamax vessels. (The Florida Times Union Jacksonville.com, 2013)

The Caribbean, Central America and South America

The Freeport Container Terminal in the Bahamas can already accommodate Post-Panamax vessels. (Miami Herald Americas, 2012)

The port of Caucedo in the Domican Republic and the Panama terminals are able to handle the Post-Panamax ships at this moment. (Inter-American Development Bank, 2013)

The Moin Container Terminal in Costa Rica is dredging the canal to accommodate Post-Panamax vessels. The project is expected to be completed in 2016. (McClatchy, 2012) (Ticotimes.net, 2012)

About 30 miles west of Havana, Cuba, a project will be executed in Mariel to handle Post-Panamax ships. There will be a new area for containers with an initial capacity of 3 million containers per year. (The Panama News, 2013) (Progreso Weekly, 2013)

The port of Cartagena in Colombia already receives Post-Panamax vessels. (SeeNews Shipping, 2013)

The port of Veracruz (Mexico) isn't able to expand. Therefore Veracruz 2 will be built in three phases between 2013 and 2025. After finishing this project the port of Veracruz is able to accommodate Post-Panamax vessels. (Lloyd's Loading List, 2013)

The above information about the surrounding ports is summarized in Table D-4. A slash mark indicates that the port will not able to handle Post-Panamax vessels or this isn't known yet. A question mark indicates that the moment when the port can handle the Post-Panamax vessels isn't known.

TABLE D-4: SURROUNDING PORTS: ABILITY TO HANDLE POST-PANAMAX VESSELS AND THE DEEPENING, EXPANDING OR A COMPLETE NEW PORT

Port	**When able to handle Post-Panamax vessels?**	**Deepening, expanding or a complete new port?**
North America		
New York/New Jersey (U.S.A.)	2014	deepening
Savannah (U.S.A.)	2016	deepening
Virginia (U.S.A.)	already able	/
Houston (U.S.A.)	/	/
Charleston (U.S.A.)	2019?	deepening
Miami (U.S.A.)	2015	deepening
Jacksonville (U.S.A.)	/	/
Everglades (U.S.A.)	2016	expansion
Baltimore (U.S.A.)	already able	/
Caribbean, Central America and South America		
Colon (Panama)	already able	/
Balboa (Panama)	already able	/
Manzanillo (Panama)	already able	/
Cartagena (Colombia)	already able	/
Kingston (Jamaica)	/	/
San Juan (Puerto Rico)	/	/
Freeport (Bahamas)	already able	/
Caucedo (Dominican Republic)	already able	/
Limon Moin (Costa Rica)	2016	expansion
Veracruz (Mexico)	2025?	new port
Puerto Cabello (Venezuela)	/	/
Mariel (Cuba)	?	new port

2.2 Geographical position of the surrounding ports

The geographical position of the ports close to Jamaica is shown in Figure D-5. The color represents the ability to handle Post-Panamax vessels and the size of the dot represent the throughput of 2011 of the port (see Table D-3). For instance, New York has a throughput of 5 million TEU, which is relatively high compared to the other ports, and has therefore a relatively large dot. The port of Kingston has a throughput of 1.8 million TEU, which is why the dot is smaller than the dot of New York.

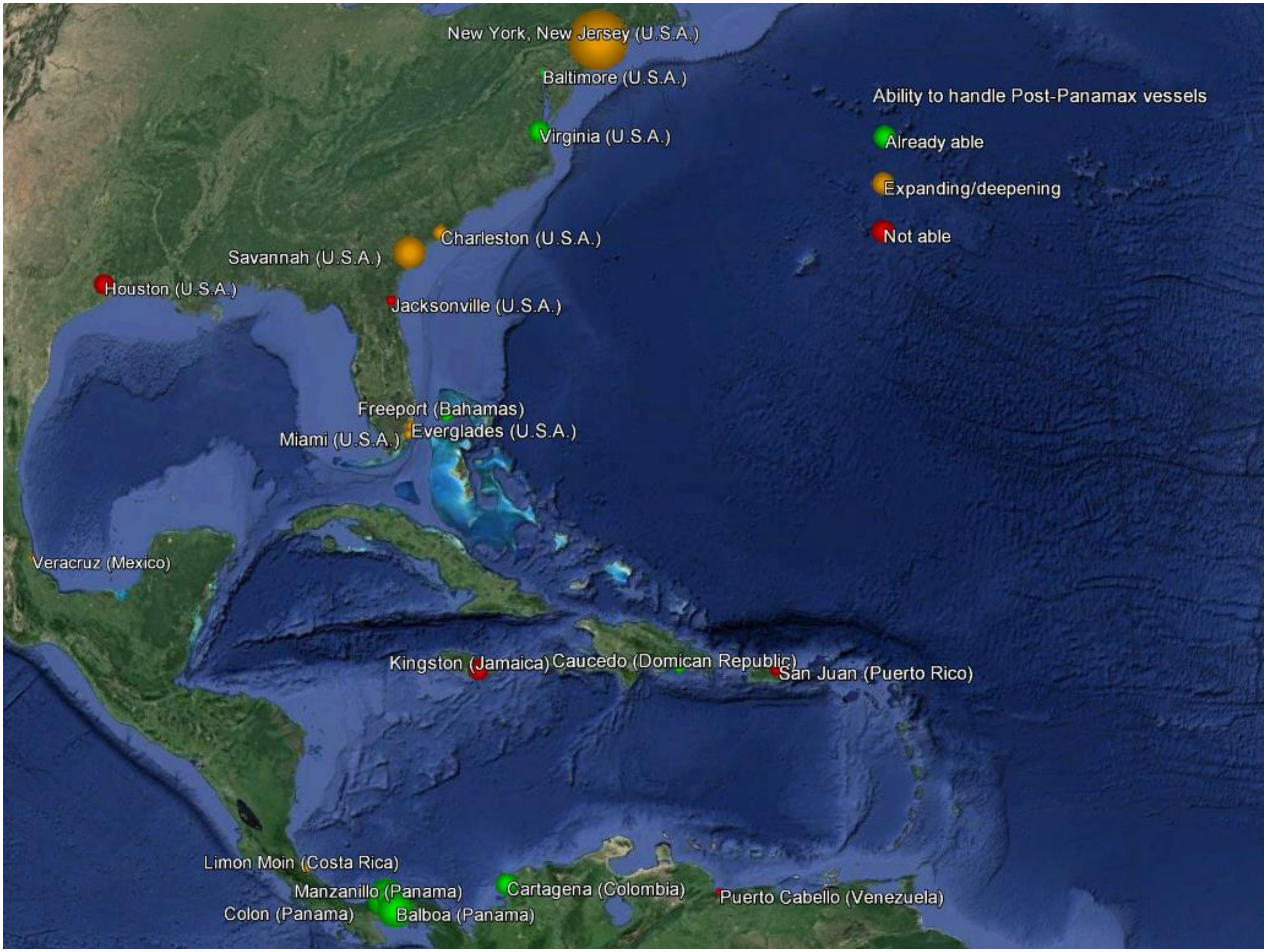


FIGURE D-5: THE SURROUNDING PORTS OF JAMAICA

2.3 Price and efficiency of other ports

It is assumed that the price of the surrounding ports is determined by a price per container and a price per type of vessel. It is assumed that there is no significant difference between the prices of transshipment at different ports.

The ports which want to handle Post-Panamax ships must all have special cranes for this type of ships and it is assumed that these ports will all have the same kind of equipment. The efficiency of a port is normally about what a port can do with a certain surface. In this section efficiency is only about the waiting time and the handling time (mooring, unloading, loading and sail out again). It is also assumed that all the ports have more or less the same waiting time and handling time. These two factors together cause that the efficiency of all the ports will be more or less the same.

Because of these assumptions it is determined that there is no significant difference in the price and efficiency between the new port and the surrounding ports and this will not be taken into account as a different criterion to determine the competitiveness of the surrounding ports.

Because the price and the efficiency of the surrounding ports will not be taken into account. The competitiveness will only be determined looking at the geographical position of the surrounding ports and their ability to handle Post-Panamax vessels.

3 Key growth drivers of the Panama Canal expansion project

In 2012 12.2 million TEU is transited in the Panama Canal. In 2006 the containerized cargo shipped between Northeast Asia and the U.S. East Coast (using the Panama Canal) is more than 50% of the total containerized cargo passing the Panama Canal. This route is also expected to be the key growth driver of the Panama Canal. (Panama Canal Autorithy, 2006) This is further explained in appendix A, Background information. As shown in Table D-1, in 2012 14,421 million TEU is shipped from Asia to North America (12% of the total shipped containers in the world) and 7,529 million TEU from North America to Asia (4% of the total shipped containers in the world). (World Shipping Council, 2013) (Hapag Lloyd, 2013)

Figure D-6 shows the cost for shipping a container between Shanghai and North America. The equivalence line before and after expansion shows the opportunities for shipping containers via the East Coast instead of the West Coast of North America after the expansion. This will cause that more containers will be handled at port at the East Coast. It must be noted that there are a few factors the equivalence line depends on are uncertain, such as the energy price, increase in toll of the Panama Canal and the capacity of the inland rails in North America. (Rodrigue & Notteboom, 2011)

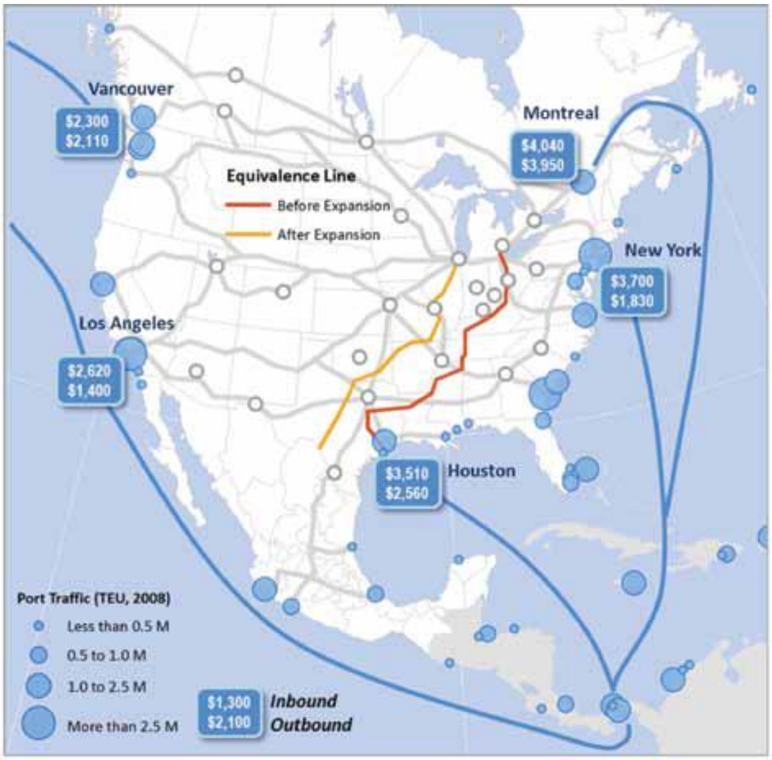


Figure D-6: Shipping rate in USD for a 40-foot container with Shanghai, selected port pairs, mid 2010 (Rodrigue & Notteboom, 2011)

The main key growth driver for the expansion of the Panama Canal is assumed to be the change in handling containers at the East Coast of North America instead of the West Coast of North America. The containers will not be transported to the ports at the West Coast and further transported over land, but will be transported to the East Coast and then transported over land. Even though there could also be a growth in the trade between the West Coast of the United States and the East Coast of South America. Especially Brazil must be taken into account, because of its emerging market. (Dengo, 2012)

Next to this the annual global growth of containers must be taken into account. The latest container port demand projections from Drewry forecasted a compound average global annual growth of 5.4% to 2017. (Drewry, 2013) This annual growth will effect on containerized cargo through the Panama Canal.

4 Competitiveness of surrounding ports for different areas

The competitiveness of the other ports will be discussed for the following areas:

- South of North America
- Middle of North America
- South of North America
- Europe
- Africa
- South America

It is assumed that only the transshipment for containers transiting the Panama Canal will be taken into account. The different destination areas are shown in Figure D-7.

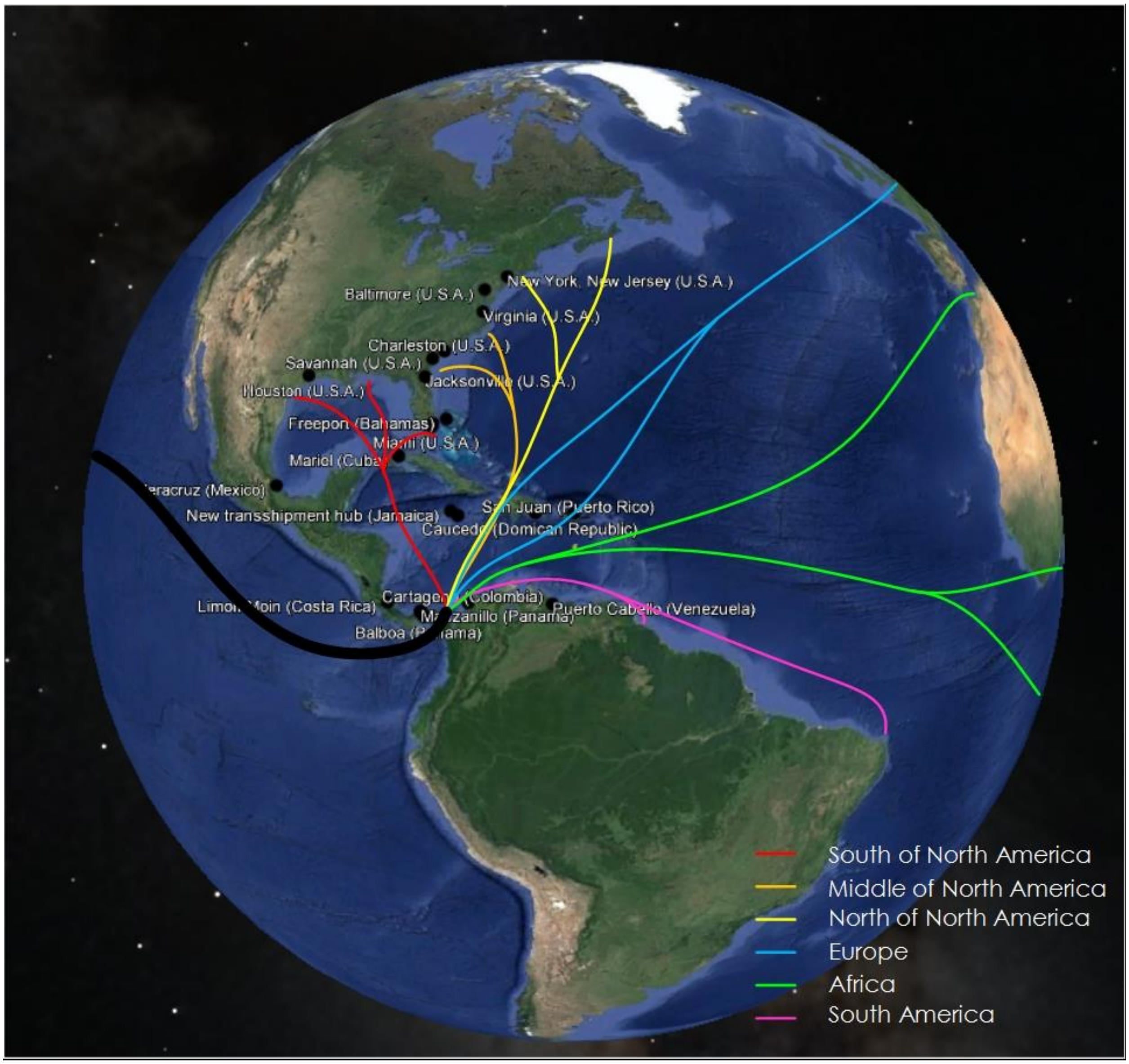


Figure D-7: The destination of containers through the Panama Canal divided in multiple areas

4.1 South of North America

Containers which have the west of the south of North America as destination could be shipped to Veracruz. Containers which have the middle of this area as destination could be shipped to Houston and containers with the east of this area as destination to Miami or Everglades, see Figure D-7. However, Houston cannot handle Post-Panamax vessels, Veracruz cannot handle Post-Panamax until 2025 and Everglades cannot handle Post-Panamax until 2016. Therefore transshipment in ports in (north) Panama, Jamaica or Cuba (see Figure D-7) could be very interesting alternatives. However, for Jamaica and Cuba an additional 350 kilometers has to be traveled (except for the route via Cuba to the east of the south of North America).

4.2 Middle of North America

Containerized cargo with the middle of North America as destination could be directly shipped to the ports of Jacksonville, Charleston or Savannah, see Figure D-7. Though, Jacksonville can’t handle and Charleston can’t handle Post-Panamax vessels until 2019. These vessels could also transship their cargo at the ports in Panama, the new port in Jamaica, Mariel or Freeport/Miami (see Figure D-7). The ports in Panama are more or less 1000 kilometers further away from the middle of North America than the new port in Jamaica and Mariel. Freeport and Miami are again 600 shipping kilometers closer to the middle of North America than Mariel (Mariel requires a detour of 200 kilometers) and 1100 shipping kilometers closer than Jamaica.

4.3 North of North America

For the shipping of containers to the north of North America region there are multiple possibilities. The containers could be directly shipped to the ports in that region, such as Virginia, Baltimore or New York/New Jersey, but also could be transshipped at ports further away from the destination such as the new port in Jamaica (almost no detour) or Freeport and ports in the middle of North America region (but these routes require a detour of more or less 300 kilometers). These ports are shown in Figure D-7.

4.4 Europe

Containers going to Europe could be transshipped at the ports of Panama, Cartagena, Caucedo and the new port in Jamaica, see Figure D-7. All these ports can handle Post-Panamax vessels when the Panama Canal expansion is finished and the corresponding shipping routes have no detour or a very small detour.

4.5 Africa

Post-Panamax vessels transiting the Panama Canal with Africa as destination could transship their containers at several ports such as the ports in Panama, Cartagena and with a destination in the north of Africa at the new port in Jamaica or at the port of Caucedo (see Figure D-7).

4.6 East Coast of South America

Containers which will be shipped to the east coast of South America could be transshipped at the ports in Panama or the port at Cartagena (see Figure D-7). Puerto Cabello is also at the route, but isn’t able to accommodate Post-Panamax vessels. The new port in Jamaica and Caucedo could also transship the containers, but that will take an extra 700 shipped kilometers.

5 Expectations of the new transshipment port in Jamaica

The new port in Jamaica has good opportunities for transshipping containers transiting the Panama Canal with the south of North America and the middle of North America as destination. Vessels with the north of North America and South America as destination could transship their containers at the new port of Jamaica. This isn't the most optimal location, but a good alternative. For container vessels with multiple ports at the East Coast of North America as destination (the middle and the north of North America) the new port in Jamaica is a location which has a large potency to accommodate these vessels (but there are competitive ports such as Mariel and Freeport).

The highest share of opportunities for the new port in Jamaica is the transshipment of containers with North America as destination. This is caused by the amount of containers which has to be shipped to North America is by far the largest stream transiting the Panama Canal and the stream of containers going to the East Coast of North America is assumed to be the key growth driver of the Panama Canal expansion. The East Coast becomes more attractive for transshipping a part of the containers to North America compared to the West Coast, because the shipping costs to the East Coast become lower after expansion of the Panama Canal (by using larger ships, the Post-Panamax ships).

For containers transiting the Panama Canal which have to be transshipped west of the Canal and have to be shipped to Europe or the north of Africa the new port would have a perfect position. Containers with South America as destination could be transshipped at the new port in Jamaica, but this brings an extra detour.

It must be stated that container trade between (the East Coast of) North America and (the North and East Coast of) South America also brings opportunities for transshipment in Jamaica (but also for other ports in the Caribbean). Next to that, Jamaica still could do transshipment to serve the other islands in the Caribbean by doing the transshipment from Post-Panamax vessels to feeder vessels.

To attract shipping companies to the new transshipment port in Jamaica the price and efficiency of the new port must be competitive with/better than other ports. This means that the new port must not have a too large waiting time, the port must have suitable equipment and technology and the dwell time of containers must be appropriate. It must be noted when these factors aren't good enough to compete with other ports, shipping companies probably will switch to another port. The shipping companies are not dependent on the port in Jamaica, because the port hasn't a large hinterland and will be used for transshipment primary.

In appendix G, Design values, the expected throughput of the new transshipment port is determined. The expected throughput is equal to almost 7 million TEU per year. The expected throughput transiting the Panama Canal is equal to 32.4 million TEU in 2025, see appendix A, Background information. This means the expected throughput of the new transshipment hub will then be 21.6% of the total expected volume transiting the Panama Canal. It is possible for Jamaica to achieve this percentage. Jamaica has a good geographical position for a transshipment port and will be able to handle the Post-Panamax vessels, but the shipping lines must choose for Jamaica. This also depends on the price and efficiency of the new port.

6 Nicaragua Canal

Even though there are uncertainties about the Nicaragua Canal project, it is possible the Canal will be built. More information about the Nicaragua Canal is given in appendix A, Background information. When the Canal will be built, the government expects the first ships that can pass will be after six years and the total construction time will take ten years. This Canal allows mega-container ships, which are double the size of the container ships that can pass the Panama Canal after expansion. When the decision making process proceeds extremely rapid, the first ships will transit the Canal in 2020.

The construction of the Canal has an impact on the ports in the Americas west of the Canal. When mega-container ships could transit the Canal, these ports probably want to expand or deepen their port to accommodate these vessels. The new port of Jamaica has a good geographical position for a transshipment port (this is for the Nicaragua Canal quite the same as the Panama Canal), but it is questionable if the port will deepen or expand. The competitiveness with other ports is uncertain, will the other ports be able to accommodate these mega-container ships? Next to that, it isn't sure what happens in the (early) future with the new transshipment port in Jamaica. Concluding, the construction of the Nicaragua has an influence on the transshipment port in Jamaica, but in this stage it isn't possible to identify the consequences for Jamaica.

7 References

American Association of Port Authorities. (2012, 4 30). *North America contraner traffic 2011 port ranking by TEUs*. Retrieved 17 9, 2013, from http://aapa.files.cms-plus.com/PDFs/NORTH%20AMERICA%20PORT%20CONTAINER%20TRAFFIC%20RANKING%202011_1361895265064_1.pdf

Dengo, M. (2012). The Panama Canal expansion and its impact on world trade. *Port Technology International*, pp. 12-13.

Drewry. (2013, 8 11). *Slow growth still means big absolute increases.* Retrieved 10 1, 2013, from Drewry Martime Research: http://ciw.drewry.co.uk/port-developments/slow-growth-still-means-big-absolute-increases/

Economic Commission for Latin America and the Caribbean. (2012). Port container traffic in Latin America and the Caribbean 2011. *FAL Bulletin, 3*(307).

Examiner.com. (2013, 9 16). *Labor meets Biden at Port of Charleston*. Retrieved 9 17, 2013, from http://www.examiner.com/article/labor-meets-biden-at-port-of-charleston

Frankel, E. G. (2002). The challange of container transshipment in the Caribbean. *IAMA Panama 2002 Conference Proceedings.*

Gozde, I. (2012). Logistics Connectivity in the Caribbean: Current Challenges and Future Prospects. *Stocktaking note for the Caribbean Growth Forum.* Kingston.

Hapag Lloyd. (2013). *Annual report 2012.* Retrieved 10 1, 2013, from Hapag Lloyd: http://www.hapag-lloyd.com/downloads/news/hapag_lloyd_annual_report_2012_en(1).pdf

Inter-American Development Bank. (2013, 3 16). *Cental America and Dominican Republic need to boost logistics coordination, IDB studies show*. Retrieved 9 17, 2013, from http://www.iadb.org/mobile/news/detail.cfm?Language=English&id=10379#getPage(1042,",")

Kaluza, P., Kolzsch, A., Gastner, M. T., & Blasius, B. (2010). The complex network of global cargo ship movements. *Interface, 7.*

Lloyd's Loading List. (2013, 6 12). *Mexico Focus: Veracruz thinks big*. Retrieved 9 17, 2013, from http://www.lloydsloadinglist.com/freight-directory/sea/mexico8200focus-veracruz-thinks-big/20018051852.htm;jsessionid=BACB85DB88B469902FDA656ACABD85FC.f11b1cefac76ad95c7627468fee9bde7e866d022#.UjscpcbmN7F

McClatchy. (2012, 11 23). *Latin American ports ready for Panama Canal expansion*. Retrieved 9 17, 2013, from http://www.mcclatchydc.com/2012/11/23/175384/latin-american-ports-ready-for.html#.Ujir1sbmN7G

Miami Herald Americas. (2012, 11 22). *As Panama Canal expands, Latin America rushes to be ready*. Retrieved 9 16, 2013, from http://www.miamiherald.com/2012/11/22/3108959/as-panama-canal-expands-latin.html

Miami Herald Americas. (2012, 11 18). *Competition heats up as U.S. ports prepare for Panama Canal expansion*. Retrieved 9 16, 2013, from http://www.miamiherald.com/2012/11/18/3104323/competition-heats-up-as-us-ports.html

NPR. (2013, 5 6). *Port Of Baltimore Seeks Boost From Panama Canal Expansion*. Retrieved 9 16, 2013, from http://www.npr.org/2013/05/06/180914866/port-of-baltimore-seeks-boost-from-panama-canal-expansion

Panama Canal Autorithy. (2006). *Proposal for the Expansion of the Panama Canal.*

Progreso Weekly. (2013, 9 20). *Raul Castro signs decree for Mariel Development Zone.* Retrieved 9 23, 2013, from Progreso Weekly: http://www.progresoweekly.us/20130920-raul-castro-signs-decree-mariel-development-zone/

Progressive Railroading. (2013, 4). *Panama Canal expansion spurs, railroads, ports to prepare for new business*. Retrieved 9 16, 2013, from http://www.progressiverailroading.com/rail_industry_trends/article/Panama-Canal-expansion-spurs-railroads-ports-to-prepare-for-new-business--35793

Rodrigue, J., & Notteboom, T. (2011). The Panama Canal expansion: Business as usual or game-changer? *Port Technology International*, pp. 10-12.

SeeNews Shipping. (2013, 4 22). *Colombias Cartagena port to boost capacity by 2017*. Retrieved 9 17, 2013, from http://shipping.seenews.com/news/colombias-cartagena-port-to-boost-capacity-by-2017-report-348360

The Florida Times Union Jacksonville.com. (2013, 3 31). *Deepening Jacksonville ship channel would cost $733 million*. Retrieved 9 17, 2013, from http://jacksonville.com/news/metro/2013-05-30/story/deepening-jacksonville-ship-channel-would-cost-733-million

The Panama News. (2013, 8 6). *Cuba developing a new mega-port and free zone*. Retrieved 9 17, 2013, from http://www.thepanamanews.com/pn/v_19/issue_06/economy_special_07.html

Ticotimes.net. (2012, 8 10). *Court OKs Moin port project*. Retrieved 9 17, 2013, from http://www.ticotimes.net/More-news/Top-Story/Court-OKs-Moin-port-project_Friday-August-10-2012

World Shipping Council. (2013). *Trade Routes*. Retrieved 9 24, 2013, from http://www.worldshipping.org/about-the-industry/global-trade/trade-routes

Appendix E Port model & financing scheme

When a new port will be realized in Jamaica, this has to be regulated well. For Jamaica and CHEC the best balance has to be found looking at the owning and operating of the new port. The kind of port model that will be applied and the financing scheme have to be defined. The rights, duties and responsibilities per party have to be known and the arrangements between CHEC and Jamaica have to be well formulated.

1 Port model

There are different kinds of port models which can be implemented at the new port in Jamaica. Four different port models can be distinguished:

1. **Public service port**
   In this model there is a public port authority. This port authority owns and operates all equipment, so fulfills the function of both port authority and port operator. The infrastructure, superstructure and port labor are regulated by the public sector. The other functions are for the majority by the public sector regulated.
2. **Tool port**
   In this model there is also a public port authority which owns all equipment, but this equipment is operated by private firms. The infrastructure and superstructure are regulated by the public sector, the port labor by the private sector and the other functions by a combination of both.
3. **Landlord port**
   In this model there is a public port authority which is not involved in port operations and there are private operators (generally concessionaires). The infrastructure will be regulated by the public sector, the superstructure and port labor by the private sector and the other functions by a combination of both.
4. **Private service port**
   In contrast to the first three models this model has a private port authority which owns and operates all equipment, so fulfills the function of both port authority and port operations. Port infrastructure is financed/built/owned by the private sector. The infrastructure, superstructure and port labor are regulated by the private sector. The other functions are for the majority regulated by the private sector.

(Turpin, 2013)

In Table E-1 the different types of port models are given. The kind of organization per component of the port are indicated.

TABLE E-1: DIFFERENT TYPES OF PORT MODELS WITH THE KIND OF ORGANIZATION PER COMPONENT OF THE PORT

No.	Type	Infrastructure	Superstructure	Port labor	Other functions
1	Public service port	Public	Public	Public	Majority public
2	Tool port	Public	Public	Private	Public/Private
3	Landlord port	Public	Private	Private	Public/Private
4	Private service port	Private	Private	Private	Majority Private

(World Bank, n.d.)

China Harbour Engineering Company (CHEC) is a company that is privately owned and not part of the government. This company wants to invest in the development of the new port in Jamaica. CHEC did more projects in Jamaica in which CHEC operates the constructions, see appendix B, Stakeholder analysis. It can be concluded that the infrastructure will be paid by the Chinese company and not by the government of Jamaica. The first three port models include a public port authority and this port authority also owns the infrastructure. This is not suitable for the case of the new port in Jamaica. The fourth port model will be most suitable for the project, because it has a private port authority which will also finance and build the infrastructure. The private service port model will be the most suitable model for the new port. The advantage of a private service port is that the investment will be done by the private sector. This results in a higher efficiency in the port, because companies wants to make the most possible profit. A private company has other priorities than the government. The private companies for instance could have less priority for the nautical safety and the environmental aspects.

Within the choice of a private service port model there are two sub-models:

1. Full privatization
   With a full privatization the land will be transferred from the public to the private sector and will then be privately owned. The government also transfers the regulatory functions to the private companies. Full privatization includes some risks, such as the possibility that the private sector will sell the land for non-port activities.
2. Full concession
   The private company will be the concessionaire and will have both the functions of port authority and port operator. All the rights and obligations of the concessionaire will be defined in a concession contract. The land will not be sold and the public sector still will be the owner of the land.

(Turpin, 2013)

For the project of the new port in Jamaica a full concession will be appropriate, because the land will still be owned by the Jamaican government, but CHEC will fulfill both the functions of port authority and port operator. The owning of the land by the Jamaican government is important, because there is no risk that CHEC could sell the land (this is a risk in case of a full privatization) and probably the government doesn't want to sell their land to CHEC anyway. (World Bank, n.d.)

2 Financing scheme

A concession contract is often combined with a financing scheme, like Build, Operate and Transfer (BOT). A BOT arrangement is a project based on the granting of a concession by the government to a concessionaire. The concessionaire will be responsible for the construction, financing, operation and maintenance of a facility during the term of the concession. After this term the facility will be transferred to the government at no cost or at a pre-determined price. During the concession period the concessionaire owns, operates, maintains and operates the facility. (World Bank, n.d.)

In this case the facility will be an entire port complex. The project includes the development of an entire port complex, so this port will be a green field port. A BOT agreement is an appropriate financing scheme for the new port, because CHEC will then be responsible for constructing, financing, operating and maintaining the new port. CHEC does the investments and can operate the port in the way they want it. Jamaica doesn't have financial responsibilities and the land will be transferred back to Jamaica after the concession period.

The port operator, CHEC, takes the role of a landlord port authority for the assets it has agreed to construct. The terminals of the new port will be sub-leased by the master concessionaire to third parties. In this case CHEC will be the master concessionaire.

In a BOT scheme there will be a contract, which contains clauses that cannot be changed. For example, duration of the concession and payments will be included in the contract. There will also be a license, in which the permitting changes in activities or performance by CHEC will be explained. (World Bank, n.d.)

The financial distribution could be organized such that CHEC collects all port dues, including wharfage and berth dues. The government Jamaica is paid by CHEC for leasing the land with a base fixed fee plus a variable fee based on revenue or cargo. The government of Jamaica then benefits from the increasing value of the port. (World Bank, n.d.)

With a BOT scheme, CHEC will build and operate the port, but is also is responsible for completing the project and operating it in a financially feasible way with the associated risks. After the concession period, the assets are transferred back to the government of Jamaica. The value of the transfer of the port depends on the economically and/or technically condition of the port. After the transfer the government could lease out the port or grant another concession and enter it into a management contract. (World Bank, n.d.)

There are some planned BOT projects which failed, because their terms are negotiated without looking at the profitability of the project. First the financial feasibility and the debt repayment capacity of the project has to be investigated, by using the BOT agreement and the business plan to make estimates of likely revenues, costs, debt repayment and profit of the private sector. (World Bank, n.d.)

3 Consequences for Jamaica

With the BOT arrangement the government of Jamaica gives CHEC the responsibility for constructing, financing, operating and maintaining the port. Jamaica doesn't have to invest in the new port and doesn't have to take care of the financial risks. The land of the port will be transferred to CHEC, but after the period of concession Jamaica gets the land back together with the new port. At that point Jamaica can decide what to do with the port, for instance lease the port or grant a concession for a management contract, as mentioned in chapter 2.

The construction of the new port possibly will employ 2.000 people and after construction 10.000 people will be employed. The Prime Minister of Jamaica has said that "it will be a non-negotiable requirement that the majority of these workers will be Jamaican nationals." (Jamaica Information Service, 2013) In earlier projects in Jamaica CHEC used Jamaican subcontractors (see appendix A, Background information), which is also possible in this project.

The government of Jamaica will receive a base fixed fee and a variable fee based on the revenue or based on the cargo. This means that Jamaica will also benefit when business is going better.

Because CHEC owns and operates the port equipment and builds the port infrastructure, Jamaica doesn't have much influence on the activities in the port itself and on the design of the new port. The contract must carefully be established, because the fees, the duration and the price of the transfer after the concession period are determined in the contract. If Jamaica wants that its people (and the sub-contractors) will be employed, this must also be defined well or clear agreements must be made.

However, there are some indirect financial risks for the current port of Kingston. When there will be a new port in Jamaica, the transshipment activities of the current port in Kingston probably will be moved to the new port in Jamaica, because of its (probably) better equipment, price or lower handling time. For the transshipment part of the port a new function must be established, so the port of Kingston still has enough activities and could make profits.

Probably not only the infrastructure in the new port is taken into account in the design, but also the hinterland connection. During the construction a connection to the port is needed and after the construction this connection to the port is used for the transportation of employees. This connection could be a road connection, but rail is also possible. CHEC has already done more projects in Jamaica for the construction of roads in Jamaica, see appendix A, Background information. For the design of the new port the hinterland connection should be included. This is designed in appendix N, Hinterland connection. When the hinterland connection is also taken into account in the design, this has to be included in the contract.

4 Consequences for CHEC

When a private service port is chosen and the BOT agreement will take place, CHEC has got the freedom to construct and operate the new port in the way they want it. Although CHEC is responsible for the financial risks and has to do all the investments. Therefore the investigation of the financial feasibility and the debt repayment capacity are very important. The contract with Jamaica is of great importance for CHEC, especially for the payments and the duration of the concession.

5 References

Jamaica Information Service. (2013, 05 01). *CHEC to invest US$1.5 billion in transshipment port*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/122-parliament/33743-chec-to-invest-us15-billion-in-transshipment-port

Turpin, F.-M. (2013, 4 12). PPP in ports, landlord port model. Tbilisi, Georgia. Retrieved 10 4, 2013, from http://www.traceca-org.org/uploads/media/04_Module_C_PPP_Francois_Marc_Turpin_new.pdf

World Bank. (n.d.). *World Bank port reform tool kit; Module 3: Alternative port management structures and ownership models.* Retrieved 10 4, 2013, from http://rru.worldbank.org/Documents/Toolkits/ports_fulltoolkit.pdf

Appendix F Redevelopment of the port of Kingston

The port of Kingston has at this moment a high transshipment percentage of 85% of the total throughput. When the new port is realized the transshipment probably will be moved from the port of Kingston to the new port, because the new port will have a higher efficiency and can handle larger vessels. The space that normally is used for transshipment could therefore be used for another purpose.

1 Possibilities for redevelopment

The current dry area of the port of Kingston is equal to 194 hectares (=1.94 km^2). (Commonwealth Network, n.d.) With a transshipment percentage of 85% and a throughput of 2.8 million TEU it can be calculated that ((1-0.85)*2.8=) 0.42 million TEU per year is used for import and export. The import and export could stay at the port of Kingston. There are three terminals at the port of Kingston. The import and export could be located at the smallest terminal, the North terminal. It has an area of 47 hectares and has 535 meters of berth. For instance, Rotterdam Container Terminal handles 0.5 million TEU at 17 hectares. (Port of Rotterdam, 2013) The port is less efficient, but the area is three times as big. Therefore the area is large enough for the import and export and there is also enough area left if the import and export increase.

The space which is released is equal to (194-47=) 147 hectares. Jamaica has the opportunity to use this area for other activities. A few of them are mentioned in the next sections.

1.1 Export of limestone

The port of Kingston could specialize in the use of 50 billion tons of limestone reserve, which can be found in the hills at the north of Angels (at the north of Spanish Town). (Scott Williams, 2013)

The government of Jamaica hopes to attract investors to develop the limestone through secondary processing and value added services. Limestone can be used for the manufacturing of consumer products, such as animal feed and cosmetics. The price of limestone is between $10 per ton and $300 per ton, when pharmaceutical grade limestone is used. (The Gleaner, 2013)

“Most of the country’s limestone output is used in the local construction industry as well as in the manufacture of calcined and hydrated lime for various applications, such as bauxite refinement, flocculants, filters and agricultural purposes.” (Jamaica Information Service, 2012)

Limestone could also be used for the manufacturing of steel worldwide. Precipated calcium carbonate could be made from limestone and is the most expensive product that can be made from limestone, even with cheap energy. Precipated calcium carbonate is used in almost every modern manufactured item. (Scott Williams, 2013)

1.2 Tourism

The port of Kingston could be used to create tourism in Kingston. Berths for cruise ships and hotels could be developed to create tourism in Kingston and around.

1.3 Deep sea fishing

At this moment there is no deep sea fishing terminal in the port of Kingston. Deep sea fishing could be an activity that could be developed. However, because of the smell a deep sea terminal brings, they are mostly not placed in an environment where the surrounding suffers from it. If deep sea fishing will be developed in the port of Kingston, the location in the port must be chosen well-considered.

1.4 Container handling

The port of Kingston has a depth of 13 meters, so at this moment it could handle Panamax ships. (World Port Source, n.d.) When the new transshipment port will be more efficient, a part of the container transshipment which now is transshipped at the port of Kingston moves to the new port. When the port of Kingston has lower tariffs than the new port, it still could be an attractive alternative for transshipping containers. For instance, it could be profitable for containers with a very low value of time which are shipped with Panamax vessels (or smaller). The efficiency will not be as high as in the new port, but because of the low value of time of the cargo it doesn't matter. Maybe containers with a very low value of time can be unloaded at the current port and transported to the new port where they will be loaded to a Post Panamax vessel in the new port, or the other way around. This will require a good connection between the current port and the new port.

The mentioned possibilities are only a few examples, but there are more possibilities for the redevelopment of the port of Kingston. It depends on the policy of the government which of the different possibilities will be chosen.

2 Conclusion

There are different possibilities for the redevelopment of the port of Kingston. A few possibilities are the export of limestone, increasing the tourism in Kingston, deep sea fishing and container handling. Probably there are more possibilities than the ones which are mentioned. It depends on the policy of the port authority what will happen with the current port of Kingston.

3 References

Commonwealth Network. (n.d.). *Find freight, shipping and logistics expertise in Jamaica*. Retrieved 10 10, 2013, from Commonwealth Network: http://www.commonwealthofnations.org/sectors-jamaica/business/freight_shipping__logistics/

Jamaica Information Service. (2012, 3 27). *Mining minister focusses on limestone*. Retrieved 10 8, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/111-ministry-of-science-technology-energy-and-mining/30178-mining-minister-focuses-on-limestone

Port of Rotterdam. (2013, 5). *Container terminals and deport in the Rotterdam Port area*. Retrieved 10 11, 2013, from Port of Rotterdam: http://www.portofrotterdam.com/en/Business/containers/Documents/Containermap.pdf

Scott Williams, T. (2013, 9 29). A suggestion for Dr. Davies. *Jamaica Observer*. Retrieved from http://m.jamaicaobserver.com/mobile/columns/A-suggestion-for-Dr-Davies_15146908

The Gleaner. (2013, 4 28). Gov't seeks to develop multi-billion dollar limestone industry. *The Gleaner*. Retrieved from http://jamaica-gleaner.com/latest/article.php?id=44455

World Port Source. (n.d.). *Port of Kingston*. Retrieved 10 10, 2013, from World Port Source: http://www.worldportsource.com/ports/commerce/JAM_Port_of_Kingston_137.php

Appendix G Design values

Before a port can be designed certain design values should be set. For the basic layout the following design values will be determined in this chapter; the available surface for the transshipment port and the industry. For the transshipment port the maximum expected throughput, the average dwell time, the number of berths and the quay length will be determined. The design values for the port area, the transshipment port and the industrial area are separated in different chapters.

1 Port area

The design values for the port area are the dividing of the available surface into transshipment port and industrial area and wet and dry area. Also the design values for the approach channel are determined in this chapter.

1.1 Available surface

In the summary of appendix A, Background information, it is written that the port area will have a total surface of 3,000 acres, which is equal to 12 km^2. Besides a transshipment port the development of an assembly plant, a steel fabrication plant, a cement plant, infrastructure related and supporting the port area and perhaps a power plant for the port area are mentioned in the news articles. It is assumed that 50% of the port area will be used for industry and the other 50% for the transshipment port. The transshipment port will be 6 km^2 (wet and dry). Using Maasvlakte 2 of the Port of Rotterdam, the Netherlands, as a reference the dry surface of 50% of the port seems reasonable. (Port of Rotterdam, n.d.) This port is chosen as a reference because this is a new part of the port of Rotterdam and consists for a large part of container terminals. About 3 km^2 of the transshipment port will be dry area and 3 km^2 will be wet area.

1.2 Approach channel

The approach channel has 3 dimensions; length, width and depth. Also the turning circle is determined. The maximum vessel dimensions have to be known to determine all the above mentioned parameters. In this case is the Post-Panamax ship is leading. The dimensions of this ship are presented in Table G-1.

TABLE G-1: POST-PANAMAX DIMENSIONS

Post panamax dimensions		
Bs (width) =	49	m
D (draught)=	15.2	m
L (length)=	366	m

1.2.1 Required length

The length of the approach channel is determined by the stopping length of the ship and the bathymetry. The minimum required length is the stopping length which depends on the procedure of the arrival of the vessel.

The procedure of the arrival of a vessel is as follows (Velsink, Approach Channels, 2012):
L_1: Distance to slow down from entrance speed (v_s) until 2 m/s.
L_2: Distance to tie up the tugboats and to maneuver them in position
L_3: The final stopping distance
The total length of the approach channel is $L_{total} = L_1 + L_2 + L_3$

Distance to slow down from entrance speed (L_1)

A slow down to 4 knots ≈ 2 m/s is required. The assumption is made that the ship has a velocity of 20 knots ≈ 10 m/s before the speed reducing is started.

$$L_1 = (v_s - 2)\frac{3}{4}\,L_s = (10-2)\frac{3}{4} * 366 \;\approx 2200m$$

Distance to tie up (L_2)
It takes about 10 minutes to tie up the tugboats and to maneuver them in position. This is about 600 seconds. During these 600 seconds the speed of the ships remains 2 m/s.
$L_2 = v_s * 600 = 2 * 600 = 1200\,m$

Final stopping distance (L_3)
De stopping length depends of the length of the vessel (L_s)
$L_3 = L_s * 1.5 = 366 * 1.5 \approx 500\,m$

The total length of the approach channel is
$L_{total} = \ 2200 + 1200 + 500 \approx 3900\,m$

The waves (H_s) and the current (u) determine how much of the approach channel length is within the port basin. If $H_s > 1.5$m the tug boats cannot fasten, so the tie up has to be done in the sheltered area of the port (L_2). For proper rudder control the speed of the vessel is at least 2m/s (L_1). Additional is a requirement which is determined by the cross current. The drift angle should not exceed a tangent of about 1:4. So if there is a cross current of 1m/s, the minimum speed is 4m/s for proper rudder control.

The H_s is assumed most of the time less than 1.5 meters (so an acceptable downtime) and the cross current is assumed most of the time less than 0.5 m/s. This results in minimum approach channel of:

Inside the port:	~500m
Outside the port:	~3400m

For every location a wave and current investigation needs to be done to make a scheme of the probability of exceedance. After this investigation the assumptions about the wave height and current can be verified and the downtime can be determined. If the downtime is acceptable the assumption is right, otherwise a larger part of the approach channel has to be inside the port design.

The additional length of the approach channel is determined by the bathymetry. If there is a big shallow area, the approach channel has to be longer than the determined length for the approach channel. This is because of the dredged lane. A ship has to be inside the boundaries of this lane, otherwise the ship gets stacked on the ground because of the small depth.

1.2.2 Required width

For designing the approach channel width a choice has to be made between a one-way channel and a two-way channel. There are two factors important for making this choice:

- The amount of ships arriving and leaving the port in one day
- The length of the approach channel

It is not preferable that there is congestion in the approach channel, because this will lead to waiting time for shipping companies. The longer the approach channel, the more time a ship will be in the approach channel. So a short approach channel can designed one way, because ships spend not a long time in the approach channel. If there are a lot of ships the capacity for a short one-way approach channel is not sufficient. Therefore for all the designs a two way approach channel is assumed to be necessary.

The two-way approach channel has two basic lanes, a separation distance between the lanes, bank clearance at both sides and some additional factors which are determined by wind, wave height, etc.

In Table G-2 the formula is shown and the calculation is made. This results in a required width of 500 meters.

TABLE G-2: REQUIRED WIDTH FOR A TWO-WAY CHANNEL

Required width for two-way channel		
Width =	2 * (W_{basic} +W_{bc} + Sum(W_a)) + W_{sp}	
W_{basic} =	1.7 * Bs	h < 1.25 * D
$W_{bank\ clearance}$ =	1.0 * Bs	-
$W_{additional}$ =	1 * Bs	wave heigt > 3m
	0.1 * Bs	seabed char.
	0.5 * Bs	cross-winds
$W_{separation\ distance}$	1.6 * Bs	8-12 kn
Width =	**500 m**	10.2 * Bs

1.2.3 Required draught

The minimum draught is determined by several factors and the ship size. The design is without a tidal window and a maximum wave height of 1.5m. For the sinkage and the keel clearance the standard values are used (Velsink, Manoeuvring inside port, 2012). The formula and calculation is presented in Table G-3. The minimum draught is 18 meters.

TABLE G-3: REQUIRED DRAUGHT FOR THE APPROACH CHANNEL

Required draught without tidal window		
h_{gd} =	D -h_t + S_{max} + a + h_{net}	
h_{gd} = guarateed depth	-	m
D (draught ship) =	15,2	m
h_t (tidal elevation) =	0	m
S_{max} (max. sinkage)=	0,5	m
a (vertical motion) =	1,5	m
h_{net} (keel clearance)=	0,5	m
h_{gd} =	**18**	m

1.2.4 Turning circle

The turning circle is inside the port and is needed for the maneuverability inside the port. The turning circle is two times the largest vessel in case of container vessels. This results in 2 * $L_{s,max}$ = 2 * 366 = 732 m. Oil tankers should have a larger turning circle, because they have a large draught and are less maneuverable. In that case the turning circle has to be larger than 2 * L_s.

2 Transshipment port

For the transshipment port the quay length should be determined. To determine the quay length the expected throughput, average dwell time and number of berths are needed. These values will be set using data from reference ports.

2.1 Maximum expected throughput and average dwell time

To get to the required number of berths and thus the required quay length the maximum expected throughput and dwell time have to be determined. Reference ports are used to require these numbers.

2.1.1 Throughput and dry surface reference ports

To determine the maximum expected throughput the reference ports (see appendix C, Reference ports) are used. These reference ports are used to create the graph in Figure G-1. In this graph the horizontal axis shows the throughput in million TEU per year, the vertical axis shows the dry surface in squared kilometers.

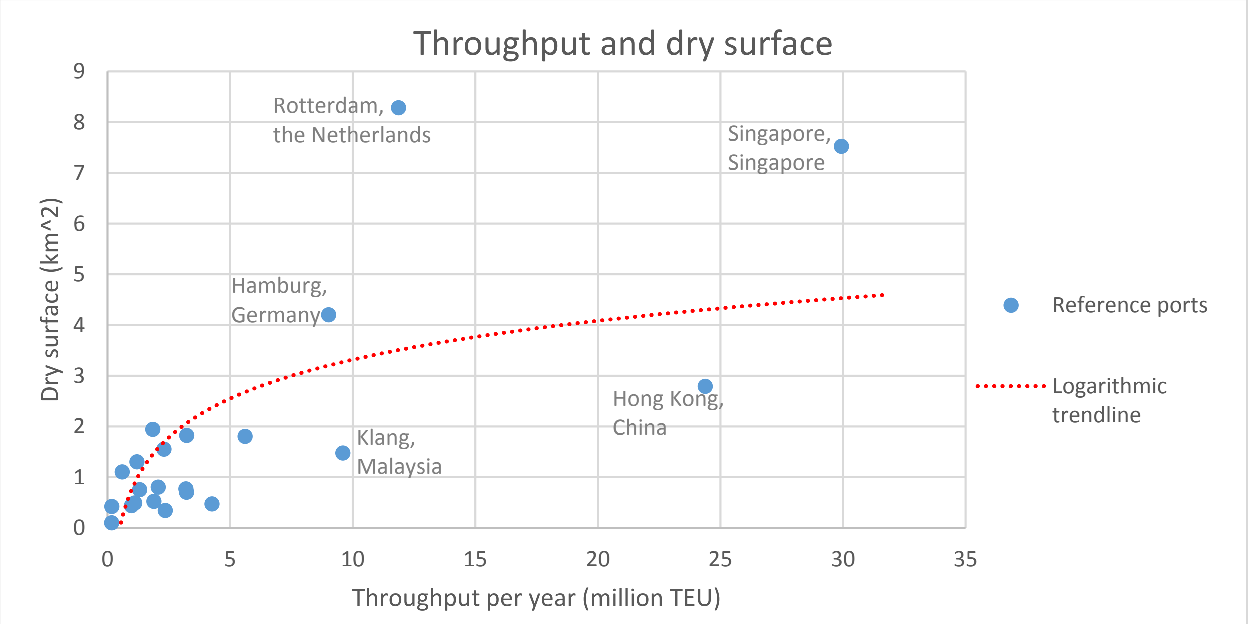


FIGURE G-1: GRAPH OF THROUGHPUT PER YEAR AND DRY SURFACE OF THE PORTS FROM APPENDIX C, REFERENCE PORTS

In the graph in Figure G-1 a logarithm trendline is drawn to show the relation between the throughput and the dry surface including scale effects. This line does not present the complete reality, because the number of reference ports is small (it is 22) and the small number of larger ports (5), which influence the curve of the trendline. Also the relation between the throughput and the dry surface depends also on the chosen design, the used equipment and the type of vessels. This trendline will therefore not be used directly to determine the maximum expected throughput.

The most efficient way for container handling in a port is using a straight quay with a linear storage yard. This can be concluded from the port design of ports with a high throughput per surface unit (Ligteringen & Velsink, 2012). Four of the reference ports/terminals are chosen as reference for the maximum expected throughput, because of their design. These are the Euromax Terminal Rotterdam in the Netherlands, Freeport in the Bahamas, Salalah in Oman and Tanger-Med in Morocco. The Euromax Terminal Rotterdam is also chosen because this terminal runs mostly automatic and is known as very efficient. The other three ports are all three ports with a transshipment percentage of 99%. The throughput, dry surface and quay length per port are given in Table G-4.

TABLE G-4: THROUGHPUT, DRY SURFACE AND QUAY LENGTH PER REFERENCE PORTS WITH A LINEAR DESIGN

	Throughput (TEU/year)	Dry surface (ha)	Quay length (m)
Euromax Terminal Rotterdam, the Netherlands	2,100,000 [2]	84 [3]	1,500 [2]
Freeport, Bahamas	1,116,272 (2011) [4]	49 [5]	1,036 [4]
Salalah, Oman	3,200,700 (2011) [3]	77 [6]	2,039 [5]
Tanger-Med, Morocco	2,070,000 (2011) [3]	80 [7,8]	1,612 [6,7]

As mentioned above all these four ports are linear designed ports, they exist of one long quay with a connected storage yard, which is relatively small. These ports and their throughput can be scaled such that the area becomes 3 km^2 (300 ha). This is done by assuming the width of the quay to be constant and by expanding the length of the quay and the connected storage area. The throughput and quay length change, this is shown in Table G-5.

TABLE G-5: SCALING FACTOR, SCALED THROUGHPUT AND QUAY LENGTH PER REFERENCE PORT WHEN LINEAR SCALED TO A SURFACE OF 300 HECTARES.

	Scale factor	Scaled throughput (million TEU/year)	Scaled quay length (km)
Euromax Terminal Rotterdam, the Netherlands	3.6	7.5	5.4
Freeport, Bahamas	6.1	6.8	6.3
Salalah, Oman	3.9	12.5	8.0
Tanger-Med, Morocco	3.8	7.8	6.0

As shown in Table G-5 the maximum expected throughput of the new port can be between 6.8 million and 12.5 million TEU per year. These amounts of throughput can only be used in the case of a linear port design. The maximum expected throughput does not only depend on the available dry surface and a linear design. Additional research is necessary to determine the maximum expected throughput. This will be done in the next subsections.

2.1.2 Dwell time reference ports

The throughput of the scaled reference ports Euromax Terminal Rotterdam, Freeport and Tanger-Med are in the range of 6.8 to 7.8 million TEU per year (see Table G-5). Salalah has a very large scaled throughput compared with the other three reference ports.

Not only the amount of dry surface will determine the throughput, another important factor is the average dwell time of the containers at the storage area. The shorter the average dwell time, the more containers can be handled in one year with the same storage area (in case the equipment en quay length are sufficient to handle more containers). A shorter dwell time can be a disadvantage for the shipping companies, because if their containers have a longer dwell time than allowed they pay a fine, so their flexibility is less.

To determine the dwell time for the new transshipment port the reference ports will be used. The list of the four reference ports from section 2.1, Maximum expected throughput, are extended with five reference ports. This is done to gain insight in the competitors of the new transshipment port and to gain insight how big ports operate. Three ports are possible competitors of the transshipment port in Jamaica (see appendix D, Competitiveness). These are Manzanillo in Panama, Caucedo in the Dominican Republic and Savannah USA. The possible competitors Miami in

---

[2] (Ligteringen & Velsink, 2012)

[3] (Euromax Terminal Rotterdam, n.d.)

[4] (Containerisation International, 2012)

[5] (Freeport Container Port Transshipment, 2013)

[6] (Salalah Port Services Co., 2013)

[7] (A.P. Moller - Maersk Group, n.d.)

[8] (EUROGATE Tanger S.A., 2013)

USA, Havana in Cuba and the new port in Cuba are not used, because of the lack of information about these ports. The other two reference ports are Singapore and Hong Kong in China. These two are chosen because they are part of the most important ports in the world.

The formula below shows the relation between surface area, throughput, dwell time, efficiency of the area and the occupancy. (Ligteringen & Velsink, 2012)

$$A = \frac{N_c \cdot \overline{t_d} \cdot A_{TEU}}{r_{st} \cdot 365 \cdot m_c}$$

In which:

A	Dry surface of the terminal (m^2)
N_c	Throughput per year (TEU/year)
$\overline{t_d}$	Average dwell time (days)
A_{TEU}	Required area per TEU inclusive equipment travelling lanes (m^2/TEU)
r_{st}	Average stacking height / nominal stacking height (0.6 to 0.9)
m_c	Acceptable average occupancy rate (0.65 to 0.70)

The throughput and the dry surface of all chosen reference ports is known. The required area per container depends on the equipment used for transporting the container in the storage area. The rough numbers are shown below:

- Semi-automatic 10 m^2/TEU
- Portal cranes 11 m^2/TEU
- Straddle carrier 13 m^2/TEU
- Reach stacker 15 m^2/TEU

The average stacking height / nominal stacking height is assumed to be the same for all the used reference ports and is set to 0.75. (Ligteringen & Velsink, 2012) For all chosen reference ports the occupancy is also assumed to be the same, this is 70%. With this information the average dwell time can be calculated. The information and the calculated dwell time per chosen reference port are shown in Table G-6.

.

TABLE G-6: THROUGHPUT, DRY SURFACE, CALCULATED THROUGHPUT PER KM^2, REQUIRED AREA PER CONTAINER AND CALCULATED AVERAGE DWELL TIME PER REFERENCE PORT

	Throughput (TEU/year)	Dry surface (km^2)	Throughput per km^2 (TEU/km^2)	Required area per container (m^2/TEU)	Average dwell time (days)
Euromax Terminal Rotterdam, the Netherlands	2,100,000	0.84	2,500,000	10	7.7
Freeport, Bahamas	1,116,272	0.49	2,278,106	13	6.5
Salalah, Oman	3,200,700	0.77	4,156,753	11	4.2
Tanger-Med, Morocco	2,070,000	0.80	2,587,500	11	6.7
Manzanillo, Panama	1,899,802	0.52	3,653,465	11	4.8
Caucedo, Dominican Republic	960,000	0.25	3,840,000	11	4.5
Savannah, USA	2,944,684	2.00	1,469,990	11	11.9
Singapore, Singapore	29,937,700	7.52	3,981,077	10	4.8
Hong Kong, China	24,384,000	2.79	8,739,785	10	2.2

As shown in Table G-6 the average dwell time differs a lot for the different reference ports. The average dwell time of Hong Kong is 2.2 days which results in a high throughput per square kilometer. Because this port does also a lot of transfer to barges, this port is not comparable to the other ports (Ligteringen & Velsink, 2012). The average dwell times of Salalah, Manzanillo, Caucedo and Singapore lie in the same range, 4.2 to 4.8 days. Their throughput per square kilometer is between 3.7 and 4.2 million TEU. Three of the reference ports with a linear design have an average dwell time between 6.5 and 7.7 days and a throughput per square kilometer between 2.3 and 2.6 million TEU. Savannah has the highest average dwell time of the chosen reference ports, this is 11.9 days. The throughput per square kilometer of Savannah is the lowest of Table G-6, namely 1.5 million TEU. As mentioned before, a lower dwell time will lead to a higher throughput (assuming that the equipment and storage yard is sufficient), but also to less flexibility for the shipping companies, a higher dwell time will lead to a lower throughput but to high flexibility for the shipping companies.

2.1.3 Trade-off between throughput and dwell time

The maximum expected throughput strongly depends on the average dwell time. There should be a trade-off between the maximum expected throughput and the average dwell time.

Looking at Table G-5 the scaled throughput of the four reference ports with a linear design from subsection 2.1.1 can be read. These scaled throughputs are summarized in Table G-7 with the associated average dwell time. The other reference ports used in subsection 2.1.2, Dwell time, will not be used as a reference, because the designs of these ports are not really efficient designed, like the linear ports.

TABLE G-7: SUMMARIZE OF THE SCALED THROUGHPUT AND THE AVERAGE DWELL TIME PER REFERENCE PORTS FROM SUBSECTION 2.1.1, THROUGHPUT AND DRY SURFACE REFERENCE PORTS

	Scaled throughput (TEU/year)	Average dwell time (days)
Euromax Terminal Rotterdam, the Netherlands	7,500,000	7.7
Freeport, Bahamas	6,834,318	6.5
Salalah, Oman	12,470,260	4.2
Tanger-Med, Morocco	7,762,500	6.7

The scaled throughput of the Euromax Terminal Rotterdam, Freeport and Tanger-Med are in the same range (6.8 million – 7.8 million TEU), this can be seen in Table G-7. Also their average dwell time lie within the same range (6.5 – 7.7 days). The outlier of the four reference ports is Salalah, with a scaled throughput of 12.5 million TEU and an average dwell time of 4.2 days. This can be explained by the low average dwell time, which leads to a high throughput.

Since the surface of the port is already defined, the average dwell time determines the maximum expected throughput using the formula of subsection 2.1.2. The throughput can be calculated when the average dwell time is set, assuming the following values for the different parameters in the mentioned formula. Also the assumption is made that the storage area is determining the maximum throughput and not the quay length and the (un)loading cranes. The quay length will be enough for every amount of throughput and the Post-Panamax-Cranes can unload and load the vessels fast.

A	Dry surface of the terminal	3,000,000 m^2
A_{TEU}	Required area per TEU including equipment travelling lanes (m^2)	11 m^2/TEU
r_{st}	Average stacking height / nominal stacking height (0.6 to 0.9)	0.75
m_c	Average occupancy rate (0.65 to 0.70)	0.70

It is assumed that portal cranes will be used in the new port, which will lead to a required area of 11m^2 per TEU including equipment travelling lanes. With an average dwell time of 7.5 days (close to the Euromax Terminal Rotterdam) the maximum expected throughput will be 7 million TEU per year. When the dwell time is set to 6.5 days (close to Freeport, Bahamas and Tanger-Med, Morocco) the maximum expected throughput will be 8 million TEU.

An average dwell time of 4 days (close to Salalah, Oman) will lead to a maximum expected throughput of 13 million TEU per year.

In appendix A, Background information, it is assumed the most container traffic through the Caribbean is through the Panama Canal. If the average dwell time will be 4 days, the expected throughput of the transshipment port is 13 million TEU per year. This is 41% of the total container flow through the Panama Canal. It is not realistic to assume that the new port will handle such big share of the complete flow (see appendix D, Competiveness). Besides that it is not realistic to assume that the complete container flow through the Panama Canal will need transshipment in the Caribbean. The transshipment can also be elsewhere or there can be no transshipment at all. Operating an average dwell time of 4 days is unnecessary short, because the large throughput, of 13 million TEU per year, will probably not be achieved. It will lead to less flexibility for the shipping companies. A maximum expected throughput of 7 or 8 million TEU per year is more realistic. These throughput will be respectively 22% or 25% of the total container flow through the Panama Canal.

