The Dikkowita Marina Project

The implementation of a marina in the Dikkowita Fishery Harbour

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PREFACE

This report is the final product of a multidisciplinary project for our master programme at the Delft University of Technology. It describes the research about the implementation of a marina in the Dikkowita Fishery Harbour. This subject has overlap with both our civil engineering master tracks Hydraulic Engineering and Transport & Planning.

In this report one can read about the possibilities of the implementation of a marina in the harbour of Dikkowita. Very important is the economic value of a marina for Sri Lanka and what kind of effects this gives to the country. Therefore, this report is informative for governmental organisations, but also for companies who see opportunities to invest in marinas or who would like to help to develop this sector.

During our stay we had the pleasure to have a meeting with CDR International. Their practical advice and support with respect to fishery harbours, coastal and marine engineering combined with their experience in Sri Lanka was really helpful for us. We also met marina expert Mr. S. Arrol, who gave us valuable information about marinas in Sri Lanka and was willing to meet us twice during his short stay in Sri Lanka. We are very thankful for the meetings with both of these parties.

We are grateful for the hospitality of EML Consultants and its employees, who gave us a beautiful place to work and were very friendly and helpful during our stay. We would like to specially thank Mr. C. Fernando for giving us this project and providing us with help and information, whenever we needed this. It was a great collaboration, where he could share his knowledge about the fishery harbours and projects and we were able to share what we learned about marinas. Last we would like to thank Mr. H.J. Verhagen, who put us in touch with Mr. Fernando and helped us with the preparations for our study trip to Sri Lanka.

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SUMMARY

The harbour of Dikkowita, situated just 10 kilometers north of Colombo, is one of the biggest fishery harbours of Asia. The construction was finished in 2011 and after 4 years of use the capacity of the export part is not reached and is not likely to be reached in the future. The large basin is underutilized, which is a waste of the investment. Next to that, the local fishermen are not contented with the export fishery fleet in their surroundings. They accuse them of fishing in their waters and reducing their chances at exporting fish. Beyond that this is true or not, this gave a very political controversial situation.

A solution for the underutilization could be the implementation of a marina in the Dikkowita Harbour. A marina perfectly fits into the Western Province Megapolis Planning Project, a project to make the western coast of Sri Lanka one of the most important economic centres of South Asia. Implementing a marina would start a completely new business in the country and would contribute to an even more attractive waterfront. Therefore, it perfectly fits in this development project. It will have a high economic value and will also attract tourists. Besides, the Sri Lankan environment is perfect for yachting. This is because of its beautiful beaches and warm double monsoon climate, where half the year the weather is calm, which is ideal for motor yachts, and the other half of the year moderate winds occur, which is ideal for sailing. From the stakeholder analyses can be concluded that next to the governmental organisations the local fishermen are very important. This led to the decision to leave the northern part the same and only change the southern basin.

In this report, three alternatives where introduced. One solution was to completely remove the export part of the harbour and implement a marina there, while the other two solutions were about combining a marina with the export part of the harbour. For a combination of a marina and the export harbour, the southern basin has to be expanded. The two solutions differ in the moment of construction of this expansion. The different solutions are compared in a multi-criteria decision analysis. The solution without the export harbour, *Full Marina*, is safer for the yachtsmen, has higher boat accessibility, is more elegant and has lower investment costs than the other alternatives. These are reasons why this solution is tested as best in the multi-criteria analysis.

The *Full Marina* was worked out to give an impression of the implementation of a marina. This marina provides place for 218 yachts. Facilities like the hotels, restaurants, shops, car parking, boat lifting, restrooms and a boat parking area are present. For this marina, the outside breakwater has to be raised to reduce overtopping. Also a floating breakwater has to be implemented to ensure that waves inside the harbour will be low enough. To make the marina a success, the infrastructure also has to be upgraded. The harbour has to be connected to Colombo and Negombo with higher quality roads. The investment will most likely be done by an investor. The government gains profit from the project, but the investor will have a negative net present value. However, profit can be generated from other facilities, like hotels, restaurants and shops.

Figure 1 Impression of the final design

TABLE OF CONTENTS

ABBREVIATIONS

The following list describes the meaning of various abbreviations used throughout this report.

MCDA	Multi-criteria decision analysis
NPV	Net present value
CFC	Ceylon Fisheries Corporation
CFCH	Ceylon Fishery Harbours Corporation
DFAR	Department of Fisheries and Aquatic Resources
HM	Harbour manager
MFARD	Ministry of Fisheries and Aquatic Resources Development
STDA	Sri Lanka Tourism Development Authority
TPR	Tidal prism ratio

Used currency exchange rates:

1	United States Dollar	=	140.31	Sri Lankan Rupees
1	Euro	=	159.72	Sri Lankan Rupees
1	Euro	=	1.13	United States Dollar

1 INTRODUCTION

1.1 CONTEXT OF RESEARCH

In Sri Lanka the Ceylon Fishery Harbour Corporation (CFHC) is continuously trying to improve the standards of the fishermen. Money is invested in new fishery harbours as well as in the improvement of old harbours. Despite these harbours are never profitable, they create a lot of value for the local economy. Lower class people are provided with jobs, a very important issue in this country (Ceylon Fishery Harbours Corporation, 2015; Fernando, 2015).

Most of the fishery harbours in Sri Lanka are of very small scale. The fishery harbour of Dikkowita is however one of the largest of Asia with 11.7 hectares of basin area. The harbour, which was finished in June 2011, has cost 53 million euros, partly funded by a HSBC and a Dutch association, the ORET-programme. Royal HaskoningDHV was the supervisor of the project and the designer and constructor was BAM international (BAM International, Presentation Dikkowita Fishery Harbour Project).

This huge investment made it possible to also accommodate space for international fishing boats with the purpose to export fish. However, the size of this export part of the harbour seems to be too high. Capacities are not reached and are not likely to be reached in the future. The underutilized harbour must therefore be prepared for some changes. A possibility to give more value to the non-used space is implementing a marina. Building a marina could be the start of a completely new business in Sri Lanka, a business which totally fits here between the beautiful beaches and could generate a lot of economic value.

1.2 PROBLEM DEFINITION

As mentioned above, the harbour was partly funded by the ORET-programme. A part of this fund was a gift, the other part was a soft-loan provided together with the HSBC. The Sri Lankan government has to pay back this loan. Therefore, the harbour has to make enough profit and has to be valuable enough for the economy. Unfortunately, due to various reasons the harbour turned out to be not profitable enough and not valuable enough for the economy.

The objectives of the new harbour were to create a good berthing place for the local fishermen and to boost economy by creating an export fishery harbour. However, a conflict arose between the local fishermen and the export fishery part of the harbour. Local fishermen claim that the international fleet would fish in their waters and would reduce their chances at exporting fish (Harbour Manager Dikkowita). Beyond that these claims are true or not, a political controversial issue exists and the export harbour has been closed for a while.

Another reason of the disappointing revenues of the Dikkowita Harbour is the low amount of foreign boats that actually make use of the harbour. This is the part where the most income should be generated (Fernando, 2015). Most of the time three to six boats are found in the basin, where anchorage facilities are for 40 to 50 vessels. Much more money could be earned if more companies would unload their vessels here.

So concluded can be that the combination of the two basins, the export and local fishermen basin, gives conflicts because the fishermen feel disadvantaged by the presence of the export fleet. Besides that, the export part of the harbour is not functioning well with respect to its low utilization. Filling up the underutilized part of the harbour with a marina could be a solution for the capacity problem. However, this will not be a solution for the conflict between the local fishermen and the export harbour. A solution for both the problems could be to replace the export harbour by a marina. This would on the other hand be a waste of the chance to make Sri Lanka a major fish export country.

Implementing a marina immediately gives another problem. It would be the first marina in Sri Lanka, so it is hard to predict what the demand will be and what the market would look like. No knowledge about marinas is available in the country and the business would start at zero.

1.3 GOAL

The goal of this research project is to investigate the implementation of a marina in the harbour of Dikkowita to utilize the overcapacity of the fishery harbour and to possibly evade the conflicts with the fishermen. Essential is to find a more profitable solution which creates more value for the country than the present situation. The implementation of the marina has to be worked out in a design.

1.4 STRUCTURE AND SCOPE OF THE REPORT

The report consists of three parts, namely the analysis, a proposition of the different solutions and a last part where the best solution is worked out in more detail. The analysis, chapter 2, focusses on four different subjects. First the original harbour is analysed and the problems are given. The possible solution, a marina, is discussed in the following part. Next subject are the weather conditions around Dikkowita and if these weather conditions are good enough for yachting. The last part is a stakeholder analysis, followed by a conclusion. In chapter 3 the three best solutions for the problem are presented. Of these three solutions the layout, implementation of a floating breakwater, number of berths, water quality and the costs and incomes are discussed. The different designs are tested in a multi-criteria decision analysis. The best design follows from this analysis and is worked out in more detail in chapter 4. This final design gives an impression of how a marina could look like in the harbour of Dikkowita.

Noted must be that the final design of the report is not fixed and many other harbour layouts are possible, which is directly the reason that no structural designs are made. This report focusses on the possibility of implementing a marina in the Dikkowita Harbour and therefore also gives an impression of how that could look like. Giving a structural design is not the goal of this research.

2 ANALYSIS

The analysis exists of four parts. The first part is a view on the current harbour. Surroundings, facilities inside the harbour and the current use of the harbour are discussed here. In the next part is discussed weather a marina is a good option for the Dikkowita harbour and what design criteria are important here. Then a system analysis is done, where all weather and water conditions are analysed and where is reviewed if the ocean around Dikkowita is a good place for boating. The last part of the analysis is the stakeholder analysis and the chapter ends with a conclusion.

2.1 HARBOUR ANALYSIS

In this chapter the current harbour of Dikkowita is analysed. At first, the surroundings of the harbour are discussed. Secondly, the harbour itself and its facilities are analysed. The chapter concludes with investigating the current incomes and expenses of the total harbour and the two different parts of the harbour separately.

2.1.1 SURROUNDINGS

Before analysing the harbour itself, it is necessary to analyse the surroundings. In figure 2 it is shown which area is used for what function. The orange area is the urbanized area, the purple area is the power plant and the light blue area is the Dikkowita Harbour. The roads and waterways are also given in this figure.

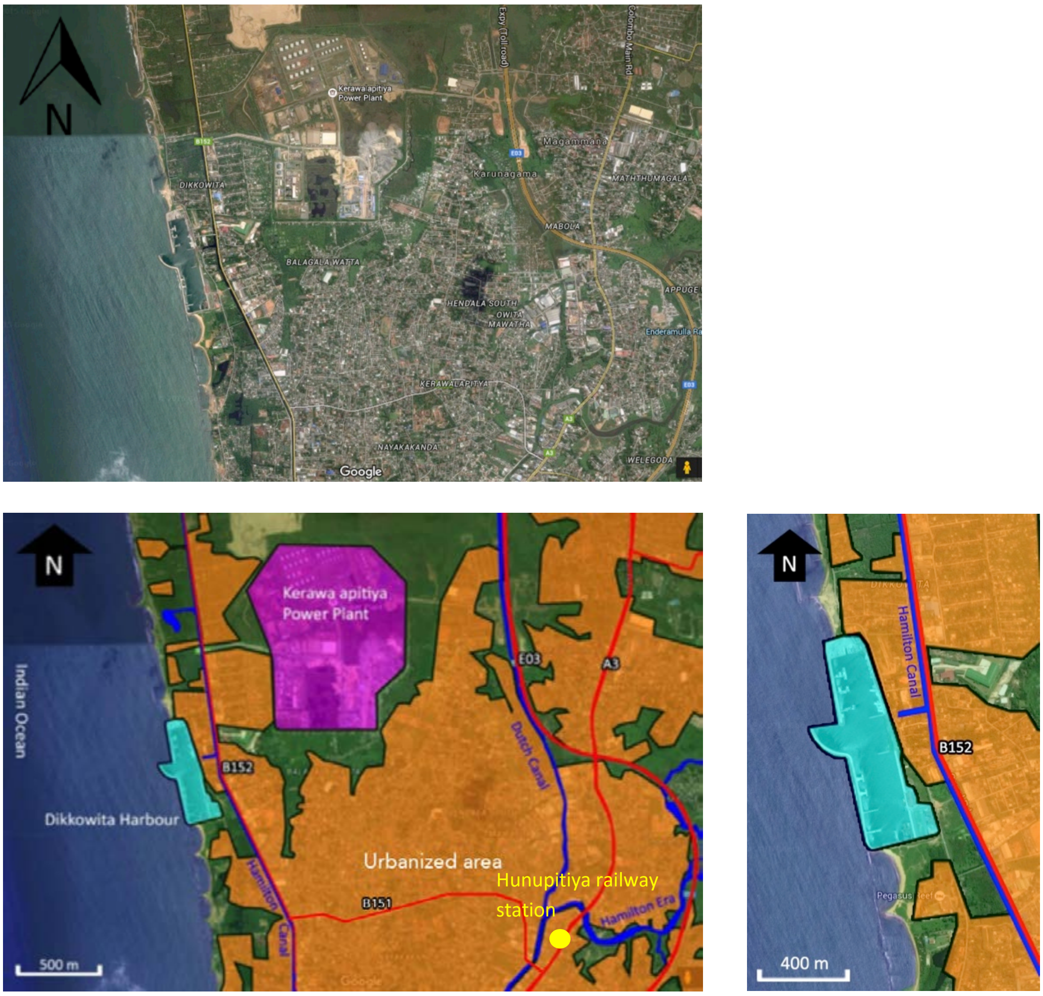


Figure 2 Analysis of the surroundings (Google, 2015)

The harbour is located in an urbanized area of the suburbs of Colombo. Along the coastline south of the harbour are beaches, hotels and restaurants located.

The Kerawalapitiya Power Plant, also known as the Yugadanavi Power Plant, is a large power station in the area of Dikkowita. It is the second largest power plant of Sri Lanka and generates 1800 GWh annually. 100.000 square meters of the area around Dikkowita is used for this power plant. (Nizam)

The canal closest to the harbour is the Hamilton Canal. This canal links the Kelani River with the Negombo Lagoon. The Hamilton Canal is part of the Dutch Canal, which links the Kelani River with the Puttalam Lagoon. The Dutch Canal was intended for the transport of spices, like for example cinnamon, but the local fisherman now use the canal to anchor their boats near their houses and to get to the sea. The canal is now too crowded by fishing boats to use for transportation. However, with all the fishing boats in the canal, a Sri Lankan ambiance is created and therefore the canal could have some touristic interest (Deputy Harbour Manager Dikkowita, 2015).

The north of the harbour cannot be expanded without demolition of urbanized area around it. At the south of the harbour, there are beaches and some unused land situated. This land could most easily be used for an expansion.

The road closest to the harbour is the B152. It is a small and busy road with one lane per direction, which makes it impossible for cars to drive faster than 20 kilometers per hour. There are a lot of traffic jams along this road. While the distance is only 10 kilometers, travelling by car from Dikkowita Harbour to the city centre of Colombo takes 1 to 1.5 hours. Further away from Colombo, the roads get quieter. Negombo is around 25 kilometers up north from Dikkowita and going there by car takes about 1.5 hours as well.

The express way, the E03, offers a fast connection between the Bandaranaike International Airport and Colombo. The express ways in Sri Lanka are not used very much and therefore have an overcapacity.

The closest train station, the Hunupitiya Railway Station, is more than 5 kilometers away from the Dikkowita Harbour, which is approximately half an hour by taxi in the current situation. The B152 and B151 roads connect the harbour with this train station. It is about 15 minutes by train to the central station in Colombo, Colombo Fort Station.

From Dikkowita many busses with small intervals ride up and down to Colombo and Negombo, but the quality is poor. They follow the B152 road and have a low speed, since they are dependent on the busy traffic on this road. The busses are local busses with often more passengers than seats and the seats are far below Western standards. The closest bus stop from Dikkowita Harbour is a 1.2 kilometers walk or taxi ride.

2.1.2 INSIDE TE HARBOUR

The harbour is divided into two areas. The northern basin is used by local fishermen to berth their boats. The facilities on this side of the harbour are therefore purely for the local fishermen, such as fuel dispensing units, toilets and a fish auction hall. The northern basin is designed for a capacity of 400 to 450 fishing boats, but due to ignorance of the fishermen about berthing their boats the right way (see figure 4), the capacity of the harbour drastically decreased. When the berths are used according the fingering method the capacity could be 400 to 450 fishing boats, but the fishing boats now berth parallel to the quay as can be seen in figure 3. This decreases the capacity of the northern basin to 200 fishing boats. Dimensions and other facts of the northern basin are shown in table 1.The fishing boats in the northern basin stay on average two or three days in the harbour, depending on the weather conditions and if some repairs have to be carried out. (Deputy Harbour Manager Dikkowita, 2015)

Figure 3 Method used in the Dikkowita Harbour

Figure 4 Fingering method

The southern basin of the harbour is used for the export. International boats come to this section to get supplies for their mother ship and to unload their fish. When the fish is unloaded, it will be processed in the processing hall. The fish will be loaded into trucks and transported to the Bandaranaike International Airport. From this airport the fish will be transported to countries all over the world and will be at their destination in 24 hours. The amount of boats on this side of the harbour is 3 to 6 boats on average. The total capacity of the southern basin is 40 to 50 boats, which means that this capacity is fa from reached. (Deputy Harbour Manager Dikkowita, 2015)

All office buildings are situated in the southern part of the harbour. The two parts are separated by fences and are highly secured because of the political problems between the local fishermen and the export sector as discussed before.

Table 1 shows some facts about the dimensions of the harbour and table 2 shows the main facilities in the harbour. An overview of the current harbour with all these facilities and their location is given in figure 5.

Table 1 Facts of the harbour (BAM International, Presentation Dikkowita Fishery Harbour Project)

Item	Location	Value
Area	Land	8.1 ha
	Basin	11.7 ha
Capacity	Northern Basin	200 (max. 450)
	Southern Basin	150
Quay wall length	Northern Basin	240 m
	Southern Basin	334 m
Draught	Northern Basin	-3.0 m
	Southern Basin	-5.0 m
	Harbour mouth	-6.0 m
Breakwater length	Northern	370 m
	Southern	660 m

Table 2 Main facilities available (Ceylon Fishery Harbours Corporation)

Southern basin	Northern basin
- Berthing for 40 to 50 Multi-day vessels at a time	- Berthing for approx. 400 to 450 Multi-day/One-day vessels
- 3 Offloading and packing units (350m² * 3)	- Auction, Net mending facilities
- 2 bunkering piers, 3 finger piers	- 3 finger piers (45m each)
- Administrative building with all the facilities	- Administrative building / Fuel office/ canteen
- Office places for registered companies	
- Ice- plant (20 tons per day / storage capacity 40 tons)	- Ice- plant (20 tons per day / storage capacity 40 tons)
- Waste management system	- Waste management system
- Oil spill protection equipment & firefighting systems	- Oil spill protection equipment & firefighting systems
- Vehicle packing areas	- Vehicle packing areas
- Space for containers storage facilities	- Fuel dispensing units / storage capacity
- 24 hrs security	- 24 hrs security
	- Providing safe and easy anchorage facility for 340 multi-day fishing vessels and 150 one day IBM boats

1. Main Gate
2. Weigh Bridge & Office
3. Security Office
4. Generator Room
5. Office Building
6. Vehicle Park
7. Ice Plant & Cold Storage
8. Offloading Building
9. Vehicle Park
10. Quay Wall
11. Pump House
12. Water Stock Tank
13. Groyne
14. Becon Lamp
15. Bunkering Pier
16. Finger Pier
17. Coast Guard Office
18. Net Mending Hall
19. Fish Auction Hall
20. Fuel Dispensing Units
21. Fuel Office
22. Toilets
23. Waste Water Treatment Plant
24. Slipway & Boat Yard

Figure 5 Overview of the current harbour (Google, 2015)

2.1.3 DEMAND FOR THE HARBOUR

In the northern basin of the harbour the local fishing boats are situated and in the southern part of the harbour the foreign boats are located. The local fishing boats are not allowed to use the southern part of the basin. For both basins the demand is described.

NORTHERN BASIN

As mentioned before, the northern basin has a capacity of approximately 400 to 450 boats. However, the fishermen are berthing in the wrong way and therefore there is only place for approximately 200 boats. On a busy day the number of boats exceeds 200, so some boats have to berth at another place. Despite that the total intensity is smaller than 400 boats not the maximum income is reached. There would be enough space if the fishermen berth in the right way. (Deputy Harbour Manager Dikkowita, 2015)

SOUTHERN BASIN

The southern basin has a capacity of approximately 40 to 50 boats. In the past there was an average intensity of 3 to 6 boats, but around the general elections in Sri Lanka of 2015, this part of the harbour was blocked and therefore no foreign fishing boats are entering the southern basin at the moment. It is expected that, when the political situation is stable again, this will change in the near future to the past situation (Harbour Manager Dikkowita). Taking into account that the harbour was already operating for 4 years, not much growth is expected in the intensity of export fishing boats. Concluded can be here that the capacity of 40 to 50 vessels is too high and thus will not be reached.

2.1.4 COSTS AND INCOMES

The current costs and incomes of the harbour are obtained using the monthly incomes and expenses sheets of the harbour, see appendix I (Deputy Harbour Manager Dikkowita, 2015). Because the export harbour stopped operating around February 2015, the costs and incomes of the harbour of the whole year of 2014 are used. The total costs, expenses and operational results of the north side, the south side and the total harbour are given in table 3.

Table 3 Profit calculations of the current harbour, see appendix I

	Northern basin (fishery)	Southern basin (export)	Total Harbour
Total income	$ 162,359.65	$ 604,704.03	$ 767,063.68
Total expenses	$ 61,060.67	$ 148,668.27	$ 209,728.94
Operational results	$ 101,355.68	$ 455,979.05	$ 557,334.74

The local fishery part of the harbour earns most money with the selling of fuel for the fishing boats, but the profit of this part of the harbour is less than 20% of the total profit of the harbour. This shows that the export part is the main profit maker of the harbour.

NORTHERN BASIN

The northern harbour part for local fishing boats generates revenue by different services and fees. General values for these services are given below. (Deputy Harbour Manager Dikkowita, 2015)

- The local fishing boats stay on average 2 or 3 days in the harbour
- In the season time there are 140 vessels on average in the harbour
- The income on berthing per boat per day is:
  - LKR 50 for 30 ft boat
  - LKR 100 for 34 to 45 ft boat
  - LKR 250 for 45 to 55 ft boat
  - LKR 1000 for 55 to 75 ft boat
- The income on processed fish is LKR 1/kg
- Each boat needs on average 4,000 litres of fuel. The revenue on one litre of fuel is LKR 2.37
- The average fish catch of a foreign vessel is 8,000 kg
- The price of lifting a boat out of the water is LKR 30,000
- The maintenance costs paid to the harbour are on average $30 per feet per year
- The average ship length distribution for 455 ships is:
  - 25 to 32 feet, 85 boats
  - 34 to 38 feet, 50 boats
  - 40 to 45 feet, 150 boats
  - 50 to 55 feet 100 boats
  - 60 to 65 feet 40 boats
  - 75 to 125 feet 30 boats

SOUTHERN BASIN

The export fishery harbour generates revenue by different services and fees. Some average values for these services are given below. (Deputy Harbour Manager Dikkowita, 2015)

- The international fishery boats stay on average 3 days in the harbour
- In the off season time there are 2 or 3 foreign vessels on average in the harbour
- In the season time there are 5 or 6 foreign vessels on average in the harbour
- The income on berthing is $80 per day per berthing boat
- The income on processed fish is LKR 1/kg
- Each boat needs on average 8,000 litres of fuel. The revenue on one litre of fuel is LKR 2.37
- The average fish catch of a foreign vessel is 8,000kg
- On average, the water supply for foreign vessels is 1,500 boxes per month. One box contains 24 water bottles. The income per water bottle is LKR 27
- Mostly Taiwanese vessels berth at the export harbour. These vessels don not buy ice, because they use the chilled water technology for their fish
- Food income is LKR 10,000 per month per 7 boats
- The price of lifting a boat out of the water is LKR 30,000
- The maintenance costs paid to the harbour are on average $30 per feet per year. An average foreign vessel is 80 feet

2.2 MARINA ANALYSIS

In this chapter the idea of implementing a marina in the harbour of Dikkowita is analysed. Therefore, it is explained why a marina is needed and why it is good for the country. The end of this chapter focusses on the dimensional criteria and facilities in a new marina.

2.2.1 DEMAND FOR A MARINA

The Ministry of Megapolis & Western Development in Sri Lanka is responsible for a new project, the Western Region Megapolis Planning Project. This project is about making the western region of Sri Lanka an important economic centre in South-Asia. To reach this goal there must be invested in for example, the business centres, recreation and entertainment, shopping districts and infrastructure. (Opportunity Sri Lanka, 2015)

What could fit into this plan is the implementation of a marina. Marinas are the infrastructure of the yachting and boat building industry. No marinas means no yachts, so by implementing a marina in Sri Lanka a completely new business could be created. This could boost the domestic boat building industry and could create a lot of jobs. Marinas also contribute to a beautiful waterfront, which is always attracting for a country. Sri Lanka is mostly visited by tourists for the beautiful nature and beaches. Creating an attractive, modern urbanized place could be a very good variation for tourist. If the implementation of marinas would increase the tourism with only 5%, according to 'Government's tourism targets for 2016', an extra income for the country could be 140 million dollars each year. (Arrol, 2014)

Worldwide more than 15 thousand marinas exist, but only three marinas of international class are located in the Indian Ocean, see figure 6. Sri Lanka could be a precursor in South-Asia by starting up the marina business. The position of Sri Lanka, in the middle of the Indian Ocean, makes the country also an attractive place for international sailors. With the double monsoon climate, Sri Lanka is an ideal place for marinas. Half the year the weather is calm, so ideal for motor boats and the other half of the year more moderate winds occur, so ideal for sailing. Together with the warm and clean coastal waters this concludes that Sri Lanka has a good position and has good weather conditions for a marina (Arrol, 2014).

Figure 6 Nearest international class marinas (Arrol, 2014)

Despite the fact that Sri Lanka could be a great place for marinas, which also fits into the Western Region Megapolis Planning Project, the real demand for marinas is unsure. Sri Lanka is comparable with Thailand, where also only a few people have a tradition of yachting. Nevertheless, the marinas in Thailand are acknowledged as an important asset for the hugely important tourism sector. (Arrol, 2014)

Important to note is that the yachts in the marina should be mostly from the local people, so for example the Colombo citizens. If we take for example the harbour of Galle, where only tourist boats come, the demand is disappointingly low. In table 4 you can see the number of boats that have visited the harbour since 2010. After some pirate attacks in 2011 the number of boats decreased drastically, where the number of boats is now going to be around 60 boats each year (Deputy Harbour Manager Galle, 2015). Taking into account that Galle is a more touristic city than Colombo and has a perfect location because of the main sailing routes, the number of boats with touristic purposes will be very low in Dikkowita. This of course could grow when Sri Lanka would be more known as a marina country. Nevertheless, tourist will not often enter the harbour by yacht, but they could come to visit a nice marina with restaurants, hotels and other tourist attractions.

Table 4 Number of boats in Galle (Deputy Harbour Manager Galle, 2015)

Year	Number of boats
2010	79
2011	119
2012	43
2013	31
2014	55
2015 (till 21st of September)	47

2.2.2 DIMENSIONAL CRITERIA

In this subchapter information about the dimensional criteria is given. All these criteria come from the Autralian Guideline for building marinas (Committee CE-030, 2001).

WATER DEPTH

The criteria of the water depths of a marina normally depend on the dimensions of the yachts. The Dikkowita Harbour is already designed and realized with depths from 3 to 5 meters. Since a depth of 4 meters is enough for yachts with a length of 30 meters and powerboats with a length of more than 50 meters, as seen in figure 7, changing of water depth is not desirable. Yachts with a length of more than 30 meters are still able to berth in the deeper southern basin with a water depth of 5 meter (Committee CE-030, 2001).

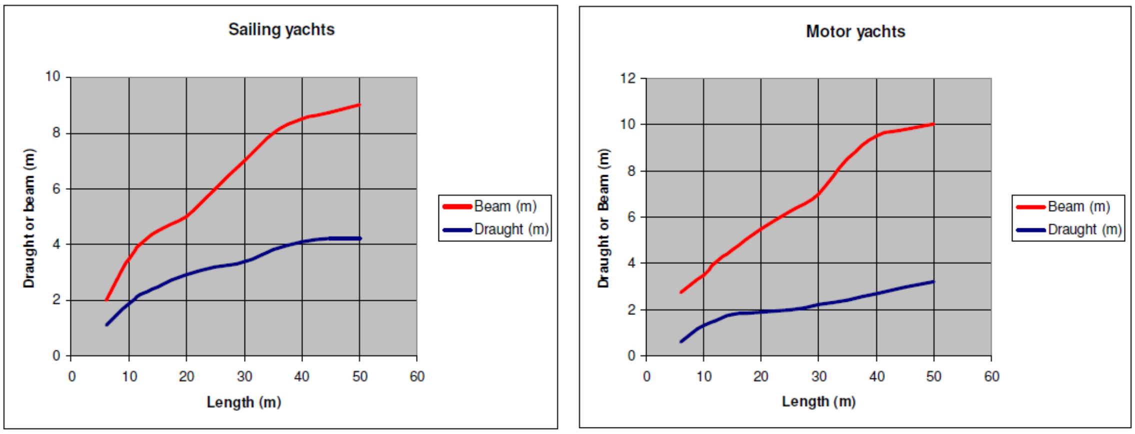


Figure 7 Vessel draughts and beams (Wijdeven, 2015)

ENTRANCE CHANNEL

For an entrance channel, the minimum width should be the greatest of (Committee CE-030, 2001):

- 20 m
- (L + 2) m, where L the is overall length of the longest boat in the marina in meters
- 5B m, where B is the beam of the broadest mono-hull boat in the marina in meters

Using the existing width of the channel of 50 meters, yachts with a maximum length of 48 meters and a maximum width of 10 meters are allowed to enter the harbour.

BERTH SIZES

With the given water depths and channel width, only the maximum dimensions of the yachts have been found. In order to berth the yachts efficient, places for smaller and bigger yachts have to be designed. Since the demand and the dimensions of yachts are still unknown, reference projects are used to have a good estimation of the share of different yacht sizes.

A scale comparable marina is the Bandar Al Rodwa Marina in Oman. In this marina there are mooring facilities for around 150 boats of different lengths. There are places for small boats, with minimum length of 8 meters, but also for boats 5 times that size.

Figure 8 Bandar Al Rodwa Marina, Oman (Marina Bandar Al Rowdha, 2015)

Another reference project is the Galle harbour, which is also located in Sri Lanka. There they have berthing facilities for approximately 50 yachts with a length of 15 meters and a draught of 3 meters.

Since Galle is located in the same country and probably attracts the same tourists as Dikkowita will, the berthing area will be designed for yachts with an average length of 15 meters. The amount of berthing places in the harbour can then be calculated and could be adjusted with berthing places for smaller or bigger places.

According to the Australian Guidelines (Committee CE-030, 2001), using a maximum length of 15 meters, the berth length has to be 15 meters and the the fairway between the berthing places have to be 1.5 times the maximum length and therefore has to be 22.5 meters. The interior channel has a minimum of 1.5L, and therefore has to be 22.5 meters. A larger width of the interior channel (1.75L = 26,25 meters) is preferable.

Table 5 (Committee CE-030, 2001) shows that a double berthing place for yachts with a length of 15 meters needs a width of 11 meters.

Table 5 Minimum berth dimensions for mono-hull boats (Committee CE-030, 2001)

Boat length (*L*), m	Boat beam (*B*), m	Width of berth (*b*), m	
		Single berth	Double berth
6	2.8	3.8	6.6
7	3.1	4.1	7.2
8	3.4	4.4	7.8
9	3.7	4.7	8.4
10	4.0	5.0	9.0
11	4.3	5.3	9.6
12	4.4	5.4	9.8
13	4.6	5.6	10.2
14	4.8	5.8	10.6
15	5.0	6.0	11.0

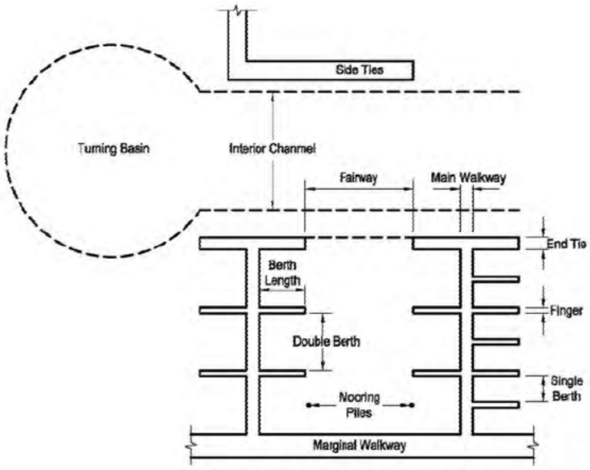


Figure 9 Design of a marina (Committee CE-030, 2001)

Since the Dikkowita Harbour is located in an area with stormy conditions during the monsoon, waves inside the harbour might exceed a height of 300 millimeters and therefore, mooring piles should be implemented between the two places of a double berth. The width of a mooring pile has to be added to the total width of the double berth, and will give a total of 11.5 meters.

The fingers have a length of 0.8 * 15 = 12 meter and a width of 900 millimeters. Because the minimal width of the harbour is 160 meters, see appendix XIV, probably the walkway will be longer than 100 meters. Therefore, the walkway should have a minimum width of 2.4 meters. The last years walkways are often designed with a larger width for the convenience of the users, therefore a width of 3 meter is appropriate for the walkway.

For double berths, 5 mooring piles in total should be provided on the walkway for berthing the 2 boats. Figure 10 shows the final design dimensions.

