Waihi Beach to the future

an objective review

Hamilton, October 2003

Joost Brugmans
Ronald van Dijk
Joost van der Lans
Raoul Loeffen

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By

Joost Brugmans

Ronald van Dijk

Joost van der Lans

Raoul Loeffen

Jan Wagner

Delft University of Technology

The Netherlands

Delft University of Technology

Department of Civil Engineering and Geotechnics

The University of Waikato

Te Whare Wānanga o Waikato

New Zealand

Waikato University

Department of Earth Sciences

Coastal Marine Group

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View of Waihi Beach from atop of Bowentown

Preface

Part of the master phase of the study civil engineering at the Technical University Delft is the fourth-years-project. In September 2002 the idea arose to work out our project in a foreign country (New Zealand). From then on we contacted companies and universities to tell them about our idea and ask them if they could provide us an interesting project. In November 2002 we received a very interesting and actual assignment from professor Terry Healy of the University of Waikato, the erosion problems in Waihi Beach.

After a year of preparation we arrived at The University of Waikato to settle us in a nice office to execute our assignment. While we executed our project we were confronted with a lot of practical things you aren't aware of during your study. We weren't executing a fictive plan but had to coop with real people.
In our project it was very important to distil the opinion of the people involved in the problems and meanwhile stay objective. We had to deal with all different kind of persons. These persons don't have the knowledge about the same things you have and sometimes interpret things wrong because of a lack of understanding. So the use of right formulated and good English questions was very important.

We were confronted with a lot of different problems (storm water flooding, coastal erosion and coastal flooding) we had to deal with. So it was a big challenge to define an objective, which could be realised in the short time span we had available (eight weeks).

This project was a big experience for us and something we are proud of. We can recommend every other student to organize such a foreign experience.

Wishing you a lot of pleasure by reading the report,

The DAC-team,

Joost Brugmans
Ronald van Dijk
Jan Wagner
Raoul Loeffen
Joost van der Lans

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Executive Summary

Waihi Beach is a village consisting out of 2300 properties, located in the Bay of Plenty on the North Island of New Zealand. It can be seen as a 9 km long tombolo beach. Dunes used to protect most of the land, but have decreased in size through natural erosive processes and through urban development in the dune areas. The long and short-term coastal processes result in erosion and flooding problems. At some places dunes are partly eroded, while elsewhere they don't exist at all and a seawall protects the properties (over a total distance of about 2,3 km). The natural process of accretion and erosion can't take place here.

Two and Three Mile Creek are the two biggest creeks that flow through the village. During heavy rainfall some properties suffer storm water flooding. This flooding is divided in two appearances: flooding of the creeks (due to blocking) and secondly flooding because of a lack of proper drainage to the creeks.

The creeks have outlets in the sea, which meanders over the beach. This causes erosion problems over about 500 m of beach per creek. In calmer weather the discharge of the creeks is little and the waves are small, which causes accretion of the beach. This causes blocking of the creeks and by that flooding of the nearby properties.

In New Zealand the Central Government, the Regional Councils and the District Councils are the three levels of government. They all have their own policies and responsibilities. Waihi Beach is part of the Western Bay of Plenty District (Regional Council), which is part of the Environmental Bay of Plenty Region (District Council).

The institutional and decision-making system has been looked at. Recommendations have been made, how to make improvements to the system.

Coastal hazard problems are often difficult to solve, because they exceed the Districts borders or the Districts institutional measures. A national Integrated Coastal Zone

Management Committee could help with collecting data, knowledge and experiences from other coastal projects, in order to ease a process for the District Council.

At this moment the WBOP District Council has decided to design a seawall to address the erosion problem. This was the cheapest option that provided direct safety to the nearby properties. A lot of local interest groups and residents don't agree with this solution. A good cost-benefit analysis has to be made. Increasing benefits for more people could create financing options. Besides that communication with the community (including holiday residents) to create commitment and awareness is important.

The main problem for the beach is the erosion problem near the seawall and the creeks. The seawall isn't a very satisfying solution for this problem. Beach stabilisation options could be. These options result in wider beaches, which increase the amenity values. Two beach stabilisation options have been looked at more closely.

