The future of Bocagrande

Appendices

Contents

Appendix A. Stakeholder analysis

Actor	Interests	Goals	Current situation	Causes
Municipality of Cartagena (the Mayor and the departments)	- Wellbeing of the citizens of Cartagena -Commercial activities on Bocagrande	- Increase the economic position of the city and improve the quality of life of its population, with emphasis on low-income communities - Increase income by increasing space for commercial activities (hotels, restaurants, bars, SM-Enterprices)	- Inaccessibility of Bocagrande - Damage to infrastructure due to overtopping of waves - Increase of Hotels & SMEs - Damages to buildings & property	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Severe storms - Rainfall - Increased # of buildings
Hotel Owners	- Making profit - Continuity of their business	- Convincing the mayor to do something about the accessibility and the floodings - Increasing protection against floodings	- Inaccessibility of their Hotel - waterlogging - Decrease of beach during raining season - Low occupation	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Severe storms - Rainfall - Increased of # of buildings
Public Transport providers	- Making profit	- Making more trips with more people - Decreasing their travel time	- Damage to vehicles due to salt water - Increase of travel time	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Server storms - Rainfall

				- Increased # of buildings
Residents of Bocagrande	- Good livable environment, high quality of life	- Increasing protection against floodings - Convincing the authorities to do something about the accessibility and the floodings	- Damage to their property due to floodings - Long commuting - Inaccessibility of their homes	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Server storms - Rainfall - Increased # of buildings
Part-time residents of Bocagrande	- Attractive holiday environment	- Retaining their attractive holiday address - High occupation rate	- Damage to their property due to floodings - Inaccessibility of their apartment	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Severe storms - Rainfall - Increased # of buildings
Tourists & visitors	- Nice and untroubled vacation	- Having an untroubled and nice vacation	- Bad access to hotel and other tourist sites - Small beaches during rainy season	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Severe storms - Rainfall - Increased # of buildings
Naval Base Cartagena	- Protection of the nation	- Expand and relocate their base to Tierra Bomba	- Unsafe position of the base	- Only one access point to the sea
SMEs	- Sell goods and services on Bocagrande	- Increasing protection against floodings - Convincing the mayor to do	- Damage to their property due to floodings - Less customers during floodings	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity

		something about the accessibility and the floodings	- Inaccessibility of their businesses	- Lack of drainage - Sea level rise - Severe storms - Rainfall - Increased # of buildings
Regional Port Society (SPRC)	- Make profit from the exploitation of the port - Concerned with the general interest of Cartagena (Cpt. Salas is very concerned with the development of Cartagena)	- Optimal profitability - Contribute to the development of Cartagena - Better Connectivity between Bocagrande and the rest of the city, especially Manga - Better flow of traffic through Manga	- Bad accessibility of Bocagrande and Manga - Flooding and erosion threaten future of Bocagrande	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Severe storms - Rainfall - Increased # of buildings
Employees Bocagrande	-Earning money	- Decrease of travel time - Increase of work	- Long commuting time	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Severe storms - Rainfall - Increased # of buildings

Table A.1 Directly affected stakeholder inventory

Actor	Important Resources	Replaceability	Dependency	Critical?
Municipality of Cartagena (the Mayor and the departments)	-Funds and connection to department of Bolivar - Decision power over every project concerning public space - Regulation - Including mitigations and adaptions to climate change	Low	High	Yes
Hotel Owners	- Money to implement own solutions against flooding - Lobby through association and directly with higher governmental institutions - Blocking power (court)	High	Medium	No
Public Transport providers	- Local knowledge of roads and flooding areas - Strikes - Busses	High	Medium	No
Residents of Bocagrande	- Blocking power (court) - Voting power	Low	High	Yes
Part-time residents of Bocagrande	- Money to implement solutions against flooding - Blocking power on local issues	Medium	Low/Medium	No
Tourists & visitors	- Money to spend on holiday	Medium	High	Yes
Naval Base Cartagena	- Institutional power, direct link to ARMADA	Low	High	Yes
SMEs	- Blocking power - Voting power	Medium	Medium	No
Regional Port Society (SPRC)	- Funds - Lobby power through Cpt. Salas	Low	Medium	Yes
Employees Bocagrande	- Voting power	High	Medium	No

Table A.2 Directly affected stakeholder resources, replaceability, dependency and criticality

Direct actors

The direct actors, are those actors who are directly affected by the problem(s). The actors have different issues concerning the problems and different resources they can use to support their goals. Below the actors are described in more debt with some explanation concerning their interests and resources.

Municipality of Cartagena (mayor and the departments)

The municipality of Cartagena has to deal with several issues concerning Bocagrande. The main issue is the inaccessibility of Bocagrande. The road capacity became insufficient due to the great increase in the number of buildings (hotels, restaurants, apartments) on Bocagrande in the last 10 years. The inaccessibility becomes even worse when Bocagrande is flooded, due to high water, a storm, heavy rainfall or a combination of these three. The floodings also cause damage to buildings and infrastructure. Besides solving these issues, the municipality wants to increase their economic position by increasing the commercial activities on Bocagrande even more, to attract more tourist and to increase their income. Every commercial activity; restaurant, bar or hotel, has to pay taxes, which increases the income of the municipality.

There does not seem to be a very stable political situation in Cartagena. Over the last period the mayor was replaced a lot of times (Ramos 2011). This does not help to create a stable local political climate. Multiple stakeholders indicate that they do not have faith in good local governance. But the mayor is very important in order to move forward, since he has to approve and implement new projects.

Dealing with the local government might be a delicate matter because of the lack of stability and the fact that they have made certain plans themselves. Important is that these plans are just preliminary plans and nothing is final. This plan is not regarded as something that is really going to happen because of the low support among involved parties.

Hotel owners

The main issue of the hotel owners is the decrease of the accessibility of Bocagrande. Since the last 10 years more and more hotels were built on Bocagrande, but the infrastructure lagged behind. During high season (July/August, December/January) a trip form the airport to the end of Bocagrande will take you 50 minutes instead of 15 in low season (appendix B.2). The second issue of the hotel owners is the nuisance due to flooding. It depends of the hotel what kind of inconvenient they suffer due to flooding. Some of the hotels are not accessible, others have damage on property, this depends strongly where on Bocagrande the hotel is located. The third issue is the loss of beach during the winter months (November, December, January, and February). Hotel owners try to take care of their own situation. This is not a very strange thing considering that they have a business to run and have no support of the municipality on these three issues. The Hilton has for instance constructed groins close to their Hotel to protect their property and to gain more beach. Recently they performed maintenance on them and rebuilt one completely. This is done without the support of the municipality. For any work done near the ocean one needs permission from DIMAR, which they received.

The bigger hotels seem to be concerned with the problems on Bocagrande, and they really feel the need for solutions for the general good. They have invested in protecting themselves and their business. It is questionable if they would be willing to contribute to realizing solutions to the problems. Maybe the best is to at least involve them in solving things very locally (close to their Hotel). For instance the Hilton might be willing to partly fund measures that stop the street in front of their entrance to flood.

Public Transport providers

The public transport providers consists of taxies and buses, which are not really organized. Many taxies are just one man businesses and the bus transport is divided into small companies running their own lines with a number of busses. These do not cooperate to raise efficiency but just perform their own routes. So buses can be very empty during the day. This does not contribute to the accessibility of Bocagrande. The main issue for the busses and taxies is the inaccessibility of Bocagrande and the damage to their vehicles due to flooding. Especially during high season a trip to Bocagrande takes a lot of time and since the payment of a bus or taxi trip is based on travel distance, the operators are losing money. Due to flooding the travel time increases even more and due to the salt water their vehicles corrode.

It is currently almost impossible to steer this sector because they are all separate businesses. There is however a project that could contribute greatly to structuring public transport: The TransCribe project. The problem is that it is not yet ready for use because of some difficulties. The main problem seems that street vendor in the Bazurto area do not want to move and that local government has not been of very much help to solve this problem (appendix B.4). So the project is on a stand-still and what has been built is not used as planned and is already deteriorating. This problem is a matter of great attention. It is also important to take into account that the bus operators and drivers are not really supporting the TransCaribe project, because it's a change in the way of working and thinking.

Besides the busses they own the only resource the taxies and busses have is the opportunity to strike. But whether this affects the government more than themselves is doubtful.

Residents of Bocagrande

The people living on Bocagrande have to deal with the lack of accessibility every day. In high season the travel time to outside Bocagrande triples. This affects their commuting time negatively. The second issue the residents encounter are the floods. In some parts of Bocagrande the access to apartments can be blocked, especially on Castillo Grande and on El Laguito near the Hilton, some apartments are not attainable during a flood. The floods also cause damage to buildings and to property. The car parking of many apartment buildings is below the building, which are flooded during a flood. This causes a lot of damage to the cars and to the building.

Part-time residents of Bocagrande

From all the apartments on Bocagrande, a large part is used as part-time residence. Especially people from Medellin and Bogota have an apartment on Bocagrande for the weekends and holidays. These apartments are also for rent for tourist and visitors. Since 2006 the rent of these so called parahotelerias increased, which influenced the occupation of the hotels negatively. The owners of these apartments are less involved than the permanent residents. They only are interesting in the potential damage to their property caused by floods.

Tourists & visitors

The tourist and visitors of Cartagena choose Cartagena as a holiday destination because of the combination of beaches and cultural beauty. The tourists and visitors are a very important source of income for Cartagena. The last couple of years the amount of tourist has increased.

Cartagena knows two high seasons, July/August and December/January. During these seasons Bocagrande is almost complete inaccessible and the beaches are crowded. For the tourist it is important to have good access to their hotel or apartment and to other touristic sites. Improvement of the accessibility could make the stay of tourists much more pleasant. The tourists are important for the economy of the city and therefore are as a group a very important actor to keep in mind.

Naval Base Cartagena

The Naval base of Bocagrande is located on the North end of Bocagrande and does not have nuisance of the inaccessibility and floodings. The base has no room to expand and has only one exit way by water, which is very unusual for a naval base. That is why they want to move to the island of Tierra Bomba. This project is approved and the president has openly given his support to the project, also financially. But it will still take a long time before the movement can take place. Estimates are that it might take at least 8-10 more years (appendix B.2) The movement does give a lot of room and opportunities for solutions. But the city should not wait for this to happen, because it is very uncertain what exactly will happen with this plan. The movement of the base should be considered in the designing of solutions but depending heavily on the movement of the base might not be wise. This issue should be well considered.

SMEs

The small and medium enterprises are mostly shops, bars and restaurants owners on Bocagrande. They all have to deal with the floods and inaccessibility as well. Depending on the location on Bocagrande, some of the SMEs have to deal with these problems through the whole year and some only during some months. These actors are less influential actors, but nonetheless they might be able to influence on very local issues. When designing and implementing solutions it is wise to keep in mind that it does effect these actors.

Regional Port Society (RPSC)

The regional port society is the responsible actor for all the business concerning the harbour. The harbour is located in the Manga neighbourhood, which is an island. Many people use the island to pass through to other parts of the city, especially the people traveling from and to Bocagrande. For the port society it is important to have a good connection with the hinterland. That is why the port society is very interested and directly involved in the accessibility issue of Bocagrande. Captain Salas, is the director of the port society and is an important man with a lot of influence in the (local) government.

Employees Bocagrande

The employees on Bocagrande consists mostly of people working in the tourist industry (hotels, bars, restaurants). Most of the employees will be commuters that live in other parts of the city. Apart from the registered jobs, there are also many unregistered small vendors on the streets and the beaches. This increases the commuting especially in high season when there are more tourists. The employees have no real resources, apart from the power to vote once every four years.

Actor	Interests	Goals	Current situation	Causes
Governance (National): - National government of Colombia (including ministries) - ARMADA - DIMAR - ANLA - PROEXPORT - Department of Bolivar	- Wellbeing of the citizens of Colombia	- Improve the economic position of the country and improve the quality of life of its population - National government wants to prevent large damage from bad weather and climate change	- Problems Bocagrande are bad for Cartagena and indirectly for the country	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Server storms - Rainfall
Supporting institutions: - CIOH - INVEMAR - IDEAM - UNGRD - Universities (of Cartagena) - Society of Engineers and Architects	- Good reputation of the institute, by providing quality information to the (government) bodies they support	- Contribute to the development of Colombia and/or parts of Colombia by providing their service, expertise and knowledge	- Bocagrande faces problems that are related to their fields of expertise	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Server storms - Rainfall
Representative bodies: - Cartagena Tourism Corporation - COTELCO - ASOTELCO	- Representation of the interest of their members in various economic branches - Secondary interest for the complete industry and the common good of Colombia	- Strengthen the position of their members and/or a complete industry	- Problems on Bocagrande threaten the (long-term) prospects of economic activities on Bocagrande	- Lack of maintenance infrastructure - Lack of protection against high sea level - Insufficient road capacity - Lack of drainage - Sea level rise - Server storms - Rainfall

Table A.3 Indirectly affected stakeholder inventory

Actor	Resources	Replaceability	Dependency	Critical?
National government of Colombia	- Funds - Licenses - Decision power	Low	High	Yes
Department of Bolivar	- Funds (Oil royalties) - Decision power - Regulation	Low	High	Yes
DIMAR	- Policy making and regulating - Grant or deny licenses for any construction around the water	Low	High	Yes
ARMADA	- Decision power - Demanding power	Medium	Low	No
PROEXPORT	- Identify market opportunities - Support in the design of action plans - Contact between tourism branch and ministry of Commerce and Tourism	Medium	Low/Medium	No
National Environmental Licensing Authority (ANLA)	- Grant or deny licenses, permits and environmental procedures - Develop environmental regulations	Low	Medium	Yes
Risk Management Department (UNGRD)	- Supporting in information and advice for policy on regional level	Medium	Low/Medium	No
CIOH	- Oceanographic and hydrographic knowledge - Producing and executing research projects	Medium	Medium	No
INVEMAR	- Knowledge about oceanographics and marine ecosystems - Perform basic and applied research	Medium	Low/Medium	No
IDEAM	- Knowledge, data and environmental information	Medium	Low/Medium	No
Universities of Cartagena	- Knowledge	Medium	Low	No

Society of Engineers and Architects	- Knowledge on engineering and architecture	Medium	Low/Medium	No
Cartagena Tourism Corporation	- Local knowledge on tourism - Lobby	Medium	Medium	No
COTELCO	- Lobby for the hotels that are a member	Medium	Low	No
ASOTELCA	- Lobby for the hotels that are a member	High	Low	No

Table A.4 Indirectly affected stakeholder resources, replaceability, dependency and criticality

Indirect actors

In the first table the indirectly affected stakeholders are categorized into three group; Governance, Supporting institutes, and Representative bodies. This is done because of the great resemblance in interests, goals and perceptions among some stakeholders. The governance category has a lot of stakeholders, most of them are national government ministries and institutes. The supporting institutions are all institutes that have the main task of supporting actors in the governance category. Representative bodies are institutes that represent public or private entities, or a combination of both.

In the second table the stakeholders are assessed individually because their resources and criticality are unique to them. Most indirect stakeholders are not found to be critical actors. Only four are named critical: The national government (actually consisting multiple entities), the department of Bolivar, DIMAR and ANLA. They have resources that are crucial or can be crucial for the success of a project in Cartagena. DIMAR and ANLA must grant licenses and the national government and the district of Bolivar are primarily important because of their ability to fund a project. The other stakeholders are not critical because they are not necessarily needed in order to start a project to improve the situation of Bocagrande. Most are knowledge institutes that can be used to provide information.

Hierarchical chart

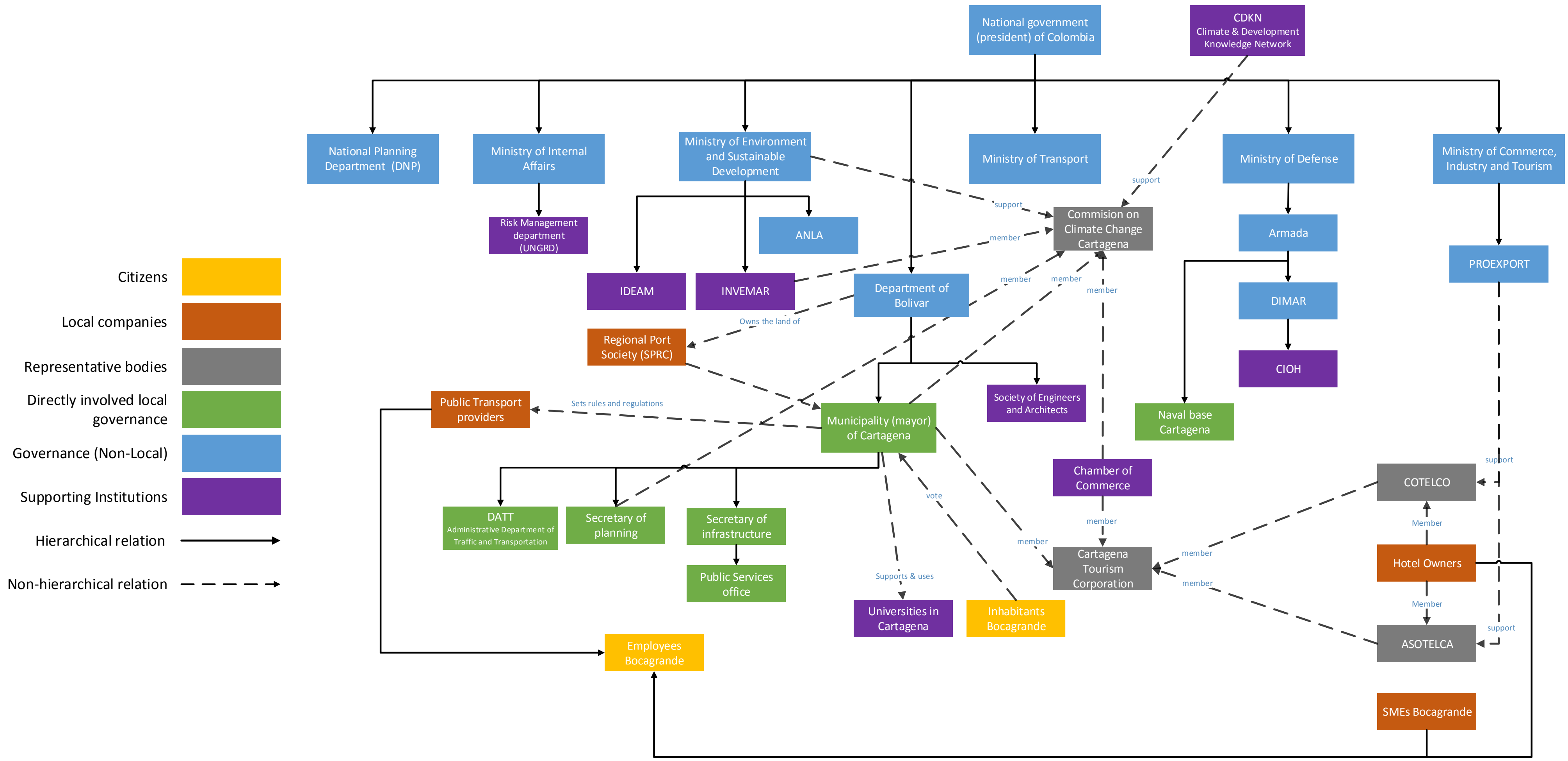


Figure A.1 Hierarchical chart of stakeholders

Boskalis

CB&I

Appendix B. Meetings

In this appendix the most important information gained from meetings with several people from different organizations will be presented.

Appendix B.1 Meeting CIOH

Date: 07-05-2013

Present:

- Captain Ricardo Molares (Director of CIOH Cartagena)
- Adriana Puenno
- Okke Scholtes, Erik Henry, Yorian van Leeuwen, Geert Wanders, Bart van Velzen

CIOH (Centro de Investigationes Oceanograficas e Hidrograficas) is a section of DIMAR (Portal Maritimo Colombiano).

As a response to the call for an entity devoted to oceanographic, hydrographic and related areas, the National Colombian Navy, through the General Maritime Directorate (DIMAR) since 1975, created the Oceanographic and Hydrographic Research Center, in Cartagena, with the responsibility to develop the Colombian Navy and DIMAR investigation programs and support other entities. Together, these entities and the CIOH, promote the defense, knowledge and exploitation of the sea resources as well as human safety at sea.

The CIOH performs the following activities, among others in the marine research field: Carry out scientific research on board Colombian Navy and the General Maritime Directorate research oceanographic vessels.

Analyze obtained data during the abovementioned cruises and assess them from the oceanographic, physical, chemical, biological and geological standpoint.

Partake in joint research projects with national and international entities.

Influence

Meeting every month with other institutes to discuss the problems, but not real impact on decision making, only advisory for DIMAR. But governmental authority in Bogota doesn´t listens to local institutes. CIOH doesn´t have and doesn´t want responsibility for any project, because they are afraid of losing their jobs. So they won´t take the risk by proposing a project. Therefore projects proposed from outside the country are taken more seriously.

Stakeholder DIMAR

What they do;

- Provide advice and assistance to the government in policy making and programs related to maritime activities and execute them within the limitations of its jurisdiction.

- Regulate, authorize and control concessions and permits in waters, low tide lands, beaches and other public use assets of the areas under their jurisdiction.
- Regulate, authorize and control the construction and use of islands and artificial structures within the areas under their jurisdiction.
- Regulate, authorize and control the building of ports and public piers as well as their operation in compliance with valid regulations.
- Authorize and control dredge work, refilling and other related tasks of ocean engineering on low tide lands, beaches and other public use assets within its area of jurisdiction.

Jurisdiction

The General Maritime Directorate exerts its jurisdiction as far as the exterior boundary of the exclusive economic area, in the following areas: maritime interior waters, including intercoastal waterways and marine traffic canals: all marine and river-marine systems; territorial seas, contiguous area, exclusive economic area, sea bed and marine subsoil, supra-adjacent waters; coasts, including beaches, low tide land, country ports located within its jurisdiction; islands, islets, cays and the rivers.

Flooding

Main problem indicated by captain Molares is the flooding of large parts of Cartagena. Not only Bocagrande is flooded but also other neighborhoods due to heavy rain showers, high water in the bay, stormy weather and the lack of a good drainage system, the sun is all they have to remove the water. Every once a year whole Bocagrande is flooded due to a combination of elements; high water level in the bay due to heavy rain showers and high tide and stormy weather.

