MAY 1, 2018

MANGROVE PROJECT SURINAME

CIE4061-09 MULTIDISCIPLINARY PROJECT

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Course
CIE4061-09 Multidisciplinary Project

Master programmes
Construction Management and Engineering
Hydraulic Engineering

Universities
Delft University of Technology
Anton de Kom University of Suriname

Project location
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Project sponsors:
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PREFACE

This report has been made for the course Multidisciplinary Project (CIE4061-09), with a project group of five students from two different disciplines. A project in Suriname related to mangrove rehabilitation was executed. The rehabilitation was researched at the Weg naar Zee coast taking into account the socio-technical factors.

First, we would like to thank the project's sponsors because their contributions made our project possible. We would also like to extend our gratitude to supervisors Dr.ir. M. Bosch-Rekveldt and Ir. S. Tas for their useful guidance and support throughout this entire project. Gratitude should also be extended to Prof.dr.ir. J. Winterwerp (TU Delft) and Ir. S. Sangster (Boskalis) for their advice during this project.

Finally, to our supervisor in Suriname, professor of Water and Climate at the Anton de Kom University of Suriname (AdeKUS), Prof. Dr. S. Naipal. We would like to extend our gratitude to him for guiding us for eight weeks and giving us insightful and valuable knowledge, but also for taking the time to answer our questions and facilitating us during our time in Suriname.

Delft, May 2018

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SUMMARY

The Weg naar Zee (WnZ) region of Suriname's capital Paramaribo is dealing with coastal erosion. Images from the past 30 years have shown coastal retreats of up to 1.3 km. Mangrove forest used to be present in large numbers at the location. These mangrove forests enhance accretion, but due to different reasons, the number of mangroves has decreased significantly. Reasons are extensive land-use, climate change and periodic absence of mudbanks. Also, mangrove trees are removed by local people.

Several attempts have been made to rehabilitate the mangrove at WnZ. Sediment Trapping Units have been constructed, with the purpose to enhance accretion and thereby create conditions for mangrove development. The units consist of walaba poles with bamboo as filling material. From bed level change results, field observations and interviews, it could be concluded that there is room for improvement. Therefore, the following goal of the project had been formulated: 'To present methods for mangrove rehabilitation at the WnZ coast, which can be supported by the key stakeholders'.

To present mangrove rehabilitation methods, it was necessary to gain insight regarding the WnZ stakeholders' involvement when it comes to coastal management. Fourteen key stakeholders were identified. Then, the stakeholders were analyzed in order to understand their power, interests, goals, resources and overall position. On the basis of dependency and replaceability, three critical actors were found: *Government of Suriname, AdeKUS* and *Inhabitants of the WnZ region.* Especially stakeholders who are classified as the 'irritant' type need to be engaged so that they do not block the project. *Inhabitants of the WnZ region* belong to this category and therefore a survey among this group was conducted.

Knowing the WnZ inhabitants' involvement and the current situation at WnZ, the success factors and design requirements were then determined. The analysis showed out that the most important success factors and design requirements were that the mangrove forest must have a width of 450 m, must be dense and must consist of more than one mangrove specie. Also, a minimum bed slope of 1:1000 and a minimum sedimentation of 0.6 meter is required.

Knowing the success factors and design requirements, resulted in the analysis of which mangrove rehabilitation designs are applicable and supported by the WnZ region stakeholders. The first step was conducting a Multi-Criteria Analysis (MCA) in which five alternatives with their variants are weighed on seven criteria of which the technical-, environmental- and feasibility criteria have the highest weighting. From this analysis the top three variants are: 1) *Adapted STU*, 2) *STU with Nourishment* and 3) *STU with chenier*. These three variants are more elaborated into three preliminary designs. In the first design, the STUs are adapted such that sedimentation inside the STUs is expected. In the second design, a nourishment is placed inside the adapted STUs. In this design dredged material is taken from a borrow pit 4 km from the shore. In the third design a chenier is placed 2 km from the shore.

Finally, support by stakeholders for the mangrove rehabilitation designs can only be gained if they are engaged. This was tackled by composing a comprehensive stakeholder engagement plan. In this plan, the following three strategies are formulated: 1) *Setting up a bamboo farm,* 2) *Setting up a Mangrove Vacation Resort* and 3) *Growing salt-tolerant plants.* These strategies can contribute to the economic development of the region if implemented, which could then also benefit the various stakeholders.

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LIST OF ABBREVIATIONS

A

ABS: Stichting Algemeen Bureau voor de Statistiek (National Statistical Office of Suriname)
ADEK: Anton de Kom Universiteit van Suriname (Anton de Kom University of Suriname)
AMTO: Avond Middelbaar Technisch Onderwijs (intermediate technical vocational education)

C

CPI: Christelijk Pedagogisch Instituut (Christian Pedagogical Institute)

E

ESIA: Environmental and Social Impact Assessment

F

FAST method: Function Analysis System Technique method

G

GLO: Gewoon Lager Onderwijs (Primary school)

H

HAVO: Hoger Algemeen Voortgezet Onderwijs (High School) HBO: Hogere Beroeps Opleiding (College)

I

IDB: Islamic Development Bank
IMEO: Instituut voor Middelbaar Economisch en Administratief Onderwijs (Institute for Mid-level vocational Training)

K

km: Kilometer(s), Unit of length
kN: Kilonewton, Unit of force

L

LBGO: Lager Beroepsgericht Onderwijs (Low level vocational training)
LTS: Lagere Technische school (Low level technical training school)
LVV: Ministerie van Landbouw Veeteelt en Visserij (Ministry of Agriculture, Husbandry and Fishery)

M

m: Meter(s), Unit of length
MCA: Multi-Criteria Analysis
MHWL: Mean High Water Line
MSL: Mean Sea Level
MULO: Meer Uitgebreid Lager Onderwijs (Secondary school)

N

n: Newton, Unit of force

NATIN: Natuurtechnisch Instituut (intermediate technical vocational education)

S

s: Second, Unit of time

SME: A small or medium-sized enterprise

SPI: Surinaams Pedagogisch Instituut (Surinamese Pedagogical Institute)

STU: Sediment Trapping Unit

U

UNDP: United Nations Development Programme

V

VWO: Voorbereidend Wetenschappelijk Onderwijs (pre-university secondary education)

W

WnZ: Weg naar Zee

WO: Wetenschappelijk Onderwijs (scientific education at university)

LIST OF SYMBOLS

d	Water depth	[m]
g	Gravitational accelaration	[m/s^2]
H	Wave height	[m]
$H_{1/3}$	Significant wave height	[m]
H_{max}	Maximum wave height	[m]
H_{m0}	*Significant wave height*	[m]
L	Wave length	[m]
T	Wave period	[s]
T_m	Mean wave period	[s]
T_{m0}	Zero-crossing wave period	[s]
T_p	Peak wave period	[s]
$U10$	Wind velocity at 10 m height	[m/s]
ϑ	Angle	[degrees]

1. INTRODUCTION

Suriname is the most threatened country of South-America and the Caribbean when it comes to sea level rise (Van Maele, 2016). Wetlands International (2016) also underlined this statement and further affirmed that even though Suriname is known as the greenest country on earth, "they belong to one of the seven globally most endangered countries by sea level rise". For some years now, the Surinamese coast has been affected by coastal erosion on several places. This is due to the large-scale mangrove removal at the coast, sea level rise and increasing wave strengths (Teunissen, 2003). In February of 2015, a tragedy had struck at Weg naar Zee, a coastal region in the capital city of Suriname. Due to a high tide, big parts of this region had been flooded and the locals suffered a lot of damage (Starnieuws, 2015). This region is one of several areas in Suriname that has clearly been affected by coastal erosion over the years and will be counted as the area of interest in this report.

In order to observe the extent to which the Surinamese coast has suffered from coastal erosion, the coastal part between the Suriname River and the Coppename River has been analyzed with satellite images of Google Earth. The images that were analyzed vary for the period between 1985 and 2016. The analysis can be seen in Figure 1.1.

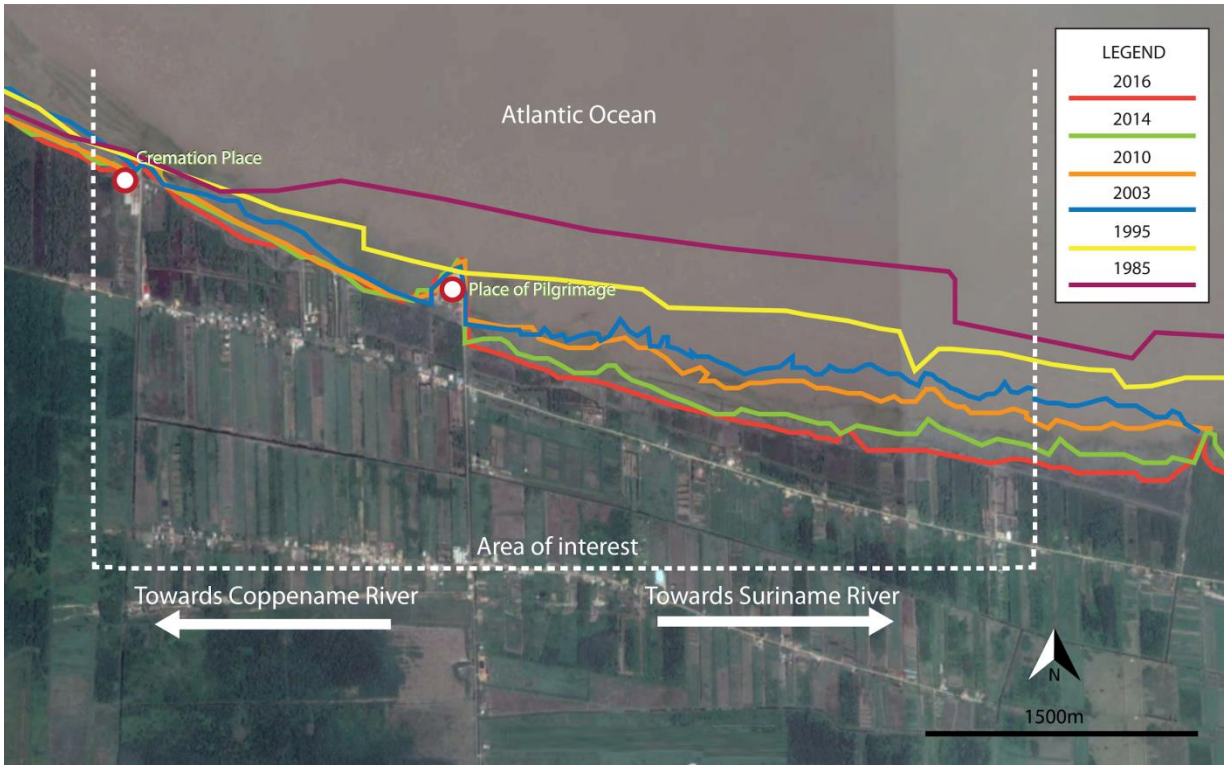

Figure 1.1 Evolution of the coastline in the WnZ region (Source: Google Earth, 2016; own illustration)

In Figure 1.1, the various coastline positions are shown in different colors. Each color represents a specific year (see legend on right), showing where the coastline was located. It can be seen that the coastline in the area of interest is very dynamic. This is troubling, as the area of interest also shows several households, farms and locals who live and work very near to the receding coastline. Furthermore, the erosion that took place at the area of interest over the years is clearly seen. A

retreat of up to 1.3 km has occurred from 1985 until 2016. But there is also a more positive phenomenon, as it can be seen that on the western side of the area of interest, accretion has taken place over the years.

Sea level rise has shown to drive coastal erosion (Leatherman, Zhang & Douglas, 2000). As such, the main causes of net erosion are visually displayed in Figure 1.2. To begin, the coastal buffer zone is necessary for the coastal habitat, among which the mangroves, to survive. This zone is the area between intensively used land and the sea. It is usually between two dikes, in which the first dike lets through relatively more overflow during high water levels. Thus, the zone forms a breeding area for habitat (Building block, n.d.). Urbanization near the coast causes a decrease of the coastal buffer zone as dikes are built there. Therefore, there is less room for the sea. Because of the decrease in room for the sea, the sediment balance will be disrupted and there will be *Less onshore sediment transport* (Figure 1.2).

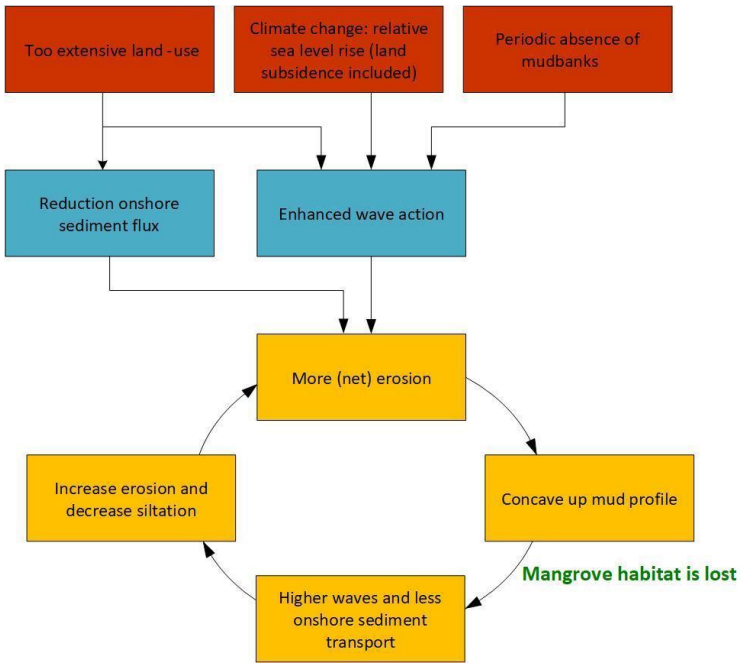

Figure 1.2 Main causes of erosion in Suriname (Source: own illustration)

Also, higher waves (*Enhanced wave action*) will be present due to a more reflective coast. *Too extensive land-use* thus leads to *Enhanced wave action* and *Reduction of onshore sediment flux*, which are important causes for Erosion (Figure 1.2). A *concave-up mud profile* is then shaped which leads to the loss of mangrove habitat. This causes *Enhanced wave action* and decreases the *Onshore sediment transport* further, which results in more *Erosion*. According to Winterwerp (2015) this is a snowball effect.

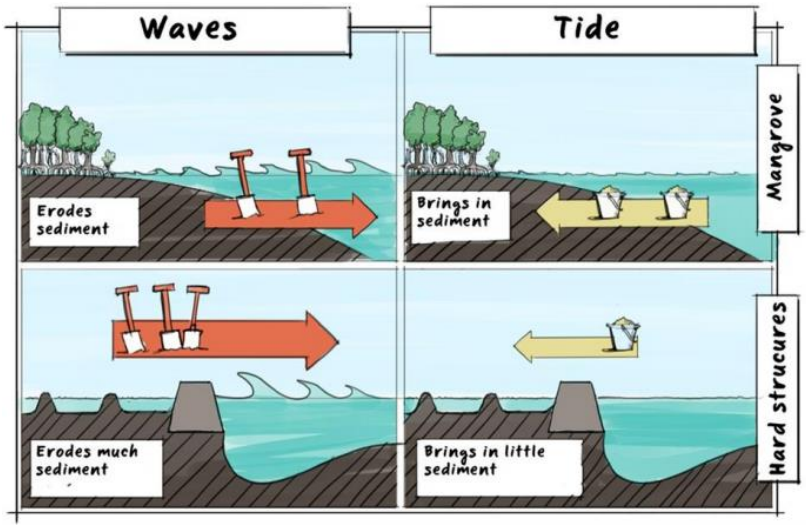

Figure 1.3 Dike in bufferzone because of extensive land use (Source: Winterwerp, 2015)

Removal of mangroves also contributes to this coastal erosion snowball effect. At the Surinamese coast, not only extensive land-use and removal of mangroves can be observed, but also climate change and the periodic absence of mud banks lead to enhanced wave action (Figure 1.3).

The erosion problem proceeds further as for decades, little attention has been paid to coastal erosion and climate change problems in the Weg naar Zee region. However, this changed due to the 2015 disaster. This led to temporary evacuations, flooded houses and local protests. The affected locals demanded immediate prevention measures from the Surinamese government. As the presidential elections of 2015 were also close, the then acting government had to act quickly and thus announced that a concrete dike would be constructed (Starnieuws, 2015). However, as of yet nothing has happened. Fortunately, the WnZ region has been spared from a similar flood to this day, but the coastal erosion continues.

1.1 Problem statement

After the 2015 flood, a project was initiated by the Anton de Kom University of Suriname (AdeKUS) in the same year to prevent coastal erosion in a sustainable and cheaper way. This project received support from various stakeholders. This project was conducted under the direction of Sieuwnath Naipal, who is the professor of Water & Climate at AdeKUS. The 'Building with Nature' project entails the construction of narrow wooden dams off the coast, which allows seawater to flow in, while trapping sediment. The project's ultimate aim is to plant mangroves within such a sediment trapping structure (Fernandes Bottling Company N.V., 2015). In the meantime, the first mangrove plants have already been planted. According to S. Naipal (personal communication, November 21, 2017), several stakeholders were not excited about the project as they feel it is too time-intensive in order to be successful and less effective in protecting the region. Currently, there is still a large group of locals who do not support the project, although they are affected the most. But, in order to conduct the mangrove rehabilitation process successfully, it is essential to gain their support. Therefore, this report aims to present mangrove rehabilitation methods, involving sustainable designs against coastal erosion, whilst setting up a stakeholder plan to engage key stakeholders so support can be gained for the designs.

1.2 Research goal and questions

The research goal is: "To present methods for mangrove rehabilitation at the Weg naar Zee coast, which can be supported by the key stakeholders". This goal is ensued by the following main research question:

"Which mangrove rehabilitation methods, supported by key stakeholders, can be implemented at Weg naar Zee in order to mitigate coastal erosion?"

The research question is supported by the following five sub-questions:

1. *What is the current situation at the WnZ region?*
2. *How are the stakeholders of the WnZ region involved when it comes to coastal management?*
3. *What are the success factors and design requirements for mangrove rehabilitation?*
4. *Which mangrove rehabilitation designs can be applied in the WnZ region?*
5. *In which ways can stakeholders be engaged when it comes to mangrove rehabilitation?*

1.3 Scope

The project focuses on mangrove rehabilitation. Therefore, the rehabilitation of mangroves is defined as the action of improving the health of the forest (Urbanska, Webb, & Edwards, 1997). Bringing back the ecosystem to its original health is left out of the scope. Furthermore, the project's focus will only be on coastal erosion and not on other failure mechanisms.

The project scope will focus on the coast of the WnZ region (Figure 1.4). This coastal area is located in the northwest of Suriname's capital: Paramaribo. The area has a stretch of 7 km and is the place where most erosion takes place.

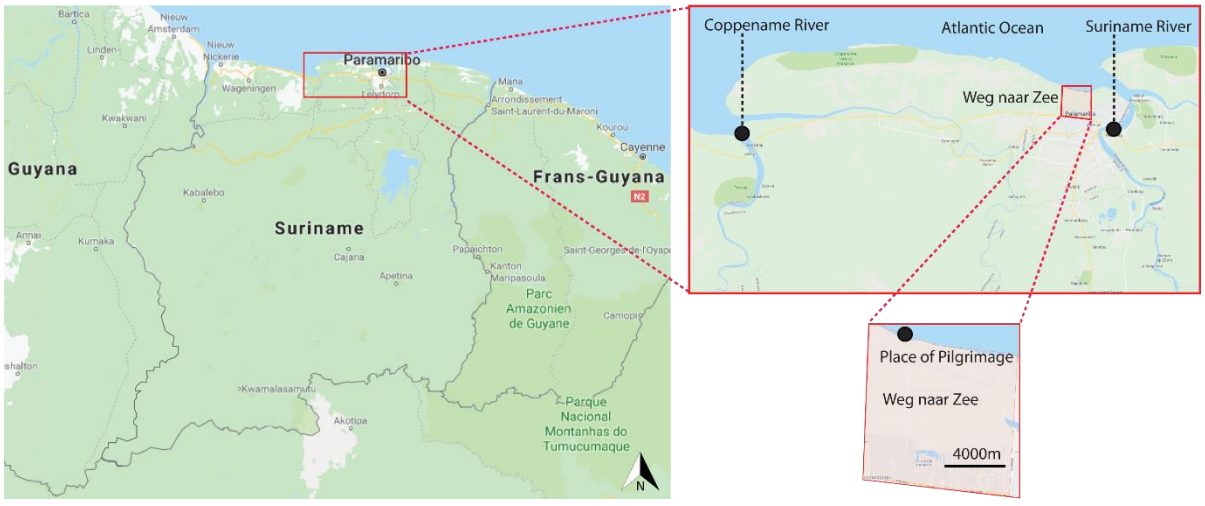

Figure 1.4 Project scope (Source: Google Maps, 2017; own illustration)

In Figure 1.4, the Place of Pilgrimage is also indicated. On the eastern side of the Place of Pilgrimage, several attempts have been made to trap sediment using Sediment Trapping Units (STUs). Therefore, the project's scope will lie in this area which has a coastal stretch of 1 km.

1.4 Approach

A functional analysis helps to translate client's needs, AdeKUS, into a clear overview of functions. Using the Function Analysis System Technique (FAST) method, all functions are listed which the designs need to fulfil after project delivery. The project goal: *"To present methods for mangrove rehabilitation at the Weg naar Zee coast, which can be supported by the key stakeholders"* is used as starting point to compose the diagram (Figure 1.5). From this point, the functions can be formulated by asking "How can this goal be achieved?". Finally, by asking *"Why do we want to achieve this?"*, it can be checked whether the functions are well defined by reading the diagram from right to left (Hertogh et al., 2017).

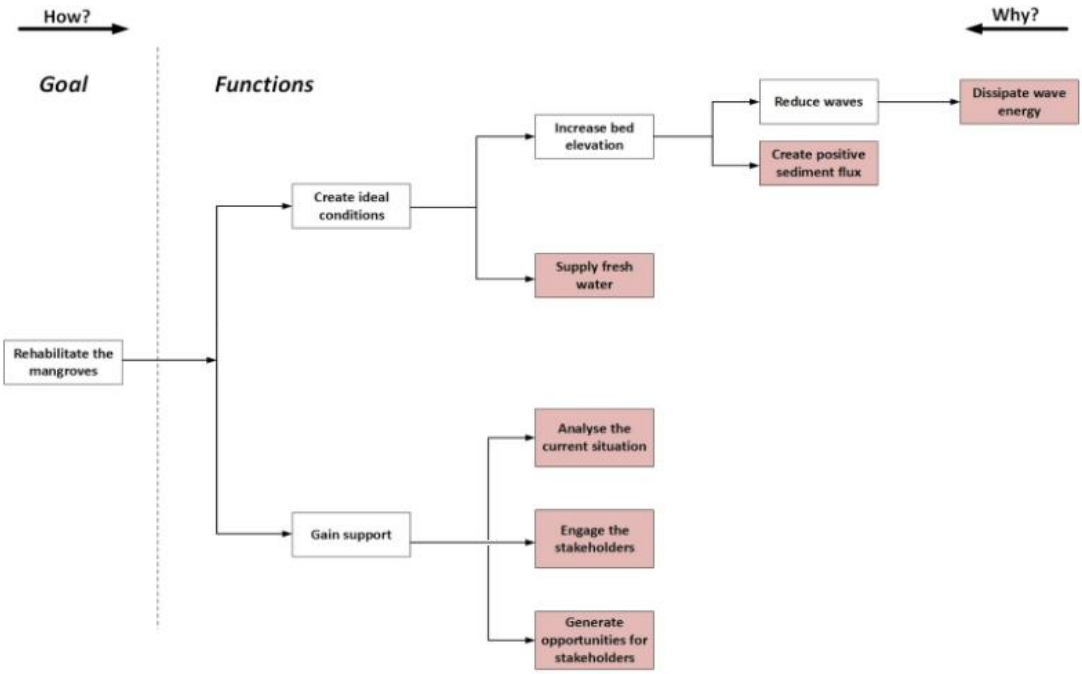

Figure 1.5 Functional analysis diagram (Source: own illustration)

1.5 Report structure

The report is divided into eight chapters. First, the current situation at the WnZ region will be analyzed in terms of organization, identified key stakeholders, coastal climate and the hydro- and morphodynamics. Due to a lack of available data and the project time frame of eight weeks, a hands-on engineering approach is suitable. The state of the mangroves at WnZ and the already built STUs will be examined during several field observations, both from land as from sea (by airboat). Then, the stakeholders of the WnZ region will be further identified and finally analyzed in chapter 3. The design requirements, including the analysis of the conducted survey in the WnZ region, can be found in chapter 4. Based on these design requirements, different possible solutions will be determined. Hereafter, alternatives which can be implemented in the best possible way at the WnZ region, will follow from a Multi-Criteria Analysis in chapter 5. These alternatives will be further worked out in the preliminary designs, which can be found in chapter 6. Because of the uncertainty that comes with 'Building with Nature', it is important to monitor and maintain the designs during their operational stage. Thus, both a general plan and a plan for each preliminary design will be included. Chapter 7 will present a stakeholder engagement plan for the WnZ region. Finally, chapter 8 will present the conclusion, recommendations and discussion.

2. CURRENT SITUATION OF THE WEG NAAR ZEE REGION

In this chapter the current situation of the WnZ region will be analyzed. First an overview of the region will be shown, which includes the identification of the fourteen key stakeholders. Secondly the physical aspects will be looked at which are the general coastal climate, morpho- and hydrodynamics. In paragraph 2.3, the mangrove species that grow in the coastal area of Suriname will be given. Finally, the current Sediment Trapping Units (STUs) that are built in the WnZ area will be discussed and analyzed in paragraph 2.4, in order to prevent that previous mistakes will be repeated. All these aspects will be used as input for the preliminary designs.

2.1 Overview of the Weg naar Zee region

Weg naar Zee is one of the twelve regions in the district of Paramaribo (Figure 2.1). According to ABS (2016), which is the National Statistical Office of Suriname, the WnZ region has a population of ca. 14000 and a population density of 390 people per km^2. The entire region has a surface of ± 41 square kilometers. The land in this region is currently being used for a variety of activities such as agriculture, animal husbandry and urbanization. In the WnZ region the main mean of existence is agriculture, which is intensively practiced, and has made the region known to be the largest vegetable producer of the Paramaribo district (Naipal et al, 2014). In the north, the region is bordered by the Atlantic Ocean.

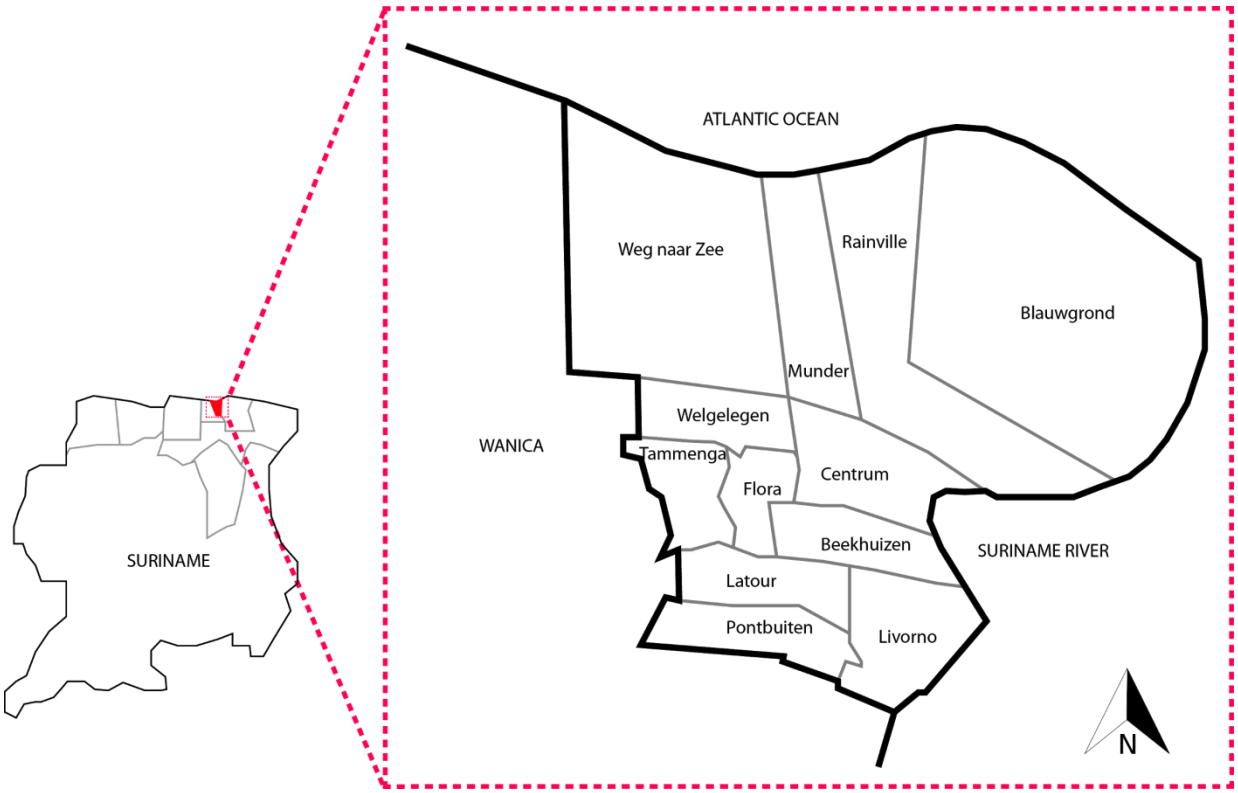

Figure 2.1 All twelve regions in Paramaribo, including the WnZ region, at the top left (Source: own illustration)

Figure 2.2 shows an overview of the region's organization. This overview has been composed based on field trips and observations by the Mangrove Project Suriname team. Between the Place of Pilgrimage (in blue) and the STUs (in orange), an irrigation channel is present (not schematized).

Behind the STUs lies the old mangrove forest (in green) which is surrounded by dikes made out of clay (in pink). The area behind the old mangrove forest is used for agriculture, animal husbandry and housing.

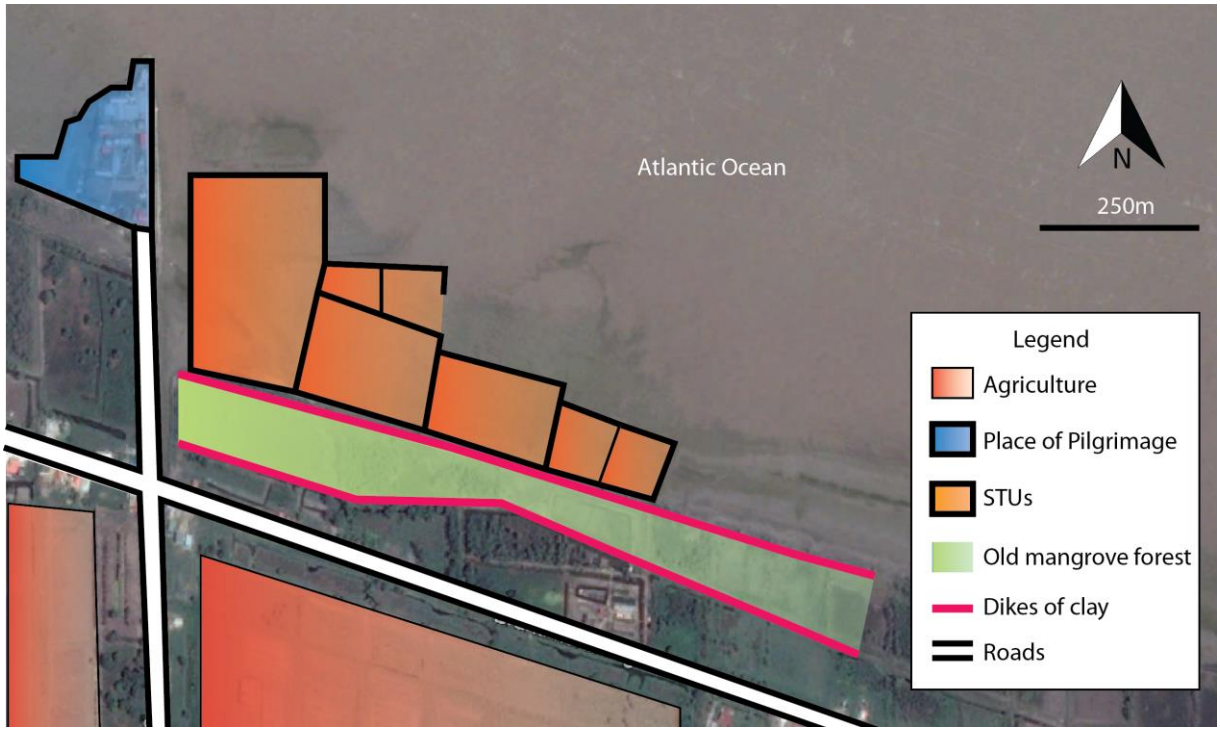

Figure 2.2 Organization of the Weg naar Zee region (Source: Google Earth, 2016; own illustration)

This paragraph ends with an overview of the stakeholders which have been identified for the Weg naar Zee region (Table 2.1). These stakeholders were found by first executing a literature research. Subsequently, brainstorm sessions and interviews were held with those who were deemed important for this research. The list of interviewed stakeholders can be found in Appendix D, section D.8.

Stakeholders of the Weg naar Zee region					
1.	Inhabitants of the Weg naar Zee region	6.	Place of Pilgrimage	11.	Cremation place Weg naar Zee
2.	Government of Suriname	7.	Visitors of Place of Pilgrimage	12.	Engineering firms
3.	Anton de Kom University of Suriname	8.	SME business owners	13.	NGOs
4.	Agricultural farmers	9.	Tourists	14.	Embassies
5.	Fishers	10.	Recreationists		

Table 2.1 Key stakeholders at the Weg naar Zee region

The reasons the fourteen stakeholders from Table 2.1 are taken along is because 1) they are closely involved with the research problem and/or, 2) they cooperate directly or indirectly with this research and/or 3) they are involved to a lesser extent, but also have interests in this research. All these fourteen stakeholders are discussed in more detail in Appendix D, section D.1.

2.2 Physical aspects

In this paragraph the physical aspects of the WnZ region will be presented. First the coastal climate at WnZ will be explained. Then, the morphodynamics will be described in subparagraph 2.2.2. Finally, the hydrodynamics are determined in subparagraph 2.2.3.

2.2.1 Coastal Climate at Weg naar Zee

The coast of Suriname can be defined as a muddy coast with propagating mud banks in front of the coast. Suriname has an amero-trailing edge coast, which means that the coast is located away from the plate boundaries and is tectonically stable. A trailing edge coast can be characterized by wide continental shelves, low gradients and large sediment supplies. A wider shelve causes more frictional damping, what results in lower wave energy and is favorable for the development of extensive sedimentary features (Bosboom et al., 2015).

2.2.2 Morphodynamics

This subparagraph contains information regarding the sediment characteristics, the bathymetry, the mudbank and chenier migration along the coast of Suriname.

Sediment characteristics

The Surinamese coast mostly consists out of mud. Some of the potentially relevant characteristics for design will be further elaborated in this paragraph. As mud is mostly a mixture of clay with water and organic material, it contains cohesion. This also means that the flocculation process plays an important role in the settling of mud. Flocculation occurs due to the coherence between the particles, which form larger flocs and, in this way, increase the settling velocity.

The amount of flocculation that occurs increases with increasing suspended sediment concentration until it reaches a critical point where sediment blockage/hinder happens. This phenomenon is known as lutocline (Dankers et al., 2007).

The amount of interaction between the bed and the water above it, depends on forcing, settling velocity and the state of the bed. The forcing is due to the waves and currents, where the waves ensures the stirring-up of the sediment, while currents lead to the mixing and transport of the stirred-up sediment.

Bathymetry

For the bathymetry in front of the coast, data from measurements executed in 2013 during high water are used (see Appendix A). In Figure 2.3 the bathymetry perpendicular to the coast is plotted. Also, the difference between the soft mud layer and the hard subsoil are plotted in Figure 2.4. As the

muddy coast of Suriname is highly dynamic the bathymetry changes continuously, so this needs to be taken into account when using the bathymetry.

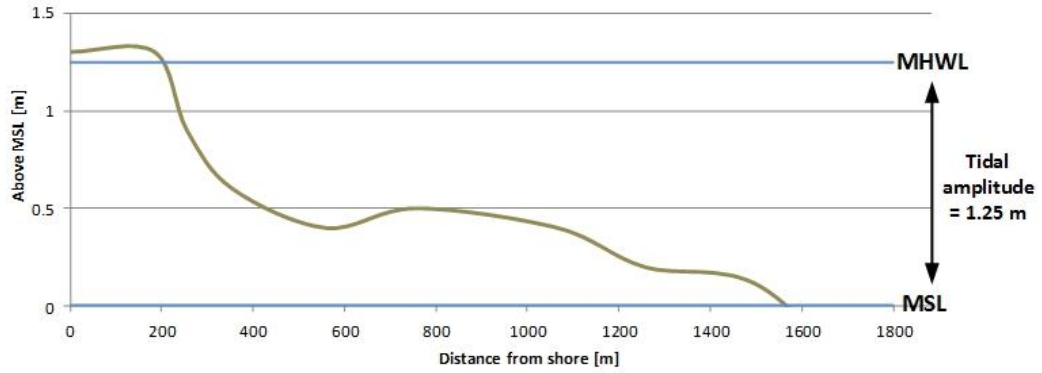

Figure 2.3 Bathymetry for the Weg naar Zee region in 2013 (Source: Naipal, 2013; own illustration)

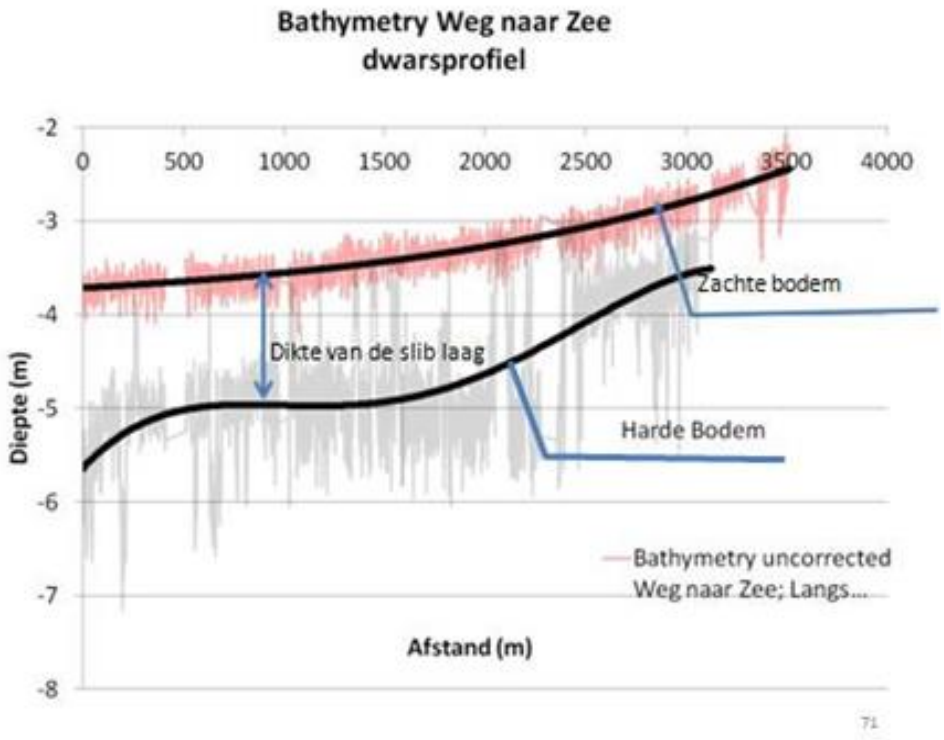

Figure 2.4 Thickness soft mud layer (Source: Naipal, 2013)

Mudbank and chenier migration along the coast of Suriname

The coast of Suriname is very dynamic. The sediment that originates from the Amazon River, goes into the ocean and is transported by the Guyana current in westward direction along the coast of Suriname. The sediment transport in the form of suspended sediment is $250 \cdot 10^6$ m^3/year and in the form of mud banks it is $100 \cdot 10^6$ m^3/year (Figure 2.5). The suspended load at the mouth of the Amazon river consists of over 50 % clay-sized material and of less than 5 % of sand-sized material (Rine et al., 1985). According to Kamerling (1974) the coast of Suriname consists of heavy clay, which consists of more than 50% of clay particles smaller than 2 micrometers.

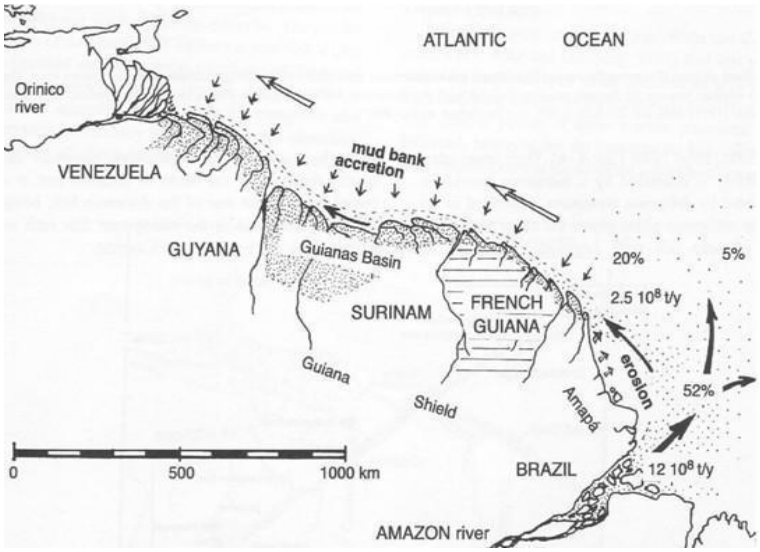

Figure 2.5 Sediment Transport from Amazone River (Source: Augustinus, 1978)

The yearly sediment transport is distributed so that most of it occurs in the months of April and May, with a value of $25 \cdot 10^6$ ton per month. Assuming a density of 1730 kg/m^3 (Engineering Toolbox, 2010) for fine mud, this leads to a sediment transport of $14 \cdot 10^6$ m^3 per month during April and May. Relatively less sediment passes the coast during the remaining months. An overview of the sediment transport for each month is given in Figure 2.6 (Augustinus, 2006).

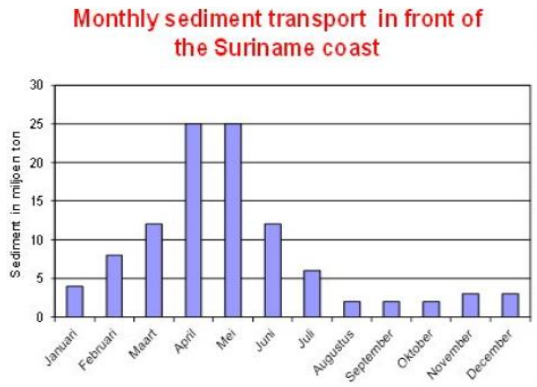

Figure 2.6 Monthly sediment transport along Suriname Coast (Source: Augustinus, 2006)

The mudbanks are extended seaward until a depth contour of -20 m. They are separated by interbank areas. The cause of the migration of the mudbanks is sedimentation on the west side of the mudbank (mainly in the form of fluid mud) and simultaneous erosion at the east side (Figure 2.7). The average migration velocity is equal to 1.5 km/year. The average length of the smallest coastal unit (over the period of 1947-2004) is about 45 km. Therefore, the cyclic alternation of coastal accretion and erosion has a period of 30 years (Augustinus, 2006).

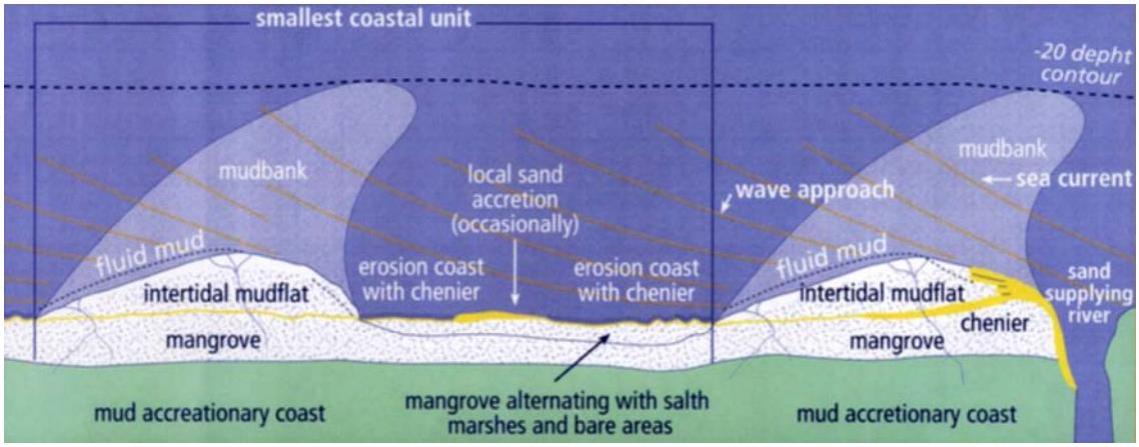

Figure 2.7 Mudbanks along coast of Suriname (Source: Augustinus, 2006)

However, in the last 30 years the mudbanks have not been constant. They have increased in number but have decreased in size and their displacement has sped up. The waves, mangroves and mudbanks all affect the erosion and accretion of the Surinamese coast. This makes the processes and morphology very complex and they are therefore not fully understood yet (Future Deltas, 2015).

As mudbanks have a function of dissipating waves, the absence of these mudbanks play a great role in the erosion of the Surinamese coast. Another important characteristic of the Surinamese coast are the cheniers, which usually develop between two mudflats. The coastal plain of Suriname is characterized as a chenier plain, which consists of 'shallow based' ridges, made out of sand or shell material, on clay. Cheniers naturally develop at the coast that is accreding, thus generally at the west side of a mudbank (Daniel, 1989 p.286). The cheniers in east and west Suriname both have another consistency. In the east (the location of interest) the cheniers consist of medium to coarse sand originated from the Marowijne river and the coast of French Guiana. The sand is brought in suspension by the breaking waves and transported in westward direction by beach-drift. Since the beach-drift takes place around mean high water level, the cheniers are formed at, or just above this water level (Augustinus et al., 1980).The average height of the cheniers are between the 0.5-2.5 m and can have a width between 10-600 m (Daniel, 1989).

Due to overwash the chenier gradually moves landward and the crest is increasing in height. The higher the crest the more dominant the beach drift becomes and the chenier extends in westward direction due to the alongshore supply of sediment (Augustinus, 1980).Therefore the cheniers provide a natural protection against the erosion due to waves (Daniel, 1989 p.285).

2.2.3 Hydrodynamics

This subparagraph will explain the tidal regime, currents and waves in the Weg naar Zee region.

Tidal regime

The tidal environment along the coast of Suriname can be characterized as semi-diurnal (Bosboom et al., 2015). This means that twice a day there is high water and twice a day there is low water. The

semi diurnal character can clearly be seen from the tidal signal shown in Figure 2.8. The maximum tidal range is around 2.5 m and the mean tidal range is around 1.8 m (Rine et al., 1985).

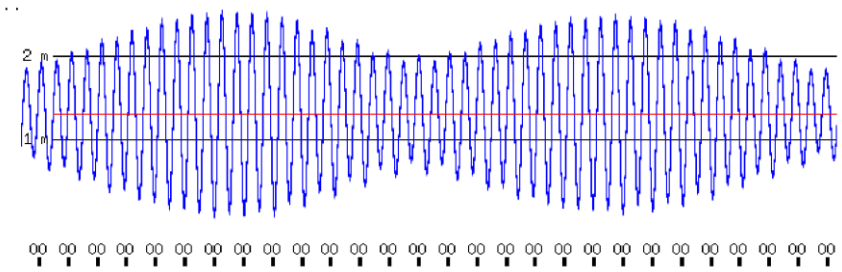

Figure 2.8 Tidal curve in front of the coast of Paramaribo, 6.0000° N, 55.2333° W (Source: Pentcheff et al., n.d.)

The direction of the tide is almost perpendicular to the coast. This is indicated in Figure 2.9.

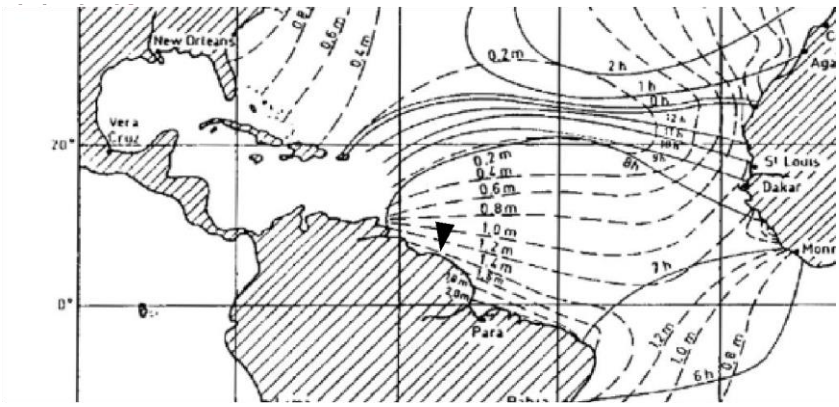

Figure 2.9 Tidal propagation in front of the coast of Paramaribo (Bosboom et al.,2015)

Currents

The Surinamese coast is dominated by the Guyana current. The longshore current flows from east to west as shown in Figure 2.10. The Guyana current can vary between 0.2 and 4.2 knots (Gyory et al., n.d.). The currents along the Weg naar Zee region are stated to be around 0.5 m/s and 0.6 m/s during the large part of the year. The current is highest in April, namely 0.9 m/s (Rine, 1980).