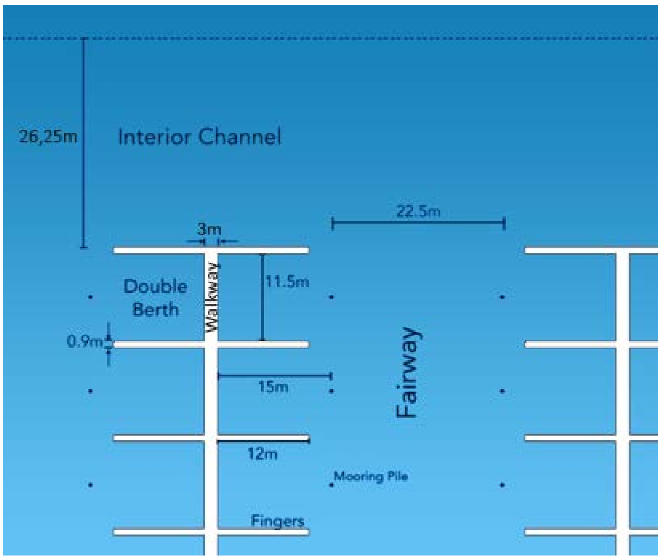


Figure 10 Design dimensions

2.2.3 FACILITIES

In a marina there are required facilities that should be available for the yacht owners. Beside these necessary facilities there are also optional facilities that can be used to create more comfort and an attractive waterfront. A list of all these necessary and optional facilities can be found in appendix II (Committee CE-030, 2001). A part of the necessary facilities of a marina already exists in the current harbour, these facilities and equipment could be (partly) reused. A few important necessary facilities that should be available close to or at the berthing places are explained below:

- Electricity: This should be available at every berth place. This will be provided by one pedestal per double berth, located on the walkway in the middle of the double berth.
- Water supply: Water hoses should be provided at the tail of every walkway. These hoses are connected to the water pipeline system of the harbour from which the quality is appropriate for cleaning, showering etc. Drinking water should be available in the harbour.
- Sullage and contaminated waste disposal: A sewage pump-out facility should be provided in the harbour. For solid waste disposal garbage receptacles with self-flossing lids are placed at the head, middle and tail of the walkways.
- On the tail and on the head of each gangway a fire hydrant and a fire hose should be provided. This equipment needs to be maintained in accordance with AS1851, the Australian standard for maintenance of fire protection systems and equipment. An audible fire alarm should be installed, a fire procedure needs to be set up and all marina staff have to receive instructions about this procedure.
- Sanitary facilities: There should be two sanitary facilities with toilets and showers. In case that less than 40 berths will be realized in the harbour, only one facility is enough.

2.3 SYSTEM ANALYSIS

This chapter starts with the geography and climate. The ocean and wind dynamics are discussed, where first all conditions outside the harbour are mentioned. These conditions have an influence on the navigability in front of the harbour. Later on, these outside conditions will be transformed to the inside conditions of the harbour. With this information can be concluded weather this harbour is useable for yachts and what kind of improvements have to be done.

2.3.1 GEOGRAPHY AND CLIMATE

Sri Lanka is located on the Northern Hemisphere between 5^{o}55 N and 9^{o}50 N and between 79^{o}41 O and 81^{o}52 O. The island is situated in the Indian Ocean, southwest of India. The harbour of Dikkowita is located at the west coast of Sri Lanka at approximately 11 kilometers north of Colombo. (Google, 2015).

The average temperature in Sri Lanka is around 27 degrees Celsius. The temperature is relatively constant around the year. The annual rainfall is not evenly balanced over the entire island. For example, the rainfall in the northern part of the island is about 1250 millimeters in a year and in the southwest approximately 3500 millimeters in a year. The climate in Sri Lanka can be characterized in four different seasons. These different seasons are discussed below and displayed in figure 11 (Department of Meteorology Sri Lanka, 2012).

First Inter-monsoon season (March – April): During this season most rainfall, about 700 millimeters, is in the south west of the island. In the other part of the country the rainfall varies between 100 and 250 millimeters.

Southwest monsoon season (May – September): In this monsoon season most of the rainfall is in the south western part of Sri Lanka. At the south western coast it is between 1000 and 1600 millimeters. Further inland, the rainfall could be more than 3000 mm. The rainfall around the Dikkowita Harbour is approximate 750 millimeters.

Second Inter-monsoon season (October – November): This is the period with the most evenly balanced distribution over Sri Lanka. Most places receive at least 400 millimeters of rain during this season. In the south western part of the island this could be more, between 750 and 1200 millimeters. The Dikkowita Harbour receives approximate 750 millimeters of rain in this period. Because of depressions and cyclones in the Bay of Bengal during this season, the whole country experiences strong wind.

Northeast monsoon season (December – February): During this season the eastern part of the country receives most rain, between the 500 and 1200 millimeters. The western part of the island receives between 100 and 500 millimeters of rain. For the Dikkowita Harbour the rainfall is approximately 200 millimeters.

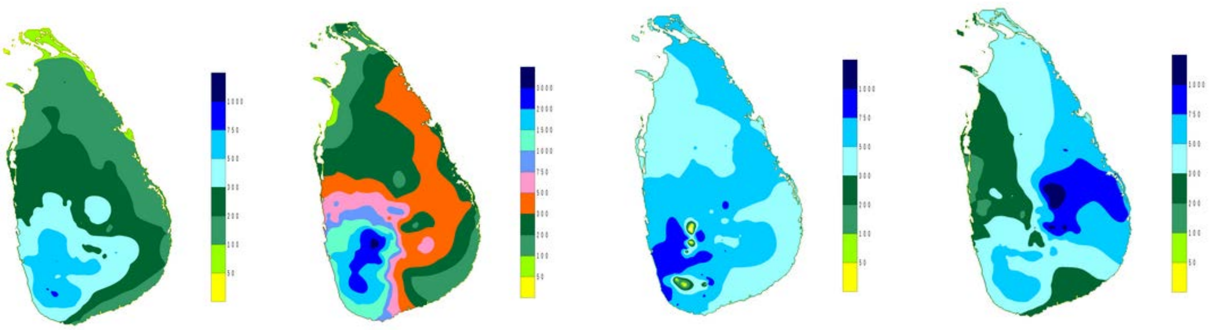


Figure 11 Rainfall distribution for each season. Frist: First Inter-monsoon. Second: Southwest monsoon. Third: Second Inter-monsoon. Fourth: Northeast monsoon (Department of Meteorology Sri Lanka, 2012)

2.3.2 OCEAN CURRENTS

Sri Lanka is located in the middle of the Indian Ocean, the Bay of Bengal and the Arabian Sea. In all these seas different temperatures and different salinities occur, which give density differences to the waters and are therefore drivers for the ocean currents. However, the main drivers of the ocean currents are the monsoons. The seasonal differing winds give almost contrary directions to the currents. The directions of the currents are visible in figure 12. In the left figure the main current during the Northeast monsoon and in the right figure the current during the Southeast monsoon is given (de Vos, Pattiaratchi, & Wijeratne, 2014).

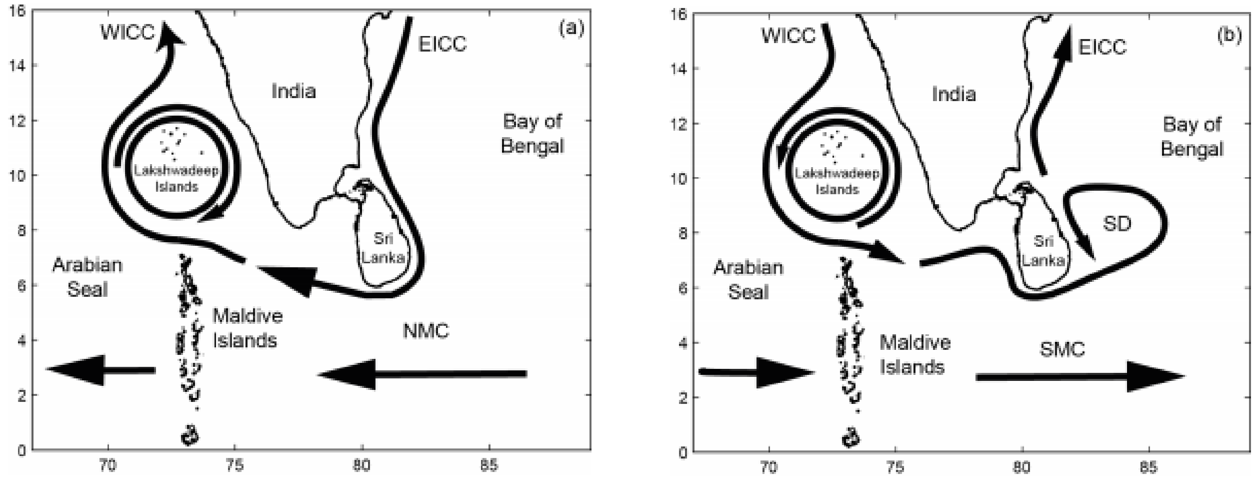


Figure 12 Ocean current during Northeast monsoon on left side and during Southwest monsoon on right side

These currents have different main velocities. The current during the Southwest monsoon has a velocity between 0.5 meters per second and 1.0 meters per second and the current during the Northeast monsoon has a velocity which is almost always below 0.3 meters per second. Looking to the figures one can see that Northeast monsoon has a main current which does not cross the waters in front of the harbour of Dikkowita. Velocities will thus be even lower than 0.3 meters per second. During the Southwest monsoon the main current does cross the waters in front of the Dikkowita Harbour and thus a velocity between 0.5 meters per second and 1.0 meters per second can be taken as representative in this research (Tomczak, 2003).

2.3.3 TIDE

In this subchapter the tide is divided into two different parts, first the tidal character and second the tidal range. The tidal character gives information about how many times a day high and low water occurs. The tidal range is important because of the different water elevations in the harbour.

TIDAL CHARACTER

There are four different tidal characters, these are displayed in table 6. The type of the tide can be expressed by the form factor (F). This factor is determined as the ratio of the amplitudes of the sum of the two main diurnal components K1 (lunar-solar) and O1 (lunar) and the sum of the two main semi-diurnal components M2 (lunar) and S2 (solar). The form factor can be calculated with the following formula:

$$F = \frac{K_1 + O_1}{M_2 + S_2}$$

Table 6 Tidal character expressed by the form factor F (Bosboom & Stive, 2015)

Tidal character	Form factor value F
Semidiurnal	0 - 0.25
Mixed, mainly semidiurnal	0.25 - 1.5
Mixed, mainly diurnal	1.5 - 3
Diurnal	> 3

Because of the short distance between Colombo and Dikkowita, it is assumed that the tidal constituents of Dikkowita and Colombo are the same. Then data of the stations in Colombo can be used to calculate the form factor for the Dikkowita Harbour. See table 7 for the data.

Table 7 Tidal constituents at station along coastline of Colombo (de Vos, Pattiaratchi, & Wijeratne, 2014)

Tidal constituents	Amplitude (m)
M2	0.18
S2	0.12
K1	0.07
O1	0.03

The form factor calculated with the data from the table above is 0.33. According to table 6 the tidal character at the Dikkowita Harbour is mixed, mainly semidiurnal. When using figure 13 (Bosboom & Stive, 2015), the same tidal character holds for the Dikkowita Harbour. This means there will be low water and high water two times each day.

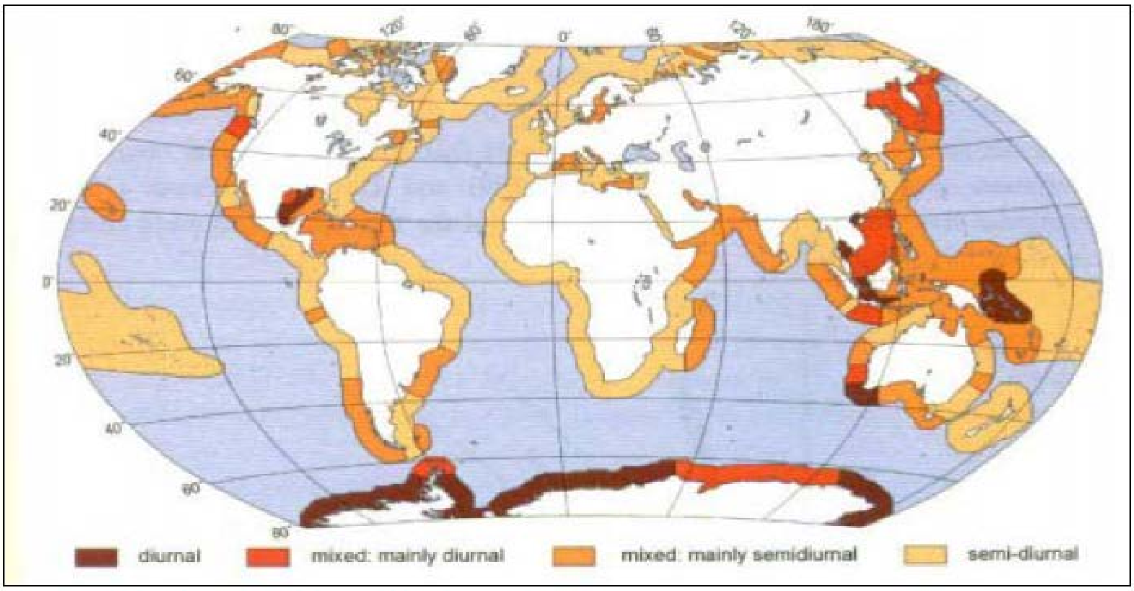


Figure 13 Tidal environments of the world. (Bosboom & Stive, 2015)

TIDAL RANGE

The tidal range is the difference between high water and low water. The tidal range is not always the same. The smallest range occurs when there is neap tide and the largest range during spring tide. For the yachts it is important to know the largest ranges, because this gives the largest water level differences in the harbour. There are three categories of spring tide:

- Micro-tidal regime: mean spring tidal range < 2 meters
- Meso-tidal regime: mean spring tidal range 2-4 meters
- Macro-tidal regime: mean spring tidal range > 4 meters

According to figure 14 there is a micro-tidal regime for the harbour of Dikkowita. To make this range more precise, the results of the Colombo weather station are analysed. In appendix III the results of these measurements are displayed. From these results follows that the spring tidal range is approximately 0.7 meters.

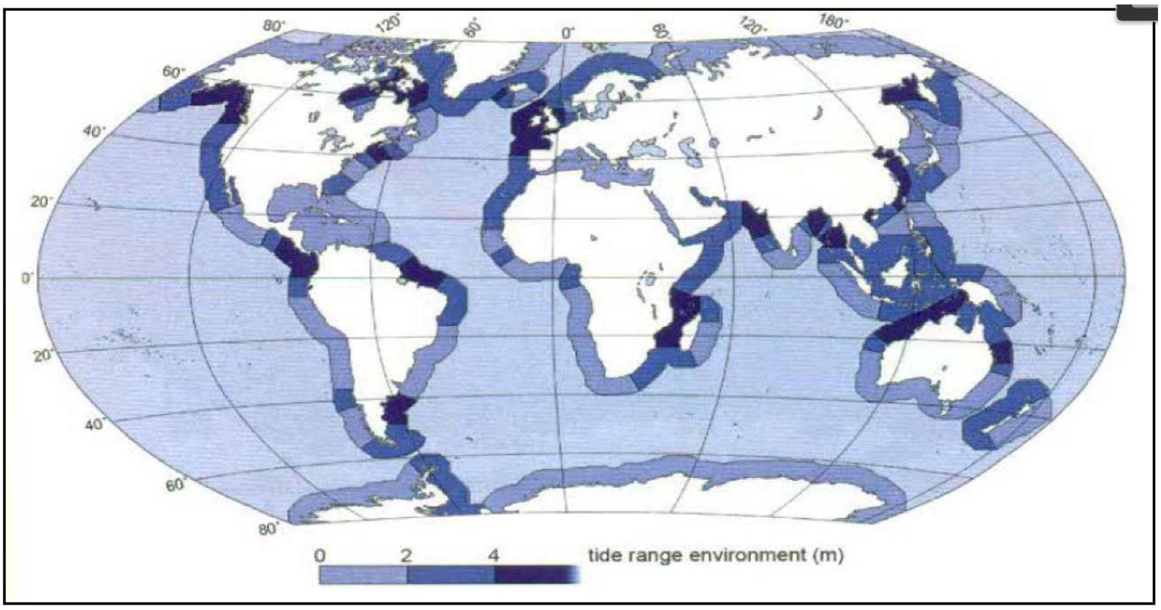


Figure 14 World distribution of mean spring tidal range. (Bosboom & Stive, 2015)

2.3.4 WIND CLIMATE

The wind data is obtained by using waveclimate.com of BMT ARGOSS, which means that all the figures, tables and data in this subchapter are from BMT ARGOSS (BMT ARGOSS, 2015). In this subchapter data of the wind speed in combination with the direction can be found for each monsoon season. Wind is of course a very important parameter for the navigability.

WIND VERSUS DIRECTION

In all roses, in figures 15 to 18, the percentage of occurrence of all wind speeds are found in combination with the direction it is coming from. The different monsoon seasons can easily be distinguished. In the Southwest monsoon and the Northeast monsoon the wind is blowing from respectively west, southwest and northeast. During the Inter-monsoon seasons a transition is visible between the monsoon seasons. In the Southwest monsoon season wind is blowing hardest, which is quite logical, because in this period the wind can develop above see.

For each season the mean wind speed, the wind speed with a 1% chance of exceedance and the Beaufort wind speed scale for each wind speed is given (Bosboom & Stive, 2015).

<u>First Inter-monsoon season (March - April):</u>

*M*ean wind speed: 2.8 m/s
Beaufort scale: 2
Wind speed 1% chance of exceedance: 7.6 m/s
Beaufort scale: 4

<u>Southwest monsoon season (May – September):</u>

Mean wind speed: 6.2 m/s
Beaufort scale: 4
Wind speed 1% chance of exceedance: 10.0 m/s
Beaufort scale: 5

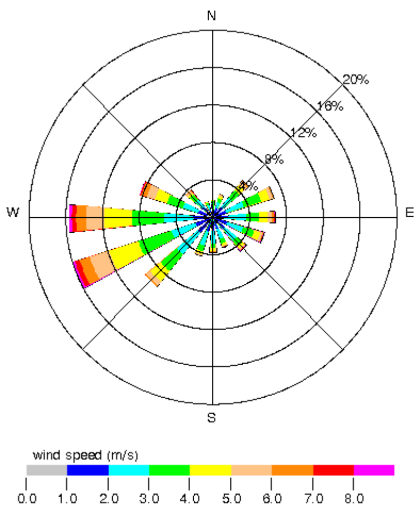


Figure 15 Rose wind speed vs. direction First Inter monsoon

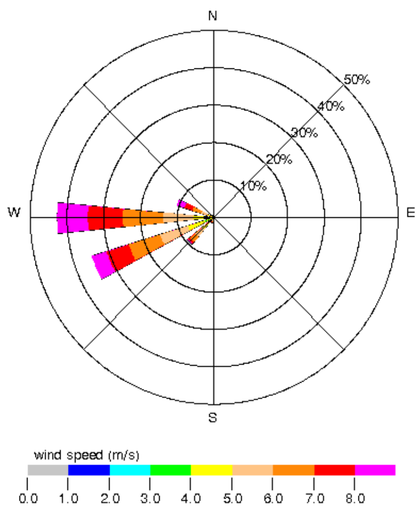


Figure 16 Rose wind speed vs. direction Southwest monsoon

Second Inter-monsoon season (October – November):

Mean wind speed: 4.0 m/s
Beaufort scale: 3
Wind speed 1% chance of exceedance: 9.2 m/s
Beaufort scale: 5

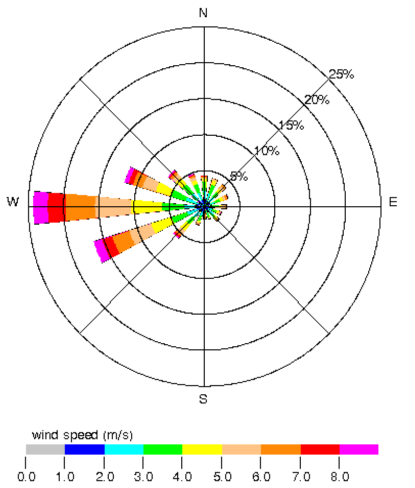


Figure 17 Rose wind speed vs. direction Second Inter -monsoon

Northeast monsoon season (December – February):

Mean wind speed: 3.4 m/s
Beaufort scale: 3
Wind speed 1% chance of exceedance: 8.2 m/s
Beaufort scale: 5

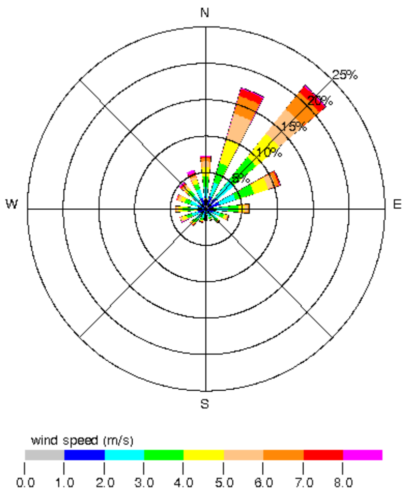


Figure 18 Rose wind speed vs. direction Northwest monsoon

2.3.5 WAVE CLIMATE

The wave data is also obtained by using waveclimate.com of BMT ARGOSS, which means that all the figures, tables and data in this subchapter are again from BMT ARGOSS (BMT ARGOSS, 2015). More information about this programme is given in Appendix IV. In this subchapter the wave heights, periods and direction are given, where the heights and periods are given in the different monsoon seasons. Waves inside the harbour are also discussed by looking at the wave direction in combination with the wave height and period in the different monsoon seasons. The wave climate is very important for navigability, especially inside the harbour.

WAVE HEIGHT VERSUS SEASON

In the scatter table, table 8, you will see the wave heights during the different months and thus seasons. Logically during the Southwest monsoon, from May to September, the waves are the highest. As mentioned before wind is blowing hardest in this period and is blowing from the Indian Ocean towards the land giving both larger swell as wind waves. The months belonging to the Inter-monsoons (March, April, October and November) are clearly a transition between the two monsoons. During the Northeast monsoon the waves are lowest, because wind is mostly coming from the land.

Table 8 Scatter table, monthly distribution of wave height (m)

lower	upper	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
0.5	1.0	30.0	36.0	16.0	3.1	0	0	0	0	0	0.5	5.3	18.9
1.0	1.5	67.7	59.0	70.3	54.4	8.1	0.9	0.1	0.5	2.7	24.8	65.7	71.8
1.5	2.0	2.3	4.8	13.4	36.2	40.0	17.9	11.6	27.8	42.3	48.4	23.8	8.5
2.0	2.5	0	0.2	0.3	5.5	39.4	52.8	56.1	51.8	42.6	21.5	4.5	0.8
2.5	3.0	0	0	0	0.6	10.4	24.8	28.9	16.7	10.1	3.8	0.6	0
3.0	3.5	0	0	0	0	1.8	3.3	3.3	2.8	2.1	0.9	0.1	0
3.5	4.0	0	0	0	0	0.3	0.3	0	0.4	0.1	0.2	0.0	0
4.0	4.5	0	0	0	0	0	0.1	0	0	0	0	0	0
4.5	5.0	0	0	0	0	0	0	0	0	0	0	0	0
total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

WAVE HEIGHT VERSUS WAVE DIRECTION

In the figures below the wave height and wave direction are given in a rose. In the left rose you will see the data of all the waves, in the middle rose you will see the data of sea waves and in the right rose you will see the data of the swell waves. Most waves are coming from the west, south or in between. Combining the swell and sea wind wave data in the roses to the total wave data rose, you will see that the swell waves are dominant, because the rose almost reduces to the swell wave data rose. Concluded can be that there is a swell dominated wave climate in front of the harbour of Dikkowita.

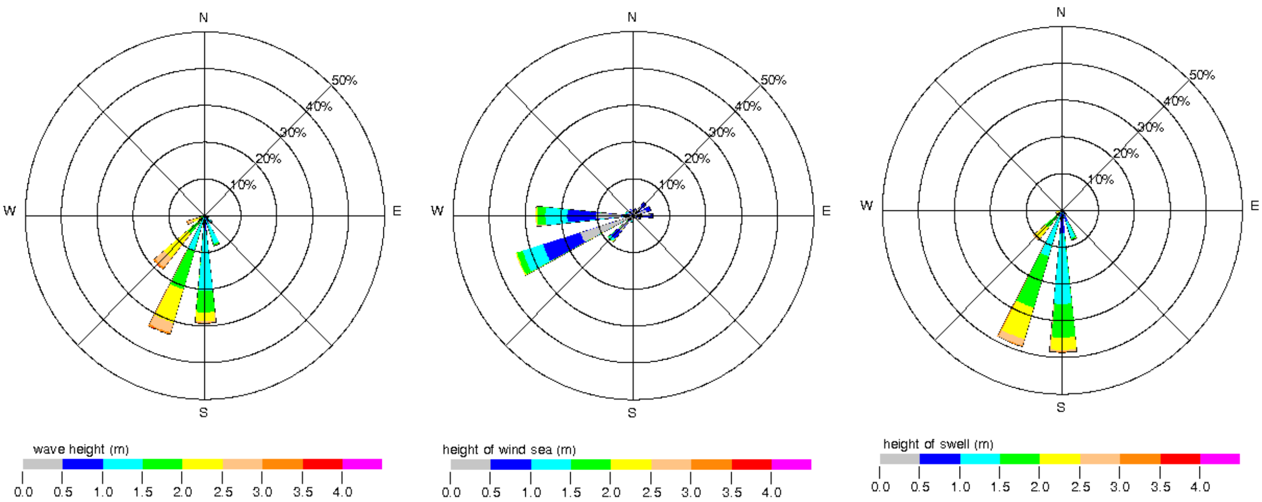


Figure 19 Wave height versus direction in front of the harbor of Dikkowita, on the left of all waves, in the middle of sea waves and on the right of swell waves

WAVE HEIGHT VERSUS WAVE PERIOD

In table 9 you can see the percentage of occurrence of wave height versus the mean period. Again it is clearly visible that the sea in front of the harbour of Dikkowita is swell dominated. Wave periods between 9 and 13 seconds have the highest appearance, where periods of around 10 seconds are swell waves. Sea wind waves, which have a period of around 3 seconds, do not seem to appear in this scatter table. However, these waves are certainly present, but in such a low percentage that they are not displayed (Holthuijsen, 2007).

Table 9 scatter table, percentage of occurrence of wave height (m) in rows versus wave period (s) in columns

	lower	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	
lower	upper	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	total
0.0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
0.5	1.0	0	0.0	0.0	0.3	0.9	1.8	2.7	2.2	0.9	0.2	0.0	0.0	0	0	0	9.0
1.0	1.5	0	0.0	0.2	0.9	2.6	5.4	8.7	9.3	5.6	2.1	0.5	0.1	0.0	0	0	35.4
1.5	2.0	0	0.0	0.2	1.5	3.7	5.4	4.8	3.3	2.4	1.3	0.4	0.1	0.0	0.0	0	23.1
2.0	2.5	0	0	0.1	1.5	4.3	5.6	5.7	3.6	1.5	0.6	0.2	0.1	0.0	0.0	0	23.1
2.5	3.0	0	0	0.0	0.3	1.5	1.7	1.8	1.2	0.9	0.4	0.2	0.1	0.0	0	0	8.0
3.0	3.5	0	0	0	0.0	0.2	0.3	0.2	0.1	0.1	0.2	0.1	0.0	0.0	0	0	1.2
3.5	4.0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0	0	0.1
4.0	4.5	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0	0	0.0
4.5	5.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
total		0.0	0.0	0.5	4.4	13.2	20.1	23.8	19.8	11.5	4.8	1.4	0.4	0.1	0.0	0.0	100.0

In the tables below all significant wave heights and periods during the different monsoons are given. Significant wave height is calculated as shown in appendix V. In these tables it is clearly visible wind sea waves do appear. In these tables again is visible that the highest waves are during the southwest monsoon.

Table 10 Wave data First Inter-monsoon (March – April)

	H_s [m]	T_p [s]
Swell	1.6	11.8
Wind sea	0.2	3.2
Total	1.7	11.6

Table 12 Wave data Southwest monsoon (May –September):

	H_s [m]	T_p [s]
Swell	2.4	11.4
Wind sea	1.4	4.3
Total	2.6	10.0

Table 11 Wave data Second Inter-monsoon (October –November)

	H_s [m]	T_p [s]
Swell	1.9	10.7
Wind sea	1.0	3.5
Total	2.1	10.2

Table 13 Wave data Northeast monsoon (December – February)

	H_s [m]	T_p [s]
Swell	1.3	11.3
Wind sea	0.6	3.5
Total	1.4	10.8

OVERTOPPING OF THE BREAKWATERS

With the significant wave heights determined in chapter 2.3.5 the amount of overtopping of the breakwaters can be calculated. The overtopping calculations can be found in appendix VI. For the overtopping calculations the European Overtopping Manual from the EurOtop Team is used (EurOtop, 2007). Out of these calculations follows that most of the time the amount of overtopping does not result in dangerous situations. However, for pedestrians it is dangerous to walk along the breakwaters when there is a storm with a significant wave height of 3.8 meters. Assumed that the duration of such a storm is two hours, then twelve of these storms are expected during one Southwest monsoon. Besides the danger during the severe storm, the overtopping of the breakwater close to the harbour entrance is dangerous for pedestrians during the entire Southwest monsoon.

The maximal overtopping volume of a wave during a severe storm is not a problem for the larger yachts, with respect to significant damage or sinking. However, close to the entrance the larger yachts could be damaged. For the smaller boats the maximal overtopping volume of a wave during a severe storm in the southern basin and northern basin is not a problem, but in the entrance the overtopping could cause sinking of the smaller boats when the boat are set 5 to 10 meters from the breakwater.

During the other periods of the year the overtopping is a lot less than during the Southwest monsoon. However, there is always a chance of overtopping.

In figure 20 an overview of the dangerous parts of the breakwaters with respect to the yachts and the pedestrians is given. The parts of the breakwater that are indicated with red are dangerous with respect to sinking of the small boats and dangerous for the pedestrians during the entire Southwest monsoon. The breakwaters indicated with orange are dangerous for pedestrians during a severe storm in the Southwest monsoon and could make it less comfortable for yachtsmen. The yellow parts are not a problem with respect to the yachts. However pedestrians should also be careful along these parts, because they cannot see the incoming waves and this could cause unexpected situations.

Figure 20 Overview of the dangerous parts of the breakwater for the yachts and pedestrians with respect to overtopping (Google, 2015)

WAVES INSIDE THE HARBOUR

Despite the harbour is enclosed by breakwaters, there are still some waves inside the harbour. From the sea, waves are coming in the basin following the blue arrow showed in figure 21. All swell is coming from the south and southwest and is thus blocked by the breakwaters. Incoming waves, clearly visible in figure 21, must be sea wind waves with an angle of approximately 315°. During the year, the probability of occurrence of sea wind waves in this direction are low, as can be seen in the scatter table below. However, these waves could have a significant height.

Figure 21 Waves coming into the harbor (Google, 2015)

Table 14 Scatter table, percentage of occurrence of height of wind sea (m) in rows versus direction of wind sea (degrees) in columns

	lower	337.5	22.5	67.5	112.5	157.5	202.5	247.5	292.5	
lower	upper	22.5	67.5	112.5	157.5	202.5	247.5	292.5	337.5	total
0.0	0.5	2.9	6.0	8.0	1.7	1.4	13.2	19.7	2.5	55.4
0.5	1.0	0.4	2.2	1.1	0.2	0.1	7.1	14.8	0.4	26.3
1.0	1.5	0.0	0.0	0.0	0.0	0.0	3.1	10.0	0.1	13.3
1.5	2.0	0.0	0	0.0	0.0	0	0.9	3.3	0.0	4.2
2.0	2.5	0.0	0	0	0	0	0.2	0.6	0.0	0.7
2.5	3.0	0	0	0	0	0	0.0	0.1	0	0.1
3.0	3.5	0	0	0	0	0	0.0	0.0	0	0.0
3.5	4.0	0	0	0	0	0	0.0	0.0	0	0.0
4.0	4.5	0	0	0	0	0	0	0.0	0	0.0
4.5	5.0	0	0	0	0	0	0	0	0	0.0
total		3.4	8.3	9.1	1.8	1.5	24.5	48.3	3.1	100.0

The chance of occurrence of the combination of wave height and period of these waves are given for each monsoon season in the scatter tables 15 to 18. During the Southwest monsoon almost no waves come into the harbour. During the First Inter-monsoon there are only a few very small waves coming into the basin. On the other hand, from October to February, incoming waves are quite high and up to 1.5 meters. Two things must be noted here. First of all, these are waves measured on sea and not in the harbour. When the wave is going through the harbour mouth between the breakwaters a lot of energy will be dissipated and the wave will get smaller. Unfortunately there is no wave data available from inside the harbour. Second thing to mention is that the probability of occurrence of these bigger waves is very low.

For each table a representative wave height and period is calculated. How this is done can be found in Appendix V. These representative values are necessary for comparing the situations and for calculations with these wave parameters.

Table 15 Scatter table, percentage of occurrence of height of wind sea (m) in rows versus mean period (s) at 315° in columns. First Inter-monsoon (March - April)

	lower	01	02	03	04	05	
lower	upper	02	03	04	05	06	total
0.0	0.5	0	0.4	0.9	0.4	0	1.7
0.5	1.0	0	0	0.0	0.0	0	0.0
1.0	1.5	0	0	0	0	0	0.0
total		0.0	0.4	0.9	0.4	0.0	1.7

Representative wave height: 0.25 meters
Representative wave period: 3.5 seconds
Chance at these wave values: 1.7%

Table 16 Scatter table, percentage of occurrence of height of wind sea (m) in rows versus mean period (s) at 315° in columns. Southwest monsoon (May - September)

	lower	01	02	03	04	05	
lower	upper	02	03	04	05	06	total
0.0	0.5	0	0.0	0.0	0	0	0.0
0.5	1.0	0	0	0	0.0	0	0.0
1.0	1.5	0	0	0	0.0	0	0.0
1.5	2.0	0	0	0	0	0	0.0
total		0.0	0.0	0.0	0.0	0.0	0.0

Representative wave height: 0.63 meters
Representative wave period: 3.8 seconds
Chance at these wave values: 0%

Table 17 Scatter table, percentage of occurrence of height of wind sea (m) in rows versus mean period (s) at 315° in columns. Second Inter-monsoon (October - November)

	lower	01	02	03	04	05	06	
lower	upper	02	03	04	05	06	07	total
0.0	0.5	0	2.2	3.3	0.9	0.1	0	6.5
0.5	1.0	0	0	0.3	0.5	0.0	0	0.8
1.0	1.5	0	0	0	0.1	0.1	0	0.2
1.5	2.0	0	0	0	0	0.0	0	0.0
2.0	2.5	0	0	0	0	0	0	0.0
total		0.0	2.2	3.6	1.5	0.2	0.0	7.5

Representative wave height: 0.33 meters
Representative wave period: 3.5 seconds
Chance at these wave values: 7.5%

Table 18 Scatter table, percentage of occurrence of height of wind sea (m) in rows versus mean period (s) at 315° in columns. Northeast monsoon (December - February)

	lower	01	02	03	04	05	06	07	
lower	upper	02	03	04	05	06	07	08	total
0.0	0.5	0	1.8	3.6	2.0	0.1	0	0	7.5
0.5	1.0	0	0	0.4	0.8	0.0	0	0	1.2
1.0	1.5	0	0	0	0.2	0.2	0.0	0	0.4
1.5	2.0	0	0	0	0	0.1	0.1	0	0.2
2.0	2.5	0	0	0	0	0	0.0	0	0.0
2.5	3.0	0	0	0	0	0	0	0	0.0
total		0.0	1.8	4.0	3.0	0.4	0.1	0.0	9.3

Representative wave height: 0.39 meters
Representative wave period: 3.7 meters
Chance at these wave values: 9.3%

2.3.6 SAILING AROUND DIKKOWITA

Yachtsmen mostly go sailing when the weather is good. Good in this case means that it is not to cold, not raining, not too windy, but windy enough and waves are not too high. However, the wave heights inside the harbour and the ocean currents are also important, because navigability in and in front of the harbour also has to be good. In this paragraph the results from the system analysis will be combined with requirements of yachtsmen to go sailing. Some numbers of the analysis are summarized in table 19.