The design of the port will probably not be a linear quay. This is because the width of the area should be rather long, which would be accompanied with a lot of costs for wave protection. If a port with a linear design will use portal cranes the required area per TEU including equipment travelling lanes of 11 m^2/TEU. In the case of a non-linear port design the required area per TEU will be slightly more than 11 m^2/TEU. A higher value for the required area per TEU will decrease the maximum expected throughput, assuming the other parameters to be constant. Therefore it is assumed that the maximum expected throughput for the average dwell time of 6.5 and 7.5 days to be less than calculated above, so respectively nearly 8 and nearly 7 million TEU/year).
As mentioned in subsection 2.1.2, Dwell time reference ports, a higher average dwell time will lead to more flexibility for the shipping companies, which is preferable. To be more appealing for the shipping companies and be a better competitor in the Caribbean an average dwell time of 7.5 days is chosen instead of 6.5 days. The chosen average dwell time of 7.5 will lead to a lower maximum expected throughput than an average dwell time of 6.5 days. An average dwell time of 7.5 days and a required area per TEU of slightly larger than 11 m^2 will lead to a maximum expected throughput of nearly 7 million TEU/year.

2.2 Number of berths & quay length

Normally the quay length will be calculated using the number of berths coming from the queuing theory. (Ligteringen & Velsink, 2012) In this case, this should be done using assumptions. With the queuing theory the number of berths for scaled reference ports will be calculated using the scaled throughput. Also the scaled quay length of the reference ports will be used to calculate the number of berths needed to determine the quay length of the new transshipment port.

Since the maximum expected throughput is nearly 7 million TEU per year (see section 2.1, Maximum expected throughput and average dwell time) Freeport looks like a good reference port, with a scaled quay length of 6.3 kilometer (Table G-5 of subsection 2.1.1). However Freeport has a linear design, a long quay with a storage yard with a relative small width, and can therefore use the available space very efficient. As said in section 2.1 it is not likely to assume the port layout will be a linear design. Also the Euromax Terminal Rotterdam can be a good reference because it has an average dwell time of 7.7 days (Table G-7), which is almost the same as the design value for the average dwell time for the new port (see section 2.1, Maximum expected throughput and average dwell time).

2.2.1 Berth length

If the quay length is known, the number of berths can be calculated with the next formula (Ligteringen & Velsink, 2012):

$$L_q = \begin{cases} L_{s,max} + 2 \cdot 15 & for\, n = 1 \\ 1.1 \cdot n \cdot (\overline{L_s} + 15) + 15 & for\, n > 1 \end{cases}$$

In which:

L_q Quay length (m)

n Number of berths

$L_{s,max}$ Length of the largest vessel frequently calling at the port (m)

$\overline{L_s}$ Average length of the calling ships

A single berth should be designed with the length of the largest vessel expected (increased with an extra length fore and aft for the mooring lines). When the quay is designed for more than one vessel, for every berth the average ship length is increased with 15 meter for mooring lines and is multiplied with a factor of 1.1 (10%). This length plus 15 meter (one length extra for mooring lines) is the total quay length.

There can be concluded that when finger piers are used instead of a linear quay the total quay length should be a little more than for a linear design. This is because of the length of the largest vessel should be used in case of finger piers and not the average length.

As average vessel length the average of one Post Panamax vessel and two Panamax vessels is chosen. This is a simplification of reality. Since Freeport does a lot of transshipment (99%) and transporting containers with a Post Panamax vessel is cheaper than with a Panamax vessel, it is assumed that two Panamax vessels will arrive and their containers will be load on one Post Panamax vessel, or the other way around. It is assumed that this also holds for the Euromax Terminal Rotterdam. The length of a Post Panamax vessel is 366 meter and the length of a Panamax vessel is 294 meter. (Panama Canal Authority, 2006) The average vessel length can be calculated and is equal to 318 meter.

2.2.2 Queuing theory

The number of required berths can be calculated with the queuing theory (Groenveld, 2001). First a few assumptions should be made. After that the number of berth are calculated for the scaled reference ports Freeport and Euromax Terminal Rotterdam and afterwards for the new transshipment port. With the number of berths the quay length can be calculated.

The queuing theory uses the annual throughput and the average load per vessel to calculate the number of vessels per year. For these calculations an average load per vessel of 4,000 TEU is used. This average load is based on 100% transshipment between two Panamax vessels with a load of 3,000 TEU and one Post Panamax vessel with a load of 6,000 TEU. This composition of vessels is also used for the average vessel length in subsection 0. These two assumptions, the average vessel load and length will be checked in this subsection.

With a(n) (un)loading rate in moves per hour the average (un)loading time per vessel can be calculated. It is assumed that the (un)loading rate is 180 moves/hour. This represents 6 cranes which work on average speed of 30 moves/hour. This time plus 2 hours for mooring leads to the average handling time per vessel. With this average handling time the total service time can be calculated. The total service time divided by the working hours of a working year (which is 8400 hours, assuming a 24 hour operating port) rho can be calculated. With rho the number of berths needed can be calculated. The number of berths should be calculated iteratively. The number of berths divided by rho will be called the utilization. Using tables from (Ligteringen & Velsink, 2012) the percentage of waiting time for the total service time can determined. A certain number of berths and utilization will lead to an acceptable waiting time percentage.

Mostly a waiting time of 10% of the service time is taken as a maximum, so this will be assumed in the following calculations. From (Ligteringen & Velsink, 2012) table IV will be used, this table is made with an $M/E_2/n$ distribution. This means a negative exponential inter arrival time distribution and an Erlang 2 service time distribution for n serving points (the practical number of berths).

To check the assumption of an average vessel load of 4,000 TEU the number of berths for the unscaled reference ports Freeport and Euromax Terminal Rotterdam is calculated. This will be compared with the number of berths calculated with the quay length and the average vessel length of 318 meters.
The throughput of Freeport is 1.1 million TEU (see Table G-4). The number of berths for a waiting time percentage less than 10% is 3 berths. With an average vessel length of 318 meter, the number of berths can be calculated using the quay length. The quay length of Freeport is 1.0 kilometer (see Table G-4), which lead to 3 berths. The number of berths is the same for both calculations. Euromax Terminal Rotterdam has a throughput of 2.1 million TEU (see Table G-4). With an average load per vessel of 4,000 TEU this will lead to 4 berths. The number of berths calculated with an average vessel length of 318 meter and the quay length of 1.5 km (see Table G-4) is about 4 berths. The number of berths is the same for both calculations.
The assumptions for the average vessel load and the average vessel length lead both the same number of berths in different calculation. Therefore it is assumed that it is reasonable to use these assumptions.

For Freeport a scaled throughput of 6.8 million TEU per year is used (see Table G-5). For a waiting time of at least 10% of the service time 8 berths are needed. This will lead to a waiting time of 3% of the service time. The scaled quay length can be calculated using the formula from subsection 0. In case the port has a linear design, the quay will exist of 8 berths. With an average vessel length of 318 meters, the total quay length will be almost 3 kilometer. If the port design will exists of finger piers with a different pier for every berth and the largest vessel will have a length of 366 meter (Post Panamax), the total length will be about 3.2 kilometers.
These calculations can also be made for the scaled Euromax Terminal Rotterdam, with a scaled throughput of 7.5 million TEU. For this port 8 berths also lead to an acceptable waiting time percentage, in this case less than 9% of the service time. The quay length will also be 3 kilometer for a linear port design and 3.2 kilometer for separate finger piers.
The same calculation can be made for the new transshipment port. The maximum expected throughput is nearly 7 million TEU (see subsection 2.1.3), for this calculation this is round to 7 million TEU. Also 8 berths seem to be needed to operate with an acceptable waiting time percentage, which is the same as for the scaled reference ports. The waiting time percentage will be less than 5% of the service time. The quay length for the new transshipment port will be the same as for the two reference ports above, namely 3 to 3.2 kilometer (respectively linear design and finger piers).

A few important assumptions are made in the calculations above. One important assumption is the expected average vessel load. This can be completely different in reality. A lower average will lead to more vessels per year, but a lower (un)loading time. It looks like more berths are needed because of increasing amount of vessels, but it is possible that less berth are needed because the service time decreases. However this can lead to a difference of one berth extra for an operation in practice. Another important assumption is the (un)loading rate, this requires about 48 cranes for 8 berths. Also the uncertainties of the average dwell time and the maximum expected throughput are part of the calculation.

The calculated quay length is less than the scaled quay length of the reference ports. The calculated quay length for a linear design is almost 3 kilometer, whereas the scaled quay length is for Freeport 6.3 kilometer and for Euromax Terminal Rotterdam 5.4 kilometer (see Table G-5). This can be explained by the fact that with linear scaling the quay length also the number of berths will be scaled linear, which is not done in the queuing theory. Why linear scaling is not correct and will lead to an overestimation is shown in the subsection 2.2.4.

2.2.3 Linear scaling

The number of berths can also be calculated with linear scaling. The number of berths will be calculated with the scaled quay length.

The scaled quay length of Freeport is 6.3 kilometers (see Table G-5). If the average vessel length is 318 meters, the number of berths is 17. The same calculation can be made for the Euromax Terminal Rotterdam. The scaled quay length is 5.4 kilometer (see Table G-5) will give an estimation of 15 berths.

It can be concluded that the number of berths for the new transshipment port should be between 15 and 17 berths. The Euromax Terminal Rotterdam has almost the same average dwell time for container as the new transshipment port, so 15 berths is assumed to be enough. The quay length for a linear design will be 5.5 kilometer and for a design with finger piers the total quay length will be 5.9 kilometer.

2.2.4 Scaling with normal distribution

One side mark on the calculation of subsection 0 is the usage of linear scaling. Linear scaling will lead to an overestimation of the needed number of berths. This can be explained using a normal distribution for scaling.

Assuming the arrival of a ship is normally distribution. The normal distribution have an average of μ arriving ships, a variance of var = σ^2 and a standard deviation of σ. This distribution is shown in Figure G-2. The number of berths will be designed using the cumulative chance a certain number of vessels will arrive.

For instance, if a waiting time for 10% of the vessels is allowed (note: this is not the same as a maximum waiting time of 10% of the service time. This calculation is about that 10% of the ships has to wait). If the number of arriving vessels is larger than the number of berths a vessel should wait before it can be served. The number of berths should be equal to the number of arriving vessels with a cumulative chance of 90%. Such a percentage can also be expressed in a distance (seen from the average) of a multiple of the standard deviation σ. If the number is berths is less than this found number, more than 10% of the arriving vessels should wait.

When it is allowed that 2.3% of the vessels have a waiting time, a 97.7% cumulative chance can be found at a distance of 2 times σ on the right side of the average. This is shown in Figure G-2. The number of vessels that arrive with a 97.7% cumulative chance will determine the number of berths. The difference between this number and the average of this distribution gives the (average) number of reserve berths. This is equal to 2·σ.

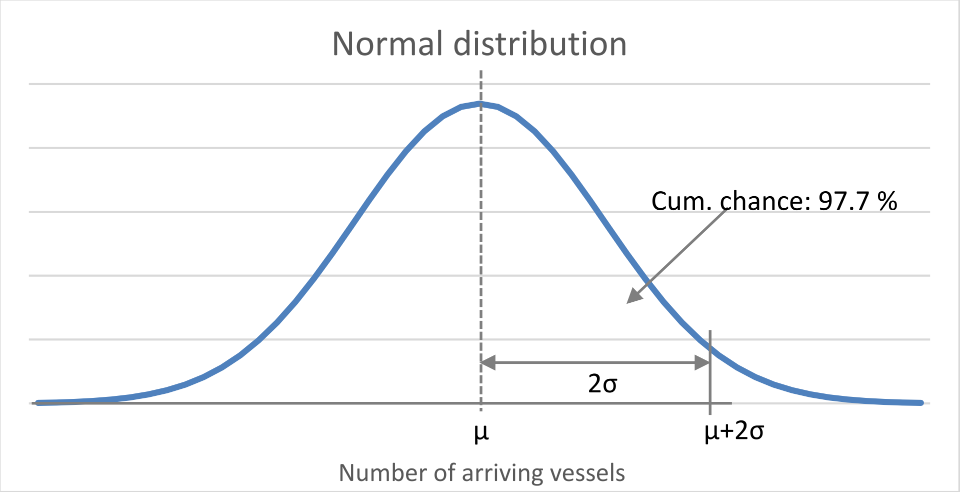


FIGURE G-2: A CUMULATIVE CHANCE OF 97.7% IN A NORMAL DISTRIBUTION WITH AN AVERAGE OF μ AND A STANDARD DEVIATION OF σ

When the average of the distribution is scaled with a factor x, the variance of the distribution is also scaled with this factor x. The average will be x·μ and the variance will be x·var (= x·σ^2). The standard deviation is the square root of the variance √(var) = √(σ^2) = σ√(x·σ^2), when multiplied with factor x it becomes √(x·var) = √(x·σ^2),this can also be written as √x·σ. This is shown in Figure G-3.

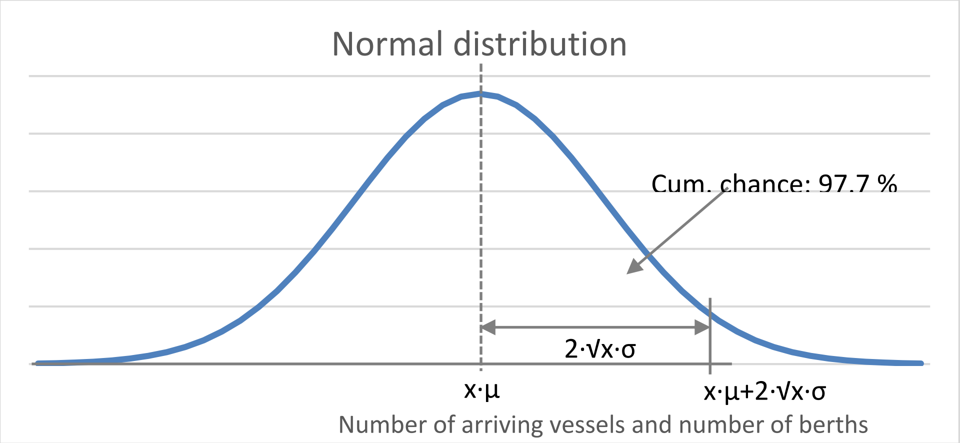


FIGURE G-3: A CUMULATIVE CHANCE OF 97.7% IN A NORMAL DISTRIBUTION WITH AN AVERAGE OF X·μ AND A STANDARD DEVIATION OF √X·Σ

With a waiting time for 2.3% of the vessels, as mentioned in a previous example, the distance between the average x·μ and the cumulative chance of 97.7% will be 2·√x·σ, this is shown in Figure G-3. The number of (average) reserve berths is 2·√x·σ. The average of arriving vessels is scaled by a factor x, but the (average) number of reserve berths is scaled with factor √x, which is less than x. It can be concluded that linear scaling will lead to an overestimation of the number of needed berths.

2.2.5 Determine number of berths and quay length

In this subsection three different methods are used to determine the number of berths. The different methods and outcomes per port are shown in Table G-8. These numbers are an overview of the estimation in subsection 2.2.2 and 2.2.3.

TABLE G-8: OVERVIEW OF ESTIMATIONS FOR THE NUMBER OF BERTHS WITH DIFFERENT METHODS FOR THE REFERENCE PORTS AND THE NEW PORT

	Queuing theory	Linear scaling
Freeport, Bahamas	8 berths	17 berths
Euromax Terminal Rotterdam, the Netherlands	8 berths	15 berths
New transshipment port	8 berths	15 berths

The estimations for the number of berths for the new transshipment port with different methods in Table G-8 can be used to calculate the quay length, as is done in the corresponding sections. For a clear overview this information is summarized in Table G-9. There is a distinction made between the quay length for a linear design and the total quay length for separated berths on finger piers.

TABLE G-9: OVERVIEW OF CALCULATED QUAY LENGTHS, FOR A LINEAR PORT DESIGN AND FOR SEPARATE FINGER PIERS, FOR THE DIFFERENT ESTIMATION METHODS OF THE NUMBER OF BERTHS FOR THE NEW TRANSSHIPMENT PORT

	Queuing theory	Linear scaling
Estimated number of berths	8 berths	15 berths
Quay length for linear design	2.9 kilometer	5.5 kilometer
Quay length for separate finger piers	3.2 kilometer	5.9 kilometer

As discussed in subsection 2.2.4 linear scaling will lead to an overestimation of the number of berths and therewith an overestimation of the quay length. Looking at Table G-9 a more accurate estimation for the number of berths for the new transshipment is between 8 berths. The quay length should be between 2.9 and 3.2 kilometer (a port design with 8 linear berths and a port design with 8 separate berths on finger piers respectively).

In the calculation with the queuing theory are a few assumptions made for unknown parameters. The maximum throughput is one of the important unknown parameters in both calculations. The maximum throughput is limited by the available dry surface, but determined by the average dwell time (see subsection 2.1.2, Dwell time reference ports). If the average dwell time will be lower than 7.5 days, the throughput will be higher than 7 million TEU per year. More throughput will lead in both calculations to more berths and therefore more quay length (assuming the (un)loading rate is constant).

To make sure the operation of the designed transshipment port is not limited by the designed quay length, the design value for the quay length will be 6 kilometer and the number of berths will be 15, to provide enough quay length for a possible higher throughput. This value is based on the number of berths needed with linear scaling and a port design with 15 separate berths on finger piers. This is very a conservative choice, but in this way the designed quay length won't be too small.

The design value for the quay length of 6 kilometer will be used for the designs that are used to come up with one advised location. This is done in appendix J, Further investigation of five port locations. After selecting advisable locations a sensitivity analysis is carried out to investigate the influence on the costs if the quay length is designed at 3 kilometer. This is done in appendix K, Sensitivity analysis. The conclusion of this analysis is that costs change a lot if a quay length of 3 kilometer is designed instead of 6 kilometer. Since 3 kilometer quay length is enough according to the queuing theory, it is not wrong to take this as the design value instead of the conservative length of 6 kilometer. Due to this conclusion the number of berths for the transshipment port changes from 15 to 8 berths. Another consequence of the decreased quay length is that the wet area of the transshipment port is also decreased from about 3 square kilometer to 1.5 square kilometer. This surface of 1.5 square kilometer can be used for the industrial area of the port, to create more additional value for the port.

3 Industrial area

After the sensitivity analysis the industrial area of the new port has a surface of about 6.5 km^2. The facilities shown in Table G-10 will be placed in the industrial area of the new port. The needed surface and the needed quay length per facility are given.

TABLE G-10: DIVISION OF FACILITIES WITH THEIR NEEDED SURFACE IN THE NEW PORT

Facility	**Needed number of berths**	**Needed quay length**
Related and supporting infrastructure	-	-
Assembly plant (cars)	2	0.65 km
Steel fabrication plant	2	0.65 km
Logistics center	-	-
Cement plant	2	0.65 km
Power plant	-	-
Major IT facility	-	-
Manufacturing facilities	-	-
Total	***6***	***1.95 km***

The total quay length must be around 2 kilometer. The power plant needs a pipeline to deep water which is connected to a jetty. The division of the industrial area is further explained in appendix H, Industrial area of the port.

4 Overview of design values

This chapter gives an overview of the design values as discussed and determined in the above chapters. The design values for the first designs and after the sensitivity analysis, for 3 kilometer quay length instead of 6 kilometer, are summed below in Table G-11.

TABLE G-11: OVERVIEW DESIGN VALUES FOR FIRST DESIGN AND SENSITIVITY ANALYSIS

			First design	**After sensitivity analysis**
Surface port area	Transshipment port	Dry	3 km^2	
		Wet	3 km^2	1.5 km^2
	Industrial area	Dry	5 km^2	6.5 km^2
		Wet	1 km^2	
Approach channel	Width		500 m	
	Length in port		At least 500 m	
	Diameter turning circle		At least 732 m	
	Depth	Transshipment port	At least 18 m	
		Industrial area	At least 15 m	
Average dwell time			7.5 days	
Maximum expected throughput			Nearly 7 million TEU	
Number of berths	Transshipment port		15 berths	8 berths
	Industrial area		not determined	6 berths
Quay length	Transshipment port		6 km	3 km
	Industrial area		not determined	2 km

The designs are made with the assumptions of a non-linear quays and the usage of portal cranes

A few side marks should be made on these design values. A lot of assumptions are made to come to these values. A few of the assumptions about the transshipment port are shown below:

- required area per TEU inclusive equipment travelling lanes
- (un)loading rate of the cranes
- average vessel length
- average vessel load
- allowed maximum waiting time percentage

Other assumptions can lead to another design value of the average dwell time. The average dwell time is one of the factors that determines the maximum expected throughput. The number of berths and the quay length are partly based on the maximum expected throughput. Therefore it can be said that a different average dwell time can lead to a change in throughput and thereafter change the number of berths and the quay length.

5 References

A.P. Moller - Maersk Group. (n.d.). *APM Terminals Tangier S.A. Brochure.* Retrieved 10 01, 2013, from APM Terminals: http://www.apmterminals.com/uploadedFiles/Tangier%20Brochure_English.pdf

Containerisation International. (2012). *Top 100 Container Ports 2012.* Retrieved 09 24, 2013, from Containerisation International: http://europe.nxtbook.com/nxteu/informa/ci_top100ports2012/index.php?startid=60#/68

EUROGATE Tanger S.A. (2013). *Africa's Gateway to the World.* Retrieved 10 01, 2013, from EUROGATE Tanger: http://www.eurogate-tanger.com/live/tanger_site/show.php3?id=1&nodeid=1&_language=en

Euromax Terminal Rotterdam. (n.d.). *Euromax Terminal Rotterdam*. Retrieved 10 01, 2013, from ECT: http://www.ect.nl/en/content/euromax-terminal-rotterdam

Freeport Container Port Transshipment. (2013). *Introduction*. Retrieved 10 01, 2013, from Freeport Container Port: http://freeportcontainerport.com/freeport-container-port/1#1

Groenveld, R. (2001). *Service Systems in Ports and Inland Waterways.* Delft: VSSD.

Ligteringen, H., & Velsink, H. (2012). *Ports and Terminals.* Delft: VSSD. Retrieved 10 01, 2013

Panama Canal Authority. (2006). *Proposal for the Expansion of the Panama Canal.* Retrieved 10 01, 2013

Port of Rotterdam. (n.d.). *Master Plan of business activity*. Retrieved 09 24, 2013, from Maasvlakte 2: http://www.maasvlakte2.com/en/index/show/id/595/Master+Plan+for+business+activity

Salalah Port Services Co. (2013, 10 01). *Organisation - Operations*. Retrieved from Port of Salalah: http://www.salalahport.com/organisation.aspx?id=7865

Velsink, H. L. (2012). Approach Channels. In *Ports and Waterway* (p. 272). Delft: VSSD.

Velsink, H. L. (2012). Manoeuvring inside port. In *Ports and Waterways* (p. 272). Delft: VSSD.

Appendix H Industrial area of the port

To increase the value of the new port, space is reserved for industrial activities which are not directly related to the (container) transshipment port. The industrial area can be used for many different facilities. There are multiple news articles in which is stated which kind of facilities will be located in the industrial area of the new port, see appendix A, Background information. Per news article the named facilities are listed.

May 1st, 2013

- Logistic center
- Industrial plants
- Cement plant
- Perhaps a power plant

(Jamaica Information Service, 2013a)

May 8th, 2013

- Manufacturing facilities
- Major IT facility
- Cement plant
- Possible development of a power plant to provide electricity to the industrial complex

(Jamaica Information Service, 2013b)

September 11th, 2013

- Related and supporting infrastructure
- Assembly plant
- Steel fabrication plant

(Jamaica Information Service, 2013c)

1 Division of facilities in industrial area

The facilities in the most recent article (September 11th, 2013) are assumed to be required anyway. When enough space is left the other mentioned facilities could also be included. The dry port area reserved for industry is equal to 6.3 km^2 for the chosen location, Goat Islands (option 5). This option for the location is further explained in appendix K, Sensitivity analysis.

1.1 Assembly plant

The article of the 11th of September mentions an assembly plant. (The industrial plants of the article of the 1st of May are assumed to be an assembly plant and a steel fabrication plant). There are different types of assembly plants, but in this case the assembly plant will be used for the assembling of gantry cranes. At this moment the assembling of gantry cranes is done in China, but much of the demand for gantry cranes is in the Americas. Therefore Jamaica is a good location for assembly the gantry cranes and the distribution of them. It is assumed that much area is needed for the assembly of gantry cranes. There must be space for the loading and unloading of the vessels, the storage of components, space for putting together the components and the storage of cranes which are ready for transportation. The assumed needed area is equal to 1.5 km^2. Two berths are assumed to be needed with a total quay length of approximately 0.65 kilometers.

1.2 Steel fabrication plant

The steel fabrication plant is assumed to be used for export and the surface of the plant is assumed to be equal to 0.5 km^2. General cargo is transported from the steel fabrication plant to the vessels. The transportation of general cargo takes a lot more time than containers, because of the long (un)loading time. Therefore it is assumed that two berths will be needed with a total length of approximately 0.65 kilometers.

1.3 Related and supporting infrastructure

10% of the area of Maasvlakte 2, Rotterdam (the Netherlands) consists of infrastructure. (Maasvlakte 2, 2013) The related and supporting infrastructure of the new port is also assumed to be 10% of the total industrial area, equal to 0.5 km^2. No quay length is needed.

1.4 Logistics center

A logistics center could contain warehouses, freight forwarders and repair depots. There are very small and very large logistics centers in the world, but the logistics center that will be constructed could probably have the same dimensions as the logistics center in the port of Tanjung Pelepas in Malaysia. Tanjung Pelepas is a port with a transshipment percentage of 96% of the total throughput. This port had a throughput of 5.6 million TEU in 2011 and has an international procurement center and distribution, logistics and warehousing activities area of 1.6 km^2. The new port could have a logistic center of 1.5 km^2. (Arend, 2009) (UNESCAP, 2002) The logistics center must have a good connection with the transshipment port, so the products can be transported from the logistics center to the vessels. This means the logistics center doesn’t need to have its own quay.

1.5 Major IT facility

Also a major IT facility will be constructed in the industrial area of the port. The needed surface is assumed to be equal to 0.3 km^2 and the facility doesn’t need any quay length.

1.6 Cement plant

Also a cement plant is named in the news articles of the 1st of May and the 8th of May. It is assumed that the cement plant will be used for export. There already is a cement plant in Jamaica, the Caribbean Cement Company Limited. The surface of this plant is more or less 0.5 km^2 and is located close to the current port of Kingston. The surface of the new cement plant is assumed to be more or less equal to the surface of the current cement plant, so will be 0.5 km^2. One berth is needed for the delivery of material and one berth is needed for the distribution of cement. The two berths together have a length of 0.65 kilometers.

1.7 Power plant

The possible power plant (to provide the port with energy) mentioned in the news articles of the 1st and the 8th of May is also compared to a power plant which currently is situated in Jamaica, the Old Harbour Power Plant. This power plant is located in the Portland Bight Area and has a surface of approximately 0.25 km^2. The power plant for the industrial area is assumed to be twice as large. The current power plant has a surface of 0.25 km^2, so the new port will be 0.5 km^2. The power plant will use LNG, which is dangerous cargo and should be handled with care. Therefore a pipeline and a jetty will be constructed outside the port, where these ships can berth. Therefore no quay length inside the port is needed for the power plant.

1.8 Manufacturing facilities

The rest of the area will be used for factories, which is equal to 0.8 km^2. The industrial area is an attractive place for locating a factory, because it is very close to the transshipment port. The factories don’t need any quay length, because the products can be transported to the transshipment port and can be distributed from there.

2 Overview

All the named facilities can be placed in the industrial area of the new port and an overview is shown in Table H-1.

TABLE H-1: DIVISION OF FACILITIES WITH THEIR NEEDED SURFACE IN THE NEW PORT

Facility	Needed surface	Needed quay length
Related and supporting infrastructure	0.5 km^2	-
Assembly plant	1.5 km^2	0.65 km
Steel fabrication plant	0.5 km^2	0.65 km
Logistics center	1.6 km^2	-
Cement plant	0.5 km^2	0.65 km
Power plant	0.5 km^2	-
Major IT facility	0.3 km^2	-
Manufacturing facilities	0.9 km^2	-
Total	**6.3** km^2	**1.95 km**

The used surface of the industrial area is equal to 6.3 km^2 and the total needed quay length is 1.95 kilometers. The power plant needs a pipeline which is connected to a jetty. This division is based on a lot of assumptions, because the exact plans are at this moment not known. This division will be used to make a layout of the industrial area of the new port.

3 References

Arend, M. (2009, 11). The Pelepas Free Zone: More than just cost advantages. *Site Selection*. Retrieved from http://www.siteselection.com/features/2009/nov/Port-of-Tanjung-Pelepas-Malaysia/

Jamaica Information Service. (2013a, 05 01). *CHEC to invest US$1.5 billion in transshipment port*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/component/content/article/122-parliament/33743-chec-to-invest-us15-billion-in-transshipment-port

Jamaica Information Service. (2013b, 05 08). *Local contractors to benefit from MIDP*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/list/33800

Jamaica Information Service. (2013c, 09 11). *Prime Minister's Statement on the official trip to China*. Retrieved 09 13, 2013, from Jamaica Information Service: http://www.jis.gov.jm/news/list/34998

Maasvlakte 2. (2013). *Maasvlakte 2*. Retrieved 10 11, 2013, from Maasvlakte 2: https://www.maasvlakte2.com/

UNESCAP. (2002). *Problems in developing logistics centres for ports in the escap region*. Retrieved 10 8, 2013, from Unescap: http://www.unescap.org/ttdw/publications/tfs_pubs/pub_2194/pub_2194_ch5.pdf

Appendix I Site selection

This chapter consists of the possible locations for the area of the port and the selection of the five ports with the most potential. This chapter is about making a pre-selection of the all the possible locations before investigating all the locations in detail.

1 Locations

To find the ideal location for a port in Jamaica different potential areas are selected and studied. Selecting the potential areas is done by looking at various kinds of maps to indicate where on the island of Jamaica is more or less enough space to develop a port with a total area of 3000 acres (12 km^2). This first step resulted in sixteen possible locations for the area of the port, see Figure I-1. Those areas are located at places where only small settlements or even none inhabitants are situated along the coast.

FIGURE I-1: MAP OF THE POSSIBLE LOCATIONS OF THE TRANSSHIPMENT HUB

(1) Portland Bight - Great Goat Island
(2) Portland Bight - Cockpit
(3) Portland Bight - Mitchell Town
(4) Portland Cottage South West
(5) Maccary Bay
(6) Long bay
(7) Alligator Pond – Calabash Bay
(8) Parottee
(9) Black River
(10) Crawford – West
(11) Belmont
(12) Savanna-la-Mar
(13) Little Bay
(14) Duncans
(15) Buff Bay
(16) Bowden Harbour

Before explaining all the sixteen locations there are two locations which directly drop out. The main reasons to drop these locations in the north are the cliffs and the very narrow shelf which make port development a lot more complicated, expensive and time consuming. Second to that is the main focus of the new port area. It is about supplying and receiving vessels from the Panama Canal which is south of Jamaica. This means that the most strategic place for the port area is in the south of Jamaica. Because of the cliffs, narrow shelf and the location on the north the numbers 14 and 15 (transparent the map in Figure I-2) are not selected as possible locations.

Kingston Harbour is not on the list of the selected areas, because the harbour of the main capital of Jamaica is surrounded by inhabited area. A small expansion of Kingston Harbour is possible, but expanding Kingston Harbour with 12 km^2 is not considered realistic. This leaves fourteen locations left which will be further explained.

FIGURE I-2: MAP OF THE 14 POSSIBLE LOCATIONS

1.1 Portland Bight - The Great Goat Island

This is the most notorious area (see Figure I-3) where the discussion about the transshipment hub is started (see appendix A, Background information). The Great Goat Island and the Little Goat Island are in Portland Bight which is a protected area. Figure I-5 and Figure I-6 show the mangroves on the Goat Islands and show the reason why this area is of high environmental en ecological value. Underneath the water some coral is found and the area north of the islands is used as a fish sanctuary for growing up juvenile fish.

The Goat Islands aren't of any use for the local economy. The fishermen are somewhere else in Portland Bight. The hinterland connection around the Goat Islands isn't high developed although the new highway is only 4 km away. From the Goat Islands Spanish town and even Kingston are within an acceptable reach.

For possibilities for a port this place looks promising. It is a perfectly sheltered area and it has a lot of low depths around the islands. Translating this into an engineering point of view the wave energy will reduce and in case of a hurricane the waves are relatively low. The area of Portland Bight is also big enough for expansion in the future. The amount of dredging is relatively low because of deeper areas and the two existing bauxite terminals (the five red circles west of the Goat Islands in Figure I-4) which already require high depths.

FIGURE I-3: MAP OF THE AREA AROUND GREAT GOAT ISLAND WITH POSSIBLE PORT AREA

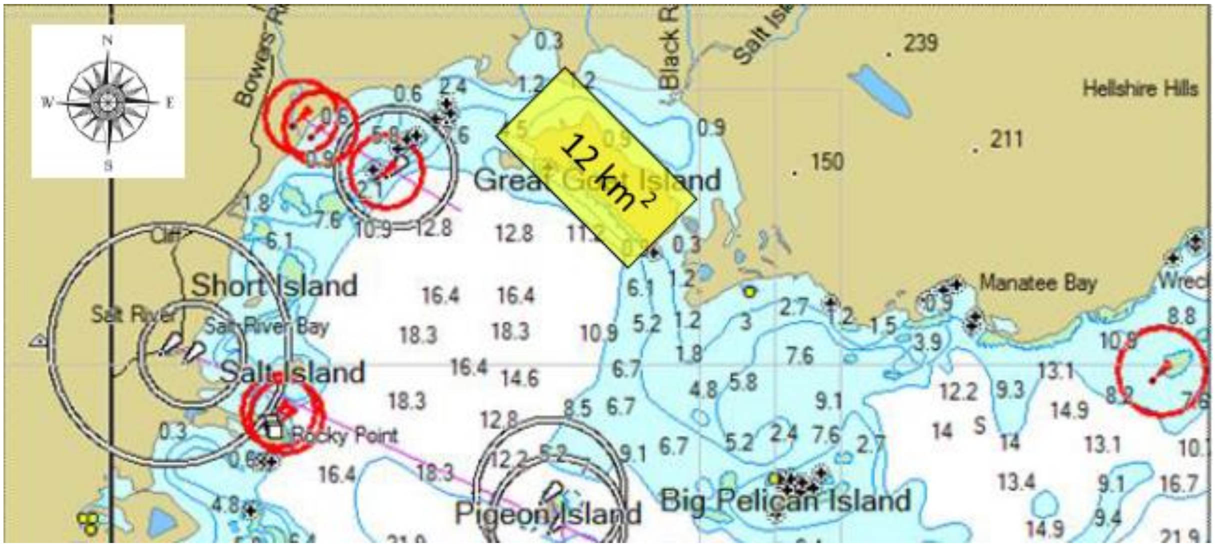


FIGURE I-4: BATHYMETRY AROUND THE GREAT GOAT ISLAND WITH POSSIBLE PORT AREA

In Figure I-5 there is a map of the area in the lower left corner with a red arrow which indicates the viewing direction. The Great Goat Island is far from a flat area. Unfortunately the elevation map is unavailable, but the highest point of the Great Goat Island is about 100 m (Gleaner, 2013).

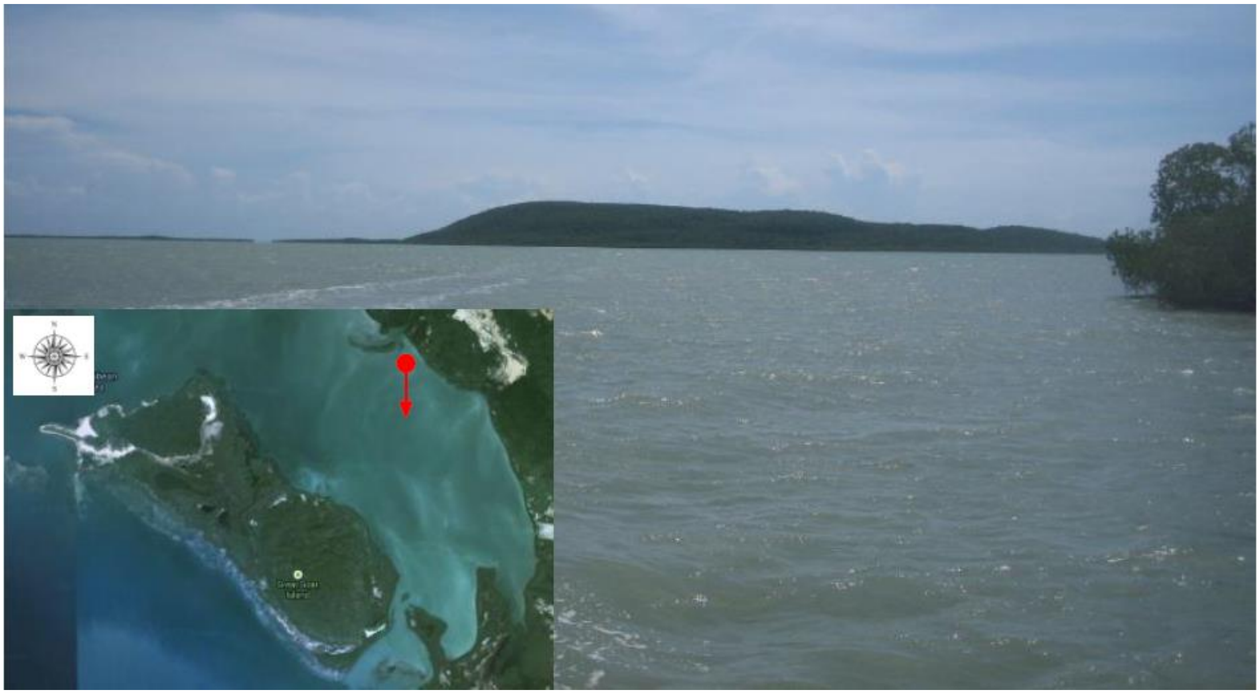


FIGURE I-5: PICTURE OF THE GREAT GOAT ISLAND MADE FROM THE BLACK RIVER

FIGURE I-6: MANGROVES ON THE GREAT GOAT ISLAND

1.2 Portland Bight – Cockpit

A little bit to the west of the Great Goat Island (see Figure I-7) lies the town Cockpit. It lies between the port of Cockpit and the port of Rocky Point, both Bauxite ports. Between these ports there is not much of any activity. This site lies very close to the Great Goat Island and has more or less the same connectivity. Also on this site there are no fishermen, because of a fish sanctuary so it is prohibited to catch fish. This location is open to the eastern and southeastern waves. Advantage is that the location is in the end of Portland Bight. This is a fairly shallow bay so waves will lose much of their energy (see Figure I-8). Also there are various (more or less dead) coral reefs which will break a lot of waves.

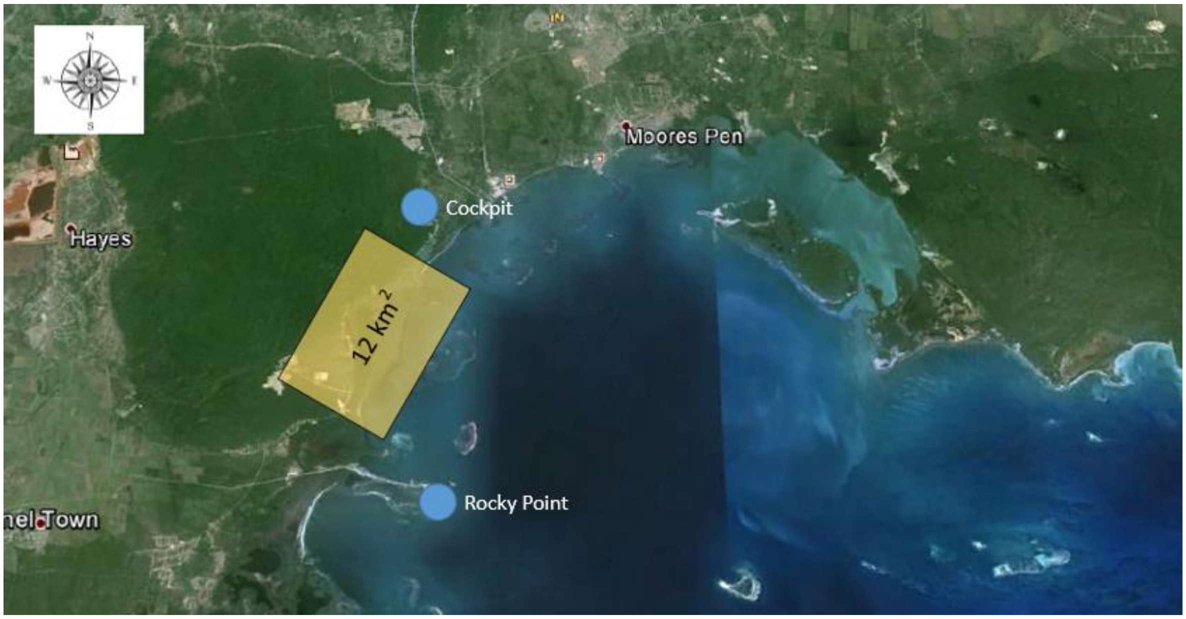


FIGURE I-7: MAP OF THE AREA AROUND PORTLAND BIGHT - COCKPIT

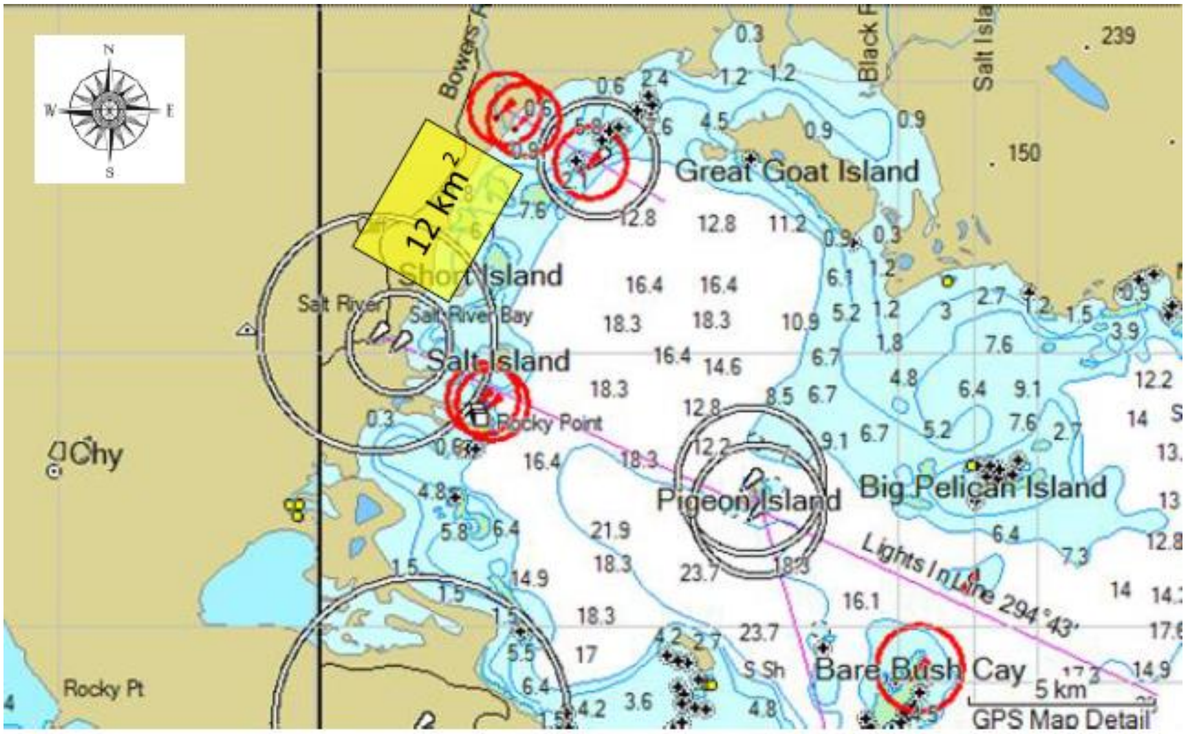


FIGURE I-8: BATHYMETRY AROUND PORTLAND BIGHT - COCKPIT

In Figure I-9 and Figure I-10 the elevation map of the place is given. The yellow lines are contour lines which increase by 20 meters every step. On the lines (very) little numbers are given to indicate the height of the contour line. There is a relatively small ridge which can also be seen in Figure I-10. Figure I-11 shows the swamp and mangroves in front of the hill.

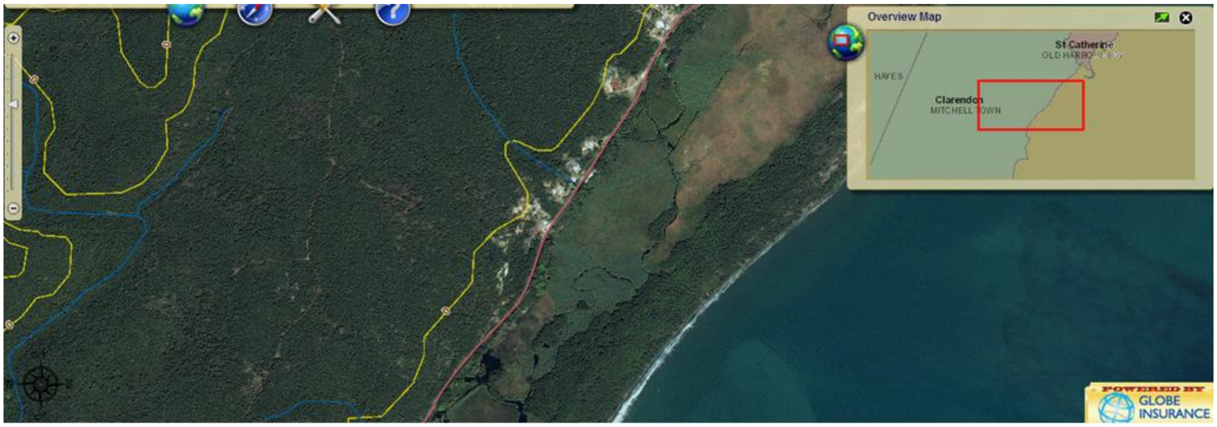


FIGURE I-9: ELEVATION MAP OF AREA AROUND PORTLAND BIGHT - COCKPIT 1 (JAMAICA, 2013)

FIGURE I-10: ELEVATION MAP OF AREA AROUND PORTLAND BIGHT - COCKPIT 2

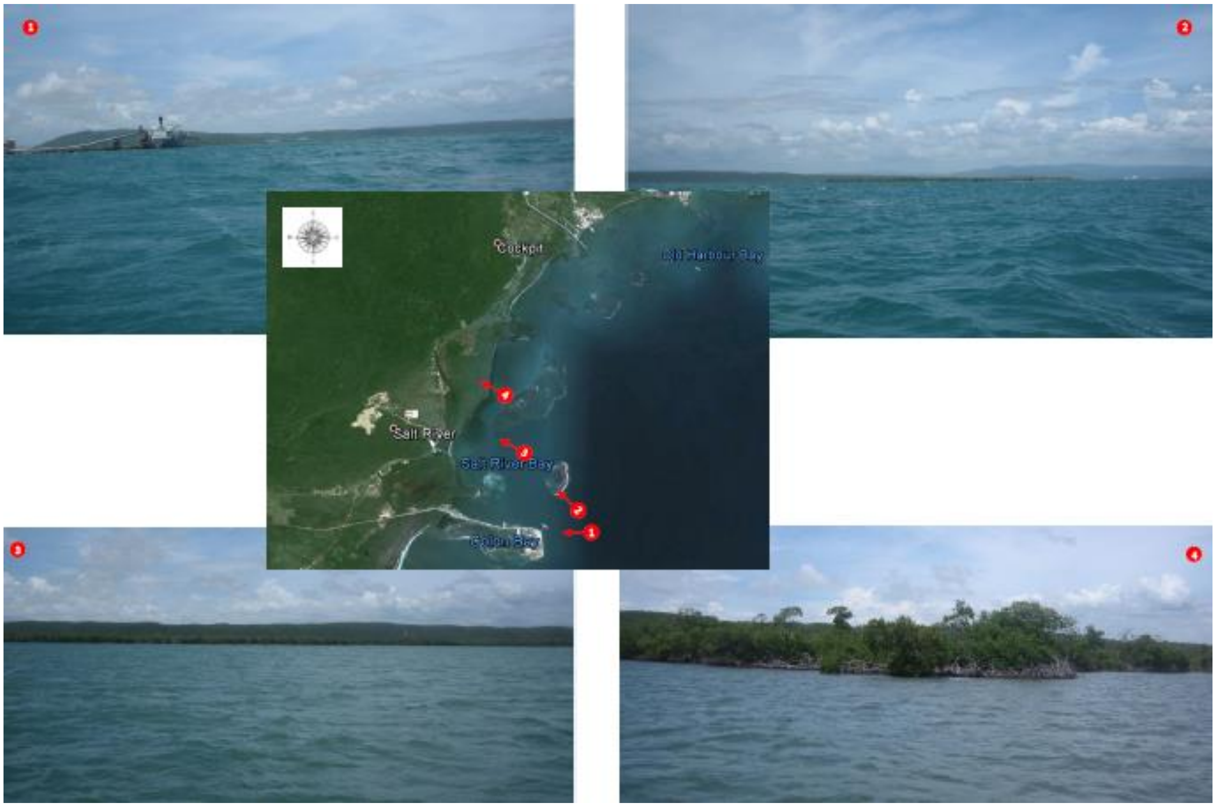


FIGURE I-11: PICTURES FROM DIFFERENT DISTANCES AND ANGLES NEAR PORTLAND BIGHT - COCKPIT

1.3 Portland Bight - Mitchell Town

In the south of the bay is an open area south of Mitchell Town (see Figure I-12). This big wetland is relatively sheltered. This location is very shallow which can be seen on the bathymetry and the elevations map in Figure I-13 and Figure I-14. There is more than enough space for the new port area and the possibility to create extra land in the future. A problem is that almost the whole area needs to be reclaimed. The wetland isn't really in use by the local people; only fishermen had to pass this wetland if they want to catch fish. The area is a little remote because there isn't large city nearby and the roads aren't well-developed. The biggest town nearby is Hayes (approx. Population of 10.000 (Mondiale, 2013)) which is at a distance of 10 km.

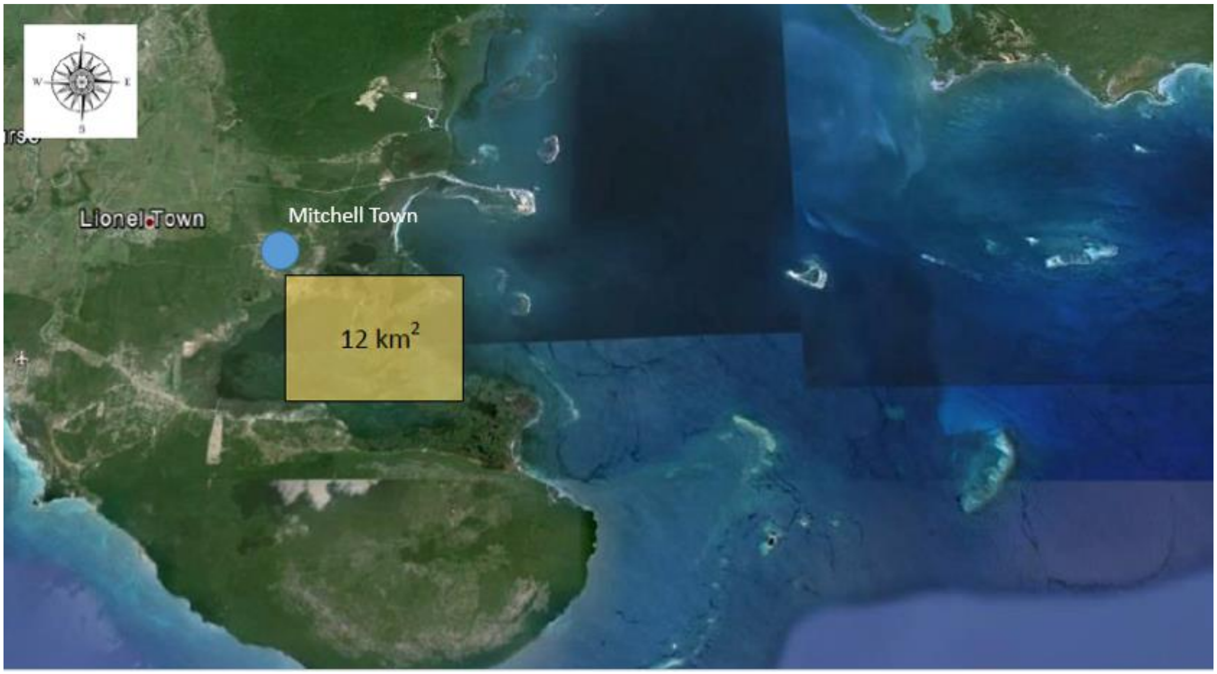


FIGURE I-12 : MAP OF THE AREA AROUND PORTLAND BIGHT - MITCHELL TOWN

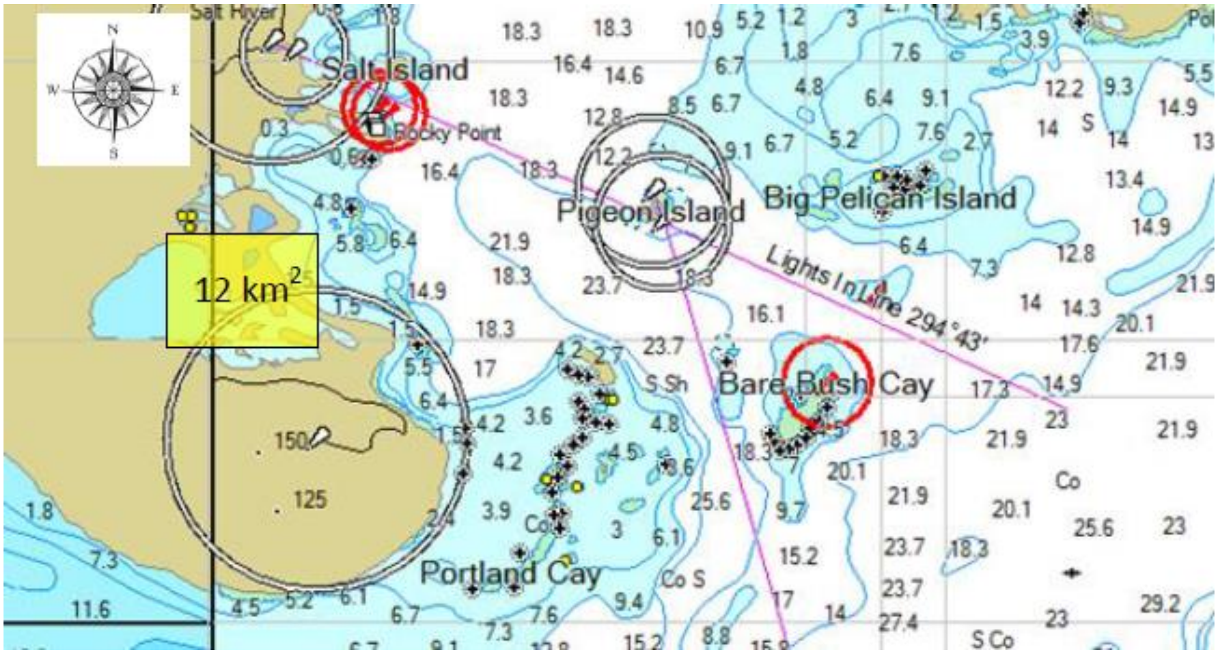


FIGURE I-13: BATHYMETRY AROUND PORTLAND BIGHT - MITCHELL TOWN

When compared with the previous two locations there is more dredging work. The dredged material can be used to reclaim the wetland (see Figure I-14, Figure I-15, and Figure I-16). At this location floodings occurred during hurricanes because of its low lying surroundings. Constructing of a port area here will provide some extra coastal protection to the Portland Cottage lying behind, so a well-designed port area can increase the safety of the people living in the hinterland.

FIGURE I-14: ELEVATION MAP OF AREA AROUND PORTLAND BIGHT - MITCHELL TOWN 1

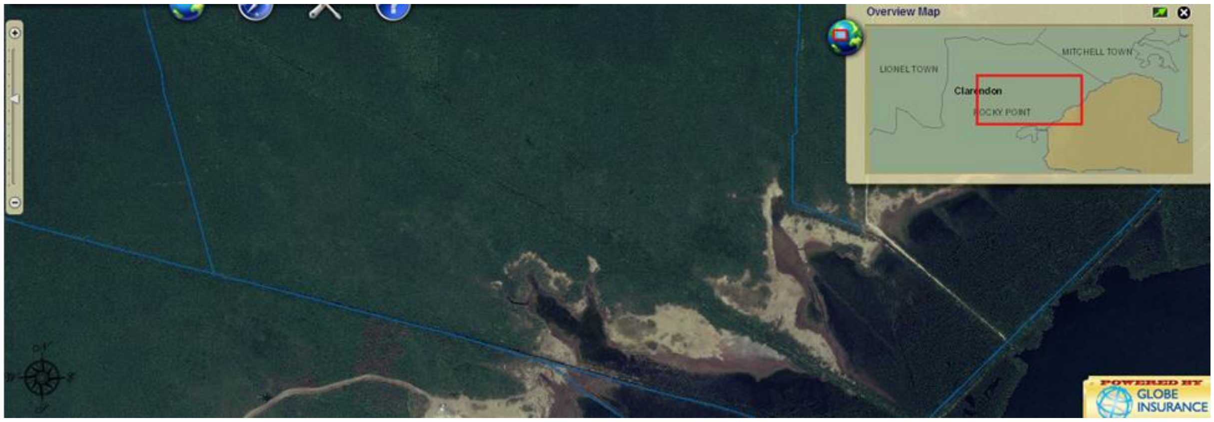


FIGURE I-15: ELEVATION MAP OF AREA AROUND PORTLAND BIGHT - MITCHELL TOWN 2

FIGURE I-16: SITE VISIT PICTURES OF WETLAND AREA AROUND MITCHELL TOWN

1.4 Portland Cottage - Jackson Bay

Portland Cottage (South West) is lying to the west of the most southern point of Jamaica, just inside the protected region Portland Bight. It has the same hinterland as the previous option, Portland Bight – Mitchell Town.

FIGURE I-17: MAP OF THE AREA AROUND PORTLAND COTTAGE

Because this area is lying west on the peninsula (see Figure I-17) it is relatively protected from direct wave impact coming from the east. A big problem is however the longitudinal waves transporting the sediment to the north(west) of this area (Rocky point). At the moment the beach is already eroding. A port area design should include this important aspect and try to stimulate the coastline.

The approach channel could be an issue because of the large shallow area of Jackson Bay (see Figure I-18). An approach channel perpendicular to the currents results in complex maneuverability of the incoming ships. A wider channel, longer stopping length and tugboats are needed. Costs and benefits should be carefully calculated, because of the amount of dredging and dredged material needed.

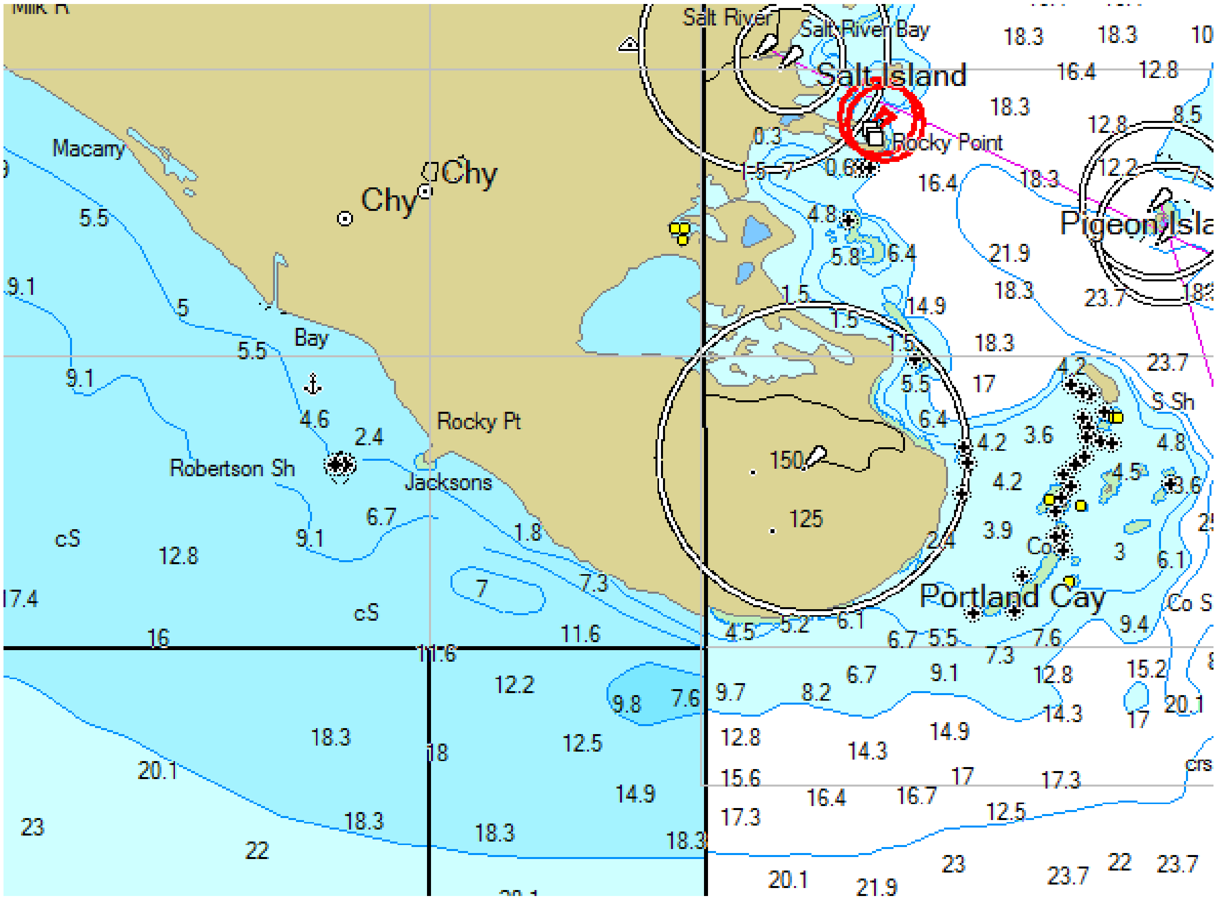


FIGURE I-18: BATHYMETRY AROUND PORTLAND COTTAGE

The elevation maps are present in Figure I-19 and Figure I-20. It looks that the area is far from flat, but in Figure I-21 it is shown that the area is relatively flat. There is only a small hill in the northeast side of Figure I-20. In case of a port the area would be lifted a few meters, because a large part of the area is almost at sea level.