One option is executing nourishment and keeping the shoreline in place by renourishing every 5 years. First nourishment is needed to create a healthy beach profile, and after that for widening the beach. Due to the longshore and crosshore transport, about 125.000m^3 of renourishment is needed every 5 years. The creeks are trailed by constructing groynes through the surf zone (225 m). These groynes (made from geotextile bags) also decrease the required amount of 5-year renourishment.

The second option is executing nourishment in combination with breakwaters. Offshore breakwaters composed out of geotextile tubes are required at Waihi Beach according the Multi Criteria Assessment between eleven possible options of breakwaters. A preliminary design is made for this breakwater option. With different amounts of nourishment and the number of breakwaters, the shoreline response is determined. Renourishment is needed to compensate the sand transport induced by the breakwaters from the adjacent areas to the leeside. Also to address the long-term erosion trend periodically renourishment is required (50.000m^3 10-yearly). The creeks are trailed by constructing geotextile bags on the beach, until the shoreline. Some additional sand removal to prevent blocking is probably needed.

The nourishment option and the breakwater option are compared in a Multi Criteria Assessment. The breakwater option is the most favourite, mainly because of the lower costs, $5,5 mln instead of $7,4 mln (NPV over a 50-year period). The breakwater option also creates more amenity values (no hard construction can be seen and natural processes are restored) and protects a bigger part of the beach.

At the end the breakwater option is compared to the seawall in a cost-benefit analysis. To quantify the benefits the increase of value of the beachfront properties are examined. The conclusion of this analysis is that an extra increase of value of 1.6% in a time span of 5 years will completely compensate the difference of costs between the breakwater option and the seawall. This percentage seems reasonable so the design of the breakwaters is the most preferable solution for the erosion problem in Waihi Beach.

1 Introduction

Waihi Beach is a 9km long barrier beach, located in the Bay of Plenty on the North Island of New Zealand. In Waihi Beach people started building properties near the shoreline in the 30's. Since then the community grew to about 2300 properties nowadays. To drain the areas landwards of Waihi Beach two creeks (Two-Mile and Tree-Mile Creek) flow into the sea.

The Bay of Plenty borders the South Pacific Ocean. Because of that a lot of coastal hazards occur: coastal erosion, coastal flooding and storm water flooding of the creeks. Because people have chosen to settle themselves near the coastline, the coastal hazards become of major importance.

Seawalls have been built from 1967 to protect the properties against the coastal erosion and coastal flooding. Due to a lack of maintenance and a proper design, these seawalls have lost their function. As a result of this problem the proposal has been made to refurbish the seawall, which does not seem to satisfy with the preferences of the majority of the community. There are possibilities to design a proper solution, which satisfies more objectives of the community.
To address the storm water flooding the proposal has been made to re-divert the creeks in a future stage.

This report consists of three main parts (see Figure 1-1):
Part A contains the description of New Zealand and Waihi Beach. The coastal hazards are specified as well as the characteristics of the study area (e.g. Geology, Morphodynamics and the Coastal hazards).
Part B holds the analysis to the decision-making process in New Zealand and in Waihi Beach. To execute this analysis in a structural way, use is made of an Integrated Coastal Zone Management model.

Part C presents the objectives of a technical solution and two preliminary designs (renourishment and breakwaters) to address the coastal erosion, the protection of the upland real estate and the preservation of the amenity values.

It is necessary to read Part A before reading Part B or Part C, to know the study area and the problems. Part B and Part C are independent of each other. However, it is recommended to read Part B before Part C to understand the background of the decision of proposing the seawall.