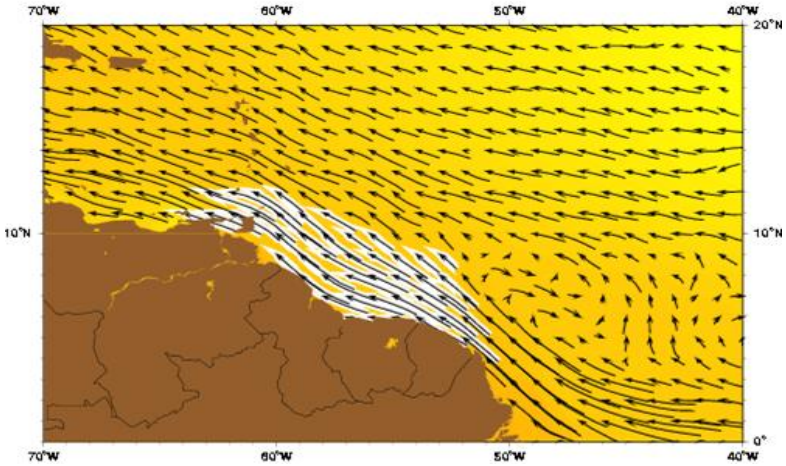

Figure 2.10 Guyana current along the coast of Suriname (Source: Gyory et al., n.d.)

Waves

From ARGOSS, which provides site-specific and detailed information on the offshore wind and wave climate anywhere on the world's oceans and seas, 25 years of wave model data is obtained. The data is taken from a location 70 km from the area of interest, this is done to obtain a data set that is not influenced by the bathymetry of the coast. The offshore location shown in Figure 2.11. From this data wave heights and directions can be retrieved. A distinction is made between the wind driven waves and swell waves. Also, two periods with their own wave climate are distinguished, namely a period with higher waves (winter period) and one with smaller waves (summer period). In Figure 2.12 it can be seen that the highest wave heights occur between January and March and the lowest wave heights occur between July and September.

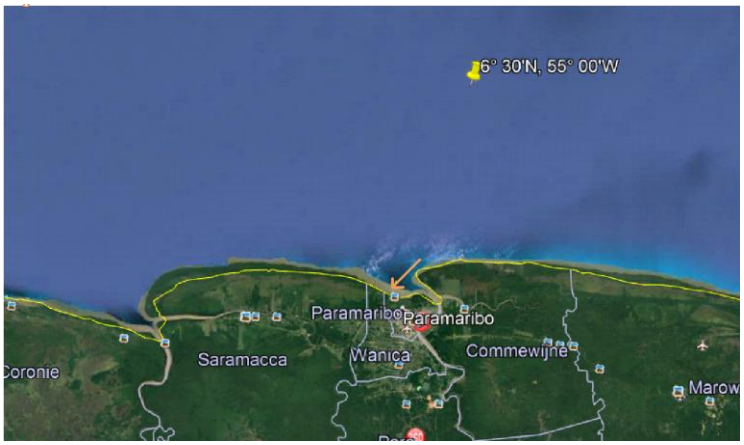

Figure 2.11 Offshore location where the data is retrieved from (Source: Google Earth, 2017)

In appendix B.1, the dominant wave directions for both summer and winter periods are shown. During the winter, the dominant wave direction is NE for both swell and wind waves. The swell waves in the summer are also directed to the northeast. Comparing the wind and wave directions, it can be observed that the wind-driven waves are more eastward directed during the summer period, which coincides with the more easterly blowing wind (see Appendix C). The maximum wind velocity observed around 10 m above the water surface is 14.4 m/s with a direction of 60 degrees (BMT ARGOSS, 2017).

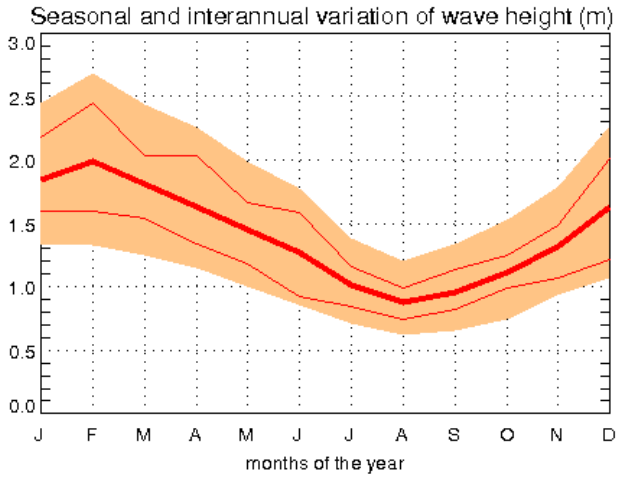

Figure 2.12 Seasonal and inter annual variation of wave height (Source: BMT ARGOSS, 2017)

The wave amplitude near the coast of Suriname is between 0.5 m and 1.6 m. This means that the wave height can vary between 1 m and 3.2 m (Rine et al., 1985). From the wave data obtained from ARGOSS, the significant wave height will be determined for both the wind- and swell waves, see Appendix B, section B.1 for a clear overview. The significant wave height will be determined by taking the average of 1/3 of the highest waves. Also, the average peak period and mean wave direction of 1/3 of the highest waves are determined.

To obtain the wave characteristics at the location of interest, the offshore characteristics are transformed with the 1D wave model *SwanOne*. The bathymetry that will be used as input for SwanOne is obtained from two different sources. For the bathymetry up to 1.7 km, measurement data is used. For the bathymetry more offshore, no measurements are available; therefore, data from *Navionics* will be used (Appendix B, section B.2). Due to the highly dynamic coastline the bathymetry can be different now. This uncertainty and the limitations of SwanOne should be taken into account in the consideration of the obtained wave height. In Table 2.2 the obtained near shore wave characteristics are shown.

	H_{m0}[m]	T_p [sec]	Dir [degrees]	Maximum setup [m]
Sea waves	0.33	1.88	50	0.045
Swell waves	0.29	1.92	50	0.062

Table 2.2 Near shore wave characteristics (for elebaroted explanation: Appendix B)

Now that most of the wave characteristics are known, the wavelength can be calculated using linear wave theory:

$$L = \frac{g}{2\pi} T^2 \tanh\left(\frac{2\pi d}{L}\right) \quad [2.1]$$

By iterating the wavelength and using the simple rule of thumb formula (for a depth of 1 m), it needs to be checked whether the case is situated in deep, shallow or intermediate water:
Deep water: $\frac{d}{L} > 1/2$, Shallow water: $\frac{d}{L} < 1/20$, and in between is intermediate water. By applying these rules, the result is that the case is situated in intermediate water as $\frac{d}{L} \approx 0.2$ with the sea waves having a wavelength of 4.8 m and the swell waves having a wavelength of 4.9 m.

2.3 Mangroves at the Weg naar Zee region

The coast of Suriname mostly consists of three types of mangroves, namely: 1) black mangroves (Avicennia/Parwa), 2) white mangroves (Laguncularia racemose/Akira) and 3) red mangroves (Rhizophora/Mangro) (Teunissen, 2004). Each specie has its own inundation time and thus settles in a different tidal zone (Table 2.3).

Mangrove species	Local name	Zone	Description Tidal zone
Black mangrove/ Avicennia	Parwa	Low tidal zone	Below MSL
Red mangrove / Rhizophora	Mangro	Mid tidal zone	Between MSL and MHWL
White mangrove/ Laguncularia	Akira	High tidal zone	Around MHWL

Table 2.3 Mangrove species with corresponding tidal zone (Source: Verhagen, 2017)

2.4 Sediment Trapping Units (STUs)

At Weg naar Zee several attempts have been made to stop the coastal erosion. During field observations by the Mangrove Project Suriname team, it was observed that several structures were created. These consisted out of tires, earthen dikes, concrete dikes, sand bags, garbage and even used cars (Figure 2.13 - Figure 2.15). Remarkable is that all these attempts are short term solutions as scour holes or salt intrusion are likely to appear, leading to structural failure. Therefore, the rehabilitation of the mangroves is a more sustainable solution.

Figure 2.13 Broken concrete dike (Source: Haage, 2017)

Figure 2.14 Students walking on sand bags that are placed to stop erosion of the coast, (Source: Haage 2017)

Figure 2.15 Wall of tires to protect the coast (Source: Kalloe, 2017)

As was mentioned in the first chapter, AdeKUS initiated the construction of the Sediment Trapping Units (STUs) at the Weg naar Zee region. This project is led by Professor S. Naipal. The STUs are permeable dams, which are made up of walaba poles with bamboo filling (Figure 2.16 & Figure 2.17). Walaba and bamboo are two wood types found in Suriname. The purpose of the STU is to trap mud and thereby create conditions for the mangroves to grow naturally. A trial and error type of approach is used. The hydro- and morphodynamics were not considered very much in detail and therefore the approach was more based on intuition.

The idea is based on the Dutch 'kwelders' in the Wadden Sea. However, Suriname has a muddy coast and a tropical climate and therefore the 'Building with Nature' project in Demak (Indonesia) was used as a reference project to rehabilitate the mangroves by using Sediment Trapping Units. In Demak the sediment trapping units are made off bamboo poles with brushwood filling material. Part of the waves are transmitted and part are reflected. The transmitted waves have lost part of their energy through the brushwood filling material. For the sediment transport into the STUs transmitted waves are required. Also too much reflection of waves will cause scour in front of the STUs. It is therefore important that the filling material contains features which leads to minimal wave reflection. The parameters which are important are i.a. permeability and width of the filling material.

Figure 2.16 Walaba poles and bamboo as filling material for the STUs at the coast of Weg naar Zee (Source: Çete, 2017)

Figure 2.17 Bamboo poles with openings to prevent floating (Source: Çete, 2017)

Just east of the Place of Pilgrimage, the first STU was constructed in 2015. A budget of US$ 15000 was made available by an NGO, Friends of Green Suriname for the construction of one STU (Wetlands International, 2016). The STU consists of a box closed off by permeable fences and it has openings on the seaside to let sediment in. One STU has a width of 100 m, a length of 200 m and a height of 3 m (2/3 of the pole goes into the soil). A permeable fence consists of two rows of poles with filling material in between (Figure 2.15). The poles have a distance of 0.75 m to each other and the filling material has a width of 0.5 m. The filling material is made out of bamboo. This first STU showed some successful results (accretion in the STU) of up to 0.5 m in November 2015 (Naipal, personal communication, November 21, 2017). After some accretion, Professor Naipal planted some mangroves by himself by putting seeds into the soil (Figure 2.18).

Figure 2.18 Planted mangroves at WnZ (Source: Çete, 2017)

However, in February 2016 erosion occurred again. The wind direction and wave height changed during this period and the design was not sufficient enough to keep the accumulated sediment in the unit. Besides this problem, it also occurred that during the construction, the permeable dams already structurally failed the same day during the flood period. Bamboo has been used as filling material but started floating.

In spite of all the problems that have occurred, the professor adapted his methods according to his findings. Eight STUs have been constructed so far, in seaward and in eastward direction of the Place of Pilgrimage. In Figure 2.19 and Figure 2.20, an indication of the current situation is shown. The first STU (outer left of Figure 2.19) will be expanded in seaward direction according to the scale model (Figure 2.21). There are three STU's in seaward direction. Only the second STU has been constructed so far. The third STU will have openings which are more in the direction of the waves, to trap sediment more efficiently. Also, the third STU will be constructed to have a wave reduction function, so the sediment that is trapped behind will not be washed away. Finally, the bamboo filling material now has holes in it and is bound together (Figure 2.17). This is done with the purpose so that sediment can get trapped into the bamboo, making it heavier and thus prevents it from uplifting. This is still a work in progress, as some bamboo poles are still empty.

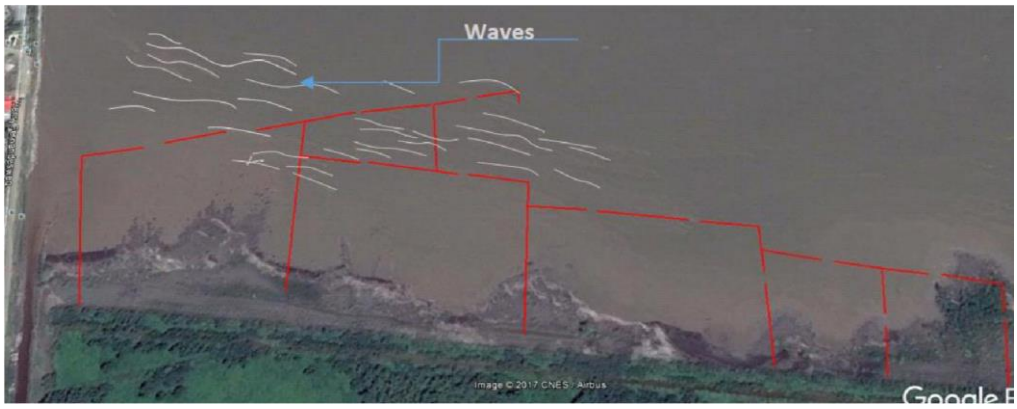

Figure 2.19 Current situation of the sediment trapping units (Source: Naipal, 2017)

Figure 2.20 Drone picture of the STUs in 2018 (Source: Ameerali, 2018)

Figure 2.21 Scale model of the three STUs (Source: Haage, 2017)

3. STAKEHOLDER IDENTIFICATION & ANALYSIS

This chapter will analyze the stakeholders of the Weg naar Zee region. First the methodology will be addressed in paragraph 3.1. Subsequently, the identified stakeholders will be discussed in paragraph 3.2. Finally, paragraph 3.4 will present the conclusions of the stakeholder analysis. This chapter aims to provide a preliminary view on who is involved in the project scope at the Weg naar Zee region.

3.1 Methodology

This paragraph will explain the methodology applied for further identifying and finally analyzing the Weg naar Zee stakeholders.

Identification phase

The first step is the identification of the stakeholders. In paragraph 2.1 the list of stakeholders was already presented. The interviews with several key stakeholders were held with the intention to gather more valuable information, aside from the literature search. Furthermore, interviewing stakeholders resulted into a better understanding of their perceptions, interests, goals, resources and thus their positions overall. The names of the interviewed stakeholders will appear throughout the rest of this and upcoming chapters in reference to statements they made during their interviews. An overview of the interviewed stakeholders can be found in section D.8 of Appendix D.

Analysis phase

After the stakeholders were identified, the next step was to analyze them. The applied stakeholder models are mostly tables and maps which help analyze stakeholders and can all be found in Appendix D. These models vary in analysis but are dependent on each other because the findings of one model are used in the subsequent models. The models in section D.2-D.6 from Appendix D, are stakeholder identification and analysis techniques by Bryson (2004). The model in section D.7 is derived from stakeholder mapping theory by Murray-Webster & Simon (2006). All these models are used because they show interesting aspects such as:

- Stakeholders' classification on the basis of their level of replaceability and importance.
- Stakeholders' criticality (critical or non-critical) based on their replaceability and dependency.
- Stakeholders' dedication (dedicated or non-dedicated).
- Stakeholders who share the same interests, perceptions, interests and goals.
- Which stakeholders would form potential partnerships.
- How to engage stakeholders based on their typology (type).

3.2 Stakeholder identification

Stakeholder identification table

It is known that ignoring key stakeholders' interests and information held by especially them, leads to bad project outcomes (Tuchman, 1984). When decisions are made and executed without involving (key) stakeholders' interest and information, this leads to failure or even disaster (Nutt, 2002). As there are multiple stakeholders in the Weg naar Zee region, it is important to understand all of their

different perceptions. This analysis is executed in Table 3.2, by understanding what each stakeholder's interest, problem perception, goal and resources are.

No.	Stakeholder	General interest of stakeholder	Problem perception	Goal	Resources
1	**Inhabitants of the Weg naar Zee region**	Live safely, keep the charm of the area.	Flooding and land loss.	To live in a flood-safe region, where nature, social- and economic environment are untouched.	Protests.
2	**Government of Suriname**	Preserving Suriname's nature, coast and livelihood for all Surinamese people [7]. Sufficient economic opportunities (e.g. sufficient fruitful land for farmers). Nature conservation and proper spatial planning [6]. Formulating, monitoring and adjusting development plans for Suriname [8].	The Surinamese coastline is eroding at high rates on several places along the coast. Failure of civil engineering works and other coastal management measures [2]. Less fruitful agricultural coastal land for farmers and less fishery due to salt intrusion. Less economic activity.	Mitigating coastal erosion and protecting the people [7]. Maintaining: 1) Fruitful agricultural land, so that regional industry in is unaffected. 2) Stable salt intrusion level, so fishing industry is unharmed. To formulate a development plan which can be used for coastal management at Weg naar Zee [3] [4]. Reaching a point of awareness about the impacts of climate change on society [5].	Decision-making power, execution power and state capital for coastal management investments. Issuing permits, rule-making power. Policy-making on nature conservation and land allocation. Generating development plans.
3	**AdeKUS**	Providing tools to preserve the Surinamese coast at Weg naar Zee [1].	Locals (incl. government) are not aware of the serious impacts of climate change [1].	Offering the necessary tools and education to protect the Surinamese coast [1].	Knowledge, network and facilities for involved researchers.
4	**Agricultural farmers**	Making profit with farming activities (crops and animals e.g. cows).	Flooding and salt intrusion causes the farmers to lose their agricultural harvest, and thus incomes.	Maintaining sufficient fruitful land to uphold their profits around the Weg naar Zee region.	Protesting, labour strike.
5	**Fishers**	Making profit with fishery.	Loss of mangroves implies biodiversity loss, salt intrusion and thus reduction of fishers' income.	Maintaining the types and amount of fish available at Weg naar Zee to ensure their sole source of income.	Protesting, labour strike.
6	**Place of Pilgrimage**	Facilitating the religious people to pray and facilitating tourists.	Non-existence due to flooding and erosion [8].	To maintain the Place of Pilgrimage so that faithfuls and tourists can keep on visiting.	Protesting, donations to adapt against continued land loss.
7	**Visitors of Place of Pilgrimage**	Visiting the Place of Pilgrimage during regular visiting days and religious festivals.	Closure of the Place of Pilgrimage [8].	Maintaining their regular Pilgrimage site.	Protests.

8	**SME business owners**	Making profit with their business.	No business income.	To keep making profit by retaining their customers/clients.	Protests.
9	**Tourists**	Visiting the Weg naar Zee region.	Not being able to visit the tourist sites in the Weg naar Zee region due to closure or even non-existence.	Being able to visit the Weg naar Zee region.	Money.
10	**Recreationists**	Enjoying the nature of the Weg naar Zee region, angling and hiking.	Affected natural area, less space for hiking, lesser fishes and birds.	Maintaining their recreational spots in the Weg naar Zee region.	Protests.
11	**Cremation place Weg naar Zee**	Facilitating those who wish to be cremated at the Weg naar Zee cremation place.	Non-existence due to flooding and erosion.	Continuation of their cremation business.	Protests.
12	**NGOs**	Preservation of ecosystem, maintaining livelihood for locals.	Climate change and all of its effects causes problems for preserving nature/ecosystem and livelihood for locals [6].	Preservation of world-wide nature and livelihood for locals in a sustainable way [6].	Donations, capital for investments and international networks.
13	**Engineering firms**	Providing a solution for the lack of coastal management by the government, as this may lead to the assignment being awarded to them [9].	Mangroves (STUs) being chosen as the preferred coastal management measures, causing them to miss out on capital-intensive assignments (missed profits).	To acquire coastal management assignments by the government [9].	Knowledge, expertise, (inter)national connections and tools.
14	**Embassies**	Assisting countries in facing climate change issues.	Climate change and its impacts on society and the world.	To aid countries who actively try to tackle climate change in a sustainable way [10].	Capital, network, donations.

Table 3.1 Stakeholder identification table

[1] Anton de Kom Universiteit van Suriname. (n.d.).
[2] Ministerie van Openbare Werken, Transport & Communicatie. (n.d.).
[3] Ministerie van Ruimtelijke Ordening, Grond- en Bosbeheer. (n.d.).
[4] Stichting Planbureau Suriname. (n.d.).
[5] Starnieuws. (2015, February 20).
[6] Conservation International Suriname. (n.d.).
[7] Nieuws-Suriname (n.d.).
[8] United News. (2016, May 5).
[9] Worldnieuws Suriname. (2016, February 19)
[10] United News (2016, May 12)

3.3 Stakeholder analysis

As was explained in paragraph 3.1, the entire stakeholder analysis (maps, tables and elaborations) is conducted in Appendix D. This paragraph will present mainly the conclusions of the analysis.

Adapted Power versus Interest grid

This subparagraph starts with a Power vs. Interest grid where the position of some stakeholders is compared between **2017 (current situation)** and the **situation before 2015**, the implementation year of the Sediment Trapping Units (STUs). This grid (Figure 3.1), is composed based on findings of the previous paragraphs and the stakeholder interviews.

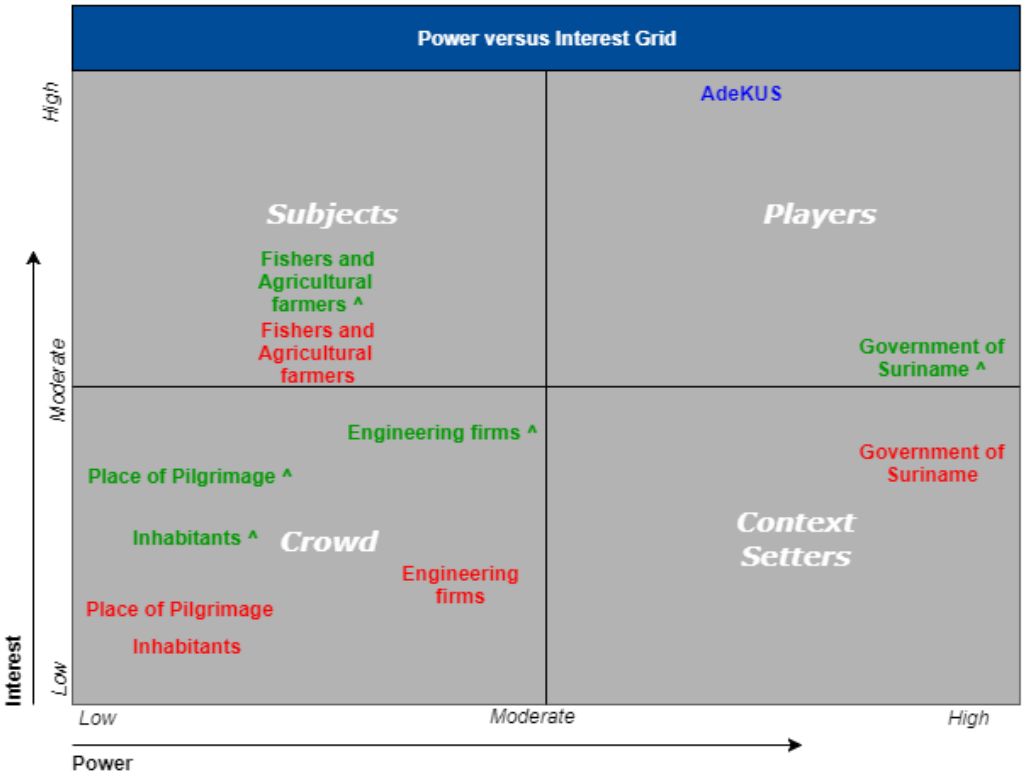

Figure 3.1 Comparison between old (red) and current (green) situation of the position of some actors in the Power vs. Interest (Source: own illustration)

From the grid it is observed that after the STUs were implemented at WnZ in 2015, the attitude of some stakeholders has changed. This caused them to switch from positions in the grid. The stakeholders in the red color indicate the stakeholders' positions before 2015, while the green colored stakeholders indicate their current position (end of 2017). It can be concluded from the grid, that several stakeholder groups' interest for STUs has grown over the past two years (2015-2017).

After the flood in 2015, the *Government of Suriname* was put under pressure by the local community to take drastic measures against a flood happening again. In response to this, the former Minister of Public Works promised that a dike of eight km would be constructed and that only the financing needed to be completed. It was the government's intention to borrow money from the Islamic Development Bank (IDB) to build the dike at the WnZ region. However, the IDB loan never got off the ground for unclear reasons (Starnieuws, 2015). After the interview with A. Amatali, it became clear that the plans were put on hold due to the lack of finances and other political interests given the presidential elections of 2015 (A. Amatali, personal communication, December 7, 2017). The 2016 and 2017 annual speeches of the Surinamese president show that the government is currently more interested in supporting mangroves and STUs as coastal protection measure (Kabinet van de president, 2016 & Kabinet van de president, 2017). This change of attitude can be explained due to

the poor economic situation, which means large capital investments (e.g. concrete dike) cannot easily be made. Thus, the stakeholder *Government of Suriname* has made a leap from Context Setters to Players in the Power vs. Interest grid.

As Figure 3.1 shows, the stakeholder groups *Fishers* and *Agricultural farmers* have not moved a lot from position in the last two years. After the interview with stakeholder W. Bajnath (personal communication, December 4, 2017), it became clear that this stakeholder group currently has more confidence in the STUs. They do remain Subjects, which means that the interest is slightly above moderate, and their power remains between low and moderate.

As Figure 3.1 shows, the stakeholders *Place of Pilgrimage* and the *Inhabitants of the WnZ region* started out as having a very low interest in mangroves as coastal management measure, combined with a low power concerning coastal management policy.

Figure 3.1 also shows that after two years the interest of the *Place of Pilgrimage* has increased quite significantly, slightly more compared to the *Inhabitants of the WnZ region*, whose interest has also increased. Their power does not change (R. Bajnath, personal communication, December 6, 2017). The two stakeholder groups thus remain in the Crowd section of the Power vs. Interest grid.

Finally, Figure 3.1 shows that the stakeholder *Engineering firms* started out having slightly more interest compared to the *Place of Pilgrimage* and the *Inhabitants of the WnZ region*. This was also the case for power, as the Engineering firms' power is almost moderate compared to the low power of the latter. The position switch for the Engineering firms can be explained by the increased interest in 2017 to almost moderate, considering the sustainability factor of applying mangroves as coastal management measure. They remain in the Crowd section of the Power vs. Interest grid.

Remaining stakeholder models

The most important finding from the **Resource dependency table** (Table D.3, Appendix D) showed out that the *Inhabitants of the Weg naar Zee region*, *Government of Suriname* and *AdeKUS* are highly important and low replaceable. The analysis also showed that there are stakeholders who are highly important, but also highly replaceable. These are: *Fishers* and *Agricultural farmers*, *Engineering firms* and the C*remation place Weg naar Zee*.

Based on the **Critical Actor Table** (Table D.4, Appendix D), the following actors have been deemed critical actors: *Inhabitants of the WnZ region*, *Government of Suriname* and *AdeKUS*.

From the **Stakeholder map** (Table D.5 in Appendix D) it can be seen that the previously characterized critical actors *Inhabitants of the WnZ region*, *Government of Suriname* and *AdeKUS* can be clustered together as dedicated actors. The difference is that AdeKUS and Government of Suriname are actors with the same perception, interests and goals and that the stakeholder group Inhabitants of the WnZ region is an actor with a different perception, interest and goal.

It became clear from the **Problem-frame stakeholder map** (Table D.6 in Appendix D) what each stakeholders' position is, and they were clustered in the following four categories: 1) weak supporters, 2) strong supporters, 3) weak opponents and 4) strong opponents. It shows that the stakeholders *AdeKUS*, the *Government of Suriname* and the stakeholder group *NGO's/Embassies* are strong supporters.

The results from the stakeholder typology model (Table D.7 in Appendix D), were used in order to get a better understanding of how to engage the stakeholders. According to Junior et al. (2015) there are five ways for engaging stakeholders, namely:

1. Inform: Helping stakeholders in grasping dilemmas and choices by supplying them with information which is objective.
2. Consult: Acquiring feedback on dilemmas and choices from stakeholders.
3. Involve: Guaranteeing that the stakeholders their issues and interests are continually apprehended and regarded, by directly working with them during the whole project.
4. Empower: Providing the stakeholder with decision-making power to a certain degree.
5. Collaborate: Partnering with the stakeholder in every detail of the decisions.

These five ways can be found in the table below for every stakeholder. The table also shows a summarized overview of the most important elements from the stakeholder analysis.

Stakeholders	Resource dependency	Critical actor	Problem frame Stakeholder Map	Stakeholder typology	How to deal with them	Type of involvement
Inhabitants of the WnZ region	High Importance/ Low Replaceability	Yes	Weak opponent	**Irritant**	Need to be engaged so that they do not block the process	**Consult/ Inform**
AdeKUS	High Importance/ Low Replaceability	Yes	Strong supporter	**Saviour**	You should do whatever is needed to satisfy them	**Collaborate/ Empower**
Government of Suriname	High Importance/ Low Replaceability	Yes	Strong supporter	**Saviour**	You should do whatever is needed to satisfy them	**Collaborate/ Empower**
Agricultural farmers/ Fishers	High Importance/ High Replaceability	No	Weak supporter	**Friend**	Should be used as a confidant or sounding board	**Consult/ Inform**
Place of Pilgrimage	Low Importance/ Low Replaceability	No	Weak opponent	**Irritant**	Need to be engaged so that they do not block the process	**Consult/ Inform**
SME business owners	Low Importance/ High Replaceability	No	Weak opponent	**Irritant**	Need to be engaged so that they do not block the process	**Consult/ Inform**
Tourists/ Recreationists/ Visitors of Place of Pilgrimage	Low Importance/ High Replaceability	No	Weak supporter	**Acquaintance**	Need to be kept informed so they keep supporting	**Inform**
Cremation place Weg naar Zee	High Importance/ High Replaceability	No	Weak opponent	**Irritant**	Need to be engaged so that they do not block the process	**Consult/ Inform**
NGOs/ Embassies	Low Importance/	No	Strong supporter	**Friend**	Should be used as a	**Collaborate/**

	Low Replaceability				confidant or sounding board	**Consult**
Engineering firms	High Importance/ High Replaceability	No	Weak opponent	**Tripwire**	Need to be understood to avoid tripping up	**Consult/ Inform**

Table 3.2 Conclusion of the stakeholder models in Appendix D

Table 3.2 shows that the *inhabitants of the WnZ region* are critical actors and can be classified as the 'irritant' type. Therefore, it is needed to consult and inform them from the beginning of the process in order to engage them so that they do not block the process. This is necessary to do for especially this group of stakeholders as they will be affected the most by coastal erosion and its effects. The tool that will be used to consult the locals is surveying in the WnZ region. The aim of the surveys is to get a better understanding about the current situation of the region, their position and views about coastal erosion and what their wishes are. This information will then be used as input for the design requirements. The results of these surveys will be discussed in the next chapter.

4. DESIGN REQUIREMENTS

This chapter will present the design requirements for the variant study and the preliminary designs which will be further elaborated in the next two chapters. Paragraph 4.1 will present the methodology of the conducted survey. In paragraph 4.2 the results of the survey are presented. Paragraph 4.3 will discuss the shift from dikes towards mangroves and the reasoning behind this. Paragraph 4.4 will address the success factors, while paragraph 4.5 presents the requirements and wishes which are stated by the stakeholders of the WnZ region.

4.1 Methodology

The inhabitants of the Weg naar Zee region are affected the most by coastal erosion and its consequences. Also, in 2015 big parts of this region were flooded as result of a high tide. Therefore, it is important to gather as much as possible information from the locals with the aim to gather as much as possible information to know what their experience is and what their wishes are.

Survey scope

The surveys were conducted among the Weg naar Zee inhabitants. The scope of the survey area can be seen in Figure 4.1. In this figure it can be observed that the most northern part of the WnZ region was split into six neighbourhoods.

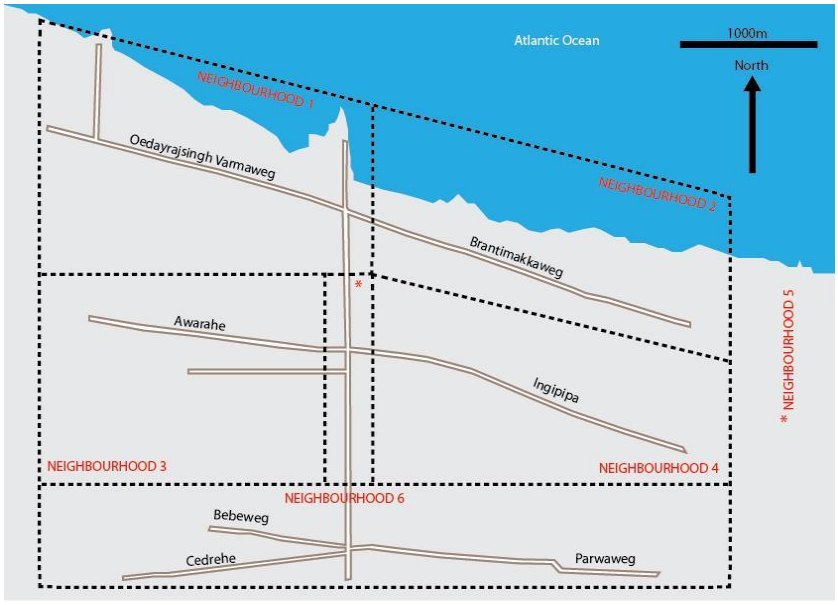

Figure 4.1 Scope of surveyed areas (Source: own illustration)

Survey population

After deciding on the scope, information was gathered to define the sample population. This information was deemed to be available at the National Statistical Office of Suriname (ABS). However, the issued data by ABS (2016) appeared to be on regional level. Thus, for defining the survey scope, it was important to gain data on a street level, but this was unavailable. In order to complete the survey within the defined scope, the number of households were counted on the basis of a satellite photo (2017) on Google Maps (Figure E.1, Appendix E).

It appeared that there are 248 households in the defined area. According to recently released statistics from ABS (2016), an average Surinamese household consists of a family of four persons. Therefore, it was assumed that an approximation of 992 inhabitants live in this part of the WnZ region. The survey was for persons with a minimum age of 18. Therefore, an assumption was made that each household consists of two persons who have at least reached the minimum age. This results in an approximation of 496 inhabitants who live in the survey scope of six neighbourhoods and who have reached the minimum age of 18.

It was determined that 217 surveys had to be completed in order for the survey to be reliable. To determine this, statistical data (Baarda & De Goede, 2006) and obtained data from Google Earth and ABS were used and can be found in Appendix E, section E.1.

This minimum of 217 surveys was achieved by surveying for two full days in the area with the help of bachelor and master students from AdeKUS. The complete survey (translated to English) and its results are shown in Appendix E, section E.2 and E.3. The relations and conclusions which can be drawn from these surveys will be shown in the next paragraph. In Figure 4.2 an impression is given of how WnZ respondents were approached at their residences during surveying.

Figure 4.2 Projectteam members C. Çete and A. Ma-Ajong busy surveying two female respondents in the Weg naar Zee region (Source: Hardwarsing, 2017).

4.2 Survey results

A total of 219 responses were received from the surveys, with each survey consisting out of 32 questions. The surveys were analyzed with the help of charts which illustrate how the inhabitants of WnZ think about coastal management and what their point of view is. In this subparagraph, the most interesting and important results will be presented textually. A complete overview of all charts can be found in section E.3 of Appendix E. In the remainder of this chapter the entire protection of the coast (defense against erosion and flooding) will be clustered together under the term **"coastal management"**.

In Figure 4.3, the number of respondents is divided among the six different neighbourhoods. This figure also indicates the title of the ground per neighbourhood.

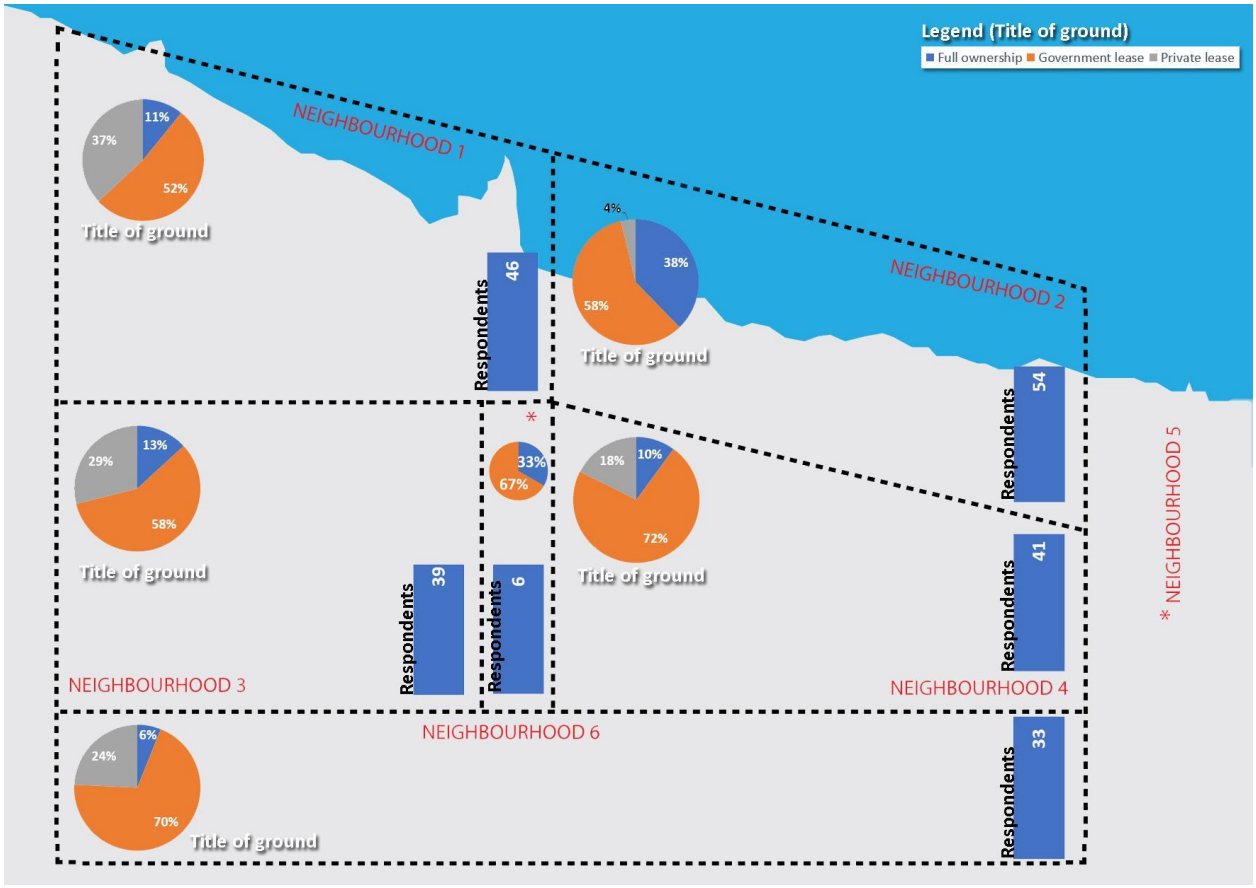

Figure 4.3 Scope results per neighbourhood (Source: own illustration)

The answer options for title of ground were: a) Full ownership, b) Government lease and c) Rent. Figure 4.3 shows that most of the title on land in the surveyed WnZ region is government lease. This is followed by rent, meaning the land is rented from a private person. Finally, a small group said they have full ownership of the land they live on.

Safety

Safety is an important driver and as can be seen from the survey, the WnZ inhabitants are very dissatisfied with their own safety against flooding given the current coastal management (140 respondents, 64%), followed by a group of not satisfied/nor dissatisfied (28 respondents, 13%) and another group who is dissatisfied (27 respondents, 12%). This only leaves a group of 11% (24 respondents) who is satisfied with their own safety against flooding. It can thus be concluded that a minimum of 76% (167 respondents) is currently not satisfied with their own safety against flooding in the WnZ region they reside in. This can be seen in Figure 4.4.

Figure 4.4 Inhabitants satisfaction against flooding given current coastal management (Result survey question 7)

Although the survey showed that 76% of the inhabitants in the WnZ region do not feel safe against flooding, 130 respondents (58%) are not willing to move to a safer place and only 71 respondents (32%) would be willing to move (Figure 4.5). What this means is that although they feel unsafe and are dissatisfied with their safety against flooding, they are still reluctant to move away from this area. Through the stakeholder interviews, it became apparent that this reluctance has mainly to do with the emotional connection the inhabitants feel with their homes in the WnZ region. Some have lived there for generations long and most want the government to act in protecting them and their homes against flooding. From the group that is willing to move, it became apparent during the surveys that they only wanted to move if the government could offer them similar living conditions or a piece of land, or a ready-to-move-in home.

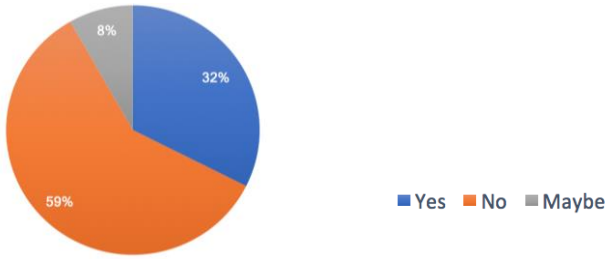

Figure 4.5 Amount of inhabitants who are willing to move out of the WnZ region (Result survey question 8)

Sea level rise

Only 93 respondents (42%) of the respondents is aware of sea level rise and a large group of 126 respondents (58%) is not (Figure 4.6, left). This large number is worrying and therefore indicates that the inhabitants are not quite being informed in a proper way about sea level rise. It also became apparent during the surveys, that most of the people didn't exactly know what sea level rise is. This became clear when a lot of explaining was needed to explain the concept, which they eventually grasped on to answer the questions related to sea level rise. Of the respondents, 81 (38%) have experienced burden from the flooding in 2015 (Figure 4.6, right).

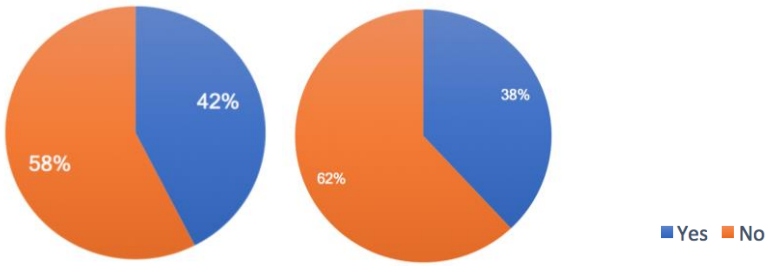

Figure 4.6 Left: Amount of inhabitants who are aware of seal level rise (Result survey question 9); Right: Amount of inhabitants who have experienced burden from the flooding (Result survey question 12)

Figure 4.7 shows that neighbourhoods 1 and 2 experienced the most flooding and therefore can be seen as the most vulnerable neighbourhoods when compared to the other four neighbourhoods.

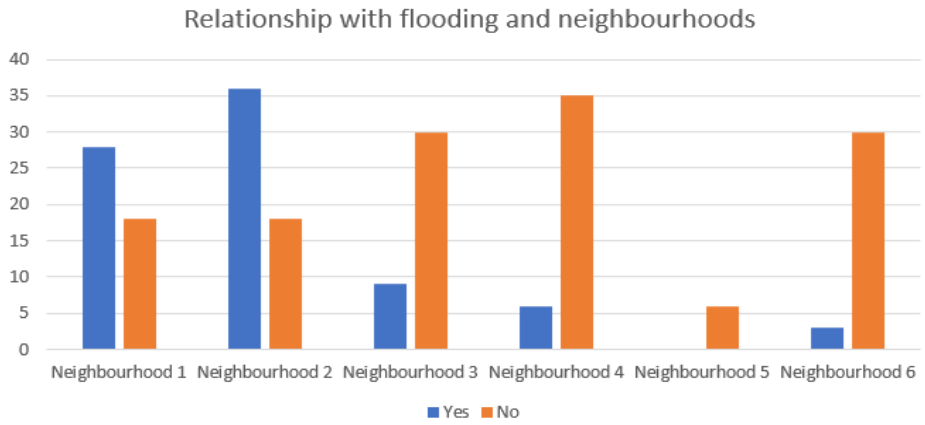

Figure 4.7 Relation between flooding in the WnZ region and the WnZ neighbourhood the respondents reside in (Source: Figure E.36, Appendix E)

Coastal management

The majority of respondents (130) said that they do not know what a STU is (73%), 30 respondents (14%) said that they do know what a STU is, but do not know how it works. The team of invigilators immediately used this as an opportunity to explain the concept of the STU to the respondents as part of creating awareness. Only 29 respondents (13%) said that they knew what a STU was and how it works (Figure 4.8). It is interesting that majority doesn't know what the STUs are as this might also mean that they haven't seen the STUs which are currently at the coast. It also turned out through comments made by the inhabitants during the survey, that although they live in the WnZ region, they do not visit the coast where the STUs are regularly.

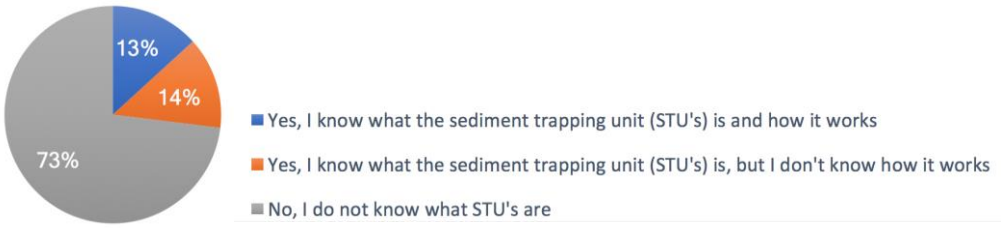

Figure 4.8 Amount of inhabitants who know what a Sediment Trapping Unit is (Result survey question 14)

Furthermore, an interesting result of the survey is that the majority of the respondents would prefer to have a dike as solution for coastal management. A total of 142 of the total 219 respondents (65%) wants a dike of concrete to protect them against sea level rise and the consequences coming with it. Furthermore, it turned out that 38 respondents (17%) want a combination of the STUs with a dike, while only 27 respondents (12%) want the STUs (Figure 4.9).

Figure 4.9 Type of coastal management wanted by the inhabitants of the WnZ region (Result survey question 16)

In the next paragraph it will be explained how the wish of the majority for concrete dikes will be dealt with.

4.3 From concrete dike to mangroves

In this paragraph, the decision-making process with multi-stakeholders will be explained with the help of process management principles. Subparagraph 4.3.1 explains the attitude development of the Weg naar Zee inhabitants. Subparagraph 4.3.2 explains the decision-making and subparagraph 4.3.2 will explain the lessons learned.

4.3.1 Attitude development Weg naar Zee inhabitants

This subparagraph starts with the inhabitants' views regarding mangroves (based on survey results) and ends with a comparison to give more insight into how the WnZ inhabitants' attitudes regarding mangroves has developed.

Inhabitants' views regarding Mangroves

The survey results show that 76% of the inhabitants (166 respondents) are aware that mangroves can be used as coastal management measure (Figure 4.14). The result that such a large number of inhabitants would be aware of mangroves as coastal management measure was quite unexpected, because even though they are aware, still the majority prefers the construction of a dike as measure. Further results show that 134 respondents (62%) do not know that they can earn money working in a mangrove related sector or with mangroves in general (Figure 4.15, left). Furthermore, 47% of the locals (102 respondents) is willing to follow a training for a job in the mangrove sector. Also, the minority of the locals is not interested in a training for a job in a mangrove related sector and 15% (32 respondents) is not sure about it (Figure 4.15, right).

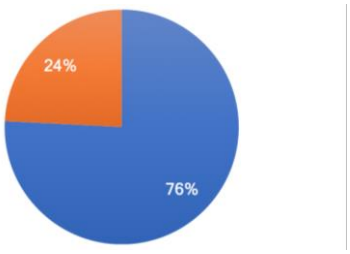

Figure 4.10 Inhabitants who are aware of mangroves as coastal management measure (Result survey question 19)

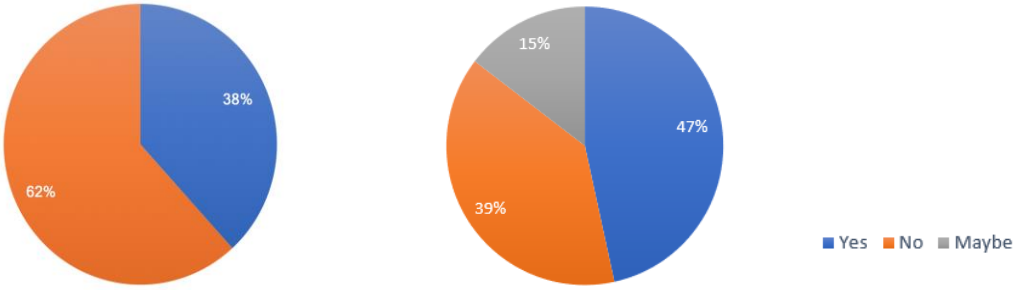

Figure 4.11 Left: Inhabitants who know they can also earn money in a mangrove related sector (Result survey question 20); Right: Inhabitants who are interested in a training for a job in the mangrove sector (Result survey question 22)

Comparison

Finally, this report's survey is compared with another WnZ survey from 2015 on the basis of inhabitants' preference for coastal management measures. This will offer more insight into the locals' positions in 2015 and their current position at the end 2017. The survey from 2015 is from a Ministry of Public Works, Transport and Communication project. The subject of that research was: "Dike Crematorium - Gummelskanaal at Weg naar Zee" for which an Environment and Social Impact Assessment (ESIA) was made (P-all Projects Supply Suriname N.V., 2015). According to the consultancy's CEO, Juan Pigot, this research was conducted among 50 households in the WnZ region (personal communication, December 26, 2017).