FIGURE I-19: ELEVATION MAP OF AREA AROUND PORTLAND COTTAGE 1

Figure I-20: Elevation map of area around Portland Cottage 2

Figure I-21: Site visit pictures of the area around Portland Cottage - Jackson Bay

1.5 Maccary Bay

To the northwest of the previous location lies Maccary Bay (see Figure I-22). This area looks very similar to the previous location, but it lies just outside the protected area. On the landside there are many (abandoned) fish ponds where shrimps are cultivated. On the south and on the north are two rivers which will provide some sediment.

FIGURE I-22: MAP OF THE AREA AROUND MACCARY BAY

If the port area is constructed in a clever way the coastline at Rocky Point can get a boost to prevent future erosion. There is a fairly large shallow area in front of Maccary Bay (see Figure I-23) so a lot of dredging is needed.

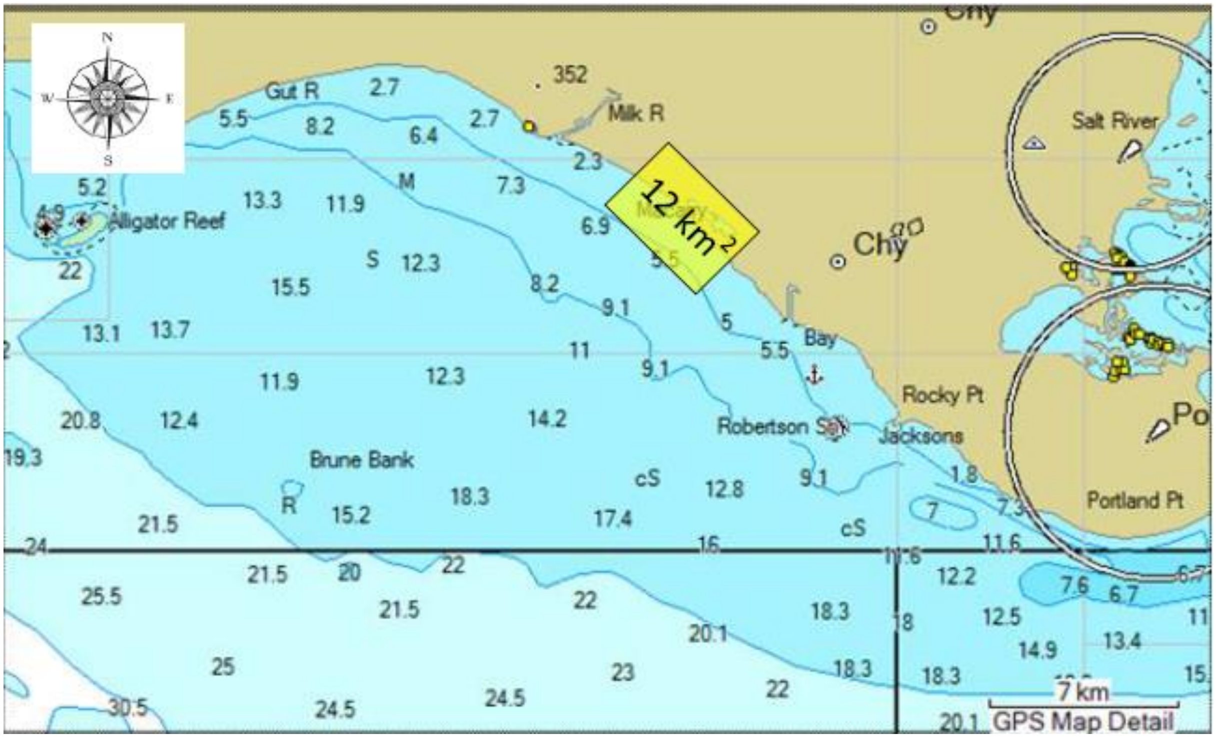


FIGURE I-23: BATHYMETRY AROUND MACCARY BAY

The elevation maps (Figure I-24 and Figure I-25) and the picture (Figure I-26) made during the site visit show that the area is flat. The area is already a couple of meters above sea level.

FIGURE I-24: ELEVATION MAP OF AREA AROUND MACCARY BAY 1

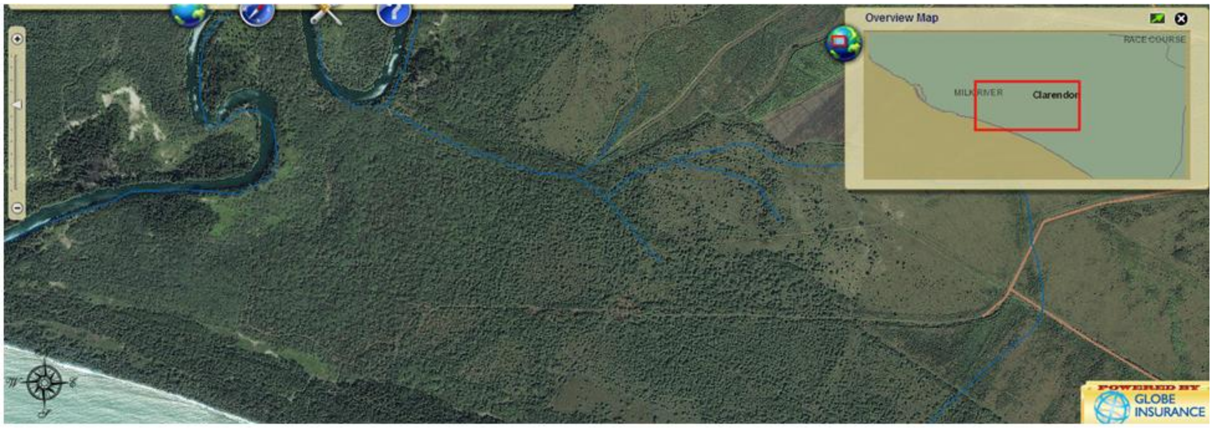


FIGURE I-25: ELEVATION MAP OF AREA AROUND MACCARY BAY 2

FIGURE I-26: SITE VISIT PICTURE OF THE DRY AREA AROUND JACKSON BAY

1.6 Long bay

More to the west is the next possible location at Long Bay (see Figure I-27). The land itself is rather high, see Figure I-29 and Figure I-30. This results in a lot of excavation or in a lot of land reclamation. In case of land reclamation the potential port area should be constructed mostly in the sea. However the bay itself is rather shallow (see Figure I-28) there is a lot of sand needed for reclamation. The dredged material of the approach channel (which is a lot) could be used for this reclamation. Overall is this process relatively expensive.

This location has no cities close by and also lies far away from the highway. The beach is not used for tourism and neither many locals are living here.

FIGURE I-27: MAP OF THE AREA AROUND LONG BAY

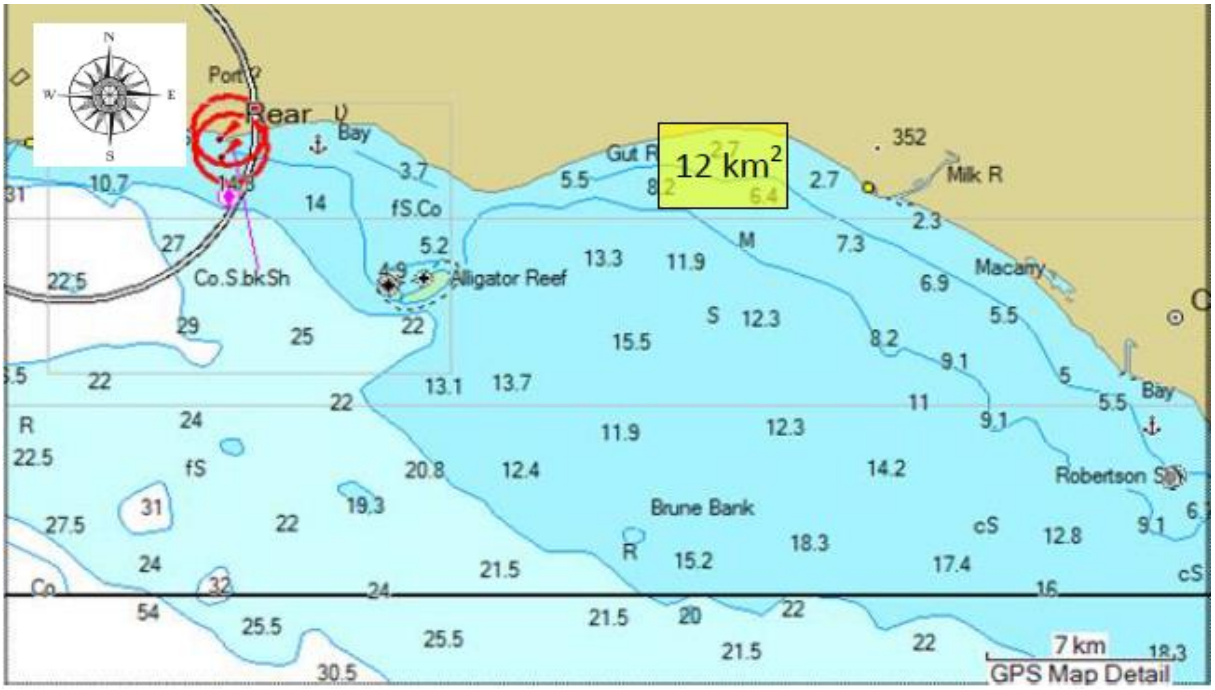


FIGURE I-28: BATHYMETRY AROUND LONG BAY

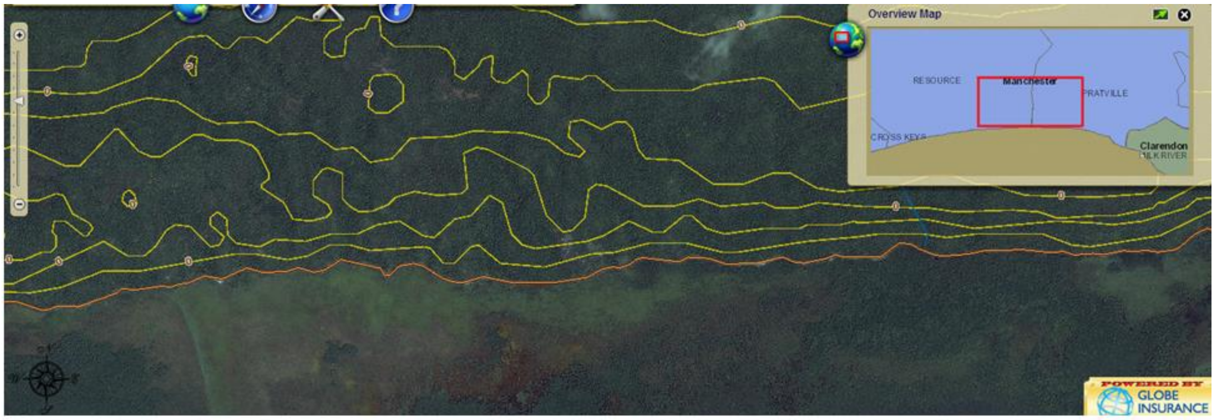


FIGURE I-29: ELEVATION MAP OF AREA AROUND LONG BAY 1

FIGURE I-30: ELEVATION MAP OF AREA AROUND LONG BAY 2

1.7 Alligator Pond – Calabash Bay

Alligator Pond is a fishing village and therefore the beach is mainly used for stalling fishing boats. The selected area lies almost entirely in the sea because of the high hills on the land side, see Figure I-33 and Figure I-34. It reaches to the Alligator Reef where a lot of wave energy is absorbed (see Figure I-31 and Figure I-32). Alligator Pond is lying far away (aprox. 50 km) from (other) towns of importance. Also the highway is 20 km far away, and even then a large distance still needs to be travelled before reaching any bigger communities.

FIGURE I-31: MAP OF THE AREA AROUND ALLIGATOR POND

Because the place lies very close to some deeper areas the amount of dredging needed for the approach channel is negligible. The reefs are at the dominant wave direction side, so the breakwater can be constructed relatively cheap.

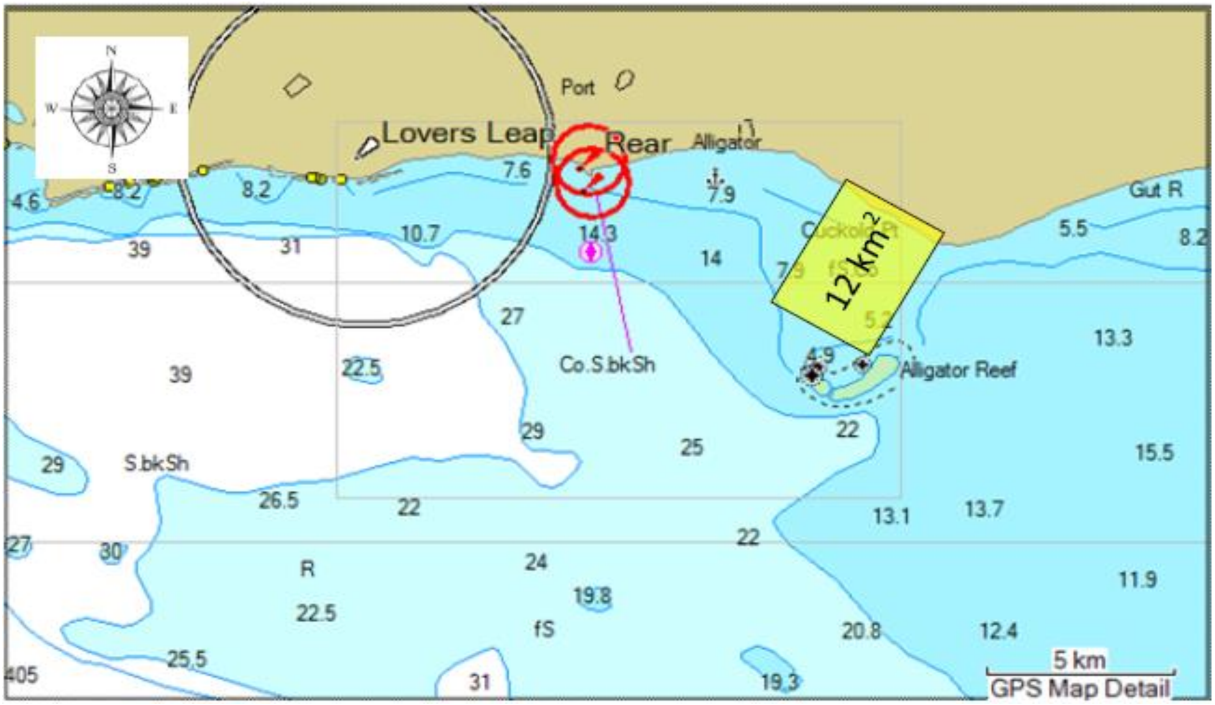


FIGURE I-32: BATHYMETRY AROUND ALLIGATOR POND

FIGURE I-33: ELEVATION MAP OF AREA AROUND ALLIGATOR POND 1

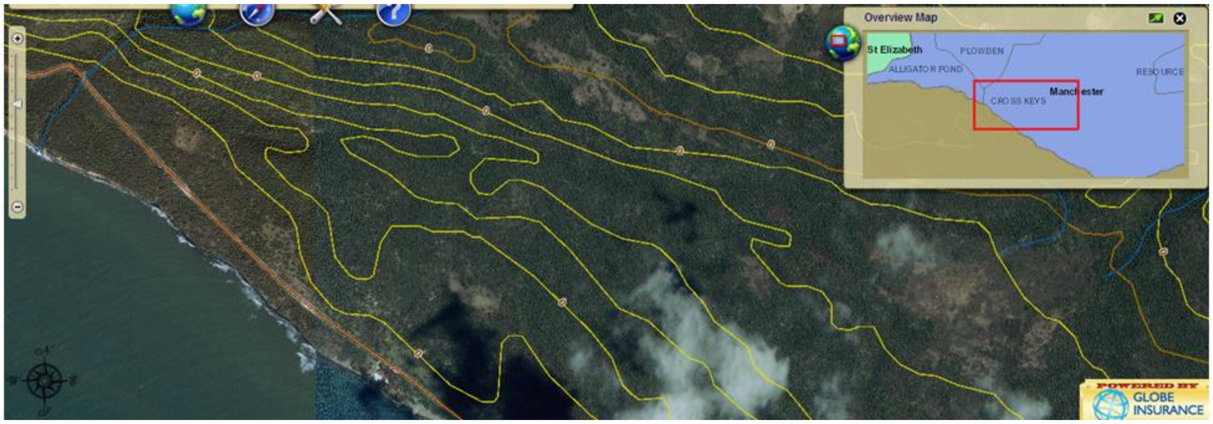


FIGURE I-34: ELEVATION MAP OF AREA AROUND ALLIGATOR POND 2

1.8 Parottee

A few kilometers south of the Parottee Pond lies Parottee Bay (see Figure I-35). This location is relatively flat (see Figure I-37) and possibly easy to elevate. If the entrance to the port is pointed to the northwest the port will be sheltered very well and the ships won't have much trouble maneuvering inside. Wave conditions from the south of the future port area will be much higher than on the west side (see Figure I-36). Heavier protection is needed at the south.

As for the whole area around Black River, the beach is used by fishermen. However, a few houses on the beach are built for middle/higher class and a few expensive houses can be found here. When the port area is realized these houses need to be destroyed and/or replaced.

FIGURE I-35: MAP OF THE AREA AROUND PAROTTEE

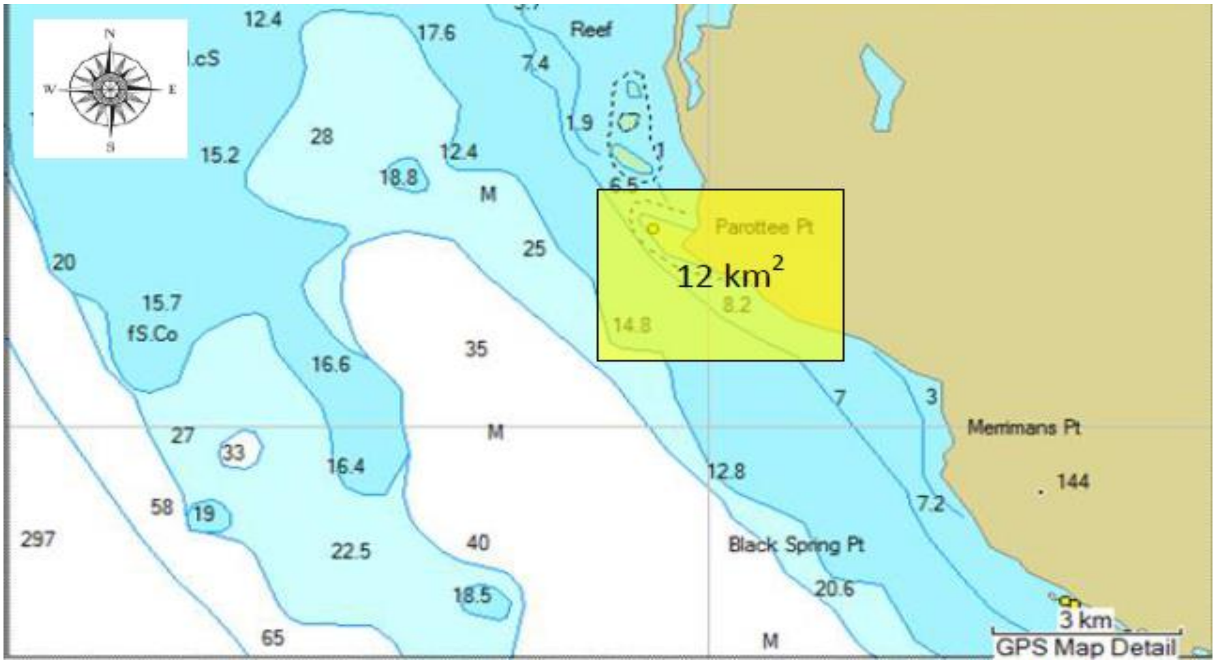


FIGURE I-36: BATHYMETRY AROUND PAROTTEE

Not much dredging is required for this area. Figure I-36 shows can see the depths are around 25 meter relatively soon. The other shallower area to the west is almost sufficient for the Post Panamax ships.

FIGURE I-37: ELEVATION MAP OF AREA AROUND PAROTTEE 1

FIGURE I-38: ELEVATION MAP OF AREA AROUND PAROTTEE 2

As Figure I-37 and Figure I-38 show the area is flat and apart from the few houses on the beach there isn't much around (see Figure I-39). The area contains a lot of trees and a dried up wetland where goats are grazing.

FIGURE I-39: SITE VISIT PICTURE OF AREA AROUND PAROTTEE

1.9 Black River

In the north of Parottee Pond and in the south of the city Black River flows the Black River and nearby the sea its wide floodplains. These floodplains can be transformed into a port area (see Figure I-40) if the river is guided to the sea by canalizing the river and installing some hydraulic structures. The floodplains are the main downfall to this area. On the Black River a lot of tourist boats are found to sail up the river to go for crocodile spotting.

The highway A2 crosses the city Black River which continues its way to Savanna-la-Mar to the west and to Santa Cruz to the east. However, the highway to Savanna-la-Mar is in bad condition and should be improved if trucks need to take this route.

FIGURE I-40: MAP OF THE AREA AROUND BLACK RIVER

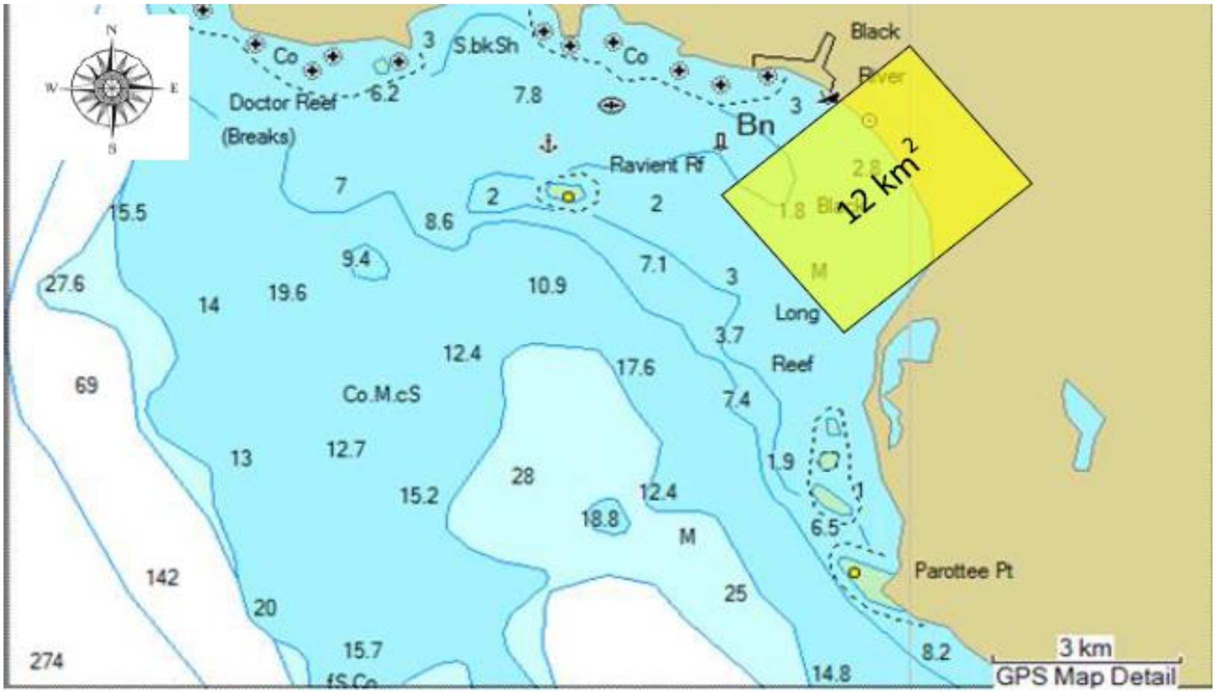


FIGURE I-41: BATHYMETRY AROUND BLACK RIVER

Because the bottom of the sea is relatively flat (see Figure I-41) there are much expansion possibilities. However a long approach channel should be dredged in order to get the bigger ships into the port.

FIGURE I-42: ELEVATION MAP OF AREA AROUND BLACK RIVER 1

FIGURE I-43: ELEVATION MAP OF AREA AROUND BLACK RIVER 2

FIGURE I-44: SITE VISIT PICTURE OF THE AREA AROUND BLACK RIVER

1.10 Crawford – West

(South)West of Crawford (see Figure I-45) lies an open area called Fonthill Nature Reserve. This area is completely uncultivated. Though the location looks very vulnerable to wave attacks, it is not. In front of the coast the sea is shallow and further into the sea some reefs are found which break a lot of wave energy (see Figure I-46).

The area is owned by the Petroleum Company of Jamaica (PCJ) who reserved the area for a petroleum port. During the site visit the whole area was locked down by the PCJ. The area is not close to a major city and the roads are not well-developed.

FIGURE I-45: MAP OF THE AREA AROUND CRAWFORD

FIGURE I-46: BATHYMETRY AROUND CRAWFORD

The port area can be expanded to the south-southwest of the land this area is perfect for the approach of the bigger ships. Figure I-46 shows that the port area can be constructed in such a way an very short (less than 300m) approach channel needs to be dredged. The land area is about 10 meters above sea level, but further it is relatively flat as shown in Figure I-47 and Figure I-48.

FIGURE I-47: ELEVATION MAP OF AREA AROUND CRAWFORD 1

FIGURE I-48: ELEVATION MAP OF AREA AROUND CRAWFORD 2

1.11 Belmont

Between the cities New Hope and Belmont lies another possible location (see Figure I-49). At a first look the area is big enough to provide enough space for the port area. However when looking at contour maps Figure I-51 and Figure I-52 a lot of hills are obstructing the plans. This pushes the port area more to the seaside as shown in Figure I-49. This also is not an option as high depths are reached very soon (see Figure I-50).

This gives the conclusion that on second hand this area does not have enough space to support the construction of our port area. That is why the area Belmont will not come back in the rest of this chapter.

FIGURE I-49: MAP OF THE AREA AROUND BELMONT

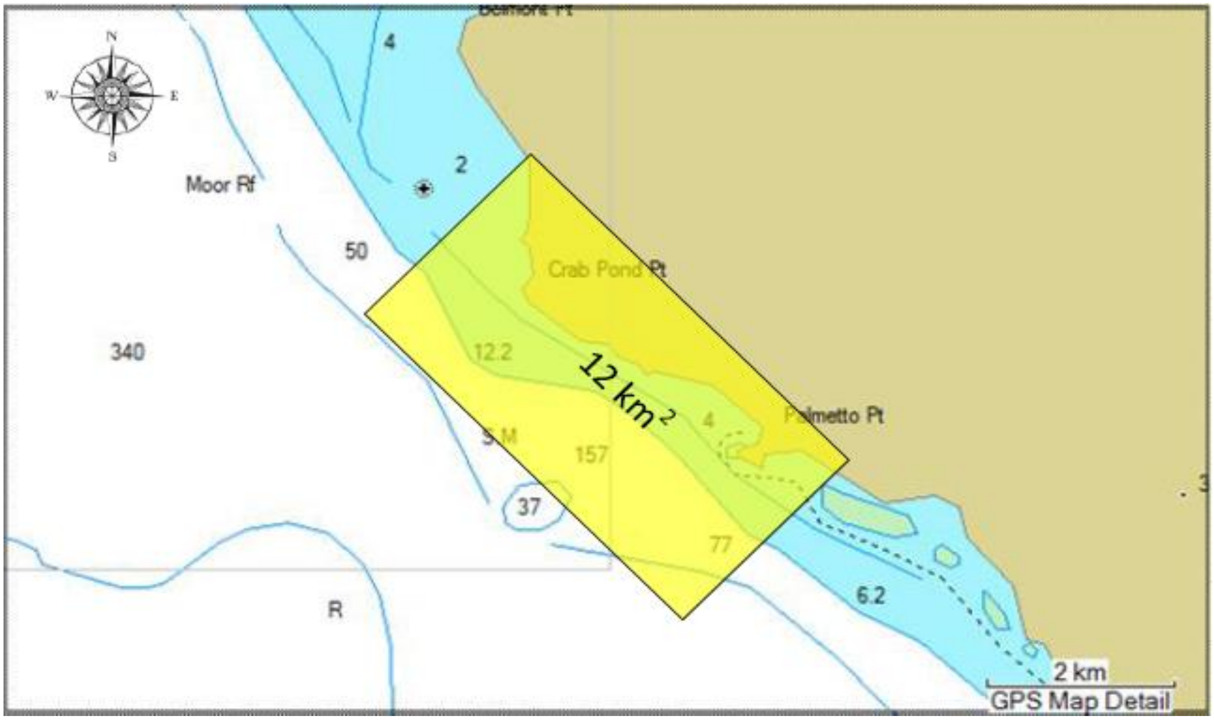


FIGURE I-50: BATHYMETRY AROUND BELMONT

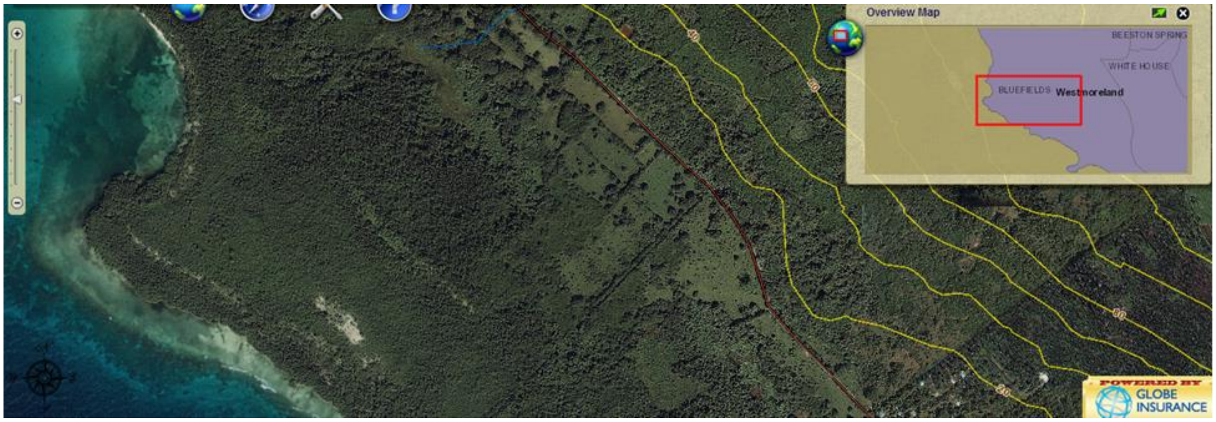


FIGURE I-51: ELEVATION MAP OF AREA AROUND BELMONT 1

FIGURE I-52: ELEVATION MAP OF AREA AROUND BELMONT 2

1.12 Savanna-la-Mar

A more shallow area can be found further to the west. West of Savanna-la-Mar (see Figure I-53) lies an open terrain with low lying land (see Figure I-55 Figure I-56) and close to the already existing port of Savanna-la-Mar. The area is protected by reefs and a shallow bay. Possibilities for expansion are mostly to the sea side. The beach and the bay are used by local fishermen.

FIGURE I-53: MAP OF THE AREA AROUND SAVANNA-LA-MAR

At this site a lot of dredging is needed (see Figure I-54). Because the already existing port of Savanna-la-Mar only copes with small ships there is no approach channel that can be used. The alignment of the new approach channel is also not ideal, because of the dominant waves from the southeast.

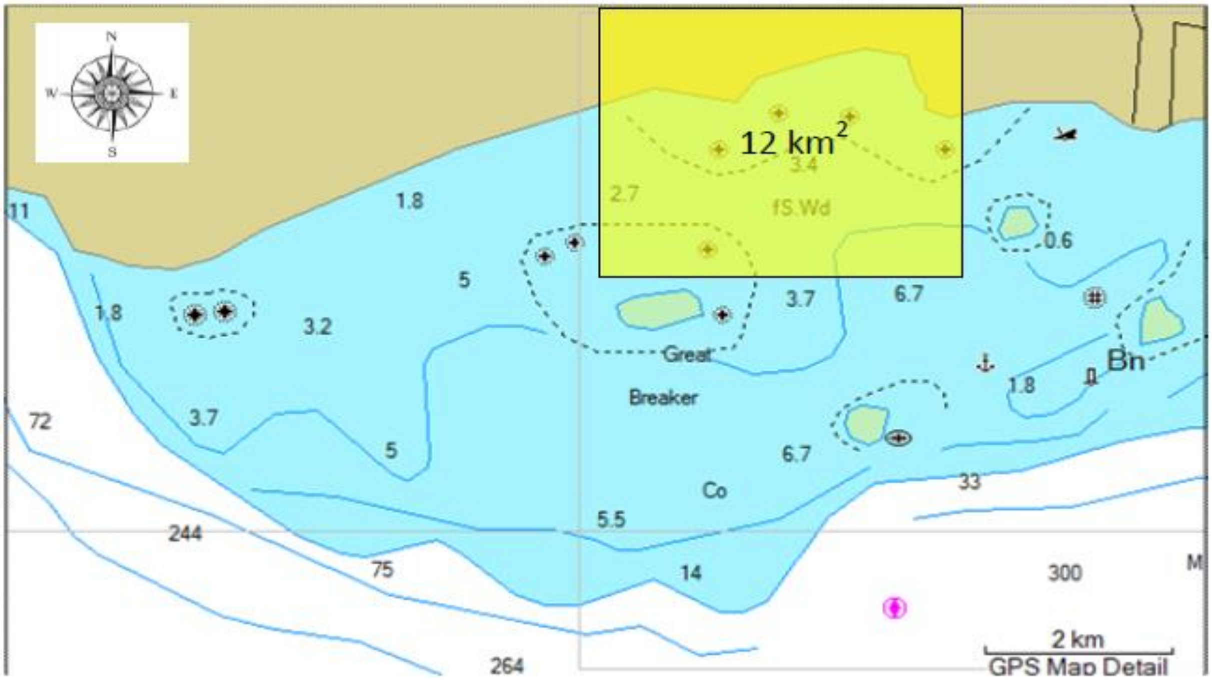


FIGURE I-54: BATHYMETRY AROUND SAVANNA-LA-MAR

Figure I-55: Elevation map of area around Savanna-la-Mar 1

Figure I-56: Elevation map of area around Savanna-la-Mar 2

Figure I-57: Site visit pictures of the area of Savanna-la-Mar

1.13 Little Bay

A bit more to the west lies another possible location, see Figure I-58. Also here the beach is used by local fishermen and the area is very shallow (see Figure I-60 and Figure I-61). Possibly both areas (Savanna-la-Mar & Little Bay) can be used together to create an even bigger port area. The land area behind the beach is used by local village people living of the sea and their cows and goats. The area lies close to Savanna-la-Mar and Negril. However this area is lying the most to the west of all possible locations which makes it the furthest away from Kingston and its regions where the main industry is focused.

FIGURE I-58: MAP OF THE AREA AROUND LITTLE BAY

When looking at land reclamation, digging and dredging this area looks promising. The area to the sea is really shallow and the approach channel can be constructed with little effort in the perfect alignment (see Figure I-59). Construction of a breakwater might give some problems though. Because the port should be constructed right into the sea into the dominant waves the breakwater might become the head of expenditure. Designing this breakwater is very important with future expanding keeping in mind. Removing the breakwater in the future is not favorable.

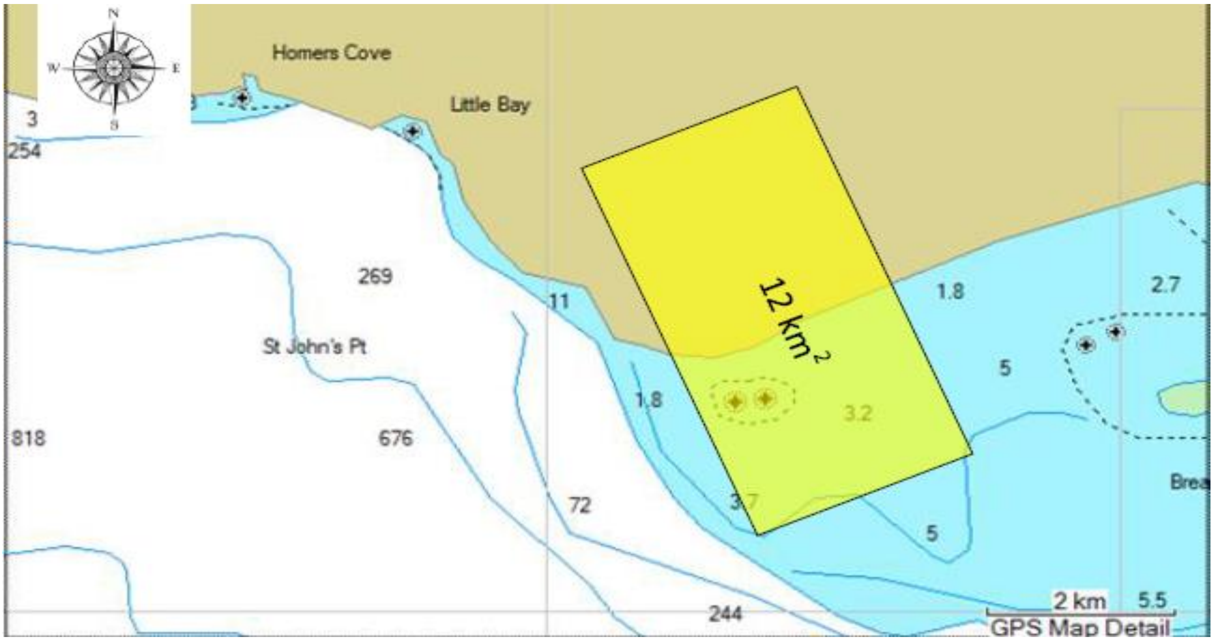


FIGURE I-59: BATHYMETRY AROUND LITTLE BAY

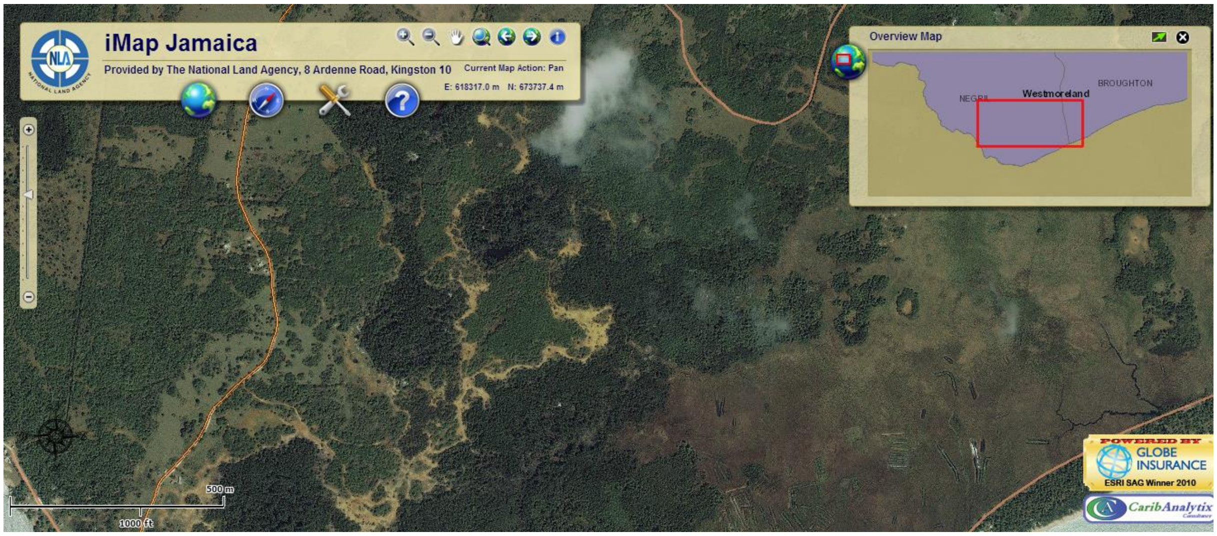


FIGURE I-60: ELEVATION MAP OF AREA AROUND LITTLE BAY

FIGURE I-61 SITE VISIT PICTURES AROUND THE AREA OF LITTLE BAY

1.14 Duncans

On the north of Jamaica lie two other possible locations. North of Duncans lies an open area which, by looking at Figure I-62, looks promising. However big cliffs can be found here which makes the construction on land very difficult. Also the narrow shelf (see Figure I-63) makes the construction in the water very difficult. This fact makes this location a drop out and will not be investigated further as mentioned in chapter 1, Locations.

FIGURE I-62: MAP OF THE AREA AROUND DUNCANS

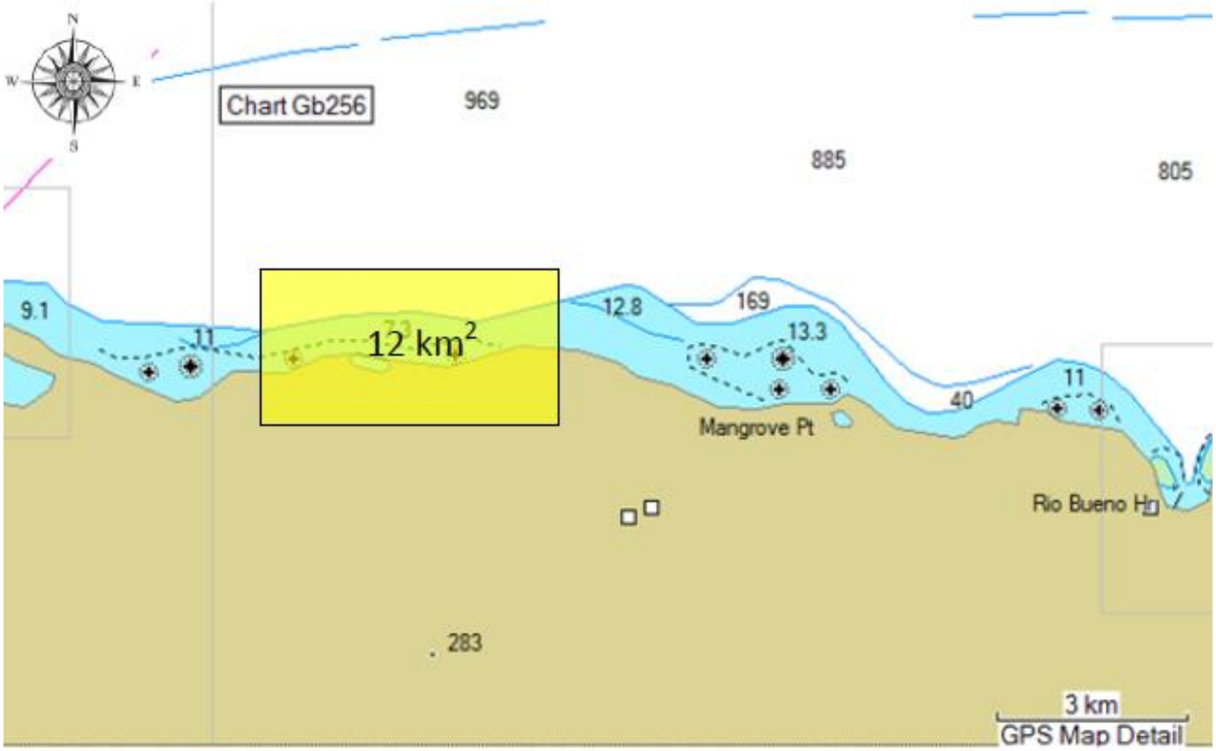


FIGURE I-63: BATHYMETRY AROUND DUNCANS

1.15 Buff Bay

The other location on the north of Jamaica is around Buff Bay (see Figure I-64). This location has the same problem as Appendix I 1.14 Duncans. The cliffs continue their way and can also be found here (see Figure I-66). Again the lack of available flat land makes this location a drop off and will also not be investigated further.

FIGURE I-64: MAP OF THE AREA AROUND BUFF BAY

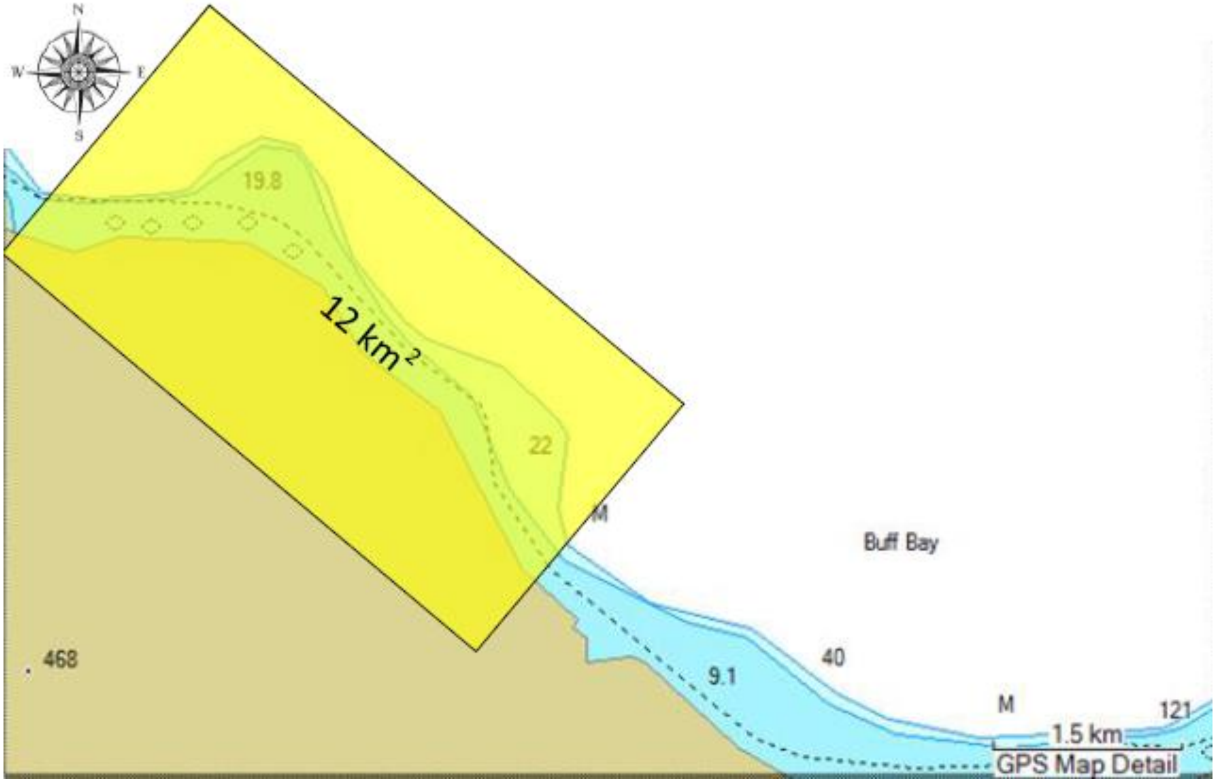


FIGURE I-65: BATHYMETRY AROUND BUFF BAY

FIGURE I-66: ELEVATION MAP OF AREA AROUND BUFF BAY

1.16 Bowden Harbour

On the other side of island of Jamaica, east of Kingston lies Bowden Harbour. A natural bay with possibilities to create a port area both in the harbour and to the east land inwards (see Figure I-67, Figure I-69, and Figure I-70). This location is different from the other potential locations. It lies east of Kingston on the east side of Jamaica. The area around Port Morant and Morant Bay copes with a high unemployment rate. Though some resorts are located at Morant Bay.

FIGURE I-67: MAP OF THE AREA AROUND BOWDEN HARBOUR

For extra protection against possible hurricanes a small breakwater is an option to the east side of the mouth of the bay. This will boost the total protection of the whole behind lying area. Dredging isn't much apart from the bay. Required depths are found relatively soon (see Figure I-68).

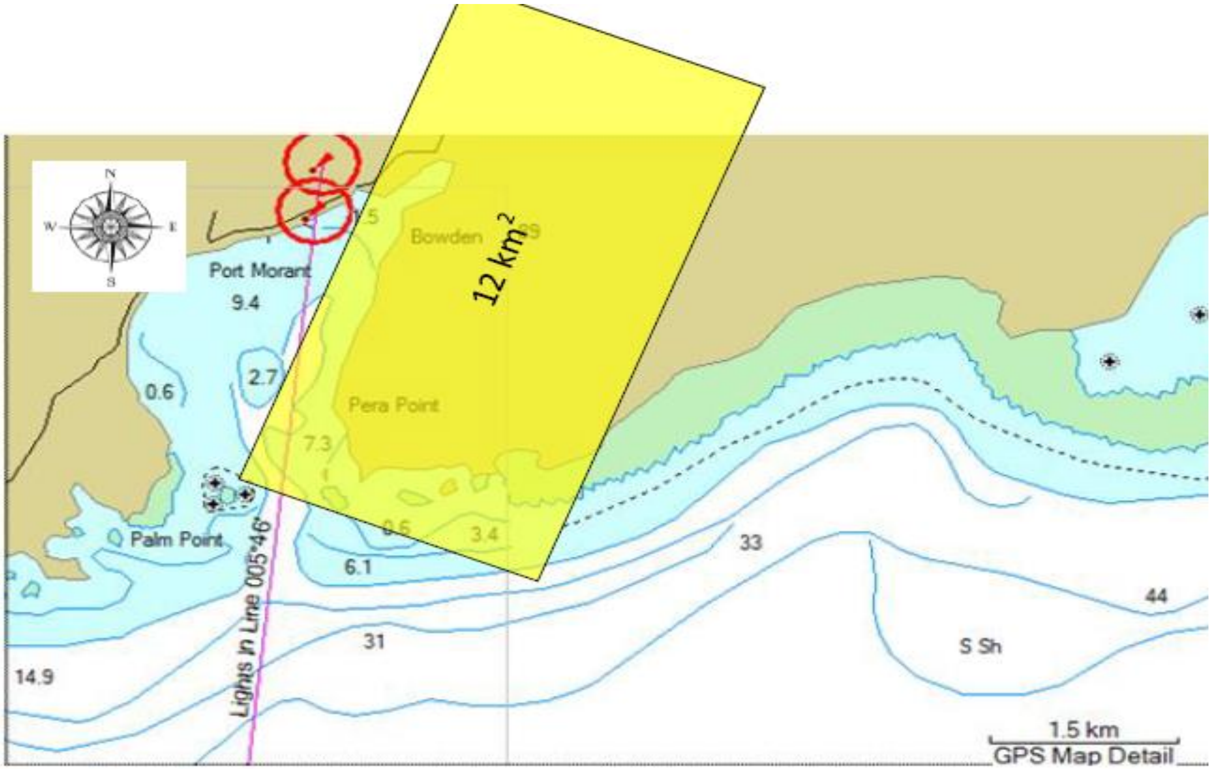


FIGURE I-68: BATHYMETRY AROUND BOWDEN HARBOUR

FIGURE I-69: ELEVATION MAP OF AREA AROUND BOWDEN HARBOUR 1

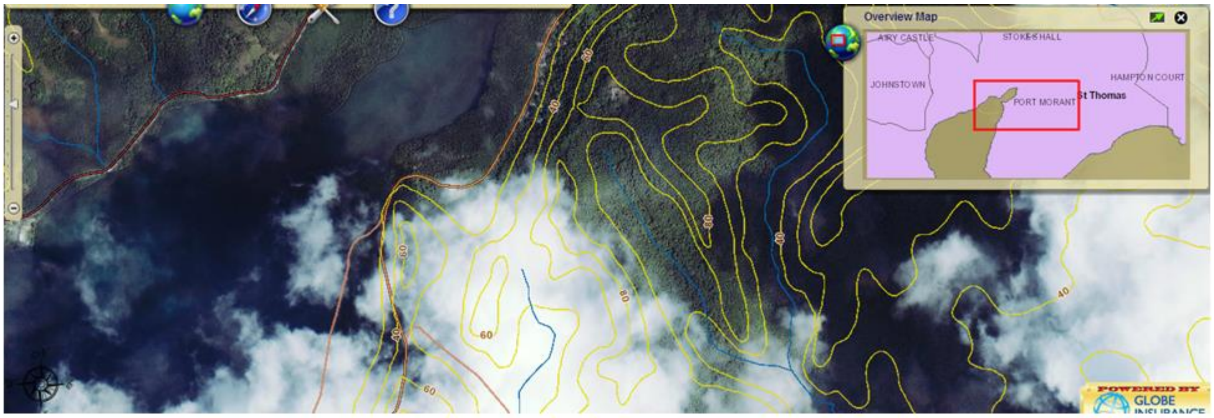


FIGURE I-70: ELEVATION MAP OF AREA AROUND BOWDEN HARBOUR 2

2 Criteria

To compare and pre-select the different locations criteria have been drawn up. The criteria that are used are listed below in alphabetical order.

Building time and method

The time it takes to build a port area can be very variable. Because the expansion of the Panama Canal will be ready relatively soon (2015/2016) the new port should be in operation as soon as possible to be competitive right after the opening of the Panama Canal.

Less land reclamation reduces the building time dramatically. When new land is created waiting time for the sand to settle should be taken into account. This may take months or even years depending on the building method (applying drainage, applying surcharge of sand, doing nothing). Also for this criterion it is better if the preparation time for the land is less, so flat land is easier to prepare the building site than high hills. Here the building method can also reduce the building time and should be valued against the investment costs.

Combination with coastal protection

To create additional value for Jamaica coastal protection could be integrated into the design of the port for instance if the coastline is eroded by longitudinal waves. If the design of the new port area includes a breakwater for sheltered berthing, the breakwater can stimulate the coastline by sand accumulation outside the port area. Dredged material can also be used to nourish the endangered beach. Areas which are flooded once in a few years could be protected (in)directly. Another option is if the port area is designed in the weakest area of the coastal zone. The port area creates an integrated coastal defense against nature. If the economic value of the area is increased (by creating the port area) there is need for higher protection. Already existing factors can benefit from this.

Dredging of approach channel

The creation of the approach channel is an important factor when designing a port area. It can be a crucial factor when looking at the possible locations. When designing the approach channel the bathymetry of the area and the dominant wave direction should be taken into account. Because the main wave direction is from the east or south-east the approach channel should be pointing to the east or south-east. This might conflict with the ideal channel when looking at the bathymetry. Between these two criteria the best option should be found.

The amount of dredging can be selected under the criterion environment or building time, but because of its importance there is chosen for a separate criterion. This criterion includes if the amount of dredged material is useful for the development of the port area. The sand balance of dredging and reclamation is also taken into account.

Economic value for the area

A port can give a boost to the local economy. If a region faces a high unemployment rate creating a port area can be great opportunity. Economic boosting of Jamaica on its own is left out of consideration here. That's a bigger question and does not differ for each of the locations. The criteria here looks more at regional level so the Jamaican nation as a whole should benefit the most as possible from the new port area. This criterion takes the nowadays use of the area into account. If there are already some positive economic activities (like work for the fishermen) this is negative for this criterion.

Environmental

This criterion takes into account all environmental damage the port area development will make to the whole area. Potential ports located in an environmentally protected area score low on this criterion, so the score is inversely related. Damage to nature is taken into account which is different at each of the possible locations. Destroying alive coral reef is given a lower score than building on a dead coral reef (which will also get a low score). No matter what actions will be taken to develop the port area, the environment must be better than before. Destroying something means building it up somewhere else or giving an extra boost to the environment elsewhere.

It is also possible to improve (parts of) the local environment by building the port area. Making sheltered areas not only for ships but also for fish sanctuaries for instance.

Dredging surplus is also taken into account here. If a lot of dredging is needed it could also give some problems to the environment. If dredged material for the approach channel is not suitable for land reclamation it will be dumped somewhere else. Not only gives this aspect higher cost but will also be bad for the environment (because of transport).

Maintenance

Sediment transport from rivers or longitudinal drift can settle in the approach channel or inside the wet area of the port. This results in a lot of maintenance dredging which not only costs a lot of money, but also causes downtime of the port (which cost indirectly money). Low maintenance time and costs are location dependent and thus affect the location choice. The score of this criterion will be an estimation, otherwise all the alternative sites will be modeled which costs a lot of time.

Nearby city

Still much is uncertain about the Chinese plan. Whether Chinese or Jamaican will work in or at the new port area connection with the mainland is important. If an (existing) mayor city is close for providing housing and food to the workers, this is preferable.

Possibility to expand

CHEC wants an area of 12 km^2 (Observer, 2013) which already seems much, but because of many uncertainties in container traffic forecast the port might even grow in the future. To make sure this growing in the future can occur an area larger than 12 km^2 is required. Therefore it is positive if the location has possibilities to expand in the near or later future.

Road and rail connections

Despite the ports main focus lies on transshipment of containers overseas, a hinterland connection could be interesting. Existing bauxite or oil docs can use the shelter of the created port to berth. The port area could benefit from already existing road and railway connections. This industry also needs hinterland connection. Next to the transshipment port space of the port area is reserved for industry.

Wind and wave climate

The hydraulic aspects (tides and currents) and oceanography (wind and wave climate) are very important aspects for a port. The tide is assumed mixed semidiurnal, small and more or less the same all around Jamaica. If there is a rough climate berthing, loading, and unloading is impossible, so a sheltered place is required. Next to the usability of the port the port area itself should also be protected against heavy storms and hurricanes. During these rare events it is acceptable to shut down the port for economic activity, but should be operative as soon (and cheap) as possible after the storm. The degree of artificial protection like breakwaters will be considered, but natural shelter is preferred as it gives less building costs.

3 Weights

The criteria are established, but they are not equal in importance. To rate the criteria each criterion is given a weight. Though this is a subjective method it is one of most 'fair' selection methods currently present. The goal is to try to approach the selection as much as objective as possible.

The ten different criteria are given different values for their importance. This is done by making a matrix and giving priorities over each other. Every criterion will be compared with the other nine criteria. The more important criteria gets one point, the other criteria gets none. In the end the criteria with the most points is the most important criterion.

All the criteria should get at least one point to prevent a score of zero. Otherwise the other criteria are infinite times as more important as the lowest criteria. The total score is calculated by adding one point for every horizontal score of 1 and one point for every vertical score of 0 to the criteria. The criterion Maintenance for instance gets two 1's in its row and one 0 in its column, so a total score of 3.

TABLE I-1: WEIGHTS OF THE CRITERIA

	Building time and method	Combination with coastal protection	Dredging	Economic value for the area	Environmental	Maintenance	Nearby city	Possibility to expand	Road and Rail connections	Wind and wave climate	**Total score:**
Building time and method	1	1	0	0	1	0	1	0	1	0	**4**
Combination with coastal protection	x	1	0	0	0	1	1	0	1	0	**4**
Dredging	x	x	1	0	0	1	1	0	1	0	**6**
Economic value for the area	x	x	x	1	1	1	1	1	1	1	**10**
Environmental	x	x	x	x	1	1	1	0	1	1	**7**
Maintenance	x	x	x	x	x	1	0	0	1	0	**3**
Nearby city	x	x	x	x	x	x	1	0	1	0	**3**
Possibility to expand	x	x	x	x	x	x	x	1	1	1	**9**
Road and rail connections	x	x	x	x	x	x	x	x	1	0	**1**
Wind and wave climate	x	x	x	x	x	x	x	x	x	1	**7**

In Table I-1 the result of weighting of the criteria is shown. The weights are made based on the perspective of the government, but also keeping in mind that the costs do not raise to the extremes.

The result show that none of the criteria is more important than economic value for the area, thus this is most important criterion. This is mainly because people are hard to move. Problems occurring when dealing with wind, waves and the environment have technical solutions. Breakwaters can be constructed or can be made stronger and the environment can be compensated at another side. Of course this is can only be done to a certain extend. That's why environment and wind and wave climate still come out relatively well with a score of 7.

According to this method the least important criterion to be taken into account is the existing road and rail connections. This is also because new rail and road connections can give a second boost to the area, so it is more important that the port area is located near a big city. Besides this the new port area is assumed to focus for almost 100% to transshipment of containers on sea ships, inland transport will be hardly used. If this should change in the future roads and railways can still be constructed.

Table I-2 is a summary of the total score and their relative influence.

TABLE I-2: LIST OF RANKED CRITERIA

	Score	**Value**
Economic value for the area	**10**	19%
Possibility to expand	**9**	17%
Environmental	**7**	13%
Wind and wave climate	**7**	13%
Dredging	**6**	11%
Building time and method	**4**	7%
Combination with coastal protection	**4**	7%
Nearby city	**3**	6%
Maintenance	**3**	6%
Road and rail connections	**1**	2%

4 Score

After giving weight to the different criteria the locations get a score for every different criterion. The sum of the scores times their weight gives an amount of points. To present the amount of reached points in perspective the amount of points will be divided by the maximum possible score. In Table I-3 the scores and the total score of all the locations are showed. The location with the highest score (max 100 points) is the most ideal location.