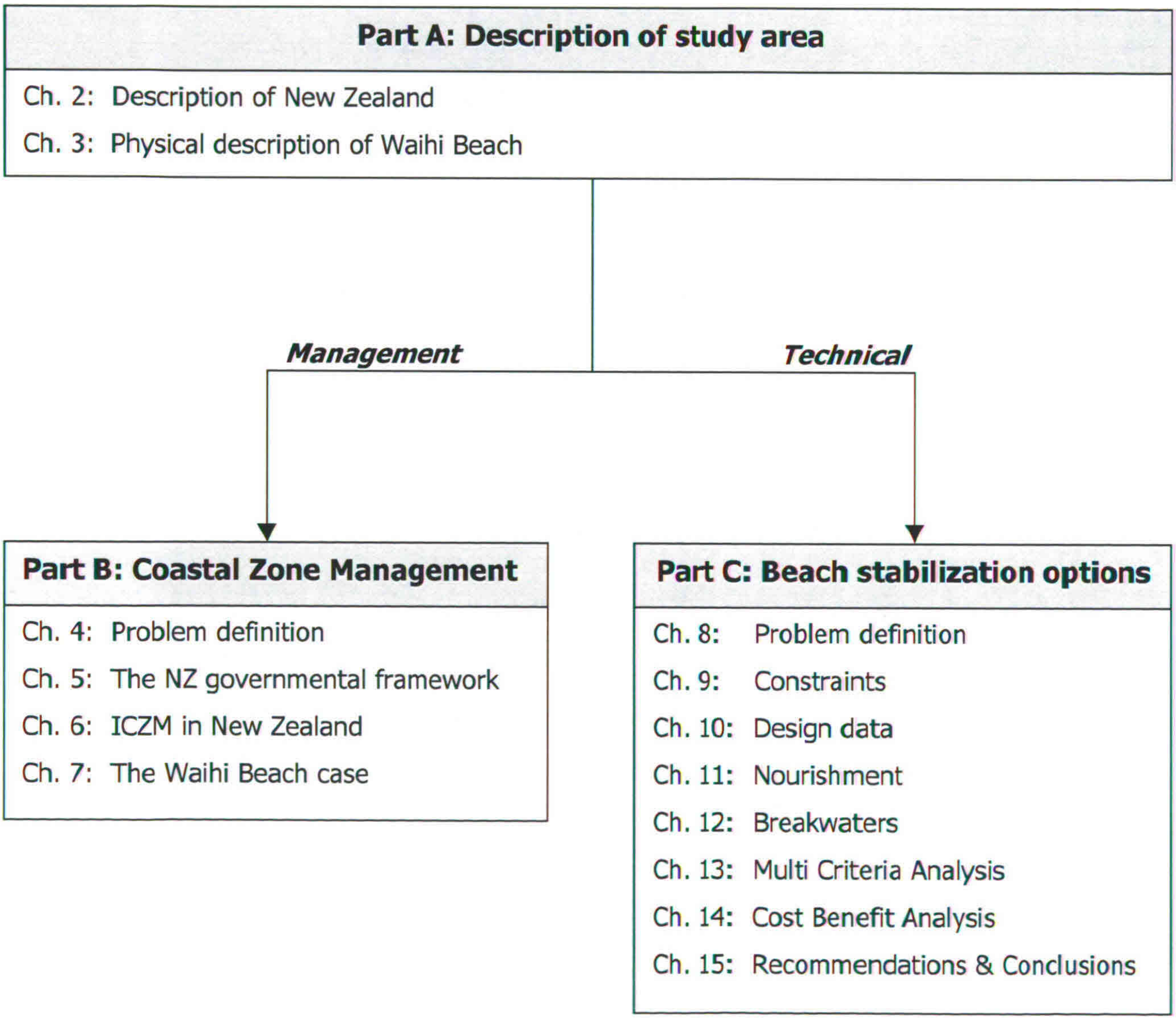

Figure 1-1 Structure of report

Part A

Description of study area

Overview of Waihi Beach

2 Description of New Zealand

2.1. Introduction

This chapter contains a global introduction to New Zealand. The second paragraph contains information about the topography of the country. The third paragraph provides information about population and demography and the final paragraph contains a description of the coastal environment.

2.2. Location and topography

New Zealand is a relative young country, which arose 100 million years ago out of the Pacific. New Zealand stretches 1600 kilometres from north to south and consists of two large islands with some smaller islands around. New Zealand lies at the southern Hemisphere between 34 S and 47 S at the southeast side of Australia. Its western coastline faces the Tasman Sea and its eastern coastline the Pacific. The surface of New Zealand is 268.000 square kilometres divided in 115.000 square kilometres North Island and 151.000 square kilometres South Island.

Figure 2-1 New Zealand

The movement of the Pacific tectonic plate formed both the North and the South Island, but the processes were actually different. At the North Island the Pacific tectonic plate slides underneath the Continental plate, which causes a subduction zone. This resulted in a lot of volcanoes and thermal areas. So the landscape of the North Island consists of large lakes formed by volcanic explosions, hills, mountains produced by folding and uplift and in the centre a high plateau. Because of a lot of rainfall a notable feature of the geography is the great number of rivers. The longest river is the Waikato River (425 kilometres) and the Whanganui is the longest navigable river.