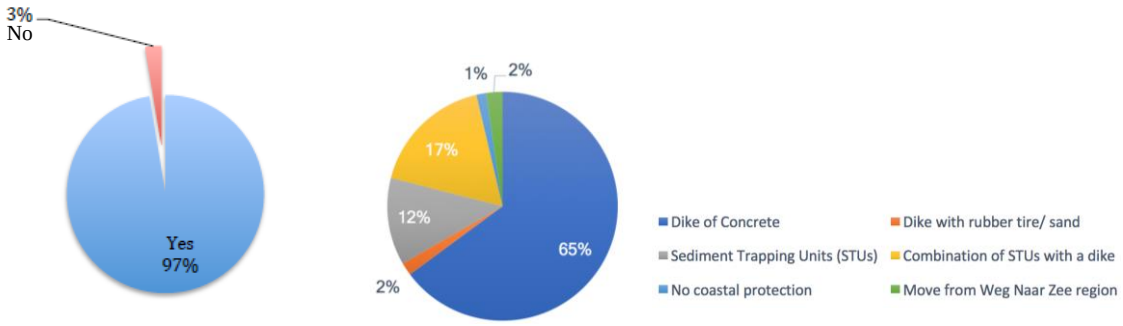

Figure 4.12 The result of preferences for coastal management measures in the research conducted by the consultancy (left), compared with the survey conducted by Mangrove Project Suriname (right) (Source: P-all Project Supply Suriname N.V., 2015)

As mentioned earlier, 142 respondents (65%) of the Weg naar Zee survey want a dike, 27 respondents (12%) want STUs (mangroves) and the survey conducted by Mangrove Project Suriname also adds a new dimension which is a combination of mangroves with a dike. Among 38 (17%) of the respondents prefer this option. The research of P-all Projects Supply Suriname N.V. (2015) showed that a vast majority, 97% of the respondents, preferred the construction of a dike (left graph of Figure 4.19) and only 3% of the respondents had a wish for another coastal management measure. Thus, it can be seen from Figure 4.19 that the attitude and position of the respondents has changed during the years as currently they are now more open to the building with nature solutions. Previously it was 97% of the respondents who clearly chose for a dike, but that huge number has now been dropped to 67%.

Finally, all of these results have given a lot of practical insight into the stakeholders' actual wishes, perceptions and interests. Given these results, the next subparagraph will describe the decision-making for the WnZ stakeholders when it comes to coastal protection.

4.3.2 Decision-making

Earlier in this chapter it is indicated that the goal of the executed survey was to measure how safe the locals of Weg naar Zee feel with the current coastal management and what their wishes and requirements are. The survey's aim was to use the results as input for the next paragraphs of this report (4.4 Success factors & 4.5 Design requirements). However, it is not self-evident that all wishes can be included directly in the project requirements. Chapter 3 identified that the WnZ coastal management project consist of many stakeholders. These various stakeholders have different views and interests, which means that at some point during decision-making there will be trade-offs for important decisions. Because of this, the chance arises that not every stakeholder can be pleased during the project process. De Bruijn & Ten Heuvelhof (2008, p. 49) state that in such a situation the

risk of a deadlock arises, 'When a number of actors support view A and a number of other actors support view B, there is little room for a compromise'.

In the case of the Weg naar Zee coastal management, there were also tradeoffs and at some point, it was necessary to take decisions in order to go further with the project. The wish of the majority of the local residents for the construction of a dike will not be elaborated in the preliminary designs for the following reasons:

- The construction of a dike is not part of the scope of this research.
- The construction of a dike will increase the wave action and therefore the erosion of the coast is enhanced (Figure 1.3).
- According to A. Amatali (personal communication, December 7, 2017) the government will certainly not be able to finance the construction of a dike in the coming years, due to the current economic crisis in Suriname.
- According to the latest annual speeches of the Surinamese president, the government is now more open in supporting mangroves as coastal management measure where possible.
- From subparagraph 4.3.1, it can be seen that the attitude of the WnZ inhabitants is changing. Compared with the situation before the implementation of the STUs in 2015, their attitude towards 'Building with nature' is now more open.

These reasons reinforce the evidence for applying a sustainable, natural and cheaper coastal management measure at Weg naar Zee. The solution that applies for such a situation is the use of mangroves as natural coastal protection. Friess (2016) emphasized in his recent research the fact that mangrove forests survive in a dynamic and physiologically stressful environment and also survive high amounts of salinity. According to Friess (2016), the mangrove forests are also known for regulating "key processes such as hydrodynamic wave attenuation". In the case of coastal protection at Weg naar Zee the latter is extremely important. The fact that mangroves have a unique biodiversity value also ensures possible benefits for the local residents. In this case one can think of the new ecosystem that will be developed whereby fish, shellfish, crabs, but also birds and other animals will settle. In the long term this can also lead to benefits in various sectors, such as fishery, tourism, recreation and education. These are key reasons that has led to the decision that mangroves will be used in the coastal management variants and preliminary designs in the following chapters.

It is expected that the majority of the local residents will at first be displeased with this trade-off. However, from Figure 4.13 it can be seen that the majority (85%) of the local residents indicated in the survey that the government need to pay for the construction of a dike and because the government currently has no money available for this issue, there will be a stalemate. The stalemate is undesirable because the current situation is so urgent that it is better to take action sooner rather than later. Therefore, a sustainable and cheaper solution in the current setting is an ideal opportunity. What needs to be worked on is to get everyone on the same page. De Bruijn & Ten Heuvelhof (2008) address various strategies for reaching a compromise for all involved stakeholders who all have different views. The next paragraph will discuss how to deal with the stakeholders during the process and which lessons can be learned from the past.

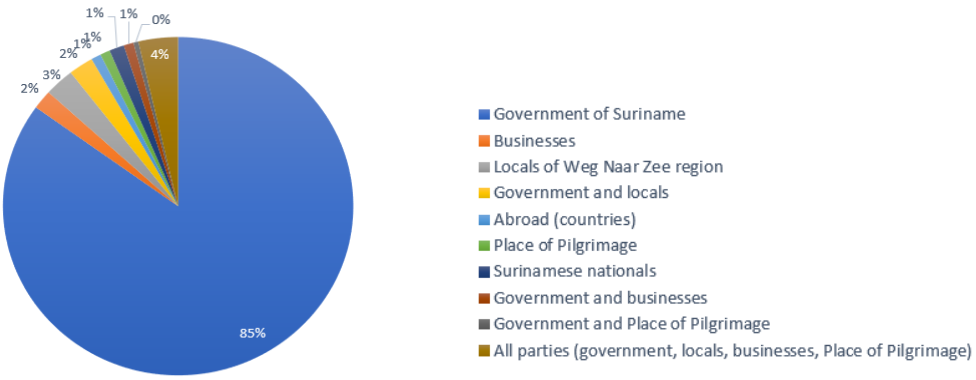

Figure 4.13 Who the inhabitants think should pay for coastal management measures (Result survey question 17)

4.3.3 Lessons learned

In the previous paragraph it was shown that decisions have to be made during the process and the execution in this coastal management of Weg naar Zee. According to literature it is important that a process of decision-making has to contain the following four core elements (De Bruijn, Ten Heuvelhof, & In 't Veld, 2010):

1. Openness;
2. Protection of core values;
3. Progress;
4. Substance.

During the literature study, it has been noticed that during the process when the STUs were initiated by AdeKUS in 2015, little attention was given to these four core elements. If openness is considered, it can be concluded that almost nothing was done to provide the locals with information about the pilot project. This became clear during surveying in the WnZ area in November 2017. Here the majority of surveyed locals (73%) claimed that they were not aware of what a Sediment Trapping Unit was, how it worked and how it looked like (Figure E.13, Appendix E). This meager information flow creates a knowledge gap for the locals about the existence of sustainable alternatives. This can also be a reason that the locals are tempted to choose for the obvious solution, the construction of a dike. Furthermore, if projects are executed without involving the locals, a higher chance will exist of locals feeling left-out and that their vision is not respected as much. This can work counter-productive for project execution, resulting in more opponents instead of supporters. When such a situation arises, this can have consequences for project continuation. This can then have consequences for the quality of the project.

To prevent that the coastal protection designs of WnZ in the coming chapters will face the same issues, it is of importance to handle adequately from the beginning. The first thing in handling adequately is involving stakeholders from the immediate start of the process. With the stakeholder models which have been analyzed in previous sections for this project, the various stakeholder positions have been determined. An important involvement type is to *inform*. During surveying it was asked if the locals received information about coastal protection. The majority of the locals strongly denied this. The information flow from institutions is limited. The media only spends attention to WnZ in the case of a flooding. Interesting were the comments made by unemployed and retired locals who live under the poverty line. This group of locals said that they do not have the resources (e.g.

television and/or radio) to be kept up to date by the media concerning issues as sea level rise or climate change. To also be able to reach and consult this group of locals, other possibilities than (social) media should be looked at and pursued. S. Naipal (personal communication, January 12, 2018) stresses the importance of informing and involving, as the locals expect information about the coastal safety issues, but this is currently not being provided. In chapter 8, some recommendations are given that can help contribute in involving stakeholders from the immediate start of the process.

In addition to the inhabitants' attitude switch, the decision-making and the lessons learned, success factors must also be considered. These will be addressed in the next paragraph.

4.4 Success factors

In this paragraph the main factors for a design to be successful are given. The difference between the success factors and the design requirements is that in the design, the success factors cannot be guaranteed beforehand because of the uncertainty that comes with the 'Building with Nature' concept. Even though the success factors cannot be guaranteed, they should be aimed for to achieve a healthy mangrove forest. Therefore, monitoring has to be done, which will be explained for every preliminary design. The design requirements are to be guaranteed in the design beforehand. The success factors, the design requirements and the results of the stakeholder analysis (wishes) are the input for the variant study. In the variant study the pros and cons of the alternatives will be stated. Using this information, three variants will be chosen for preliminary design.

The success factors of the project are determined by looking at a healthy mangrove forest near the area of Weg naar Zee and also by executing a literature study. The project can be claimed to be a success, if the following factors are achieved:

- Involvement of the locals during the lifetime of the design, as mentioned in the previous paragraph.
- A mangrove forest at WnZ with a width of 450 meters. According to Janssen (2016) a mangrove forest with a width of 450-900 meters (sparse forest) is able to reduce wave heights to a safe level. For a dense forest, 100 meters is sufficient (Janssen, 2016).
- The mangrove forest of 450 m needs to be dense to fulfil as coastal protection (Appendix F).
- The mangrove forest should consist of more than one species to enhance biodiversity and therefore resilience (Wesenbeeck, 2017).
- A minimum slope of 1:1000 (Schiereck et al., 2016).
- Minimum Sedimentation of 0.6 meter. In figure 4.14 the current bathymetry and the required bed level are shown.

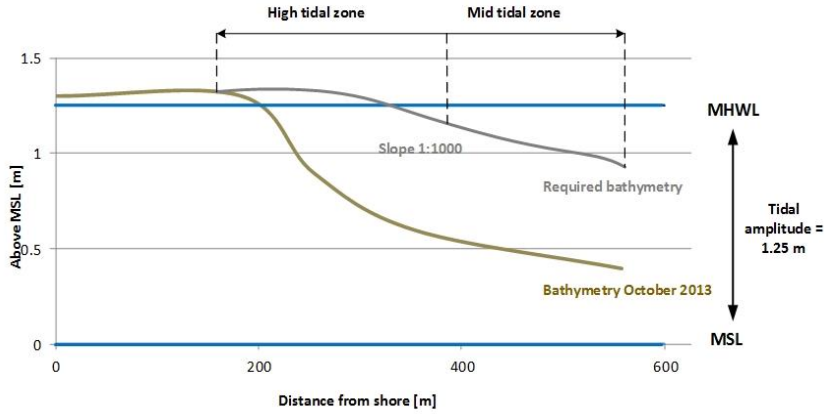

Figure 4.14 Current bathymetry and required bed level (Source: own illustration)

4.5 Requirements

In this paragraph the requirements are listed. The requirements can be divided into functional (Table 4.1) and technical requirements (Table 4.2-4.3). The requirements are SMART formulated: Specific, Measurable, Achievable, Realistic and Time bounded (Mind Tools Content Team, n.d.). If applicable, the verification method is also given. The requirements have been defined by taking along the client and stakeholders' wishes. Finally, the important boundary conditions and the extra considerations that need to be taken into account are also listed (Table 4.4).

Functional requirements	Verification method
The design must dissipate incoming waves with a significant wave height of 1.67 m (offshore conditions).	Measurement
The design must supply fresh water to the mangroves.	Measurement
The design must create a positive sediment flux.	Inspection
The design must have a minimum lifetime of 10 years. The structure must stay in place for 10 years, such that there is enough time for the bed elevation to increase (5 years) and the mangroves to be fully grown (5 years).	Inspection

Table 4.1 Functional requirements

Technical requirements	Verification method
The structure must be emerged during daily conditions to have more wave dissipation (relative to be submerged).	Inspection
The structure must withstand currents with a maximum velocity of 0.9 m/s.	Measurements
There must be a minimum length of ¼ of the Pole length left above the sedimentation layer, because the clay can stir up again if this is not the case. Thus, will not lead to more sedimentation in the STU (Naipal, personal communication, November 21, 2017)	Inspection
Filling material must not wash away.	Inspection

The structure must have a permeability of 30-50% (to allow for wave transmission and limit wave reflection).	Measurement
Scour holes around the structure must be minimal.	Inspection

Table 4.2 Technical requirements

From client and stakeholder interviews, the requirements and wishes became clear (Table 4.3).

Social requirements	Verification method
The design must create a 450 m wide mangrove forest within 10 years (S. Naipal, personal communication, November 24, 2017).	Inspection
The design must include a buffer zone behind the mangrove rehabilitation area.	Inspection
The design should be sustainable; negative environmental impact should be eliminated completely through skillful, sensitive design (McLennan, 2004).	Inspection
The structure should be made of local material.	Inspection
The design should generate other land use opportunities than the current use.	Inspection
The coastal protection should give a feeling of safety.	Inspection
The design should generate other land use opportunities than the current us.	Inspection

Table 4.3 Social requirements

Finally, a couple of boundary conditions and some important considerations also need to be taken into account.

Boundary conditions
A clay dike is present right behind the coastline.
Eight sediment trapping units are present in front of the coast.
Along the coastline of Weg naar Zee the Place of Pilgrimage is present, which has a length of 200 meters into the sea.
An irrigation channel is present on the east side of the Place of Pilgrimage.
Important considerations
The design must be resistant against sea level rise of 1.6 m in 2100 (Nijbroek, 2014).
Since the project is dealing with a muddy environment the structure can have a subsidence of 0.5 meters.

Table 4.4 Boundary conditions and important considerations

Now that the design requirements have been entirely specified, the analysis shifts towards the variant study in chapter 5.

5. VARIANT STUDY

In this chapter, the possible alternatives are determined. This is done by looking at the two main functional requirements, which are wave dissipation and sediment inflow. Doing this results in a number of alternatives from which three of the most realistic and effective solutions follow out of a Multi-Criteria Analysis. These three alternatives are worked out in more detail in chapter 6. Also, a design for the buffer zone and fresh water supply are included in chapter 6.

5.1 Alternatives

The STUs that are already built at Weg naar Zee will stay in place in each of the alternatives which will be presented in this paragraph. However, there are some design mistakes that were made during the implementation of those STUs, which were discussed in paragraph 2.4. In each of the alternatives, the already present STUs are improved and expanded if necessary. This is discussed further in chapter 6. After having done a literature study and brainstorm sessions, a list of possible alternatives with their variants have been determined and rated (section G.1 of Appendix G). Based on the two main requirements, wave dissipation and sediment inflow, the following five alternatives have the most potential:

1. Adapted STU;
2. STU with nourishment;
3. STU with Chenier;
4. STU with Floating breakwater;
5. STU with integrated breakwater.

The alternative “STU with an offshore nourishment” has relatively less potential than the other five, because there is already enough sediment available offshore. So, it is not necessary to place extra sediment offshore. The five most potential alternatives with their variants are more elaborated in the following paragraphs.

5.1.1 Adapted STU

The design is based on improving the current STUs. Different design aspects of the current STUs have been determined during field observations. Based on literature and more successful reference projects in Indonesia and the Wadden Sea, recommendations can be made to improve the current design. This can be done by changing the material, orientation, dimensions and openings of the STUs.

5.1.2 STU with nourishment

A certain emergence time is necessary for the development of particular mangrove species. This means that each mangrove specie is only able to grow in a specific bed level range. To speed up the process of sedimentation, the bed level inside the STUs can be brought to the right level by doing a nourishment inside the already existing STUs. The walls still need to be permeable so that water can flow through and the waves can be damped through the structure. Important disadvantages of this design are the high costs and the disruption of the ecosystem during the nourishment.

5.1.3 STU with chenier

Since cheniers are already naturally present at the coastal plain of Suriname, additional artificial cheniers can be placed to create calmer conditions inside the STUs. The cheniers will dissipate parts of the incoming waves, which will create a calmer climate for the sediment to settle in the STUs. The height of the cheniers must not be too high, otherwise no waves will be present to (partly) transport the sediment onshore. The height must also not be too low, otherwise the wave breaking will not be enough to create a calm climate. Therefore, modeling is needed to obtain the right height and dimensions of the artificial chenier. Also, a suitable location must be chosen to obtain the right sediment for the artificial chenier. A disadvantage of the chenier is that a lot of erosion can occur at the coast behind the breakwater edges. This happens if the breakwater is not designed correctly. Another disadvantage is the difficulty to predict the coastline response to the chenier.

5.1.4 STU with floating breakwater

For the development of young mangrove plants, it is important to have mild wave conditions. To reduce the wave action, a breakwater could be used. However, a traditional breakwater could lead to problems. The first problem is that a breakwater could lead to scour holes because of reflection and the muddy character of the coast. The second problem is that breakwater could lead to interference of the sediment patterns and therefore sedimentation in the sediment trapping units would be difficult to realize. To prevent these problems, the floating breakwater is introduced. A floating breakwater also dissipates wave energy, but without interfering the sediment transport patterns as much as a traditional breakwater. It is anchored to the ground and applicable on soft coastal bottoms. Besides this, there is minimum interference with fish migration. Maintenance wise, only periodic inspection is necessary.

There are some points to consider when it comes to using a floating breakwater. It is only effective in mild wave conditions and the wavelength should be limited. The natural oscillation period should be much longer compared to the wave period and the width should be in the order of half the wavelength. Furthermore, there is only limited experience with the floating breakwater and therefore the performance is uncertain. However, they have been constructed at some places in the world. These were meant to shelter harbours or prevent erosion of a mangrove forest.
The floating breakwater has the following variants which could be applicable at WnZ:

- Floating breakwater with tires;
- Box floating breakwater;
- Bamboo floating breakwater.

The box floating breakwater is used most often. It is made out of reinforced concrete and is either empty inside or made out of a light core material to achieve the required draft. Because of the heavy concrete there is a risk of sinking. Therefore, the usual dimensions are limited to a width of a few meters. The connections could be flexible. This allows rolling along the breakwater axis. The connections could also be pre or post tensioned, which makes them act as a single unit. In this case the wave reduction is higher, but the forces between the modules are also higher. The primary points of concern are the mooring system and the modular system. The box type is either a solid rectangle or a barge (Coastal Wiki, 2017).

Furthermore, the floating breakwater with tires is less effective but low in costs and can be removed easily. Also, it can be constructed with low skilled labour and the necessary equipment is on a minimum level. Furthermore, it is subjected to lower anchor loads, gives less reflection and dissipates relatively more wave energy (Coastal Wiki, 2017).

5.1.5 STU with integrated breakwater

This alternative focuses on improving the wave breaking function of the current STUs without increasing the resistance for sediment inflow. Possible variants within the integrated breakwater are:

- Integrated breakwater of tires;
- Integrated breakwater of bamboo.

5.2 Multicriteria analysis

The five most potential alternatives with their variants will be evaluated with a Multi-Criteria Analysis (MCA). A list of different criteria will be made of which each have a different weight. A detailed description of the criteria and their weight are explained in section G.3 of Appendix G. The weights are based on the project requirements and the additional benefits for the stakeholders. All variants will be rated between -2 and 2. An overview of the definition of the ratings is shown in Table 5.1.

Rating	Definition
-2	Very bad
-1	Bad
0	No effect
1	Good
2	Very good

Table 5.1 Definition of ratings used in the MCA

The completed MCA can be found in section G.2 of Appendix G. The total score of each variant is the sum of all its individual scores. The MCA's limitations have been taken into account and can be found in paragraph 8.3. The top three variants are based on the highest total score out of the MCA, thus the highest values. These three variants will be worked out in more detail including a cost estimation, which will be made for each of the three variants in chapter 6. In Table 5.2 the top results obtained from the MCA analysis are listed. It can be seen that the STU with nourishment obtained the highest score, followed by the STU with Chenier and finally the Adapted STU.

Top results	Score
STU with Nourishment	24
STU with Chenier	12

Adapted STU	8
Floating breakwater of concrete	2
Floating breakwater of bamboo	-3
STU with integrated breakwater bamboo	-6
STU with integrated breakwater tires	-14
Floating breakwater of tires	-15

Table 5.2 Obtained results from the MCA analysis

Explanation results

In the following section the MCA results will be explained.

STU with nourishment

This design obtained the highest score, because it received good points with respect to the Efficiency, Reliability, Environment and Side effects. Relative to the other alternatives, this is the most efficient solution as within a shorter time frame, sedimentation (artificially) takes place and the bed is elevated. It scores high on reliability, as it is sure to say that there is sedimentation inside the STUs due to the nourishment instead of waiting for it to take place after positive net sediment flux. Also, a high score on Environment is achieved, because no additional materials are used during its lifetime which could lead to negative impacts on the environment. On the short-term scale, some ecosystems might be killed, but on the long-term the system is able to recover itself. A high score on Side effects is achieved, because due to the nourishment there is no reduction in sediment supply downstream the area of interest, so there will be no down drift erosion. Aesthetically this is a relatively good solution as no additional structures are visible to the human eye which could decrease the naturalness of the coast.

However, this alternative has a bad score on Feasibility, namely on the sub-criteria: Constructability and Availability of the material. This is due to the relatively long time for fine sediment to settle, even if it is protected with fences to ensure a much calmer environment. Also, the coast is very shallow which makes it hard to reach by ship and the pipes to be constructed have a large distance to cover. Finally, the material for the nourishment has to be dredged from a location with the same sediment characteristics as at WnZ and also the borrow pit needs to be far enough from the coastline in order to have minimal impact on the coast itself.

STU with Chenier

For this design the side effects are limited, thus this design scores high on the Side effects criterion. The scour hole development is also assumed to be less than the nourishment design. However, if it is not designed well, there can be downdrift erosion. Also, technical characteristics of this design have a

positive score due to the flexibility and the simplicity of the design. If more sand is needed, a vessel can relatively easy dump sand on the right location (paragraph 6.3). The durability of the design gets a negative score, because the natural process of these sand ridges evolves along and across the coast. The sustainability sub-criterion on the other hand, scores positively because this design tends to mimic the natural sand ridge development at the coast of Suriname. The Reliability of such a sand ridge is low, because more local data and modeling is needed of the coast to predict the transformation of such an artificial sand ridge.

Adapted STU

The adapted STU scores good on the side effects, because the filling material will be optimized such that wave reflection will be minimal and thus less scour holes develop. Since the filling material will be changed from bamboo to a more permeable filling material like brushwood, the durability of this material decreases, and more maintenance will be needed. Due to this, also the feasibility decreases due to the higher maintenance and the less available material. Also, this design scores high on the efficiency, due to the optimization in terms of wave dissipation and sediment inflow. Lastly the reliability scores well, because the features of this design are taken from reference projects which have already shown positive results. Nevertheless, it will be adapted to some extent to the conditions at WnZ.

STU with floating breakwater

The floating concrete breakwater has a high score due to its robustness. It is less vulnerable to human and natural interferences. The two variants with the tires have a relatively lower score than the concrete breakwater. This is due to the negative impact of the tires on the environment. Rubber tire material consists of toxic compounds which leads to a decrease of aquatic life (Stephensen, et al., 2003). Since the lifetime of the intervention with tires is approximately ten years, this could lead to a significant decrease of aquatic life and this should be prevented. A floating breakwater is not feasible for WnZ, due to the large wave length and small water depth (section G.2 of Appendix G for the calculations of the dimensions). Therefore, the floating breakwater scored really low for the Feasibility criterion, namely on the sub-criteria Constructability.

STU with integrated breakwater

The STU with integrated breakwater bamboo has a high score on Simplicity as there is experience in the construction of STUs (given the current situation). Also, it is a flexible solution as the poles and bamboo from the STUs are easy to add and/or remove. Furthermore, it has a high sustainability as bamboo has no negative impact on the ecosystems that are present. The solution is a feasible one as it has been shown that the materials are available and that the STUs are maintainable. The negative part of this design is the weight which is achieved on the criteria Effectiveness and Side effects. Because of the more wave breaking effect, scour holes are predicted to be present. Also, the effectiveness of this design decreases because the sediment inflow can be interrupted or even blocked due to the wave breaking right in front of the structure.

6. PRELIMINARY DESIGNS

In this chapter the three variants: 1) Adapted STU, 2) STU with nourishment and 3) STU with chenier are further worked out into preliminary designs. Simple calculations and estimations of construction costs and time are made. Also, the construction method, limitations and monitoring are mentioned in each design. Furthermore, in every preliminary design the buffer zone and fresh water supply are included, which is explained in paragraph 6.1. Besides the monitoring in every preliminary design, there are some general monitoring aspects which hold for all three preliminary designs. These are mentioned in the final paragraph of this chapter: General monitoring.

6.1 Bufferzone and freshwater supply

The area in between the primary and secondary dike (Figure 2.2) will be reserved to fulfill as the buffer zone. The bufferzone has a brackish environment. During high water, the wave attack ensures a certain amount of overtopping and seepage, which feeds the bufferzone with salt water. This means that this area is frequently flooded and is not meant for certain land use like housing (Deltares, n.d.) The buffer zone also provides a breeding area for different bird species and for mangrove grow.

Freshwater supply is one of the requirements to have a healthy mangrove forest. The sources of fresh water can be a permanent freshwater stream or artificial sand dunes can be used. During the rain season no further measures need to be taken, because the rain homogenizes the salinity in the area.

6.2 Preliminary Design 1: Adapted STU

In this paragraph the first preliminary design, the adapted STU, is elaborated. The design is based on improving the current STUs. Different design aspects of the current STUs have been determined during field observations. Based on literature and more successful reference projects in Indonesia and the Wadden Sea, recommendations are made to improve the current design. This is done by changing the material, the orientation, the dimensions and the openings of the STUs. Furthermore, the construction phases of the STUs are different from the current situation, as this now takes place in different phases. Also, the construction method is given. Next an estimation of the construction time and costs is made. Finally, the limitations of the design are shown, which are taken into account during the monitoring stage.

Material Choice

One of the main observations during the field trip was that lots of the bamboo fill material was washed out as this material was not constraint sufficiently in vertical direction (Figure J.3). Furthermore, stacking up the bamboo in between the walaba poles as fill material will decrease the permeability of the fences which is not favorable. The fence has to be permeable as wave reflection must be limited to eventually prevent scour and prevent hindrance for future mangrove expansion. Therefore, it is advised to use brushwood as fill material instead of bamboo. This will increase the structure's permeability. To vertically constrain the structure horizontal bamboo beams will be used as this material is available in Suriname and the costs/m are low. To connect the horizontal bamboo beam, nylon ropes will be used as they are easier to knot in comparison to steel wires. To prevent the individual brushwood branches from floating out, a net will be used. As the durability of these

materials is not very high regular maintenance is required. An impression of the chosen material and design is shown in Figure 6.1.

Figure 6.1 Impression of design (Source: Dutchwatersector, 2018)

The vertical walaba poles are considered to be a good choice as from field observation it could be concluded that they were still standing in a straight and stable position after all the filling material had been washed out. It is also a good choice based on another MCA analysis, which was conducted by Pultoo (2015). Three different types of wood: 1) basralocus, 2) manbarklak and 3) walaba, were examined. The three types were weighed on four criteria with each a different weighing factor: durability [2], degradation [2], occurrence [1] and price [4]. This analysis showed that walaba scores the highest on almost all criteria. Walaba is a material of durability class 1, highly available in Suriname and is cheaper than the other two wood types. The only disadvantage of walaba is that it is not resistant against attacks by pole worms (Pultoo, 2015). So, for the first preliminary design it is also chosen to use walaba as material for the poles. Furthermore, during the operational phase of the STU it will be monitored on pole worm attack.

Orientation, openings and overview of the STUs

The orientation of the STUs will stay the same as in the current situation (paragraph 2.4). In the original design, the waves attack the structure under an angle. Therefore, the forces of the waves on the structure are less in comparison to the case where the angle of attack is zero. For this reason, the orientation of the structure is left as the original case. Furthermore, the waves that are reflected have less interference with the new incoming waves which is favorable for the prevention of scour holes as there will be less standing waves and therefore less bottom velocities.

Currently, the openings are in the direction of the wind and waves (Figures 2.18, 2.20 and 6.2, left). This is chosen because the waves stir up the sediment and partly take care of the transport of this sediment towards the coast. However, inside the STUs a calm wave condition is needed for the sediment to settle down and therefore the passing through of waves should be prevented as much as possible. It is the tidal inflow that has to take care of the inflow of sediment and not the waves. Therefore, the width of the openings should be chosen in such a way that it is wide enough to still have tidal inflow and small enough to prevent as much as possible the waves from passing through. This depends on the tidal range. In reference projects openings of 5-10 m have been applied for a

tidal range of 1 m (Winterwerp, 2014; Kwelderwerken, 2011). The tidal range in the WnZ area is approximately 1.8 m. Therefore, an opening width of 15 m is chosen as a starting point. Furthermore, the orientation of the opening will deviate from the current situation to prevent waves from passing through. As the tidal currents take care of the sediment inflow and as these tidal currents propagate more perpendicularly towards the coast (chapter 3, hydrodynamics), the opening will look more like the ones that are applied in Indonesia (not tilted, but perpendicular to the fences), see Figure 6.2, right.

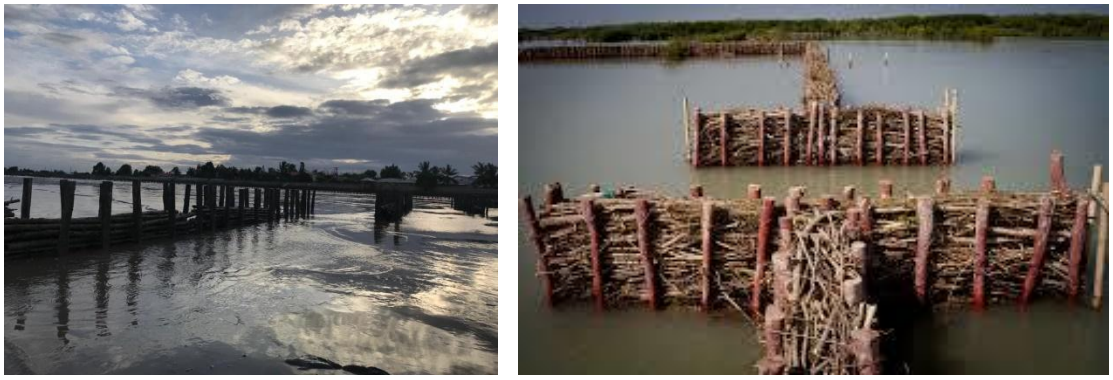

Figure 6.2 Left: Tilted orientation of the STU openings at Weg naar Zee (Source: Çete, 2017); Right: Impression of the STU opening in Indonesia (Source: Nanang Sujana, n.d.)

Behind the opening another fence will be applied which (like the front fence) also has the function to dissipate wave energy. Next to this fence there are two more openings so again water and sediment are able to flow in. When the tidal flow reverses, part of the sediment that has flowed in will flow out and part will stay in the unit. The purpose of the design is that sedimentation takes place inside the STU where a calmer wave climate exists (Figure 6.3).

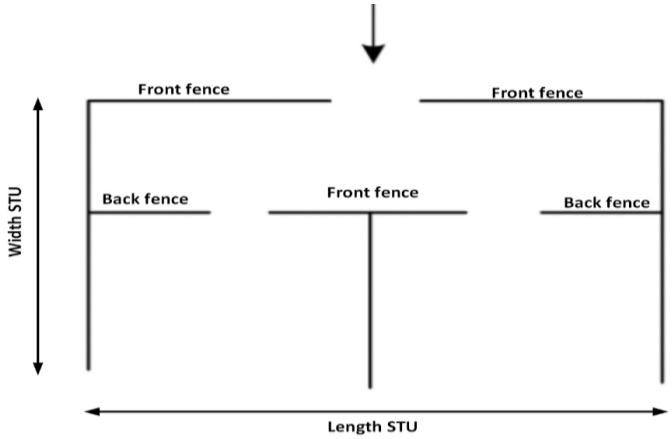

Figure 6.3 Location of the openings one STU (Source: own illustration)

In Figure 6.3 the front & back fences and width & length of one STU are shown. Currently the STUs have lengths and widths in the order of 100-300 m. However, grids of these sizes turn out to be too large due to internal wave set-up (Dijkema et al., 2011). Reference projects have lengths and widths of the STUs of approximately 100 x 100 meters (Winterwerp, 2014; Kwelderwerken, 2011). These numbers are good to have an order of magnitude for the starting point of the determination of the dimension of one STU. Since the hydrodynamic and morphodynamic conditions deviate from the reference cases and the performance (bed elevation per unit of time) is dependent on the dimensions, monitoring is an important part in the operational stage of the STUs.

Furthermore, one of the requirements is that the width of the mangrove forest is 450m and therefore the STUs will be constructed until this width is reached. An overview of the dimensions is shown in Figure 6.8. Note that the STUs will be constructed in phases. In Figure 6.4, the current situation is shown. Every next phase starts when the required sedimentation of 0.6 m is reached. The phases are shown in Figures 6.5-6.8. In Figure 6.8, it can be seen that the number of STUs is equal to 37. The length and the width of each STU is approximately 100 x 100 m. Some of the walaba poles of the current STUs will stay in place to decrease the costs. Furthermore, openings are placed on the east side of the STUs as the longshore currents (which transport sediment) travel from east to west.

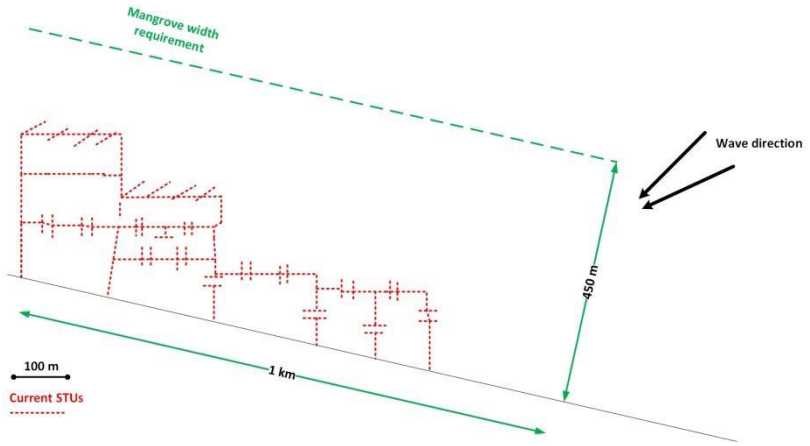

Figure 6.4 Current situation STUs (Source: own illustration)

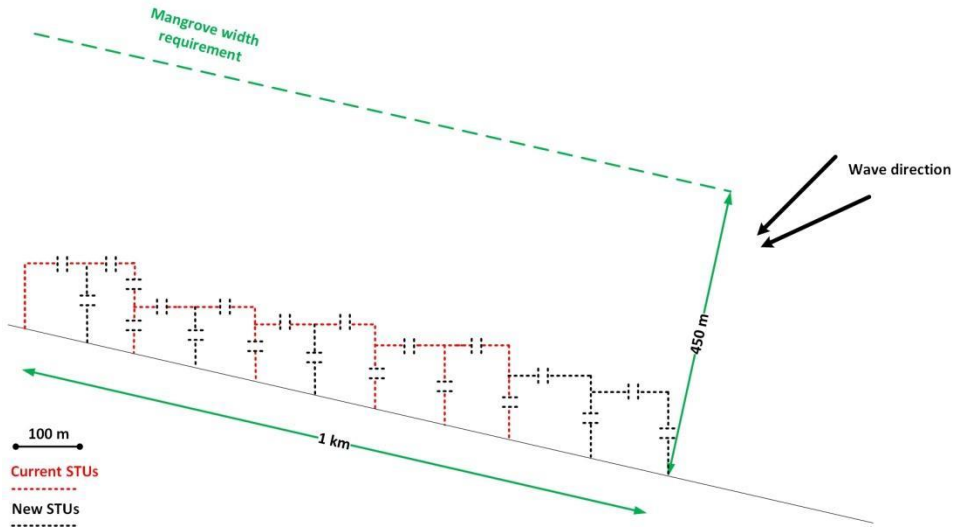

Figure 6.5 Phase 0 of construction STUs (Source: own illustration)

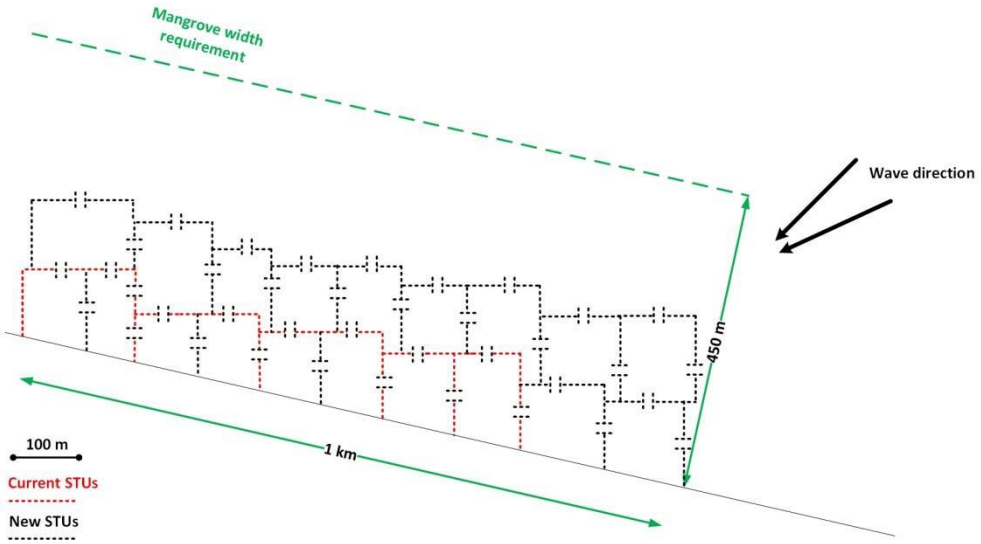

Figure 6.6 Phase 1 of construction STUs after required sedimentation in phase 0 is reached (Source: own illustration)

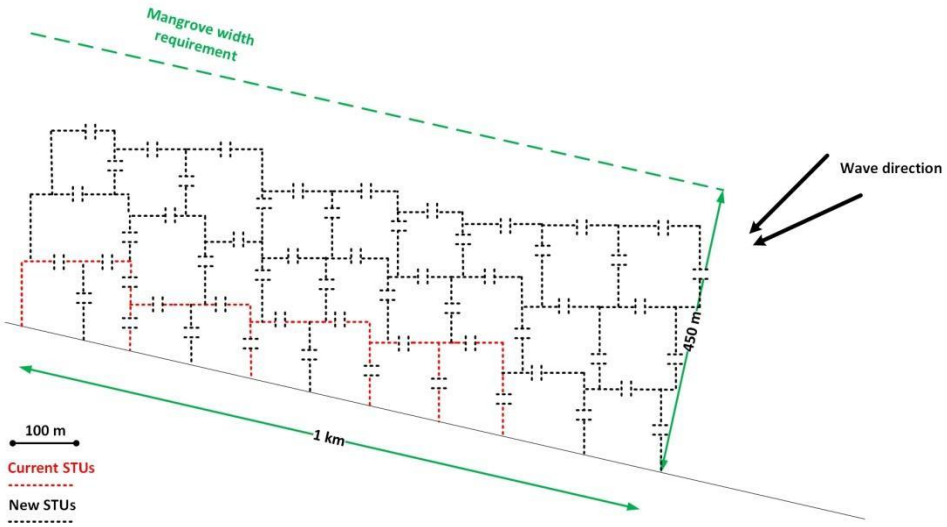

Figure 6.7 Phase 2 of construction STUs after required sedimentation in phase 1 is reached (Source: own illustration)

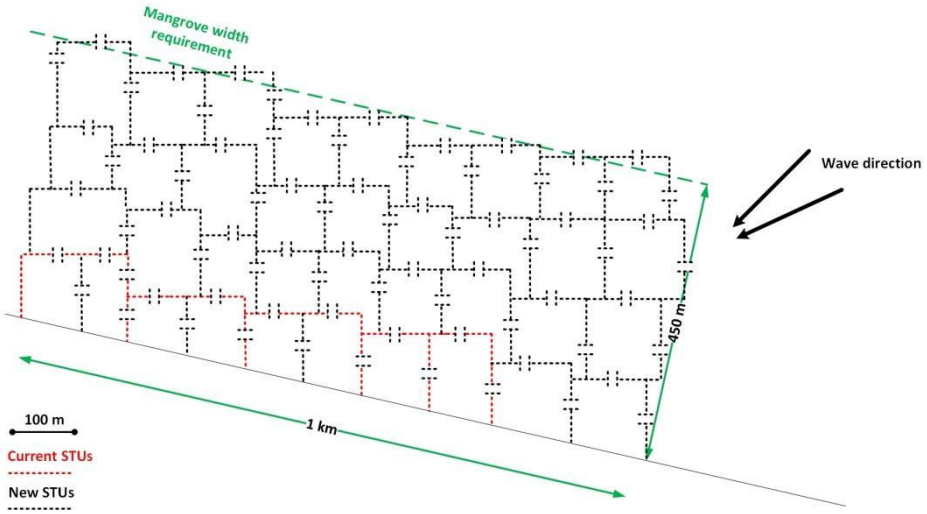

Figure 6.8 Final phase after required sedimentation in phase 2 is reached (Source: own illustration)

Pole height and filling material

An estimation of the pole height and the height of the brushwood filling material is based on the following:

- The required sedimentation is 0.6 m (chapter 4).
- Sedimentation can take place until ¾ of the height of the fill material (chapter 4).
- The length of the pole is ⅓ L above the dense mud layer and ⅔ L in the dense mud layer to ensure stability (chapter 4).
- The soft mud layer is around 0.5 m (chapter 3).
- As the permeable structures are less effective in dissipating wave energy when they are submerged (Mai, 1999), the level of the brushwood filling should be at least HWL + the amplitude of the daily waves (0.6+0.15 m in total).

This means that above the dense mud layer, the height of the poles and brushwood material should be 0.5 + 0.85 = 1.35 m. The height inside the dense mud layer is twice as large, which is therefore 2.70 m. So, the total height is 4 m (for the poles only). To be able to constrain the filling material in vertical direction, there should be a difference in height level between the poles and filling material. Therefore, the poles will be 0.5 m higher than the brushwood filling material and therefore a total pole height of 3·1.35 + 0.5 = 4.55 m is needed. Furthermore, the chosen height of the brushwood filling material allows for the required sedimentation of 0.6 m, as the STUs can be filled until ¾ of the 0.85 m height, which is 0.64 m. Since in current practice the distance between the poles is equal to 0.75 meters, this will be used as a first estimate. The same holds for the distance between the poles in the direction of the flow, which is 0.65 meters. An overview of the dimensions is shown in Figure 6.9. Note that in reality the brushwood filling material is porous and has irregular shapes, which is not represented well in this figure.

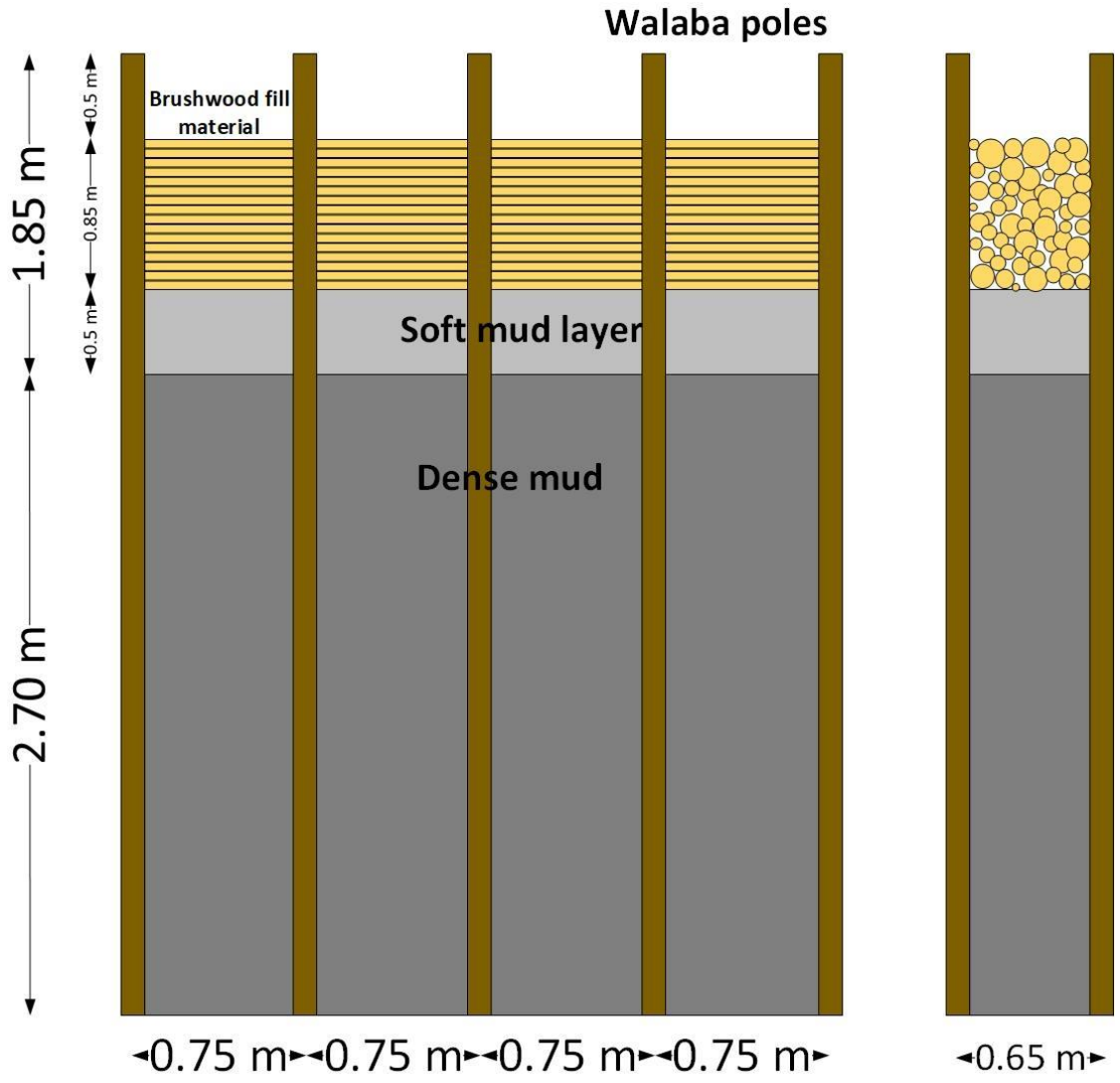

Figure 6.9 Height of poles and brushwood material and distance between the poles, front of structure and cross section respectively (Source: own illustration)

Construction Method and Time

The STUs will be constructed in four phases. The reason that the STUs are constructed in phases is that this is more efficient to trap sediment compared to building all the STUs at once. Once the bed level in the STUs has increased with 0.6 m, the next row of STUs can be constructed. The construction phases are shown in Figure 6.4-6.8.

The current situation is shown in Figure 6.4. The STUs that are not part of the first row (along the coast) will be removed. This material will be used to split the current STUs that are part of the first row (along the coast). Next, new STUs will be constructed until the 1 km distance along the coast is achieved. This part of the construction is called phase 0 and is shown in Figure 6.5. Once one row is constructed and the required sedimentation is reached, the construction of the next row can start. This process continues until the fourth row of STUs is constructed. Phases 1, 2 and 3 are shown in Figures 6.6-6.8.

The construction will take place during ebb which is two times, for 6 hours every day (construction will also take place during night, so lights will be provided). However, only two times of 4 hours will be used, as during the first and last hour of the ebb period, the water level relative to the bottom is not equal to zero.

The assumptions made for the construction method are based on interviews and conversations with local constructors. The construction will take place as follows: the walaba poles of the STUs will be placed first, after which the brushwood filling material is placed, closed off with the horizontal bamboo beams that will be connected to the walaba poles with nylon ropes. An excavator with a pontoon is needed. The excavator has one controller. There are two persons on the pontoon who place the walaba pole on the bucket of the excavator. In the mud there are two persons who keep the poles in a straight line. Furthermore, there is one person who is in charge of leading this process. The placement of one pole into the soil takes about 30-50 seconds. An average of 40 seconds will be used. In the meanwhile, more walaba poles are brought from land to sea using an airboat. See Figure 6.10 and 6.11.

During the placement of the walaba poles, the brushwood filling material can be prepared by placing it into the nets on the dry land. To increase efficiency, the brushwood filling material can be placed in between the walaba poles that have been placed already. When the filling material is placed, this has to be closed off immediately to prevent uplifting. For this job, six working men are needed. This will be done by using manpower, see Figure 6.12.

