A feasibility study for a network of marinas in the Buenos Aires province

Including a conceptual design of such a marina

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Multidisciplinary Project, course code CIE4061-09
part of the Master Degree
at the Delft University of Technology,

Project period:	September 3, 2018 – November 9, 2018	
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Preface

This report is written on behalf of Hidrovia SA in order to study the feasibility of a network of marinas along the coast of the Buenos Aires province. The project was initiated by Hidrovia SA and is the result of an international collaboration between the Technical University Delft and the University of Buenos Aires. This report presents an analysis of the shore of the province and shows the considerations that have to be made when composing a network which allows sail yachts to sail across the shore from Buenos Aires all the way to Bahia Blanca. In addition, a marina design is proposed for the city of Pinamar.

We of the multi-disciplinairy project team, want to thank our enthusiastic supervisor Cecilia Norman from the University of Buenos Aires for the pleasurable meetings and her relevant knowledge which made this report possible. Moreover, we had a fantastic time in Argentina, have seen this beautiful country and are glad to experience a different culture.

1st November 2018,
Stijn Dijsselbloem, Wouter van Adrichem, Chris Zeeuw van der Laan, Konrad Bartczak and Daniël Baas

Summary

The marina infrastructure in Argentina is limited to the Rio de la Plata and the rest of the coastline lacks marina facilities making, it impossible for sailing yachts to travel to more touristic locations of the Buenos Aires province. It has even been said that Argentinians live 'with their back towards the sea', meaning not enough attention has been paid to the opportunities that the sea has to offer. In this report, the feasibility of developing a network of marinas along the Buenos Aires province coast is studied and a conceptual marina design proposed. The network will extend the current network of marinas on the Parana river upstream from the city of Buenos Aires and on the southern coast of Uruguay. As an additional end product, a typical design for a marina will be delivered and basic marina facility requirements provided. The objective of this study will be meeting the demands of the multiple parties in terms of executing a feasibility study in combination with a conceptual design of such a marina. To accomplish this research objective, the following research question is defined:

What would be an optimal configuration for a network of marinas along the Buenos Aires province coastline?

Firstly, a general analysis has been executed aimed at the coastline of the Buenos Aires province. This analysis consists of studying the current fleet, both quantitatively and qualitatively. This study sets out the size of the fleet, and made a division between local and travelling fleet. The number of travelling yachts is distinguished at a maximum of 50 boats per night per marina. Moreover, the maximum sailing distance of these sailing yachts is equal to 110 kilometres a day. In this same analysis, the hydrodynamics along the coast are studied. A SwanOne model is established to identify the hydrodynamics conditions along the shore. This model is based on the coastline angle, wave angle, wave height, wave period, wind speed and bathymethry. Furthermore, information about the coastal geomorphology is retrieved from previous research. The last part of the analysis section is a stakeholder analysis. Here, the actors are distinguished and stakeholders are identified. This analysis defined the actors; project developers, municipalities and the province of Buenos Aires, as most critical for the project's process.

Secondly, a Multiple-Criteria Decision Analysis (MCDA) has been performed in order to rate potential marina locations on suitability. The goal of this analysis is to find the most suitable places to build a marina, which defines the whole network as described in the research objective. Before the MCDA was executed a location selection along the coast was made. Within this location selection the existing marinas are neglected and a total of 36 towns and cities have been identified suitable for a marina.This MCDA is based on the Weight-Sum Model (WSM), and uses a total of eight different criteria to set out the most suitable marina location. This eight criteria are defined as; accessibility from land, dredging costs, natural harbour, touristic value, waves, sediment transport, tides and dynamics of population. For the weighting, each project member provided a relative importance for each criteria. The average of all 5 group members is used as the final weighting. The result of the MCDA is a suitability score for every considered location for a marina.

The results of the analysis and the MCDA are then used to construct the final network of marinas and mooring spots. Two different phasings are proposed, each with it's own short term objective but both leading to the same final network. The first short term objective is connecting the marina of Mar del Plata with the marinas around the city of Buenos Aires, extending the sailing range of the fleet of the estuary's marinas. The second short term objective is the gradual expansion of the safe sailing range around Mar del Plata. The proposed final network consists of new marinas in Atalaya, San Clemente, Pinamar, Mar Chiquita, Necochea, Balneario Oriente and Bahia Blanca. Extra mooring spots need to be placed around Punta Indio, Miramar, Balneario Orense and Monte Hermoso. Together with the existing marinas of the City of Buenos Aires, Quilmes, Ensanada and Mar del Plata, they form the final network design.

Then, Pinamar is chosen to be the location for which the conceptual design was made. Pinamar has been chosen based on the availability of data for the coast of Pinamar and the similarity of the geographical situation with other locations along the coast. For this specific location, the geological and hydrodynamic conditions have been determined and used for the design of the marina. Moreover, local stakeholders have been

considered in this specific location. The Pinamar region shows different stakeholders then that were defined in the general stakeholder analysis, such as the Department of Tourism and the urban development project Costa Esmeralda. Additionally, a Strength, Weaknesses, Opportunities and Threats (SWOT) analysis has been executed to define these aspects of the marina project and to be able to define strategies that will engage certain stakeholders. These strategies are defined in combination with a visitor profile. This turned out that the implementation of shuttle service between the marina and certain locations nearby plus the realisation of sufficient green area are most beneficial for this project.

Fifthly, a conceptual design for a marina in the Pinamar region is proposed in the design section. This conceptual design is based on geological and hydrodynamic conditions, such as; failure rates, wave characteristics and sediment compositions. Together with the fleet analysis the characteristics of the marina were defined. The marina will cover approximately 200 metres of shore and is designed to have a failure rate of 20% in its life cycle of 50 years. The marina is destined for a combination of sailing- and motor yachts, and will suit 130 berthing spots and an additionally 100 dry stacking spots. Additionally, the marina facilities a harbour office, launching- and retrieval crane, a ramp, gas station, sailing school, sanitary and emergency services. The implementation of breakwaters will act as coastal defense structures and are design to withstand storms with a return period of 250 years, which is equal to waves with a height of 3.14 metres.

Lastly, the final steps of this study are the conclusions and the recommendations. The conclusion is focused on the discussion of the research objective and answering of the main research question. The result of this study is that there is not an unique answer to the research question, but based on the criteria taken into account an optimal network configuration turned out to be sufficient. Due to the economic situation of Argentina at this moment, this ideal network will not be the most feasible network. However, this ideal network can be taken as a guideline for future marina development projects.

Additionally, the study conducted in this report is made within limited time and limited resources available. The recommendation of this study is to conduct further research and to include more criteria for determining the best marina locations. Most of all the cost related aspects are highly relevant. Due to Argentina's economic situation, the costs aspect of developing a network of marinas will play a big role in the feasibility of such a network. Moreover, the data found and used in this study can be stated as insufficient. A lot of data is incomplete or too specific regarding particular locations or fields. There fore, it is recommended that the current studies are further extend and new studies are conducted regarding the economical, geographical and hydrodynamical aspects. When it comes to stakeholders and process design, incorporating stakeholders during the process and starting dialogues with these stakeholders is highly advisable. The goal of incorporating them is that the progress of the project is uniform and maintained.

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Units		
A_{str}	[-]	Coefficient depending on the type of structure
B	$[m]$	Crest width
c	$[kPa]$	Cohesion of soil
c_0	[-]	Coefficient for stone stability
c_1	[-]	Coefficient for stone stability
c_2	[-]	Coefficient for stone stability
d	$[m]$	Water depth at the toe
D	$[m]$	Water depth at the L_D distance
d_{10}	$[m]$	Nominal rock diameter for which 10% is smaller
d_{15}	$[m]$	Nominal rock diameter for which 15% is smaller
d_{50}	$[m]$	Nominal rock diameter for which 50% is smaller
d_{n50}	$[m]$	Nominal rock diameter/size of concrete cubes
d_{85}	$[m]$	Nominal rock diameter for which 85% is smaller
d_{90}	$[m]$	Nominal rock diameter for which 90% is smaller
Dir	$[°N]$	Wave direction
E	$[MPa]$	Young's modulus
g	$[m/s^2]$	Gravitational acceleration
H	$[m]$	Wave height
H_D	$[m]$	Design wave height
H_l	$[m]$	Thickness of a soil layer
H_s	$[m]$	Significant wave height
H_{si}	$[m]$	Incoming significant wave height
H_{st}	$[m]$	Transmitted significant wave height
H_{ss250}	$[m]$	Significant wave height during a storm with a return period of 250 years
H_{ss50}	$[m]$	Significant wave height during a storm with a return period of 50 years
H_{ss50}	$[m]$	Significant wave height during a storm with a return period of 50 years
h	$[m]$	Water depth
h_t	$[m]$	Toe water depth
I	[-]	Influence factor for distribution of pressure as a function of depth
K_t	[-]	Transmission coefficient
L_D	$[m]$	Design wave length
m_v	$[MPa^{-1}]$	Coefficient of compressibility
M_{cubes}	$[kg]$	Mass of cubes
$M_{50-filter}$	$[kg]$	Nominal mass of filter
N	[-]	Number of waves
N_{od}	[-]	Number of displaced units
$p_{f,TL}$	[%]	Probability of failure during the lifetime of the breakwater
q	$[ls^{-1}m^{-1}]$	Overtopping discharge
R	years	Return period
$R_{u1\%}$	[-]	Run up exceeded by 1 percent of the waves
R_c	$[m]$	Crest level above still water
s	$[m]$	Settlement of the slope
$Stab$	[-]	Stability number for single layer concrete cubes
S_d	[-]	Damage level
T_L	years	Lifetime of the breakwater

Units		
T_m	$[s]$	Mean wave period
α_{rear}	[°]	Slope of the rear
γ_b	[-]	Breaker berm parameter
$\gamma_{c'}$	[-]	Safety factor for cohesion of soil
γ_{cu}	[-]	Safety factor for undrained shear strength of soil
γ_f	[-]	Roughness factor for concrete blocks
γ_{fc}	[-]	Roughness concrete
γ_{sat}	$[kN/m^3]$	Saturated unit weight
γ_β	[-]	Approach angle factor
$\gamma_{\phi'}$	[-]	Safety factor for angle of internal friction of soil
Δ	[-]	Relative density
Δp	$[kPa]$	Additional surcharge at the surface
ν	[-]	Poisson's ratio
ξ	[-]	Iribarren number
ρ	$[kN/m^3]$	Water density
ρ_s	$[kg/m^3]$	Density solids
ρ_w	$[kg/m^3]$	Density solids
ϕ	[°]	Angle of internal friction of soil

List of Abbreviations

Abbreviations	
ACM	Argentinian Continental Margin
ACS	Argentinian Continental Shelf
AEHG	Asociación Empresaria Hotelera Gastronómica
CACEL	Cámara Argentina de Constructores de Embarcaciones Livianas
CERC	Coastal Engineering Research Center
CPT	Static Cone Penetration Tests
CPTu	Static Cone Penetration Tests with a measurement of pore pressure
EC7	Eurocode 7
FoS	Factor of Safety
IPGAP	Interest, Problem and perceptions, Goals, Attitude and Power
LHA	Laboratorio de Hidraulica Aplicada (The Argentine Hydrographic Service)
MCDA	Multiple-Criteria Decision Analysis
PIA	Power, Interest and Attitude
PIANC	World Association for Waterborne Transport Infrastructure
SHN	Servicio de Hidrografia Naval (The Argentine Hydrographic Service)
SLS	Serviceability Limit State
SWOT	Strengths Weaknesses Opportunities Threats
SWAOM	The Southwestern Atlantic Ocean Margin
TOWS	Threats Opportunities Weaknesses Strengths
ULS	Ultimate Limit State
USNOAA	United States National Oceanic and Atmospheric Administration
Vibro-CPTu	Vibratory Static Cone Penetration Tests
WSM	Weighted Sum Model
YCA	Yacht Club Argentino

1 Introduction

Argentina has a long coast line of 4,989 km [13]. Nevertheless, the number of marinas along the coast is low. This has limited the interaction of the local inhabitants with the water. The marina's that are present are spaced so far from each other, that coastal navigation requires advanced skills, which makes coastal navigation not accessible to the general public. The creation of a net of marinas will facilitate the local real estate industry, tourism industry, recreational and water sport related activities, and accessibility from the sea to coastal cities.

This document presents a feasibility study of a network of marinas along the province's coast and the proposal of a conceptual marina design. This project is initiated by Hidrovia SA, and is executed within the collaboration of the Technical University of Delft and the University of Buenos Aires.

As described previously, there is an increasing demand regarding a network of marinas. This demand comes from the inhabitants of the cities along the coast, sailing boat and yacht owners and private investors, e.g. real estate companies. Furthermore, these marinas have to contain certain facilities and the sailing distances between the marinas have to be taken into account. As of importance for the local inhabitants is the contribution the seasonal users will have on the local economy and the presence of sufficient berths available for the local fleet within the marinas.

The objective of this study will be meeting the demands of the multiple parties in terms of executing a feasibility study in combination with a conceptual design of such a marina. To achieve this objective, this feasibility study will focus on the following aspects; the characteristics of the fleet (local and seasonal fleet), nature, sediment transport, wave and climate characteristics and sailing distances. Additionally, the locations of the marinas will be determined within this study and will also enhance the facilities that are required within these marinas. For example; such facilities can be the presence of sailing schools, gas stations, yards for small repairs, dry docking facilities, etc. All these aspects that will contribute to the objective and feasibility study will be further elaborated in this report. To accomplish this research objective, the following research question is defined:

What would be an optimal configuration for a network of marinas along the Buenos Aires province coastline?

This report is structured according the following chapters. The combination of these chapters will together achieve the research objective and answer the research question. First, Chapter 2 illustrates the methodology applied in this feasibility study. Then, the analysis is presented in Chapter 3 that consists of all the relevant data that is acquired to determine the network of marinas. This relevant data consist of a fleet analysis, geographical analysis, hydrodynamic conditions, coastal geomorphology and stakeholder analysis. Based on this analysis an Multiple-Criteria Decision Analysis (MCDA) is executed in Chapter 4. Furthermore, Chapter 5, discusses the result of this MCDA in combination with the fleet analysis that will form the network of marinas that is most sufficient for the coast of the province. Moreover, Chapter 6 determines the location for the conceptual design and presents all the related data for this region, which Chapter 7 uses to present the conceptual design of a marina in Pinamar. Finally, Chapter 8 and 9 present the conclusion and discusses the recommendations for this study and further studies in the future.

2 Methodology

The goal of this feasibility study will be the development of a network of marinas along the coast of the Buenos Aires Province. To reach this goal, a couple of steps will be taken that together lead to a proposed network, with distinct locations for marinas and mooring places that together can give an impulse to the recreational sailing activities of the region. The network will extend the current network of marinas on the Parana river upstream from the city of Buenos Aires and on the southern coast of Uruguay. As an additional end product, a typical design for a marina will be delivered and basic marina facility requirements provided. To accomplish these final goals, the study is divided in multiple steps to achieve the research goal. This Chapter gives an explanation on the contents of these steps.

Firstly, a general analysis will be executed aimed at the coastline of the Buenos Aires province. This analysis consists of studying the current fleet, both quantitatively and qualitatively. To set limits to the maximum sailing distances between two mooring places, the characteristics of the sailing yachts have to be known. Furthermore, the number of yachts has to be distinguished to be able to assess future capacities of marinas. The fleet will be divided in a local fleet and a travelling fleet. In this same analysis, the hydrodynamics along the coast will be studied. Tidal information will be retrieved from measuring stations to be able to provide information on tidal amplitudes along the coast. Also, offshore wave records will be used to model the onshore wave heights along the coast with the SwanOne software. Furthermore, information about the coastal geomorphology will be retrieved from previous research. The last part of the analysis section will be a stakeholder analysis. Here, the actors will be distinguished and stakeholders will be identified. The identification of the stakeholders will result in a division based on their interest, power and attitude, which defines the criticallity of this stakeholder.

Secondly, a MCDA will be performed in order to rate potential marina locations on suitability. The goal of this analysis is to find the most suitable places to build a marina, which will define the whole network as described in the research objective. The important aspects in this MCDA are the definition of criteria and the method used to generate results on which the decisions are based. The criteria definition is a result of what is found important and follows from the analysis aspects. Moreover, the criteria in relation to each other are also rated on the relevant importance and how much they influence the eventual result. The result of the MCDA is a rating of locations, this rating will be used to define the most suitable network of marinas in the following step.

Thirdly, the results of the analysis and the MCDA will be used to select the most suitable locations for the network of marinas. The strategy for determining the network will be explained and the final network will be presented. Moreover, the phasing of the network will be discussed.

Fourthly, one specific location will be selected for a conceptual marina design. For this specific locations, the geological and hydrodynamic conditions will be determined and used for the design of the marina in the marina analysis. Moreover, local stakeholders are also of consideration when studying the specific location. A new specific stakeholder analysis is conducted, in combination with a SWOT- and TOWS analysis and a stakeholder engagement plan. The SWOT- and TOWS analysis will be used to determine certain strategies to engage these stakeholders. The goal and most important aspects of a engaging stakeholders and applying strategies is that progress of the project is uniform and maintained, and that all the stakeholders have a prospect of net gains.

Fifthly, the design itself is considered in this step. The parameters and findings in the previous step will be used to determine a conceptual design. This conceptual design is based on geological and hydrodynamic conditions, such as; failure rates, wave characteristics and sediment compositions. But also on the previously made fleet analysis, which will define the number of berthing spots within the marina. Additionally, beside the technical aspects and characteristics of the marina also the specific facilities will be determined. Moreover, the design is a only a preliminary design and should be optimised with more extensive testing, numerical and/or scale modelling.

Finally, the conclusion of the conducted study and related design will be presented. Accordingly, recommendations will be given for further research to continue the process of future development of the network of marinas.

3
Analysis

This chapter is about the analysis phase of the project. In this phase the fleet, the geographical characteristics, the hydrodynamic conditions, the coastal geomorphology and the stakeholders will be analysed.

3.1 Fleet analysis

This section will elaborate upon the analysis of the fleet. Specifically the fleet that will use the net of marinas and mooring places in the future. Three sailing yacht related aspects are important when designing a marina: the distances between the marinas (thus the considered sailing distances), the boat characteristics of the fleet and the size of the fleet that can be expected. In order to estimate these aspects, the fleet is divided into two parts, defined as the local and the seasonal fleet. The local fleet consists of boats from the local population that will stay in the same marina all year long. These boats will belong to owners that live nearby in the cities located along the coast and do not have the ambition to travel along the coast. The seasonal fleet consists of boats that will sail along the coast of the Buenos Aires province and will use the marinas for short stays. These boats will not be laying in the marinas all year long but only during the peak season and for short duration.

3.1.1 Seasonal fleet

The seasonal fleet in Argentina is estimated with numbers from Cámara Argentina de Constructores de Embarcaciones Livianas (CACEL) and the regattas held in the provinces by Yacht Club Argentino (YCA) [83, 84]. CACEL is an organisation that facilitaties the registration of new built light boats in Argentina. The data of new registrations ranges from 1980 till 2017. CACEL keeps track of the region of origin, sizes and type of boats shown in appendix A. In Buenos Aires, the YCA organises regattas throughout the year, all sailing different routes and hosting different types of boats. One of the regattas organised by this yacht club is from Buenos Aires towards Mar del Plata. The boats that are participating in this regatta are considered as governing sizes for boats travelling along the coast, as sailing yachts are expected to be the main user of the marina network shown in Appendix A.

The distances between the marinas are determined based on the characteristics of the considered sailing yacht and the sailing distance which it is able to sail within one day. The smallest boat participating in the regatta is a 30 feet boat. A sailing yacht of 30 feet can travel at an average speed of 6 nautical miles per hour (nm/h) according to Federico Norman and Machiel Brouwer [6, 51]. Federico Norman is a local sport sailor with 24 years of sailing experience. Furthermore, Machiel Brouwer is an experienced sailor who has crossed the ocean four times in the past and has sailed around 20,000 nautical miles (nm).

To verify the above determined sailing speed a hull speed calculation is executed. The following equation; $v = 1.34 * \sqrt{\lambda}$ can be used to determine the hull speed of a sailing yacht and can eventually be used to determine the average sailing speed [4]. In this equation is λ expressed in feet and v is expressed in nm/h. The equation is based on a method which is commonly used by American sailors. The hull speed is the speed of a sailing yacht in an ideal situation when exceeding the hull speed the resistance increases very fast, without hydrodynamical lift. The speed of a boat can be higher. A 30 feet boat can reach a hull speed of 7.3 nm/h. Therefore, the 6 nm/h previously depicted by Mr. Norman and Mr. Brouwer is taken as a proper estimation for the average speed.

The maximum distances between marinas can be estimated based on the average sailing speed of the boats along the coast during a certain time frame. The time frame of one full day of sailing is estimated at a maximum of 10 hours. This time frame leads to a distance of 60 nm a day. One nautical mile is equal to 1.852 kilometres; so a distance of 60 nm is equal to ≈ 110 kilometres.

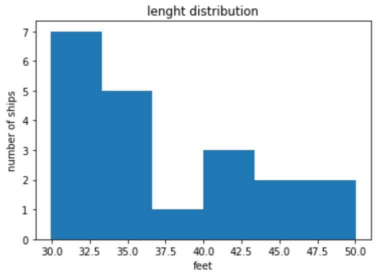

Figure 3.1: Length sailing yachts

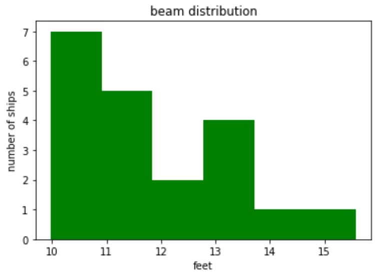

Figure 3.2: Beam sailing yachts

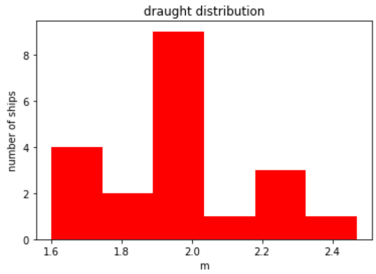

Figure 3.3: Draft sailing yachts

The sailing yachts participating in the previously considered regatta are used as reference to be able to determine the sailing yachts that the considered marinas can expect as seasonal fleet. These yachts are distributed according their sizes in Figure 3.1, Figure 3.2 and Figure 3.3. From these figures one can see that the boat lengths range between a minimum of 30 feet up to 50 feet, and depths reaching up to 2.5 metres.

Numbers of CACEL are used to be able to determine the size of the seasonal fleet. The life cycle of a sailing yacht is estimated to last approximately 30 years. The minimum length of a sailing yacht that is able to travel south along the coast is set at 30 feet. In the last 4 years only 1.8% of the registered boats were 30 feet or longer. This leads to a total expected amount of 2,250 boats of potential marina users. In addition, only a small number of yachts is expected to travel down south at the same time, and therefore the seasonal fleet is estimated between 30 up to 50 sailing yachts per night per marina.

3.1.2 Local fleet

As mentioned previously, the local fleet is the fleet that consist of boats from the local population and will use the marina or berthing place throughout the year. A mixture of berthing places and dry stocking facilities will be provided to serve as facilities for the local population depending on the location. The data from CACEL shows that newly registered boats are mostly motor boats and thus the local fleet is considered as the same type of boats with similar characteristics.

As mentioned above, the local fleet will be estimated according to the boats currently in use at the cities and owned by inhabitants of the surrounding areas. The local fleet will mainly consist of smaller boats and sport fishing ships. Along the coast between Mar del Plata and Bahia Blanca a fishing industry is active and the marinas considered within this project can also be intended for these ships. The size of the local fleet is based on an educated guess; for every 5,000 inhabitants within 1.5 hours driving near the marina a boat is to be considered that will be located within the marina.

Sport fishing is a popular sport in Argentina, and with the new marina an increase in ocean sport fishing is expected. Moreover, recreational sailing is also popular and has been a sport well practised at high level for several years now. Argentina won 1 medal during the Summer Olympics held in Brazil in 2016 and 2 medals during the Summer Olympics in the United Kingdom in 2012 [81, 82]. Due to this national and international attention sailing is becoming more popular. When building a new marina certain facilities could be realised which will increase the attention and popularity even more. The new marinas should facilitate sailing lessons for the (local) inhabitants aiming at all the ages.

3.1.3 Expected fleet

When constructing a new marina it's important to know what sizes boats will come by and need berthing places. This is important to determine the size of the marina. The data of the fleet analysis is used to draw a best fit probability distribution function. For the fit the Gamma (3.1) and the Rayleigh distribution (3.2) were used, because both these functions were suited for the skewness of the distribution.

$$p(x) = x^{k-1}\frac{e^{-x/\theta}}{\theta^k\Gamma(k)} \tag{3.1}$$

$$p(x;scale) = \frac{x}{scale^2}e^{\frac{-x^2}{2\cdot scale^2}} \tag{3.2}$$

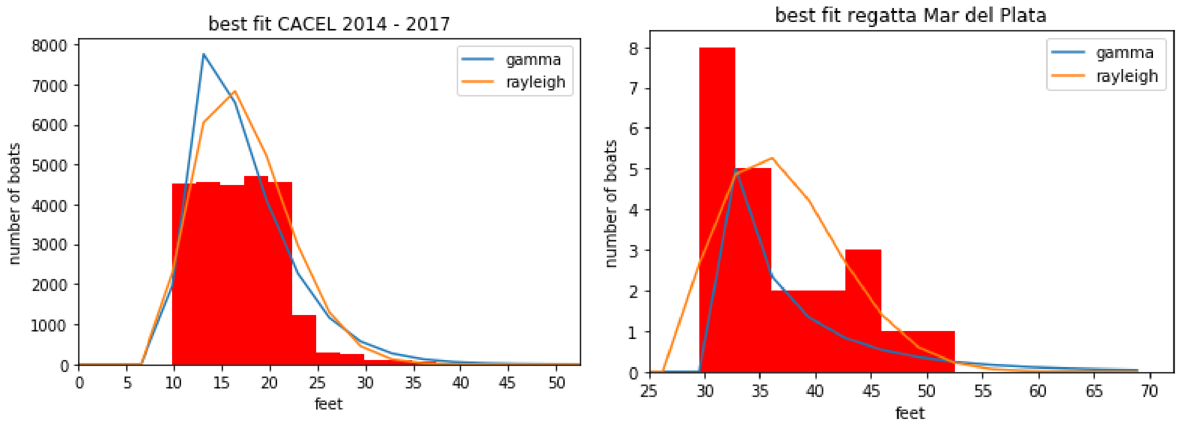

Figure 3.4: Best fit to determine fleet size

The distributions were tuned untill the optimal fit is found. the optimal fit is shown in Figure 3.4. The probability density function is then used as a likely hood distribution for vessel sizes. The distributions are used to estimate the sizes needed for the design marina. The distribution represents sizes in feet to a percentage of occurrence. This leads to an expected distribution of vessels what helps determining the local fleet and the expected seasonal fleet for the marina design.

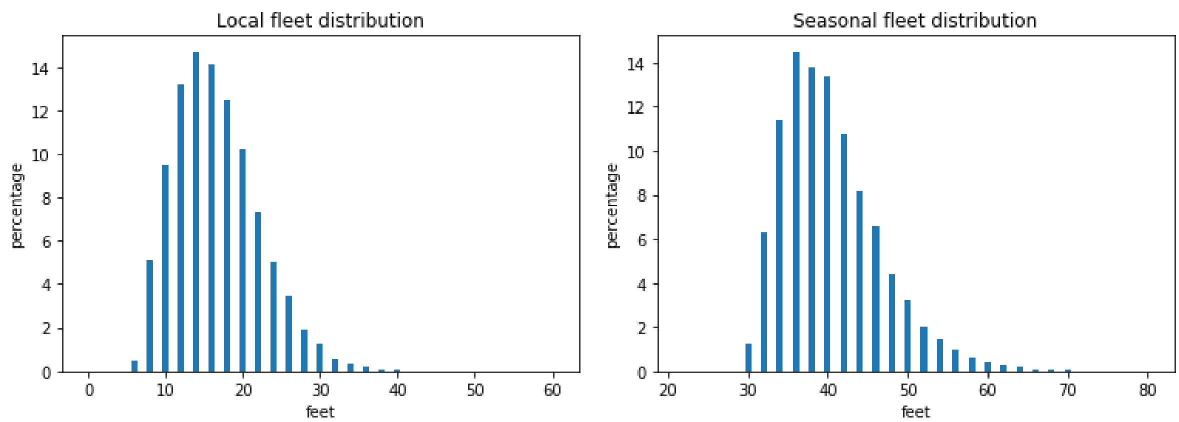

Figure 3.5: Local and seasonal fleet distribution

3.2 Geographical analysis

This section will elaborate upon the current situation of the coastline as it is. The province of Buenos Aires is located in the east of the country. The northern part of the coast is part of the estuary of the river Rio de la Plata. Here, a sediment rich fresh water environment is found.

Along the coast of the Buenos Aires province, three main cities are found that are used for subdividing the coastline: Buenos Aires in the north, Mar del Plata in the middle and Bahia Blanca in the south, as shown in Figure 3.7. The sailing distance from Buenos Aires to Mar del Plata is approximately 472 kilometres and from Mar del Plata to Bahia Blanca approximately 454 kilometres.

Figure 3.6: Argentina

Figure 3.7: Buenos Aires Province

An assessment has been made regarding the marinas that are present in the Buenos Aires province and are visualised in Figure 3.8 and Figure 3.9. The overabundance of marinas along the Parana river mouth becomes immediately apparent. This overabundance is in sharp contrast with the rest of the province's coastline. Only the cities of La Plata and Mar del Plata have marinas (defined as having multiple berths for yachts). Yacht clubs are more abundant, but these cannot be classified as marinas. Often these yacht clubs have a ramp for yachts and a dry stacking terrain. If you are making a trip along the coast these clubs are not sufficient as a refuge, as such, they can not be part of the network. What more can be observed is the coast of Uruguay, where a well developed network of marinas is present. This can be explained by the coastline topography. Uruguay has a rocky coastline and there are ample possibilities for natural harbours. The coast of the province of Buenos Aires does not provide these possibilities, as the coast is made of mudflats near the river mouth and wide beaches south from Bahia de Samborombón.

The coast of the Buenos Aires province can hence be split in different parts, each with their own challenges. From north to south, first there is the delta. In the delta there are countless marinas present, mainly for motoring boats. For the sake of the aim of this project, it is not very interesting to look at this part of the coast. This area, including Buenos Aires and up to La Plata can be seen as a base from which the sailing yachts travel southward along the coast. Next, from La Plata to Punta Piedras (eastern cape) is a stretch of coast that is 100 kilometres in length. This area is very scarcely populated. However, from Punta Piedras on into the Bahia de Samborombón, the population density gets even lower. The Bahia de Samborombón is a bay with a large inter-tidal area, which attracts a lot of birds. There are multiple protected nature reserves in this bay. The Rio de la Plata is a very shallow sea, which is a major challenge to constructing a marina in this area.

At the south end of the bay, at Punta Rasa, the coast changes dramatically. The mud flats make way for wide sand beaches. There are many touristic beach towns on the east facing beaches in the 70 kilometres stretch southward from Punta Rasa. There, the coastline changes in orientation and the following 70 kilometres to the south is similar, with coastal towns like Pinamar and Villa Gesell. More southward, there is more nature to be found, like the Albufeira Mar Chiquita, a lagoon. Which is very attractive, because this is only 30 kilometres from Mar del Plata. This city can be considered as another base, because there is already a large marina present. As a city with 860,000 inhabitants, there are a lot of possible future users. From Mar del Plata, the coastline orientation is more southward and in 40 kilometres there is the touristic town of Miramar. A further 85 kilometres westward is the city of Necochea, with 100,000 inhabitants an important consideration. The last stretch is again very scarcely populated. From Necochea it is more than 300 kilometres to the big delta of Bahia Blanca. The beaches are still very wide, and multiple dune areas are natural reserves. The lack of people is a challenge to build marinas here. Also, there are no natural harbours along the stretch of coast.

Figure 3.8: Northern Stretch of the Province of Buenos Aires

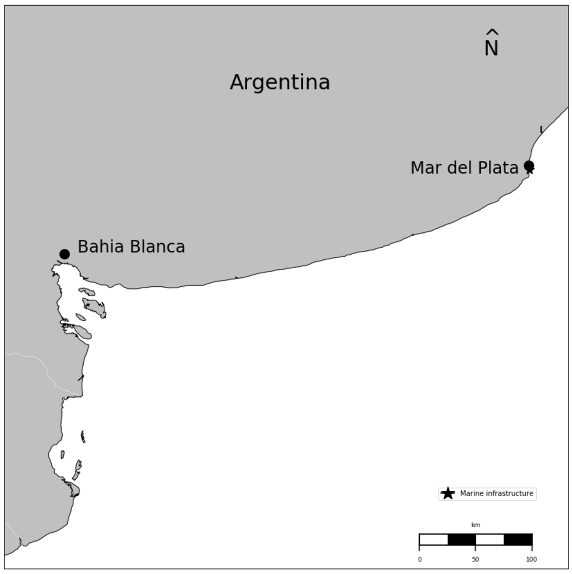

Figure 3.9: Southern stretch of the Province of Buenos Aires

3.2.1 Nature along the coast

Along the coast of the province of Buenos Aires, several nature reserves are found. Most of them are situated on the stretch between Buenos Aires and San Clemente del Tuyu. The first reserve that is found is located between Quilmes and La Plate and is called Parque Provincial Pereyra Iraola and covers a stretch of 5 kilometres. Further southwards, after the city of Magdalena, the Reserva de Biosfera Parque Costero del Sur is found. As this reserve extends for approximately 70 kilometres, it is of great importance for the coastal area. The third reserve further towards the south is the Reserva Natural de Bahia de Samborombon. The 50 kilometres stretch is located within the Samborombon bay, as shown in Figure 3.10.