Accessibility

Most of the hotels are located on Bocagrande and in the old city. Since a law, which inclines that the Hotel in the first 30 years doesn't have to pay National tax the first 30 years, many hotels have been built on Bocagrande, especially since 2006. Since 2006 more and more hotels are being build. This increases the amount of traffic, however the infrastructure is not getting upgraded, so traffic jams arise.

Appendix B.2 Meeting Hilton

Date: 23-05-2013

Present:

- Mr. Vinod Agarwal (General manager of the Hilton Cartagena)
- Mr. Eduardo Perez (General manager of Compania Hotelera de Cartagena de Indias S.A.)
- Okke Scholtes & Erik Henry

Meeting to talk about the problem perception and power the Hilton has regarding flooding, erosion and accessibility.

No cost estimates of damage due to flooding, erosion and bad accessibility. And costs from these problems for society are very hard to calculate because they say nobody keeps track of this. They deal with water by keeping their hotel dry with pumps. They do have big problems with a lot of water in front of the Hotel entrance. It is a weak point in El Laguito.

They take their own measures against erosion around the Hilton. They constructed and maintain the groins close to them.

-They don't think highly of the local government.

-It seems to help but they are going to monitor the improvement now.

- El Laguito lake was opened once, about 5 years ago. But it closed again within a year because it was just a one-time dredging and nothing else.

-Accessibility is main problem in their opinion. In good conditions it takes about 15 minutes to the airport from the Hilton, in quite common bad conditions it takes about 45 minutes. So roughly 3 times more.

-Lower occupancy is due to massive increase in hotels and beds. Also the (illegal) apartment rent.

-After storms the beach is very small, there are no measures except to just wait for it to naturally return. This is more less a cycle of a year. Towards the and of the year (Nov,dec) the beach decreases and in march it starts to grow again. This is roughly the cycle.

-Some key things for improvement in their eyes: Moving of the Naval Base, Implementation of TransCaribe, Some sort of water transportation system (probably easiest to implement on short term). They don't agree with bicentinario project with 4 lane road on the coast (Carrera 1).

-Mr Perez sees moving of Naval base as key to have space for solutions. But it will take a long time till the movement is complete. About 8 years at least. (so probably 10+ years) so other solutions in the mean time are needed.

-TransCaribe is not finished, main problem is bazurto area. Wholesalers don't want to move. So the project is on a stand still and what has been built is not used and is already deteriorating.

-Agree that they have built too much and to close to the sea. Used to be a large 'buffer'. In the last 10 years a lot of buildings are constructed.

-El Laguito was artificially made at a certain point. It only existed partially through nature. Other than that no nourishment.

- Mr. Perez brought us in contact with Mr. Rizo Pombo, who is a hydrolic engineer and former consul for the Netherlands here in Cartagena. He was involved in bringing Royal Haskoning and Boskalis to Cartagena. According to Mr. Perez he has a great amount of knowledge of the area.

Appendix B.3 Ligia Salazar (SPRC consultant)

Date: 22-05-2013

Present:

- Ligia Salazar (Consultant for the Regional Port Society (SPRC). Her expertise is urban planning and development)
- Okke Scholtes & Erik Henry

Financing projects in Cartagena

The financing of a project can be done through several different ways.

- Local government
- Local government in cooperation with businesses
- Local government tries to approve the project through the council, which decides whether or not the residents should pay an extra tax for the plan. This can be just for the people who have direct benefit of the plan, or all the residents of Cartagena if the project benefits all in a certain way (like protection against flooding).
- Local government can ask for finance by the Department of Bolivar. Due to a law (decentralize of benefit resources) which is entered in 2011 the Department have the power to agree on a project and finance the project.
- Local government can ask for financing at the different (national) governmental funds.

Since 2011 the Government in Bogota wants to decentralize more, so that the responsibility moves from Bogota to the local governments. Therefore the benefits from natural resources is directly going to the Departments instead of to Bogota. The department wants a clear and well developed plan before they will approve and finance the project. The problem with the plans right now is, that the local government does not have the power, will, knowledge or whatsoever to come up with a good developed plan.

- The department of Bolivar wants to use its new funds from oil royalties to help develop good plans for the region. But this requires that quality plans are submitted to them to request funding. There is a recent plan for a drainage system on Bocagrande which the department knows about, and they support this plan. But the local government of Cartagena must submit it to them in order for them to fund it. And even though they asked the local government to hand it in, for some reason, they have not done it yet. The fact that the department even asks for a plan to be submitted for funding shows that they are interested in the local situation and are dedicated to solve problems.

Cotelco and Asotelca are the two organizations which represent some of the hotels in Cartagena. Cotelco is the biggest one. They are not that powerful and do not have a direct link to Bogota.

Appendix B.4 Meeting TransCaribe

Date: 28-05-2013

Present:

- Amalia Toro (Advisory Department of Transportation & contact World Bank)
- Angelica Padilla (Assistant Transport Department)
- Okke Scholtes, Geert Wanders & Erik Henry

-Amalia is involved in the social aspects of the TransCaribe project. She gives feedback to the World Bank on this subject. They find socialevelopment very important and want to ensure that vulnerable people are not harmed or enforced in any way.

-Apart from this, Amalia is also an inhabitant of El Laguito. We asked about her experience with the different problems we are investigating. She indicates that near the Hilton the flooding problems are the worst and that this is the only spot that can get totally unpassable by car at times. Sometimes it can take about 5 hours before she can pass by car again.

-She finds the poor accessibility the biggest problem. And especially the impact of floodings on the accessibility, because then the conditions become the worst.

-About the TransCaribe project she told us about two major problems it has encountered; counteraction of wholesalers in the Bazurto area, that was also mentioned by mr. Perez in a previous meeting at the Hilton, and the change of thinking, especially for the users of the line and the bus operators. Miss Toro explained what exactly happened there. A short summary:

When the designs and plan for the Transcaribe was finished the next step was to do a social analysis of the 422 plots that the new infrastructure would cross. A precise description of the activities of every plot was made to gain insight in the social situations. Then the legal hassle began to relocate people and businesses and to compensate people for this. In centro and in the Bazurto area there are many street vendors (centro about 400 along the route, bazurto around 900) and this became a problem. In centro the situation as resolved by giving them financial support, licenses and guidance to start an official business elsewhere. This worked out pretty well. But in Bazurto the cooperation was not present. The vendors were not keen on moving and certainly not for the same price as the vendors accepted in centro. This meant that the work could not be executed in that area. The main problem was that the local government did not help TransCaribe in this process. Which is actualy very strange since they own 95% of the shares. What did not help was a change of mayor, who was not keen on picking up where his predecessor left of. He did not want to do an 'unpopular' thing as to impose on these street vendors. So the project could not continue in that area. They couldn't make the part of the line on the side of the Bazurto market where all the vendors are. So one way was finished but the other way was not. What happened is that the Spanish contractor sued TransCaribe because they could not complete their job because they hadn't provided them with the necessary plots to do so. As a result of this the part that couldn't be constructed yet was taken out of the initial construction contract with the Spanish contractor.

Another issue concerns the acceptation of the new line and its new way of working. The bus drivers have to learn and practice with the new busses and accept that they have to drive a certain agreed line and stop at certain agreed points on that line. Also the bus users have to learn that they must wait for the bus at a certain point and that they cannot randomly stop and enter a bus at any point. This system change causes a lot of friction and resistant by the users and the operators. Therefore the TransCaribe project teaches the operators about the systems and try to inform the users of the new line. At this moment the last piece of construction work is put up for tendering again. But still the success depends on the support of the new mayor that will be elected soon. But hopes are that it will be a stronger mayor that will support the project.

-Miss Padilla assisted in answering some more transport and economical related questions. She told that they do not calculate the value of time for different purposes of travel (business, commuting leisure etc). They don't make the last step from amount of travel time saved to the economic value of this. She can provide us with an overview of the different costs and benefits that were taken into account in the TransCaribe project. She will also provide us with an overview of the TransCaribe infrastructure as it was designed.

Appendix B.5 Cartagena tourism corporation

Date: 04-06-2013

Present:

- Maria Emilia Bonillas Guardo (marketing director of the tourism corporation)
- Okke Scholtes, Erik Henry, Geert Wanders

The tourism corporation is started in 2011 to improve the competitive position of Cartagena. The tourism corporation is a mix of local government (the mayor), commercial companies and representatives bodies like Cotelco and Asotelco. The main focus of the corporation is to increase the amount of tourism, visitors and businessmen, by promoting the city as an attractive tourist city. Because the corporation is started in 2012, there are not yet targeted goals. They recognize the problems regarding the accessibility, the floodings and the decrease of beaches but for now they don't have a strategy or plan to do something about these problems. Their first focus point is to increase the number of international flights to Cartagena directly, instead of through Bogota. Only flights from Miami and Panama are direct flights.

Position & Power

The tourism corporation seems to have influence and some power. They are connected to the commercial companies as well to the Mayor. Representative bodies have more influence on the mayor through this corporation than by itself. For the hotel owners this is an opportunity to strengthen their position.

Data

Hard data about the increase of hotels or about the economic income through the tourism branch is also not known. They have some information about how much money a businessman and a tourist from a cruise ship spend. The corporation is in cooperation with the Chamber of Commerce working on a complete economic impact of the tourism branch.

Appendix B.6 Meeting José Henrique Rizo Pombo

Date: 04-06-2013

Present:

- Dr. Jose Henrique Rizo Pombo
- Bart van Velzen & Yorian van Leeuwen

José Henrique Rizo Pombo, an engineer that has worked for the Dutch consulate in Colombia for over 20 years was interviewed in order to get a better insight on the problems in the area. He has worked on many projects and problems in the area of Cartagena. He has also been mayor of the city between September 1977 and September 1978. This document gives a summary of the interview.

Erosion

- Sediment transport rates are periodically changing, alternating higher and lower transport rates make the Cartagena coast very dynamic.
- Sediment transport direction is towards the south, north from Cartagena and towards the north, south of the island of Tierra Bomba. The two longshore currents meet at the island of Tierra Bomba and are directed offshore over the continental shelf at that point.
- Along Bocagrande there used to be sand dunes, these have been removed and buildings have been built along the coast instead.
- Wind causes erosion of the beaches' surface and moves sand to the adjacent streets and buildings where it is removed.
- The lake at El Laguito used to be connected to the sea, because of sedimentation it is now a closed lake. Dredging of the opening is difficult, around 25.000m^3/yr of sand accretes there. Once a cutter suction dredger opened the lake, but before it was finished the accretion was too much for the dredger to sail out through the opening.
- Iribarren groyne has become porous, now sediment can be transported through the structure.
- A lot of fluctuations in sediment input by Río Magdalena, as well as sediment input due to eroding islands and moving sand bars on the seabed.
- There is a plan to reconstruct a beach at the south side of El Laguito, with T groynes and sand nourishments the sediment should be kept in place.

Flooding

- A dike around Bocagrande is more expensive than raising the peninsula.
- Because of the very permeable soil at Bocagrande, too much seepage will occur when the sea water level is higher than the ground level. A 18m - 30m sand subsoil is present, providing insufficient resistance against seepage.
- A lot of pumps need to be installed to get rid of incoming water.

Creation of El Laguito

- In order to create the Current El Laguito sand was dredged from what us currently the lake of El Laguito. The depth after dredging was approximately 14m.

Appendix C. History of the coast

This appendix discusses the coast around Cartagena over the last century. In order to understand the coastal problems around Cartagena it is important to understand the characteristics of the coast. Natural processes and human interventions have caused significant impacts on the considered coastal system in the past century. Global changes in the coastal system often have local impacts, therefore the global coastal system is considered next to the local situation.

Global

The global coast is briefly explained as only the most important sources and sinks are considered. The examined area covers the coast between the mouth of the Río Magdalena in the north and Barú in the south. The Colombian Caribbean coast consists of sandy beaches, mangrove forests and rocky outcrops. Figure C.1 shows the geographic area of the considered global coast, the arrows indicate the dominant sediment transport direction that is determined by the dominant wave direction from the northeast.

Figure C.1 Considered coastline with sediment transport direction

Sources and sinks

An important aspect of the coastal system with respect to sediment budgets is sources and sinks. Changes in sources and sinks along the coastline generally influence the coast in the direction of the sediment transport. Figure C.2 shows the sources and sinks along the coast from the Magdalena River to Galerazamba, these were identified by Deltares in 2012. The two upper red arrows indicate the dominant sediment transport direction, where the lower arrow represents the sediment transport in the months October and November.

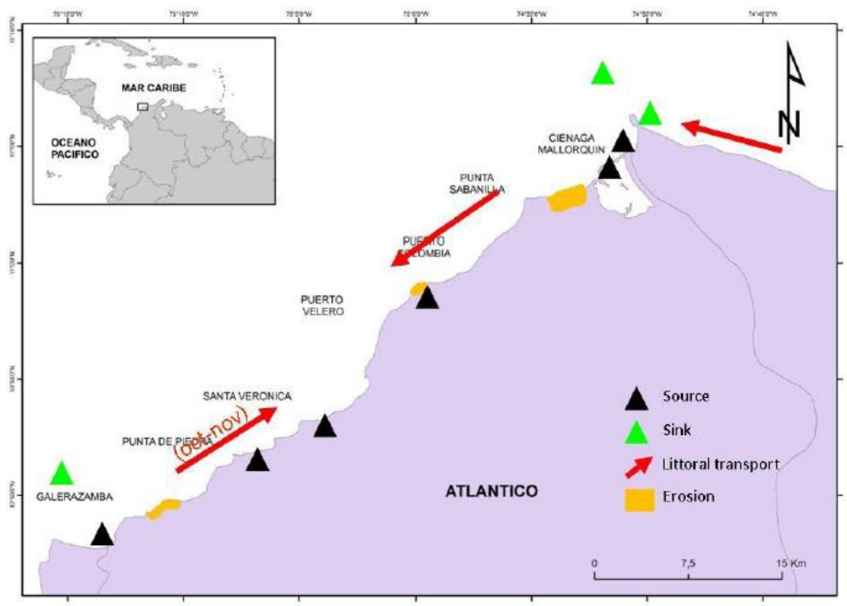


Figure C.2 Sources and sinks between Magdalena River and Galerazamba

The two most important sources for the coastal system with respect to Cartagena are the Magdalena River that flows into the Caribbean at Barranquilla and the Dique Channel that flows into the Cartagena Bay. These two sources are discussed below.

Magdalena River

The Magdalena River is a large river with high sediment content. The average discharge from 1942 – 2000 was approximately Q_{avg}=7000 m^3/s and the average sediment transport is approximately 150*10^6 t/year. The sediment from the Magdalena River contains around 10-20% sand and the rest is mostly mud. This sediment has fed the coast for a very long time (Restrepo & López, 2007) & (Molares R. B., 2011).

However in 1936 two breakwaters were constructed at the mouth of the river to reduce sedimentation problems and increase navigation near the port of Barranquilla, which is located close to the mouth of the Magdalena River. Since the construction of the breakwaters, sediment is discharged over the continental shelf on a steep slope (40°) (Restrepo & López, 2007). Less sediment reaches the coast, as significant amount is discharged offshore. Figure C.3 shows the bathymetry at the mouth of the Magdalena River, it can be seen that the depth increases rapidly in offshore direction. The Colombian Caribbean coast is close to the fault line between the Caribbean tectonic plate and the South American plate, this leads to steep offshore slopes and a relatively short continental shelf.

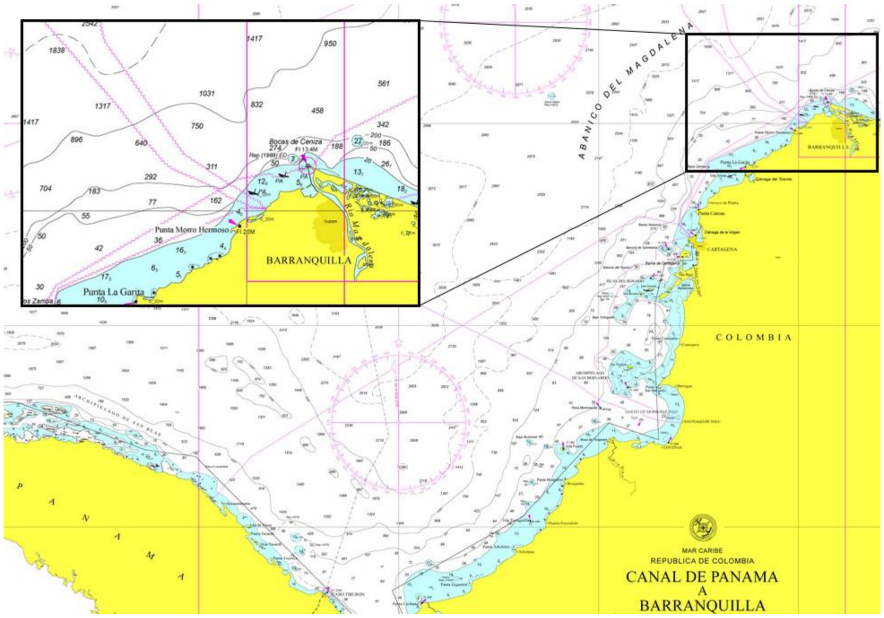


Figure C.3 Nautical chart of Colombian Caribbean coast

The construction of the breakwaters has resulted in considerable erosion downstream of the river mouth. Figure C.4 shows aerial photos of the Magdalena River mouth in 1936 and in 2002. The top left image (a) shows the overview of the river mouth in 2002 and indicates the locations of the three images below it, where coastline changes between1989 – 2000 are shown. The top right image (b) shows the situation in 1936 with two locations that are shown in image (c) as well. It is clear that the construction of the breakwaters has induced a significant effect on the nearby coast.

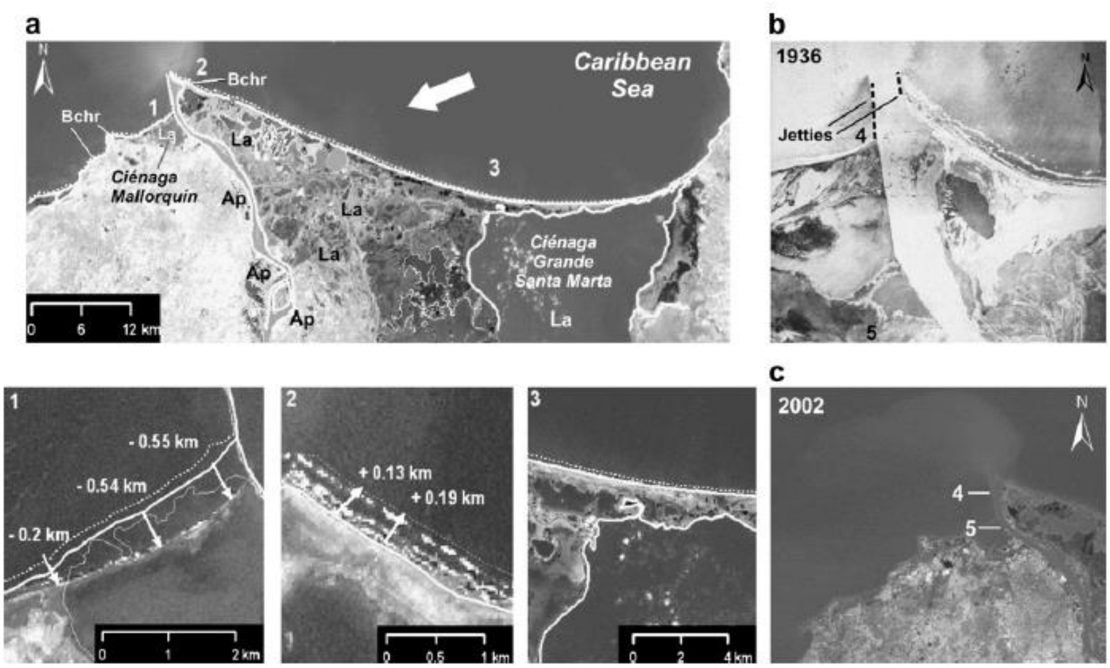


Figure C.4 Coastline changes around the mouth of the Magdalena River

Considering the significant amount of sediment discharged by the Magdalena River and the construction of breakwaters in 1936, it is concluded that the reduction of sediment input affects the coast over a large distance, even until Cartagena.

Dique Channel

The Dique Channel is a man-made branch of the Magdalena River that discharges into the Cartagena Bay. The channel was dug in 1650 and was modified in the last century. In the 1940´s to 1960´s the Dique Channel experienced siltation problems and two additional side channels were made south of Barú to reduce the amount of sediment discharging into the Cartagena Bay. See .

Figure C.5 Dique channel outflows

The Dique Channel´s total discharge is approximately 10% of the Magdalena River´s discharge. The discharge into the Cartagena bay is approximately 400 m^3/s, the amount of sediment delivered into the Cartagena bay is approximately $6*10^6$ t/year (Molares R. B., 2011). The Cartagena bay has a relatively mild wave and current climate, therefore most of the sediment settles close to the mouth of the channel. This leads to 50-100m/year progradation of the Dique Channel delta.

Temporary sources and sinks

The construction of the breakwaters at the Magdalena River mouth has had significant impact on the southward coast. In particular an island called Isla Verde experienced so much erosion that it has completely disappeared. Figure C.6 shows the situation before and after the severe erosion at Isla Verde respectively. The black circle indicates ´Punta Morro Hermoso´.