Figure 6.10 Airboat and excavator at the coast of Weg naar Zee (Source: Naipal, 2015)

Figure 6.11 Slamming the walaba poles into the soil (Source: Naipal, 2015)

Figure 6.12 Placing the filling material between the walaba poles (Source: Naipal, 2015)

Assuming that around 5000 poles have to be slammed into the soil in every phase (with the placement of one pole taking 40 seconds) and knowing that 8 hours each day are available for construction, an estimation of the construction time can be made. It has to be taken into account that not the full 8 hours can be used for the placement of the poles, as preparation, transport of the poles, change of shifts, cleaning up etc. also need to happen in this period. Therefore, it is assumed that only 4 of the 8 hours can be used efficiently each day for slamming the poles into the ground. So, in the first phase, the placement of the poles will take 14 days.

The placement of the filling material and closing it off immediately will take up more time than slamming the poles into the soil. Every 0.75 m, two walaba poles are present. Assuming that filling up and closing off the permeable fences over this distance will take 10 minutes, the total construction time is equal to 106 days. To finish the construction of Phase 1 within a month, the efficiency has to be increased. Therefore, four groups will be working on this aspect, which decreases the construction time to 27 days. Assuming that this process can start 1 day after the start of the placement of the walaba poles, the total construction time of Phase 1 is 28 days. Once the STUs of Phase 1 are built, the bed level change has to be monitored. If the required bed elevation of 0.6 m is reached, the construction of the second phase can start. From results of the pilot project at Weg naar Zee, bed level elevation of 0.5 m has been realized within a time frame of 2 months. (Naipal et al., 2014). This number is used to have an indication of the total time it takes for the realization of the design. It has to be noted that the next construction phase will only take place if the required sedimentation is actually reached. For Phase 0, 2 and 3 the same method has been applied as Phase 1. In Phase 0, less time is needed as the STUs that are already present in the first row along the coast, will stay in place. The Gantt Chart of the construction is shown in Figure 6.13. The total time for the realization of the STUs is 287 days. The calculation of the total construction time can be found in Appendix H.

It is recommended to start the construction right before the arrival of a mudbank. This way sedimentation is more easily achieved, as the sediment availability is large. Furthermore, the presence of a mudbank creates a calmer wave climate, and therefore sediment is able to settle more

easily. The prediction of a mudbank arrival is further explained in the section Recommendations (chapter 8).

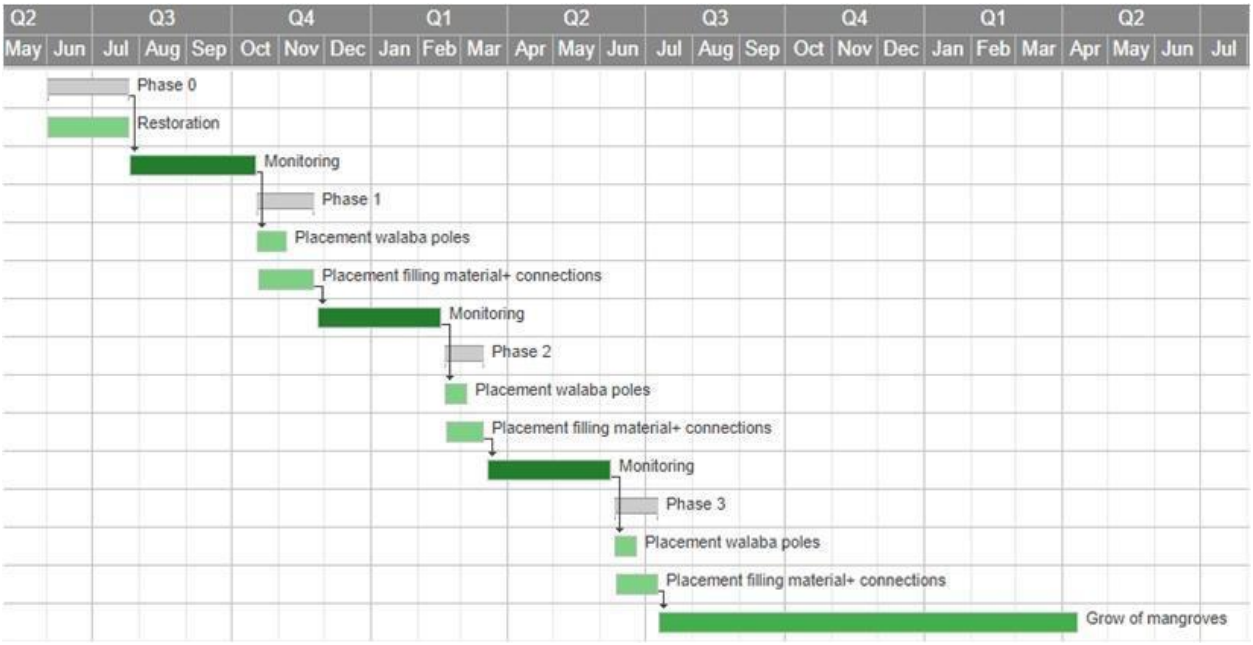

Figure 6.13 Gantt Chart of the construction for Preliminary design 1 (Source: own illustration)

Limitations

In this section the limitations of the first preliminary design are mentioned. How to deal with these limitations is elaborated in the next section, Monitoring. The first preliminary design has some adaptations from the current situation, which is based on the analysis of past failures.

In the design of the permeable fences horizontal bamboo beams are used to prevent the bamboo filling material from uplifting. These bamboo beams are connected to the walaba poles by nylon ropes. It is difficult to determine upfront whether these joints are sufficient for the transfer of the loads from the bamboo beams to the walaba poles and therefore it is uncertain to say whether the structure provides enough resistance against uplifting.

Next the length and width of the STUs and the width of the openings have been determined based on reference cases. However, the situation at Weg naar Zee deviates from the reference cases in Indonesia and the Wadden Sea as the hydro- and morphodynamics are different. Therefore, at WnZ these dimensions may not be ideal.

Furthermore, the durability of the materials that are used is not high. Therefore, regular maintenance is required. Also, the attack of pole worms is possible, which would even require more regular maintenance. And even though the structure in the new design is more permeable, scour holes in front of the structure are still likely to occur.

Monitoring

Based on the limitations, aspects that have to be monitored are determined. Aside from general monitoring for this specific preliminary design, there are some additional monitoring aspects. For every aspect that has to be monitored, options are given to apply in case of design failure.

First of all, scour holes are likely to appear due to reflection. Therefore, it has to be inspected. This can simply be done by visual inspection, since the coast is dry during ebb. If from this inspection it can be concluded that large scour holes do appear, they have to be filled up again. The reason for this is that scour holes can lead to instability of the structure and to hindrance of future mangrove expansion. A bed protection is not chosen as it limits the sediment inflow and is difficult to apply on the soft mud layer.

Since walaba poles are sensitive to the attack of pole worms, this should be monitored as well through visual inspection. If the attack is minimum, the poles can simply be replaced by new ones. When severe attack appears, other options have to be considered. Other materials do not score as well on material properties as walaba poles (Material Choice section, above). However, if the design is different (e.g. more material, different structure), the structure might provide enough resistance, so this could be an option. Another option is to increase the level of silicic acid in the poles, as the attack of pole worms is dependent on this (Pultoo, 2015).

Uplifting of the bamboo filling material was one of the main problems at Weg naar Zee. To prevent this, horizontal bamboo beams are connected to the vertical walaba poles with nylon ropes. The effectiveness of these connections is uncertain and therefore this should be monitored as well. This can be done by visual inspection. If the connections fail due to uplifting, other connections have to be considered such as stainless screws.

Since the length and width of the STUs are determined based on reference cases, the performance of the different STUs (different lengths and widths) has to be monitored as well. This performance is based on the bed level elevation per unit of time. When certain dimensions perform better than others, these can be used in a later stage when more STUs are built. The same holds for the width of the openings of the STUs. It has to be monitored whether the openings are stable enough. If for the same length and width of the STUs, certain opening widths perform better than others, these can also be used in a later stage.

Cost Estimation

In total, around 4700 meters of new fence needs to be constructed and 2700 meters of already existing fence need to be restored. For restoring the existing STUs, the main task is to place new filling material until the required height with the right connections is reached. In the cost estimation (Table H.4, Appendix H) only the construction costs are taken into account. So, the monitoring and maintenance costs are excluded. The survey results at WnZ have shown that twelve people from the local community are willing to volunteer in the construction and monitoring phase (Appendix E.3). So, this is also extracted from the costs. It is assumed that these people are willing to work for 30% of the total construction time. For the cost estimation, digital sources and professor S. Naipal have been consulted. The cost overview is given in Appendix H. The total construction costs amount to €116000,-
.

6.3 Preliminary Design 2: Nourishment

This paragraph describes preliminary design 2. This design consists of a nourishment inside the STUs. Also, for this design the adapted STUs, elaborated in preliminary design 1, are applied. It is explained how the nourishment will be executed, where the borrow pit will be located and how much sediment will be needed to obtain the required bed level. Also, the suitable equipment is chosen, the costs are estimated and finally the limitations and monitoring are described.

Execution method

For this design, it is chosen to place a nourishment in front of the coast, because this is more effective than an offshore nourishment. An offshore nourishment needs more time for the sediment to reach the coast and so it will take more time before the right conditions are created for the mangroves to rehabilitate. Offshore nourishment will also result in more sediment transport in offshore direction. Another decision that needs to be taken, is the placement of the nourishment. This will be placed on the full stretch of the coastline and not in the form of a peninsula. This is chosen, since the STUs will be built in several phases, which will start from the landside. This will provide more area for mangrove rehabilitation (Julianus, 2016).

In this design, the main goal is to keep the nourished sediment in place and therefore the nourishment will be placed inside the adapted STUs. This will ensure that less sediment is possible to flow out and also calmer conditions are created for the sediment to settle and mangroves to grow.

The nourishment will be executed in different phases on a smaller scale. Also, every STU will be nourished in several steps. This is done to increase the settling time of the particles, as less particles will decrease the hindered settling. After several attempts, more knowledge is gained, and the optimum repetition can be found by weighing the settling time against the costs.

In the first phase of the process, the first row of STUs (closest to the shore) will be repaired or build, and a nourishment is placed inside the STUs. Then the sediment needs time to redistribute and settle until a stable bed profile is obtained. After the profile is stabilized a new nourishment will be placed inside the STU. After the bed in the STU has reached the required level, the next phase can be started. In Figure 6.14-6.17, the four construction phases are shown.

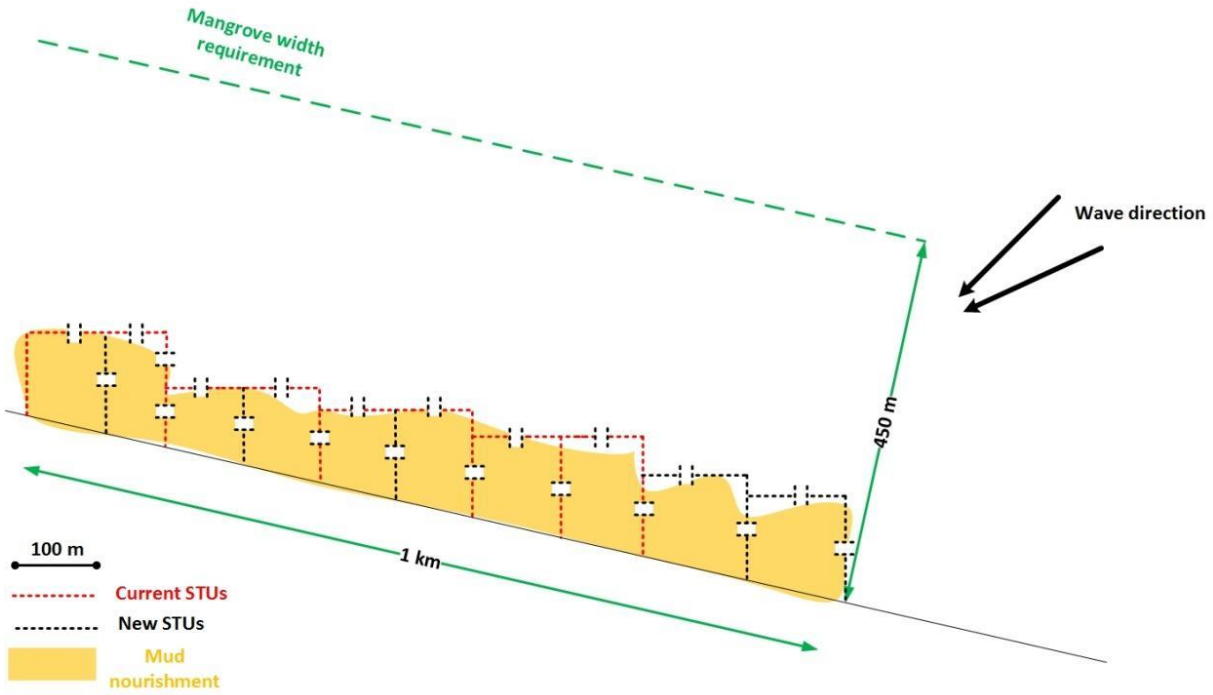

Figure 6.14 Phase 0 (Source: own illustration)

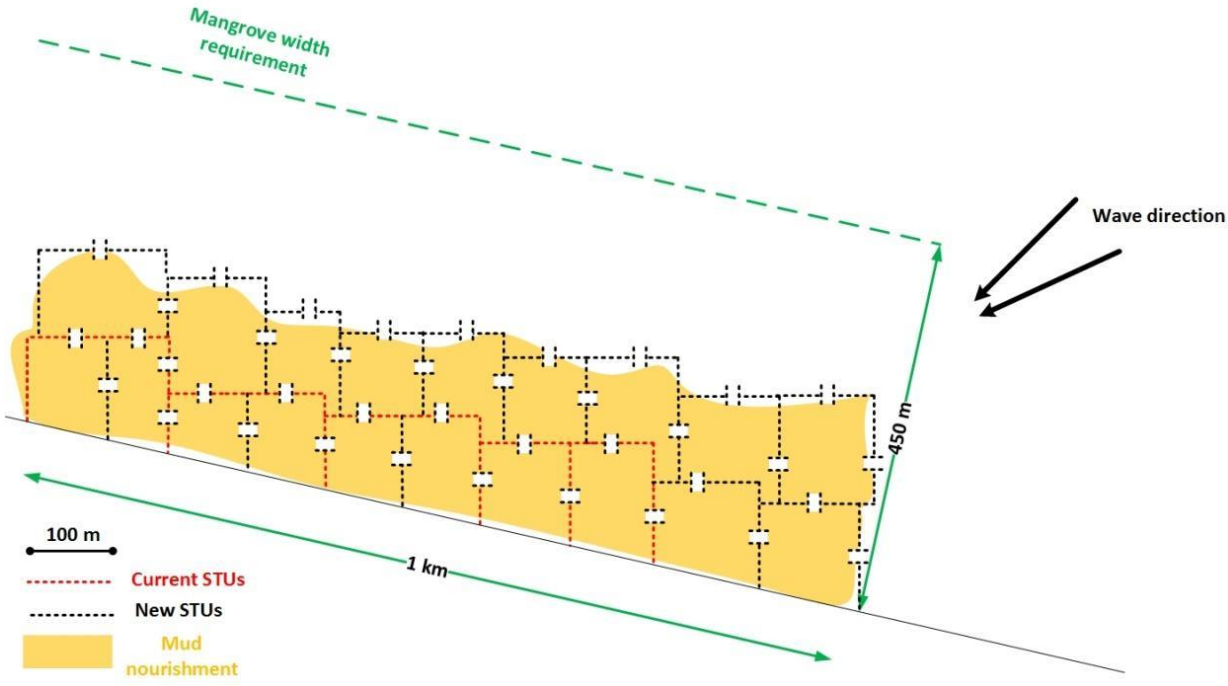

Figure 6.15 Phase 1 (Source: own illustration)

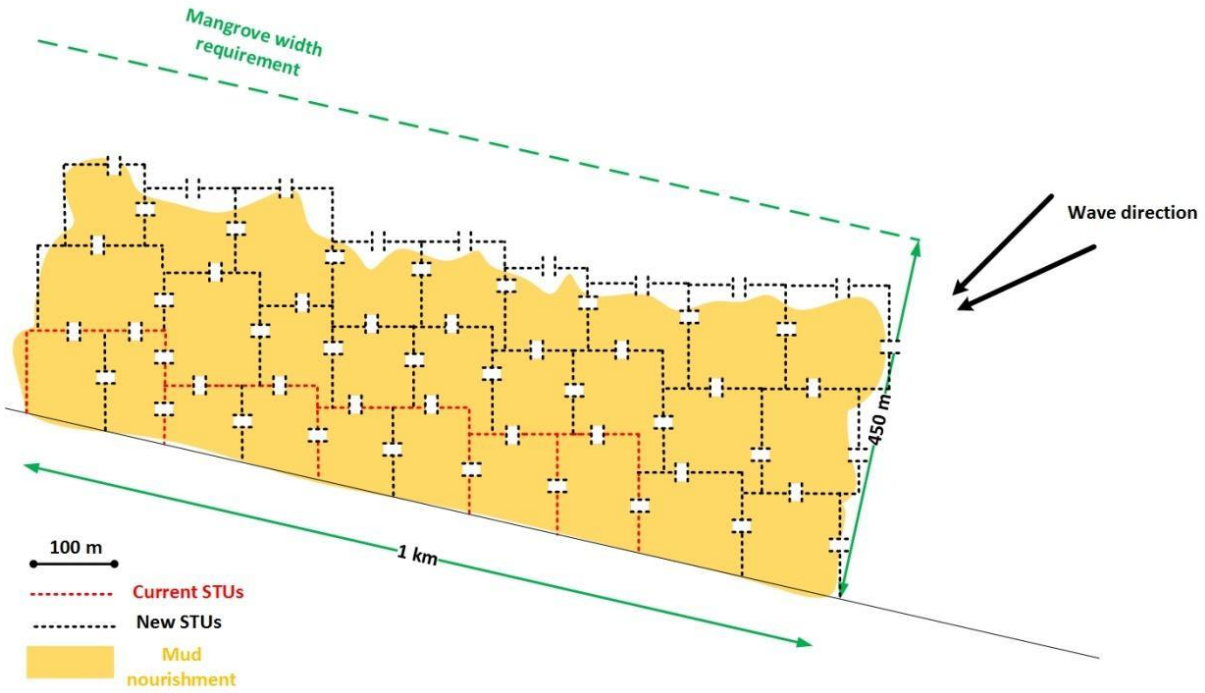

Figure 6.16 Phase 2 (Source: own illustration)

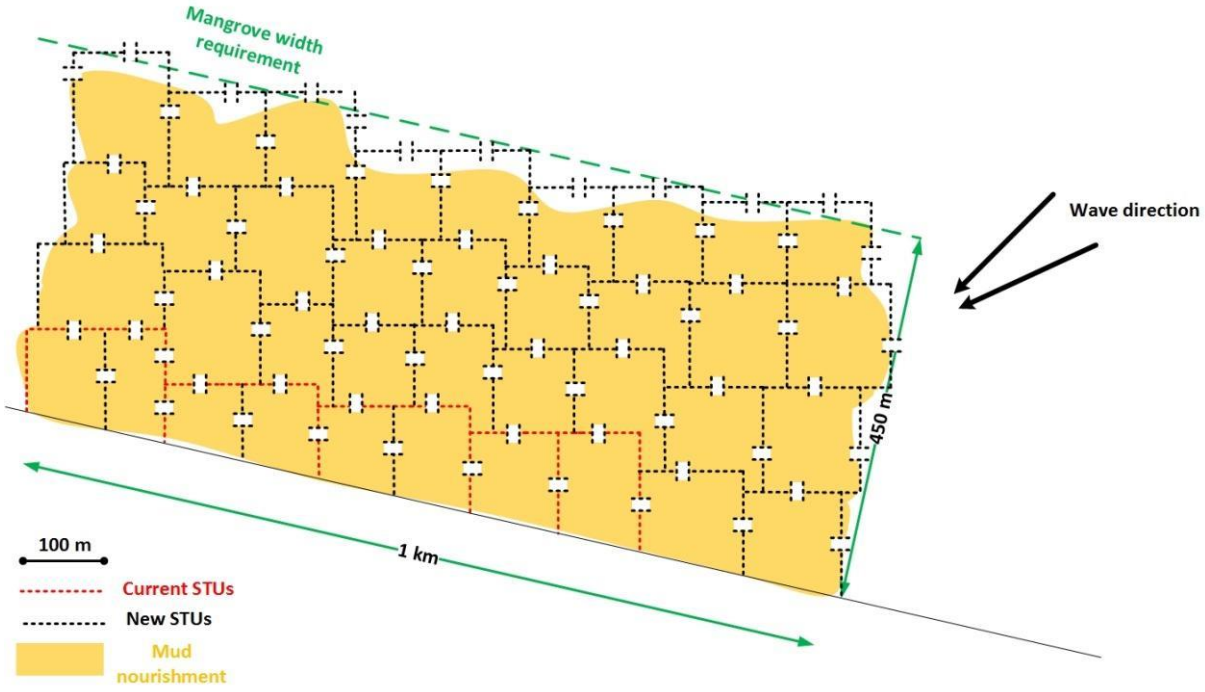

Figure 6.17 Phase 3 (Source: own illustration)

Nourishment volume

To determine the volume of sediment needed for the land reclamation, the following three assumptions are made:

1. The bathymetry in cross-sectional direction is simplified (Figure 6.18).
2. Parallel depth contours are assumed to be perpendicular to the coast.
3. A sediment loss of 20% is assumed.

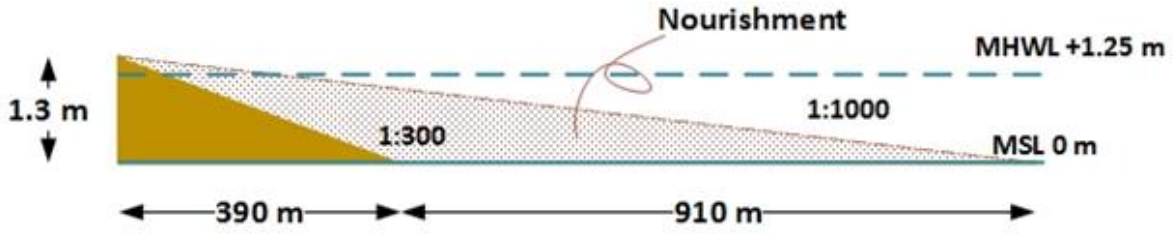

Figure 6.18 Simplified cross-sectional area of the bathymetry at WnZ and the required nourishment area (Source: own illustration)

The necessary nourishment volume based on the geometrical calculations is around 591500 m^3. Including the losses, the total volume is 710000 m^3.

Period of nourishment

During the nourishment operations, a calm environment is required. After the settlement, the mud still needs time to consolidate by its own weight. This can be achieved more easily during the period between June until September, in which mild wave conditions hold. This period also contains the main dry season in Suriname, in which the evaporation rate is the highest and the rainfall is low. This increases the crust forming of the mud nourishment.

Borrow pit

The following theory is obtained from the master thesis on mud nourishments in Demak by Julianus (2016). This theory is applied for the coast at the WnZ region. It is known how to choose the location of the borrow pit for sandy coasts. For this type of coast there is a transition between the shelf and the shore face. This transition, called the depth of closure, is where the waves start feeling the bottom, which makes them capable of transporting sediment. Beyond the point of the depth of closure, dredging activities can take place. However, for mud coasts there is no depth of closure and therefore the dredging location is approached in a different way. The reaction of the mud coast system is still unknown. Still, through elaborations, a dredging location can be chosen which will be explained in this paragraph.

First of all, the borrow pit location is site specific. The WnZ coast contains plenty of fine sediments. Therefore, the borrow pit can be considered as a relocation of fine sediments. This relocation reduces the time for the sediment transport to the coast. Secondly, the borrow pit could negatively influence the sediment household of the coast since it can be filled up by cross-shore sediment transport. If this is the case, it is better to move the borrow pit further offshore. However, if the borrowed pit is filled up by longshore sediment transport it has minimal influence on the sediment household of the coast. Therefore, the borrow pit location can be closer to the coast. But since sediment transport in cross-shore direction is dominant at the WnZ coast, this effect will not be taken into account.

The dredging and transportation of the fine sediments has to be performed by local equipment. It is advised that the nourishment area stays within a range of 4 km. This distance is based on the assurance of transport and reachable bottom depth by the local equipment in Demak. However, this distance may deviate for the WnZ coast. Assuming that at least a draft of 2m is needed for the local equipment and based on the bathymetry, a range estimation is made equal to 4.3km.

Besides the sediment household and local equipment, the cost-benefit ratio is an important factor that influences the location choice of the borrow pit. This is important to avoid unfavorable high costs. Furthermore, the sediment properties at the location of the borrow area should be similar to the properties at the nourishment location (Julianus, 2016).

Equipment

First, the sediment needs to be dredged from the borrow pit. Based on the available draft at the borrow pit of 2m, the most suitable dredging equipment will be chosen. The Cutter Suction Dredger (CSD) has available drafts which are smaller than 2m and applicable for every soil type, but can only work in an environment with wave heights around 0.2-0.5 m (Van Damme, 2018). Based on these properties, the CSD is suitable for dredging. To reduce the transport distance, the CSD from Watermaster with a minimum draft of 0.6 m can be used. This amphibious multipurpose dredger is especially designed for shallow waterways. An example of the CSD is shown in Figure 6.19.

Figure 6.19 Cutter Suction Hopper Dredger (Source: Watermaster, n.d.)

The CSD has a cutting mechanism at the inlet of the suction tube. This mechanism loosens the bed and the material is sucked up by a pump. The material is transported to the STUs by pipeline. As the water depth near the STUs is very small, it is more efficient to use hydraulic filling by a pipeline. The CSD from Watermaster has a maximum pumping distance of 1.5 km. If the pumping distance is too large, a floating booster station can be used which increases the pump capacity. To avoid mud segregation, the mud must be pumped in the lower part of the water column.

The CSD is a multipurpose dredger and can also be used for the piling of the walaba poles. For this the Piling bucket for wooden piles can be used. The dredger is amphibious and can work on the soft mud layer with its spuds in the harder clay layer (Figure 6.20). Another purpose for which this dredger can be used, is the cleaning of the channel (Figure 6.21). This will again give room for the river and will improve the aquatic life in the channels.

Figure 6.20 The watermaster on soft soil (Source: Watemaster, n.d.)

Figure 6.21 Cleaning of a channel with the amphibious vehicle of Watermaster (Source: Watemaster, n.d.)

Execution time

In Figure 6.22 an estimation is shown of the total construction time, it will take three summers to complete the total process. If the construction is completed, the mangroves can rehabilitate.

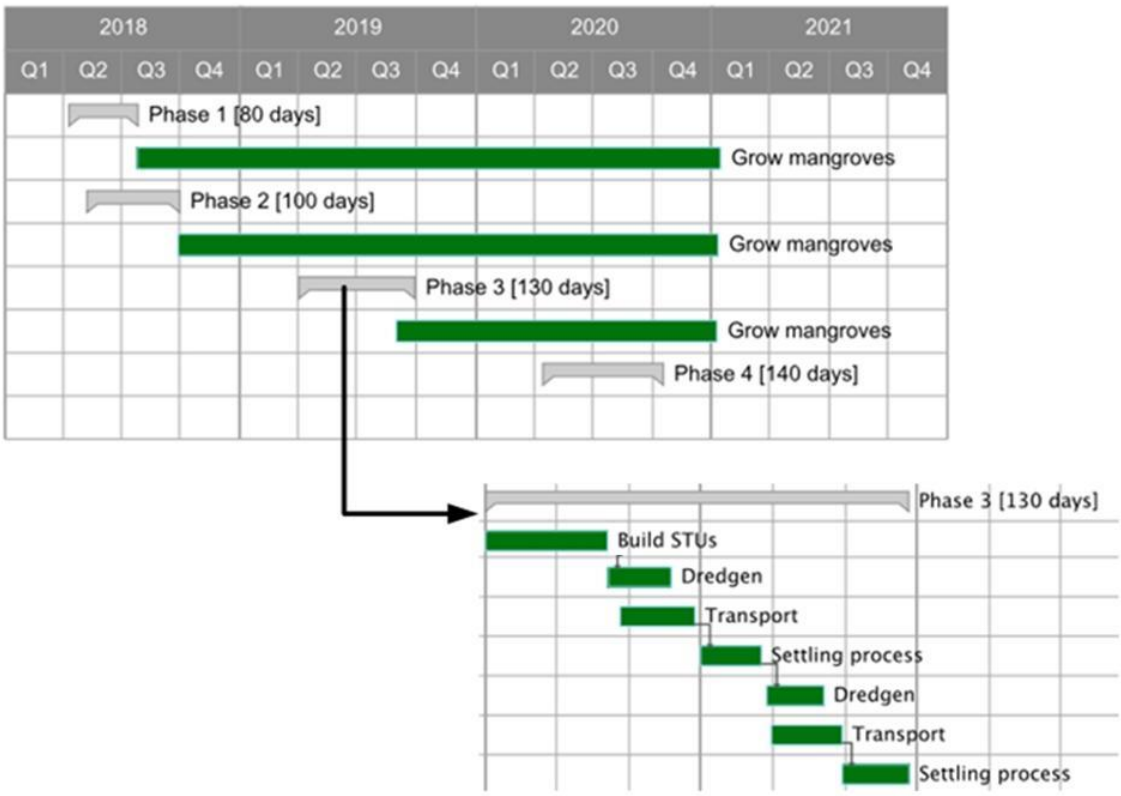

Figure 6.22 Gantt Chart of the construction for Preliminary design 2 (Source: own illustration)

If a net sediment discharge capacity of 300 m^3/h is assumed, the total nourishment volume of 710000 m^3 can be dredged in 2400 hours. Taking into account that the workability can never be 100%, 90% is assumed. This will result in an estimated total dredging time of 2700 hours. A week will have 75 working hours. This means 15 hours a day, in two different shifts. Since the nourishment will be executed in four phases, the amount of nourishment in each phase will be estimated based on the depth profile: first phase 10%, second phase 20%, third phase 40% and the last phase 30%. To fasten the process, more CSD's can be used during the third and fourth phase of the project.

Cost estimation

For the execution of the design, a cost estimation is made. The main cost drivers in this process are the equipment and materials to be used. An overview of the estimated costs is given in Table 6.1.

	Costs
Cutter Suction Dredger (CSD)	€4 500 000,- [1]
Transport (pipeline)	€1 500 000,-
Building of the STUs	€116 000,-
Total costs	**€6 116 000,-**

Table 6.1 Cost estimation for preliminary design 2

[1] For a CSD with a capacity of 300 m^3 /hr, the costs are estimated to be 100 000 €/week (Van Oord.,n.d.)

Limitations

The increase of suspended mud in the water at the nourishment site can lead to disturbances to the aquatic ecosystem. This can be reduced by decreasing the pumping rate, which leads to less turbulence behind the pipe outlet (see next section: Monitoring).

Also, the time scale of the settling and consolidation process of mud can be in the order of days to weeks (van Rijn, 2015). Furthermore, the particles return into suspension fast in the presence of turbulence and will increase the construction time (settling and consolidation time will increase).

Monitoring

Specific monitoring for this nourishment design is needed, next to the general monitoring aspects which will be explained at the end of this chapter. The monitoring is for the most part due to the limitations that rise with the design (see earlier section: Limitations).

Since mud is used for the land reclamation, it is important to make sure that there is as little turbulence present in the STU. By measuring the velocity, turbulence and mud concentration in the water column, the pumping rate can be adjusted. Decreasing this leads to a decrease of the velocity and turbulence in the STUs.

Also, the properties and thickness of the formed layer must be measured over time to know whether the required sedimentation level will be reached within the predicted lifetime of approximately three years (see section: Construction method). If this is not the case, the consolidation process of mud can be accelerated by placing a thin layer of sand on top of the clay layer (van Rijn, 2015).

6.4 Preliminary design 3: STU with chenier

In this section, the STU with chenier is elaborated. First, estimates are made for the location, dimensions and sediment characteristics of the chenier. Thereafter, the construction method, cost estimation, expected development in time and limitations of the chenier are described. Finally, the monitoring and recommendations for a model are given.

Location

The placement of artificial cheniers can take over the function of the mudbank. They partly break the waves and thus help against erosion. Cheniers also increase the sedimentation in the STUs, because it decreases the offshore sediment flow (Julianus, 2016). The location of the chenier is based on the following aspects, namely the effect of the chenier on the wave climate, the bathymetry and the generation of return currents. The effectiveness is important, as placing the chenier too far will lead to less wave breaking and placing it too close will cause a too mild wave climate where no sediment is stirred up. An optimum location needs to be found so the sediment is stirred up and transported inside the STUs. From modelling studies, done by Julianus (2016), it was observed that the introduction of a chenier leads to smaller shear stresses behind the chenier up to 1 km. After 1 km, wind waves will be generated and the shear stress increases again. So, the chenier must be placed more than 1 km from the shore to have sediment import in the STUs.

Also, the bathymetry of the coast needs to be taken into account for the determination of the location. As the coast has a very gentle slope, the bed is above MSL in the first 1.5 km from the coast. The crest of the cheniers are naturally at MSL, therefore it is chosen to place the chenier at a distance of 2 km from the shore.

Not only the sediment inflow needs to be checked but also the size of the return currents which take sediment offshore, must be analyzed. For emerged structures, waves break on the structure which drives a current pattern. Between two emerged breakwaters the current is seaward directed and can transport a lot of sediment offshore, which counteracts the accretion process. The current increases when the distance from the breakwater to the shore becomes smaller (Bosboom et al., 2015). To find the optimal location for the cheniers, which leads to the highest accretion rate in the STUs, modelling studies need to be executed. A Delft3D model can be made, where different locations from the shore will be modelled. The model to be made is further elaborated in the recommendations at the end of this section.

Dimensions

The dimensions of the chenier are very important, therefore further modelling needs to be done. Since the cheniers are naturally present in front of the coast of Suriname, the dimensions of the artificial chenier will be chosen in the same order of magnitude as the natural cheniers. As the natural cheniers in front of the coast are between 10-600 m, a width of 200 m is chosen.

The length to distance relation (development of a salient) is used to determine the length of the chenier: $0.5 < L/Ds < 1.3$ (Bosboom et al., 2015). So, with a distance of 2 km from the shore a minimum chenier length of 1 km is required. Lee side erosion/ west side of the pilgrimage can be a side effect of placing a breakwater. However, the chenier is placed relatively further away from the coast then the conventional breakwater. Thus, the lee side erosion is not expected to be severe.

The height of the crest of the chenier must not be too high, otherwise there will be no waves left which are important to bring the sediment onshore. If it is too low, the wave breaking effect will not be enough. From modelling studies (Visser, 2017) it has resulted that a low nourishment with a long alongshore length give the best results to counteract coastal erosion. So, the crest of the chenier will be placed around mean sea level. This is comparable to the natural cheniers. From the bathymetry follows that the chenier will have a height of 1 m.

Sediment characteristics

At Weg naar Zee the natural cheniers consist of medium to coarse sand originated from the Marowijne river and the coast of French Guiana. To imitate the natural behavior of the coastal plain, the artificial cheniers will be made of the same composition as the natural cheniers, so medium to coarse sand. To check what the optimal grain size is for the development of the cheniers modelling needs to be done. This is further elaborated in the recommendations.

Expected development in time

The longshore current also transports coarse sediment from the Amazone- and the Marowijne river. In time the chenier will move westward due to the alongshore current. Also, the presence of the mudbanks will affect the propagation of the cheniers. If a mudbank is present on the westside of the

chenier, the sediment supply is blocked and the chenier will decrease in height and sediment will be washed over the chenier to the landward side. So, if the natural supply is not sufficient there needs to be a constant artificial supply of sediment until the STUs are filled with sediment. Besides propagation in the westward direction, the chenier also propagates towards the shore due to the incoming waves and tidal propagation.

Construction method

A possible location for the sand pit is upstream of the Surinam river, which is around 50 km from the construction place. Sand will be taken from the pit and transported to the construction place by a barge. This barge is limited by its draft. Therefore, it is needed to transport the sediment from the barge via a pipeline to the chenier. The required volume of sand for the construction of the chenier is around 100000 m^3. If a barge with a capacity of 1000 m^3 and a required draft of 3 m is used, the barge needs to be filled 100 times. The barge can unload during high water at a distance of 4 km from the shore. This means that the pumping distance equals 2 km. Furthermore, a booster station is needed for such a large pumping distance, this is located halfway of the length of the pipeline. In Figure 6.23, the vessel and pipeline are shown with corresponding distances relative to the coast.

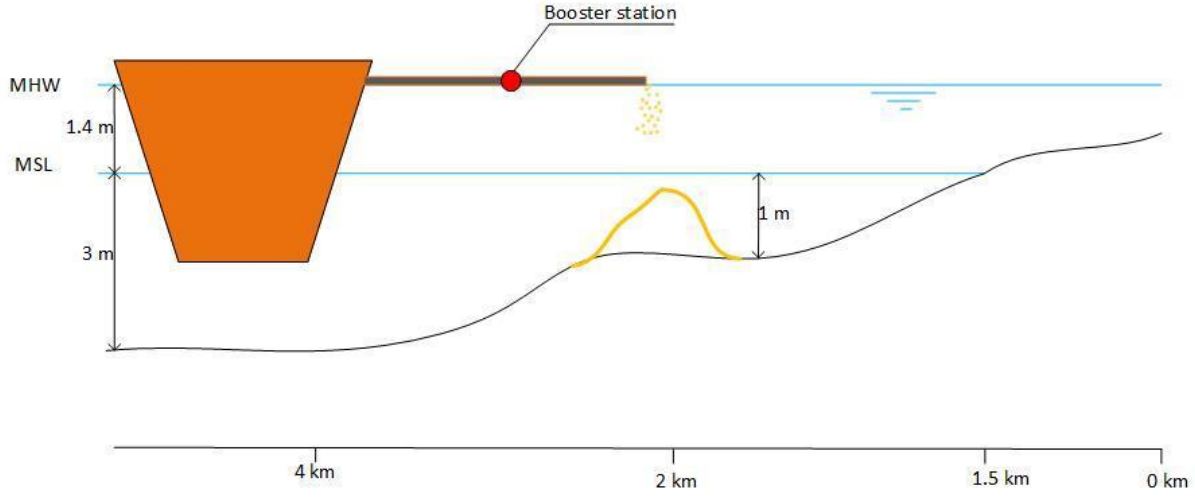

Figure 6.23 Construction method, placing of the chenier (Source: own illustration)

In order to calculate the construction time, first the cycle time needs to be estimated. The cycle time consists of the following four components: 1) loading time, 2) sailing time with full load, 3) unloading time and 4) sailing time without load.

The barges have a sailing speed of around 50 km/h when unloaded, this means that the unloaded sailing of the vessel will take 1 hour. The loaded sailing speed will be around 35 km/h, therefore the loaded sailing will take around 1.5 hour.

To estimate the unloading time of the barge a pumping capacity must be assumed. With a distance of 2 km a booster station after 1 km of the pipeline is required to increase the pumping capacity. For a pumping distance of 1 km a pumping capacity of 200 m^3/h is assumed (Dredging pumps, n.d.). From this follows that it will take 5 hours to unload one barge, this falls inside the duration of the high tide, as the barge is limited by its draft. During low tide, the barge sails back and loads the sediment. For the loading of the barge hydraulic excavators with a working capacity of 58 m^3/h will be used. To

decrease the loading time four excavators will be used. This results in a total loading time of 4.5 hours for one barge (Bulk excavation, 2018). Dependent on the borrow pit, the excavators will load from land or on a pontoon from the water.

Summing up the four components results in a total cycle time of 12 hours. The total cycle time is shown in Figure 6.24. To minimize the construction time two barges will work simultaneous and the barges will be unloaded twice a day during high tide. From this follows that the total construction time equals 25 days. Between June until September the wave climate is mild and so the construction of the chenier will take place in this period. A working week of 5 days is assumed. So, the construction of the chenier will take in total 5 weeks.

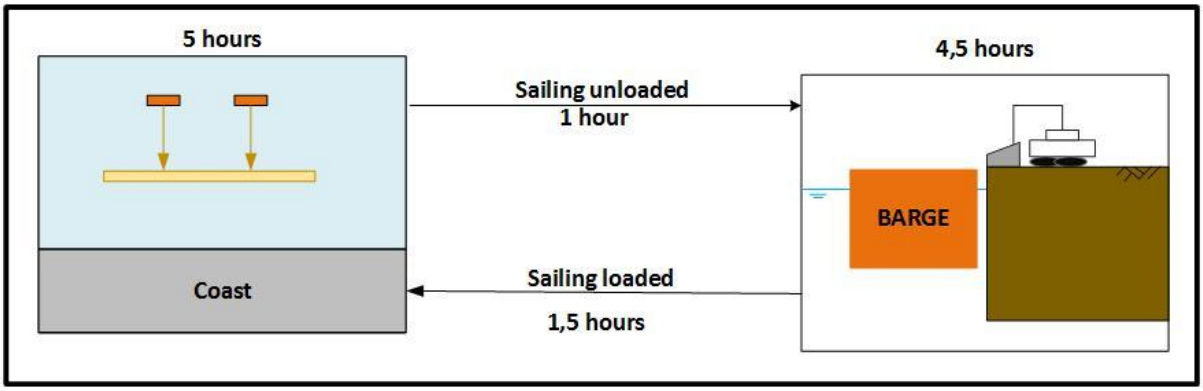

Figure 6.24 Total cycle time of the construction of the chenier (Source: own illustration)

Costs

The largest cost drivers for this design are given in Table 6.2. The costs for the barges are estimated at €100 000,-/week which is based on costs for different equipment given by Van Oord (Van Oord, n.d.). The cost for the excavators are estimated at €130,-/week (Digitcontracting, 2018).

	Costs
Barge	€1 000 000,-
Excavators	€312 000,-
Transport (pipeline, 2km)	€750 000,-
Building of the STUs	€116 000,-
Total costs	**€2 178 000,-**

Table 6.2 Estimation of the construction costs

Limitations

The first limitation is the large difficulty to predict the behavior of the coast after the chenier is build. Therefore, it is essential to predict the behavior using models, with different input parameters

(sediment size, location and dimensions). This is further explained in the last part of this design: Recommendations. The second limitation is that the cheniers will move westward and in cross-shore direction and due to wave action will decrease in height. Therefore, the chenier must be maintained regularly.

During the building stage, the sediment flows into the water via the pipeline, which results in some degree of turbidity. This can have a negative influence on the aquatic environment. However, the use of the pipeline decreases this effect relative to "dumping sediment" with a dumping vessel.

Another limitation which comes with emerged structures is that they block the horizon and so they are not attractive in terms of aesthetics.

Monitoring

In this design the following aspect needs to be monitored:

- The development of the chenier in time. Using aerial photographs, the place and the spreading of the chenier can be tracked. The chenier must fulfill its function until the mangrove forest is fully developed. If the lifetime of the chenier is smaller, maintenance is needed.
- The wave reduction due to the chenier. The wave height prior to the chenier and after the construction of the chenier must be measured at a location just before the STUs.
- The amount of sediment stirring behind the chenier. The sediment stirring is necessary for sediment to flow into the STUs. If it is not enough, the right sedimentation level will not be met. The sediment stirring can be measured by the sediment concentration over the water depth.
- The lee side erosion downstream of the chenier. Aerial photographs can be used to monitor this. If the lee side erosion is present in the area of interest, the chenier length should be increased.
- The sediment concentrations inside the STU. If the concentrations are too high, hindered settling will slow down the settling process.
- The turbidity caused by the dumping of the sediment. If the turbidity is too high, it is better to opt for another construction method with less turbidity.

Additional measures:

- If from monitoring it follows that one of the above aspects is insufficient for the sedimentation inside the STUs, the dimensions of the chenier can be adjusted.
- If the stirring up of sediment at the landside of the chenier is insufficient, agitation dredging can be used to increase the sediment concentrations behind the chenier. In the case of agitation dredging, the mud is brought into suspension again and is transported to the shoreline due to natural processes, for example by the tidal currents.

Recommendations

For this design it is recommended to make a model and check what the optimal parameters are to obtain the optimum wave climate for the sediment flow towards the STUs. First, the location of the chenier must be optimized. Second, the given dimensions: length, width and height, need to be checked. From this the parameters can be changed in such a way that the climate becomes better

and more sedimentation takes place. Also, different sediment sizes can be put into the model, such that the timescale in which the chenier disappears is not too small, otherwise too much maintenance will be needed during the lifetime of the chenier. To make a numerical model it is advised to use Delft3D. The three different modules: 1) Wave, 2) flow and 3) sediment can be used to model the different aspects in the area. In the flow module the tidal and meteorological forcing must be put as input parameters. In the wave module the offshore conditions are transformed to nearshore conditions. The following input parameters are needed: bed level, initial water level, wind speed and wind direction. Here it must be reminded that the SWAN wave transformation does not hold here, because the bed consists of mud instead of sand. In the sediment module the suspended transport of cohesive soils is taken. For this module both initial- and boundary conditions are needed. Also, physical parameters about the composition of the soil are needed. In each computational time step, the bed level is adjusted for the morphodynamics and the hydrodynamics are computed with the new hydrodynamics (Figure 6.25).

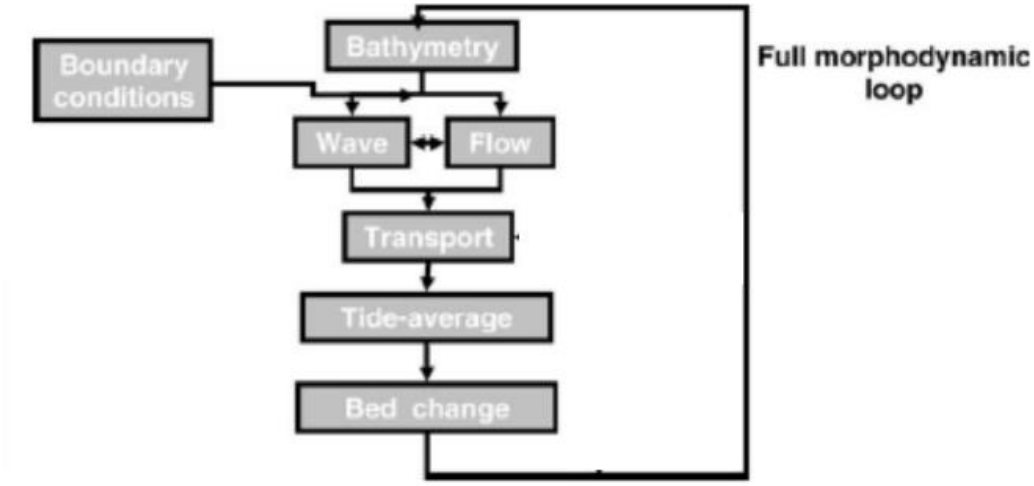

Figure 6.25 Morphodynamic loop in the Delft3D model, (Source: Walstra, 2017)

After the model is made validation is needed. For the wave and flow part, tidal data and water level data can be used. For the morphological validation no data is available, therefore expert judgement and the knowledge about the visually observed accretion inside the STUs can be used.

6.5 General monitoring

Apart from the monitoring of the preliminary designs, there are some general aspects that have to be monitored for all designs. These aspects are derived from the functional and technical requirements and the client's wishes (paragraph 4.5 Requirements). The purpose of monitoring is to see whether these requirements are reached or not. If they are not reached, additional measures have to be taken. Most of the monitoring will be done through inspection, while for some parts measurements have to be done. In this section an enumeration will be given of the aspects that have to be monitored. It will be explained how the monitoring will be performed and what additional measurements can be taken if monitoring outcomes show negative results. The design must dissipate incoming wave energy. Through water level and pressure measurements before and after the structures, the dissipated wave energy can be measured. It is hard to determine the required wave dissipation beforehand. So, additional monitoring has to be performed in the following way. Wave

reflection must be minimal to prevent scour holes. Monitoring this will be done through visual inspection as the coast is dry during ebb. Also, the wave transmission has to be in a certain range: not too small to allow for enough sediment transport (and thereby create a positive sediment influx) and not too large because calm conditions have to be created for the development of mangroves. The rest of the wave energy must be dissipated through the structure. To monitor this, the wave height in front of and inside the structure must be measured. Also, the bed level changes and the development of the mangroves have to be measured to keep an eye on this. If from these four measurements it can be concluded that the dissipation is not enough, the structural design must be changed. It is recommended to increase the width of the permeable structure to increase the wave dissipation.

If from the measurement of the mangrove development it follows that this is not enough, the salinity of the water inside the STUs has to be measured. If the salinity of the water is high, additional measures can be taken to supply enough fresh water such as a permanent freshwater stream or artificial sand dunes.

It has to be visually inspected if the structural elements of the design are still present and in position. This has to be done to check whether the structure is still providing resistance against the hydrodynamic loads. The inspection has to be done for ten years, as this is the structure's lifetime (paragraph 4.5). If from inspection it can be concluded that the structural elements are no longer in position or fulfilling their function, measures have to be taken. If the damage is small, the elements can be replaced. However, if the damage is large, a new design has to be made. It is recommended to take a new look at the hydrodynamic loads and the failure mechanisms of the structure. Furthermore, the horizontal displacement has to be inspected. This can be done in a simple way: by looking at the poles and seeing if they are still standing in a straight position. If this is not the case, the poles have to be replaced with longer poles. Also, the part of the pole that is submerged in the soil should be more than 2/3 of its total length.

7. STAKEHOLDER ENGAGEMENT PLAN

In previous chapters it was discussed that at some point during the process of a project with multi-stakeholders there will be decision makings and tradeoffs. As a result, there is a chance that not every stakeholder will be satisfied with decisions that are made. Therefore, to get everyone on the same page it is necessary to have an engagement plan. This chapter will present the stakeholder engagement plan. First, the engagement approach will be described in paragraph 7.1. In paragraph 7.2, 7.3 and 7.3 the three strategies for stakeholder engagement in the Weg naar Zee (WnZ) region will be discussed. Finally, paragraph 7.5 will present the conclusion.