Table 19 Summarizing table of system analyses

	Rain [mm/season]	Current [m/s]	Beaufort wind speed scale, mean/high [-]	Significant wave height outside harbour [m]	Wave height inside harbour [m] with chance	Wave period Inside harbour [s]
First Inter – monsoon	700	<0.5	2/4	1.7	0.25 [1.7%]	3.5 [1.7%]
Southwest – monsoon	750	0.5 – 1.0	4/5	2.6	0.63 [0%]	3.8 [0%]
Second Inter –monsoon	750	<0.5	3/5	2.1	0.33 [7.5%]	3.5 [7.5%]
Northeast - monsoon	200	<0.3	3/5	1.4	0.39 [9.3%]	3.7 [9.3%]

First of all, the temperature around the coast of Sri Lanka is always high enough to go sailing. The amount of rain is quite high, especially in the Inter-monsoons (the amount of rain seems almost equal during the Southwest monsoon as during the Inter-monsoon, but the period of the Southwest monsoon is longer). Furthermore, in the Southwest monsoon currents are quite strong and the wave height on sea is quite big. This makes sailing less comfortable. Noted must be that sailing is best possible with a Beaufort wind scale of 3 or 4. Sailing with stronger winds is also quite possible with some adjustments to the sails (Peter). So during the Southwest monsoon, the Second Inter-monsoon and the Northeast monsoon sailing is good possible looking at the wind. During the first Inter-monsoon winds are often not strong enough, but this is on the other hand better for a motor boat.

But besides above named averages, it is important to note that the weather in Sri Lanka does not really stick to the script. During rainy Inter-monsoons you also have bright and beautiful days and thus good days for sailing (SelectiveAsia). So unless you have seasons where in advance weather conditions seem to be better, in every season there will be good days for sailing.

In the summarizing table above, the tidal window is not present. A large tidal window could give problems for berthing boats in the marina. In this micro-tidal regime the tidal window is not very big. With 0.7 meters this will not give a lot of problems. To keep the marina comfortable and safe finger peers could be used.

Last important criterion is about the waves inside the harbour. According to the Australian Guidelines for designing a marina the wave height inside the harbour must be lower than 0.3 meters for a comfortable and safe use (Committee CE-030, 2001). Waves thus have to be lowered, which can be done using a floating breakwater (the choice of this type of breakwater is explained in chapter 3.2). This kind of breakwater only works with waves with a period lower than 5 seconds (PIANC, 1994) and can thus be used in all these cases. Halving the wave height, which is necessary with the waves during the Southwest-monsoon, could be a problem with these kinds of structures. However, these waves are hardly ever occurring, so could be neglected. Still it is necessary to implement a floating breakwater, both for comfort as for safety during all the seasons.

2.4 STAKEHOLDER ANALYSIS

In this chapter the stakeholders are discussed. In the first paragraph all stakeholders are divided into role groups. Also, an explanation of the stakeholders is given. In the second paragraph the objectives of the stakeholders are given. Thereafter, all connections between the stakeholders are discussed, followed by an assessment of power and interest of the stakeholders. The last paragraph gives a conclusion about the stakeholders.

2.4.1 EXPLANATION AND ROLE OF THE STAKEHOLDERS

In table 20 all stakeholders involved are given. Of all the stakeholders an explanation is given of what the stakeholder represents in this research. All stakeholders are also assigned to a role group. The CFHC plays a role in two groups and is therefore assigned to two groups.

Table 20 Stakeholders and their role and explanation

Role	Stakeholder	Explanation
Government	Sri Lanka Government	Government of Sri Lanka
	Ministry of Fishery and Aquatic Resources Development	Part of the government which regulates among other things the fishery sector
	Ministry of Tourism	Part of the government which regulates tourism
	Sri Lanka Tourism Development Authority	Authority set up by the Sri Lanka government to develop tourism in the country
	Department of Fishery and Aquatic Resources	Part of the Ministry of Fishery and Aquatic Resources Development which mandate management, development and conversation of the fisheries and aquatic resources
	Ceylon Fisheries Corporation	Leading commercial organisation, guiding and promoting fish production and trade for the benefit of producer and consumer
	Harbour manager	Manager of the harbour of Dikkowita
Government/ Operator	Ceylon Fishery Harbours Corporation (CFHC)	Corporation responsible for delivering of good quality fishery harbours and related services for the fishing community
Operator	PUM Senoir Experts	Dutch company with volunteers who advise companies in developing countries
Financer	ORET-programme	A programme of the Ministry of Foreign Affairs of the Netherlands that supports development of sustainable projects in developing countries
	HSBC	Banking and financial service institution
	Atradius	Loan insurer
User	Local fishermen	The local fishermen using the harbour of Dikkowita or fishermen who are potential user of the harbour of Dikkowita
	Foreign fishermen	The foreign fishermen using the harbour of Dikkowita
	Tourist	Tourist who will use the marina
	Local People	People living in the surrounding of the harbour of Dikkowita, so all people who could be potential users or will have potential hindrance or benefit of the marina

2.4.2 OBJECTIVES OF THE STAKEHOLDERS

In table 21 the objectives of all stakeholders are given.

Table 21 Stakeholders and their objective

Stakeholder	Objective
Sri Lanka Government	A harbour which is best for the whole country.
Ministry of Fishery and Aquatic Resources Development	A harbour with enough space for the fishing boats and space for expansion.
Ministry of Tourism	A marina which attracts tourists.
Sri Lanka Tourism Development Authority	A marina which attracts tourists and therefore contributes to the development of tourism.
Department of Fishery and Aquatic Resources Development	A harbour which satisfies the fishermen.
Ceylon Fisheries Corporation	A fair fish market with fair prices and equal chances for export and local fishery.
Harbour manager	A well-functioning harbour with enough profit and no overcapacity.
Ceylon Fishery Harbours Corporation (CFHC)	A harbour with functions and services which are good for the fishermen.
PUM Senoir Experts	A well-functioning harbour which has added value to the local community.
ORET-programme	A well-functioning harbour where the full capacity is used to make the given subsidy worth its money. Beside that the harbour has to be more profitable so the loan could be refunded.
HSBC	A more profitable harbour to ensure the refund of the given loan.
Atradius	A more profitable harbour to ensure the refund of the given loan.
Local fishermen	A harbour which provides enough capacity and good services for the fishing boats. Foreign fishing boats should not be allowed in Sri Lankan fishery waters.
Foreign fishermen	A harbour which provides enough capacity and good services.
Tourist	A marina where tourist activities could be done.
Local People	A harbour which not gives any hindrance and a marina which could be used as recreational activity. Investments in the surroundings because of the marina could also give profit to everybody.

2.4.3 CONNECTIONS BETWEEN THE STAKEHOLDERS

Starting with the governmental stakeholders (blue colour in figure 22) the central government of Sri Lanka is most important. The government exists of ministries where two of them are the Ministry of Fishery and Aquatic Resources Development and the Ministry of Tourism. The Ministry of Fishery and Aquatic Resources Development is divided into six departments where three of them play a role in this case, namely the Department of Fisheries and Aquatic Resources, the Ceylon Fishery Harbour Corporation and the Ceylon Fisheries Corporation. They all work together to improve circumstances for the fishermen. The Ceylon Fishery Harbour Corporation is in this case also the operator of the harbour. As operator they get advice from PUM senior expert (operators green). The CFHC also appoints the harbour manager (Ministery of Fisheries and Aquatic Recourses Development Fisheries, 2015).

The harbour manager is responsible for well-functioning of the harbour. The governmental institutions form his boundary conditions and therein he has to deal with all the users (local people, fishermen and tourist, all in orange). One group of users, the fishermen, gets help from the Ceylon Fisheries Corporation for establishing good prices for the fish.

Last not mentioned stakeholder, which belongs to the governmental role group, is the Sri Lanka Tourism Development Authority. This is a part of the Ministry of Tourism and has the goal to make tourism one of the main drivers of the Sri Lanka's economic growth.

In red in figure 22 all financial stakeholders are visible. The Sri Lanka Government has a loan from the HSBC and the ORET-programme. This loan is insured by Atradius (BAM International, BAM International Leaflet, 2011).

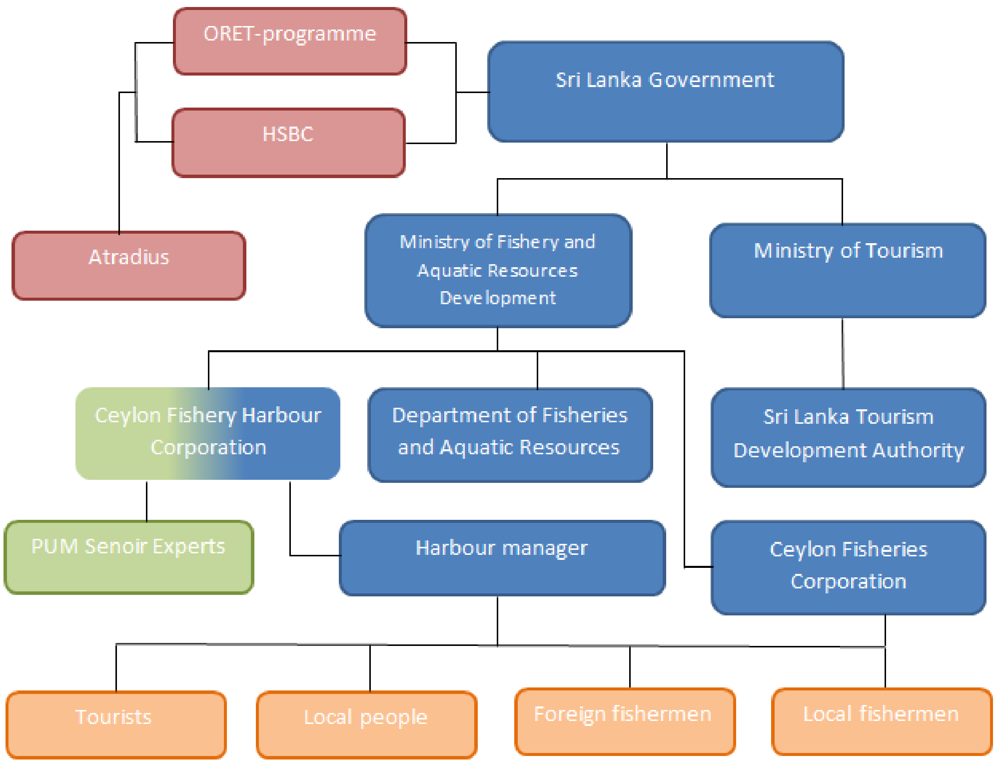


Figure 22 Connection diagram between stakeholders

2.4.4 POWER VS INTEREST STAKEHOLDERS

In figure 23 the power-interest diagram is displayed. On the vertical axis the amount of power of a stakeholder is shown. When a party is located in one of the upper squares, this party has a lot of power and therefore major influence on the project. The stakeholders in the lower squares have little influence on the project. On the horizontal axis the amount of interest in the project is displayed. A stakeholder in one of the squares on the right side of the diagram has a strong interest in this project. Parties in the squares on the left side have little interest. The stakeholders in the upper right square are the most important parties of the project. The stakeholders in the upper left and the lower right square are equally important and the parties in the lower left square are least meaningful.

Upper right square

- Government: The Sri Lankan government is the party with the greatest influence on the project, so therefore this stakeholder is located highest on the vertical axis. The interest in the project is slightly more than average, because the government is not closely involved in the project, but in the future the project could provide extra income for the government and is of added value of the country.
- Ministry of Fisheries and Aquatic Resources Development (MFARD): This party is less powerful than the government, but is also an important authority. On the other hand this stakeholder is more closely involved in the project and thus has more interest.
- Ceylon Fishery Harbour Corporation (CFHC): This authority is powerful because it is a governmental organisation and the operator of the harbour. This party has a great interest because they are the operator of the harbour which is about to change.
- Department of Fisheries and Aquatic Resources (DFAR): This authority is powerful, but has less interest than the three stakeholders mentioned above. This party has a great interest because the project is related to a fishery harbour and aquatic project.
- Local fishermen: The local fishermen are a powerful group and for the harbour manager it is difficult to control them. When there are changes in the harbour, it could have an effect on their income.

Upper left square: There are no stakeholders in this project with a lot of power and little interest.

Lower right square

- Local people: The local people are less powerful and interested than the local fishermen, because they are not using the harbour at the moment. However when they own a yacht in the future they can place it in the marina. Besides the local yacht owners, there are also people living very close to the harbour and future changes can change their lives.
- Ministry of Tourism: This authority is a party with power, but the interest of this ministry on a harbour project is less than the governmental parties mentioned in the upper right square. Therefore this party is located slightly below average. This ministry has a great interest in this project, because it can stimulate tourism in the future.
- Sri Lanka Tourism Development Authority (STDA): This stakeholder is a part of the Ministry of Tourism and therefore slightly less powerful, but more closely involved in tourist stimulating projects like this.
- Tourists: The tourists in this project have little influence on the project, but a new marina could be interesting for tourists. The new hotels and waterfront development is attractive for the tourists.
- Foreign fishermen: This is not a powerful party, but implementing a marina will be at expense of the foreign berthing places, so the foreign boats have to move to another place. Therefore they have great interest in this project.
- Atradius: This insurance company has no influence on the project. When there is too little profit, the government cannot pay back the loans and this will cost Atradius a lot of money. Therefore, this party has a great interest in this project.

- Harbour Manager (HM): The harbour manager is serving the governmental institutions and therefore does not have a lot of power himself. He is involved in each change of the harbour, but these changes do not really change his current position or his income. His work will change so he has more than average interest.

Lower left square

- PUM Senior Experts: This company just has an advisory role and therefore does not have a lot of influence. They however do their work on voluntary basis and thus have interest.
- ORET: ORET has some influence because the Sri Lanka government owes ORET money. They are insured against non-refunding of the Sri Lanka government. However, they do support projects in developing countries and thus have interest in this project.
- HSBC: HSBC also has some influence because the Sri Lanka government owes them money. They do have less interest than ORET, because they do not have a special interest in projects in developing counties and are insured against non-refunding of the Sri Lanka government.
- Ceylon Fisheries Corporation (CFC): As governmental organisation it has some influence on what happens in this fishery harbour. However, this project does not have that much influence on their mission and therefore interest is not high.

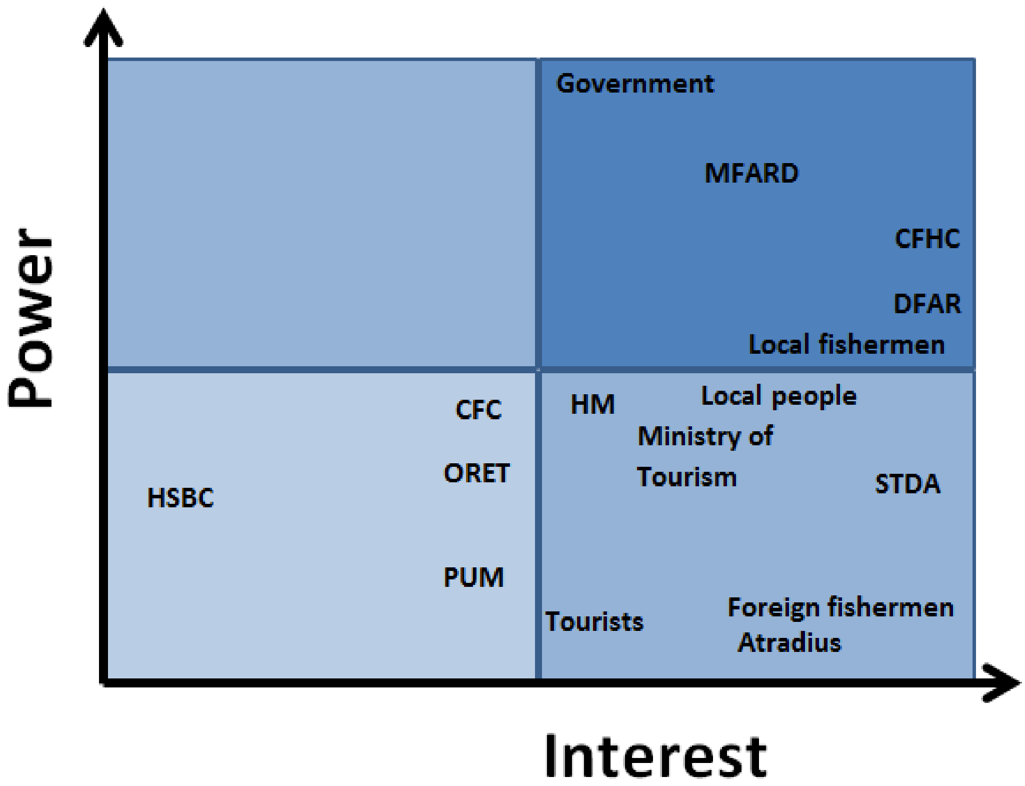


Figure 23 Stakeholder power vs. interest diagram

2.4.5 CONCLUSION STAKEHOLDERS

The stakeholders in the top right square of the power vs. interest diagram, figure 23, are the most important ones. Four of the five stakeholders belong here to the governmental stakeholders. These stakeholders have the same objectives or objectives that are derived from each other. Serving the will of the Ceylon Fishery Harbour Corporation (CFHC) and the Department of Fisheries and Aquatic Resources (DFAR) will therefore also serve the will of the other two governmental organisations (central government and the ministry). These stakeholders will provide the budget for the redesign and are therefore very powerful. Their goal is to satisfy the fishermen but also to have enough profit to repay the loans the ORET-programme and HSBC.

The other important stakeholders are the local fishermen. Not serving their will shall give a lot conflicts. Avoiding these conflicts will save a lot of money and problems.

For the stakeholders only with a lot of interest economic opportunities are very important. In case of implementing a marina there will be invested in the surroundings where a lot of people can get benefit from. Tourist will come and money will be spent in this area. For Atradius a marina is of course of economic importance, because the loans of the ORET-programme and HSBC can be paid to Atradius.

The foreign fishermen will experience the most disadvantages. They will have to find a new place to load and unload their ships. Since they do not have a lot power here and they will probably generate less money than a marina, this will not be an obstacle to carry out this project.

HSBC, the ORET-programme, PUM Senior Experts and the Ceylon Fisheries Corporation (CFC) have so little power and so little interest that the opinion of these stakeholders can be neglected in this project.

2.5 CONCLUSION OF THE ANALYSIS

Around the south of the harbour, there is space available for expansion. The quality of the infrastructure in the surroundings is low. Therefore, the accessibility from the harbour of Dikkowita to Colombo, Negombo, the Hunupitiya Railway Station and the Bandaranaike International Airport is poor.

All facilities in the harbour are of international quality and work fine. However, in the harbour some problems exist. The local fishermen are not satisfied with the export fishery harbour and, besides that, the export fishery harbour is functioning far from its capacity. This makes the big southern basin underutilized, which is a waste of the investments.

A marina fits perfectly in the Western Province Megapolis Planning Project, a project to make the west coast of Sri Lanka an important economic centre in the South of Asia. A marina could be the start of a complete new business, which will be good for among others job creation. And despite the yachts in the marina will be mostly from the local people, the marina will contribute to the beautiful waterfront and will therefore be attractive for tourists. To make the marina a success, a marina culture must be created. Next to that it must be safe and comfortable to use the harbour, so international guidelines must be followed.

Where a marina is built the sailing conditions of course have to be good. Around Dikkowita it is possible to sail all year long, because of the constant high temperature. During every season there are enough moments where weather conditions are good enough for sailing. From May to November there are stronger winds, which is good for the sailing yachts, and from December to April winds are more moderate, which makes it a good time for motor yachts. Most of the time during the year there is a possibility of waves higher than 0.3 meters in de harbour. To avoid this, which is necessary for a marina, a breakwater must be placed.

In the harbour the important stakeholders are governmental parties dealing with the fishery business. At the moment they are in control of the harbour and together with the general government of Sri Lanka they have control of the budget and they have the power to decide what will happen with the harbour. From the other parties the local fishermen have the most influence, because they could give a lot of problems when they are not satisfied. Interests on the other hand are very high for local people and touristic organisations. A marina could give a lot of opportunities for them.

So by implementing a marina the underutilization of the harbour could be solved. The marina will create a lot of economic possibilities, as well for the country as for the local people. And this all while a marina fits perfectly in the Sri Lankan weather circumstances.

3 HARBOUR DESIGN ALTERNATIVES

3.1 POSSIBLE SOLUTIONS

The requirements that follow from the analysis are:

- The local fishermen cannot be removed from the harbour. The local fishermen are an important stakeholder and removing them will give resistance against this project, because they will be afraid to lose income or their entire jobs
- The local fishermen need one of the basins of the harbour for themselves. Mixing will give too much problems
- The fishery part needs a depth of at least 3 meters and the export part needs a depth of at least 5 meters
- It is preferred to give the export part one basin and the marina one basin
- From figure 7 can be concluded that the depth of a marina must be 4 meters
- A floating breakwater for the marina is needed

It follows from the requirements that the local fishermen cannot be removed from the harbour. In the northern part they have all the facilities they need and the water depth is sufficient. Mixing the yachts or export boats with fishermen is not an option. Locating the yachts in the northern part of the harbour will only be acceptable for sailing yachts with a length of maximum 20 meters. For the export boats, this part of the harbour is too shallow. For placing larger sailing yachts or export boats in the northern basin dredging is required, this will cause extra costs. Logically could be determined now that the local fishermen must not be relocated, because this would bring unnecessary costs. Furthermore a marina and export fishery harbour will not fit in one basin, because the basin will be too small for that. This will only be possible when the basin will be enlarged.

The remaining possibilities are:

1. *Full Marina*: Only yachts in the southern basin
2. *Direct Expansion:* A direct expansion of the basin with both a marina and the export boats in the southern basin
3. *Phased Expansion*: Both a marina and the export boats in the southern basin, which will be expanded when that is required by the demand

In the next chapters these three alternatives are described in more detail. In the alternatives a net present value is given for both the government and the investor. This is done because for the implementation of a marina a private investor is needed. For both the investor and the government it is important to know what their profit will be. Before the explanation of the alternatives, it is explained where the floating breakwater is located.

3.2 FLOATING BREAKWATER

In the southern basin wind waves can be found coming from the northwest, as can be seen in figure 24 to 27. As found in chapter 2.3.5, swell is only coming from the southwest and is therefore blocked by the original breakwater. The wind waves are quite small and were no problem for the international fishing boats. Now the basin will also be used by yachts. Yachtsmen are most of the time less qualified and need more comfort than the shippers of commercial vessels, which are the reasons why lower waves are allowed inside a marina than inside the commercial fishery harbour.

For the reduction of the wave height in the harbour a breakwater must be implemented. Different types of breakwaters could be used for wave height reduction, namely:

- Rubble mound breakwater
- Vertical wall breakwater
- Floating breakwater

The most common type of breakwater is the rubble mound breakwater. However, this type of breakwater has a large base cut into the basin size (US Design Guides). For the marina it is important to keep the basin large as possible, because more berths could be created and so higher incomes could be generated. Therefore, this type of breakwater will not be useful in this case.

Vertical wall breakwaters and floating breakwaters require less space. The main design concern of the vertical wall breakwater is stability (US Design Guides), which makes it less appropriate for berthing of boats, which could be a problem in a harbour. On the other hand, berthing on a floating breakwater is possible.

Only wind waves are coming in with a short period of around 4 seconds (see chapter 2.3.5), which could be (partly) blocked by a floating breakwater. A floating breakwater gives the best results when it is used in deep water. Unfortunately this is not the case (see appendix XIII). However, in the transitional water depth, which is the case here, a floating breakwater still has significant effect.

Other advantages of a floating breakwater in comparison with to the other two breakwaters are the better water circulation and sediment flow around the breakwater and the easier manufactory and placement (Farmer, 1999). This is why the floating breakwater is chosen in this place.

3.2.1 LOCATION OF THE FLOATING BREAKWATER

The location of the breakwater is very important for a good result, so waves low enough for in a marina. The breakwater must lie in the path of the waves and preferable parallel to the wave crests. On the other hand navigability must be remained. In figure 24 to 27 different options for the location of the floating breakwater are given. Note that the finger and bunkering piers will be relocated in the new design and the red bars, presenting the floating breakwater, are not on scale.

ALTERNATIVE 1

Figure 24 Floating breakwater alternative 1 (Google, 2015)

ALTERNATIVE 2

Figure 25 Floating breakwater alternative 2 (Google, 2015)

ALTERNATIVE 3

Figure 27 Floating breakwater alternative 3 (Google, 2015)

ALTERNATIVE 4

Figure 26 Floating breakwater alternative 4 (Google, 2015)

These alternatives have to be compared on navigability and functionality. On the basis of functionality, alternative 2 seems to be the best option. The floating breakwater lies parallel to the wave crests, lies in the path of the waves and will block most of the waves outside the basin. Only navigability is much worse in this alternative. Boats must make difficult bends to arrive in the southern basin. This alternative can therefore not be used.

Alternative 3 is almost equal in functionality to alternative 2. Waves will only be (partly) blocked inside the basin here which gives slightly bigger waves inside the basin. Navigability however is much better here.

With alternative 1 again the functionality is a bit lower. The wave front can find a way between the floating breakwater and the groyne. So in this case some of the highest incoming waves will not be blocked. Navigability is better here than in alternative 3 because the approach for a boat can be almost straight here.

Alternative 4 is comparable with alternative 3. Functionality is only a bit lower because the floating breakwater does not lie parallel to the wave crests. Navigability is about the same. The breakwater here will be shorter, which reduces the costs. This will however not weight up against the lower functionality.

3.2.2 CONCLUSION

Alternative 1 and alternative 3 are the best solutions. Which one will be chosen depends on the inner layout of the basin, so the placement of finger piers etc. to keep the navigability good.

3.3 ALTERNATIVE I: FULL MARINA

3.3.1 DESCRIPTION

In the first alternative the export sector is totally removed out of the southern basin and replaced by a marina. A global image of this alternative is shown in figure 28. This alternative has some positive and negative influences on the harbour and the region around it.

Advantages:

- The export sector of the harbour is totally removed. This will remove the conflicts between the local fishermen and the export fishery sector. A marina has a different market, which reduces the appearance of such conflicts.
- It is expected that a marina is more profitable than the export harbour. Removing the export sector completely and replacing it for a marina will most probably increase the profit.

Disadvantages

- The export part already generates income for the harbour in the original situation. Deleting this part completely will remove all income from the southern basin. Relying solely on the newly generated income of the marina is more risky, because not much is known about the income of marinas in Sri Lanka.

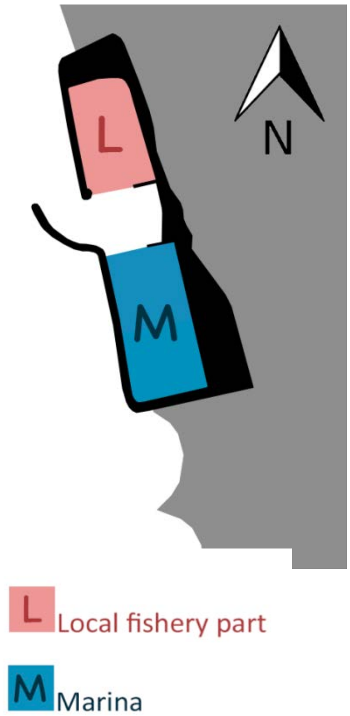


Figure 28 Alternative I: *Full Marina*

3.3.2 FLOATING BREAKWATER

As mentioned in the conclusion of chapter 3.2, the choice of the location of the floating breakwater is dependent on the layout of the basin. In this alternative only floating jetties for the berths of the yachts have to be placed. Yachts need to be as close as possible to the other facilities (for example changing rooms and car parking), which is why the floating jetties will be connected to the land side. The location of the floating breakwater now follows from the figures below. In the right figure navigability will be better, especially when the floating jetties will be longer (note that these figures are not on scale and therefore the berths are not presenting the real number and size of the berths). The floating breakwater will thus be placed like in alternative 3, as can be seen in figure 30.

Figure 29 Alternative 1, bad navigability (Google, 2015)

Figure 30 Alternative 3, good navigability (Google, 2015)

3.3.3 NUMBER OF BERTHS

With the knowledge that the berthing of a boat will cover around 170 square meters (see appendix VII), an estimation of the total amount of berths can be made for this alternative. The southern basin is not exactly rectangular, but it is assumed to be for this estimation. The width of the basin is 160 meters and the length of the quay wall is 340 meters. Therefore, the southern basin has a surface of 54400 square meters. The floating breakwater will probably use a surface of $50 \cdot 50 = 2500$ square meter. Removing this surface and the channel surface (see appendix VII) leaves a surface of $54400 - 26 \cdot 340 - 2500 = 43060$ square meters for berths. The estimated amount of berths for the first alternative is now approximately 255 for boats of 15 meter length.

At the start of operation there will not be a demand of 255 berths, because yachting is very new in Sri Lanka. The construction can be done in phases to shift some of the initial costs to the future. The first phase will be to place one jetty. The width of the southern basin is 160 meter, which means that the jetty can be 134 meters long. The 15 meter boats will need a minimum width of 6 meters, so the amount of berthing 15 meters yachts on the jetty will be approximately 44 (for the numbers see chapter 2.2.2).

Information about the actual demand of berths and the speed of the growth in the demand can be obtained in the first phase. This will give more insight in the next steps. A second phase could be to implement a second jetty in de marina when the demand of berths approaches the supply. This phased construction can continue till the capacity of berths in the marina is reached.

3.3.4 WATER QUALITY

The quality of the water will contribute to a high class marina. Therefore, it is important to follow the PIANC guideline for protecting water quality in marinas (PIANC, 2008). Despite that the current dimensions of the harbour will make it sometimes difficult and expensive to satisfy a requirement, it is preferred to meet the requirements mentioned in the guidelines in the final harbour design. For example, increasing the length of the basin will increase the costs significantly and making the basin very shallow will give navigation problems for the larger yachts.

In this research four criteria are used to determine the water quality:

- E-folding time: A measure of the flushing time of the basin
- Aspect ratio: The ratio between the length and the width of a rectangular basin, which is of influence of the flushing or exchange coefficient
- A/a ratio: Tells something about the spatial variability of mixing inside the harbour
- Tidal prism ratio: Tells which part of the total volume is flushed away during one tidal cycle

In appendix VIII these criteria are calculated and discussed, the results of it are displayed in table 22.

Table 22 Water quality scores for the southern basin.

Factor	Result	Required	Score (good, poor)
E-folding time	3.9 days	< 4 days	Good
Aspect ratio	0.47	Between 0.5 and 2	Good
A/a ratio	145	Minimum > 200 Preferred > 400	Poor
Tidal Prism Ratio	0.13	Minimum > 0.25 Preferred > 0.35	Poor

3.3.5 COSTS AND INCOMES

The investment for a marina will be significant. Because there is almost no knowledge about marinas in Sri Lanka, it would be wise to subcontract such a project. A private investor with a lot of experience has much higher changes to make the marina a success. Besides that, the investment in a marina in Sri Lanka could be too risky for the government.

Appendix X gives explanations and calculations about the costs and incomes of the marina, the export harbour and the fishery harbour. The profit of the marina is only dependent on the amount of berths; therefore, for the *Full Marina,* the total costs and income of the harbour can be calculated. This is done for both the government part and the investor part. A net present value (NPV) of the profit is made to make a good comparison between the alternatives. An explanation of the used method to calculate this NPV is given in appendix IX. The results are given in table 23. The northern part of the harbour is not taken into account, because this part is the same for each alternative. The profit of the fishery harbour in the current situation is given in appendix I.

Table 23 Net present values for investor and government *Full Marina*

Governmental profit	Investor profit
$8,120,000.-	$-10,620,000.-

Noted must be that the investor loses money on the marina, but will get profit from the other facilities in the harbour, like hotels, restaurants and shops.

3.4 ALTERNATIVE II: DIRECT EXPANSION

3.4.1 DESCRIPTION

The second alternative keeps the export part in the southern basin of the harbour and expands this basin to create more space to realize a marina. Figure 31 shows a global image of this alternative. The export part is located in the northern part of the basin. This has different reasons, namely:

- Export fishing boats are mostly larger than the yachts and it is practical to situate larger boats nearer to the harbour mouth.
- For a marina lower waves are allowed than for a commercial fishery harbour. Closer to the entrance of the harbour waves will be higher so it is better to place the fishery export harbour there.
- The marina requires more on-land facilities. More space is available on the south side for these facilities.
- In the point of view of the yacht owner it seems preferable to sail through a part of the export harbour, which is less neatly and luxury than the marina itself, instead of having commercial boats sailing through the marina all the time.

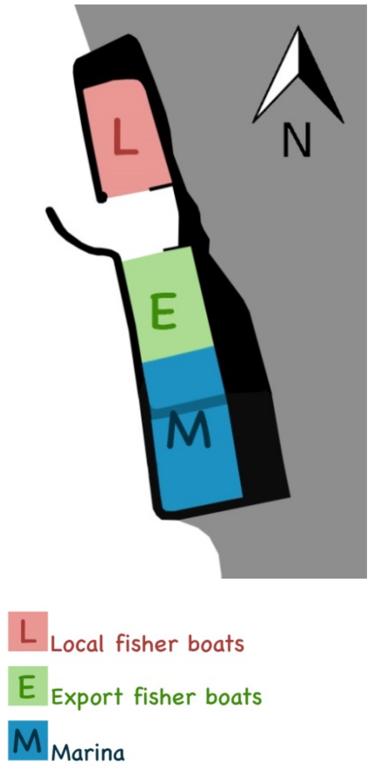


Figure 31 Alternative II: *Direct Expansion*

A combination of an export harbour and marina gives a lot of economic value. The underutilized southern basin will now not only be used as export fishery harbour but also as marina. Only implementing a marina in the basin will be a waste of the opportunity to make Sri Lanka more important as fish exporter. With this alternative the chance to develop the export fishery part of the harbour, despite of the fact that the growth was very low in the near history, remains. With some effort the export harbour could grow and can be of high economic value for the country. People are working in the processing, transportation and managing of this harbour part. The marina also has its economic value and creates jobs, which is the same as in the *Full Marina* alternative.