TABLE I-3: SCORES OF ALL THE LOCATIONS ON THE CRITERIA AND A TOTAL AMOUNT OF POINTS REACHED

		Building time and method	*Combination with coastal protection*	*Dredging (Amount)*	Economic value of the area	*Environmental*	*Maintenance*	*Nearby city*	*Possibility to expand*	*Road and Rail connections*	*Wind and wave climate*	**Total (max 100 points)**
1	Great Goat Island	*3*	*1*	*4*	*4*	*1*	*3*	*4*	*2*	*4*	*5*	**61**
2	Portland Bight - Cockpit	*3*	*1*	*4*	*4*	*1*	*3*	*4*	*3*	*3*	*4*	**61**
3	Portland Bight - Michell Town	*2*	*5*	*2*	*2*	*1*	*3*	*2*	*4*	*3*	*4*	**55**
4	Portland Cottage South West	*4*	*4*	*3*	*4*	*4*	*2*	*2*	*3*	*2*	*4*	**69**
5	Maccary Bay	*5*	*4*	*1*	*4*	*4*	*2*	*2*	*5*	*3*	*4*	**73**
6	Long Bay	*1*	*1*	*1*	*3*	*3*	*2*	*2*	*3*	*2*	*4*	**50**
7	Alligator Pond - calabash Bay	*1*	*2*	*5*	*2*	*3*	*4*	*4*	*1*	*2*	*4*	**54**
8	Parottee	*3*	*1*	*4*	*3*	*2*	*4*	*2*	*2*	*1*	*4*	**55**
9	Black River	*3*	*2*	*2*	*3*	*1*	*1*	*3*	*3*	*2*	*4*	**51**
10	Crawford -West	*2*	*1*	*5*	*4*	*3*	*5*	*3*	*4*	*2*	*3*	**69**
12	Savanna-La-Mar	*3*	*2*	*2*	*3*	*3*	*3*	*5*	*4*	*2*	*4*	**64**
13	Little Bay	*4*	*1*	*4*	*3*	*3*	*5*	*4*	*2*	*2*	*4*	**63**
16	Bowden Harbour	*1*	*2*	*5*	*4*	*3*	*3*	*3*	*2*	*2*	*3*	**60**

To underpin the scores for every location the most extreme scores are explained below:

(1) Portland Bight - The Great Goat Island. Because of its location in the back of the bay the wind and wave climate will be ideal for the port area, so the score is high. Also it is the location which is close to Kingston and surroundings and after finishing the highway easily accessible by car. Because its location in the back the first taught is a lot of dredging for the approach channel needs to be done, but the bay has already a relatively deep approach channel (not deep enough). It scores lowest on environmental impact because it lies in the middle of a protected area. Some land needs to be reclaimed and excavated so it scores medium on criterion building time.

(2) Portland Bight - Cockpit. This area shows many similarities with the previous location. It scores lower on road and rail connections because it lies a little more out of the more domestic areas. This fact makes the location score high at possibility to expand, because more space is found here.

(3) Portland Bight - Mitchell Town. This also shows a lot of similarities with the above mentioned potential locations. Though it lies even more away from the big neighboring cities. A big plus here is the combination with coastal protection. The wetlands itself and the area behind it (including Portland Cottage) where washed away by recent tropical storms. Building a port area here will reduce the chance of flooding dramatically. The surrounding villages live from the fish industry so therefore it scores lower on economic value.

(4) Portland Cottage South West – Jackson Bay. This area looks very promising. However the location lies far away from the bigger cities and a lot of dredging needs to be done, the area is big enough, the nature is less beautiful than the above locations (although the area lies on the border of the protected Portland Bight area) and there isn't much living in the area.

(5) Maccary Bay. This area gets the highest average score. There is a lot of space to expand in the future, it is a flat open area and the land is already some meters above sea level. Back in the days this area exists of many fish ponds, but nowadays the ponds aren't in use. The building time is low and it lies outside a protected area. The possible port area is protected from direct waves and wind impact by the Portland Cottage peninsula. Mayor downfall however is the high amount of dredging needed for the approach channel. This could be after further analyses the deathblow to this spot.

(6) Long bay. Except from the size of the area there aren't much positive aspects. Even the size is not optimal, there is much land needed to be reclaimed which results in a long building time. Away from the civil world, no need for coastal protection, and with a long approach channel which will require much maintenance it turns out to be the least favorite spot.

(7) Alligator Pond – Calabash Bay. This is a perfect spot when looking only at the approach channel. It is pointing to the west (most favorable because of the dominant wave direction) and is very short. This results in high points for the dredging and the maintenance criteria. Because there is not much space to build on land the criteria building time and possibility to expand score low. Because there are already lying some natural breakwaters (the alligator reef) extra coastal protection isn't needed here.

(8) Parottee. The location is far away of the main towns and roads. A little bit of land reclamation should be needed and the approach channel will give a challenge. Some nature is harmed and there is some living in there. In the future there are a few possibilities to expand the port area. All in all it is a pretty decent spot, but nothing special.

(9) Black River. In contrary with the previous one this is a location full with extremes. The Black River itself is the main problem. The possible location lies right in its flood plains. Technically looking this is solvable, however it scores low on the environmental criteria. Next to that the approach channel should be extremely large. This will bring high costs along the way. On the other side the wind and waves will be calm and building time will be low because of the few amount of land reclamation that needs to be done.

(10) Crawford – West. The Fonthill Nature Reserve is a protected area which has a big negative impact on the total score for this location. Further this land is owned by a Petroleum company. Though there is a highway close to the spot this highway doesn't lead to any important cities. Next to the average other scores it scores high on building time and amount of needed dredging which in total makes this potential area one of the best possibilities.

(12) Savanna-la-Mar. This is another good spot for a potential port area. Enough area to construct a port area both on land and in sea. Both relatively flat and not too high or deep, which results in a low building time. Expanding the port area is possible when more than 3000 acres are needed. Because it lies close to Savanna-la-Mar the local economy could get a big boost. Because of the shallow area the dredging for the approach channel is low/medium.

(13) Little Bay. Little bay scores more or less the same total score as the location Savanna-la-Mar, however expanding is more complex. The waves are coming from the east so the breakwater must protect the port area from those waves. Expanding is only possible to the west, so than the breakwater should be removed. This is very expensive so the port area layout isn't that easy. It scores high on dredging because west of the port area is directly a deep shelf.

(16) Bowden Harbour. This location does not score great overall. It lies very much away of the bigger cities of Jamaica, it is a little area and there are a lot of hills preventing a quick realization of the port area. A big plus is the amount of dredging that is needed. Because the sea is deep enough only a few hundred meters out of the coast a short approach channel is sufficient. High unemployment rates are found in this area which will make the new port area a good local investment.

5 Conclusion

As mentioned in the first two sentences of this chapter: the goal is to select all the possible locations in Jamaica and to pre-select five locations. Those locations have the best potentials or are most discussed in the media. The five locations will be investigated further and in more detail. The scores of the locations ranked are showed in Table I-4.

TABLE I-4: REACHED POINTS

Location	*Score*
Maccary Bay	**73**
Portland Cottage South West	**69**
Crawford -West	69
Savanna-La-Mar	**64**
Little Bay	**63**
Portland Bight - Cockpit	61
Great Goat Island	**61**
Bowden Harbour	60
Portland Bight - Michell Town	55
Parottee	55
Alligator Pond - calabash Bay	54
Black River	51
Long Bay	50

The results in **Error! Reference source not found.** doesn't lead directly to Maccary Bay as the best option. The method used (based on the MCA) will only give a rough indication of the locations and characteristics. The amount of dredging is not exactly determined and depends on the port area lay-out. Locations can score badly on road and rail connections, but building new roads and railways can give a second boost to the economy. Including the design of the port area is an environmental stimulating program to reinforce nature. Of course money plays a role too. If a location scores better, but finally it turns out that is twice expensive, the best option is difficult to find.

Because of this five locations are selected that didn't score the best but has the best perspective. These five locations are bold in **Error! Reference source not found.**. The five locations will be viewed in detail and for all the five locations a concept including some rough numbers and costs will be sketched.

The reason why Crawford isn't selected is because of the land is owned by a Petroleum company. The discussion in the media is about the destroying of the Goat Islands and building the new port area over there. That's the reason the Goat Island is selected over Portland Bight – Cockpit.

6 References

Gleaner. (2013, 08 23). *Selling Our Birthright.* (P. Espeut, Editor) Retrieved 09 19, 2013, from Jamaica Gleaner: http://jamaica-gleaner.com/gleaner/20130823/cleisure/cleisure3.html

Jamaica, N. L. (2013, Oktober 10). *iMap*. Retrieved from www.nla.com: http://www.nla.gov.jm/map.asp

Mondiale, P. (2013, 10 9). Retrieved from http://www.populationmondiale.com/wg.php?x=&men=gcis&lng=en&des=wg&srt=npan&col=abcdefghinoq&msz=1500&geo=-109#sthash.IQM1y4mz.dpbs

Observer, J. (2013, september 9). *Gov t admits Goat Islands under serious consideration.* Retrieved from JamaicaObserver.com: www.jamaicaobserver.com/pfversion/Gov-t-admits-Goat-Islands-under--serious-consideration--for-trans-shipment-hub_14922802

Appendix J Further investigation of five port locations

The pre-selected five possible port locations are further investigated in this chapter. The goal is to find the best possible location for the new to develop port area. To achieve this goal the Multi Criteria Analysis (MCA) method is used. First designs are drawn for all the locations. Basic calculations are made using guidelines and the rough cut and fill balances are presented. To compare the different locations and designs the costs are estimated by indicators. The costs include dredging, reclamation, excavation and the costs for the breakwater.

For the Goat Islands multiple layouts are presented to show the different possibilities. The Goat Islands lie in a complex bay with a high environmental and ecological value, which result in a lot of options to sketch a port layout. More layouts for this location are also preferable for the Chinese Harbour Engineering Company (CHEC), who is from the beginning interested in the Goat Islands. The other locations include one port design, because the locations are on a straight coastline so there isn't a conceptual and significant variety in layouts.

1 Design parameters

In Table J-1 the conclusion of the appendix G, Design values, is presented. The conclusion contains all the values of the design parameters. With the parameters the first lay-outs are made for the five locations.

Table J-1: Design parameters

			First design
Surface port area	Transshipment port	Dry	3 km^2
		Wet	3 km^2
	Industrial area	Dry	5 km^2
		Wet	1 km^2
Average dwell time			7.5 days
Approach channel	Width		500 m
	Length in port		At least 500 m
	Diameter turning circle		At least 732 m
	Depth	Transshipment port	At least 18 m
		Industrial area	At least 15 m
Maximum expected throughput			Nearly 7 million TEU
Number of berths	Transshipment port		15 berths
	Industrial area		unknown
Quay length	Transshipment port		6 km
	Industrial area		unknown

For all the designs rough cost estimations are made. The cost estimations are including the amount of dredging, the amount of reclamation, the costs for the breakwater and the excavation costs. The other costs for the quay walls, cranes etc. are not included in this price. The costs estimations are based on the following indications:

• Price per cubic meter dredging	7 U.S. Dollar
• Price per cubic meter reclamation	13 U.S. Dollar
• Price per cubic meter breakwater	200 U.S. Dollar
• Price per cubic meter excavation	15 U.S. Dollar

2 Locations including first designs

For the five locations a first port layout is designed. All the locations have their own subsection. For the Goat Islands there are five first designs made, because of the complexity of the area. The other locations containing one design.

2.1 Goat Island

The five alternatives are presented in the following subsections. To give an overview of the location of this alternative site Figure J-1 is showed below.

FIGURE J-1: OVERVIEW MAP OF JAMAICA AND THE GOAT ISLANDS ARE MARKED WITH A RED DOT

The Goat Islands are in an environmental protected area. In this protected area there is a second division made which is even more protected. This area contains a lot of coral and/or there is a fish sanctuary. These more protected areas can be seen in Figure J-2, the areas are outlined with a red line.

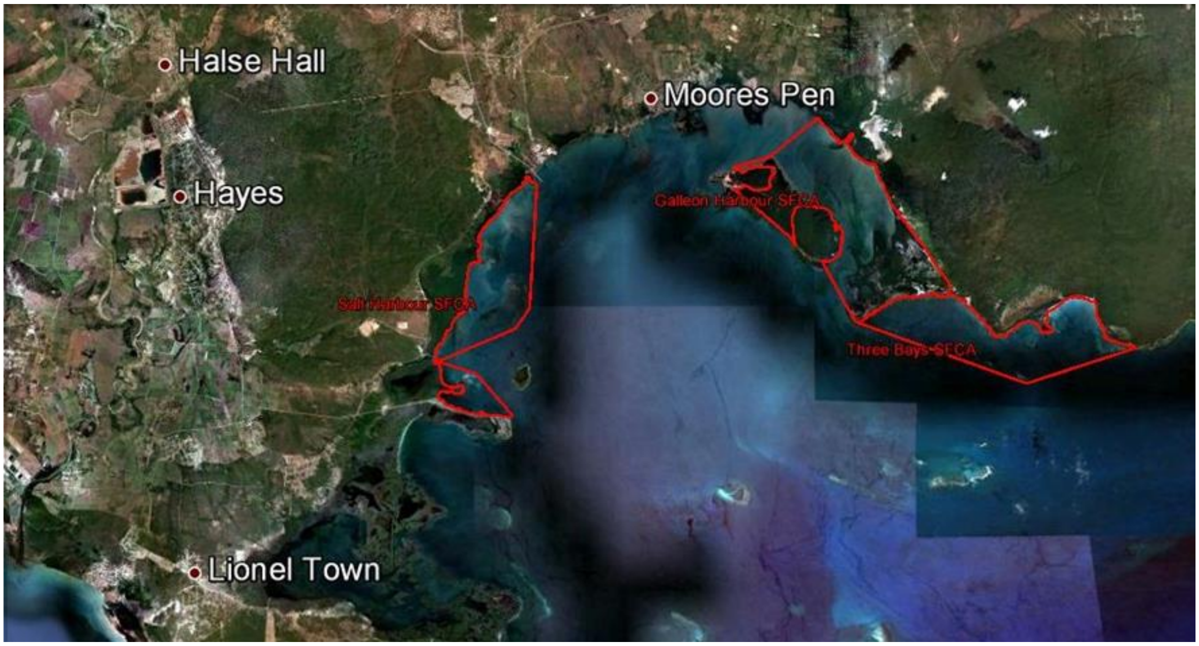


FIGURE J-2: MORE PROTECTED AREAS IN PORTLAND BIGHT, SUCH AS FISH SANCTUARIES

2.1.1 Goat Islands Design 1

The design in Figure J-3 focuses on using the Goat Islands as natural shelter for the ships. The turning circle is south of the Great Goat Island and the north of the Little Goat Island land is reclaimed to get to the required surface area and to make a connection to the mainland. In Table J-2 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-2 are shown in Table J-3.

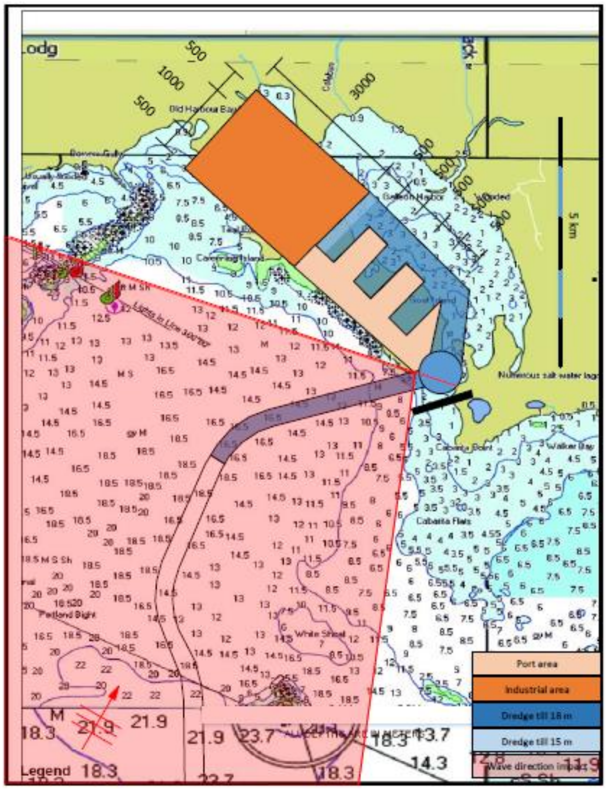


FIGURE J-3: GOAT ISLANDS DESIGN 1

TABLE J-2: KEY NUMBERS OF GOAT ISLANDS DESIGN 1

Key numbers

Areas		
Total area excl. appr. channel	12.3	km^2
Dry area for transshipment	2.8	km^2
Wet area for transshipment	3.1	km^2
Dry area for industrial	6.0	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	8.3	km
Quay length for industrial	1.8	km
Length approach channel	5.0	km
Length of breakwater	1.3	km

Volumes		
Total amount of dredging	76.3	mln. m3
Total surplus material	82.7	mln. m3
Volume of breakwater	0.1	mln. m3

Total costs	**1,160**	**mln. U.S. Dollar**

Advantages

• Berthing	Berthing is behind the Goat Island which is natural sheltered. This design uses the calmest waters as possible.
• Breakwater	Only a small breakwater is needed to prevent high waves coming into the turning basin.
• Mainland connection	The connection with the mainland is realized by connecting the Little Goat Island with the mainland.

Disadvantages

• Approach Channel	It is not ideal, because of the bend and the perpendicular incoming waves.
• Environment	The Goat Islands are destroyed and also the fish sanctuary is harmed.
• Dredging	The cut and fill balance is not optimal. Relatively much dredging is needed and not much of it is used. The approach channel and mainly all the wet area will get filled up fast caused by siltation of the river discharging into the area which results in a lot of maintenance dredging.

TABLE J-3: DETAILED EXCEL SHEET TO COME UP WITH THE KEY NUMBER PRESENTED IN TABLE J-2

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	11	m
Length	5.0	km
Total volume	**17.5**	**mln. m^3**

Inside port		
Wet area for transshipment	3.1	km^2
Average current depth	1	m
Depth required	18	m
Wet area for industrial	0.4	km^2
Average current depth	0	m
Depth required	15	m
Total volume	**58.75**	**mln. m^3**

Reclamation material needed

Storage area transshipment		
Reclaimed area	2.8	mln. m^2
Meters lifted	0	m
Total volume	**0.0**	**mln. m^3**

Storage area industrial		
Reclaimed area	4.8	mln. m^2
Meters lifted	7	m
Total volume	**33.6**	**mln. m^3**

Breakwater

Breakwater I		
Length	1250	m
Local depth	1	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	25	m
Cross section	100	m^2
Total volume	**0.1**	**mln. m^3**

Excavation Hill

Great goat island		
Length	1.5	km
Width	1	km
Footprint	1.5	km^2
Height on top	80	m
Total volume	**40.0**	**mln. m^3**

Excavation of the hill is used to reclaim

Total amount of dredging	**76.3**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	530	mln. U.S. Dollar

Total amount of reclamation	**0.0**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	0	mln. U.S. Dollar

Total volume	**0.1**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	30	mln. U.S. Dollar

Total volume	**40.0**	**mln. m^3**
Price per cubic meter	15	U.S. Dollar
Total costs	600	mln. U.S. Dollar

Summary

Areas		
Total area excl. appr. channel	12.3	km^2
Dry area for transshipment	2.8	km^2
Wet area for transshipment	3.1	km^2
Dry area for industrial	6.0	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	8.3	km
Quay length for industrial	1.8	km
Length approach channel	5.0	km
Length of breakwater	1.3	km

Volumes		
Total amount of dredging	76.3	mln. m^3
Total surplus material	82.7	mln. m^3
Volume of breakwater	0.1	mln. m^3

Total price dredging, reclamation, excavation, and breakwater	**1,160**	**mln. U.S. Dollar**

2.1.2 Goat Islands Design 2

This design contains the turning circle in the north of the Goat Islands. Most of the wet area of the port is constructed in shallow waters. The Goat Islands are mostly used for the construction of dry surface area. In Table J-4 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-4 are shown in Table J-5.

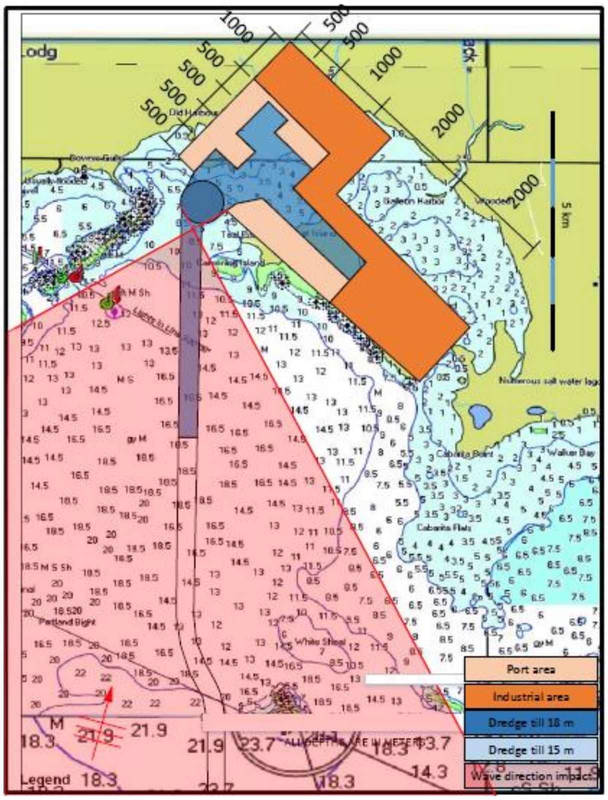


FIGURE J-4: GOAT ISLANDS DESIGN 2

TABLE J-4: KEY NUMBERS OF THE GOAT ISLANDS DESIGN 2

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	2.8	km^2
Wet area for transshipment	3.0	km^2
Dry area for industrial	6.0	km^2
Wet area for industrial	0.0	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.0	km
Length approach channel	5.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	60.5	mln. m3
Total surplus material	81.8	mln. m3
Volume of breakwater	0.0	mln. m3

Total costs	**1,020**	**mln. U.S. Dollar**

Advantages

• Berthing	The wet area of the port is sheltered because of the Goat Islands.
• Breakwater	No breakwater is needed, because of natural sheltering.
• Mainland connection	A part of the port area is already on the mainland.
• Environment	The fishing area is saved from any harm.
• Approach channel	It is approaching in a straight line.

Disadvantages

• Environment	Although the fish sanctuary is saved the Little - and Great Goat Island are still used for the port.
• Dredging	As almost no land is reclaimed there is hardly any balance. Almost all the dredged and excavated material (coming from the Great Goat Island) cannot be used.

Table J-5: Detailed excel sheet to come up with the key numbers presented in Table J-4

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	13	m
Length	5.0	km
Total volume	**12.5**	**mln. m^3**

Inside port		
Wet area for transshipment	3.0	km^2
Average current depth	2	m
Depth required	18	m
Wet area for industrial	0.0	km^2
Average current depth	0	m
Depth required	15	m
Total volume	**48**	**mln. m^3**

Total amount of dredging	**60.5**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	420	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	1.8	mln. m^2
Meters lifted	5	m
Total volume	**8.8**	**mln. m^3**

Storage area industrial		
Reclaimed area	2.0	mln. m^2
Meters lifted	5	m
Total volume	**10.0**	**mln. m^3**

Excavation of the hill is used to reclaim

Total amount of reclamation	**0.0**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	0	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	0	m
Local depth	0	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	23	m
Cross section	76	m^2
Total volume	**0.0**	**mln. m^3**

Total volume	**0.0**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	0	mln. U.S. Dollar

Excavation Hill

Great goat island		
Length	1.5	km2
Width	1	km2
Footprint	1.5	km^2
Height on top	80	m
Total volume	**40.0**	**mln. m^3**

Total volume	**40.0**	**mln. m^3**
Price per cubic meter	15	U.S. Dollar
Total costs	600	mln. U.S. Dollar

Summary

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	2.8	km^2
Wet area for transshipment	3.0	km^2
Dry area for industrial	6.0	km^2
Wet area for industrial	0.0	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.0	km
Length approach channel	5.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	60.5	mln. m^3
Total surplus material	81.8	mln. m^3
Volume of breakwater	0.0	mln. m^3

Total price dredging, reclamation, excavation, and breakwater	**1,020**	**mln. U.S. Dollar**

2.1.3 Goat Islands Design 3

This option is relatively similar with design 1. Difference however is the use of the water behind of the Great Goat Island instead of the Goat Islands themselves. In this way the islands are saved, but the fish sanctuary is destroyed. Special care should be taken at the rivers flowing into this bay. An opening should be left open to cope with the discharges. In Table J-6 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-6 are shown in Table J-7.

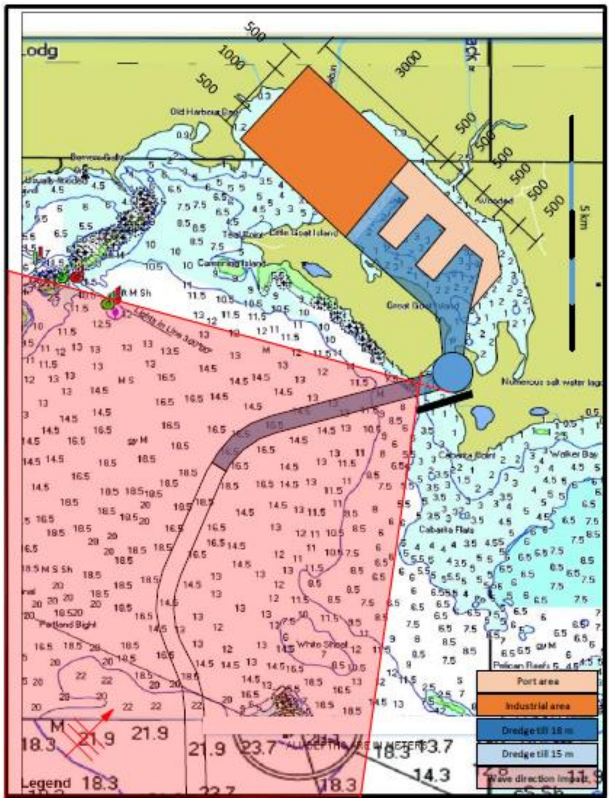


FIGURE J-5: GOAT ISLANDS DESIGN 3

TABLE J-6: KEY NUMBERS OF GOAT ISLANDS DESIGN 3

Key numbers

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	2.8	km^2
Wet area for transshipment	3.4	km^2
Dry area for industrial	6.0	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	7.3	km
Quay length for industrial	1.3	km
Length approach channel	5.0	km
Length of breakwater	1.3	km

Volumes		
Total amount of dredging	77.9	mln. m3
Total surplus material	19.4	mln. m3
Volume of breakwater	0.1	mln. m3

Total costs	**1,340**	**mln. U.S. Dollar**

Advantages

• Berthing	The Goat Islands are used as natural sheltering.
• Breakwater	Only a small breakwater is needed to protect the port area.
• Mainland connection	The connection to the mainland is made at the back of the port area.
• Environment	The Goat Islands are saved.

Disadvantages

• Approach Channel	Approaching the port is difficult when the river discharges are higher than usual and the approach channel isn't straight.
• Environment	Almost the whole fish sanctuary is harmed.
• Dredging	No balance in dredged material is found here. Although a big area is reclaimed, there is still a surplus. This is because the amount of dredging is enormous. The maintenance dredging is also high, because of the siltation caused by the river.

TABLE J-7: DETAILED EXCEL SHEET TO COME UP WITH THE KEY NUMBERS PRESENTED IN TABLE J-6

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	11	m
Length	5.0	km
Total volume	**17.5**	**mln. m^3**

Inside port		
Wet area for transshipment	3.4	km^2
Average current depth	1.5	m
Depth required	18	m
Wet area for industrial	0.4	km^2
Average current depth	2.5	m
Depth required	15	m
Total volume	**60.4**	**mln. m^3**

Total amount of dredging	**77.875**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	550	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	2.8	mln. m^2
Meters lifted	6	m
Total volume	**16.5**	**mln. m^3**

Storage area industrial		
Reclaimed area	6.0	mln. m^2
Meters lifted	7	m
Total volume	**42.0**	**mln. m^3**

Total amount of reclamation	**58.5**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	760	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	1250	m
Local depth	1	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	25	m
Cross section breakwater	100	m^2
Total volume	**0.1**	**mln. m^3**

Total volume	**0.1**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	30	mln. U.S. Dollar

Summary

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	2.8	km^2
Wet area for transshipment	3.4	km^2
Dry area for industrial	6.0	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	7.3	km
Quay length for industrial	1.3	km
Length approach channel	5.0	km
Length of breakwater	1.3	km

Volumes		
Total amount of dredging	77.9	mln. m^3
Total surplus material	19.4	mln. m^3
Volume of breakwater	0.1	mln. m^3

Total price dredging, reclamation, excavation, and breakwater	**1,340**	**mln. U.S. Dollar**

2.1.4 Goat Islands Design 4

Goat Islands design 4 combines the designs of number 2 and 3. By approaching the port from the north side the rivers can discharge more easily and siltation is less. In this design the Goat Islands themselves are saved, but the fish sanctuary is completely destroyed. Some of the already existing land on the north side is used. In Table J-8 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-8 are shown in Table J-9.

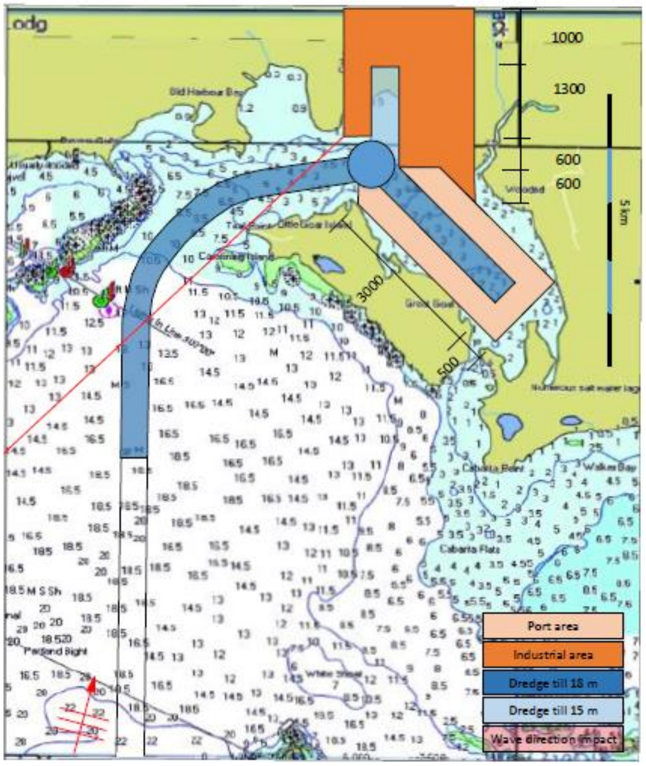


FIGURE J-6: GOAT ISLANDS DESIGN 4

TABLE J-8: KEY NUMBERS OF THE GOAT ISLANDS DESIGN 4

Key numbers

Areas		
Total area excl. appr. channel	11.3	km^2
Dry area for transshipment	3.8	km^2
Wet area for transshipment	1.5	km^2
Dry area for industrial	5.1	km^2
Wet area for industrial	1.0	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.7	km
Length approach channel	8.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	77.3	mln. m3
Total surplus material	35.9	mln. m3
Volume of breakwater	0.0	mln. m3

Total costs	**1,080**	**mln. U.S. Dollar**

Advantages

• Berthing	The berthing takes place in natural calm water.
• Breakwater	No breakwater is needed at all.
• Mainland connection	The port area is partly on the mainland.
• Environment	The Goat Islands are left unharmed.

Disadvantages

• Approach Channel	Maneuverability is difficult because of the length of the channel and the bend in the channel.
• Dredging	A lot of dredging is needed and only half of the dredged material is used.
• Environment	The fish sanctuary is completely destroyed.

Table J-9: Detailed excel sheet to come up with the key numbers presented in Table J-8

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	8	m
Length	8.0	km
Total volume	**40**	**mln. m^3**

Inside port		
Wet area for transshipment	1.5	km^2
Average current depth	2	m
Depth required	18	m
Wet area for industrial	1.0	km^2
Average current depth	1	m
Depth required	15	m
Total volume	**37.3**	**mln. m^3**

Total amount of dredging	**77.3**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	540	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	3.8	mln. m^2
Meters lifted	6	m
Total volume	**22.5**	**mln. m^3**

Storage area industrial		
Reclaimed area	3.2	mln. m^2
Meters lifted	6	m
Total volume	**18.9**	**mln. m^3**

Total amount of reclamation	**41.4**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	540	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	0	m
Local depth	0	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	23	m
Cross section	76	m^2
Total volume	**0.0**	**mln. m^3**

Total volume	**0.0**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	0	mln. U.S. Dollar

Summary

Areas		
Total area excl. appr. channel	11.3	km^2
Dry area for transshipment	3.8	km^2
Wet area for transshipment	1.5	km^2
Dry area for industrial	5.1	km^2
Wet area for industrial	1.0	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.7	km
Length approach channel	8.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	77.3	mln. m^3
Total surplus material	35.9	mln. m^3
Volume of breakwater	0.0	mln. m^3

Total price dredging, reclamation, excavation, and breakwater	**1,080**	**mln. U.S. Dollar**

2.1.5 Goat Island Design 5

This design is based upon design 2, but is shifted to the north. In this way the Great Goat Island is saved and there is a better connection with the mainland. In the future the port can expend even further to the north which can be seen in Figure J-7. In Table J-10 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-10 are shown in Table J-11.

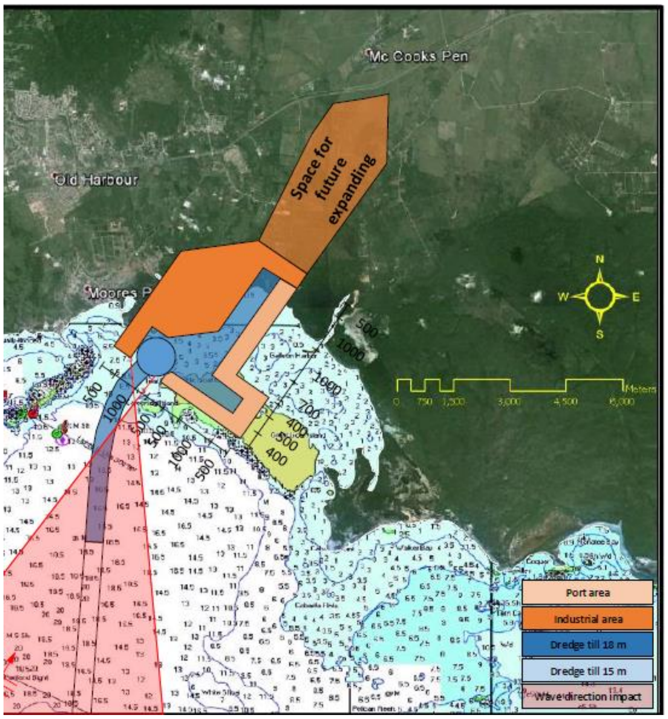


FIGURE J-7: GOAT ISLANDS DESIGN 5

TABLE J-10: KEY NUMBERS OF THE GOAT ISLANDS DESIGN 5

Key numbers

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.2	km^2
Wet area for transshipment	4.1	km^2
Dry area for industrial	5.3	km^2
Wet area for industrial	0.0	km^2

Lengths		
Quay length for transhipment	6.6	km
Quay length for industrial	5.5	km
Length approach channel	5.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	79.8	mln. m3
Total surplus material	51.8	mln. m3
Volume of breakwater	0.0	mln. m3

Total costs	**920**	**mln. U.S. Dollar**

Advantages

• Berthing	This design is sheltered from the highest waves.
• Breakwater	No breakwater is needed.
• Mainland connection	The mainland connection can be very good developed, because the port area is partly constructed at the mainland.
• Environment	Next to the untouched fish sanctuary also the Great Goat Island is left unharmed.
• Approach Channel	Approaching this port area is easy.

Disadvantages

• Environment	Little Goat Island is harmed.
• Dredging	No balance can be found, because much dredging is needed and not much land is reclaimed.

TABLE J-11: DETAILED EXCEL SHEET TO COME UP WITH THE KEY NUMBERS PRESENTED IN TABLE J-10

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	12	m
Length	5.0	km
Total volume	**15**	**mln. m^3**

Inside port		
Wet area for transshipment	4.1	km^2
Average current depth	2	m
Depth required	18	m
Wet area for industrial	0.0	km^2
Average current depth	0.5	m
Depth required	15	m
Total volume	**64.8**	**mln. m^3**

Total amount of dredging	**79.8**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	560	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	1.5	mln. m^2
Meters lifted	7	m
Total volume	**10.5**	**mln. m^3**

Storage area industrial		
Reclaimed area	3.5	mln. m^2
Meters lifted	5	m
Total volume	**17.5**	**mln. m^3**

Total amount of reclamation	**28.0**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	360	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	0	m
Local depth	0	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	23	m
Cross section	76	m^2
Total volume	**0.0**	**mln. m^3**

Total volume	**0.0**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	0	mln. U.S. Dollar

Summary

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.2	km^2
Wet area for transshipment	4.1	km^2
Dry area for industrial	5.3	km^2
Wet area for industrial	0.0	km^2

Lengths		
Quay length for transhipment	6.6	km
Quay length for industrial	5.5	km
Length approach channel	5.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	79.8	mln. m^3
Total surplus material	51.8	mln. m^3
Volume of breakwater	0.0	mln. m^3

Total price dredging, reclamation, excavation, and breakwater	**920**	**mln. U.S. Dollar**

2.1.6 Total overview of option Goat Islands

To compare the five alternative designs of the Goat Islands the layouts are shown in one picture, see Figure J-8. The main advantages and disadvantages of the Goat Islands area is listed below the figure.

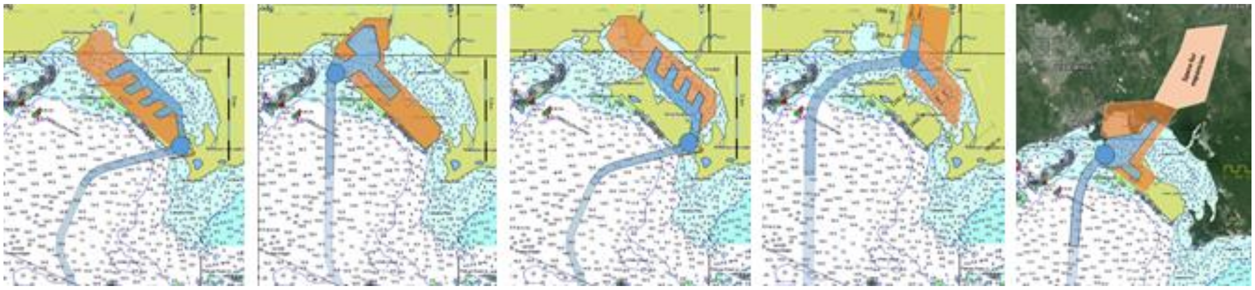


FIGURE J-8: OVERVIEW OF THE DIFFERENT PORT LAYOUTS IN THE AREA AROUND THE GOAT ISLANDS, FROM LEFT TO RIGHT, DESIGN 1 TO DESIGN 5

Advantages

- Close to the economic center of Jamaica: Spanish Town, Kingston and the highway are nearby.
- The Portland Bight Bay and the Goat Islands provide sheltered berthing, which is preferable for handling container ships.

Disadvantages

- The Portland Bight Bay is an environmentally protected area. Inside the bay there are a few fish sanctuaries including one just behind the Goat Islands which have a very high ecological value. Not all the designs harm this sanctuary, but for all the designs the building process disturbs this sanctuary.
- A lot of dredging is needed and in case of enlarging the approach channel up to a draught of 27 meters (the port wants to handle bigger vessels than Post-Panamax ships, like Chinamax vessel) the amount of extra dredging is enormous and the approach channel is very long.

2.2 Jackson Bay

To give an overview of the location of this alternative site Figure J-9 is presented below.

FIGURE J-9: OVERVIEW MAP OF JAMAICA AND PORTLAND COTTAGE IS MARKED WITH A RED DOT

Because Jackson Bay is not in a sheltered Bay the wave impact is higher than the Goat Islands which result in the construction of a heavily breakwaters. Not only from the main wind and wave direction (east), but also from other sides the port needs protection. In case of a hurricane the head and the tail of the hurricane will create waves from all directions. There is not much living in the area so the whole area can be used for developing the port.

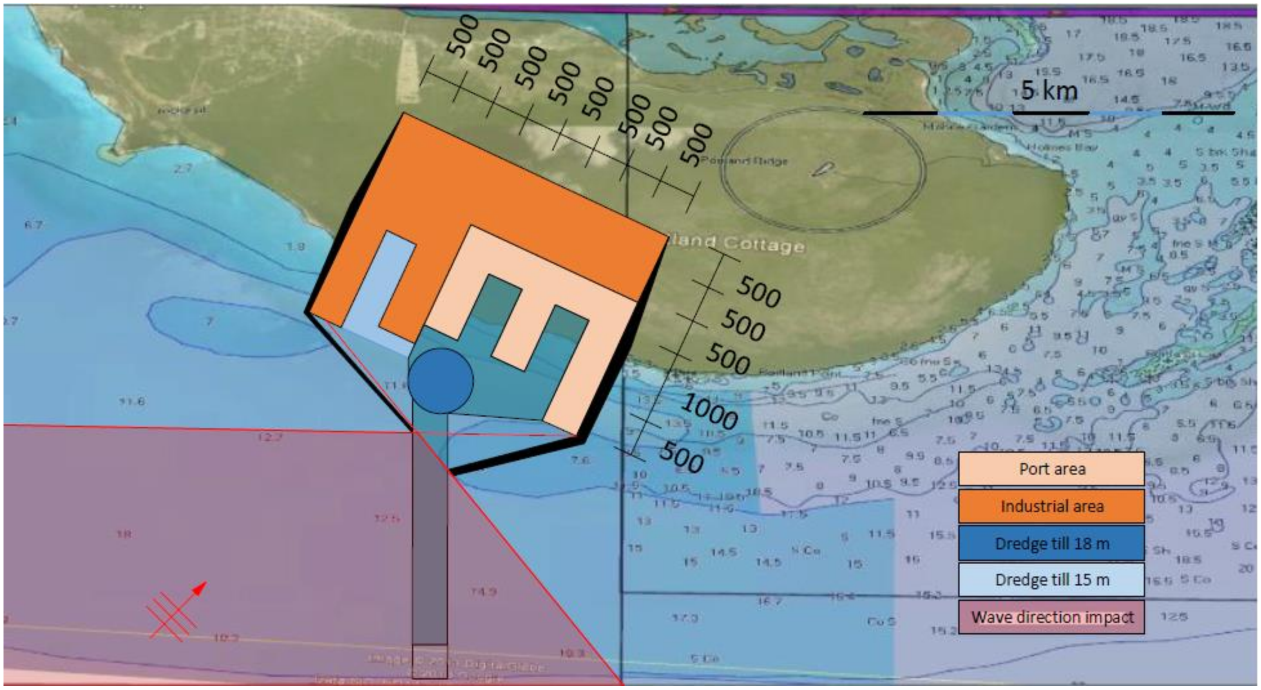


FIGURE J-10: PORTLAND COTTAGE PORT LAYOUT

The approach channel is preferable from east to west, but is designed from north to south, see Figure J-10. The reason for this alignment is the amount of dredging. A three times longer approach channel has to be dredged in case of an east-west alignment, because of the bathymetry. The disadvantage of this design is approaching. The perpendicular incoming waves result in a rolling motion of the vessels in the approach channel. In Table J-12 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-12 are shown in Table J-13.

TABLE J-12: KEY NUMBERS OF JACKSON BAY

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	3.0	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	0.9	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.8	km
Length approach channel	4.0	km
Length of breakwater	7.0	km

Volumes		
Total amount of dredging	51.1	mln. m3
Total surplus material	25.7	mln. m3
Volume of breakwater	2.7	mln. m3

Total costs	**1,230**	**mln. U.S. Dollar**

Advantages

• Berthing	When the breakwaters are constructed the vessels can berth in calm water.
• Environment	At the site is not much of any (valuable) nature. However, the area is just within the boundaries of the Portland Bight protected area
• Approach Channel	The approach channel is short.
• Settlement	The site itself is abandoned. Closest community is Portland Cottage which lies a little more to the northwest of the port.
• Expansion	The land around this area is big and flat.
• Dredging	Few dredging has to be done and more than half of the dredged material can be used for reclamation.

Disadvantages

• Breakwater	Heavy breakwaters need to be constructed to prevent high waves inside the port and protecting the port in the event of a hurricane.
• Approach Channel	The incoming waves are perpendicular which result in a rolling motion of the vessels.
• Mainland connection	Because Jackson Bay is far away from living the connection to the bigger cities is not of high quality.

TABLE J-13: DETAILED EXCEL SHEET TO COME UP WITH THE KEY NUMBERS PRESENTED IN TABLE J-12

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	13	m
Length	4.0	km
Total volume	**10**	**mln. m^3**

Inside port		
Wet area for transshipment	2.7	km^2
Average current depth	6	m
Depth required	18	m
Wet area for industrial	0.9	km^2
Average current depth	5	m
Depth required	15	m
Total volume	**41.1**	**mln. m^3**

Total amount of dredging	**51.1**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	360	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	1.0	mln. m^2
Meters lifted	11	m
Reclaimed area	2.0	mln. m^2
Meters lifted	3	m
Total volume	**17.0**	**mln. m^3**

Storage area industrial		
Reclaimed area	0.9	mln. m^2
Meters lifted	7	m
Reclaimed area	0.8	mln. m^2
Meters lifted	3	m
Total volume	**8.4**	**mln. m^3**

Total amount of reclamation	**25.4**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	330	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	1500	m
Local depth	9	m
Height	7	m
Crest width	15	m
Slope 1:	1	-
Footprint	31	m
Cross section breakwater	368	m^2
Total volume	**0.6**	**mln. m^3**

Breakwater III		
Length	1000	m
Local depth	3	m
Height	5	m
Crest width	15	m
Slope 1:	1	-
Footprint	23	m
Cross section breakwater	152	m^2
Total volume	**0.2**	**mln. m^3**

Breakwater II		
Length	2000	m
Local depth	7.5	m
Height	3	m
Crest width	25	m
Slope 1:	1	-
Footprint	46	m
Cross section breakwater	373	m^2
Total volume	**0.7**	**mln. m^3**

Breakwater IV		
Length	2500	m
Local depth	11.5	m
Height	3	m
Crest width	20	m
Slope 1:	1	-
Footprint	49	m
Cross section breakwater	500	m^2
Total volume	**1.3**	**mln. m^3**

Total volume	**2.7**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	540	mln. U.S. Dollar

Summary

Areas		
Total area	11.8	km^2
Dry area for transshipment	3.0	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	0.9	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.8	km
Lenth approach channel	4.0	km
Length of breakwater	7.0	km

Volumes		
Total amount of dredging	51.1	mln. m^3
Total surplus material	25.7	mln. m^3
Volume of breakwater	2.7	mln. m^3

Total price for dredging, reclamation and the breakwater	**1230**	**mln. U.S. Dollar**

2.3 Maccary Bay

To give an overview of the location of this alternative site is presented below.

FIGURE J-11: OVERVIEW MAP OF JAMAICA AND MACCARY BAY IS MARKED WITH A RED DOT

At Maccary Bay a long approach channel is needed to reach from the deeper seas to the coast. To make this long approach channel visible the scale of Figure J-12 is enlarged. Also the design of Jackson Bay is presented in this figure to give a feeling for the dimensions. Along the approach channel for the Maccary Bay port there is much low lying area that prevents higher waves to reach the coast. Although a lot of waves lose their energy along the way the area still needs to be protected by some smaller breakwaters. The area is used in the past for the fishing industry. The land area is open, abandoned and flat, so perfect for developing the port and expanding the port in the future.

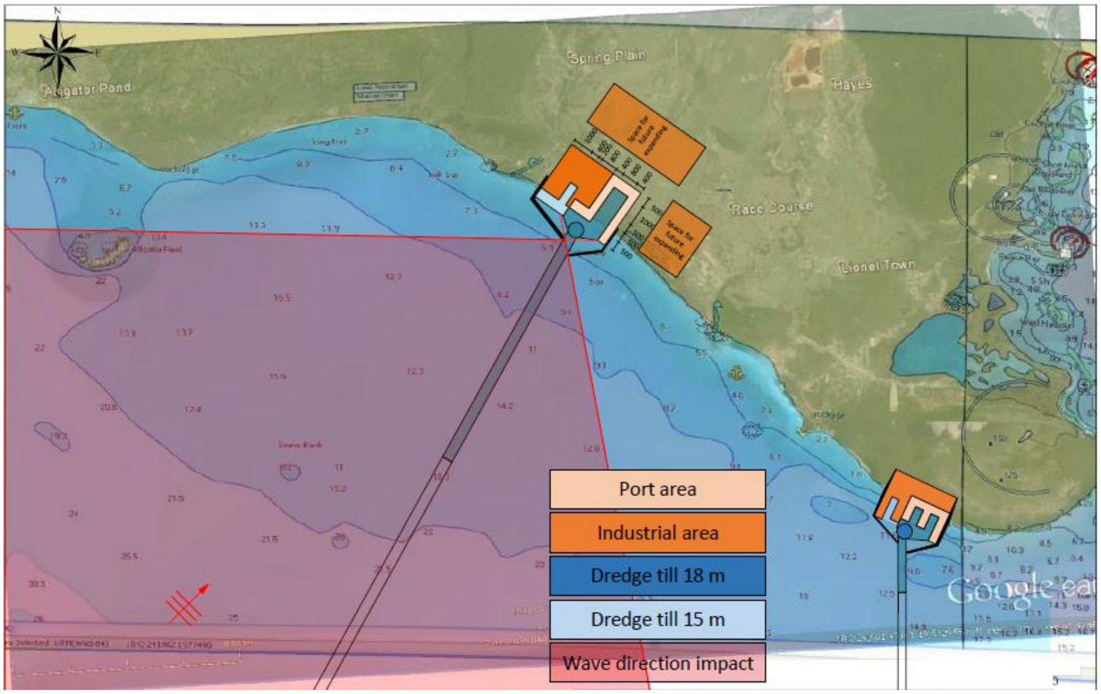


FIGURE J-12: MACCARY BAY PORT DESIGN

Figure J-13 is zoomed in at Maccary Bay. The details are more visible than Figure J-12. In Table J-14 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-14 are shown in Table J-15.

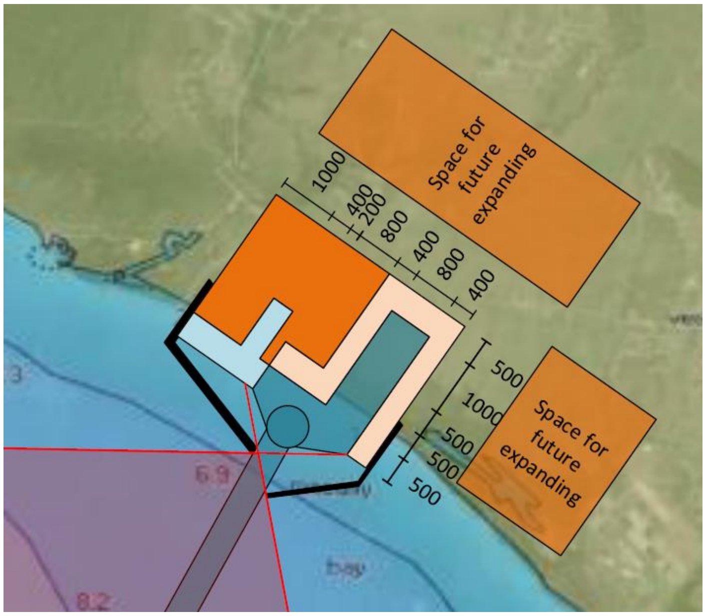


FIGURE J-13: ZOOMED IN ON PORT DESIGN MACCARY BAY

TABLE J-14: KEY NUMBERS OF MACCARY BAY

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	2.6	km^2
Wet area for transshipment	2.8	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	1.2	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.6	km
Length approach channel	12.0	km
Length of breakwater	8.0	km

Volumes		
Total amount of dredging	101.9	mln. m3
Total surplus material	99.8	mln. m3
Volume of breakwater	1.6	mln. m3

Total costs	**1,060**	**mln. U.S. Dollar**

Advantages

• Berthing	When ships pass the breakwaters the ships can berth easily.
• Mainland connection	It is well connected to the main land because the port is designed on the mainland.
• Environment	The site isn't in any protected area and is occupied by no longer in use fishery ponds. Because of this industry in the past there isn't valuable nature.
• Settlement	The site itself is abandoned. Closest community is Portland Cottage which lies close the drawn design, a little more to the northwest.
• Expansion	Because of the large area the space for expansion is enormous.

Disadvantages

• Breakwater	Breakwaters are needed to create calm water.
• Approach channel	The length of the approach channel is a large downfall in terms of dredging and easily approaching.
• Mainland connection	The larger cities are still a bit far away from this site.
• Dredging	Because there is more than enough space on the land not much land needs to be reclaimed. On the other side a lot of dredging is needed to create the approach channel which results in a high surplus of dredged material.

Table J-15: Detailed excel sheet to come up with the key numbers presented in Table J-14

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	12	m
Length	12.0	km
Total volume	**36**	**mln. m^3**

Inside port		
Wet area for transshipment	2.8	km^2
Average current depth	0	m
Depth required	18	m
Wet area for industrial	1.2	km^2
Average current depth	2	m
Depth required	15	m
Total volume	**65.9**	**mln. m^3**

Total amount of dredging	**101.9**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	710	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	0.3	mln. m^2
Meters lifted	7	m
Total volume	**2.1**	**mln. m^3**

Storage area industrial		
Reclaimed area	0.0	mln. m^2
Meters lifted	0	m
Total volume	**0.0**	**mln. m^3**

Total amount of reclamation	**2.1**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	30	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	3000	m
Local depth	2.5	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	28	m
Cross section	139.75	m^2
Total volume	**0.4**	**mln. m^3**

Breakwater II		
Length	5000	m
Local depth	5.5	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	34	m
Cross section breakwater	232.75	m^2
Total volume	**1.2**	**mln. m^3**

Total volume	**1.6**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	320	mln. U.S. Dollar

Summary

Areas		
Total area	11.8	km^2
Dry area for transshipment	2.6	km^2
Wet area for transshipment	2.8	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	1.2	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.6	km
Lenth approach channel	12.0	km
Length of breakwater	8.0	km

Volumes		
Total amount of dredging	101.9	mln. m^3
Total surplus material	99.8	mln. m^3
Volume of breakwater	1.6	mln. m^3

Total price for dredging, reclamation and the breakwater	**1060**	**mln. U.S. Dollar**

2.4 Savanna-la-Mar

To give an overview of the location of this alternative site Figure J-14 is presented below.

FIGURE J-14: OVERVIEW MAP OF JAMAICA AND SAVANNA-LA-MAR IS MARKED WITH A RED DOT

The layout is designed in such a way that the breakwater and the port are combined. The area in front of the port is shallow which reduces the wave energy almost to zero. In this design the breakwater is more an integrated revetment than really a breakwater.

The length of the approach channel is not very long, but because of the very shallow area a lot of dredging is needed. The approach channel is directed to the southwest to realize easy approach for the sailing ships. There is enough space for future expansion. In Table J-16 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-16 are shown in Table J-17.

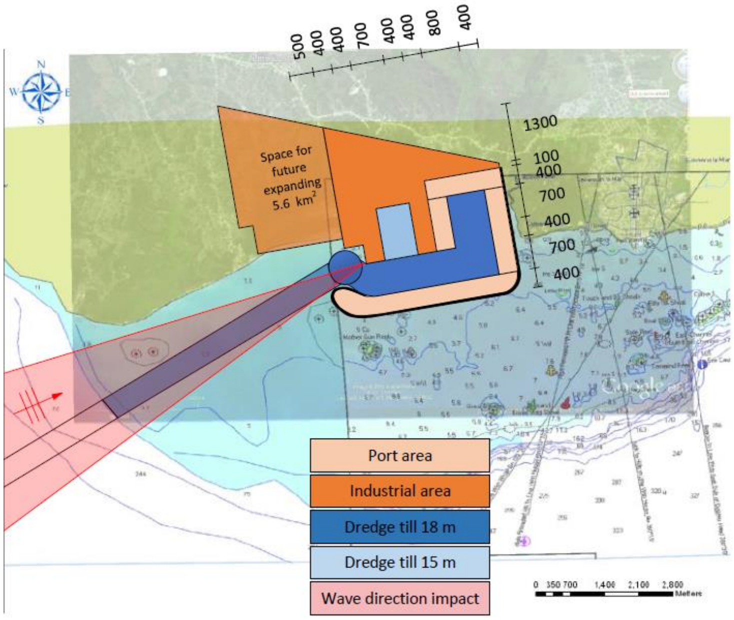


FIGURE J-15: SAVANNA-LA-MAR PORT DESIGN

TABLE J-16: KEY NUMBERS OF SAVANNA-LA-MAR

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	3.4	km^2
Wet area for transshipment	3.0	km^2
Dry area for industrial	4.7	km^2
Wet area for industrial	0.8	km^2

Lengths		
Quay length for transhipment	6.4	km
Quay length for industrial	2.9	km
Length approach channel	5.5	km
Length of breakwater	6.5	km

Volumes		
Total amount of dredging	96.4	mln. m3
Total surplus material	73.4	mln. m3
Volume of breakwater	0.8	mln. m3

Total costs	**1,150**	**mln. U.S. Dollar**

Advantages

• Berthing	Lying behind reefs and shallow area the location is very sheltered.
• Environment	The location is not in a protected area and the nature has no significant value.
• Approach Channel	A straight channel, which is aligned ideally for the ships that will sail in.
• Settlement	Only a few houses need to be moved in order to construct the port area.
• Expansion	Expansion is possible both on land and in the shallow sea.
• Breakwater	The reefs and shallow sea will break most of the waves, a small integrated revetment is sufficient.

Disadvantages

• Mainland connection	Although close to Savanna-la-Mar and relatively close to Montego Bay the site lies on the west part of Jamaica. This means far away from Kingston and the most population of Jamaica.
• Dredging	A lot of dredging is needed, resulting in a material surplus.

Table J-17: Detailed excel sheet to come up with the key numbers presented in Table J-16

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	4	m
Length	6.0	km
Total volume	**42**	**mln. m^3**

Inside port		
Wet area for transshipment	3.0	km^2
Average current depth	3	m
Depth required	18	m
Wet area for industrial	0.8	km^2
Average current depth	2	m
Depth required	15	m
Total volume	**54.4**	**mln. m^3**

Total amount of dredging	**96.4**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	680	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	2.8	mln. m^2
Meters lifted	6	m
Total volume	**16.6**	**mln. m^3**

Storage area industrial		
Reclaimed area	1.1	mln. m^2
Meters lifted	6	m
Total volume	**6.5**	**mln. m^3**

Total amount of reclamation	**23.0**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	300	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	6500	m
Local depth	3	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	22	m
Cross section	129.5	m^2
Total volume	**0.8**	**mln. m^3**

Total volume	**0.8**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	170	mln. U.S. Dollar

Summary

Areas		
Total area	11.8	km^2
Dry area for transshipment	3.4	km^2
Wet area for transshipment	3.0	km^2
Dry area for industrial	4.7	km^2
Wet area for industrial	0.8	km^2

Lengths		
Quay length for transhipment	6.4	km
Quay length for industrial	2.9	km
Lenth approach channel	5.5	km
Length of breakwater	6.5	km

Volumes		
Total amount of dredging	96.4	mln. m^3
Total surplus material	73.4	mln. m^3
Volume of breakwater	0.8	mln. m^3

Total price for dredging, reclamation and the breakwater	**1150**	**mln. U.S. Dollar**

2.5 Little Bay

To give an overview of the location of this alternative site Figure J-16 is presented below.

FIGURE J-16: OVERVIEW MAP OF JAMAICA AND LITTLE BAY IS MARKED WITH A RED DOT

More to the west of Savanna-la-Mar is the location Little Bay. At this moment a few fishermen and goat herders are found here. The sea is as calm as the location at Savanna-la-Mar, but is probably rougher in the event of a hurricane.

The approach channel is very short, so a good balance between cut and fill is found. In Table J-18 the key numbers of this design are presented. The price includes all the dredging, reclamation, excavation and the building costs of the breakwater. The calculations to come up with the key numbers in Table J-18 are shown in Table J-19.

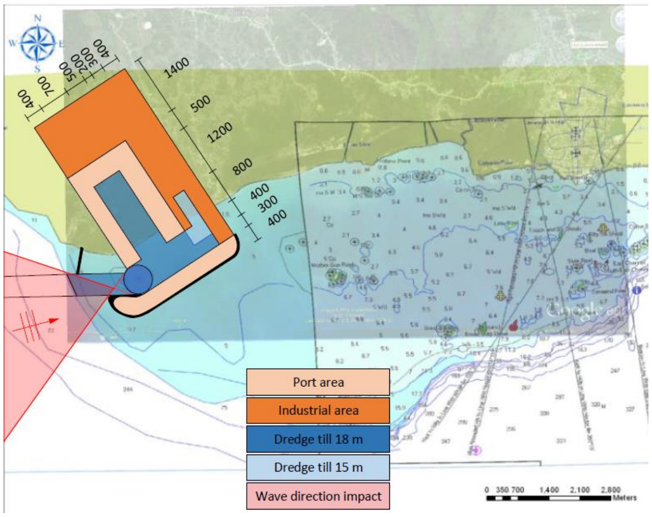


FIGURE J-17: LITTLE BAY PORT DESIGN

TABLE J-18: KEY NUMBERS OF LITTLE BAY

Key numbers

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.6	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.8	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	6.7	km
Quay length for industrial	2.0	km
Length approach channel	1.3	km
Length of breakwater	4.7	km

Volumes		
Total amount of dredging	63.8	mln. m3
Total surplus material	53.3	mln. m3
Volume of breakwater	0.6	mln. m3

Total costs	**720**	**mln. U.S. Dollar**

Advantages

• Berthing	When the breakwaters are constructed the waves will be reduced to an acceptable level.
• Environment	This location is not in a protected area. It is a flat area and a there are a few trees, but not valuable nature.
• Approach Channel	It is easy and (very) short approaching to the port.
• Settlement	Only a few houses need to be moved in order to construct the port area.
• Expansion	Expansion is possible more into the sea (like Maasvlakte II) or to the east (location of alternative Savanna-la-Mar).
• Breakwater	The breakwater is integrated in the design. It can be a small breakwater, because of the shallow zone. The term revetment is maybe more suitable in this design.
• Dredging	This location has the lowest amount of dredging needed to be done. However there is a big percentage surplus.

Disadvantages

• Mainland connection	Although close to Savanna-la-Mar and relatively close to Montego Bay the site lies on the west part of Jamaica. This means far away from Kingston and the most population of Jamaica.