7.1 Engagement approach

In this paragraph, the approach for engaging the WnZ stakeholders will be presented. This approach is based on SWOT tables and the SWOT/ TOWS matrix, which have all been composed with the input from the three preliminary designs. The SWOT analysis consists out of the following four elements: strengths, weaknesses, opportunities and threats. Since three preliminary designs have been described in the previous chapter, there will be three SWOT analyses. These analyses are shown in Table 7.1 to Table 7.3.

Preliminary design 1: Adapted STU	
Strengths	**Weaknesses**
• Sustainable structure • Flexible structure	• Scour Holes • Not very robust, thus easier to demolish • Bad and limited infrastructure conditions
Opportunities	**Threats**
• Self-sufficient for materials as bamboo and wood are available in Suriname	• Lesser availability of bamboo in the direct environment

Table 7.1 SWOT-analysis for preliminary design 1

Preliminary design 2: Nourishment	
Strengths	**Weaknesses**
• More reliable • Less side effects • Speeding up the sedimentation process	• Scouring • Failure of structure due to scouring • High costs • Disturbing the current ecosystem during disposal of the clay
Opportunities	**Threats**
• Mangroves can be planted at an earlier stage • Mangroves will grow faster • Evolvement of a new ecosystem is possible	• The authorities have little or no experience with nourishment • Bad and limited infrastructure conditions for nourishment

Table 7.2 SWOT-analysis for preliminary design 2

Preliminary design 3: Chenier	
Strengths	**Weaknesses**
• Increase the sedimentation in the STUs	• Unattractive in terms of aesthetics • Requires a lot of maintenance
Opportunities	**Threats**
• Cheniers are naturally present in front of the coast	• Negative influence on the aquatic environment • Uncertainty about the behavior of the coast

Table 7.3 SWOT-analysis for preliminary design 3

The SWOT analysis is useful in this research as according to Leijten (2016), weaknesses and threats contribute to identifying problems, while strengths and opportunities contribute to proposing solutions. Due to coupling the strengths and weaknesses of the preliminary designs with the identified opportunities and threats, it was possible to develop ideas and strategies. This analysis is performed in the so-caled TOWS matrix. The TOWS analysis is frequently used as a tool for situational analysis and combines the external threats and opportunities with the preliminary design its internal weaknesses and strengths (Weihrich, 1982). By linking the strengths and weaknesses with the opportunities and threats in Table 7.4 a handful of ideas were formulated. The formulated ideas are not blueprint solutions to engage stakeholders but are helpful to achieve it.

	Strengths: - Sustainable approach - Unused land is available - Return of mangroves - Evolvement of new ecosystem	Weaknesses: - Silted soil - Less leisure activities - Bad and limited infrastructure conditions - Limited to no experience with coastal protection solutions
Opportunities: - Self-sufficient for materials - Use of land acquisition - Tourism - Employment - Other land use options	***SO:*** - *Use sustainable materials for the coastal protection solutions* - *Necessary materials can be produced locally* - *Develop ecotourism* - *Plant mangroves on the reclaimed land* - *Create ecotourism related to employment opportunities*	***WO:*** - *Water desalination* - *Using salt-tolerant plants as vegetables* - *Generate income by selling salt-tolerant plants* - *Produce salt* - *Plan and encourage public transport for this region* - *Provide training in agriculture (silted soil), maintenance, tourism and building with nature concept to create employment for the locals*
Threats: - Less bamboo is available -Diverging viewpoints of stakeholders -Insufficient funding for coastal protection measure - Inflation	***ST:*** - *Plant bamboo to use it for STUs* - *Plant bamboo on a large scale to sell it and generate income* - *Develop land to generate funds* - *Create job opportunities*	***WT:*** - *Give the region a facelift* - *Explore more leisure activities* - *Develop and update the current infrastructure*

Table 7.4 TOWS-analysis based on the three SWOT tables

The TOWS analysis resulted in three strategies which will be worked out in the following paragraphs. The first strategy is generated by combining the **strengths** and **threats** (cell ST), the following ideas came along: *Plant bamboo to use it for the STUs*, *Plant bamboo on a large scale to sell it and generate income, Create job opportunities* and *Develop land to generate funds*. From these ideas the first strategy is as follows: Setting up a bamboo farm.

The second strategy is generated by combining the **weaknesses** and **threats** (cell WT), the following ideas came along: *Give the region a facelift*, *Explore more leisure activities* and *Develop and update the current infrastructure*. Also, some ideas that were generated by combining the **strengths** and **opportunities** (cell SO) are applicable for the second strategy. These are: *Plant mangroves on the reclaimed land, Develop ecotourism and create employment opportunities.* From these ideas the second strategy is as follows: Setting up a mangrove vacation resort.

The third strategy is generated by combining the **weaknesses** and **opportunities** (cell WO), the following ideas came along: *Using salt-tolerant plants as vegetable* and *Generate income by selling salt-tolerant plants.* From these ideas the third strategy is as follows: Growing Salt-tolerant plants.

Before the three engagement strategies will be presented it is worth noting that each of them is achievable no matter the choice of the preliminary designs (Adapted STU, Nourishment and Chenier). In the next paragraph, the first strategy will be presented.

7.2 Engagement strategy 1: Setting up a Bamboo farm

The first strategy is: **Setting up a Bamboo farm** and is focused on the realization of a bamboo farm at the WnZ region. In paragraph 6.2 it is described that preliminary design 1 (Adapted STU), will use bamboo as material. In the current situation at the WnZ region, bamboo is also being used as filling material for the STUs. These are bought from random people and transported to the WnZ location from far distances, which thus also entails costs. The bamboos are then being prepared on location by workers for use in the STUs (X. Van Ams, personal communication, January 8, 2017). A major threat is that less bamboo will be available nearby the WnZ region and that the costs of obtaining this material are going to increase. According to Van Ams nearby bamboo planting are cut off for other land use plans which leads to going further for bamboo purchase (X. van Ams, personal communication, January 8, 2017).

The TOWS analysis (Table 7.4) shows that unused land is available in the WnZ region which opens up the way for several new land use opportunities. One of the opportunities is that the available land can be used to realize a bamboo farm. By setting up such a farm, several stakeholders will become involved and the *land will be developed to generate funds*. So, by linking this possible threat of *less bamboo* with the strengths: *available and unused land* in Table 7.4, the first strategy of setting up a bamboo farm was formulated.

7.2.1 Stakeholder opportunities

The stakeholders' involvement in this strategy is explained with the help of several opportunities (Table 7.5) which have been clustered for this strategy. In Table 7.6 the various opportunities with their potentials and problems are addressed.

No.	Opportunity	Stakeholders	Potentials	Problems
1	Bamboo farm	AdeKUS/ Government of Suriname/ Inhabitants of the WnZ region/ Agricultural farmers	The bamboo can be used as material for the STUs (self-sufficient). Employment is created by starting up the bamboo plantation. Besides own use, the bamboo can also be sold for various purposes. By operating the plantation on a larger scale, opportunities will be created to export the bamboo plants.	Available land has already been issued by the government for other purposes. Difficulties with changing the land use plans. The owners of the unused land refuses to sell or donate. Salt intrusion will cause the land to be infertile. Possible difficulty obtaining permits as it concerns nature. Bad infrastructure in the WnZ region. Lack of investors and capital. Poor management. Loss of mangroves

				along the coast. Lack of purchase. Poor maintenance.
2	Bamboo farm educational tours	Tourists/ Recreationists/ AdeKUS/ SME business owners/ Inhabitants of the WnZ region/ Agricultural farmers	An interesting destination for especially students, researchers and nature lovers. Profits for tour operators (SME business owner). The locals can be used as guides.	Finding reliable people to train them to become skillful guides. No interest for the tours. Bad management.
3	Processing bamboo	SME business owners/ Inhabitants of the WnZ region/ Government of Suriname	Bamboo plants can be processed and used for different purposes. Therefore, this will also provide the locals with job opportunities and profits for investors.	Lack of purchase. Inflation. Bad management.

Table 7.5 Overview of potentials and problems for strategy 1: Bamboo farm

1. Bamboo farm

The primary purpose of the bamboo farm is that the planted bamboos will be used for STUs. This is cost-effective for the coastal protection designs where bamboos are used as material, since no bamboos will need to be purchased from third parties. Furthermore, it saves transport costs and the availability of bamboos makes the realisation of the STUs more certain, as the probability of bamboo scarcity will be very low. In Figure 7.1 it is displayed how personnel are preparing the bamboos as filling material for the current STUs at Weg naar Zee.

Figure 7.1 Bamboo being prepared for use in the Sediment Trapping Units at the WnZ coast (Source: Ma-Ajong, 2017)

In addition to the use for STUs, the bamboo can also be used for business purposes. Bamboo is used extensively among the Hindu community in Suriname. According to Sanatan Dharm (n.d.) the Hindus use this as a flag pole. Such a flag is usually placed in the front yard after a prayer service and has both religious and social meanings (Sanatan Dharm, n.d.). Also, when operating the bamboo farm on a larger scale it is advisable to not only look at the local market, but to also think in terms of export. Especially with the current economic crisis in Suriname, production and export need to be stimulated. In addition, several stakeholders will make profit and employment opportunities will be created for, among others, the local residents and agricultural farmers.

Of course, setting up such a plant brings risks and requires proper handling. The Government of Suriname, which is an important stakeholder in this bamboo farm, need to provide their full cooperation and support for a successful start-up. It is the government that is responsible for issuing land, land use plans and issuing permits. If one of these links fails than it is a big threat for the realization of the bamboo farm. On the other hand, the government also benefits from providing support, because they can generate money through governmental lease and taxes.

When identifying suitable land for the bamboo farm, it is important to look for unused land that is not affected by salt intrusion. It was found during the interviews and surveys that most of the grounds on the southern side of the Oedayrajsingh Varmaweg (neighbourhood 1) and Brantimakkaweg (neighbourhood 2) were not affected by flooding and therefore have little to no problems with salinized soil (Figure E.36, Appendix E,). When identifying proper land, it is also important to look at available land where there will be no loss of mangroves and where the infrastructure is already present. The latter is important to interest investors to invest in such a project. Taking into account all these factors, this leads to the identification of the piece of land that is displayed in Figure 7.2. The area of this piece of land is 40 hectares (400000m²). During the identification of suitable land for this strategy it was also taken into account that this sector can grow in the future. As a result, there is as much as 200 hectares of extra land available if necessary for expansion of the bamboo farm in the future.

Figure 7.2 Overview of the bamboo farm related to strategy 1 in the WnZ region (Source: Google Earth, 2018; own illustration)

Finally, in order to be able to operate and maintain the bamboo plant, it is important that good management and a maintenance plan are drawn up from the beginning. To conclude, the opportunity of setting up a bamboo farm connects to following four ideas of the ST cell (Table 7.4): *Plant bamboo to use it for STUs*, *Plant bamboo on a large scale to sell it and generate income, Create job opportunities* and *Develop land to generate funds*

2. Plantation education tours

The bamboo farm can also be used for educational and recreational purposes. Educational tours can be organized which are very interesting for students and researchers, but also for recreationists and tourists. For this group of visitors, a part of the bamboo farm can be arranged in such a way that the visitors can discover the several species of bamboo and learn more about it. In Figure 7.3, an impression is given of a bamboo farm that was transformed into an ecotourism destination in Lubao, Pampanga. This figure shows that a bamboo farm can be used for many purposes and could therefore also be applicable in Suriname.

Figure 7.3 Bamboo farm transformed into an Eco Village in Lubao, Pampanga (Source: Tulabut, 2017)

For recreationists, a walk through such a bamboo farm can be very calming and relaxing after a stressful day. Moreover, the tours meant for the tourists are profitable for the investors and indirectly the government also generates income through taxes. Furthermore, the locals can also be trained as guides for the educational tours. The opportunity of exploiting educational tours connects to two ideas from the ST cell (Table 7.4): *Create job opportunities* and *Develop land to generate funds.* It also connects to one idea from the WT cell (Table 7.4) which is: *Explore more leisure activities*. Also, this opportunity will contribute to *developing ecotourism*, which is an idea of the SO cell in Table 7.4

3. Processing bamboo

In recent years, the use of the bamboo plant has increased in both the fields of engineering and non-engineering. This section will demonstrate that the bamboo plant can indeed be used for multiple purposes when processed. According to Liese (2003) bamboo was used for centuries as a traditional material for constructions. However, over the years bamboo was increasingly used in other sectors as well and processed into various end products. Bamboo can be used for different purposes as is shown in Figure 7.4. Bamboo's multi-use will also provide the inhabitants of the WnZ region with job opportunities and possible profits for investors such as the Government of Suriname. SME business owners are involved as they as entrepreneurs can for example sell their bamboo products in their shops.

Figure 7.4 Some products that were made from bamboo as base product (Source: Nagaland, 2015)

The opportunity of processing bamboo connects to the following ideas from the ST cell (Table 7.4): *Plant bamboo on a large scale to sell it and generate income, Create job opportunities* and *Develop land to generate funds.*

7.2.2 Stakeholder involvement

Table 7.6 gives an overview of the opportunities from this strategy that covers the several ideas. The green cells of this table mean that the opportunity has covered the concerned idea.

Opportunity ⇓	Idea 1: Plant bamboo to use it for the STUs	Idea 2: Plant bamboo on a larger scale to sell it and generate income	Idea 3: Develop land to generate funds	Idea 4: Create job opportunities	Idea 5: Develop ecotourism
1) Bamboo farm					
2) Plantation education tours					
3) Processing bamboo					

Table 7.6 Overview of potentials and problems for strategy 2: Mangrove Vacation Resort

7.3 Engagement strategy 2: Setting up a Mangrove Vacation Resort

The second strategy is: **Setting up a Mangrove Vacation Resort.** From the TOWS analysis it became clear that the following ideas are coupled to strategy 2: *Give the region a facelift*, *Explore more leisure activities* and *Develop and update the current infrastructure* (WT cell) and *Develop land to generate funds* and *Create job opportunities* (ST cell). From these ideas the strategy for a mangrove vacation resort to engage stakeholders was obtained.

The resort is to be situated at the coast of the Weg naar Zee region. The exact architectural calculations for the placement of the structure itself will not be calculated in this report, as it falls

outside of this research scope. It is advised to take the most optimal structure placement into account for the resort as early possible, preferably in the pre-design phase. Research in Suriname has already been done on a similar project, the furnishment and design of a Mangrove Park at the Weg naar Zee region (Gesser, 2017).

The total required area for the mangrove vacation resort and its activities are 3500 square meters (0.35 hectare). This estimation has been made on the basis of the area calculations of the above-mentioned report by Gesser (2017). Figure 7.5 shows the available area that is identified for this strategy. This area is large enough for the implementation of the vacation resort since it is about 11 hectares big.

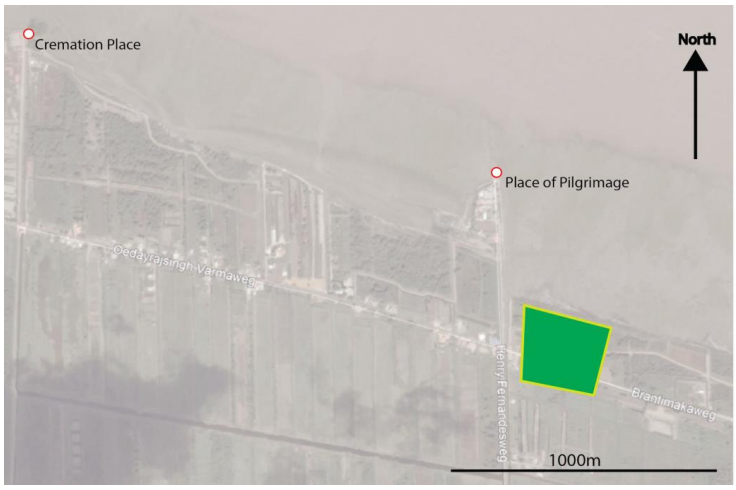

Figure 7.5 Overview of the resort and its attractions related to strategy 2 in the WnZ region (Source: Own illustration)

7.3.1 Stakeholder opportunities

In the Table 7.7, the stakeholders *Recreationists*, *Visitors of Place of Pilgrimage* and *Inhabitants of the WnZ region* have been clustered together into a temporary stakeholder group **Recreationists**. For every identified opportunity (read: attraction), involved stakeholders, potentials and problems will be described generally without going into extreme details. The potentials and problems are looked at from the viewpoint of realizing the mangrove vacation resort. This must not be mistaken with the potentials and problems which may arise if the mangrove vacation resort is already realized and operating.

No.	Opportunity	Stakeholder	Potentials	Problems
1	Vacation resort	Tourists/ Recreationists	Attractive. More tourism. Profits for investors. Nature preservation (mangrove vacation park). Leisure activity. Longer stay due to possibility of sleeping. Meeting place.	Obtaining building and exploitation permits as it concerns nature. Bad infrastructure. No interested investors and no capital for investments. Loss of mangroves along the coast.
2	Walking bridges	Tourists/ Recreationists	Appealing attraction. Bird sightseeing. Photos.	No investments and not obtaining permits.

3	Mud activities	Tourists/ Recreationists/ SME business owners	More tourists. Unique Selling Point (USP). Profits. Several possible mud activities. Leisure activity.	Smaller target audience (mud).
4	Small market	Tourists/ Recreationists/ Agricultural farmers/ Fishers/ SME business owners	Profits for agricultural farmers and fishers of WnZ. Attractive for inhabitants of WnZ. Meeting place.	Obtaining permits from government for market exploitation.
5	Restaurant	Tourists/ Recreationists/ SME business owners/ Agricultural farmers/ Fishers	Eatery. Meeting place. Outing for inhabitants of WnZ and others. Profits for SME business owners. Appealing attraction. Use of local WnZ region crops, fishes and animals for food.	No capital for investments.
6	Souvenir shop	Tourists/ Recreationists/ SME business owners	Profits for inhabitants of the WnZ region who produce souvenirs. Brand growth for Suriname as tourists collect Surinamese souvenirs.	High rents for shop/booth owners.
7	(Air)boat tours	Tourists/ Recreationists/ SME business owners	Profits for (air)boat owners who give tours. Appealing attraction.	Acquiring capital or investors for buying airboats.
8	Bamboo rafting, kayaking & canoeing	Tourists/ Recreationists/ SME business owners	Profits for bamboo rafting, kayaking and canoeing entrepreneurs. Appealing attraction.	Finding instructors. Acquiring bamboo for building rafts. Investments in kayaks and canoes. Investments in supporting equipment (e.g. life vests).
9	Petting zoo	Tourists/ Recreationists/ SME business owners/ Agricultural farmers/ Fishers	Appealing attraction. Profits for petting zoo owner. Animal husbandry farmers and fishers can place their animals in petting zoo and also make a profit.	Target audience mainly kids and parents. Finding investments for petting zoo.
10	Mangrove tours	Tourists/ Recreationists/ SME business owners/ Fishers	Appealing attraction for especially nature lovers. Profits for tour operators. Fishers can be used as tour guides as they know the area well.	Finding reliable and skillful tour guides. Bad management.

Table 7.7 Overview of potentials and problems for strategy 2: Mangrove Vacation Resort

The identified opportunities of Table 7.7 will now shortly be explained without going into too much detail such as requirements for management and/or operation.

1. Vacation resort

The resort should be attractive for mainly tourists and recreationists. The realization of this resort could be the first in Suriname to border the Atlantic Ocean. The idea for the resort is to not literally border the Atlantic Ocean, but to let it be very near as seen in Figure 7.5. With the realization of a sustainable resort, more tourists can be attracted. The resort itself also has the possibility of preserving nature and mangroves, as it is a mangrove vacation park and people will be coming partly or mainly for the mangroves. Removal and hacking of many mangroves would thus not be feasible and absolutely not advised. This opportunity connects to all the ideas from the WT cell (Table 7.4): *Give the region a facelift*, *Explore more leisure activities* and *Develop and update the current infrastructure.* It also connects to all two ideas in the ST cell (Table 7.4): *Plant mangroves on the reclaimed land* and *Develop ecotourism and employment opportunities.*

2. Walking bridges

There are several options available for this opportunity, which is mainly intended for tourists and recreationists. Walking bridges can be build which give people the opportunity to walk between the mangroves as was built in February 2012 by Professor Naipal in the coastal area of the Coronie district in Suriname (S. Naipal, personal communication, January 9, 2017). An image of the walking bridge in Coronie can be seen in Figure 7.6. Another option is a walking bridge which connects the mangrove vacation resort with the sea. A walking bridge connecting the mangroves with the sea is also a possibility. This opportunity connects to all the ideas from the WT cell (Table 7.4): *Give the region a facelift*, *Explore more leisure activities* and *Develop and update the current infrastructure.* It also connects to all two ideas in the ST cell (Table 7.4): *Plant mangroves on the reclaimed land* and *Develop ecotourism and employment opportunities.*

Figure 7.6 Walking bridge through the mangrove forest at the coast of Coronie (Source: Naipal, September 2012)

The walking bridge which was constructed in the district of Coronie can be seen in Figure 7.7.

Figure 7.7 An American student walking on the bridge through the mangrove forest into the sea at the coast of Coronie (Source: Naipal, February 2016)

3. Mud activities

The mud activities can range from mud baths to mud sleds. Figure 7.8 shows how a mud sled looks. The stakeholders involved in this activity are Tourists, Recreationists and SME business owners.

Figure 7.8 Mud sled (Source: Vos Iz Neias, 2012)

A plus point of mud activities is that more tourists may be attracted to visit and participate. Mud activities in the sea along the WnZ coast are until now unique in that area and can thus be seen as a Unique Selling Point (USP). Problems with the mud activities might be that there is a smaller target audience compared to for example kayaking and canoeing. For this reason, it cannot be necessarily said that mud activities give the region a facelift. This is because kayaking and canoeing can both be done while staying relatively dry. This opportunity connects to one idea from the WT cell (Table 7.4):

Explore more leisure activities. It also connects to all two ideas in the ST cell (Table 7.4): *Plant mangroves on the reclaimed land* and *Develop ecotourism and employment opportunities.*

4. Small market

The stakeholder groups which are involved in the small market consists of Tourists, Recreationists, Agricultural farmers, Fishers and SME business owners. The small market is best placed in close proximity of the resort. It gives the local agricultural farmers and fishers of the WnZ region the possibility to sell their crops, animals, fish, etc. With this they have a chance to make profits for themselves. The market is also interesting for SME business owners, as someone who for example sells small crafts, drinks or other merchandise can also sell on the market and make profit. The market is also attractive for the inhabitants of the WnZ region as they can buy stuff and meet one another here. This opportunity connects to two ideas from the WT cell (Table 7.4): *Explore more leisure activities* and *Develop and update the current infrastructure.* It also connects to one idea in the ST cell (Table 7.4): *Develop ecotourism and employment opportunities.*

5. Restaurant

The stakeholder groups involved with this opportunity are Tourists, Recreationists, SME business owners, Agricultural farmers and Fishers. A restaurant which is located in the resort, provides food and is another meeting place for people. The aim for the resort's restaurant is to use only local produce from mainly the WnZ region agricultural farmers and fishers. This provides profits for these agricultural farmers and fishers. Thus, a win-win situation. This opportunity connects to two ideas from the WT cell (Table 7.4): *Explore more leisure activities* and *Develop and update the current infrastructure.* It also connects to all one idea in the ST cell (Table 7.4): *Develop ecotourism and employment opportunities.*

6. Souvenir shop

The idea for the souvenir shop is to be situated in the mangrove vacation resort. The stakeholder groups involved are Tourists, Recreationists and SME business owners. The inclusion of the SME business owners in this opportunity is related to people who sell their crafts, merchandise and souvenirs to interested parties such as tourists. By selling souvenirs, these entrepreneurs can make profit. Selling souvenirs also generated brand growth for Suriname as tourists collect Surinamese souvenirs. This opportunity connects to one idea from the WT cell (Table 7.4): *Develop and update the current infrastructure.* It also connects to one idea in the ST cell (Table 7.4): *Develop ecotourism and employment opportunities.*

7. (Air)boat tours

The stakeholder groups involved in this activity are Tourists, Recreationists and SME business owners. The possibility of giving tours in an airboat or other type of boat is attractive for tourists and people in general. It takes you straight into the muddy nature of the mudbanks in front of the Surinamese coast. Those interested can take tours and this generates profits for the entrepreneur (SME business owner) who has invested in 1 or several boat(s) which can be used for giving tours along the coast. An impression of an airboat on mud can be seen in Figure 7.9. With this airboat Professor S. Naipal gave an excursion to the Mangrove Project Suriname members and other interested university students. To conclude, this opportunity connects to two ideas from the WT cell (Table 7.4): *Give the region a*

facelift and *Explore more leisure activities*. It also connects to all two ideas in the ST cell (Table 7.4): *Plant mangroves on the reclaimed land* and *Develop ecotourism and employment opportunities.*

Figure 7.9 Airboat at the WnZ region which was used by Professor Naipal to give a tour to the Mangrove Project Suriname team (Source: Naipal, 2017)

8. Bamboo rafting, kayaking and canoeing

For the activities bamboo rafting, kayaking and canoeing, the stakeholder groups Tourists, Recreationists and SME business owners are involved. These activities are appealing, maybe even more so that because canoeing and kayaking can be done while staying relatively dry. Bamboo rafting is more water intensive when it comes to staying dry. Entrepreneurs renting out the bamboo rafts, kayaks or canoes can make profits with the rental to customers for one or several hours. In Suriname, "korjaal" is the word for a small boat made out of wood and can be used as a canoe in order to support the local businesses. This boat is displayed in Figure 7.10. This opportunity connects to two ideas from the WT cell (Table 7.4): *Give the region a facelift* and *Explore more leisure activities.* It also connects to all two ideas in the ST cell (Table 7.4): *Plant mangroves on the reclaimed land* and *Develop ecotourism and employment opportunities.*

Figure 7.10 "Korjaal" on the Suriname river (Source: Stoel. n.d.)

9. Petting zoo

In the petting zoo adults and children can come and look at the farm animals provided by the agricultural farmers and fish provided by the fishers of the WnZ region. The owner of the farm (SME

business owner) can make profits for example through the entrance fee people pay to visit, pet and feed the animals. This opportunity connects to two ideas from the WT cell (Table 7.4): *Explore more leisure activities* and *Develop and update the current infrastructure.* It also connects to one idea in the ST cell (Table 7.4): *Develop ecotourism and employment opportunities.*

10. Mangrove tours

Tours through the mangroves can be organized for the Tourist and Recreationists stakeholders. SME business owners are taken along as they will manage and prepare the tours through a touring company for example. Fishers have been taken along as they can also provide tours for interested parties through the mangroves. With a little training the fishers will be ready as guide as they also know the area pretty well. Mangrove tours are an appealing attraction for especially nature lovers. The mangrove tour operators can make profits by providing services. This opportunity connects to all the ideas from the WT cell (Table 7.4): *Give the region a facelift*, *Explore more leisure activities* and *Develop and update the current infrastructure.* It also connects to all two ideas in the ST cell (Table 7.4): *Plant mangroves on the reclaimed land* and *Develop ecotourism and employment opportunities.*

7.3.2 Stakeholder involvement

Table 7.8 gives an overview of the opportunities that covers the several ideas. The green cells of this table mean that the opportunity has covered the concerned idea.

Opportunity ⇓	Idea 1: Give the region a facelift	Idea 2: Explore more leisure activities	Idea 3: Develop and update the current infrastructure	Idea 4: Plant mangroves on the reclaimed land	Idea 5: Develop ecotourism and employment opportunities
1) Vacation resort					
2) Walking bridges					
3) Mud activities					
4) Small market					
5) Restaurant					
6) Souvenir shop					
7) (Air)boat tours					
8) Bamboo rafting, kayaking and canoeing					
9) Petting zoo					
10) Mangrove tours					

Table 7.8 Overview of weaknesses and ideas per opportunity

7.4 Engagement strategy 3: Growing salt-tolerant plants

The last strategy to engage the stakeholders is the use of saline land to grow salt tolerant plants. The survey results made it clear that the people from especially neighborhood 1 and neighborhood 2 had suffered from salinized soil. Figure 7.11 shows that the majority of the residents (56%) who do agriculture on a smaller scale are not satisfied with the current harvest. The dissatisfaction is because many have lost their crops as a result of flooding, infertile soil and/ or other issues as indicated in the right pie-chart of Figure 7.11

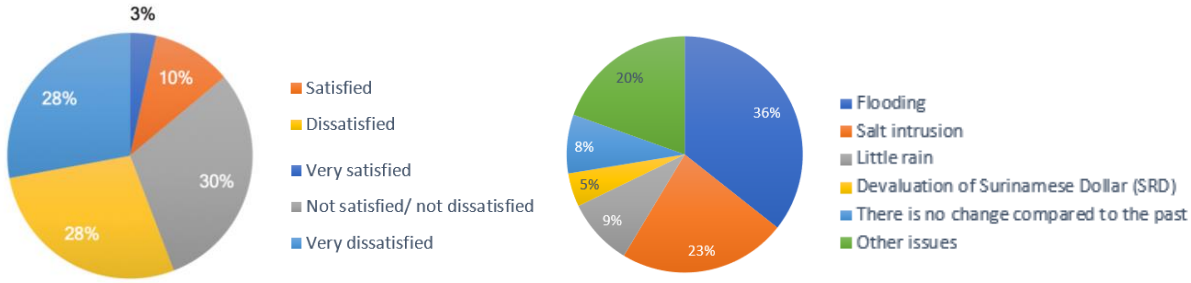

Figure 7.11 Left: Agricultural farmers who are satisfied with their harvest (Result survey question 26); Right: Agricultural farmers' possible reasons for the current harvest (Result survey question 27)

Large farmers have also suffered enormous losses due to salinized soil. Wim Bajnath, the chairman of the agricultural cooperation of the Kwatta region, indicated during the interview that his organization has no know-how in the field of salt-tolerant plants and that they are open to experimentations with plants on saline ground (W. Bajnath, personal communication, December 4, 2017). According to Bajnath (personal communication, December 4, 2017) experiments with salt-tolerant plants have never been carried out in Suriname as far as he knows. Although that does not mean that it is impossible and that such an experiment would immediately fail. Furthermore, it appears from an email conversation with Robert Adrichem that there is also interest from Dutch organizations, such as Stichting Biosfera, to carry out such experiments in Suriname at the Weg naar Zee region (R. Adrichem, personal communication, November 28, 2017). This is because salt-tolerant plants have already been successfully implemented in the Netherlands and they have the necessary knowledge and experience. Therefore, the last strategy in this chapter will be about creating an opportunity (growing salt-tolerant plants) from a phenomenon (infertile soil) which have caused a lot of trouble for the inhabitants and farmers.

7.4.1 Stakeholder opportunities

In Table 7.9 the opportunity of growing salt-tolerant plants will be addressed while the potentials and problems of this strategy are described.

Opportunity	Stakeholder	Potentials	Problems
Growing salt-tolerant plants	Agricultural farmers/ AdeKUS/ SME business owners/ Inhabitants of the WnZ region/ Government of Suriname/	More profits for Agricultural farmers and SME business owners. Different possible salt-tolerant plant alternatives (e.g. sea cabbage). Expansion of range in vegetable type. Export opportunities.	Failure of growth. Locals do not approve of salt-tolerant plants. Lack of sale. Insufficient experience.

Table 7.9 Overview of potentials and problems for strategy 3: Salt tolerant plants

Growing salt-tolerant plants will mostly be done by Agricultural farmers. The techniques and expertise to grow the salt-tolerant plants can be taught by AdeKUS, Ministry of Agriculture and Animal Husbandry and experts from befriended organizations abroad. The Inhabitants of the WnZ region are involved, as they are the target audience that visits the market to buy the salt-tolerant crops. Agricultural farmers can sell their crops to market vendors, who are seen as SME business owners. Finally, the Government of Suriname is involved in this strategy as they can facilitate the issuing of land on which the salt-tolerant crops are to be planted and support the farmers with offering training in this sector.

The potentials for this opportunity are more profits for agricultural farmers and SME business owners. Also, the introduction of salt-tolerant plants introduces different possible alternatives as vegetables (e.g. sea cabbage). An expansion of range in vegetable type is created and opportunities for export are created, which again means more profits for the salt-tolerant plant farmers.

There are also some threats which are identified with this strategy. One is the failure of growth of the salt-tolerant plants. Another threat is that the locals of the WnZ region (and Surinamese people) may not approve of salt-tolerant plants and this can lead to less or almost no sales. Finally, insufficient experience from the farmers with salt-tolerant plants can also cause problems for realizing this strategy. It is therefore highly advised to work with organizations or experts who have this knowledge and experience with growing salt-tolerant plants. According to Wageningen Environmental Research (2018), it is best to bring salt-tolerant crops to the market as a regional product (e.g. from the WnZ region) to try and smoothen its adoption onto the local market.

Overall, a good governance process would have to be in place for this opportunity to be successful (Wageningen Environmental Research, 2018). The Surinamese government would have to give subsidies to the farmers who are interested to grow salt-tolerant crops. This would stimulate the development of the salt-tolerant crops market. The government also has the power to back these farmers by blocking unwanted developments such as large-scale import of crops from other countries. Research has to be done either by AdeKUS or other research institutes in cooperation with other international research institutes who already have the knowledge and experience. Finally, Surinamese businesses have an important role and the power to bring research results to the people and implement this in practice. Usually investors are coupled to businesses and if they see potential in this market they could be the ones to give or attract venture capital. In Figure 7.12 an example is given of sea cabbage, a salt-tolerant plant.

Figure 7.12 Salt-tolerant plant: sea cabbage (Source: Restoration Seeds, n.d.)

To conclude, the opportunity of planting salt-tolerant plants on saline soil connects to the following two ideas from the WO cell (Table 7.4): *Using salt-tolerant plants as vegetable* and *Generate income by selling salt-tolerant plants.*

7.4.2 Stakeholder involvement

Table 7.10 gives an overview of the opportunity that covers the several ideas. The green cells of this table mean that the opportunity has covered the strategy.

Opportunity ⇓	Idea 1: Use salt-tolerant plants as vegetable	Idea 2: Generate income by selling salt-tolerant plants
Planting salt-tolerant plants on saline soil		

Table 7.10 Overview of weaknesses and ideas per opportunity

7.5 Conclusion

In order to compose the stakeholder engagement strategies, it was necessary to perform the SWOT and TOWS analyses. First, three SWOT tables were made of the three preliminary designs that were presented in chapter 6. The information of these SWOT tables was used to formulate the ideas in the TOWS matrix. The results from the TOWS analysis led to the formulation of three strategies: 1) Setting up a bamboo farm; 2) Setting up a mangrove vacation resort and 3) Growing salt-tolerant plants. The three strategies that are elaborated in this chapter show how the various stakeholders can be involved when it comes to sustainable coastal management. For example, all three strategies show that employment opportunities are being created which, in turn, also entails economic development to the region. The economic development of the WnZ region is ultimately the trigger for the community and the other interested stakeholders. If they are made aware of the economic benefits, they will gradually provide more support to carry out the coastal management project in a sustainable way. In addition to the stakeholder engagement plan presented in this chapter, a stakeholder table is given in Appendix I. This table has helped in understanding how to deal with the various stakeholders for the coastal management solution at Weg naar Zee.

8. CONCLUSION, RECOMMENDATIONS AND DISCUSSION

In this chapter the conclusion, recommendations and discussion will each be addressed in separate paragraphs.

8.1 Conclusion

By integrating the disciplines of Hydraulic Engineering and Construction Management & Engineering, conclusions have been composed for the coastal erosion problem at the Weg naar Zee region. This discipline integration has focussed on results regarding: preliminary designs for mangrove rehabilitation methods, stakeholders, dilemmas and solutions. Coastal management in this report has focussed on a defense system against coastal erosion which can be supported by the key stakeholders of Weg naar Zee. For this report, with the Anton de Kom University of Suriname (AdeKUS) as client, an attempt has been made to adequately answer the main research question: "***Which mangrove rehabilitation methods, supported by key stakeholders, can be implemented at Weg naar Zee in order to mitigate coastal erosion?***". The rest of the paragraph will now present the results which ultimately answer the research question.

To present mangrove rehabilitation methods, it was necessary to gain insight regarding the Weg naar Zee stakeholders' involvement when it comes to coastal management. Fourteen key stakeholders were identified. On the basis of dependency and replaceability, three critical actors were found: *Government of Suriname, AdeKUS* and *Inhabitants of the WnZ region* of which the client is also present. Finally, the analysis also shows that *AdeKUS*, the *Government of Suriname* and *NGO's/Embassies* are 'strong supporters' of the "building with nature" project.

Knowing the success factors and design requirements, resulted in the analysis of which mangrove rehabilitation designs are applicable and supported by the WnZ region stakeholders. The first step was conducting a Multi-Criteria Analysis (MCA) in which five alternatives with their variants are weighed on seven criteria, of which the technical-, environmental- and feasibility criteria have the highest weighting. From this analysis the top three variants are: 1) Adapted STU, 2) STU with Nourishment and 3) STU with chenier. These three designs are more elaborated into three preliminary designs. In the first design, the STUs are adapted such that sedimentation inside the STUs is expected. In the second design, a nourishment is placed inside the adapted STUs and dredged material is taken from a borrow pit 4 km from the shore. In the third design a chenier is placed 2 km from the shore.

Finally, support by stakeholders for the mangrove rehabilitation designs can only be gained if they are engaged. This was tackled by composing a stakeholder engagement plan. In this plan, the following three strategies are formulated: 1) Setting up a bamboo farm, 2) Setting up a Mangrove Vacation Resort and 3) Growing salt-tolerant plants. These strategies will contribute to the economic development of the region, which could ultimately also benefit the various stakeholders.

All of the above gives an answer on the formulated research question. However, the final implementation choice lies with the client, AdeKUS.

8.2 Recommendations

The first recommendation is to educate the locals by executing awareness campaigns, door-to-door visits, and training on site. Results in chapter 4 and Appendix E (section E.3) showed that the majority of WnZ inhabitants is unaware of climate change and its consequences. The results also showed that the majority have little knowledge of other possible solutions for coastal protection. This means that due to the unfamiliarity, people can show a certain attitude. Therefore, education, training and awareness can help in giving people other insights. Furthermore, it is recommended that awareness already starts in primary schools. The process of sustainable designs can be presented to school students using easy-to-understand illustrations. Next to the locals, other interested stakeholders can also be informed about sustainable designs e.g. radio and TV.

The second recommendation concerns the wish of the Surinamese government to make the country a foodshed (Abisoina, 2016). In this case, it is necessary to heavily invest in agriculture. Results in Appendix E (section E.3) have shown that 10% of the residents at WnZ are unemployed residents. Employment can be created in this sector since farming is already being done on a large scale in this region. Also, civil servants who are willing can be deployed in this sector which can result in a growth of agriculture. This measure will also result in the dilution of the civil service, which is currently overcrowded. To stimulate this sector even more, the government can facilitate the locals with training and knowledge, but also the provision of land.

Furthermore it is recommended to start the construction of the designs right before the arrival of a mudbank. This way sedimentation is more easily achieved, as the sediment availability is large. The presence of a mudbank creates a calmer wave climate and therefore sediment can settle more easily. Satellite images of the past 40 years are available and therefore past mud bank propagation behaviour along the coast can be registered. Based on this data, future predictions on mud bank migration can be made. From these predictions a better decision can be made to determine the starting time of the construction of the STUs.

Another recommendation regarding preliminary design 2, nourishment, are experiments. As settling and consolidation of the specific mud at WnZ is not understood yet, experiments can be executed to get a better insight into these processes. This is recommended as these processes are dependent on several aspects such as pH and concentration (Hendriks, 2016). The timescales of these processes can be known by doing experiments in order to optimize the cycle. Also, the properties and thickness of the formed layer can be measured and examined to get an indication of the consolidation process for this specific mud at WnZ.

Another important recommendation is boosting the economic development of this area. Chapter 7 presented three engagement strategies: 1) Setting up a bamboo farm, 2) Setting up a mangrove vacation resort and 3) Growing salt-tolerant plants. Regardless of the preliminary design choice for the Weg naar Zee region, it is likely that these strategies will generate funds and create job opportunities. As Suriname is one of the most threatened countries due to sea level rise, the final recommendation is an analysis about the effects of climate change which needs to be accounted for. This can then be executed to investigate different sea level rise scenarios.

8.3 Discussion

Unexpected findings

While analyzing the surveys it became clear that the WnZ locals are now more open to mangroves as coastal protection compared to earlier research executed in 2015 when the majority (97%) wanted a concrete dike (P-all Projects Supply Suriname N.V., 2015). This finding was surprising and the reason that it has appeared in this report in contrast to earlier reports could be because of the factor time. This report's survey was done at the end of 2017, meaning the Sediment Trapping Units (STUs) were already in place since 2015 and the locals may now be a bit more familiar with the 'Building with Nature' concept. The significance of this finding strengthened the argument that building a concrete dike does not have to be the only option and that sustainable coastal protection can also be successfully applied at the Surinamese coast.

Limitations

During the research, several limitations were faced. The first limitation was a lack of hydrodynamic- and morphodynamic data of the current state at WnZ. Since the coast is highly dynamic, the used bathymetry from previous years can differ from the current situation, which influences the validity of the structural calculations and nourishment volumes. The applied bathymetry might also contain measurement errors. For the applied wave data, wave model calculations from previous years were used. These calculations do not represent the wave climate in the future, since climate change is not taken into account. A reason for the lack of data is the absence of reported data.

The second limitation has to do with the lack of data surrounding the Weg naar Zee stakeholders. This could be reasoned by the observation that stakeholder management is not a familiar concept in Suriname. Regarding scientific findings on stakeholders, there was little to find and if found, it often dated back to the 20th century. To fill the gap, surveys and interviews were conducted to understand stakeholders' actual positions.

The third limitation regards the stakeholder interviews. In a few instances interviews were not held or rejected by stakeholders who were identified as interesting additions to this research. This could mainly be because they did not want to participate. The most frequent issue, if an argument for non-participation was given, was that the stakeholders felt they would rather not share information with students that might be published, even if anonymity was guaranteed.

The fourth limitation has to do with the Multi-Criteria Analysis (MCA). An MCA can give a misleading image if a wrong balance is made between the criteria. This can occur if a certain aspect is split up in sub-criteria, while other aspects are summarized into one criterion. Also taking into account the cost aspect in the criteria list is not fully correct as they are counteracting. Therefore, the costs are excluded from the analysis.

The final limitation regards the use of the wave transformation model SWAN. This model can only be used for coastlines with a sandy bed. In this case, Suriname has a mud coast which has more bed friction. Therefore the waves will be lower than calculated with the SWAN model. So, the designs are on the safe side regarding the wave height. To calculate the wave heights a Swash model can be used where a mud bed can be inserted.

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APPENDIX A. BATHYMETRY

In this appendix the bathymetry is found for the Weg naar Zee region and was executed during high (5 – 6 October 2013). The legend displays the deepness in meters. The symbol resembling a black tilted square at the bottom left represents the Cremation Place. The symbol on the right represents the Place of Pilgrimage.

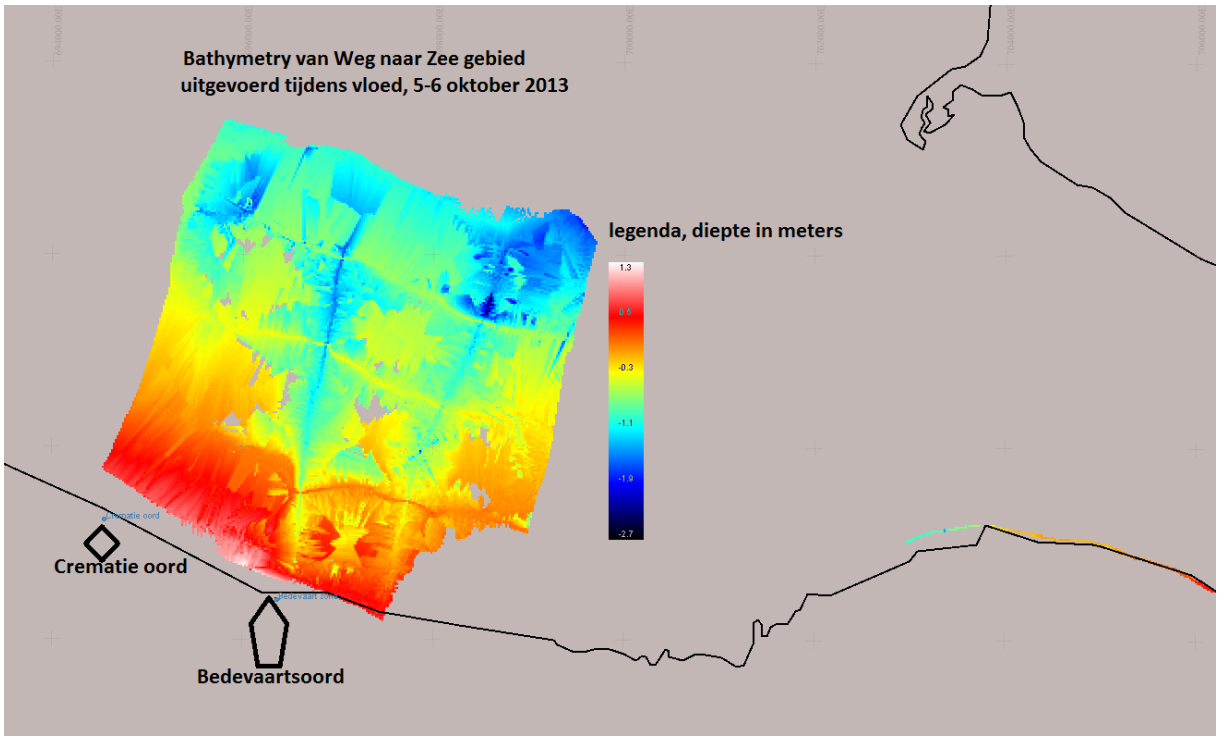

Figure A.1 Bathymetry Weg naar Zee area, 2013 (Naipal, 2013)

APPENDIX B. WAVES

Appendix B will present the wave characteristics in section B.1, whilst the determination of these characteristics can be found in section B.2.

Appendix B.1 Wave characteristics

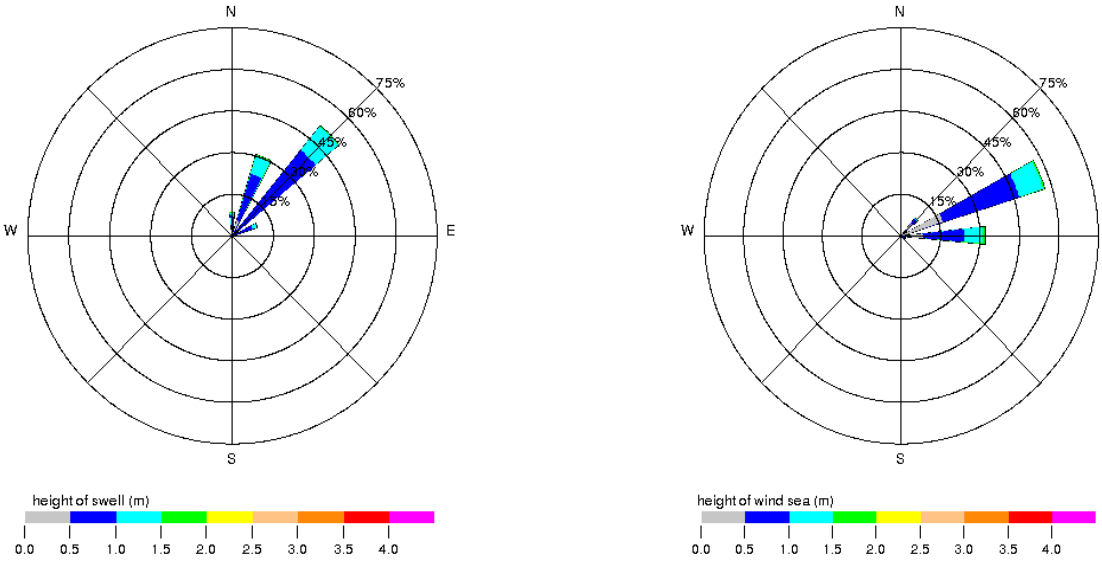

Figure B.1 Direction and height of swell and wind waves during Summer (July-September) (Source: BMT ARGOSS, 2017).

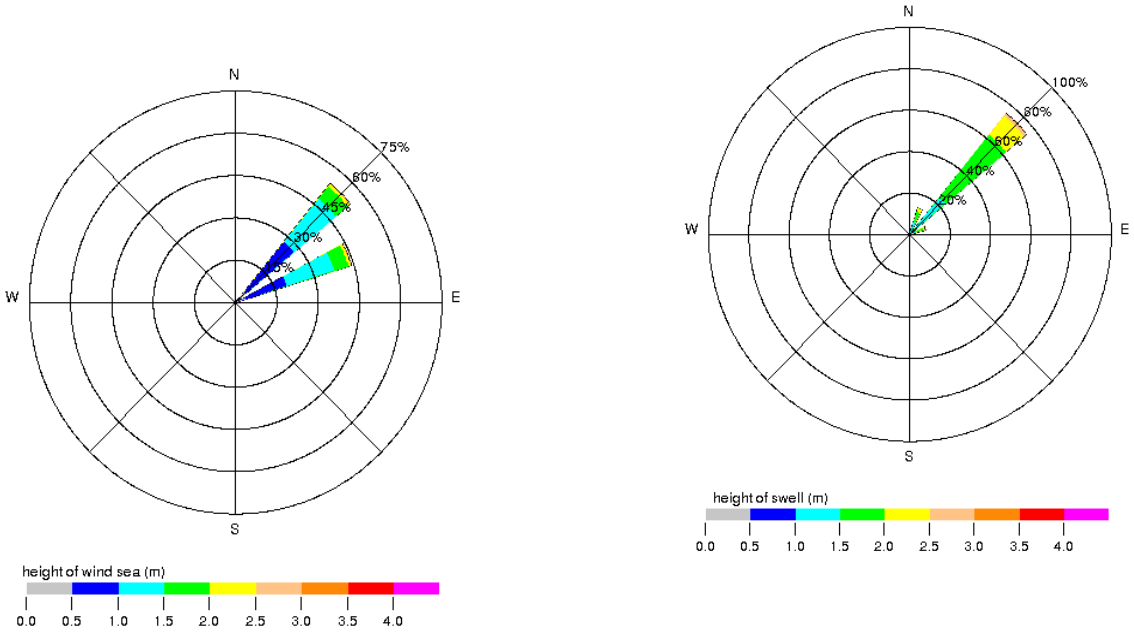

Figure B.2 Direction and height of swell and wind waves during Winter (January-March) (Source: BMT ARGOSS, 2017).