With this alternative the harbour is directly expanded. Along the waterline, there can be invested directly in the waterfront and the feeling of the 'marina village' can directly be created. In the beginning there will not be so many yachts, but boats in the export part of the basin also support the ambiance brought by a harbour. This harbour will therefore directly be attractive for tourists or other visitors. Because the number of yachts is expected to grow gradually, this part of the harbour will be built up in phases. Different floating jetties can be placed at different times, all when they are needed. This method is already explained in the *Full Marina* as the phased construction.

3.4.2 FLOATING BREAKWATER

In these alternatives the export harbour is in the north of the basin. An essential facility here is the processing unit. Because of the land space required and the necessary logistics, this unit has to be placed on the land side. For this unit and the berthing space for 3 vessels in front of this unit, about 120 meters of quay is needed. There is also space needed to turn and berth here. A rough estimation of quay wall needed is 150 meters. Placement of the finger piers for the commercial export fishing boats has to be on the breakwater side, otherwise there will not be enough space available for the marina on the southern side. With finger piers on the breakwater side the location of the floating breakwater of alternative 3 will be a problem for the navigability, so for this alternative option 1 for the location of the floating breakwater is chosen. This is shown in the figures 32 and 33.

Figure 33 Alternative 1, good navigability (Google, 2015)

Figure 32 Alternative 3, bad navigability (Google, 2015)

3.4.3 EXPANSION LENGTH AND NUMBER OF BERTHS

It is important to know how many meters the expansion has to be. To determine how much extra space is really needed for the expansion an estimation of the size of the export harbour and the marina should be done. The estimated lengths are displayed in figure 34 and explained below.

Figure 34 Estimated basin lengths of new export harbour and marina expansion (Google, 2015)

Starting again on the export side, around 150 meters of quay wall is necessary on the land side, see chapter 3.2. On the breakwater side approximately 50 m must be available, in the length of the basin, for the floating breakwater. The space needed for two finger piers is based on the design drawings of the current harbour (appendix XIV). The two finger piers need about 210 meters of basin length, 80 meters between the two finger piers, 60 meters above the northern pier, 60 meters below the southern pier and approximately 5 meters of jetty width. This gives a total length needed on the breakwater side of 260 meters. The export harbour only needs 150 meters of basin length on the land side. However, the marina cannot be placed here, because then there is not a clear distinction between the marina and the export harbour. Therefore, the export harbour needs 260 meters of basin length. In the current export harbour there is space for 40 to 50 vessels. The basin area available for export vessels is in the new situation 75% smaller. Therefore, in this harbour there are approximately 30 to 40 berthing places.

With a basin length of the export harbour of 260 meters, there is 80 meters of basin length left for the marina. It is assumed that 200 berths are needed in the new marina. Around 170 square meters is the surface area of one berth. This gives 34000 square meters needed for the berthing places. The basin is approximately 175 meters width in the southern part of the basin. 26 meters of this is needed for the fairway. The total basin length needed for 200 berths is about 230 meters. This results in an expansion length of 150 meters.

3.4.4 WATER QUALITY

In appendix VIII the criteria out of table 24 are calculated and discussed, the results of it are also displayed in table 24. The different factors are briefly discussed in chapter 3.3.4 of alternative I.

Table 24 Water quality scores for the southern basin with expansion

Factor	Result	Required	Score (poor, good)
E-folding time	3.9 days	< 4 days	Good
Aspect ratio	0.33	Between 0.5 and 2	Poor
A/a ratio	209	Minimum > 200 Preferred > 400	Good
Tidal Prism Ratio	0.13	Minimum > 0.25 Preferred > 0.35	Poor

3.4.5 COSTS AND INCOMES

The net present value of the profit of the *Direct Expansion* is calculated in the same way as for the *Full Marina*. Even if the export part has decreased in size, the same profit for the export harbour is used as in the current situation, because the demand of the export harbour is very low. Results of the NPV of the profit of the *Direct Expansion* option are given in table 25.

Table 25 Net present values for investor and government *Direct Expansion*

Governmental profit	Investor profit
$13,320,000.-	$-12,900,000.-

Again must be noted that the investor loses money on the marina, but will get profit from the other facilities in the harbour, like hotels, restaurants and shops.

3.5 ALTERNATIVE III: PHASED EXPANSION

3.5.1 DESCRIPTION

In alternative III, the southern basin will also be divided into a marina and export fishery harbour as shown in figure 35. The area available for the two harbour functions in just the old southern basin is quite small and one must be efficient with space. When the demand exceeds the supply, the basin will be expanded. This alternative has some advantages and disadvantages.

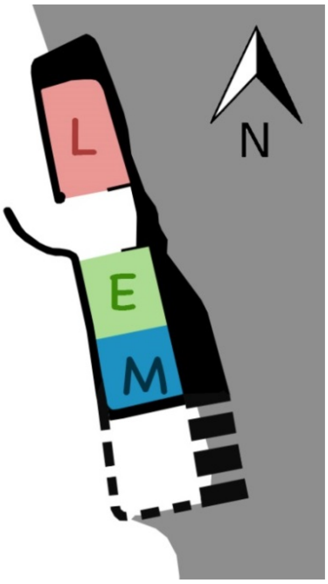


Figure 35 Alternative III: *Phased Expansion*

Advantages:

- Of both the export fishery harbour and marina the demand is low in the beginning, so not much space in needed.
- Postponing the big investment of enlarging the basin is therefore possible and on itself, cost effective.
- The conversion could be made very fast and income can be generated in short time.
- Even when the demand for export fishery facilities or for the marina will not grow as expected, no big investments are done yet.
- There is a large flexibility, when in the future there is for example a large overcapacity in the export part, the marina can also be enlarged to the north.

Disadvantages:

- When connecting the original basin to the expansion, the harbour cannot be used for a while.
- Only a part of the marina village can be connected to the water in the beginning, because space needs to be remained for the expansion of the basin.

3.5.2 FLOATING BREAKWATER, EXPANSION LENGTH AND NUMBER OF BERTHS

For this alternative the position of the floating breakwater, the expansion length and the assumed number of berths will be the same as in the *Direct Expansion* alternative. When the basin length for the export harbour is 260 meters, there is an area of 80 meters by 175 meters available for the marina before the expansion is realized. This area provides space for approximately 70 yachts. However before the expansion is done, it could be useful to start with one pier in the export harbour. This results in more marina berthing places before the expansion is realized. For the export harbour this will not a problem for the first years, because the 30 to 40 places as mentioned in the *Direct Expansion* will result in overcapacity in the beginning. When the demand of the total basin reaches the supply, then the expansion can be done to enlarge the basin. However, mixing a part of the marina with the export part is not preferred with respect to marina quality. For the cost calculations it is assumed that the basin expansion will take two years. Although there is a possibility to place the yachts temporarily in a part of the export harbour, there is assumed that when there are 70 yachts in the harbour the expansion must be finished.

3.5.3 WATER QUALITY

In appendix VIII the criteria out of table 26 and 27 are calculated and discussed, the results of it are also displayed in table 26 and 27. The different factors are briefly discussed in chapter 3.3.4 of alternative I.

Table 26 Water quality scores for the southern before the expansion

Factor	Result	Required	Score (good, poor)
E-folding time	3.9 days	< 4 days	Good
Aspect ratio	0.47	Between 0.5 and 2	Good
A/a ratio	145	Minimum > 200	Poor
		Preferred > 400	
Tidal Prism Ratio	0.13	Minimum > 0.25	Poor
		Preferred > 0.35	

Table 27 Water quality scores for the southern basin after the expansion

Factor	Result	Required	Score (poor, good)
E-folding time	3.9 days	< 4 days	Good
Aspect ratio	0.33	Between 0.5 and 2	Poor
A/a ratio	209	Minimum > 200	Good
		Preferred > 400	
Tidal Prism Ratio	0.13	Minimum > 0.25	Poor
		Preferred > 0.35	

3.5.4 COSTS AND INCOME

The net present value of the profit of the *Phased Expansion* is again calculated in the same way as the NPV of the profit of *Full Marina*. The only difference with the *Direct Expansion* is that the expansion costs are paid a few years later. This will have a positive effect on the net present value of the profit of this alternative. The expected construction time of the expansion is two years. The results are given in table 28.

Table 28 Net present values for investor and government

Governmental profit	Investor profit
$13,320,000.-	$-12,070,000.-

Again must be noted that the investor loses money on the marina, but will get profit from the other facilities in the harbour, like hotels, restaurants and shops.

3.6 DECISION

This chapter describes the multi-criteria decision analysis (MCDA) that is used to order the alternatives in a balanced and fair way. In line with the multi-criteria analysis manual by the Department for Communities and Local Government of London (Department of Communities and Local Government, 2009), this MCDA is set up following the next steps:

1. *Establish the decision context. What are the aims of the MCDA, and who are the decision makers and other key players?*
2. *Identify the options.*
3. *Identify the objectives and criteria that reflect the value associated with the consequences of each option.*
4. *Describe the expected performance of each option against the criteria. (If the analysis is to include steps 5 and 6, also 'score' the options, i.e. assess the value associated with the consequences of each option.)*
5. *'Weighting'. Assign weights for each of the criteria to reflect their relative importance to the decision.*
6. *Combine the weights and scores for each of the options to derive an overall value.*
7. *Examine the results.*
8. *Conduct a sensitivity analysis of the results to changes in scores or weights.*

3.6.1 DECISION CONTEXT

The aim of the MCDA is to make a choice which alternative is most suitable for the implementation of a marina in the harbour of Dikkowita. The alternatives have different implementations of the marina with their own advantages and limitations. This choice is based on the data available for this research. The result of this MCDA will be part of the recommendation for the Sri Lankan government, or more specific the Ministry of Megapolis & Western Development. The government will make the final decision about implementing a marina.

3.6.2 ALTERNATIVES

The options in this MCDA consist of the three alternatives for the marina implementation, described in detail in chapter 3.3 to 3.5. The main differences are the location of the berthing places and facilities, the consequences of the implementation to the other harbour users and the addition of an optional expansion.

Alternative 1

Full Marina

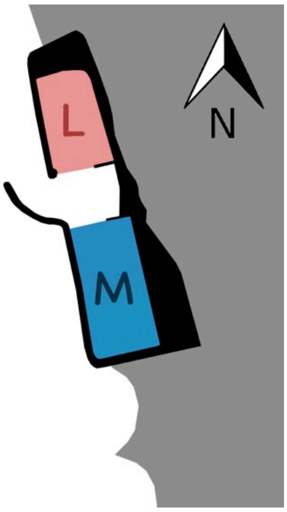


Figure 36 Alternative 1, *Full Marina*

Alternative 2

Direct expansion

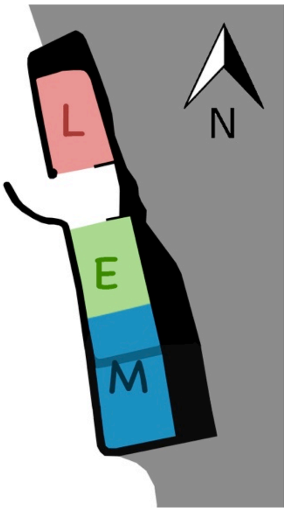


Figure 38 Alternative 2, *Direct Expansion*

Alternative 3

Phased expansion

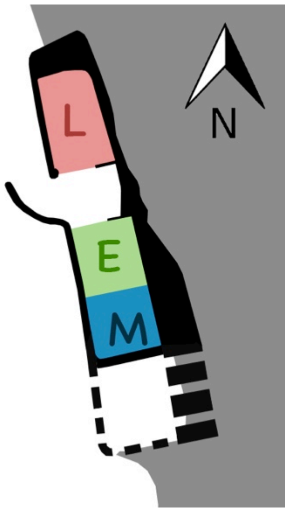


Figure 37 Alternative 3, *Phased Expansion*

3.6.3 OBJECTIVES AND CRITERIA

The objectives and criteria that are used to test the options are:

Investor profit
The amount of income generated for the investors after subtraction of the total costs. This criteria is important for the investors and the Sri Lankan Government. A higher investor profit makes the project more attractive for the investors. This is also positive for the government, because this makes it more easy to find an investor for the project.

Governmental profit
The amount of income generated for the government after subtraction of the total costs. Logically, this criteria is important for the Sri Lankan Government. Profit for the government is positive for Atradius, ORET-programme and HSBC, because then the government can repay the loans for the Dikkowita Harbour.

Economic value
The measure of the economic benefit provided by the marina. Only aspects that have a different contribution in each option are taken into account, like the added economic value of an export harbour. Of course economic value is important for the government, but also the local people have profit from better economy.

Local fishermen satisfaction
The satisfaction of the local fishermen in the harbour.

Marina berthing capacity
The amount of berthing places for yachts inside the marina. This criteria is important for the potential yacht owners, the local people and the tourists.

Fishery berthing capacity
The amount of berthing places for fishing boats inside the export part of the harbour. Logically, this criteria is important for the foreign fishermen.

Boat accessibility
Ease of navigating in the harbour. This criteria is important for the foreign fishermen and the yacht owners (local people and tourists).

Sustainability
The minimisation of negative ecological effects. This is beneficial for all the visitors, so the tourists, local people and fishermen. A sustainable environment also contributes to the reputation of Sri Lanka. Therefore, this is beneficial for the government.

Harbour elegance
The measure of how convenient the looks of the final harbour layout are. This criteria is important for all the visitors of the harbour. An elegant harbour is also positive for the Ministry of Tourism, because this will enlarge the attractiveness of Sri Lanka.

Safety
The safety for the people using the harbour. Only aspects that have a different contribution in each option are taken into account, like mixing boats with different purposes, the density in the harbour and on land and the relationship between local fishermen and the export fishery sector. This is criteria is important for all the users of the harbour, so the tourists, local people, fishermen and the people who work in the harbour.

Water quality
The quality of the water inside the harbour. Logically, a good water quality contributes to the comfort of the yachtsmen.

Construction time
The total time of construction. This criteria is again important for all the users of the harbour, because during construction the harbour and surroundings cannot be used optimally.

Ignored criteria
Some common used criteria are ignored in this MCDA as they have the same values for each option, or depend on the further design, like the durability and the traffic accessibility. Here it is assumed that these two factors will have sufficient quality, regardless the chosen alternative, otherwise the harbour design does not satisfy the requirements of a high quality marina.

3.6.4 EXPECTED PERFORMANCE

The expected performances per criteria are:

Investor profit
The net present value of the investor profit for each alternative, calculated in appendix XI, is:

	NPV
Full Marina	$ -10,620,000.-
Direct Expansion	$ -12,900,000.-
Phased Expansion	$ -12,070,000.-

Therefore, the *Direct Expansion* will get the lowest score, the *Phased Expansion* a slightly higher score and the *Full Marina* will get the highest score.

Governmental profit
The net present value of the governmental profit of each alternative, calculated in appendix XI, is:

	NPV
Full Marina	$ 8,120,000.-
Direct Expansion	$ 13,320,000.-
Phased Expansion	$ 13,320,000.-

Therefore, the *Full Marina* will get the lowest score and the other two alternatives get a high, equal score.

Economic value
The bigger size and the presence of an export part of the *Direct Expansion* and *Phased Expansion* will add more activities and jobs in and around the harbour and therefore the economic value will be higher than the economic value of the *Full Marina.*

Local fishermen satisfaction
The stakeholder analysis in chapter 2.4 shows that the local fishermen play an important role. Their desires are keeping or expending their berthing space and they see the export fishing boats as competition. They will mostly be satisfied with the *Full Marina*. Between the *Direct Expansion* and *Phased Expansion* there is not a big difference in satisfaction with respect to the local fishermen.

Marina berthing capacity
The marina berthing capacity is almost fully dependent on the size of the marina. The *Full Marina* will have the largest marina area with an estimate of 240 berths. The marina of the *Phased Expansion* only has a part of the southern basin in the starting phase and a maximum of 200 berths after the expansion. Therefore, the *Full Marina* will have the highest score and the *Direct Expansion* and the *Phased Expansion* will both have a lower score.

Fishery berthing capacity
The fishery berthing capacity depends on the sizes of export fishery harbour. The local fishery harbour does not have any influence, because it has the same size for every alternative. The *Full Marina* has no export part., while the *Phased Expansion* and the *Direct Expansion* do have an export part. This export part has the same size for both alternatives. Therefore, the *Direct Expansion* and the *Phased Expansion* will have the highest score and the *Full Marina* will have the lowest score.

Boat accessibility
The combination of the export part and the marina in the southern basin can cause more congestion since the boats have different paths through the harbour as well as the density of boats in the harbour will be higher. The *Full Marina* will get a higher score than the expansion options.

Sustainability
The expansion of the harbour will cause a higher ecological footprint. That is why the *Full Marina* will get a higher score than the expansion options.

Harbour elegance
The use of the total southern basin for the marina will give the ability to adjust the full layout to the convenience of the yacht owners. It is less convenient for them to navigate through the export fishery part first before they will reach the marina. The *Full Marina* layout offers the most space and freedom to focus fully on the yacht owners and will get the highest elegance. This is also because the fishery harbour will have a negative effect of how the harbour the looks and smells. Since the *Direct Expansion* offers more space in the southern basin than the *Phased Expansion* during the first phase, yacht owners will suffer less from the export fishery than they will in the *Phased Expansion* and there will be less space and freedom for the marina part. Therefore, the *Full Marina* will get the highest score, and the *Phased Expansion* the lowest.

Safety
Safety will decrease when the density of boats will increase and boats with different purposes will be combined. This results in the highest score for the *Full Marina* and the lowest score for the *Phased Expansion*.

Water quality
In appendix VIII the water quality is discussed for each alternative. In chapters 3.3 to 3.5 the results are displayed for each alternative. For the *Full Marina* the aspect ratio has a better score than for the expansion options. The expansion options score better on the A/a ratio then the *Full Marina.* For the E-folding time and the tidal prism ratio the scores are equal for all the alternatives. The scores are not very different, but for a smaller basin it is easier to keep it clean. Therefore, the *Full Marina* gets a slightly higher score than the expansion options. The *Phased Expansion* and the *Direct Expansion* will get an equal score.

Construction time
The *Full Marina* will have the least construction time and therefore the highest score, since there is no expansion needed. The *Direct Expansion* will get the second place, because expending the harbour and constructing the on land facilities can be done in the same time, which is not possible in the *Phased Expansion*.

3.6.5 WEIGHTING

Table 29 is used for the determination of the weights of the different criteria. Each cell describes which of the two criteria is the most important. A criterion from the left column gets a '1' when it is more important than the other criterion from the top row and a '0' when it is less important. '0.5' is used when the importance of the two criteria is almost the same.

Table 29 Weights of the MCDA criteria

	Criteria	1	2	3	4	5	6	7	8	9	10	11	12	Weight
1	Investor profit	x	1	0	0	1	1	1	0	1	0	1	1	7
2	Governmental profit	0	x	0	0	1	1	1	0	1	0	1	1	6
3	Economic value	1	1	x	1	1	1	1	0	1	0	1	1	9
4	Local fishermen satisfaction	1	1	0	x	1	1	1	0	1	0	1	1	8
5	Marina berthing capacity	0	0	0	0	x	1	0	0	0	0	0	1	2
6	Fishery berthing capacity	0	0	0	0	0	x	0	0	0	0	0	1	1
7	Boat accessibility	0	0	0	0	1	1	x	0	0,5	0	1	1	4,5
8	Sustainability	1	1	1	1	1	1	1	x	1	0	1	1	10
9	Harbour elegance	0	0	0	0	1	1	0,5	0	x	0	1	1	4,5
10	Safety	1	1	1	1	1	1	1	1	1	x	1	1	11
11	Water quality	0	0	0	0	1	1	0	0	0	0	x	1	3
12	Construction time	0	0	0	0	0	0	0	0	0	0	0	x	0

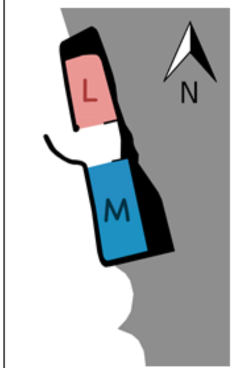
The table results into a top 3 of important criteria:
1. Safety
2. Sustainability
3. Economic value

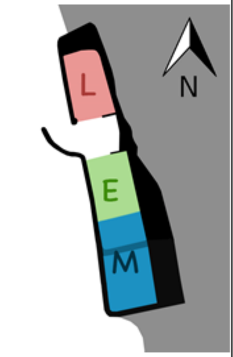
Construction time, fishery berthing capacity and marina berthing capacity are the least important criteria. The final outcome of the weight of the construction time is 0, but will be changed in the final analysis into 1 in order to take the construction time into account as well.

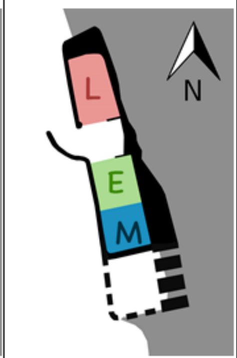
3.6.6 RESULTS

Each option will now be tested on the different criteria. The score of an option for each criterion will between 1 and 10, based on the expected performance. For the investor profit and the governmental profit a difference of 0.58 million will result in a difference of 1 point in the score. This is based on the largest difference in the profit divided by 9 (the amount of steps between 1 and 10). For the governmental profit the difference in profit between the *Full Marina* and the *Expansions* is 5.2 million, this will give a difference of 9 points. Therefore, for the governmental profit the *Full Marina* scores 1 point and the *Expansions* score 10 points. For the investor profit these differences are smaller. For the other criteria a score of 1 is given to the alternative with the poorest performance. The other alternatives will be rated with respect to the poorest. For example, a difference in score of 9 points indicates a large performance difference.

Table 30 Scores MCDA







		Full Marina		Direct Expansion		Phased Expansion		
Criteria		Score	Score * Weight	Score	Score * Weight	Score	Score * Weight	Weight
1	Investor profit	5	35	1	7	3	21	7
2	Governmental profit	1	6	10	60	10	60	6
3	Economic value	1	9	7	63	7	63	9
4	Local fishermen satisfaction	8	64	1	8	1	8	8
5	Marina berthing capacity	7	14	1	2	1	2	2
6	Fishery berthing capacity	1	1	7	7	7	7	1
7	Boat accessibility	5	22,5	1	4,5	1	4,5	4,5
8	Sustainability	6	60	1	10	1	10	10
9	Harbour elegance	8	36	2	9	1	4,5	4,5
10	Safety	3	33	1	11	1	11	11
11	Water quality	3	9	1	3	1	3	3
12	Construction time	8	4	3	1,5	1	0,5	0,5
	Total score		293,5		186		194,5	

There is quite a difference between the final outcomes of the *Full Marina* and the other two alternatives, so it is clear that the *Full Marina* is assessed as the best solution.

The *Full Marina* is the best solution, because the combination of a marina and export fishery harbour in one basin gives some complications. Most important is the reduction of the safety, but other problems are the reduction of the boat accessibility, the lower capacity for yachts, the lower water quality and the lower harbour elegance. These things make the *Full Marina* function more as a whole and make it more comfortable and attractive to stay for tourist and yachtsmen. Therefore, this also seems more attractive to build the *Full Marina* and to make this investment. On the other hand, for the investor the profit is most important, which is also higher here. With the *Full Marina* the local fishermen are also satisfied, because the export fishery fleet will finally be gone.

Following from the smaller ecological footprint of the *Full Marina*, the sustainability is higher here. This is a important criteria for the government, because this is of influence of the reputation of the country. A disadvantage for the government is the lower economic value. Chances to be a big fish export country are reduced, which also lowers the profit for the government. However, it can be concluded with this MCDA that these two points do not have the same weight as the others mentioned before.

3.6.7 SENSITIVITY

A sensitivity analysis needs to be conducted to have an impression of the robustness of the results. The scores for the criteria could be different in reality than stated here. While criteria like water quality, safety and berthing capacity will probably not show large differences in reality, criteria like governmental and investor profit are a lot more difficult to estimate. Therefore, the investor profit and governmental profit for the *Full Marina* will be decreased by 10% and the scores are recalculated to show the sensitivity of changes in the profit to the results. The scores of the local fishermen satisfaction and sustainability for the *Full Marina* will also be decreased by 10%, because the real outcomes of these criteria are also highly uncertain.

Table 31 Sensitivity analysis

Changed criteria	**New score *Full Marina***	**New score *Direct Expansion***	**New score *Phased Expansion***
Investor profit	279.5	186	194.5
Governmental profit	293.5	198	206.5
Local fishermen satisfaction	287.1	186	194.5
Sustainability	287.5	186	194.5
Investor profit Governmental profit	279.5	198	206.5
All changed criteria	**267.1**	**198**	**206.5**

Table 31 shows the new scores of the alternatives after one or more criteria are changed. When the scores both profits, the local fishermen satisfaction and the sustainability are decreased for the *Full Marina,* this alternative remains the best solution and the difference in scores between the other alternatives is still high. Therefore, it can be said that the results of the MCDA are robust.

4 FINAL DESIGN

In this chapter an impression is given of what the marina in the harbour of Dikkowita could look like. The construction will probably be financed by a private investor who will have his own view, so this will possibly not be the final design. First an overview of the marina is given, followed by an explanation of the basin and harbour land layout. After this, something will be told about phased building of the project. This is followed by a part about the breakwaters, the water quality and the infrastructure around the harbour of Dikkowita. At the end the final costs and incomes are discussed.

4.1 MASTER PLAN

An overview of the marina can be seen in the figures below and in appendix XVI. The southern basin is completely transformed into a marina. The basin and harbour land layout are explained in the coming subchapters.

Figure 39 Overview 1 of the Dikkowita Marina

Figure 40 Overview 2 of the Dikkowita Marina (Google Earth, 2015)

4.1.1 BASIN LAYOUT

As can be seen in figure 41, there are more than 200 yachts in the harbour, with lengths from 8 meters up to 30 meters. Berthing places for long yachts are situated close to the harbour mouth and the smaller places are more to the end of the basin. All jetties are floating and connected to the land side. In this way the berths are as close as possible from the other facilities. On the north side the floating breakwater is clearly visible. On the north side there is also the place where boats can be lifted out of the water.

Figure 41 Top view of the Dikkowita Marina (Google, 2015)

Appendix XII shows a drawing of the Dikkowita Marina with its dimensions. The actual amount of berths per boat length are now known and displayed in table 32.

Table 32 Amount of berths per boat length

Boat length (m)	Amount of berths
30	8
25	16
20	38
15	44
12	49
10	27
8	36
Total	218

The floating breakwater is also shown in the drawing with a length of 60 meters, a width of 3 meters and an angle of 45°. The calculations for these dimensions are given in chapter 4.2.2.

4.1.2 HARBOUR LAND LAYOUT

After berthing their yachts, people get on land via the finger piers and walkways. They will face a wide boulevard where many people hang around. They look at the yachts, have some food in restaurants, relax at the benches and walk from the shops back to their hotel. The impressive main marina building has a central position on the boulevard with a pool in front. In this building the main information desk can be found, together with harbour offices, a bar, restrooms, a first aid service and a terrace around the pool and harbour side. Also restaurants, hotels and shops can be found along the boulevard.

Figure 42 Impression of the Dikkowita Marina boulevard

There are hotels and apartments in this design with different dimensions and classes. The eye-catcher is the around 15 floors tall hotel at the south side, with a rooftop pool and sky lounge. The second biggest hotel is located at the northern part of the marina, has a surface of more than 2000 square meters and 3 floors with a restaurant and pool on top. Between the main marina building and the tall hotel there is a shopping mall and there are four white buildings with apartments.

On a further distance from the water parking facilities are created. There is one public parking area with around 50 places and there is one secured parking area with around 200 places. In the north corner of the harbour there is a boat parking area offering places with and without roofing.

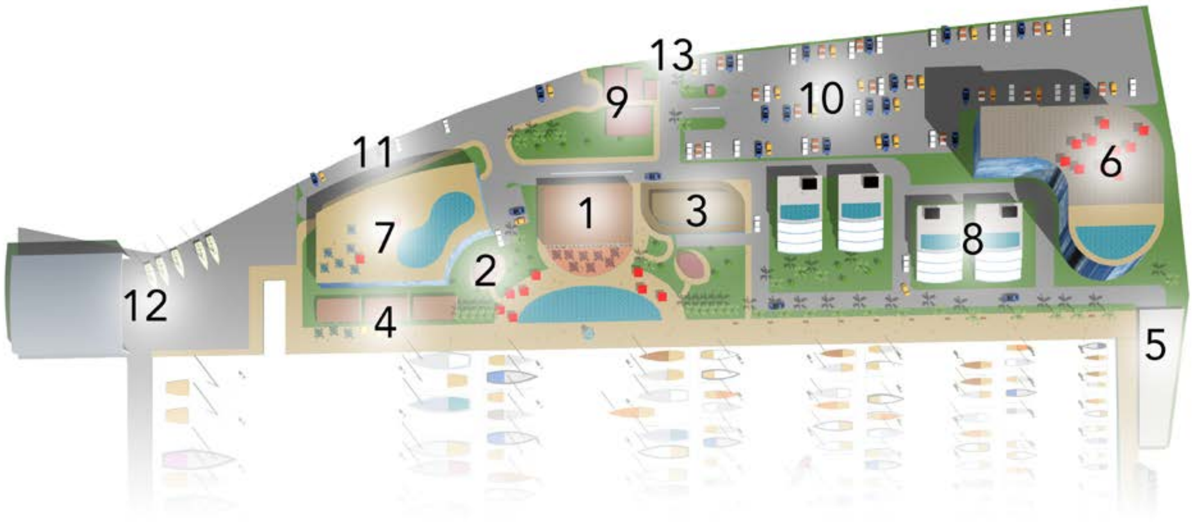


Figure 43 Map of the Dikkowita marina

1. Main Building
2. External restrooms
3. Shopping mall
4. Restaurants and shops
5. Boat shop
6. 15 floors hotel with rooftop pool and sky lounge
7. 3 floors hotel with rooftop pool and restaurant
8. Apartments
9. Security, electricity, sewage
10. Secured parking area
11. Public parking area
12. Boat parking area
13. Main entrance/exit

4.1.3 PHASED CONSTRUCTION

The number of yachts in the harbour will be very low the first years, because yachting will be new in Sri Lanka. This is why first only one floating jetty will be placed. This has to be a jetty for average length boats and thus will be one of the two jetties in the middle, see figure 41. When looking at what kind of boats will berth here, the second jetty has to be for smaller or bigger boats. This can go on until the basin is full. Noted must be again, that the design showed is not fixed and does not have to be the final design. The berth sizes will depend on the demand.

The main building is the most important land facility. This must be finished before opening of the marina, just like the car parking and the security, electricity and sewage building. Together with the first jetty the marina can be used. All the other buildings could still be under construction at this time. However, it is important to finish those buildings as soon as possible to create the marina ambiance, which will attract people.

4.2 BREAKWATERS

In this chapter the outside breakwater is discussed with respect to overtopping and the floating breakwater with respect to wave reduction inside the basin.

4.2.1 BREAKWATER OVERTOPPING

In figure 44 again the overview of the dangerous parts of the breakwaters with respect to the yachts and the pedestrians is showed during the Southwest monsoon as discussed before in chapter 2.3.5. At the red part critical damage could occur to small yachts, the orange part could possibly give discomfort to all yachts and for all the parts along the breakwater there could be danger for pedestrians.

Figure 44 Overview of the dangerous parts of the breakwater for the yachts and pedestrians with respect to overtopping (Google, 2015)

To avoid unlikely events with pedestrians the path behind the breakwater will be closed completely for them. Of course the waterway cannot be closed. Therefore, a wall has to be placed on top of the breakwater to reduce overtopping. However, the height of this wall is hard to determine, because not much research has been done on this. In the Overtopping Manual from The EurOtop Team (EurOtop, 2007), one research is showed for the height of the vertical wall placed on top of a slope. The slope to use for the results from this research must be between 1:2.5 and 1:3.5, where the slope of the breakwater is 4:3. This research can thus not be used, but could give an indication of how high the wall must be. For a wall with a high foot, which is the case here, the wall height must be $0.5 \cdot \mathrm{H_{m0}}$. Taking for $\mathrm{H_{m0}}$ the significant wave height during normal water conditions, so 2.4 meters, the overtopping in most cases will probably be reduced enough. The wall of 1.2 meters is to make it more comfortable to sail in the harbour during normal weather conditions and to make it safe to sail through the entrance during storms. How much the effects of the vertical wall on top of the breakwater really are and if the size of this wall is correct, must be investigated in more detail. Another option is to use some regulations and to provide people with information when the situation is not safe at that moment.

4.2.2 FLOATING BREAKWATER DIMENSIONS

For the dimensioning of the floating breakwater PIANC guidelines are used (PIANC, 1994). The calculation can be found in appendix XIII. In this calculation the transmitted wave height, so the wave height in the basin is calculated by determining the transmission coefficient. In table 33 all the incoming waves with their period are given. In the table the transmission coefficients and transmitted wave heights can also be found. All the transmitted wave heights are lower than 0.3 meters, the criterion for waves inside a marina. The determined dimensions of the floating breakwater are:

- Width: $\mathrm{W} = 3 \text{ meters}$
- Depth of the floating breakwater: $\mathrm{D} = 2.5 \text{ meters}$
- Length: $\mathrm{L} = 60 \text{ meters}$

Table 33 Summarizing table of the wave heights in the basin

Season	Representative wave height [m] and probability	Representative wave period [s] and probability	Transmission coefficient c_t	Transmitted wave height [m]
First Inter-monsoon	0.25 [1.7%]	3.5 [1.7%]	0.42	0.11
Southwest monsoon	0.63 [0%]	3.8 [0%]	0.46	0.29
Second Inter-monsoon	0.33 [7.5%]	3.5 [7.5%]	0.42	0.14
Northeast monsoon	0.39 [9.3%]	3.7 [9.3%]	0.44	0.17

4.3 WATER QUALITY OF THE FINAL DESIGN

Not every criterion of the water quality of the southern basin had a good rating in alternative I. The values for the criteria are repeated in the table below. All information about the water quality can be found in appendix VIII. A measure to upgrade the water quality is to make curves in the corners of the basins. However, this will lower the amount of berths, because the basin area gets smaller and the shape of the basin gets less practical. Therefore, this is not applied in the design.