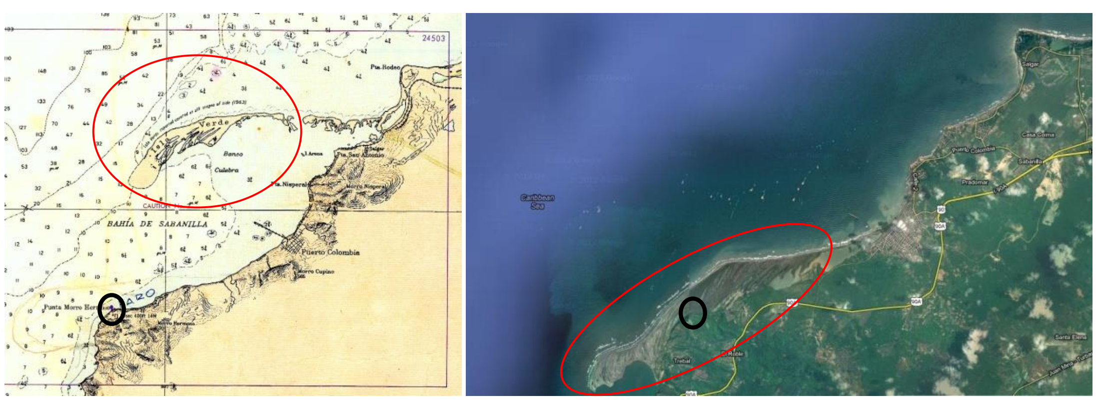


Figure C.6 Isla Verde before and after disappearance

It can be seen that accretion has taken place and a spit has formed around punta Morro Hermoso, after the island has disappeared. Isla Verde might have worked as a temporary source of sediment to compensate for the reduced input by the Magdalena River.

Local history of the coast

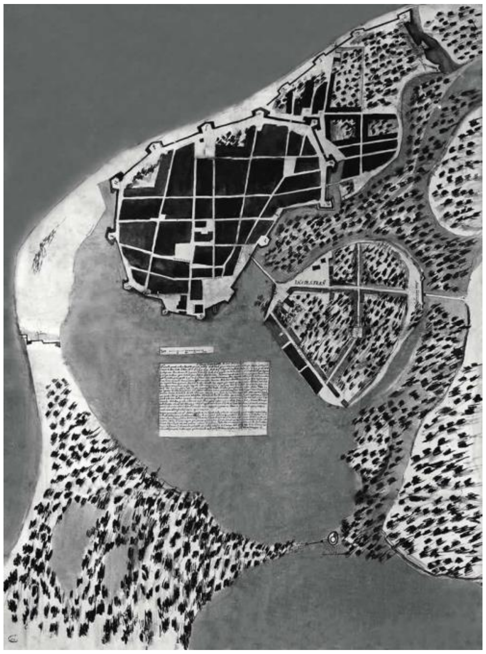


Figure C.08 Map 1597 Centro, access to Bocagrande and Manga

In order to understand what is currently happening and what will happen in the future to the coast of Cartagena, it is a good idea to first look at what has changed along the coast in its past. With the local changes to the coast known it is possible to understand the results of the changes (often man made).

As of this moment a limited amount of information is available of which some might be of insufficient quality, it might contain errors. The information that is available and of good quality is for the greater part photos found in documents and on the internet. In most cases it is hard to find the source of the photo to verify its quality. It is therefore assumed that the photos and maps are of good quality and a history of the coast is built from the changes visible in different photos. The first source of information is old maps. Although these are drawn and might therefor be inaccurate it is a good source of information to see what has changed over a longer period.

Figure C.9 Map 1735 – Centro, access point Bocagrande

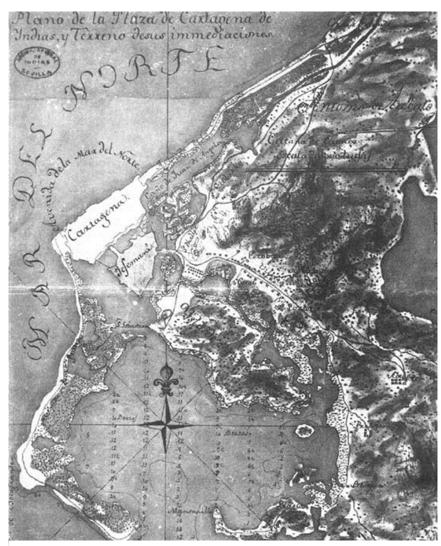


Figure C.100 Map 1763 – Centro, Bocagrande, Manga and more

These maps are hand drawn and very old, they do however give a very general idea about the shape of the coast. It can be seen that the original shape of the coast does not differ much from the current situation. We might therefor assume it to be in a very rough “equilibrium”.

According to the map of 1597 Manga and Bocagrande used to be (nearly) connected. Between 1771 and 1778 the Spanish build a submerged wall from the end of Bocagrande to the nearby island of Tierra bomba in the south west. This wall was to be just below sea level in order to protect Cartagena de Indias from pirates whose ship would crash on the wall. It can be seen that between the building of the wall (1778 and 1822 the wall had stabilized the southern tip of Bocagrande more or less, the first signs of el Laguite can be seen. The submerged wall is still here today.

More than a hundred years later there are images from the 1940’s (from the Universidad del Norte). In 1941 the first hotel was built in the south of Bocagrande: Hotel Caribe. The images below (one the zoomed in version of the other) do not indicate the presence of Hotel Caribe, it is therefore assumed that these images are taken in 1940.

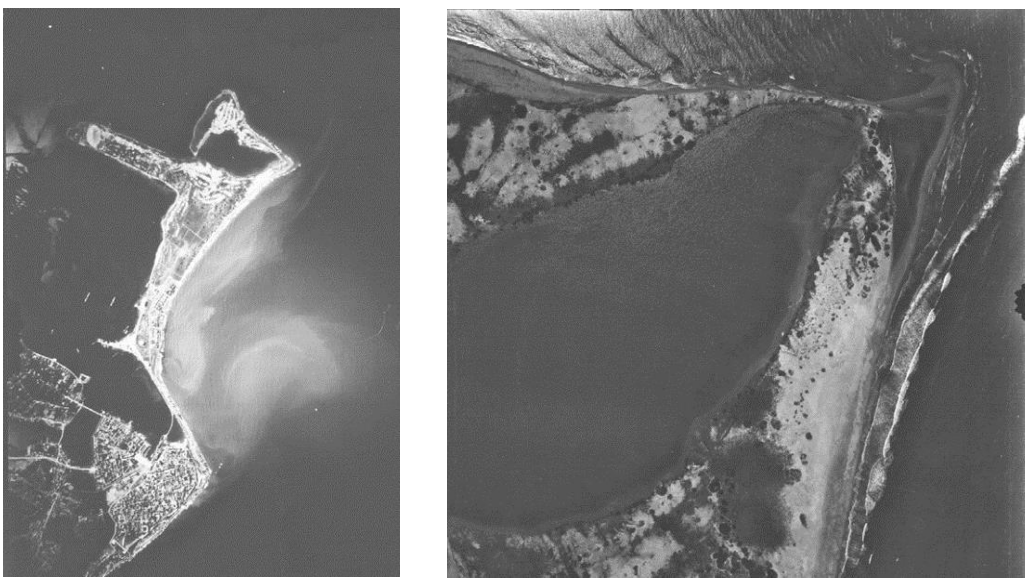


Figure C.11 1940 - Connection between Bocagrande and El Laguito

Looking at the photos from 1940 there’s quite a few interesting phenomena that are visible. First of it seems that Hotel Caribe, which is now on the end of Bocagrande, has not yet been build. Although it is not very clear in the first photo it is clear in the last.

The second interesting point is that El Laguito has grown considerably compared to the map of 1822. El laguito looks like a sand spit that has grown of the end of Bocagrande. A lot of sediment would be necessary but the photos show a lot of sediment in front of the coast. Castillogrande seems to have grown in, especially in width, compared to the older maps. The last thing to note is that a few roads seem to have been built on Bocagrande, buildings however seem to be scarce.

The next sequence of photographs is from the 1950’s. For some the year the photo was taken is available, for others certain landmarks are used to roughly estimate it.

Figure C. 12 Hotel Caribe at the end of Bocagrande and the house in front of hotel caribe

Hotel Caribe is, with its unique shape, an important landmark. It was constructed in 1941; this made it the first large building at the end of Bocagrande.

The building visible above is can also be seen in the photo of 1950. The large road is Av. San Martin (or Carrera 2), which today is still the large entrance road to Bocagrande. Also visible is the hard structure that is built along the coast at the entrance of the peninsula. It is not very clear, but this hard sea defense is not easily identified in the photos of the 1940's. What is very important to notice is the fact that Bocagrande used to have a natural dune system as can be seen in figure C.12**Error!**

Figure C.13 Around 1954 - Hotel Caribe

eference source not found..

Clearly distinguishable from the previous photo are the groynes that are under construction. There also seems to be a hard sea defense in front of Hotel Caribe. This picture is surely taken in the year 1952.

Comparing the 1952 to the (estimated) 1954 photo, not much has changed. Hotel Caribe is still close to the water on both sides. On the right top side of the photo (1954) a new road seems to be construction/under construction.

Figure C.14 (around) 1960 - No iribarren Groyne, no El Laguito

The above picture is from the 1960's according to the Universidad del Norte (Barranquilla). It shows no groyne in the direction of Tierra Bomba parallel to the coast (called escollera) neither does it show the groyne named Iribarren. It does show a large amount of new buildings and the instability of El Laguito (the sand spit) at the end of Bocagrande).

Figure C.15 (around) 1960, same location as shown used before

Figure C.16 (around) 1960 - More and higher buildings

The above two images are (estimated) from the beginning of the 1960's. This estimation is done by looking at the structures. Hotel Caribe (on the right of the black and white image) is still very close to the beach.

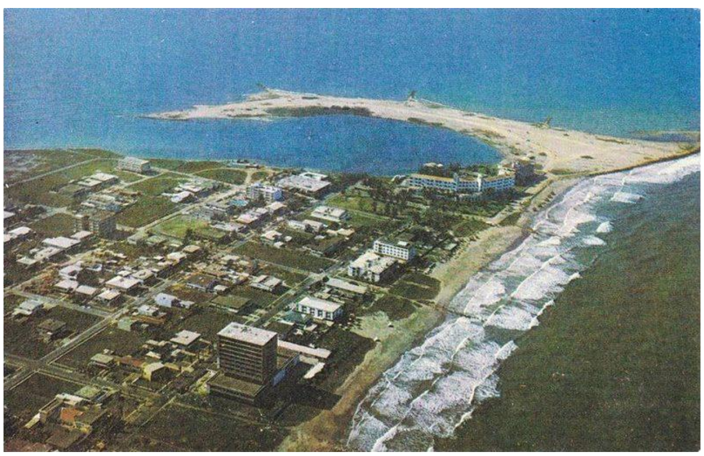


Figure C.17 Escollera and more groynes are constructed, as is el Laguito (man-made)

The above photo shows the creation of El Laguito. Although there already was a sand spit it was further filled by humans (information obtained by speaking to one of our supervisors). The newly created land had to be protected and stabilized, therefore a set of new groynes were constructed. This new land could be reached by a road that was constructed next to Hotel Caribe. The next photo is of 1964 and the previous of around 1960, therefore the construction of El Laguito was between 1960 and 1964.

Figure C.18 1964 - Escollera constructed, together with other groynes, more buildings, 1972 start of skyscraper, 1975 completion iribarren groyne

Through conversations it was found that the Iribarren groyne (as seen in the above photo) was constructed around 1975. This construction caused the beach on the Bocagrande side (on the photo to the right) to widen. The previously used groynes are being covered by sand due to the widening of the beach.

Figure C.19 Around 1976 Before the Hilton was built

With the newly gained land (El Laguito) new apartment building and houses were built. In the southern tip of El Laguito (to the right on the photo) more groynes were constructed to stabilize the peninsula.

Figure C.20 1978 - Before building of the Hilton

Because of the different angle it is hard to see, but the five groynes as noted in the above photo are actually. The five that can be seen most right groynes as can be seen in the previous photo. The last (most southern) groyne is made a lot longer but also the other ones have increased in length. This has caused the land to become wider in certain areas of El Laguito.

The above photo also has the area drawn in red on which the Hilton would be built. The Hilton is built in 1981.

Figure C.21 Around 1981 - Just after the building of the Hilton. No tennis fields and pool yet

The above photo has probably been taken not too long after construction of the Hilton. The size of the most southern beach of El Laguito has grown but the “lake” behind the Hilton does not show any signs of sedimentation yet.

Around the same time, or maybe a little earlier (but after the construction of el Laguito), two pictures were taken of Castillogrande. The first from Bocagrande in the direction of Castillogrande, the other in the opposite direction.

Figure C.22 Castillogrande (somewhere between 1970 - 1985)

Although the images are not of the best quality, and the exact year is hard to determine (although 1974 would be a good estimate considering the structures), something very obvious is noticeable. At the time these images were taken Castillogrande hardly had any beach on the west side.

With the newly created land by the accretion at the beaches next to the Hilton the hotel has built tennis fields and a pool. With the groynes however “full” with sediment it passes the last groyne and starts to fill up the “lake” behind the Hilton.

Figure C.23 around 1987 and 1989 new groyne and longer existing groynes

In order to prevent the sediment accretion to the entrance to the “lake” a new groyne is constructed and the current one is made longer. Sadly this did not have a very long term effect as can be seen in the following photo. Also interesting (but harder to see) are the offshore breakwaters at the coast of Castillogrande.

Figure C.24 El Laguito entrance closing

The photo above shows the closure of the El laguito "lake" and the sediment forming beaches on the western side of Castillogrande. The rebuilt groynes on Bocagrande are now visible for the first time and can therefore be assumed to have been built in the late 1980's or 1990's.

With the sediment moving around el Laguito it closes of the "lake" of El Laguito. With it closed the sediment spread along the coast of Castillogrande forming a beach (with the help of offshore breakwaters). This can be seen in the following photo where it is obvious that the beaches are starting to form.

Currently the sediment supply has been plenty (either by human interference, but more likely by nature), therefor the lake is now fully closed and there is so much sediment on the beaches of Castillogrande that most of the offshore breakwaters are covered by sand. This can be seen in a very recent photo below.

Figure C.25 Recent image taken from the Hilton

On the coast of Bocagrande facing the Caribbean more and more structures are being built very close to the shore. Because the road and buildings are so close to the shore (too close) there is little or no buffer zone. With the repair and maintenance of the groynes and offshore breakwaters the beach widens, however this is not enough for a structural buffer zone. El Laguito and Castillogrande do not seem to suffer of lack of sediment due to these interferences.

In the photos below these changes can be observed (notice that this is a snapshot taken at a certain moment).

Figure C.26 March 2000 – Bocagrande groynes

Figure C.27 March 2004 - Bocagrande groynes

Looking at images above it is uncertain whether these changes in beach width are due to the groyne maintenance or due to nourishments that might have taken place. What can however be said is that, when looking at the changes over a longer period, that structurally there does actually not seem to be erosion. After speaking to professors from the University and the director of the CIOH it seems very unlikely that regular beach nourishment have been performed over all these years.

Appendix D. Seasonal and sea level rise induced erosion

The coast of Bocagrande is prone to seasonal variations and thereby induced coastline changes. This is called incidental erosion. However, due to predicted relative sea level rise additional structural erosion is expected. Erosion due to storm surges is a similar process as erosion due to sea level rise, although the erosion due to storm surge is mostly temporary and erosion due to sea level rise is permanent.

Incidental erosion

This paragraph discusses the incidental erosion along the coast of Bocagrande. As is concluded from the system analysis, there are no signs of structural erosion in the considered area. Since there are still signs of occasional erosion, temporary conditions on the coast are investigated. Some stretches of coastline have very narrow beaches because buildings have been constructed close to the shoreline. The narrow beaches indicate there is only a very limited buffer of sand for changes in the beach profile due to changing wave climate or water level.

Seasonal variations

The wave climate at Cartagena is relatively constant and mild. However, there are some fluctuations throughout the year. As is shown in the boundary conditions the waves are lower in August to October and highest from December to March. These fluctuations generate different beach profiles over the year, this is comparable to winter and summer profiles in more seasonal areas. Higher waves cause a ´winter´ profile with a gentle slope and offshore bars. Lower waves transport the bars back to the shore, producing a steeper slope and longer beaches. See figure D.1.

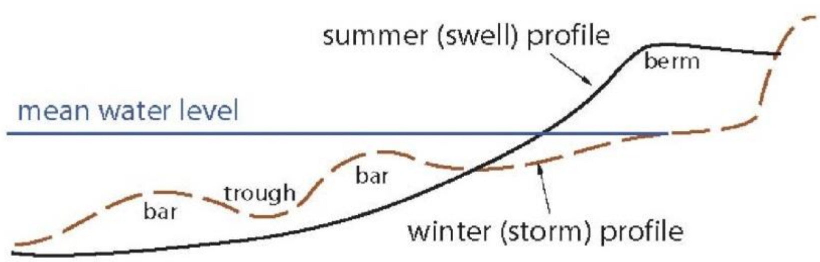


Figure D.1 Summer and winter beach profiles

The difference in beach profiles over the year was also indicated by the Hilton Hotel (see appendix B.2 – meeting Hilton), where, according to them, the beaches loose sand during November – March and gain sand in the rest of the year.

The seasonal variations have a somewhat longer timescale than storm induced variations. As statistically the highest waves occur during December – March, the hurricane season is from June – November. The hurricanes produce higher waves as well, however more incidentally.

Storm erosion

The lower waves from the north (east) in most of the year account for the gross of the sediment transport in southern direction. Occasional storms from southwestern direction temporarily reverse the steady transport of sediment towards the north. The sand transported northwards should be transported back south when the normal conditions return.

The temporary higher waves caused by storms change the beach profiles to represent a storm profile, see Figure . A storm profile can be compared to a winter profile, however on a shorter time scale.

Because storm waves caused by hurricanes often occur in combination with a rise in water level (storm surge), additional (occasional) erosion takes place. The relation between erosion and a rise in sea level is assumed to be approximated by Bruun's rule, see Figure D.2.

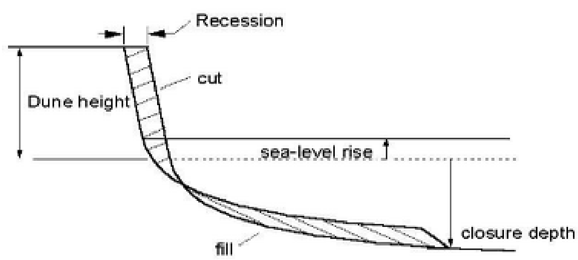


Figure D.2 Erosion due to sea level rise

Local example

In Cartagena some beaches are very narrow and can barely withstand additional shoreline retreat without damage to adjacent structures. Figure D.3 shows an image of the beach at the tip of Bocagrande, taken from the Iribarren groyne. It can be seen that only a very narrow beach is present. The picture was taken at the 22nd of January which means it is during the higher wave season. It is assumed that the erosion is caused by one or more storms not long before this picture was taken as well. Possibly a hurricane at the end of 2010, hurricane Tomas, has contributed to the erosion shown in the picture.

Figure D.3 Beach at tip of Bocagrande

Because buildings are located just behind the wall on the right, beach nourishment was carried out to make sure a following storm would not damage the structures. Figure D.3 shows the result after the nourishment.

The problems that occur due to this incidental erosion can be described as follows:

1. The beaches have too little sediment to be able to form the required profile without causing damage to structures. The sediment would return to its original location as is the case with winter and summer profiles. This means that a larger buffer should be sufficient to withstand storms in the future.
2. Sediment lost due to higher waves does not come back fast enough to have large enough beaches in milder circumstances. Incidental erosion causes more erosion than accretes (shortly) after the storm season. If for instance a 1/10 year storm occurs, it takes more than a few months for the sediment to return to its original position. This results in too small beaches to provide safety for surrounding buildings in the next months, and nourishments are required.
3. Tourist activities are limited if the beaches are very small, a few months or a year of narrow beaches reduce incomes for local businesses. Nourishments are required to have enough beach for local businesses even though the sediment will return by itself after some time.

Relative sea level rise

The sea level currently rises with 6mm/year relative to the land. A relative sea level rise of 50cm is expected over the next 50 years, this means an increasing speed at which the sea level is rising. As no structural erosion has been observed over the last century, it is expected that only the additional sea level rise results in erosion. An average of 10mm/year relative sea level rise is 4 mm/year faster than the current rate. This 4mm/year additional sea level rise accounts for a coastline retreat of approximately 0,4m/year, see appendix E: boundary conditions.

Appendix E. Boundary conditions

This appendix discusses the boundary conditions that are used in the erosion, flooding and wave overtopping sections of the Project.

Topography

The area that is considered in the project is shown in the following images.

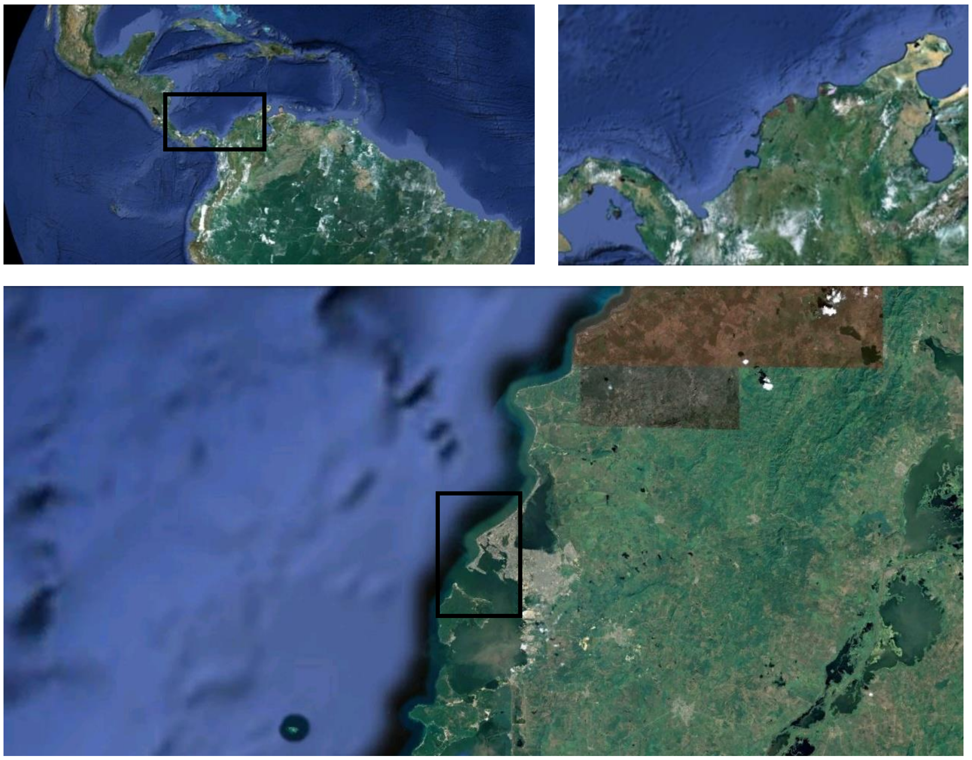


Figure E.1: Location of Cartagena

The areas of interest are shown in Figure E.1: Location of Cartagena.