These nature reserves are an important factor in the planning of the network of marinas. They influence the decision in two ways: on the one hand legislation may limit any constructions within the parks, on the other hand these parks can attract more visitors when accessible from the seaside. Between the southern border of the Reserva Natural de Bahia de Samborombon and the city of San Clemente del Tuyu, two more relatively small parks are found; Reserva Natural Provincial Rincon de Ajo and Parque Nacial Campos del Tuyu, both located in the delta region of the Rio Ajo. The Samborombon Bay is well known region for sport fishing. Collaboration with local fisherman can help the development of recreational sailing activities long the Samborombon Bay.

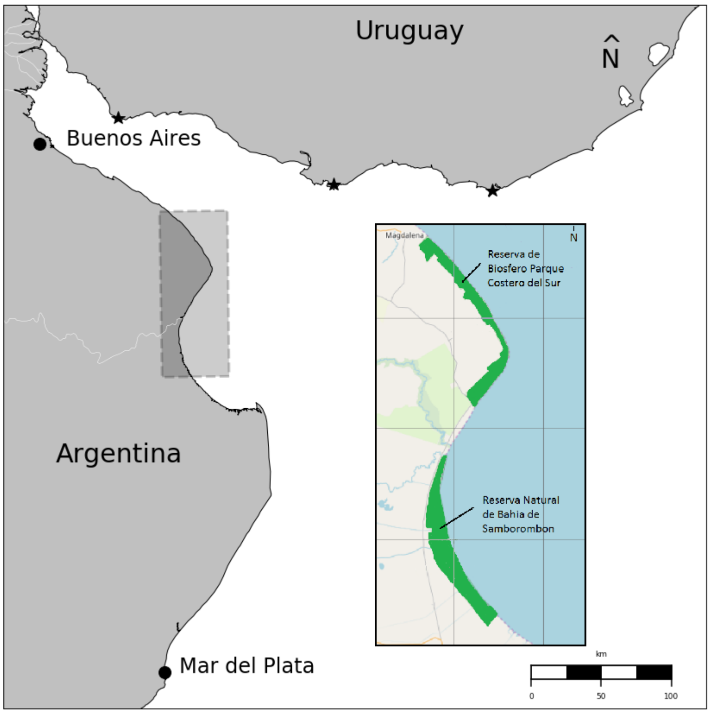

Figure 3.10: Two reserves in the northern stretch of the coastline

Furthermore, a few other protected areas are found. Reserva Natural de la defensa baterias Charles Darwin is located next to Monte Hermoso and the 46 squared kilometres Laguna Mar Chiquita Albufera north of Mar Chiquita. These relatively small parks are of less influence than the ones around the Samborombon Bay but should still be taken into account.

3.3 Hydrodynamic conditions

The local hydrodynamic conditions are needed when selecting locations for the marinas as they can influence the value of a certain location. Large tidal amplitudes increases the costs of a marina, as the basin and channels have to be deeper to secure safe navigation and prevent damage to yachts in low tide conditions. Wave action influences the choice as well, as a more energetic wave climate requires more protection of the marina against waves and limits the navigation of yachts in the entrance channel. Storm surge set-ups of water levels are not considered for the location analysis, but will be taken into account for the conceptual marina design. The factor that influencing storm surge levels the most is the geographic location. In a closed basin water will pile up at the end of the basin, while for a straight coast the piled up water can flow away on both sides, resulting in lower set-ups. As there are only two enclosed basins; Rio de la Plata Estuary and the Bay of Bahia Blanca, the storm surge levels are not taken into account.

3.3.1 Tides

The Servicio de Hidrografia Nacional (SHN) provides tidal data from different measuring stations along the coast. As not all of the locations along the coasts have their own measurements, approximations can be made based on the available data and the distance along the coast, as shown in Figure 3.11. The tidal regime along the Buenos Aires province coasts is classified as mixed preponderantly semi-diurnal. The tidal amplitude is the most important aspect of the tides along the coast, as it is the difference in tides that will bring complexity, and therefore costs to the design of a marina. The tidal amplitude is mostly influenced by the bathymetry and geography. This can also be seen from the data displayed in Figure 3.11, as near the bay of Bahia Blanca, where the depths become smaller and the width of the bay decreases, the tidal amplitude increases.

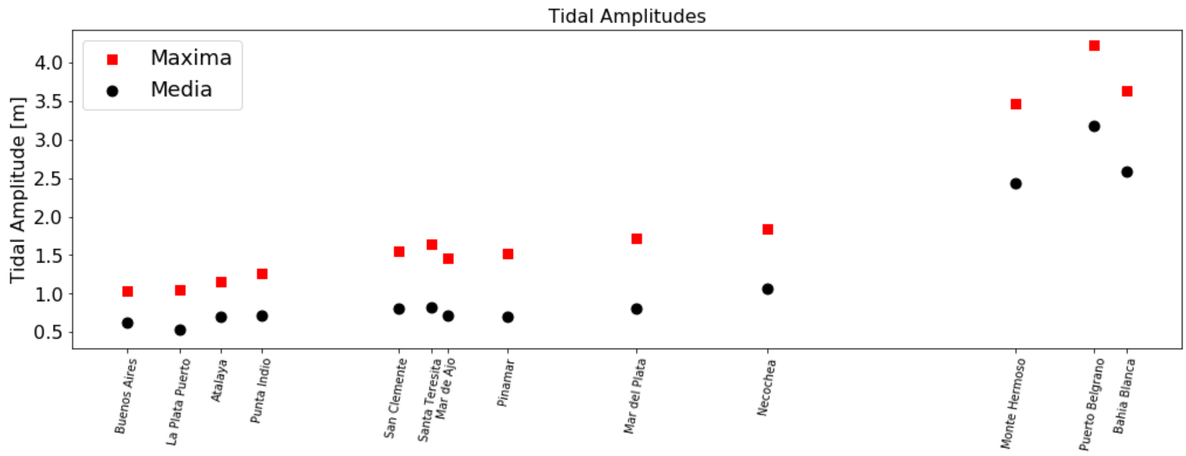

Figure 3.11: Tidal ranges along the Buenos Aires Province coast

3.3.2 Waves

The amount of wave action can greatly influence the potential of constructing a marina at a certain location. Higher waves require a better, more expensive protection of the marina, e.g. breakwater construction. Also higher waves will influence the navigability of the sailing yachts, as they can create unsafe conditions for sailing.

To assess the wave heights along the coast of the Buenos Aires province, first offshore wave climates are retrieved from offshore buoys and the wave roses are positioned on the map to assess which wave roses and directions are relevant for the coast, as shown in Figure 3.12, Figure 3.13 and Figure 3.14 [75]. The data consists of measurements of wave data with a time step of 3 hours, from 1992 until 2018. For practical reasons, the coastal stretch will be divided in 3 zones, A, B and C. A stretches from The city of Buenos Aires until San Clemente del Tuyu, B from San Clemente del Tuyu until Mar del Plata and C from Mar del Plata until Bahia Blanca.

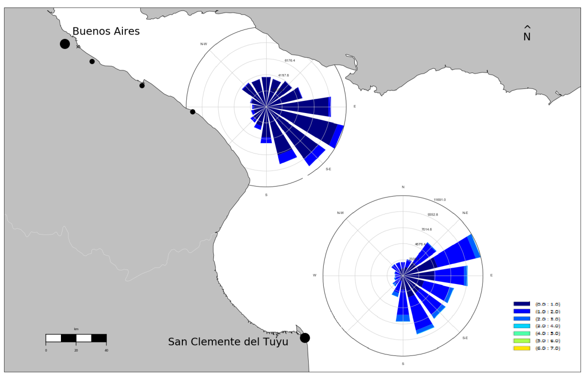

Figure 3.12: Wave roses zone A

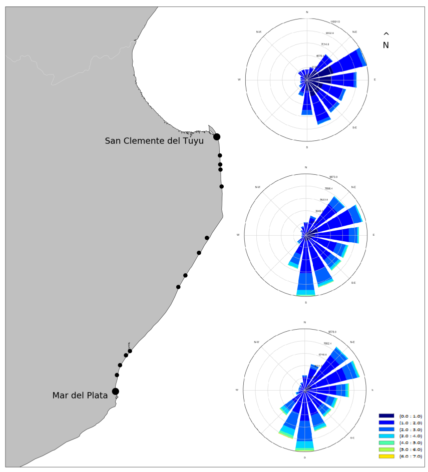

Figure 3.13: Wave roses zone B

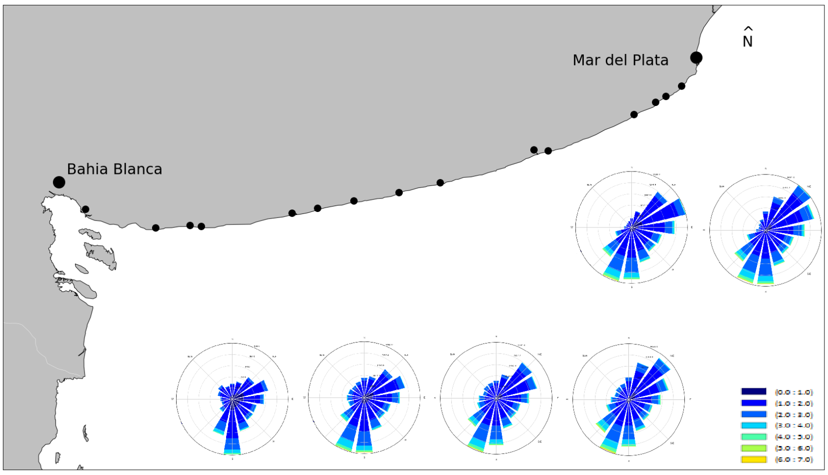

Figure 3.14: Wave roses zone C

The waves that the marina will be designed for are not necessarily daily waves, but extreme waves. An extreme value analysis was carried out on the available data. In this case waves with a return period of 50 years were compared. Multiple extreme distributions were fitted and an estimate of the 50 years wave is based on that, as can be seen in Figure 3.15.

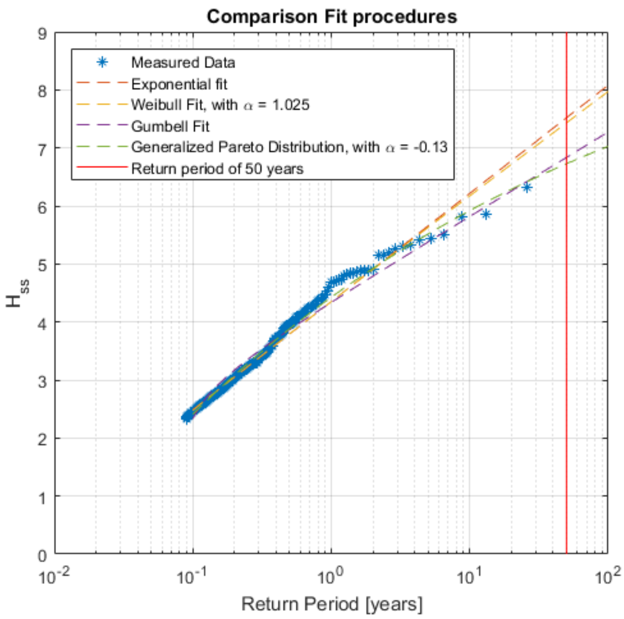

Figure 3.15: Example of extreme wave analysis of wave rose 3 for zone B

When waves approach the coast, the wave heights can change and therefore a near shore transformation is carried out to estimate the near shore wave heights. To do this, SwanOne is used. As input of the SwanOne modelling, bathymetry data is needed. Using the navigational charts of Navionics [49], estimates are made for the coastal cross-sectional profiles.

To estimate the onshore transformed wave height, first the angle of the coast relative to the waves has to be estimated. The normative wave direction is qualitatively estimated from the wave roses and wave height data. This is necessary, because a wave that is incident with a large angle will have a larger decrease of height, because of refraction. When the wave direction and the coast orientation for a certain point on the coast is chosen, the onshore wave height can be estimated from the data. This wave height was chosen as the wave height that occurs on average only once in every 50 years. For this purpose an extreme value analysis was conducted. This analysis returns a significant wave height with corresponding wave period and wind speed.

Now all the data is available for a SwanOne model; the coastline angle, wave angle, wave height, wave period, wind speed and bathymetry [30]. In Figure 3.16 the results of the wave analysis can be observed. There are some notable observations. In the Rio de la Plata, the wave height is low, because the estuary is relatively shallow. Also, the highest waves come from the south, which explains why zone C has the highest waves. However, westward of Monte Hermoso the ocean is getting so shallow that the wave heights decrease again. Near Bahia Blanca, the model that is being used for estimating wave heights cannot be applied anymore, because ocean waves cannot penetrate into the estuary. Therefore wave heights are estimated based on the fetch and wind for this location. A diagram provided by the U.S. National Oceanic and Atmospheric Administration (USNOAA) is used for this purpose, which can be found in Appendix F

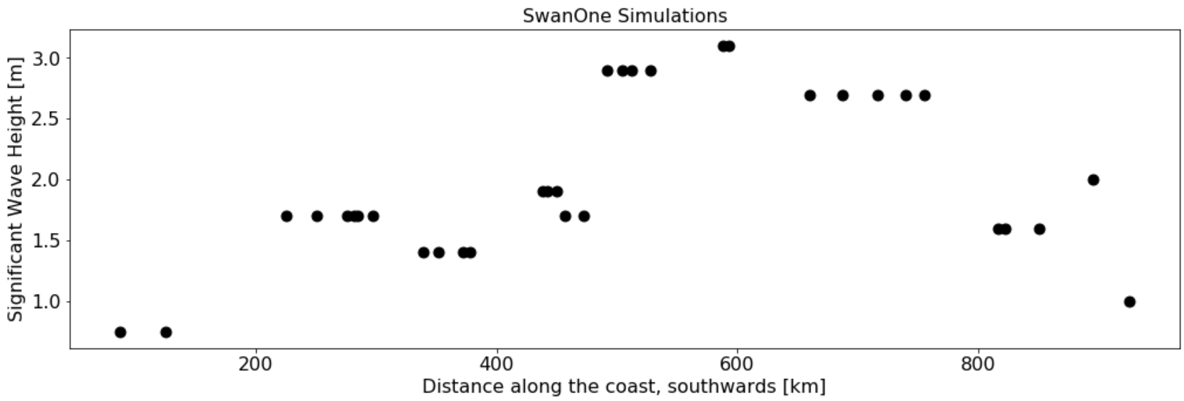

Figure 3.16: Results of the SwanOne nearshore transformations

3.4 Coastal geomorphology

This section describes the conditions related to sedimentation and erosion. Furthermore, it evaluates the most relevant criteria, such as water depths, long shore transport rates and changes in the coastline. Also, it tackles the critical engineering geological issues and parameters, including possible geo-hazards, that may have an impact on the project implementation. The sources, especially the ones coming from local marine authorities, come from different years, and often are outdated. Another problem is the lack of digitalisation of information and limited accessibility to the technical studies regarding the Argentina region on the internet. Both can have a negative impact on the accuracy of this analysis.

The whole area, that is being investigated, lies on the Argentinian continental margin. It is one of the most extensive margins in the world, and it covers around $2.0 \cdot 10^6$ squared kilometres [8]. At the latitude of Rio de la Plata, the margin is around 550 kilometres wide. The Argentinian continental shelf covers an area of $9.6 \cdot 10^5$ squared kilometres, and is practically purely siliclastic [73].

The sediment distribution on the shelf is a resultant of multiple processes, and there are several factors that influence the travel capacity, such as water depth, flow velocity, roughness of the bottom of the basin, sediment grain size distribution and wave climate. The origin of oceanic sediment is two-fold; seabed sediment is composed of foraminifera (primitive, mostly marine organisms), whilst most of the "transportable" sediment, i.e. sediment in suspension, comes from the continent and is derived from the processes of land and coastal erosion. The suspended sediment, that is introduced to the Colorado basin (Bahia Blanca area) comes from the southern, Patagonian areas of Argentina [37]. Sediment-rich water is moved by currents and waves northwards, and is subtly supported by the rivers flowing to the sea such as Río Sauce Grande and Quequén Grande River. Finally, sediments mix in the area of the terrace of the Rio de la Plata with the sediment coming from the main sediment source, the inflow from the Rio de la Plata. The map of the continental margin and the Argentinian shelf is shown in Figure 3.17.

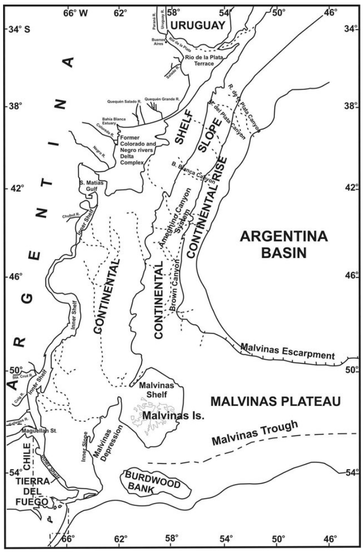

Figure 3.17: Main physiographic provinces of the SWAOM continental margin [43, 54]

The process of sediment transport is determined by three factors: tidal currents, horizontal circulation of water (which is greatly determined by strength and direction of winds) and oscillatory action of waves over the seabed. In terms of the direction of sediment transport, most common forms are sea bed sand ribbons created by strong tidal currents and sand waves. The grain size is getting finer in the direction of transport paths, and the finer material is carried even further by the more frequent weaker currents. In general, the direction of transport of suspended silt and clay is greatly determined by wind-driven currents, and does not necessarily correspond to the direction of sediment transport. In the analysed region, which is a coastal environment, an important sediment transportation form is long-shore drift [76].

The main sources of water in the analysed area, i.e. the Argentinian Continental Shelf, are sub Antarctic water flowing from the Drake Passage between the Malvinas Islands and the Argentinian coast and the Malvinas current [32]. From the rivers in the north, there is a freshwater inflow from the Rio de la Plata. The Patagonian rivers from the south add less than 2,000 m^3/s to the balance [28]. From the north, the discharge of the Parana, Uruguay and Paraguay rivers ranges from 15,000 m^3/s for the dry season to 26,000 m^3/s during the wet season [31]. The river flow from the Rio de la Plata and its inflow to the Atlantic ocean, is mostly driven by the outflow of these rivers. The Rio de Parana brings most of the sediments to the Rio de la Plata basin, and the concentration of the suspended load is approximately 150-300 milligrams per litre (mg/l), or 100-300 mg/l, whereas for Rio Uruguay the suspended sediment concentration ranges from 25-70 mg/l or 35-80 mg/l [41, 46, 59]. The corridors of flow are shown in Figure 3.18. Both bed and suspended sediment grain size tend to decrease in the direction from inner (near the delta) to the outer part (near the ocean) of the Rio de la Plata estuary.

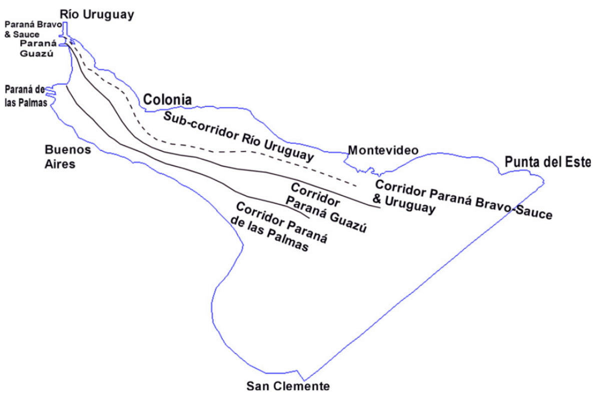

Figure 3.18: Corridors of flow along the Rio de la Plata [59]

3.4.1 Coastal sediment processes

Starting from the south, approximately 243.8 megatons a year ($Mt{\cdot}yr^{-1}$) of sediment is brought to the sea from the eroded Patagonian cliffs [37]. The fluvial input to that number is negligible, because the rivers of Patagonia and the Pampas do not carry high amounts of sediment, and bigger rivers have an estuary environment, absorbing most of the sediment input [73]. However, the influence of the rivers Rio Quequen Saldo, Rio Tres Arroyes and Quequen Grande should be taken into account. The amount of sediment that is bypassing the Patagonian coast is estimated to be 70.0 $Mt{\cdot}yr^{-1}$ [28, 60]. The export from the shelf to the slope is estimated as 17.0 $Mt{\cdot}yr^{-1}$ [60]. At the northern part of the analysed region, the influencer is the Rio de la Plata river, which carries large amounts of suspended load. The carried material content is different according to two sources; Scarubbi [62] defines the content as 15% sand, 60% silt and 25% clay, however, Fosatti [26] defines it as 0.5% sand, 37% silt and 62.5% clay.

It is estimated that, in total, 160.0 $Mt{\cdot}yr^{-1}$ of sediment is carried by the Parana river, which settles in the Parana discharge zone. The finer sediments are carried further. It is also worth to mention, that from that inflow, between 57.0 $Mt{\cdot}yr^{-1}$ and 130.0 $Mt{\cdot}yr^{-1}$ of sediment is discharged to the shelf, mostly silts [27].

3.4.2 Sediment transport rates

At each point of the coast, sediment transport is a vector with long-shore (perpendicular to the shoreline) and cross-shore components. The Buenos Aires Province coastline is dominated by long-shore transport towards the north.

The most important factors for sediment transport in zone A, are the Rio de la Plata's estuary in its northern part, and Samborombón Bay in its southern part. The zone A outstretches from the estuary of the Rio de la Plata river to the coastal city of San Clemente del Tuyú. The whole zone consists entirely of the Rio de la Plata, which has complex river/estuary/oceanic dynamics, where freshwater and seawater mix. While being one of the largest estuaries in the world, covering around 35,000 squared kilometres and ranging from 20 to 220 kilometres wide, it is a relatively shallow water body with water depths not exceeding 10 metres. It shows both fluvial and estuary characteristics, and the sediments are spread by wave and current action over the great area. The annual mean flow is around 22,000 m^3/s provided by the Parana, Paraguay and Uruguay rivers. The whole area is greatly covered with fine sediment, both deposited and as a suspended load [27].

The Rio de la Plata can be divided into two sectors: the inner and the outer sector, divided by the topographic attribute Barra del Indio. The inner area is the part from the delta towards Punta Piedras-Montevideo line. In here, there is a gently sloping fan near the delta, with water depths of 1 up to 4 metres, and a gentle plain area spreading towards the division line. The area has a fluvial regime, and is subjected to tides that control the flow direction. The outer sector extends towards Punta del Este and San Clemente del Tuyu (or actually Punta Rasa) line. For this reserach, the most important part of the outer sector is very shallow Samborombon Bay and the central part of the outer estuary. These are flat areas of depths from 5 up to approximately 20 metres, with brackish water and subjected to tides of low amplitude (smaller than 0.50 metres). The bathymetry of the area can be seen in Figure 3.19.

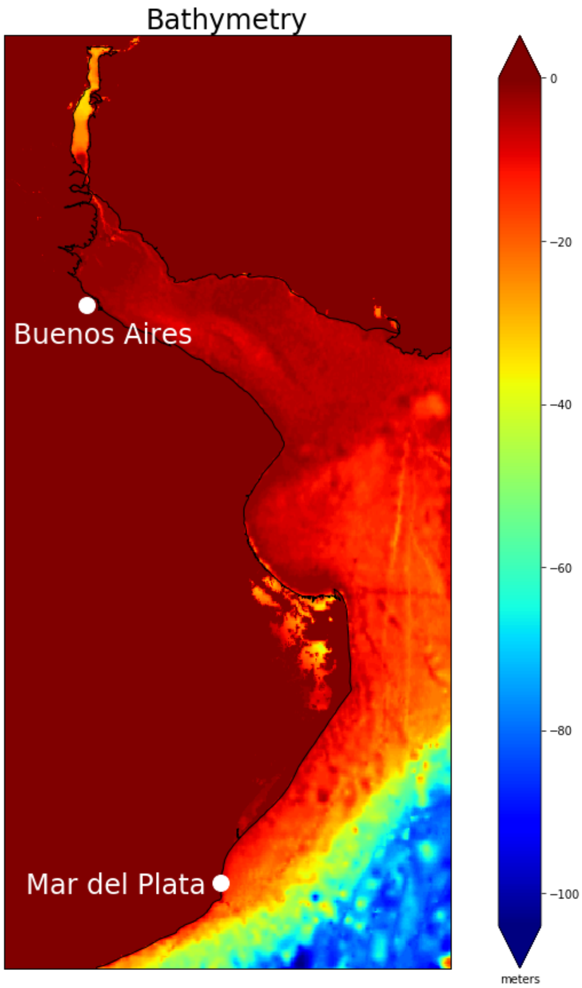

Figure 3.19: Bathymetry of zones A and B

Figure 3.20: Projected Magdalena Channel location [10]

An aspect, that can have a positive influence on feasibility of the marina construction in this zone is the projected Magdalena Channel. According to Norman [10], all the necessary field studies have been made, and the channel with a total length exceeding 61.0 kilometres will stretch from El Codillo to the Beta zone, in the Samborombon Bay, as seen in Figure 3.20.

There have not been conducted any researches about long-shore sediment transport rates in zone A, that would have data publicly accessible. There is also next to none data regarding erosion/accumulation at the beaches done. Therefore, long-shore sediment transport rates have to be studied by field investigation, or roughly estimated basing on discharge of the rivers and sediment concentration. Considering the sediment-rich waters and low water depths of Samborombon Bay, it is especially important to investigate sediment rates in these location, which are considered to be suitable for future moorings/marinas.

For the zone B, the shallow part is narrower , but the depths do not exceed 20 metres for a first few kilometres from the shore. The bathymetry from San Clemente del Tuyú till Mar del Plata can be considered uniform and is shown in Figure 3.21. According to Scalise & Schnack [63], the total transport rate of long-shore transport between Punta Rasa and Punta Medanos can be estimated as 526,000 cubic metres a year ($m^3 \cdot yr^{-1}$), whereas the net long-shore transport varies between 90,000 and 150,000 $m^3 \cdot yr^{-1}$ towards the north.

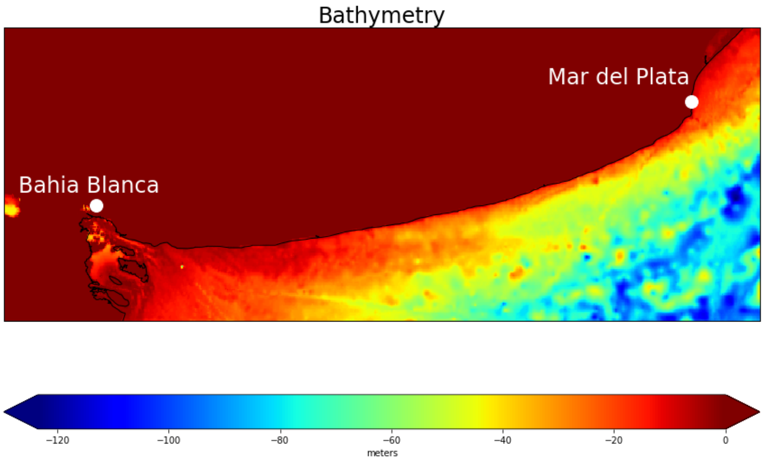

Figure 3.21: Bathymetry of zone C

Regarding the Pinamar area, more research has been performed. Estimated by the Argentine Hydrographic Service (LHA), total transport rate is equal to 1,550,000 $m^3 \cdot yr^{-1}$, and the net transport is 750,000 $m^3 \cdot yr^{-1}$. The transport to the south was evaluated at 1,150,000 $m^3 \cdot yr^{-1}$, while the one to the north was given as 400,000 $m^3 \cdot yr^{-1}$ [40].

Location	Net transport towards the north ($m^3 \cdot yr^{-1}$)
San Clemente del Tuyu	27,000
Mar del Tuyu	40,000
Mar de Ajo	36,000
Pinamar	80,000
Villa Gesell	89,000
Mar Chiquita	174,000
Mar del Plata	431,000

Table 3.1: Sediment transport rates along the Buenos Aires province coast [7]

The littoral drift increases towards the north from Mar del Plata, due to the orientation of high-energy waves and currents caused by storms. Beaches towards the south from Mar del Plata are dominantly sandy, coarse-grained. In the area of Mar del Plata, the beach drift is estimated as 100,000 $m^3 \cdot yr^{-1}$, and increases towards the north [9]. Other estimations of the upper bound of the beach drift for this area are 60,000 $m^3 \cdot yr^{-1}$ for the Mar del Plata harbour, and 220,000 $m^3 \cdot yr^{-1}$ for the Mar Chiquita inlet [38].

Regarding the sediment budget of beaches, the coastal stretch from Mar Chiquita to Miramar was classified as an erosive coast with pockets beaches. According to the studies made during the period from 1983 to 2004 [23], Pinamar beach registered an accumulation of approximately 1370 $m^3 \cdot yr^{-1}$, Villa Gesell recorded an accretion of around 900 $m^3 \cdot yr^{-1}$. As seen in Figure 3.22, the Mar Chiquita Barrier grew from north to south. However, the contemporary beach drift is from the south to the north.

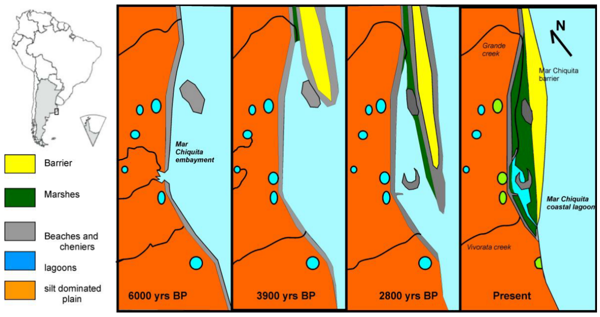

Figure 3.22: Evolution of the Mar Chiquita sandy barrier [23, 39, 72]

Lastly, zone C can be separated into two parts; the western part influenced by the Bahia Blanca bay, and the eastern part, where the geomorphologic processes are limited to wave and current action, including the activities of the Rio Quequen Saldo, Rio Tres Arroyes o Claromeco and Quequen Grande rivers. Bahia Blanca is a plain estuary and is characterised by a freshwater input that is small compared to the tidal prism.

On the west side of Quequén, port beaches can be found (Médano Blanco, Kabryl and Asilo) composed out of well-sorted fine sands. Whereas, on the east side of the port, the Bahía de los Vientos and Costa Bonita beaches are made of medium to coarse sands [45]. The mean grain sizes analysed at the beaches mentioned above are shown in Table 3.2.

Beaches	Mean grain size (μm)	Foreshore slope (%)	Sediment budget (m^3)
Costa Bonita	462.0	4.6	-24.1
Bahia de los Vientos	296.0	7.7	-47.5
Asilo	216.0	2.1	53.2
Kabryl	231.0	2.9	76.8
Medano Blanco	217.0	3.2	-55.9

Table 3.2: Mean grain size per analysed beach [45]

The studies of Merlotto 2013 [45] of the sediment budgets, have shown that accumulation happens only on two beaches at the Necochea side, the ones closest to the port. The port's breakwaters and the general urbanisation of the dune fields cause a reduction of the sediment supply to the Quequén beaches.

In Miramar, the net sediment transport rate towards the north is equal to 422,000 cubic metres per year [7]. In the Bahia Blanca estuary, the main channel is being dredged in order to ensure the passage of ships. Due to the small runoff from terrestrial sources, the channel's maintenance mostly depends on the tidal in- and outflow. The bottom of the smaller channels are mostly muddy, whereas the wide tidal plain's bottom is composed of fine sand with approximately 25% of mud. Upward of the profile, the silt and clay fractions sum rises to approximately 75% [56].

The Bahia Blanca estuary was a site for the assessment of erosion and sediment transport rates. The studies, which were separated by 6.75 years, have shown a net erosion for the whole area of $2.4 \cdot 10^6$ cubic metres [44]. Based on the rates of dredged sediment, it was calculated that approximately 250,000 $m^3 \cdot yr^{-1}$ are still exported from the reach. Erosion was concentrated on the right margin of the channel, while accumulation was spotted on its left margin [44].

In the Bahia Blanca estuary, the median grain size D_{50} is equal to 109 micrometres, and the estimated residual bedload sediment transport towards the sea is calculated as 138 kilograms per second (kg/s), which is equal to 4.35 $Mt \cdot yr^{-1}$ for spring tide and 46.9 kg/s, which is equal to 1.48 $Mt \cdot yr^{-1}$ for the neap tide [56].

During the design phase of this project the sediment transport and assessment of the dredging processes sediment properties should be evaluated. Mostly, the sediment properties are approximated numbers. One of the few researches made in the analysed region shows the properties as presented in Appendix G.

3.4.3 Erosion and accumulation

The coast of Buenos Aires province is mostly subjected to low or moderate erosion trends. The most affected areas are the counties of General Pueyrredon and Partido de la Costa. The most important factor for erosion of the northern part of the coast of Buenos Aires Province are storm tides [61, 64]. In here, beach erosion is greatly dependent on storm surges accompanied by high-energy waves caused by strong winds. A general assessment of erosion that touches the analysed region is shown in Figure 3.23.