Figure 45: Blockage of entrance cross section by floating breakwater (Google, 2015)

However, the A/a ratio changes due to the floating breakwater, because the cross sectional area of the entrance of the basin gets smaller. The breakwater is not located directly in the entrance, but is assumed it blocks water like the yellow line (figure 45) in the cross sectional area of the entrance (red line is the breakwater, blue line the cross sectional area). Where the floating breakwater has a length of the 60 meters, the length of the yellow line will be $\frac{60}{\sqrt{2}}$. With a depth of 2.5 meters of the floating breakwater this reduces the cross sectional area of the entrance from 375 to 291 squared meters. The A/a ratio now changes to 187 and so almost satisfies the requirement of 200.

The tidal prism ratio becomes better when the basin gets less deep. At the moment the basin is 5 meters deep, while for the largest yachts the depth just has to be 3 to 4 meters (Committee CE-030, 2001). Costs could be saved on dredging the first years if only is dredged till 4 meters depth. Volume of water at high tide will be in that case $V_{high\ tide} = 236640\ m^3$ which makes the tidal prism ratio 0.16. This is also not enough according to the requirements.

Despite that not all the requirements are met, no further measures are taken. This is because these parameters do not clearly give a view on how good or how bad the water quality will become. This has to be investigated. An example of another important factor to investigate is the water quality around Dikkowita.

Table 34: Water refreshment score for the southern basin

Factor	Old result	New results	Required	Score (good, poor)
E-folding time	3.9 days	3.9 days	< 4 days	Good
Aspect ratio	0.47	0.47	Between 0.5 and 2	Good
A/a ratio	145	187	Minimum > 200 Preferred > 400	Poor
Tidal Prism Ratio	0.13	0.16	Minimum > 0.25 Preferred > 0.35	Poor

4.4 INFRASTRUCTURE

In this subchapter adjustments to the infrastructure around Dikkowita are proposed. First the roads are discussed, followed by the public transport, existing of busses and trains.

An elegant marina where people come to spend their holidays in a luxury way requires a convenient infrastructure with good connections to important places in the surroundings. The visitors of the marina of Dikkowita need to have the ability to get to Colombo, Negombo and the international airport easily. A direct connection from the harbour to the express way will provide a connection which gives this ability. Figure 46 shows this express way and other infrastructure around the harbour.

Figure 46 Location Dikkowita Harbour and roads (Google, 2015)

A first option to improve the connection to the express way is to upgrade the B151 road. This road has to deal with the same traffic problems as the B152, as discussed in chapter 2.1.1. An upgrade is needed in order to make the quality of the infrastructure sufficient for the harbour users. It has to have the function of a distributor road and therefore needs fewer intersections. At these intersections traffic needs to be regulated by traffic control systems to prevent disturbance of the traffic flow. Depending on the traffic demand, extra lanes can be added to prevent traffic jams.

A second option is to create a new road between the B152 and the express way. This new road can be implemented both on the north and south side of the Kerawalapitiya Power Plant, see figure 47. On the north side, there is plenty of space. The south side has to deal with a residential area of Dikkowita and a residential area of Karunagama. A disadvantage of the north option is the detour for traffic between the Dikkowita Harbour and Colombo of around two kilometers. For both roads the same requirements apply as for the first option of upgrading the B151: the traffic has to be able to flow fluently.

Figure 47 Options for new roads (Google, 2015)

The infrastructure in the direct surroundings of the harbour needs an upgrade as well. In 2013, BAM International already designed a new bridge across the Hamilton Canal to add a connection between the harbour and the B152, see figure 48. The report was handed to the Sri Lankan ministry and the construction started, however the bridge has never been finished (BAM International).

Figure 48 Entrances of the harbour and unfinished bridge (Google, 2015)

To upgrade the directly surrounding infrastructure of the harbour, a first and easy step would be to finish the bridge following the design of BAM International. In that way, both the fishery harbour and the marina are well connected to the B152. The next step is the upgrade of the part of the B152 that is used by the harbour traffic. That would be the part between the Kerawalapitiya Power Plant and the B151, see figure 48. Again intersections need to be controlled by traffic systems and lanes have to be added when the demand is higher than the capacity of a single lane per direction.

The B152 and B151 roads connect the harbour with this train station. An upgrade of these roads to improve the car infrastructure, will improve the accessibility to the train as well. From the Hunupitiya station, see figure 46. The local busses might be sufficient for the Sri Lankan harbour visitors who are used to this public transport system, but are definitely not convenient for the luxury tourists.

Both current public transport systems, bus and train, are not sufficient. A shuttle service can be launched with shuttle busses from the Dikkowita Marina straight to Colombo, Negombo and the international airport. Since the shuttle busses will use the same infrastructure as the car traffic, the demand for an upgrade of the road infrastructure will be even higher.

4.5 TOTAL COSTS AND INCOMES

The total amount of berths for the masterplan is now known and is less than the estimated amount of berths, namely 218. The total costs and incomes of the harbour will also be different now. The construction costs of the necessary and optional facilities will change a bit, together with the construction costs for the jetties. The new construction costs for the jetties in every phase are shown in table 35. The total costs for the necessary and optional facilities are given in table 36.

Table 35 Jetty construction costs per phase

Phases	Jetty costs
Phase I	$ -1,693,375
Phase II	$ -1,693,375
Phase III	$ -1,693,375
Phase IV	$ -1,693,375
Phase V	$ -1,616,403.59
Total	**$ -8,389,904.37**

Table 36 Final costs of the marina facilities

Necessary facilities	Optional facilities
$ -1,430,000.-	$ -22,990,000.-

Al other marina costs and incomes dependent on the total amount of berths will also change. This will result in a new net present value for the government and the investor, where the optional facilities are not taken into account. This NPV is calculated in appendix XI and the results are given in table 37.

Table 37 Net present value of the final profits

Governmental profit	Investor profit
$ 8,100,000.-	$ -10,210,000.-

Still the investor loses money on the marina facilities, but as mentioned before, the investor must get his profit from the optional facilities like hotels, restaurants and shops.

4.6 MARINA DEVELOPMENT STRATEGY

The yachting culture is a culture of luxury. Buying and maintaining a yacht on itself is already expensive. Therefore, a marina should also be focussed on luxury. International standards must be reached to make the marina a success in the way that many people like to have their yacht in this harbour, but also in a way that the marina will be an attractive place to visit.

Besides that, just one marina on its own would not be very economic valuable. A culture of yachting has to be created which not could be done with just one marina. More marinas have to be built to make it a living and profitable business, but somewhere a start has to be made. Dikkowita could be a good place to start, because it is close to Colombo, the most densely populated place of the country. More importantly, there are also a lot of rich people living in this city, which could be potential buyers of yachts.

A second marina could be created in Colombo with the Port City project. A design impression of a harbour in Beruwala is already made by the company Marina Lanka, visible in figure 50. This could be the third marina in Sri Lanka. In Galle they already started with the construction of a marina. Here only some adjustments have to be made to make the marina of international standards. In Mirissa, because of its great location, sometimes international yachts are berthing here. So makes Mirissa als a potential location for a marina (Deputy Harbour Manager Dikkowita, 2015). Together, this already forms a very attractive yacht culture, where people can choose where they would like to have their boat according to their wishes, like location and berthing costs.

Figure 49 Possible marina locations (Google, 2015)

Figure 50 Design impression of marina in Beruwala (Arrol, 2014)

The above mentioned places are all situated on the southwest coast, for now the most attractive coast to start with marinas. Marinas on the east coast can be developed directly after the marinas on the southwest coast, because of the opposite monsoon season with regard to the southwest coast (stage 2, figure 51). This combination gives great opportunities for the use of motor and sailing yachts during the different seasons, as explained in chapter 2.3.7 (Arrol, 2014). After that, a touristic highlight like Negombo could also be an attractive place. The coastline between stage 1 and 2 could also be developed at the same time, see figure 51.

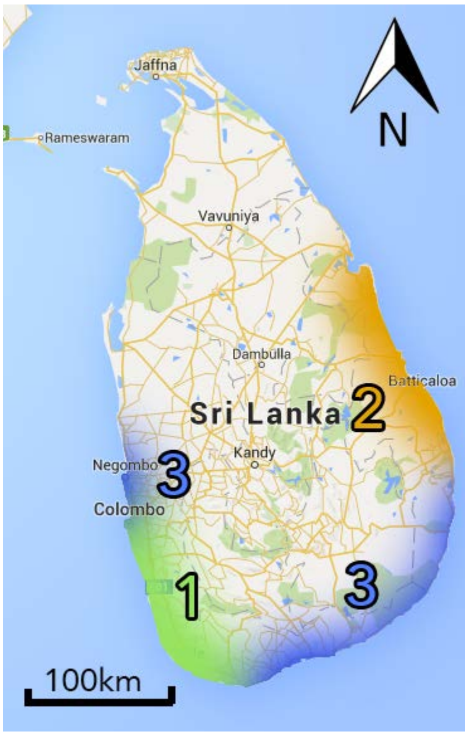


Figure 51 Phases of the marina development strategy (Google, 2015)

5 CONCLUSION

In this research the implementation of a marina in the Dikkowita Fishery Harbour is investigated to increase the profitability by utilizing the overcapacity of the current harbour. A marina fits perfectly in the harbour. It will solve the current problems and will create economic possibilities for the country as well as for the local people. Besides, the weather conditions in Sri Lanka are excellent for yachting.

Three possible designs for the division of the harbour were found. These where tested with a multi-criteria decision analysis (MCDA) on important criteria such as safety, sustainability, economic value and stakeholder satisfaction. The *Full Marina* option, in which the entire export sector is removed, obtained the highest score and is used for a further design. It is very important for the success of the marina, that it is elegant and therefore attractive to visit. The *Full Marina* also scored high on this criterion.

This solution completely removes the conflicts between the local fishermen and the export sector. The layout and the use of the northern basin will remain the same, so the local fishermen will keep all facilities they have nowadays. The southern basin will be fully used for marina purposes and therefore no mixture between different kinds of boats is present. A disadvantage is the total removal of the export part. This is a loss of governmental income and economic value.

An impression of the marina can be found in figure 52. In the harbour basin there is place for 218 yachts of different lengths between 8 and 30 meters. All the jetties are directly connected to the land, where in the middle the main harbour building can be found with the offices, restaurants and restrooms. The high buildings are hotels, the four equal lower buildings are for apartments and there is a shopping centre. On the left side there is a place where boats can be lifted out of the water and stalled on land or in the storage hall for maintenance. Very important is also the big parking lot on the side of the road, where more than two hundred cars can park. For safe and comfortable use of the marina, the height of the outside breakwater is increased to reduce the overtopping of water. Besides that, a floating breakwater is placed at the basin entrance to lower the waves coming into the basin. To improve the water quality, the water depth in the basin is changed from five to four meters.

Figure 52 Overview of the marina

The *Full Marina,* without the optional facilities, will generate profit for the government, but not for the investor. The net present value (NPV) for the government will be around eight million US dollars, where the NPV of the investor will be a loss of around 10 million US dollars. The investor could accomplish a positive NPV by generating income from the optional facilities, such as hotels, which are not taken into account in this research.

The harbour needs to have better connections with Colombo, Negombo and the Bandaranaike International Airport. These infrastructure upgrades around the harbour will improve the connectivity and will therefore contribute to the quality of the marina. A successful marina could be a stepping stone for new projects to implement marinas along the whole coast of Sri Lanka.

6 RECOMMENDATIONS

There are some actions that could be done and affairs that should be taken into account after this report. First, the design shown in the master plan is an impression of how the new marina could look like. The private investors involved in the project could have a different view on the final design. Therefore, the structural design, which is not addressed in this report, should be made after the final design is created.

Secondly, the wave data used in the calculations is obtained from measurements on open water. The waves inside the harbour are estimated with the use of these waves, because there were no actual measurements of the waves present inside the harbour. It is recommended that these measurements are done to increase the validity of the wave calculations.

Besides the inaccurate wave data, the effect of a floating breakwater is most of the times hard to predict. Also because it is not located in deep water, where floating breakwaters are most efficient, it would be wise to test the breakwater first in a physical model. When this is done, a more efficient and precise design could be made. Another suggestion in the report is to place a vertical wall on the top of the outside breakwater. The effect and size of this breakwater must be investigated in more detail.

Last unsure point about the inside of the basin is the water quality. Not all the criteria for a good water quality are satisfied, so investigated must be what the effects of certain adjustments are really and if it is worth it to make these costly changes to the design. The water quality around the harbour should also be checked, because this will have an effect on the quality inside the harbour.

Another advice is to look at the costs and incomes of the harbour. In this research the actual harbour is already making profit, while basically all the fishery harbours in the country do not achieve this. Further research on this is recommended to get a more reliable overview of the current profit of the harbour. This way there can be concluded if the marina is more profitable than the export harbour.

Outside the harbour, the infrastructure is not sufficient enough to ensure a fast connection between the harbour and places where users could come from. This connection could be improved by constructing a new road between the B152 and the express way. A choice should be made between the two alternatives of this new road. The infrastructure in the direct surroundings can be upgraded by finishing the bridge connecting the harbour with the B152. Upgrading the B151 and B152 will improve the connection between the harbour and the Hunupitiya Railway Station, where shuttle busses could be used to further increase the quality of the public transport from and to the harbour of Dikkowita.

A last note is about the development of marinas in Sri Lanka. Just one marina on itself will probably not give the expected results. More marinas need to be built to create a yachting culture in the country. This is important to make the marinas well known in Sri Lanka and to create the needed demand. Only in this way it will have the promised economic and touristic value.

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APPENDICES

APPENDIX I: CURRENT HARBOUR PROFIT

Dollar	Total income			Total expenses			Operational results			Total salaries		
Months in 2014	North	South	Cummulative	North	South	Cummulative	North	South	Cummulative	North	South	Cummulative
January	$ 12,142.34	$ 43,378.12	$ 55,520.46	$ 5,413.56	$ 13,124.81	$ 18,538.37	$ 7,155.26	$ 29,826.83	$ 36,982.09	$ 2,221.01	$ 4,382.59	$ 6,603.60
February	$ 14,300.55	$ 51,088.27	$ 65,388.83	$ 3,791.51	$ 9,192.26	$ 12,983.77	$ 10,139.28	$ 42,265.78	$ 52,405.06	$ 3,468.37	$ 6,843.93	$ 10,312.30
March	$ 17,512.22	$ 65,330.03	$ 82,842.25	$ 5,183.62	$ 12,866.81	$ 18,050.44	$ 12,328.60	$ 52,463.22	$ 64,791.81	$ 3,157.92	$ 6,708.78	$ 9,866.70
April	$ 11,026.28	$ 64,783.66	$ 75,809.94	$ 5,703.59	$ 12,954.61	$ 18,658.20	$ 5,322.69	$ 51,829.06	$ 57,151.74	$ 3,655.88	$ 6,797.50	$ 10,453.38
May	$ 10,524.26	$ 66,901.79	$ 77,426.04	$ 5,607.36	$ 13,557.17	$ 19,164.53	$ 4,916.90	$ 53,344.62	$ 58,261.52	$ 3,709.11	$ 7,774.87	$ 11,483.98
June	$ 8,167.34	$ 59,241.56	$ 67,408.91	$ 4,743.75	$ 15,338.01	$ 20,081.76	$ 3,423.59	$ 43,903.55	$ 47,327.14	$ 2,732.26	$ 7,697.44	$ 10,429.71
July	$ 11,875.94	$ 53,016.37	$ 64,892.31	$ 4,882.46	$ 12,679.57	$ 17,562.03	$ 6,993.47	$ 40,336.81	$ 47,330.28	$ 3,174.68	$ 6,576.74	$ 9,751.42
August	$ 15,191.01	$ 37,936.73	$ 53,127.74	$ 4,854.50	$ 12,373.32	$ 17,227.83	$ 10,336.51	$ 25,563.40	$ 35,899.91	$ 3,291.31	$ 6,793.47	$ 10,084.79
September	$ 15,201.93	$ 31,400.36	$ 46,602.29	$ 4,652.64	$ 12,387.58	$ 17,040.21	$ 10,549.30	$ 19,012.78	$ 29,562.08	$ 3,037.45	$ 6,743.12	$ 9,780.57
October	$ 18,831.08	$ 43,721.63	$ 62,552.71	$ 5,330.00	$ 11,653.68	$ 16,983.67	$ 13,501.08	$ 32,067.95	$ 45,569.03	$ 3,733.44	$ 5,868.99	$ 9,602.43
November	$ 17,396.56	$ 40,748.98	$ 58,145.54	$ 5,473.42	$ 11,418.72	$ 16,892.13	$ 11,923.14	$ 29,330.26	$ 41,253.41	$ 3,996.35	$ 6,557.79	$ 10,554.14
December	$ 10,190.14	$ 47,156.54	$ 57,346.68	$ 5,424.27	$ 11,121.74	$ 16,546.01	$ 4,765.87	$ 36,034.81	$ 40,800.67	$ 3,996.35	$ 6,557.79	$ 10,554.14
Yearly	**$ 162,359.65**	**$ 604,704.03**	**$ 767,063.68**	**$ 61,060.67**	**$ 148,668.27**	**$ 209,728.94**	**$ 101,355.68**	**$ 455,979.05**	**$ 557,334.74**	**$ 40,174.12**	**$ 79,303.03**	**$ 119,477.15**
Share	21.9%	78.1%		29.2%	70.8%		19.3%	80.7%		33.6%	66.4%	

Dollar	Total berth income			Gate pass			Total fuel income			Rent income		
Months in 2014	North	South	Cummulative	North	South	Cummulative	North	South	Cummulative	North	South	Cummulative
January	$ 1,076.26	$ 6,776.18	$ 7,852.44	$ -	$ 1,012.03	$ 1,012.03	$ 18,531.89	$ 873.53	$ 19,405.42	$ -	$ 12,030.68	$ 12,030.68
February	$ 2,114.35	$ 13,312.05	$ 15,426.40	$ -	$ 880.18	$ 880.18	$ 301,263.62	$ 14,200.53	$ 315,464.15	$ -	$ 12,030.68	$ 12,030.68
March	$ 1,662.19	$ 13,822.17	$ 15,484.37	$ 3.56	$ 1,126.07	$ 1,129.63	$ 473,452.42	$ 26,238.90	$ 499,691.32	$ -	$ 16,378.15	$ 16,378.15
April	$ 1,554.40	$ 13,143.92	$ 14,698.32	$ -	$ 1,407.58	$ 1,407.58	$ 277,532.12	$ 25,464.83	$ 302,996.95	$ -	$ 16,378.15	$ 16,378.15
May	$ 1,413.28	$ 12,167.44	$ 13,580.72	$ 3.56	$ 1,485.98	$ 1,489.54	$ 271,405.87	$ 27,235.31	$ 298,641.17	$ -	$ 16,378.15	$ 16,378.15
June	$ 1,079.92	$ 13,276.45	$ 14,356.37	$ -	$ 1,478.85	$ 1,478.85	$ 187,211.25	$ 11,237.76	$ 198,449.01	$ -	$ 13,462.19	$ 13,462.19
July	$ 1,484.91	$ 12,671.01	$ 14,155.92	$ -	$ 1,446.78	$ 1,446.78	$ 295,468.49	$ 15,032.23	$ 310,500.72	$ -	$ 12,895.59	$ 12,895.59
August	$ 2,086.79	$ 9,404.02	$ 11,490.81	$ -	$ 762.59	$ 762.59	$ 377,250.20	$ 12,618.40	$ 389,868.61	$ -	$ 12,895.59	$ 12,895.59
September	$ 2,583.89	$ 8,298.37	$ 10,882.26	$ -	$ 705.57	$ 705.57	$ 396,605.60	$ 903.04	$ 397,508.65	$ -	$ 12,895.59	$ 12,895.59
October	$ 1,647.76	$ 9,534.83	$ 11,182.59	$ -	$ 958.58	$ 958.58	$ 515,882.68	$ 15,163.91	$ 531,046.59	$ -	$ 16,672.90	$ 16,672.90
November	$ 2,127.41	$ 8,402.11	$ 10,529.52	$ 7.13	$ 865.93	$ 873.06	$ 436,470.89	$ 7,274.12	$ 443,745.02	$ -	$ 16,672.90	$ 16,672.90
December	$ 1,222.64	$ 10,434.69	$ 11,657.33	$ -	$ 1,136.76	$ 1,136.76	$ 260,717.70	$ 10,234.07	$ 270,951.77	$ -	$ 17,826.91	$ 17,826.91
Yearly	**$ 20,053.80**	**$ 131,243.23**	**$ 151,297.04**	**$ 14.25**	**$ 13,266.91**	**$ 13,281.16**	**$ 3,811,792.73**	**$ 166,476.64**	**$ 3,978,269.37**	**$ -**	**$ 176,517.50**	**$ 176,517.50**
Share	13.7%	86.3%		0.1%	99.9%		95.5%	4.5%		0.0%	100.0%	

Dollar	Weighbridge			Other income			Other expenses		
Months in 2014	North	South	Cummulative	North	South	Cummulative	North	South	Cummulative
January	$ 7.67	$ 48.29	$ 55.96	$ -	$ 7.21	$ 7.21	$ 132.08	$ 6.23	$ 138.30
February	$ 15.07	$ 94.87	$ 109.94	$ -	$ 6.27	$ 6.27	$ 2,147.11	$ 101.21	$ 2,248.31
March	$ 11.85	$ 98.51	$ 110.36	$ 0.03	$ 8.03	$ 8.05	$ 3,374.30	$ 187.00	$ 3,561.30
April	$ 11.08	$ 93.68	$ 104.75	$ -	$ 10.03	$ 10.03	$ 1,977.97	$ 181.49	$ 2,159.46
May	$ 10.07	$ 86.72	$ 96.79	$ 0.03	$ 10.59	$ 10.62	$ 1,934.31	$ 194.11	$ 2,128.42
June	$ 7.70	$ 94.62	$ 102.32	$ -	$ 10.54	$ 10.54	$ 1,334.25	$ 80.09	$ 1,414.35
July	$ 10.58	$ 90.31	$ 100.89	$ -	$ 10.31	$ 10.31	$ 2,105.80	$ 107.13	$ 2,212.94
August	$ 14.87	$ 67.02	$ 81.89	$ -	$ 5.43	$ 5.43	$ 2,688.66	$ 89.93	$ 2,778.59
September	$ 18.42	$ 59.14	$ 77.56	$ -	$ 5.03	$ 5.03	$ 2,826.61	$ 6.44	$ 2,833.04
October	$ 11.74	$ 67.95	$ 79.70	$ -	$ 6.83	$ 6.83	$ 3,676.70	$ 108.07	$ 3,784.77
November	$ 15.16	$ 59.88	$ 75.04	$ 0.05	$ 6.17	$ 6.22	$ 3,110.73	$ 51.84	$ 3,162.57
December	$ 8.71	$ 74.37	$ 83.08	$ -	$ 8.10	$ 8.10	$ 1,858.14	$ 72.94	$ 1,931.07
Yearly	**$ 142.92**	**$ 935.37**	**$ 1,078.29**	**$ 0.10**	**$ 94.55**	**$ 94.65**	**$ 27,166.65**	**$ 1,186.48**	**$ 28,353.13**
Share	13.7%	86.3%					95.5%	4.5%	

Table 38 Total incomes original harbour Dikkowita (Deputy Harbour Manager Dikkowita, 2015)

The orange coloured boxes contain the missing information in the monthly overviews of January and February. These values are calculated with the average share of March to December of the northern and southern basins with respect to the cumulative value. These shares are used to calculate a representative value for the northern and southern basin in January and February.

APPENDIX II: MARINA FACILITIES

Table 39 Marina facilities (Committee CE-030, 2001)

Necessary facilities	Optional facilities
Marina administration offices	Kiosk/coffee shop
Showers and toilets for customers and visitors	Mini-market
Showers, toilets and other amenities for marina employees	Liquor shop
Site electrical supply for power and lighting	Restaurant
Site sewerage and treatment system	Laundromat
Fuel storage tanks and reticulation system for petrol, diesel and LPG	Club rooms
Solid waste collection and disposal facilities	Sailing/navigation school
Firefighting services and equipment	Power/sailboat hire and charter office and support facilities
Storm water drainage system	Retail outlets
Communications facilities, including office telephones and two-way radio	New and used boat sales office and display area
Boat dry storage facilities including dinghy storage	Trailer boat and outboard motor sales office and display area
Hardstand areas for boat repair and maintenance	Providoring service
Hardstand drainage and pollution control system	Commercial office space
Access for pedestrian and vehicular traffic	Boat valet service office and support facilities
Navigation	Sail making/canopy repair office and work area
Oil spill containment equipment	Workshops and secure storage for tools, equipment and materials
Security systems	Landscaping
Lifebuoys	
Vehicle parking	

APPENDIX III: TIDAL RANGE

These tidal range results in the two tables below are actually for fishery purposes, but this also gives a good approximation for the spring tidal range around Colombo.

Table 40 : Maximum tidal range per month from 2013 – 2015 (Mobilegeographics, sd)

Month in 2013	Max tidal range (m)	Month in 2014	Max tidal range (m)	Month in 2015	Max tidal range (m)
January	0,8	January	0,8	January, 2015	0,8
February	0,7	February	0,7	February	0,7
March	0,7	March	0,7	March	0,8
April	0,7	April	0,7	April	0,8
May	0,8	May	0,8	May	0,7
June	0,7	June	0,7	June	0,7
July	0,7	July	0,7	July	0,6
August	0,7	August	0,6	August	0,6
September	0,7	September	0,7	September	0,7
October	0,8	October	0,8	October	0,7
November	0,7	November	0,7	November	0,7
December	0,7	December	0,7	December	0,6

Table 41 Maximum tidal range per month in 2015 (Tides4Fishing, sd)

Month in 2015	Max tidal range (m)
January	0,7
February	0,7
March	0,7
April	0,8
May	0,7
June	0,7
July	0,7
August	0,6
September	0,7
October	0,7
November	0,7
December	0,6

The average value for these measurements results in a maximum tidal range of 0.7 meters.

APPENDIX IV: BMT ARGOSS

BMT ARGOSS is a consultancy company which provides wave and wind data all over the world on www.waveclimate.com. Satellites measurements are made and registered since 1992. These data could be uploaded in kind of configurations to get an idea about the wave and wind climate.

Waveclimate.com also provides wave and wind data calculated with models, which are calibrated with the satellite data. Hereby must be noted that with models calculated wave heights, wave lengths etc. show less variability than real data. This must be taken into account when working with extremes.

To find data an area of interest must be chosen. For this case the area is chosen as small as possible as a square of 50 kilometers. The harbour of Dikkowita is in the middle of the square with coordinates given in figure 53.

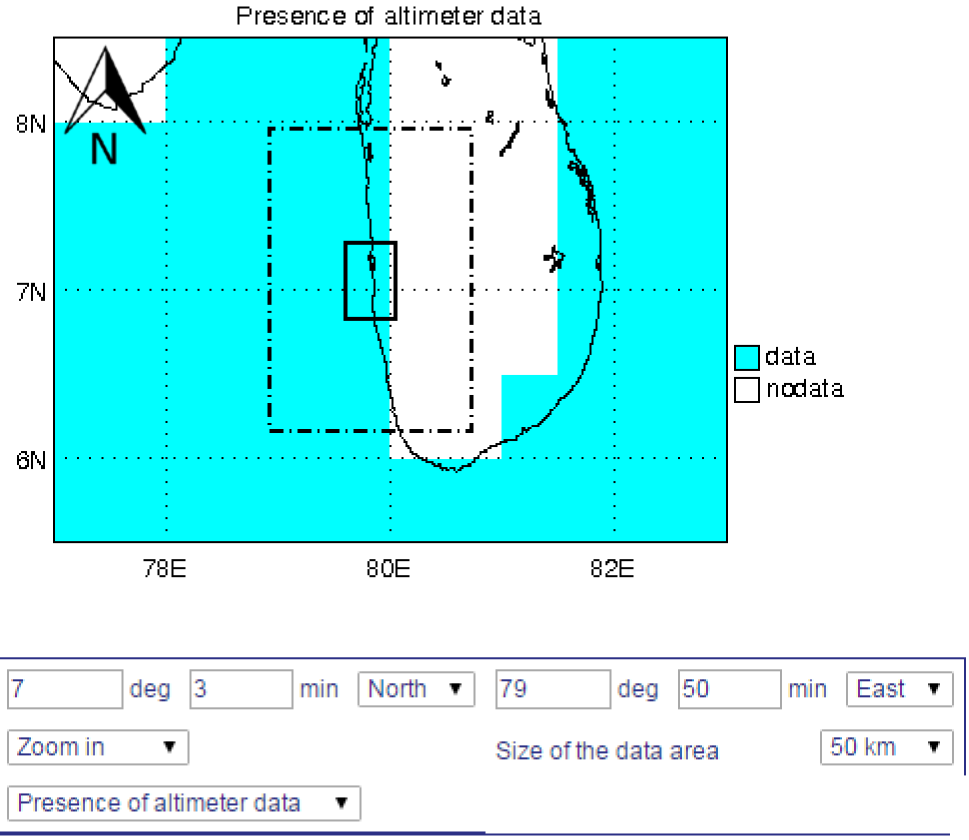

Figure 53 Area of interest BMT ARGOSS data (BMT ARGOSS, 2015)

APPENDIX V: WAVE HEIGHT AND PERIOD

In this appendix is showed how significant wave height and representative wave height and period are calculated with the data of BMT ARGOSS (BMT ARGOSS, 2015).

SIGNIFICANT WAVE HEIGHT

Calculating the significant wave height is done with the data of ARGOSS BMT. The table found in the left two columns is as ARGOSS BMT provided it, but with two additions. A wave height of 0 with a 100% probability of exceedance is added at the top. At the bottom the highest possible wave is added, which is taken as 30% higher than the 1% exceedance probability wave. This is just an assumption and is done to make it possible to calculate the bin sizes and the bin averages. Then the bin size, so the probability of a certain wave, and the bin average, the average height of the waves in that bin, must be multiplied. Taking sum of the highest 30% of the waves and dividing that by 30% gives the average wave height of the highest 30% waves, or the significant wave height.

Table 42 Wave height data and calculation of significant wave height

Prob. of exc. (%)	Wave height (m)	bin size	bin average	size*bin		
100	0					
90	1	10	0.5			
80	1.1	10	1.05			
70	1.2	10	1.15			
60	1.2	10	1.2			
50	1.3	10	1.25			
40	1.4	10	1.35			
30	1.5	10	1.45			
20	1.6	10	1.55	15.5		
10	1.7	10	1.65	16.5		
5	1.9	5	1.8	9		
2.5	21	2.5	11.45	28.625		sum of
1	2.3	1.5	11.65	17.475		highest 30% waves
	2.99	1	2.645	2.645		89.745
					Hs	2.9915

REPRESENTATIVE WAVE HEIGHT AND PERIOD

The representative wave height and period are calculated using the relative weights of the wave heights and periods. This is done in table 43. Lower and upper column represent values for wave height, where the rows show wave periods.

Table 43 Calculation of representative wave height and period

	lower	1	2	3	4	5	6	7			
lower	upper	2	3	4	5	6	7	8	total	Average Bin Value	total*BinVal
0.0	0.5	0	1.8	3.6	2.0	0.1	0	0	7.5	0.25	1.875
0.5	1.0	0	0	0.4	0.6	0.0	0	0	1	0.75	0.75
1.0	1.5	0	0	0	0.2	0.2	0.0	0	0.4	1.25	0.5
1.5	2.0	0	0	0	0	0.1	0.1	0	0.2	1.75	0.35
2.0	2.5	0	0	0	0	0	0.0	0	0	2.25	0
2.5	3.0	0	0	0	0	0	0	0	0	2.75	0
	total	0	1.8	4	2.8	0.4	0.1	0	9.1	rep. wave height	0.381868132
	Average Bin value	1.5	2.5	3.5	4.5	5.5	6.5	7.5			
	total*BinVal	0	4.5	14	12.6	2.2	0.65	0			
								rep. wave period	3.73077		

APPENDIX VI: OVERTOPPING OF THE BREAKWATER

In this appendix the overtopping of the breakwaters is determined. For the overtopping calculation the European Overtopping Manual from The EurOtop Team is used (EurOtop, 2007).

OVERTOPPING CALCULATION

To check the amount of overtopping over the breakwater two points of the breakwater are used for the calculations, see figure 54 for the locations. These points are chosen because of the angle of incidence of the largest waves, see chapter 2.3.5. The overtopping in the northern basin is expected to be less than the overtopping at the points A and B. In figure Y the breakwater cross section of location A is displayed, this cross section is also used for location B.

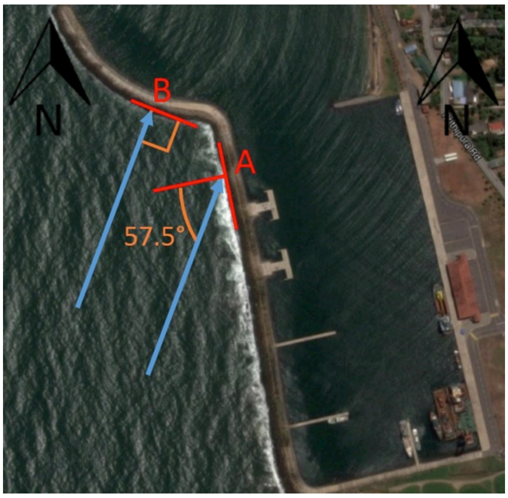

Figure 55 Locations of point A and B (Google, 2015)

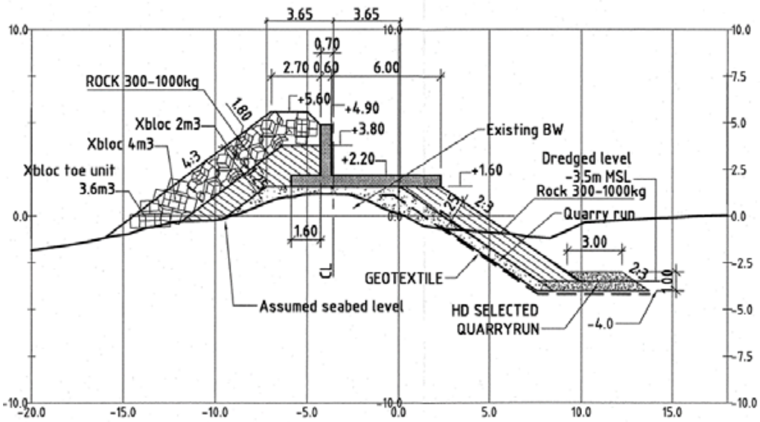

Figure 54 Cross section of breakwater at location A (see appendix XV, cross section 11)

The following formula is used for calculating the overtopping discharges:

$$\frac{q}{\sqrt{g \cdot H_{m0}}} = a \cdot \exp\left(-b \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)$$

$\mathrm{q} = \text{overtopping discharge } (\mathrm{m^3/s/m})$

$\mathrm{H_{m0}} = \text{incident significant wave height (m)}$

$\mathrm{a} = \text{scale parameter } (-)$

$\mathrm{b} = \text{shape parameter } (-)$

$\mathrm{R_c} = \text{Crest freeboard (m)}$

$\gamma_\mathrm{f} = \text{influence factor for roughness elements on a slope } (-)$

$\gamma_\beta = \text{influence factor for oblique wave attack } (-)$

For the incident significant wave height H_{m0} the significant wave height H_s is used. In chapter 2.3.5 it is determined that the largest significant wave height is in the Southwest monsoon. The swell waves are used in this calculation, because these are the highest waves. The significant wave height of the swell waves in the Southwest monsoon is 2.4 meters. This value is determined by taking the average of the highest 30% of all the wave measurements during this monsoon period. This wave height can be used to determine the overtopping discharges during this entire monsoon. However, there could be a severe storm during this monsoon with a much higher significant wave height and higher overtopping discharges. Therefore, there is also a calculation with a higher significant wave height, to give an indication of the overtopping during a storm.