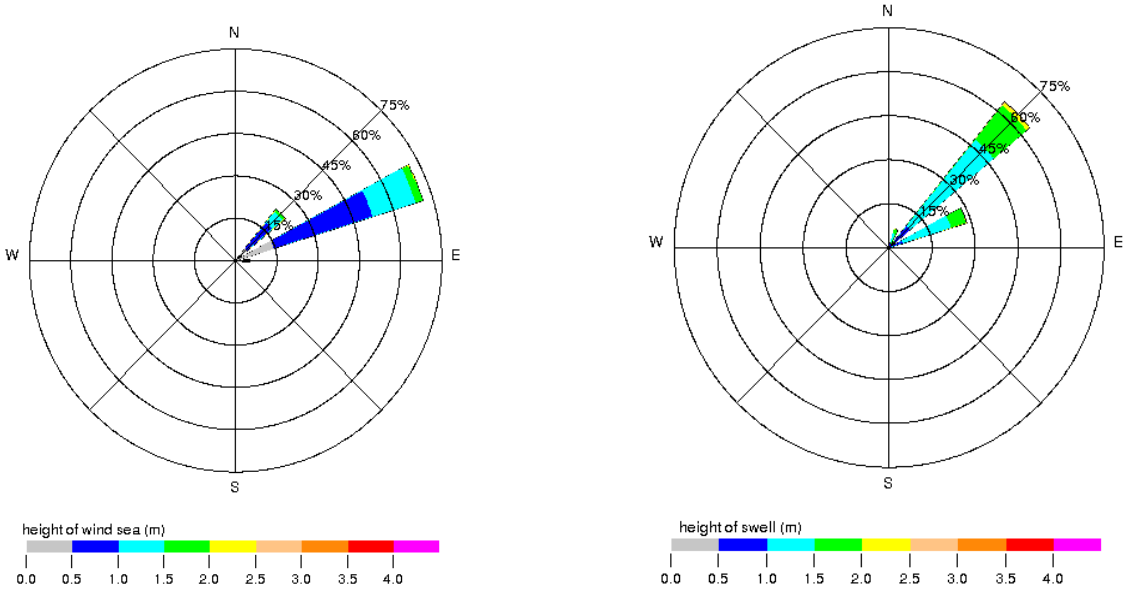

Figure B.3 Direction and wave height in April and May (Source: BMT ARGOSS, 2017).

Appendix B.2 Determination wave characteristics

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Service,www.waveclimate.com												
2	Created,15dec17 13:34												
3	Missing value,999												
4	Latitude (deg N),6.50000												
5	Longitude (deg E),-55.0000												
6	Begin,01jan92 00:00												
7	End,31dec16 21:00												
8	Timestep (hours),3												
9	Datasource,wavemodel												
10													
11	Code,Explanation												
12	u10,One hour wind speed at 10m asl												
13	u10d,Wind direction at 10m asl (nautical)												
14	Hs,Significant wave height												
15	Hsd,Mean wave direction (nautical)												
16	Tz,Zero-crossing wave period												
17	Tm,Mean wave period												
18	Tp,Peak wave period												
19	_sea,Suffix for wind-sea												
20	_swl,Suffix for swell												
21													
22	Year,Month,Day,Hour,u10,u10d,Hs,Hsd,Tz,Tm,Tp,Hs_sea,Hsd_sea,Tz_sea,Tm_sea,Tp_sea,Hs_swl,Hsd_swl,Tz_swl,Tm_swl,Tp_swl												
23	,,,[UTC],[m/s],[deg],[m],[deg],[s],[s],[s],[m],[deg],[s],[s],[s],[m],[deg],[s],[s],[s]												
24	1992,01,01,00, 8.20, 76.0, 1.34, 66.0, 4.51, 5.30, 6.72, 1.29, 70.0, 4.38, 5.01, 6.72, 0.37, 4.0, 8.79, 8.89, 8.95												
25	1992,01,01,03, 7.60, 78.0, 1.30, 65.0, 4.56, 5.40, 6.72, 1.16, 73.0, 4.22, 4.77, 6.11, 0.59, 31.0, 7.59, 7.78, 7.39												
26	1992,01,01,06, 6.20, 82.0, 1.24, 63.0, 4.64, 5.54, 6.72, 0.82, 78.0, 3.64, 3.96, 4.59, 0.93, 51.0, 6.43, 6.74, 6.72												
27	1992,01,01,09, 5.40, 74.0, 1.18, 61.0, 4.79, 5.72, 6.71, 0.60, 79.0, 3.31, 3.54, 3.79, 1.02, 54.0, 6.09, 6.49, 6.71												
28	1992,01,01,12, 6.00, 78.0, 1.15, 58.0, 4.87, 5.85, 6.71, 0.69, 74.0, 3.59, 3.92, 4.58, 0.92, 49.0, 6.66, 6.91, 6.71												
29	1992,01,01,15, 4.80, 74.0, 1.14, 56.0, 4.98, 5.96, 6.70, 0.45, 72.0, 3.09, 3.24, 3.44, 1.04, 53.0, 5.98, 6.47, 6.70												

Figure B.4 Overview of the retrieved dataset (Source: ARGOSS, 2017)

With a data set obtained from the offshore location shown in Figure B.4 and B.5, which is located 70 kilometers from the location of interest, the wave height and peak period can be calculated. The data set consists of 73057 wave model calculations with a 3 hours timestep. In Figure B.6 a overview is given of the retrieved dataset from (BMT ARGOSS, 2017).

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Figure B.5 Map of Suriname with the offshore model point and the location of interest (Source: Google Maps, 2017)

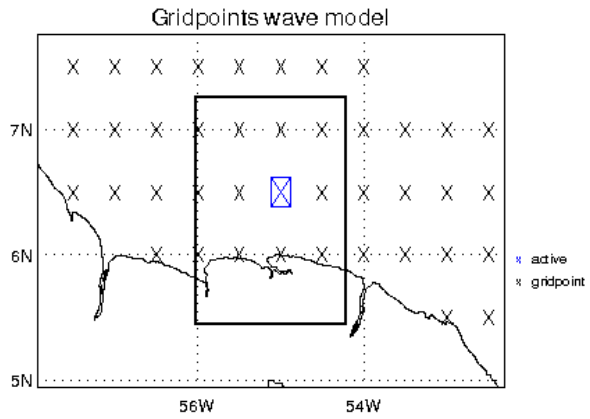


Figure B.6 The offshore model point with coordinates: 6° 30'N, 55° 00'W (Source: BMT ARGOSS, 2017).

To obtain the offshore significant wave height ($H_{1/3}$), the data set is ordered from high wave height to low wave height. Then, the mean is taken from 1/3 of the highest waves. With this ordered data set the peak wave period, the mean wave period, the zero-crossing wave period and the maximum wave height in the data set are also shown in Table B.1.

	$H_{1/3}$ [m]	T_p [sec]	T_m [sec]	T_{m0} [sec]	Mean wave direction [degrees]	H_{max} [m]
Sea waves	1.14 m	5.53 s	4.70 s	4.16 s	63 degrees	3.24 m
Swell waves	1.67 m	8.81 s	8.21 s	7.56 s	46 degrees	3.32 m

Table B.1 Offshore wave characteristics

To obtain the wave characteristics at the location of interest the offshore characteristics are transformed with the 1D wave model SWAN. SwanOne uses the 1D-mode of the full SWAN model. The 1D-mode assumes that the offshore bathymetry can be represented by parallel depth contours such that the bathymetry can be represented by one average line normal to the coast (Figure B.7).

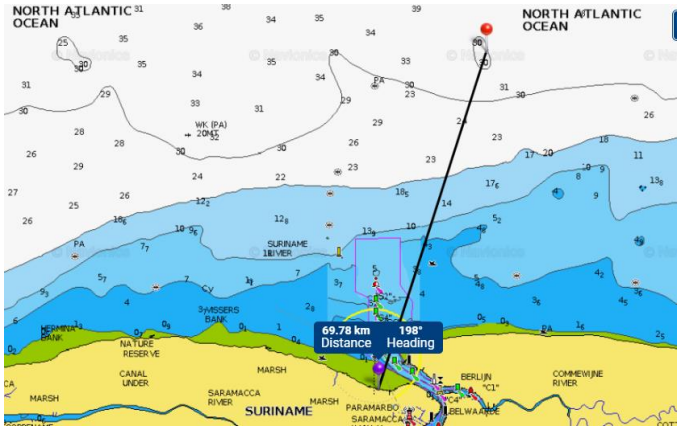


Figure B.7 Bathymetry coast Suriname (Source: Navionics, 2017)

The full SWAN model represents the wave field in terms of the 2D-frequency-direction wave spectrum which then evolves towards the coast including effects of wind, current, water level, depth, shoaling and refraction effects. The initial conditions at the offshore location can be specified in terms of wave parameters:

- For the bathymetry up to 1.7 kilometers, measurement data are used. For the bathymetry more offshore no measurements are available, therefore data from Navionics will be used. Bathymetry: 198 degrees off the normal to the coast, with a distance of 70 km (Figure B.7).
- Wind max: U10 = 14.4 m/s with 60 degrees wind direction.
- Sea waves: $H_{m0} = H_{1/3} = 1.14$ m, $T_p = 5.53$ s, $\theta = 63$ degrees.
  In Figure B.8 and Figure B.9 the input parameters and the orientation with respect to the coast is shown.

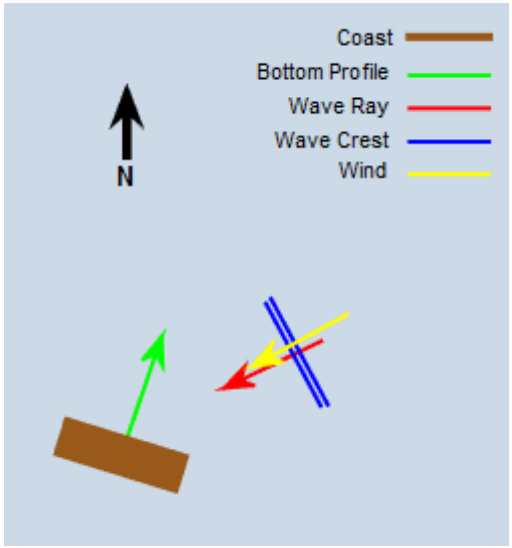


Figure B.8 Orientation of the bottom profile, wave- and wind direction with respect to the coast (Source: own illustration)

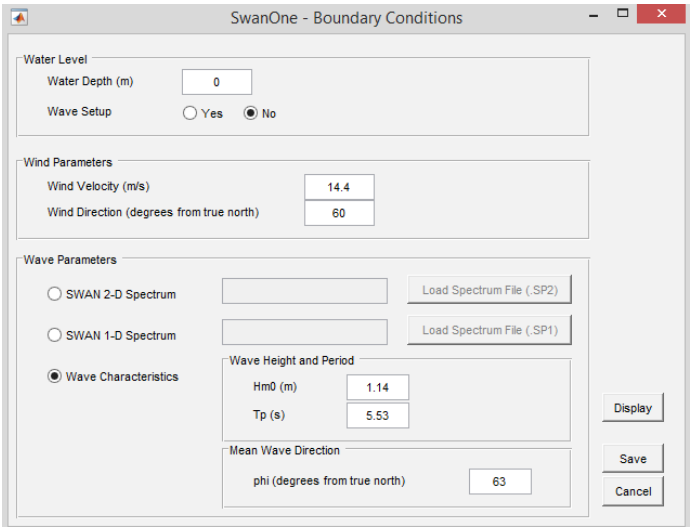


Figure B.9 Input parameters in SwanOne (Source: own illustration)

- **Swell waves:** H_{m0} = H1/3 = 1.67 m, T_p = 8.81 s, θ = 46 degrees.
  In Figure B.10 and Figure B.11 the input parameters and the orientation with respect to the coast is shown.

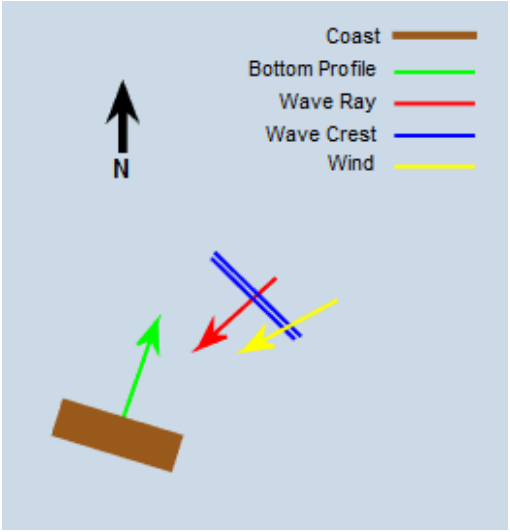


Figure B.10 Orientation of the bottom profile, wave- and wind direction with respect to the coast (Source: own illustration)

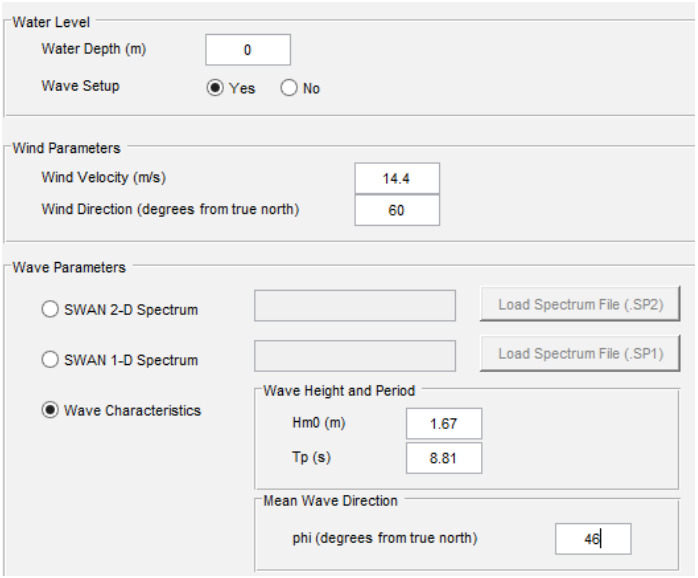


Figure B.11 Input parameters in SwanOne (Source: own illustration)

After all input parameters are set, SwanOne transforms the offshore wave characteristics along the depth line. In the following sections the results are shown. From the obtained results the wave characteristics at the location of interest can be read from the graphs and are shown in Table B.2.

	H_{m0} [m]	T_p [sec]	Dir [degrees]	Maximum setup [m]
Sea waves	0.33	1.88	50	0.045
Swell waves	0.29	1.92	50	0.062

Table B.2 Near shore transformed wave characteristics

Results sea waves

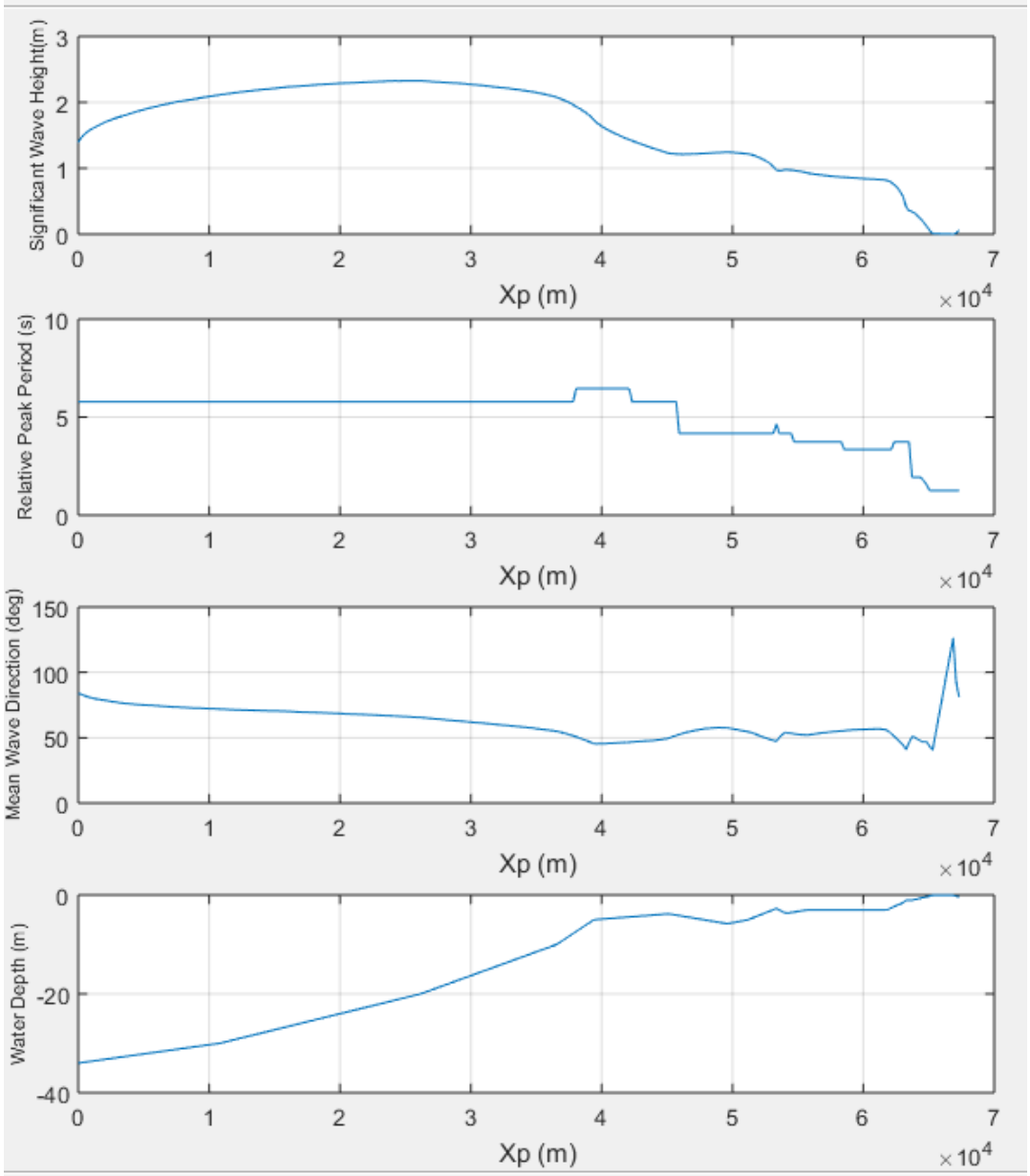


Figure B.12 Results SwanOne for sea waves (Source: own illustration)

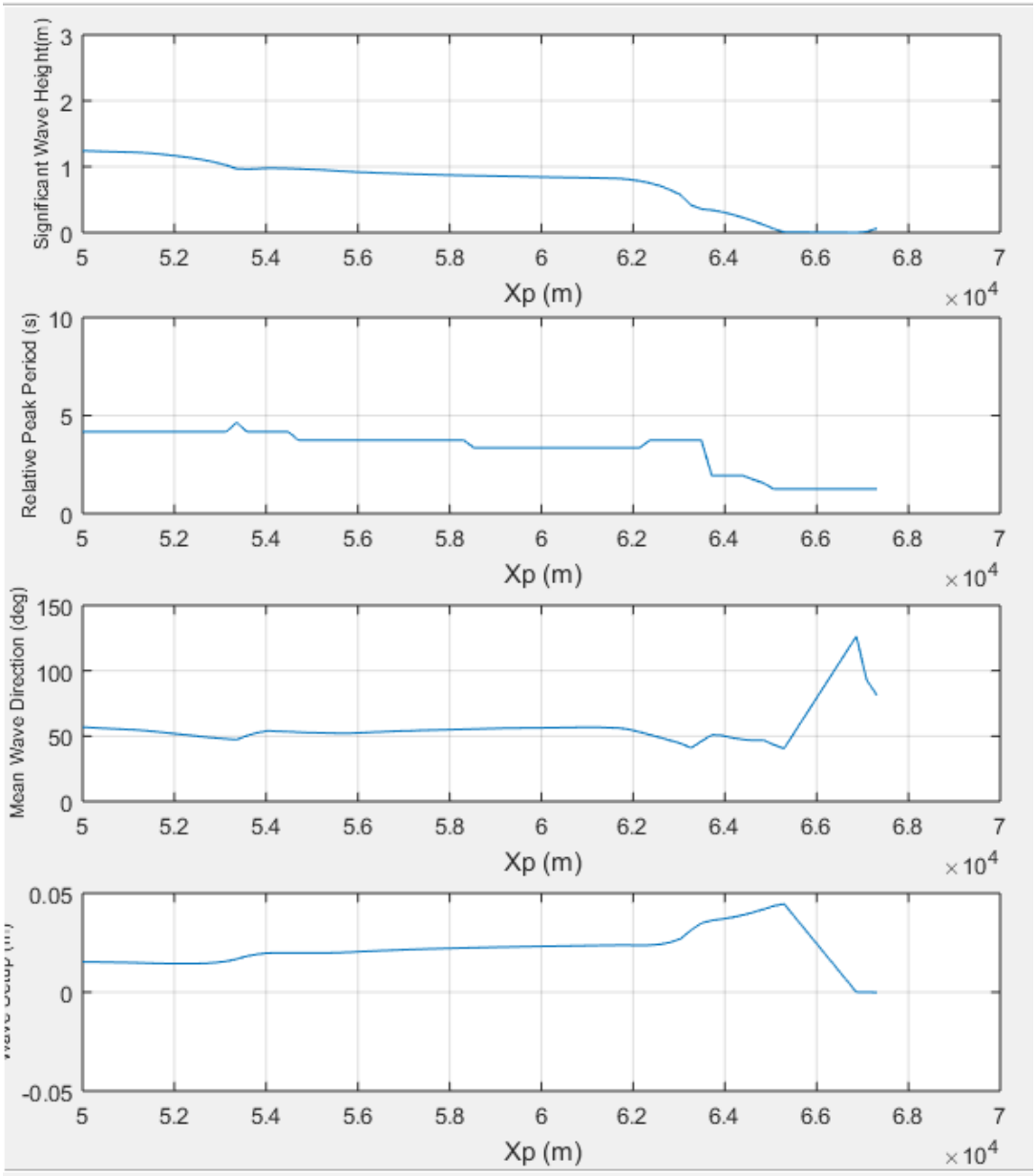


Figure B.13 Results SwanOne for sea wave (Source: own illustration)

Result swell waves

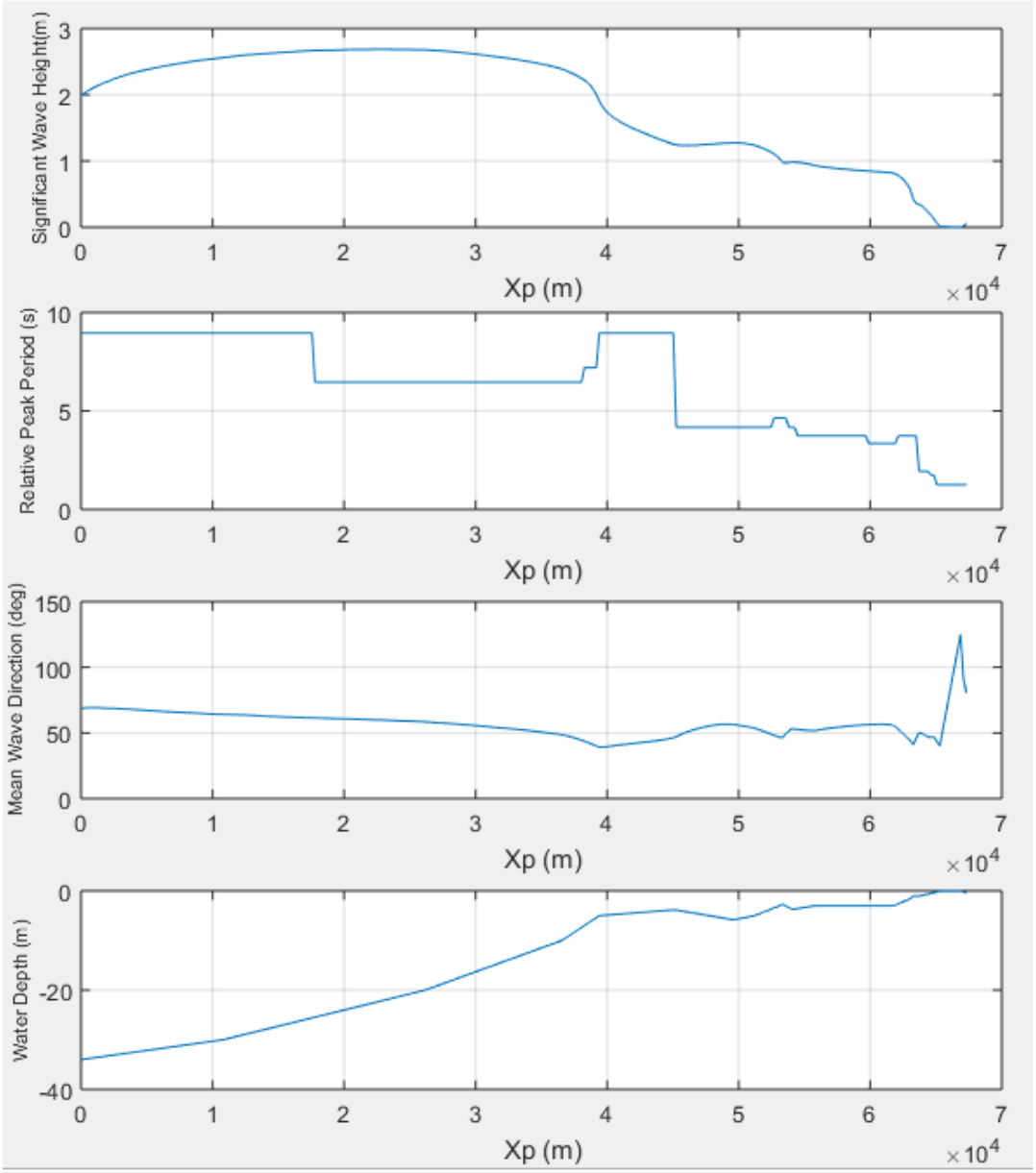


Figure B.14 Results SwanOne for swell waves (Source: own illustration)

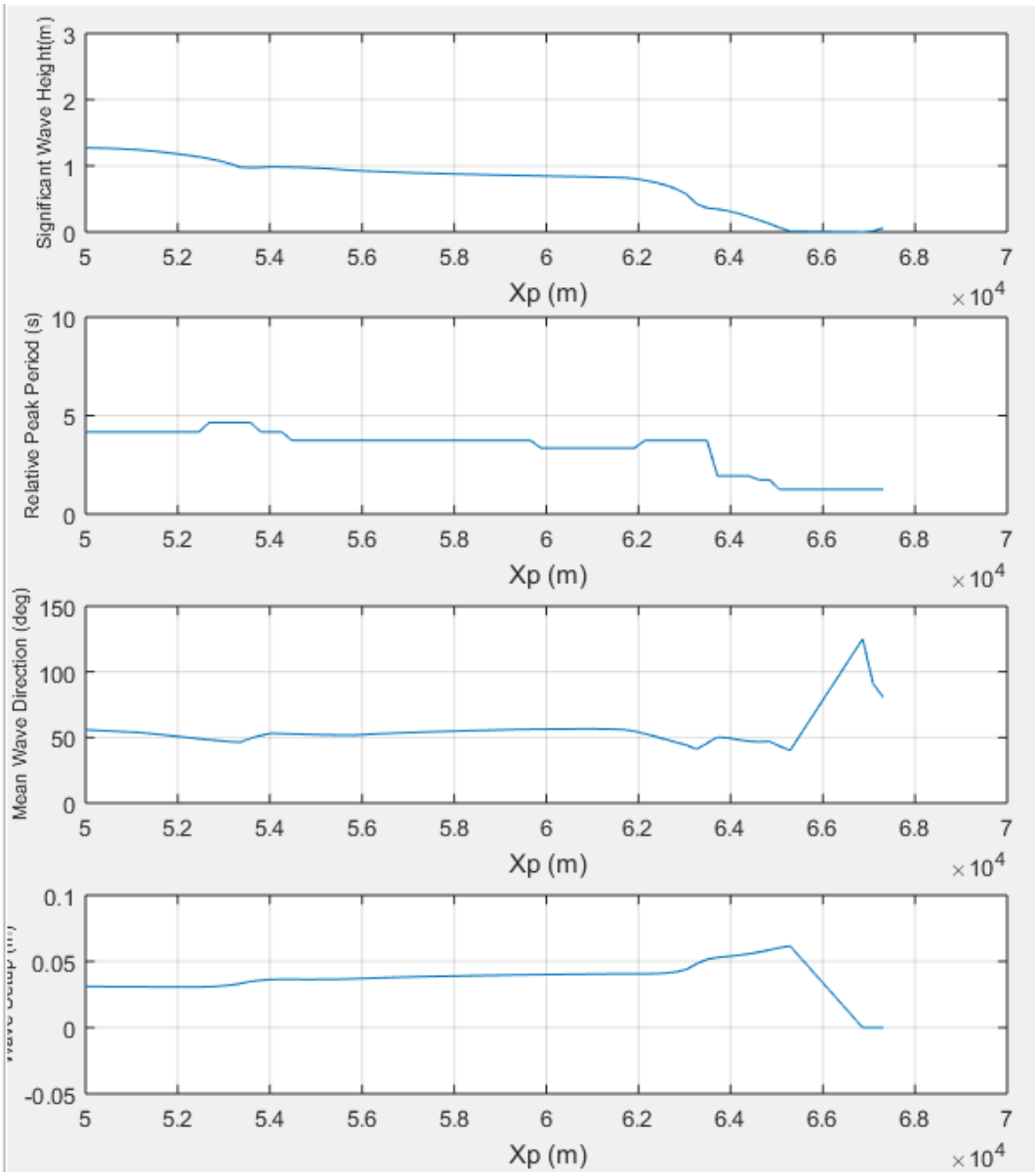


Figure B.15 Results SwanOne for swell waves *(Source: own illustration)*

APPENDIX C. WAVE PATTERNS

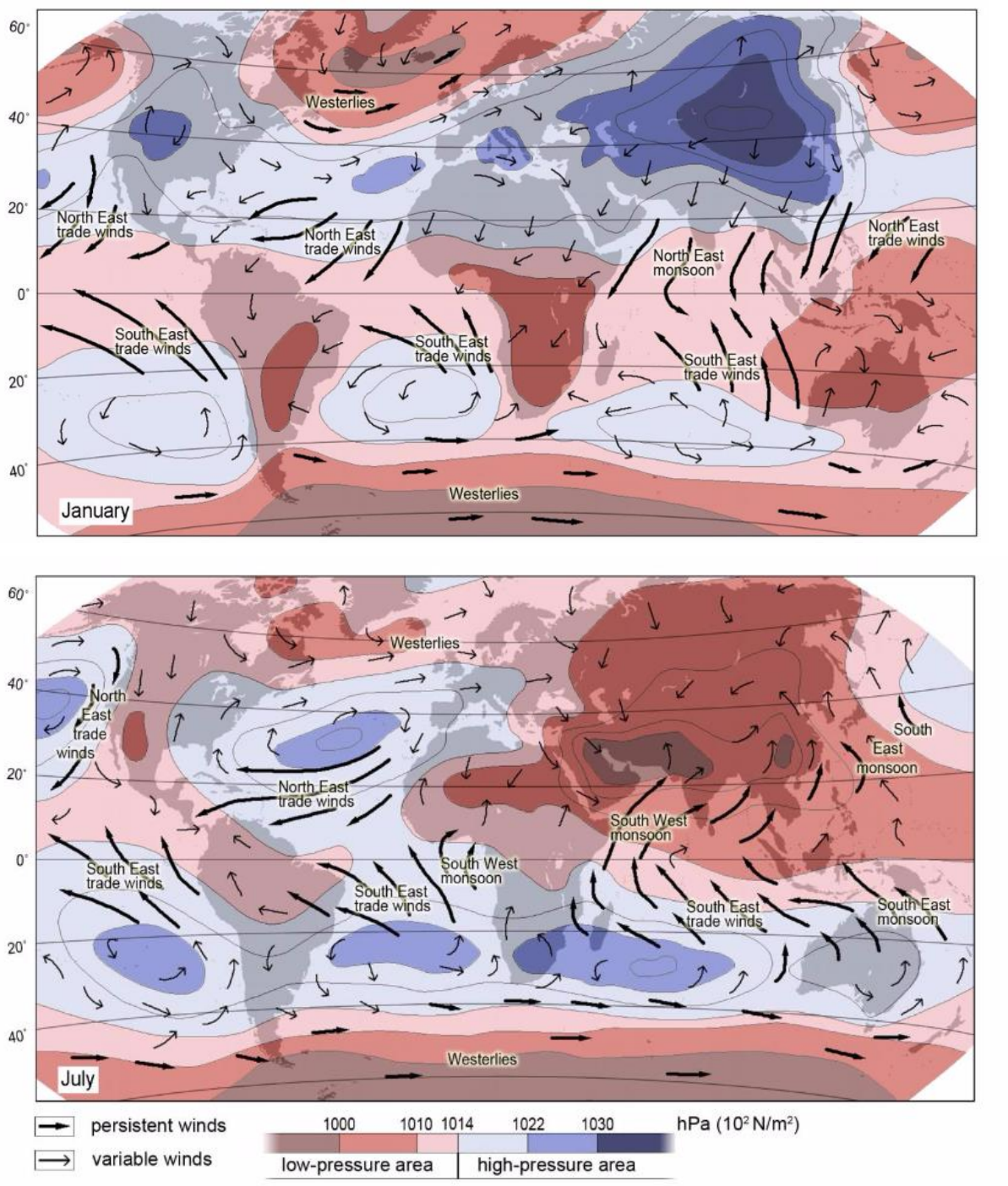


Figure C.1 Wind patterns in January and July (Bosboom et al.,2015)

APPENDIX D. STAKEHOLDER ANALYSIS

In this appendix the entire identification and the analysis of the stakeholders can be found, including tables and models.

D.1 Stakeholder identification

In this section, the stakeholders which have been identified will briefly be explained.

Stakeholder group 1 are the **Inhabitants of the Weg naar Zee** *region* who are affected by the coastal issues in the region.

Stakeholder group 2 is the **Government of Suriname**. In this group, six ministries have been identified for this project. These are: 1) Ministry of Public Works, 2) Transport and Communication, 3) Ministry of Agriculture, Animal Husbandry and Fishery, 4) Ministry of Regional Development, 5) Ministry of Education, Science and Culture and 6) Ministry of Physical Planning, Land and Forest Management.
The stakeholder Cabinet of the President of the Republic of Suriname is taken along as the government led by President D.D. Bouterse shapes its policy and goals for Suriname in government statements and the president's annual speeches (Government of Suriname, n.d.). The stakeholder Planning Office Suriname is taken along as here development plans are formulated, coordinated, monitored and adjusted so that this leads to the promotion of material prosperity in Suriname (Stichting Planbureau Suriname, 2017). All of these governmental stakeholders have been taken along as they are all involved with the coastal issues in the WnZ region.

Stakeholder 3 is the **Anton de Kom University of Suriname (AdeKUS)**. This is the only university in Suriname, located in the capital Paramaribo. This stakeholder is involved in the coastal erosion problem at Weg naar Zee under the direction of Professor of Climate Change and Water, S. Naipal. From 2015 onwards, AdeKUS has started projects in cooperation with other stakeholders to protect the coast in a sustainable way (Starnieuws, 2015).

Stakeholder groups 4 and 5 are the **Agricultural farmers** and **Fishers** (agricultural corporations, animal husbandry, beekeepers and -farmers), who are also being affected by the same coastal issues in the WnZ region.

This also applies to stakeholder 6, the **Place of pilgrimage** and stakeholder 7, **Visitors of the Place of pilgrimage**. The Place of pilgrimage is initially a place for religious Hindus who come there to pray and is used for religious Hindu festivals. This place is also a well-known tourist attraction in Suriname (Ramchand, 2016).

Stakeholder group 8 are **Small-to-medium enterprise (SME) business owners** e.g. grocery shops, cafe, bars and restaurants. These are also affected by the coastal issues in the WnZ region.

Stakeholder group 9 are the **Tourists** and stakeholder group 10 are the **Recreationists** visiting the place or enjoying a day out for e.g. leisure or sightseeing.

Stakeholder 11 is the **Cremation place Weg naar Zee**, which is commonly used for Hindu faithfuls who' would like Weg naar Zee to be their final resting place.

Stakeholder 12 are the **Engineering firms** and stakeholder 13 the **NGOs** who are also quite involved with the coastal issues in the WnZ region.

The final stakeholder, 14, consists of the **Embassies** who have supported the coastal issues of the WnZ region by donating to the mangrove rehabilitation currently undertaken by AdeKUS. The main embassies which have donated are: The Dutch embassy, the American embassy and the Canadian embassy (S. Naipal, personal communication, November 22, 2017).

D.2 Power versus Interest grid

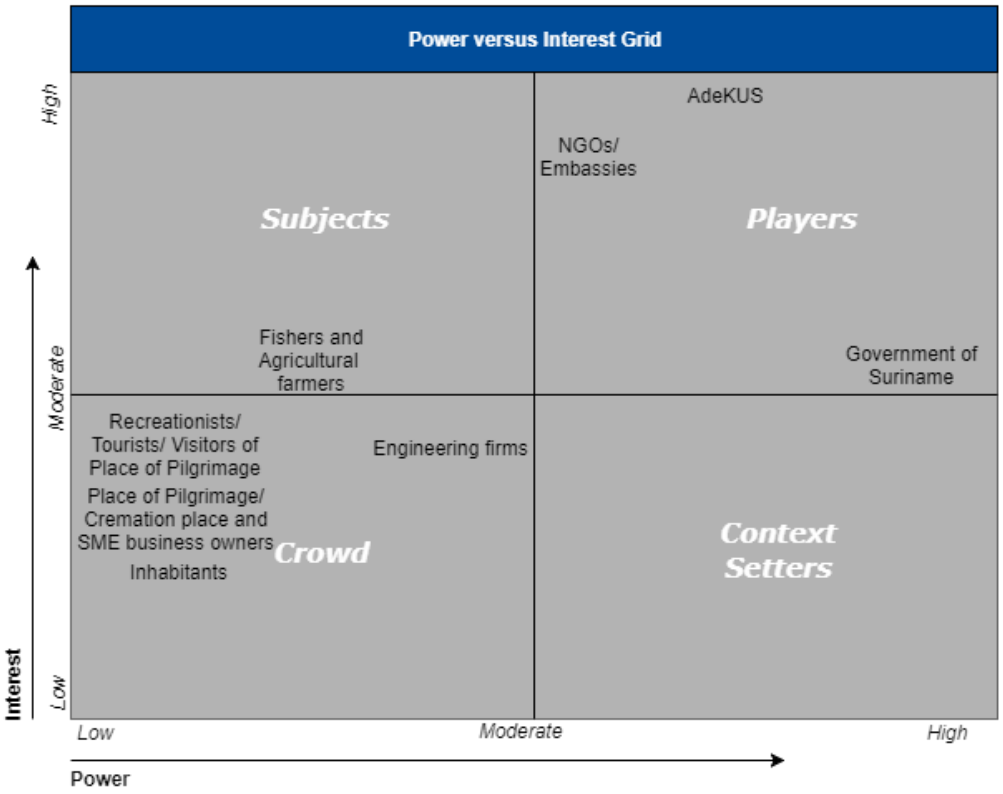


Figure D.1 Power versus Interest grid (Source: own illustration)

The Power vs. Interest grid is used to place stakeholders in a 2x2 matrix, based on their power and interest. This results in the following four stakeholder categories: Crowd, Context Setters, Subjects and Players. This grid helps in identifying the stakeholder positions. Players have a high interest and significant power. Subjects have interest in the issue at hand but have little power to control or influence. Context setters have power, yet they have little interest in the issue. Finally, stakeholders belonging to crowd, have little interest in the issue and little power (Bryson, 2004).

Players cell

The stakeholder *Government of Suriname* has a relative high power and moderate interest. Their interest in sustainable coastal management at WnZ is moderate. Due to the current economic recession of the country this issue does not have high priority for the Surinamese government

(Macdonald, 2017). Their power is high as they have the resources (e.g. capital) for coastal management.
The power of stakeholder *AdeKUS* is between moderate to high power. They do not have high power, because they do not have the government's resources regarding coastal management. Their interest is high, as they are currently actively involved with the Sediment Trapping Units (STUs) at Weg naar Zee (Conservation International Suriname, 2016).
The stakeholder *NGOs* and *Embassies* have moderate to high power, as they have sufficient investment power, but no decision-making power regarding coastal management policies. Their interest is moderate because they are mostly international NGOs, making their interest for the Surinamese coast high, but not extremely high.

Subjects cell

The stakeholder *Engineering firms* have moderate interest, as the government currently does not give enough priority to sustainable coastal management, as explained above. The Government of Suriname also lacks funds for a new WnZ dike as they had payment issues for the Commewijne dike, which was completed in 2017 (Abisoina, 2017). As soon as the sustainable coastal management at WnZ becomes government priority, this stakeholder will switch from moderate to high interested in order to get the tender. Their power is moderate as they have knowledge and tools, but no decision-making power.
Fishers and *Agricultural farmers* have high interest in the issue, as they seek to maintain their profits and have low to moderate power given they produce e.g. fish and crops, which fall under the national production of Suriname. Some of these crops and fish are also exported (Government of Suriname, n.d.).

Crowd cell

The *Inhabitants of the WnZ region*, *Place of Pilgrimage*, *Cremation place WnZ* and *SME business owners* have low power, as the extent to which they can influence the decisions surrounding coastal management is not high. According to the interviews, this group of stakeholders is not heard often, and the authorities takes no action until the situation deteriorates to crisis point (R. Bajnath, personal communication, December 6, 2017).
The *Visitors of Place of Pilgrimage, Recreationists and Tourists* stakeholders have a relatively low interest, given they visit the place and can always make the (rational) choice to visit a different leisure spot, Place of Pilgrimage or sightseeing place. It is also obvious that their power is relatively low concerning the issue (e.g. no decision-making power).

D.3 Resource dependency table

Resource Dependency Table		
	LOW IMPORTANCE	HIGH IMPORTANCE
LOW REPLACEABILITY	- Place of pilgrimage - NGOs - Embassies	- AdeKUS - Government of Suriname - Inhabitants of the Weg naar Zee region

HIGH REPLACEABILITY	- Visitors of Place of pilgrimage - SME-business owners - Tourists - Recreationists	- Fishers - Agricultural farmers - Engineering firms - Cremation place Weg naar Zee

Table D.1 Resource dependency table

This table will classify all the stakeholders of the Weg naar Zee region on the basis of their level of replaceability and importance. These two aspects can be either high or low. The stakeholders are also classified based on the Power vs. Interest Grid from the previous section.

Low Importance - Low Replaceability

The *Place of Pilgrimage* has been categorized in this cell, because after the flooding in 2015 Surinamese government presented a dike plan wherein the Place of Pilgrimage was not taken into account (P-all Projects Supply Suriname N.V., 2015). Therefore, this indicates their level of importance. On the other hand, some unique religious festivals are organized only at this location which makes the Place of Pilgrimage low replaceable (Ramchand, 2016).

The *NGOs* are also not that important, because although some of them have contributed to mangrove projects at WnZ, they are not the designated authority. Furthermore, their funding is limited and big investments in these types of project should not be carried by the NGOs, but by the government themselves. The NGOs interested in the coastal protection in the Weg naar Zee region are low replaceable, as there aren't many NGOs involved in this issue.

Embassies are also low replaceable, given that the involved countries only have one designated embassy. Embassies are categorized as low important, because initially they are representing their country and have other tasks and obligations than to support coastal protection projects in Suriname.

High Importance - Low Replaceability

The *Government of Suriname* is highly important as they are needed for the start (e.g. permits), execution and completion (e.g. capital) of a project. Without their support and backing, building a dike or more Sediment Trapping Units, is impossible.

The stakeholder *AdeKUS* is low replaceable and are highly important as they initiated the pilot project with mangroves and Sediment Trapping Units and possess a lot of knowledge and expertise on this in Professor Naipal (Conservation International Suriname, 2016).

Finally, the *Inhabitants of the Weg naar Zee region* are highly important, because their lives and livelihood are at stake in this coastal defense issue. When it comes to replaceability, it could be discussed that the inhabitants can easily be replaced by letting others live in the area, but from the interview with R. Hardjo inhabitants (personal communication, December 8, 2017) some interesting information was gained. According to him, the grounds of the northern part of the WnZ region, particularly neighbourhood 1 and 2, are mainly government lease. Despite that, almost every resident has built their own house and made other investments. This issue is politically very sensitive in Suriname and procedurally almost impossible to replace this group with new. Therefore, this stakeholder is low replaceable.

Low Importance - High Replaceability

The *Visitors of Place of Pilgrimage, Tourists, Recreationist* and *SME business owners* are low important as they have no influence on the start and completion of a project. They are also highly replaceable as

new visitors, new SME business owners, new tourists and new recreationists can be attracted to the WnZ region.

High Importance - High Replaceability

Finally, the fourth cell categorizes the high importance and high replaceability stakeholders. *Fishers* and *Agricultural farmers* are highly replaceable, as there can always be new fishers and new farmers. However, they are highly important, as they are needed for the development of not only the region, but also for the country as they contribute to the national production of Suriname.

The *Engineering firms* are highly replaceable, because there are other engineering firms who can participate in the coastal protection issues. These do not have to be local and on an international level there are more than enough engineering firms available. The Engineering firms are highly important as they are the ones who will execute coastal protection projects as they have the manpower, knowledge, tools and expertise for doing so. They can thus be seen as a key player when it comes to their importance in starting and completing coastal protection projects.

The *Cremation place Weg naar Zee* is quite an important stakeholder as they are the only one in Paramaribo and surroundings since its existence. Compared to the Place of Pilgrimage, the Cremation place generates less income, making it more difficult for the management team to proprietary measures against flooding. That is why there have been plans since the flooding of 2015 to move this place even more to the south (R. Hardjo, personal communication, December 8, 2017). Therefore, the Cremation place Weg naar Zee is highly replaceable.

D.4 Critical actor table

Critical Actor Table			
ACTOR	REPLACEABILITY (HIGH/LOW)	DEPENDENCY (LOW/MODERATE/HIGH)	CRITICAL ACTOR (YES/NO)
Inhabitants of the Weg naar Zee region	Low	High	Yes
Government of Suriname	Low	High	Yes
AdeKUS	Low	High	Yes
Fishers	High	Moderate	No
Agricultural farmers	High	Moderate	No
Place of pilgrimage	Low	Low	No
Visitors of Place of pilgrimage	High	Low	No

SME-business owners	High	Low	No
Tourists	High	Low	No
Recreationists	High	Low	No
Cremation place Weg naar Zee	Low	Low	No
NGOs	Low	Moderate	No
Engineering firms	High	Low	No
Embassies	Low	Low	No

Table D.2 Critical actor table

The Critical Actor Table is necessary for deciding which stakeholder is critical/noncritical. This is done on the basis of each stakeholders' replaceability and dependency. The replaceability can either be low/high and the dependency can either be low/moderate/high. The level of replaceability was already determined in the resource dependency table (Table D.1). The dependency is based on the stakeholders' power and importance. When a stakeholder has a high dependency and a low replaceability level, they become a critical actor. A stakeholder is counted as a noncritical actor when it has a high replaceability level and a low dependency level.

D.5 Stakeholder Map

	Dedicated Actors		Non-Dedicated Actors	
	CRITICAL ACTORS	NON-CRITICAL ACTORS	CRITICAL ACTORS	NON-CRITICAL ACTORS
ACTORS WITH SAME PERCEPTION, INTERESTS AND GOALS	- AdeKUS - Government of Suriname	- NGOs - Embassies		- Tourists - Recreationists - Visitors of Place of pilgrimage
ACTORS WITH DIFFERENT PERCEPTION, INTERESTS AND GOALS	- Inhabitants of the Weg naar Zee region	- Fishers - Agricultural farmers - Place of pilgrimage - Cremation place Weg naar Zee - SME-business owners		

Table D.3 Stakeholder map

The Stakeholder Map is made with the results of the Resource Dependency table and the stakeholder identification table. In the Stakeholder Map, a division is made between dedicated/non-dedicated actors. Also, a distinction is made between actors with the same or different perception, interests and goals.

The dedication of the stakeholders is determined on the basis of their position in the resource dependency table. For this project it is assumed that stakeholders with a higher degree of importance are more dedicated than other stakeholders who are less important. Stakeholders with the same perception, interests and goals are positioned based on their focal interest. For example, the stakeholders who are critical actors and are focused on protecting the coast (a complementary perception), have the same goal.