Bathymetry

The bathymetry of the area around Cartagena was measured using sonar equipment for depths larger than 1.5m. For smaller depths the bathymetry was measured on 34 points along the coast with survey equipment. The bathymetry that is used for the project was measured in March 2003, by the University of Cartagena. However this bathymetry is 10 years old, the data is considered to be representative for the current bathymetry as no newer bathymetric information is available during the project.

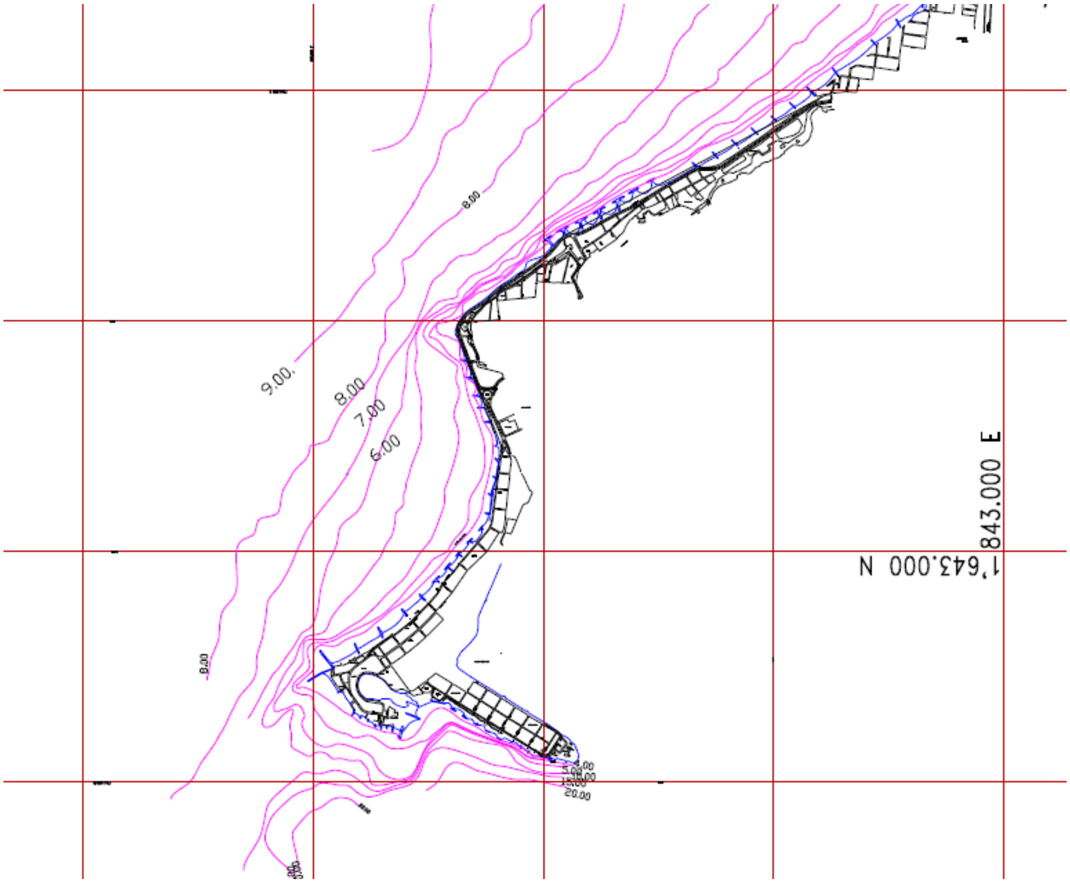


Figure E.2: Bathymetry Cartagena Coast March 2003 (Source: University of Cartagena)

Elevations

The elevations of the Bocagrande peninsula were measured using a vehicle with survey equipment. Along the coast of Bocagrande, Castillogrande and El Laguito the elevation of the road was measured. The results are shown in Figure E. to Figure E.67. The graphs with the blue line in the figures with the measurement results give the elevation of the road with respect to the national reference plane IGAC. Mean sea level is located at IGAC -0,43m (Royal Haskoning, 1996). The graphs are difficult to interpret, because the elevations don't seem to correspond to observations. In Figure E. the measurements relative to mean sea level are plotted next to measurements relative to the IGAC plane, however the measurements don't seem to be consistent with the 43cm difference. It is not clear what the actual elevations are with respect to mean sea level, therefore the measurements are only used as an indication for the elevations of the roads around Bocagrande, Castillogrande and Laguito and to address the relative elevations between the measurements.

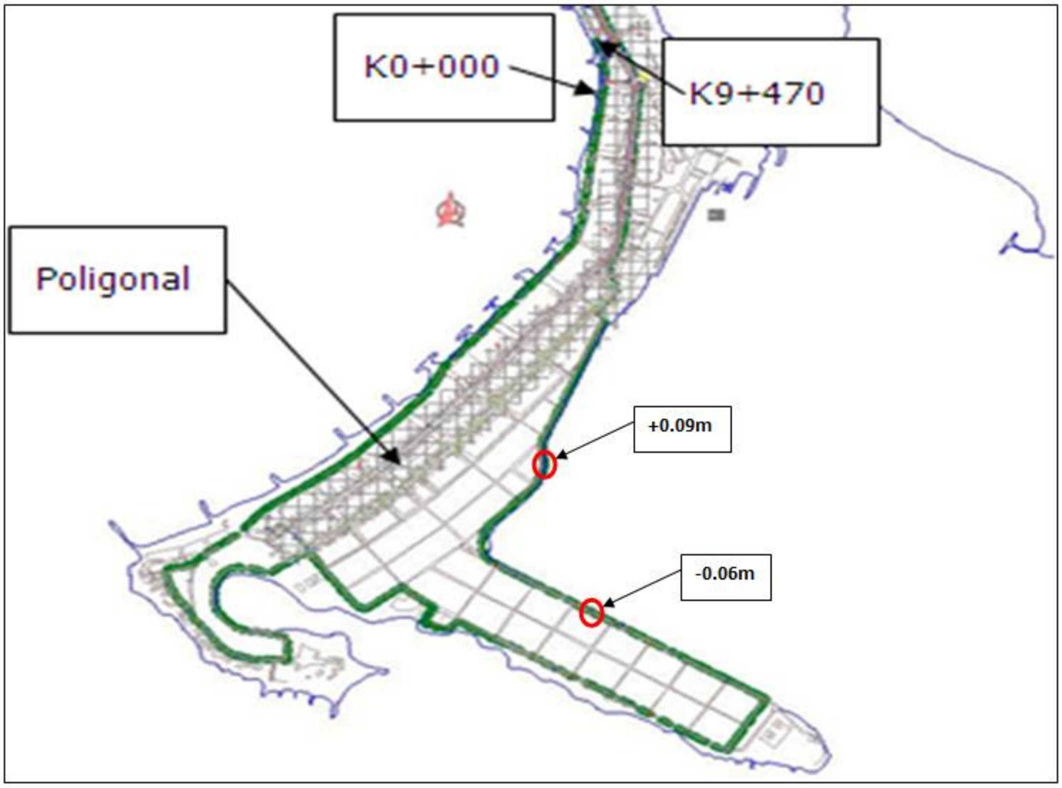


Figure E.3 Measured area with lowest points

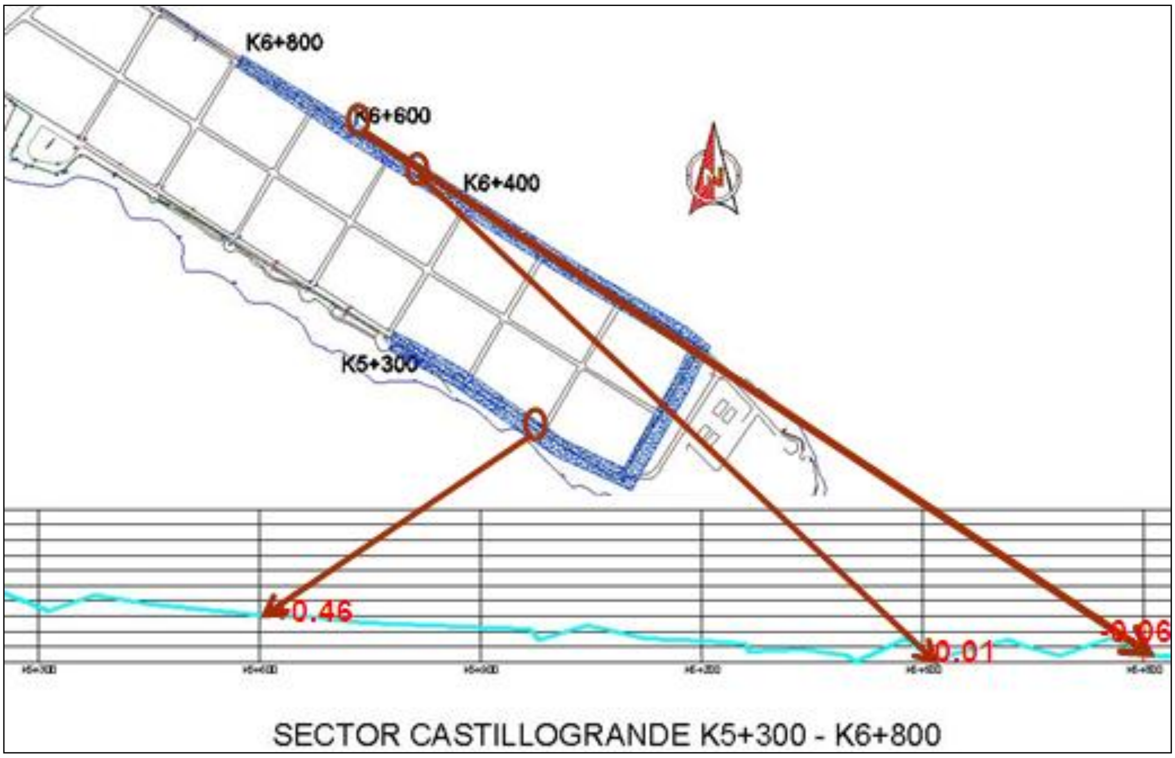


Figure E.4 Castillogrande elevations

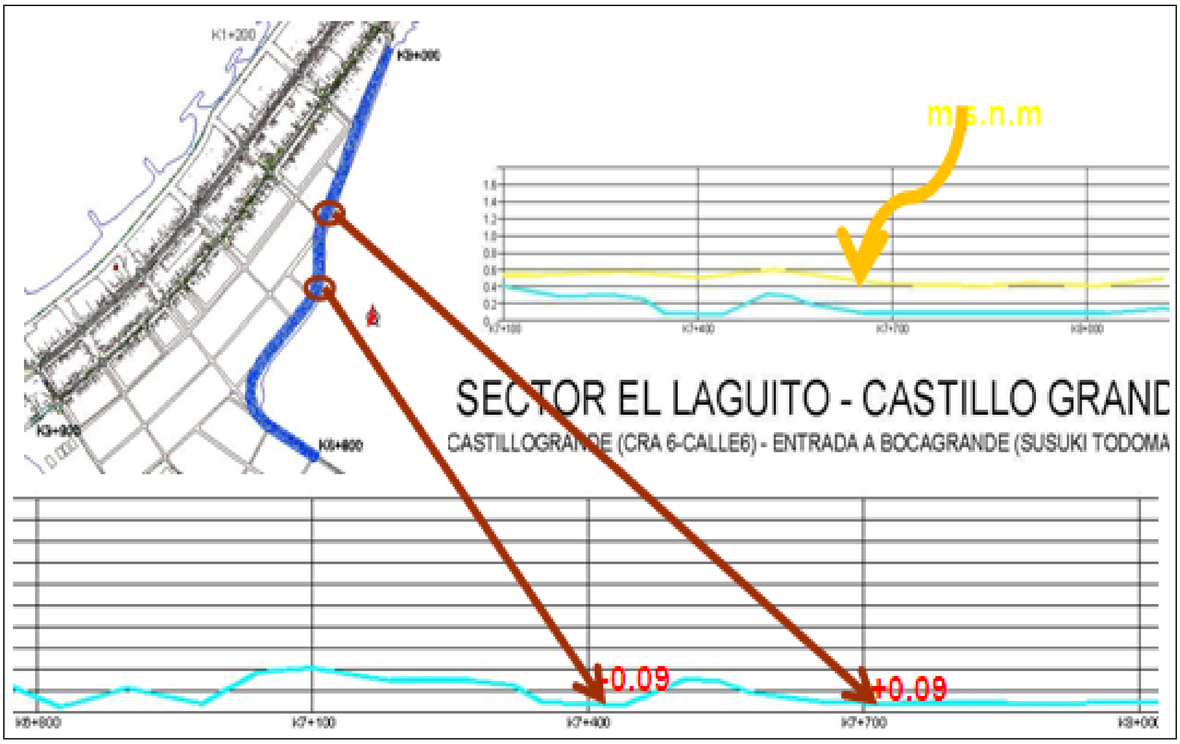


Figure E.5 Bocagrande bay side elevation

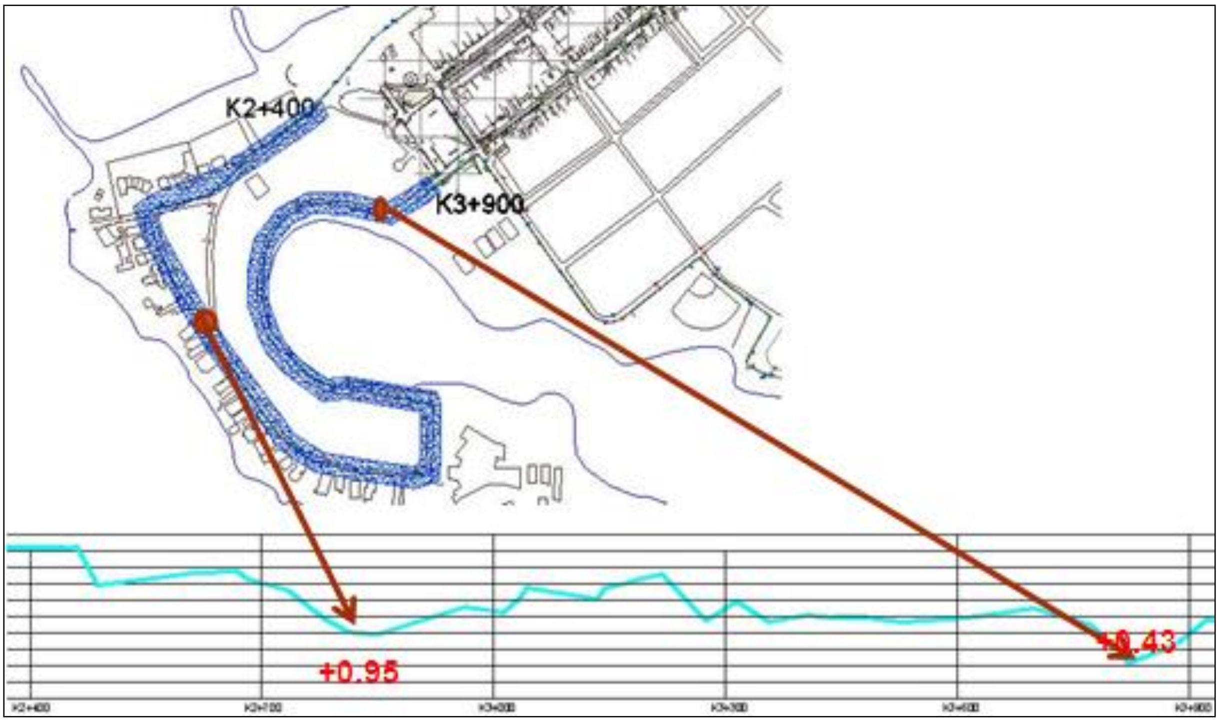


Figure E.67 El Laguito elevations

Climate

The boundary conditions for the climate of the area around Cartagena consist of the following conditions: wind, storm surge, waves, tide and precipitation.

Waves

The wave climate around Cartagena is relatively mild. The predominant offshore wave direction on the Caribbean is East (-northeast). However Cartagena is sheltered from waves from eastern direction the waves will undergo diffraction and refraction processes before they reach Cartagena, resulting in lower wave heights and changed wave directions. The predominant near shore wave direction at Cartagena is NNE, see Figure E.. Breaking heights of near shore waves at Cartagena from NNE direction are usually between 0.3m – 1.2m (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003).

In the period from November to July the wave climate has a very constant direction and the waves are higher than in the period from August to October when the direction is less constant. See Figure E. & Figure E.88. Even though the waves are lower in the period of August to October this period does overlap with the hurricane season. During the hurricane season occasional storms are expected that generate higher waves. The predominant direction of storm waves is WNW – WSW with a breaking height of approximately 1.5m – 2.4m (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003).

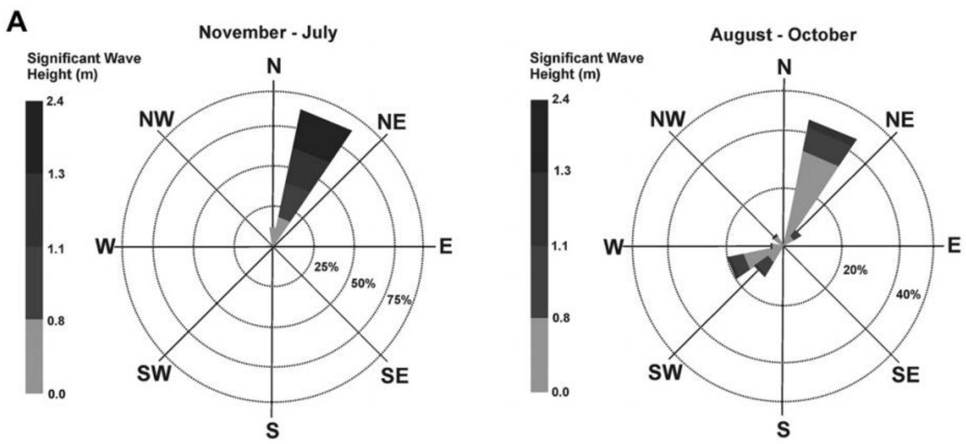


Figure E.7 Wave direction and height (Restrepo, Oterob, Casasc, Henaod, & Gutiérreze, 2012)

According to (Young & Holland, 1996) and Argoss wave data, the waves are lowest in the months of August – October as well. Waves are highest from December – March according to Argoss wave data (Figure E.99) (ARGOSS, 2013), but highest from May – July according to (Young & Holland, 1996) (Figure E.88). It is assumed that waves are highest in the period December – March on average, but during the hurricane season occasional high waves could occur due to occasional storm events.

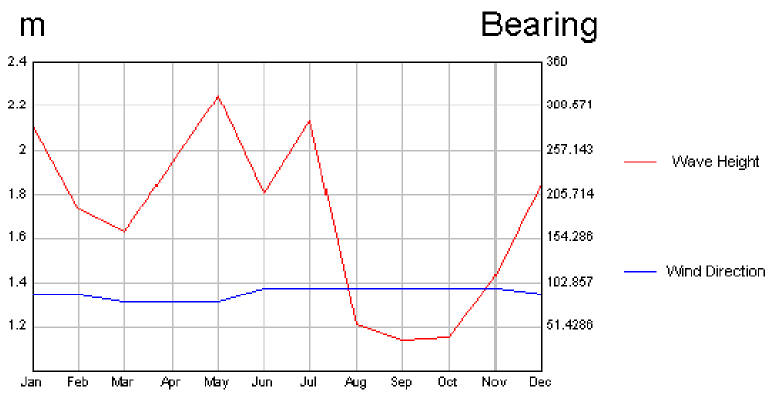
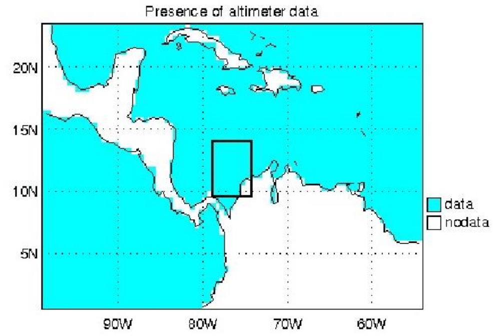


Figure E.88 Yearround average wave height and wind speed distribution off Cartagena (Young & Holland, 1996)



Monthly distribution of wave height (m)

lower	upper	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.0	0.5	83	235	379	584	1738	744	260	1165	2933	3219	817	188
0.5	1.0	696	777	1938	3664	5906	3949	1923	5412	9976	11272	5402	1541
1.0	1.5	3398	3224	5805	9116	9525	6283	5828	9962	11169	12039	10011	4615
1.5	2.0	7624	7936	9936	12168	9969	8959	9050	10493	8677	7895	9211	9030
2.0	2.5	10623	8951	10152	9306	7966	7955	10299	8135	4143	3472	7472	10952
2.5	3.0	9368	7972	7426	5249	4848	7061	8468	4466	1618	1546	4014	8655
3.0	3.5	6283	5505	4058	2074	2196	3855	4411	1631	272	437	1628	4675
3.5	4.0	2838	2523	1481	406	669	1217	1459	482	86	99	288	1868
4.0	4.5	990	1082	651	56	184	301	535	140	7	13	21	540
4.5	5.0	270	264	169	0	18	57	115	11	1	1	1	107
5.0	5.5	43	44	54	0	0	11	5	0	1	1	0	8
5.5	6.0	0	15	10	0	0	2	0	0	0	0	0	0
6.0	6.5	0	2	0	0	0	0	0	0	0	0	0	0
6.5	7.0	0	0	0	0	0	0	0	0	0	0	0	0
total		42216	38530	42059	42623	43019	40394	42353	41897	38883	39994	38865	42179

Figure E.99 Argoss wave height data, top: location, bottom: monthly wave height distribution(www.waveclimate.com)

The near shore wave data is insufficient to calculate reliable values, and as a SWAN model is used by earlier studies the wave heights that are mentioned above are used as input for analyses and designs.