For the severe storm overtopping calculation there is assumed that during the monsoon there is in total 24 hours (1 day) of severe storm. The monsoon period is from May to September, this includes 153 days. The probability of appearance of a severe storm is: $\frac{1}{153} = 0.65\%$. The significant wave height of such a severe storm will be:

$$P(H' > H) = e^{-2(\frac{H}{H_s})^2}$$

$$H = H_s \cdot \sqrt{-\frac{\ln(P)}{2}} = 3.8 \text{ m}$$

The scale parameter a and the shape parameter b are 0.2 and 2.3 for rubble mound structures, according to the European Overtopping Manual.

The crest freeboard R_c of the breakwater is the point of the structure where the water cannot flow back to the seaside. For rubble mound structures the height of the rubble mound armour should not be taken as the crest freeboard, therefore the crest freeboard for the breakwater will be 4.9 m, see figure 55.

The roughness parameter γ_f is 0.45 for X-Blocks.

The oblique wave attack parameter γ_β is equal to 1 when there is a perpendicular wave attack. According to chapter 2.3.5 the swell wave direction is 247.5° for the highest swell waves. For the southern basin the waves approaches the breakwater with an angle of 57.5°, see point A in figure 54. For these waves a factor smaller than 1 should be used. This can be calculated with the formula below:

$$\gamma_\beta = 1 - 0.0063|\beta| \text{ for } 0^\circ \leq |\beta| \leq 80^\circ$$

From this formula follows that γ_β is 0.64 for an angle of 57.5°. The waves that approach the breakwater of around the harbour entrance are perpendicular to the breakwater, see point B in figure 55, so for these waves a factor of 1 is needed. Therefore, the highest overtopping discharges will be at the harbour entrance.

Now the overtopping discharges of the breakwater locations A and B can be determined during the entire monsoon and in a severe storm. The results are displayed in table 44.

Table 44 Overtopping discharges for breakwater locations A and B during entire monsoon and severe storm

Location and storm type	$q\ (m^3/s/m)$	$q\ (l/s/m)$
Point A during total monsoon ($H_s = 2.4$ m)	$1.8 \cdot 10^{-7}$	$1.8 \cdot 10^{-4}$
Point A during severe storm in monsoon ($H_s = 3.8$ m)	$1.5 \cdot 10^{-4}$	0.15
Point B during total monsoon ($H_s = 2.4$ m)	$6.8 \cdot 10^{-5}$	$6.8 \cdot 10^{-2}$
Point B during severe storm in monsoon ($H_s = 3.8$ m)	$6.4 \cdot 10^{-3}$	6.4

The 2% wave run-up formulas for deterministic design and safety assessment are recommended according to the European Overtopping Manual.

$\frac{R_{u2\%}}{H_{m0}} = 1.75 \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \xi_{m-1.0}$ with a maximum of: $\frac{R_{u2\%}}{H_{m0}} = 1.00 \cdot \gamma_b \cdot \gamma_{f\,surging} \cdot \gamma_\beta (4.3 - \frac{1.6}{\sqrt{\xi_{m-1.0}}})$

$R_{u2\%}$ = 2% wave run-up (m)

γ_b = influence factor for a berm (−)

$\xi_{m-1.0} = \text{Iribarren number } (-)$

The berm factor γ_b is 1 for this situation, because there is no berm in the breakwater.

The Iribarren number can be calculated with the following formula: $\tan\alpha \, / \sqrt{\frac{H_{m0}}{L_{m-1.0}}}$.

The deep water wave length can be determined with the following formula: $\frac{g \cdot T^2{}_{m-1.0}}{2\pi}$

The spectral period $T_{m-1.0}$ is equal to 1.1 times the peak period T_p. The peak period is approximately the same as the period of the significant wave height $T_{1/3}$. According to chapter X the swell waves in the Southwest monsoon ($H_s = 2.4$ m) have a period of 11.4 seconds, this will give a spectral period of 10.4 seconds. For the swell waves during the severe storm there is assumed that the wave steepness is equal to the swell waves during the entire monsoon. This gives a significant wave height period of 14.4 seconds and thus a spectral period of 13.1 seconds.

The slope of the breakwater is 4:3, see figure 55. Now the Iribarren number can be determined. The Iribarren number is equal to 11.1 during the entire monsoon and equal to 11.2 during a severe storm.

$\gamma_{f\ surging}$ is equal to 1.0 for $\xi_{m-1.0} > 10$.

Now the 2% wave run-up height of the breakwater locations A and B can be determined during the entire monsoon and in a severe storm. The results are displayed in table 45.

Table 45 2% wave run-up height for breakwater locations A and B during entire monsoon and severe storm

Location and storm type	$\mathbf{R_{u2\%}(m)}$	**Maximal** $\mathbf{R_{u2\%}}$ **(m)**	$\mathbf{R_{u2\%}(m)}$ **chosen for further calculations**
Point A during total monsoon ($H_s = 2.4$ m)	13.4	5.8	5.8
Point A during severe storm in monsoon ($H_s = 3.8$ m)	21.3	9.3	9.3
Point B during total monsoon ($H_s = 2.4$ m)	21.1	9.2	9.2
Point B during severe storm in monsoon ($H_s = 3.8$ m)	33.5	14.5	14.5

With the overtopping discharges an average value is given for the overtopping during a storm. However, not all the waves have the same overtopping volume. Therefore, the largest overtopping volume of a wave should be determined. This can be done with the following formula:

$V_{max} = a \cdot [\ln(N_{ow})]^{4/3}$

The scale factor a can be determined with the following formula: $a = 0.84 \cdot T_m \cdot \frac{q}{P_{ov}}$, with T_m the wave period, q the overtopping discharge and P_{ov} the probability of overtopping per wave. This probability can be calculated with the following formula: $P_{ov} = \exp\left[-(\sqrt{-\ln 0.02}\,\frac{R_c}{R_{u2\%}}\right]$.

The number of overtopping waves N_{ow} can be calculated by multiplying the total number of waves with the probability of overtopping waves: $N_{ow} = P_{ov} \cdot N_w$. The total number of waves can be calculated by dividing the storm duration by the wave period. There is assumed that the duration of one storm during a monsoon is 2 hours.

Now the maximal overtopping volume in a storm of the breakwater locations A and B can be determined. The results are displayed in table 46.

Table 46 Maximum overtopping volume of breakwater locations A and B during entire monsoon and severe storm

Location and storm type	$\mathbf{P_{ov}}$ (%)	$\mathbf{a\ (m^3)}$	$\mathbf{N_w(-)}$	$\mathbf{N_{ow}(-)}$	$\mathbf{V_{max}(\ m^3/m)}$	$\mathbf{V_{max}(\ l/m)}$
Point A during total monsoon ($\mathbf{H_s = 2.4\ m}$)	6	$2 \cdot 10^{-5}$	695	45	$1.5 \cdot 10^{-4}$	0.15
Point A during severe storm in monsoon ($\mathbf{H_s = 3.8\ m}$)	33	0.005	550	184	0.045	45
Point B during total monsoon ($\mathbf{H_s = 2.4\ m}$)	33	0.002	695	227	0.017	17
Point B during severe storm in monsoon ($\mathbf{H_s = 3.8\ m}$)	64	0.109	550	352	1.156	1156

INTERPRETATION OF THE OVERTOPPING VOLUMES

According to the European Overtopping Manual a volume (V_{max}) of 5,000 – 50,000 l/m could give significant damage or could cause sinking of larger yachts, thus the larger yachts are safe for this kind of damage in the southern basin. A max volume of 1,000-10,000 l/m will cause sinking of small boats of 5 to10 meters from wall and damage to larger yachts. During a severe storm the V_{max} is larger than 1,000 l/m. When pedestrians are walking along the breakwater, they do not have a clear view of incoming waves. The limit mean discharge for this condition is 0.03 l/s/m. This value is exceeded during the severe storms and during the entire monsoon at location B.

APPENDIX VII BERTH SURFACE

To estimate the amount of berths in the harbour for the different alternatives, a design value for the surface of one berthing boat is calculated. For this design value the dimensional criteria of a marina discussed before in chapter 2.2.2 are used. The area of the berth itself, a part of the pontoon, a part of a finger pier and a part of the fairway combined is the surface area for one berthing boat. In figure 56 the surface area for one berthing boat is displayed. This area will be around 170 square meters.

The width of the interior channel in the harbour is preferred to be around 26 meters for 15 meter boats. This area cannot be used for berthing places. The length of this channel times approximately 26 meters needs to be removed from the total harbour surface when calculating the amount of berths.

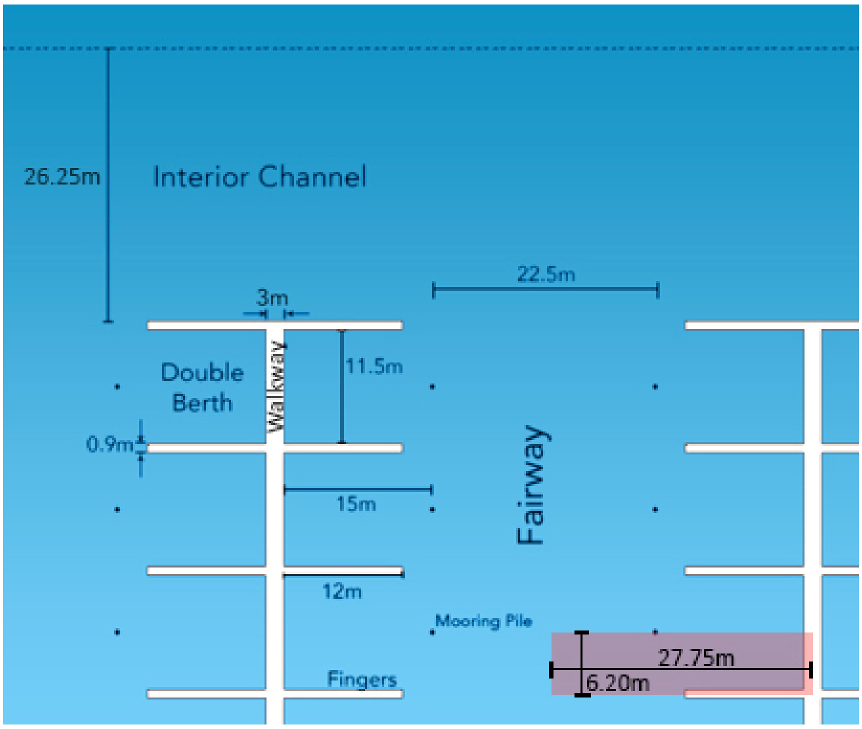

Figure 56 Area required for one berth

APPENDIX VIII: WATER QUALITY

To reach a high quality marina, it is important to ensure a good quality of the water inside the marina. This can be done by a frequent refreshment of the water. The PIANC guideline for protecting water quality in marinas (PIANC, 2008) is used to improve the quality of the current southern basin.

ASSUMPTIONS

To be able to discuss the water quality in the marina a few assumptions are done to simplify the model. These are mentioned in the below paragraphs.

The influence of the swell waves and currents are not taken into consideration, because the breakwaters of the harbour are constructed in such a way that the swell waves and currents are hardly present in the harbour. The influence of the wind is neglected as well, because of the small dimensions of the harbour. Therefore, the water circulation in the harbour is primarily based on the tidal prism.

Only the water quality in the southern basin is discussed, therefore this basin is considered as a harbour with the entrance next to the southern groyne of the spending beach of the harbour. This simplification is done, because the water flowing into the harbour through the main can easily flow into the southern basin, see figure 57. Because of the limited time for this research available this model is simplified. This simplification will influence the results, so for a more reliable result a more complicated and extensive research should be done. However, with this simplification a good indication can be given about the differences with respect to the water refreshment in each alternative, see chapter 3.3 to 3.5 and what aspects should be taken into consideration for improving the water quality in the final design of the marina.

Figure 57 Flow direction of the water into the southern basin (Google, 2015)

The southern basin is assumed to be a perfect rectangular basin. For the *Full Marina* alternative a rectangular of 340 meters by 160 meters is assumed, see figure 58. For the expanded alternatives a rectangular of 477 meters by 160 meters is assumed, see figure 59. The current southern basin has a water depth of 5 meters, therefore this value is used in the calculations. The basin entrance has a width of 75 meters.

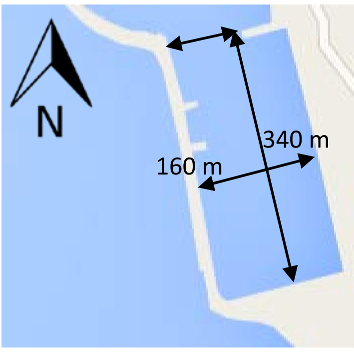

Figure 58 Harbour dimensions of alternative *Full Marina* (Google, 2015)

The amount of pollution in the water around the harbour and in the harbour itself is outside the scoop of this research. Further research could give an indication about the current and the expected situation.

The water quality in the marina will be discussed with respect to the following factors: E-folding time, aspect ratio, A/a ratio and the Tidal Prism Ratio. These are explained and calculated in the following paragraphs.

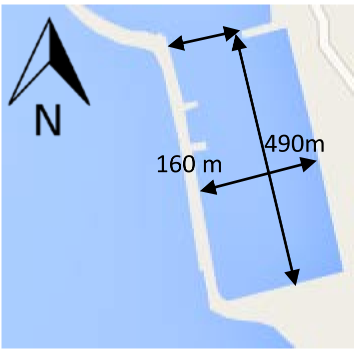

Figure 59 Harbour dimensions of the alternatives with expansion (Google, 2015)

E-FOLDING TIME

The flushing time is the time required to reduce initial pollutant concentrations within a semi-enclosed water body to a prescribed value. A measure for computing the flushing time is the E-folding time. This can be calculated analytically with the following formula:

$$t_{e-fold} = \frac{V_L + \frac{V}{2}}{V} \cdot t_{m_2}$$

V_L is the water volume in the basin at low water, so $V_{L,Full\,Marina} = 272{,}000\;m^3$ and $V_{L,Expansion} = 392{,}000\;m^3$. V is the tidal volume, so $V_{Full\,Marina} = 38080\;m^3$ and $V_{Expansion} = 54880\;m^3$. $t_{m_2}$is the period of the m_2 tidal constituent (12.42 hours). For all alternatives the E-folding time is 95 hours (3.9 days). A complete water exchange of a basin in four days is good according to the US Environmental Protection Agency (PIANC, 2008). The flushing time of all alternatives satisfy this requirement.

ASPECT RATIO

The flushing coefficient (E) is an average exchange coefficient for the flushing exchange efficiency. The basin geometry influences the flushing in the basin. For a rectangular basin this ratio can be calculated by determining the aspect ratio of the basin.

The basin geometry influences the flushing exchange ratio. The basin aspect ratio is the ratio between the length and the width of the basin (L/B). According to the guidelines L is in this case perpendicular to the quay wall and B parallel to the quay wall. When the length and the width are equal the highest flushing efficiency occurs, see figure 60. The aspect ratio of the *Full Marina* is: $\frac{160}{340} = 0.47$. The aspect ratio of the *Expansions* is: $\frac{160}{490} = 0.33$. According to PIANC a rectangular basin with an aspect ratio less than 0.5 and greater than 2 should be avoided. The aspect ratio of the *Full Marina* satisfies this requirement, but the aspect ratio of the expansion options does not. Making the length (L) of the basin relatively longer with respect to the wide (B) is a possible solution to increase the aspect ratio.

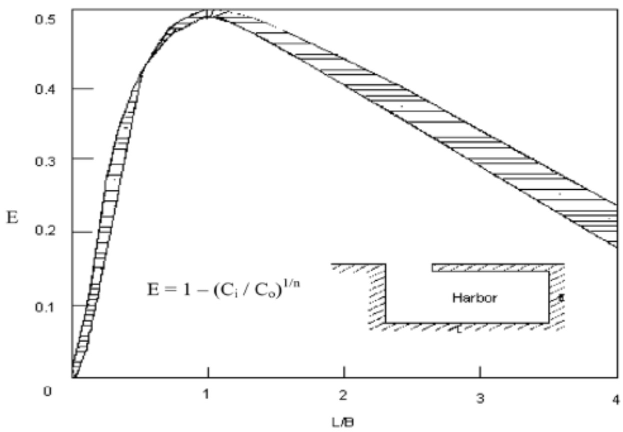

Figure 60 Flushing Exchange Coefficient as a function of basin Aspect ratio (PIANC, 2008).

E-S RATIO

The flushing coefficient itself is not sufficient to give an indication about the flushing, circulation and mixing in the basin, because this coefficient does not include the spatial variability of the mixing process. For example, it is possible to have a good circulation on average, when one half of the basin has a very good circulation and one half a poor one. To avoid this, the standard deviation (S) of the average exchange coefficient (E) should be taken into account. PIANC gives the following requirement for good flushing:

$$E - S > 0.1$$

There is a relation between the basin area (A) and the cross sectional area (a), therefore the cross sectional area of the entrance of the basin is influencing the flushing in the basin.

$a = 375\ m^2, A_{Full\ Marina} = 54400\ m^2, A_{Expansion} = 78400\ m^2.$

This gives a ratio of 145 for the *Full Marina* and a ratio of 209 for the expansion options. This ratio should be greater than 200 to have an E-S value larger than 0.1. In an ideally situation the ratio should be larger than 400. Both the expansion options *and t*he *Full Marina* do not satisfy the minimum requirement of 200.

A mouth which is too wide compared to the surface area of the basin could cause zones at the far edge inside the basin, where no or less flushing. By increasing the surface area of the basin or decreasing the cross sectional area will give a larger A/a value. Another option where one can think of is to create more entrances to solve the flushing problems for the deeper zones. However, PIANC states that most of the time it is better to have one entrance instead of two entrances with in total the same cross sectional area. Only when the aspect ratio is larger than 4, more than one entrance could be a solution because one entrance cannot flush the total basin in this situation.

TIDAL PRISM RATIO

Another factor for good flushing is the tidal prism ratio (TPR). The TPR is the ratio between the volume of water entering the basin during flood and the total basin volume at high tide.

$$TPR = \frac{V}{V_{high\ tide}}$$

$V_{Full\ Marina} = 38080\ m^3, V_{Expansion} = 54880\ m^3,$

$V_{high\ tide,Full\ Marina} = 291040\ m^3, V_{high\ tide,Expansion} = 419440\ m^3$

This results in a TPR of 0.13 for all alternatives. According to PIANC this ratio should be at least 0.25, but preferable 0.35. The TPR values of the alternatives do not satisfy these requirements.

A higher TPR value will provide better flushing in the harbour. Increasing the TPR can be done by creating an area within the basin that has a bottom elevation near extreme low water. Another option is to make the basin shallower. When the southern basin has a depth of 3 meters, the TPR is about 0.23. For a depth of 2.5 meters the value is about 0.28. Another advantage of increasing the TPR is the higher velocity near the entrance, because this will reduce the sedimentation around the entrance.

BASIN CURVATURE

The corners of all the alternatives are angular. However, when the corners of the basin are more round instead of angular, the circulation can be improved. The rounding of the corners will result in the elimination of local stagnation zones, but it does not improve the gross flushing in the basin (Nece, Falconer, & Tsutsumi, 1976). According to PIANC, for good circulation the minimum radius should be larger than a quarter of the minimum characteristic dimension of the basin. When the radius is smaller than an eight of the minimum dimension, this will result in poor circulation. The minimum dimension of the current southern basin is 170 meters, therefore for good circulation the radius of the rounding in the corners should be at least: $160/4 = 40$ meters.

APPENDIX IX: NET PRESENT VALUE CALCULATION

For each alternative the building costs, maintenance costs and the incomes will be different. An alternative with high building costs can compensate these costs with lower maintenance costs or more income than the other alternatives. By comparing the building costs, maintenance costs and the incomes of the harbour an indication can be given about the total profit of the new harbour. This comparison can be done by discounting all the cash flows of the project. The future costs and incomes will be converted to a present value. The sum of these present values minus the investment costs gives the net present value.

$$NPV = C_0 + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

C_0 = Costs at start project
C_t = Cash flow in a year
r = Discount rate
t = number of year, project start at year 0
T = assumed lifetime

The real lifetime of an investment for a new marina will be more than 50 years, but for calculating the net present value a life time of 25 years is chosen. After 25 years, it could be hard to make predictions, which would make the calculations too inaccurate.

DISCOUNT RATE

To convert the future values to a present value a discount rate should be used. It is hard to predict the value of future cash flows, especially for long term projects. There are various factors that can influence the discount rate. The bank interest rate, inflation rate, and a risk premium are some of these factors (Reavis). It is assumed that these three factors are the most important ones for this project. The total discount rate used for this project is 11.5%. The explanations for the chosen values of the bank interest rate, inflation rate and the required risk premium, see table 46, are given in the next paragraphs.

Table 47 Results of discount rate calculations

Bank interest rate	3.5%
Inflation rate	4%
Required risk premium	4%
Total discount rate	**11.5%**

BANK INTEREST RATE

The average annual real interest rates in Sri Lanka from 1980 to 2014 are displayed in the table 48. From this follows that the average interest rate in Sri Lanka is 3.8 %.

Table 48 The annual real interest rates from 1980 to 2014 in Sri Lanka (The World Bank, 2015)

Year	Rate (%)	Year	Rate (%)	Year	Rate (%)	Year	Rate (%)	Year	Rate (%)	Year	Rate (%)
1980	-0.8	1986	5.3	1992	9.4	1998	5.3	2004	0.6	2010	2.7
1981	-1.6	1987	1.9	1993	9.4	1999	10.1	2005	0.3	2011	1.4
1982	5	1988	2.1	1994	7.6	2000	8.3	2006	1.4	2012	4
1983	-3.1	1989	2	1995	8	2001	5	2007	2.7	2013	5.5
1984	-5.9	1990	-5.6	1996	6.7	2002	1.2	2008	2.2	2014	2.6
1985	12.7	1991	7.9	1997	5.3	2003	4.9	2009	9.2	**Average:**	**3.8**

The investors can come from all over the world. Therefore interest values from central banks of America, Europe, Australia and China are also taken into account. The long-term graphs of these central banks are displayed in figures 61 to 64. The average interest rates are indicated with the orange line. The average values are 3.0% for America, 1.5% for Europe, 6.0% for China and 3.0% for Australia. The average of Sri Lanka, America, Europe, China and Australia is: $Interest\ rate = \frac{3.8+3.0+1.5+6.0+3.0}{5} = 3.5\%$. This value is taken as a representative interest rate.

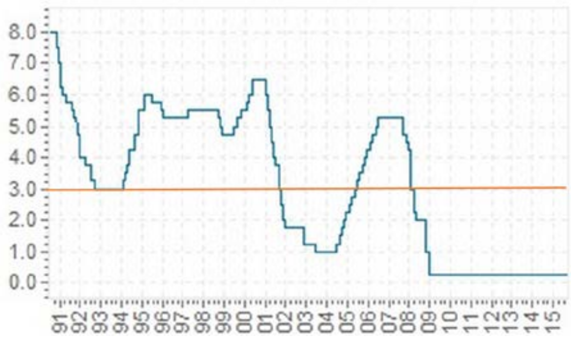

Figure 61 American interest rate FED - long-term graph 1991-2015 (Global-rates.com, 2015)

Figure 63 Chinese interest rate PBC – long-term graph 2005-2015 (Global-rates.com, 2015)

Figure 62 European interest rate ECB – Long-term graph 1999-2015 (Global-rates.com, 2015)

Figure 64 Australian interest rate RBA – long-term graph 1991-2015 (Global-rates.com, 2015)

INFLATION RATE

In figure 65 the annual inflation rates of Sri Lanka over the last 30 years are displayed. The average inflation rate is 10%. The inflation rates where fluctuating a lot during this time period. For the last 5 years (2010 to 2015) the inflation rates are more stable and considerably lower than in the other periods. The forecasts of the Sri Lankan inflation rates are 4.2% in 2020, 3.2% in 2030 and 3% in 2050 (Tradingeconomics, 2015). These values are also much lower than the average inflation rate over the last 30 years. For the future, an average of 10% seems to be too high compared to the future expectations and according to the inflation rates of the last 5 years. Therefore, an inflation rate of 4% is assumed to be a more suitable value to use.

Figure 65 Annual Sri Lanka inflation rates 1985-2015 (Tradingeconomics, 2015)

REQUIRED RISK PREMIUM

This extra risk premium is different for every project. For a low risk project a low value should be chosen, this will be around 1% (Reavis, sd). For this project a higher value should be chosen, because risks are higher here. This is because the development of marinas is very unpredictable and the inflation rate is changing a lot. Therefore, assumed is a risk premium of 4%.

APPENDIX X: MARINA COSTS AND INCOMES

In this appendix, the different costs and incomes of the marina are discussed, for the construction part as well as the operational part. Also some influences of the marina that cannot be expressed in money will be discussed here.

CONSTRUCTION COSTS

The price per square meter for the construction of a new jetty in Sri Lanka is approximately LKR 450,000 (Fernando, 2015) and the construction costs of the fingers is assumed to be half the price of the jetty. The jetty surface area needed for one berthing place for a 15 meter boat can be determined with the dimensional criteria for a marina. The walkway length per berth is $\frac{11.5}{2}+\frac{0.9}{2}=6.2$ meters. The width of this walkway per berth is 1.5 meters (total walkway width is 3 meters). This gives a total walkway surface area of 9.3 square meters. The total length of the finger is 12 meters and the width is 0.9 meters. The surface area of the finger per berth is $\frac{0.9}{2}\cdot 12=5.4$ square meters. Thus the total jetty surface area is 14.7 square meters. The construction price per berthing place is: LKR 5,400,000. This is equal to approximately $38,500.

The costs of the floating breakwater are estimated on a value of $10,000 per meter (Costs of Floating Breakwaters, 2015). The total length of the floating breakwater is 60 meters, see Appendix XIII for more information about the dimensions of the floating breakwater. Therefore, the total costs for the floating breakwater are $600,000.

Appendix II shows the necessary and optional facilities of a marina. The costs to build the necessary facilities are given in table 49. Some facilities are already available and do not need to be built again.

Table 49 Costs of necessary facilities (Dock Builders Supply, 2014) (Vanasse Hangen Brustlin, 2014) (Marina Accessories, 2015) (Fernando, 2015)

Necessary Facilities	Amount	surface (m^2)	(Average) amount of floors	Already available (Y / N)	Costs per m^2	Costs per piece	Total costs
Marina administration offices	1	700	2	N	$ 356.35	$ 498,890	$ 498,890
Showers and toilets for customers and visitors	1	25	1	N	$ 142.54	$ 3,563	$ 3,563
Changing rooms	2	40	1	N	$ 142.54	$ 5,702	$ 11,403
Electricity building	1	30	1	Y		$ -	$ -
Fuel storage tanks and reticulation system for petrol, diesel and LPG	1			N		$ 200,000	$ 200,000
Solid waste collection and disposal facilities	6			N		$ 250	$ 1,500
Fire fighting pedestals	8			N		$ 450	$ 3,600
Communications facilities, including office telephones and two-way radio				Y		$ -	$ -
Boat dry storage facilities including dinghy storage	1	1000		N	$ 142.54	$ 142,540	$ 142,540
Hardstand areas for boat repair and maintenance	1	2500		N	$ 30.00	$ 75,000	$ 75,000
Land Infrastructure (except roads)	1	25000		N	$ 5.00	$ 125,000	$ 125,000
Roads	1	4400		N	$ 30.00	$ 132,000	$ 132,000
Security systems	1	55		N	$ 356.35	$ 19,599	$ 19,599
Power pedestals	109			N		$ 500	$ 54,500
Vehicle parking	109	12		N		$ 1,500	$ 163,500

Some assumptions about these facilities are made to simplify the calculations. First, the administration office also contains showers and toilets for marina employees. Secondly, the land infrastructure is a collection of multiple facilities, these facilities are given below.

- Site electrical for power and lighting
- Site sewerage and treatment system
- Water drainage system
- Hardstand drainage system
- Pollution control system

The necessary facilities need to be financed before the marina is in operation. There are also some optional facilities that can be constructed to improve the marina, but these facilities can be (partly) constructed when the marina is in operation. Table 50 gives an indication of the construction costs for some of these optional facilities based on the amount of land available (25,000 square meters).

Table 50 Costs of optional facilities (Vanasse Hangen Brustlin, 2014; Fernando, 2015)

Optional Facilities	Amount	surface (m^2)	(Average) amount of floors	Already available (Y / N)	Costs per m^2	Costs per piece	Total costs
Hotels / Restaurants / Supermarket	13	545	4	N	$ 783.97	$ 1,709,055	$ 22,217,710
Recreation (Swimmingpool/sportingfields)	1	1750		N	$ 150.00	$ 262,500	$ 262,500
Boulevard	1	3330		N	$ 30.00	$ 99,900	$ 99,900
Boat shop	1	520		N	$ 783.97	$ 407,664	$ 407,664
Vehicle parking	200	12		N		$ 1,500	$ 300,000

OPERATIONAL COSTS AND INCOMES

The marina generates income by the rent that needs to be paid for berthing in the marina. A good estimation about the price for berthing boats is made by investigating other medium priced marinas all over the world. The berth prices in 2015 for seven harbours from the Netherlands, Two from Oman and one from Singapore have been investigated for 15 meter boats. The prices of annual berthing boats and 1-day berthing boats can be very different. On average, the share of 1-day berthing will be around 2% of all berthing places. The resulting average 1-day berthing price per meter per day is $2.09 and the annual berthing price per meter per day is $0.96. It is assumed that people in Sri Lanka with a yacht could afford themselves to pay these prices as well. The data used for the berthing price calculations is given in table 51.

Table 51 Berth price calculations

Harbour	Country	1-day berthing (/m/day)	Annual berthing (/m/day)
Breskens	The Netherlands	$ 2.02	$ 0.65
De Eemhof	The Netherlands	$ 1.96	$ 0.61
Makkum	The Netherlands	$ 1.74	$ 0.64
Bruinisse	The Netherlands	$ 2.58	$ 1.02
Volendam	The Netherlands	$ 1.74	$ 0.71
Scheveningen	The Netherlands	$ 2.77	$ 0.68
Willemstad	The Netherlands	$ 2.19	$ 0.77
Sea Oman	Oman	$ 1.72	$ 1.16
RSYC	Singapore	n/a	$ 1.61
Almouj	Oman	n/a	$ 1.79
	Average	**$ 2.09**	**$ 0.96**

Besides the berth revenue, there are also various other services a marina is able to get revenue from. The report used to predict these values is the coastal marina report from the Netherlands for the city Katwijk (Bieleman, Snippe, Haaijer, Beelen, Mulhof, & Ginkel, 2008). On average this will be between €800 and €1000 per berth per year. French marinas where used to calculate this average, the income on these services is likely to be lower in Sri Lanka. Therefore, an average value of $700 per berth per year is assumed to be more credible.

The operational costs of a marina are for European marinas between €500 and €1000 per berth per year (Bieleman, Snippe, Haaijer, Beelen, Mulhof, & Ginkel, 2008). This is also more likely to be lower in Sri Lanka due to lower labour costs. The operational costs for a marina in Sri Lanka are therefore estimated at $500 per berth per year. The operational costs will not have a linear relationship with the amount of berths. When there are fewer berths in the marina, the operational costs will be respectively higher per berth. Therefore, in the first four years of the marina construction the operational costs will be multiplied by a factor of 1.5. The operational costs of the consecutive four years will be multiplied by a factor of 1.2.

REGIONAL ECONOMIC INFLUENCES

The hospitality industry in the marina will also generate income. Restaurants, bars and shops will, on average, generate $70 per 1-day boat per day (Bieleman, Snippe, Haaijer, Beelen, Mulhof, & Ginkel, 2008). The expenses of an annual boat owner are much lower, but a value is difficult to determine. Again this value is more likely to be lower for Sri Lanka, because of the cheaper restaurants, bars and shops in comparison with Europe. Therefore a value of $40 per 1-day boat per day is assumed to be more credible.

Market revenue and revenue on other services in the marina is in Europe estimated between €2800 and €5000 per boat per year (Bieleman, Snippe, Haaijer, Beelen, Mulhof, & Ginkel, 2008). Again, this value is lower in Sri Lanka and is estimated around an average of $2800. 100 berths will lead to a purchase of 100 boats (Bieleman, Snippe, Haaijer, Beelen, Mulhof, & Ginkel, 2008).

In the table below an overview of all the costs, revenue and other effects of a marina in Sri Lanka is displayed.

Table 52 Summary of costs and incomes of the marina

Construction costs			
Jetty costs	$	38,500	/ berth
Floating breakwater costs	$	600,000	
Necessary facilities	$	1,588,056	
Optional facilities	$	23,925,402	
Operational costs and incomes			
Berth revenue	$	5,380	/ berth / year
Income various services	$	700	/ berth / year
Total revenue	$	6,080	/ berth / year
Operational costs	$	-500	/ berth / year
Total profit	$	5,680	/ berth / year
Regional economic influences			
Revenue market and services	$	2,800	/ berth / year
Revenue hospitality industry	$	292	/ berth / year
New boats manufactured on the long term	1		/ berth

EXPANSION COSTS

The expansion costs of the southern basin are based on the expansion of the breakwater, expansion of the quay wall and the dredging costs. The total expansion is approximately 150 meters by 180 meters, see figure 66. For more information about the 150 meters of expansion to the south, see chapter 3.4. It is assumed that the material of the current southern side of the basin can be moved to the southern side of the expansion. On the west side there will be a new breakwater and on the east side there will be a quay wall. The marina does not need a quay wall on the southern side of the basin, because the yachts are berthing along the jetties. The total expansion costs are displayed in the table below and the explanation of each part of the costs can be found in the next paragraphs.