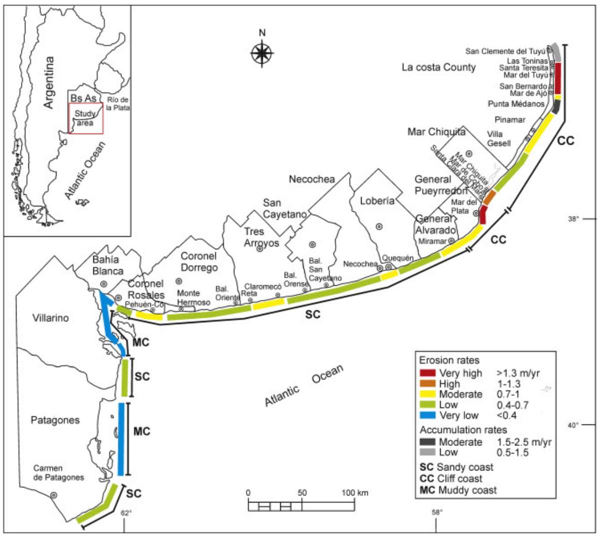

Figure 3.23: Coastal erosion rates in Buenos Aires province [39]

For Villa Gesell, erosion rates range from 0.5 metres a year ($m{\cdot}yr^{-1}$) in the south to 2.0 $m{\cdot}yr^{-1}$ in the northern area. Mar Chiquita's northern region is characterised by sandy fore dunes retreating by 1.0 $m{\cdot}yr^{-1}$, whereas its southern region is defined by low-altitude cliffs with erosion rates from 1.0 up to 4.0 $m{\cdot}yr^{-1}$. In the city of General Pueyrredon, several groin fields were constructed to limit the erosion. The erosion rate for the Mar del Plata beaches is approximately 0.5 $m{\cdot}yr^{-1}$ and rising [38]. It is also worth to mention that the cities of Miramar and Mar del Plata have their coast fixed (due to revetments), so there are no erosion problems that have to be taken into account [38]. However, for Miramar's city embayment, the erosion process is getting stronger due to the afforestation of a dune fields nearby. Necochea city was facing issues with erosion, but due to the coastal works, the erosion rate was established at approximately 0.5 and 1.0 $m{\cdot}yr^{-1}$ [38]. However, the erosion rates towards the east tend to be higher due to the construction of the Qeuquen-Necochea port.

The only erosion defences are located in the partidos (municipalities) General Pueyrredon, General Alvarado and Mar Chiquita. Groins can be found in the cities of Miramar and Mar del Plata. Also, in the cities of Necochea and Mar del Plata there are breakwaters constructed next to the entry of the harbours.

3.4.4 Coastal barriers and sediment deposition

The Argentinian coastal zone is strongly influenced by long-shore sediment transport, which supply beaches and barriers systems. At the Buenos Aires province coast there are a few sandy barriers created as shown in Figure 3.24. From the La Plata River estuary southwards, different barriers can be distinguished; Cabo San Antonio barrier, Mar Chiquita barrier and Southern barrier.

Figure 3.24: Location map of Argentine barriers [39]

The Cabo San Antonio barrier is a complex barrier built of wave-deposited ridges, and was created due to a constant beach drift for the last 5800 years [15]. The Mar Chiquita barrier evolved from Villa Gesell's sandy silty sediments, which finally closed the bay from the sea, and created a coastal lagoon. Nowadays, the lagoon is subjected to the reversal in beach drift growing from south to north. The Southern Barrier mostly consist of transverse and barchanoid dunes and is widely grown by grass. Cliff-top dunes can be widely spotted, because of intense erosion. At the western part of the Southern Barrier, there is an evolved spit, which encloses the tidal flats of the eastern Bahia Blanca Bay. Many of the developed cities and estates in Buenos Aires Province came into existence after afforestation of the dunes on which ornamental trees have been planted [39].

A sandy beach-dune system is stretching out for around 180 kilometres from Punta Rasa towards the south, to Mar del Plata. At the northern part of this region, the dunes tend to be active or unstable. For 30 kilometres from Mar Chiquita to Mar del Plata, the coast is characterised by dune scarps and low cliffs [61]. The coast is predominantly microtidal and wave-dominated. In the area of Pinamar, resort facilities are often located on the backshore zone. Heavy storms cause property losses and severe erosion of the coast. Nearby the harbour of Mar del Plata, an erosive process is happening towards the north, i.e. the direction of the net littoral drift.

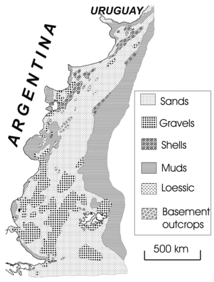

Figure 3.25: Sediment distribution in the continental shelf and upper slope [54, 73]

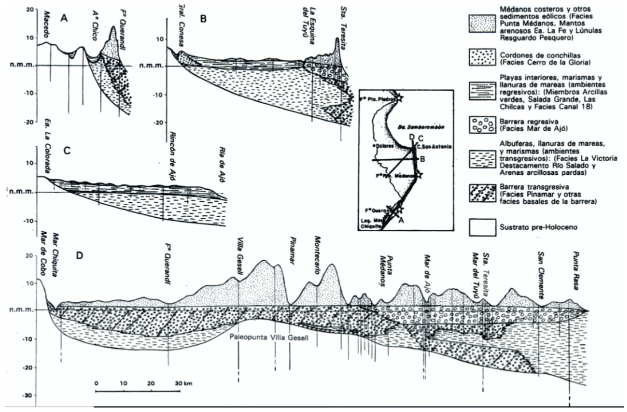

Figure 3.26: Stratigraphic cuts typical of different sectors of the Buenosairean coast [73]

The sediment distribution on the shelf is shown in Figure 3.25, whereas a more specific stratigraphy of a big part of the analysed region is shown in Figure 3.26. As seen in Figure 3.26, usual stratification at the region of Pinamar consists of transgressive barrier underlying shells, and coastal sand dunes with other eolian sediments as the top layer, which lay above the mean sea level. In Figure 3.26, the following geological units can be found in the stratigraphic chart:

(a) Typical cutting of the Mar Chiquita lagoon area (Faro Querandi area)

(b) Typical cut of Cape San Antonio

(c) Typical cut of the southern sector of the Samborombon bay

(d) Cut along the coastline between the Mar Chiquita lagoon and Punta Rasa.

3.4.5 Sediment transport capacity model

The sediment transport that is found in the literature has been shown to be highly debatable, as the values that are stated are too widely ranged to draw conclusions from. This is the reason that another approach was taken towards sediment transport. A model is developed to make estimations. The goal of this model is to define which locations are best suited for building a marina, with respect to sediment transport. More sediment transport is mostly unfavourable for a marina. The access channel needs more maintenance dredging in case of more sediment transport. And the erosion near a breakwater will be heavier. The model that was used is based on the transport capacity of the waves. Sediment transport is the transport capacity and sediment availability combined, but this latter was hence omitted.

The working of the model is based on the CERC-formula. This formula was developed by Coastal Engineering Research Center (CERC) of the US Army Corps of Engineers [5]. The CERC-formula is a simple formula that relates the wave direction and wave height to the sediment transport. The formula only includes wave induced transport, transport due to tides or other currents is omitted. In Equation 3.3, the basic structure of the CERC formula is displayed, in which the calibration factors are omitted.

$$S \propto H^{2.5} sin 2\phi \tag{3.3}$$

The same wave data as in Subsection 3.3.2 is used. This data consists of wave height measurements and direction on offshore wave buoys for every 3 hours. With this data gross transports can and need to be calculated, net transports are not of interest. Gross transports are needed, because a net transport does not say anything about the amount of sediment that passes a point in a year. For instance, one day the waves may cause sediment transport to the left while on the next day it might be to the right. In this case, the net transport will be small, while still an access channel is subjected to sedimentation. Therefore sediment transport to the right and to the left is calculated separately, this is the concept of gross transport. The data is first split up. The splitting is based on the coastline orientation of the the location of interest. The waves on this coast were split in 2 parts of 90 degrees of incidence, the division line being perpendicular to the coast. The sediment transport was calculated by putting the wave height and wave angle for every time step in the CERC formula.

The summation of all the contributions per part give the sediment transport. The number is however not calibrated, because of the lack of recent data. Therefore, there is no useful unit that can be given to this number. The gross transports hence only have a meaning relative to each other, and no absolute numbers can be deduced.

The results of the model are displayed in Figure 3.27. The result is for most places a transport to the north. The maximum values have a high correspondence with locations with the highest wave heights. That is to be expected, because wave heights contribute to the sediment transport with a power of 2.5. The results for the Bahia Blanca estuary are not accurate, as this is an estuary where offshore waves cannot penetrate, the model cannot be right for this location. Therefore they are omitted in the figure. It is however known from the literature that there are problems with sedimentation in the estuary. Therefore, the maximum sediment transport that is in the model was also taken for this location.

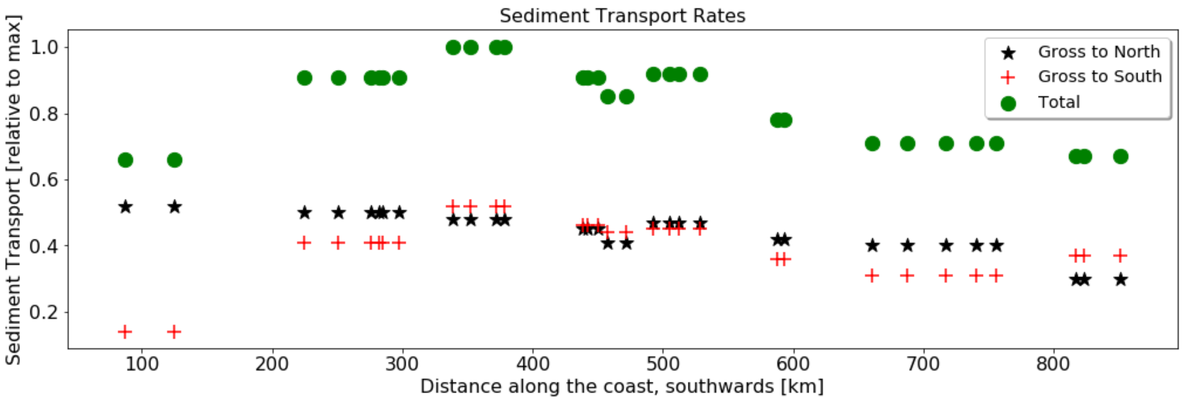

Figure 3.27: Gross and total sediment transport rates

3.4.6 Geohazards

The coastal zone of Buenos Aires Province possesses a high level of risk of hydrogeological hazards. It is seriously affected by coastal erosion, sea level rise, storm surges and faces problems with freshwater aquifers being intruded by saltwater. The counties of Necochea and Mar Chiquita are subjected to drift obstruction. Quequen, Santa Clara and Mar de Cobo cities areas are characterised by low-altitude cliffs, whereas in Mar Chiquita receding foredunes can be found. For the counties of General Pueyrredon, General Alvarado, Villa Gessel and Partido de la Costa, the erosion rates are a reason for the high hazard index [39].

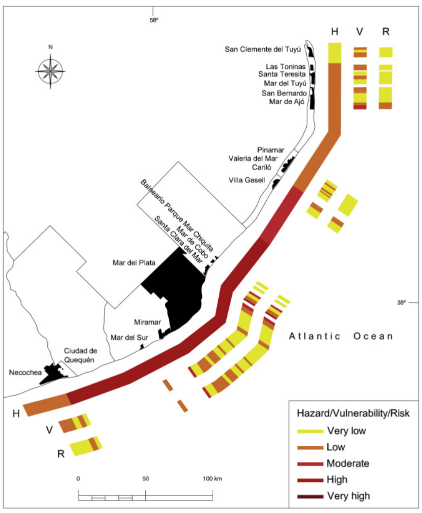

Figure 3.28: Threats, vulnerability and risks along the coast of Buenos Aires Province [39]

3.5 Stakeholder analysis

Multiple stakeholders are involved within projects, it is not only necessary to know who these stakeholders are, but also which specific roles, interests, power to influence the project and attitude towards the project they have. In this paragraph, all stakeholders are identified and put together in a network diagram to be able to map the inter-dependencies. Furthermore, all the identified stakeholders are analysed, their interests were studied and finally a power versus interest grid will be presented.

3.5.1 Actors

First, all the involved actors, and thus stakeholders, were identified. The identification of these actors has been done based on the project information, interviews with involved persons in the project related industry and brainstorm sessions [51, 52, 84]. The actors identified in this analysis can be classified according to seven stakeholder groups. These groups are as follows: project developers, public authorities, partners, financial institutions, knowledge institutions, environmental organisations and users [36]. These groups of stakeholders have been initiated to cluster the related stakeholders with each other, based on their common interest, involvement and potential financial stake. The identified actors are shortly described based on their division in the following sections.

Project developers

Project developers are the actors that either initiate the project or obtain a large stake when it comes to executing the project. These actors usually own the plots on which the to be executed project will have to be build and seek for an investment with at least a sufficient amount of return. Beside the project developers will fall the executing parties which are identified as contractors. These parties are the actors which will execute parts of the project in terms of building or facilitating project related activities.

Public authorities

Public authorities will be the actors that are related to the government and are concerned with public interests. In this case the public authorities have been identified as the national government, the province and the municipalities of the locations which are under consideration of this project. All of these actors have a different level of interest within this project but got a certain level of power which will enable them to influence the project.

Partners

Partners are the actors that are collaborating or want to collaborate in the extend of the project. Moreover, partners could also be identified as actors that will be involved to prevent negative effects that could harm the path of the project. These partners are identified as the yacht clubs located all over the province and country, the fishing industry located in Mar del Plata and Bahia Blanca, and the coastal operators along the shore. The yacht clubs will experience benefits when new marinas will be built along the coast of the province. Moreover, the fishing industry and coastal operators can experience negative effects of the new marinas and need to be considered and involved in this project.

Financial institutions

Financial institutions are the actors that are willing to invest in the project or will partially facilitate in the finances. Financial institutions usually are interested up to a certain extent but will hold a lot of power and thus their demands will have to be met in order to bring the project to a success. Within this project the financial institutions have been identified as real estate developers and (potential) investors.

Knowledge institutions

Knowledge institutions are bodies of knowledge that will have their stake within the project based on their experiences and extend of their knowledge. Knowledge institutions could have large interests but hold a small amount of power. Within this project the emergency authorities have been identified as knowledge institutions.

Environmental organisations

Environmental organisations are the actors that are concerned about sustainability and the environmental stakes with regards to the area where the project will be implemented. In this project the stakes of these organisations will apply on the building methods and the influence the project could have on the shore of the province. Nature preservation groups and environmental interest groups have been identified as the environmental organisations within this project.

Users

Users are the actors that will make use of the to be considered project. In this case the inhabitants, tourism industry and sailing yacht owners have been identified as users for this project. The inhabitants have specific interests within the project and want to experience benefits from a project that will be implemented in their 'backyard'. The tourism industry and sailing yacht owners will have somewhat different interests within the project. In general, all these actors have a positive attitude towards this project.

3.5.2 Network diagram

After all the actors have been identified they can be put together in a network diagram. This is network diagram will present the relationships, the structure and the dependencies between the different actors within this project. The relationships between the actors (this could either be a one-sided dependency or an interdependency) are linked with each other by arrows. The actor network diagram is presented in Figure 3.29.

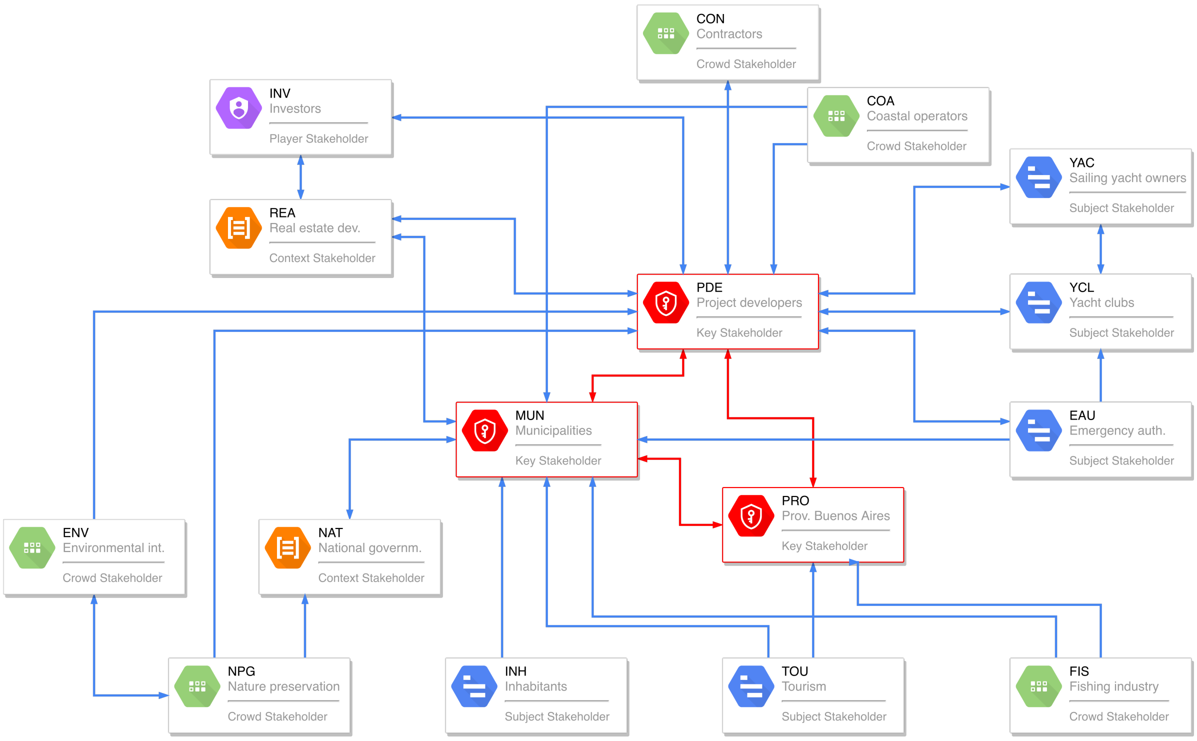

Figure 3.29: Actor network diagram

On the basis of the power of the actors and their interests, all actors are categorised as either a crowd, a subject, a context or a key stakeholder. More on this, as well as the power and interest relations towards each other, can be found in Section 3.5.5.

3.5.3 Identification of stakeholders

Based on provided documentation, interviews held with Cecilia Norman, Fedirico Norman and César Zazzali and Mariela Erricolo from CACEL [51, 52, 84], experience gained during specific cases of large construction projects during the Masters Degree of Construction Management and Engineering and an additional brainstorm session all the actors have been identified. These actors have several specific characteristics such as interests, problem perceptions and goals. To get good insight into this information an Interest, Problem and perceptions, Goals, Attitude, and Power (IPGAP) table is created.

The IPGAP-table gives an overview of all the different stakeholders in the project. Stakeholders may have various interests which will benefit them. They also have various problem perceptions, things they do not want to happen. At the end, the stakeholders will have a general goal. The different stakeholders also have a different commitment to the project.

The problem perceptions and the goals for every stakeholder group have been defined below. The full IPGAP table, which describes all the specific interests per stakeholder, can be found in Appendix B.

Project developers

The project developers and the contractors share the same goal; maximise their profit. Both actors foresee problems on their way to achieving this goal. The project developers will require a number of financing parties in combination with a suitable business model that will generate sufficient return on investment and profits. Moreover, the contractors are anxious of using sustainable building methods and materials, because the initial costs of these products are higher and will reduce their profit.

Public authorities

In general, the municipalities, the province of Buenos Aires and the national government all share the same goal for their cities and coastline. This goal is defined according multiple aspects; such as an increase in dwellings, raise national and international popularity, economic growth and an increase in job opportunities. In addition, the municipalities thrive for a better accessibility of their cities as a result of the implementation of the net of marinas. The latter could be a problem because not all the municipalities will get a marina which will result in an unfair benefit distribution along the coast. Furthermore, some locations will not experience an increase in accessibility because marinas will be implemented at locations which are suitable in terms of finances and popularity.

Partners

These partners are identified as the yacht clubs located all over the province and country, the fishing industry located in Mar del Plata and Bahia Blanca, and the coastal operators along the shore.

The partners share different goals regarding this project. The yacht clubs want to expand their network of yacht clubs which will result in an increase of the number of members and which will allow these members to sail safely towards the south of the province and back. The problem that comes along with this goal is an insufficient growth in members and will eventually result in an insufficient usage of the net of marinas.

The fishing industry located in Mar del Plata and Bahia Blanca together with the coastal operators along the shore share somewhat the same goals. Both actors are aiming to not experience any hindrance or interruptions during their work and in their working areas. Moreover, the fishing industry is thriving to expand their businesses and the net of marinas is a good opportunity. The problems that they fear is interruptions of their fishing grounds and interruption of the sediment transport, which can be of a big problem for the coastal operators.

Financial institutions

Real estate developers together with the investors both want to maximize their profits and have a maximum return on investment as possible. It is important for the real estate developers that there is a sufficient increase in the popularity for the marinas from the inhabitants which will result in more sold apartments and berthing places. Moreover, the investors want to keep the risks as low as possible and will need to find other financing parties together with a suitable business model.

Knowledge institutions

The emergency authorities are having as only goal their presence and accessibility of the specific area where these marinas will be implemented. A problem that could be the case is that the marinas are not close to a hospital or clinic, which will hamper their work and will result in use of expensive transportation methods such as helicopters.

Environmental organisations

The nature preservation group are thriving for no interruption of or harm to the current flora and fauna, plus the national parks that are located along the shore. In addition, the environmental interest groups have required that the marinas will consist of innovative solutions and are built with sustainable building methods. The problem with these methods is that they are more expensive to use and implement, which will prevent the contractors and project developers from using them.

Users

First, the inhabitants want to experience the benefits of the to be implemented marinas. Which will be expressed in an increase in job opportunities and economical benefits, besides sustaining the pleasant living environment. The inhabitants fear an interruption of their daily lives and their residential area as they know it. Second, the tourism industry will thrive for a sufficient number of hotels and recreational activities for their sector. An insufficient number of restaurants, hotels and activities will result in negative effects of the marinas and will instead of increasing the popularity will decrease it. Lastly, the sailing yacht owners want to extend their current sailing routes which will make them able to sailing along the coast of the province. Due to the fact that are currently no marinas available this sailing route is not used at the moment and the locations are not accessible from the water. It could possible that this new route is therefore unattractive for the people owning a sailing yacht.

3.5.4 Key stakeholders and typology

Key stakeholders are stakeholders that are most critical for the process. The criticality of the stakeholder is based on their replace-ability, their resource importance, and their dependency. The criticality of each stakeholder is presented in Appendix B

The table and Figure 3.29 shows that the project developers, the municipalities and the province of Buenos Aires are the critical actors in this process.

The typology of each of the stakeholders is based on their power, interest level and attitude towards the project. The level of attitude can vary from supportive, neutral or resistant. According to Hillson and Simon [33], stakeholders can be mapped into eight different typologies with regard to their power, interest and attitude. These eight typologies are defined for each stakeholder in Appendix B

3.5.5 Power versus interest versus attitude grid

A proper distinction based on the power, interest and attitude can be made for the stakeholders involved in the project. Power and interests are important to find the main stakeholders, but it is also important to identify allies and opponents. Allies can be defined as stakeholders who have a positive perspective of the implementation of a net of marinas, and opponents are the stakeholders who has a negative perspective. The stakeholders have been presented in Figure 3.30, from a low to a high power, interest and attitude.

As previously described with the stakeholder identification, the position of the stakeholders in this grid, i.e. the extend of a specific stakeholders' power, interest, and attitude is identified based on interviews held with Cecilia Norman, Fedirico Norman and César Zazzali and Mariela Erricolo from CACEL [51, 52, 84] and experience gained during specific cases of large construction projects during the master. Additionally, a brainstorm session has been held with all the project members to specifically discuss the identification of the stakeholders and their roles in terms of interest, power and attitude. In these interviews the relevant importance of certain stakeholders was depicted and the importance of, for example, investors, the involvement of the (national) government and the attitude of certain stakeholders was also elaborately discussed. Furthermore, the previously performed researches in the same region of interest as the project described in this document was also of help in determining the positions of the relevant stakeholders in the grid.

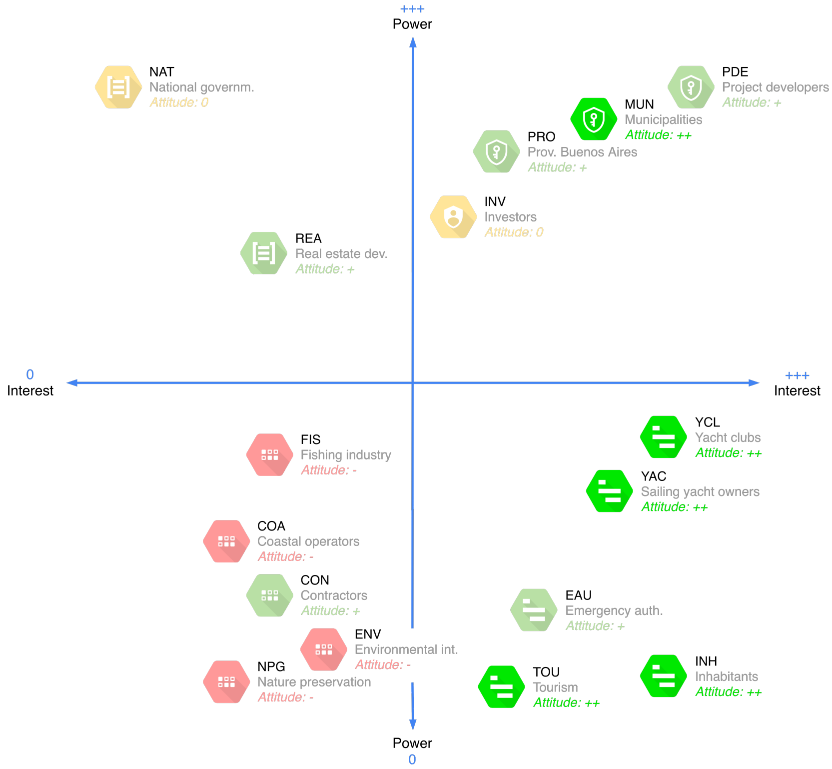

Figure 3.30: Power versus Interest versus Attitude (PIA) grid

The PIA grid shows that the environmental interest groups and nature preservation groups both have a negative attitude towards the project. They may not be really powerful, but they will actively participate in the process as long as their demands are kept. The two other actors that have a negative attitude according to the grid, are defined as the coastal operators and the fishing industry. Although their power and interest is not significant, they could hamper the process and could use the inhabitants as a soundboard of their negative attitude and could eventually influence their attitude. It is important that these actors with a negative attitude towards the project are kept as friends. This can be achieved by letting them actively participate in the process which will eventually prevent them from using their resources to hamper the progress of the project.

Furthermore, the actors that are positioned with a neutral attitude towards the project in the grid, are the national government and investors. The national government is a stakeholder with high power but almost no interest. They may be inactive in their support or opposition, but will become dangerous when ignoring their wishes or not involving them in the process. It is important that these stakeholders will not fall into a negative attitude, because they can become a time bomb and use their blocking power to hold up the process. The same holds for the investors, although the investors have more interest within the project and are prepared to act as an active stakeholder during the process.

Last, the grid shows also a two attitude-neutral stakeholders. These stakeholders may be inactive in terms of their support, but it might be dangerous to ignore their wishes. Especially the more powerful actors, like the national government, should not fall into a negative attitude. This stakeholder can become a time bomb and block the whole process.

3.5.6 Conclusion

The stakeholder analysis has depicted the most important stakeholders present in this project regarding the network of marinas. These most important stakeholders, i.e. critical stakeholders, have been identified as; the project developers, municipalities and the province of Buenos Aires. This means that the governmental authorities and potential project developers have to be closely involved within this project. The most important aspect that comes forward from the conversations with the relevant persons is that the governmental authorities have to be satisfied in order to make this project into a success. The most important aspect and wish of these authorities is the involvement of the local inhabitants and make public orientated aspects integrated in the design of a marina. This private-public distribution in the marina will be further elaborated in Chapter 7. Furthermore, the dependence on investors when considering the construction of a marina is inevitable. Thus, potential investors, which could also be real estate companies and project developers, are important in terms of complying with their wishes. Lastly, the local inhabitants, authorities and companies need to experience a positive influence of the implementation of marinas along the shore of their cities.

4

Multiple-Criteria Decision Analysis

In this chapter a Multiple-Criteria Decision Analysis (MCDA) is executed. The goal of this analysis is to find the most suitable places to build a marina. First the criteria that are in the analysis are discussed. Next, the criteria are given a relative importance, a weight. Then, the criteria are scored for every possible marina location. And finally, the conclusions are drawn from this analysis.

4.1 Methodology

A Multiple-Criteria Decision Analysis (MCDA) is used to facilitate the decision-making process, which is in this case defining the best locations for the marinas. A MCDA is a tool that structures problems and aims to solve decisions which involve multiple criteria. The result of a MCDA is not an optimal solution to the problem statement, but will allow the initiators of the MCDA to decide which alternative is the best, plus including a ranking of these alternatives [2].

Many MCDA methods have been predefined and initiated, such as the Weighted Sum Model (WSM) which will be applied in this project. The WSM is the best known and a widely used method within decision-making studies [2]. This method uses numerical measures for each criterion based on the alternative. These numerical measures multiplied by a certain weight factor will result in a weighted average score. A weight factor, or called weighting, is the relative importance of the criteria which will have their influence as a percentage of the total [42]. Weight factors will be defined and differ for every single criterion. The alternative which results in having the highest weighted average will be defined as the most suitable alternative based on the criteria initiated.

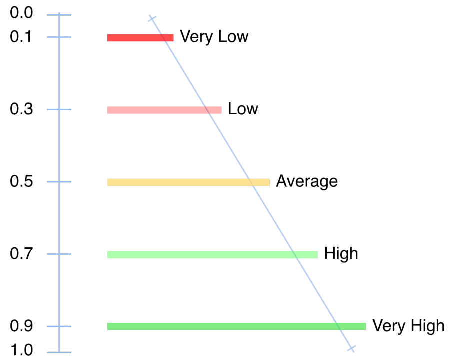

Figure 4.1: Score scaling MCDA

When conducting a MCDA based on the WSM, it is required that the qualitative and quantitative criteria values are expressed in numerical terms, so-called; scoring. Scoring is the extent in which the alternatives meet the maximum preferred value based on each criteria [42]. Furthermore, these numerical terms have to be normalised in order to equally weigh these scores, which will prevent the domination of one criterion over others [29, 42].

The score scaling that is chosen in this WSM and will be used consistently is based on the single decimal scores between 0.0 and 1.0. The average score on this scale is defined as 0.5, which means that a less favourable result of the criterion will be lower than that, and a more favourable result of this criterion will be higher. The scores close to 1.0 are defined as extremely favourable, the scores close to 0.0 are defined extremely unfavourable. The definitions of the scores between both ends of the scales are separated based on the same definition in terms of favourable or not favourable. The complete range and definition of the scale is presented in Figure 4.1. This scoring system means that every value is normalised to the maximum value of its criterion, so that the maximum value is always a 1.0. The scoring system is not necessary linear, as will be explained for each criterion in Section 4.3.

The result of this MCDA will be a ranking based on the results of the weighted averages of the different alternatives. In addition, a ranking of the results divided over the zones that have been created along the coast will be presented. These results per zone will give the specific preferences for the locations along these stretches. The result of the MCDA is not binding and will be discussed in end of this chapter.

4.2 Locations

In order to meet the goal of the MCDA, locations should be selected. Some locations are obviously better than others, so a first selection can be made. For instance, a marina close to a town has a lot of benefits. Because a town provides costumers, facilities and accessibility. It is possible to construct a marina if a city is not present, but this possibility will be considered only if it is really necessary, i.e. on a stretch of coast without towns and to complete the network. Therefore all the towns and cities along the coast have been identified. From Buenos Aires to Bahia Blanca, 36 coastal towns and cities could be identified. This list can be found in the Appendix E.

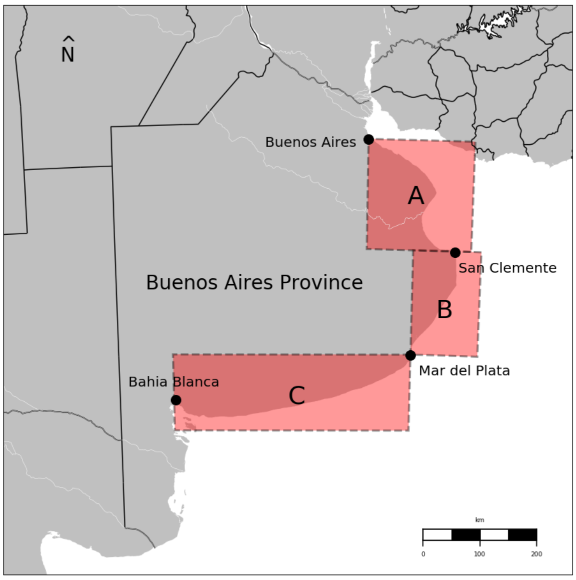

Figure 4.2: Zone division of the Buenos Aires province coastline

Some of these cities have obvious advantages, for instance if they are closer to a really big city or have some natural harbour. Some other cities are, however, not top priority for a new marina, because there is already a marina, or they are to close to an existing marina. This cities can already be filtered from the list. For instance the first 3 cities on the list, Buenos Aires, Quilmes and Ensenada and Berisso (the coastal cities of La Plata), already have one or multiple marinas, so they can be omitted. The same applies for Mar del Plata. These big cities function as nodes in the network. Along the coast, 29 places for a Marina remain. As Bahia Blanca is considered as the last location of the coastal stretch, and because of it's size, it will be used as the end node of the network. Lastly, San Clemente del Tuyu will be considered as a node, as there already has been done research on developing a marina and the key location of the city as it is located after a relatively long stretch of uninhabited area (roughly 165 kilometres). This already jump-starts the network and makes it possible to divide the coastal stretch in 3 distinct zones, as shown in Figure 4.2.