D.6 Problem-frame stakeholder map

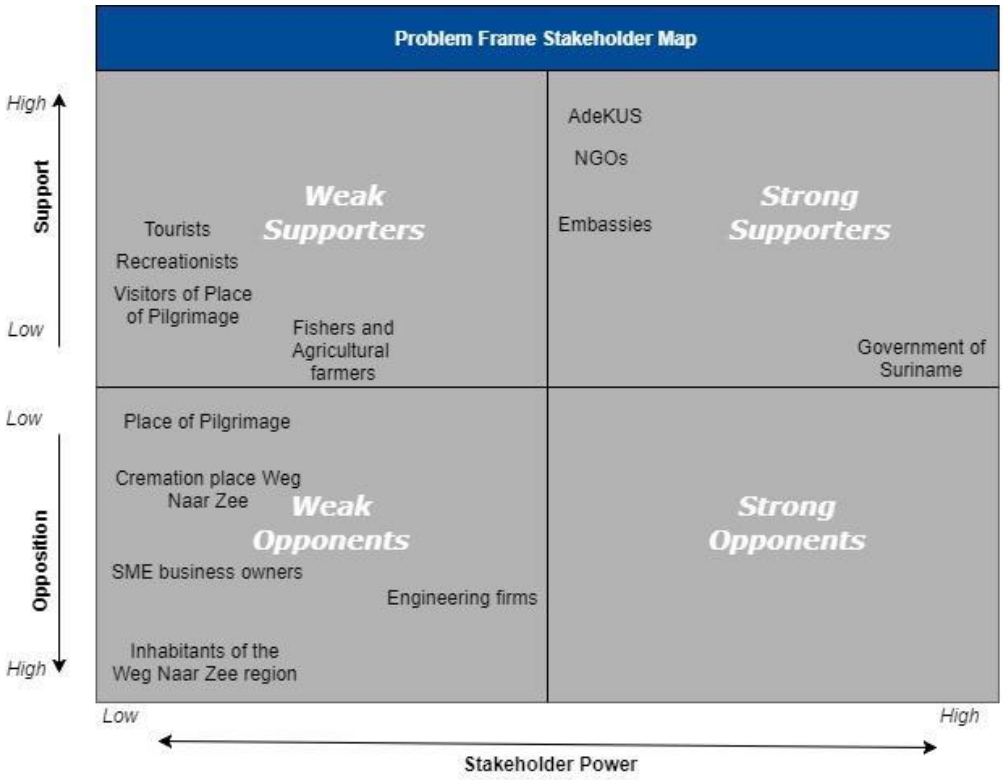


Figure D.2 Problem-Frame Stakeholder map (Source: own illustration)

The Problem-frame stakeholder map is convenient in helping to construct problem definitions which may probably lead to winning partnerships. When preferable problem definitions are found which can inspire action by an alliance of stakeholders that is large enough, this can procure selection of favored solutions and also safeguard them during execution (Bryson, 2004). The Problem-frame stakeholder map is a crucial step in connecting stakeholders to different problem definitions.

Weak Supporters

The stakeholders *Tourists, Recreationists, Visitors of Place of Pilgrimage* are categorized as weak supporters. It has emerged from the presentations during the UNDP Climate Conference in Paramaribo that this group of stakeholders are supportive when it comes to coastal protection in a

sustainable way (U. Satnarain, personal communication, December 13, 2017). On the other hand, they have low power to influence coastal protection decisions.
The stakeholders *Fishers* and *Agricultural farmers* have a little bit more power than the previous stakeholder group, because of their contribution to the national production and eventually Suriname's export industry. Bajnath (personal communication, December 6, 2017) stated that their support is on the same level as the earlier mentioned stakeholder group, making them weak supporters.

Strong Supporters

The stakeholders *AdeKUS* and *NGOs* fall under the category of strong supporters because they have high support but also valuable resources (AdeKUS: tools/knowledge; NGOs: capital) for finding a solution to protect the coast at Weg naar Zee. They are also both strong supporters of mangroves as coastal protection which involves the Sediment Trapping Units (STUs). Both stakeholders have moderate power (subparagraph 3.1.1).
The stakeholder *Embassies* also has a moderate interest in mangroves as coastal protection. It is less, because they do not have the same resources compared to AdeKUS and the NGOs. To give meaning to this statement, it is to be pointed out that the NGO, Conservation International Suriname, has invested in STUs themselves after the 'Building with Nature' pilots by Professor Naipal of AdeKUS turned out to be successful (Conservation International Suriname, 2016). The embassies have moderate power.
Finally, the *Government of Suriname* currently has low interest in protecting the WnZ coast. The Suriname president has indicated in his annual speech of 2016 that planting mangroves must be continued and eventually supported with the construction of dikes (Kabinet van de president, 2016). However, to date little of this support has been observed, partly because of the lack of financial means since Suriname is struggling with an economic crisis and partly because it was more of a political media stunt (A. Amatali, personal communication, December 7, 2017). The stakeholder power of the government is high, because they have the planning power, decision-making power, they issue permits and are in charge with executing this type of projects.

Weak Opponents

The stakeholders *Inhabitants of the Weg naar Zee region, Cremation place Weg naar Zee, Place of Pilgrimage* have low stakeholder power, because their influence on coastal erosion issues is marginal. They are currently not supporting mangroves as coastal protection (S. Naipal, personal communication, November 21, 2017). As time developed, the STUs were build and the neighbouring Place of Pilgrimage saw its consequences. Therefore, this actor is now more open to mangroves as coastal protection approach, but still prefers a dike (R. Bajnath, personal communication, December 6, 2017). For this reason, this stakeholder is not a strong opponent, but a weak opponent. On the other hand, the majority of the residents do not want wet feet and persist that the government is obliged to build a dike, making them a strong opponent of mangroves as coastal protection
The *SME business owners* and *Cremation Place Weg naar Zee* also have low stakeholder power for the same reason as the other stakeholders in this category. The only difference is that their opposition is not low, but moderate. The reason is that they believe that the dike is the best solution, given that they do not have the patience for the mangroves to grow (R. Hardjo, personal communication, December 8, 2017).

The stakeholder *Engineering Firms* have low-moderate stakeholder power. The reason why is that they do not have the decision-making power the government has, but they are necessary for either solutions 1) mangroves as coastal protection or 2) building a dike, which the Surinamese government will choose. They are strong opponents, because the main goal of these firms is to make profit. Making profit means they want to build the dike and win this tender, as more money is involved in this solution.

D.7 Stakeholder typology

Stakeholder Typology Table			
TYPOLOGY	CHARACTERISTICS	STAKEHOLDERS	HOW TO DEAL WITH THEM
Acquaintance	Insignificant Passive Backer	Tourists Recreationists Visitors of Place of pilgrimage	Need to be kept informed so they keep supporting
Sleeping Giant	Influential Passive Backer		Need to be engaged to wake them up, and support
Saviour	Influential Active Backer	AdeKUS Government of Suriname	You should do whatever is needed to satisfy them
Friend	Insignificant Active Backer	Embassies Agricultural farmers Fishers NGOs	Should be used as a confidant or sounding board
Saboteur	Influential Active Blocker		Need to be engaged in order to disengage
Irritant	Insignificant Active Blocker	Inhabitants of the Weg naar Zee region Cremation place Weg naar Zee SME-business owners Place of pilgrimage	Need to be engaged so that they 'stop' to block
Tripwire	Insignificant Passive Blocker	Engineering firms	Need to be understood to avoid tripping up
Time Bomb	Influential Passive Blocker		Need to be understood, before the bomb goes off

Table D.4 Stakeholder Typology

D.8 Stakeholder Interview list

Name	Occupation	Stakeholder
Mr. Ramon Bajnath	Hindu priest/ Manager	Place of Pilgrimage
Mr. Wim Bajnath	Chairman of Landbouwcoöperatie Kwatta	Agricultural farmers
Mr. Armand Amatali	Head civil servant of the Water department	Ministry of Public Works, Transport and Communication
Mr. Rin Hardjo	Chairman of neighbourhood association	Inhabitants of the WnZ region
Mr. Rabinderpersad Hanoeman	Chairman of the Weg Naar Zee region council	Inhabitants of the WnZ region
Mr. Maurice Kromoredjo	Assistant of Professor S. Naipal	AdeKUS
Mr. Xaviero van Ams	Assistant of Professor S. Naipal	AdeKUS
Mr. Sieuwnath Naipal	Professor of Water and Climate Change	AdeKUS

Table D.5 Interviewed stakeholders

The stakeholder typology model has been derived from Murray-Webster & Simon (2006). In this model eight stakeholder types are identified. This identification is done through an assessment of the stakeholders' interest, power and attitude. The stakeholders' interest and power are gathered from the previous grids. The stakeholder' attitudes are gathered from assessing the Stakeholder Map. Each stakeholder type has certain characteristics, which can be found in the table below.

The most interesting finding from the stakeholder typology is that the stakeholder *AdeKUS* and *Government of Suriname* are of the type **saviours.** This means they have the following characteristics: Influential, active and backer. The best way to deal with them is to do whatever is needed to satisfy these stakeholders. Finally, the stakeholder *Inhabitants of the Weg naar Zee region*, *Cremation place Weg naar Zee*, *SME business owners* and *Place of Pilgrimage* are of the type **irritant**. This means they have the following characteristics: Insignificant, active and blocker. The best way to deal with them is to engage them so that they do not block the project or process, as they could have this power.

Although the stakeholder *Government of Suriname* is currently classified as the 'saviour' type, the current economic crisis can have an impact on their stakeholder position, such that they could shift from 'saviour' to 'saboteur' (MacDonald, 2017). On the other hand, the stakeholder *Place of Pilgrimage* is currently classified as 'irritant', but it has been observed that they are now more open to support mangroves as coastal management measure. This means that there is a possibility that in the near future this stakeholder's position can shift from 'irritant' to 'friend' (R. Bajnath, personal communication, December 6, 2017).

APPENDIX E. SURVEY

This appendix belongs to chapter 4 of the report and contains the data for determining the survey population in paragraph E.1. The entire survey can be found in paragraph E.2. The results of the conducted survey are displayed in paragraph E.3

E.1 Data Weg naar Zee households

In this appendix some data that was needed in order to determine the survey population is presented. First of all, it was necessary to gain data about the number of households per street in the Weg naar Zee region which would be surveyed. As this data was not available at ABS, it was decided to count the number of households on the basis of the latest satellite photo of Google Maps (2017) which can be seen in Figure E.1. In Table E.1, the number of households is indicated per neighbourhood.

Neighbourhood	Total number of households
Neighbourhood 1	85
Neighbourhood 2	33
Neighbourhood 3	57
Neighbourhood 4	26
Neighbourhood 5	12
Neighbourhood 6	35
Total	**248**

Table E.1 Number of households per neighbourhood

Figure E.1 The scope of the WnZ region that was used for determining the survey population (Source: Google Maps, 2017)

After this was completed, the following statistical data was applied in order for the survey data to be reliable.

Acceptable margin of error	5%
Level of confidence	95%
Study population	496
Variation	50%

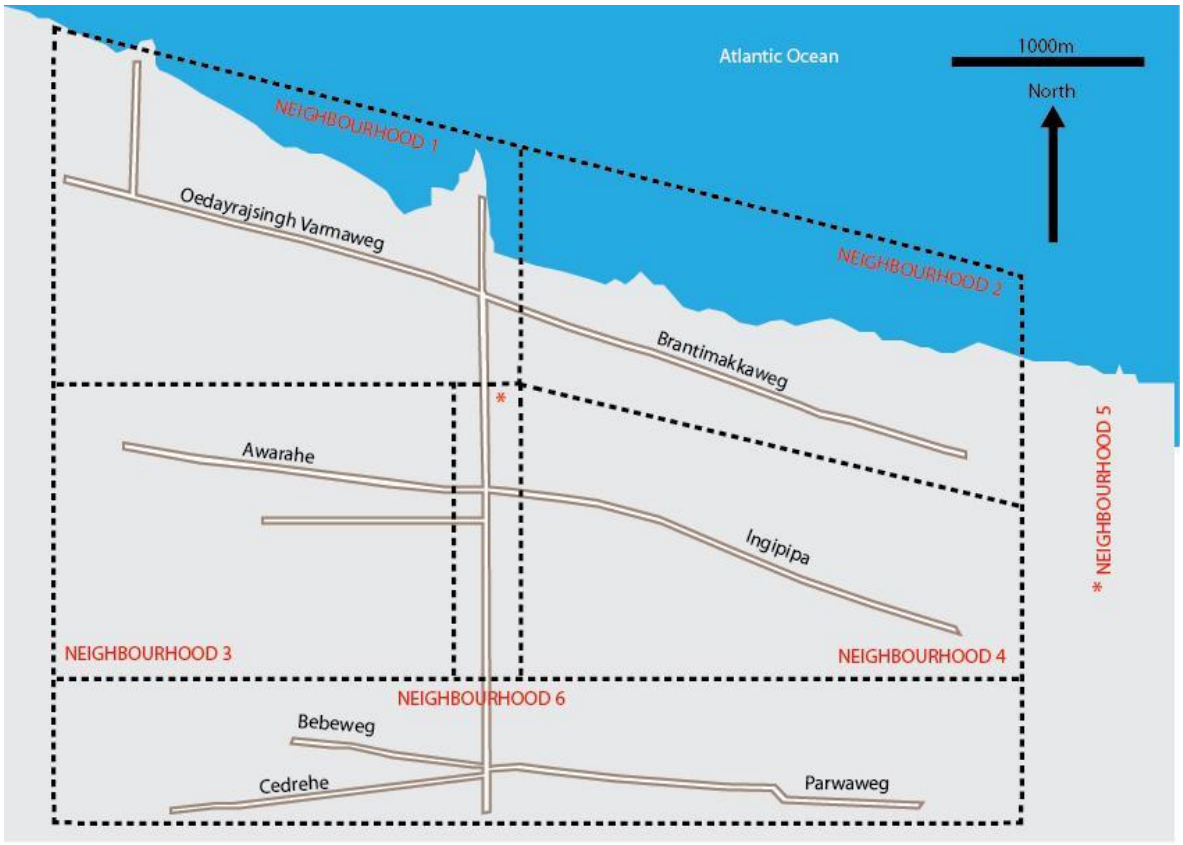
Table E.2 Factors for determining sample population (Source: Baarda & De Goede, 2006)

E.2 Survey

This section will present the survey which was used. The language of the survey was in Dutch, as this is the official language in Suriname. The survey was conducted in two full days with the help of bachelor and master students from AdeKUS. The 32 survey questions and their answers have been translated into English, to make it more compatible with the result graphs which are in English.

Survey Weg naar Zee by Mangrove Project Suriname

Question 1. In which Weg Naar Zee neighbourhood do you reside? Use the map for an indication of each of the six neighbourhoods.



- Neighbourhood 1
- Neighbourhood 2

- Neighbourhood 3
- Neighbourhood 4
- Neighbourhood 5
- Neighbourhood 6

Question 2. What is your gender?

- Male
- Female

Question 3. What is your ethnicity?

- Indian
- Javanese
- Afro-Surinamese
- Other

Question 4. What is your highest level of education?

- GLO
- LTS
- LBGO
- MULO
- SPI/CPI/IMEAO
- NATIN/AMTO
- HAVO/VWO
- HBO/WO

Question 5. What is the tile of the land you are currently living on?

- Full ownership
- Government lease
- Rent
- Not applicable

Question 6. What is your daily occupation?

- Agriculture
- Fishery
- Animal husbandry
- Poultry farming
- Beekeeping
- Entrepreneur
- Market vendor
- Civil servant
- Retired
- Unemployed

Question 7. Are you satisfied with your own safety against flooding in the WnZ region?

Very satisfied 0 0 0 0 0 Very dissatisfied

Question 8. Are you willing to move to a safer place?

- Yes
- No
- Maybe

Question 9. Are you aware with the fact that Suriname is in the top 10 of most endangered countries facing sea level rise?

- Yes
- No

Question 10. Are you aware that the climate is changing and if so, which of the following could be the cause(s)?

- Yes, sea level rise
- Yes, land loss
- Yes, flooding
- Yes, heavy showers
- Yes, violent gusts/whirlwinds
- Yes, less fish
- Yes, less birds
- Yes, salt intrusion
- Yes, sun is brighter than before
- Yes, the four climate seasons of Suriname are not stable
- No, didn't notice anything

If the respondent answered NO on question 10, proceed to question 14. If the respondent answered YES on question 10, continue with question 11.

Question 11. How many years ago did you first witness the sea level rise at WnZ?

- 0 - 5 years ago
- 5 - 10 years ago
- 10 - 20 years ago
- 20+ years ago
- I don't know the period
- I haven't witnessed sea level rise

Question 12. Did you experience any burden from flooding?

- Yes
- No

Question 13. If you received any burden from flooding, which measures did you apply against it?

- _____

Question 14. Do you know what a Sediment Trapping Unit (STU) is?

- Yes, I know what a STU is; I know how it works
- Yes, I know what a STU is; I don't know how it works
- No, I don't know what a STU is

Question 15. Do you know what a dike is and how it works?

- Yes, I know what a dike is; I know how it works
- Yes, I know what a dike is; I don't know how it works
- No, I don't know what a dike is

Question 16. Which of the following options is the most favourable for you?

- Dike of concrete
- Dike with rubber tire/sand
- Sediment Trapping Units (STUs)
- Combination of STUs with a dike
- Move from WnZ region
- No coastal protection

Question 17. If a dike should be build, who should pay for it?

- Government
- Businesses
- Inhabitants of the Weg naar Zee region
- Place of pilgrimage
- Surinamese locals
- All of above parties
- Government and Surinamese locals
- Government and businesses
- Government and Place of pilgrimage
- Other countries

Question 18. Are you willing to contribute to the dike if it is constructed?

- Yes: Labour
- Yes: Knowledge
- Yes: Money
- Yes: Voluntarily giving up my land to the government
- Yes: Maintenance of the dike when it is constructed
- Yes: Labour, Knowledge, Money, Voluntarily giving up my land to the government and Maintenance of the dike when it is constructed.
- No

Question 19. Did you know that mangroves can protect the coast?

- Yes
- No

Question 20. Did you know that you can earn money with mangroves?

- Yes
- No

Question 21. In the case you weren't aware of mangroves, would you like to know more about it?

- Yes
- No

Question 22. Are you willing to follow a training, etc. for a job in a mangrove related sector such as: Fishery, ecotourism, etc?

- Yes
- No
- Maybe

Question 23. Which sectors will experience the most burden in case of an eventual flooding?

- Agriculture
- Animal husbandry
- Fishery
- Cremation place
- Place of pilgrimage
- Businesses
- Housing sector

Question 24. Did you notice any changes in the nature after the STUs were built in 2015?

- Land acquisition
- Land loss
- Less birds
- More birds
- Less fish
- More fish
- Growth of mangroves
- Loss of mangroves
- Higher waves
- Waves are being broken further from the coast line
- No changes

Question 25. How do you momentarily obtain information about climate change (sea level rise, floods, erosion)?

- Radio
- Television
- Newspapers
- Internet
- Social media (Facebook, Twitter, etc.)
- Door-to-door visits
- I don't get any information

If agriculture is a source of income for the respondent, continue with questions 26 through 28.

Question 26. Are you content with your harvest in 2017?

Very satisfied 0 0 0 0 0 Very dissatisfied

Question 27. What could be the reason that your harvest in 2017 is more/less than your harvest in 2014?

- _____

Question 28. What can be done according to you, to improve the agricultural sector?

- _____

If animal husbandry is a source of income for the respondent, continue with questions 29 through 31.

Question 29. Are you content with the animal husbandry sector nowadays (2017)?

Very satisfied 0 0 0 0 0 Very dissatisfied

Question 30. What could be the reason that the animal husbandry sector in 2017 has grown/stagnated compared to 2014?

- _____

Question 31. What can be done according to you, to improve the animal husbandry sector?

- _____

Question 32. In which age category do you belong?

- 18
- 25
- 25 - 35
- 35 - 45
- 45 - 60
- 60+

E.3 Survey results

This section will present all of the survey results and additional relations which were found through analyzing the survey results.

Results Question 1:

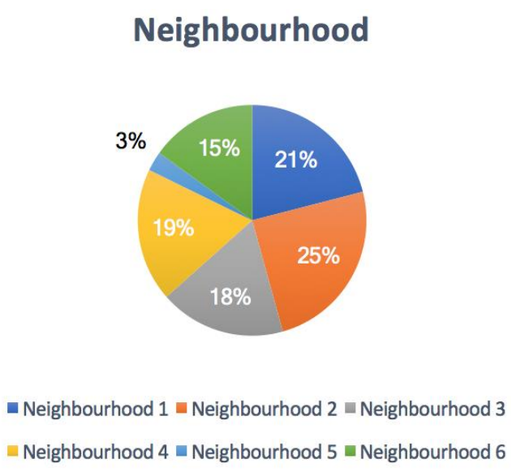


Figure E.1: Survey result for question one (Source: Own illustration)

Results Question 2:

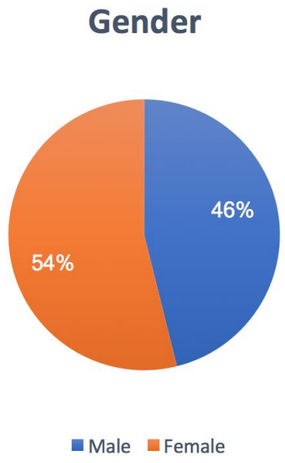


Figure E.2: Survey result for question two (Source: Own illustration)

Results Question 3:

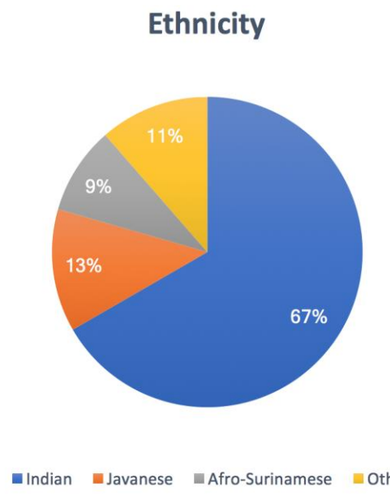


Figure E.3: Survey result for question three (Source: Own illustration)

Results Question 4:

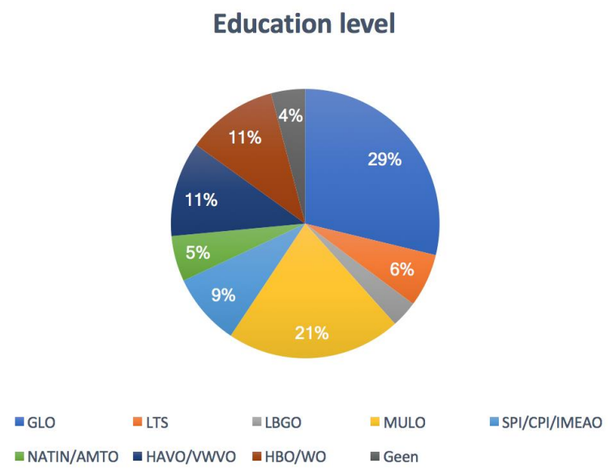


Figure E.4: Survey result for question four (Source: Own illustration)

Results Question 5:

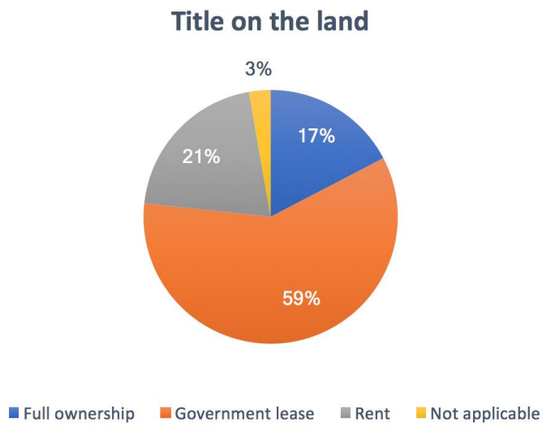


Figure E.5: Survey result for question five (Source: Own illustration)

Results Question 6:

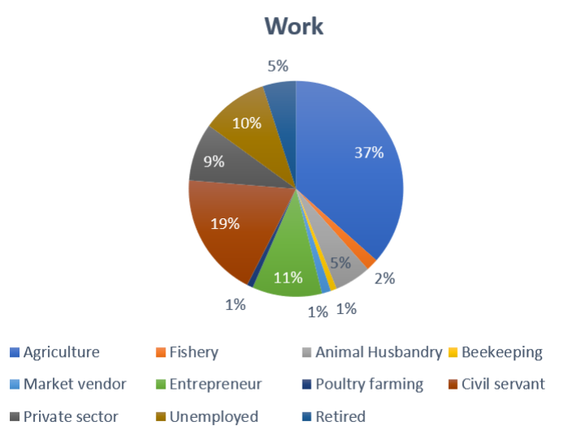


Figure E.6: Survey result for question six (Source: Own illustration)

Results Question 7:

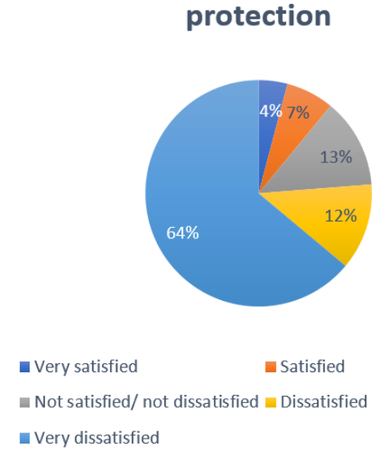


Figure E.7: Survey result for question seven (Source: Own illustration)

Results Question 8:

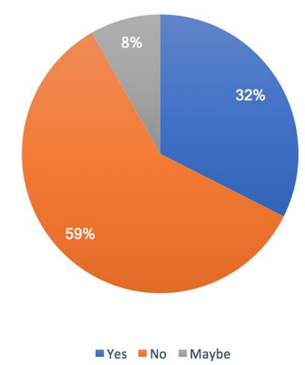


Figure E.8: Survey result for question eight (Source: Own illustration)

Results Question 9:

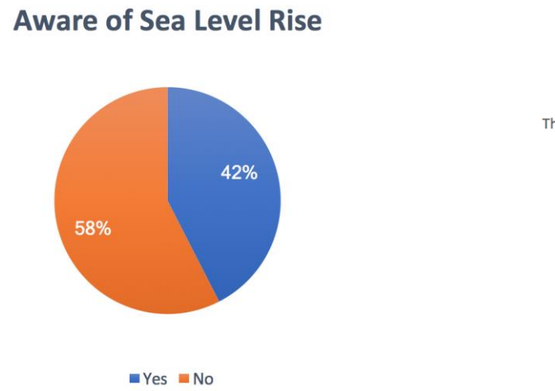


Figure E.9: Survey result for question nine (Source: Own illustration)

Results Question 10:

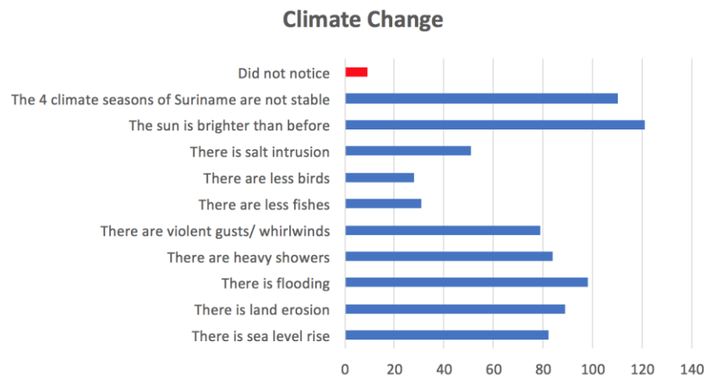


Figure E.10: Survey result for question ten (Source: Own illustration)

Results question 11:

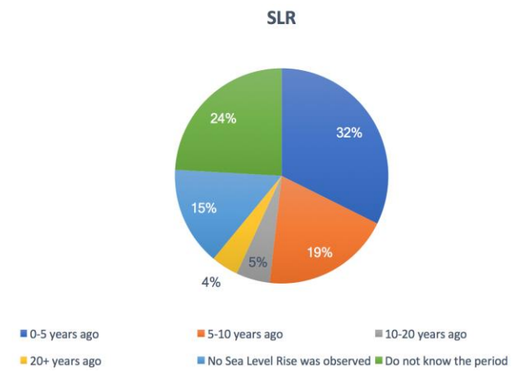


Figure E.11: Survey result for question eleven (Source: Own illustration)

Results Question 12:

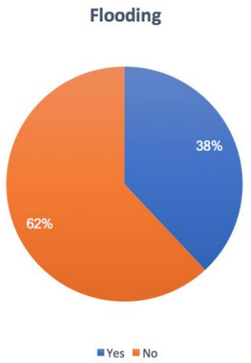


Figure E.12: Survey result for question twelve (Source: Own illustration)

Results Question 13:`

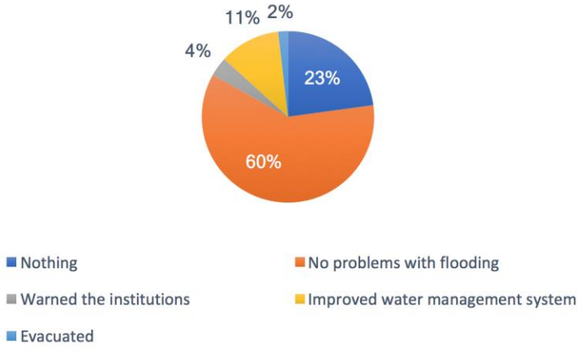


Figure E.13: Survey result for question thirteen (Source: Own illustration)

Results Question 14:

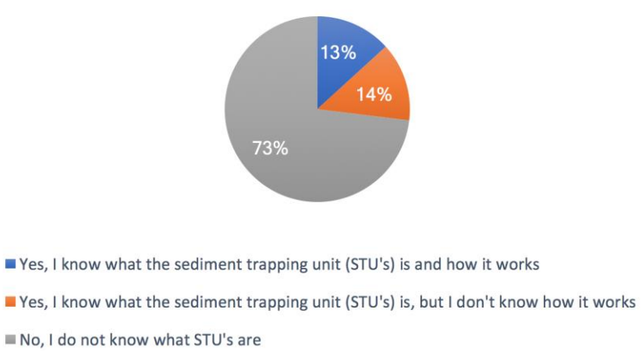


Figure E.14: Survey result for question fourteen (Source: Own illustration)

Results Question 15:

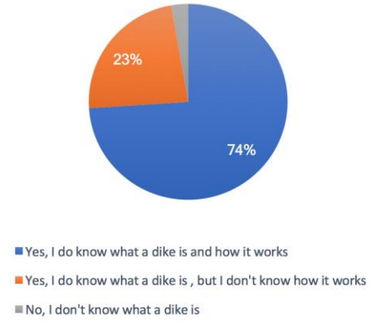


Figure E.15: Survey result for question fifteen (Source: Own illustration)

Results Question 16:

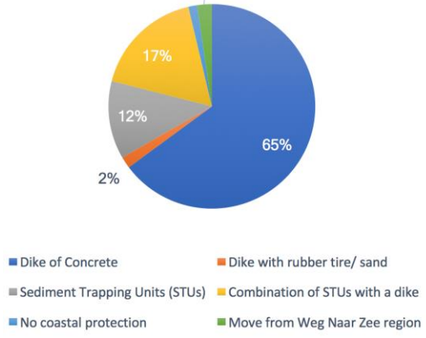


Figure E.16: Survey result for question sixteen (Source: Own illustration)

Results Question 17:

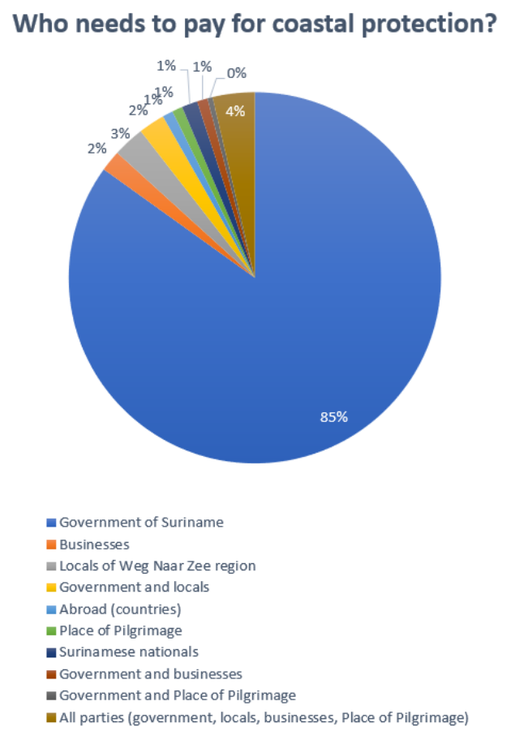


Figure E.17: Survey result for question seventeen (Source: Own illustration)

Results Question 18:

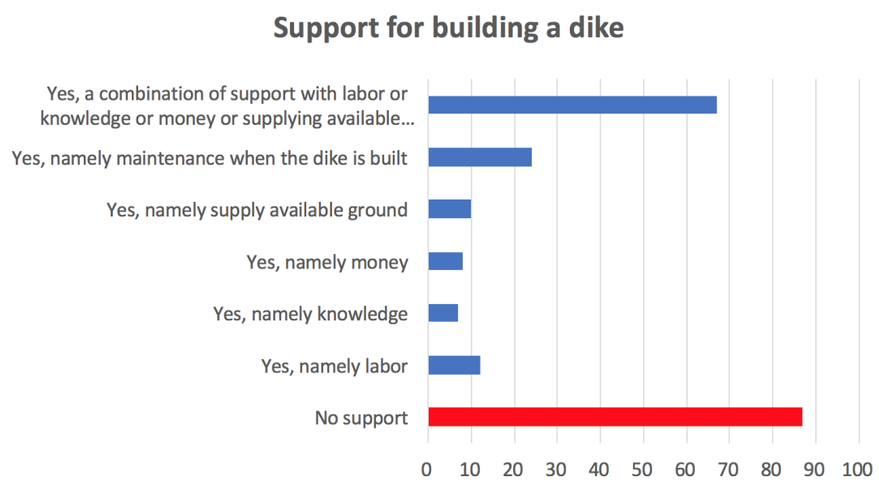


Figure E.18: Survey result for question eighteen (Source: Own illustration)

Results Question 19:

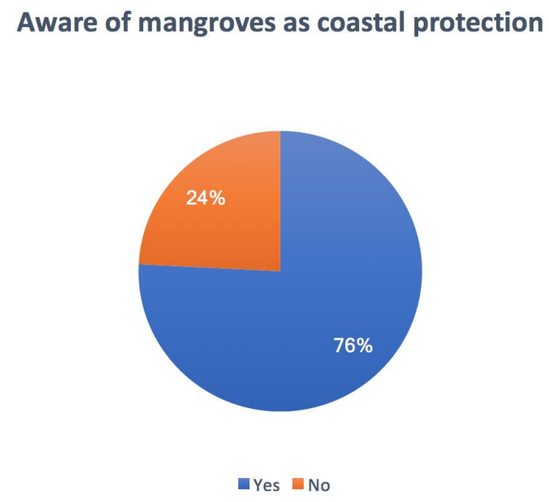


Figure E.19: Survey result for question twenty (Source: Own illustration)

Results Question 20:

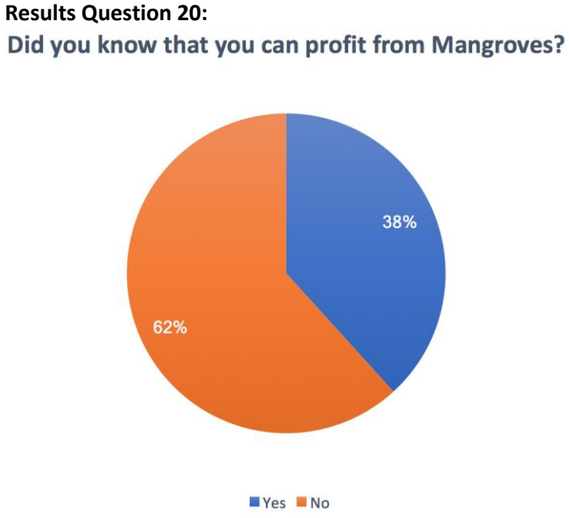


Figure E.20: Survey result for question twenty (Source: Own illustration)

Results Question 21:

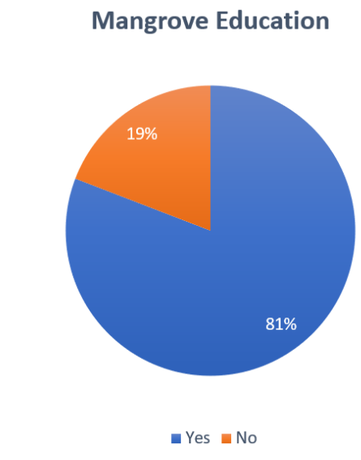


Figure E.21: Survey result for question 21 (Source: Own illustration)

Results Question 22:

Figure E.22: Survey result for question 22 (Source: Own illustration)

Results Question 23:

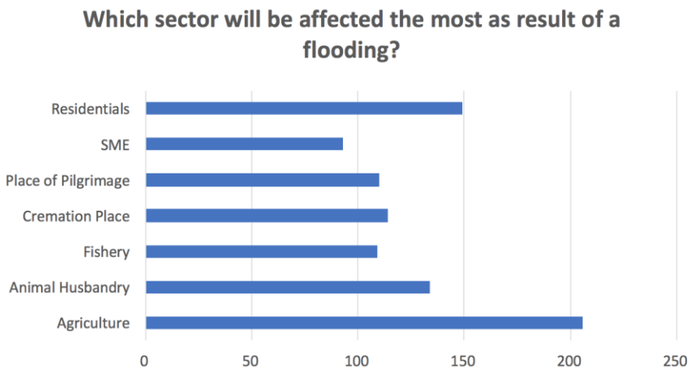


Figure E.23: Survey result for question 23 (Source: Own illustration)

Results Question 24:

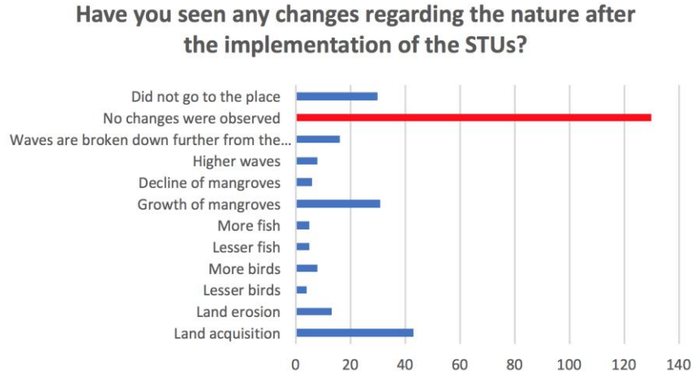


Figure E.24: Survey result for question 24 (Source: Own illustration)

Results Question 25:

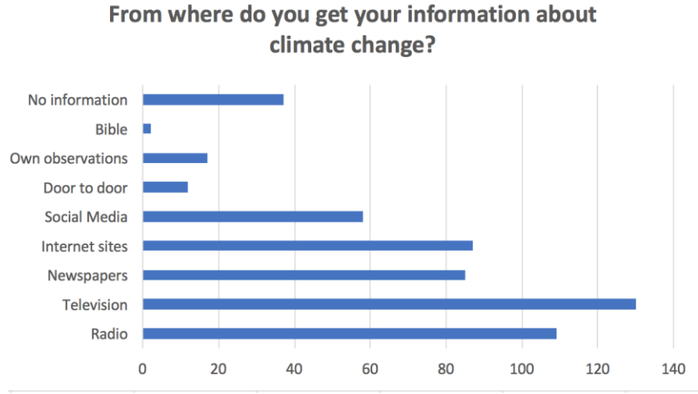


Figure E.25: Survey result for question 25 (Source: Own illustration)

Results Question 26:

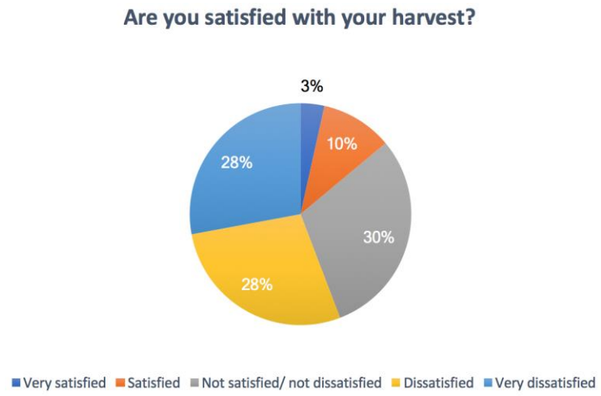


Figure E.26: Survey result for question 26 (Source: Own illustration)

Results Question 27:

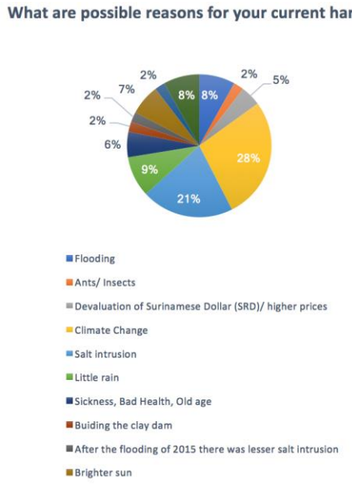


Figure E.27: Survey result for question 27 (Source: Own illustration)

Results Question 28:

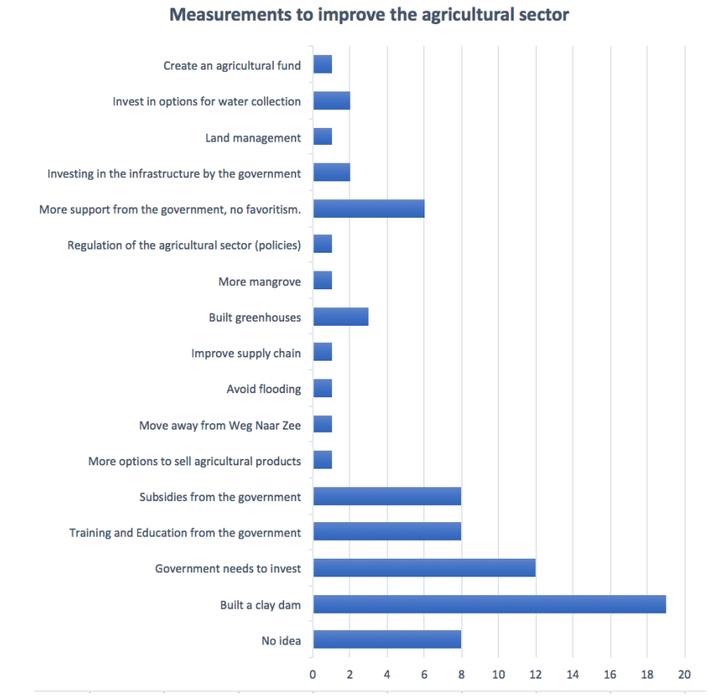


Figure E.28: Survey result for question 28 (Source: Own illustration)

Results Question 29:

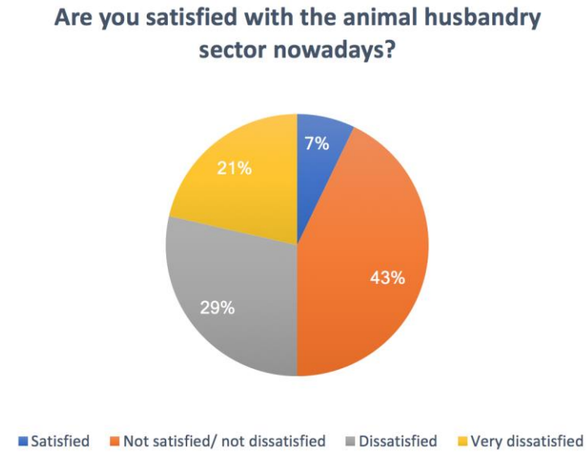


Figure E.29: Survey result for question 29 (Source: Own illustration)

Results Question 30:

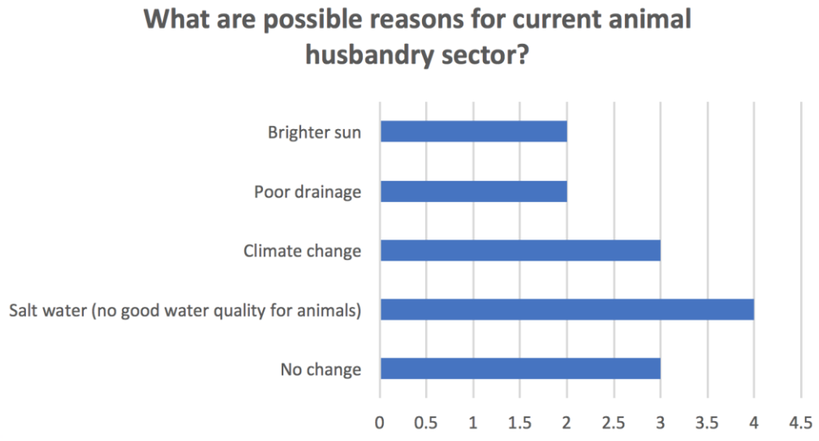


Figure E.30: Survey result for question 30 (Source: Own illustration)

Results Question 31:

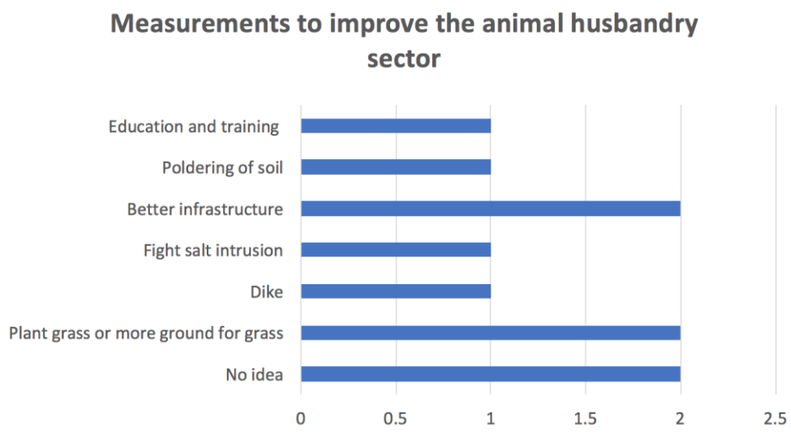


Figure E.31: Survey result for question 31 (Source: Own illustration)

Results Question 32:

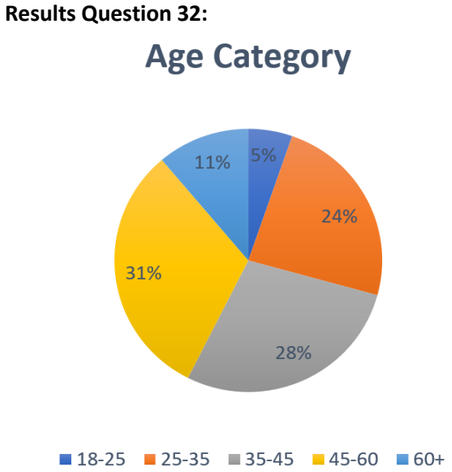


Figure E.32: Survey result for question 32 (Source: Own illustration)

The following figures represent the relations which were found through analyzing the survey results.