Table 53: Expansion costs

Breakwater expansion	\$624,560.11
Quay wall expansion	\$1,500,000
Dredging costs	\$693,000
Total costs	\$2,817,560.11

BREAKWATER EXPANSION COSTS

The current breakwater consists of X-Blocks. Therefore, this type of breakwater is also assumed for the expansion. The slope of the current breakwater has a slope of 4:3 and the height of the construction is approximately 6 meters, these values are also used for the expansion. To make an estimation of the costs the breakwater is simplified to the trapezoid displayed in figure 67. The surface of the cross section of this trapezoidal is used to calculate the volume of material in the breakwater. The volume factor used is 0.65. The net volume of one meter breakwater can now be calculated: $V_{net} = A_{cross\ section} \cdot 0.65 = 33.15\ m^3/m$. The X-Blocks are made of concrete and therefore a material density of $2500\ kg/m^3$is assumed. Now the total weight of per meter breakwater can be calculated: $M = V_{net} \cdot \rho_{concrete} = 33.15\ \cdot 2500 = 82875\ kg/m$. The price of 1000 kilograms of concrete in Sri Lanka is approximately LKR 3500 (Fernando, 2015). This is equal to approximately \$24.82. Then the material breakwater costs per meter will be around \$2057. The costs for placing the breakwater are approximately 40% of the material costs (Fernando, 2015), about \$823 per meter. This gives a total costs per meter breakwater of approximately \$2,880.

The costs of relocating the materials of the southern side of the current basin is estimated on 1.3 times the costs of the placing costs of a new breakwater, thus about \$1070 per meter old material. The already existing southern wall has a length of 180 meters, this can be seen in figure 66. The new breakwater should be 150 meters long. This gives a total cost of \$624,560.11 (calculated with unrounded values).

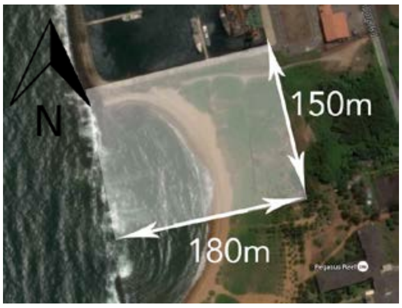

Figure 66 Expansion dimensions (Google, 2015)

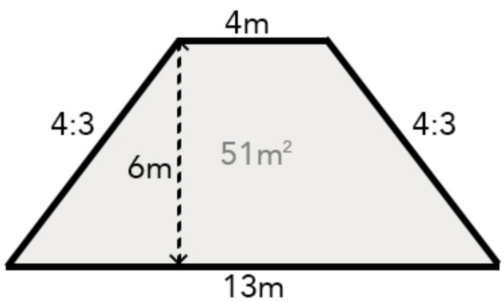

Figure 67 Simplified cross sectional area of breakwater

QUAY WALL COSTS

In total there is 150 meters of new quay wall needed for the expansion. The price for one meter of quay wall is approximately $10,000 (Gijt, 2011). This will result in a total cost of $1,500,000.

DREDGING COSTS

For calculating the dredging costs there is assumed that 2/3 of the area consist of land 1 meter above mean sea level and 1/3 is water with an average depth of 3 meters, in figure 68 these areas are shown. The total basin should be dredged to a depth of 4 meters, in this case also larger yachts can enter the new basin. The total amount of ground that should be removed is approximately:

$$\frac{2}{3} \cdot 180 \cdot 150 \cdot 5 + \frac{1}{3} \cdot 180 \cdot 150 \cdot 1 = 99000m^3$$

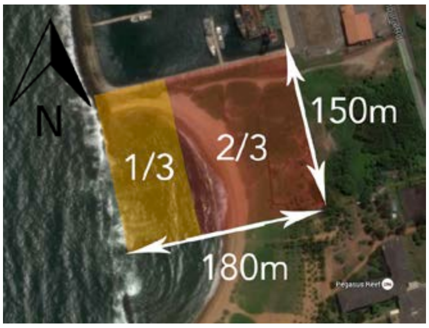

Figure 68 Indication of the area that should be dredged: The yellow area has a water depth of 3 meters and the red area is 1 meter above mean sea level (Google, 2015)

The dredging costs for the period 1980 to 2002 are shown in figure 69 (Eisma, 2006). In order to estimate the dredging costs for this project extrapolation is applied, see figure 70. The dredging costs for 2016 will be around $7 per cubic meter. This will result in a total dredging cost for the expansion of $693,000.

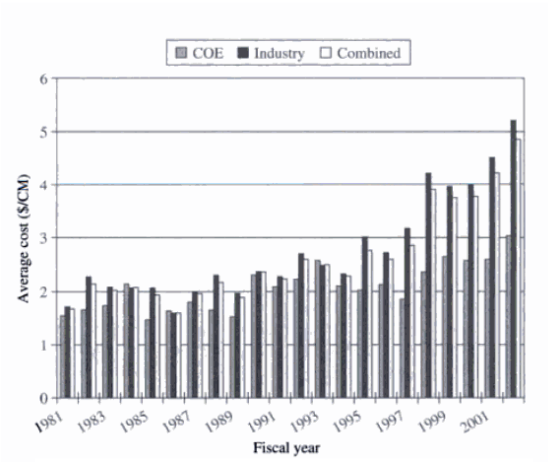

Figure 69 Average cost per cubic meter dredged between 1980 and 2002 (Eisma, 2006)

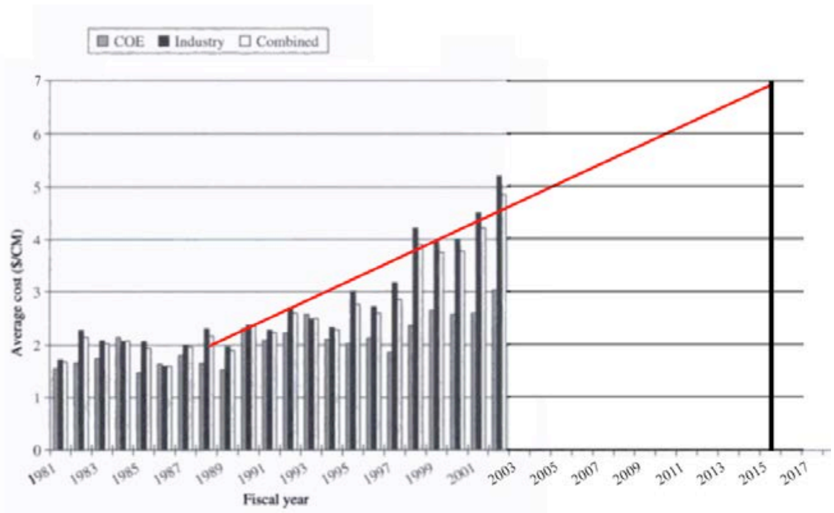

Figure 70 Extrapolation of the dredging costs per cubic meter of figure 69.

APPENDIX XI: NET PRESENT VALUE CALCULATIONS

This appendix contains all the calculation tables for the net present value for both the government and the investor for every alternative. These tables are divided into the construction phases with their own capacity. For every year the expected number of boats is given. It is expected that the number of boats will increase linearly with ten boats each year.

The first tables show the incomes of the government for each year. These incomes are divided into water rent, land rent and export harbour incomes. The water rent is assumed to be 5% of the total berth income of the marina. The land rent is estimated at $27.37 per square meter per year (Fernando, 2015). The export incomes are derived from the current incomes as seen in appendix I.

The last three tables show the costs and incomes of the investors for each year. The incomes are divided into berth revenues and services provided in the marina. The investor will have no income of the export fishery harbour part. The berth revenues and services are derived in appendix IIX. The costs of the investor are divided into the land and water rent, operational costs, construction costs for the necessary facilities, construction costs for the floating breakwater and construction costs for the expansion. The land and water rent are as explained above. The remaining costs are also derived in appendix IIX.

The last columns of all the tables contain the cash flows. The net present value is determined with the inflation and discount rate. Those rates are determined in appendix IX.

GOVERNMENTAL PROFIT FULL MARINA

In table 54, the calculations of the net present value of the governmental profit in the case of the *Full Marina* are shown.

Table 54 Net present value calculations of the governmental profit of the *Full Marina*

Full Marina - Government part				Income							
Phase	Capacity (berths)	Year	Boats	Water rent	Land rent	Export	Total cashflow	cashflow incl inflation	Discount rate	Discounted value	Discounted value incl infl
		0	0	$ -	$ -	$ -	$ -	$ -	11.5%	$ -	$ -
		1	10	$ 2,689.87	$ 684,192.00	$ -	$ 686,881.87	$ 714,357.14	11.5%	$ 616,037.55	$ 640,679.05
I	44	2	20	$ 5,379.74	$ 684,192.00	$ -	$ 689,571.73	$ 745,840.79	11.5%	$ 554,663.66	$ 599,924.22
		3	30	$ 8,069.60	$ 684,192.00	$ -	$ 692,261.60	$ 778,700.15	11.5%	$ 499,396.67	$ 561,753.33
		4	40	$ 10,759.47	$ 684,192.00	$ -	$ 694,951.47	$ 812,994.92	11.5%	$ 449,629.72	$ 526,003.17
II	88	5	50	$ 13,449.34	$ 684,192.00	$ -	$ 697,641.34	$ 848,787.36	11.5%	$ 404,816.18	$ 492,520.79
		6	60	$ 16,139.21	$ 684,192.00	$ -	$ 700,331.20	$ 886,142.39	11.5%	$ 364,463.69	$ 461,162.84
		7	70	$ 18,829.07	$ 684,192.00	$ -	$ 703,021.07	$ 925,127.77	11.5%	$ 328,128.74	$ 431,795.04
		8	80	$ 21,518.94	$ 684,192.00	$ -	$ 705,710.94	$ 965,814.15	11.5%	$ 295,411.85	$ 404,291.51
III	132	9	90	$ 24,208.81	$ 684,192.00	$ -	$ 708,400.81	$ 1,008,275.23	11.5%	$ 265,953.21	$ 378,534.35
		10	100	$ 26,898.68	$ 684,192.00	$ -	$ 711,090.67	$ 1,052,587.90	11.5%	$ 239,428.76	$ 354,413.05
		11	110	$ 29,588.54	$ 684,192.00	$ -	$ 713,780.54	$ 1,098,832.35	11.5%	$ 215,546.59	$ 331,824.08
		12	120	$ 32,278.41	$ 684,192.00	$ -	$ 716,470.41	$ 1,147,092.21	11.5%	$ 194,043.83	$ 310,670.43
		13	130	$ 34,968.28	$ 684,192.00	$ -	$ 719,160.28	$ 1,197,454.72	11.5%	$ 174,683.71	$ 290,861.22
IV	176	14	140	$ 37,658.15	$ 684,192.00	$ -	$ 721,850.14	$ 1,250,010.89	11.5%	$ 157,252.99	$ 272,311.29
		15	150	$ 40,348.01	$ 684,192.00	$ -	$ 724,540.01	$ 1,304,855.63	11.5%	$ 141,559.61	$ 254,940.86
		16	160	$ 43,037.88	$ 684,192.00	$ -	$ 727,229.88	$ 1,362,087.92	11.5%	$ 127,430.63	$ 238,675.18
		17	170	$ 45,727.75	$ 684,192.00	$ -	$ 729,919.75	$ 1,421,811.03	11.5%	$ 114,710.29	$ 223,444.22
V	255	18	180	$ 48,417.62	$ 684,192.00	$ -	$ 732,609.61	$ 1,484,132.65	11.5%	$ 103,258.31	$ 209,182.38
		19	190	$ 51,107.48	$ 684,192.00	$ -	$ 735,299.48	$ 1,549,165.10	11.5%	$ 92,948.37	$ 195,828.20
		20	200	$ 53,797.35	$ 684,192.00	$ -	$ 737,989.35	$ 1,617,025.54	11.5%	$ 83,666.72	$ 183,324.09
		21	210	$ 56,487.22	$ 684,192.00	$ -	$ 740,679.22	$ 1,687,836.14	11.5%	$ 75,310.92	$ 171,616.12
		22	220	$ 59,177.09	$ 684,192.00	$ -	$ 743,369.08	$ 1,761,724.36	11.5%	$ 67,788.72	$ 160,653.75
		23	230	$ 61,866.95	$ 684,192.00	$ -	$ 746,058.95	$ 1,838,823.09	11.5%	$ 61,017.05	$ 150,389.67
		24	240	$ 64,556.82	$ 684,192.00	$ -	$ 748,748.82	$ 1,919,270.96	11.5%	$ 54,921.11	$ 140,779.52
		25	255	$ 68,591.62	$ 684,192.00	$ -	$ 752,783.62	$ 2,006,797.92	11.5%	$ 49,522.03	$ 132,017.64
									NPV	**$ 5,731,591**	**$ 8,117,596.00**

GOVERNMENTAL PROFIT PHASED AND DIRECT EXPANSION

In table 55, the calculations of the net present value of the governmental profit in the case of the *Phased Expansion* and *Direct Expansion* are shown. This net present value is equal, because the same amount of land and basin is used for rent.

Table 55 Net present value calculations of the governmental profit of the *Direct* and *Phased Expansion*

Phased and Direct Expansion - Government part				Income							
Phase	Capacity (berths)	Year	Boats	Water	Land	Export	Total cashflow	cashflow incl inflation	Discount rate	Discounted value	Discounted value incl infl
		0	0	$ -	$ -	$ -	$ -	$ -	11.5%	$ -	$ -
		1	10	$ 2,689.87	$ 684,192.00	$ 455,979.05	$ 1,142,860.92	$ 1,188,575.35	11.5%	$ 1,024,987.37	$ 1,065,986.87
I	44	2	20	$ 5,379.74	$ 684,192.00	$ 455,979.05	$ 1,145,550.79	$ 1,239,027.73	11.5%	$ 921,434.81	$ 996,623.89
		3	30	$ 8,069.60	$ 684,192.00	$ 455,979.05	$ 1,148,240.65	$ 1,291,614.57	11.5%	$ 828,339.40	$ 931,769.17
		4	40	$ 10,759.47	$ 684,192.00	$ 455,979.05	$ 1,150,930.52	$ 1,346,425.92	11.5%	$ 744,645.62	$ 871,130.05
II	88	5	50	$ 13,449.34	$ 684,192.00	$ 455,979.05	$ 1,153,620.39	$ 1,403,555.59	11.5%	$ 669,404.44	$ 814,432.85
		6	60	$ 16,139.21	$ 684,192.00	$ 455,979.05	$ 1,156,310.26	$ 1,463,101.36	11.5%	$ 601,762.57	$ 761,421.63
		7	70	$ 18,829.07	$ 684,192.00	$ 455,979.05	$ 1,159,000.12	$ 1,525,165.09	11.5%	$ 540,952.85	$ 711,857.04
		8	80	$ 21,518.94	$ 684,192.00	$ 455,979.05	$ 1,161,689.99	$ 1,589,852.97	11.5%	$ 486,285.49	$ 665,515.27
III	132	9	90	$ 24,208.81	$ 684,192.00	$ 455,979.05	$ 1,164,379.86	$ 1,657,275.61	11.5%	$ 437,140.33	$ 622,187.00
		10	100	$ 26,898.68	$ 684,192.00	$ 455,979.05	$ 1,167,069.73	$ 1,727,548.29	11.5%	$ 392,959.80	$ 581,676.51
		11	110	$ 29,588.54	$ 684,192.00	$ 455,979.05	$ 1,169,759.59	$ 1,800,791.15	11.5%	$ 353,242.60	$ 543,800.76
		12	120	$ 32,278.41	$ 684,192.00	$ 455,979.05	$ 1,172,449.46	$ 1,877,129.36	11.5%	$ 317,538.01	$ 508,388.59
		13	130	$ 34,968.28	$ 684,192.00	$ 455,979.05	$ 1,175,139.33	$ 1,956,693.36	11.5%	$ 285,440.82	$ 475,279.95
IV	176	14	140	$ 37,658.15	$ 684,192.00	$ 455,979.05	$ 1,177,829.20	$ 2,039,619.08	11.5%	$ 256,586.72	$ 444,325.18
		15	150	$ 40,348.01	$ 684,192.00	$ 455,979.05	$ 1,180,519.06	$ 2,126,048.14	11.5%	$ 230,648.16	$ 415,384.31
		16	160	$ 43,037.88	$ 684,192.00	$ 455,979.05	$ 1,183,208.93	$ 2,216,128.14	11.5%	$ 207,330.67	$ 388,326.47
		17	170	$ 45,727.75	$ 684,192.00	$ 455,979.05	$ 1,185,898.80	$ 2,310,012.86	11.5%	$ 186,369.52	$ 363,029.28
V	200	18	180	$ 48,417.62	$ 684,192.00	$ 455,979.05	$ 1,188,588.67	$ 2,407,862.55	11.5%	$ 167,526.68	$ 339,378.31
		19	190	$ 51,107.48	$ 684,192.00	$ 455,979.05	$ 1,191,278.53	$ 2,509,844.20	11.5%	$ 150,588.16	$ 317,266.55
		20	200	$ 53,797.35	$ 684,192.00	$ 455,979.05	$ 1,193,968.40	$ 2,616,131.79	11.5%	$ 135,361.60	$ 296,593.94
		21	200	$ 53,797.35	$ 684,192.00	$ 455,979.05	$ 1,193,968.40	$ 2,720,777.07	11.5%	$ 121,400.54	$ 276,643.67
		22	200	$ 53,797.35	$ 684,192.00	$ 455,979.05	$ 1,193,968.40	$ 2,829,608.15	11.5%	$ 108,879.41	$ 258,035.35
		23	200	$ 53,797.35	$ 684,192.00	$ 455,979.05	$ 1,193,968.40	$ 2,942,792.47	11.5%	$ 97,649.69	$ 240,678.72
		24	200	$ 53,797.35	$ 684,192.00	$ 455,979.05	$ 1,193,968.40	$ 3,060,504.17	11.5%	$ 87,578.20	$ 224,489.57
		25	200	$ 53,797.35	$ 684,192.00	$ 455,979.05	$ 1,193,968.40	$ 3,182,924.34	11.5%	$ 78,545.47	$ 209,389.37
									NPV	**$ 9,432,598.93**	**$ 13,323,610.25**

INVESTOR PROFIT FULL MARINA

In table 56, the calculations of the net present value of the investor profit in the case of the *Full Marina* are shown.

Table 56 Net present value calculations of the investor profit of the *Full Marina*

Full Marina - Investor part				Income			Costs											
Phase	Capacity (berths)	Year	Boats	Berths	Services	Export	Water rent	Land rent	Operational	Construction	Necessary facilities	Floating breakwater	Expansion	Total cashflow	cashflow incl inflation	Discount rate	Discounted value	Discounted value incl infl
		0	0	$ -	$ -	$ -	$ -	$ -684,192.00	$ -	$ -1,693,375.19	$ -1,213,095.95	$ -600,000.00	$ -	$ -4,190,663.14	$ -4,190,663.14	11.5%	$ -4,190,663.14	$ -4,190,663.14
		1	10	$ 51,107.48	$ 7,000.00	$ -	$ -2,689.87	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -661,774.38	$ -688,245.36	11.5%	$ -593,519.63	$ -617,260.41
I	44	2	20	$ 102,214.97	$ 14,000.00	$ -	$ -5,379.74	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -606,356.77	$ -655,835.48	11.5%	$ -487,728.90	$ -527,527.58
		3	30	$ 153,322.45	$ 21,000.00	$ -	$ -8,069.60	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -550,939.15	$ -619,731.62	11.5%	$ -397,446.83	$ -447,073.63
		4	40	$ 204,429.93	$ 28,000.00	$ -	$ -10,759.47	$ -684,192.00	$ -52,800.00	$ -1,693,375.19	$ -	$ -	$ -	$ -2,208,696.73	$ -2,583,862.78	11.5%	$ -1,429,014.45	$ -1,671,744.78
II	88	5	50	$ 255,537.41	$ 35,000.00	$ -	$ -13,449.34	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -459,903.92	$ -559,543.44	11.5%	$ -266,865.71	$ -324,682.94
		6	60	$ 306,644.90	$ 42,000.00	$ -	$ -16,139.21	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -404,486.31	$ -511,804.22	11.5%	$ -210,501.22	$ -266,351.20
		7	70	$ 357,752.38	$ 49,000.00	$ -	$ -18,829.07	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -349,068.69	$ -459,350.59	11.5%	$ -162,924.66	$ -214,397.74
		8	80	$ 408,859.86	$ 56,000.00	$ -	$ -21,518.94	$ -684,192.00	$ -66,000.00	$ -1,693,375.19	$ -	$ -	$ -	$ -2,000,226.27	$ -2,737,447.77	11.5%	$ -837,298.26	$ -1,145,900.48
III	132	9	90	$ 459,967.34	$ 63,000.00	$ -	$ -24,208.81	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -251,433.46	$ -357,868.22	11.5%	$ -94,395.06	$ -134,353.60
		10	100	$ 511,074.83	$ 70,000.00	$ -	$ -26,898.68	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -196,015.85	$ -290,151.34	11.5%	$ -65,999.78	$ -97,695.80
		11	110	$ 562,182.31	$ 77,000.00	$ -	$ -29,588.54	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -140,598.23	$ -216,444.52	11.5%	$ -42,457.69	$ -65,361.66
		12	120	$ 613,289.79	$ 84,000.00	$ -	$ -32,278.41	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -85,180.62	$ -136,376.91	11.5%	$ -23,069.72	$ -36,935.37
		13	130	$ 664,397.27	$ 91,000.00	$ -	$ -34,968.28	$ -684,192.00	$ -88,000.00	$ -1,693,375.19	$ -	$ -	$ -	$ -1,745,138.20	$ -2,905,783.38	11.5%	$ -423,893.30	$ -705,813.50
IV	176	14	140	$ 715,504.76	$ 98,000.00	$ -	$ -37,658.15	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 3,654.61	$ 6,328.61	11.5%	$ 796.15	$ 1,378.67
		15	150	$ 766,612.24	$ 105,000.00	$ -	$ -40,348.01	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 59,072.23	$ 106,385.74	11.5%	$ 11,541.45	$ 20,785.50
		16	160	$ 817,719.72	$ 112,000.00	$ -	$ -43,037.88	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 114,489.84	$ 214,437.33	11.5%	$ 20,061.76	$ 37,575.30
		17	170	$ 868,827.20	$ 119,000.00	$ -	$ -45,727.75	$ -684,192.00	$ -127,500.00	$ -3,040,378.19	$ -	$ -	$ -	$ -2,909,970.73	$ -5,668,333.43	11.5%	$ -457,315.45	$ -890,804.99
V	255	18	180	$ 919,934.69	$ 126,000.00	$ -	$ -48,417.62	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 185,825.07	$ 376,447.50	11.5%	$ 26,191.28	$ 53,058.72
		19	190	$ 971,042.17	$ 133,000.00	$ -	$ -51,107.48	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 241,242.69	$ 508,261.96	11.5%	$ 30,495.21	$ 64,248.82
		20	200	$ 1,022,149.65	$ 140,000.00	$ -	$ -53,797.35	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 296,660.30	$ 650,019.25	11.5%	$ 33,632.73	$ 73,693.45
		21	210	$ 1,073,257.13	$ 147,000.00	$ -	$ -56,487.22	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 352,077.92	$ 802,303.92	11.5%	$ 35,798.64	$ 81,576.81
		22	220	$ 1,124,364.62	$ 154,000.00	$ -	$ -59,177.09	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 407,495.53	$ 965,731.32	11.5%	$ 37,160.01	$ 88,066.20
		23	230	$ 1,175,472.10	$ 161,000.00	$ -	$ -61,866.95	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 462,913.15	$ 1,140,949.23	11.5%	$ 37,859.73	$ 93,313.48
		24	240	$ 1,226,579.58	$ 168,000.00	$ -	$ -64,556.82	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 518,330.76	$ 1,328,639.40	11.5%	$ 38,019.83	$ 97,456.39
		25	255	$ 1,303,240.80	$ 178,500.00	$ -	$ -68,591.62	$ -684,192.00	$ -127,500.00	$ -	$ -	$ -	$ -	$ 601,457.18	$ 1,603,386.42	11.5%	$ 39,566.99	$ 105,479.12
																NPV	**$ -9,371,970**	**$ -10,619,934.39**

INVESTOR PROFIT DIRECT EXPANSION

In table 57, the calculations of the net present value of the investor profit in the case of the *Direct Expansion* are shown.

Table 57 Net present value calculations of the investor profit of the *Direct Expansion*

Phase	Capacity (berths)	Year	Boats	Berths	Services	Export	Water rent	Land rent	Operational	Construction	Necessary facilities	Floating breakwater	Expansion	Total cashflow	cashflow incl inflation	Discount rate	Discounted value	Discounted value incl infl
		0	0	-	-	-	$ -	$ -684,192.00	$ -	$ -1,693,375.19	$ -1,213,095.95	$ -600,000.00	$ -2,817,560.11	$ -7,008,223.25	$ -7,008,223.25	11.5%	$ -7,008,223.25	$ -7,008,223.25
		1	10	51,107.48	7,000.00	-	$ -2,689.87	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -661,774.38	$ -688,245.36	11.5%	$ -593,519.63	$ -617,260.41
I	44	2	20	102,214.97	14,000.00	-	$ -5,379.74	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -606,356.77	$ -655,835.48	11.5%	$ -487,728.90	$ -527,527.58
		3	30	153,322.45	21,000.00	-	$ -8,069.60	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -550,939.15	$ -619,731.62	11.5%	$ -397,446.83	$ -447,073.63
		4	40	204,429.93	28,000.00	-	$ -10,759.47	$ -684,192.00	$ -52,800.00	$ -1,693,375.19	$ -	$ -	$ -	$ -2,208,696.73	$ -2,583,862.78	11.5%	$ -1,429,014.45	$ -1,671,744.78
II	88	5	50	255,537.41	35,000.00	-	$ -13,449.34	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -459,903.92	$ -559,543.44	11.5%	$ -266,865.71	$ -324,682.94
		6	60	306,644.90	42,000.00	-	$ -16,139.21	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -404,486.31	$ -511,804.22	11.5%	$ -210,501.22	$ -266,351.20
		7	70	357,752.38	49,000.00	-	$ -18,829.07	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -349,068.69	$ -459,350.59	11.5%	$ -162,924.66	$ -214,397.74
		8	80	408,859.86	56,000.00	-	$ -21,518.94	$ -684,192.00	$ -66,000.00	$ -1,693,375.19	$ -	$ -	$ -	$ -2,000,226.27	$ -2,737,447.77	11.5%	$ -837,298.26	$ -1,145,900.48
III	132	9	90	459,967.34	63,000.00	-	$ -24,208.81	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -251,433.46	$ -357,868.22	11.5%	$ -94,395.06	$ -134,353.60
		10	100	511,074.83	70,000.00	-	$ -26,898.68	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -196,015.85	$ -290,151.34	11.5%	$ -65,999.78	$ -97,695.80
		11	110	562,182.31	77,000.00	-	$ -29,588.54	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -140,598.23	$ -216,444.52	11.5%	$ -42,457.69	$ -65,361.66
		12	120	613,289.79	84,000.00	-	$ -32,278.41	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -85,180.62	$ -136,376.91	11.5%	$ -23,069.72	$ -36,935.37
		13	130	664,397.27	91,000.00	-	$ -34,968.28	$ -684,192.00	$ -88,000.00	$ -1,693,375.19	$ -	$ -	$ -	$ -1,745,138.20	$ -2,905,783.38	11.5%	$ -423,893.30	$ -705,813.50
IV	176	14	140	715,504.76	98,000.00	-	$ -37,658.15	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 3,654.61	$ 6,328.61	11.5%	$ 796.15	$ 1,378.67
		15	150	766,612.24	105,000.00	-	$ -40,348.01	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 59,072.23	$ 106,385.74	11.5%	$ 11,541.45	$ 20,785.50
		16	160	817,719.72	112,000.00	-	$ -43,037.88	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 114,489.84	$ 214,437.33	11.5%	$ 20,061.76	$ 37,575.30
		17	170	868,827.20	119,000.00	-	$ -45,727.75	$ -684,192.00	$ -100,000.00	$ -923,659.20	$ -	$ -	$ -	$ -765,751.74	$ -1,491,608.19	11.5%	$ -120,341.45	$ -234,413.17
V	200	18	180	919,934.69	126,000.00	-	$ -48,417.62	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 213,325.07	$ 432,157.45	11.5%	$ 30,067.29	$ 60,910.81
		19	190	971,042.17	133,000.00	-	$ -51,107.48	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 268,742.69	$ 566,200.31	11.5%	$ 33,971.46	$ 71,572.74
		20	200	1,022,149.65	140,000.00	-	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 710,275.14	11.5%	$ 36,750.43	$ 80,524.73
		21	200	1,022,149.65	140,000.00	-	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 738,686.15	11.5%	$ 32,960.03	$ 75,108.27
		22	200	1,022,149.65	140,000.00	-	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 768,233.59	11.5%	$ 29,560.57	$ 70,056.14
		23	200	1,022,149.65	140,000.00	-	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 798,962.94	11.5%	$ 26,511.72	$ 65,343.84
		24	200	1,022,149.65	140,000.00	-	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 830,921.45	11.5%	$ 23,777.33	$ 60,948.52
		25	200	1,022,149.65	140,000.00	-	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 864,158.31	11.5%	$ 21,324.96	$ 56,848.84
																NPV	**$ -11,896,356.77**	**$ -12,896,681.76**

INVESTOR PROFIT PHASED EXPANSION

In table 58, the calculations of the net present value of the investor profit in the case of the *Phased Expansion* are shown.