For every zone, the existing residential areas are mapped. These areas will be analysed on multiple criteria in the MCDA. As can be seen in Figure 4.3, a potential bottleneck can already be found by just looking at these areas. From Atalaya until San Clemente del Tuyu, there is a extended stretch without residential areas.

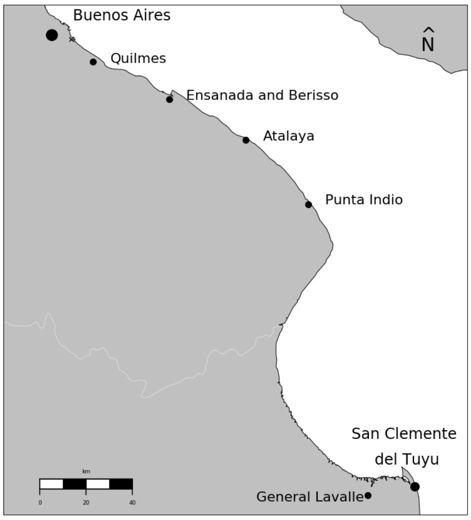

Figure 4.3: Residential areas in Zone A

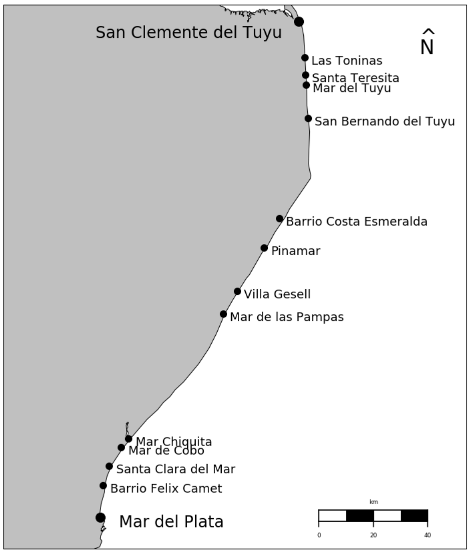

Figure 4.4: Residential areas in zone B

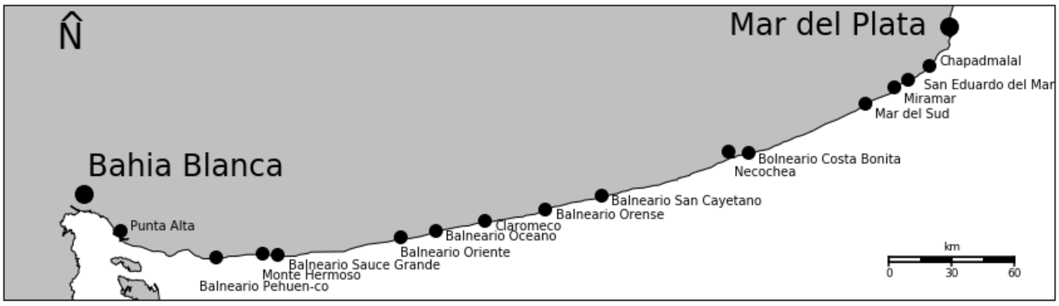

Figure 4.5: Residential areas in zone C

4.3 Criteria definitions

In order to execute the analysis, the criteria should be defined properly, so that they can be quantified. For this analysis, eight different criteria have been selected that are of importance for an optimal marina location. The weighting of the criteria relative to each other is discussed in the next section.

4.3.1 Accessibility from land

One of the criteria is accessibility from the land side, which is a positive influence for a possible marina location. A marina with good accessibility will attract more costumers, hence the location is better. Public transportation is not considered, as it is not representative. Accessibility in this criterion does not include accessibility from the seaside. Accessibility is defined as the number of people that live within 1.5 hours drive from the possible marina location. With this definition, the type of road is automatically assessed, as you travel with a different velocity on every type of road. However, if a good road leads to nowhere, it cannot be called accessible. Therefore, the number of people that live in the area is considered. The method that was used is as follows: First, the area within you can travel by car in 1.5 hours from the possible marina location is researched by using Google Maps. After that, the inhabitants of the partidos (municipalities) that are in this area are summed, which gives the metric used.

The scoring for this criterion was decided not to be linear, because scores near big cities would be exaggerated, while in reality the hypothetical marina cannot serve all this people. It was decided that the scores need to account for a saturation. Therefore, an exponential scale is used in such a way that lower numbers are scored higher relative to higher numbers. An exponential scale with the power of 1/3 was found to be correct. For example; Atalaya was given the maximum score of 1.000 for 4.5 million inhabitants within an 1.5 hours drive. The score for Mar Chiquita (850,000 inhabitants) is 0.570 and the lowest score was given to Claromeco (65,000 inhabitants) as 0.244 on this exponential scale.

4.3.2 Dredging costs

The dredging costs define the accessibility from sea. This is very dependent on the bathymetry, as the water should be deep enough to allow for sailing with our design boat. For this metric the distance to the nearest 3 metres depth contour is taken in metres. Average depth and channel width are considered to be negligibly differing with respect to this distance. That is why the volume can be estimated by taking the length only. The depths are taken from the charts of Navionics [49]. Note that this criterion does not reflect maintenance dredging, this is incorporated in the criterion sediment transport.

The scoring for this criterion is on a linear scale. The maximum distance gets a score of 0.0 and the minimal distance a score of 1.0.

4.3.3 Natural harbour

Some places have possibilities for a natural harbour. For instance; places that have a river mouth or a sandbank on which waves already break, protecting the location from waves. This is an inexpensive way of creating a marina, because no breakwater is needed and is therefore beneficial for the suitability of the location.

The scoring for this criterion is simple. If there is a possibility of constructing the marina in a sheltered place, a natural harbour, the score is 1.0, if there is not, it is 0.0.

4.3.4 Touristic value

Recreational boat users are considered as tourists. Places get a higher score if there is already something to see or to do in the surroundings of the possible marina. If there are touristic attractions, natural or cultural, hotels, restaurants or campsites, they will naturally provide the tourists. For instance; a place with beautiful, often visited, sand beaches will most of the times count more restaurants as well. It is not necessary to account for the beach itself, as the number of restaurants automatically reflects its touristic value. Therefore the touristic value criterion is based on the number of hotels, campsites and restaurants within a 15 minutes drive. This gives an idea of the touristic value of the possible marina location. On Google Maps, almost all restaurants, hotels and campsites are labelled. First, the area withing a range of 15 minutes by car is estimated, and then all the restaurants, campsites and hotels within this area are counted.

The scoring for touristic value is linear. For instance; a double amount of restaurants, hotels and campsites means a double touristic value.

4.3.5 Waves

Waves are important for the design of the marina. Higher waves mean stronger, higher and more expensive breakwaters, hence a less favourable location for a marina. Also the access to the marina is worse if the waves are higher, as they may hinder yachts from safely entering the marina.

The scoring for waves is as follows: Wave energy is a better measure for the strength of the waves then wave height. Because wave energy is the wave height to a power two, the wave height is taken to this power. The scores are normalised by dividing by the maximum score. A higher wave height is less favourable for harbour design, therefore the final scores are subtracted from 1, and thus inverted.

4.3.6 Sediment transport

Sediment transport is important in case a breakwater for a marina needs to be constructed. Larger sediment transport means a higher deposition rate on one side and erosion on the other side of the breakwater, which is unfavourable for a marina location. Furthermore, the higher the sediment transport, the higher the filling up of the approach channel and therefore the more frequent maintenance dredging. For these applications net transport rates are insufficient, it does not say anything about how much sediment passes a point. Therefore, it is needed to work with gross transport rates. A simple model, as described in Chapter 3, was used to obtain these rates. It should be noted that the results of the model have no unit, they only have a meaning relative to each other.

The scoring for this model was done on a linear scale. The score of 0.0 corresponds to the maximum value and the 1.0 to a value of 30,000. A higher sediment transport means a less favourable situation for building a marina.

4.3.7 Tides

As mentioned earlier in Section 3.3.1, tides are relevant for the design of a marina. The tidal amplitudes vary along the coast and on several locations along the coast of the Buenos Aires province measuring stations have recorded water levels. From these water levels the tidal amplitudes were retrieved. In Figure 3.11 the tidal amplitudes are plotted versus the distance along the coast. As not all locations of the MCDA have measuring stations, interpolation between the data points is done to gain tidal amplitude predictions of the missing locations.

A large tidal amplitude is unfavourable for a marina design and therefore its score should be set low. The tidal amplitudes are rated in comparison with the highest tidal range, e.g. the tidal amplitudes are normalised by dividing the tidal amplitude by the highest amplitude, 3.18 metres in Puerto Belgrano, Punta Alta.

4.3.8 Dynamics of population

The last criteria that will be included in the MCDA is the dynamics of the population. The National Institute for Statistics (Instituto Nacional de Estadistica y Censos) has made predictions of the changes in population per municipality until the year 2025. The estimated growth or decrease in population per residential area is calculated between the year 2018 and 2025. This number is derived based on a weighted average of the growth or decrease per *partido* (municipality).

For the scoring, the difference between the current population and the predicted population is used. For weighting the change rates with the absolute size of the population, a weighted average growth rate is found per location.

4.4 Scoring and weighting

The criteria described in Section 4.3 are combined in a table and can be found in Appendix E. This table gives an overview of all the alternatives with their related numerical values expressed in their related unit for the different criteria.

As previously described, the scoring of the MCDA is based on single decimal scores between 0.0 and 1.0, in other words; the scores of the criteria are normalised to one. The definitions of the scores are evenly divided between the maximum and minimum levels, in which a score of 1.0 is highly preferable and a score of 0.0 is highly unfavourable. The numerical values per criteria have been transformed to the single decimal scores and are presented in a single table and can be found in Appendix E. Based on this method , and by normalising the scores, all the different criteria have been quantified and it will be able to compare the numerical values [29, 42].

If the full scoring of the criteria per alternative is completed, the following step is the determination of a weighting factor. A weighting factor, or called weighting, is the relative importance of the criteria which will have their influence as a percentage of the total [42].

The weight factors are determined in a subjective manner based on a rating for every criterion. All the individual group members will assign a rating per criterion which indicates their relative importance, and these combined will determine the weight factors. This method is used because of the knowledge that is gathered during the project thus far. This makes the project members qualified to determine the weighting of the criteria, and to make the definition of the factors as objectively as possible. By executing it individually, it will not bias the distinct ratings. The ranking is based on giving one criterion more value than another criterion. This in terms of a percentage in which the criterion should influence the preference score and weighted averages. For example; accessibility by land should weigh for 20% when calculating the preference score for an alternative. The rating per criteria evaluated by the group members is presented in Table 4.1.

	Criterion							
Subject	1	2	3	4	5	6	7	8
Project member 1	15%	20%	10%	5%	15%	15%	5%	15%
Project member 2	22%	14%	14%	15%	7%	9%	11%	8%
Project member 3	19%	10%	17%	11%	11%	13%	13%	6%
Project member 4	10%	10%	15%	15%	15%	10%	15%	10%
Project member 5	30%	10%	20%	4%	10%	20%	5%	1%
Average	19.2%	12.8%	15.2%	10%	11.6%	13.4%	9.8%	8%

Table 4.1: Evaluation of weights per criterion

The weighting factors will be calculated per criterion based on these percentages. The weight factors will be calculated based on the averages per criterion, using Equation 4.1 [29].

$$RW_k = (W_1 + \cdots + W_m)/m \tag{4.1}$$

Then, these weight factors will be normalised, which will result in the weight factors per criterion that will be used in the analysis. The factors will be normalised to better reflect the relative importance of each of the criteria, and the sum of these weight factors will be equal to 1.0 [42]. Equation 4.2 is used to determine these normalised weight factors [29]. The results of this equations, the weight factors used, are presented in Table E.2, in the Appendix E.

$$NW_k = W_k/(RW_1 + \cdots + RW_m) \tag{4.2}$$

4.5 Results

Based on the scores and weighting per criteria it is possible to calculate the preferences of the alternatives using the weighted averages of these criteria. The preference for each alternative can be calculated using Equation 4.3 below [29]. These preferences are the result of the MCDA.

$$PRE_i = \sum_k NW_k \times N(i)_k \tag{4.3}$$

The results of this MCDA are a ranking of the locations which are highly favourable for the implementation of a marina based on the pre-set criteria. This ranking consists of the preference scores calculated with the weighted averages. A rank per zonal stretch is presented in Table 4.2, Table 4.3 and Table 4.4.

No.	Location	Score
1	Atalaya	0.775
2	San Clemente del Tuyu	0.559
3	Punto Indio	0.502
4	General Lavalle	0.466

Table 4.2: Ranking locations zone A

No.	Location	Score
1	Mar del Plata	0.719
2	Mar Chiquita	0.602
3	Pinamar	0.534
4	Villa Gesell	0.514
5	Mar Azul	0.503
6	Mar de Ajó	0.492
7	Mar del Tuyu / Costa del Este	0.487
8	Barrio Felix Camet	0.475
9	Santa Teresita	0.470
10	Las Toninas	0.466
11	Mar de Cobo	0.459
12	Santa Clara del Mar	0.459
13	Costa Esmeralda	0.443

Table 4.3: Ranking locations zone B

No.	Location	Score
1	Necochea	0.568
2	Bahía Blanca	0.554
3	Costa Bonita	0.540
4	Balneario Oriente	0.469
5	Punta Alta	0.461
6	Balneario Sauce Grande	0.446
7	Monte Hermoso	0.445
8	Balneario Pehuen-co	0.413
9	Miramar	0.410
10	San Eduardo del Mar	0.394
11	Chapadmalal	0.380
12	Mar del Sur	0.373
13	Balneario San Cayetano	0.355
14	Claromeco	0.331
15	Balneario Orense	0.330
16	Balneario Oceanco	0.322

Table 4.4: Ranking locations zone C

4.6 Conclusion

Based on all the pre-set criteria, a MCDA is executed that defines the best locations for implementing marinas along the coast of the province of Buenos Aires. Within this MCDA, the criteria regarding accessibility from land, tourism, dredging, natural harbours, waves, sediment transport, tides and the dynamics of the population are considered. As shown in the previous section the locations that already have or must have a marina are San Clemente del Tuyu, Mar del Plata and Bahia Blanca. The following chapter will continue on these results and will, in combination with the previously conducted fleet analysis, determine at which locations will be at least a mooring place needed. Later on, the definitive locations for the marinas will be determined. This selection will be based on the sailing yacht characteristics in terms of sailing distances and sailing speed.

5

Network definition

Using the results of the Analysis in Chapter 3 and the MCDA in Chapter 4, the final network will be designed. First the strategy will be explained, then the final result will be elaborated on, and lastly the phasing of the network will be discussed.

5.1 Strategy

With the results of the MCDA, the fleet analysis and the geographic analysis, the final network of marinas along the coast of the Buenos Aires province can be configured. The approach in configuring the network will consist of two parts: defining marina locations based on the MCDA scores, and the minimum and maximum sailing distances and then completing the network with additional necessary berthing spots. In Figure 5.1 and Figure 5.2, the first steps of the network configuration can be seen. The color of the dots are related to the MCDA score, whereas the grey circles are representing the half-day and full-day sailing distances.

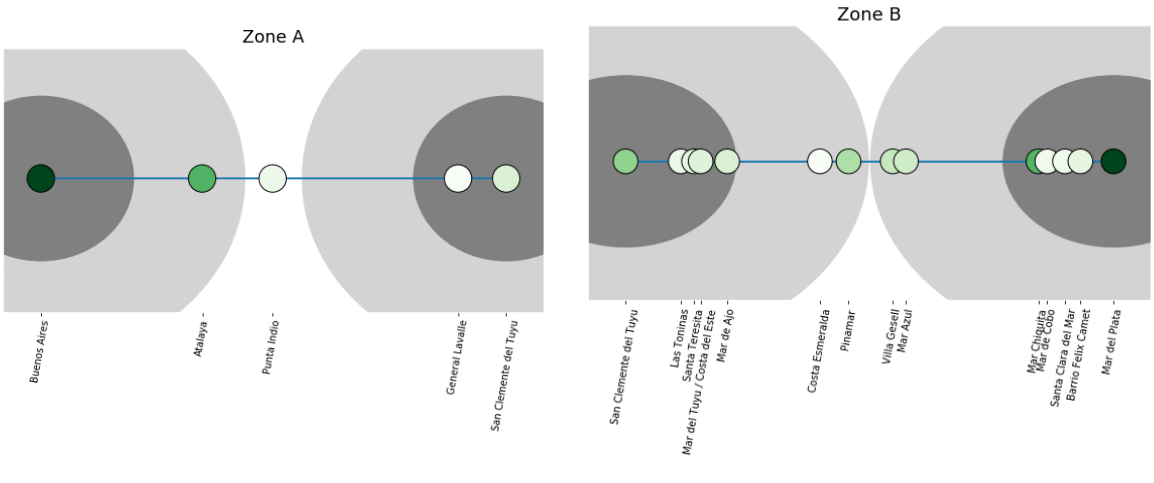

Figure 5.1: Network optimisation process stretch zone A and B

For zone A, in Figure 5.1 it can be seen that Atalaya would be a suitable marina location according to its MCDA score and moreover, it lies within the ranges defined earlier. However, the journey from Atalaya until San Clemente del Tuyu is too long to be sailed in once. Even if an extra berthing spot will be located at Punta Indio, the ranges are still too large according to the maximum sailing distance defined in Section 3.1.1. The reason for this situation is defined in Section 3.2.1, as there are two large nature reserves along this stretch of coast. For the final network, Atalaya will be appointed a marina and en extra berthing spot. in between the nature reserves will be recommended.

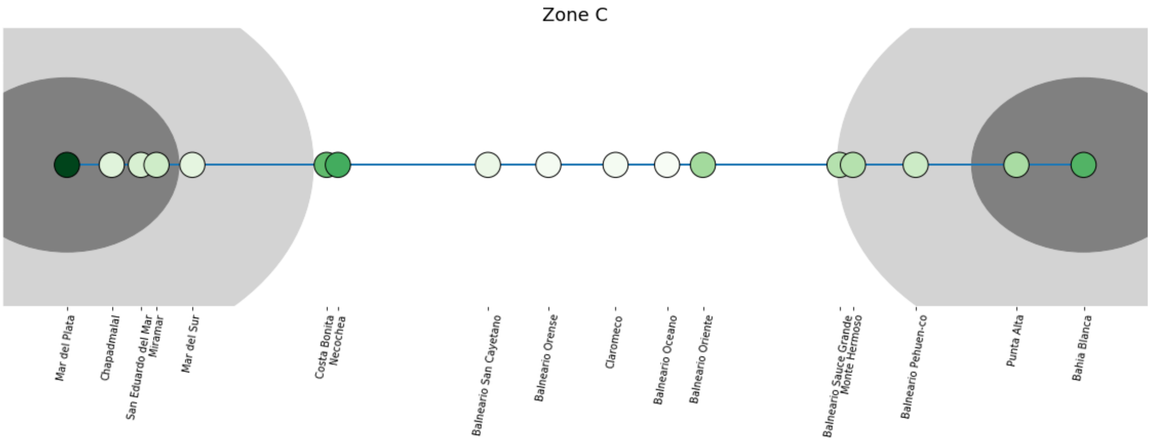

Figure 5.2: Network optimisation process stretch zone C

Figure 5.1 shows the stretch of zone B. Here, according to the MCDA, the cities of Pinamar and Mar Chiquita are defined as the most suited locations for a marina. Pinamar is located just within the maximum sailing distance and is therefore selected as marina location. Furthermore, Mar Chiquita has a high score for suitability for a marina. However, it lies relatively close to Mar del Plata. For the network, Mar Chiquita is appointed a marina as well, therefore closing the network in zone B. No extra berthing spots are needed when Pinamar and Mar Chiquita both have marinas.

For the less touristic stretch of the Buenos Aires province coast, zone C, there are many locations with low MCDA scores, see Figure 5.2. Necochea is one of the most suited locations for a marina, but lies just outside the range of the maximum sailing distance. However, the first location within this range, Mar del Sur, has a low suitability for a marina. To solve this issue, Necochea will be appointed a marina, and Marimar will only need a berthing spot. Further south, Balneario Oriente is the most suiteable location for a marina. Though, in between Necohea and Balneario Oriente, one extra berthing spot is needed to cover the whole stretch. In between Balneario Oriente and Bahia Blanca, also one extra berthing spot is necessary, with Monte Hermoso being used as berthing spot, also this stretch is covered and the network is completed.

5.2 Final network proposal

Combining all the marina locations and berthing spots from all three zones , the final network can be constructed, see Figure 5.4. The full network starts at the city of Buenos Aires, passes the existing marina of Mar del Plata and ends at a proposed marina in Bahia Blanca. The sailing distances between the locations are shown in Figure 5.3.

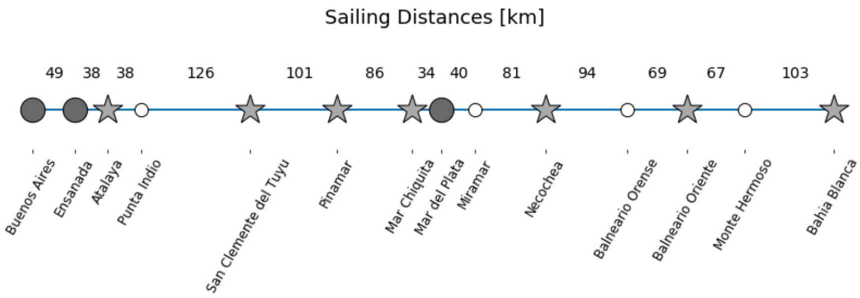

Figure 5.3: Sailing distances final network proposal

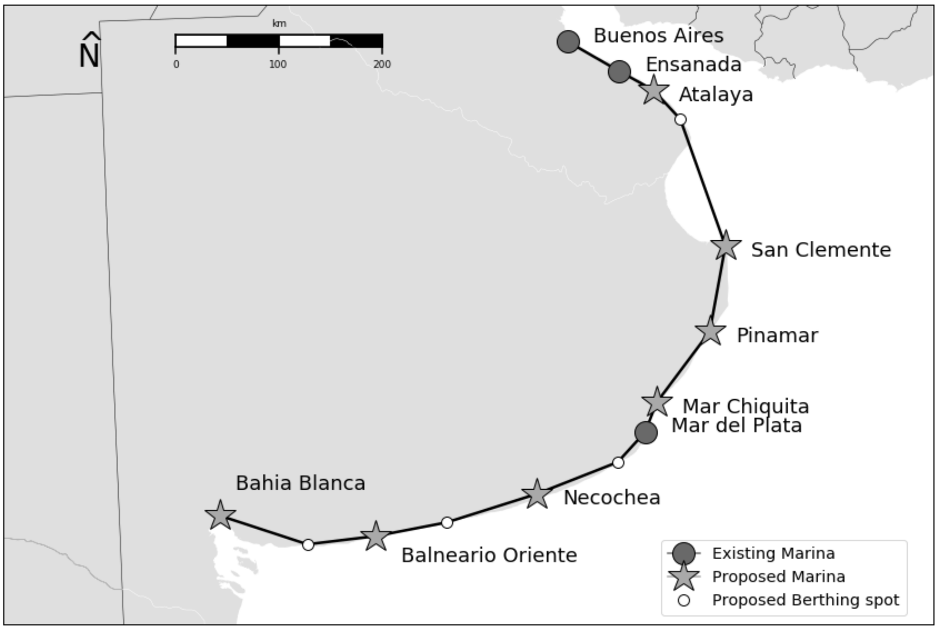

Figure 5.4: Final network proposal

5.3 Phasing

As the proposed network is the ideal network, it can be considered unrealistic to construct the whole network in once. Phasing is therefore an important aspect as well. Some marinas have more importance to the network than the others, and sequencing can be recommended for construction.

For the phasing of the network, two objectives can be distinguished: the connection between all existing marinas in the Rio de la Plata estuary and the marina of Mar del Plata, and the gradual expansion of sport sailing activities around the touristic area of Mar del Plata.

For the first objective, it is important thatthere is sufficient amount of mooring places along the coast. However, apart from mooring places, full marina facilities are required to be able to continue the route to the south. In this case, the marina proposed in San Clemente del Tuyu will play an important role, as it is located halfway between Mar del Plata and Buenos Aires. An extensive research about the possibility of constructing a marina there has already been done, and can be further elaborated in Sivori's technical report [66]. To guarantee a safe travel from Buenos Aires to San Clemente del Tuyu, several mooring spots must be provided on the way. Especially the feasibility of a berthing spot in between San Clemente and Atalaya should be investigated, as this could be a potential bottleneck for the network. The stretch that should be covered in once is too long, therefore the berthing spot is highly needed, though possibly complex to set because of presence of the Nature Reserves along this stretch as described in Section 3.2.1. The same holds for the stretch between San Clemente and Mar del Plata. There, additional mooring spots should be provided as well. In this way, the Buenos Aires marinas will be connected with the Mar del Plata marina as shown in Figure 5.5. Later, the other suggested marinas in Atalaya, Pinamar and Mar Chiquita should be constructed to finalise the network. Then, from Mar del Plata southwards, the rest of the network can be constructed, extending the network gradually until Bahia Blanca.

The second objective can be the expansion of recreational sailing around Mar del Plata. As Mar del Plata is one of the few locations along the coast with an already existing marina, another objective could be the mobilisation of the recreational fleet of Mar del Plata. By starting to construct the proposed marinas nearby Mar del Plata, the yacht owners do not have to sail back to Mar del Plata, but can stay at the new marinas during the night, extending the sailing radius around Mar del Plata. For this objective, the construction of the proposed marina of Mar Chiquita and upgrading the already existing mooring spot in Necochea to a full marina, would be the first on the list as shown in Figure 5.6. Before developing the marina of Necochea, a mooring buoy should be placed around Miramar, to secure safe navigation towards Necochea. After this first phase, the marina of Pinamar can be constructed, further extending the sailing the sailing radius around Mar del Plata. From there on, the sailing radius can gradually be expanded by constructing the marinas of San Clemente del Tuyu, Atalaya and Balneario Oriente and their mooring spots in between, concluding the final network just like the first objective.

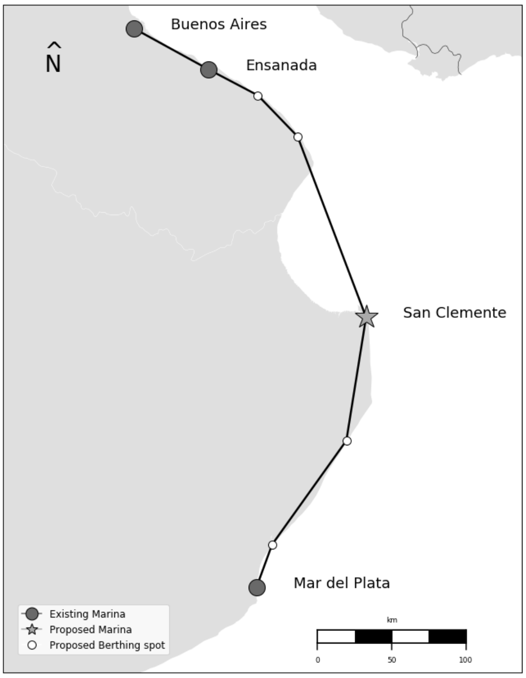

Figure 5.5: Phasing first objective, the final network

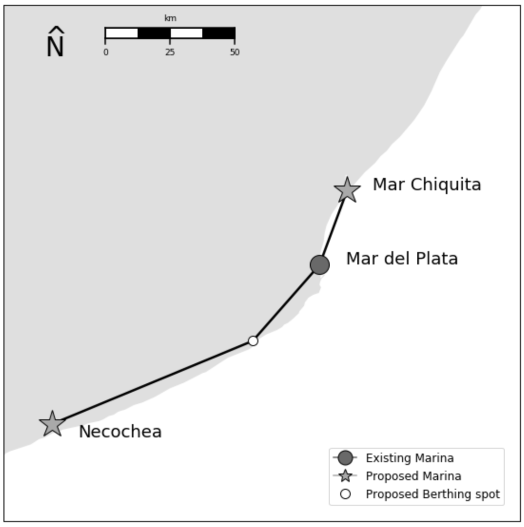

Figure 5.6: Phasing second objective, expansion around Mar del Plata

To conclude, the phasing of the network can be dependent on the short term goal of the project. The long term goal of creating a network of marinas along the Buenos Aires Province coast can be achieved via multiple ways, for example, the two aforementioned methods, i.e. the connection between Buenos Aires and Mar del Plata and the expansion of the sailing activities around Mar del Plata. In Table 5.1, two proposed construction scheme can be found for both objectives separately. The Appendix D shows how the construction of sequent marinas influence the expending of safe-sailing range.

	Connecting network		Expansion from Mar del Plata	
Step	Type	Location	Type	Location
1	mooring	Atalaya	marina	Mar Chiquita
2	mooring	Punta Indio	mooring	Miramar
3	mooring	Pinamar	marina	Necochea
4	mooring	Mar Chiquita	marina	Pinamar
5	marina	San Clemente	marina	San Clemente
6	marina	Pinamar	mooring	Balneario Orense
7	mooring	Miramar	marina	Balneario Oriente
8	marina	Necochea	mooring	Punta Indio
9	mooring	Balneario Orense	marina	Atalaya
10	marina	Balneario Oriente	mooring	Monte Hermoso
11	mooring	Monte Hermoso	marina	Bahia Blanca
12	marina	Bahia Blanca	-	-

Table 5.1: Proposed phasing both objectives

5.4 Conclusion

In this chapter, the final network has been designed based on the results of the analysis in Chapter 3 and the MCDA of Chapter 4. The outcome is a network of marinas and mooring spots along the Buenos Aires province coast, see Figure 5.4. Except for the Samboronbom Bay, all marina and mooring spots are within the sailing limits of the considered fleet, as shown in Figure 5.3. As most area of the coastline of the Samboronbom Bay is part of national reserve parks, a separate study has to be conducted for this area. Another note about the proposed network should be made for the marina of Mar Chiquita. Strictly taken, this marina is necessary as the sailing distance between Pinamar and Mar del Plata is too long. However, as the difference is small, this marina can also be discarded. As the results of the MCDA pointed Mar Chiquita as a highly suitable location for a marina, it is included in the proposed final network.

Moreover, two different phases are proposed, each with their own accompanying objectives. It is up to the decision makers which short term objective would be favorable. The two elaborated objectives, connecting Buenos Aires with Mar del Plata and the expansion of recreational sailing around Mar del Plata are considered as the most important objectives.

6

Marina Analysis

This chapter will focus on the boundary conditions of the chosen location for the conceptual marina design. One specific location is selected for the marina design. For this location, the hydrodynamic, geotechnical, geographic and social-economic conditions will be elaborated, forming a base for the design made in Chapter 7.

The limited resources and data available constrains the decision on which location will be selected for the conceptual marina design. Most data is available for the coast of Pinamar, and therefore this location has been selected for the marina design. Furthermore, the geographical situation of Pinamar can be found at more locations around the coast, e.g. no river mouth or bay for natural shelter, but oceanic gently sloping beaches. In this chapter, all relevant data for Pinamar will be gathered to set the boundary conditions for the marina design.

6.1 Hydrodynamic conditions

For the design of the marina, multiple hydrodynamic aspects must be taken into account. Tidal sea levels, storm surge, sea level rise, significant wave height and storm wave height are the most important ones for the design.

The SHN has a water level measuring station at Pinamar, and therefore the tidal information can already be retrieved. The average water level is 0.92 metres, the median high water level is 1.26 metres and the median low water level is 0.56 metres. For the design, also the maximum and minimum water levels are relevant. For Pinamar, they correspond to 1.82 metres maximum and 0.21 metres minimum during spring tide.

The sea level rise at the Buenos Aires Province coast is estimated to be 2-5 millimetres per year [50]. With a proposed lifespan of 50 year, the sea level rise would be 0.1 metres until 0.25 metres. For safety reasons the upper limit of 0.25 metres will be used.

The storm surge setup is another important factor for the design of the marina. No measurements have been done for Pinamar, however for Mar del Plata there has been done research on storm surge levels. As the geographical situation and orientation are similar, these data will be used for the design. Fiore et al.[24] filtered the tides from measured water levels in the period 1956 - 2005 to obtain so-called *residuals*. These *residuals* represent storm surge levels. In Figure 6.1 the *residuals* are displayed with their corresponding number of occurrences in this period of time, with hourly measurements. The highest measured surge was 1.92 metres in 1999, the lowest -1.35 metres in 1959. The data is extrapolated to obtain statistics for the design of the marina.