TABLE J-19: DETAILED EXCEL SHEET TO COME UP WITH THE KEY NUMBERS PRESENTED IN TABLE J-18

Amount of Dredging

Approach Channel		
Width	0.5	km
Depth	18	m
Average current depth	4	m
Length	1.3	km
Total volume	**9.1**	**mln. m^3**

Inside port		
Wet area for transshipment	2.7	km^2
Average current depth	0	m
Depth required	18	m
Wet area for industrial	0.4	km^2
Average current depth	0	m
Depth required	15	m
Total volume	**54.7**	**mln. m^3**

Total amount of dredging	**63.8**	**mln. m^3**
Price per cubic meter	7	U.S. Dollar
Total costs	450	mln. U.S. Dollar

Reclamation material needed

Storage area transshipment		
Reclaimed area	1.2	mln. m^2
Meters lifted	7	m
Total volume	**8.3**	**mln. m^3**

Storage area industrial		
Reclaimed area	0.3	mln. m^2
Meters lifted	7	m
Total volume	**2.2**	**mln. m^3**

Total amount of reclamation	**10.5**	**mln. m^3**
Price per cubic meter	13	U.S. Dollar
Total costs	140	mln. U.S. Dollar

Breakwater

Breakwater I		
Length	4000	m
Local depth	3	m
Height	4	m
Crest width	15	m
Slope 1:	1	-
Footprint	22	m
Cross section	129.5	m^2
Total volume	**0.5**	**mln. m^3**

Breakwater II		
Length	700	m
local depth	3	m
height	4	m
Crest width	15	m
Slope 1:	1	-
footprint	29	m
Cross section	154	m^2
Total volume	**0.1**	**mln. m^3**

Total volume	**0.6**	**mln. m^3**
Price per cubic meter	200	U.S. Dollar
Total costs	130	mln. U.S. Dollar

Summary

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.6	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.8	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	6.7	km
Quay length for industrial	2.0	km
Length approach channel	1.3	km
Length of breakwater	4.7	km

Volumes		
Total amount of dredging	63.8	mln. m^3
Total surplus material	53.3	mln. m^3
Volume of breakwater	0.6	mln. m^3

Total price for dredging, reclamation and the breakwater	**720**	**mln. U.S. Dollar**

2.6 Summary of the locations

The summary of all the locations is showed in Table J-20. This summary is made to give a quick overview between the advantages and disadvantages of all the locations. A minus is not good, a zero is medium and a plus is good. The Goat Islands designs 1 to 4 are not presented in this table, because Goat Islands Design 5 is assumed to be the best of the five alternatives. This will be tested later in the MCA.

TABLE J-20: SUMMARY OF ALL THE ADVANTAGES AND DISADVANTAGES OF THE LOCATIONS, FOR THE GOAT ISLANDS IS ONLY DESIGN 5 PRESENTED.

	Goat Islands design 5	Jackson Bay	Maccary Bay	Savanna-la-Mar	Little Bay
Approach channel	O	+	-	O	+
Berthing	+	+	+	+	+
Breakwater	+	-	-	O	O
Dredging 18 m	O	+	-	-	+
Dredging 27 m	-	O	-	-	+
Environment	-	O	+	+	+
Expansion land	O	+	+	+	-
Mainland connection	+	O	O	O	O
Settlement	O	+	+	+	+

3 Define criteria

The criteria are established after consulting CHEC (CHEC, 2013). The criteria differ from the criteria in the appendix I, Site selection, because the designs are in more detail and CHEC (CHEC, 2013) pointed out their interest. The main interest of CHEC is the investment and the expected earnings of the investment. The second main interest is developing the port close to the largest population (Kingston) and about a good social implementation in Jamaica. CHEC wants a port development that improves the living of the Jamaica people the most (social aspect), by for instance creating jobs or improving the infrastructure.

The final criteria for the comparison of the locations and designs:

- **Close to Kingston**
  One of the main reasons CHEC is very interested in the Goat Islands is because it is very close to the economic heart of the country. Kingston and the surrounding area provide labor and industry. Lying close to Kingston is a big plus.

- **Expansion (space, costs)**
  The future lies in uncertainty. Larger ships are being designed and new trade routes are formed. What the new Panama Canal will bring isn't good predictable. How other ports react to this change is also not exact determined. It is possible that the new port needs space to expand in the future. If there is space for expansion this is a positive thing for the port. These expansion possibilities also require new investments. Two things are important for this criterion: enough area to expand and the costs of this expansion. This criterion includes both.

- **Dredging to 27 meter**
  Next to expanding on land also the visiting vessels can become larger in the future. If China gets a bigger share in the Caribbean, China max vessels could be sailing around in the future. Next to that, if the port wants to handle other ships than container carriers drafts can be even bigger. This criterion is about the costs of an approach channel with a depth of 27 meter.

- **Environmental, ecology**
  The environment has also a big impact in the decision making. Fish sanctuaries are hard to replace. Protected areas are protected for certain reasons. These areas are somehow special, so it is hard to compensate for this elsewhere. Also building in a protected area can lead to heavy protest by the local people and maybe the nation as a whole. This results in uncertainties which increase the building time (and costs) dramatically.

- **Maneuverability to and inside the port**
  Ships have less rudder control when sailing with crosscurrents and crosswinds. The alignment of the approach channel makes a huge difference whether or not ships can maneuver easily or not. A short approach channel is preferable for shipping companies. Also inside the port there shouldn't be any currents or narrow channels which makes maneuvering more difficult.

- **Dredging surplus**
  All the dredging that is needed for creating the wet area should be used for reclaiming the land. In case of a surplus the extra material needs to be dumped somewhere else. Of course this can be accounted for in the costs estimation, but because this isn't only an economic aspect it is taken as a separate criterion. By dumping the dredged material the environment is harmed.

- **Improvement of coastal protections**
  As mentioned by CHEC social impact is very important. A port design which stimulates the surrounding coastline is preferable for the Jamaican Government and the local people. The new port would increase the safety against flooding. This is a social aspect and therefore selected as criterion for this MCA.

Note: Not taken as criteria are amount of dredging, construction of breakwater, the wave climate around the port and reclamation of the area. These aspects are taken into account in the total cost estimation (a higher wave climate results in a bigger breakwater, so more costs).

4 Weights

In Table J-21 the criteria are weighted against each other. Lying close to Kingston is found to be the most important criterion. Also Expansion, Environment and Improvement of the coast are criteria with a heavy weight. A sorted overview of Table J-21 is given in Table J-22. The percentage each criterion is also showed in Table J-22.

TABLE J-21: THE TOTAL WEIGHT OF EACH CRITERION IS SHOWN IN COLUMN MOST TO THE RIGHT. TO COME UP WITH THESE WEIGHTS EVERY CRITERION IS RATED AGAINST EVERY OTHER CRITERION.

	Close to Kingston	Expansion (space, costs)	Dredging to 27m	Environmental, ecology	Maneuvarability to and inside the port	Dredging surplus	Improvement of coastal protection		**Total Score Weights**
Close to Kingston	1	1	1	1	1	1	1	*7*	**7**
Expansion (space, costs)	x	1	1	0	1	1	1	*5*	**5**
Dredging to 27m	x	x	1	0	0	0	0	*1*	**1**
Environmental, ecology	x	x	x	1	1	1	0	*3*	**5**
Maneuvarability to and inside the port	x	x	x	x	1	0	0	*1*	**2**
Dredging surplus	x	x	x	x	x	1	0	*1*	**3**
Improvement of coastal protection	x	x	x	x	x	x	1	*1*	**5**
	0	*0*	*0*	*2*	*1*	*2*	*4*		

TABLE J-22: PERCENTAGE OF EACH CRITERION

	Score	**Percentage**
Close to Kingston	7	**25%**
Expansion (space, costs)	5	**18%**
Environmental, ecology	5	**18%**
Improvement of coastal protection	5	**18%**
Dredging surplus	3	**10%**
Maneuvarability to and inside the port	2	**7%**
Dredging to 27m	1	**4%**
Total	*28*	***100%***

5 Scores

Every design gets a score for every criterion. The total sum of the score per criterion multiplied by the associated weight gives the total score. Dividing the total score by the maximum score scales all the scores between 20 and 100 (minimum score and maximum score).

5.1 Points and explanation of the points

In Table J-23 the score per criterion and the total score is showed. Below the table the given scores are explained. If a location scores a 5 on a criterion, it is the best score it can get. If a location gets a 1 on a criterion that is the lowest score it can get.

TABLE J-23: SCORE PER CRITERION AND TOTAL SCORE

Weights	25%	18%	4%	18%	7%	10%	18%	
	Close to Kingston	Expansion (space, costs)	Dredging to 27m	Environmental, ecology	Maneuvarability to and inside the port	Dredging surplus	Improvement of coastal protection	**Total score (max 100 points)**
Goat Islands Design 1	5	4	1	2	3	2	1	**59**
Goat Islands Design 2	5	4	1	1	4	2	1	**57**
Goat Islands Design 3	5	4	1	1	3	5	1	**62**
Goat Islands Design 4	5	4	1	2	1	4	1	**61**
Goat Islands Design 5	5	4	1	2	3	4	1	**64**
Jackson Bay	3	3	3	4	4	5	4	**73**
Maccary Bay	3	4	1	5	3	1	3	**65**
Savanna-la-Mar	1	5	3	5	4	2	1	**56**
Little Bay	1	4	5	5	5	4	2	**64**

The scores are not explained per location, but the scores are explained per criterion.

- **Close to Kingston**
  These scores are easily understandable. The Goat Islands are close to Kingston and the highway to Kingston. Maccary Bay and Jackson Bay are a little more abandoned so doesn't get the perfect score. Savanna-la-Mar and Little Bay are at the other side of Jamaica and the furthest away from Kingston, so they get the minimum score.

- **Expansion (space, costs)**
  Actually all the nine possible ports have enough space to even double the size of their area. The difference lies in the costs for the expansion. Savanna-la-Mar is relatively cheap to expand because expanding is in the direction of the approach channel and the land is relatively flat and abandoned. Jackson Bay and Maccary Bay have enough space, but the design of the expansion has to include the (shifting) breakwaters which are expansive. The port of Little Bay has to make a breach to expand to the east. For expansion of the Goat Islands a few houses have to be removed.

- **Dredging to 27 meter**
  Dredging up to 27 meter depth is very expensive the Goat Islands. The length of the approach channel will increase dramatically because of the enormous relatively shallow Portland Bight. As Maccary Bay already has an enormous approach channel deepening it further will increase costs significantly. Jackson Bay and Savanna-la-Mar need to increase the length of the approach channel a little bit, but not as much as the designs

of the Goat Islands. Little Bay is the perfect location according to this criterion, as the beginning of the approach channel is already at a depth of around 70 meter so no increase of the length is needed.

- **Environmental, ecology**
  The Goat Islands score low on this criterion, because of their location in the Portland Bight Protected Area. Design 2 and design 3 of the Goat Islands score even lower, because they harm the fish sanctuary currently present behind the Goat Islands. The other locations score the maximum as no protected area is harmed, except for the Jackson Bay area who just lies within the boundaries of the Portland Bight Protected Area.

- **Maneuverability to and inside port**
  Here some difference is found between the various Goat Islands options. Design 4 is by far the least favorable for shipping maneuverability. A long approach channel and bends in the end make it tough to approach. Design 1 and 3 cope with some currents from the rivers discharging in the back of the port and score also a relatively low score. Design 5 has a little bend in the end which is not ideal. For the other locations Maccary Bay scores medium for its long approach channel. Jackson Bay isn't optimal because of the cross winds and currents. However the approach channel length is reasonable. Savanna-la-Mar has an average length but is aligned perfectly. Little Bay combines short length and perfect alignment to make it a perfect score for a close to perfect approach channel.

- **Dredging surplus**
  This score is given by looking at the total volume of dredged material surplus. The amount of material surplus divided by 20 gives an inverse score. The number 20 is chosen because this result in scores between 1 en 5, see Table J-24. In the last column is the indication presented if this criterion was only about costs. An indicator of 3 US Dollar per cubic meter is used.

TABLE J-24: SURPLUS DREDGED MATERIAL

Dredging	Dredging surplus	Amount divided by 20	Number (6-last colom)	If t was only costs in mln US Dollar
Goat Islands Design 1	80	4.0	2	240
Goat Islands Design 2	80	4.0	2	240
Goat Islands Design 3	20	1.0	5	60
Goat Islands Design 4	35	1.8	4	105
Goat Islands Design 5	50	2.5	4	150
Jackson Bay	25	1.3	5	75
Maccary Bay	100	5.0	1	300
Savanna-la-Mar	75	3.8	2	225
Little Bay	50	2.5	4	150
		Divided by 20		Price per cubic meter 3

- **Improvement of coastal protection**
  Only Little Bay, Maccary Bay and Jackson Bay can be designed to stimulate the coastline. By the accumulation of coastline some extra protection is created for surrounding areas. Little Bay protects the behind lying land for extreme weather conditions only a little bit, so gets a slightly higher score then the minimum. At Maccary Bay and Jackson Bay a long-shore current erodes the beaches. A port at these locations reduces the erosion. Jackson Bay gets the higher score because it is at the start of this erosion problem and thus influences the whole coast. The other locations get a score of one.

5.2 Total score

A summary of the total points per design is listed in Table J-25. The locations are ranked with the design with the most points above and the design with the least number of points at the bottom. Jackson Bay and Maccary Bay have the best scores. The Goat Islands option 5 shares the third place with Little Bay.

TABLE J-25: LOCATIONS AND DESIGNS RANKED ON TOTAL POINTS (MAXIMUM TOTAL SCORE IS 100 POINTS) FROM HIGHEST TO LOWEST

Ranked by total score	
Jackson Bay	72.9
Maccary Bay	65.0
Goat Islands Design 5	63.6
Little Bay	63.6
Goat Islands Design 3	62.1
Goat Islands Design 4	60.7
Goat Islands Design 1	59.3
Goat Islands Design 2	57.1
Savanna-la-Mar	56.4

This ranking changes a lot when the scores are divided by the investment costs. In Table J-26 the scores divided by the estimated costs (see chapter 3) can be found. The costs include the dredging, reclamation, breakwater and excavation costs. The last column of Table J-26, score/costs, is ranked from high to low in Table J-27.

TABLE J-26: TOTAL POINTS DIVIDED BY INVESTMENT COSTS

	Total score (max 100 points)	Costs (million U.S. Dollar)	**Total score/ costs**
Goat Islands Design 1	59	1,160	5.1
Goat Islands Design 2	57	1,020	5.6
Goat Islands Design 3	62	1,340	4.6
Goat Islands Design 4	61	1,080	5.6
Goat Islands Design 5	64	920	6.9
Jackson Bay	73	1,230	5.9
Maccary Bay	65	1,060	6.1
Savanna-la-Mar	56	1,150	4.9
Little Bay	64	720	8.8

TABLE J-27: LOCATIONS AND DESIGNS RANKED ON TOTAL SCORES/COSTS FROM HIGHEST TO LOWEST

Ranked by total score/cost	
Little Bay	8.8
Goat Islands Design 5	6.9
Maccary Bay	6.1
Jackson Bay	5.9
Goat Islands Design 4	5.6
Goat Islands Design 2	5.6
Goat Islands Design 1	5.1
Savanna-la-Mar	4.9
Goat Islands Design 3	4.6

In Table J-27 is shown that Little Bay gets by far the highest score/cost ratio. This is because of its low investment costs and its average score (see Table J-25).

6 Conclusion

The conclusion that Little Bay is the winner of this MCA is not right. Everything is well considered, but there are some assumptions made in the design values such as the quay length. A change in the design values changes everything; the design itself, the score on some criterion and the costs.

Also the costs include not all of the costs. The costs include only the dredging-, reclamation- and the breakwater part of the costs. For a correct analysis the score have to be divided by the total costs (including quay walls, cranes etc.).

The above two arguments demonstrate that a sensitivity analysis has to be made. After the sensitivity analysis it is possible to make a well informed choice about the best possible location.

The four best designs are selected for this analysis. Goat Islands design 5 is best alternative of all the Goat Islands variants, because is scores better and is cheaper. By adapting all the Goat Islands variants, Goat Islands Design 5 would still be the best of all the Goat Islands variants. The design of Savanna-la-Mar scores very low and is very expensive. Therefore this design will not be included in the sensitivity analysis.

The sensitivity analysis will be done for Goat Islands Design 5, Jackson Bay, Maccary Bay and Little Bay. This is done in appendix K, Sensitivity analysis.

7 References

CHEC. (2013, 09 27). Presentation 27/09/2013. (W. B. Marloes Brands, Interviewer)

Appendix K Sensitivity analysis

The result of the MCA is not sufficient to select the best possible location (see appendix J, Further investigation of five port locations). There are uncertainties in the design values and in the costs. Therefore this sensitivity analysis is made. This is only done for the four best designs, as stated in appendix J, Further investigation of five port locations. In this analysis the length of the quay is adapted. The sensitivity of the total costs is also presented in this report. This analysis is done to see the influence of the difference in quay length on the outcome of the MCA.

1 Design values

In appendix G, Design values a questionable assumption is made. A quay length of 6 kilometer is taken for the designs in the Multi Criteria Analysis (see appendix J, Further investigation of five port locations). As the appendix already stated this 6 kilometer is very conservative. A quay length of 3 kilometer looks more reasonable if the queuing theory is applied. In this chapter a sensitivity analysis for the four best locations is made to see if (and how much) designs, scores, costs and total result (score divided by the costs) are changed. The four best locations are the same based on the total score and based on the total score divided by the costs, only the ranking differs. These four locations are Goat Islands Design 5, Jackson Bay, Maccary Bay and Little Bay.

This sensitivity analysis is based on the reducing of the quay length from 6 kilometer to 3 kilometer. The associated design parameters are shown in Table K-1.

Table K-1: Design parameters for sensitivity analysis based on appendix G, Design values

			First design	**Sensitivity analysis**
Surface port area	Transshipment port	Dry	Total area of 12 km^2	
		Wet		
	Industrial area	Dry		
		Wet		
Approach channel	Width		500 m	
	Length in port		At least 500 m	
	Diameter turning circle		At least 732 m	
	Depth	Transshipment port	At least 18 m	
		Industrial area	At least 15 m	
Average dwell time			7.5 days	
Maximum expected throughput			Nearly 7 million TEU	
Number of berths	Transshipment port		15 berths	8 berths
	Industrial area		unknown	6 berths
Quay length	Transshipment port		**6 km**	**3 km**
	Industrial area		unknown	

2 Goat Islands Design 5

In this adapted design two major changes are made, see Figure K-1. In the south of the port Little Goat Island is used for terminal area only. In this way a part of the Little Goat Island doesn't have to be excavated and dredged. Also the wet area inside the port is reduced because of the less quay length. The key numbers for both designs are shown in Table K-2.

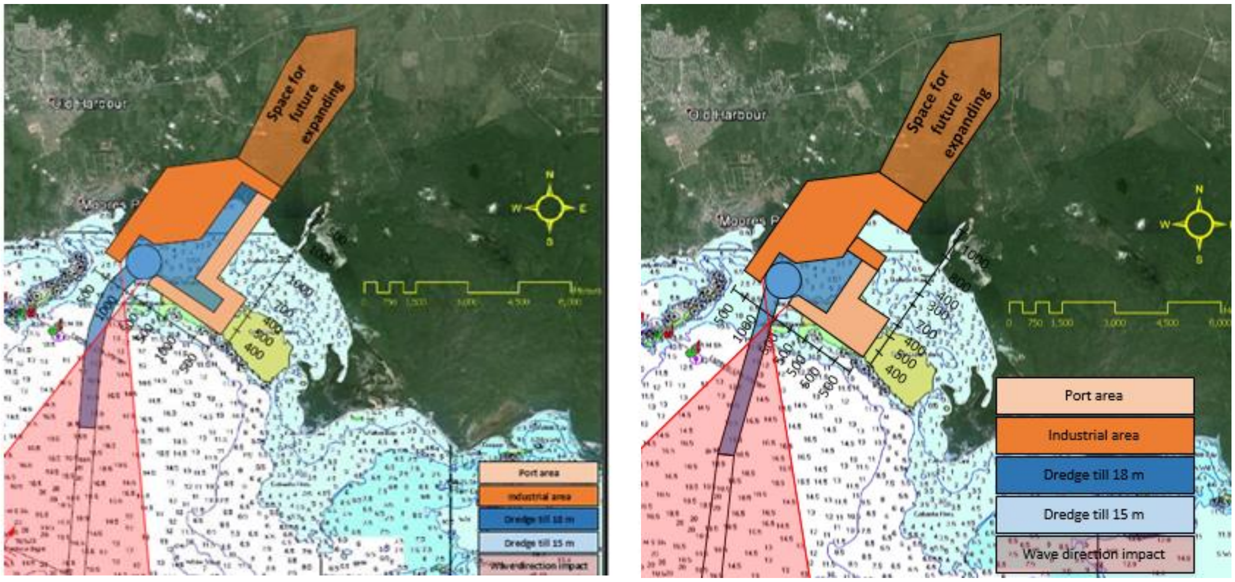
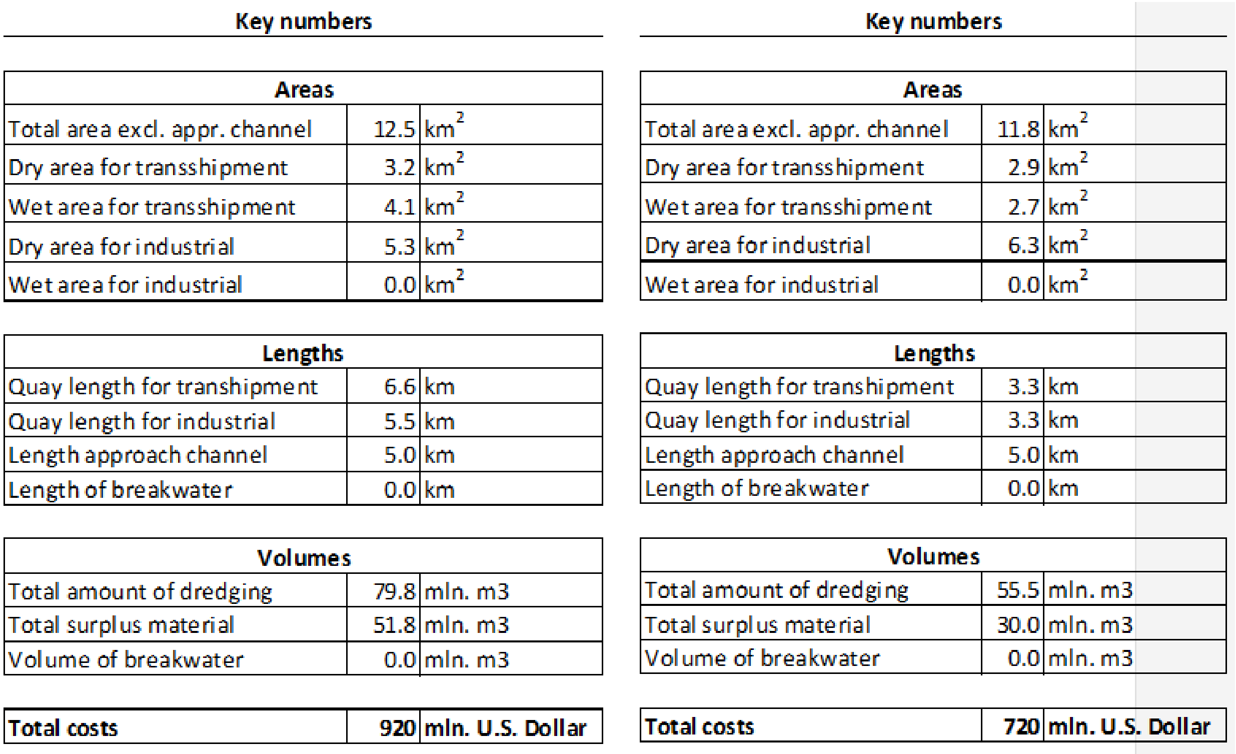


FIGURE K-1: LEFT FIGURE SHOWS THE GOAT ISLANDS DESIGN 5 WITH A QUAY LENGTH OF 6 KM (ORIGINAL). RIGHT FIGURE SHOWS THE ADAPTED DESIGN WITH A QUAY LENGTH OF 3 KM FOR TRANSSHIPMENT.

TABLE K-2: KEY NUMBERS OF THE ORIGINAL DESIGN (LEFT) AND THE ADAPTED DESIGN (RIGHT)



Key numbers

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.2	km^2
Wet area for transshipment	4.1	km^2
Dry area for industrial	5.3	km^2
Wet area for industrial	0.0	km^2

Lengths		
Quay length for transhipment	6.6	km
Quay length for industrial	5.5	km
Length approach channel	5.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	79.8	mln. m3
Total surplus material	51.8	mln. m3
Volume of breakwater	0.0	mln. m3

Total costs	**920**	**mln. U.S. Dollar**

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	2.9	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	6.3	km^2
Wet area for industrial	0.0	km^2

Lengths		
Quay length for transhipment	3.3	km
Quay length for industrial	3.3	km
Length approach channel	5.0	km
Length of breakwater	0.0	km

Volumes		
Total amount of dredging	55.5	mln. m3
Total surplus material	30.0	mln. m3
Volume of breakwater	0.0	mln. m3

Total costs	**720**	**mln. U.S. Dollar**

Both above mentioned changes in design reduce the amount of dredging and thus the costs, which can be seen in Table K-2. By reducing the quay length, also the total surface of the wet area is decreased. The transshipment surface will be the same and the total surface will be almost the same. This leads to a larger surface for industry.

In Table K-3 an updated version of the previously used scores for Goat Island is found. The most changes are in the cost (and in score/costs) and a minor change is found in the score. Dredging surplus is a little more favorable than before. Including the weight of the dredging surplus the total score increases with 2 points.

TABLE K-3: THE ADAPTED AND THE OLD MCA SCORES OF THE GOAT ISLANDS DESIGN 5

	Close to Kingston	Expansion (space, costs)	Dredging to 27m	Environmental, ecology	Maneuvarability to and inside the port	Dredging surplus	Improvement of coastal protection	**Total score (max 100 points)**	Costs (million U.S. Dollar)	Total score/ costs
Goat Island Design 5 Adapted	**5**	**4**	**1**	**2**	**3**	**5**	**1**	**66**	**720**	**9.1**
Goat Island Design 5 Old	5	4	1	2	3	4	1	64	920	6.9

3 Jackson Bay

The layout of Jackson Bay changes much, see Figure K-2. The amount of dredging and especially the breakwater are making this location expensive. Because of the reduced quay length the port can reduce its width along the coast. In this way the west breakwater can be reduced by a few hundred meters. Also less dredging for the wet area inside the port is needed. The key numbers for both design are shown in Table K-4.

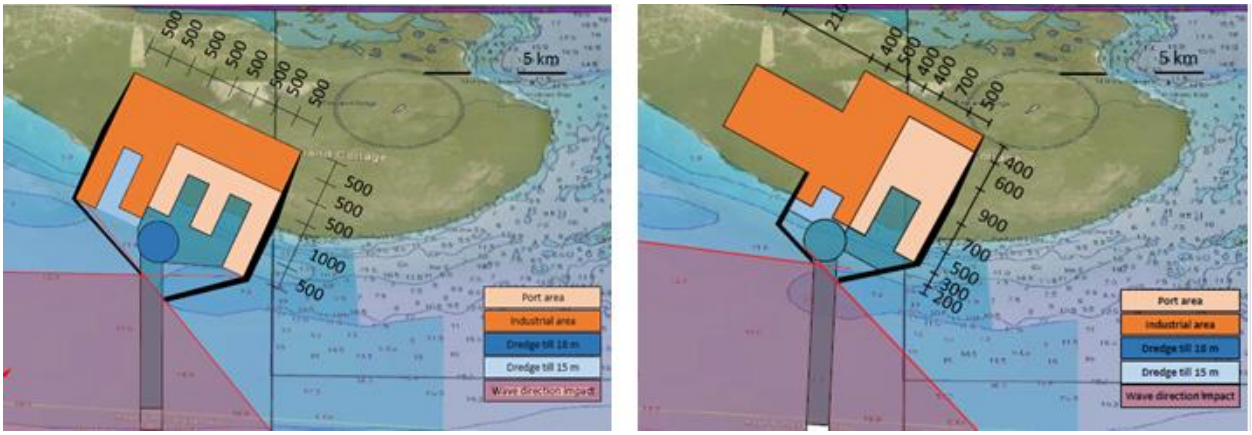


FIGURE K-2: LEFT FIGURE SHOWS THE JACKSON BAY DESIGN WITH A QUAY LENGTH OF 6 KM (ORIGINAL). RIGHT FIGURE SHOWS THE ADAPTED DESIGN WITH A QUAY LENGTH OF 3 KM FOR TRANSSHIPMENT.

TABLE K-4: KEY NUMBERS OF THE ORIGINAL DESIGN (LEFT) AND ADAPTED DESIGN (RIGHT)

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	3.0	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	0.9	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.8	km
Length approach channel	4.0	km
Length of breakwater	7.0	km

Volumes		
Total amount of dredging	51.1	mln. m3
Total surplus material	25.7	mln. m3
Volume of breakwater	2.7	mln. m3

Total costs	**1,230**	**mln. U.S. Dollar**

Key numbers

Areas		
Total area excl. appr. channel	13.4	km^2
Dry area for transshipment	3.5	km^2
Wet area for transshipment	1.7	km^2
Dry area for industrial	7.6	km^2
Wet area for industrial	0.6	km^2

Lengths		
Quay length for transhipmen	3.1	km
Quay length for industrial	2.3	km
Length approach channel	4.0	km
Length of breakwater	4.5	km

Volumes		
Total amount of dredging	41.9	mln. m3
Total surplus material	28.2	mln. m3
Volume of breakwater	1.7	mln. m3

Total costs	**810**	**mln. U.S. Dollar**

In the Table K-4 the wet areas of the port are downgraded and the dry areas are enlarged. This is caused by the shortening of the quay length for transshipment. The tables also show the length of the breakwaters, which is reduced because of the new design. This is reflected in the total costs which are almost decreased by one third.

The adapted version of Jackson Bay reduced the total costs very much. However this comes with the price of less maneuverability inside the port. Therefore the adaption scores a little bit lower in total score, but higher on the “total score/costs”, see Table K-5.

Table K-5: The adapted and the old MCA scores of Jackson Bay Design

	Close to Kingston	Expansion (space, costs)	Dredging to 27m	Environmental, ecology	Maneuvarability to and inside the port	Dredging surplus	Improvement of coastal protection	**Total score (max 100 points)**	Costs (million U.S. Dollar)	Total score/ costs
Jackson Bay Adapted	**3**	**3**	**3**	**4**	**3**	**5**	**4**	**71**	**810**	**8.8**
Jackson Bay Old	3	3	3	4	4	5	4	73	1230	5.9

4 Maccary Bay

The design of Maccary Bay also has some changes, see Figure K-3. The wet area can be reduced a lot. This results in the transshipment area lying closer to the coast. This reduces the amount of dredging a lot. As for the location Jackson Bay Maccary Bay can also be shorted in width to reduce the length of the breakwaters. By removing half of the wet area the surface of the industrial area becomes larger. The key numbers for both designs are shown in Table K-6.

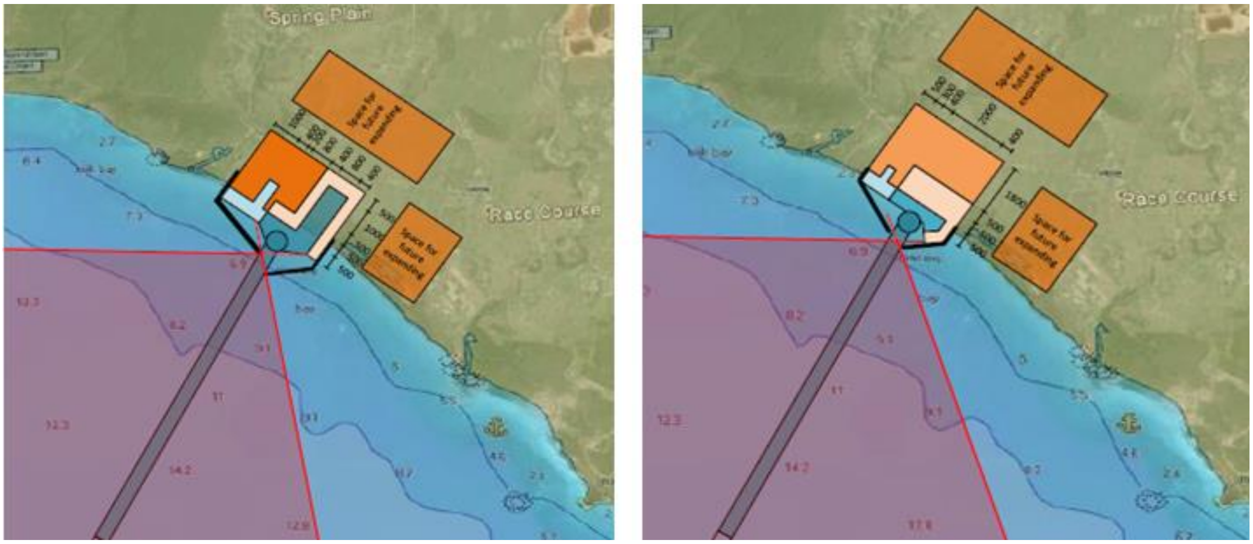


FIGURE K-3: LEFT FIGURE SHOWS THE MACCARY BAY DESIGN WITH A QUAY LENGTH OF 6 KM (ORIGINAL). RIGHT FIGURE SHOWS THE ADAPTED DESIGN WITH A QUAY LENGTH OF 3 KM FOR TRANSSHIPMENT

TABLE K-6: KEY NUMBERS OF THE ORIGINAL DESIGN (LEFT) AND ADAPTED DESIGN (RIGHT)

Key numbers

Areas		
Total area excl. appr. channel	11.8	km^2
Dry area for transshipment	2.6	km^2
Wet area for transshipment	2.8	km^2
Dry area for industrial	5.2	km^2
Wet area for industrial	1.2	km^2

Lengths		
Quay length for transhipment	6.5	km
Quay length for industrial	3.6	km
Length approach channel	12.0	km
Length of breakwater	8.0	km

Volumes		
Total amount of dredging	101.9	mln. m3
Total surplus material	99.8	mln. m3
Volume of breakwater	1.6	mln. m3

Total costs	**1,060**	**mln. U.S. Dollar**

Key numbers

Areas		
Total area excl. appr. channe	12.5	km^2
Dry area for transshipment	2.9	km^2
Wet area for transshipment	1.3	km^2
Dry area for industrial	7.5	km^2
Wet area for industrial	0.8	km^2

Lengths		
Quay length for transhipmen	3.0	km
Quay length for industrial	2.2	km
Length approach channel	12.5	km
Length of breakwater	4.5	km

Volumes		
Total amount of dredging	68.3	mln. m3
Total surplus material	65.5	mln. m3
Volume of breakwater	1.0	mln. m3

Total costs	**710**	**mln. U.S. Dollar**

Table K-6 shows the difference between the previous and new key numbers. Half of the wet area is assigned to the dry industrial area. Also the breakwaters are much shorter. Less dredging leads to a lower dredging surplus (but is still high). Total costs are reduced with more than 30%.

Table K-7 shows the differences in the MCA score with the adaption to 3 kilometer of quay length instead of the previously required 6 kilometer. The expansion possibilities for the adapted design score a bit less than for the original design. This can be seen when looking at Figure K-3. Expanding of the dry area is easily done, but increasing the wet area is difficult. On all sides the constructed port needs to be demolished. The dredging surplus isn't extreme anymore, but it still is not good balanced. The total scores divided by the costs is improved a lot.

Table K-7: The adapted and the old MCA scores of Maccary Bay Design

	Close to Kingston	Expansion (space, costs)	Dredging to 27m	Environmental, ecology	Maneuvarability to and inside the port	Dredging surplus	Improvement of coastal protection	**Total score (max 100 points)**	Costs (million U.S. Dollar)	Total score/ costs
Maccary Bay Adapted	**3**	**3**	**1**	**5**	**3**	**3**	**3**	**66**	**710**	**9.3**
Maccary Bay Old	3	4	1	5	3	1	3	65	1060	6.1

5 Little Bay

In the adapted design of Little Bay the wet area changes a lot, see Figure K-4. The north-south channel is removed because enough quay length can be established by using the main channel only. The transshipment port area is packed together, so the interaction between terminals is easier. The width of transshipment port is also increased a little bit. The costs increases, but it provides more efficiently in handling of the containers. The quays for the industrial area are relocated to the west because of the bundling of the container terminals. The key numbers for both designs are shown in Table K-8.

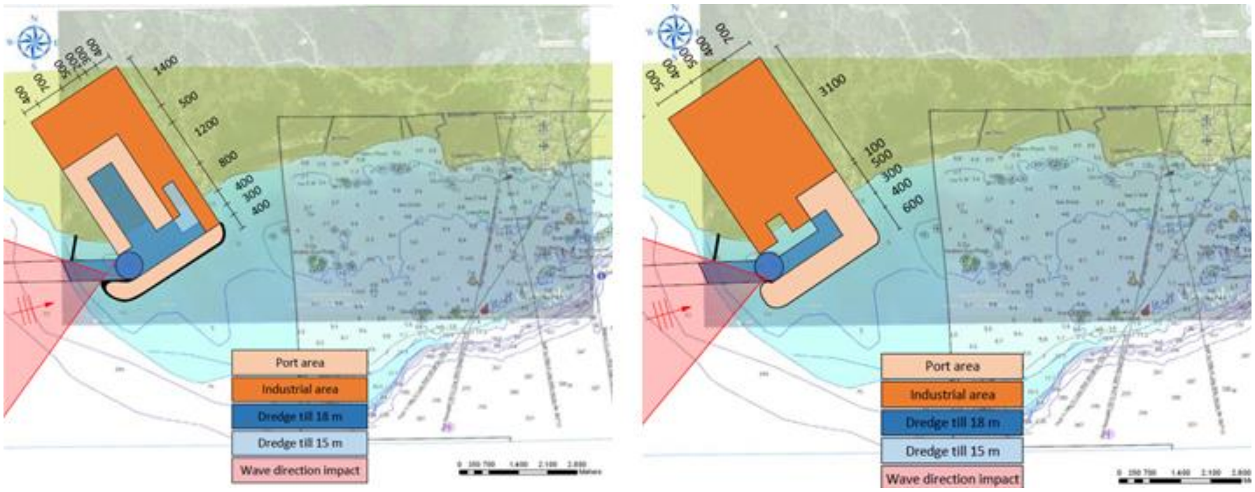


FIGURE K-4: LEFT FIGURE SHOWS THE LITTLE BAY DESIGN WITH A QUAY LENGTH OF 6 KM (ORIGINAL). RIGHT FIGURE SHOWS THE ADAPTED DESIGN WITH A QUAY LENGTH OF 3 KM FOR TRANSSHIPMENT.

TABLE K-8: KEY NUMBERS OF THE ORIGINAL DESIGN (LEFT) AND ADAPTED DESIGN (RIGHT)

Key numbers

Areas		
Total area excl. appr. channel	12.5	km^2
Dry area for transshipment	3.6	km^2
Wet area for transshipment	2.7	km^2
Dry area for industrial	5.8	km^2
Wet area for industrial	0.4	km^2

Lengths		
Quay length for transhipment	6.7	km
Quay length for industrial	2.0	km
Length approach channel	1.3	km
Length of breakwater	4.7	km

Volumes		
Total amount of dredging	63.8	mln. m3
Total surplus material	53.3	mln. m3
Volume of breakwater	0.6	mln. m3

Total costs	**720**	**mln. U.S. Dollar**

Key numbers

Areas		
Total area excl. appr. channel	12.9	km^2
Dry area for transshipment	3.0	km^2
Wet area for transshipment	1.1	km^2
Dry area for industrial	8.3	km^2
Wet area for industrial	0.6	km^2

Lengths		
Quay length for transhipment	3.0	km
Quay length for industrial	2.4	km
Length approach channel	1.3	km
Length of breakwater	4.7	km

Volumes		
Total amount of dredging	33.7	mln. m3
Total surplus material	16.2	mln. m3
Volume of breakwater	0.6	mln. m3

Total costs	**600**	**mln. U.S. Dollar**

The wet area for transshipment is more than halved, but the 3 km quay length for transshipment is reached. The effects of the reduction of this area can be seen in the total costs. Aside from this not much is changed in the key numbers, see Table K-8.

Looking at the MCA scores in Table K-9, Little bay scores lower on expansion in the adapted design. This is because the width of the dry transshipment area is increased so it is more expensive to expand the wet area inside the port. Dredging surplus is better however, so the total score doesn't fall much. Little Bay gets an even higher "total score / costs" because of the reduction in price.

TABLE K-9: THE ADAPTED AND THE OLD MCA SCORES OF LITTLE BAY DESIGN

	Close to Kingston	Expansion (space, costs)	Dredging to 27m	Environmental, ecology	Maneuvarability to and inside the port	Dredging surplus	Improvement of coastal protection	**Total score (max 100 points)**	Costs (million U.S. Dollar)	Total score/ costs
Little Bay Adapted	**1**	**3**	**5**	**5**	**5**	**5**	**2**	**62**	**600**	**10.4**
Little Bay Old	1	4	5	5	5	4	2	64	720	8.8

6 Overview and additional costs

An overview of the MCA scores of the four locations (old and adapted) is shown in Table K-10. In this table also the additional costs are presented.

TABLE K-10: OVERVIEW, THE COSTS ARE IN MILLION US DOLLAR (THIRD AND FOURTH COLUMNS FROM THE RIGHT SIDE)

	Close to Kingston	Expansion (space, costs)	Dredging to 27m	Environmental, ecology	Maneuvarability to and inside the port	Dredging surplus	Improvement of coastal protection	**Total (max 100 points)**	Costs dredging+reclamation+breakwater	Costs incl. Additional costs	Score/ costs	Score/ total estimated costs
Goat Island Design 5 adapted	5	4	1	2	3	5	1	**66**	**720**	**1420**	**9.1**	**4.6**
Goat Option 5	5	4	1	2	3	4	1	64	920	1620	6.9	3.9
Jackson Bay adapted	3	3	3	4	3	5	4	**71**	**810**	**1510**	**8.8**	**4.7**
Jackson Bay	3	3	3	4	4	5	4	73	1230	1930	5.9	3.8
Maccary Bay adapted	3	3	1	5	3	3	3	**66**	**710**	**1410**	**9.3**	**4.7**
Maccary Bay	3	4	1	5	3	1	3	65	1060	1760	6.1	3.7
Little Bay adapted	1	3	5	5	5	5	2	**62**	**600**	**1300**	**10.4**	**4.8**
Little Bay	1	4	5	5	5	4	2	64	720	1420	8.8	4.5

In Table K-10 there is a column with the Cost incl. Additional costs (third column seen from the right side). This column contains the costs (dredging, breakwater and reclamation) plus the estimated additional costs, for example the costs for the quay walls and the cranes. The estimated additional costs are approximately 700 million U.S. dollar. If the total scores are divided by the estimated total costs, another ranking (compared with the ranking if there is only divided by the costs without the additional costs) is visible, see last column of Table K-10. Jackson Bay has a higher score/total costs than Goat Islands Design 5. Also the scores are closer to each other.

This analysis is done to demonstrate that the ratio score/costs of the locations cannot be compared. The ratio of the score/total costs cannot be compared, because of the unknown additional costs. The additional costs are different at all the locations, because the building method or time is different and thus cheaper/more expensive

7 Conclusion of sensitivity analysis

Reducing the required quay length for transshipment port has a big influence on the design of the port. On the MCA score it doesn't have much of an effect, but on the costs it does. Even up to 33% costs reduction can be accomplished when reducing the quay length to 3 kilometer. Hundreds of millions can be saved if a less conservative approach is chosen. The influences of the adapted quay length are explained per locations:

- **Jackson Bay and Maccary Bay**

Those locations look the best options if it was only about the score and not the investment costs. Those designs create the most value for the area of Jamaica and are the most ideal locations for the possible port. However, with this high score comes a heavy price tag. Maccary Bay needs a lot of dredging and Jackson Bay needs a lot of artificial protection against extreme waves.

- **Little Bay**

This design is an above average alternative when looking at the score only. A major downfall of Little Bay is the location, it is three hour driving away from the economic heart of Jamaica, Kingston. Besides this criterion (and the improvement of coast protection criterion) it scores very high on the other five criteria. The port designs at Little Bay have the lowest costs requirements with both designs (6 kilometer and 3 kilometer quay length). A short approach channel is necessary which results in a low amount of dredging and not much reclamation is needed.

- **Goat Islands Design 5**

This port layout gets the same total score as Little Bay with 6 kilometer of quay length and gets a higher score when a quay wall of 3 kilometer is used. It gets the maximum score at the most important criterion "Close to Kingston", scores high at "Expansion possibilities" and has a low dredging surplus. It scores low at "Dredging to 27m" and the "Environment", because of the Portland Bight area. The investment requirements are relatively low, but still about 100 million U.S. dollar higher than Little Bay.

Summarizing, the conclusion can be made that there are **four winners**. All locations are winners in different ways. The scores lie close to each other. This makes them very sensitive to the assumptions which are made for weights (e.g. the rankings change if little changes to the weights are made). Also some things are not taken into account because of lack of knowledge (e.g. if the government has a policy to increase the economic activity in the west of Jamaica Little Bay is more favorable). Next to that not all the costs are included. If the costs of the hinterland connections are taken into account, the Goat Islands option will be less expensive than the other alternatives. Finally the additional costs (i.e. depending on building costs) are not taken into account which will make a big difference.

To make a real comparison all the locations have to be designed in a final stage.

- First of all, some of the design values have to be set by the investor. The design life time and the probability of failure have to be established. With those parameters the design return period of waves can be calculated. The wave and wind data has to be analyzed and the modeling of the waves near shore, the associated design wave height for the return period can be found. With this parameter the breakwaters and the port can be designed in more detail and a good estimation can be given for the costs.
- The designed breakwaters in the sensitivity analysis are too rough and also the price per cubic meter is the same, which is not true in reality.
- The sedimentation in the port and approach channel have to be simulated for the costs of maintenance dredging.
- The dredged material has to be investigated. Is the material being used for reclaiming? The currents have to be modeled to see if the approach channel is realistic and doesn't lead to unnecessary downtime.
- The bathymetric survey has to be done for establishing the real amount of dredging.

- Also an environmental Impact Assessment has to be made for every location. What is really the consequence of building and operating the port? Which environmental aspects are important? Where and how is the environment compensated in case of destroying some environmental areas?
- A Social Impact Assessment has to be made. Which part of Jamaica need the economic boost the most? Which location is preferable for (the Government of) Jamaica?
- For all the locations a timeframe of the building process should be made. A shorter building time is preferable, because of the finishing of the second Panama Canal in 2015.
- The investor of the port wants to make a return on the investment so the costs are very important. The dredging costs are expected to be constant per cubic meter and the same for all the locations. This is probably not true in reality.
- For every locations the dredging and reclamation costs has to be exactly determined.
- The price for the Post-Panamax cranes and the portal cranes would probably the same, but the price for the quay walls at the different locations are not the same. Constructing quay walls in an initial shallower area is probably cheaper.

After making for all the four locations a final and detailed design the policy makers can come up with a decision.

Because of limited time for this project only one location will be investigated further. This further design is not a complete design with all the details. For example, bathymetric survey, currents and even sand quality cannot be checked in this project because of the limiting time.

The location Goat Islands looks the most interesting. It looks like media (and public opinion), government, and CHEC are focusing more on the Goat Islands. Although three very good alternatives are found, it would be a challenge to show all stakeholders that it is possible to use the Goat Islands for a port and keep the environment in mind. Design 5 for the Goat Islands is chosen as design to be further investigated and designed.

Appendix L Layout of the port

For the new port a possible layout is made. The port layout is divided in the industrial area and the transshipment part. The layout of the industrial area is made by placing first the facilities which need quay length and afterwards the other facilities. The layout of the transshipment area is made using a reference terminal at the port in Dubai.

In Figure L-1 the rough design of the new port is shown. The orange part of the port shows the industrial area of the port and the beige part of the port shows the transshipment area of the port. Some changes are made in the original design, which is shown in appendix J, Further investigation of five port locations.

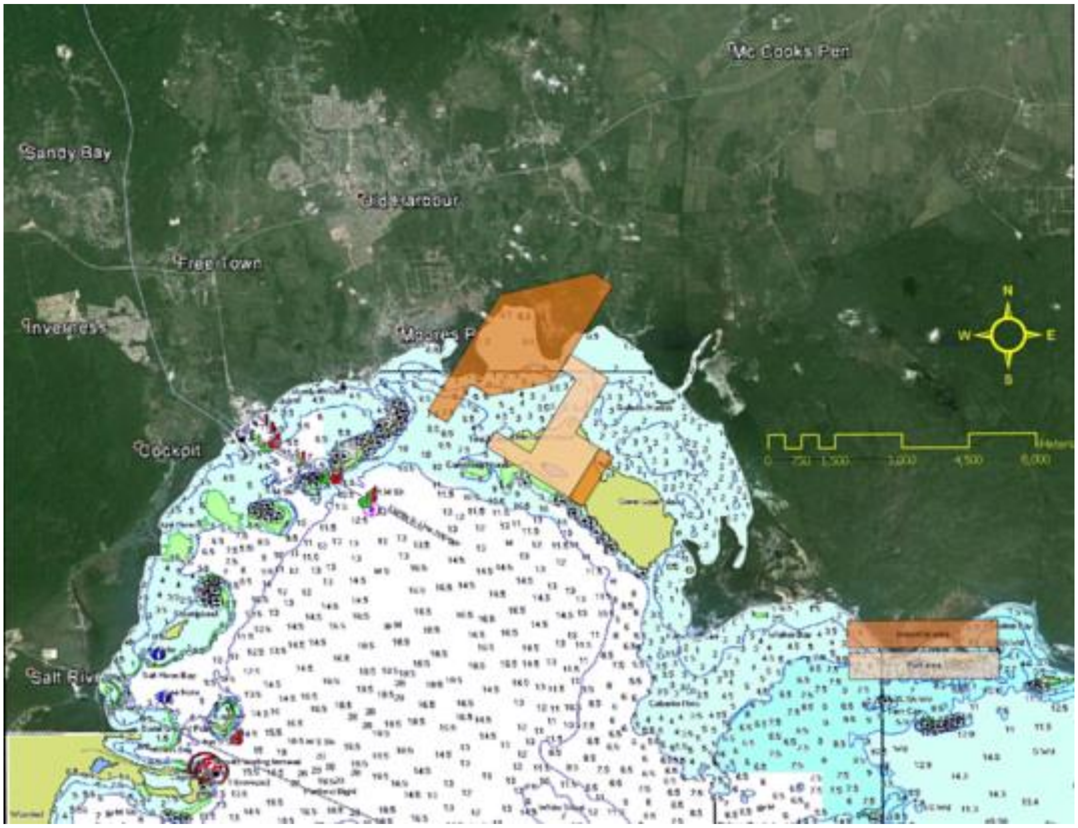


FIGURE L-1: A POSSIBLE LAYOUT OF THE PORT

1 Industrial area

There are several facilities which will be located in the industrial area of the port, see appendix H, Industrial area of the port. These facilities are a power plant, an assembly plant, a steel fabrication plant, a cement plant, an IT facility, a manufacturing facility and a logistics center. The allocation of the industrial facilities of the port is shown in Figure L-2. The facilities are all connected to the supported and related infrastructure.

The power plant will be placed at first in the layout of the port, because the placement has a lot of constraints. The power plant is assumed to be a LNG power plant, which is hazardous liquid bulk. The power plant must be located at a place which is not close to the villages (like Moores Pen) and not close to the factories. Also the mean wind direction has to be taken into account in case of fire. For the LNG transshipment a jetty has to be constructed. It is the cheapest when the pipeline from the power plant to the jetty is as short as possible, so preferable is a pipeline on land and a short pipe at the bottom of the sea. Next to that, the pipeline to the jetty must not be located very close to the navigation channel. Then the possibility a ship will hit the pipeline is reduced. These are the reasons the power plant will be located at the most south part of the port, see Figure L-2, just behind the transshipment part of the port. This adjacent

part of the transshipment area contains empty containers and buildings and equipment (see section 2.1). The location for the power plant in the transshipment part is the most far away of the quay. This causes that the storage area of the containers stays the closest to the quay, which is beneficial for the stacking of the containers. In this way the power plant isn't close to the valuable industrial activities, working and living people and the pipeline to the jetty is short.
In the old design, see appendix J, Further investigation of five port locations, the location where the power plant is placed was originally transshipment area. Therefore the design is changed. Because the power plant is located in the transshipment area, some area of the industrial area changed in transshipment area and there are some changes in the dimensions of the industrial area.

After the power plant the facilities which need quay length are placed, because they all need to be placed at the waterfront. There are three facilities in the industrial area which need 0.65 kilometer quay length: the assembly plant, the steel fabrication plant and the cement plant. In the design the cement plant has a quay length of 1.0 kilometer, the assembly plant has two parts of quay with a length of 0.5 and 0.76 kilometers. The steel fabrication plant has a quay with a length of 0.65 kilometers and a quay with a length of 0.3 kilometers. It can be concluded that in this design there is more quay available than needed. Therefore at some places no quay wall has to be constructed, but a pile of stones with a slope will also satisfy.

The steel fabrication plant is located further away in the port than the cement plant. The vessels which berth at the steel fabrication plant have a longer (un)loading time, so the occupancy is higher at a steel fabrication plant. The chance of a collision is smaller if the quay located at the entrance of the port is less occupied. Therefore the cement plant instead of a steel fabrication plant will be developed at the entrance of the part.

There will be a combination of rail and road through the port. The width of the combination of rail and road is equal to 50 meters. All industrial facilities will be connected to the road (and rail). When the surface of the needed infrastructure is measured this is equal to 0.2 km^2, less than the assumed 0.5 km^2 in appendix H, Industrial area of the port. Therefore the manufacturing facilities become (0.5-0.2=) 0.3 km^2 larger. The rest of the area will be used for an IT facility, manufacturing facilities and a logistics center.

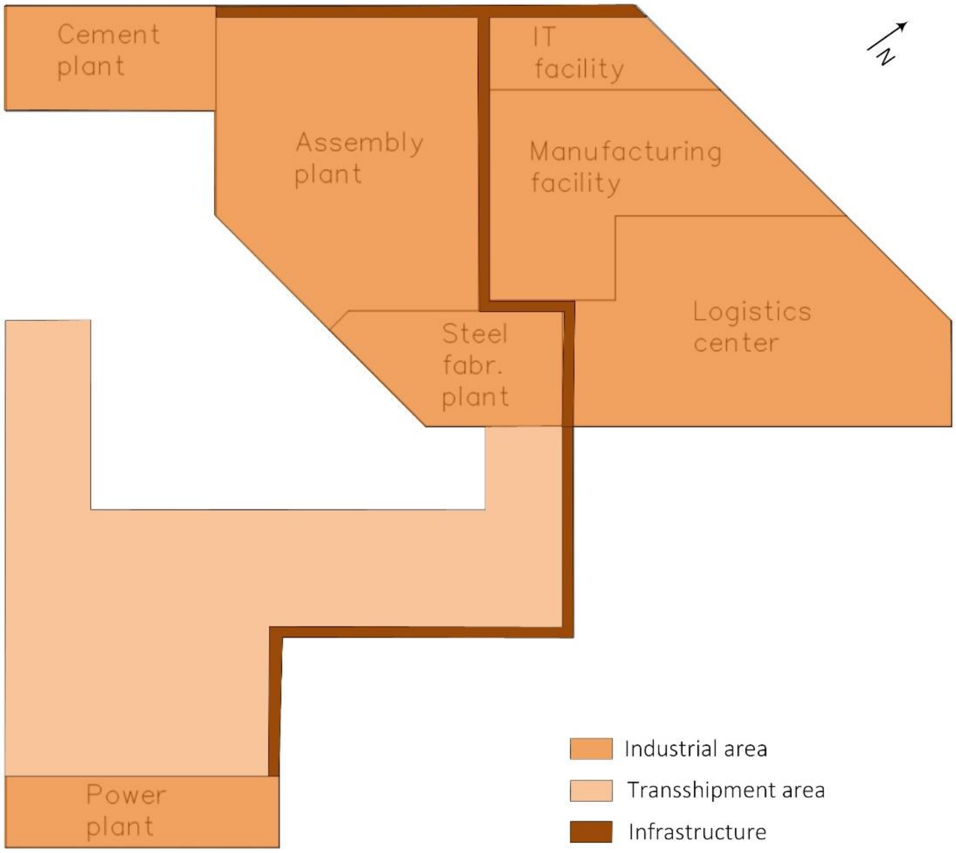


FIGURE L-2: LAYOUT OF THE INDUSTRIAL AREA OF THE PORT (FIGURE IS ROTATED)

2 Transshipment area

A few assumptions are made to determine the expected throughput of the new port, see appendix G, Design values. With the expected throughput the layout of the transshipment area of the port can be made. A distinction between the storage yard, the apron area and the other area in the port is made. The possible layout of the transshipment area of the port is shown in Figure L-3.

FIGURE L-3: THE LAYOUT OF THE TRANSSHIPMENT PART OF THE PORT (FIGURE IS ROTATED)

2.1 Within the storage yard

Within the storage yard it is assumed that portal cranes/gantry cranes will be used, see appendix G, Design values. There are different types of gantry cranes: rubber tyred gantry, rail mounted gantry and automated stacking cranes. (Ligteringen & Velsink, 2012) A rubber tyred gantry crane requires good subsoil conditions (high wheel loads on the pavement). The state of the subsoil is not known, so rubber tyred gantry cranes will not be used. The automated stacking crane has very high investment and maintenance costs. Because these high costs and because the labor costs in Jamaica are not extremely high (so automation is not that beneficial compared to the other two systems) the automated stacking crane is not very suitable in the new port. The rail mounted gantry crane (see Figure L-4) is suitable for the new port. This system has a good space utilization, is reliable, has a low maintenance and automation is possible. However, this system requires a high investment and is inflexible, but it is assumed that the cranes will be positioned appropriately for a long period and no flexibility is necessary.

FIGURE L-4: RAIL MOUNTED GANTRY CRANES IN THE PORT OF JEBEL ALI, DUBAI (GULF PETROCHEMICALS & PETROCHEMICALS ASSOCIATION, SD)

Terminal 2 at the port of Jebel Ali (Dubai) is a terminal which uses rail mounted gantry cranes. (DP World) An overview of the terminal is shown in Figure L-5. The depth along the quay is 17 meters, so the terminal is able to handle Post-Panamax vessels. The expansion of this terminal is completed in June 2013. (The National, 2013) The area of the terminal is 182 hectares (including space for buildings and equipment) and the capacity is equal to 6 million TEU per year. (CSS Group, 2013) This means that 3.3 million TEU per squared kilometer could be handled. When the throughput is assumed to be 70% of the capacity, like mentioned in the appendix G, Design values, the throughput per squared kilometer is equal to (0.7*3.3=) 2.3 million TEU per squared kilometer.
The new port in Jamaica is expected to handle 7 million TEU at an area of 3 km^2. The expected throughput per square kilometer is also 2.3 million TEU per squared kilometer. The terminal in the port of Jebel Ali is good comparable with the new port in Jamaica. The throughput per squared kilometer is equal to the expected throughput of the new port in Jamaica.

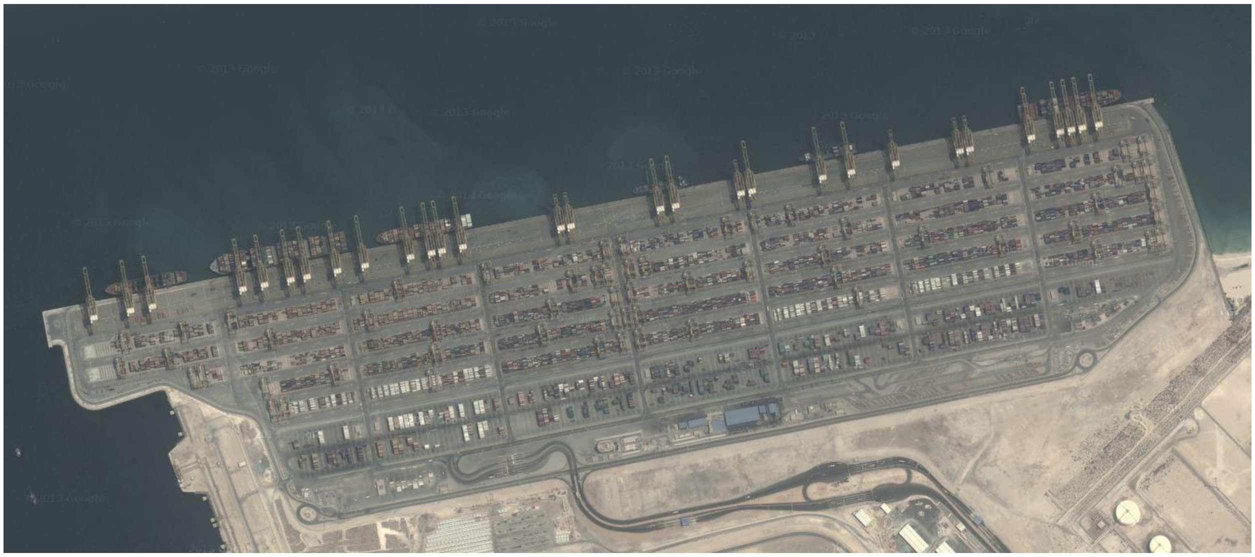


FIGURE L-5: TERMINAL 2 OF THE PORT OF JEBEL ALI, DUBAI

The layout of the storage area of the new transshipment port will be based on the layout of the terminal at the port of Jebel Ali, see Figure L-5. The rail mounted gantry cranes stack 10 containers wide and up to 7 containers high. The length of a stacking area is equal to 325 meters (50 containers) and the width is equal to 30 meters (10 containers). (The stacking areas close to the sides of the area have a larger or shorter length.) The cranes have an overhang, which allows picking up and putting down the containers next to the stacking area (at the long side). The space between two stacking areas (at the long side) is equal to 30 meters. There is space for the rails, an area for the picking up and putting down the containers and there is enough space for vehicles to pass. Between the stacking areas (at the short side) there is a two-way lane for transporting the containers.