Storm wave heights

For the design of the Tidal inlet at La Bocana in the north of Cartagena, Royal Haskoning determined that a once in a year 12-hour storm has a significant wave height H_s=2.5m and a wave period of T=8s (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003).

Research was done on the wave heights induced by hurricane Lenny in 1999 along the Caribbean coast by the CIOH. The significant wave height by hurricane Lenny in Cartagena was H_s= 2.4m. (Ortiz, 2009).

The near shore significant wave height for a 1/50 year storm is estimated roughly by adding 10% to the wave height for every factor of 10x the return period. Therefore a 1/10 year storm is approximately 2,75m and a 1/100 year wave height is 3,025m. For a 1/50 year storm 3,0m will be used.

Wind

The wind climate in Cartagena is relatively mild, just as the wave climate the off shore wind direction is predominantly East(northeast). Closer to Cartagena the predominant wind direction is Northeast. Figure E. shows the area of interest from which the Argoss wind data is used. Figure E.1110 show the wind data for the area of interest.

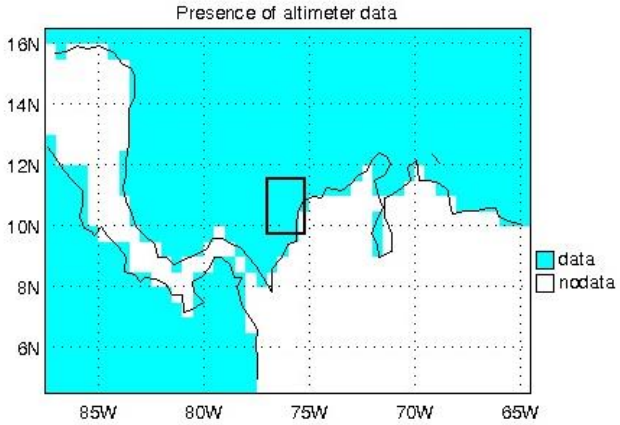


Figure E.10 Area of interest

Monthly distribution of wind speed (m/s)

lower	upper	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00	01	16	23	9	15	116	41	17	90	37	101	35	0
01	02	48	75	51	108	219	189	201	264	385	453	195	33
02	03	59	122	92	139	355	344	345	454	537	603	238	72
03	04	106	154	162	176	432	472	420	490	696	567	376	127
04	05	152	161	171	311	610	530	415	680	711	667	477	213
05	06	183	181	210	357	481	597	391	666	555	583	511	266
06	07	226	238	377	600	542	534	481	578	524	564	622	373
07	08	338	301	485	686	619	617	503	469	418	434	645	467
08	09	513	439	599	690	659	497	575	389	328	374	549	623
09	10	804	628	868	805	516	355	539	368	242	236	394	741
10	11	822	717	927	608	302	287	417	216	107	105	317	851
11	12	691	748	618	415	161	184	351	126	57	72	163	559
12	13	594	494	440	188	120	94	184	91	26	26	78	350
13	14	396	371	332	82	25	42	121	51	2	11	39	204
14	15	180	223	108	13	9	14	29	1	2	0	12	52
15	16	18	53	16	0	1	4	10	0	0	0	5	17
16	17	0	16	11	0	0	0	1	0	0	0	0	0
17	18	0	3	1	0	0	0	3	0	0	0	0	0
18	19	0	0	0	0	0	0	0	0	0	0	0	3
19	20	0	0	0	0	0	0	0	0	0	0	0	1
20	21	0	0	0	0	0	0	0	0	0	0	0	0
total		5146	4947	5477	5193	5167	4801	5003	4933	4627	4796	4656	4952

Copyright ARGOSS, March 2013

Figure E.1110 Wind speed distribution per month

Occurrence of wind speed (m/s) in rows versus wind direction in columns

	lower	348.75	11.25	33.75	56.25	78.75	101.25	123.75	146.25	168.75	191.25	213.75	236.25	258.75	281.25	303.75	326.25	
lower	upper	11.25	33.75	56.25	78.75	101.25	123.75	146.25	168.75	191.25	213.75	236.25	258.75	281.25	303.75	326.25	348.75	total
00	01	20	27	22	84	75	30	6	10	31	16	16	36	89	38	2	11	513
01	02	60	38	67	185	275	142	14	24	53	34	48	143	171	62	27	36	1379
02	03	93	92	162	328	404	250	44	29	78	47	118	240	267	122	54	59	2387
03	04	177	219	237	354	443	209	42	26	141	128	118	261	259	153	50	104	2921
04	05	329	341	543	435	351	171	54	36	184	189	145	195	166	71	70	171	3451
05	06	334	587	918	607	295	100	42	28	161	196	234	143	70	34	34	141	3924
06	07	322	917	1454	730	218	51	21	26	160	193	111	110	45	18	28	53	4457
07	08	179	1021	1598	644	120	9	10	10	79	117	48	19	8	1	9	27	3899
08	09	109	1043	2152	735	101	10	6	11	75	57	28	3	2	1	1	4	4338
09	10	88	969	2257	810	68	2	2	13	24	19	15	3	1	0	0	10	4281
10	11	37	725	2292	628	50	2	0	9	14	12	6	1	0	0	1	10	3787
11	12	32	539	2102	620	32	0	0	0	6	14	3	0	0	0	0	0	3348
12	13	13	348	1607	610	11	0	0	0	5	13	6	0	0	0	0	0	2613
13	14	0	134	954	437	5	0	0	0	1	0	7	0	0	0	0	0	1538
14	15	0	53	579	311	3	0	0	0	1	0	0	0	0	0	0	0	947
15	16	0	8	215	141	0	0	0	0	0	0	0	0	0	0	0	0	364
16	17	0	4	55	22	0	0	0	0	0	0	0	0	0	0	0	0	81
17	18	0	0	25	7	0	0	0	0	0	0	0	0	0	0	0	0	32
18	19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
total		1793	7065	17240	7688	2451	976	241	222	1013	1035	903	1154	1078	500	276	626	44261

Figure E.1211 Wind speed vs. Direction

The wind data is used to calculate storm surge and wave heights at Cartagena. Therefore only certain wind directions are considered. Wind from (north)East – South(west) directions cannot generate storm surges or waves because the wind is offshore directed. These directions are not taken into account for the design wind speed. Only the two columns with directions 348.75-33.75 degrees are used to calculate the design wind speed, because these have sufficient wind speed and fetch to generate storm surges and waves at the Cartagena coast.

A Weibull distribution is used to calculate the design storm for 1/50 years. The wind speed for a 1/50 years 12h storm is approximated to be 17.5 m/s.

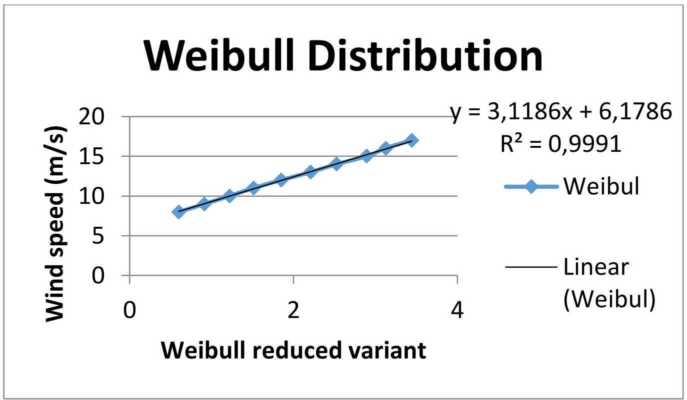


Figure E.13 Weibull distribution wind speed

	lower	348.75	11.25	348,75										
lower	upper	11.25	33.75	33,75		Cumulative	P	Q	Qs	LN(Q)	s/y		Ws	
0	1	180	139	319		319	0,00873518		0,99126482	0,00877355	723,623319		0,12756411	
1	2	261	248	509		828	0,02267313		0,97732687	0,02293412	713,448616		0,19371627	
2	3	486	579	1065		1893	0,05183603		0,94816397	0,05322783	692,159698		0,2793491	
3	4	801	1034	1835		3728	0,10208385		0,89791615	0,10767859	655,478792		0,37947806	
4	5	1189	1709	2898		6626	0,1814398		0,8185602	0,20020833	597,548947		0,49693157	
5	6	1456	3191	4647		11273	0,30868863		0,69131137	0,36916495	504,657302		0,64838802	
6	7	1728	4758	6486		17759	0,48629481		0,51370519	0,66610573	375,004792		0,83806873	
7	8	1190	4821	6011		6011	0,32041578	0,67958422	637,416021	6,45742254	496,096482		0,59799881	
8	9	756	3899	4655		10666	0,56855011	0,43144989	404,678428	6,00309275	314,958422		0,9104133	
9	10	705	2934	3639		14305	0,76252665	0,23747335	222,738126	5,40599676	173,355544		1,21681926	
10	11	418	1839	2257		16562	0,88283582	0,11716418	109,894142	4,69951756	85,5298507		1,5102889	
11	12	196	1170	1366		17928	0,95565032	0,04434968	41,5977825	3,72804686	32,3752665		1,84834504	
12	13	88	495	583		18511	0,98672708	0,01327292	12,4493364	2,52166732	9,68923241		2,2060481	
13	14	5	170	175		18686	0,99605544	0,00394456	3,69980277	1,30827951	2,87953092		2,52175502	
14	15	3	56	59		18745	0,99920043	0,00079957	0,74996002	-0,28773538	0,5836887		2,89185571	
15	16	1	9	10		18755	0,99973348	0,00026652	0,24998667	-1,38634767	0,1945629		3,12472632	
16	17	0	4	4		18759	0,9999467	5,3305E-05	0,04999733	-2,99578558	0,03891258		3,4414523	
17	18	0	1	1		18760	1	0	0	#NUM!	0		#DIV/0!	
18	19	0	0	0		18760	1	0	0	#NUM!	0		#DIV/0!	
19	20	0	0	0		18760	1	0	0	#NUM!	0		#DIV/0!	
total		9463	27056	18760										
												alpha	1,85	
												A	0,32035489	
												B	-1,9774658	
												R	0,99953632	
												beta	3,12153816	
												gamma	6,17273494	
									Vwind for condition 1/		50	Vwind	17,4450108	m/s

Figure E.1412 Weibull distribution calculation

Tide

The tide in Cartagena is mainly semi-diurnal as can be determined by the form factor F. The form factor is the ratio of the amplitudes of the sum of the two main diurnal components and the sum of the main semi-diurnal components, being K1 & O1 and M2 & N2 respectively for the tide at Cartagena Bay.

Figure E. shows a sample representation of a one month tidal cycle for Cartagena Bay, based on the local tidal constituents (Molares, 2011).

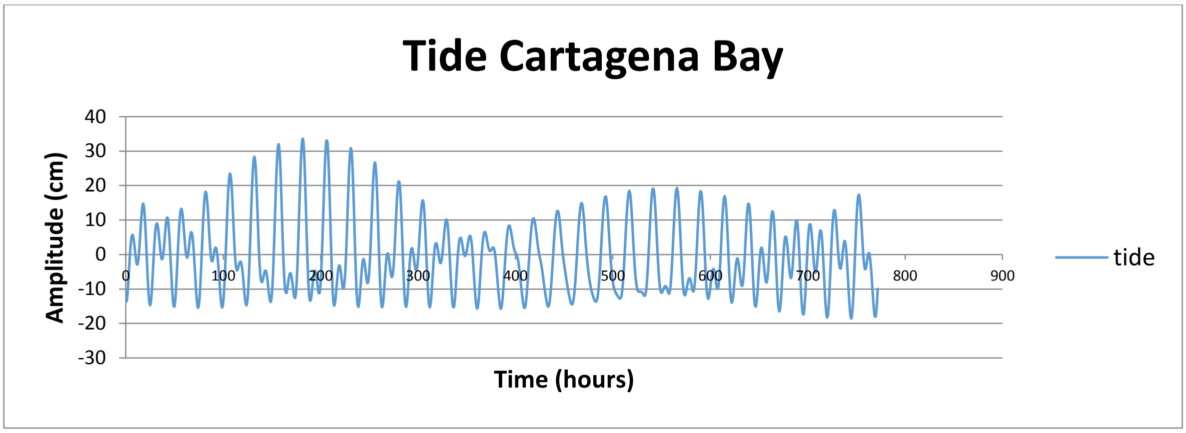


Figure E.15 One month tidal cycle Cartagena Bay

The average tidal range in Cartagena is 0,35m and spring tidal range is 0,55m (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003). The tide is unevenly distributed, averagely ranging between -0,2m MSL and +0,35m MSL. The maximum spring tidal amplitude for 1/100yr is 0,55m above MSL (Royal Haskoning, 1996).

Storm surge

A storm surge is a rise in the water level generated by meteorological effects. Low pressure and wind cause the water level to rise. Three mechanisms that have significant impact on the meteorological conditions can be identified to potentially cause storm surges.

Hurricanes

In the months June – November hurricanes occur on the Caribbean Sea. Some of the hurricanes on the Caribbean also affect the Colombian coast even though they do not hit the coast directly. It is assumed that hurricanes will not make a landfall close to Cartagena, as this has not occurred in the last 100 years (Ortiz, 2009). Hurricanes within a distance of 300km from the shore could affect the coast. As the number of hurricanes that is closer than 300km to the Cartagena coast is small, the chance of storm surges due to hurricanes seems to be small as well. No measurement data was found on storm surges due to hurricanes, therefore it is difficult to find the exact relation between hurricanes and storm surges, but it is assumed that hurricanes do cause storm surges on the Caribbean coast of Colombia.

Cold fronts

Cold fronts originated from northern areas, such as Alaska, are known to occur on the Caribbean. The cold fronts dissipate before they reach Cartagena; therefore only swell waves caused by the cold front affect the coast at Cartagena (source: Local Hazardous Weather Conditions, United States Naval Research Laboratory).

Local storms

Storm surges on the Cartagena coast are probably mostly generated by local storms, as cold fronts and hurricanes do not often approach the coast to a sufficient distance to generate significant storm surges on the Cartagena coast. In order to calculate the storm surge height due to local storms, the calculated wind speed distribution can be used for the wind set-up. However, the simple formulations for storm surge heights do not generate representative values for the Cartagena coast, because the large depth of the Caribbean and the local topography are too complex.

Measurements

The only data that was found on storm surge heights is originated from the Dutch company Royal Haskoning. For the construction of the tidal inlet of the Cienaga de la Virgen, Royal Haskoning installed water level measurement devices at the coast at Cartagena. Based on the measurements, Royal Haskoning calculated a maximum storm surge height of 1m on top of the tide level (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003). However the probability of the 1m storm surge was not found, it is assumed that the value of 1m storm surge height is 1/50 years as the tidal inlet is probably constructed for a 50 year period.

Precipitation

The climate in Cartagena knows a dry season and a wet season. The dry season extends from December – April, and from May the amount of precipitation increases steadily with a sharp increase in October, Figure: E.. The average annual rainfall is estimated to be 994mm (Universidad de Cartagena, 2009).

The change in rainfall is mostly caused by the location of the ITCZ (Inter Tropical Convergence Zone), (Molares, 2011).

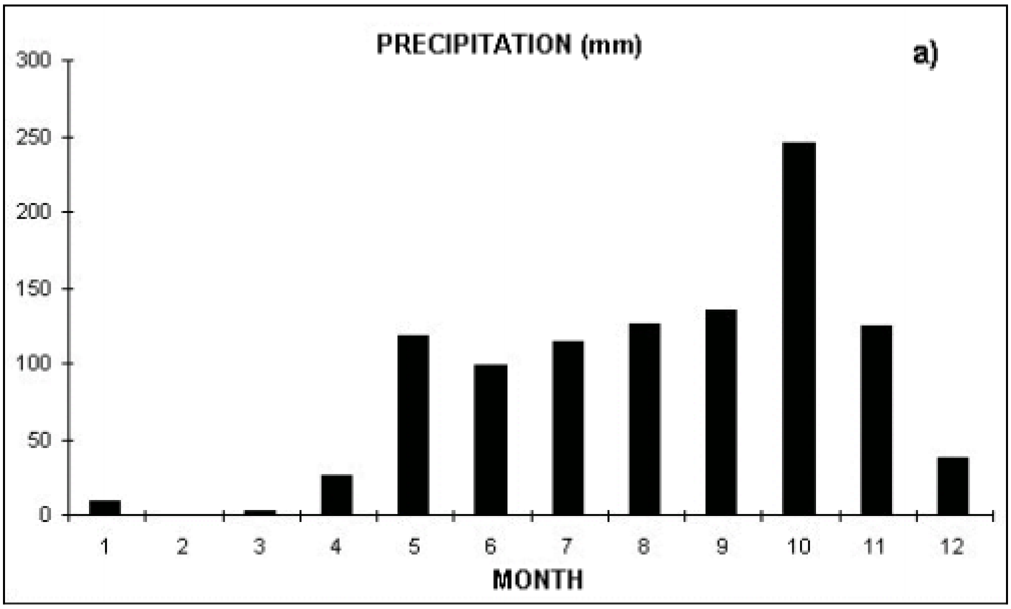


Figure: E.16 Monthy precipitation Cartagena (Source: Colombian national meteorological agency (IDEAM))

Extreme precipitation

Although the annual precipitation in Cartagena does not differ much from countries such as the Netherlands, it does have a very different intensity. The average annual rainfall of Cartagena is 994mm (Universidad de Cartagena, 2009) which is spread over the months April to November since the months December to March have an average rainfall of 0mm. Of these months October has a much higher rainfall than the other months.

Even within the months it does not rain continually and the majority of the precipitation is spread over several days. A study has been done to approximate the maximum precipitation in 24 or 48 hours, based on measurements taken from the airport of Cartagena. Table E.1 presents the return periods of maximum rainfall in 24 and 48 hours, as well as the relative amount in 24 and 48 hours.

Table E.1 Return period of maximum rainfall in 24 and 48 hours

Período de Retorno	Pmáx	Pmáx	P48/P24
	48 Horas	24 Horas	
1	71.58	60.06	1.19
2	113.82	90.76	1.25
5	169.66	131.34	1.29
10	211.9	162.04	1.31
20	254.14	192.73	1.32
50	309.98	233.31	1.33
100	352.23	260.01	1.33

(Universidad de Cartagena, 2009)

The same study also shows that within the 24-hour time period most of the precipitation is concentrated even further. The result: nearly 100% of the precipitation within 24 hours actually falls within 5 hours.

Sea level rise

Due to climatological changes the sea level rises (amongst others) in the Caribbean. Water level measurements in combination with land subsidence have shown a trend of approximately 6mm/yr relative sea level rise in Cartagena according to INGEOMINAS (Servicio Geológico Colombiano), see Figure E..

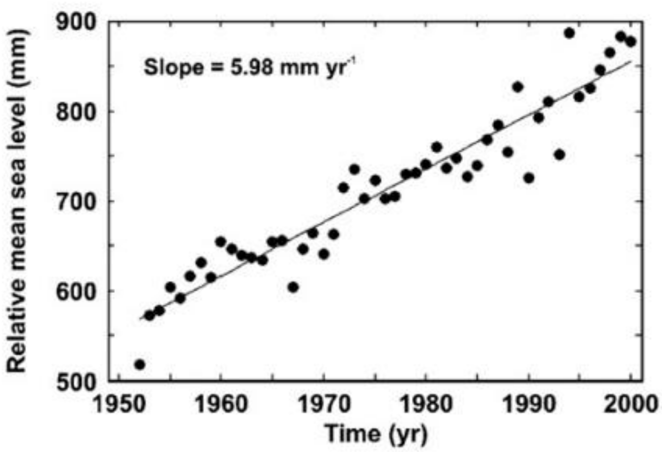


Figure E.17 Relative mean sea level measurements (Restrepo & López, 2007)

According to another study (Restrepo, Oterob, Casasc, Henaod, & Gutiérreze, 2012) the rate of relative sea level rise has increased over the last decades, see Figure E.1813.

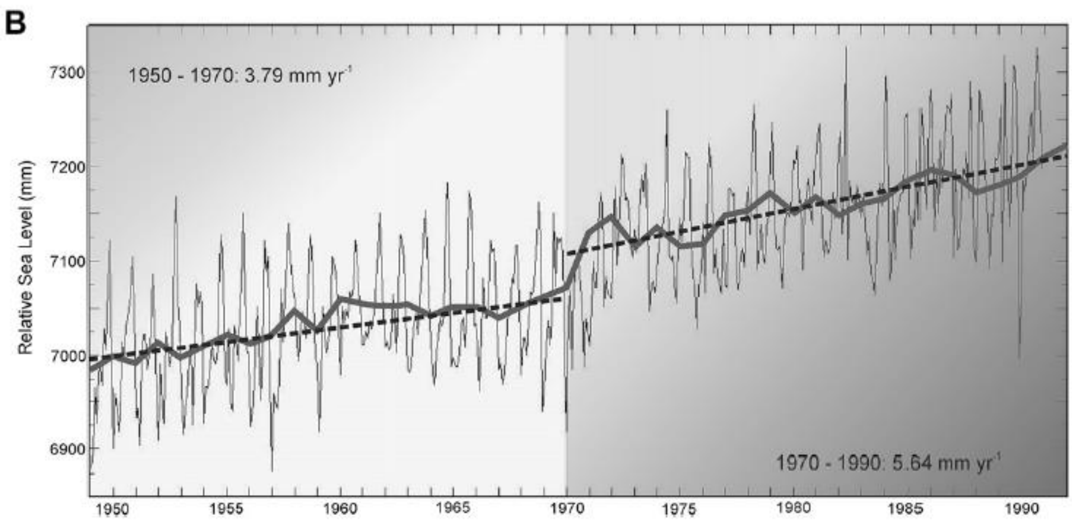


Figure E.1813 Increase of rate of relative sea level rise

It is expected that in the year 2100 the sea level rise is 1m above current mean sea level (Alianze Clima y Desarrollo, 2012). That implies that the rate of sea level rise is expected to increase in the coming years.

The expected sea level rise in the next 50 years is expected to be 0,50m, which is consistent with a rise of 1,0m in 2100. This results in an average sea level rise of 10mm/year in the next 50 years.