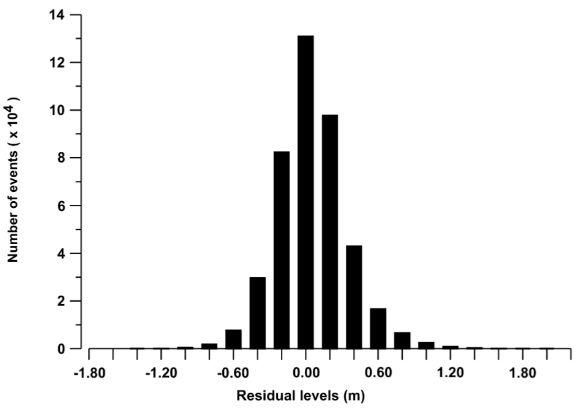

Figure 6.1: Measured residuals for the period 1956 - 2005, hourly measurements [24]

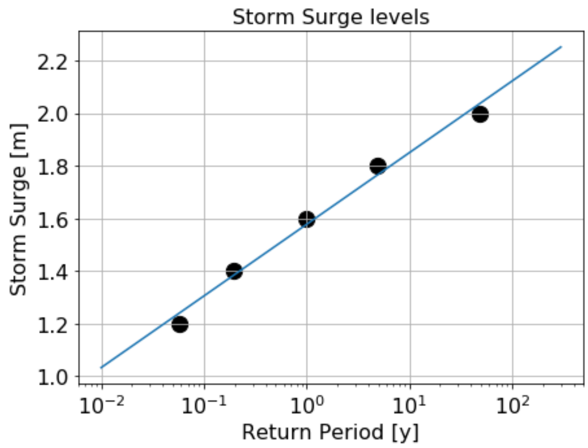

Figure 6.2: Extrapolated return periods of the storm surge levels

6.2 Geotechnical conditions

6.2.1 Stratification

The geological profile of the region of Pinamar, described by Violante [74] in Figure 3.26, consists of transgressive barrier underlying shells and coastal sand dunes with other eolian sediments as the top layer laying above the mean sea level. Seabed formations, that can be found at the shoreface seabed are, for example, sand waves (large-scale cross-beddings), sand ribbons (several small cross-beddings) and sand ridges (sets of small cross-bedings) [57].

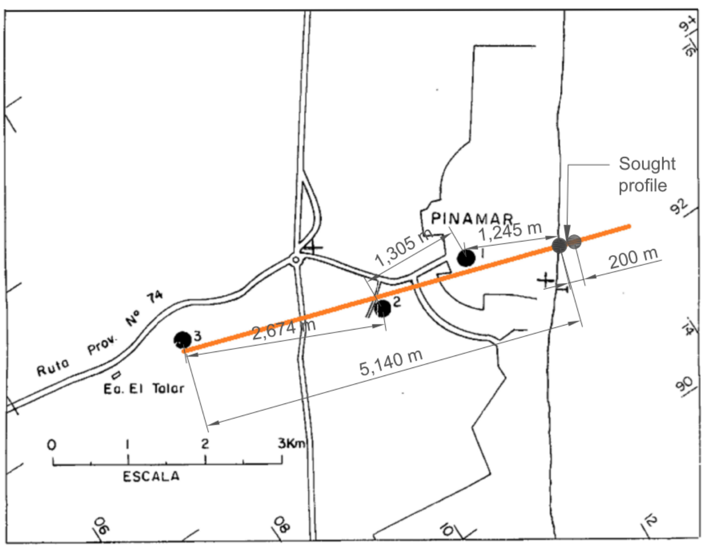

Figure 6.3: Modified map of the geological drillings in the Pinamar area [55]

For the assessment of the geological structure and parametres, a report of Dr. Gerardo Parker [55] was used. The Figure 6.3 shows locations of the boreholes, and Table 6.1, Table 6.2 and Table 6.3 show landform genesis of the region. The elevation of the locations of the boreholes was investigated using Google Maps Find Altitude [18], and the approximate elevation of boreholes 1, 2 and 3 is equal to 10.0 metres, 16.0 metres and 3.0 metres above the sea level respectively.

Depth [m]	Formation
0.0 - 0.1	Organic soil
0.1 - 8.5	Fm. Punta Médanos
8.5 - 15.3	Fm. Pozo N^o8
15.3 - 23.7	Fm. Pozo N^o10

Table 6.1: Lithology - Borehole 1

Depth [m]	Formation
0.0 - 12.1	Fm. Punta Médanos
12.1 - 16.9	Fm. Pozo N^o8
16.9 - 25.4	Fm. Pozo N^o10

Table 6.2: Lithology - Borehole 2

Depth [m]	Formation
0.0 - 0.2	Organic soil
0.2 - 2.6	Fm. Pozo N^o17
2.6 - 9.25	Fm. Pozo N^o8
9.25 - 21.0	Fm. Pozo N^o10

Table 6.3: Lithology - Borehole 3

The geological structure, that needs to be described, is the space between the coast and the end of breakwater, i.e. around 200 metres. For the design, ideally, a few cross-section between the northern and southern borders of the marine should be checked. The existing geotechnical data is very limited and consists of only three boreholes. The spacing between those exceed 1,000 metres, and they are made in the area of the city of Pinamar. The geotechnical conditions in the shoreface area are based on these soundings, and are assumed to be same at the marina location as they are in the Pinamar city.

Appendix C show the lithostratigraphy logged in the boreholes. The layers were classified according to the Eurocode 7 [12] and grouped, so to create continuous layers of soil of similar properties. The boreholes locations don't fit perfectly in line, but because of a lack of the exact coordinates of the boreholes and the large distance between the designed object and the soundings, the profile was simplified to fit the line as shown in the Figure 6.3. For the geotechnical design, boundary conditions are essential to be set and these are the characteristics of each subsoil layer such as: internal friction angle ϕ, cohesion c, specific weight γ. These characteristics of the derived geological structure are shown in the Table 6.4.
The cross-section of the geological layering is attached in Appendix C. The symbols in the cross-section are used according to the Unified Soil Classification System [20]. The following assumptions were made to create a soil profile in the area of interest, i.e. under the breakwater:

- The layer XII (sandy clay) was neglected due to the small thickness.
- The fine sand was only found in the second borehole and it was reaching depths of 12 metres. Then, the thickness of fine sand deposit found in the boreholes, decreased in the direction to the sea. It can be assumed that the fine sand was being deposited due to wave activity and aeolian processes. Therefore, its thickness should be significantly smaller in the sea.
- The thickness of the low bearing capacity layer, the layer XI (organic clay), was assumed to be the same as in borehole 1. Although thickness is expected to be smaller under the seabed, this approach is safer.
- Layers II and IV seem to be the same deposit, but the deposition processes has changed over the time and clay became more sandy in the later deposition period. Hence, the sandy clay was found in Borehole 1 and should be present in the profile under the breakwater. The same applies to the layer V, where sand became more clayey in the newer deposition.
- Layers VI, VII and IX have a similar genesis. Layers VI and VII were deposited in the later times, and here also sediment was more clay-rich (visible in comparison between VI and VII layers).
- Layers III and VIII are sand lenses, whereas layer X was possible a bathtub-shaped lense of shells, that might have been created in the lagoon environment.
- The lowest soil type, that was spotted in all boreholes, was clay (or sandy clay). Since it is cohesive soil, the more conservative approach was used and the lowest, IX layer (clay), was made over 10.0 metres deep.

Depth $[m]$	Classification	Cohesion $[kPa]$	Peak friction angle $[^o]$	Residual friction angle $[^o]$	Saturated unit weight $[kN/m^3]$	Reference
0.0 - 0.5	FSacl	0.0	32.0	30.0	19.0	[53]
0.5 - 1.25	orCl	10.0	17.0	17.0	14.0	[53]
1.25 - 2.25	saCl	13.0	27.0	27.0	18.5	[68], [48]
2.25 - 5.25	clSa	7.0	30.0	28.0	17.5	[68], [48]
5.25 - 7.90	saCl	13.0	27.0	27.0	18.5	[68], [48]
7.90 - 20.00	Cl	11.0	20.0	20.0	17.0	[53], [48]

Table 6.4: Geological layers and selected strength parameters

The biggest uncertainty in this profile is how the profile, 200 metres from the coastline to the sea, differs from the one inland. The erosion and sedimentation activities of the sea can make this profile much different from those found in the boreholes. One thing that is quite sure, is the additional layer of contemporary sediments over the described layers. The material should be the same sort of what was found in the upper part of the boreholes, however, compaction can be different. For the preliminary design, basing on the D_{50} value for sediment in this region (c.a. 0.20 millimetres), this layer is conservatively assumed to be low compacted silty fine sand. The thickness is assumed to be 2 metres, however, this should be still treated as the important uncertain to dilute.

Another uncertainty is the influence of the shell content, which is described as 'Or' - Organic content. For low content of marine organisms skeletons in the layer, the parameters should not vary much and as seen, it is neglected in the classification. But as the fraction of shells rise, the parameters may go worse. Layers with a low fraction of shell, or only containing some fragments, were described as there was no shell material, however, the geotechnical parameters were taken as the lower bound as shown in Table 6.4. But since marine life in this region was very vivid, the shell-rich layers are of special interest, especially Layer XI consisting of almost 5 metres of shells. In case of spotting layers containing shells during the geological investigation, additional test should be performed to define the strength parameters of such soil domains.

6.2.2 Sedimentation and erosion

According to the research of Calderon [7], the total sediment transport rate including tidal currents is 564,200 cubic metres per year, whereas net sediment transport rate (towards the North) is equal to 562,900 cubic metres per year. Considering other research made by [40], these numbers are given as 1,555,500 and 750,300 cubic metres per year, respectively.

The Pinamar coast is shaped by a stable profile of undernourished dunes [7], and faces moderate erosion. The observed erosion rate between 1957 and 2009 can be averaged at 1.0 metre per year [38]. The sand grain size at Pinamar's beaches ranges from around 0.155 millimetres to 0.26 millimetres, with an average of 0.19 millimetres [7]. As seen in Table G.1, the mean values of D_{10}, D_{50} and D_{90} are equal to 0.147 millimetres, 0.212 millimetres and 0.400 millimetres, respectively. It corresponds positively to [40], where the D_{50} is said to be in range of 0.15 and 0.30 millimetres.

6.3 Socio-economic characteristics

This section will focus on the socio-economic characteristics of the marina that will be designed for the city of Pinamar. First, information and general statistics regarding the city of Pinamar will be discussed. Second, the local stakeholders will be discussed. Then, a touristic related visitor profile will be composed and presented. Based on the stakeholders, the city of Pinamar and the visitor profile, a SWOT- and TOWS analysis is conducted. Finally, stakeholder engagement strategies are proposed which will influence the interests and/or attitudes of specific stakeholders in a positive manner.

6.3.1 The city of Pinamar

Pinamar is a city located along the Argentine coast and is part of the municipality of Pinamar. It is developed and planned based on a strict building code and is completely artificially built due to the implementation of pine trees, which strengthen the naturally sand dunes and made the location suitable for construction activities. The economy is fully fuelled by the tourism sector and is in full operation during the summer season [77]. The municipality of Pinamar has a coastline of 25 kilometres, consisting of beaches which are the main attraction of this region [78].

Currently, Pinamar has 30,491 inhabitants, but the prospects for the coming 7 years show that the population will grow to 34,182 inhabitants [35]. These numbers show that the city of Pinamar is growing and is able to locate more visitors and tourists in the coming years. Moreover, these numbers are showing that the economy of Pinamar is growing. This statement is accompanied by the tourism related statistics of Pinamar. The statistics of the past years show that the there is a growth in visitors, hotels and occupied accommodation spots in the city of Pinamar.

In 2010, a total of 269,283 visitors visited the city and occupied an establishment, which grew to a total of 312,923 visitors occupying an establishment in 2017 [35]. In terms of total available accommodation spots, this number grew from 1,032,545 spots in 2010 up to 1,133,507 spots in 2017 [35]. Lastly, the number of hotels grew from 116 hotels in 2010 up to 119 hotels in 2017 [35]. These statistics show a growth over the last couple of years, which will continue in the coming years as the city of Pinamar will grow and more project developers will settle and execute their projects in this municipality. An example is the Costa Esmeralda project, which will be discussed later on in this section.

The city of Pinamar focuses on a good organisation and assuring sufficient security [7]. These two aspects will attract visitors from the higher-class. This kind of visitors are of positive influence for the implementation of a marina, due to the fact that most of the marina users are located in this class. The profile of these visitors will be extensively discussed in Section 6.3.3. Looking at the history of the Pinamar city, the private sector and project developers have had a strong influence in developing the city [17]. The latest project, Costa Esmeralda, which is currently in its executing phase, will have a positive influence on the growth of inhabitant and touristic sector, and could also embrace the opportunities of a marina in Pinamar.

6.3.2 Local stakeholders

As described in Section 3.5, the stakeholder analysis will identify and map all the involved actors within this project. The stakeholder analysis previously conducted was focused on the involved actors within the implementation of the net of marinas in general. This section will focus on the actors involved in the particular region of the marina design within the municipality and city of Pinamar. The local stakeholders have been identified as; Dirección de Turismo, Costa Esmeralda, Asociación Empresaria Hotelera Gastronómica and Asociación de Concesionarios de Playa del Partido de Pinamar [17].

In Figure 6.4, a power versus interest versus attitude grid (PIA) based on Pinamar is presented. The related stakeholders will be described accordingly. Within this explanation, their interests and attitude will be depicted. This PIA grid is deviating from the grid previously presented in this report, due to the differences in local actors instead of general actors.

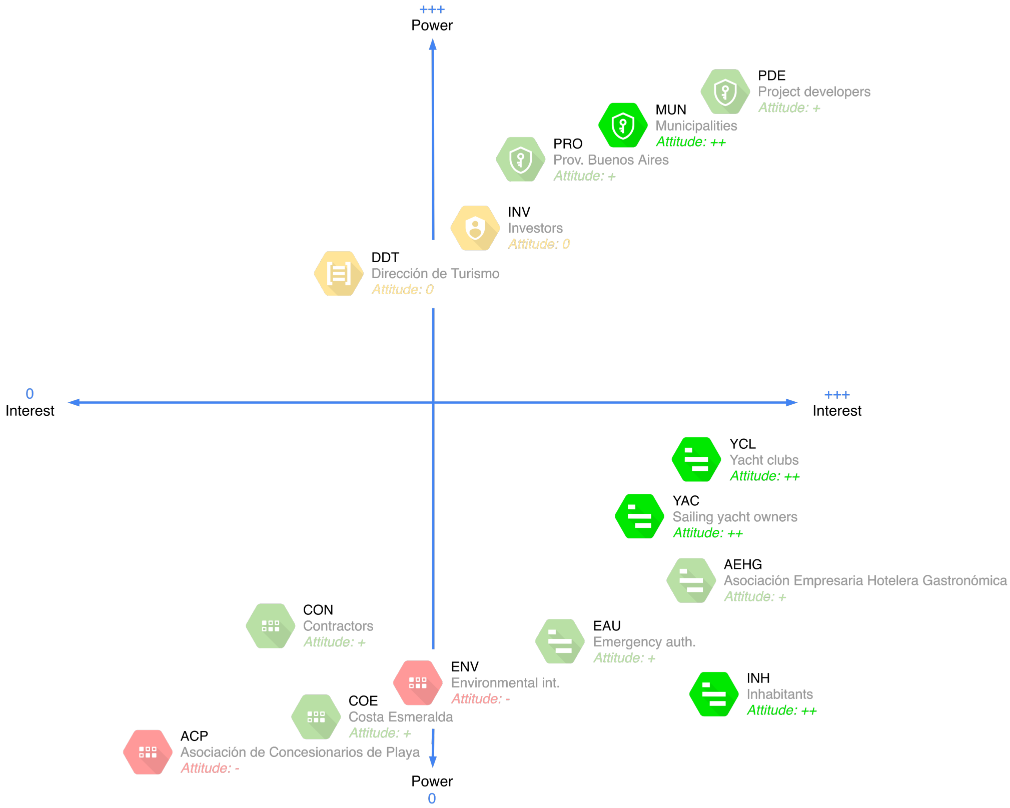

Figure 6.4: Power versus Interest versus Attitude (PIA) grid related to Pinamar

Direccioón de Turismo

The Department of Tourism, which falls under the Ministry of Education, Culture, Science and Technology, is the public authority that is responsible for the touristic sector in Argentina. This department focuses on optimal conditions and competitiveness that will lead to a balanced sector in the country. In addition, it aims to improve the quality of life of the visitors as well as for the residents itself [79].

The Ministry of Education, Culture, Science and Technology has allocated a budget of approximately 225 million dollars for the year 2019 [47].

The attitude towards the marina will be neutral. A marina will have positive effects on the touristic sector within the municipality of Pinamar, but also for the province of Buenos Aires. On the other side, the marina will result in more loss of green space and overcrowded periods within the city itself. This will result in a neutral perspective in terms of interest. In terms of power, this actor has its influence on the allocation of the public budget, which makes them a potential financing party. Additionally, the Department of Tourism has blocking power because they are responsible for assigning permits and could have their influences on the coastal land-use plans.

The above will result in their role as a sleeping giant based on the role definition defined by Hilson Simon [33]. Based on these statements, they could be influential, acting passively and are backing the development and progress of the project; they need to be engaged in order to awake them.

Costa Esmeralda

The Costa Esmeralda Is an urban development project which covers 3,200 metres of coast and 1,000 hectares of forest, which offers in total 3,900 lots to build houses upon. The project offers a residential and an urban area. It is located on the border of the municipality of Pinamar and La Costa [80]. In addition, this urban development project offers possibilities to practice water sports and cares about the environment.

This urban project is developed jointly by project developer JPU Desarrollos and private investor Eidico. Currently, 1,249 houses were built and 93 more are under construction [16].

The role and position of the Costa Esmeralda project is one of mixed aspects. On the one side, the marina will result in an extra activity of people living within this neighbourhood, will attract more people that want to move towards this neighbourhood, and the investors and developers behind this project could be potential partners or investors for the marina in terms of financing. But on the other side, the implementation of the marina will result in differences in sediment transport along the coast and will influence the beach at the location of this project. The level of interest will therefore be neutrally but scaled slightly towards the negative perspective. In terms of power, the project will not have a sufficient level of power to influence the decision regarding the implementation of the marina, unless the companies behind Costa Esmeralda will be financially involved within the marina project, which will be neglected for now.

Thus far, the above will result in their role as an acquaintance based on the role definition defined by Hilson Simon [33], when not considering Costa Esmeralda as an investor or project developer of the project. Based on these statements, they are insignificant, acting passively and are backing the development and progress of the project; they need to be kept informed and communicated with developments.

Asociación Empresaria Hotelera Gastronómica

The Asociación Empresaria Hotelera Gastronómica (AEHG), or translated as; Business Association of Hotels and Restaurants, is a non-profit organisation which consist of entrepreneurs in the field of hotels and restaurants in the municipality of Pinamar. This organization represents the interests of the sector and promotes its development. In addition, it ensures the maintenance and condition of their partners and provides information in terms of economical, institutional and technical aspects [1].

The implementation of a marina will attract more visitors towards the municipality and city of Pinamar, which will result in more customers and revenue for the hotels and restaurants located within this area. Therefore, the attitude towards the marina project will be positive, also in terms of interests. On the other hand, this association has an insufficient extend of power and leverage to significantly influence the project and be involved in the decision-making process.

The above will result in their role as a friend based on the role definition defined by Hilson Simon [33]. Based on these statements, they are insignificant, acting actively, and are backing the development and progress of the project; they should be used as a confidant and/or sounding board.

Asociación de Concesionarios de Playa del Partido de Pinamar

The Asociación de Concesionarios de Playa del Partido de Pinamar or translated as; Beach Concession Association of the municipality of Pinamar, is the association of beach concessions which consist of proprietors in the field of sport, water and leisure activities on the beach. This association consists of all the proprietors on the beach and represents their interests.

The Beach Concession Association of the municipality of Pinamar will have a negative perspective towards the implementation of a marina nearby. The current proprietors on the beach will see this marina as competition and will influence the current sediment transport along the coast. Moreover, the new marina will result in more visitors in the municipality and city of Pinamar, which could have a positive effect on these proprietors, although this cannot be assured. Therefore, the interest of these association will be on the negative perspective and this association will not have sufficient power to influence the project and be involved in the decision-making process.

The above will result in their role as a trip wire based on the role definition defined by Hilson Simon [33]. Based on these statements, they are insignificant, acting passively, and could block the development and progress of the project; they need to be understood in order to not engage them to ‘tripping’ the project.

6.3.3 Visitor profile

In this section, a profile of the visitors will be sketched in order to determine the interests and the opinions of these visitors. Most Pinamar visitors (51%) get a monthly income between 3,000 and 12,000 dollars (US$). In general, these visitors come from the province of Buenos Aires (39%) and Gran Buenos Aires (23%) [34]. Gran Buenos Aires, or Greater Buenos Aires, refers to the city of Buenos Aires and their adjacent 24 municipalities.

The motivation of visiting Pinamar is mainly based on the interest in the beach (39%) or because the visitors simply like Pinamar as a destination (32%). The car is the main method of transport towards this coastal city (78%), this statistic is correlated with the origin of the visitors, due to the fact that Pinamar is only a 4-hour drive away from the capital; Buenos Aires [34]. Moreover, the people that visit Pinamar have already done it on a previously occasion (33%) and more visitors state that they usually go to this destination on a yearly basis (21%). A large portion (44%) of the public that visits Pinamar, even tough it is for once a year or for multiple times a year, did stay in a paid accommodation [34]. Visitors that are staying in Pinamar and visiting Pinamar are mostly occupied by activities as going to the beach and other beach related activities (84%). Besides beach related activities, doing hikes and walking across the nature is the second most popular activity (48%) [34].

Beside the statistics and background of the visitors, it is very important what the opinion and the experience of their stay in Pinamar look like.

The security aspect, is very important for visitors from the higher-class, scores high on a level of satisfaction. The visitors found that the security is on a sufficient level and are feeling themselves safe during their time in the city. Furthermore, the level of quality of service and care within restaurants, accommodations and the public environments are also outstanding when considering these aspects [34]. Although, many people are expressing their discomfort and discontent about the lack of cleanliness in the city. Also, the traffic disorder and the number of cars present in the city are unfavourite aspects and make the visitors feel uncompliant with. Visitors express a general dissatisfaction with the progress of building works and a loss of green space among the city [34].

These positive aspects are something that the city of Pinamar needs to encourage and maintain them on its level. In contradiction, the negative aspects depicted above can be improved by the implementation of a marina and need to be taken in consideration.

6.3.4 SWOT/TOWS Analysis

In this section a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is performed. A SWOT analysis will identify the strengths and weaknesses of the project, and the opportunities and threats of the environment. A variation on a SWOT analysis is a Threats, Opportunities, Weaknesses and Strengths (TOWS) analysis. A TOWS analysis pairs the internal aspects with the external aspects of the SWOT analysis to initiate strategic intentions [21].

The SWOT and TOWS analysis will help defining engagement strategies for the different involved stakeholders. The internal strengths and external opportunities can be used to build upon and should be exploited for the interest of the project. The internal weaknesses and external threats should be eliminated and mitigated in order to negatively influence the progress of the project.

SWOT

The SWOT matrix of the marina project in Pinamar is presented in Figure 6.5. In addition to the description of a SWOT analysis, this matrix is based on internal strengths and weaknesses plus the external opportunities and threats [21].

STRENGTHS

1. Economic and touristic impulse for the region.
2. Makes the city of Pinarmar accessible from sea.
3. A positive influence on the current occurring erosion and sediment transport problems for the city of Pinamar.
4. Strategical topographical location which is easily accessible from the capital.
5. Improvement of offshore and along shore safety due to the presence of emergency services.

WEAKNESSES

1. Excessive dredging costs.
2. Generating a delivery model which generates sufficient revenue and return on investment.
3. Reliance on project developers, governments and investors.
4. Marina not accessible by sailing yachts due to the sailing distances along the coast.
5. Area vulnerable to harsh weather conditions.

OPPORTUNITIES

1. Opportunities for the organisation of a regatta along the coast of the Buenos Aires province.
2. Opportunities of establishing a sailing school for the local population.
3. Further population and touristic visitors growth in the region.
4. A large urban development project nearby.
5. Creation of green living environment.

THREATS

1. A reduction of natural area might create opposition.
2. Prohibiting constructing activities along the shore by the government.
3. Lower- and middle-class opposition due to the development of a higher-class orientated project.
4. Corruption that influences the progress and results of the project.
5. The current hydrodynamic conditions could be negatively influenced due to the effects of climate change.

Figure 6.5: SWOT Matrix

TOWS

The SWOT matrix of the marina project in Pinamar is presented in Figure 6.6. The SWOT matrix in combination with the TOWS matrix will eventually offer the definitions and opportunities for the stakeholder engagement strategies [21].

SO STRATEGIES

Use the strengths to take advantages of the opportunities:

The economic and touristic impulse in combination with the accessibility from sea will fuel and allow for further population growth of the region. In addition, the accessibility from sea will allow the large urban development project to become more successful and can be used to develop a partnership or collaboration between the two projects.
(S1, S2, O3, O4)

The implementation of a shuttle service between the marina and the city of Pinamar, and between the marina and Costa Esmeralda, the urban development project will result in even more economic and touristic impulse in the region and establish a more green and eco friendly living environment because less vehicles will be using the roads nearby.
(S1, S2, S4, O3, O4, O5)

OW STRATEGIES

Overcome weaknesses by taking advantage of opportunities:

The excessive dredging costs and the difficult methods of initiating a sufficient delivery model could be covered by organising a regatta along the shore in which the marina is implemented. In addition, a sailing school could be established which also contributes in covering these costs.
(W1, W2, O1, O2)

A collaboration or partnership with the nearby large urban development project will make the marina project less dependent on new project developers, governments and investor. In addition, this will also enhance and guarantee a sufficient delivery model.
(W2, W3, O3)

TS STRATEGIES

Use strengths to avoid threats:

The economic and touristic impulse could be used to create a sufficient amount of natural area to cover the usage of the marina. In addition, the impulse could be used to generate and initiate developments focussed at the lower- and middle-class inhabitants.
(S1, T1, T3)

The implementation of a marina will positively influence the current sediment related problems and will most likely result in more sediment deposition in front of the shore which will create more natural area and a wider beach. In addition, the marina and the described result will be better guarded against the climate change effects and sea level rises.
(S3, T1, T2, T5)

TW STRATEGIES

Minimize weaknesses and avoid threats:

The development of a marina could be used to engage the local population and raise their interest towards water related activities, which will enhance and generate a positive public opinion and will engage the public authorities to share the same public opinion.
(W3, T2, T4)

The implementation of breakwaters protects the marina and the related hinterlands from harsh weather conditions and excessive dredging costs. The breakwaters will additionally create a living environment for mammals that live in the ocean, such as seals and sealions.
(W1, W5, T1)

Figure 6.6: TOWS Matrix

6.3.5 Stakeholder engagement strategies

From the strategies of the TOWS, strategies to engage stakeholders are created. These are:

Initiating a shuttle service between the city of Pinamar and the marina will prevent more cars in the streets thus the interest of the inhabitants will decrease due to the discomfort about excessive traffic and vehicles in the city. Moreover, a shuttle service between the urban development project of Costa Esmeralda and the marina could be initiated to raise the interest of this stakeholder. The interest of the Costa Esmeralda project will be raised because it will be beneficial for the inhabitants of this neighbourhood and will also attract new inhabitants.

Additionally, the interest of investors has to be raised to ensure financial investments and a sufficient number of financial assets, which will result in the realisation of the marina. First, by implementing a marina along the coast, an east Argentinean coast regatta could be organised, which is the first accessible regatta for the public and leisure practising sailors. The organisation of a regatta will generate more revenue plus public interest both nationally and internationally. Second, the urban development project Costa Esmeralda could be offered private berthing spots in the marina which will also generate additional revenue. Both these strategies could result in more interested and powerful investors.

The attitude and interest of the Department of Tourism could be raised by implementing a local sailing school, in which other water sports related activities are implemented, that is aimed at the lower- and middle-class inhabitants of the city of Pinamar. Both the attitude and interest will be raised because the Department of Tourism is also focused on improving the quality of life for the visitors, as well as for the residents.

The attitude and interest of the environmental interest groups, and Department of Tourism, could be raised by ensuring natural living environments on top of the breakwaters for sea mammals such as seals and sea lions. Involving the environmental interest groups in the process will not only change their attitude and interest but they will also contribute to improve the overall quality of the project. The latter will be beneficial for the Department of Tourism because they want to improve the quality of life in the region of the to be implemented marina. Furthermore, the implementation of the marina will also come with the necessary coastal defense structures. The location of the marina in combination with the coastal defense structures will increase the sediment deposition and will reduce the current erosion of the beaches in front of Pinamar. The latter will be beneficial for all the beach related concessions who are part of the Beach Concession Association of the municipality of Pinamar. This association will be engaged in a positive manner and will solve the problems they are currently facing.

In general, the development of a marina could be accompanied by the development of an additional green area in terms of a park or a natural destined area. The opinions of inhabitants and visitors have shown that the general thoughts about the city of Pinamar and the region is the diminishing effect of their success in the decrease of green area. When developing such a park or natural area will highly influence the attitude of multiple organisations, public departments, inhabitants and the visitors.

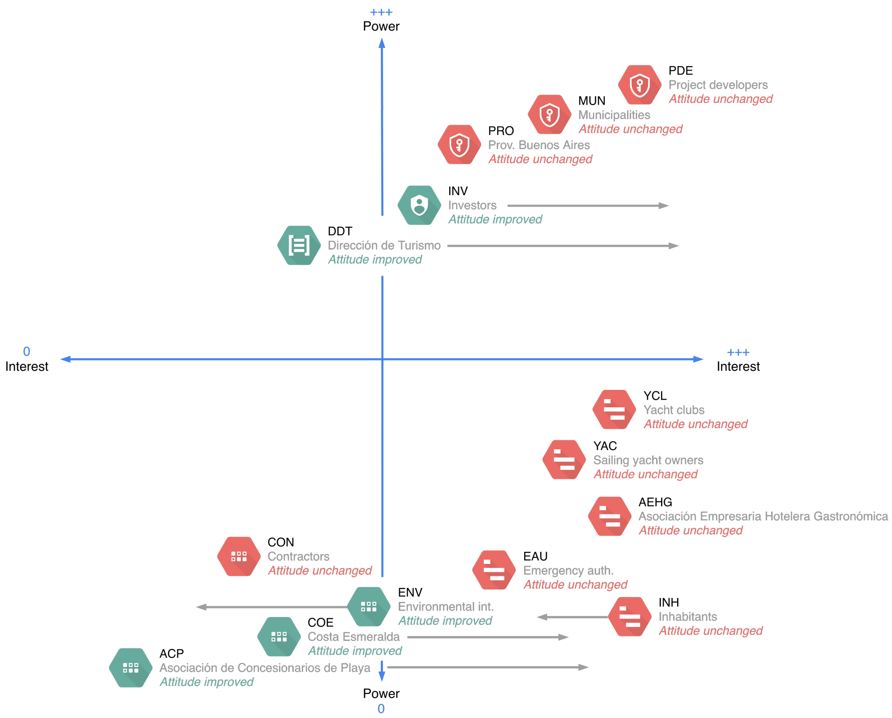

Figure 6.7: Stakeholder engagement plan

7
Design

The marina along the coast of Pinamar is designed to suit the conditions along the coast and the needs of boats berthing in the marina. The chapter is setup first with a list of requirements for basic facilities that each marina should consist of. Then the location near Pinamar is pinpointed, and finally, the design of the marina is made to suit the location and the needs.

7.1 Marina template

A marina design is largely dependent on the location. The local topography can reduce the costs in creating a harbour, for instance, if it is located in a river mouth. If the initial costs of creating a marina are low, the marina can be kept small. But if the initial costs are high, i.e. when dredging and large breakwaters are needed, the marina can only break-even with a large number of mooring places. This section might be of help to a decision maker providing basic overview, and help to rapidly calculate the approximate cost. It gives an overview of the basic needs for a marina. What also should be considered, is that if a marina might not be feasible because of, for example, budgeting reasons, a dry stacking terrain or even a few mooring buoys may be. It is also recommended to consult guidelines for a marina design. There are multiple good guidelines for marina design available, for instance by PIANC [58] or national standards, as this one for California [69].

The following should be considered in a marina design:

1. Protection from waves and currents
   (a) Natural harbour
   (b) or a Breakwater
2. Safe Navigation
   (a) Approach channel
   (b) Internal channels
   (c) Sufficient water depth
   (d) Water depth buoys
3. Mooring/dry stocking facilities
   (a) Berthing
   (b) mooring
   (c) Dry stacking

4. Boat launching
    (a) Ramp
    (b) Crane
5. Supplies
    (a) Fuel supply
    (b) Water supply
    (c) Electricity
6. Facilities
    (a) Marina office
    (b) Sanitary
    (c) Shop
    (d) Restaurant
    (e) Garbage disposal
    (f) Boat workshop
    (g) Parking spaces
    (h) Sailing school
7. Security
    (a) Fencing
    (b) Guard office

The facilities that are incorporated in a marina design are a matter of economics. The initial investment for a marina can be considered as high due to necessary of dredging operations and breakwaters construction. Therefore, in order to provide any return on investment, minimum number of berthing places should be relatively high. A natural harbour can be of great help to reduce these initial costs. For a feasibility study, an economic research should be made to estimate the number of mooring places. It should take into account the local fleet (including recreational fishing) and seasonal (travelling) fleet.

If a marina is developed in a river mouth, no breakwater will have to be constructed and therefore the dredging costs will be lower. Therefore, the number of mooring places in the marina can be lower when reaching the financial break-even point. The facilities can also be kept to a minimum meaning no necessity for a ramp, crane or shop, for example, so the marina would only have a function as mooring place for passers-by and for the local fleet. Moreover, this type of marina can be expanded over time. If more berthing places are constructed, the extra income can be used to provide the first facilities, such as sanitary services. Then financial risk of building such a marina is small, and the demand for berthing spaces cannot be overestimated, if they are incremented by small amounts.

The situation in a non-natural harbour is different. The wide beaches of the Buenos Aires province's coast do not make marina design easy. A lot of dredging is needed to create an access channel, and breakwaters need to be constructed for wave protection. This makes the initial costs for building a marina high. So a lot of mooring places are needed to account for the initial costs, and this makes the investment more risky. Furthermore, the majority of the mooring places should be occupied over the year to reach a profit on the investment.