The terminal of Jebel Ali has rail mounted cranes which can move and are able to serve different stacking areas, because the rails from one stacking area are extended to another stacking area passing the two-way lanes. On average more or less 1.5 rail mounted gantry cranes per stacking area are used. A row of 7 stacking areas uses 11 cranes and a row of 8 stacking areas uses 12 cranes. Within the new port there are four different areas which have the same length of rows (and the same number of stacking areas per row). These four different areas are shown in Figure L-6. Per area the number of stacking areas per row are given and the corresponding needed gantry cranes are determined, see Table L-1. Per stacking area 1.5 gantry cranes are needed, but it isn't possible to use half gantry cranes. Therefore the number of gantry cranes needed per row is rounded. Afterwards all the needed gantry cranes per row are summed and in total 109 gantry cranes are needed.

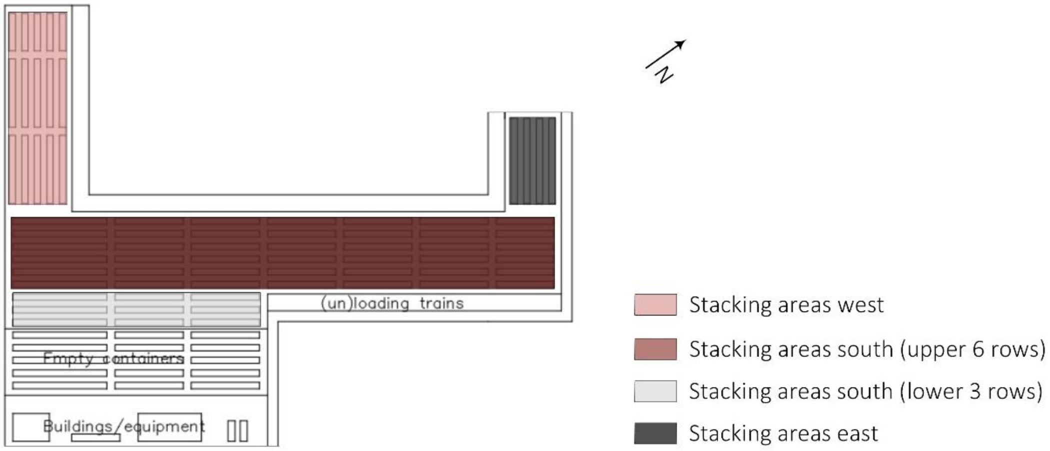


FIGURE L-6: STACKING AREAS WHICH HAVE THE SAME LENGTH OF ROWS

TABLE L-1: DETERMINATION OF THE NEEDED NUMBER OF RAIL MOUNTED GANTRY CRANES

Stacking area	Stacking areas per row	Number of rail mounted gantry cranes	Number of rail mounted gantry cranes (rounded)	Number of equal rows	Needed rail mounted gantry cranes
West	2.5	3.75	4	5	20
South (upper 6 rows)	7	10.5	11	6	66
South (lower 3 rows)	3	4.5	5	3	15
East	1	1.5	2	4	8
Total					**109**

More or less 15% of the containers are assumed to be empty containers. These are stacked at the back of the storage yard, close to the buildings and the equipment. There are 15 stacking areas with empty containers. Rail mounted gantry cranes are not necessary for stacking the containers, because all the containers are empty, so the contents of the containers are not important. Therefore empty containers handlers are necessary. Empty container handlers are able to stack the containers up to 8 containers high. (Kalmar) It is assumed that every stacking area needs one empty container handler, so 15 empty container handlers are needed. When each empty container handler could handle 1 container per minute, (15 * 1 * 60 =) 900 empty containers can be handled per hour. When maximal 3,900 container per hour will be handled, see Table L-5, a quarter of the containers which need to be handled could be empty containers. This is assumed to be reasonable.

In appendix G, Design values, it is assumed that the average needed area per TEU using a portal crane system is equal to 11m^2 and that the average stacking height divided by the nominal stacking height during full occupancy is equal to 0.75. The surface of the bottom of a container of one TEU is equal to 6.10 * 2.44 = 14.9 m^2. The maximum stacking height using rail mounted gantries is equal to 7 containers. The average stacking height would then be equal to 0.75 * 7 = 5.25 containers during full occupancy. With an occupancy of 70%, see Appendix G, Design values, the average stacking height is (0.7 * 5.25 =) 3.675 containers. The surface needed per container (of one TEU) would then be equal to 14.9 / 3.675 = 4.1 m^2. When the total area needed per container is 11 m^2 (4.1/ 11 =) 37% of the area would be used for stacking the containers.

In the design of the new port there are stacking areas with different lengths, see Figure L-7. The total surface for stacking the containers is equal to 0.86 km^2 (858,480 m^2). This is shown in Table L-2 in m^2. The total storage yard is 2.1 km^2. This means that 0.86 / 2.1 = 41% of the area is used for stacking the containers. This corresponds more or less with the made assumptions.

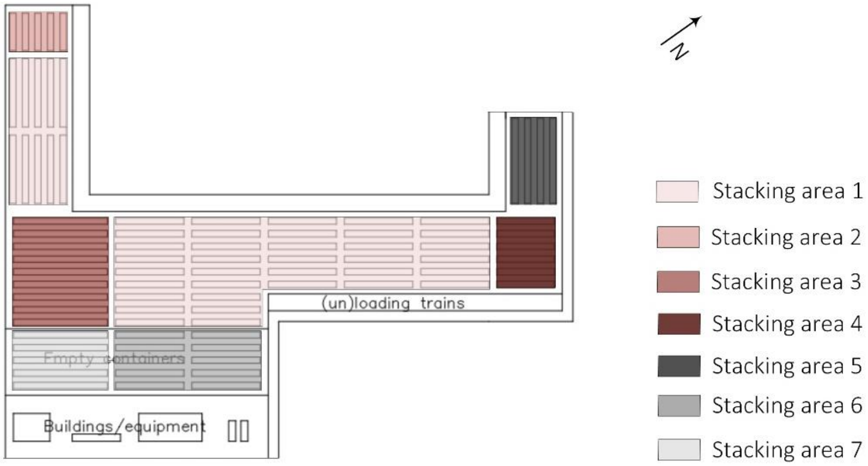


FIGURE L-7: STACKING AREAS WHICH HAVE THE SAME LENGTH

TABLE L-2: TOTAL SURFACE OF STACKING AREAS

No. Stacking area	**Length stacking area [m]**	**Width stacking area [m]**	**Number of stacking areas**	**Surface [m^2]**
1+6	325	30	56	546,000
2	178	30	5	26,700
3+7	448	30	14	188,160
4	273	30	6	49,140
5	404	30	4	48,480
				858,480

An estimation of the expected number of stacked containers and the capacity of the stacked containers is made, see

Table L-3. The capacity of the storage area is approximately 317,000 containers. With an average stacking height of 5.25 (75% of the nominal stacking height) the number of stacked containers during full occupancy is equal to approximately 237,000 containers. However, the occupancy is normally around 70%, see appendix G, Design values, (the arrival of ships is not uniform distributed), so the average number of containers on the storage yard is approximately 166.000.

TABLE L-3: EXPECTED NUMBER OF STACKED CONTAINERS AND CAPACITY OF STACKED CONTAINERS

No. stacking area	**Number of containers in length stacking area**	**Number of containers in width stacking area**	**Number of containers in height (75%)**	**Number of containers in height (capacity)**	**Number of stacking areas**	**Number of containers (75%)**	**Number of containers (capacity)**
1	50	10	5.25	7	46	120,750	161,000
2	27	10	5.25	7	5	7,088	9,450
3	69	10	5.25	7	9	32,603	43,470
4	42	10	5.25	7	6	13,230	17,640
5	62	10	5.25	7	4	13,020	17,360
6	50	10	6	8	10	30,000	40,000
7	69	10	6	8	5	20,700	27,600
						237,390	**316,520**

2.2 Apron area

Ship-to-shore cranes are needed at the quay to load and unload the vessels. To determine the number of cranes per berth, the formula of the berth productivity is used. (Ligteringen & Velsink, 2012)

$$c_b = P * f_{TEU} * N_{cb} * n_{hy} * m_b$$

In which

c_b	=	average annual productivity per berth	[TEU/yr]	=7,000,000 TEU/yr per 8 berths = 875,000 TEU/yr per berth
P	=	net production per crane	[moves/hr]	= 25 moves/hr
f_{TEU}	=	TEU factor	[-]	= 4
N_{cb}	=	number of cranes per berth	[-]	
n_{hy}	=	number of operation hours per year	[hrs/yr]	= 365*24=8760 hrs/yr
m_b	=	berth occupancy factor	[-]	= 0.35

The values of the number of berths, net production per crane and the number of operation hours per year follow from the appendix G, Design values. The values of the berth occupancy factor is an assumption. It is assumed a Super Post-Panamax crane will be used for (un)loading the vessels. These cranes are chosen, because they have a high capacity and they are able to (un)load even larger vessels. The purchase costs of these cranes are very high, so it would be very expensive to buy new cranes if the port is going to expand and is able to accommodate even larger ships. These cranes are able to handle 4 containers per move and can handle 100 containers per hour, so 25 moves per hour. (Kocks/Kranunion) With the used values it follows that the needed number of cranes per berth (N_{cb}) is equal to (2.9, so rounded) 3 cranes per berth.

The average ship is assumed to be between a Panamax and a Post-Panamax vessel. For practical reasons (including the movements of other transport equipment between the portal cranes and the storage yard) Post-Panamax vessels have not more than 5 cranes working simultaneously. (Ligteringen & Velsink, 2012) Post-Panamax vessels have length of 366 meters and Panamax vessels have a length of 294 meters, so the length of a Panamax vessel is 80% of the length of a Post-Panamax vessel. When the same movements at the quay will take place, only 4 cranes could work simultaneously for a Panamax vessel. It is also assumed that Panamax vessels do not have more than 4 cranes working simultaneously for practical reasons. The used cranes can handle the annual productivity per berth (c_b), because 5 cranes will be used for (un)loading a Post-Panamax vessel and 4 cranes for a Panamax vessel, which is both more than 3 cranes. This formula calculates the average number of cranes needed, but the maximum number of cranes needed simultaneously has to be known. Therefore the possibilities for berthing at the different parts of the quay will be examined.

There are three parts of quay length, one part of 400 meters, one part of 900 meters and one part of 1900 meters, see Figure L-3. At the part of 400 meters one Post Panamax or one Panamax vessel could berth. There is more length available than the length needed for one Post Panamax vessel. This is calculated with the next formula.

$$L_q = L_{s,max} + 2 * 15$$

In which

L_q = quay length [m]

$L_{s,max}$ = maximum ship size [m]

(Ligteringen & Velsink, 2012)

For a Post Panamax vessel:

$$400 \geq 366 + 2 * 15 = 396$$

For a Panamax vessel:

$$400 \geq 294 + 2 * 15 = 324$$

At the part of 900 meters two Post-Panamax or two Panamax vessels could berth.

$$L_q = n * (L_s + 15) + 15$$

L_q = quay length [m]

L_s = ship size [m]

n = number of berths [-]

(Ligteringen & Velsink, 2012)

For Post Panamax vessels:

$$900 \geq 2 * (366 + 15) + 15 = 777$$

For Panamax vessels:

$$900 \geq 2 * (294 + 15) + 15 = 633$$

The same can be done for the part of 1900 meters. Four Post Panamax vessels, six Panamax vessels or a combination of vessels could berth.

For Post-Panamax vessels:

$$1900 \geq 4 * (366 + 15) + 15 = 1539$$

For Panamax vessels:

$$1900 \geq 6 * (294 + 15) + 15 = 1869$$

Combination of 4 Post Panamax vessels and 1 Panamax vessels:

$$1900 \geq 4 * (366 + 15) + 1 * (294 + 15) + 15 = 1848$$

With the possibilities of the berthing of the Post Panamax and Panamax vessels three different scenarios can be distinguished, shown in Table L-4.

TABLE L-4: THREE DIFFERENT SCENARIOS FOR THE BERTHING OF SHIPS AT THE QUAY

Quay length	**Only Post Panamax vessels**	**Only Panamax vessels**	**Combination of Panamax and Post Panamax**	
	Number of Post Panamax vessels	Number of Panamax vessels	Number of Post Panamax vessels	Number of Panamax vessels
400 meters	1	1	1	0
900 meters	2	2	2	0
1900 meters	4	6	4	1
Total	**7**	**9**	**7**	**1**

For these three scenarios the number of cranes and the number of containers per hour can be determined, see Table L-5. It is assumed that only Super-Post-Panamax cranes will be used, because there is a possibility that the new port will expand and the type of vessels that will berth is not known yet. When the division of the type of vessels that will berth is known, it might be possible to buy smaller cranes to save costs. For a Post Panamax vessel 5 cranes will be used to (un)load and for a Panamax vessel 4 cranes will be used. The maximum number of cranes needed is for the combination of 7 Post Panamax vessels and 1 Panamax vessels, in total (35 + 4 =) 39 cranes. Each crane can handle 100 containers per hours. The maximum number of containers per hour that will be handled is equal to (39 * 100=) 3,900 containers per hour, see Table L-5. In that case 7 Post-Panamax vessels and 1 Panamax cranes are simultaneously (un)loading. It takes 24 hours to unload a Post-Panamax vessel with 12,000 TEU, see Table L-5 Five cranes are simultaneously unloading and need to handle (12,000 / 5 =) 2,400 containers. When these cranes can handle 100 containers per hour it will take 24 hours. The same calculation can be made for a Panamax vessel with 5,000 TEU. It will take 12.5 hours to unload a Panamax vessel.

TABLE L-5: NUMBER OF CRANES NEEDED AND THE NUMBER OF HANDLED CONTAINERS PER HOUR FOR EACH OF THE THREE SCENARIOS

	Only Post Panamax vessels	**Only Panamax vessels**	**Combination of Post Panamax and Panamax vessels**		
Type and number of vessels	7 Post Panamax	8 Panamax	7 Post Panamax	1 Panamax	7 Post Panamax & 1 Panamax
Number of cranes per vessel	5	4	5	4	
Number of cranes needed	35	32	35	4	39
Containers per vessel	12,000	5,000	12,000	5,000	
Containers/hour/crane[9]	100	100	100	100	
Number of containers/crane	2,400	1,250	2,400	1,250	
Hours	24	12.5	24	12.5	
Containers/hour/vessel	500	400	500	400	
Containers/hour	3,500	3,200	3,500	400	3,900

2.3 Between apron area and storage yard

At the port of Jebel Ali in terminal 2 yard tractors with trailers are used for the transport of container between the apron area and the storage yard. These can also be used in the new port. A low investment for the pavement is needed, they have low maintenance costs and are simple and flexible in operation. However, a large number of them is needed, they have a low throughput capacity and are labor intensive. It is also possible to use a multi trailer system. This is a yard tractor which pulls up to five trailers. These trailers stay in place while making a turn. By using this system less drivers are needed, a high throughput capacity can be reached and the traffic peaks are easily absorbed, but they are less flexible in operation. (Ligteringen & Velsink, 2012)

---

[9] Source: (Kocks/Kranunion)

The port of Jebel Ali owns 708 tractors and 785 trailers. Terminal 1 has got 446 tractors and 448 trailers, so terminal 2 has got (708 - 446 =) 362 tractors and (785 – 448 =) 337 trailers. (DP World, sd) Terminal 2 is able to handle 6 Post-Panamax vessels simultaneously. (The National, 2013) When five ship-to-shore cranes are used for each vessel, 30 cranes are working simultaneously. The terminal only has 29 cranes (CSS Group, 2013), so it is assumed that all 29 cranes are in use. 362 tractors are used to handle the containers from the 29 cranes. This could be linearly scaled to the new port in Jamaica. The new port in Jamaica has 39 ship-to-shore cranes, so (362 / 29 * 39 =) 486 tractors will be used. However, the terminal in Dubai, see Figure L-5, has a straight quay and all the storage area is close to the quay. The new port in Jamaica doesn't have a straight quay and the storage area is built further away from the quay. Therefore it is assumed that the average distance that needs to be travelled per container is larger in the new port in Jamaica, so the new port needs more tractors.

An estimation for the number of tractors using a single trailer system and a multi trailer system is made, see Table L-6. The waiting time at the quay is assumed to be one minute per tractor. The picking up time of one container at the quay is assumed to be equal to one minute per container. The container dropping at the storage yard is assumed to take 2 minutes per container. The distance and the speed at the storage yard determine the transporting time of the containers. The single trailer needs to transport the container to the stacking location and needs to drive back. With a multi trailer system the tractor makes a round trip for delivering the containers. The waiting time, picking up time, container dropping time and transporting time together are the total time needed for one trip. With this time the number of containers per hour per tractor can be determined. The total number of containers per hour handled by the ship-to-shore cranes divided by the number of containers per tractor determines the number of tractors needed. The number of containers handled by the ship-to-shore cranes in the case of Jebel Ali is assumed to be equal to 29 cranes which handle 100 containers/hour/crane.

TABLE L-6: ESTIMATION OF THE TRACTORS NEEDED FOR THE TERMINAL IN JEBEL ALI, A SINGER TRAILER SYSTEM IN THE NEW PORT OF JAMAICA AND A MULTI TRAILER SYSTEM IN THE NEW PORT IN JAMAICA

	Single trailer (Jebel Ali)	**Single trailer**	**Multi Trailer System (5 containers)**
Waiting time at quay [minutes]	1	1	1
Picking up containers [minutes]	1	1	5
Container dropping [minutes]	2	2	10
Distance from quay to stacking location [km]	0.75	1.5	5
Speed at storage yard [km/h]	30	30	30
Transporting time of containers [minutes]	1.5	3	10
Transporting time for driving back from stacking location [minutes]	1.5	3	
Total time needed for one trip [minutes]	7	10	26
Total time needed for one trip [hours]	0.12	0.17	0.43
Number of containers per hour per tractor	8.57	6.00	12.00
Number of containers handled by the ship-to-shore cranes [containers/hour]	2,900	3,900	3,900
Number of tractors needed	**338**	**650**	**338**
Number of trailers needed	**338**	**650**	**1,690**

The number of tractors needed (338), as shown in Table L-6, corresponds more or less with the real number of tractors at the terminal (362). If a single trailer system is used 650 tractors and 650 trailers are needed. If a multi trailer system is used in the new port of Jamaica 338 tractors are needed. However the number of trailers is much larger and is equal to (338 * 5 =) 1690 trailers. The investment costs of the tractors are much larger than the investment costs of the trailers. Because of this and because a multi trailer system needs less labor than the single trailers the multi trailer system will be used in the new port.

2.4 Other area

10% of the area is reserved for buildings and equipment. This area is located at the back of the dry area, so the area closest to the vessels can be used for container handling and the travelling distance will be as short as possible.

The road runs through the industrial area of the port and enters the transshipment part at the northeast. The road is extended up to the power plant. There is also space for constructing a rail connection next to the road and there is space for an (un)loading area for the trains. This can be constructed when it is necessary.

An overview of the needed equipment for the transshipment part is shown in Table L-7.

TABLE L-7: NEEDED EQUIPMENT FOR THE TRANSSHIPMENT PART OF THE PORT

Type of equipment	Needed number of this type equipment
Super Post-Panamax ship-to-shore gantry cranes	39
Rail mounted gantry cranes	109
Empty container handlers	15
Tractors (multi trailer system)	338
Trailers	1690

3 Overview layout

A layout for the industrial area and the transshipment area of the port are made. An overview of the layout of the whole port is shown in Figure L-8.

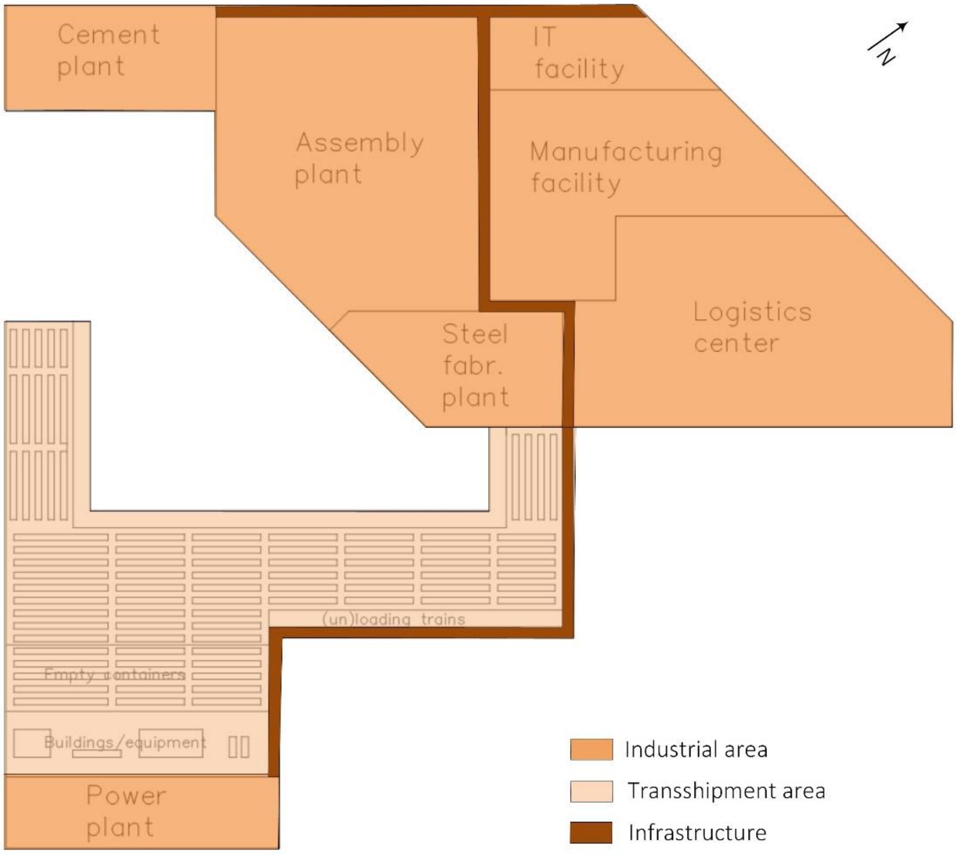


FIGURE L-8: LAYOUT OF THE NEW PORT

4 References

CSS Group. (2013, 9). *Making Of Container Terminal 2 At Jebel Ali Port*. Retrieved 10 16, 2013, from Lighthouse: http://www.cssgroupsite.com/lighthouse/making-of-container-terminal-2-at-jebel-ali-port/

DP World. (n.d.). *Facilities and service*. Retrieved from DP World: http://www.dpworld.ae/en/content.aspx?P=fxP7qHof%2FgsE0giJLkwR2A%3D%3D&mid=CW8SJWcj%2BhX1sqCpgEZqDA%3D%3D

DP World. (n.d.). *Jebel Ali Port – Dubai's gateway to the world.* Retrieved 10 25, 2013, from Port technology: http://www.porttechnology.org/images/uploads/technical_papers/PT41-14.pdf

Gulf Petrochemicals & Petrochemicals Association. (n.d.). *Logistics investment needed as trade grows*. Retrieved 10 25, 2013, from Gulf Petrochemicals & Petrochemicals Association: http://gpca.org.ae/congulf/blog/logistics-investment-needed-as-trade-grows/

Kalmar. (n.d.). *Empty Container Handler.* Retrieved from Kalmar: http://www.cargotec.com/en-global/kalmar/Products2/empty-container-handler/Pages/default.aspx

Kocks/Kranunion. (n.d.). *Boxer 4000/5000/6000.* Retrieved from Kranunion: http://www.kranunion.de/fileadmin/Downloads/Kocks/brochures/BOXER_E.pdf

Ligteringen, H., & Velsink, H. (2012). *Ports and Terminals.* Delft: VSSD. Retrieved 10 01, 2013

The National. (2013, 6 27). *DP World's Terminal 2 expansion finished at Jebel Ali*. Retrieved 10 16, 2013, from The national: http://www.thenational.ae/business/industry-insights/shipping/dp-worlds-terminal-2-expansion-finished-at-jebel-ali

Appendix M Adaptive port planning

Adaptive port planning is a method which differs from the traditional port planning and port design which uses a 30 year master plan. Because of uncertainties during the planning, design and operation it is possible that conditions change in the future. This causes the original plans to fail and this could result in a loss of cargo, loss of investment and loss of the competitive position of the port. To make plans which include this uncertainty it is possible to anticipate on the future developments and revise the master plan during the lifespan. This is called adaptive port planning. (Taneja, n.d.)

Adaptive port planning uses long-term thinking for the planning of the port. The uncertainties in the future are not only seen as risks, but also as opportunities. By imagining many futures planned adaptation could be applied. An adaptive plan consists of a basic plan (see chapter 1) and a set of pro-active actions (see chapter 2). Every few years the master plan should be revised and a revised strategy should be developed. (Taneja, n.d.)

Adaptive port planning is also used for the design of the new port in Jamaica, using the layout of appendix L, Layout of the port. A basic plan with facilities which will be constructed definitely is made. Next to that a set of pro-active actions is made, which include the construction of facilities based on the future demand. Adaptive port planning differs from construction planning as it is spread over a longer time span and decision making depends on external factors.

1 Basic plan (definitely constructed)

The basic plan consists of a few facilities which will be constructed definitely. It is assumed that the dry area of the port (industrial and transshipment) is ready for development of the facilities. The main infrastructure has to be built and (a part of) the power plant, the assembly plant and (a part of) the transshipment area have to be constructed. The power plant will be constructed, because the new port definitely needs energy. A part of the transshipment area is needed definitely, because in the beginning there will be ships (if the competitive power is large enough). The assembly plant must be constructed, because for the transshipment area cranes are needed and it is assumed there is already enough external demand for it. Basically there are no uncertainties for building these facilities. These facilities are shown with the dark red colors in Figure M-1. More details per facility will be given.

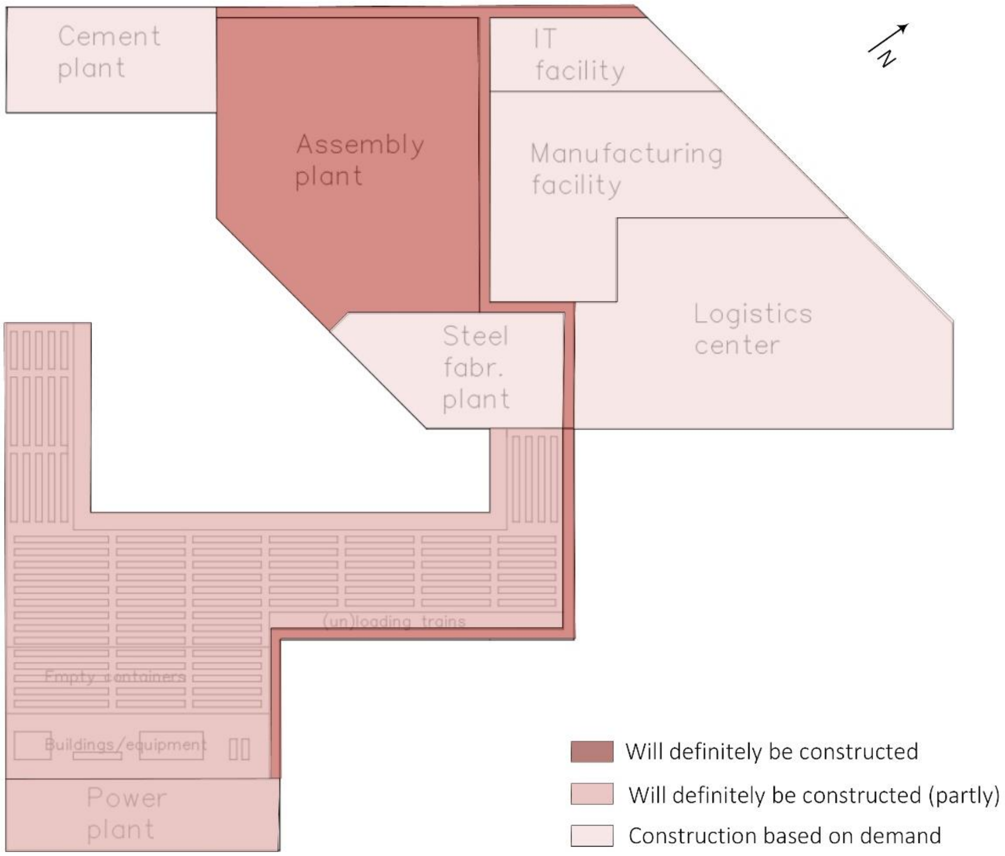


FIGURE M-1: ADAPTIVE PORT PLANNING FOR THE WHOLE PORT

1.1 Land and main road infrastructure

First there must be started with the reclamation activities. The land must be released for port activities, but doesn't need to be paved or asphalted. The main road infrastructure must be constructed, which can be used for transporting building materials and construction workers. The railway can be constructed in a later stage when this is necessary.

1.2 Power plant (partly)

It is certain that (a part of) the power plant can be built. The energy from the power plant can be used for construction of the port and also during operation of the port. It depends on the demand if the power plant with full capacity has to be built. Otherwise, the power plant can be built in steps and can expand whenever more energy is needed.

1.3 Assembly plant

The assembly plant for gantry cranes should be built before the gantry cranes in the transshipment hub will be needed. The new port already needs much cranes, so the assembly plant can be developed with full capacity. It is assumed that after the assembling of the cranes for the new port of Jamaica there is enough demand from other ports.

1.4 Transshipment area (partly)

The throughput of the new port will not directly be 7 million TEU per year. Therefore not all the ship-to-shore cranes and gantry cranes have to be bought and installed directly. When the throughput rises more equipment can be bought and used. For the transshipment area the construction could be divided in steps. This is shown in Figure M-2 and further explained in section 2.5. The construction which definitely will be constructed is located at the left of the figure. The surface at the left in the figure is chosen because then the rest of the surface will not be cornered. The rest of the surface stays empty and can be used for a facility which need expansion.

2 Pro-active actions (construction based on demand)

The set of pro-active actions consists of facilities which will be constructed when there is enough demand. These facilities are the cement plant, steel fabrication plant, IT facility, manufacturing facility and logistics center. These facilities are shown with the light color in Figure M-1. Also a part of the transshipment port will be built when there is enough demand. Due to stepwise development of the port there will be an undeveloped area which can be assigned to the facilities which have an increased demand and need more area.

2.1 Cement plant

The cement plant is assumed to be used for export. The size of the plant depends on the demand. It the (expected) demand is lower than the possible capacity the building of some parts of the cement plant in the new port can be postponed until the total demand rises.

2.2 Steel fabrication plant

For the construction of the steel fabrication plant the same holds as for the cement plant. The steel fabrication plant will be used for the export of steel. If the (expected) demand will be lower than the possible capacity, the cement plant doesn't have to be built completely. Some parts can be built and when the demand gets higher the steel fabrication plant can be expanded.

2.3 IT facility, manufacturing facility and logistics center

It isn't sure if there is enough demand for the developing of the IT facility, the manufacturing facilities and the logistics center. When there is (an expected) demand for these facilities they can be constructed. This could happen in steps.

2.4 Main railway infrastructure

The rail infrastructure can be constructed whenever it is needed. It can for example be used for transporting cargo for the industrial part of the port. Whether the rail is needed or not is a big uncertainty, however space should be reserved in case it is needed in the future. This saves a lot of costs in the future and makes the port more flexible.

2.5 Transshipment area

One part of the transshipment area is definitely constructed, see Figure M-2. When more surface is needed for transshipment the area could be extended more to the right in the figure. This larger area has also more quay length. When even this surface is not large enough, expansion is possible at the right side of the figure. This surface is not included in the original plan. For expansion one part of the port has to be breached and the quay can be extended. When the area is expanded, the main road (and railway) have to be moved. It is possible to move this infrastructure to the right in the figure and connect this at the northeast part.

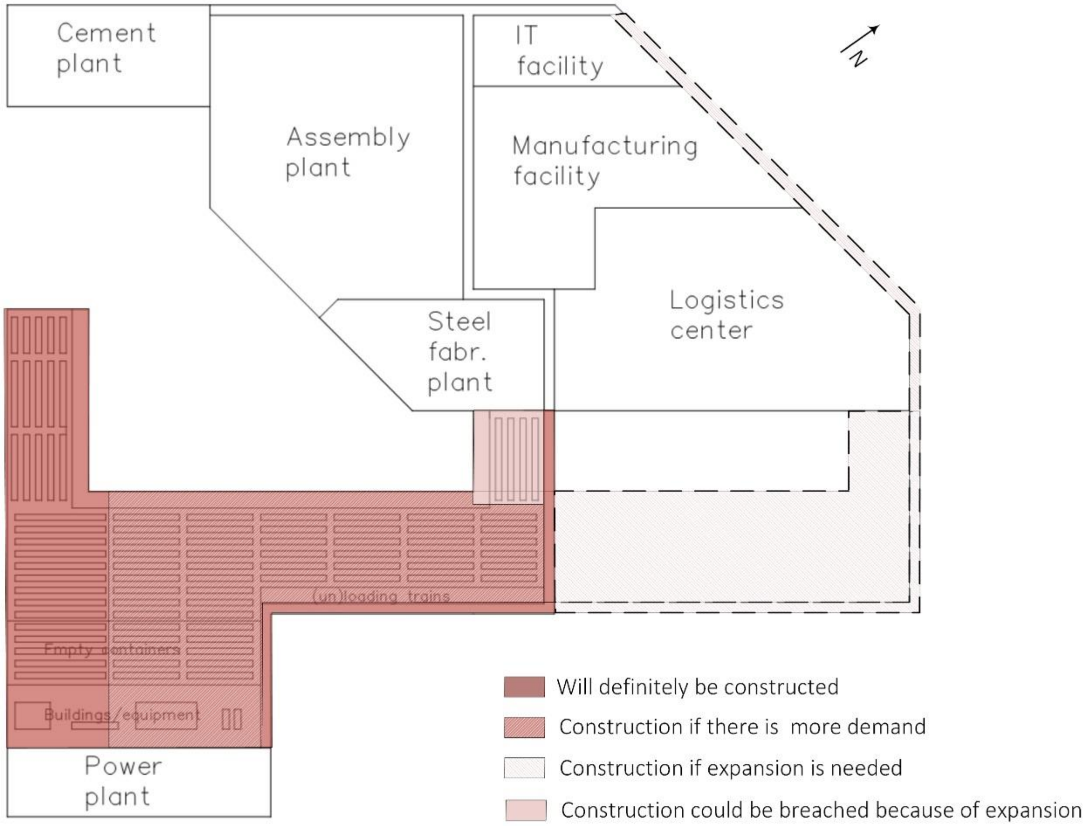


FIGURE M-2: ADAPTIVE PORT PLANNING OF THE TRANSSHIPMENT AREA

2.6 Undeveloped area

In a number of years a part of the total area has been built and a part is still empty. Only a part of the power plant and transshipment area will definitely be constructed and the other part depends on the demand, see chapter 1, Basic plan (definitely constructed), and the facilities named in chapter 2, Pro-active actions (construction based on demand). The empty parts will be assigned to facilities which need more area, because their demand is rising. This can be repeated multiple times until the whole area is fully in use. By using this way of port planning the needed area per facility could be different in the future than expected. This means the drawn borders of the area of the facilities are flexible.

The parts of the facilities which are built at first must be located at a smart location. The constructions which cannot be moved should be located at a place which allows the adjacent parcels to expand. For example, for the assembly plant this is important, because otherwise the area of the cement plant will be cornered.

3 References

Taneja, P. (n.d.). Flexible ports/terminals. *Lecture slides CIE5306 Ports & Waterways 2*. TU Delft.

Appendix N Hinterland connection

The new port must be integrated in the current infrastructure of the area. For the new port a good hinterland connection is necessary during the building phase and the operational phase. In the last named the connection will be used by people working at the port, transport of material from and to the industry and possibly transport of containers. In this appendix the current situation of the transport network by land in Jamaica is presented. After that the kind of infrastructure for the connection is discussed. At the end two options for the new connection are shown. This options only contains the route of the connections. The level of detail which includes the design of the junction, access points and road design is not included in this research.

1 Current situation

For a good overview of the current situation maps are made with the current roads and railways. One map contains all important infrastructure of Jamaica (see Figure N-1) and one map contains specifically the surrounding area of the Goat Islands (see Figure N-2). Note that the used symbols and color for this figure differ from the used legend in Figure N-1. (Google, 2013) (Ministry of Transport, Works & Housing, 2011) (Ministry of Transport and Works, 2005)

FIGURE N-1: MAP OF CURRENT SITUATION IN JAMAICA, WITH HIGHWAYS, RAILWAYS, LARGE CITIES AND THE NEW PORT

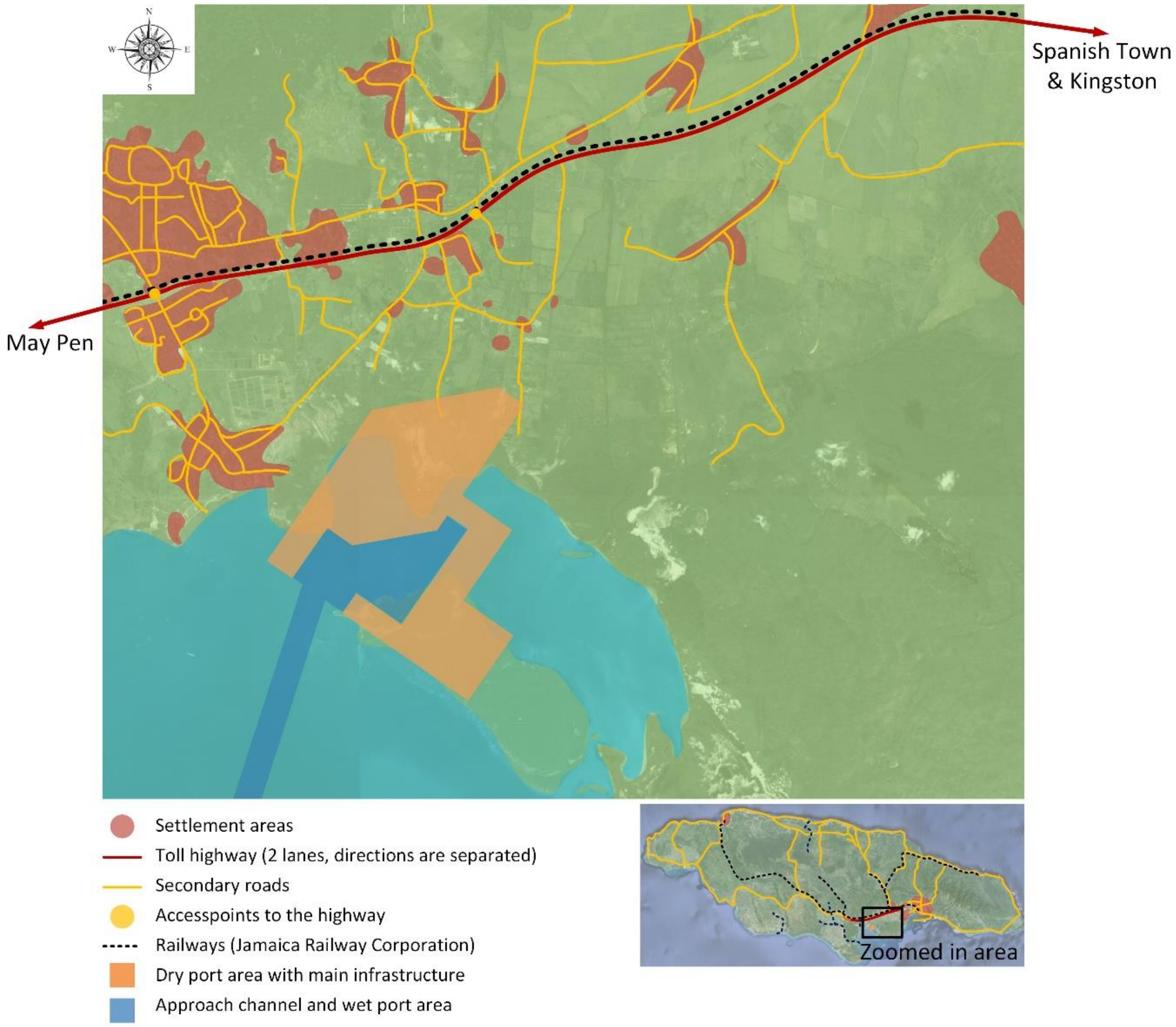


FIGURE N-2: ZOOMED IN MAP OF CURRENT SITUATION OF THE SURROUNDINGS OF GOAT ISLANDS, WITH HIGHWAYS, RAILWAYS, VILLAGES AND THE NEW PORT

In Figure N-2 the port design (see appendix J, Further investigation of five port locations…) is included to show the location and shape of the new port.

1.1 Road network

In Figure N-1 it can be seen that Jamaica has quite some highways. The highways differ a lot in width of the road and the conditions of pavement. One of the highways is a toll road, see Figure N-1 and Figure N-2. This road is very wide and in good condition.

1.2 Railway network

There are also different railway tracks in Jamaica, which all probably exist of single tracks. Most of the railway tracks are not used anymore and are overgrown with vegetation. The gray colored railways are privately owned railways, owned by some industry companies to transport for instance bauxite from the mine to the port. In July 2011 the Jamaica Railway Corporation reintroduced passenger transport by rail between Spanish Town and Charlemont (in the north of Spanish Town), but in August 2013 this rail services ended because of financial reasons. (Jamaica Gleaner, 2012)

2 Possible infrastructure

The port must be connected to the road network of Jamaica to provide the supplying of goods and people to travel to and from the port. As shown in Figure N-2 the new port is closely located to the toll road from Spanish Town to May Pen. A good connection with this highway will lead to a fast connection to Kingston and Spanish Town (and Portmore), where a big share of the population of Jamaica lives. To provide a good connection a road with two lanes for each direction is necessary, so slow trucks can be overtaken on the right lane.

Next to the highway in Figure N-2 lies a single railway track. This track is sometimes used by privately train operators to transport goods to bauxite or aluminum factories. By connecting the new port to the current rail track it is possible to transport goods from and to the new port. With this rail connection it is possible to transport containers from the new port to the current port of Kingston or the other way around (see appendix F, Redevelopment of the port of Kingston). Also goods from and to the companies of the industrial part of the port can be transported by this rail track. It also possible to operate a passenger train between the new port and for instance Kingston. A single rail track will be enough, but is less stable if there is a disturbance on the track. The development of a railway and the issues of a single or double track depends strongly on the operation plans of Jamaica Railway Corporation and the demand.

3 Possible connections

In the previous chapter, chapter 2, it is stated that road- and railway infrastructure can connect the new port to the current network of Jamaica. This new connection is designed based on the main infrastructure of the new port as designed in appendix L, Layout of the port.

Basically there are two different options, such that no villages won't be removed. The first option is the shortest track to the current highway and railway, this option is shown in Figure N-3.

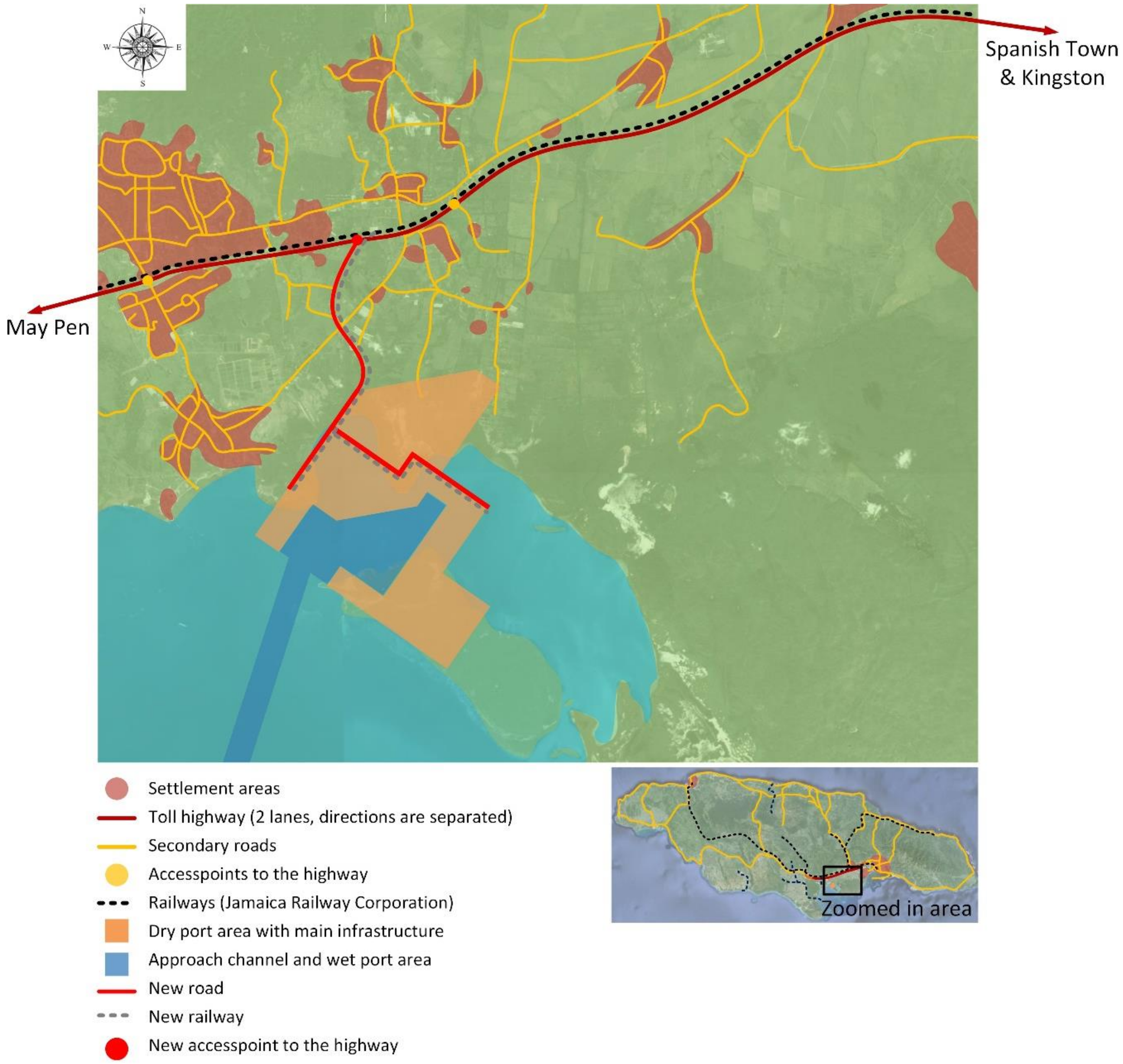


FIGURE N-3: OPTION 1 (SHORTEST TRACK) FOR A NEW ROAD- AND RAILWAY CONNECTION BETWEEN THE NEW PORT AND THE CURRENT HIGHWAY AND RAILWAY

In the first option, see Figure N-3, the new road will enter the highway just on the east of the tollgates. An advantage of this option might be the costs, because this is the shortest track to the current network. In this option villages are not directly harmed, but a disadvantage is that the new connection is relatively close to settlement areas.

In the second option the settlements areas are avoided as much as possible. This results in a longer track. This option is shown in Figure N-4.

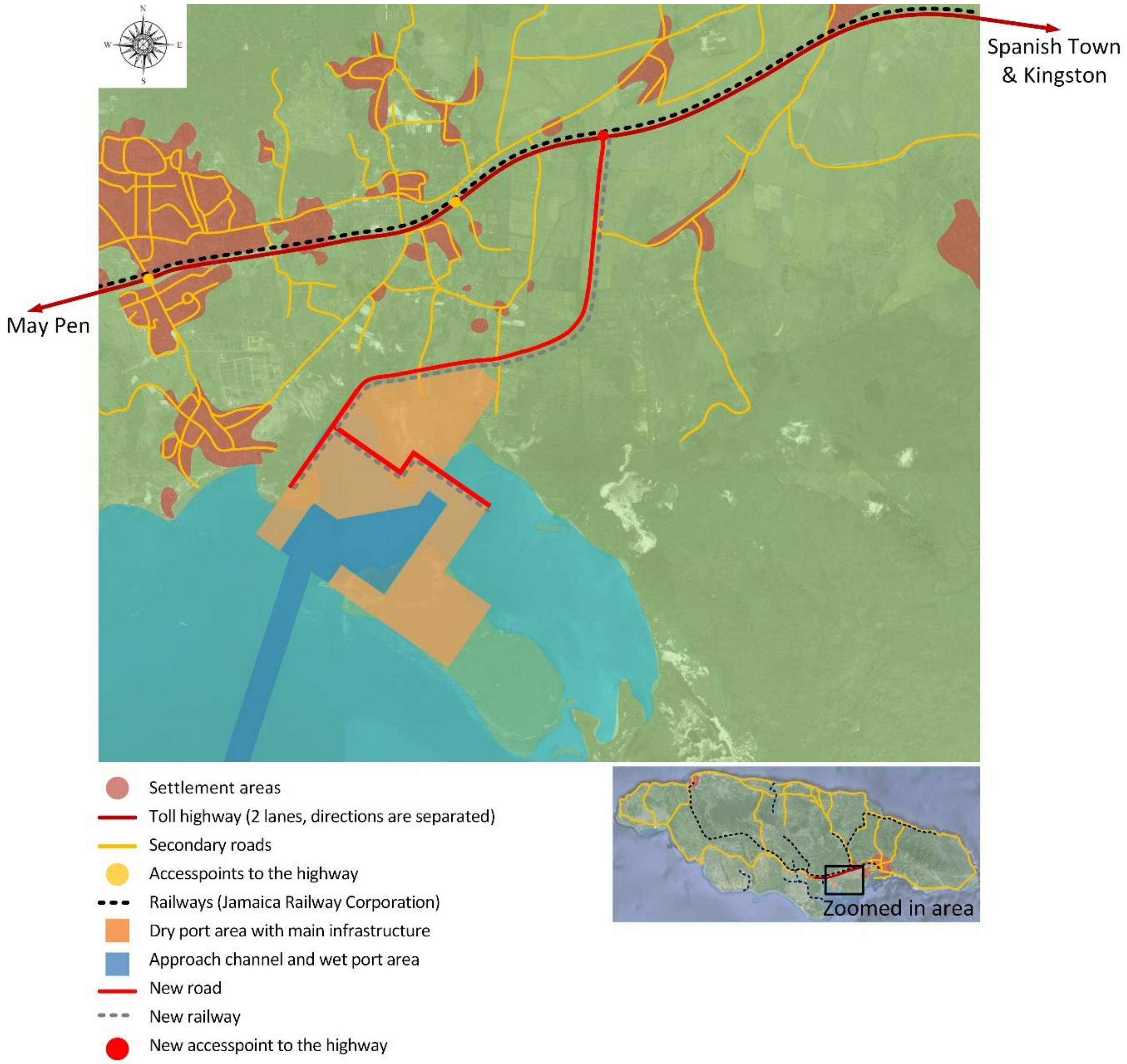


Figure N-4: Option 2 (avoiding settlement areas as much as possible) for a new road- and railway connection between the new port and the current highway and railway

The second option, in Figure N-4, is a much longer track than the first option, in Figure N-3. Therefore this option might be more expensive than the first option with the shortest track. The length of the connection of the second option is approximately twice as big as connection of the first option.

4 Conclusion

The hinterland connection is needed for transporting persons and goods from and to the new port. A big advantages of the location of the new port is the distance to the highway. This distance is small. Furthermore this highway is in good condition, so can provide a fast connection to for instance Kingston. A road connection is need anyway. The railway is not necessary to build. This strongly depends on the development of the total rail infrastructure and rail operations in the rest of Jamaica.

For the connection between the current network and the new port there are two options. The first and shorter option is possibly lower in price, but the impact might be higher, because it is closer to settlements. The second option is more expensive, but the impact on the settlements is lower. Which of the options is favorable depends on the available budget and policy.

5 References

Google. (2013). Google Earth. Retrieved 10 10, 2013

Jamaica Gleaner. (2012, 08 14). *Rail Corporation To End Passenger Service*. Retrieved 10 15, 2013, from Jamaica Gleaner: http://jamaica-gleaner.com/gleaner/20120814/lead/lead9.html

Ministry of Transport and Works. (2005). *Annual Transport Statistics Report: Jamaica in Figures 2003-2004*. Retrieved 10 10, 2013

Ministry of Transport, Works & Housing. (2011, 11). *Reports*. Kingston: Government of Jamaica. Retrieved 10 10, 2013, from Ministry of Transport, Works & Housing: http://www.mtw.gov.jm/communications/news_notices/notices/Annual%20Transport%20Statistics%20Report%202006-2007.pdf

Appendix O Wave analysis

In this appendix the extreme wave conditions at the port entrance and the downtime of the port are established. The extreme wave conditions are investigated for design purposes. There is downtime if the port is not operational, due to exceeding operational values for waves and wind. Downtime will be estimated in chapter 3.

1 Used methods and programs

The ultimate limit state and serviceability limit state will be defined in this chapter. The ultimate limit state (ULS) depends on the extreme wave height with a certain return period. The ULS gives the extreme values of the wave conditions which are needed for the design of the structures.

The serviceability limit state (SLS) is the exceedance probability of a certain wave height during operational time. With the SLS the downtime of the port can be found. To come up with the SLS and the ULS some modeling and statics has to be done.

1.1 Method to establish ULS

To come up with the extreme wave height (ULS) the programs HURWave and MIKE 21 are used. With HURWave the extreme wave, wind and surge conditions with a certain return period are gathered (offshore). This data is translated with MIKE 21 to give wave heights and surge levels near shore. The following phases can be described.

- **Design requirements**

The return period depends on the risk versus investment costs. Higher investment costs result in lower risk and lower damage once the event occurs.

- **HURWave**

HURWave contains the data of the past 160 years of hurricanes in the Caribbean. This program shows the tracks of the hurricanes, calculates the influences of the hurricane at a certain point (coordinates) and gives statistics. The output of the program gives the significant wave height (Hs), the significant wave period (To), wave direction, wind direction and wind speed for the required return period.

- **MIKE 21**

MIKE 21 is a program for wave and wind climate and surge level modeling. The modeling is based on numerical equations. A mesh has to be created and boundary conditions have to be set. The values of the boundary conditions are found by the HURwave analysis. The Mike 21 model translates the offshore wave and wind conditions to the near shore wave and wind conditions. Also the water level set up (surge) is modeled from offshore to near shore.

- **Wave and surge conditions at (the surroundings of) the port**

The result of the ULS analysis is a significant wave height at the port and at the surroundings of the port for a certain return period. Also at every location around the port the water level set up is found for the given return period.

1.2 Method to establish downtime (SLS)

To come up with the downtime (SLS) measured data offshore is used. This data is translated with MIKE 21 to give the wave heights and surge level near shore. This data near shore is compared with the maximum values of the data in which the port is still operational. The exceedance of this maximum wave height is calculated which results in the downtime.

- **Data**

A 3 hour time series between July 1999 and December 2007 in node 10 (see Figure O-1) is used. This data contains wave height, wave direction, wave period, wind speed and wind direction.

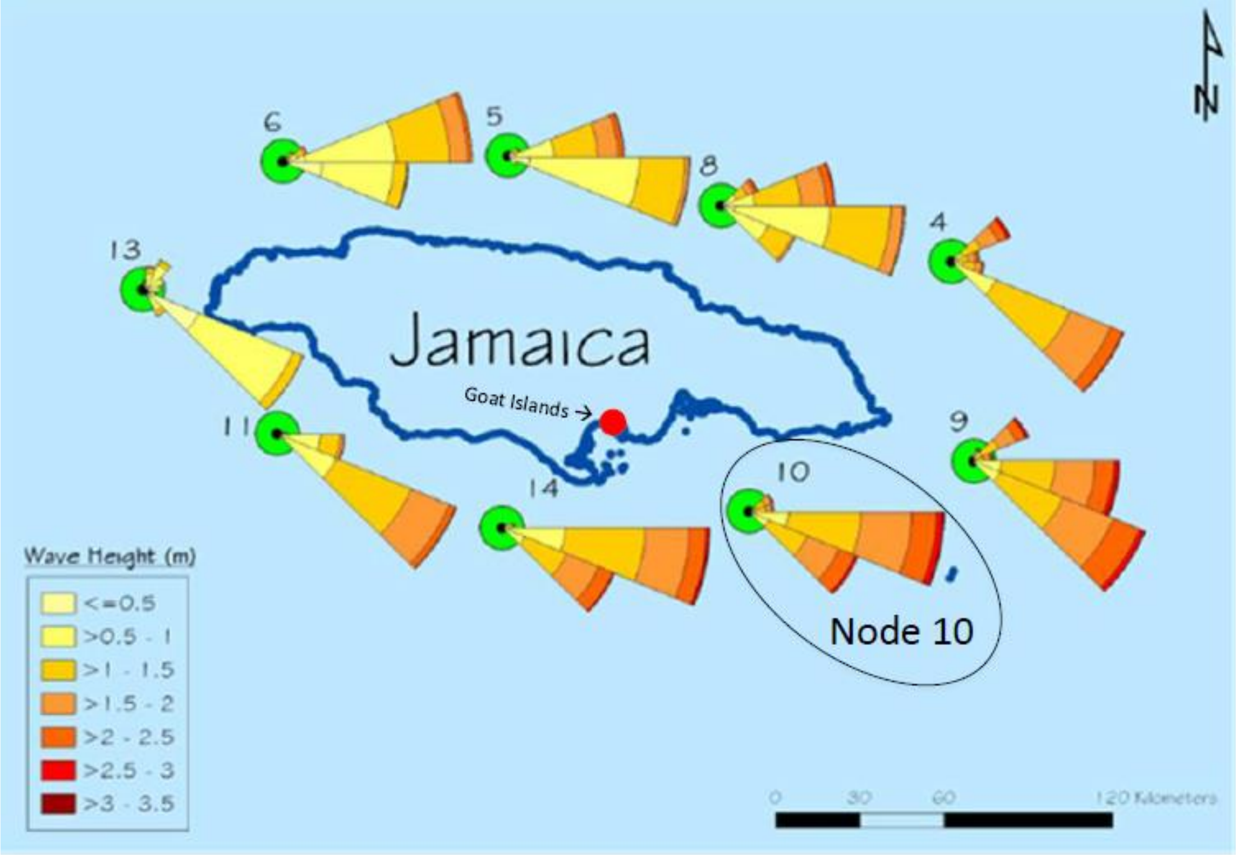


FIGURE O-1: WAVE AND WIND DATA OFFSHORE IN NODE 10

- **MIKE 21**

MIKE 21 translates the wave and wind conditions from offshore to near shore. The output of MIKE 21 is the wave height in de approach channel. The boundary conditions are the wave and wind conditions offshore in node 10.

- **Statistics**

If the wave heights in the approach channel are above a certain height it is assumed the whole day the port is shut down and thus gives one day of downtime. The waves are too high if tugboats cannot fasten to the container vessels. At that time the port is not operational. The total amount of day's downtime is divided by the 8 years and 5 months of data and then the amount of days downtime per year is known.

2 Ultimate Limit State

The ultimate limit state (ULS) gives the extreme wave condition at (the surrounding of) the port and the associated surge level. To come up with those numbers first the design requirements have to be set. After the acceptable possibility of failure is established and the associated return period is known the offshore hurricane data will be gathered with HURWave. The found conditions will set as the boundary conditions for MIKE 21 which gives the ULS as output.

2.1 Design requirements

The port must be built in such a way it can resist the determined extreme weather conditions. If the port is damaged due to extreme wave heights (direct loss of money), (parts of) the ports are not operational which result in an indirectly loss of money.

To satisfy the Ultimate Limit State the port must not fail (=major damage) during the designed peak load. To determine the acceptable extreme weather conditions the design life time and the probability of failure has to be established. Translating those to parameters with a Poisson distribution gives the return period for the acceptable extreme weather conditions.

The probability of severe damage during the lifetime of the port is given by a Poisson distribution:

$$p = 1 - e^{-fT}$$

In which:

p: probability of occurrence of the event at least once during T

f: return period of the extreme condition

T: design life time of the port

It is recommended to design a port with a design lifetime of 50 years (Thoresen, 2006). Also in appendix A, Background information, was already stated CHEC has experienced with a BOT contract for 50 year. It is assumed the new port will also have such a contract, so a design lifetime (T) of 50 years is taken.

Which of the other two parameters, probability of occurrence (p) or return period (f), should be defined as input for the above formula depends on the design approach. The Dutch approach differs from the Caribbean approach.

The Dutch approach is defining the probability of occurrence (p) on forehand to define what the acceptable probability of failure is. Following the guideline, an acceptable probability of failure for coastal structures lies between 5% and 20% (Verhagen, 2012). The acceptable probability of failure of 5% results in a return period of ones in a thousand years (1/1000) if the design life time is 50 years.

$(p = 1 - e^{-fT} = 1 - e^{-\frac{1}{1000}*50} = 0.05)$.

The Caribbean approach focuses more on the return period of the extreme condition (f). This is mainly because extremes occur far more often (and heavier) than in Europe, because of the occurrence of hurricanes. In the Caribbean a 50-year return period of hurricanes is usually used for the design of coastal structures. This return period mostly provides the best balance between capital costs and maintenance.

Looking at the Poisson formula the once in a 50 year return period results in a probability of occurrence of 63% ($p = 1 - e^{-fT} = 1 - e^{-\frac{1}{50}*50} = 0.63$). This seems too much and unacceptable for a port.
If a return period of 200 years (which is high for Caribbean standards) is used the probability of occurrence lies at 22%. This value is more acceptable, especially because in this situation (compared to the Netherlands) no lives are at stake. Designing for higher return periods is not realistic, because for higher return periods the waves get so extreme, defending the port will probably be too costly.

In Figure O-2 a simple graph is shown. This graph is an example with made-up numbers to explain the optimum return period. The graph only shows the approach of determining the optimum return period. This optimization study for the return period results in the lowest risk and optimum investment.