Sea level rise induced erosion

Because the project focuses on establishing solutions to the problems for over the next 50 year period, the sea level rise of 50cm in the next 50 years is considered. A simple relation between sea level rise and coastline retreat is used in order to give an estimate of the expected coastline retreat in the next 50 years. The required nourishment quantities can be calculated from the coastline retreat. Bruun's rule is applied to estimate the coastline retreat. Figure E.19 shows equation IV-3-5 from the Coastal Engineering Manual (USACE, 2006).

$$R = \frac{L_*}{B + H_*} S$$

where

R = shoreline retreat

S = increase in sea level

L_* = cross-shore distance to the water depth H_*

B = berm height of the eroded area

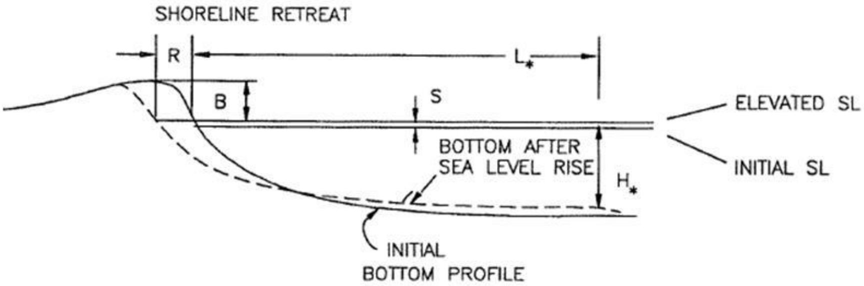


Figure E.19: Bruun's rule (Source: Coastal Engineering Manual 2006, USACE, p. 1300)

The total shoreline retreat experienced by a sea level rise of 50cm is:

$S = 0{,}50m$
$H_* = depth\ of\ closure = 5m$ (see sediment → depth of closure)
$L_* = 600m$ (average distance to depth of closure of 5m, obtained from bathymetry)
$B = 1m$ (estimated current dune height)

$$R = \frac{L_*}{B + H_*} S \approx 50m$$

The estimated coastline retreat due to a relative sea level rise of 0,50cm is 50m. However, currently sea level rise is already present without signs of structural erosion. The sediment supply is able to keep up with the current rate of sea level rise. It is assumed that the coastline retreat is only felt for additional sea level rise on top of the current 6mm/year. That means that in the next 50 years on average an additional 4mm/year sea level rise will cause the coastline to retreat.

The expected coastline retreat by the additional sea level rise over 50 years is:

$S = 0{,}2m$

$$R = \frac{L_*}{B + H_*} S \approx \mathbf{20m}$$

Sediment

As is discussed in the "Global Coast" chapter, the sediment at Cartagena originates from the large Magdalena River. The sediment consists mostly of variable grain silica sands. The grain diameter of the sand on Cartagena's beaches is relatively small. The D_{50} in the northern coast of Cartagena, just south of the tidal inlet, varies between 80µm - 100µm (Pombo, 2013). The grain size around Cartagena varies between D_{50}=140 µm – 210 µm according to (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003). It is assumed that the average grain size is somewhere in between, around 120 µm.

Depth of closure

On the basis of measurements done along the coast of Cartagena, the depth of closure in the area of Bocagrande is around 5m (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003)

Appendix F. Overtopping quantities

The wave climate on the Cartagena coast is directly related to the wave overtopping quantities. The offshore mean wave direction is NNE, which means that the northern coast is affected by most of the waves. The significant wave height under average conditions at 'Punta Santo Domingo' is between 0.3m to 1.7m. However, higher waves due to storms are mostly originating from the northwest; therefore the stretch of coast just south of Punta Santa Domingo is more affected by overtopping during high wave conditions. During storms the breaking wave heights can reach heights from 1.9m to 2.4m (Moreno-Egel, Agámez, Castro, & Voulgaris, 2003). The shoreline orientation ranges from 250° to 325°, north being 0°/360°.

In order to assess the amount of overtopping a few dimensions of the seawall have been estimated. The seawall dimensions are not the same at every location, but a rough estimate is made to be able to do a simple calculation. The slope of the seawall is around 1:1.5 – 1:2 and the freeboard with respect to mean sea level is approximately 1.75m. The formula for overtopping of simple armored slopes is (CIRIA; CUR; CETMEF, 2007):

$$q = C_r * \sqrt{g * H_{m0}^3} * \gamma_b * 0{,}2 * exp(-2{,}3 \frac{R_c}{H_{m0} * \gamma_f * \gamma_\beta * \gamma_b})$$

The crest reduction factor (CIRIA; CUR; CETMEF, 2007) can be calculated using the following formula:

$$C_r = 3{,}06 \times \exp\left(\frac{-1{,}5 \times G_c}{H_{m0}}\right)$$

And the berm reduction factor ($0{,}6 \leq \gamma_b \leq 1{,}0$) can be calculated using the formula below:

$$\gamma_b = \frac{L_{berm}}{L_{berm} + H_{m0} \times \left(Slope_{before-berm} + Slope_{breakwater}\right)}$$

Due to the very small depth in front of the seawall, under average circumstances the wave height will generally be small. Therefore overtopping values using the equation above give low values. In observations during average wave conditions it was shown that overtopping affected certain locations of the seawall more significant. This is probably caused by the local damage to the seawall, as the overtopping is worse at the damaged parts.

The overtopping calculations and its values are shown in Table F.1.

	Verification	Current situation		Future situation	
		normal	storm	normal	Storm
g	9,81	9,81	9,81	9,81	9,81
γ_f	0,6	0,6	0,6	0,6	0,6
γ_β	1	1	1	1	1
$Slope_{before\text{-}berm}$ (1:x)	10	10	10	10	10
H_{m0}	0,8	1	2,5	1	2,5
Tide	0	0,35	0,35	0,35	0,35
Storm surge	0	0	0,5	0	0,5
Sea level rise	0	0	0	0,5	0,5
L_{berm}	0	0	0	5	5
h_{crest} (MSL)	2	2	2	3	3
$Slope_{breakwater}$ (1:x)	2	2	2	3	3
γ_b	0,9	0,9	0,9	0,722	0,867
R_c	2	1,65	1,15	2,15	1,65
G_c	4	4	4	6	6
C_r	0,00169	0,0076	0,278	0,000378	0,0836
q (m3/s/m)	**1,6E-08**	**3,8E-06**	**0,087**	**1,89E-09**	**0,0097**

Table F.1 Values used for overtopping

Stone Diameter

The required stone size is calculated using the Van der Meer formula for shallow water and plunging waves (CIRIA; CUR; CETMEF, 2007).

$$\frac{H_s}{\Delta D_{n50}} = c_{pl} P^{0.18} \left(\frac{S_d}{\sqrt{N}}\right)^{0.2} \left(\frac{H_s}{H_{2\%}}\right) \left(\xi_{s-1,0}\right)^{-0.5}$$

The formula uses the following values (for the once in fifty year storm):

H_s	3	m
T	9	s
Tm-1	10	s
g	9,81	$m*s^{-2}$
cot α	3	m
ξ_{s-1}	2,40471	-
Storm duration	12	h
N	3000	waves
P	0,5	-
C_{pl}	6,2	-
$Hs/H_{2\%}$	0,714286	-
S_d	7	-
Δ	1,65	-
D_{n50}	1,088386	m
D_{50}	1,295698	m

Appendix G. Accessibility

Appendix G.1 Zones of Cartagena

Figure G.1 Zones of Cartagena

Appendix G.2 Zonal data

	Area	Jobs (%)	Population (%)	Students (Population 20-25)	Households	Entreprices	Hotelbeds	Beaches	Parks	Education
	UCG 1									(# St. Places)
1	a: Bocagrande	10,82%	2,39%	1683	3405	675	7.312	105963	34.322,86	0
2	b: Centro	10,63%	1,56%	1400	2492	728	4.409	0	103.430,23	23487
3	c: Manga	6,06%	1,61%	1124	3401	780	0	0	7.180,80	0
4	d: Pie de la Pope	4,65%	0,74%	612	1601	367	0	0	4.942,78	1152
5	e: La Cabrero	1,21%	0,41%	346	680	156	0	120976	10.286,00	0
6	f: Crespo	4,06%	1,61%	1110	2278	522	2.747	107040	3.077,37	0
7	UCG 2	4,15%	6,17%	4953	11941	438	0	0	2268,74	0
8	UCG 3	0,62%	6,10%	4852	8934	138	0	0	8542,84	0
9	UCG 4	5,19%	6,49%	5176	12906	899	0	0	117,19	0
10	UCG 5	7,96%	6,90%	5432	13335	1151	0	0	10706,86	0
11	UCG 6	9,88%	9,08%	7229	19462	584	0	0	1892,27	0
12	UCG 7	2,57%	6,58%	5515	13289	368	0	0	2220,04	0
13	UCG 8	1,47%	6,77%	5814	14087	280	0	0	9403,66	2086
14	UCG 9	2,98%	5,40%	4378	10854	698	0	0	2696,63	5893
15	UCG 10	4,48%	6,68%	5563	14154	473	0	0	3859,27	0
16	UCG 11	9,85%	3,32%	2564	6837	298	2.606	0	5210,45	0
17	UCG 12	3,35%	9,97%	7811	20449	700	0	0	37173,45	0
18	UCG 13	6,87%	4,38%	3438	9195	640	0	0	10296,59	2512
19	UCG 14	1,96%	8,61%	7184	17282	356	0	0	10559,96	3832
20	UCG 15	1,23%	5,24%	4359	10376	304	0	0	5231,24	0

Table G.1 Zonal data

Appendix G.3 Travel time difference due to tourism (minutes)

Travel time differences no tourism - medium tourism (growth factor 2002-2011=1,8)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
1	0,00	14,73	12,73	14,42	14,45	14,45	15,01	15,31	14,77	14,38	14,39	14,41	14,37	15,12	14,16	14,20	14,16	14,39	15,04	15,04	14,46	14,39	14,40	14,20	14,20	13,89
2	4,65	0,00	0,66	0,53	-0,26	-0,26	0,31	0,61	0,88	0,49	0,51	0,52	0,48	1,23	0,27	0,31	0,27	0,51	1,15	1,15	-0,24	0,51	0,51	0,31	0,31	0,62
3	10,55	8,45	0,00	0,99	1,58	2,89	1,43	2,65	2,68	3,46	3,49	3,49	3,82	3,03	3,46	3,50	3,28	3,49	4,34	4,34	2,91	3,49	3,49	3,50	3,50	3,51
4	7,49	3,12	0,05	0,00	0,75	0,98	0,60	0,44	0,48	0,08	0,10	0,11	0,08	0,83	0,06	0,10	-0,14	0,10	0,27	0,94	0,99	0,10	0,10	0,10	0,10	0,71
5	7,75	4,01	0,56	0,76	0,00	0,30	0,52	1,16	1,12	0,73	0,74	0,75	0,72	1,47	0,51	0,54	0,50	0,74	1,39	1,39	0,31	0,74	0,74	0,55	0,54	1,14
6	8,58	3,98	0,91	1,12	0,36	0,00	0,86	0,92	0,92	0,93	0,97	0,96	1,00	1,67	0,87	0,90	0,76	0,96	0,98	1,75	0,01	0,97	0,97	0,90	0,90	1,33
7	8,85	4,48	1,65	1,86	-0,67	-2,02	0,00	0,09	0,08	0,09	0,13	0,13	0,16	0,83	1,60	1,64	-0,08	0,13	0,15	0,29	-2,01	0,13	0,13	1,64	1,64	0,84
8	7,16	1,44	-0,19	-0,04	-2,37	-2,67	-0,21	0,00	-0,01	0,01	0,04	0,04	0,07	0,74	-0,16	-0,13	-0,17	0,04	0,06	0,14	-2,65	0,04	0,04	-0,12	-0,13	0,04
9	10,18	4,20	-0,20	-0,05	0,00	-2,72	0,58	-0,04	0,00	-0,06	0,01	0,00	0,03	0,73	-0,17	-0,14	-0,21	0,00	0,02	0,10	-2,70	0,01	0,01	-0,14	-0,14	0,37
10	10,03	4,05	-0,35	-0,20	-2,47	-2,89	-0,44	-0,21	-0,15	0,00	0,08	0,08	0,46	-0,01	0,55	0,54	-0,14	0,08	0,08	0,17	-2,88	0,08	0,07	0,54	0,54	0,30
11	11,20	6,60	0,82	0,18	-0,22	-3,15	0,36	-0,47	-0,51	-0,36	0,00	0,22	0,28	-1,01	0,35	0,34	0,01	0,22	0,24	0,32	-3,14	0,08	0,22	0,22	0,22	0,52
12	10,98	5,92	0,60	-0,13	-0,76	-2,72	-0,18	-0,04	-0,08	0,08	0,00	0,00	0,05	-1,01	0,12	0,11	-0,21	0,00	0,01	0,10	-2,71	0,00	0,00	0,00	0,00	0,41
13	10,81	6,21	0,43	-0,21	0,99	-3,21	0,93	-0,53	-0,47	-0,16	-0,17	-0,17	0,00	-1,02	-0,04	-0,05	-0,38	-0,17	-0,13	-0,07	-3,20	-0,17	-0,17	-0,17	-0,05	0,35
14	10,78	6,17	0,40	-0,24	1,04	0,32	0,89	0,46	0,50	-0,06	-0,05	-0,03	-0,05	0,00	0,43	0,46	-0,27	-0,05	-0,03	1,31	0,33	-0,05	-0,04	0,46	0,46	0,93
15	10,85	6,25	0,47	-0,17	1,12	0,40	0,97	0,54	0,58	1,08	1,10	1,11	1,12	-0,95	0,00	0,16	0,82	1,10	1,00	1,01	0,41	1,09	1,10	0,16	0,16	1,26
16	10,94	6,33	0,56	-0,08	1,20	-2,83	1,05	-0,15	-0,09	0,00	0,00	0,00	0,01	-0,65	0,08	0,00	-0,22	0,00	0,84	0,84	-2,82	0,00	0,00	0,00	0,00	0,60
17	10,97	6,36	0,59	-0,05	1,23	-3,36	1,08	-0,68	-0,68	0,01	0,00	0,00	0,04	-1,23	0,11	0,10	0,00	0,00	0,03	0,09	-3,35	0,00	0,00	0,11	0,10	0,46
18	10,98	6,37	0,60	-0,04	1,01	-2,72	1,09	-0,04	-0,68	0,08	0,00	0,00	0,05	-1,23	0,12	0,12	-0,21	0,00	0,08	0,10	-2,71	0,00	0,00	0,00	0,00	0,52
19	10,92	6,32	0,54	-0,09	1,19	-3,36	1,04	-0,67	-0,68	0,01	0,00	0,00	0,00	-1,23	0,07	-0,01	0,06	0,00	0,00	-0,02	-3,34	0,00	0,00	-0,01	-0,02	0,43
20	10,94	6,33	0,56	-0,08	1,20	-3,36	1,05	-0,68	-0,68	0,01	0,00	0,00	0,01	-1,23	0,08	0,00	0,06	0,00	0,00	0,00	-3,35	0,00	0,00	0,00	0,00	0,43
21	9,40	4,81	1,74	1,95	1,18	0,49	1,68	1,75	1,74	1,76	1,79	1,79	1,82	2,49	1,69	1,72	1,58	1,79	1,81	2,57	0,00	1,79	1,79	1,73	1,72	2,10
22	10,98	6,37	0,60	-0,04	0,35	-2,73	0,93	-0,05	-0,27	0,06	0,00	0,00	0,05	-1,23	0,13	0,11	-0,21	0,00	0,02	0,10	-2,72	0,00	0,00	0,00	0,00	0,50
23	10,98	6,38	0,60	-0,04	1,03	-3,36	1,10	-0,67	-0,68	0,01	0,00	0,00	0,06	-1,23	0,13	0,00	-0,21	0,00	0,08	0,07	-3,34	0,00	0,00	0,00	0,00	0,44
24	10,94	6,33	0,56	-0,08	1,20	-2,83	1,05	-0,15	-0,09	0,00	0,00	0,00	0,01	-0,65	0,08	0,00	-0,21	0,00	0,84	0,84	-2,82	0,00	0,00	0,00	0,00	0,60
25	10,94	6,33	0,56	-0,08	1,20	-2,83	1,05	-0,15	-0,09	0,00	0,00	0,00	0,01	-0,65	0,08	0,00	-0,22	0,00	0,84	0,84	-2,82	0,00	0,00	0,00	0,00	0,60
	9,51	5,66	1,02	0,81	0,97	-1,09	1,31	0,78	0,74	0,90	0,93	0,94	0,99	0,59	0,98	0,98	0,74	0,93	1,16	1,34	-1,09	0,93	0,93	0,96	0,96	1,32

Table G.2 Travel and time difference

In the table above the travel time differences between the touristic (medium tourism amount) and situation without tourism is shown. As can be seen from the color scaling, almost 14 minutes of travel time is lost from trips originating from Bocagrande. Also trips going to Bocagrande and Centro suffer from major travel time losses of respectively 9.5 and 5.7 minutes per trip.

Appendix G.4 Total travel time difference due to tourism (vehicle*hours)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
1	0,00	606,96	2,67	54,74	0,05	4,10	37,09	3,24	29,72	2,61	1,46	3,74	0,92	84,97	9,65	0,55	7,21	3,85	9,85	26,80	13,75	25,06	18,16	2,96	1,86	**951,95**
2	169,79	0,00	0,27	1,12	-0,01	-0,94	2,44	1,91	7,32	0,42	0,52	0,56	0,05	6,33	1,02	0,11	0,20	0,46	2,94	4,15	-0,97	1,27	0,93	0,19	0,12	**200,21**
3	13,69	37,30	0,00	4,49	0,37	0,37	0,17	0,08	0,54	0,18	0,21	0,48	0,24	2,95	45,15	13,44	2,15	0,40	6,73	2,12	3,99	2,88	2,20	3,19	1,95	**145,27**
4	3,09	3,36	0,03	0,00	0,19	3,19	0,17	0,16	2,95	0,04	0,06	0,15	0,03	7,38	0,19	0,04	-0,07	0,06	1,94	3,40	7,13	0,16	0,12	0,06	0,04	**33,85**
5	4,53	11,07	0,02	0,00	0,00	0,14	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,03	0,00	0,00	0,00	0,00	**15,80**
6	14,65	20,98	0,09	0,00	0,02	0,00	0,14	0,21	0,07	0,37	0,06	0,49	0,01	0,44	0,01	0,00	0,00	0,00	0,00	0,03	0,00	0,05	0,02	0,01	0,01	**37,66**
7	1,07	51,38	20,42	0,02	-0,76	-0,22	0,00	0,10	0,06	0,08	0,01	0,04	0,00	0,04	0,05	0,01	0,00	0,00	0,01	0,01	-0,43	0,02	0,01	0,01	0,01	**71,90**
8	0,67	3,67	-0,02	-0,02	-0,05	-0,11	-0,04	0,00	0,00	0,00	0,01	0,03	0,00	0,75	-0,01	0,00	0,00	0,00	0,01	0,03	-0,75	0,02	0,01	-0,01	-0,01	**4,20**
9	3,21	10,47	-0,02	-0,03	0,00	-0,38	0,40	-0,04	0,00	-0,29	0,03	0,01	0,01	1,19	-0,04	0,00	0,00	0,00	0,00	0,12	-1,00	0,00	0,00	-0,02	-0,01	**13,62**
10	13,09	81,64	-0,58	-1,94	-4,15	-0,59	-1,75	-0,02	-0,22	0,00	0,37	0,37	1,28	-0,05	0,01	0,00	0,00	0,00	0,02	0,09	-0,81	0,07	0,01	0,01	0,00	**86,87**
11	0,17	13,12	0,01	0,40	-0,09	-0,03	0,66	-0,01	-0,18	-1,42	0,00	0,55	0,00	-2,70	0,00	0,00	0,00	0,02	0,00	0,03	-0,05	0,33	0,19	0,07	0,00	**11,10**
12	5,58	8,72	0,06	-0,27	-0,14	-0,04	-0,29	0,00	-0,07	0,73	0,00	0,00	0,11	-5,75	0,00	0,00	0,00	0,00	0,00	0,01	-0,10	0,00	0,00	0,00	0,00	**8,55**
13	46,18	63,56	3,19	-3,56	2,65	-0,06	7,78	-0,02	-0,26	-0,06	-0,01	-0,02	0,00	-3,41	0,00	0,00	-1,49	0,00	-1,23	-0,21	-0,09	-0,01	-0,01	0,00	0,00	**112,93**
14	22,24	26,27	3,04	-1,10	0,27	0,16	2,86	0,33	2,51	-0,02	-0,04	-0,01	-0,04	0,00	3,22	0,40	-1,21	-0,04	-0,16	8,32	0,35	-0,05	-0,06	0,47	0,28	**67,98**
15	5,24	4,16	1,50	-0,18	0,45	0,08	0,41	0,02	0,25	0,00	0,21	0,06	0,13	-4,36	0,00	0,12	10,62	0,20	0,62	1,34	0,39	0,78	0,62	0,10	0,06	**22,79**
16	0,02	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	0,00	0,00	-3,36	0,00	0,38	0,04	-0,01	0,00	0,00	0,00	0,00	**-2,94**
17	0,91	1,24	0,33	-0,02	0,07	-0,11	0,14	-0,04	-1,85	0,00	0,00	0,00	0,10	-23,30	0,12	0,04	0,00	0,00	0,10	0,16	-0,25	0,00	0,00	0,12	0,04	**-22,21**
18	0,28	13,30	0,00	-0,10	0,33	-0,01	2,19	0,00	-0,03	0,04	0,00	0,00	0,00	-0,82	0,00	0,00	0,00	0,00	0,50	0,57	-0,01	0,00	0,00	0,00	0,00	**16,25**
19	0,09	0,39	0,01	-0,01	0,01	-0,01	0,03	-0,01	-0,21	0,00	0,00	0,00	0,00	-3,20	0,00	0,00	0,40	0,00	0,00	-0,01	-0,02	0,00	0,00	-0,03	-0,02	**-2,58**
20	0,95	0,64	0,03	-0,02	0,05	-0,01	0,07	0,00	-0,63	0,00	0,00	0,00	0,01	-10,99	0,01	0,00	0,15	0,00	0,00	0,00	-0,07	0,00	0,00	0,00	0,00	**-9,83**
21	50,00	63,83	2,81	0,00	0,05	0,65	0,10	0,24	0,55	0,72	0,34	1,12	0,04	1,33	0,05	0,01	0,01	0,02	0,11	0,88	0,00	0,26	0,11	0,05	0,04	**123,32**
22	0,48	3,13	0,00	-0,03	0,04	-0,01	0,35	0,00	-0,01	0,04	0,00	0,00	0,00	-0,22	0,00	0,00	0,00	0,00	0,00	0,00	-0,01	0,00	0,00	0,00	0,00	**3,77**
23	1,56	18,81	0,02	-0,17	0,85	-0,01	2,94	-0,01	-0,08	0,00	0,00	0,00	0,00	-1,34	0,00	0,00	0,00	0,00	0,00	0,00	-0,01	0,00	0,00	0,00	0,00	**22,57**
24	0,39	0,70	0,02	0,00	0,00	-0,02	0,01	0,00	0,00	0,00	0,00	0,00	0,00	-0,10	0,00	0,00	-2,29	0,00	0,51	0,14	-0,03	0,00	0,00	0,00	0,00	**-0,68**
25	0,27	0,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	0,00	0,00	-1,45	0,00	0,17	0,07	-0,01	0,00	0,00	0,00	0,00	**-0,48**
	358,13	**1.045,23**	**33,92**	**53,32**	**0,19**	**6,15**	**55,89**	**6,13**	**40,40**	**3,45**	**3,22**	**7,57**	**2,88**	**49,10**	**59,42**	**14,70**	**10,88**	**4,98**	**22,50**	**48,10**	**21,03**	**30,84**	**22,30**	**7,17**	**4,36**	**1.911,88**

Table G.3 Total time difference

In the table on the left all total travel times differences for a touristic period are calculated compared to a non-touristic situation. This is done by multiplying the travel time loss per trip by the amount of trips made. If the total travel time for all trips in Cartagena is summed, it turns out that 1912 vehicle*hours are added to a morning peak hour during a medium touristic season.