7.2 Marina location

The marina in Pinamar is build north of the city. The location is chosen because of a net sediment transport to the north. The sediment transport will cause erosion north of the marina. Due to the lack of more naturally suited places, the marina will be placed away of the city centre, so the main beaches of Pinamar won't suffer from erosion. This location north of the city makes it suitable for a combined project with real estate development, which increases the chances of the project to succeed. The location can be seen below in Figure 7.1.

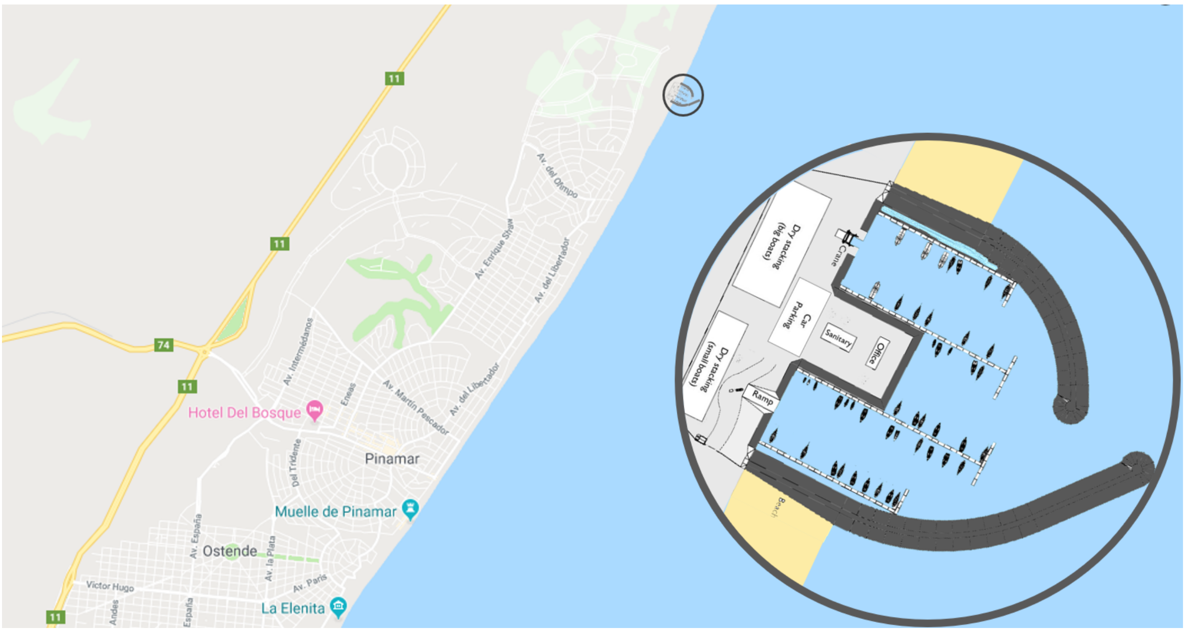

Figure 7.1: Pinamar Marina location

7.3 Marina size required

The marina needed along the coast of Pinamar will be designed in accordance with the guidelines of the Australian government [69]. This section will consist of a calculation of the required mooring space and the required dimensions of the internal channels. If this is known, the required water area size of the marina can be calculated. After that, in the following section, the breakwater can be designed.

7.3.1 Required mooring space

The marina size depends on local and seasonal fleet and the size of the boats in them. In the analyses part in Chapter 3 the design boats were determined and numbers for seasonal where estimated. The summary of fleet analysis is given in Table 7.1. The local fleet consist of two parts: the boats that will be dry stacked and the boats that need mooring places. Boats from 16 feet, and more are assumed to need mooring places in the water, smaller then 16 feet will be dry stacked. The local fleet is based on that for every 5,000 people living near the marina one buys a boat. the distribution on how they buy boats is based on the distribution of local fleet made in the analysis chapter. There is a need of 100 dry stacking places and 80 mooring places. From the boat distribution and the amount of boats a total required space needed for mooring places can be compiled.

Type	Length [feet]	Draught [m]	Beam [feet]	Amount	Berthing space [m^2]
Seasonal Fleet	30 - 55	1.6 - 2.5	10 - 15.5	50	2540
Local Fleet	16 - 55	1.2 - 2.5	6.5 - 15.5	80	1272
Total Fleet	16 - 55	1.2 - 2.5	6.5 - 15.5	130	3812

Table 7.1: Design fleet

Mooring place dimensions used to determine the size of the marina. The recommended sizes are used [69]. In the marina no finger piers will be implemented. Mooring will be done with an aid of wooden piles. This is done so no extra space will be lost, and design will be most economical. For boats below 16 feet, a dry stacking will be available.

7.3.2 Internal channels

The internal channels are designed on the longest boat that needs to use the channel. The minimum of the channel width is $1.5L$ [69]. This criteria holds for all the channels inside the marina. From the interior channel to the fairways reaching the berthing areas.

7.4 Breakwater

7.4.1 Failure mechanisms

In order to provide a safe and reliable design, all possible failure modes should be identified. Figure 7.2 shows possible failure mechanisms of a rubble-mound breakwater.

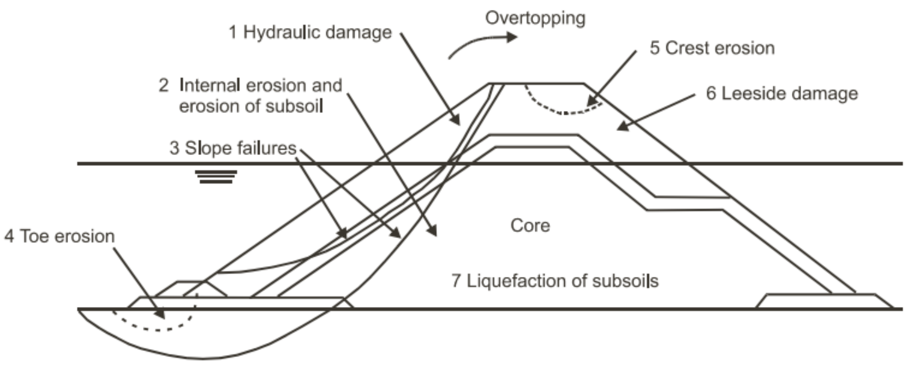

Figure 7.2: Rubble-mound breakwater failure modes [71]

The failure modes are failures that can happen during the lifetime of a breakwater. Failure modes can be related to hydrodynamic or geotechnical issues, or both. The design of the breakwater should be based on withstanding these failure modes. The hydrodynamics related failure mechanisms are shown in Table 7.4. The decisive factors for geotechnical design should be calculated according to to Ultimate Limit States (ULS) [22], and are shown in the fault tree which can be found in Figure 7.3.

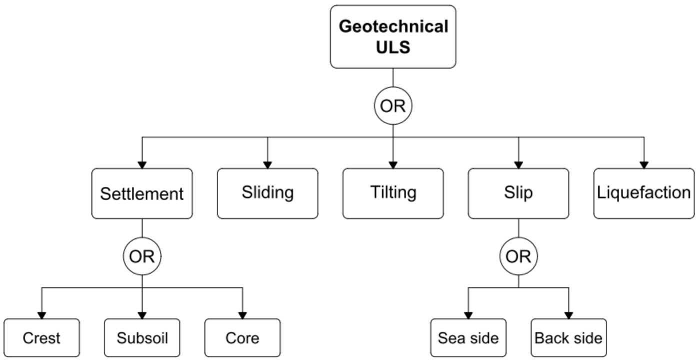

Figure 7.3: Geotechnical part of the fault tree for limit states of rubble-mound breakwater [22]

Design events
Overtopping
Transmissiom
Toe stability
Filterstability
Revetment stability

Table 7.2: Failure mechanisms breakwater

For the safety of all the boats and the mainland, the inner slope of the breakwater has to be guaranteed during the total lifetime of the breakwater. The safety for boats can be exceeded more often as it is a service limit, as presented in Table 7.3 [70].

Safety for:	Discharge [l/s/m]	V_{max} [l/m]	Allowance [-]
Damage on small boats 5-10 m	<10	<2,000	Medium
Rubble mound breakwaters rear side designed for overtopping	5-10	10,000-20,000	Low

Table 7.3: Limits overtopping discharges

By defining an acceptable probability of failure during the lifetime of the breakwater (50 years) it is possible to select an appropriate target reliability per failure mode. This could be done by the Poisson equation:

$$R = \frac{T_L}{-ln(1-p_{f,TL})} \tag{7.1}$$

R	=	return period [year]
T_L	=	lifetime of the breakwater [year] = 50
$p_{f,TL}$	=	probability of failure during the lifetime of the breakwater [-]

The $p_{f,TL}$ is in order of 5-20 % for typical lifetimes of 20-50 years, depending on the consequences when failing. Because the marina of Pinamar is a marina for small sailing boats that can be dry stacked off season a relative large $p_{f,TL}$ of 20 % is chosen for the ultimate limit state as presented by Equation 7.2[70].

$$R_{ULS} = \frac{50}{-ln(1-0.20)} = 224.07 \approx 250\ [year] \tag{7.2}$$

For the serviceability limit state a percentage of 60 is chosen, because of the lower consequences according to the overtopping manual [70]. This limit state function is given by Equation 7.3.

$$R_{SLS} = \frac{50}{-ln(1-0.60)} = 54.57 \approx 50\ [year] \tag{7.3}$$

Failure mechanism	Limit state	Criterion	Return period
Overtopping	ULS	5-10 l/s/m	250 [year]
	SLS	10 l/s/m	50 [year]
Revetment stability	ULS	$\frac{H}{\Delta\, d_{n50}} = 2.2 - 2.3$	250 [year]
Toe stability	ULS	$\frac{H_s}{\Delta d_{n50}} = \begin{cases} (0.24\frac{h_t}{d_{n50}} + 1.6)N_{od}^{0.15}, & 3 < h_t/d_{n50} < 25 \\ (6.2\frac{h_t}{h} + 2)N_{od}^{0.15}, & 0.4 < h_t/h < 0.9 \end{cases}$	250 [year]
Filter stability	ULS	$\frac{M_{cubes}}{M_{50-filter}} = 10$	250 [year]
Transmission	SLS	$K_t = -0.4\frac{R_c}{H_{si}} + A_{str}(\frac{B}{H_{si}})^{-0.31} * (1 - exp(-0.5\xi))$	50 [year]

Table 7.4: Failure modes breakwater

7.4.2 Geotechnical design

Evaluation of the soil-related failure modes follow similar criteria as those for an embankment dam, but with additional influence of severe wave action [3]. The soil mechanics problems shown in the Figure 7.3 are related to bearing capacity of the soil domain. To analyze bearing capacity of the ground, geotechnical properties of each soil layer are needed. To obtain them, a proper soil investigation program should be performed. The basic geotechnical investigation for a breakwater construction, which allows to obtain the necessary parameters, would consist of a desk studies of the geological history aspects, measurement of bottom layers thickness and laboratory analysis of bottom sediments. The full analysis of geotechnical conditions, which may allow to provide a safer and a more reliable design, would require additional on-site tests such as drillings, cone penetration tests (CPT) and geo-eletrical reasearch for subbottom profiling. The site investigation program can also be combined with environmental benchmarking [57]. The equipment needed to carry out the basic tests consist of stable floating platform, diving equipment and bottom sampler [25]. In this report, the geotechnical design is based only on desk studies.

For a preliminary geotechnical design, settlement and slip failure mechanisms were investigated. To analyze failure mechanisms in terms of a semi-probabilistic design, the partial safety factors need to be applied on the soil characteristics. According to the Eurocode 7 [11], these are:

- Friction angle $\gamma_{\phi'}$: 1.25
- Cohesion $\gamma_{c'}$: 1.25
- Undrained shear strength γ_{cu}: 1.4

For the slope stability assessment, Bishop's method was used by implementation of a model created in the D-Geo Stability program. In the model, the breakwater consisting of a gravel core and a concrete armour layer is overlaying the soil domain described in Table 6.4. The assumed strength parameters of a breakwater's materials are shown in Table 7.5.

Layer	Material	Cohesion c $[kPa]$	Friction angle ϕ $[^o]$	Saturated unit weight γ_{sat} $[kN/m^3]$
Core	Gravel	0.0	35.0	20.0
Armour layer	Concrete blocks	0.0	40.0	25.0

Table 7.5: Breakwater's materials parameters

The dynamic wave load for the rubble-mound crown wall breakwater is coming from broken waves, therefore, quasi-static dynamic analysis should be made [65], and the load should be calculated with Equation 7.4 of Minikin [] and parameters mentioned in Table 7.6.

$$F_{h.imp} = \frac{101}{3}\frac{\rho * g * {H_D}^2 * d}{L_D * D} * (d + D) = 2.24kN \tag{7.4}$$

Parameter	Description	Value	Unit
g	Gravitational acceleration	10.0	m/s^2
ρ	Water density	10.0	kN/m^3
H_D	Design wave height	3.14	m
L_D	Design wave length	225.0	m
d	Water depth at the toe	8.05	m
D	Water depth at the L_D distance	9.05	m

Table 7.6: Breakwater's design parameters

In the model, different slip surfaces at the different depths of the toe were investigated. The most critical depth for the toe of the slipping surface, was one metre below seabed, i.e. between the layer of fine sands and organic clay, what seems reasonable. The slope's steepness is assumed to be 1:1.5 because of construction reasons, such as the size of the concrete blocks. The model is shown in Figure 7.4.

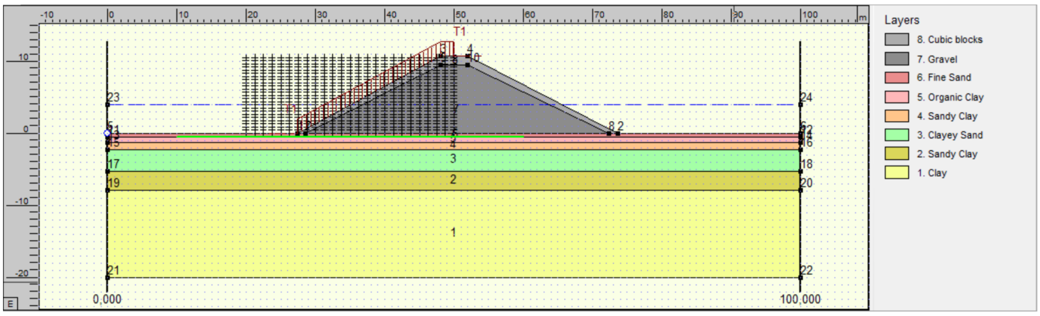

Figure 7.4: Numerical model for the slope stability of the breakwater

The Factor of Safety (FoS) received by the numerical analysis, with the distribution of a safety reduction factor over the cross-section for a slope of 1:1.5 is shown in Figure 7.5. The minimum factor of safety is equal to 0.398. As seen, the instability is mostly attracted to the toe region. To investigate, what would be the best option to implement to meet the design requirement, several models were checked:

- A model with a cohesion of 5 kilopascal added only to the gravelly core of the breakwater. It has not influenced the FoS.
- A model with a cohesion of 5 kilopascal added to the concrete cubes. It has increased the FoS from 0.398 to 1.002.
- A model with a cohesion of 10 kilopascal added to both gravelly core and concrete tubes. It has increased the FoS from 0.39 to 1.303, what would be already sufficient.

As seen above, in the numerical analysis, heavy concrete blocks without cohesion have induced the failure. The FoS in this case seems to be unreasonably low. However, the last consideration is too optimistic - gravel does not have cohesion, and factor of safety of 1.002 from second model seems to be properly calculated. To increase the factor of safety, so to meet the design requirements, either geotextiles should be used under the concrete cubes to stabilise the core of breakwater against the slip failure, or the slope ratio should be increased. The additional geotextiles should add strength comparable to cohesion of 10 kilopascal to the gravelly core. Without the geotextiles, increasing slope ratio may also be a solution. For the 1:2.0 slope, the factor of safety is equal to 1.305. For both cases economic analysis should be performed to choose the optimal solution.

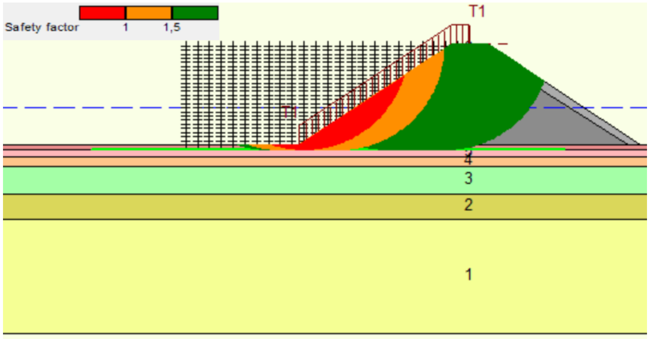

Figure 7.5: Strength reduction factor distribution for the breakwater with slopes of ratio 1:1.5

For the settlement analysis, the geological cross-section from Table 6.4 was taken, and calculations as follows in Table 7.7 were made. The Young's modulus E and the Poisson's ratio ν for each layer was taken as a lower range value according to Subramanian 2008 [67]. The influence factor I was taken from the monogram of Naval Facilities Engineering Command [48], and the maximum load for which settlement is calculated is a pressure of 220.25 kilopascal, i.e. the load in most critical spot under the breakwater structure. The final settlement was calculated using Equation 7.5.

$$s = \Delta p I m_\nu H_l = \Delta p I \frac{(1+\nu)(1-2\nu)}{(1-\nu)E} H \tag{7.5}$$

Soil type	Thickness H_l $[m]$	Influence factor I $[-]$	Young's modulus E $[MPa]$	Poisson's ratio ν $[-]$	Settlement s $[m]$
FSacl	0.50	0.50	10.0	0.25	0.005
orCl	0.75	0.50	0.5	0.45	0.044
saCl	1.00	0.50	25.0	0.30	0.003
clSa	3.00	0.49	15	0.30	0.016
saCl	2.65	0.45	25.0	0.30	0.008
Cl	12.10	0.40	15.0	0.45	0.019

Table 7.7: Table for calculation of the settlement of the breakwater

The total settlement, calculated based on conservative values of soil parameters, is equal to 94 mm. This value should be added to the breakwater's design height, and the settlement calculation should be iterated till equilibrium. For the reliable settlement analysis, a proper geological investigation should be done. The calculated value should only provide the order of magnitude of the settlements.

In order to provide a safe and an economically optimised engineering design, a geotechnical risk management program should be created. It should consist of risk-driven site investigations, and a risk-driven monitoring programmes, which will help to mitigate ground-related risks. Possible geohazards at the marinas sites can be associated with [57]:

- Seabed morphodynamics and sediment mobility: migrating large scale ripples, seabed sandy barriers
- Spatially variable soil conditions (burried channels of rivers under the seabed, canyon incision in shelf, erosion surfaces)
- Soil liquefaction (due to seismic activity)
- Locally cemented hard seabed layers (shell layers)
- Man-made hazards (existing cables/pipelines or fine-sediment filled holes created during dredging processes, for instance)

7.4.3 Hydrodynamics

The transformation of offshore to onshore waves is done with help of SwanOne. The rest of the information is from Chapter 3 - Analysis. The storm surge is an important factor in the determination of the onshore wave height. However the return periods of offshore wave heights and storm surges do not have to coincide. There is a correlation, but it is not equal to 1.0. Therefore, combinations of wave heights and storm surges have been made in order to get a more realistic estimate for the onshore wave heights. These combinations can be found in Table 7.10. The normative combinations per return period are run 1 and run 3. Apparently the storm surge level is more important than the offshore wave height. This can be explained by the bathymetry of the coast, which is relatively shallow. In shallow waters waves lose a lot of energy on bottom friction. The wave height of the used return period of the waves (R_{waves}) and the height of the storm surge (R_{surge}) can be found in Table 7.8 and Table 7.9, respectively.

Location	Return period [years]	H_{ss} [m]	T_m [s]	Dir [° N]	Wind speed [m/s]	Wind direction [° N]
offshore	250	8.20	12	125	25	125
offshore	50	7.10	11	125	23	125
offshore	5	5.54	10	125	20	125

Table 7.8: Wave conditions at Pinamar

Waterlevel	[m]
MLWS	0.21 + CM
MSL	0.92 + CM
MHWS	1.82 + CM
storm surge 250	2.23
storm surge 50	1.96
storm surge 5	1.77
sea level rise	0.25

Table 7.9: Water levels at Pinamar

Run	Return period [years]	R_{waves} [years]	R_{surge} [years]	Onshore H_{ss} [m]
1	250	5	250	**3.14**
2	250	250	5	3.07
3	50	5	50	**3.06**
4	50	50	5	3.02

Table 7.10: Combinations for onshore wave calculation with SwanOne (1 and 3 are normative)

7.4.4 Breakwater dimensions

The height of the breakwater is determined by the overtopping and controlled by the wave transmission conditions. The formula of overtopping is given in Equation 7.6.

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.1035exp[-(1.35\frac{R_c}{H_{m0}\gamma_f\gamma_\beta\gamma_v})^{1.3}] \tag{7.6}$$

The rear side of the breakwater is the governing value for overtopping. This leads to a maximum over topping of 10 litre per second per metre (l/s/m) and a crest height of 6.7 meter.

Wave transmission is the wave height at the lee side of the breakwater due to overtopping waves and/or transmission through the breakwater. Transmission focuses on the amount of waves which may pass the breakwater and is relevant for the tranquillity in the marina [71].

An operational requirement of a maximum wave height of 0.5 meter (H_s) is needed for safe boarding of boats and comfortable berthing, wave penetration through the port entrance is neglected. At this stage of the design it is presumed that we are dealing with a narrow-crested breakwater ($B/H_s < 8$), the criterion is given by De Jong [19]. The K_t is the transmission coefficient the change from initial wave to the transmission wave. As shown below in Equation 7.7.

$$K_t = -0.4\frac{R_c}{H_{si}} + 0.64(\frac{B}{H_{si}})^{-0.31} * (1 - exp(-0.5\xi)) \tag{7.7}$$

$$\xi = \frac{tan(\alpha)}{\sqrt{\frac{H_{si}}{L_0}}} \tag{7.8}$$

In which α is the slope of the breakwater, which is assumed to be normal to relatively high (1:1.5) to reduce run-up and length of the armour layer.

Return period	H_{si}	T	$L_0 = \frac{g}{2\pi} * T^2$	ξ
[year]	[m]	[s]	[m]	[-]
250	3.14	12	224.83	6.66
50	3.06	11	188.92	4.91

Table 7.11: Iribarren numbers

To ensure that the transmission wave is below the 0.5 metre for a return period of 50 years the top of the breakwater should be 0.55 meter width. Due to minimum crest width that should be 3 times the cube seize or more the minimum crest width becomes 3.75 meter.

7.4.5 Revetment

For this design single layer cubes are used as armouring layer. The reason for single layer cubes is that it is known what the properties will be. Preferable are natural rocks from the hinterland but data about the rocks was hard to find and not sure if the sizes are large enough. Therefore cubes are chosen for this initial design.

For the revetment concrete cubes are used in a single layer. The stability of these elements is given by the Hudson formula [70]. For the stability of single layer cube revetment the equation should hold. For single layer cube revetment no damage is allowed. In these values, safety factors are taken into account.

Concrete properties	
type of layer	Cubic blocks
concrete	C25 / 30
Slump	S2
Cement	low hydration heat
1 layer properties, high density	
layer coefficient [kt]	0.77
shape coefficient [ks]	1
horizontal distance	1.33
slope parallel	1.00
porosity	0.25
packing density	0.75
modified layer coefficient	1.0

Table 7.12: Properties cubes for revetment breakwater

$$\frac{H_s}{\Delta d_{n50}} = \begin{cases} 2.9 - 3.0, & N_{ed} = 0 \text{ for damage} \\ 3.5 - 3.75, & N_{ed} = 0.2 \text{ for failure} \end{cases} \tag{7.9}$$

The safety factor as shown in Equation 7.10 is derived using the Rock Manual [14].

$$\frac{H_s}{\Delta d_{n50}} = 2.2 - 2.3 \tag{7.10}$$

With expected waves of 3.14 meters, as presented in Table 7.8, and a density of concrete between 2200-2600 kg/m^3, this leads to a value between 0.89 - 1.25 metres as diameter of the cubic blocks. Blocks of 1.25 metres diameter are chosen to be sufficient enough for protection.

The under layer with the given cube properties and a porosity of 0.25 as can be seen in the above Table 7.12. According to the Rock Manual [14] an under layer with 10 percent of the mass of the cubes gives the best performances.

$$M_u \approx 0.10 * M_{cub}$$

The mass of the cubes is 1.25^3 m^3. The mass density of the concrete is 2.200-2.600 kg/m^3. This leads to cubes between 4,297-5,078 kilogram. What lead to a minimum and maximum rock weight of the under layer of 430-508 kilograms.

The under layer thickness is determined with the diameter of the rocks in the under layer. The diameter of the rocks can be obtained using Equation 7.11. The density of the rock is assumed to be 2.500 kg/m^3.

$$d_{n50min,u} = (\frac{M_{min,cub}}{\rho_{stone}})^{(1/3)} \tag{7.11}$$

$$d_{n50max,u} = (\frac{M_{max,cub}}{\rho_{stone}})^{(1/3)} \tag{7.12}$$

The diameter of the rock will be between 0.53 and 0.71 metres. Subsequently, the thickness of the layer can be determined. Stones have a blockiness of 40-50 percent [14], which leads to a layer coefficient of 0.77.

$$t_u = n * k_u * d_{n50} \tag{7.13}$$

The toe stability can be calculated with Equation 7.14, because no damage is allowed for concrete cubes, N_{od} is taken as the start of damage [14], which is: $N_{od} = 0.5$

$$\frac{H_s}{\Delta d_{n50}} = \begin{cases} (0.24\frac{h_t}{d_{n50}} + 1.6)N_{od}^{0.15}, & 3 < h_t/d_{n50} < 25 \\ (6.2\frac{h_t}{h}^{2.7} + 2)N_{od}^{0.15}, & 0.4 < h_t/h < 0.9 \end{cases} \tag{7.14}$$

The toe stability is depending on the height of the toe and the stone size used in the toe. The stability of the toe should be ensured for all water levels. The stability of the whole breakwater depends on the stability of the toe therefore a 250 return period is used. This leads to a maximum water level of 8.05 metres and a lowest water level of 4.21 metres. To ensure stability in both cases the toe of the break water should be between 0.805 and 2.53 metres, the average is used and is equal to 1.67 meter. To be able to ensure a sufficient stone size the upper stability 7.14 equation is used. These limits lead to stones with a diameter between 0.55 and 0.58 metres, the same stones as in the layer below the cubes can be used.

The sand below the breakwater is assumed to have a d_{50} of 0.201 millimetres as show in Table G.1, this gives the following grading of the sand:

- $d_{90} \approx 0.4$ mm
- $d_{10} \approx 0.15$ mm

Stability: $\frac{d_{15F}}{d_{85B}} < 5$,
Internal Stability: $\frac{d_{60}}{d_{10}} < 10$,
Permeability: $\frac{d_{15F}}{d_{15B}} > 5$

With this stability limits and the sand grading the filter layers are determined, with the layer height = 2*d_{50}.

The filter stability of single layer cubes has 2 main requirements of which one is different than for a normal filter layer. It should be large enough that the filter material is not washed out during storms, but if the filter layer is to coarse, the blocks cannot be placed in a regular smooth pattern increasing the load on the cubes that are placed irregular. A rule of thumb of design is equation 7.15 [14]:

$$\frac{M_{cubes}}{M_{50-filter}} = 10 \tag{7.15}$$

Because the failure of the filter causes failure of the breakwater, the return period is the same as for the cube revetments.

Layer	Rock weight kg	Rock size m	Layer thickens m
Single cubes	4300-5080	1.25	1.25
Layer 1	430-508	0.55-0.58	0.91
Layer 2	43-51	0.26-0.27	0.42
Layer 3	4.3-5.1	0.12-0.13	0.20
Layer 4	0.4-0.5	0.59-0.56	0.10

Table 7.13: Properties layers of the breakwater

Needed scour protection length that is advisable that 2.5 times the wave height is taken, this leads to a length of 7.85 meter. This is too short as a length of 10 meter to 15 is set as minimum. therefore it is advisable to use at least 10 meters of scour protection.

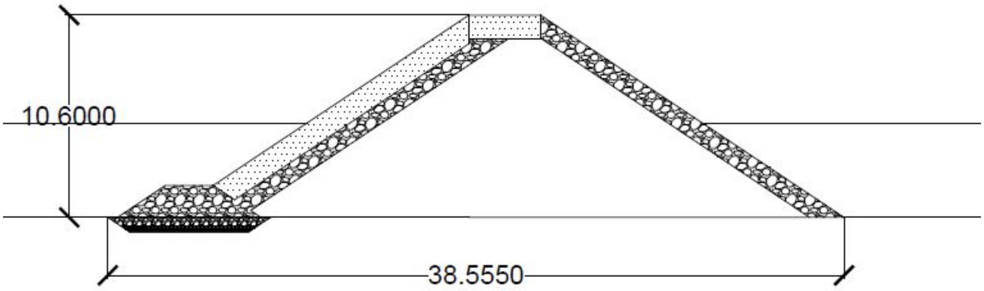

Figure 7.6: Cross section breakwater design

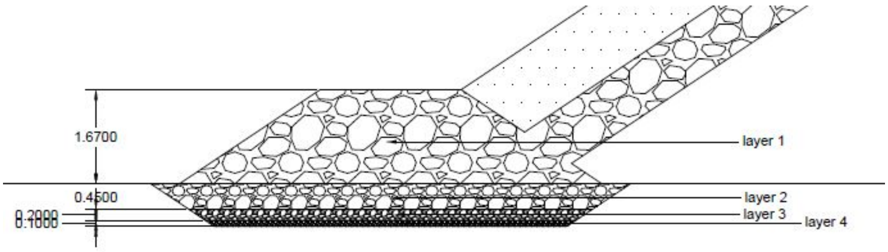

Figure 7.7: Cross section toe structure of the breakwater

7.5 Approach channel

The width of the approach channel has to be at minimum 1.5 times the maximum boat length, which makes it 23 metres [69]. The depth of this channel should be 1.5 metres below lowest boat, which is equal to 2.5 + 1.5 = 4 metres at low water. The direction of the approach channel is also important, especially for wave penetration. In Figure 3.13, it can be observed that the highest waves come from the south. Therefore the entrance of the harbour is directed towards the northeast.

7.6 Conceptual design

The overview of the conceptual design can be observed in Figure 7.8. The mooring spaces are 5 metres wide. The total length of the floating piers required are therefore $130 \cdot 5 = 650$ metres. On the heads of the piers a space for a larger vessel than the berthing spot is realised. The internal channels are 26 metres in width according to the previously stated method, in order to be sufficient for boats of 55 feet (almost 17 meter) in length.

The main wave direction is from the southeast. The entrance of the marina is positioned in order to not have waves that can penetrate into the marina. The breakwaters extend to the depth that is needed for the boats to navigate, which makes them approximately 200 meter in length. No access channel has to be dug out outside of the sheltered water area. Therefore, there is also no access channel that has to be maintained with dredging activities. The marina is partly excavated on the beach, to provide enough sheltered water area. The excavated sand can be used to fill up the part on which the buildings are made in the centre of the marina.

Dry stacking facilities are realise for small boats, which can be launched and reduced using the ramp. These facilities will be mainly used for recreational fishing boats. On the northern part of the marina, the bigger boats (such as sailing yachts) can also be dry stacked. The sailing yachts can be launched and retrieved using the crane. Next to the launching site there is a gas station.