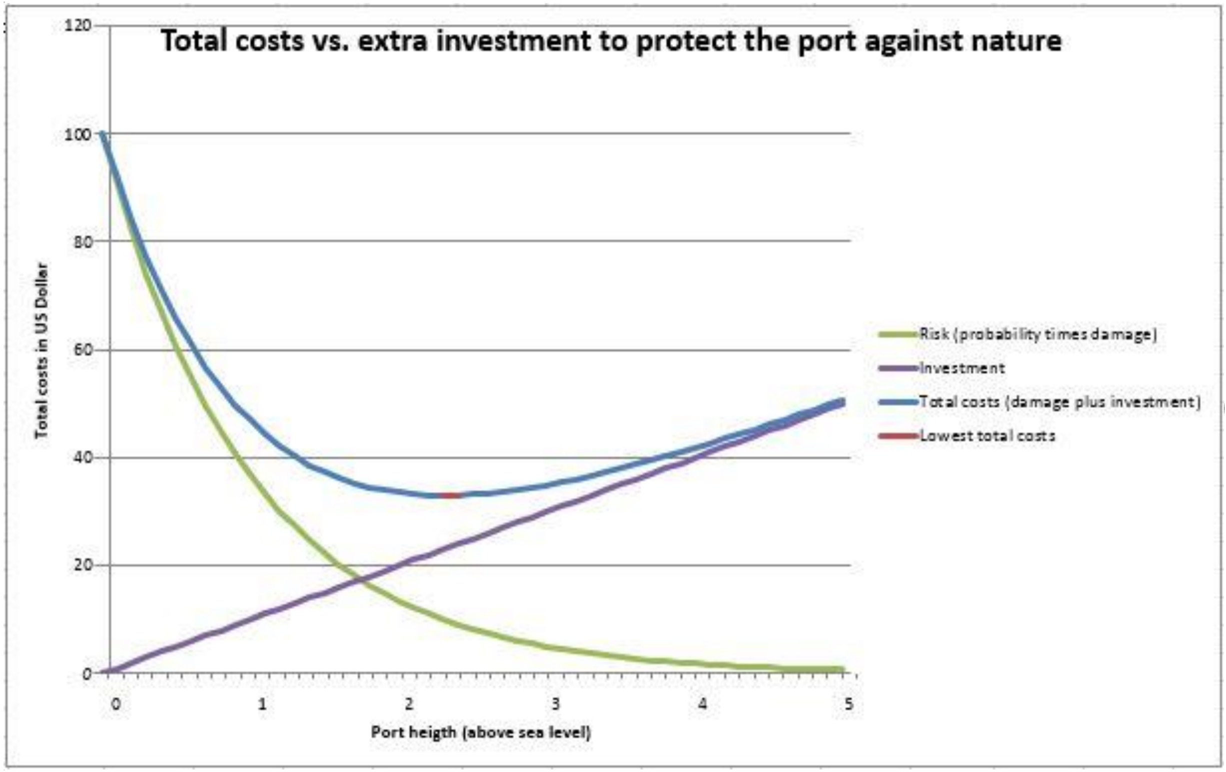


FIGURE O-2: SIMPLE GRAPH OF INVESTMENT COSTS VERSUS DAMAGE

The green line is the risk. The risk is the probability of failure times the damage. The damage is assumed constant in case of failure and only the probability changes if the difference between height of the port and MSL change. A higher investment in protecting the port against extreme conditions (higher port height) leads to a lower probability of failure. Therefore a very high investment leads to a very low probability of failure and a very low risk. However, the extra investment (purple line) causes high capital costs. Therefore the optimum point in the graph is the point where the total costs (investment + risk) is the lowest, see the brown dot on the blue line in Figure O-2.

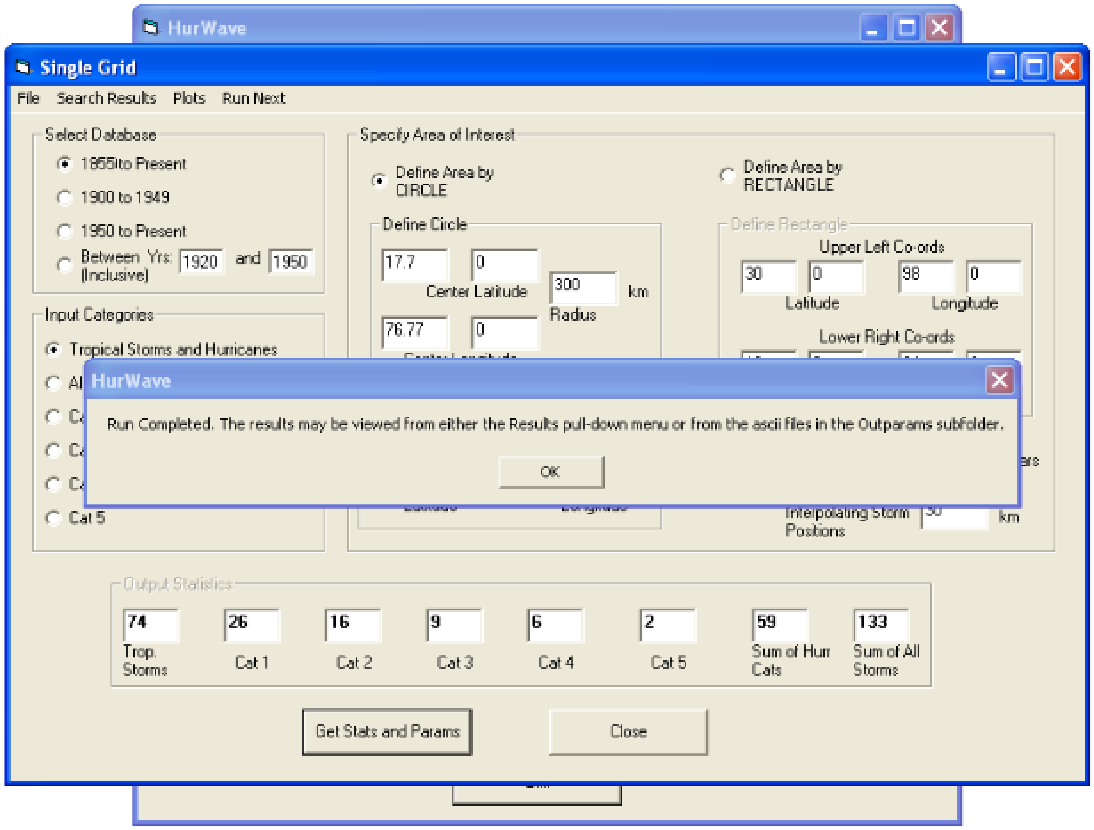
If the amount of extra investment and the risks are determined, the optimum probability of failure can be calculated. This probability of failure can be translated to return period. The best port design (in terms of money) is a design with this return period for the extreme values (ULS).
The study to come up with the optimum return period for the ULS has to be done for the final design. At this stage a lot of numbers are still unknown, so this study is beyond the scope of this project. Therefore the return period of 1/200 is used for determining the peak load at the port. This leads to a probability of occurrence of 22%.

2.2 Gathering offshore data with HURwave

To develop the characteristics of the once in a 200 year hurricane the program HURWave is used. 'HURWave is a program developed to give simple statistics of hurricane frequencies and occurrences in the North Atlantic Basin and perform external analysis to find extreme offshore conditions from parametric wave models' (Banton, 2001).

HURWave uses data from all the hurricanes from 1855 till present. For the analysis of the port all hurricanes passing within a 300 kilometer radius of the offshore point are selected. Hurricanes not passing within this circle are assumed to have no influence on the site.

Since 1855 a total of 59 hurricanes and 74 tropical storms (see Figure O-3) passed within the 300 km radius. Also the categories are given.



Select Database
● 1855Ito Present
○ 1900 to 1949
○ 1950 to Present
○ Between Yrs: 1920 and 1950 (Inclusive)

Input Categories
● Tropical Storms and Hurricanes
○ Cat 5

Specify Area of Interest
● Define Area by CIRCLE
○ Define Area by RECTANGLE

Define Circle
Center Latitude: 17.7 0
Center Longitude: 76.77 0
Radius: 300 km

Define Rectangle
Upper Left Co-ords: Latitude 30 0, Longitude 98 0
Lower Right Co-ords

Interpolating Storm Positions: 30 km

Run Completed. The results may be viewed from either the Results pull-down menu or from the ascii files in the Outparams subfolder.

Output Statistics

74	26	16	9	6	2	59	133
Trop. Storms	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Sum of Hurr Cats	Sum of All Storms

FIGURE O-3: HURWAVE INPUT DATA

Using the values of these storms and hurricanes with the parametric wave model Improved Young (1995) [10] deep water wave series are computed for different incoming directions. For the new port the wave directions East (90°), Southeast (135°), South-southeast (157.5°), South (180°), and Southwest (225°) are computed. This results in an once in 200 year wave height, maximum wind speed, and wave period for each of the directions for node 10, see Table O-1. The direction of the wind is assumed to be the same as the direction of the waves.

TABLE O-1: OFFSHORE DATA IN NODE 10 WITH A RETURN PERIOD OF 1/200 YEARS

Direction	**90°**	**135°**	**157.5°**	**180°**	**225°**
Waveheight (m)	16.21	12.38	11.32	11.28	14.09
Windspeed (m/s)	65.25	37.62	36.39	36.56	29.6
Period (s)	19.08	16.1	15.22	15.19	17.47

During a hurricane the port won't be effected by high waves only. Also increased water levels are found because of the storm surge. The water levels are increased because of the reduced atmospheric pressure (IBR) of the hurricane and because of the high wind speeds. An once in 200 year increased water level (surge) is also found with HURWave, see Table O-2. The highest astronomical tide (during spring tide) is added to get to the extreme water elevations. This is a conservative approach. The 0.25 in the third column is added for expected global sea level rise during the 50 years life time of the port (IPCC, 2013). All together this results in a final water level elevation of 1.5 meter.

TABLE O-2: SURGE LEVEL OFFSHORE IN NODE 10 WITH A RETURN PERIOD OF 1/200 YEARS

Return period (years)	**IBR (m)**	**HAT (m)**	**GSLR (m)**	**Total (m)**
200	0.77	0.45	0.25	1.5

---

[10] Improved Young is used as standard by SWIL and advised by their engineers. In an ideal case the model that is used should be validated to determine the best wave model for the model. Unfortunately, because of a tight time schedule it was not possible to carry out this validation and Improved Young was chosen.

2.3 Translate offshore data to near shore data

The results from previous sections are used as input for the model in MIKE 21. The area of interest is shown in Figure O-4.

FIGURE O-4: AREA OF INTEREST

In MIKE 21 the bathymetry is adapted. The approach channel and the port are presented in the mesh of the model that gives the results, see Figure O-5. The vertical lines indicate the location and direction of the approach channel. Here the mesh is finer because of more detail in the calculation is required.

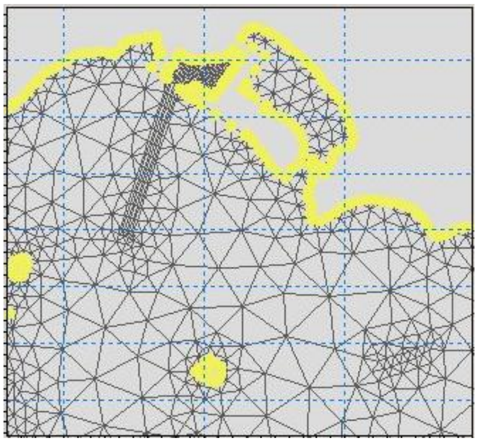


FIGURE O-5: MESH IN MIKE 21

For each of the five wave and wind directions the results are shown in the next sections. The results contain the maximum wave height and maximum surge level. Note: Legends and colors may differ for each figure.

2.3.1 Extreme wave and surge conditions if waves and winds are coming from 90°

If the hurricane waves are coming from the east and the wind is coming also from the east the following figures (Figure O-6, Figure O-7, Figure O-8, and Figure O-9) present the wave heights and the surge level with a return period of 1/200 years. Results for the three most important points are found in Table O-3.

HURwave output and MIKE 21 input	90°
Waveheight (m)	16.21
Windspeed (m/s)	65.25
Periode (s)	19.08

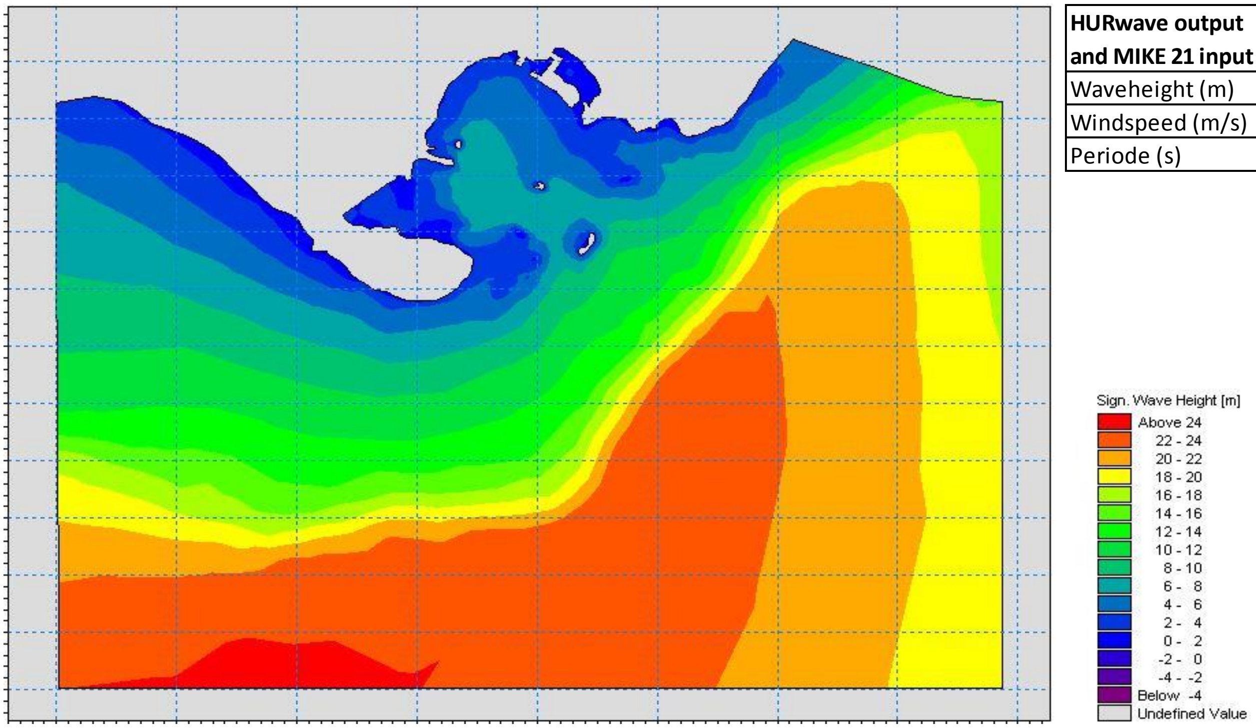


FIGURE O-6: SIGNIFICANT WAVE HEIGHTS IN THE AREA IF WAVE AND WIND CONDITIONS ARE FROM 90 DEGREES

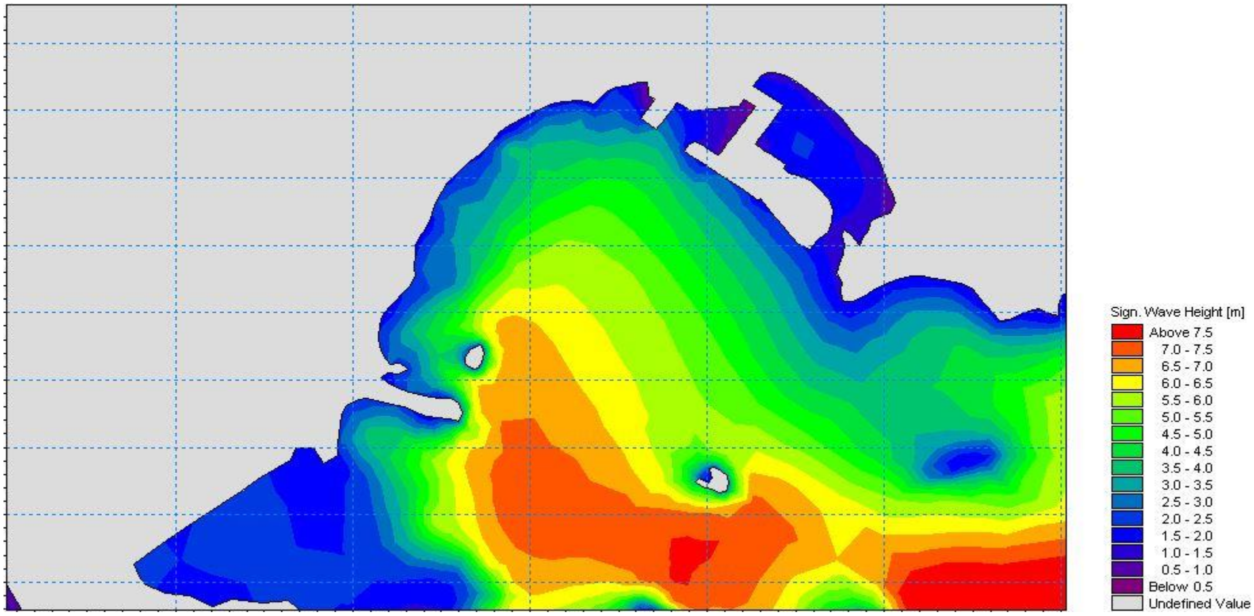


FIGURE O-7: SIGNIFICANT WAVE HEIGHTS IN THE PORTLAND BIGHT (ZOOMED AREA) IF WAVE AND WIND CONDITIONS ARE FROM 90 DEGREES

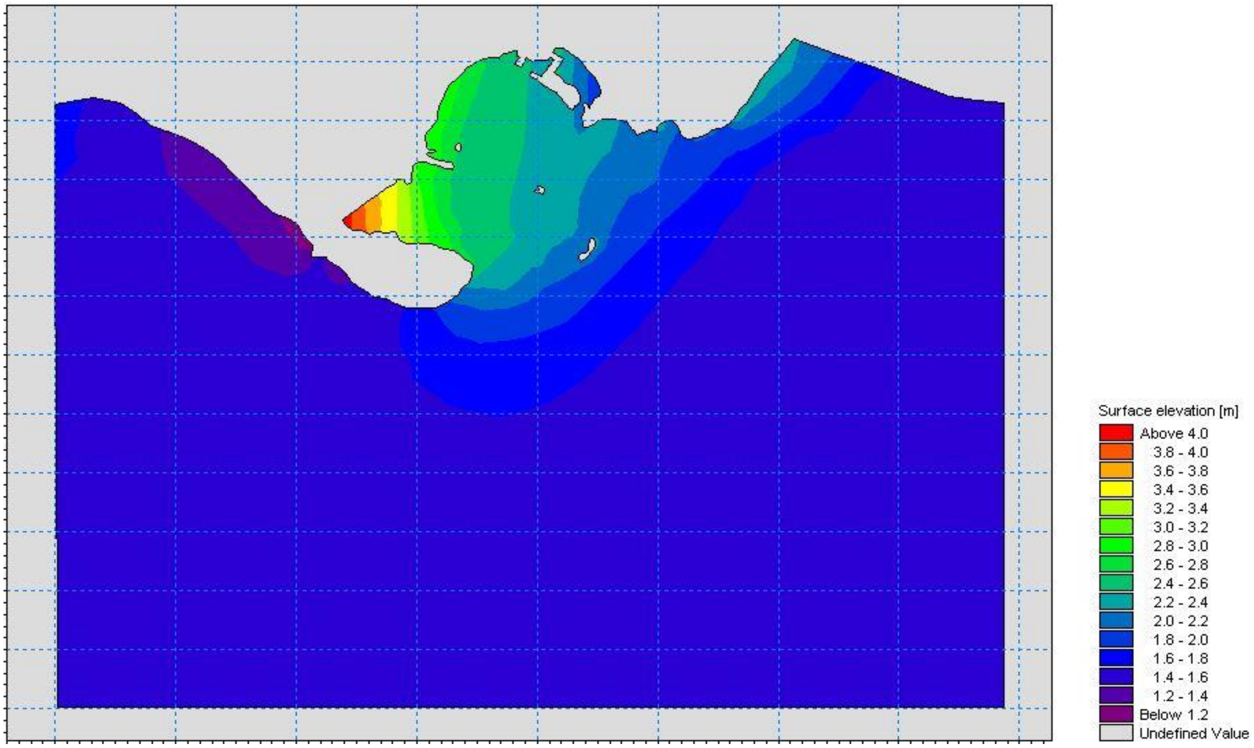


FIGURE O-8: SURGE LEVEL IN THE AREA IF WAVE AND WIND CONDITIONS ARE FROM 90 DEGREES

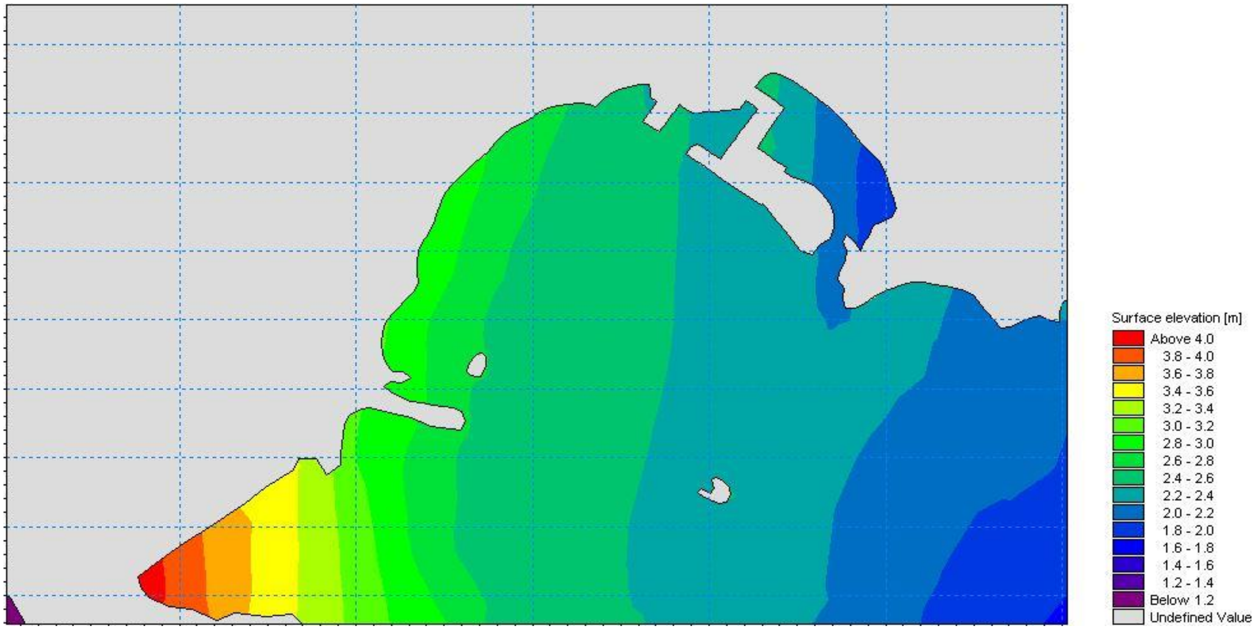


FIGURE O-9: SURGE LEVEL IN THE PORTLAND BIGHT (ZOOMED AREA) IF WAVE AND WIND CONDITIONS ARE FROM 90 DEGREES

TABLE O-3: MAXIMUM WAVE HEIGHTS, WAVE PERIODS AND WATER LEVEL SET UP AT THE THREE MOST IMPORTANT POINTS FOR 90°

Direction 90 degrees	Wave height (m)	Wave period (s)	Surge level (m)
Approach channel	5.81	4.70	2.46
Entrance of the port	2.89	3.01	2.42
Behind the port	1.67	2.58	2.48

2.3.2 Extreme wave and surge conditions if waves and winds are coming from 135°

If the hurricane waves are coming from the Southeast and the wind blows also from the Southeast the following figures (Figure O-10, Figure O-11, Figure O-12, and Figure O-13) present the wave heights and the surge level with a return period of 1/200 years. Results for most important points are found in Table O-4.

HURwave output and MIKE 21 input	135°
Waveheight (m)	12.38
Windspeed (m/s)	37.62
Periode (s)	16.1

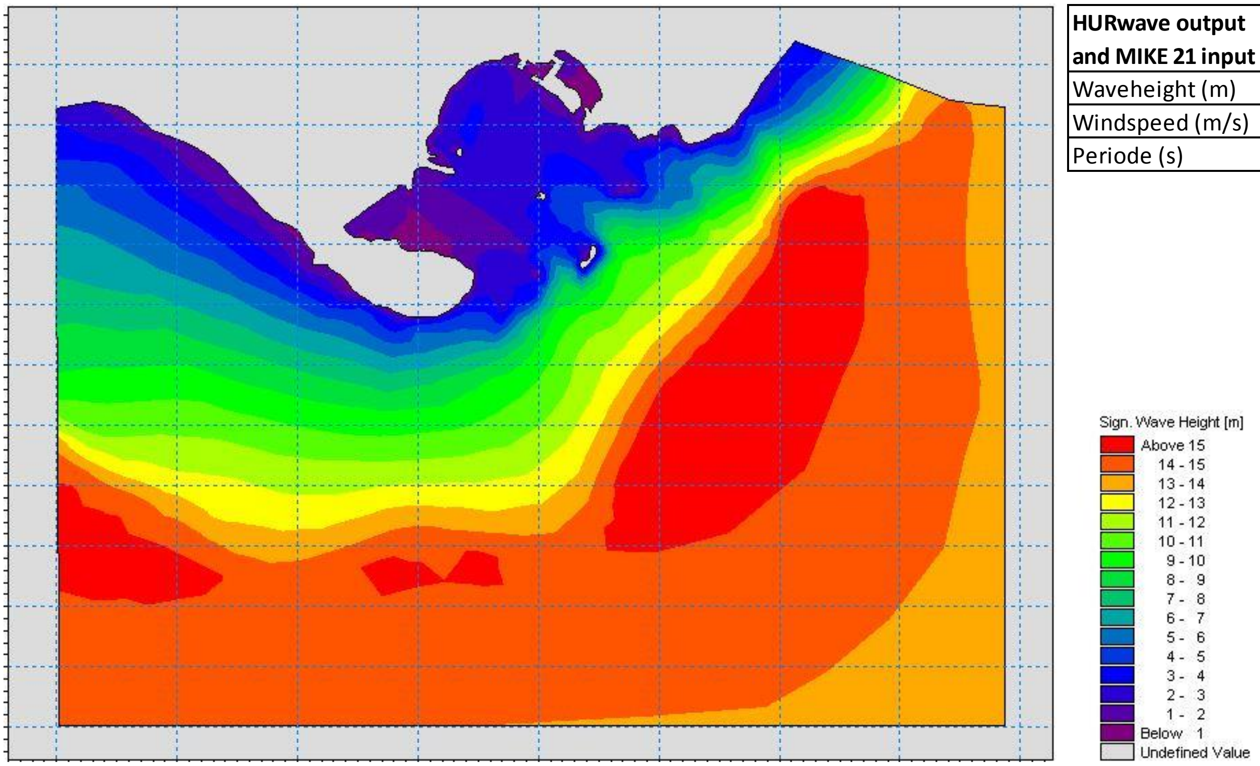


FIGURE O-10: SIGNIFICANT WAVE HEIGHTS IN THE AREA IF THE WAVE AND WIND CONDITIONS ARE FROM 135 DEGREES

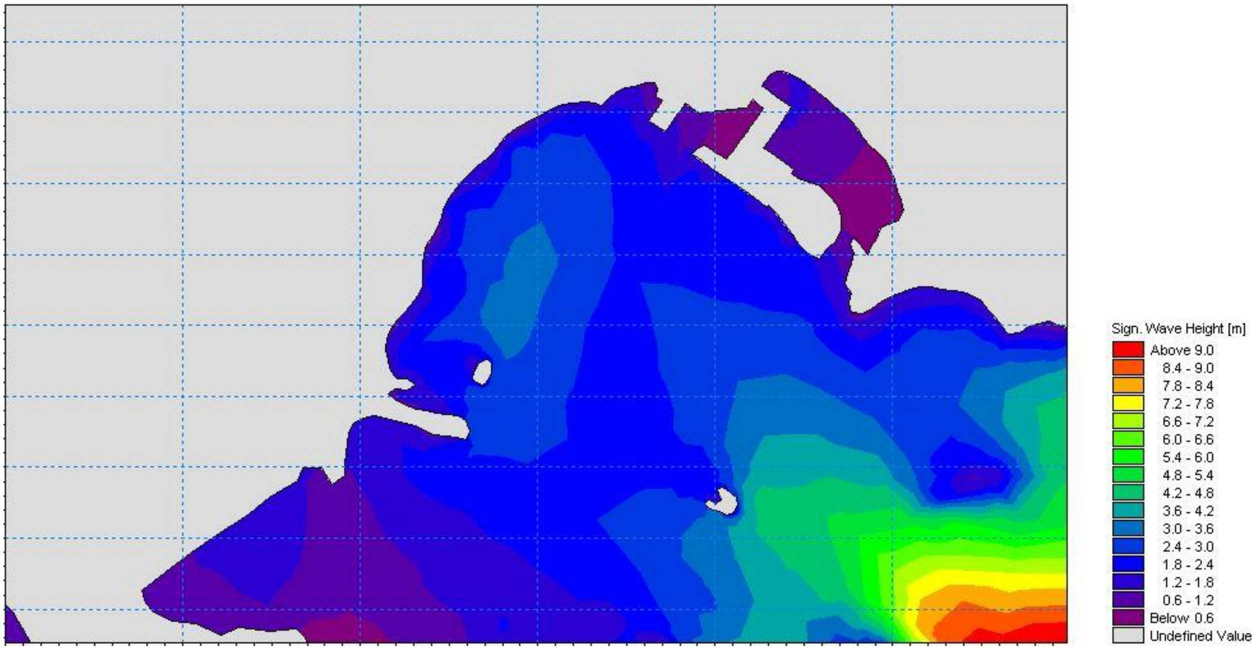


FIGURE O-11: SIGNIFICANT WAVE HEIGHTS IN THE PORTLAND BIGHT (ZOOMED AREA) IF THE WAVE AND WIND CONDITIONS ARE FROM 135 DEGREES

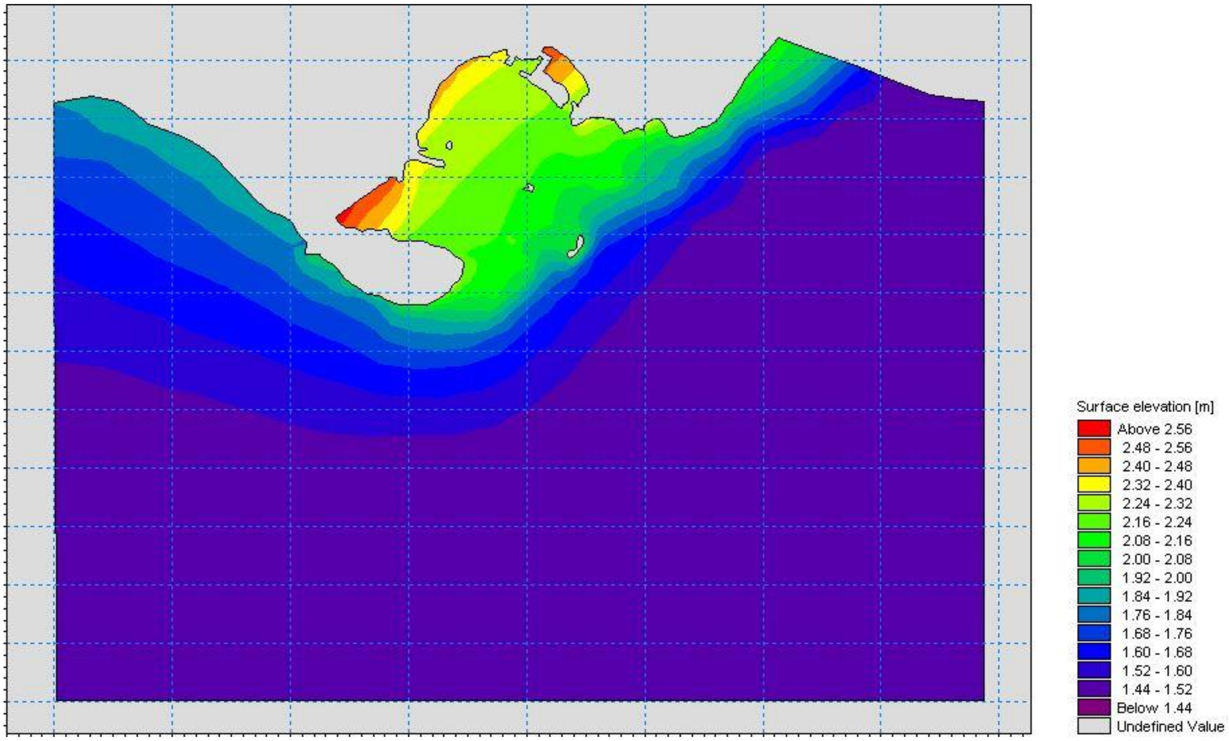


FIGURE O-12: SURGE LEVEL IN THE AREA IF THE WAVE AND WIND CONDITIONS ARE FROM 135 DEGREES

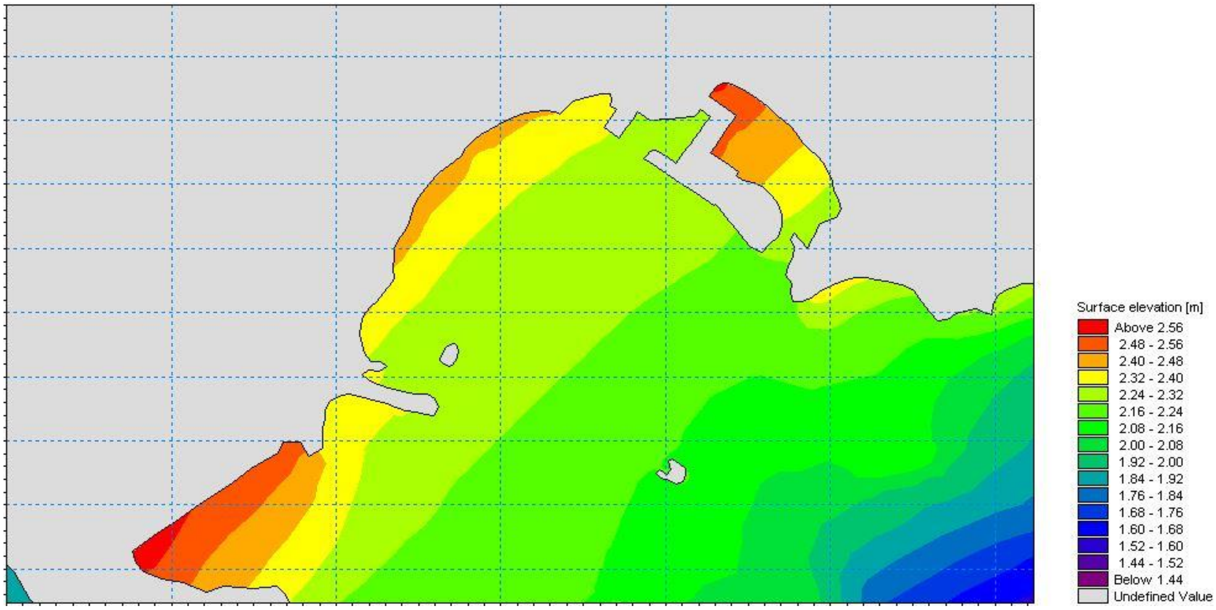


FIGURE O-13: SURGE LEVEL IN THE PORTLAND BIGHT (ZOOMED AREA) IF THE WAVE AND WIND CONDITIONS ARE FROM 135 DEGREES

TABLE O-4: MAXIMUM WAVE HEIGHTS, WAVE PERIODS AND WATER LEVEL SET UP AT THE THREE MOST IMPORTANT POINTS FOR 135°

Direction 135 degrees	Wave height (m)	Wave period (s)	Surge level (m)
Approach channel	2.36	9.80	2.26
Entrance of the port	1.22	6.70	2.31
Behind the port	1.21	3.35	2.56

2.3.3 Extreme wave and surge conditions if waves and winds are coming from 157.5°

If the hurricane waves are coming from the South-southeast and the wind blows also from the South-southeast the following figures (Figure O-14, Figure O-15, Figure O-16, and Figure O-17) present the wave heights and the surge level with a return period of 1/200 years. Table O-5 gives the results for the three most important points.

HURwave output and MIKE 21 input	157.5°
Waveheight (m)	11.32
Windspeed (m/s)	36.39
Periode (s)	15.22

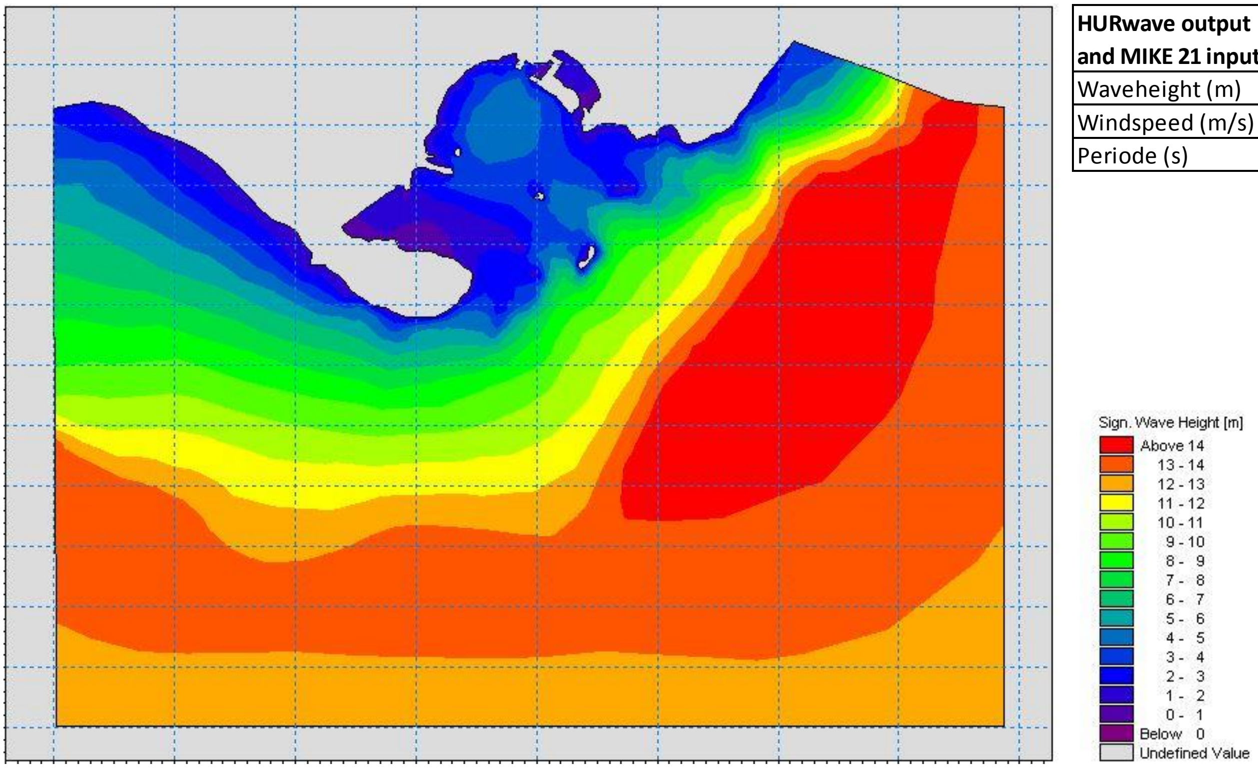


FIGURE O-14: SIGNIFICANT WAVE HEIGHTS IN THE AREA IF THE WAVE AND WIND CONDITIONS ARE FROM 157.5 DEGREES

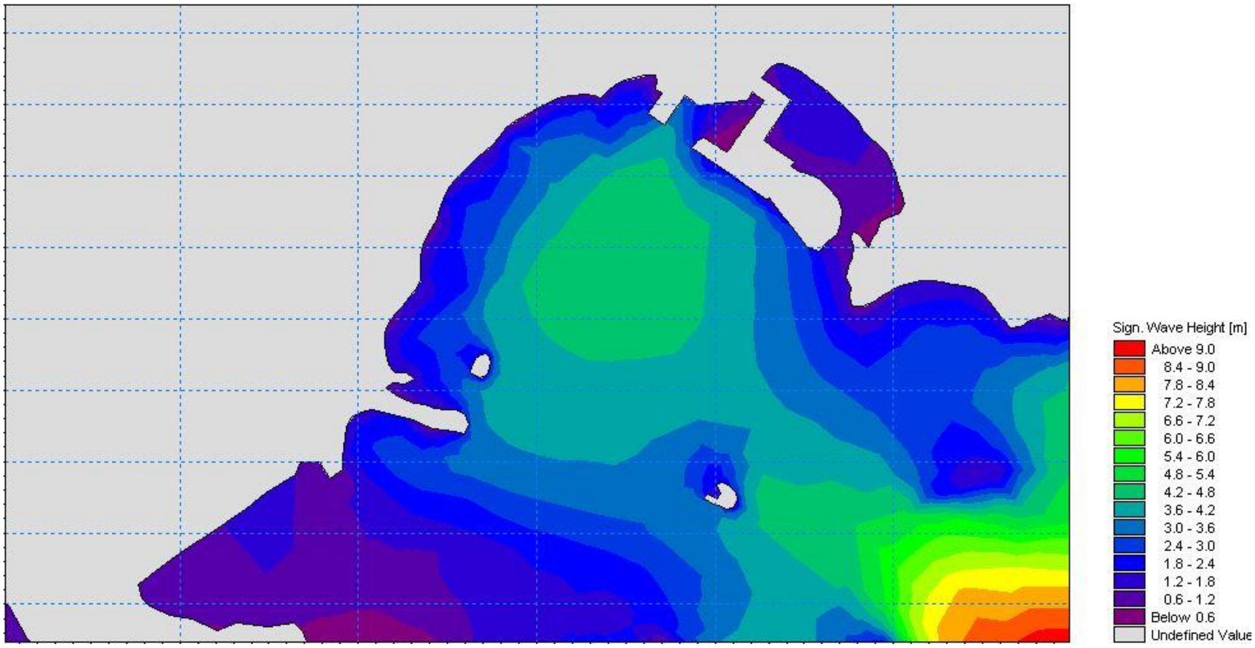


FIGURE O-15: SIGNIFICANT WAVE HEIGHTS IN THE PORTLAND BIGHT (ZOOMED AREA) IF THE WAVE AND WIND CONDITIONS ARE FROM 157.5 DEGREES

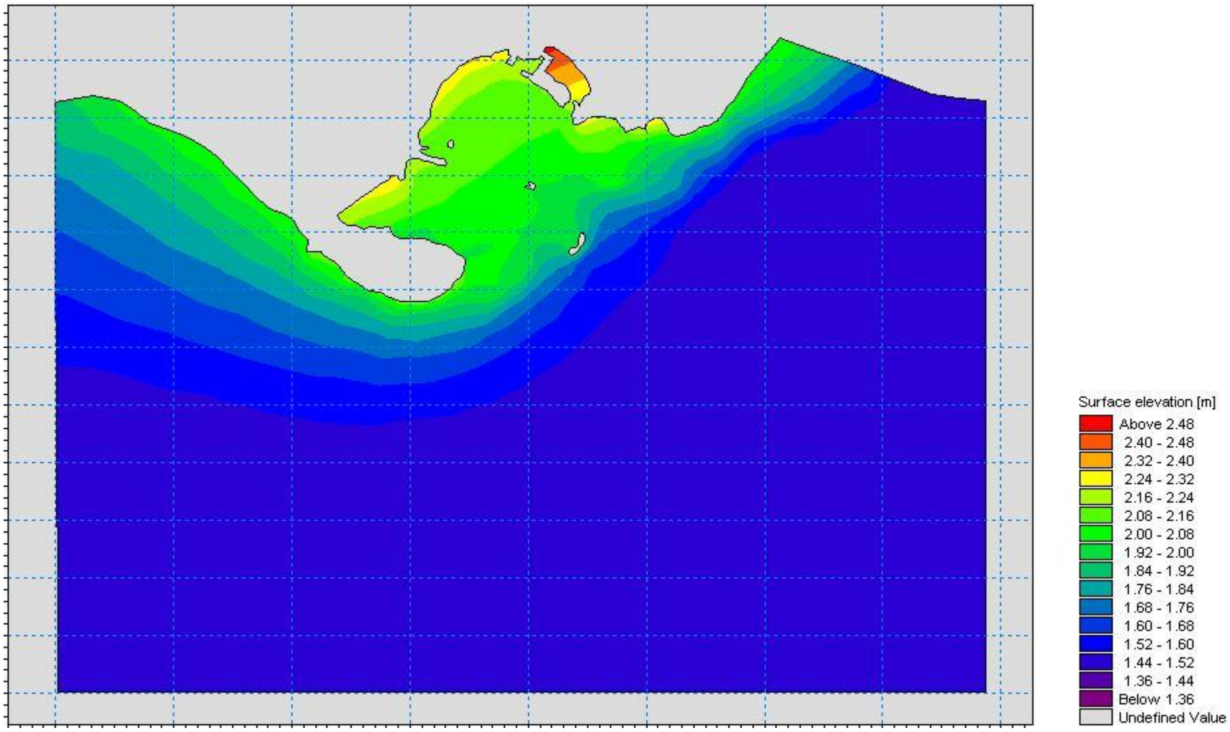


Figure O-16: Surge level in the area if the wave and wind conditions are from 157.5 degrees

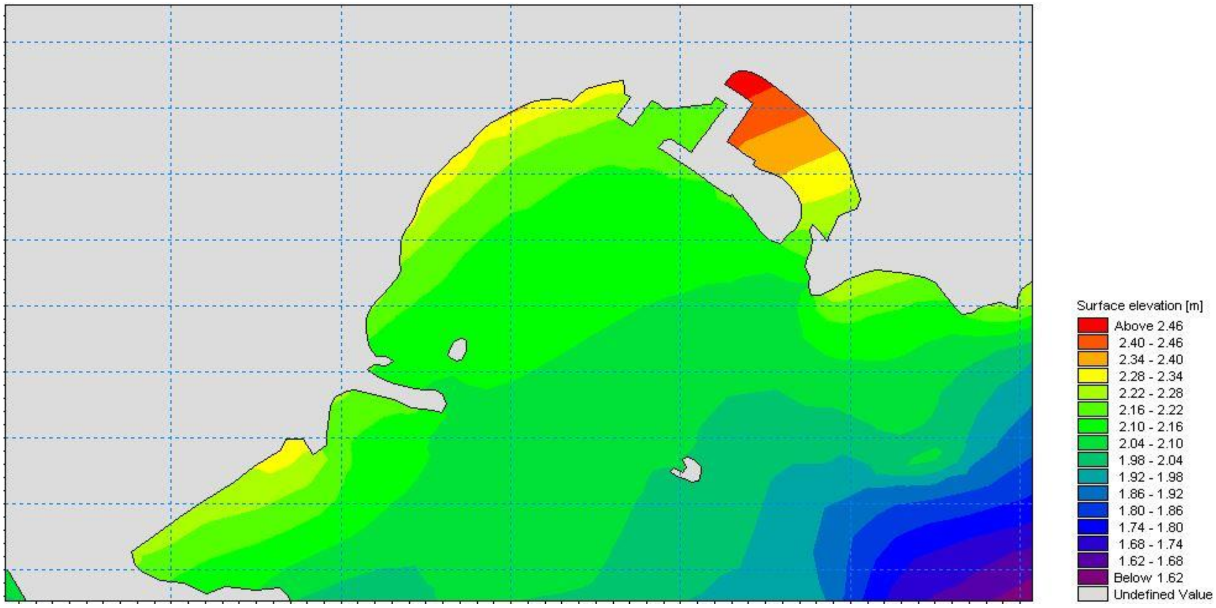


Figure O-17: Surge level in the Portland Bight (zoomed area) if the wave and wind conditions are from 157.5 degrees

Table O-5: Maximum wave heights, wave periods and water level set up at the three most important points 157.5°

Direction 157.5 degrees	Wave height (m)	Wave period (s)	Surge level (m)
Approach channel	4.57	4.66	2.12
Entrance of the port	3.46	4.41	2.17
Behind the port	1.42	2.54	2.51

2.3.4 Extreme wave and surge conditions if waves and winds are coming from 180°

If the hurricane waves are coming from the south and the wind blows also from the south the following figures (Figure O-18, Figure O-19, Figure O-20, and Figure O-21) present the wave heights and the surge level with a return period of 1/200 years. Results for the important points are found in Table O-6.

HURwave output and MIKE 21 input	180°
Waveheight (m)	11.28
Windspeed (m/s)	36.56
Periode (s)	15.19

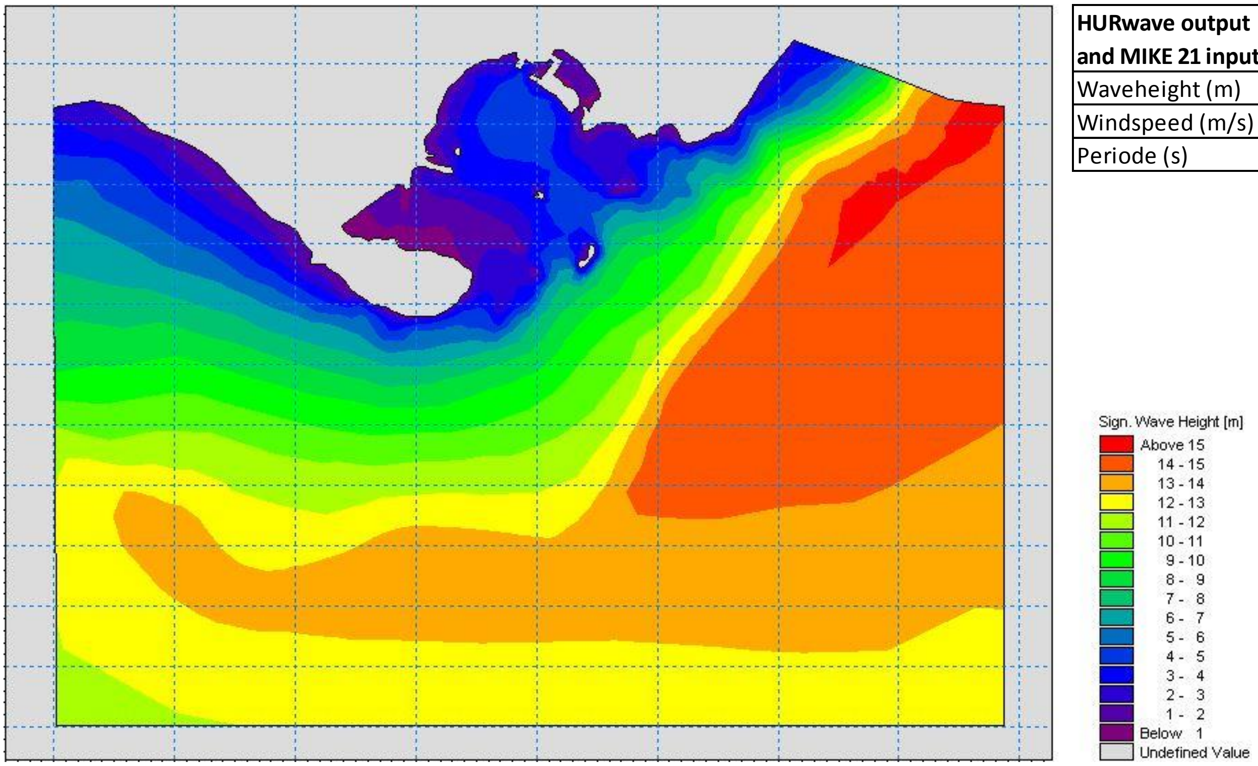


FIGURE O-18: SIGNIFICANT WAVE HEIGHTS IN THE AREA IF THE WAVE AND WIND CONDITIONS ARE FROM 180 DEGREES

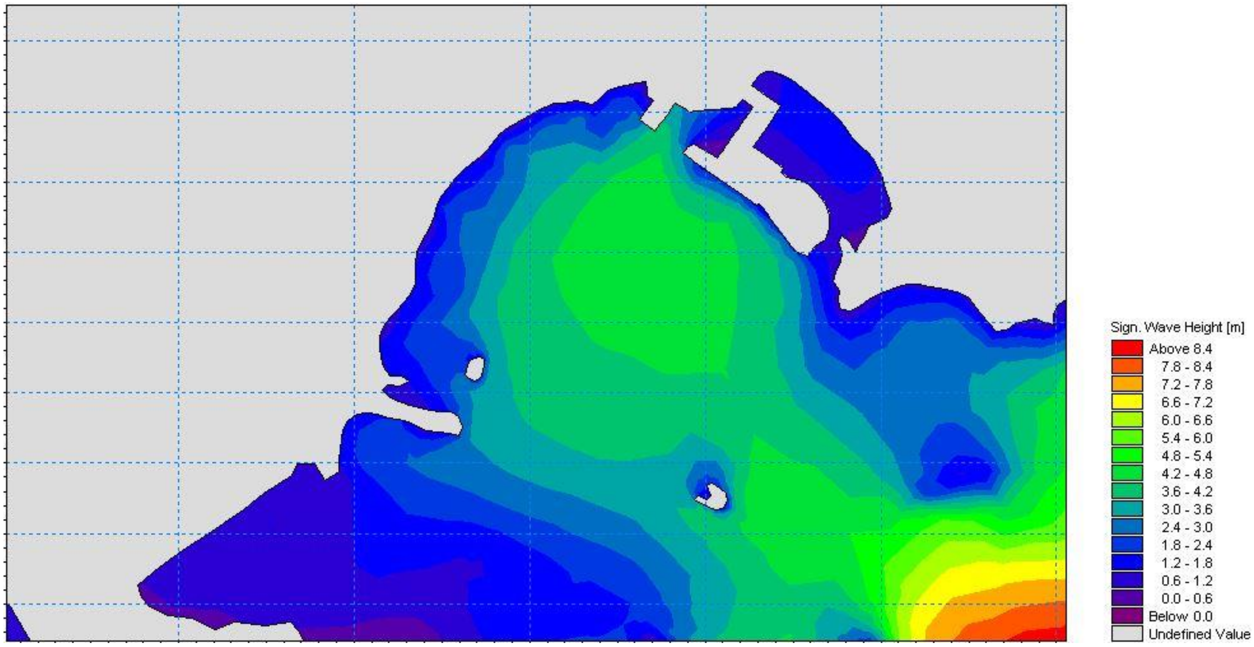


FIGURE O-19: SIGNIFICANT WAVE HEIGHTS IN THE PORTLAND BIGHT (ZOOMED AREA) IF THE WAVE AND WIND CONDITIONS ARE FROM 180 DEGREES

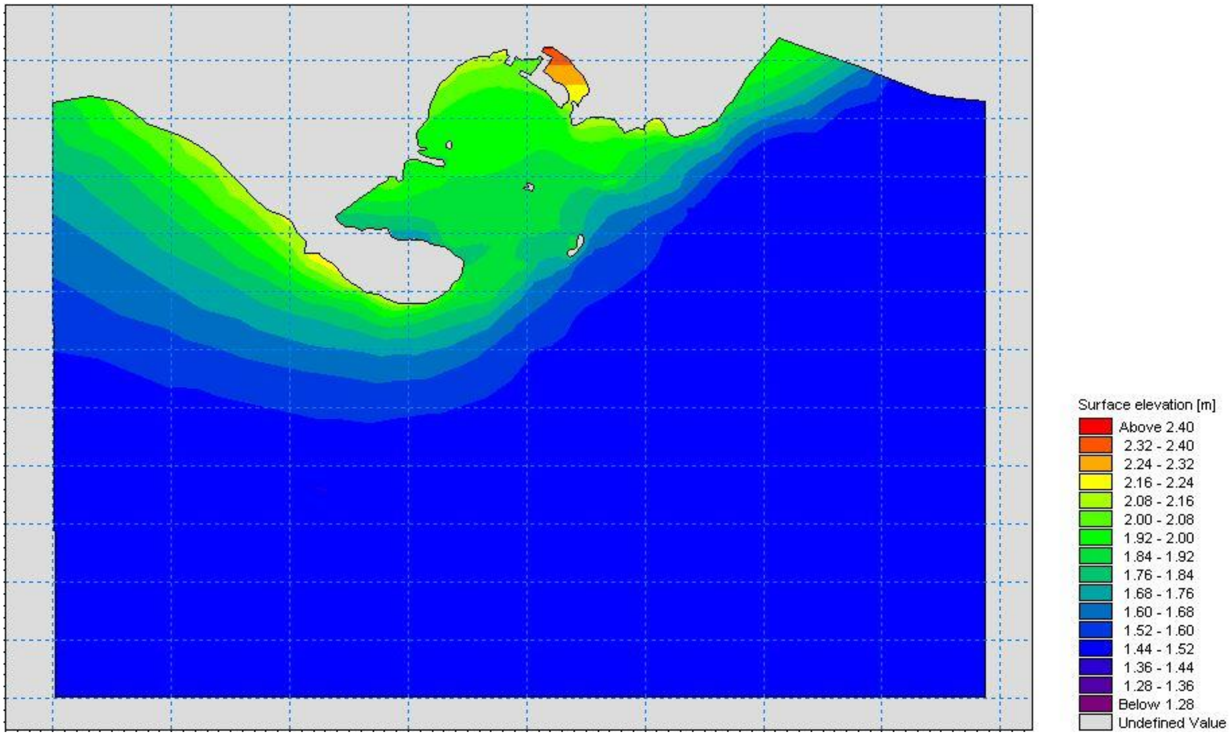


FIGURE O-20: SURGE LEVEL IN THE AREA IF THE WAVE AND WIND CONDITIONS ARE FROM 180 DEGREES

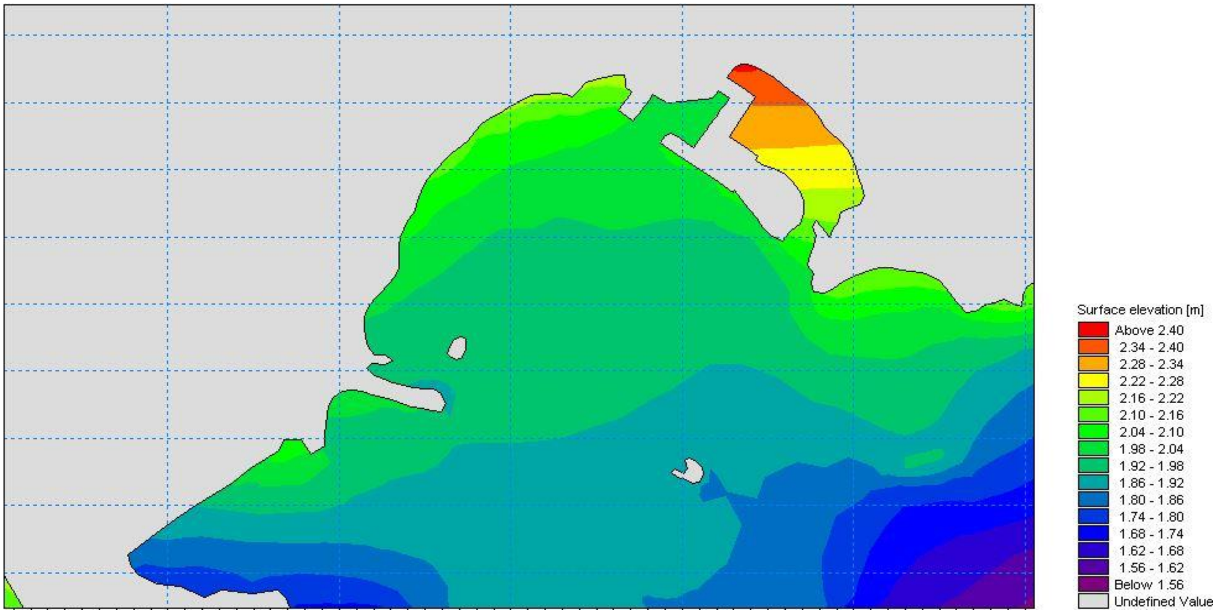


FIGURE O-21: SURGE LEVEL IN THE PORTLAND BIGHT (ZOOMED AREA) IF THE WAVE AND WIND CONDITIONS ARE FROM 180 DEGREES

TABLE O-6: MAXIMUM WAVE HEIGHTS, WAVE PERIODS AND WATER LEVEL SET UP AT THE THREE MOST IMPORTANT POINTS FOR 180°

Direction 180 degrees	**Wave height (m)**	**Wave period (s)**	**Surge level (m)**
Approach channel	4.53	4.82	1.98
Entrance of the port	4.01	4.49	2.01
Behind the port	1.29	2.54	2.41

2.3.5 Extreme wave and surge conditions if waves and winds are coming from 225°

If the hurricane waves are coming from the southwest and the wind blows also from the Southwest the following figures (Figure O-22, Figure O-23, Figure O-24, and Figure O-25) present the wave heights and the surge level with a return period of 1/200 years. Results for the three most important points are found in Table O-7.