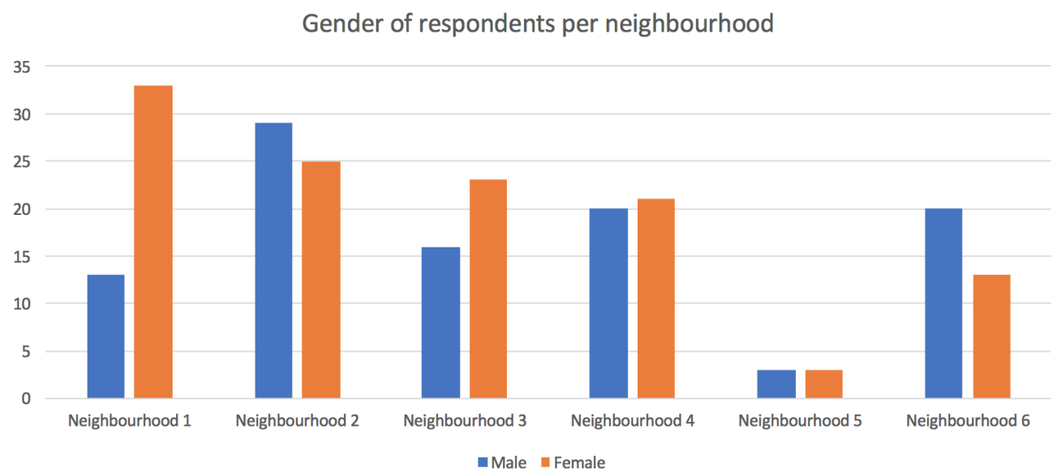


Figure E.33: Relation between the respondent's gender and the neighbourhood in the Wnz region they reside in (Source: Own illustration)

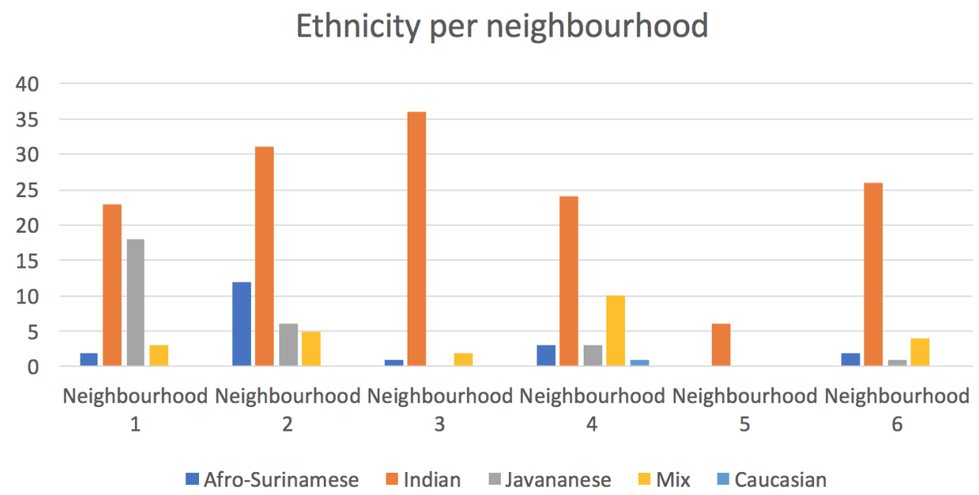


Figure E.34: Relation between the respondent's ethnicity and the neighbourhood in the Wnz region they reside in (Source: Own illustration)

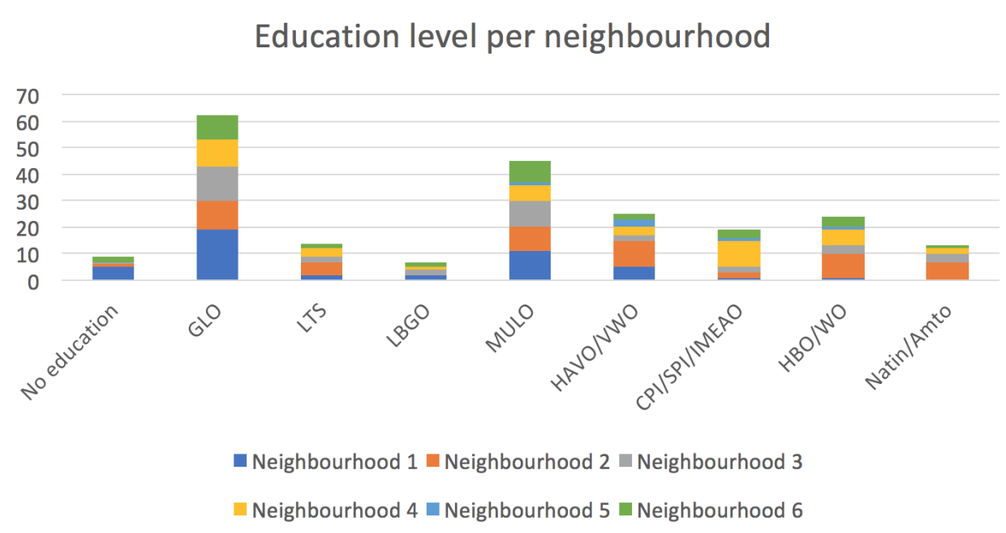


Figure E.35: Relation between the respondent's gender and the neighbourhood they belong too (Source: Own illustration)

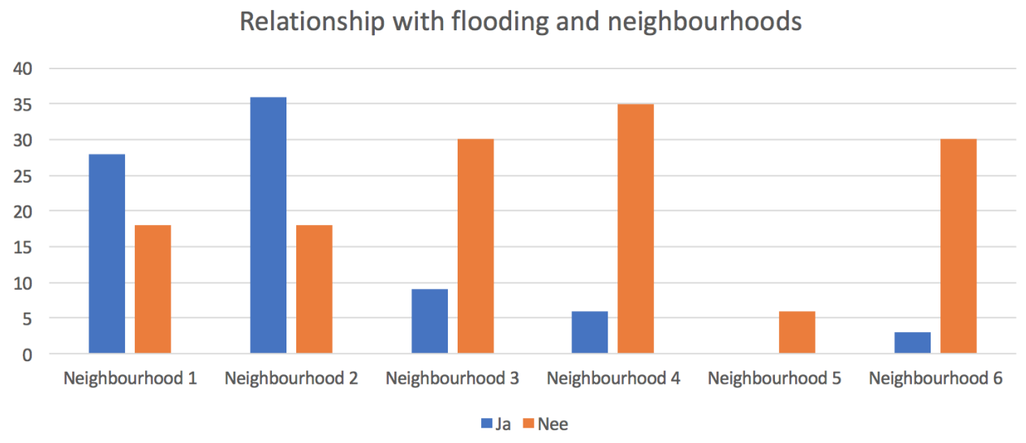


Figure E.36: Relation between flooding in the WnZ region and the WnZ neighbourhood the respondents reside in (Source: Own illustration)

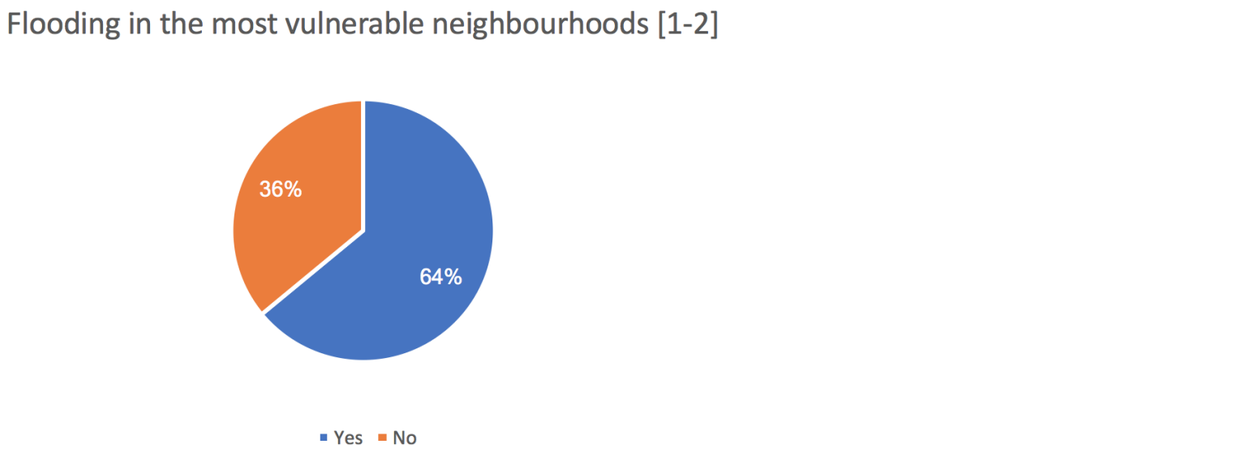


Figure E.37: Relation between flooding in the WnZ region and the most vulnerable WnZ neighbourhoods (neighbourhood 1 and 2) (Source: Own illustration)

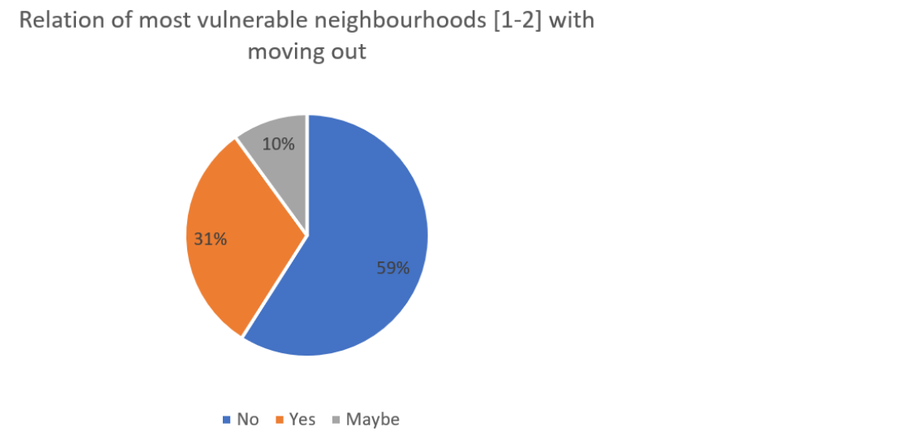


Figure E.38: Relation between the most vulnerable WnZ neighbourhood (neighbourhood 1 and 2) and the respondents who moved out (Source: Own illustration)

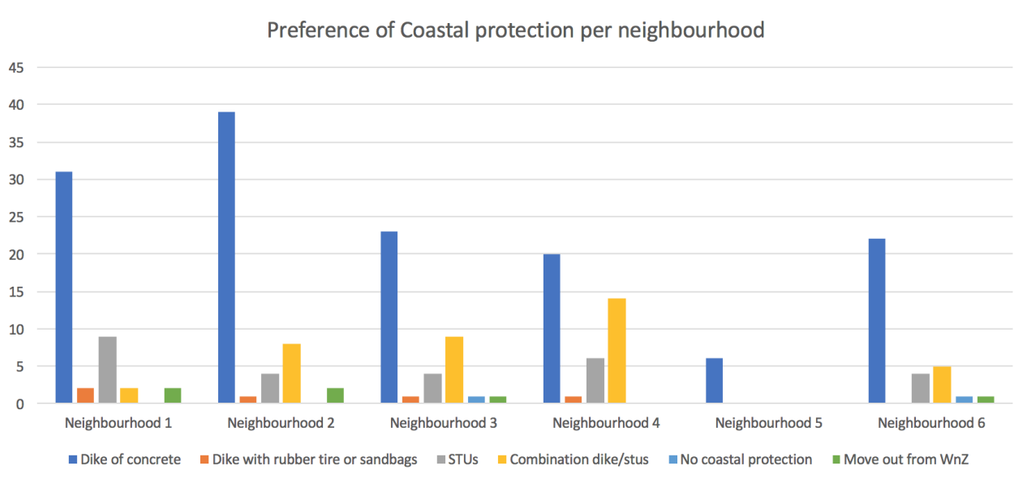
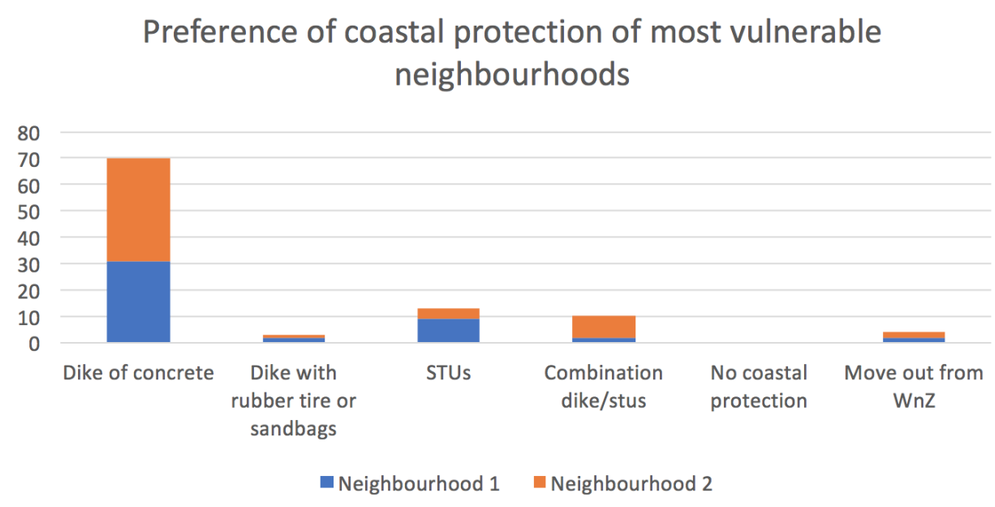


Figure E.39: Relation between the preference for type of coastal protection per neighbourhood (Source: Own illustration)



Eigure E.40: Relation between the preference for type of coastal protection for the most vulnerable neighbourhoods (neighbourhood 1 and 2) (Source: Own illustration)

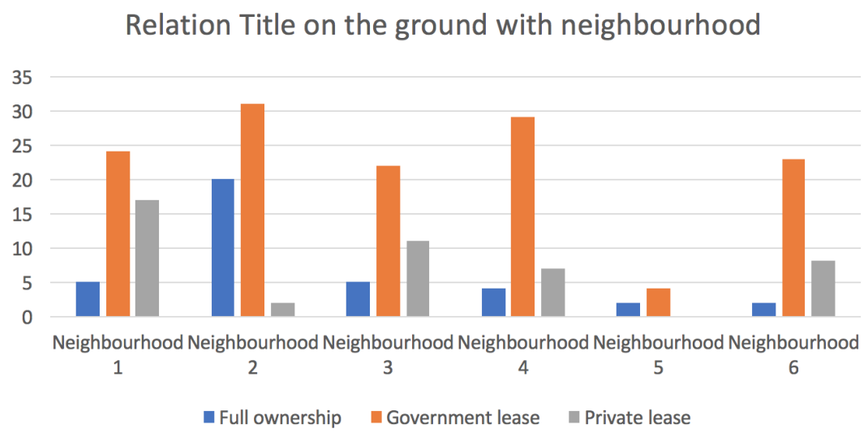


Figure E.41: Relation between the title on the ground and the WnZ neighbourhood the respondent resides in (Source: Own illustration)

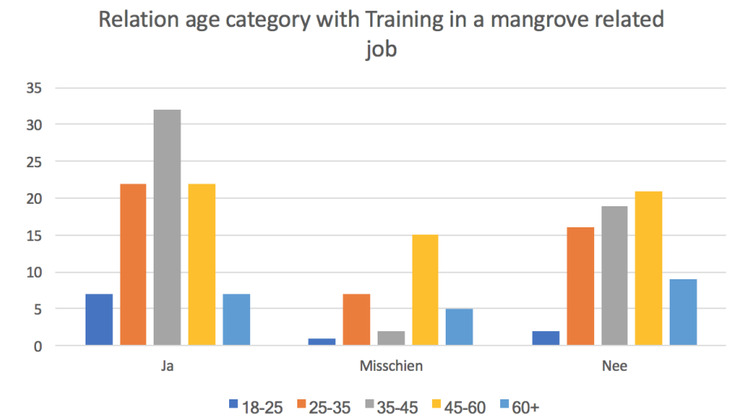


Figure E.42: Relation between the age category of the respondent and the willingness to participate/attend a training which is related to a job in the mangrove sector (Source: Own illustration)

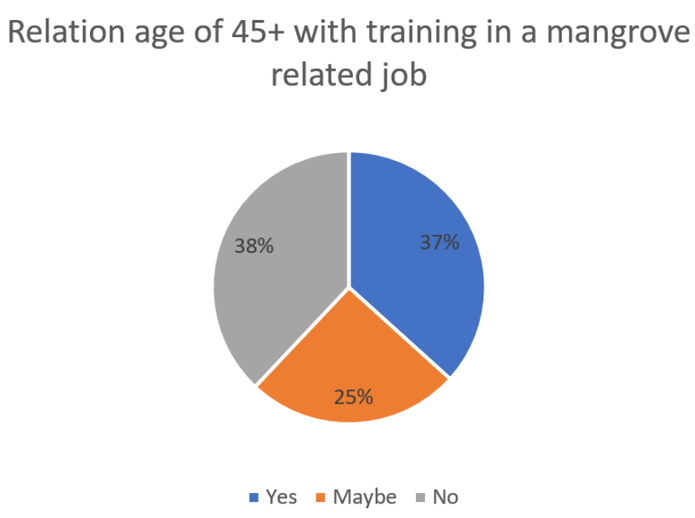


Figure E.43: Relation between the age category 45+ and the willingness to participate/attend a training which is related to a job in the mangrove sector (Source: Own illustration)

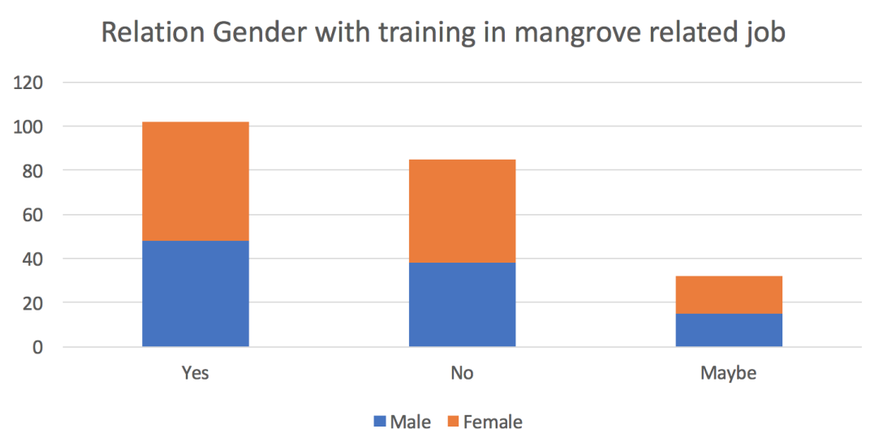


Figure E.44: Relation between the gender of the respondent and the willingness to participate/attend a training which is related to a job in the mangrove sector (Source: Own illustration)

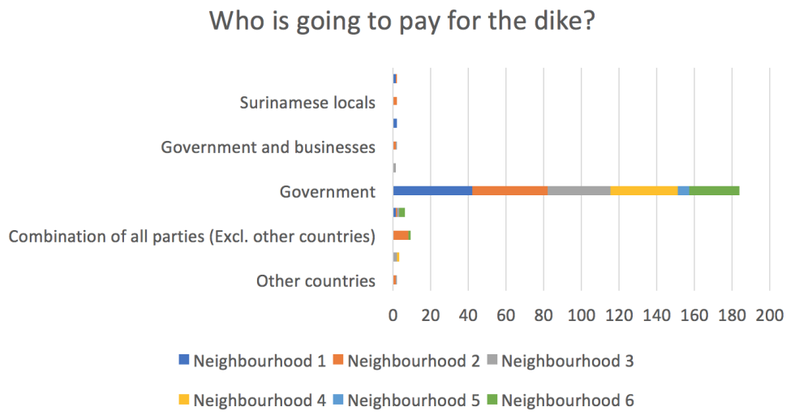


Figure E.45: Insight into who needs to pay for the dike according to the respondents of each WnZ neighbourhood (Source: Own illustration)

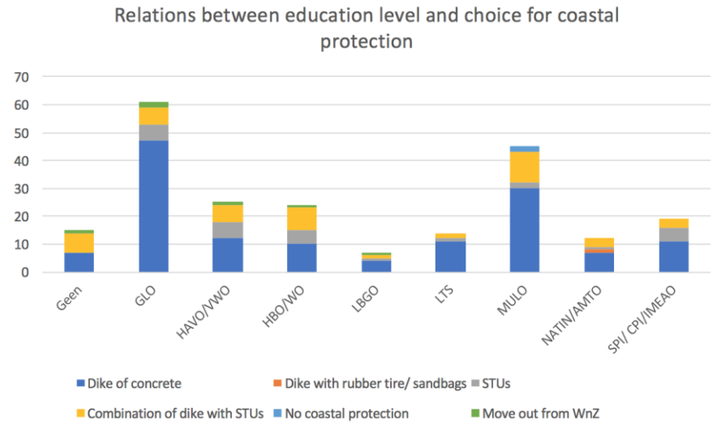


Figure E.46: Relation between the education level and the choice for the need for coastal protection (Source: Own illustration)

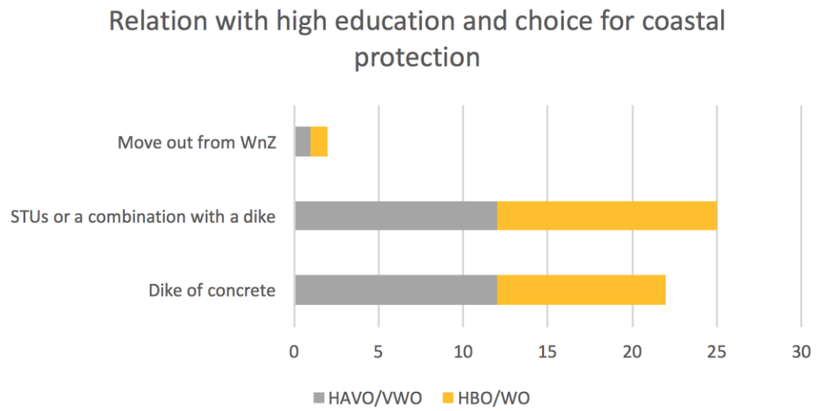


Figure E.47: Relation between respondents who have a high education and their choice for type of coastal protection (Source: Own illustration)

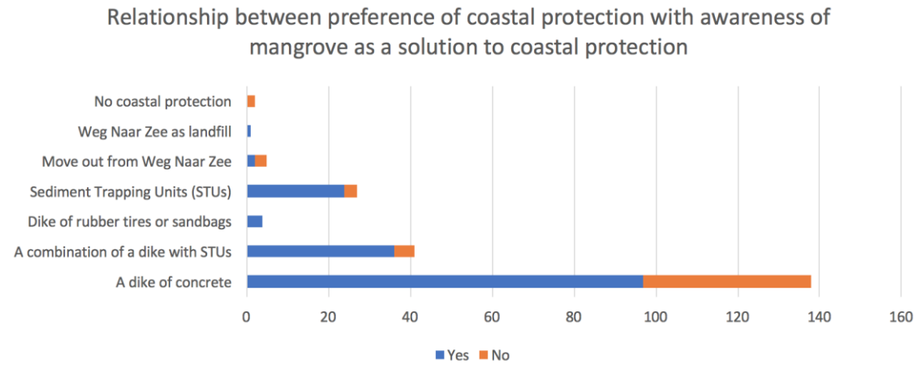


Figure E.48: Relation between the preference for the type of coastal protection and the awareness of mangrove as a solution for coastal protection (Source: Own illustration)

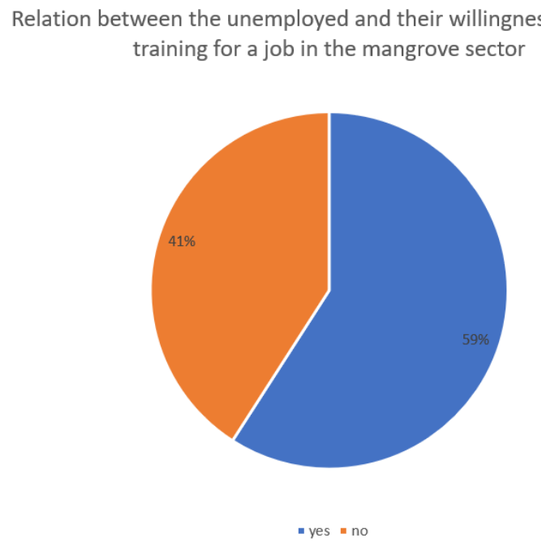


Figure E.49: Relation between the residents that are unemployed and their willingness to follow training for a job in the mangrove sector (Source: Own illustration)

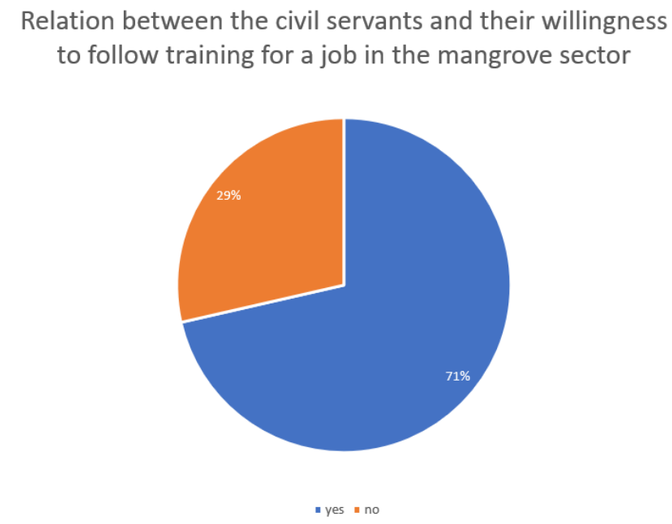


Figure E.50: Relation between the residents that are civil servants and their willingness to follow training for a job in the mangrove sector (Source: Own illustration)

APPENDIX F. MANGROVE DENSITY

The Quyn method (Verhagen, 2017):

The transmission coefficient:

$$K_t = e^{-rx} \quad [1]$$

$$K_t = e^{-bx} \quad [2]$$

$$b = -0.0481 + 0.016H_{vm} + 0.00177ln(N) + 0.0077ln(T_c) \quad [3]$$

Where:

$$H_{vm} : average\ total\ height\ of\ the\ trees\ in\ the\ fores(m)$$

$$N : density\ of\ mangrove\ tress\ taller\ than\ 1\ m\ \left(\frac{trees}{ha}\right)$$

$$T_c : Forest\ canopy\ cover\ (\%)$$

For application one may assume values for the variables between:

$$3 < H_{vm} < 5\ (m)$$

$$1000 < N < 2000\ \left(\frac{trees}{ha}\right)$$

$$80 < T_c < 99\ \%$$

Using the lower limit of the range of variables, with this from formula 3, a ***b*** coefficient of 0.010 and a transmission coefficient of 0.009 is found. From formula 1 and formula 2, it can be concluded that the value for ***r*** and ***b*** must be identical physically. With this and according to Table F.1 the density of the mangrove forest is stated to be dense.

Density of mangroves	Reduction coefficient *r*
Dense	0.010
Average	0.007
Sparse	0.004

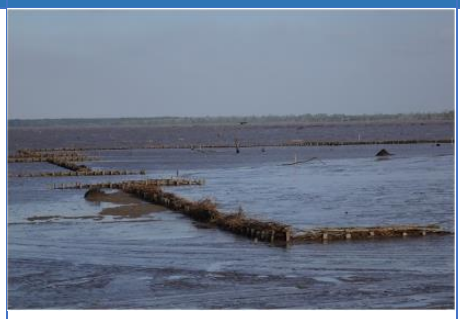
Table F.1 Reduction coefficients (Source: Verhagen, 2017)

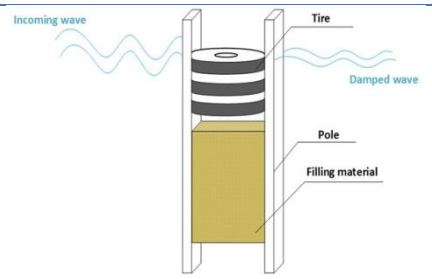
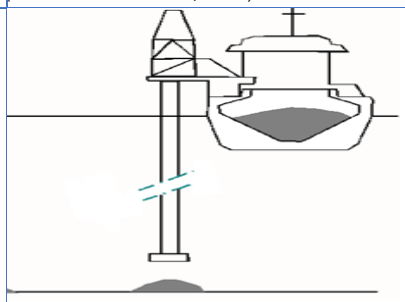
APPENDIX G. VARIANCE STUDY

This appendix contains all the possible alternatives which have followed from the literature study and brainstorm sessions.

G.1 Alternatives

In Table G.1 all alternatives are rated on the two main requirements: wave dissipation and sediment inflow. The reference situation is the current state of the STUs at WnZ. The score for the reference case is stated to be 0. Scores are given between -- and ++. After scoring it is clearly explained why each alternative is scored high or low.

Alternatives	Description	Physical Form	Wave dissipation	Sediment inflow
STU	This is the reference case, already present at the Weg naar Zee region.	 *(Naipal, 2015)*	0	0
STU with bed protection	A bed protection is placed. It makes sure that already trapped sediment does not wash out.	 *(Coir Log Installation Guide, n.d.)*	0	0
Adapted STU	The STU will be adapted such that the structure will dissipate more waves, with minimal reflection. A more permeable filling material will be used.		+	+

STU with integrated breakwater	The outer walls of the STU have an improved wave breaking function, thus the STU is designed in such a way.	 *(Own illustration)*	+	0
STU with Emerged breakwater	This emerged breakwater is always above the water level and leads to effective wave breaking before reaching the STU. The breakwater blocks the income of sediment into the STUs.	 *(Boskalis Westminster, 2015)*	++	--
STU with Offshore nourishment	An offshore nourishment leads to more sediment income and also can be seen as a submerged breakwater made of natural material.	 *(Van den Bos, 2016)*	+	+
STU with Chenier	The placement of artificial cheniers can take over the function of the mudbank, they partly break the waves and thus help against erosion.	 *(Ian West, 2005)*	+	+
STU with Submerged breakwater	This submerged breakwater is generally under water and leads to less wave breaking relative to the emerged breakwater but blocks partially the income of sediment.	 *(Kuwait reef ball company, n.d.)*	+	-

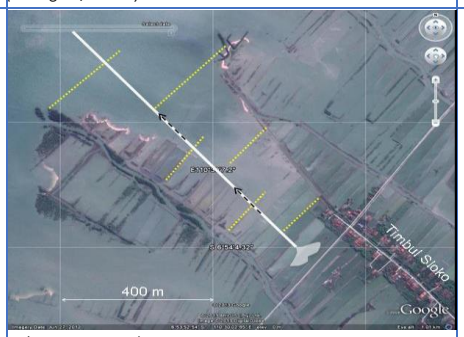
STU with Floating breakwater	This breakwater floats on water, breaks waves and does not block the sediment transport.	 *(Morgan, 2015)*	+	0
STU with nourishment	This is a nearshore nourishment inside the STUs. The STUs create calmer climate for the sediment to settle. It is also possible for the sediment to naturally flow in.	 *(Etwin , 2014)*	+	+

Table G.1 Different alternatives rated on the two main requirements

STU with bed protection

One of the problems with the current STUs is that the sedimentation is again washed away during storms. This can be minimized by placing bed protection on top of the already settled clay. The bed protection retains the sediment, but it does not dissipate the waves and also limits the sediment inflow and therefore scores a 0 for both criteria. Furthermore, bed protections are very difficult to apply on soft mud layers. Possible variants are:

- Geohooks;
- Geotextile;
- Coconot fibre.

Adapted STU

The current STU is adapted in such a way that more waves are transmitted and less wave breaking occurs. The transmitted waves will for a large part be dissipated by the structure. So this alternative scores a + for wave dissipation. By having more wave transmission, also more sediment flows into the STU. Therefore, this alternative scores a + on sediment inflow.

STU with integrated breakwater

This alternative focuses on improving the wave breaking function of the current STUs without increasing the resistance for sediment inflow. Aspects as orientation, material and structure of the outer walls will be looked at. This alternative scores a + for wave dissipation and 0 for sediment inflow. Possible variants within the integrated breakwater are:

- Integrated breakwater of tires;
- Integrated breakwater of bamboo.

STU with emerged breakwater

The emerged breakwater leads to really effective wave dissipation outside the STU, thus creates a calmer environment outside the entrance of the STUs and gets a **+** score on wave dissipation. The downside of this alternative is the blockage of sediment transportation. The alternative therefore is scored **–** for sediment inflow. Possible types of emerged breakwaters:

- Concrete breakwater;
- Gabions;
- Prefabricated emerged breakwater;
- Rubble-mound.

STU with offshore nourishment

The offshore nourishment leads to more sediment supply for the STUs and more wave breaking offshore due to the increased bed elevation offshore, which can be seen as a submerged breakwater. This alternative therefore score **+** for both criteria. The offshore nourishment can be a:

- Mud engine;
- Direct nourishment.

STU with chenier

This alternative focuses on the breaking of the incoming waves, therefore this alternative scores **+** for wave dissipation and **0** for sediment inflow.

STU with submerged breakwater

The submerged breakwater leads to relatively less wave dissipation than the emerged breakwater. But this leads on the other hand to less blockage of sediment inflow. This alternative scores **+** for the wave dissipation and **–** for the sediment inflow. Types of submerged breakwater:

- Geotube;
- Reef balls;
- Rubble mound.

STU with floating breakwater

The floating breakwater is placed at some distance of the entrance of the STUs and leads to wave reduction without blocking the sediment inflow. This alternative scores **+** for wave dissipation and **0** for sediment inflow. Type of floating breakwater:

- Box-type floating breakwater;
- Floating breakwater of tires;
- Floating breakwater of bamboo.

STU with nourishment

This alternative uses direct nourishment as a fast method of increasing the elevation in the STUs. Also, the STUs are adapted in such a way that the incoming waves are more dissipated trough the structure. It scores **+** for wave dissipation and **+** for sediment inflow.

G.2 MCA-analysis

Five alternatives with their different variants are evaluated with a Multi-Criteria Analysis (MCA). All the variants are rated between **-2** and **2**. The individual score is the multiplication of the weight of a criterion with its score. The total score of each variant is the sum of all its individual scores. An overview of the MCA is given in Figure G.1.

				Alternative 1: STU with Floating breakwater					
Weight	Criteria	Weight	Subcriteria	Variant 1a: Bamboo		Variant 1b: Concrete		Variant 1c: Tires	
(1-10)		1		Score [-2;2]	Score times weight	Score [-2;2]	Score times weight	Score [-2;2]	Score times weight
8	Technical characterist	0.3	Simplicity of structure	-2	-4.8	-1	-2.4	-1	-2.4
		0.3	Shortterm flexibility	2	4.8	-2	-4.8	1	2.4
		0.15	Redundancy	-2	-2.4	-1	-1.2	-1	-1.2
		0.1	Longterm flexibility	2	1.6	-2	-1.6	1	0.8
		0.15	Robustness	-2	-2.4	1	1.2	-1	-1.2
4	Side effects	0.3	No extra downdrift erosion	-1	-1.2	-1	-1.2	-1	-1.2
		0.7	No extra scour	0	0	0	0	0	0
9	Environment	0.2	Durability	-1	-1.8	2	3.6	1	1.8
		0.8	Sustainability	2	14.4	-1	-7.2	-2	-14.4
10	Feasability	0.3	Availability materials	1	3	2	6	2	6
		0.5	Constructability	-2	-10	-2	-10	-2	-10
		0.2	Maintainability	-1	-2	2	4	-2	-4
2	Aestetics			-1	-2	-1	-2	-2	-4
6	Efficiency			1	6	1	6	1	6
6	Reliability			-1	-6	2	12	1	6
			Total score		**-3**		**2**		**-15**

Table G.2 Multi-Criteria scores (Source: own illustration)

				Alternative 2: STU with integrated breakwater				Alternative 3: STU with nourishment	
Weight	Criteria	Weight	Subcriteria	Variant 2a: Bamboo		Variant 2b: Tires			
(1-10)		1		Score [-2;2]	Score times weight	Score [-2;2]	Score times weight	Score [-2;2]	Score times weight
8	Technical characterist	0.3	Simplicity of structure	0	0	-1	-2.4	1	2.4
		0.3	Shortterm flexibility	0	0	1	2.4	0	0
		0.15	Redundancy	0	0	-1	-1.2	0	0
		0.1	Longterm flexibility	0	0	1	0.8	0	0
		0.15	Robustness	0	0	-1	-1.2	0	0
4	Side effects	0.3	No extra downdrift erosion	-1	-1.2	-1	-1.2	2	2.4
		0.7	No extra scour	-1	-2.8	-2	-5.6	-1	-2.8
9	Environment	0.2	Durability	-1	-1.8	-1	-1.8	-1	-2
		0.8	Sustainability	0	0	-2	-14.4	1	8
10	Feasability	0.3	Availability materials	0	0	2	6	-1	-3
		0.5	Constructability	0	0	-1	-5	-1	-5
		0.2	Maintainability	0	0	1	2	0	0
2	Aestetics			0	0	-2	-4	0	0
6	Efficiency			1	6	1	6	2	12
6	Reliability			-1	-6	1	6	2	12
			Total score		**-6**		**-14**		**24**

Table G.3 Multi-Criteria scores (Source: own illustration)

				Alternative 4: STU with Chenier		Alternative 5: Adapted STU	
Weight	Criteria	Weight	Subcriteria				
(1-10)		1		Score [-2;2]	Score times weight	Score [-2;2]	Score times weight
8	Technical characterist	0.3	Simplicity of structure	2	4.8	0	0
		0.3	Shortterm flexibility	0	0	0	0
		0.15	Redundancy	0	0	0	0
		0.1	Longterm flexibility	1	0.8	0	0
		0.15	Robustness	0	0	0	0
4	Side effects	0.3	No extra downdrift erosion	-1	-1.2	0	0
		0.7	No extra scour	2	5.6	1	2.8
9	Environment	0.2	Durability	-1	-1.8	-1	-1.8
		0.8	Sustainability	1	7.2	0	0
10	Feasability	0.3	Availability materials	0	0	-1	-3
		0.5	Constructability	-1	-5	0	0
		0.2	Maintainability	-1	-2	-1	-2
2	Aestetics			-1	-2	0	0
6	Efficiency			1	6	1	6
6	Reliability			0	0	1	6
			Total score		**12**		**8**

Table G.4 Multi-Criteria scores (Source: own illustration)

G.3 Explanation of criteria and weighting

In this section the different criteria and the weighting are explained. The criteria are given a weight between 1 and 10. Each criterion is divided into different sub-criteria with a corresponding weight expressed in percentage of the main criterion.

Technical Characteristics: 8

The technical characteristics are divided into the following sub-criteria: Simplicity of the structure, Short term Flexibility, Long term Flexibility, Redundancy and Robustness. The technical characteristics are important for keeping the structure intact against natural and man-made disturbances. Also, the degree of recovering from these disturbances are covered by the technical characteristics. This criterion is very important to be able to fulfill the functions of the structure during its lifetime, thus gets a weight of 8.

Simplicity of Structure

To be able to make a complex structure experienced people must be hired with the required knowledge. As Suriname is a third world country, there is a lack of certain knowledge among the people, therefore the simplicity of the structure is important to be able to make the structure with minimum effort and knowledge. This sub-criterion gets a weight of 30%.

Short term Flexibility

Generally, in building with nature projects, the design must be monitored frequently to be certain that the requirements are reached. The design must be able to be easily adapted if this is not the case. Also, the degree of adaptability of the structure due to short term disturbances, like heavy storms, is very important. The frequency of these storms is rather high during certain periods of the year. After these storms, the structure must be able to recover fast if failure occurred. Because of the high frequency, this criterion rises in relevance and gets a weight of 30%.

Long term Flexibility

The structures ability to adapt to long term changes, like sea level rise is not very relevant. The determined lifetime of the structure is in the order of 10 years; thus, no significant sea level changes will occur. The weight is set on 10%.

Redundancy

Redundancy is increasing the reliability of the design by being able to backup a critical component of the system. For example, if one component of the system fails, the whole system fails. However, if the system has redundancy, this is prevented by a backup. The intervention is only meant for the rehabilitation of the mangroves, therefore the consequences of failure of the intervention is not high. Therefore, the weight is 15%.

Robustness

At WnZ a group of people is not very fond of the STUs and neither believe in the rehabilitation of the mangroves nor in mangroves as coastal protection (chapter 4). Therefore, vandalism has occurred in the past by the locals, which could lead to the structure not being able to perform its function.

However, this has only been in the form of garbaging at the site of the STUs and therefore did not lead to failure of the structure. Therefore, the weight is set to 15%.

Side effects: 4

Two of the side effects of the interventions are downdrift erosion and the occurrence of scour holes. As prevention or mitigation of downdrift erosion is not one of the project requirements and the occurrence of large scour holes is preventable with a bed protection, side effects have a score of 4.

No downdrift erosion

One of the aims of the intervention is to trap sediment. Once sediment is trapped at one location, a shortage of sediment supply occurs at the next location. It is hard to determine the amount of erosion on the west side of the intervention. However, the sediment supply is very large and in the past years a significant amount of accretion has occurred west of the area of interest (Figure 2.4). Also, the prevention or mitigation of the downdrift erosion is not one of the requirements and therefore 'no downdrift erosion' only has a weight of 30%.

No scour

Due to the muddy character of the Suriname coast, scour is likely to happen when placing an intervention. When a wave approaches the coast, the hard structure reflects it and standing waves occur. Therefore, the amplitude of the wave increases which leads to scour holes. Also, the sediment balance is disrupted because of a reduction of the tidal storage caused by the hard structure. This reduces the sediment flux towards the coast and therefore erosion occurs. As a minimization of scour holes around the structure is one of the requirements, the 'no scour' criterion has a weight of 70%.

Environment: 9

One of the most important wishes of the client is an environmentally friendly solution. As it is chosen to protect the coast by rehabilitating the mangroves, which is a green solution, the interventions that stimulate this should also be environmentally friendly. Therefore, the criteria 'Environment' gets a high weight of 9.

Durability

Durability is the ability of the intervention to perform its required function over a lengthy period. This is without any maintenance. This means that the intervention should function for the time of the sediment trapping and the development of the mangroves. As maintenance is not necessarily an issue, durability only has a weight of 20%.

Sustainability

The design has to be sustainable in order to be an environmentally friendly solution. This means that there should be no or limited negative impacts on the environment. This does not only hold for during the lifetime of the structure, but also during the production of the material. Since sustainability has a large impact in terms of having an environmentally friendly solution, it has a weight of 80%.

Aesthetics: 2

The client prefers the natural undisturbed state of the WnZ area, so human interventions are not stated to have a very high aesthetic value. But looking at the current state of WnZ, there are already a

lot of human interferences, like garbage disposals, dikes made out of tires etc. (chapter 2). Therefore, the aesthetics has a weight of 2.

Efficiency: 6

The time that it takes for mangroves to rehabilitate and perform as a coastal protection is an important factor. This is due to the absence of a well working coastal protection at the moment. However, the hinterland does not have a very high economic value and therefore efficiency has a weight of 6.

Reliability: 6

Reliability of a structure is important in order to guarantee its performance. Designing green solutions, decreases the reliability of its performance. Since there should be some space for innovation, the reliability has a weight of 6.

Feasibility: 9

The degree of feasibility depends on the following aspects: Availability material, Constructability and Maintenance. For the project to be realized, the feasibility is a very relevant criterion. Therefore, the weight is set on 9.

Availability Material

The availability of the material plays an important factor in the feasibility of the project and it set on 30%.

Constructability

The constructability of the structure is a key factor, because it is of no use to design a structure which cannot be constructed at a certain site. For example, if the required equipment cannot be used in a certain area. The constructability has a weight of 40%.

Maintenance

The maintenance is very important to keep the design functioning. The feasibility of the design decreases if there is no maintenance plan or if the maintenance is too complex. Difficult maintenance should thus be avoided, as it is preferred that the locals perform this maintenance. The weight is set on 30%.

G.4 Calculation Floating breakwater

In this paragraph the floating breakwater, is elaborated. First three suitable locations are chosen for a floating breakwater. For these locations the required dimensions are checked, and the feasibility of this design is discussed.

A Floating Breakwater (Figure G.1) has the advantage that it dissipates wave energy without the interference of cross shore sediment transport patterns in comparison to a traditional breakwater. This would make a good fit for the WnZ region, as the goal is to trap sediment and to create a mild wave climate for the rehabilitation of mangroves.

Figure G.1 Floating Concrete Breakwater (Source: Ingemar, n.d.)

However, the application of floating breakwater is not a common phenomenon. Usually they are applied in deep waters in combination with short waves. The applicability of floating breakwaters in other situations needs to be examined carefully. Since the coast at the WnZ region is very shallow, it has to be examined first if the floating breakwater is a feasible option in this situation.

In order to achieve wave energy dissipation, the floating breakwater needs to have a large width relative to the wavelength and needs to have a large draft. When the wavelength is too large, the design becomes uneconomic (Biesheuvel, 2013). Knowing this, three locations from the shoreline are chosen. At these three locations the wavelength and water depth are determined (Appendix B, section B.2: SwanOne Wave Transformation). The results are shown in Table G.5.

Offshore 10 km	Offshore 7.5 km	Offshore 5 km
L= 13.4 m	L= 12.9 m	L= 2.43 m
Water depth= 4 m	Water depth= 3.25 m	Water depth = 1.25 m

Table G.5 Wavelength and water depth at three locations offshore

From the results it can be concluded that the floating breakwater is not a good option to be implemented at the WnZ region. First of all, the floating breakwater needs to be placed at a location that will be under water during low tide. This is the case at a distance of 5 km from the shore. So, this means that the location of the floating breakwater would be too far from the coast. This does not only decrease the effectiveness of wave dissipation at the project location, but also increases the construction costs. Secondly, the water depth is very small. This does not necessarily mean that a floating breakwater cannot be applied. However, since the width of the breakwater would have to be larger than 2.43 m, the water depth is not sufficient to provide a large enough draft. This has to be large enough because the floating breakwater is likely to get stuck in the mud due to wave action.

Since the floating breakwater is not a feasible option, it has not been worked out any further.

APPENDIX H: PRELIMINARY DESIGN 1 – ADAPTED STU

In this appendix additional information is shown regarding the calculations for preliminary design 1: Adapted STU.

1. Construction time estimation

Phase	Total length of fences (m)	Time Placement of Walaba Poles (calendar days)	Time Placement filling material + horizontal beams + nylon ropes (calendar days)	Total time (calendar days)
Phase 0 (Restoration)	2700	0	38	38
Monitoring				60
Phase 1	1896	14	27	28
Monitoring				60
Phase 2	1360	11	19	20
Monitoring				60
Phase 3	1436	11	20	21
			Total time	**287** days

Table H.1 Construction time for preliminary design 1

2. Cost estimation

	Price per unit	Number of units	Costs
<u>Material</u>			
- Walaba Poles	€3.30 / pole	12 518	€3 793,-
- Brushwood material	€0.07/0.75m	532 224	€37 256,-
- Nets	€0.20 /piece	9 857	€1 971,-
- Bamboo beams	€0.09/1 m	19 714	€1 774,-
- Nylon ropes	€2.03/kg	1971	€4 002,-

			Total: **€48 796,-**
<u>Equipment</u>			

- Airboat - Equipment (Excavator, Slamming equipment, Lights etc.)	€284.12 /day €240/day	107 days 36 days	€ 30 401,- € 8 640,-
Working man		Number of working hours	Costs
- Working men - Volunteers	€12.64/day €12.64/day	2712 504	€34 280,- - €6 371,-
		Total Construction Costs	€116 000,-

Table H.2 Cost estimation for preliminary design 1

APPENDIX I. STAKEHOLDER ENGAGEMENT TABLE

This appendix shows the stakeholder engagement table which makes a distinction between the engagement plan for improving the current situation and the engagement plan for assisting the transition to the improved situation. This table was used a means for reference throughout chapter 7.

Stakeholder	Engagement plan for improving the current situation	Engagement plan for assisting the transition to the improved situation
AdeKUS	**Consult** - In the current situation, the government is open to STUs (Kabinet van de president, 2016). Although as of yet, the government has not funded anything related to mangroves or STUs in Suriname. It it thus advised they consult this stakeholder, to obtain AdeKUS' knowledge regarding coastal protection.	**Empower** - The best way for AdeKUS to continue providing the tools/expertise they have on sustainable coastal management (STUs), is to empower them. This has to be done by the government and the goal must be to provide AdeKUS with a certain degree of decision-making when it comes to sustainable coastal management.
Government of Suriname	**Involve** - As the government is currently not actively involved in protecting the coast at WnZ, it is advised to involve them as much as possible. In this way it is possible to work directly with the government in the entire process, while their interests are also considered and understood.	**Collaborate** - As the government holds the power for issuing permits and decision-making, it is advised to keep them as close as possible to the issue at hand. In this sense keeping them close, will make the transition to the improved situation easier.
Inhabitants of the Weg naar Zee region	**Inform** - The inhabitants of the WnZ region are directly influenced during a flood. Furthermore, among this group there is a quite big information gap about coastal management. This is why they should be informed by knowing *what* is happening, *when, where, how* and *why*.	**Involve** - It is advised to involve them as much as possible, because this creates support. If anything impactful were to happen, they could react insightfully as they live there and possibly know what's best for the WnZ region. This can even have a successful effect on the implementation.
Agricultural farmers/ Fishers	**Inform** - Currently, this group of stakeholders are very focussed on the construction of a dike. The reason is that this is a short-term and faster solution compared to the STUs and thus better for their profits (R. Hardjo, personal communication, December 8, 2017). It is advised to supply them with objective information so they can understand the choices and issues at hand.	**Involve** - To smoothen the transition it is advised to involve this group of stakeholders. This will create support for the solution at hand. The result of this engagement will be that their interests and concerns are comprehended and considered. They might add insightful ideas during the design phase as they know the WnZ region well.

Place of Pilgrimage/ Cremation place Weg naar Zee	**Inform** - Due to the locations of the Place of Pilgrimage and Cremation place Weg naar Zee, they would be harmed the most during a flood. It is advised to keep these stakeholders as informed as possible, such as to hopefully reducing the damage a possible flood could cause.	**Involve** - The experience and location of these stakeholders makes them valuable resources. They have done what they could to protect themselves from sea level rise in the past. Involving of these stakeholders during various stages can lead to insightful ideas, however the decision-making power will still belong to critical actors e.g. the government or engineering firms.
SME business owners/ Tourists/ Recreationists/ Visitors of Place of Pilgrimage	**Do nothing**	**Inform** - To facilitate a smooth transition, it is advised to inform these stakeholders. In this way they can be helped in comprehending the choices/dilemmas of the issue at hand. According to chapter 3, they are non-critical actors and informing them at this stage is sufficient.
NGOs/ Embassies	**Consult** - These stakeholders have access to various resources (e.g. finances or knowledge). By consulting them, their feedback on dilemmas/choices can be acquired.	**Empower**- It is advised to empower these stakeholders. In this way they can have a certain degree of decision-making on the issue (it is thus controlled) and this creates good support for the issue at hand. Good support comes with resources which are valuable at the moment for Suriname.
Engineering firms	**Consult** - By consulting these stakeholders, their feedback on the issue at hand can be acquired. As they have a lot of knowledge and expertise, they are best to be taken along as consultants for improving the current situation.	**Collaborate** - Once the final decision is made on for the type of coastal management measure, it will be very likely that this stakeholder will be the ones executing the project. In this phase it is advised to make them switch from consultants to collaborators. In this way they are partnered with in all decisions.

Table I.1 Stakeholder engagement table

What is interesting from Table I.1, are the ways in which the stakeholder engagement switches while moving from the "improvement of the current situation" phase to the "assisting the transition to the improved situation" phase. The table shows the engagement type which is necessary for each stakeholder in each phase. Sometimes nothing needs to be done, sometimes stakeholders need to be informed and sometimes stakeholders need to be collaborated with. This engagement table has the aim to enable the transition to an improved (desired) situation, one of sustainable coastal.