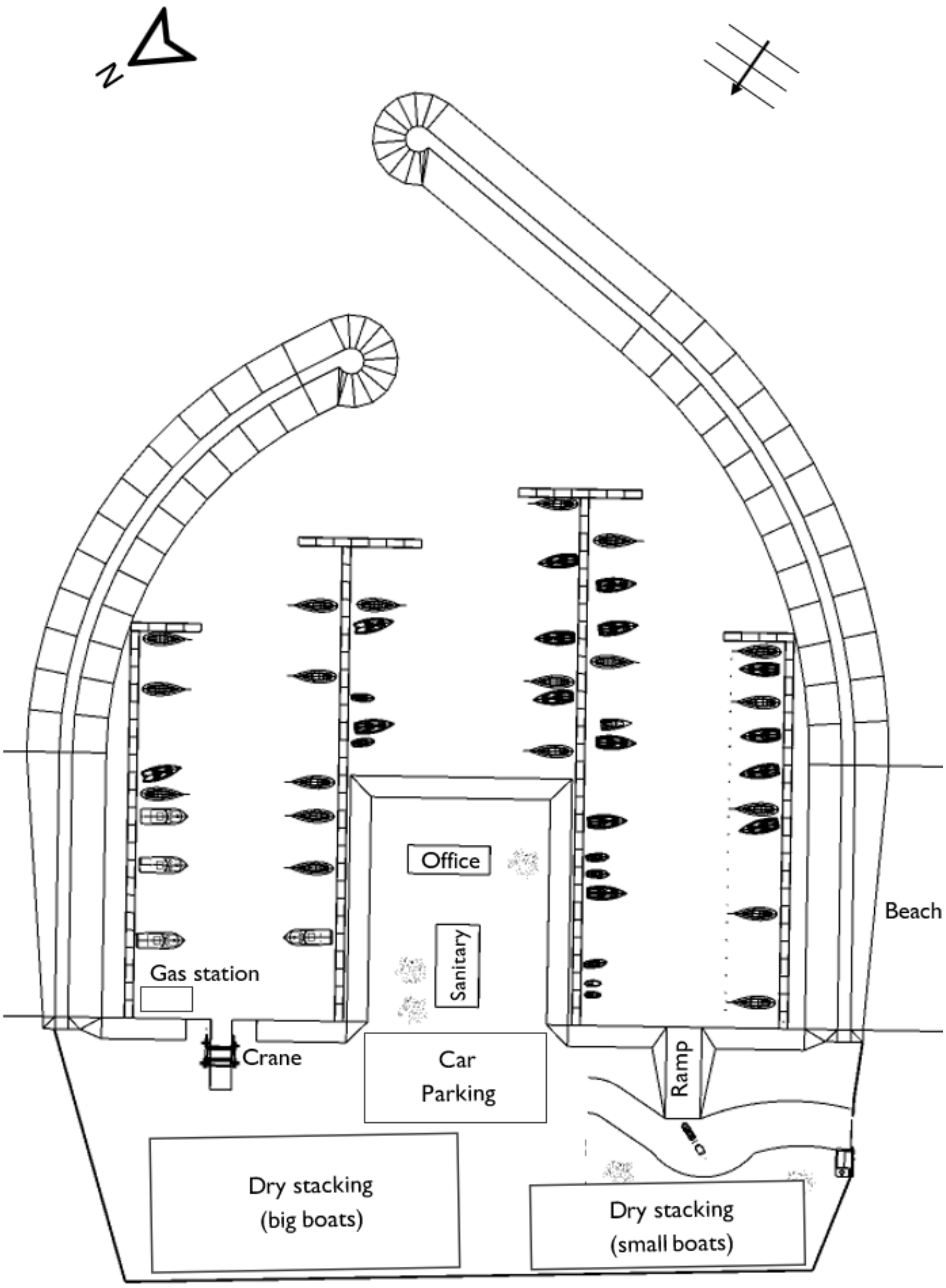

Figure 7.8: Conceptual marina design overview

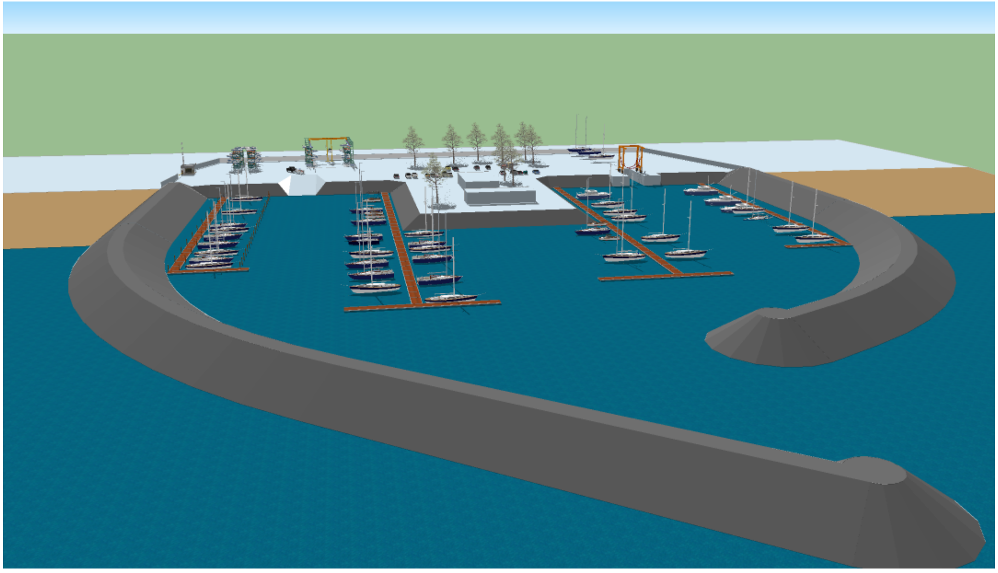

Figure 7.9: Birdseye view of the marina

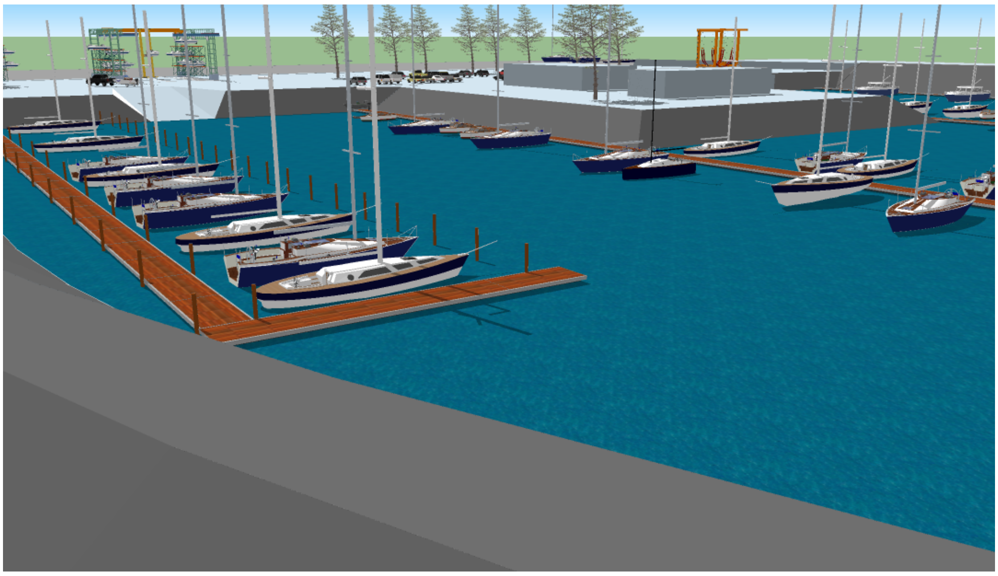

Figure 7.10: Detail of the marina

7.7 Conclusion

The overall aim was to make a conceptual design for a marina based on the parameters found in the analysis. The marina will cover approximately 200 metres of near-shore area. The internal design is made in accordance with The California manual [69] to design a marina. The marina is designed to have a failure rate of 20% in its life cycle of 50 years. The marina is destined for a combination of sailing- and motor yachts, and will suit 130 berthing spots and an additional 100 dry stacking spots. The included marina facilities consist of a harbour office, launching- and retrieval crane, a ramp, gas station, sailing school, sanitary and emergency services. The breakwater's design is based on the EC7 [11] and rock- and over topping manual [14, 70], and breakwaters are designed to withstand storms with a return period of 250 years, which is equal to waves with a height of 3.14 metres. The design is a only a preliminary design and should be optimised with more extensive testing, numerical and/or scale modelling.

8
Conclusion

In this chapter, the main research question will be answered and conclusions will be drawn from the findings of this report. As stated in the introduction, the main research question guiding the project reads as follows:

What would be an optimal configuration for a network of marinas along the Buenos Aires province coastline?

There is not an unique answer to this question. Based on the criteria taken into account for this project, the optimal configuration would be the one shown in Figure 8.1. This network is based on the results of the fleet analysis in combination with the results of Multiple-Criteria Decision Analysis (MCDA). The sailing distances between marinas are according to the sailing limits of the design yachts. The resultant network is an ideal network. Due to the economic situation of Argentina at this moment, this ideal network will not be the most feasible network. However, this ideal network can be taken as a guideline for future marina development projects. The following paragraphs are giving support to this answer, and discuss the aspects in detail.

Based on an extensive analysis and definition of criteria a MCDA is executed which defines the best locations for implementing marinas along the coast of the province of Buenos Aires. Within the MCDA the criteria regarding accessibility from land, tourism, dredging, natural harbours, waves, sediment transport, tides and the dynamics of the population are considered. The best locations for implementing a marina or mooring spots per zone have been determined.

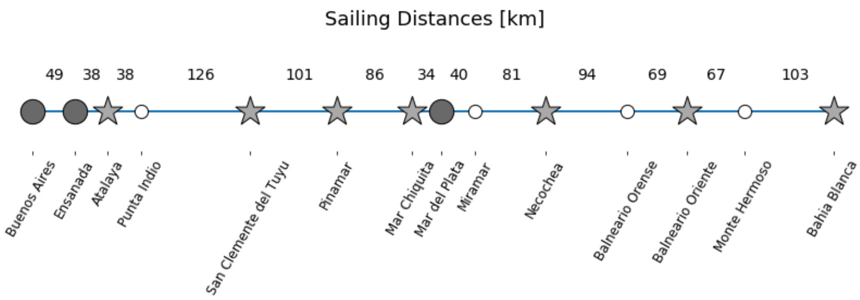

Figure 8.1: Network of Marinas, incl. sailing distances

The final network is the result of the MCDA and has been designed in accordance with the analysis of the shore. The outcome is a network of marinas and mooring spots along the Buenos Aires province coast as presented in see Figure 8.1. Except for the Samboronbom Bay, all marina and mooring spots are within the sailing limits of the considered fleet. As most area of the coastline of the Samboronbom Bay is part of national reserve parks, a separate study has to be conducted for this area. Another note about the proposed network should be made for the marina of Mar Chiquita. Strictly taken, this marina is necessary as the sailing distance between Pinamar and Mar del Plata is too long. However, as the difference is small, this marina can also be discarded. As the results of the MCDA pointed Mar Chiquita as a highly suitable location for a marina, it is therefore included in the proposed final network.

The limited resources and data available constrains the decision on which location will be selected for the conceptual marina design. Most data is available for the coast of Pinamar, and therefore this location has been selected for the marina design. Furthermore, the geographical situation of Pinamar can be found at more locations around the coast, e.g. no river mouth or bay for natural shelter and oceanic gently sloping beaches with moderate erosion rates. The resultant conceptual marina design can be considered as a suitable design for a marina in Pinamar. As the capacity and facilities of this design are more or less constant along the coast, this design can also be guiding for other marinas along the coast with the same geographical situation, e.g. gently sloping oceanic beach.

The overall aim was to make a conceptual design for a marina based on the parameters found in the analysis. The marina will cover approximately 200 metres of shore. The internal design is made in accordance with The California manual [69] to design a marina. The marina is designed to have a failure rate of 20% in its life cycle of 50 years. The marina is destined for a combination of sailing- and motor yachts, and will suit 130 berthing spots and an additionally 100 dry stacking spots. Additionally, the marina facilities a harbour office, launching- and retrieval crane, a ramp, gas station, sailing school, sanitary and emergency services. The breakwater's design is based on the EC7 [11] and rock- and over topping manual [14, 70], and breakwaters are designed to withstand storms with a return period of 250 years, which is equal to waves with a height of 3.14 metres. The design is a only a preliminary design and should be optimised with more extensive testing, numerical and/or scale modelling.

The stakeholders have been studied, identified and mapped according their interests, power and attitude. Based on this division the criticallity of each stakeholder is defined, and thus the importance of when these stakeholder has to be involved in the process is also determined. In addition, strategies have been defined in combination with the aspects of the project such as strengths, weaknesses, opportunities and threats. The goal and most important aspects of a engaging stakeholders and applying strategies is that progress of the project is uniform and maintained, and that all the stakeholders have a prospect of net gains. Two of the strategies that are defined for the Pinamar region are discussed in the section below.

Initiating a shuttle service between the city of Pinamar and the marina which will prevent more cars in the street due to the implementation of the marina, and will decrease the interest of the inhabitants, and eventually the visitors, that is caused by the excessive traffic and vehicles in the city. Moreover, another strategy that should be applied is; organising an east Argentinean coast regatta will result in public interest both nationally and internationally. Additionally, the urban development project Costa Esmeralda could be offered private berthing spots in the marina which will also generate additional revenue. Both these strategies could result in more interested and powerful investors.

9
Recommendations

This project has been executed on a feasibility level and therefore, further research is required to improve both the network design as the marina design. In this chapter, the assumptions made will be discussed, the uncertainties elaborated and recommendations will be done for further research.

9.1
Analysis

9.1.1 Hydrodynamics

For the storm surge prediction, the measured surges at Mar del Plata is used. As the surge is dependent on the geographical situation at the coast, there is an uncertainty whether the Mar del Plata data is representative for the Pinamar coastline. Moreover, the storm surge data for Mar del Plata was extrapolated to get the once in 250 year storm surge, while the measured record contains only 60 years of data, making these predictions less reliable. Therefore, it is recommended to gather storm surge data for Pinamar as well when continuing with a marina design. The sea level rise used for the marina design is a predicted rise, without taking into account possible measures that can mitigate the global warming therefore reducing the sea level rise. For the SwanOne nearshore wave transformation, bathymetry data was used from the marine navigation maps of Navionics, for more accurate predictions of the nearshore wave heights more detailed bathymetry maps are needed. Moreover, different combinations of return periods of wave heights and storm surge levels are used, which can further elaborated in a more detailed statistical analysis.

9.1.2 Fleet Analysis

An economic study should be done to get a better estimate. The study is mostly focused on numbers of CACEL, but from these numbers it is hard to make a difference what kind of boats are distributed per province. Also the regatta is used as a reference this is only a small pick of the total sizes and shapes of boats and might not give the best estimation of a fleet.

9.1.3 Geotechnical aspects

In this report, the geotechnical aspects analysis is based on the already existing reports and literature. Several researches have already been performed regarding the erosion the coast of Buenos Aires province. The results regarding erosion rates, shown in Chapter 3, were sufficient for the erosion assessment. However, for the sediment transport, the already existing reports focus mostly on the region between Mar Azul and San Clemente del Tuyú. The information about the other regions is missing, and it makes locations suitability comparison difficult. Also, the rates for each location differ significantly between different sources. Because of lack of data, the sediment transport model was set. However, due to aforementioned limited data, the model is considered to be not accurate enough. The sediment transport rates survey should be performed to allow to create more precise model. It will not only allow the locations multi-criteria assessment to be more reliable, but also, it will give an optimal forecast of maintenance cost at chosen locations.

Regarding the geotechnical design of engineering structures related to marinas, a proper site investigation should be performed. Since near-shore geological surveying is much more expensive than the onshore one, and an elaborate site investigation performed at the sea requires more planning and mobilisation of special vessels with qualified crew and staff, testing only one location might be uneconomic. The best solution would be to perform a geotechnical survey at all locations as a combined contract to avoid multiple mobilisation costs. If it is not possible, a basic site investigation should be performed in each location of interest. For breakwaters, one sounding per 50 metre length should be considered enough, whereas for other marina's facilities it should be approximately one sounding per 15 metres of building's circumference. The required drilling depth, i.e. the significant depth, should be the level at which the increase in net vertical pressure (difference between pressure at the ground after the construction compared to the initial overburden pressure) is no more than 10%.

The most crucial information that should be obtained during site investigation is the layering including soil types and thickness of each layer, and soil parameters. For obtaining the layering of soil, drillings should be performed, whereas for obtaining the soil parameters such as friction angle, cohesion, undrained shear strength, permeability and coefficients of compressibility, laboratory tests should be performed. Particular attention should be paid to low-bearing capacity layers, such as organic soils.

Specifically for the Pinamar location, as seen in analysis part, the deducted soil profile under the coast is mostly made of cohesive soils. If soil investigation will confirm it, settlement of the breakwater will be greatly determined by the consolidation process, and during the geological survey the pore pressure distribution should be checked in these layers (using CPTu tests, for example). Also, in one of boreholes, a thick layer of shell deposit was found, of which the strength parameters may vary significantly. If the executive project will include driving piles or sheet piles, shell deposit may cause problems with driveability. Since the constructed object will be subjected to the wave activity, the soil liquefaction might be an issue. If loose sand deposits shall be find, the additional examination of liquefaction susceptibility of soil domain should be proceeded, by a means of, for example, Vibro-CPTu tests..

9.1.4 Stakeholder analysis

The stakeholder analysis presented in this report is based on the project information, interviews with involved persons in the project related industry and brainstorm sessions. In order to better define the stakeholders, and to prevent excluding stakeholders from the analysis, multiple actors should be involved in this process. The distinct stakeholders should be contacted and informed regarding the project under consideration. This conversation with these stakeholders should be prepared and being executed with the goal and interests of the project in mind, in order not to influence the process of involving stakeholders later on in the project. Moreover, the importance of individually contacting the stakeholders is to define the extent of their interests and powers. This information is crucial to define the importance of each stakeholder for the process.

The stakeholder analysis can be used to define the possible gains and what roles the actors have. In addition, strategies have been defined in combination with the aspects of the project such as strengths, weaknesses, opportunities and threats. In further extend of the current study; a process design should be designed in combination with the stakeholder engagement strategies. Within the process these strategies could be used to engage certain actors and involve them in the process in order to achieve a positive attitude and preferred gains. A process design consists of process rounds, which are aimed at specific stakeholders to achieve specific gains and discuss certain issues, goal stretching, protection of core values and the definition of the 'rules of the game'. The goal and most important aspect of a process design is that progress of the project is uniform and maintained, this can be ensured by: involving stakeholders early in the process, creating prospect of gains for every stakeholder, enabling quick wins where this is possible and the prevention of the escalation of conflicts. The goal of the process is to achieve a final package deal which consists of a solution and reach a consensus with all the related stakeholders. It is important that the package deal is a net gain for each individual actor.

9.2 Multiple-criteria decision analysis

9.2.1 Criteria

The criteria considered in this MCDA were selected not only based on relevancy but also on available data. Certain aspects can be important for the marina location selection, but when there is no data available and no way of retrieving this data within the limits of the project, these aspect are discarded. On of these aspects is the local fishing activities. When a certain location already contains much fishing activities, the support for construction of a marina can improve, as fisherman might be interested in mooring their boats in (a part of) the marina. Another criteria that can be relevant for deciding on the locations is the income distribution

of the inhabitants of the locations. As sailing is considered as an expensive hobby, e.g. the costs of yachts, it can be important to know how wealthy the local population is. A city with a relative high income per capita is more suitable than a city with a low income per capita. Taking the current economic situation of

Argentina into account, the feasibility of the the proposed network is greatly dependent of financial resources that are available as investment and the return rate on these investment. As Chapter 7 shows, relatively big infrastructure should be constructed for marinas directly on the ocean beaches. The consequence of the high costs of these marinas is that the number of users must be substantial to make a profit or even play break-even on the investment. As a great deal of the costs of a marina can be contributed to the breakwaters construction costs, the cheapest marinas are the ones without or with only small breakwaters. Therefore, it is recommended to include a financial analysis in the MCDA, in order to create a more feasible network, taking into account one of the most, if not the most, important factors for the construction of a network of marinas along the Buenos Aires Province coast.

9.2.2 Scoring and weighing

The scoring and weighing are always partially subjective, as the used scale has to be set based on own opinions. The same holds for the weighing factors, averaging the weightings of all the project member lead to the final weights. For more accurate results, the number of participants of the weighing process should be increased, preferably with participants with knowledge of the criteria and field experience.

9.3 Network

The final network design, as discussed in Chapter 5, can be considered as an ideal design. When the objective of establishing the network is the most important aspect. By going deeper into the fleet characteristics and the meteoric conditions along the coasts, the maximum sailing distances can be determined more accurately. This information can then also influence the final network design. For the Samborombon Bay in the northern

stretch of the coastline, a separate solution has to be found. Due to the difficult environmental conditions and the presence of nature reserves, it has to be checked whether a suitable spot can be found for mooring. From the last mooring spot in the network (Punta Indio) until the next marina (San Clemente del Tuyu) the sailing distance is too long for sailing in one day.

9.4 Design

Here, list all of the uncertainties with regards to the design phase of the marina. Which assumptions were made and which uncertainties should be further investigated.

The amount of berthing spaces needed for the new marina are based on numbers of CACEL and the Regatta sailed along the coast. This makes it difficult to make an estimation of the boats that can be expected. Because the numbers of CACEL are per province, it is unknown if the boats are used for smaller lakes and rivers or for ocean sailing. This makes it more difficult to give an accurate number for the expected local fleet. The regatta boats are only a relatively small amount of the boats expected to be the seasonal fleet. The downside of using the regatta for the expected yachts, is that it gives a wide range of uncertainties on size distribution, leading to a high level of uncertainty.

The estimated local fleet is depended of the people living in the area. In real life, their economical capacity is of as much importance as the amount of people living nearby. In the MCDA in this report, this is not taken into account. This gives a high degree of uncertainty to the local fleet.

The breakwater is designed with the assumption that single layer cubes will be used. Single layer cubes are not the best researched armour layer. The damage allowed on a single cube armour layer is low. It might be advisable to see if other armour types are more economical.

For the stones used in the breakwater design, it is assumed that they can be supplied. This might not be the case if the change in sizes of stones leads to a new layer calculation to make sure the thickness of the layer is correct. The hinterland should be checked on a good stone quarry and the strength and sizes of the stones should be assessed. The distribution of the stones is important as well for the layers as for the core rubble.

The breakwater was calculated for a wave with a 90 degree angle of incidence on the breakwater. As the shape of the breakwater is curved, the breakwater should be tested on more angels.

The breakwater will have effect on the sediment transport and the sediment transport will have effect on the breakwater. The effects should be studied well, as the breakwater can cause erosion and sedimentation of beaches around the marina. Erosion of sediment can cause scour holes around the breakwater and make the breakwater unstable. Therefore a sediment transport study would be highly recommended.

When having selected a suitable location for a marina, attention should be paid to the mitigation of negative side-effects of the construction of the marina. When sediment transport gets blocked, erosion on the down stream side of the marina is inevitable. However, measures can be taken to mitigate this process. Beach nourishments can be done to prevent the retreat of the coastline, but also planting forests can spread out the erosion process over a longer stretch. This is also one of the reasons why it is recommended to construct a marina on the down drift side of a coastal area, where erosion problems have less consequences.

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Appendices

A

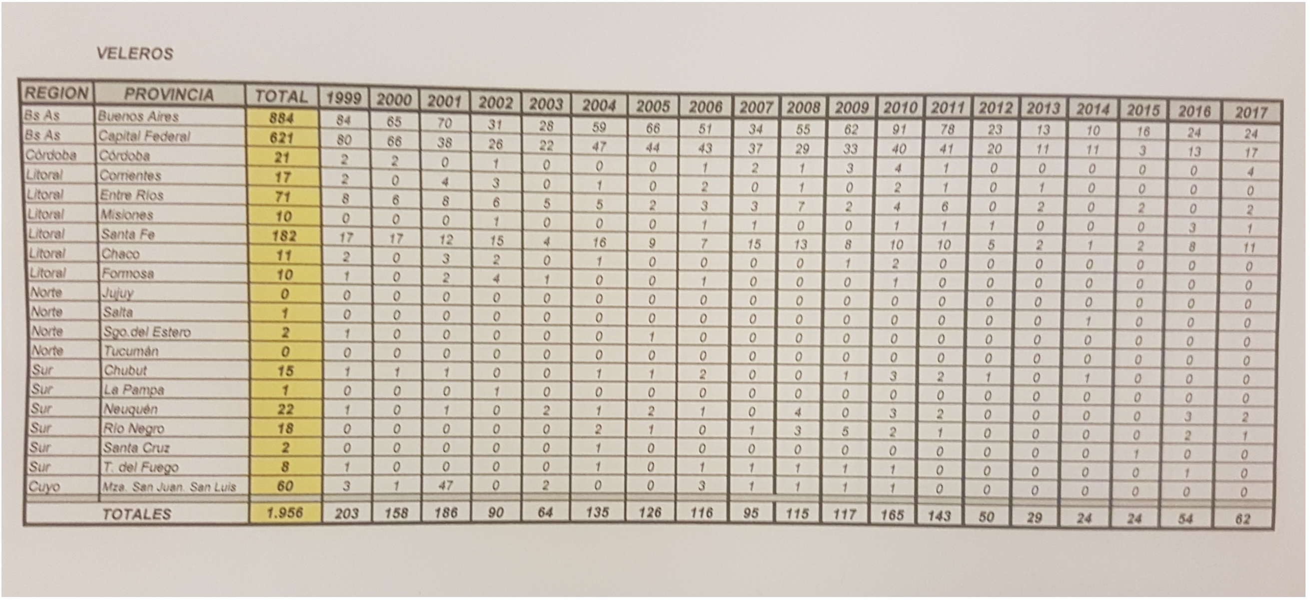
Fleet Analysis data

Sail No	Yacht Name	Owner	Type	Club	Finish Time	Length [m]	Beam [m]	Draft [m]
ARG-5400	B 612	Lucas Galvan	K 37	CRLP	DNF	11,37	3,7	2,5
ARG-3407	BWANA	Sergio Tagle	HOLLAND 44	CNSI	+3 06:04:07	13,4	4	2,2
ARG-4675	CLAWS	German Ruis Rysk	FAYD 30	CVB	DNF	9,4	3,27	1,8
ARG-4082	CROCODILE DADDY	Octavio Velez	PANDORA 31	CVB	+3 04:34:17	9,5	3,25	1,6
ARG-	DORMILON 3	Horacio Tettamanti	VICTORY 49	YCA	DNS	14,9	4,75	2,2
ARG-5705	EYE OF WHALE	Patricio Guisasola	32DUE	YCA	DNF	9,762	3,29	1,67
ARG-60	FJORD VI	Yacht Club Argentino	FRERS 43	YCA	+2 23:34:20	13,11	3,96	2,47
ARG-5349	GALE	Gerard Della Torre	PLENAMAR 350	CNO	+3 03:51:54	10,78	3,7	1,98
ARG-2357	HELENE	Alejandro Mitchell	F&C 44	YCA	+3 07:51:36	13,41	3,81	2,01
ARG-4545	HIGH RISK	Fernando Saux / Federico Volco	FAYD 30	YCCN	+2 23:41:37	9,4	3,27	1,8
ARG-3628	LIHUEN	Joaquín Dos Reis / Ignacio Ramayon	PLENAMAR 40	YCA	DNF	11,95	3,9	2
ARG-5170	MAX POWER	Arturo Morgan / Pablo Fenouil	MATCH 30	CUBA	DNF	9,12	3,04	2
ARG-4627	NICO	Marcelo Den Toom / Diego Ramos	MAGIC 33	YCA	+3 04:55:02	10,2	3,33	2,02
ARG-5448	PERICLES II	Guido Lepori / Caspar Sprungli	PANDORA 31	YCA	+2 23:56:24	9,5	3,25	1,6
URU-5555	PROMETHEUS	Harry Giuria / Alberto Mallo	IRC 305	YCU-YCPE	DNF	9,312	3,11	2
ARG-3661	RED	Luis Jimenez	ROVERE 50	CNSI	+3 00:22:41	15,26	4,24	2,3
ARG-3652	SAN SALVADOR	Leonardo Vugman / Ramiro Fehrmann	VICTORY 43	CNSE	DNS	12,98	4,17	2,01
ARG-5727	SANTA MARIA	Alejandro Cernadas / Mariano Perez	N 34.5	YCA	+2 21:34:17	10,45	3,38	1,95
ARG-3083	SOUTHERN	Santiago Braun	ARIES 37	YCA	+2 23:46:36	10,9	3,58	1,7
ARG-3230	TADEUS	Gustavo Rizzi / Ernesto Lagrava	F&C 40	YCA	DNS	12,19	3,53	2,07
ARG-5514	TATA	Quique Campolo / Cristian Pfisterer	N 34.5	CNQ	+2 19:56:32	10,45	3,38	1,95
ARG-5424	VALE 4	Mario Cappi	ROY 32	CNN	DNS	9,7	3,19	1,62

Table A.1: Boat data - Regatta Mar del Plata

Año	Cantidad
1980	8.558
1981	6.878
1982	4.997
1983	3.404
1984	3.293
1985	2.710
1986	2.266
1987	2.145
1988	1.916
1989	1.699
1990	1.353
1991	1.275
1992	1.523
1993	1.879
1994	3.584
1995	4.442
1996	4.408
1997	4.353
1998	4.528
1999	4.436
2000	3.519
2001	3.586
2002	1.694
2003	1.750
2004	2.026
2005	3.350
2006	4.342
2007	4.515
2008	5.890
2009	6.503
2010	8.174
2011	9.370
2012	7.858
2013	7.813
2014	6.901
2015	6.198
2016	5.773
2017	6.156

Figure A.1: New registered a year



VELEROS

REGION	PROVINCIA	TOTAL	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Bs As	Buenos Aires	884	84	65	70	31	28	59	66	51	34	55	62	91	78	23	13	10	16	24	24
Bs As	Capital Federal	621	80	66	38	26	22	47	44	43	37	29	33	40	41	20	11	11	3	13	17
Córdoba	Córdoba	21	2	2	0	1	0	0	0	1	2	1	3	4	1	0	0	0	0	0	4
Litoral	Corrientes	17	2	0	4	3	0	1	0	2	0	1	0	2	1	0	1	0	0	0	0
Litoral	Entre Ríos	71	8	6	8	6	5	5	2	3	3	7	2	4	6	0	2	0	2	0	2
Litoral	Misiones	10	0	0	0	1	0	0	0	1	1	0	0	1	1	1	0	0	0	3	1
Litoral	Santa Fe	182	17	17	12	15	4	16	9	7	15	13	8	10	10	5	2	1	2	8	11
Litoral	Chaco	11	2	0	3	2	0	1	0	0	0	0	1	2	0	0	0	0	0	0	0
Litoral	Formosa	10	1	0	2	4	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0
Norte	Jujuy	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Norte	Salta	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Norte	Sgo.del Estero	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Norte	Tucumán	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sur	Chubut	15	1	1	1	0	0	1	1	2	0	0	1	3	2	1	0	1	0	0	0
Sur	La Pampa	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sur	Neuquén	22	1	0	1	0	2	1	2	1	0	4	0	3	2	0	0	0	0	3	2
Sur	Río Negro	18	0	0	0	0	0	2	1	0	1	3	5	2	1	0	0	0	0	2	1
Sur	Santa Cruz	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Sur	T. del Fuego	8	1	0	0	0	0	1	0	1	1	1	1	1	0	0	0	0	0	1	0
Cuyo	Mza. San Juan. San Luis	60	3	1	47	0	2	0	0	3	1	1	1	1	0	0	0	0	0	0	0
	TOTALES	1.956	203	158	186	90	64	135	126	116	95	115	117	165	143	50	29	24	24	54	62

Figure A.2: Sailingboats per year

MATRICULACIONES REY Y JURISDICCIONALES AÑO 2017

REGION	PROVINCIA	MOTOS DE AGUA Y JET SKI	SEMIRRIGIDOS	VELEROS	CRUCEROS	LANCHAS	BOTES Y CANOAS	TOTAL
BUENOS AIRES	BUENOS AIRES	530	106	24	90	1118	107	1975
BUENOS AIRES	CAPITAL FEDERAL	74	14	17	86	253	14	458
CORDOBA	CORDOBA	6	1	4		89	6	106
CUYO	MENDOZA	1	2			11		14
CUYO	SAN JUAN	1	1			1		3
CUYO	SAN LUIS							0
LITORAL	CORRIENTES	12	2		2	357	77	450
LITORAL	ENTRE RIOS	65	5	2	6	507	55	640
LITORAL	MISIONES	27	1	1	6	244	33	312
LITORAL	SANTA FE	128	4	11	14	1209	42	1408
LITORAL	CHACO	9	1		2	173	7	192
LITORAL	FORMOSA	2				71	8	81
NORTE	CATAMARCA					1		1
NORTE	JUJUY					1		1
NORTE	SGO DEL ESTERO	1				8		9
NORTE	SALTA					4	1	5
NORTE	TUCUMAN	2			1	18	1	22
NORTE	LA RIOJA					3		3
SUR	CHUBUT	15	17		10	44	16	102
SUR	LA PAMPA	2	4			6	5	17
SUR	NEUQUEN	9	35	2	1	85	23	155
SUR	RIO NEGRO	9	36	1	2	85	27	160
SUR	SANTA CRUZ	3	4		1	11	2	21
SUR	TIERRA DEL FUEGO	6	6		1	4	4	21
		902	**239**	**62**	**222**	**4303**	**428**	**6156**

Figure A.3: Type of boat per location

MATRICULACIONES REY Y JURISDICCIONALES POR ESLORAS

ESLORAS	Año 2014			Año 2015			Año 2016			Año 2017		
	Rey	Jurisd.	Total	Rey	Jurisd.	Total	Rey	Jurisd.	Total	Rey	Jurisd.	Total
Menores a 5	753	2440	3193	684	2074	2758	371	2778	3149	555	2185	2740
De 5 a 7	2938	440	3378	2740	424	3164	1770	641	2411	2600	405	3005
De 7 a 9	199	2	201	188	0	188	128	2	130	241	0	241
De 9 a 11	77	0	77	56	0	56	47	0	47	85	0	85
de 11 a 14	30	0	30	21	0	21	20	0	20	40	0	40
Mayores a 14	22	0	22	11	0	11	16	0	16	45	0	45
			6901			6198			5773			6156