HURwave output and MIKE 21 input	225°
Waveheight (m)	14.09
Windspeed (m/s)	29.6
Periode (s)	17.47

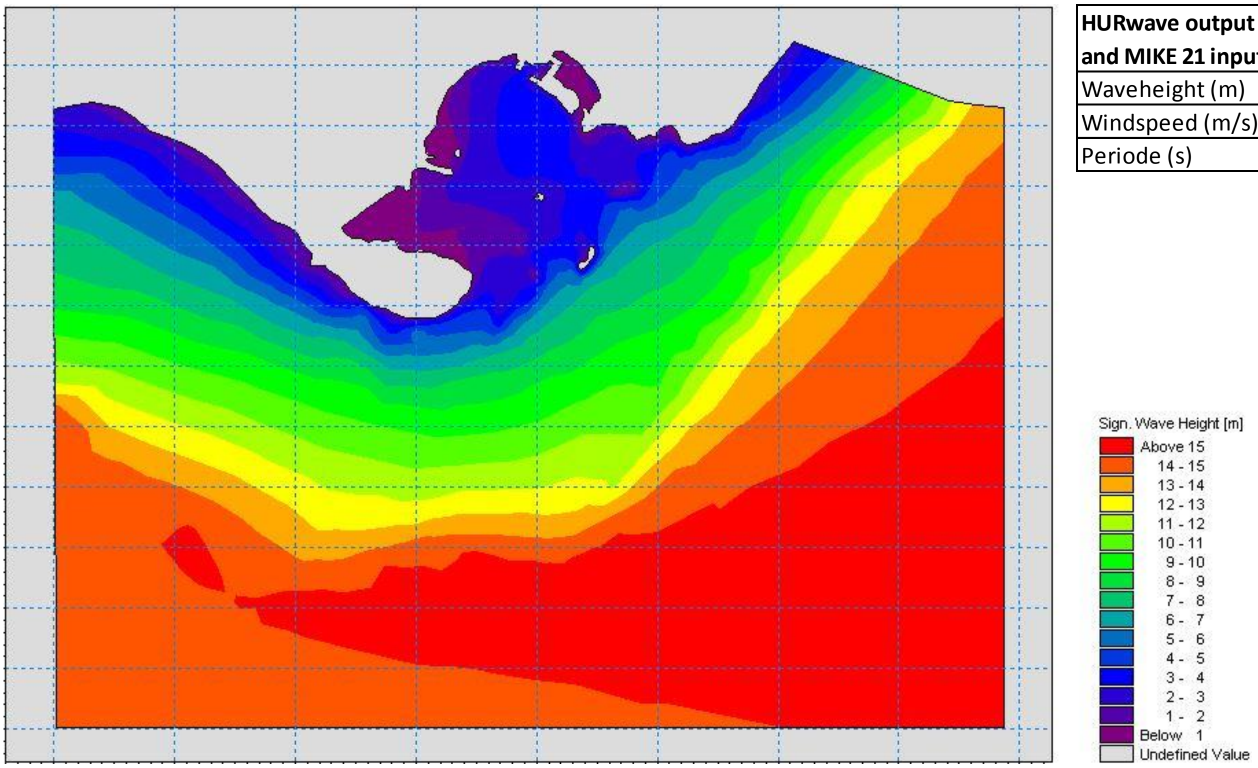


FIGURE O-22: SIGNIFICANT WAVE HEIGHTS IN THE AREA IF THE WAVE AND WIND CONDITIONS ARE FROM 225 DEGREES

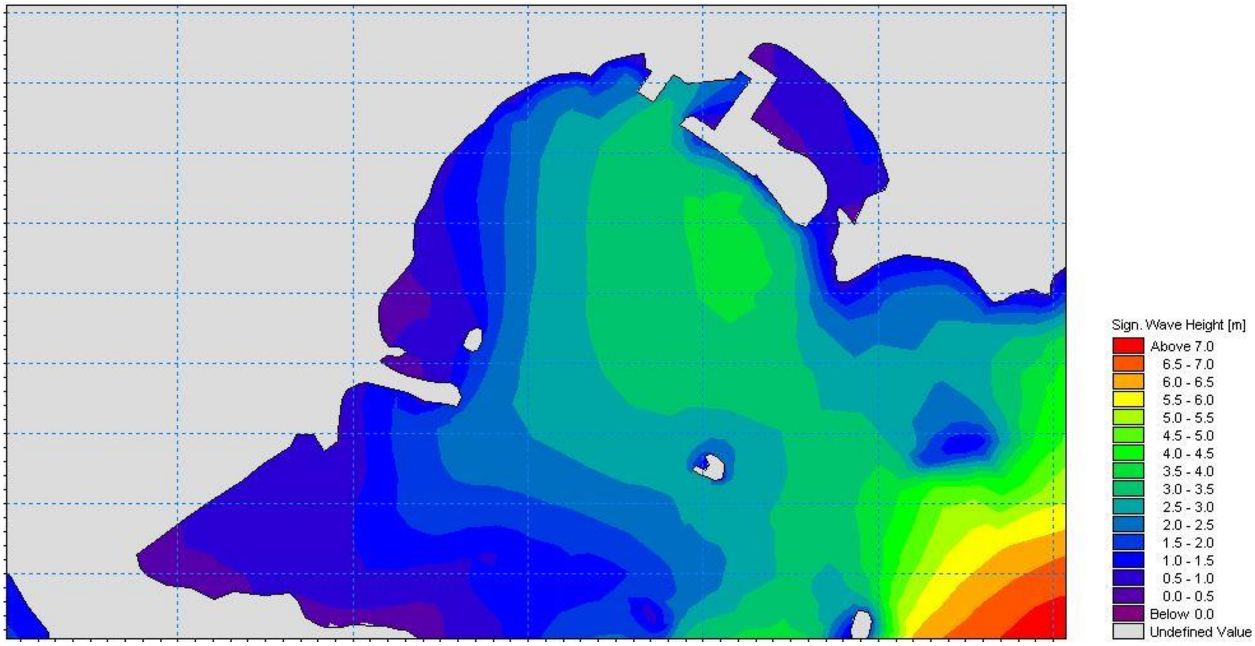


FIGURE O-23: SIGNIFICANT WAVE HEIGHTS IN THE PORTLAND BIGHT (ZOOMED AREA) IF THE WAVE AND WIND CONDITIONS ARE FROM 225 DEGREES

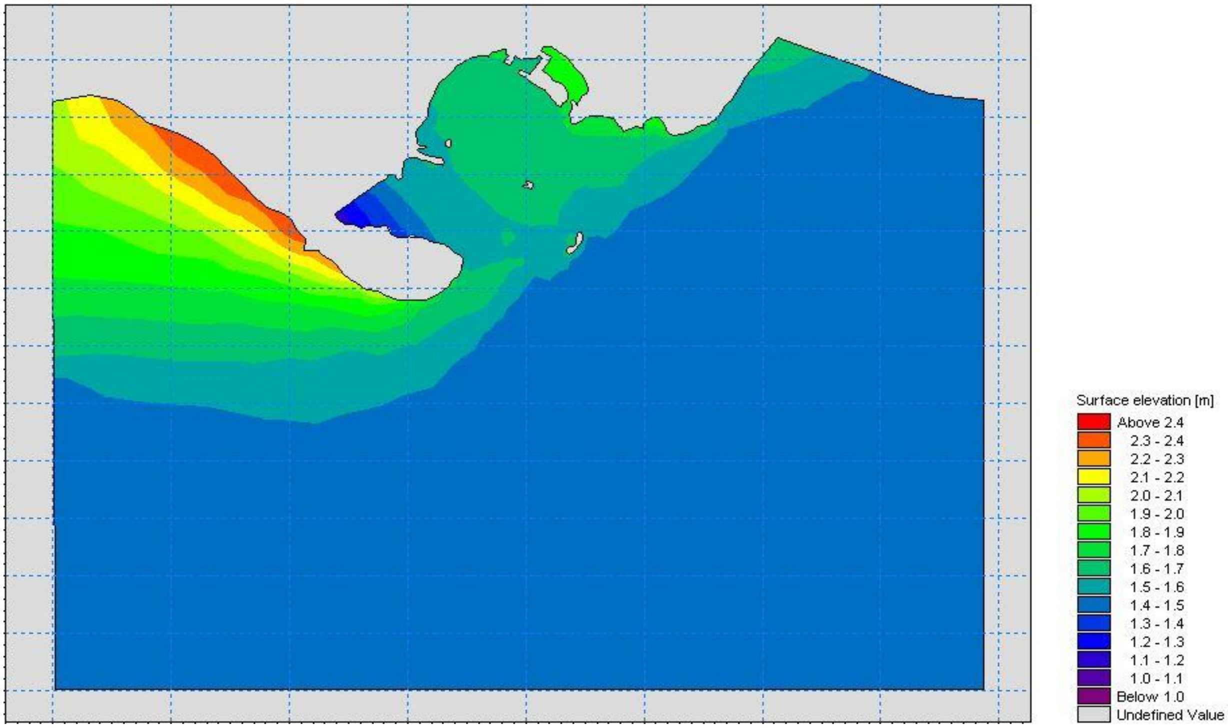


FIGURE O-24: SURGE LEVEL IN THE AREA IF THE WAVE AND WIND CONDITIONS ARE FROM 225 DEGREES

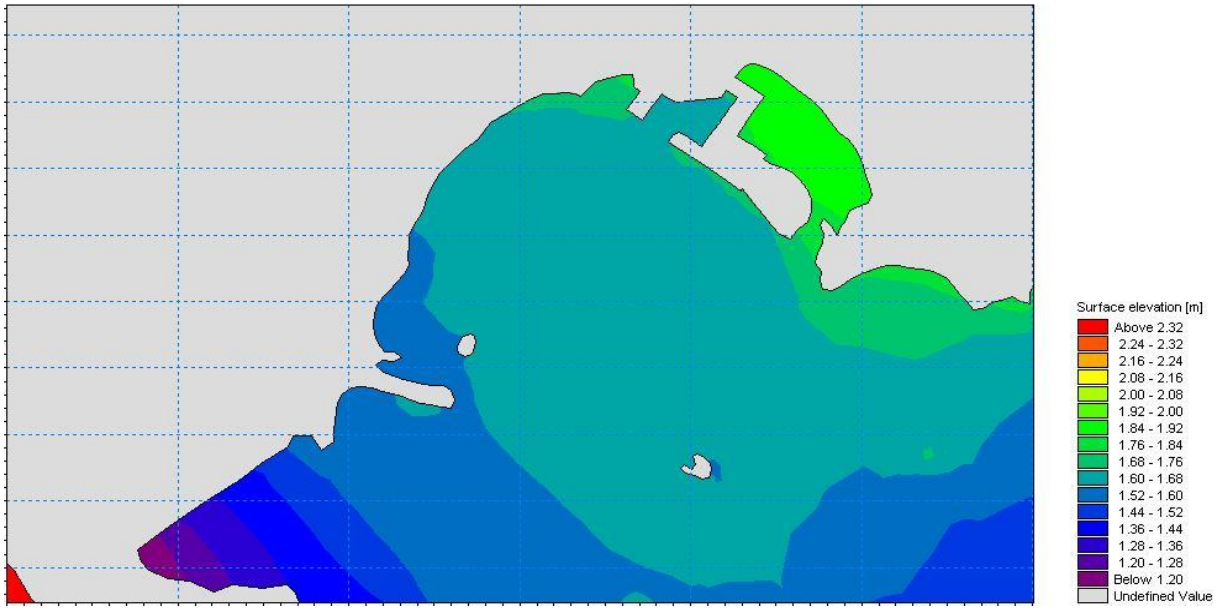


FIGURE O-25: SURGE LEVEL IN THE PORTLAND BIGHT (ZOOMED AREA) IF THE WAVE AND WIND CONDITIONS ARE FROM 225 DEGREES

TABLE O-7: MAXIMUM WAVE HEIGHTS, WAVE PERIODS AND WATER LEVEL SET UP AT THE THREE MOST IMPORTANT POINTS FOR 225°

Direction 225 degrees	**Wave height (m)**	**Wave period (s)**	**Surge level (m)**
Approach channel	3.26	3.80	1.64
Entrance of the port	3.19	4.02	1.67
Behind the port	0.68	1.91	1.89

2.3.6 Overview of wave and wind directions

All the above figures give very extreme wave heights and surge levels. A few things are worth noticing. Out of every direction the wave heights are high off shore and reduce in height dramatically once they approach the bay. However if the wind comes from an unfavorable direction the wind causes high waves and high surge levels inside the bay.

Another interesting phenomenon is what happens behind the Goat Islands. Because the water is closed off the water can't escape and high surge levels will occur as can be seen in Figure O-21. The water behind the Goat Islands is most of the time shallow and calm. During hurricanes however the back of the port needs to be protected as much as the entrance of the port. Table O-8 gives a summary of the found numbers.

TABLE O-8: MAXIMUM WAVE HEIGHTS, WAVE PERIODS, AND WATER LEVEL SET UP WITH A RETURN PERIOD OF 1/200 YEARS AT THE APPROACH CHANNEL, ENTRANCE OF THE PORT AND BEHIND THE PORT FOR ALL THE WAVE DIRECTIONS

Approach Channel	**90°**	**135°**	**157.5°**	**180°**	**225°**
Wave height (m)	5.81	2.36	4.57	4.53	3.26
Surface elevation (m)	2.46	2.26	2.12	1.98	1.64
Wave period (s)	4.70	9.80	4.66	4.82	3.80

Entrance of the port	**90°**	**135°**	**157.5°**	**180°**	**225°**
Wave height (m)	2.89	1.22	3.46	4.01	3.19
Surface elevation (m)	2.42	2.31	2.17	2.03	1.67
Wave period (s)	3.01	6.70	4.41	4.49	4.02

Behind the port	**90°**	**135°**	**157.5°**	**180°**	**225°**
Wave height (m)	1.67	1.21	1.42	1.29	0.68
Surface elevation (m)	2.48	2.56	2.51	2.41	1.89
Wave period (s)	2.58	3.35	2.54	2.52	1.91

2.4 ULS conclusion

In Table O-8 the maximum values of the wave height, wave period, and surge level are given for each of the wave directions. Those numbers have to be translated to the peak load at the entrance of the port and behind the port.

- Entrance of the port

The highest waves and the largest wave set up is if the hurricane waves are coming from the south. During an once in 200 year event the entrance of the port receives waves with an significant wave height (Hs) of 4 meter and an surface elevation of 2.03 meter, see Figure O-26.

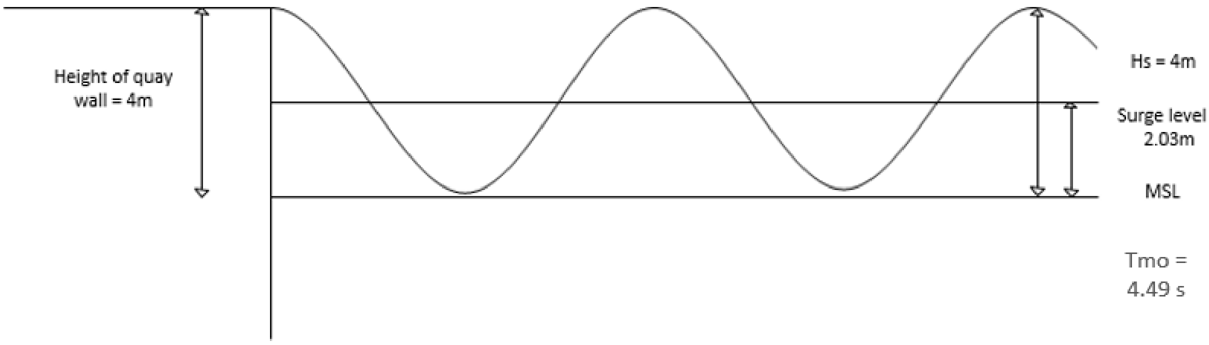


FIGURE O-26: THE EXTREME WAVE CONDITION WITH A RETURN PERIOD OF 1/200 YEARS AT THE ENTRANCE OF THE PORT

- Behind the port

The backside of the port (not inside the port) receives much lower wave heights of 1.67 meter maximum, but can get higher surge levels up to 2.48 meter, see Figure O-27. For the area behind the port these extremes occur when the wind/wave directions is coming from the East.

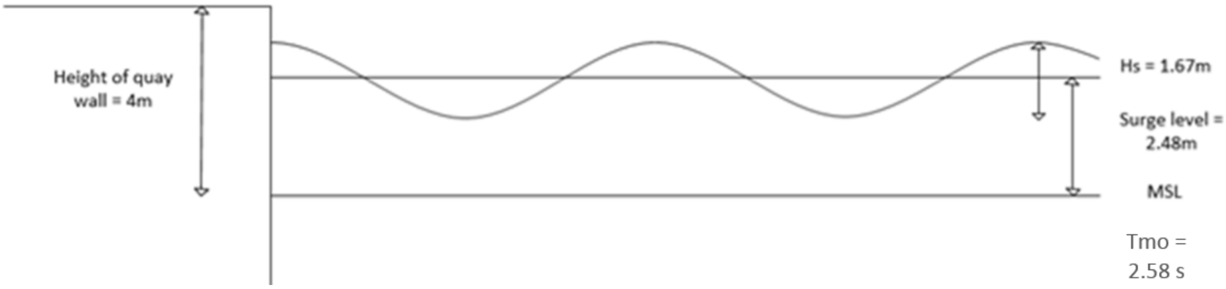


FIGURE O-27: THE EXTREME WAVE CONDITION WITH A RETURN PERIOD OF 1/200 YEARS BEHIND THE PORT VARIANT ONE

2.5 Design of the port

Now the extreme wave conditions are known measures could be taken to deal with these conditions. For this a few options are possible:

- Design a breakwater to reduce the wave heights and surge levels near the quay walls. This way repair costs (including downtime of the port) are low, but initial costs are increased dramatically.
- Increase the height of the quay walls to prevent flooding over the quay walls. Repair costs will be lower, but initial costs are increased and operational problems might occur.
- Accept the damage that is caused by the waves and rebuild after the storms. This option gives no extra capital costs, but repair costs (and indirect costs because of downtime) can be too high.
- Shut down the back of the Goat Islands permanently or only during a storm to make sure the back of the port is saved. Apart from the costs of creating the shut down the fish sanctuary will suffer a lot which is quite unfavourable. Also this option doesn't help the defence of the entrance of the port.
- Other alternatives could be applied, like sand bags on the edge of the quay wall in case of hurricanes.

However, for making a decision there are too many uncertainties. How much damage cause the waves to the current design? What are the capital costs of the options and what will be the damage reduction for these options. If these questions are answered a graph as in Figure O-26 can be constructed to find the optimum level of safety. Is the 22% probability of exceedance acceptable or should this change to a more economical probability?

Non-economical influences should also be taken into account. What influence has the port on the fish sanctuary or outflow of the Black River? The port causes higher water set up in the fish sanctuary, because of the 'barrier' behind the Goat Islands. Does this give a negative impact on the fishes' habitat?

Altogether many difficult questions are still unanswered. Because of the tight time schedule of this project the answers to these questions are left unknown. However it should be addressed that the outcome of this extreme analysis should not be left behind when designing the port into further detail as a thoughtful consideration should be made about how to deal with the influences of these extreme hurricanes.

3 Downtime of the port

Downtime of the port can also be described as the serviceability limit state (SLS). This is the state of the port in which the port can't provide any service to the incoming ships. If the serviceability limit state is too high (e.g. 5% of the time) changes in the design are needed to create a milder climate, because of unacceptable downtime. To come up with the downtime the existing data on node 10 is modeled with MIKE 21 to give day to day near shore wave data. With the near shore wave data the downtime can be calculated with statistics.

3.1 Design criteria

Downtime of the port occurs if the significant wave height is higher than 1.5 meters outside of the port in a part of the approach channel (Velsink, 2012). Whenever this happens tugboats can't fasten to the containerships and thus the containerships can't enter the port. In phase L_3, the vessels reduce their speed, see Figure O-28. In this phase waves with a significant wave height higher than 1.5 meter don't cause downtime. In phase L_2 the waves bigger than 1.5m do cause downtime, because of the fastening of the tugboats.

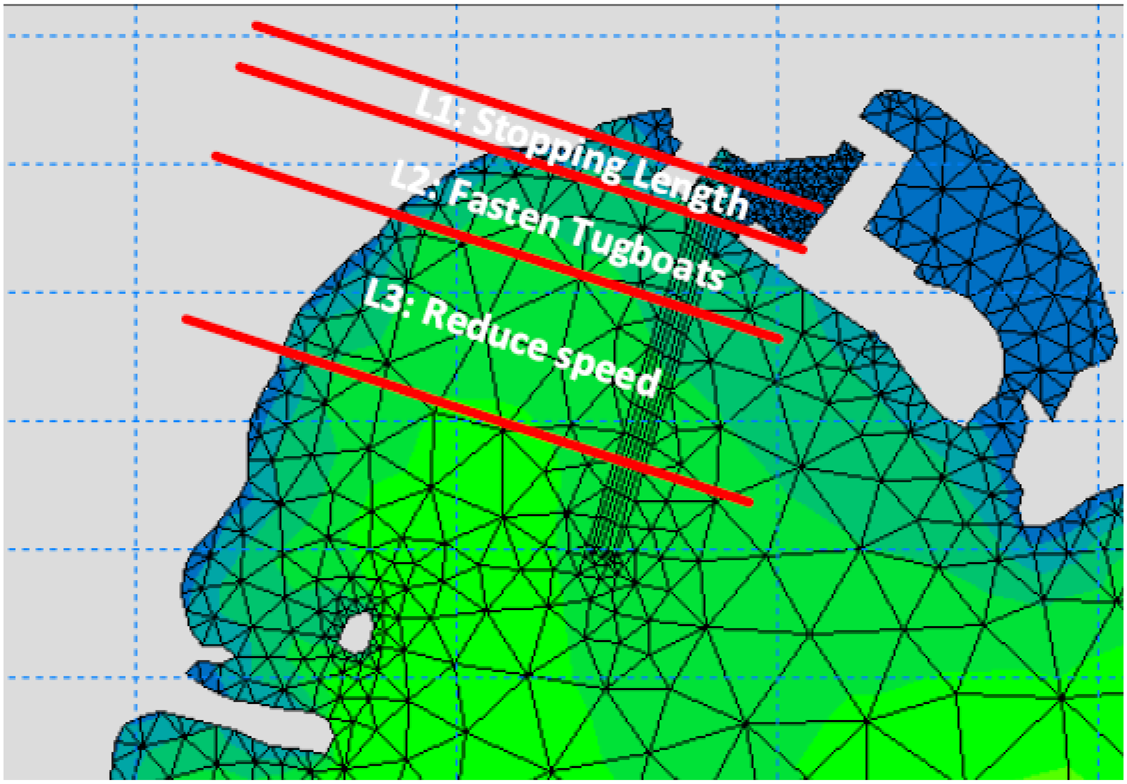


FIGURE O-28: APPROACH CHANNEL LENGTHS

Downtime of the port also occurs if the significant wave height is higher than 0.5 meter inside the port. During such wave conditions cranes have trouble grabbing and placing containers from ships. The assumption is made that this is not happening if the wave height is lower than 1.5 meter outside the port. Looking at the figures this assumption is reasonable.

Note that wind speeds disturbing container handling is not taken in the criteria. According to (FEM, 1998) a maximum wind speed of 20 m/s is used for handling containers with cranes. These wind speeds only occur with tropical storms or hurricanes when the port is already in a shut down, see Table O-9. Therefore the assumption is made that also this type of downtime is neglect able. To verify if this assumption is right the wind data at the Goat Islands has to be known. This data does not exist so far, so this assumption is not verified.

3.2 Data offshore in node 10

Using data from the past years gathered from the National Oceanic and Atmospheric Administration (NOAA) offshore conditions are gathered.

For determining the downtime the data of the daily values are used[11]. The data are gathered on site offshore at node 10 in Figure O-29. Around node 10 the depths of 1500 meter or more can be found. This means node 10 can be seen as offshore (waves are not influenced by the bottom, so deep water waves).

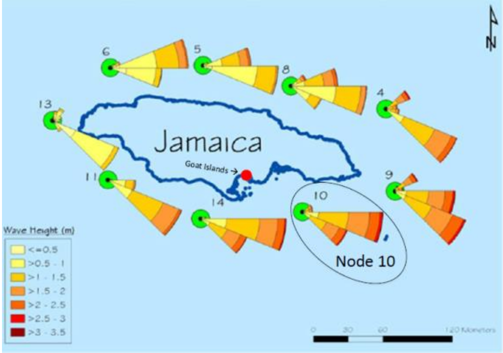


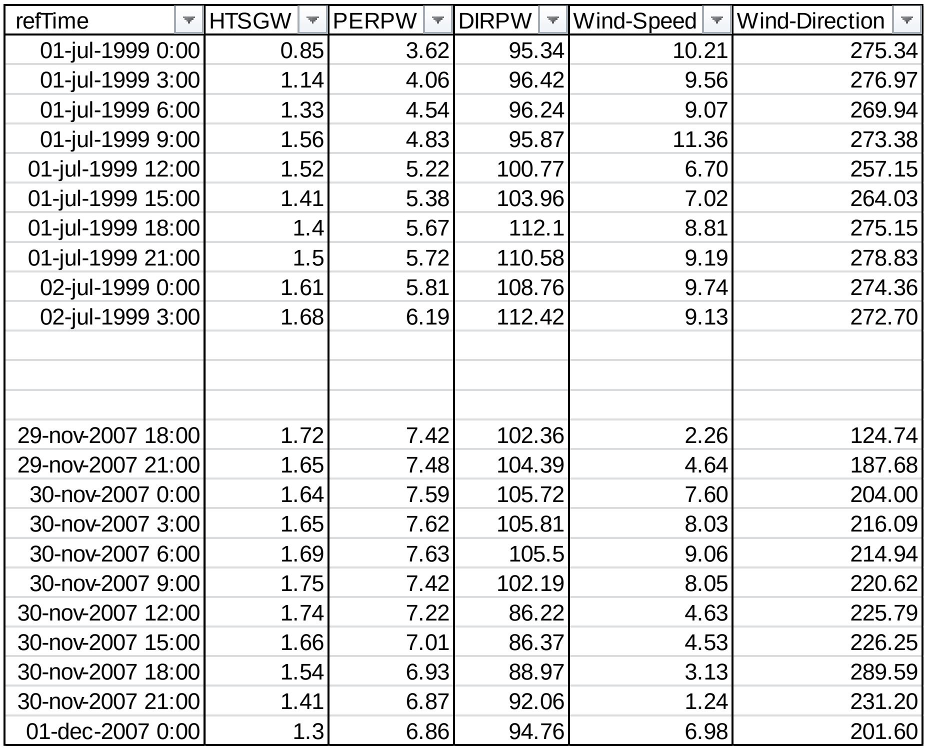
FIGURE O-29: WAVE AND WIND DATA OFFSHORE IN NODE 10

At node 10 data is gathered from 1 July 1999 to 1 December 2007. During this time period of 8 years and 5 months, every 3 hours the described variables (Significant wave height (HTSGW), wave period (PERPW), wave direction (DIRPW), wind-speed and wind-direction (where it is going not where it is coming from) are measured and recorded resulting in a total dataset of 24602 different time steps see Table O-9.

---

[11] The data from HURWave is not suitable to determine the downtime, because the program HURWave creates only hurricanes and tropical storms and no daily values.

TABLE O-9: USED RAW DATA FROM NODE 10



refTime	HTSGW	PERPW	DIRPW	Wind-Speed	Wind-Direction
01-jul-1999 0:00	0.85	3.62	95.34	10.21	275.34
01-jul-1999 3:00	1.14	4.06	96.42	9.56	276.97
01-jul-1999 6:00	1.33	4.54	96.24	9.07	269.94
01-jul-1999 9:00	1.56	4.83	95.87	11.36	273.38
01-jul-1999 12:00	1.52	5.22	100.77	6.70	257.15
01-jul-1999 15:00	1.41	5.38	103.96	7.02	264.03
01-jul-1999 18:00	1.4	5.67	112.1	8.81	275.15
01-jul-1999 21:00	1.5	5.72	110.58	9.19	278.83
02-jul-1999 0:00	1.61	5.81	108.76	9.74	274.36
02-jul-1999 3:00	1.68	6.19	112.42	9.13	272.70
29-nov-2007 18:00	1.72	7.42	102.36	2.26	124.74
29-nov-2007 21:00	1.65	7.48	104.39	4.64	187.68
30-nov-2007 0:00	1.64	7.59	105.72	7.60	204.00
30-nov-2007 3:00	1.65	7.62	105.81	8.03	216.09
30-nov-2007 6:00	1.69	7.63	105.5	9.06	214.94
30-nov-2007 9:00	1.75	7.42	102.19	8.05	220.62
30-nov-2007 12:00	1.74	7.22	86.22	4.63	225.79
30-nov-2007 15:00	1.66	7.01	86.37	4.53	226.25
30-nov-2007 18:00	1.54	6.93	88.97	3.13	289.59
30-nov-2007 21:00	1.41	6.87	92.06	1.24	231.20
01-dec-2007 0:00	1.3	6.86	94.76	6.98	201.60

To get a better overview of the data in Table O-9 the data is binned and counted. The results are given in Table O-10.

TABLE O-10: SIGNIFICANT WAVE HEIGHT, SIGNIFICANT WAVE PERIOD AND WIND SPEED OF TABLE O-9 BINNED AND RANKED

Hs	*Frequency*	*Cumulative %*
0.5	642	2.61%
1.0	4417	20.56%
1.5	9100	57.55%
2.0	6545	84.16%
2.5	3051	96.56%
3.0	678	99.32%
3.5	115	99.78%
4.0	28	99.90%
4.5	9	99.93%
5.0	4	99.95%
5.5	2	99.96%
6.0	3	99.97%
6.5	2	99.98%
7.0	2	99.99%
7.5	2	100.00%
8.0	1	100.00%
8.5	0	100.00%
More	0	100.00%

T	*Frequency*	*Cumulative %*
0	0	0.00%
1	0	0.00%
2	0	0.00%
3	8	0.03%
4	162	0.69%
5	1071	5.04%
6	3898	20.89%
7	10365	63.02%
8	7155	92.11%
9	1607	98.64%
10	199	99.45%
11	76	99.76%
12	23	99.85%
13	22	99.94%
14	10	99.98%
15	4	100.00%
16	1	100.00%
More	0	100.00%

Wind Speed	*Frequency*	*Cumulative %*
0	0	0.00%
2	677	2.75%
4	3175	15.66%
6	7317	45.40%
8	8639	80.52%
10	4106	97.21%
12	586	99.59%
14	68	99.87%
16	18	99.94%
18	8	99.97%
20	2	99.98%
22	2	99.99%
24	1	99.99%
26	1	100.00%
28	1	100.00%
30	0	100.00%
32	0	100.00%
More	0	100.00%

The extremes are easily readable from this table. Also the probability of exceedance is readable from this table. The extremes are caused by Caribbean hurricanes. However, it is not the extreme value of the hurricane, only high values caused by hurricanes. As a time step of 3 hours is used it is very unlikely the extremes of the hurricanes coincide with measured values. This principle is sketched in Figure O-30.

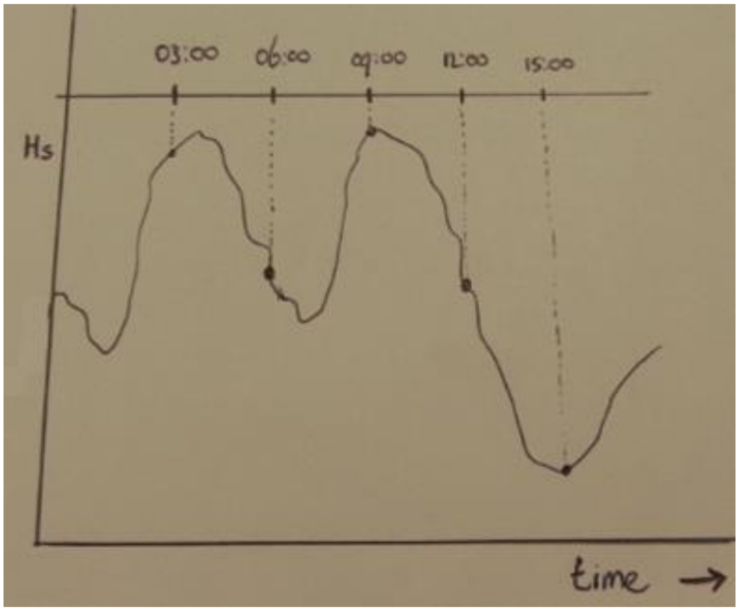
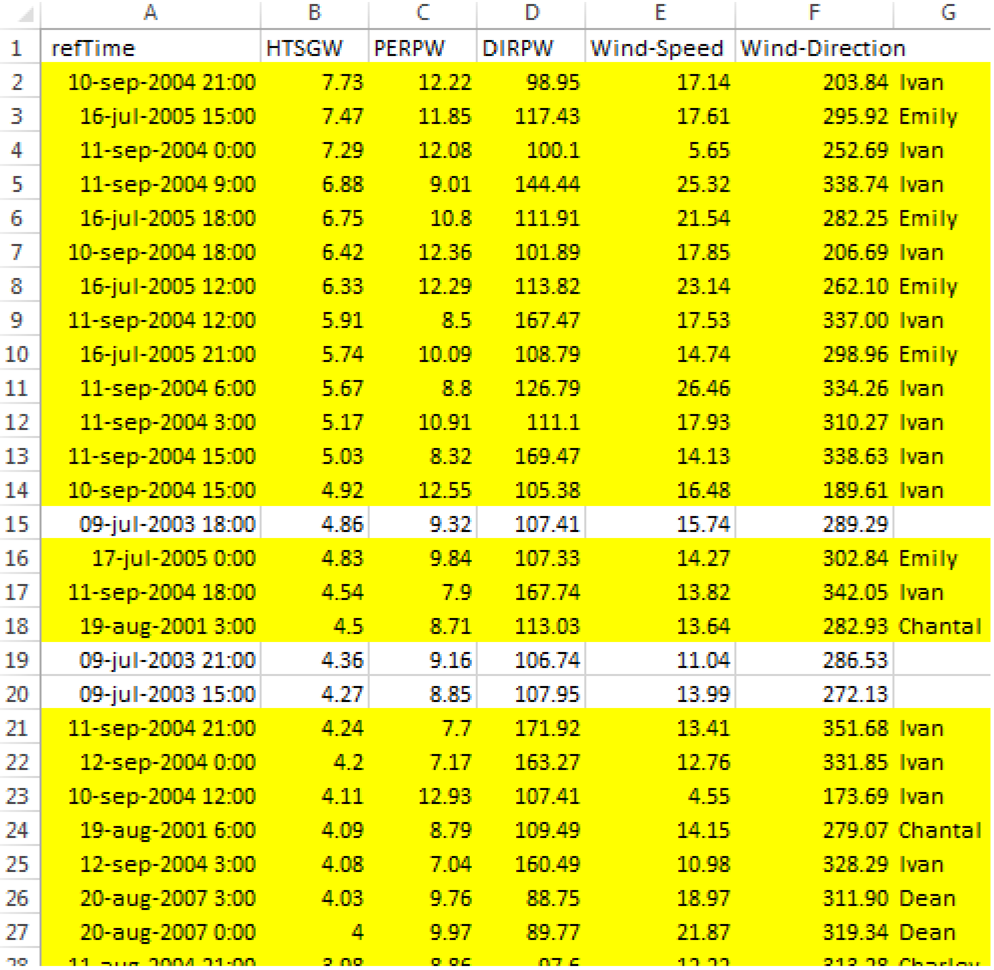


FIGURE O-30: SKETCH OF WAVE RECORDINGS

For an extreme analysis those extreme values are very important. For estimating the SLS (downtime) this isn't a problem. The downtime looks at the daily values.

It is assumed that during the occurring of a hurricane the port is shut down as no ships are sailing offshore anyways. That is why the hurricanes are filtered out of the data. If the data is sorted on highest wave height and sorted on highest wind speeds the hurricanes are easily detected. Between July 1999 and December 2007 the flowing hurricanes influenced note 10 and thereby the Goat Islands: Iris (2001), Chantal (2001), Ivan (2004), Charley (2004), Emily (2005), and Dean (2007). Out of these hurricanes Ivan was the most extreme and held on for more than a day. This results in a total downtime of 7 days (6 hurricanes and 1 extra for Ivan) during 8 years and 5 months (the duration of the raw data in Table O-9)

Table O-11: The raw data from Table O-9 ranked on wave height and wind speed. The yellow rows are hurricanes. In the last table column of the hurricane is listed.



	A	B	C	D	E	F	G
1	refTime	HTSGW	PERPW	DIRPW	Wind-Speed	Wind-Direction	
2	10-sep-2004 21:00	7.73	12.22	98.95	17.14	203.84	Ivan
3	16-jul-2005 15:00	7.47	11.85	117.43	17.61	295.92	Emily
4	11-sep-2004 0:00	7.29	12.08	100.1	5.65	252.69	Ivan
5	11-sep-2004 9:00	6.88	9.01	144.44	25.32	338.74	Ivan
6	16-jul-2005 18:00	6.75	10.8	111.91	21.54	282.25	Emily
7	10-sep-2004 18:00	6.42	12.36	101.89	17.85	206.69	Ivan
8	16-jul-2005 12:00	6.33	12.29	113.82	23.14	262.10	Emily
9	11-sep-2004 12:00	5.91	8.5	167.47	17.53	337.00	Ivan
10	16-jul-2005 21:00	5.74	10.09	108.79	14.74	298.96	Emily
11	11-sep-2004 6:00	5.67	8.8	126.79	26.46	334.26	Ivan
12	11-sep-2004 3:00	5.17	10.91	111.1	17.93	310.27	Ivan
13	11-sep-2004 15:00	5.03	8.32	169.47	14.13	338.63	Ivan
14	10-sep-2004 15:00	4.92	12.55	105.38	16.48	189.61	Ivan
15	09-jul-2003 18:00	4.86	9.32	107.41	15.74	289.29	
16	17-jul-2005 0:00	4.83	9.84	107.33	14.27	302.84	Emily
17	11-sep-2004 18:00	4.54	7.9	167.74	13.82	342.05	Ivan
18	19-aug-2001 3:00	4.5	8.71	113.03	13.64	282.93	Chantal
19	09-jul-2003 21:00	4.36	9.16	106.74	11.04	286.53	
20	09-jul-2003 15:00	4.27	8.85	107.95	13.99	272.13	
21	11-sep-2004 21:00	4.24	7.7	171.92	13.41	351.68	Ivan
22	12-sep-2004 0:00	4.2	7.17	163.27	12.76	331.85	Ivan
23	10-sep-2004 12:00	4.11	12.93	107.41	4.55	173.69	Ivan
24	19-aug-2001 6:00	4.09	8.79	109.49	14.15	279.07	Chantal
25	12-sep-2004 3:00	4.08	7.04	160.49	10.98	328.29	Ivan
26	20-aug-2007 3:00	4.03	9.76	88.75	18.97	311.90	Dean
27	20-aug-2007 0:00	4	9.97	89.77	21.87	319.34	Dean

3.3 Translating offshore data to near shore data

With the hurricanes out of the dataset of Table O-11 more or less the top 30 of wave heights and top 15 of wind speeds are filtered. The other time sets are inserted manually into MIKE 21 starting with the highest wave heights and highest wind speeds. The waves and wind speed offshore are the most important factor for the wave height near shore.

Finding the wave heights in the approach channel for all the data is the goal of this modeling step. There is downtime, if the wave height is higher than 1.5 meters in the L_2 part of the approach channel (see also 3.1, Design criteria). The modeled point is visible in Figure O-31.

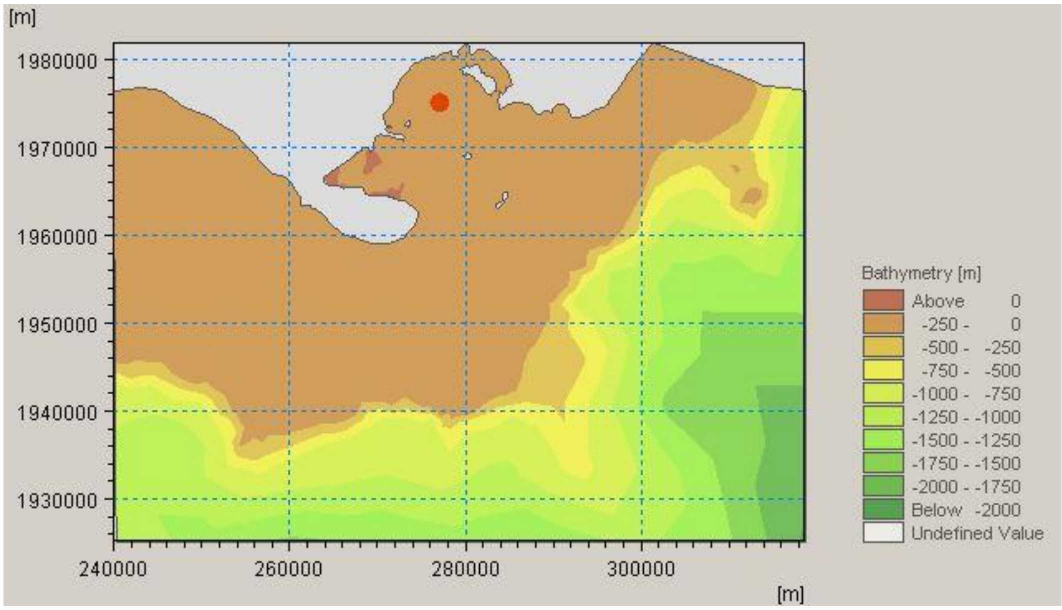


FIGURE O-31: MODELED WAVE HEIGHT IN THE APPROACH CHANNEL AT THE L_2 PART

For extra purposes the wave height at the entrance port is also modeled, see Figure O-32.

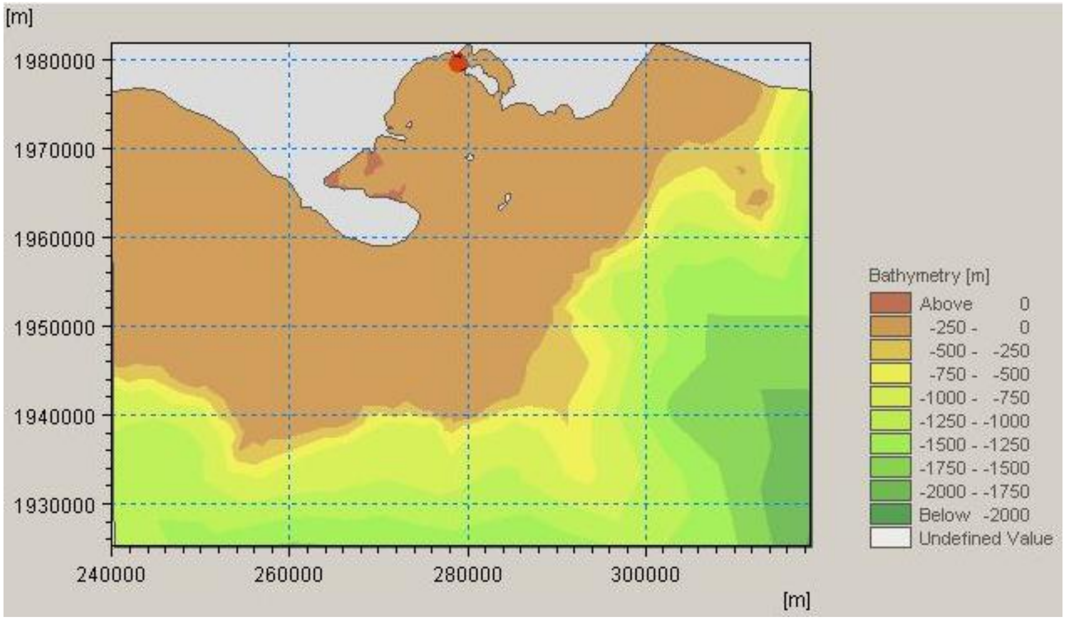


FIGURE O-32: MODELED WAVE HEIGHT AT THE ENTRANCE OF THE PORT

The other time sets (excluding hurricanes because those days give already downtime) are inserted into MIKE 21. The boundary conditions offshore are the time sets (five variables; significant wave height, period of the wave, direction of the incoming waves, wind speed and direction of the wind). MIKE 21 models the waves from offshore to the near shore. The three days which gave the highest wave heights in the approach are present below. Clearly visible in Figure O-33, Figure O-34, and Figure O-35 high offshore waves dissipate much, because of the shallow area, islands and reefs.

3.3.1 Wave heights in approach channel 9 July 2003

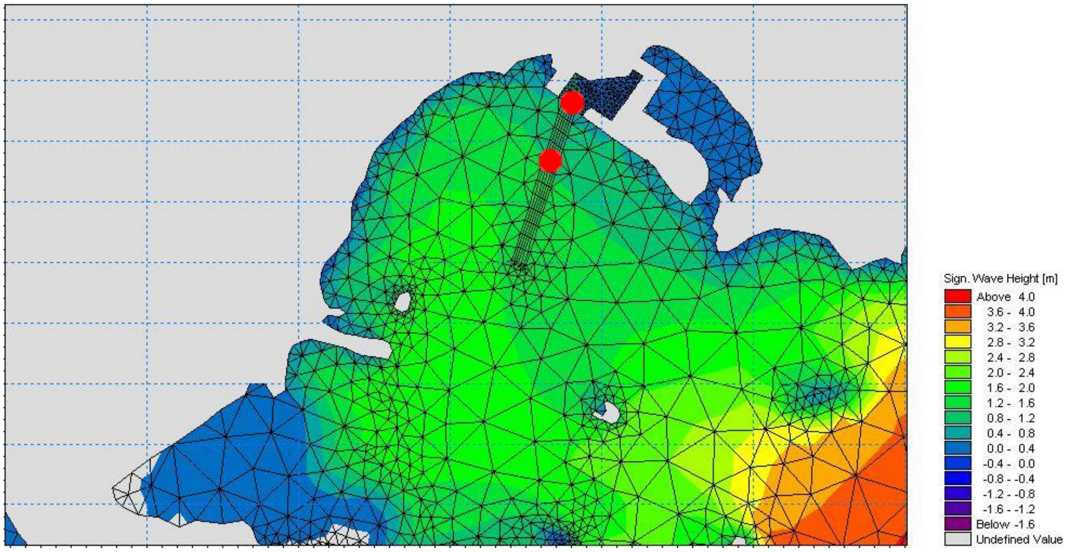


FIGURE O-33: WAVE HEIGHTS IN THE APPROACH CHANNEL AT 9 JULY 2003

During 9 July 2003 tropical storm Claudette afflicted Jamaica. Despite the high waves and high wind speeds the waves in the approach channel are just below 1.5 meter, so Claudette wasn't extreme enough to cause downtime.

3.3.2 Wave heights in approach channel 16 January 2000

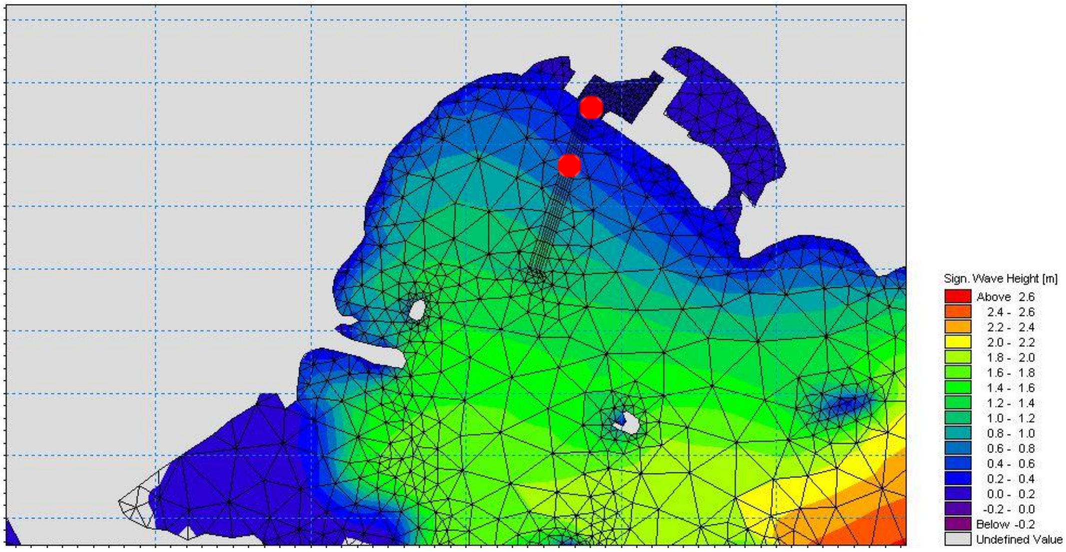


FIGURE O-34: WAVE HEIGHTS IN THE APPROACH CHANNEL AT 16 JANUARY 2000

The wave height in the approach channel at 16 January 2000 (see Figure O-34) is 1.09 meters which is lower than 1.5 meters

3.3.3 10 July 2003

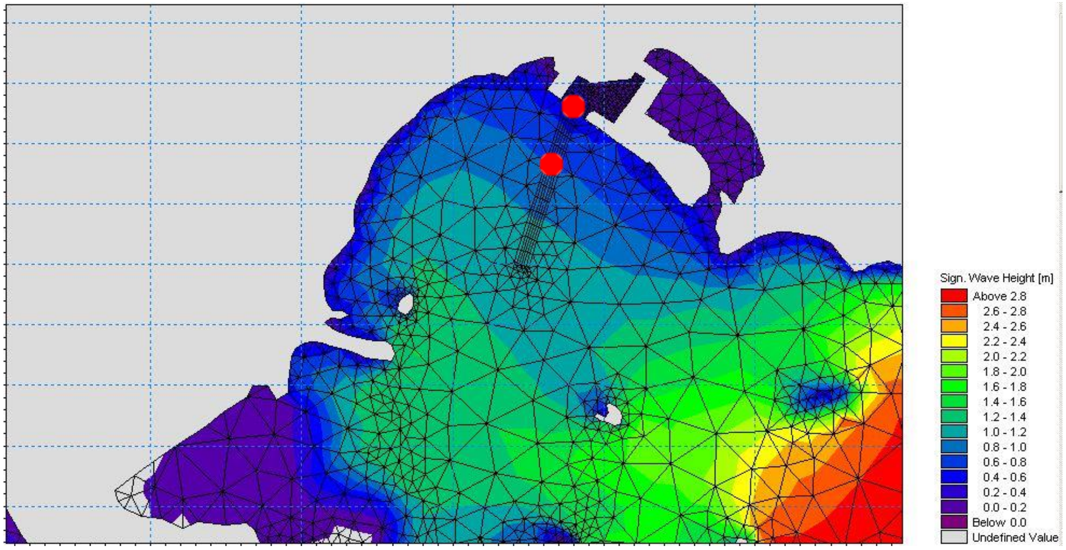


FIGURE O-35: WAVE HEIGHTS IN THE APPROACH CHANNEL AT 10 JULY 2003

The wave height in the approach channel (see Figure O-35) at 10 July 2003 is 1.03 meters which is also lower than 1.5 meters.

3.4 SLS conclusion

The total downtime in 8 years and 5 months is 7 days. All of the downtime days are caused by hurricanes. 7 days during a time series of 8 years and 5 months means less than 1 day of downtime a year which is assumed to be acceptable for a port.

4 Conclusion

The extreme wave conditions with a return period of 1/200 years at the entrance of the port are:

- Surge level	2.03 meters
- Wave height	4.01 meters
- Wave period	4.49 seconds
- Wave and wind direction	From the south

The new port is not operational during hurricanes, because of the too high waves and wind speeds. 8 years and 5 months of data is investigated and there are 7 days in which the wave height and winds speeds were too extreme. This is including the hurricanes during that period. The new port will have an average downtime of one day a year without breakwaters, so the Portland Bight gives really sheltered area for developing a port.

5 Recommendations

For the design of port at the Goat Islands some wave analysis is done, but not every aspect is (fully) investigated. Also some assumptions are made. Therefore some recommendations are made:

- Downtime

The downtime is modeled with offshore data. The waves are modeled near shore, but the wind speeds offshore are assumed the same near shore. This is not correct and for a better analysis the wind speeds of the Portland Bight has to be used for establishing the downtime. Unfortunately this data is not available.

- Return period

For the extreme wave condition the return period of 1/200 years is taken. This value is an estimation between the Dutch and the Caribbean norms. This return period should be further investigated to come up with the return period which gives the lowest risk.

- Behind the Great Goat Islands and the fish sanctuary

The extreme wave conditions give also very high values for the surge level and waves behind the port. This is because the water surface behind the Goat Islands is blocked. Due to those extreme values the back of the port needs protection. Also the impact of those conditions influences the fish sanctuary. This phenomenon should be investigated further.

- Resonance

Also a further study needs to be done for the waves in the port. It is not preferable that the waves are resonating inside the port. This can be done by modeling with MIKE 21 Boussinesq waves.

- Sedimentation and (cross) currents

The material at the bottom of the Portland Bight is not known. To establish the sedimentation inside the port and in the approach channel with MIKE 21 this should be investigated for the modeling. Afterwards the maintenance dredging can be determined. Due to this detailed modeling also the currents inside the bay can be investigated for ship sailing purposes.

6 References

Banton, J. D. (2001). Readme HURWave.

FEM. (1998). *1.001 Rules for the design of hoisting appliances.* European Federation of Materials Handling.

IPCC, I. p. (2013, 10 25). *IPCC fourth assessment panel on climate change*. Retrieved from www.ipcc.ch: http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains3-2-1.html

Thoresen, C. A. (2006). *Port Designer's Handbook: Recommendations and Guidelines.* Bodmin: MPG Books.

Velsink, H. L. (2012). *Ports and Waterways.* Delft: VSSD.

Verhagen, H. J. (2012). *Breakwaters and closure dams.* Delft: VSSD.

Appendix P SWOT analysis

SWOT analysis is an abbreviation for Strength, Weaknesses, Opportunities and Threats analysis. This analysis is generally used to identify the company's positives and negatives sides inside the company and in the external environment. After this identification a strategy can be chosen for the company. (University of Kansas, 2013) In this case, the port design will be evaluated with the SWOT analysis, so strengths, weaknesses, opportunities and threats will be known. At the end measures are presented to create a higher value for the port by making the positive sides more positive and to make the negative sides less negative. .

1 SWOT

In a SWOT analysis the strengths and weaknesses are called internal factors and the opportunities and threats are called external factors (University of Kansas, 2013). In this case the internal factors consist of the design aspects of the port. These are all location specific. The external factors in this SWOT analysis are about the opportunities and threats which are not location specific. In the external factors the opportunities and threats are discussed from the point of view from CHEC and from Jamaica. The strengths, weaknesses, opportunities and threats are described in the next sections.

1.1 Strengths

The location specific strengths of the port design can be wrapped into three different strengths. These three strengths are described and discussed below.

- **Not many changes are needed in the area**
  The area chosen for the port is very flat and there are not much settlements. It is relative easy to use this land for the port, because the area is flat. The number of settlements in the area is very low, so not much people should be moved. A few people have to be moved, which is almost unavoidable. For a possible expanding of the port the same arguments hold as for the port itself. For expansion there are not a lot of changes required in the area. This is also discussed in appendix I, Site selection.

- **Natural sheltered area**
  Besides a suitable land area for the port, the sea side of the port is also very favorable. The bay has natural calm waves because of its shallow seabed and protection from islands and reefs. This is discussed in appendix I, Site selection. Calm waves are favorable for sailing, mooring, berthing, and handling of vessels. Daily calm waves give also a low value for the downtime. In case of a storm, the waves are relatively low in the bay, which is also an advantage for the vessels and the port. This is discussed in appendix O, Wave analysis.

- **Short hinterland connection to current network**
  The location of the port is close to the current network of Jamaica. Due to the location of the port the hinterland connection will be short. The hinterland connection is discussed in appendix N, Hinterland connection.

An overview will be shown in Table P-1 in section 1.5.

1.2 Weaknesses

The location specific weaknesses of the port design can be wrapped into three different weaknesses. These three weaknesses are described and discussed below.

- **Environmental impact**
  The Portland Bight Area, which contains the bay, the surrounding land area, and the Goat Islands, is an environmental protection area. The environmental impact can be divided in different segments. The first one is the destruction of the Little Goat Island. This island will be used for the land area of the port. Another segment is the fish sanctuary behind the Great Goat Island. The new port will be constructed next to this sanctuary. During the building phase the sanctuary will be harmed for example by constructing the sheet piles. Also during operational phase the fish sanctuary will harmed. The port blocks the north entrance of the fish sanctuary, so there is only a south entrance. This will change the current situation. Next to this the water level set up and the waves will be higher than nowadays, especially during hurricanes. The last segment is the environment impact for the bay. The currents and waves will change in the rest of the bay, because of the port and the approach channel. The waves will propagate different due to the port and its approach channel. These three different segments are described in appendix J, Further investigation of five port locations and appendix O, Wave analysis.

- **Dredging to 27 meter**
  The bay is very shallow, as mentioned earlier. The shallowness of the bay is also a weakness. If dredging to 27 meters is required for very big vessels in the future, the impacts on the environment and the costs will be very high. This aspect is also described in appendix J, Further investigation of five port locations.

- **Hurricane area**
  Jamaica lies in a hurricane area. This is a weakness, because a hurricane will always have an impact on the port, no matter what the level of port protection is. In theory it is possible to create preventive measures for all possible hurricane waves. In reality this will be very expensive, therefore a risk needs to be accepted.

An overview will be shown in Table P-1 in section 1.5.

1.3 Opportunities

The non-location specific opportunities of the port can be wrapped into two different opportunities. These two opportunities are described and discussed below.

- **Throughput growth**
  One of the opportunities is a growth in the container throughput. A growth in throughput will be a direct opportunity for CHEC to make more profit. In case of a variable tariff (based on the throughput) for the land lease, as discussed in appendix E, Port model and financing scheme, a higher throughput will also be beneficial for Jamaica.

- **Boost for the economy because of jobs**
  As stated in a news article, mentioned in appendix A, Background information, it is expected that the new port will generate jobs. The new port will create jobs for Chinese people and for Jamaican people, so this is an opportunities for both parties.

An overview will be shown in Table P-1 in section 1.5.

1.4 Threats

The non-location specific threats of the port can be wrapped into two different threats. These two threats are described and discussed below.

- **Throughput decline**
  Where an increase of the throughput is an opportunity, a decline of the throughput is a threat. A decrease of the throughput will lead to a decrease of the income.

- **Impact on current port of Kingston**
  The new port will have an impact on the current port of Kingston. It is possible that the current transshipment of the port of Kingston will shift to the new port. In that case it will lead to a lower throughput for the port of Kingston. This is a threat for Jamaica.

An overview will be shown in Table P-1 in section 1.5.

1.5 Overview

In this section an overview of the strengths, weaknesses, opportunities and threats for the new port from the previous sections is shown. This overview is shown in Table P-1.

TABLE P-1: OVERVIEW OF THE STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS FOR THE NEW PORT

Internal		***External***	
Strengths	**Weaknesses**	**Opportunities**	**Threats**
Not much changes are needed in the area	Environmental impact	Throughput growth	Throughput decline
Natural sheltered area	Dredging to 27 meter	Boost for the economy because of job creation	Impact on current port of Kingston
Short hinterland connection to current network	Hurricane area		

2 Measures

With measures strengths and opportunities can be enlarged. Threats and weaknesses can possibly change in something positive or the impact can be minimized. The measures for this SWOT analysis will be given in this section.

2.1 Strengths

For the strengths there are no measures to make the strengths more positive than they already are. This is because of the fact that the strength are depended on the chosen location and not much can be changed to the location.

2.2 Weaknesses

For two of the three weaknesses measures are found. For the weakness dredging to 27 meter there will be no measure mentioned, because the shallowness of the area cannot be changed.

- **Environmental impact**
  Section 0 mentioned that this weakness can be divided in three different segments.
  One of the segments is the destruction of the Little Goat Island. If it is desirable, the destruction of this piece of nature can be compensated with new nature somewhere else.
  The second segment of the environmental impact is the fish sanctuary. During construction of the port it is almost impossible to not harm this sanctuary, but there might be ways to minimize the disturbances of the sanctuary during construction. During operational phase the fish sanctuary will also be harmed, because of the higher water levels and waves, especially during hurricanes. Maybe it is possible to mitigate this sanctuary. If this can be done, the issue of the fish sanctuary become smaller.
  The last segment is the environment impact for the bay. The currents and waves will change in the bay because of the port and the approach channel. What will change should first be further investigated, before a measure can be stated. Also the landside of the bay will change, especially the area where the port will be built. Also this impact should be investigate more, before measures can be made.

- **Hurricane area**
  Jamaica lies in a hurricane area. Luckily the Portland Bay is very shallow. This will decrease the height of the waves, but nevertheless the impact of a hurricane can be very large. In case of a hurricane the port should be closed for a (few) day(s). Since vessels don't sail during a hurricane or chose another route the demand will be lower than average in the days after. As mentioned in section 0, it is in theory possible to create prevention measures for all possible hurricane waves. In reality this will be very expensive, therefore a risk is accepted. This risk can be decreased by implementing (heavier) prevention measures.

2.3 Opportunities

For the two opportunities mentioned before measures are discussed below. With these measure the opportunities can be utilized.

- **Throughput growth**
  Causes for this opportunity can be being a good competitor or growth of the container flow through the Caribbean. The throughput can grow due to competitiveness to be better on (a) certain aspect(s) than the competitors. This can be achieved with a good strategy.
  If the overall container flow in the Caribbean grows, the throughput of the port might also grow. The flow can grow due to increase economies such as Brazil or due to an increase in import to the US or due to an increase of trade in the Caribbean. Another reason for a growing container flow might be the Nicaragua Canal, see appendix A, Background information. These factors cannot be influenced with a measure.
  The competitiveness, container flow and the trade routes are described in appendix D, Competitiveness.

- **Boost for the economy because of jobs**
  First there are workers needed for the building of the port. After the building is finished a lot of staff is necessary. More jobs could be created by the development of the industry in the port, like mentioned in appendix H, Industrial area of the port.

2.4 Threats

For the two threats mentioned before measures are discussed below. With these measure the impact of the threats might be less.

- **Throughput decline**
  This threat can happen due to competitiveness or a decreasing flow. If the competitors perform better on one or more aspects shipping companies might choose another port for their transshipment. How competitors will act is uncertain and might lead to lower income for the port. It is possible to act on the competitiveness to avoid a decreasing throughput. This can be done by a constant investigation in the strategies of the competitors.
  A decreasing flow of containers through the Caribbean can also lead to a decline in throughput. This might happen if the economy of the USA will decrease or when importance of trade routes will shift. These factors cannot be directly influenced by Jamaica or CHEC with a measure. The strategic that can be chosen against a decreasing flow of containers through the Caribbean is adapted port planning as described in appendix M, Adaptive port planning. If there is demand, the next phase of the new port will be finished. If the demand is not growing, the next phase of the port will not be build. Only an immediately drop of throughput cannot be absorbed by adapted port planning.
  The competitiveness, container flow, and the trade routes are described in appendix D, Competitiveness.

- **Impact on current port of Kingston**
  Due to the new port the throughput of the current port of Kingston can decrease. In response to this threat the port of Kingston can be redeveloped, this is discussed in appendix F, Redevelopment of the port of Kingston.

3 References

University of Kansas. (2013). *SWOT Analysis*. Retrieved 10 22, 2013, from Community Tool Box: http://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and-resources/swot-analysis/main#.UmhH8XDmN1d

Appendix Q List of figures

Appendix R List of tables