Table 58 Net present value calculations of the investor profit of the *Phased Expansion*

Phased Expansion - Investor part				Income			Costs											
Phase	Capacity (berths)	Year	Boats	Berths	Services	Export	Water rent	Land rent	Operational	Construction	Necessary facilities	Floating breakwater	Expansion	Total cashflow	cashflow incl inflation	Discount rate	Discounted value	Discounted value incl infl
		0	0	$ -	$ -	$ -	$ -	$ -684,192.00	$ -	$ -1,693,375.19	$ -1,213,095.95	$ -600,000.00	$ -	$ -4,190,663.14	$ -4,190,663.14	11.5%	$ -4,190,663.14	$ -4,190,663.14
		1	10	$ 51,107.48	$ 7,000.00	$ -	$ -2,689.87	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -661,774.38	$ -688,245.36	11.5%	$ -593,519.63	$ -617,260.41
I	44	2	20	$ 102,214.97	$ 14,000.00	$ -	$ -5,379.74	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -606,356.77	$ -655,835.48	11.5%	$ -487,728.90	$ -527,527.58
		3	30	$ 153,322.45	$ 21,000.00	$ -	$ -8,069.60	$ -684,192.00	$ -33,000.00	$ -	$ -	$ -	$ -	$ -550,939.15	$ -619,731.62	11.5%	$ -397,446.83	$ -447,073.63
		4	40	$ 204,429.93	$ 28,000.00	$ -	$ -10,759.47	$ -684,192.00	$ -52,800.00	$ -1,693,375.19	$ -	$ -	$ -	$ -2,208,696.73	$ -2,583,862.78	11.5%	$ -1,429,014.45	$ -1,671,744.78
II	88	5	50	$ 255,537.41	$ 35,000.00	$ -	$ -13,449.34	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -2,817,560.11	$ -3,277,464.03	$ -3,987,536.13	11.5%	$ -1,901,794.55	$ -2,313,823.85
		6	60	$ 306,644.90	$ 42,000.00	$ -	$ -16,139.21	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -404,486.31	$ -511,804.22	11.5%	$ -210,501.22	$ -266,351.20
		7	70	$ 357,752.38	$ 49,000.00	$ -	$ -18,829.07	$ -684,192.00	$ -52,800.00	$ -	$ -	$ -	$ -	$ -349,068.69	$ -459,350.59	11.5%	$ -162,924.66	$ -214,397.74
		8	80	$ 408,859.86	$ 56,000.00	$ -	$ -21,518.94	$ -684,192.00	$ -66,000.00	$ -1,693,375.19	$ -	$ -	$ -	$ -2,000,226.27	$ -2,737,447.77	11.5%	$ -837,298.26	$ -1,145,900.48
III	132	9	90	$ 459,967.34	$ 63,000.00	$ -	$ -24,208.81	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -251,433.46	$ -357,868.22	11.5%	$ -94,395.06	$ -134,353.60
		10	100	$ 511,074.83	$ 70,000.00	$ -	$ -26,898.68	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -196,015.85	$ -290,151.34	11.5%	$ -65,999.78	$ -97,695.80
		11	110	$ 562,182.31	$ 77,000.00	$ -	$ -29,588.54	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -140,598.23	$ -216,444.52	11.5%	$ -42,457.69	$ -65,361.66
		12	120	$ 613,289.79	$ 84,000.00	$ -	$ -32,278.41	$ -684,192.00	$ -66,000.00	$ -	$ -	$ -	$ -	$ -85,180.62	$ -136,376.91	11.5%	$ -23,069.72	$ -36,935.37
		13	130	$ 664,397.27	$ 91,000.00	$ -	$ -34,968.28	$ -684,192.00	$ -88,000.00	$ -1,693,375.19	$ -	$ -	$ -	$ -1,745,138.20	$ -2,905,783.38	11.5%	$ -423,893.30	$ -705,813.50
IV	176	14	140	$ 715,504.76	$ 98,000.00	$ -	$ -37,658.15	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 3,654.61	$ 6,328.61	11.5%	$ 796.15	$ 1,378.67
		15	150	$ 766,612.24	$ 105,000.00	$ -	$ -40,348.01	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 59,072.23	$ 106,385.74	11.5%	$ 11,541.45	$ 20,785.50
		16	160	$ 817,719.72	$ 112,000.00	$ -	$ -43,037.88	$ -684,192.00	$ -88,000.00	$ -	$ -	$ -	$ -	$ 114,489.84	$ 214,437.33	11.5%	$ 20,061.76	$ 37,575.30
		17	170	$ 868,827.20	$ 119,000.00	$ -	$ -45,727.75	$ -684,192.00	$ -100,000.00	$ -923,659.20	$ -	$ -	$ -	$ -765,751.74	$ -1,491,608.19	11.5%	$ -120,341.45	$ -234,413.17
V	200	18	180	$ 919,934.69	$ 126,000.00	$ -	$ -48,417.62	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 213,325.07	$ 432,157.45	11.5%	$ 30,067.29	$ 60,910.81
		19	190	$ 971,042.17	$ 133,000.00	$ -	$ -51,107.48	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 268,742.69	$ 566,200.31	11.5%	$ 33,971.46	$ 71,572.74
		20	200	$ 1,022,149.65	$ 140,000.00	$ -	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 710,275.14	11.5%	$ 36,750.43	$ 80,524.73
		21	200	$ 1,022,149.65	$ 140,000.00	$ -	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 738,686.15	11.5%	$ 32,960.03	$ 75,108.27
		22	200	$ 1,022,149.65	$ 140,000.00	$ -	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 768,233.59	11.5%	$ 29,560.57	$ 70,056.14
		23	200	$ 1,022,149.65	$ 140,000.00	$ -	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 798,962.94	11.5%	$ 26,511.72	$ 65,343.84
		24	200	$ 1,022,149.65	$ 140,000.00	$ -	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 830,921.45	11.5%	$ 23,777.33	$ 60,948.52
		25	200	$ 1,022,149.65	$ 140,000.00	$ -	$ -53,797.35	$ -684,192.00	$ -100,000.00	$ -	$ -	$ -	$ -	$ 324,160.30	$ 864,158.31	11.5%	$ 21,324.96	$ 56,848.84
																NPV	**$ -10,713,725.49**	**$ -12,068,262.56**

APPENDIX XII: FULL MARINA DIMENSIONS

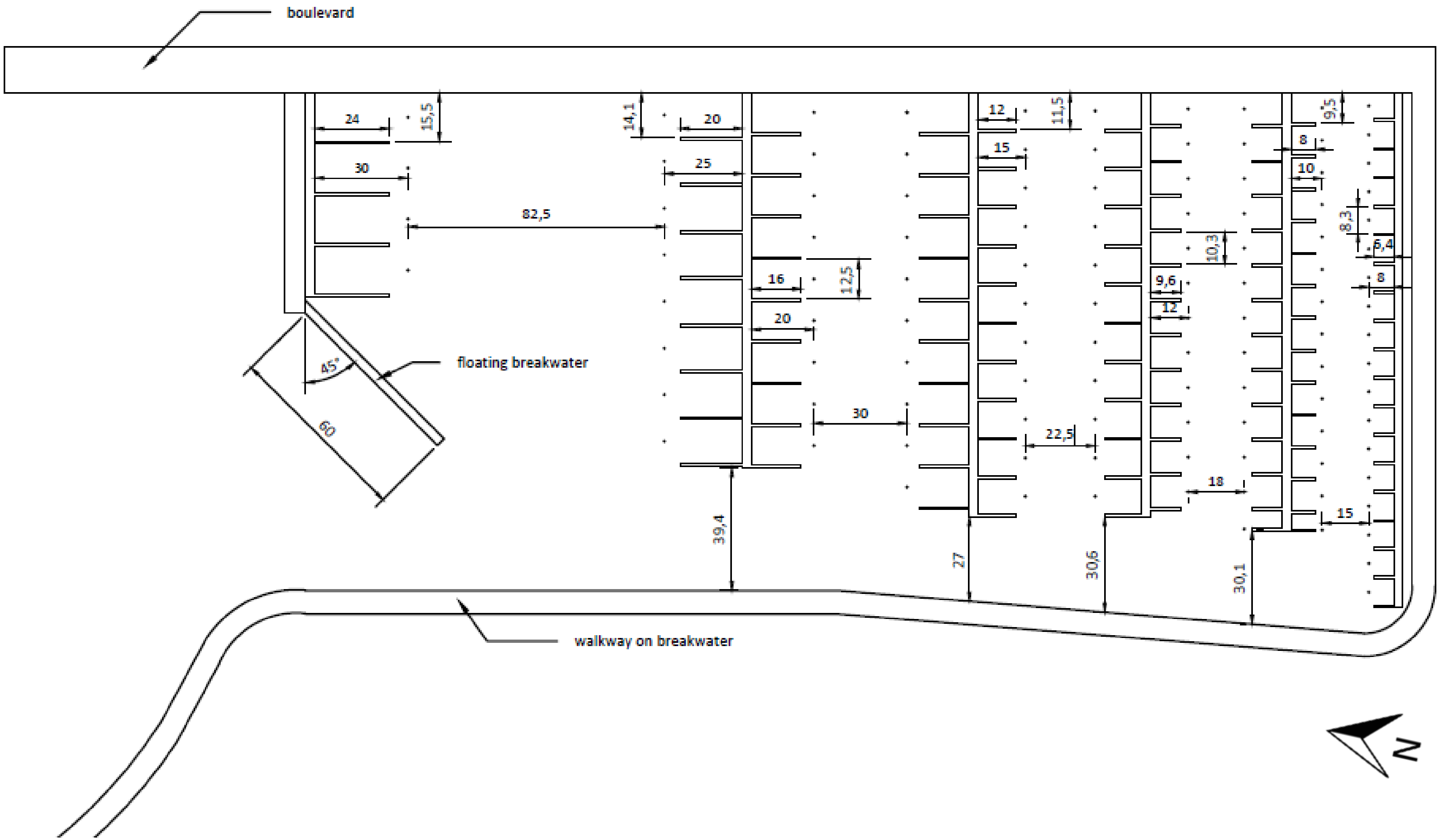

Figure 71 *Full Marina* dimensions (units in meters)

APPENDIX XIII: FLOATING BREAKWATER DIMENSIONING

For the dimensioning of the floating breakwater the PIANC guideline for floating breakwaters is used (PIANC, 1994). The dimensioning is done following figure 72. The first two steps in the left top are done in the analyses. The design criteria are from the Australian guidelines for marina design (Committee CE-030, 2001), which give that the maximum wave height inside the basin must be 0.3 meters. The wave information is obtained from the BMT ARGOSS data and can be found in the table below. In this table the representative wave heights are collected, so there will be higher waves too.

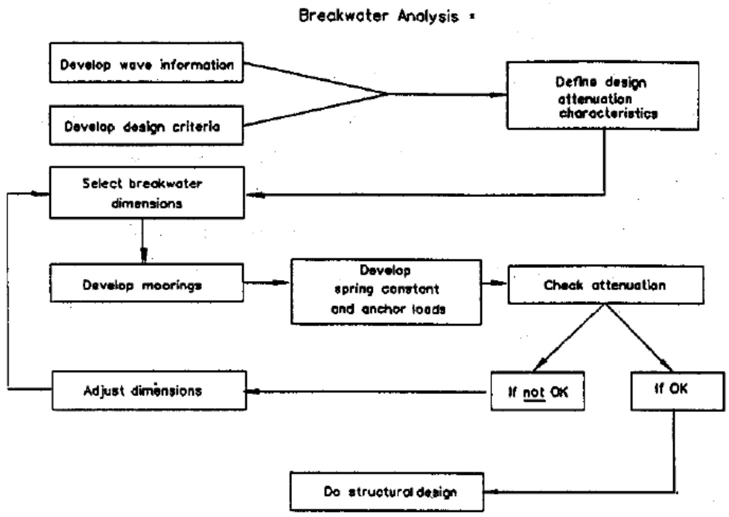

Figure 72 Design scheme for the floating breakwater

However, the waves in the harbour are never higher than about 50 centimeters (Harbour Manager Dikkowita). This could be explained with the phenomenon of energy dissipation in the entrance channel. Noted must be that the wave heights and wave periods in the table are not the real wave heights and wave periods in the harbour. Measurements have to be done to find the real wave heights and periods. For now these values are assumed to be real, even the 0.63 meters height during the Southwest monsoon, because of the very low probability.

Table 59 Wave data (BMT ARGOSS, 2015)

Season	Representative wave height [m] and probability	Representative wave period [s] and probability
First Inter-monsoon	0.25 [1.7%]	3.5 [1.7%]
Southwest monsoon	0.63 [0%]	3.8 [0%]
Second Inter-monsoon	0.33 [7.5%]	3.5 [7.5%]
Northeast monsoon	0.39 [9.3%]	3.7 [9.3%]

The wave height has to be lower than 0.3 meters, so for the First Inter-monsoon this criterion already seems to be reached. For the Second Inter-monsoon and the Northeast monsoon a wave transmission factor c_t of 0.7 would be sufficient, where $h_t = c_t \cdot h_i$. Here, h_t is the transmitted wave (the wave passing the breakwater and going into the basin) and h_i the incoming wave. For the Southwest monsoon a transmission coefficient c_t of less than 0.5 is needed. This is however with waves that are very rare, looking at the probability of those waves.

The next step is to choose dimensions for the breakwater. First the length of the breakwater will be chosen. Important here are two things, namely enough blocking of the waves and a wide enough basin entrance. The width of the harbour entrance must be 35 meters, following the criteria given in chapter 2.2. This results in a breakwater length of 60 meters with an angle of 45°(figure 73). All the other dimensions are chosen as an iterative process till the right transmission factor c_t is found.

Figure 73 Position breakwater (Google, 2015)

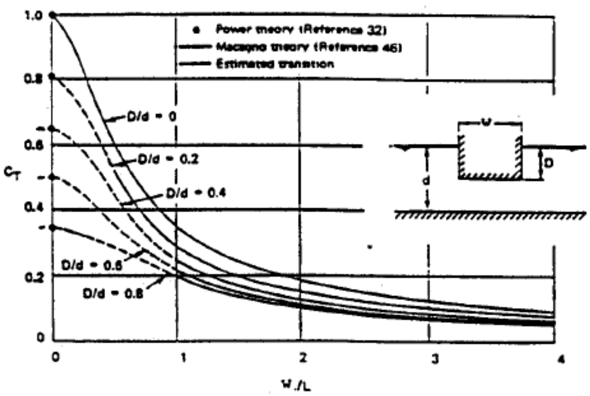

Figure 74 Transmission coefficient for L/d=2.5

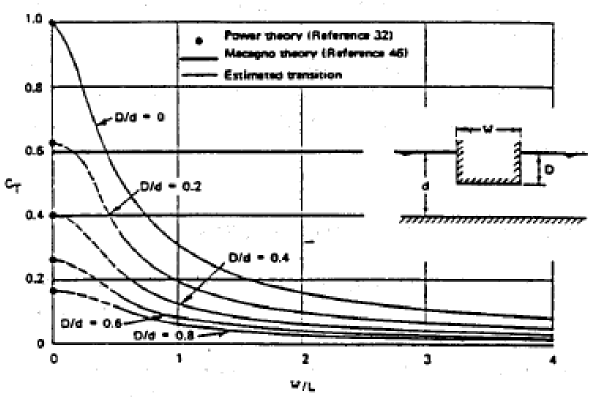

Figure 75 Transmission coefficient for L/d=5

The transmission coefficient c_t can be determined with the figures 74 and 75 (PIANC, 1994). As found in these figures three dimensionless parameters are of importance: $\frac{W}{L}$, $\frac{D}{d}$ and $\frac{L}{d}$. W is here the width of the breakwater, L the wave length, D the depth of the breakwater (as can be seen in figure 74 and 75) and d the depth of the water. The water depth is 5 meters at the position of the breakwater. For all the waves during the different monsoons this is transitional water (between deep and shallow water). The calculated wave lengths can be found in the table below.

Table 60 Wave lengths and dimensionless parameters

	Wave length	$\frac{W}{L}$	$\frac{D}{d}$	$\frac{L}{d}$	c_t with $\frac{L}{d} = 2.5$	c_t with $\frac{L}{d} = 5$	c_t
First Inter -monsoon	18 m	0.17	0.5	3.6	0.32	0.54	0.42
Southwest -monsoon	20.5 m	0.15	0.5	4.1	0.32	0.54	0.46
Second Inter -monsoon	18 m	0.17	0.5	3.6	0.32	0.54	0.42
Northeast -monsoon	19.7 m	0.15	0.5	3.9	0.32	0.54	0.44

The final dimensions are:

- Width : $W = 3$ meters
- Depth of the floating breakwater: $D = 2.5$ meters
- Length: $L = 60$ meters

With these dimensions of the floating breakwater the associated dimensionless parameters are displayed in table 60. Because the figures to find the transmission coefficient c_t belong to values of $\frac{L}{d} = 2.5$ and $\frac{L}{d} = 5$ results of those two figures are linearized. This gives all transmission coefficients below 0.5, so these dimensions of the floating breakwater will be sufficient for meeting the requirement of maximum waves of 0.3 meters inside the harbour basin.

APPENDIX XIV: DRAWING OF CURRENT DIKKOWITA FISHERY HARBOUR

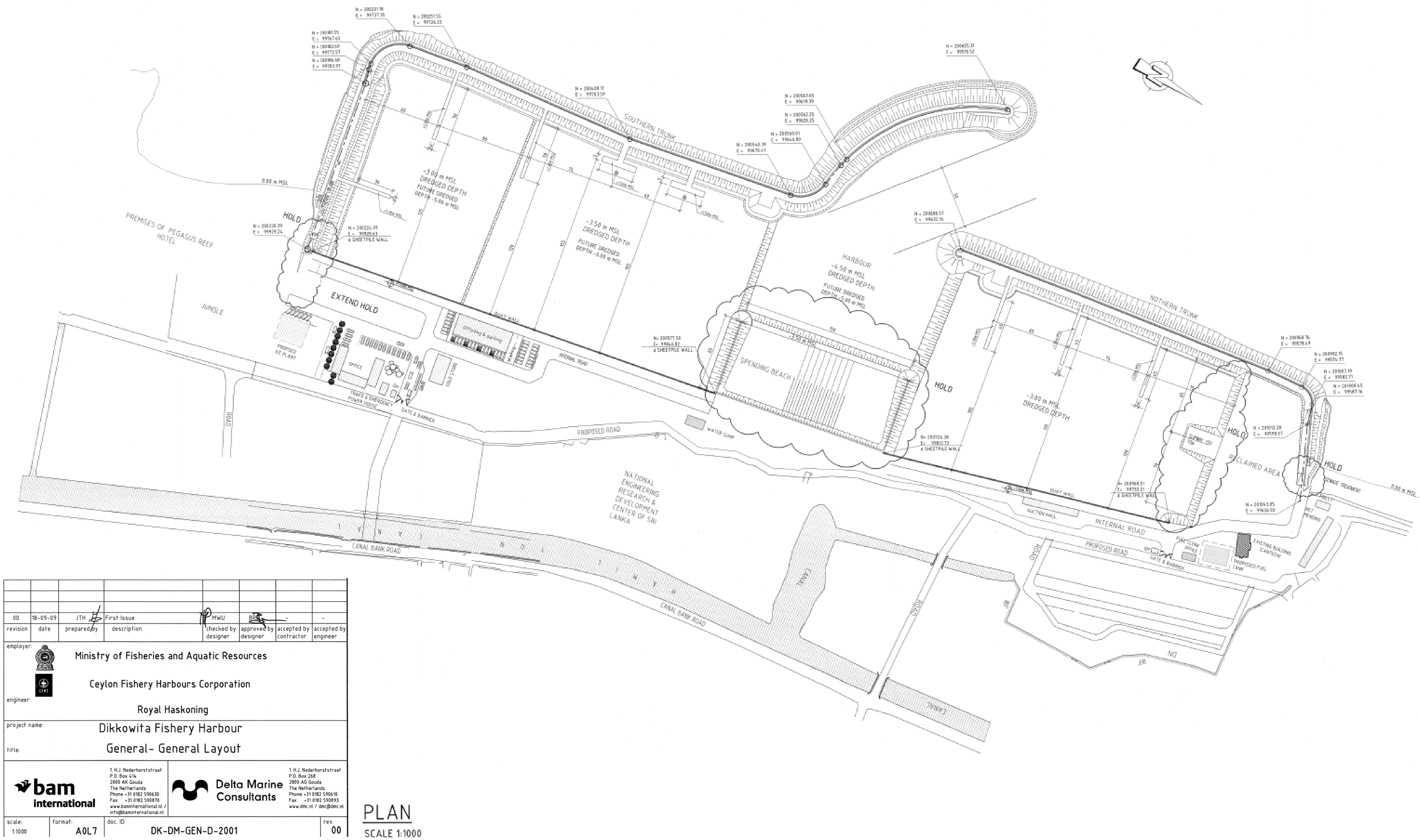

Figure 76 Original harbour map

APPENDIX XV: LAYOUT AND CROSS SECTIONS SOUTHERN REEF

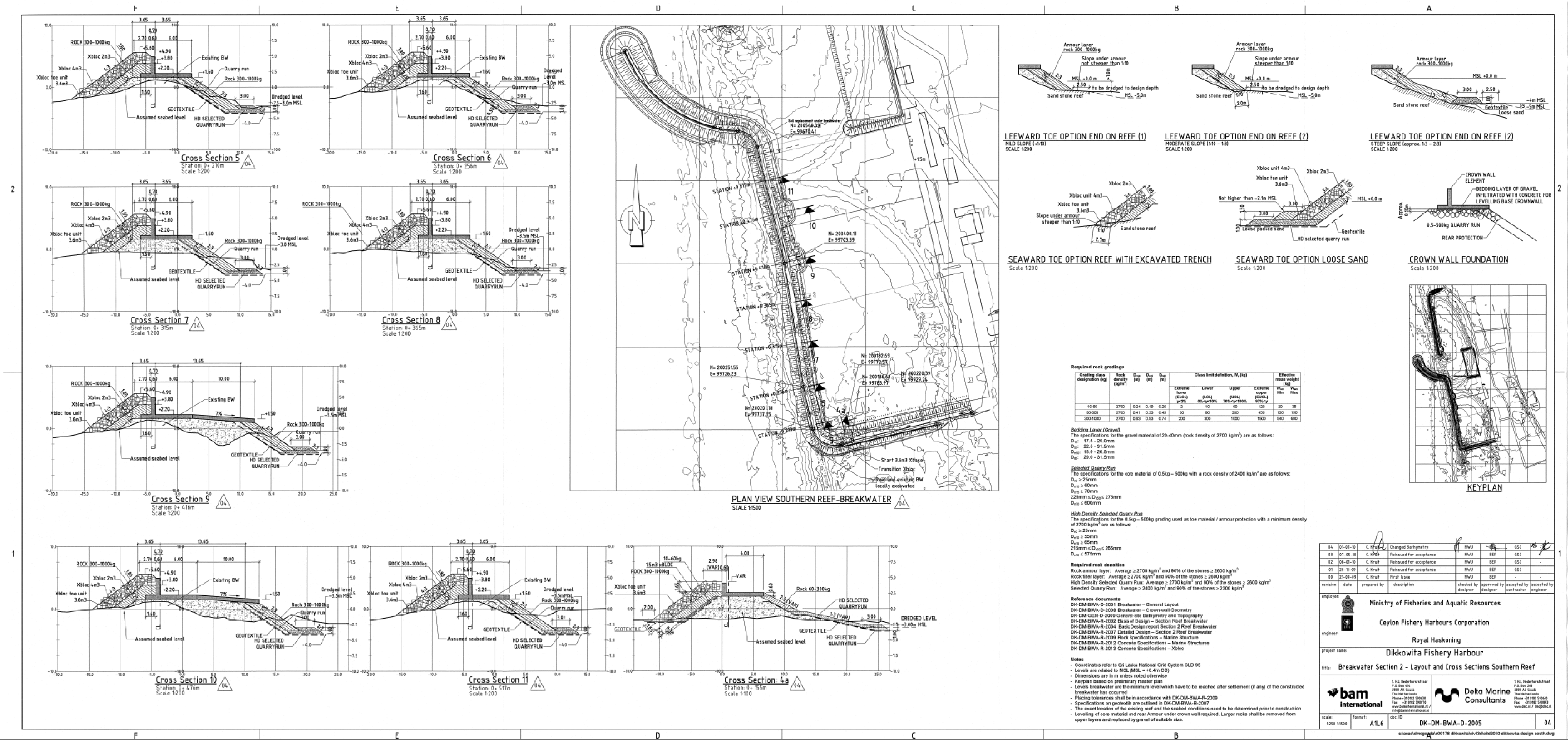

Figure 77 Layout and Cross Sections Southern Reef Breakwater Dikkowita Fishery Harbour

Figure 78: Harbour sketch, top view Dikkowita Marina (Google, 2015).

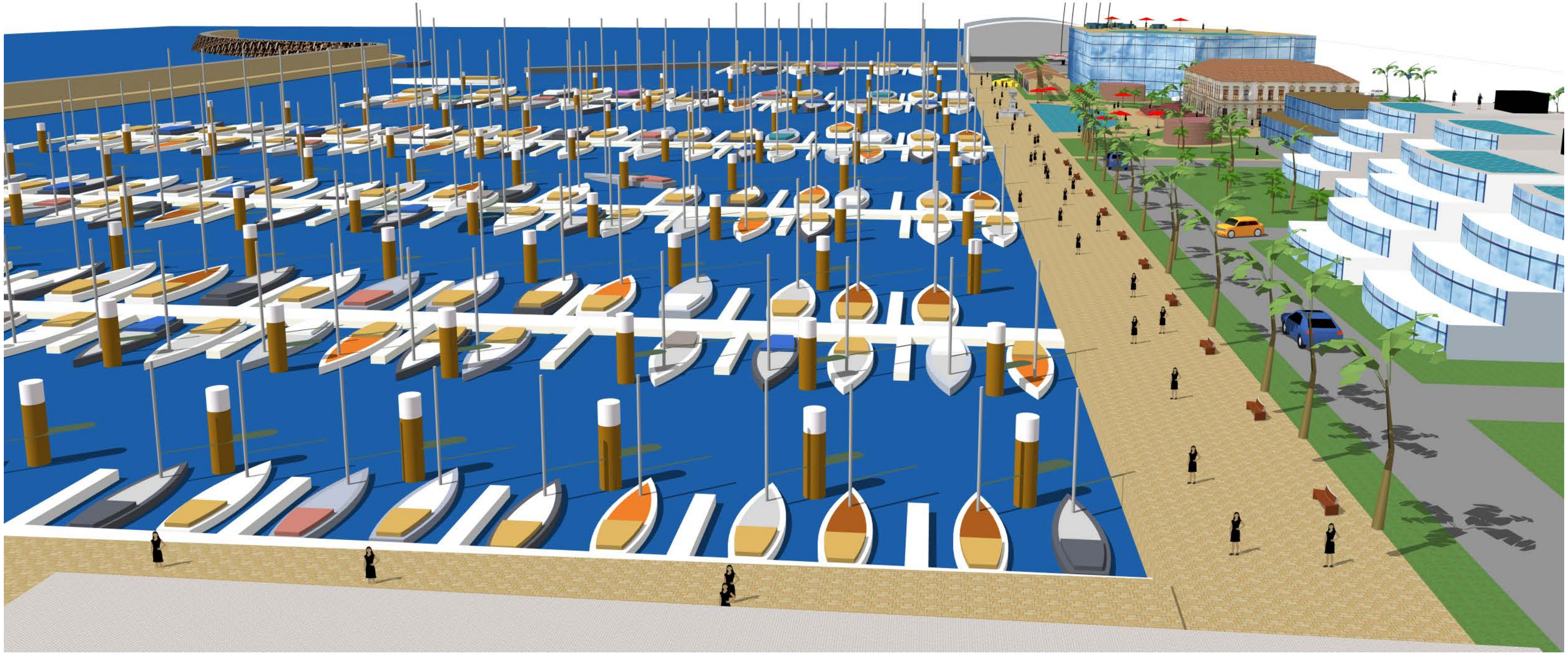

Figure 79 Harbour sketch, Dikkowita Marina southern view

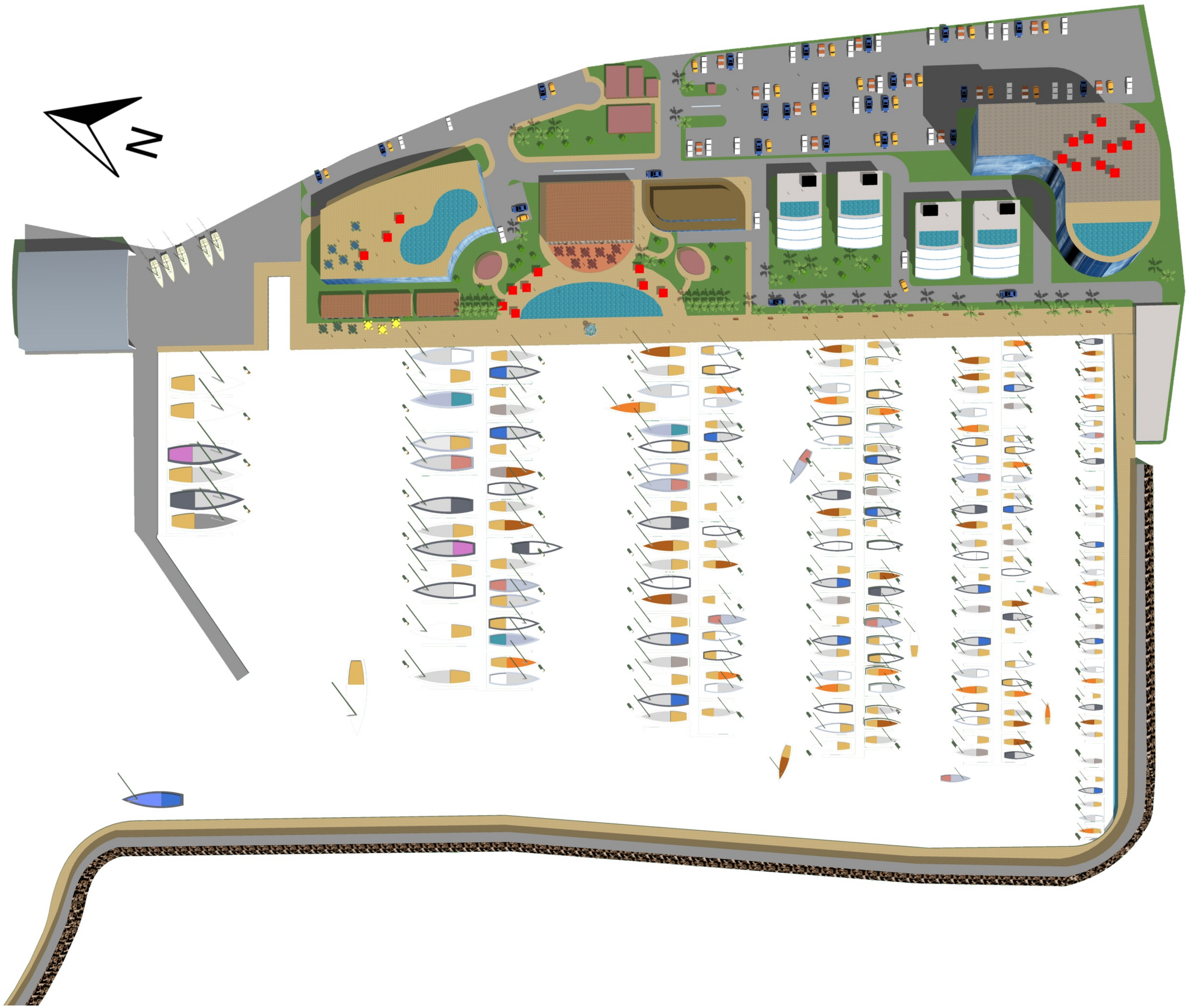

Figure 80 Harbour sketch, Dikkowtia Marina top view

Figure 81 Harbour sketch, Dikkowita Marina parking places

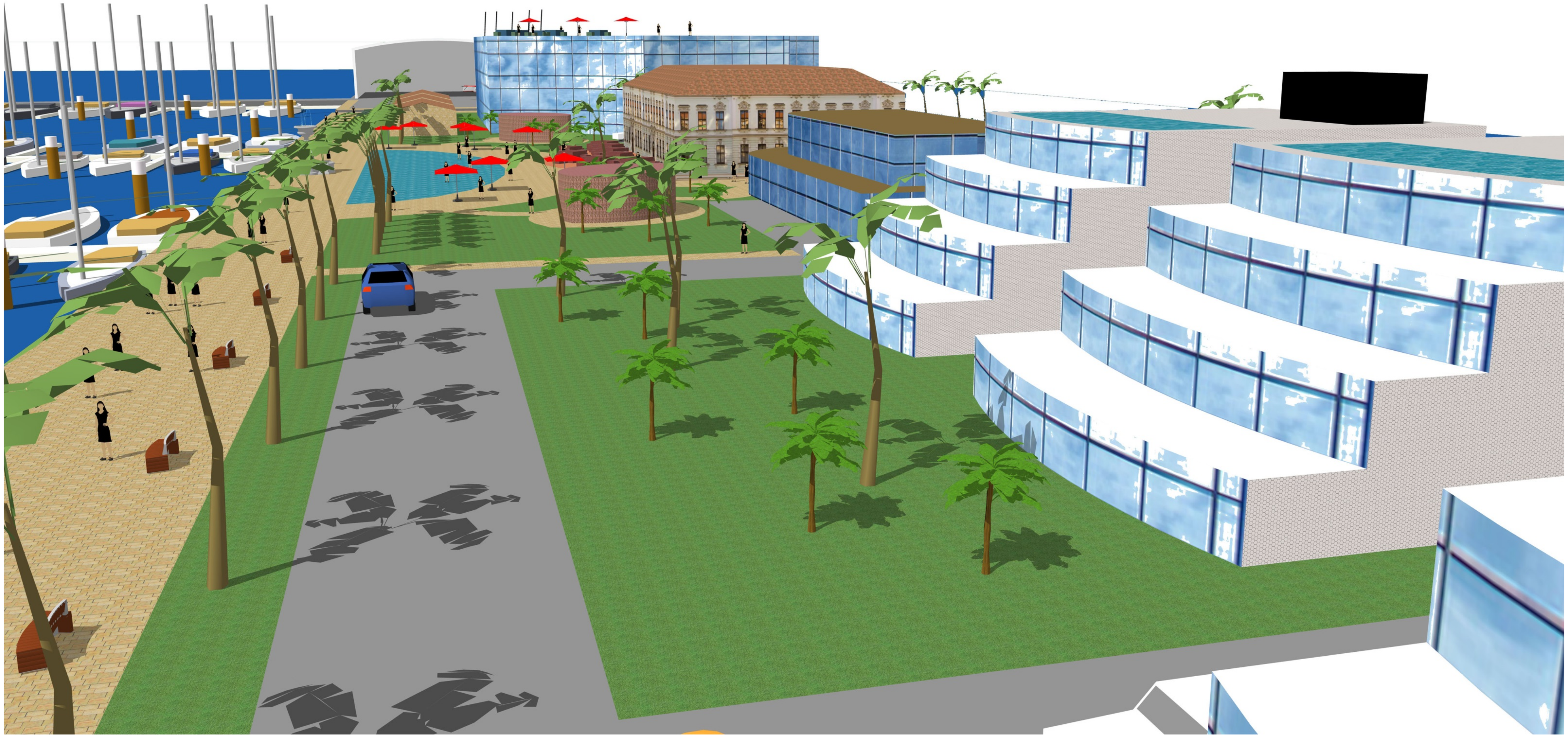

Figure 82 Harbour sketch, Dikkowita Marina Boulevard

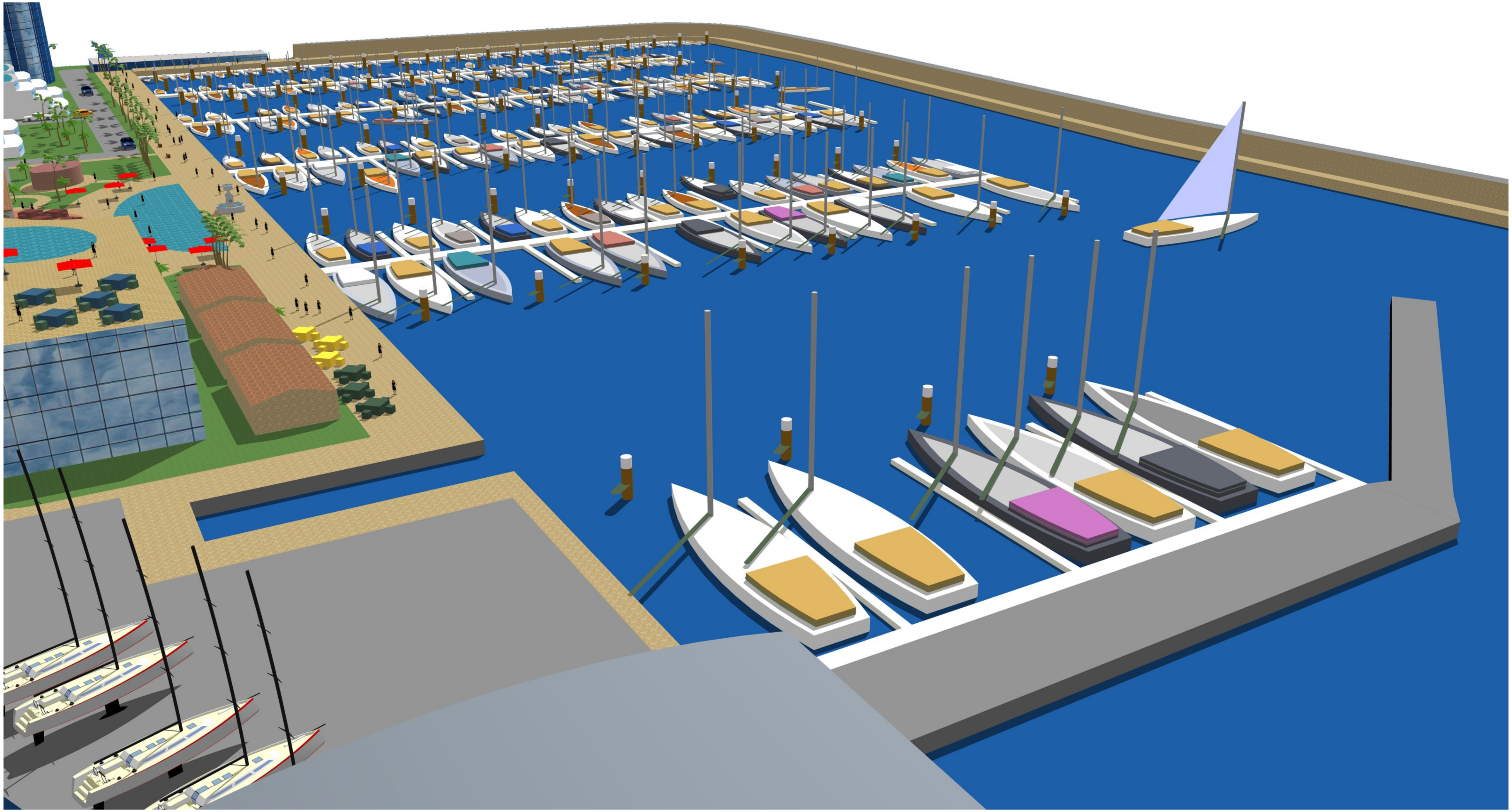

Figure 83 Harbour sketch, Dikkowita Marina yachts