Figure A.4: Size a year

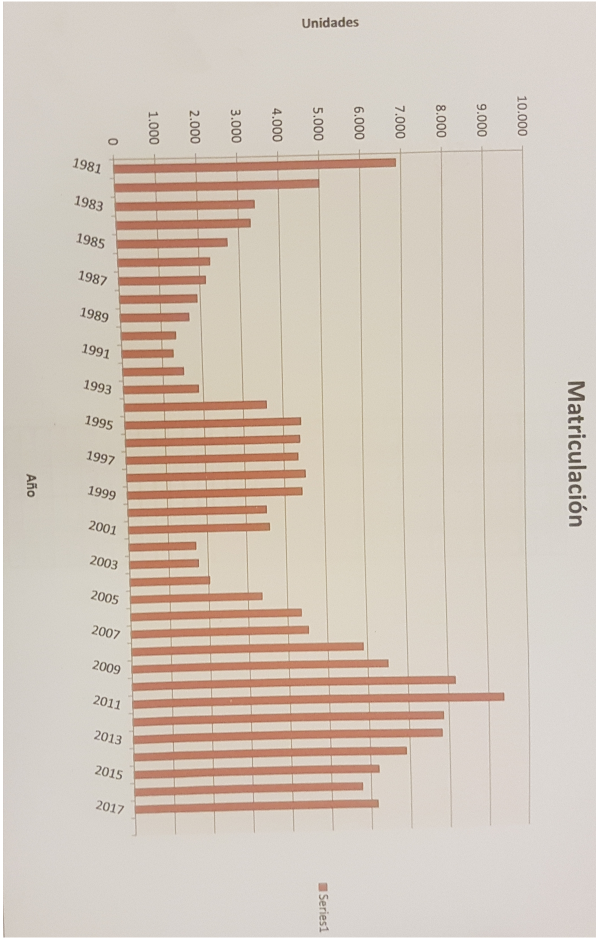


Figure A.5: New registered a year

B
Stakeholder Analysis data

Group	Name	Actor	Interest	Problem perception	Goals	Important resources	Resource description
D	PDE	Project Developers	Building grounds raise in value. Optimise profits between realising sufficient marinas and sustaining a sufficient number durable and innovative solutions. A pleasant recreational environment which meets the requirements of a state-of-the-art marina. Raise usage popularity Maximum utilisation.	Generating profits while finding sufficient number of financing parties in combination with a suitable business model.	Maximise profit.	Investments, expertise and decision-making regarding construction.	-
D	CON	Contractors	Conventional building methods. Good accessibility towards the building grounds.	Using sustainable solutions and building methods will cost the contractor more money, and will generate less profits.	Maximise profit.	Expertise	-
G	MUN	Municipality	An increase in dwellings. An increase of services to strengthen the location as residential area. Better accessibility from hinterlands towards the coastal residential areas. An increase in job opportunities. An increase in recreational water activities aimed at all generations.	Not evenly dividing the marinas along the shore of the province of Buenos Aires, which gives an unfair benefit to certain municipalities.	Increase the number of dwellings, industry, national and international popularity, economic growth, and job opportunities within the specific municipality.	Decision making, legislative power, allocating budgets.	-

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Group	Name	Actor	Interest	Problem perception	Goals	Important resources	Resource description
G	PRO	Province of Buenos Aires	Good and decent accessibility to the hinterlands. The cities located to the shore need to experience benefits from the network. An increase in job opportunities.	Not evenly dividing the marinas along the shore of the province of Buenos Aires, which gives an unfair benefit to certain municipalities. Some parts the province will still be inaccessible because a marina will only be implemented on locations which are suitable in terms of financing and popularity.	Increase the number of dwellings, industry, national and international popularity, economic growth, and job opportunities.	Decision making, legislative power, allocating budgets.	-
G	NAT	National Government	Good and decent accessibility to the hinterlands. Marinas built according international standards. An increase in job opportunities. Marinas to be equipped to be able to facilitate marine army vessels.	Not evenly dividing the marinas along the shore of the province of Buenos Aires, which gives an unfair benefit to certain municipalities.	Increase the number of dwellings, industry, national and international popularity, economic growth, and job opportunities.	Decision making, legislative power, allocating budgets.	-

Continued on next page

Group	Name	Actor	Interest	Problem perception	Goals	Important resources	Resource description
P	YCL	Yacht clubs	An increase in berthing places and marinas along the coast. Additional facilities and services for their members. Able to organise a regatta along the coast of the province. Marinas built according international standards.	An insufficient increase of (new) members and yachts using the new clubs.	Expanding the network of yacht clubs and increase the amount of members and related (sailing) yachts.	Lobbying, expertise	-
F	REA	Real estates developers	A private-public division within the marina, which includes private access to the marina and owner occupied berthing places. Being able to built owner-occupied houses in the higher segment. A private-public division within the marina, which includes private access to the marina and owner occupied berthing places. Sustainable buildings and building methods. A pleasant living environment	An insufficient increase in popularity regarding certain marinas.	Maximise profit.	Investments, expertise	-
F	INV	Investors	A long-term assurance of returns per year. Not being exposed to an extensive amount of risk.	Finding a sufficient amount of financing parties in combination with a profitable business model.	Maximise return on investment.	Investments, expertise.	-

Continued on next page

Group	Name	Actor	Interest	Problem perception	Goals	Important resources	Resource description
K	EAU	Emergency authorities	Good accessibility towards hospitals and clinics located in the hinterlands. Optional: incorporating a heli-deck located nearby the marinas. A response time of fifteen minutes. Share their knowledge with others.	Not located within a sufficient range of a hospital or clinic.	Presence and accessibility in the area.	Expertise, non-approval	The emergency services body of knowledge is so extensive and multi-faceted that only they can make proper assessments of emergency response.
E	NPG	Nature Preservation Groups	Sustainable buildings and building methods. Preserve the current landscape and flora and fauna.	The building and exploiting of marinas will interrupt the landscape and flora and fauna as it is.	No interruption of current flora and fauna and in affecting the current national parks along the shore.	Lobbying, power/influencing public opinion	-
E	ENV	Environmental Interest Groups	Sustainable buildings and building methods.	Not using sustainable building methods and implementing a sufficient number of sustainable solutions into the design.	Development of sustainable and innovative marinas.	Lobbying, power/influencing public opinion, sustainability expertise.	Environmental interest groups have various research groups and knowledge readily available about sustainability of building materials and about best practices of sustainable building worldwide.

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Group	Name	Actor	Interest	Problem perception	Goals	Important resources	Resource description
P	FIS	Fishing Industry	Expanding the fleet of fishing ships. Incorporating berthing places for fishing ships, plus their facilities in the marinas.	The building and exploiting of marinas will interrupt the fishing grounds and working fleet.	Being able to expand the industry and not being disrupted by the attendance of the sailing yachts near the shore and on the fishing grounds.	Power/influencing public opinion	-
P	COA	Coastal Operators	Afraid for interruption of the sediment transport which will influence the coastline. Expanding their business due to more popularity and customers.	Afraid for interruption of the sediment transport which will influence the coastline.	No interruption in the current sediment transport.	Protest and leaving the area.	-
U	TOU	Tourism	Sufficient number of hotels and apartments. Sufficient number of restaurants and bars. Sufficient activities nearby the marinas. Accessibility to national natural parks in the nearby regions.	Not a sufficient number of activities available which will result in a shortage of growth in tourism, and will insufficiently increase the popularity ad usage of the marinas.	Offer a sufficient number of hotels, restaurants, bars and activities.	Avoiding usage of the marinas and hinterlands, expertise	-

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Group	Name	Actor	Interest	Problem perception	Goals	Important resources	Resource description
U	INH	Inhabitants	Retaining the living environment. An increase in recreational water activities aimed at all generations. Incorporating dry stockig facilities in the to be built marinas. Incorporating facilities which will enhance the recreational activities and possibilities for water sports. An increase in job opportunities. An increase in berthing places for local fishing ships.	Interruption of daily live and changing the living environment in a negative perspective.	Continuing the pleasant living environment, an increase in job opportunities and enhancing the local economics.	Protest and leaving the area.	Residents have the unique experience and perception of living in a particular place, which cannot be matched by any static, technical information.
U	YAC	Sailing Yacht Owners	Sufficient number of berthing places. Incorporating dry stocking facilities in the to be built marinas. Good and decent accessibility to the hinterlands. Marinas built according international standards.	Insufficient number of places and facilities in the newly built marinas. Unattractive route to sail which will decrease the popularity of sailing along the coast of the province of Buenos Aires.	Extending the current sailing routes and increasing the number of berthing places.	Avoiding usage of the marinas, expertise.	-

Table B.1: IPGAP Table

Group	Name	Actor	Important resources	Replaceability Low/Moderate/High	Resource importance Low/Moderate/High	Dependency Low/Moderate/High	Critical actor Yes/No
D	PDE	Project Developers	Investments, expertise and decision-making regarding construction	Moderate	High	High	Yes
D	CON	Contractors	Expertise	High	Low	Low	No
G	MUN	Municipality	Decision making, legislative power, allocating budgets.	Low	High	High	Yes
G	PRO	Province of Buenos Aires	Decision making, legislative power, allocating budgets.	Low	High	High	Yes
G	NAT	National Government	Decision making, legislative power, allocating budgets.	Low	High	High	No
P	YCL	Yacht clubs	Lobbying, expertise	Moderate	Moderate	Moderate	No
F	REA	Real estates developers	Investments, expertise	Moderate	High	Moderate	No
F	INV	Investors	Investments, expertise	Moderate	High	High	No
K	EAU	Emergency authorities	Expertise, non-approval	Low	Low	High	No
E	NPG	Nature preservation groups	Lobbying, power/influencing public opinion	Moderate	Moderate	Moderate	No
E	ENV	Environmental interest groups	Lobbying, power/influencing public opinion, sustainability expertise.	Moderate	Moderate	Moderate	No
P	FIS	Fishing industry	Power/influencing public opinion	High	Low	Low	No
P	COA	Coastal operators	Protest and leaving the area	High	Low	Low	No
U	TOU	Tourism	Avoiding usage of the marinas and hinterlands, expertise	Moderate	Moderate	Low	No
U	INH	Inhabitants	Protest and leaving the area	Low	Low	Moderate	No
U	YAC	Sailing yacht owners	Avoiding usage of the marinas, expertise	Low	Moderate	High	No

Table B.2: Actor criticallity

Group	Name	Actor	Power 0/+/++/+++	Interest 0/+/++/+++	Attitude -/0/+/++	Role	Description
D	PDE	Project developers	+++	+++	+	Sleeping Giant	Influential passive backer
D	CON	Contractors	0	+	+	Acquaintance	Insignificant passive blocker
G	MUN	Municipalities	+++	+++	++	Saviour	Influential active backer
G	PRO	Province of Buenos Aires	+++	++	+	Saviour	Influential active backer
G	NAT	National government	+++	0	0	Time Bomb	Influential active blocker
P	YCL	Yacht clubs	+	+++	++	Friend	Insignificant active backer
F	REA	Real estates developers	++	+	+	Sleeping Giant	Influential passive backer
F	INV	Investors	++	++	0	Time Bomb	Influential active blocker
K	EAU	Emergency authorities	0	++	++	Friend	Insignificant active backer
E	NPG	Nature preservation groups	0	+	-	Trip Wire	Insignificant passive backer
E	ENV	Environmental interest groups	0	+	-	Trip Wire	Insignificant passive backer
P	FIS	Fishing industry	+	+	-	Trip Wire	Insignificant passive backer
P	COA	Coastal operators	0	+	-	Trip Wire	Insignificant passive backer
U	TOU	Tourism	0	++	++	Friend	Insignificant active backer
U	INH	Inhabitants	0	+++	++	Friend	Insignificant active backer
U	YAC	Sailing yacht owners	+	+++	++	Friend	Insignificant active backer

Table B.3: Actor typology

C

Stratigraphy of Pinamar region

Depth [m]	Lithological characterisation	Classification	Layer's code
0.0 - 0.1	Black sandy clay	saCl	XII
0.1 - 8.5	Yellowish brown fine sand with crushed shell; clay intercalations in the last meter	FSa$\underline{cl}$	I
8.5 - 9.25	Black clay with organic content	orCl	XI
9.25 - 11.0	Partly sandy greyish green clay with shell fragments	saCl	IVb
11.0 - 15.3	Clayey sand to sandy, gritty, brown clay with fragments of shell; intercalations of greenish, grey, sandy clay with hard sandy aggregates at the base	clSa/grsaCl	Vc
15.3 - 16.5	Greenish to whitish grey, very clear clay with hard and coarse sandy aggregates	csaCl	VIIa
16.5 - 17.0	Reddish brown clay to sandy clay	Cl/saCl	VIIb
17.0 - 19.5	Greyish white sandy clay with a few shell grains	saCl	VIIc
19.5 - 20.5	Dark greyish brown sand with fragments of shell and intercalations of whitish grey clay	Sa$\underline{cl}$	VIII
20.5 - 22.8	Reddish brown clay and clay with fragments of shells	Cl	IXa
22.8 - 23.7	Greenish brown clay with shells and some reddish brown clay	Cl	IXb

Table C.1: Lithostratigraphy - Borehole 1 [55]

Depth [m]	Lithological characterisation	Classification	Layer's code
0.0 - 12.1	Fine, yellowish brown sand with fragments of shell in the middle sector and light grey-green intercalations in the lower sector	FSacl	I
12.1 - 12.25	Black clay (organic content)	orCl	XI
12.25 - 14.75	Greyish green clay with fragments of shell	Cl	IIb
14.75 - 16.9	Brown to greenish brown fine to very fine sand with fragments of shell	FSa	III
16.9 - 17.65	Greenish grey to whitish grey gritty clay	csaCl	IVb
17.65 - 20.9	Brownish grey to greyish brown clayey sand with fragments of shell and coarse sand (very compacted)	clSa	Vb
20.9 - 25.4	Shells with coarse sand and gravel. Intercalations of blue-green clay. Partly, brownish grey sand with abundant shell.	grcsaOrcl	X
25.4 - 26.4	Reddish brown sandy clay interspersed with sandy grey-green clay.	saCl	VIIb

Table C.2: Lithostratigraphy - Borehole 2 [55]

Depth [m]	Lithological characterisation	Classification	Layer's code
0.0 - 0.2	Black clay with abundant plant material	orCl	XI
0.2 - 1.5	Greenish yellow to yellowish green clay with ocher spots	Cl	IIa
1.5 - 2.6	Greyish green clay with fragments of disseminated shell	Cl	IIb
2.6 - 5.25	Brown to brownish clay with crudes (very compacted)	Cl	IIc
5.25 - 9.25	Dark brown sand, shells	Sa	Va
9.25 - 12.0	Dark green clay interspersed with sandy shell	Clsa	VIa
12.0 - 14.6	Reddish brown, sandy clay with shells	saCl	VIIb
14.6 - 19.5	Greyish green clay, partly sandy, with fragments of shell (compacted)	saCl	VIIc
19.5 - 21.0	Light green, partly brownish green clay with shredded and coarse shell (very hard)	Cl	IXb

Table C.3: Lithostratigraphy - Borehole 3 [55]

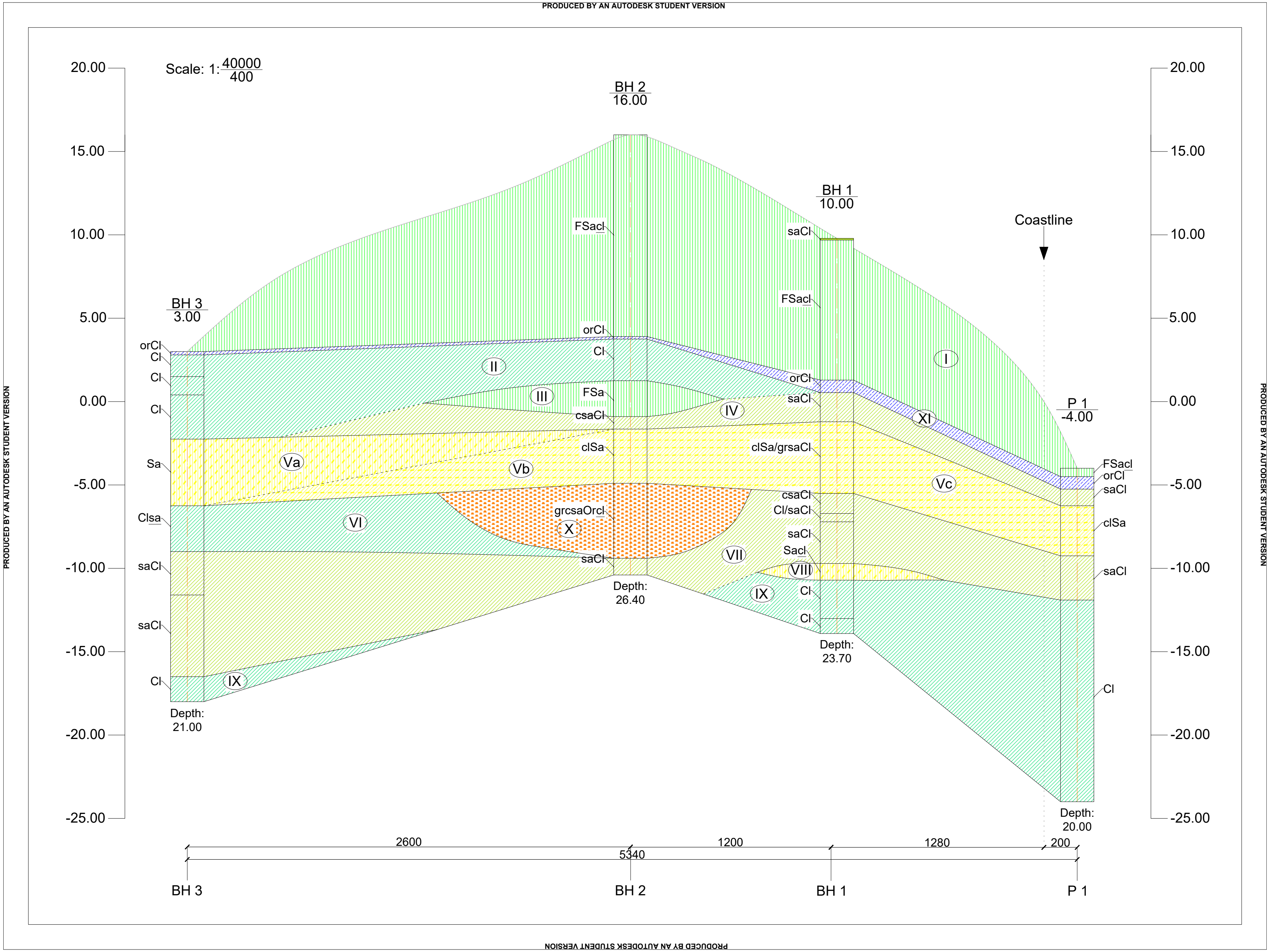

Figure C.1: Stratigraphy of Pinamar (noted scale is based on a full size A4 format)

D

Evolution of safe-cruising range

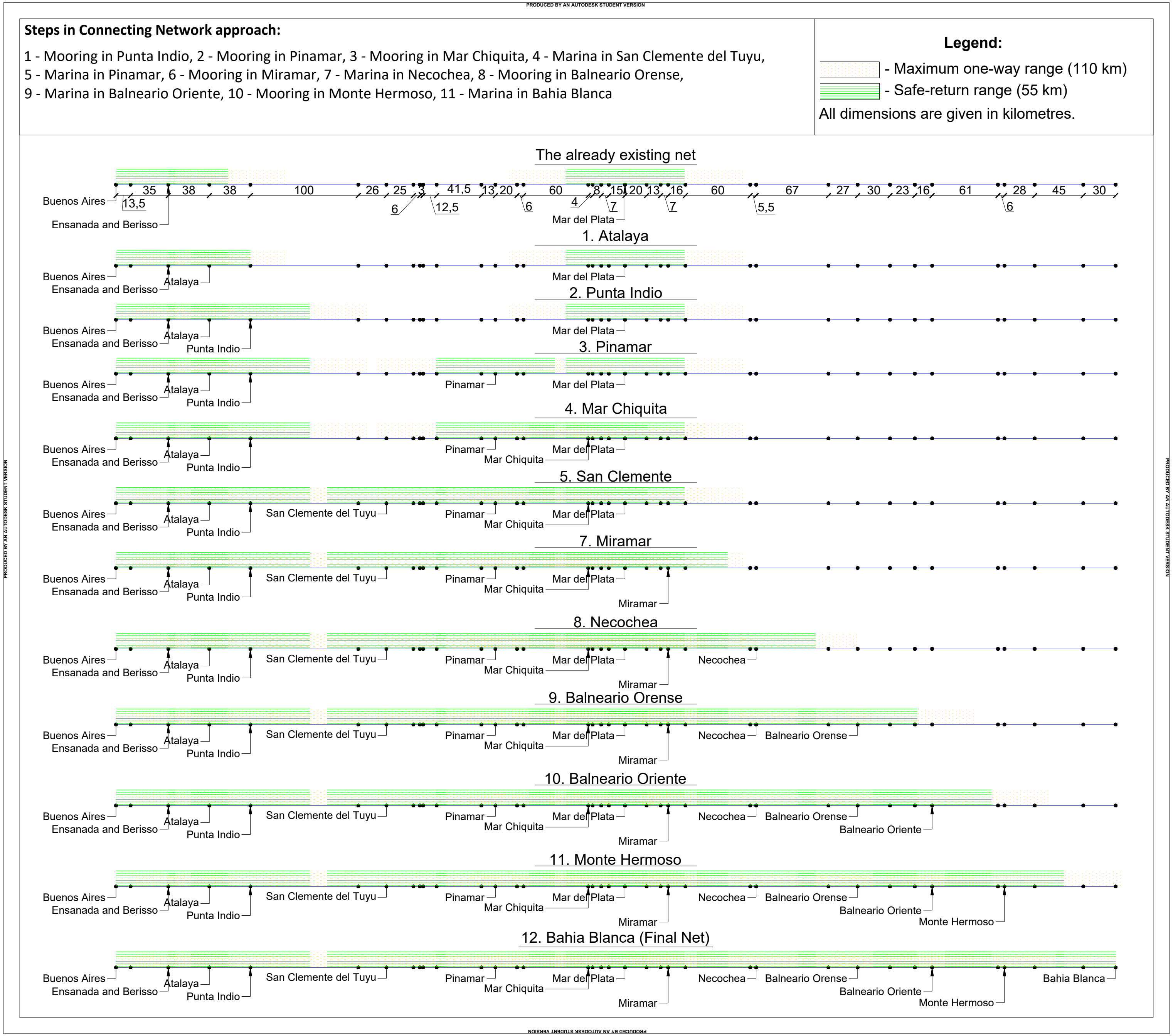

Figure D.1: Connecting Network approach

E

Multiple-Criteria Decision Analysis Matrices

	Criteria							
	Accessibility	Tourism	Dredging	Nat. harbour	Waves	Sediment	Tides	Population
Alternatives	[-]	[-]	[meters]	[Yes/No]	[sq. meters]	[-]	[meters]	[%]
Atalaya	4,498,362	28	900	Yes	0.75	42,033	0.70	3.57
Punta Indio	805,590	16	5,000	No	0.75	42,033	0.71	4.76
General Lavalle	179,344	2	11,000	Yes	1.73	57,941	0.78	7.13
San Clemente del Tuyu	179,344	82	4,500	Yes	1.73	57,941	0.80	7.13
Las Toninas	179,344	134	200	No	1.73	57,941	0.82	7.13
Santa Teresita	179,344	156	200	No	1.73	57,941	0.83	7.13
Mara del Tuyu / Costa del Este	179,344	264	500	No	1.73	57,941	0.81	7.13
Mar de Ajó	200,623	227	200	No	1.73	57,941	0.72	7.40
Costa Esmeralda	182,005	6	200	No	1.37	63,485	0.70	7.72
Pinamar	828,036	464	200	No	1.37	63,485	0.70	4.17
Villa Gesell	828,036	378	500	No	1.37	63,485	0.72	4.17
Mar Azul	828,036	299	200	No	1.37	63,485	0.72	4.17
Mar Chiquita	845,895	23	200	Yes	1.90	58,017	0.78	4.05
Mar de Cobo	845,895	73	200	No	1.90	58,017	0.78	4.05
Santa Clara del Mar	849,880	72	200	No	1.90	58,017	0.79	4.05
Barrio Felix Camet	849,880	40	200	No	1.74	54,195	0.80	4.05
Mar del Plata	875,068	534	0	Yes	1.74	54,195	0.81	3.77
Chapadmalal	787,675	40	200	No	2.90	58,365	0.85	3.26
San Eduardo del Mar	787,675	134	500	No	2.90	58,365	0.88	3.26
Miramar	834,141	201	200	No	2.90	58,365	0.89	3.16
Mar del Sur	834,141	6	200	No	3.10	49,498	0.93	3.16
Costa Bonita	821,261	12	200	Yes	3.10	49,498	1.05	2.98
Necochea	821,261	146	0	Yes	2.70	44,889	1.06	2.98
Balneario San Cayetano	158,442	3	200	No	2.70	44,889	1.46	1.13
Balneario Orense	65,509	9	200	No	2.70	44,889	1.62	0.61
Claromeco	65,509	45	200	No	2.70	44,889	1.80	0.61
Balneario Oceano	91,481	23	200	No	2.70	44,889	1.94	0.03
Balneario Oriente	91,481	10	200	Yes	2.70	44,889	2.03	0.03
Balneario Sauce Grande	443,158	155	200	No	1.56	42,675	2.39	0.97
Monte Hermoso	443,158	155	200	No	1.56	42,675	2.43	0.97
Balneario Pehuen-co	443,158	34	200	No	1.56	42,675	2.72	0.97
Punta Alta	413,828	66	0	Yes	2.00	63,485	3.18	1.50
Bahia Blanca	429,335	250	0	Yes	1.00	63,485	2.59	1.78

Table E.1: Numerical values per alternative

	Weight factor per criteria							
	Accessibility	Tourism	Dredging	Nat. harbour	Waves	Sediment	Tides	Population
Alternatives	0.192	0.100	0.128	0.152	0.116	0.134	0.098	0.0800
Atalaya	0.192	0.005	0.118	0.152	0.109	0.086	0.076	0.037
Punta Indio	0.109	0.003	0.070	0.000	0.109	0.086	0.076	0.049
General Lavalle	0.064	0.000	0.000	0.152	0.080	0.022	0.074	0.074
San Clemente del Tuyu	0.066	0.015	0.076	0.152	0.080	0.022	0.073	0.074
Las Toninas	0.066	0.025	0.126	0.000	0.080	0.022	0.073	0.074
Santa Teresita	0.066	0.029	0.126	0.000	0.080	0.022	0.072	0.074
Mara del Tuyu / Costa del Este	0.066	0.049	0.122	0.000	0.080	0.022	0.073	0.074
Mar de Ajó	0.069	0.043	0.126	0.000	0.080	0.022	0.076	0.077
Costa Esmeralda	0.067	0.001	0.126	0.000	0.093	0.000	0.076	0.080
Pinamar	0.109	0.087	0.126	0.000	0.093	0.000	0.076	0.043
Villa Gesell	0.109	0.071	0.122	0.000	0.093	0.000	0.076	0.043
Mar Azul	0.109	0.056	0.126	0.000	0.093	0.000	0.076	0.043
Mar Chiquita	0.110	0.004	0.126	0.152	0.072	0.022	0.074	0.042
Mar de Cobo	0.110	0.014	0.126	0.000	0.072	0.022	0.074	0.042
Santa Clara del Mar	0.110	0.013	0.126	0.000	0.072	0.022	0.074	0.042
Barrio Felix Camet	0.110	0.007	0.126	0.000	0.079	0.037	0.073	0.042
Mar del Plata	0.111	0.100	0.128	0.152	0.079	0.037	0.073	0.039
Chapadmalal	0.107	0.007	0.126	0.000	0.014	0.020	0.072	0.034
San Eduardo del Mar	0.107	0.025	0.122	0.000	0.014	0.020	0.071	0.034
Miramar	0.109	0.038	0.126	0.000	0.014	0.020	0.071	0.033
Mar del Sur	0.109	0.001	0.126	0.000	0.014	0.020	0.069	0.033
Costa Bonita	0.108	0.002	0.126	0.152	0.000	0.056	0.066	0.031
Necochea	0.108	0.027	0.128	0.152	0.000	0.056	0.065	0.031
Balneario San Cayetano	0.062	0.001	0.126	0.000	0.028	0.074	0.053	0.012
Balneario Orense	0.046	0.002	0.126	0.000	0.028	0.074	0.048	0.006
Claromeco	0.046	0.008	0.126	0.000	0.028	0.074	0.043	0.006
Balneario Oceano	0.051	0.004	0.126	0.000	0.028	0.074	0.038	0.000
Balneario Oriente	0.051	0.002	0.126	0.152	0.028	0.074	0.035	0.000
Balneario Sauce Grande	0.087	0.029	0.126	0.000	0.087	0.083	0.024	0.010
Monte Hermoso	0.087	0.029	0.126	0.000	0.087	0.083	0.023	0.010
Balneario Pehuen-co	0.087	0.006	0.126	0.000	0.087	0.083	0.014	0.010
Punta Alta	0.085	0.012	0.128	0.152	0.068	0.000	0.000	0.016
Bahia Blanca	0.087	0.047	0.128	0.152	0.104	0.000	0.018	0.018

Table E.2: Scoring matrix (incl. normalised scores and weight factors)

F

Wind fetch

Wave height (Fetch - Windspeed).jpg

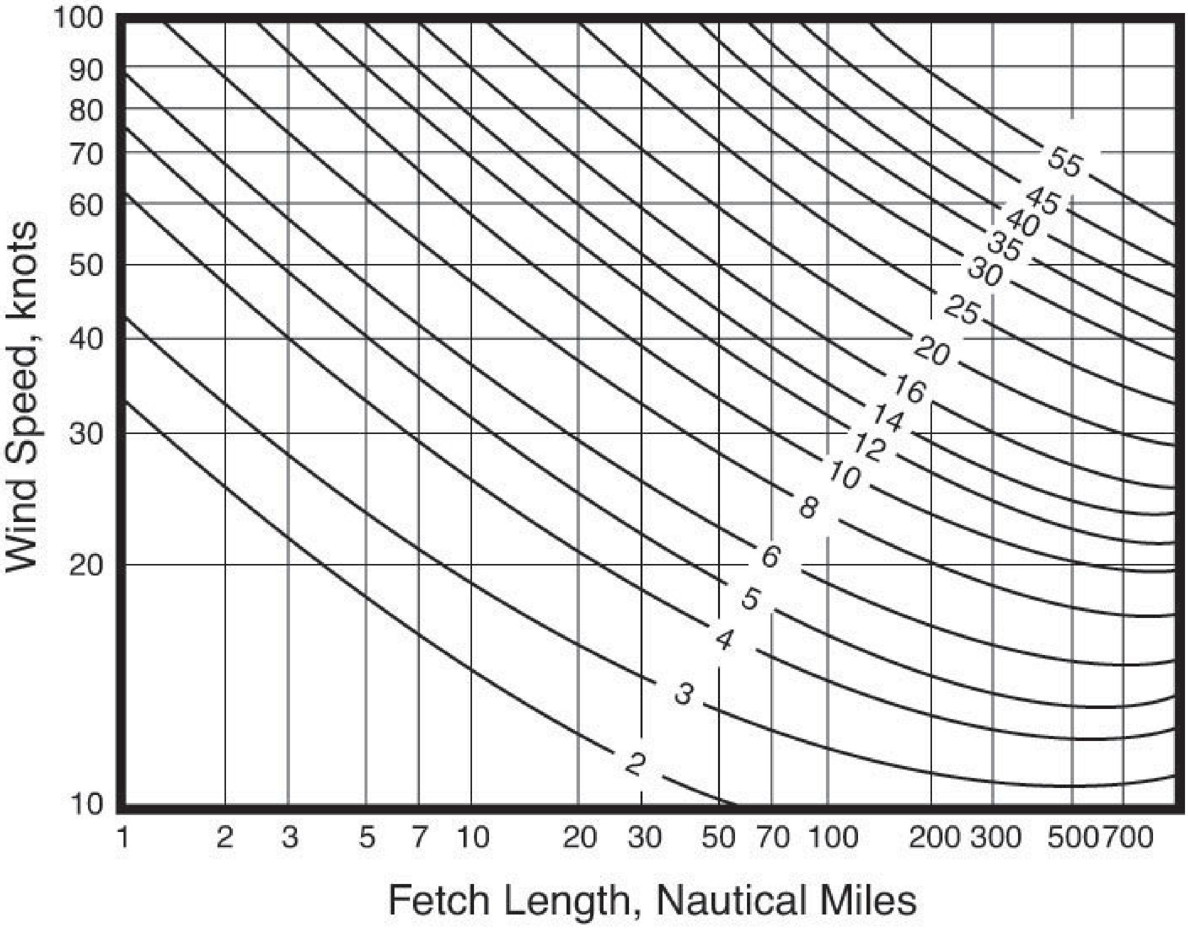

Figure F.1: Windspeed vs Fetch

G

Particle size distribution of sediment

Location	On-site description	$\mu(D_{10})$ (μm)	$\mu(D_{50})$ (μm)	$\mu(D_{90})$ (μm)	$\sigma(D_{10})$ (μm)	$\sigma(D_{50})$ (μm)	$\sigma(D_{90})$ (μm)
Punta Rosa	Sand	0.127	0.191	0.249	-	-	-
San Clemente Bay	Muddy material	-	-	-	-	-	-
Mar del Tuyu	Sand	0.134	0.202	0.337	-	-	-
Pinamar	Coarse sand	0.147	0.212	0.400	-	-	-
Villa Gesell	Coarse sand	0.172	0.318	0.500	-	-	-
Mar Chiquita Lagoon	Sand	-	-	-	-	-	-
Mar Chiquita Coast	Sand	0.142	0.207	0.366	-	-	-
Mar del Plata	Sand/Coarse sand	0.140	0.200	0.292	0.013	0.010	0.064
Mar del Plata Port	Sand	0.102	0.160	0.260	0.033	0.032	0.058
Los Acantilados Cliff	Muddy material	-	-	-	-	-	-
Los Acantilados Beach	Nourished sand	0.128	0.186	0.242	-	-	-
Miramar Beach	Coarse sand	0.181	0.304	0.413	-	-	-
Miramar Cliff	Muddy material	-	-	-	-	-	-
Miramar Dune	Sand	-	-	-	-	-	-

Table G.1: Sediment properties - grain size distribution [7]