Appendix G.5 Infrastructure capacities

	Total Capacity	Lanes	C (per lane)	V	T
Local road	600	1	600	30	20
Mainroad	1575	1,5	1050	35	30
Highway	3200	2	1600	40	40
Motor way	6000	3	2000	50	40
Overstroming B'grande	2400	3	800	20	40
Overtropping Santander	1500	1,5	1000	25	40

Table G.4 Infrastructure capacity

Appendix G.6 Growth factor calculation

As mentioned in the main report, a transportation model of the city of Cartagena is established, based on OD-matrices and traffic counts in the year 2002. Since no information is available about current traffic situation, a growth factor model is made to estimate the current transport situation in the city.

Looking at what estimating parameters could be used to transform the validated transportation model of the year 2002 to the current situation, GDP and population growth turn out to have a direct impact on the amount of traffic that is generated ((Schafer A. , 2000); (Schafer A. , 1998)). Therefore, the development of both population and economic growth in Cartagena is firstly investigated.

Looking at the BNP and population increase (Figure G.2 and G.3), subtracted from DANE, the national

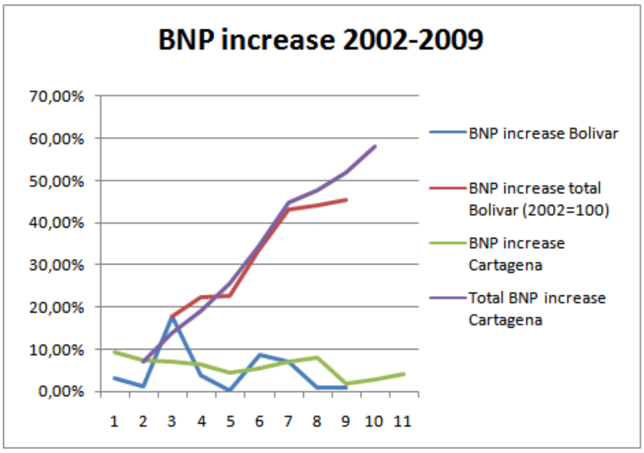


Figure G.214 BNP 2001 - 2011

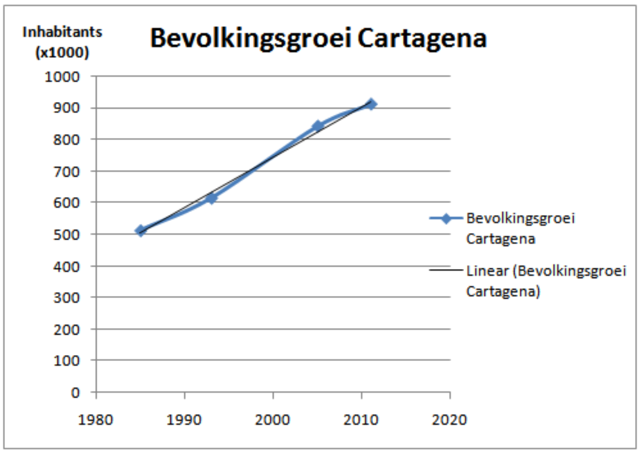


Figure G.3 Population growth

statistical database, it can be seen that they both have been increased enormously during the last 10 years. Also the relative car occupancy in Cartagena, which is a result of an increasing GDP, has risen with around 7,5% per year since 2002, as can be seen from Figure G.4.

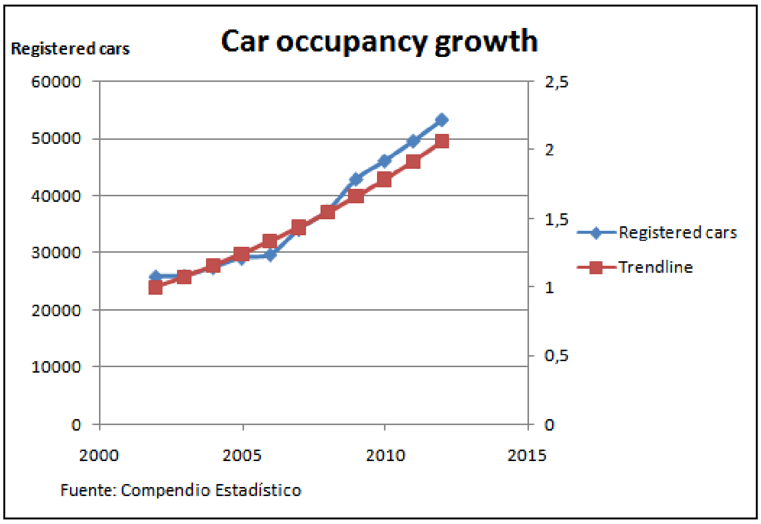


Figure G.4 Car occupancy growth

Based on the development of the parameters *population, BNP* and *car occupancy growth*, a growth-factor is chosen to increase the OD-matrix from the 2002 transportation model and create an estimation for the current situation (=2011). In Table G.5 the developments of all factors are summarized.

Since there are no traffic counts available to validate the current transportation model, the transformation from the 2002 OD-matrix to the OD-matrix of the current Cartagena traffic situation is uncertain. Besides the lack of data to check the current model, all variables have been grown exponentially during the last decade, making it hard to predict exact traffic numbers.

Therefore, not only one, but three growth-factors are chosen to transform the 2002 transportation model to the current situation. The transformation factors 1.8, 1.9 and 2.0 are chosen, because they represent the variety of the variable outcomes over the 2002-2011 period. All OD-pairs are multiplied by this factor, assuming that the extra traffic that has emerged over the last decade has spread out over the network in proportion to the 2002-deviation. This choice has been made, because there were no car occupancy, GDP or population increase data available on a zonal level. The fact that three growth factors are chosen will lead to a bandwidth of possible outcomes for the 2011 situation, instead of presuming that the one growth factor that is chosen will definitively lead to the best representation of the 2011 traffic situation in Cartagena.

Development Cartagena	**2002-2011**	
Population growth	38%	
BNP growth	58%	x
Summed increase BNP + population	118%	
Increase amount of cars	91,80%	
Increase average car occupancy	71,95%	

Table G.5 Development Cartagena

Of course, the important advice is given to collect current traffic counts and validate the 2002-2011 transformation, before using the model outcomes for policy making!

Appendix G.7 Modeling external factors and growth-factor 2002-2011

As shown in the Accessibility System Analysis, several external factors are taken into account while modeling the Cartagena traffic flows. In this appendix it is explained how the external factors are modeled. The external factors *Coastal problems* and *Tourism* are considered.

Coastal problems

Two coastal problems influencing the accessibility of Bocagrande are presented: Firstly, the overtopping along the coastal road, damaging the infrastructure and reducing capacity. Next to that, the common flooding of Bocagrande as result of the absence of a drainage system and low coastal protection, leads to lower speeds on the Bocagrande roads. In figure G.5 the exact places in the transportation model are marked, where the coastal problems are assumed. The link capacity on the flooded Bocagrande road drops from 3200 to 2400 cars per hour, the capacity along the coastal road drops from 3200 to 1500 cars per hour.

These two coastal problems are implemented in the initial transportation model to measure its influence on the criteria travel time, total travel time and link load. To estimate what benefit could be gained by solving these problems from occurring, a Value of Travel Time (VoTT)-calculation is done in chapter 6.

Figure G.5 Link Load

Impact of tourism on accessibility

The amount of tourists visiting Cartagena every year shows a rising trend of about 18% per year since 2004 (Chapter 4, Tourism future scenario). The amount of tourists in Cartagena is so large, that they have a significant impact on the traffic situation in the city, especially around the touristic hotspots like the old city centre and the peninsula of Bocagrande. To make sure that the alternatives that are proposed to improve the accessibility of Bocagrande will lead to an improvement, it is important to take the growing amount of tourists into account.

Traffic Growth factor 2002-2009 Tourism	80%	90%	100%
No tourism **Intensity/Capacity** *Bocagrande in/out* *Coastal road north/south* *Calle 30 entrance*	0,89/0,93 0,78/0,57 1,23	0,94/0,98 0,89/0,60 1,29	1,00/1,03 1,08/0,66 1,48
0,80 **Intensity/Capacity** *Bocagrande in/out* *Coastal road north/south* *Calle 30 entrance*	1,01/1,16 1,22/0,63 1,29	1,06/1,20 1,25/0,67 1,37	1,11/1,26 1,32/0,70 1,48
1,00 **Intensity/Capacity** *Bocagrande in/out* *Coastal road north/south* *Calle 30 entrance*	1,04/1,21 1,26/0,75 1,28	1,08/1,26 1,14/0,68 1,34	1,13/1,32 1,38/0,72 1,49
1,25 **Intensity/Capacity** *Bocagrande in/out* *Coastal road north/south* *Calle 30 entrance*	1,06/1,26 1,32/0,74 1,28	1,11/1,32 1,37/0,70 1,39	1,17/1,37 1,43/0,73 1,51

Table G.6 Traffic growth

Therefore, the amount of tourists that are estimated using a distribution model in which the touristic hotspots are adopted will be multiplied by the factors of 0.8, 1 and 1.25. These three growth factors for the development of a total, tourism including-OD-matrix will make sure that the impact of alternatives is also checked for a situation in which more tourists are present than at this moment in time. The results of extra tourists on the link loads around the Bocagrande – Centro-connection, is presented in table G.6

From Tabel G.6 not only the amount of tourism is varied, but at the same time, different traffic growth factors 2002-2011 are taken into account. It can be seen that tourism has a significant effect on the link loads, especially around the touristic areas of Centro and Bocagrande. The Calle 30, connecting the city centre to many residential areas, is only little influenced by the extra tourists. It can be concluded that tourists will have a high impact on the link loads, but especially the touristic areas will suffer from this extra load.

It can also be concluded that without tourism, all relative link loads around the Bocagrande – Centro-connection are around 1.0. As soon as tourism occurs, link loads pass the 1.0 border, and will definitively lead to severe traffic congestion. The current infrastructure network around Bocagrande can handle the traffic flows outside the touristic season, but as soon as (only little) tourism occurs, link loads become too high. Therefore, solutions need to be tested to improve the capacity of the Cartagena road network, preparing it for the expected tourism growth in the future.

Modeling touristic trips in Cartagena (Distribution model)

To come to the OD-matrix in which tourism is included, the *tourism specific OD-matrix* is simply added to the matrix in which all trips of cars and buses are specified. To estimate the *tourism specific OD-matrix*, the following assumptions are made.

In figure G.6 all zones that attract or produce more trips during the touristic season are shown. In Table XX it is explained why those zones are part of the touristic trips in Cartagena.

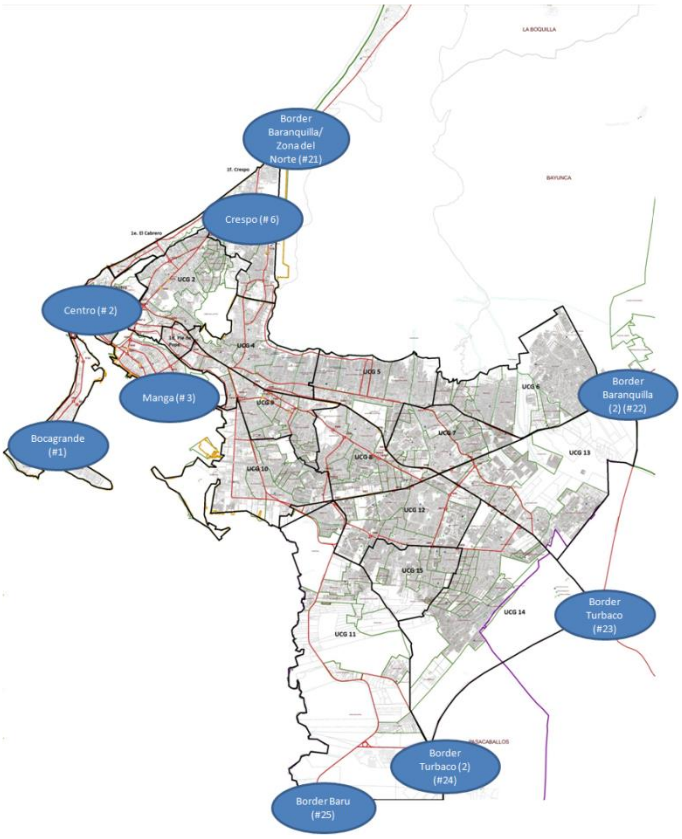


Figure 156 Distribution model

Based on touristic data, the productions per touristic 'zone' that are expected during a morning peak, can be calculated. A distinction is made between touristic traffic that enters the city during the morning peak (via the airport, cruise terminal or the access roads of the city) and the amount of tourists that already are in Cartagena (originating from hotels). Based on the hotel distribution between Zona del Norte, Centro and Bocagrande, the amount of tourists are estimated and it is assumed that tourists only make 1 trip per morning peak on average and stay in Cartagena for four days.

	Function
#1	Hotels + beach
#2	Hotels +Tourist attractions
#3	Cruise terminal
#6	Airport
#21	Hotels + road entrance tourists
#22	Road entrance Tourists
#23	Road entrance Tourists
#24	Road entrance Tourists
#25	Road entrance Tourists

Since more data is available on the productions of touristic trips, these amounts are used to calculate the attractions. The attractions during the morning peak are calculated by determining the relative importance of the touristic zone as a destination. The city centre has been given the highest attraction potential with 60% of all trips, Bocagrande comes 2nd with 30% and the rest is divided over the other zones.

A distribution model is used to connect all the estimated touristic productions and attractions. To do so, the attractions and productions are needed, as well as a deterrence function, which describes the incentive of travelling between two zones. An exponential deterrence function is used and the distance is applied as measure of accessibility. In Figure G.7 the deterrence coefficients and b are varied, to see the influence of the coefficients on the deterrence. Based on Figure G.7 the following deterrence function will be used:

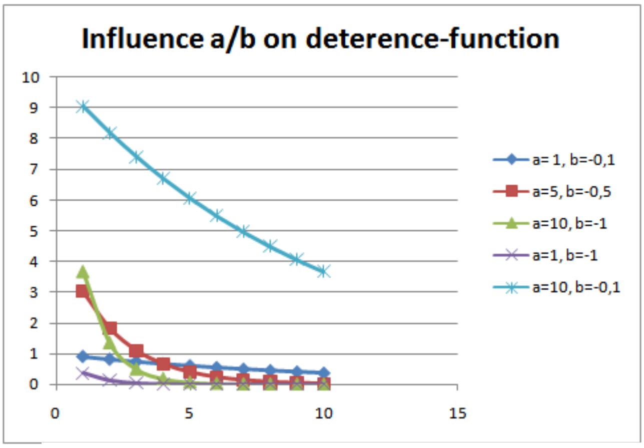


Figure G.7 deterence function

Distribution function:

$T_{ij}=a_i b_j P_i A_j f(c_{ij})$

With: $f(c_{ij})=5e^{-0,5(cij)}$

After 17 iterations to uniform the attractions and productions, figure G.8 has been used as the tourism OD-matrix. After adding the tourism OD-matrix to the OD-matrix which represents the trips of cars and buses during a morning peak hour, the total OD-matrix including tourism is ready to be assigned.

	1	2	3	6	21	22	23	24	25	
1	1.652	1.731	24	11	8	12	6	4	3	3.451,0
2	450	1.567	21	13	10	10	5	4	3	2.081,0
3	156	515	13	4	3	9	5	4	3	713,0
6	51	228	3	12	14	2	1	1	0	311,0
21	222	998	13	79	109	8	4	3	2	1.438,0
22	4	12	0	0	0	43	20	5	3	88,3
23	6	21	1	0	0	67	35	31	17	178,9
24	4	12	1	0	0	13	23	39	36	127,2
25	3	9	0	0	0	8	13	38	36	108,3
	2.549,0	5.098,0	76,5	119,0	144,4	169,9	110,5	127,4	102,0	8496,663

Appendix H. Possible solutions brainstorm sessions

This appendix contains several brainstorms that were done to formulate possible solutions for different problem areas.

Overtopping

Solution	Explanation	Pros	Cons
Do nothing	Leave it as it is	• Costs nothing	• Fixes nothing
Build a berm	Build a berm along the where this is possible to reduce wave energy	• Very effective for normal and storm conditions	• Can be expensive, depending on the volume needed
Repair damage	Repair the damage when there is too much of it	• Very direct result • Is currently needed as well	• Is simply not done • Does not really solve the problem • Needs to happen frequently, meaning lots of road closures
Place valves	Close the holes in the seawall that drain the rainwater and replace them with valves that only let water out	• Very cheap and easy to install • Very effective in draining water (if the roads drain properly to the valves) • Is part of all solutions, water simply needs to be drained better	• Only solves a very small part of the problem • Need to be designed such that they don't get clogged
Make road higher	Prevent water from getting on the road by raising it	• Water doesn't damage the road as much	• Very expensive • Not much different than a wall • Reduces the quality of the view from the city centre
Reduce slope angle of seawall	Reduce energy by reducing the angle of the slope of the seawall	• Very effective • Can be reasonably cheap if the foreshore is not too deep • Long term fix	• Impossible if the foreshore is too steep • Very expensive if the foreshore is too deep

Build wall along seawall	Right next to the seawall build a vertical wall	• Effective against overtopping • Cheap and little maintenance	• If built too high it reduces the quality of the view from the city centre
Make seawall higher	Raise the current seawall	• Cost dependent on foreshore profile • Rather effective	• Cost dependent on the foreshore profile
Different armour layer	Change the armour layer to prevent damage to the seawall.	• Effective to strengthen armour layer.	• Expensive • Not effective in reducing runup or overtopping
Offshore breakwaters	Build offshore breakwaters to reduce wave energy	• When placed correctly it could be very efficient	• Expensive • Depends on sea level

Table H.1 Overtopping solutions brainstorm

Sea side

Solution	Description	Pros	Cons
Do nothing	No changes to current situation	• Easy option	• No solution to problems
Build wall	Build a wall to prevent flooding and have a limit to erosion	• Stops erosion when it starts to threaten infrastructure • Could be combined to other measures • A promenade can be constructed on top of the wall • Resilient against sea level rise	• Reduces entrance comfort to beaches • Large impact on current situation • Should be combined with other solutions
Create dunes	Restore natural situation by creating dunes	• Very effective against erosion • Natural situation • Esthetically nice	• Need a lot of sediment • Need a lot of space • Reduces entrance comfort to beaches
Raise road using piles	Raise the road so that floodings do not affect traffic	• Traffic not affected by floodings	• Only reduces problems to floodings of the road • Reduces accessibility of

			buildings and footpaths
Remove buildings	Demolish buildings to get to the natural situation with dunes	• Natural situation	• Not realistic
Submerged breakwaters	Reduce wave attack during high wave conditions by submerged breakwaters	• No esthetic impact • Does not stop sediment transport	• Only works during storms/higher waves • Hard to design for desired effect
Nourishments	Carry out significant nourishments to enlarge beaches and thereby have a larger buffer for winter profile	• Effective • Directly result • More beach	• Requires regular maintenance nourishments •
T-groynes	T-groynes along the coast to trap more sediment and have larger beaches	• Traps more sediment than normal groynes • Increases buffer	• Impact on downstream coast • Should be combined with other measures • Esthetics
Vegetation	Grow vegetation such as mangroves or grass on sand to hold sediment in place	• Effective against erosion, especially due to wind • ‘building with nature’	• Should be combined with other measures • Requires space and/or dunes

Table H.2 Sea side solutions brainstorm

Erosion El Laguito

Solution	Description	Pros	Cons
Do nothing	No changes to current situation	• Easy option	• No solution to problems
Submerged Breakwaters	Reduces wave attack on beach during storms	• Less erosion during storms	• Hard to estimate effectiveness
Nourishments - Continuous - Periodically	Maintain beaches by nourishments	• Effective • Directly more beach	• Erosion not stopped • Should be carried out combined

			with other solutions
Extend existing groynes	Trap more sand using longer groynes	• Relatively simple	• Downstream erosion • Large wave angle reduces effectiveness
T-groynes	Trap sand physically	• Effective for larger wave angles	• Downstream erosion • Should be carried out combined with other solutions
Wall/dike	Hard structure to prevent additional erosion	• Stops erosion	• Only symptom control • No additional value created
Mangroves/vegetation	Plant vegetation to reduce erosion	• Effective	• Beaches become less usable
Relocate	Relocate buildings to avoid damage	• No problems due to erosion anymore	• Expensive • Not feasible
Closed off beach - 'champagne' Pool - Only sand	Close off a part of beach and/or water from the open sea	• No erosion problems	• No real beach
Lower Escollera dam	Lower the escollera dam to increase sediment transport into the bay	• Increased sediment supply	• Increased wave attack, especially during storms
Raise Escollera dam	Raise the escollera dam to reduce wave attack in the bay	• Reduce wave attack in bay →less erosion	• Reduces sediment supply in bay • Reduces interaction bay to open sea

Table H.3 Erosion El Laguito solutions brainstorm

Lake Laguito

Solution	Description	Pros	Cons
Do nothing	No changes to current situation	• Easy option	• No solution
Fill lake with soil	Filling the lake to prevent stagnant water	• New land created • No maintenance	• A lot of soil required • No lake anymore • Lake entrance soil cannot be used for nourishments
Periodical dredging	Dredge after the high wave season every year, lake is not open all year	• No continuous dredging • Sediment source for nourishments	• Not open all year • Every year dredging
Continuous dredging	Sand bypass system from lake entrance to escollera groyne or year-round dredging	• Continuous supply for eroding areas • Open year-round	• Costly • Complex bypass system
Pump water to sea	Pump stagnant water to sea and let the lake fill by rain and seepage	• Reduced impact due to bad water quality	• Solves problems only limited
Mechanical purification	Water treatment system	• Water quality improves	• Only solves water quality problems • Maintenance required • Costly
Underground pipe connected to sea	Law of communicating vessels	• Relatively simple • Little maintenance	• Not very effective due to limited tidal range
Solid structure	Concrete tidal inlet like La Bocana	• Rigid structure • Design could reduce speed of sedimentation	• Expensive for its function • Sedimentation still occurs
Raise escollera dam	Reduce wave attack in bay by raising Escollera dam	• Reduces speed of sedimentation • Less maintenance is required	• Reduces exchange of water in the bay • Costly • Should be combined with other measures
Pump water into lake	Let water flow out itself when the lake	• Relatively simple	• Maintenance required • Only solves part of the problem

	water level becomes high enough		
Sand trap	Trap sediment before it reaches the lake's entrance	• Effective	• Requires periodical dredging • Should be combined with other measures
Groyne extention	Extend a groyne at the Hilton hotel so that it reduces wave attack and sediment transport to the lake	• Increases beach at the Hilton hotel as well	• Obstruction for ships • Should be combined with other measures

Table H.4 Lake Laguito options

Bay side

Solution	Description	Pros	Cons
Do nothing	No changes to current situation	• Easy option	• No solution to problems
Revetment	Construct a wall or dike along the coast	• Effective against flooding • Can be combined with other measures	• Esthetics
Valves	Install valves in current drainage pipes to prevent water flowing in through the pipes during high tide	• Effective if water level is only slightly higher than the road • Can be combined with other measures • Simple solution	• Regular cleaning of pipes to avoid clogging • Should be combined with other measures • Only stops flooding if water level is not higher than the current 'revetment'
Reduction barrier in bay	Construct a partial barrier in the bay that reduces the tidal range	• Reduces flooding during spring tide	• Not effective against storm surges • Tidal range is already small so only limited effect can be reached

Raise roads	Raise the roads so that flooding does not impact accessibility	• Water will not accumulate on the streets • Provides some protection to land behind the road	• Costly compared to revetment • Limits accessibility to buildings
Protection per building	Protect the buildings separately against flooding	• Local owners pay for protection • Does not impact whole area	• Only protects 'rich' owners • Does not solve accessibility problems
Raise land	Raise the land of Bocagrande/Castillogrande to avoid flooding, sacrificing the ground floors of the current buildings	• Effective against flooding • No pumps required for draining	• Costly • Little support by local inhabitants and businesses
Retreat	Move away from the area and let it flood naturally	•	• A lot of value gets lost • Same as do nothing • No support
Storm surge barrier	Construct a storm surge barrier in the bay that closes during high water conditions	• Effective against flooding by storm surges	• Costly • Requires sophisticated monitoring • Reduces navigation for ships
Close off bay	Close off the bay and construct navigation locks at the entrances	• No flooding problems on the bay side	• Reduces navigation • Costly • Requires sluice to let out water from Dique Channel • Impacts bay ecosystem
Drainage system	Construct a drainage system with pumps that transports water to the sea in case of rain and flooding	• Reduces flooding and its impact	• Maintenance • Should be combined with other measures

Table H.5 Bay side solutions brainstorm

Appendix I. Cost analyses & unit price

Figures used to calculate the unit price of dredging/nourishment, gravel, concrete and rocks are obtained from the University of Cartagena.

Unit price dredging/nourishment

Amount	*Unit*
1	m3

Description

Equipment	rate (per hour)	Efficiency	m3
Cutter suction dredger (14"x14")	$ 2.500.000	250	$ 10.000
Equipment topography	$ 12.500	175	$ 71
Equipment bathymetry	$ 18.750	175	$ 107

Materials	per unit	m3
Fuels, lubricants, greases	$ 1.032	$ 1.032

Labor	rate (per hour)	Efficiency	m3
Staff dredge	$ 125.000	175	$ 714
Staff topography	$ 82.520	175	$ 472
Staff bathymetry	$ 105.600	175	$ 603

Total cost per m3 **$ 13.000**

Unit price gravel

Amount	Unit
1	m^3

Description

Equipment	rate (per hour)	Efficiency	m3
Crane	$ 32.760	12	$ 2.730
Crane transporter	$ 68.435	12	$ 5.703
Dump truck	$ 21.150	12	$ 1.763
Excavator	$ 68.435	12	$ 5.703
Compactor	$ 26.200	12	$ 2.183
Equipment topography	$ 33.685	12	$ 2.807

Materials	per unit	m3
Gravel	$ 30.200	$ 30.200

Transport	per unit	m3
Truck	$ 64.000	$ 64.000
Barge	$ 2.400	$ 2.400

Labor	rate (per hour)	Efficiency	m3
Surveyor	$130.600	12	$ 10.883
Assisten	$55.300	12	$ 4.608
Team	$100.462	12	$ 8.372

Total cost per m3 **$ 141.352**

Unit price concrete

Amount	Unit
1	m^3

Description

Equipment	rate (per hour)	Quantity	Efficiency	m3
Concrete vibrator	$ 51.500	1	1,1	$ 46.396
Tools	$ 1.100	1	2,0	$ 550

Materials	per unit	Quantity	Efficiency	m3
Concrete	$ 460.000	1,1	1	$ 483.000
Construction	$ 24.500	5,3	1	$ 130.585
Others	$ 2.500	1,9	1	$ 4.750

Transport	per unit	Quantity	Efficiency	m3
Fuel	$ 2.000	1	1	$ 1.000

Labor	rate (per hour)	Quantity	Efficiency	m3
Surveyor	$10.375	1	1,4	$ 7.205
Official	$5.883	2	0,3	$ 40.572
Assistant	$3.808	8	0,3	$ 105.048

Total cost per m3 **$ 819.107**

Unit price rocks 0.1-0.4m

Amount	Unit
1	m^3

Description

Equipment	rate (per hour)	Efficiency	m3
Crane	$ 32.760	10,5	$ 3.120
Crane transporter	$ 68.435	10,5	$ 6.518
Dump truck	$ 21.150	10,5	$ 2.014
Excavator	$ 68.435	10,5	$ 6.518
Compactor	$ 26.200	10,5	$ 2.495
Equipment topography	$ 33.685	10,5	$ 3.208

Materials	per unit		m3
Rocks	$ 32.600		$ 32.600

Transport	per unit		m3
Truck	$ 80.000		$ 80.000
Barge	$ 2.400		$ 2.400

Labor	rate (per hour)	Efficiency	m3
Surveyor	$130.600	10,5	$ 12.438
Assisten	$55.300	10,5	$ 5.267
Team	$100.462	10,5	$ 9.568

Total cost per m3 **$ 166.145**

Unit price rocks 0.5-0.9m

Amount	Unit
1	m^3

Description

Equipment	rate (per hour)	Efficiency	m3
Crane	$ 32.760	10,0	$ 3.276
Crane transporter	$ 68.435	10,0	$ 6.844
Dump truck	$ 21.150	10,0	$ 2.115
Excavator	$ 68.435	10,0	$ 6.844
Compactor	$ 26.200	10,0	$ 2.620
Equipment topography	$ 33.685	10,0	$ 3.369

Materials	per unit		m3
Rocks	$ 36.500		$ 36.500

Transport	per unit		m3
Truck	$ 80.000		$ 80.000
Barge	$ 2.400		$ 2.400

Labor	rate (per hour)	Efficiency	m3
Surveyor	$130.600	10,0	$ 13.060
Assisten	$55.300	10,0	$ 5.530
Team	$100.462	10,0	$ 10.046

Total cost per m3 **$ 172.603**

Cost rocks 0.9-1.2m

Amount	Unit
1	m^3

Description

Equipment	rate (per hour)	Efficiency	m3
Crane	$ 32.760	9,1	$ 3.600
Crane transporter	$ 68.435	9,1	$ 7.520
Dump truck	$ 21.150	9,1	$ 2.324
Excavator	$ 68.435	9,1	$ 7.520
Compactor	$ 26.200	9,1	$ 2.879
Equipment topography	$ 33.685	9,1	$ 3.702

Materials	per unit		m3
Rocks	$ 40.000		$ 40.000

Transport	per unit		m3
Truck	$ 88.000		$ 88.000
Barge	$ 2.400		$ 2.400

Labor	rate (per hour)	Efficiency	m3
Surveyor	$130.600	9,1	$ 14.352
Assisten	$55.300	9,1	$ 6.077
Team	$100.462	9,1	$ 11.040

Total cost per m3 **$ 189.414**

Cost rocks 1.2-1.5m

Amount	Unit
1	m^3

Description

Equipment	**rate (per hour)**	**Efficiency**	**m3**
Crane	$ 32.760	8,5	$ 3.854
Crane transporter	$ 68.435	8,5	$ 8.051
Dump truck	$ 21.150	8,5	$ 2.488
Excavator	$ 68.435	8,5	$ 8.051
Compactor	$ 26.200	8,5	$ 3.082
Equipment topography	$ 33.685	8,5	$ 3.963

Materials	**per unit**		**m3**
Rocks	$ 45.000		$ 45.000

Transport	**per unit**		**m3**
Truck	$ 96.000		$ 96.000
Barge	$ 2.400		$ 2.400

Labor	**rate (per hour)**	**Efficiency**	**m3**
Surveyor	$130.600	8,5	$ 15.365
Assisten	$55.300	8,5	$ 6.506
Team	$100.462	8,5	$ 11.819

Total cost per m3 **$ 206.580**

Construction cost

The construction cost are based on the unit price and an estimation of the amount of m3 needed for the project. The discount rate used in the calculations are based on the world fact book of the CIA (agency, 2013).

Construction cost Overtopping – Berm and raised sea wall

Description	*Activity*	*Quantity*	*Unit*	*Year*
Sea wall	Construction sea wall	110000	m3	1

Cost item	*Cost per unit*
Rocks 1.2-1.5	$ 206.580

NPC project	
Construction T-groynes	$ 22.723.755.204
Total	**$ 22.723.755.204**

Construction cost Seaside – Wall with dunes

Description	*Activity*	*Quantity*	*Unit*	*Year*
Nourishment dunes	Beach nourishment	6000	m3	1
Construction wall&prom	Concrete construction	16200	m3	1
Nourishment beach	Beach nourishment	40000	m3	every 10 years

discount rate	5%
Year	discount factor
10	0,614
20	0,377
30	0,231
40	0,142

Cost item	*Cost per unit*
Dredging/Nourishment	$ 13.000
Concrete	$ 819.107

NPC project	
Nourishment dunes	$ 77.998.971
Construction wall&prom	$ 13.269.532.544
Nourishment beach	$ 709.270.647
Total	**$ 14.056.802.162**

Construction cost erosion El Laguito – T-groynes and nourishments

Description	***Activity***	***Quantity***	***Unit***	***Year***
Groynes	Construction groynes	12000	m3	1
Nourishment beach	Beach nourishment	140000	m3	1
Construction wall	Concrete construction	1250	m3	1

Cost item	***Cost per unit***
Dredging/Nourishment	$ 13.000
Rocks 1.2-1.5	$ 206.580
Concrete	$ 819.107

NPC project	
Nourishment beach	$ 1.819.976.000
Construction T-groynes	$ 2.478.955.113
Construction wall	$ 1.023.883.684
Total	**$ 5.322.814.797**

Construction cost El Laguito - Groyne extension, dredging and sandtrap

Description	***Activity***	***Quantity***	***Unit***	***Year***
Initial dredging	Beach nourishment	63000	m3	1
Groynes	Construction groynes	5000	m3	1
Dredging sandtrap	Beach nourishment	30000	m3	1 and every 3 years

Discount rate	5%		
Year	discount factor	***Cost item***	***Cost per unit***
3	0,864	Dredging/Nourishment	$ 13.000
6	0,746	Rocks 1.2-1.5	$ 206.580
9	0,645		
12	0,557	***NPC project***	

15	0,481	Initial dredging	$ 818.989.200
18	0,416	Construction groyne	$ 1.032.897.964
21	0,359	Dredging sandtrap	$ 2.626.615.363
24	0,31	*Total*	**$ 4.478.502.527**
27	0,268		
30	0,231		
33	0,2		
36	0,173		
39	0,149		
42	0,129		
45	0,111		
48	0,096		

Construction cost El Laguito - Fill the lake with soil

Description	*Activity*	*Quantity*	*Unit*	*Year*
Nourishment lake	Land nourishment	403000	m3	1

Cost item	*Cost per unit*
Dredging/Nourishment	$ 7.800

NPC project	
Nourishment beach	$ 3.143.358.549
Total	**$ 3.143.358.549**

Construction costs Bayside - Revetment with valves

Description	*Activity*	*Quantity*	*Unit*	*Year*
Wall construction	Concrete construction	23400	m3	1

Cost item	*Cost per unit*
Concrete	$ 819.107

NPC project	
Wall construction	$ 19.167.102.564
Total	**$ 19.167.102.564**

Appendix J. T-groyne volumes

The rock volumes required for the T-groynes that are designed for the erosion problem at El Laguito are calculated using a simple geometry. For the shore perpendicular T-groyne sections the dimensions are shown in Figure J.16. The Shore parallel cross sections are equal to the offshore cross sections of the shore perpendicular groynes.

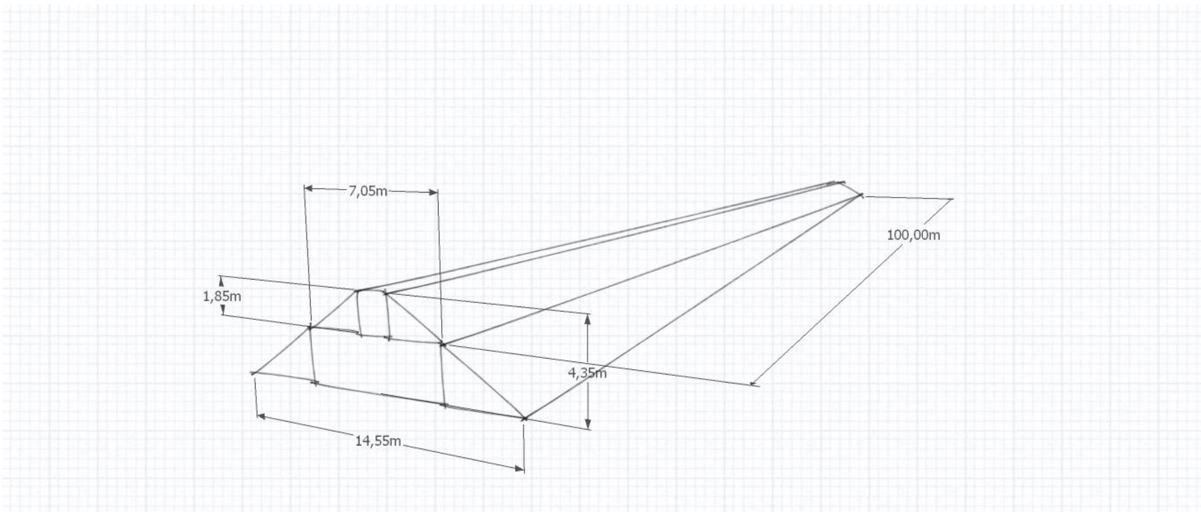


Figure J.16 Shore perpendicular groyne dimensions

The calculation of the T-groyne volumes is shown in Table J.7. The total volume is rounded upwards to 12000m^3 to account for losses and connections between the shore parallel and the shore perpendicular sections.

Table J.7 Groynes volume calculation

Volume groynes											
shore parallel											
Ltot	600										
h	2,5										
htop	1,85										
cot(alpha)	1,5										
wcrest	1,5										
Vpar	7830										
626400											
shore perpendicular											
Dmax	2,5										
L_single groyne	100										
wcrest	1,5										
cot(alpha)	1,5										
htop	1,85										
x	0	1	2	3	4	5	6	7	8	9	10
V	5,55	5,759063	5,97	6,182813	6,3975	6,614063	6,8325	7,052813	7,275	7,499063	7,725
Vperp_single groyne	1928,784375										
number of groynes	2										
Vperp_total	3857,56875										
Vtot	11687,56875										

11	etc.
7,952813	..

Appendix K. Value of travel time

Travel time can be expressed in money. This is generally done by using the Value of Travel Time (VoTT). By using the value of travel time (USD/hour) the change in travel time caused by a solution can be converted to an economic value. In the Netherlands many studies have been done on the value of time, but in Colombia this is not the case. Therefore the value will be estimated given the data that is available.

A study done by Kenneth M. Gwilliam (World Bank) suggest an appropriate approach to calculating the VoTT for countries where standard values are not available. The table below shows bases to calculate the VoTT (Gwilliam, 1997).

Purpose	Method
Work trip and business	1,33 * Average wage rate
Commuting and other non-work	0,3 * Household income per hour (adult) 0,15 * Household income per hour (child)
Walking/waiting	1,5 * Value for trip purpose

Table K.1 Bases to calculate VoTT

In this study however, there is no distinction made between different trip purposes in the transport model. The main reason for this is the lack of data. The model only takes car and bus trips between different neighbourhoods into account. This does not include specific trip purposes. Because of this simplified modelling all trips are valued as being 'commuting and other non-work' trips. The majority of trips to and from Bocagrande are assumed to be with this purpose, since many people commute to and from Bocagrande and a lot of non-working (leisure/tourists) trips occur to and from Bocagrande. Both purposes increase during high season.

Household income per hour

For the household hourly income a calculation is needed to approach its value. There are no sources that indicate this exact value.

The GDP per capita in the department of Bolivar is found to be USD 6176,70 in 2010 (Proexport, 2013). The average household size in Cartagena is found to be 4,6 in 2012 (CENAC, 2011). When multiplying these two numbers the GDP per household in Cartagena is obtained: USD 6176,60 * 4,6 = USD 28412,82

The last step is to transform the GDP per household (yearly) to an hourly income per household. To do this an assumption on the average amount of working hours in a year must be made: 50 weeks a year of 48 hours (6days of 8 hours). A year this would mean an average of: 50 * 48 = 2400

The average household income per hour can now be calculated: USD 28412,82 / 2400 = USD 11,84.

VoTT

Using the method stated by Mr. Gwilliam the VoTT in this study will be:

- 0,3 * USD 11,84 = **USD 3,55** (adult)
- 0,15 * USD 11,84 = **USD 1,78** (child)

References

agency, T. c. (2013, 01 01). *The world factbook*. Retrieved from CIA: https://www.cia.gov/library/publications/the-world-factbook/fields/2207.html

Alianze Clima y Desarrollo. (2012). *Lineamentos de Adaptación al Cambio Climática para Cartagena de Indias.*

ARGOSS. (2013, March). Monthly distribution of wave height.

CENAC. (2011). *Contexto sectoral Cartagena - Bolívar.*

CIRIA; CUR; CETMEF. (2007). *The Rock Manual. The use of rock in hydraulic engineering (2nd edition).* Londen: C683, CIRIA, London.

Gwilliam, K. M. (1997). *The Value of Time In Economic Evaluation of Transport Projects.*

Molares, R. B. (2011). *THE INFLUENCE OF THE DIQUE CHANNEL DISCHARGE ON THE SEA WATER LEVEL OF CARTAGENA BAY - COLOMBIA.*

Moreno-Egel, D., Agámez, M., Castro, E., & Voulgaris, G. (2003). *Beach Morphology and Coastal Protection along Headland Bays in.*

Ortiz, J. (2009). *Aplicación de un modelo paramétrico de vientos y un modelo de oleaje espectral para el estudio del oleaje máximo generado por el huacán Lenny, en las costas del Caribe colombiano en 1999.*

Pombo, J. H. (2013, June 4). Coastal problems in Cartagena. (Y. van Leeuwen, & B. van Velzen, Interviewers)

Proexport. (2013). *Investment Opportunities in Cartagena - Bolívar*. Retrieved from http://www.investincolombia.com.co/regional-information/cartagena.html

Restrepo, J. D., & López, S. A. (2007). *Morphodynamics of the Pacific and Caribbean deltas of Colombia, South America.*

Restrepo, J. D., & López, S. A. (2007). *Morphodynamics of the Pacific and Caribbean deltas of Colombia, South America.*

Restrepo, J., Oterob, L., Casasc, A. C., Henaod, A., & Gutiérreze, J. (2012). *Shoreline changes between 1954 and 2007 in the marine protected area of the Rosario Island Archipelago (Caribbean of Colombia).*

Royal Haskoning. (1996). *Bocana Estabilizda en la Cienaga de la Virgen.*

Schafer, A. (1998). The Global Demand for Motorized Mobility. *Transportation Research A, 32*(6), 455-477.

Schafer, A. (2000). The future Mobility of the World Population. *Transportation Research A, 34*(3), 171-205.

Stronkhorst, J., van der Spek, A., & van Maren, B. (2012). *A Quickscan of Building-with-Nature Solutions to.*

Universidad de Cartagena. (2009).

USACE. (2006). *Coastal Engineering Manual.*

Young, & Holland. (1996). *Atlas of the Oceans: Wind and Wave Climate.*