At the South Island the two tectonic plates are smashing into each other, resulting in the rise of the Southern Alps along the entire length of the South Island. The main western wind direction causes a lot of rainfall and erosion at the western part of the Southern Alps (7500 mm) compared to the eastside of the mountains (330 mm).

2.3. Population and demography

New Zealand is a sparsely populated country. Its four million inhabitants mostly live in cities. Auckland is far most the biggest city in New Zealand with 27% of the entire population. The density of the population is 13,7 people per square kilometres. Despite its rural base, New Zealand is very much an urban country with 70% of the population living in the fifteen largest cities.

5,8% of the entire population is Maori, the original Polynesian settlers of New Zealand, who migrated around 800 AD. After the Treaty of Waitangi this society had the same rights and privileges of the British and in exchange the British granted sovereignty over New Zealand. So the Maori's are well protected in New Zealand and the New Zealanders are proud of their record of racial harmony.

2.4. Nature and types of coastal areas

New Zealand has so many physical features that it's famous in the world. There is thermal activity and volcanoes, native forest, rugged mountains, green farmland, hills and abundant wildlife. Besides all this, New Zealand has also a magnificent coast.

Along the east coast of Northland there are rocky coasts, several harbours and complex patterns of inlets, estuaries, peninsulas and islands. The west coast of Northland consists

of perfect linear beaches mainly made of sand and at the south a wild and rugged coast. More to the south there is a wide variety of coastal areas consisting of beaches of black sand, sea caves and sea cliffs, which continue along the whole western coast.
At the east side to the south of North Island one will find the Coromandel, which is a large peninsula to the North of Waihi Beach, and the region Western Bay of Plenty (see figure 3-1). Lava sea cliffs and beaches of volcanic deposit and Holocene sediment, volcanic islands and several bays caracterize this coastal area.

At the South Island one can find an extremely wild coast with Fiordland at the most southern point at the west side. At the top of the southern Island you can find the Marlborough sounds, a drowned valley systems resulting from the subsidence of that part of the earth's crust. At the east coast of the South Island there are many sandy bays, beaches, headlands and rocky coasts.

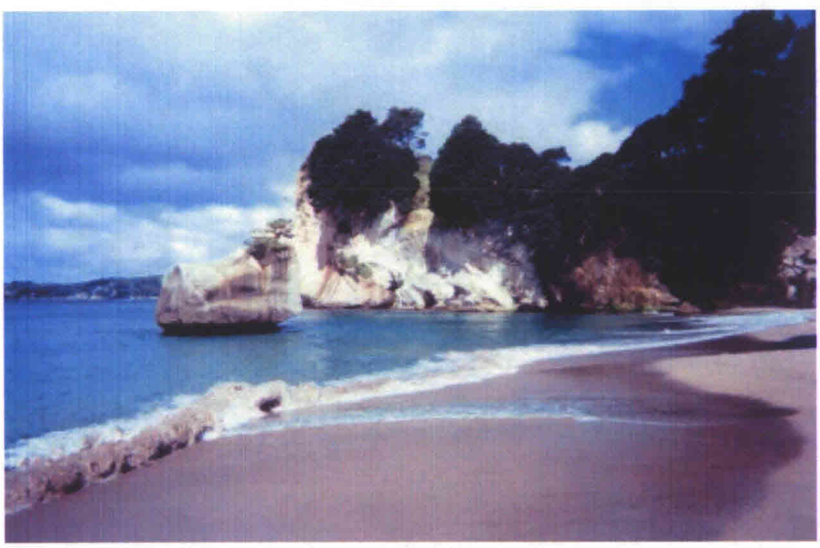

Figure 2-2 Typical view at Coromandel Peninsula.

3 Physical description of Waihi Beach[1]

3.1. Introduction

This chapter covers the physical description of Waihi Beach in the Bay of Plenty on the Northern Island of New Zealand. The second paragraph provides general information about the history and development of Waihi Beach. The third paragraph describes the geologic evolution of the study area. The fourth paragraph deals with the coastal dynamics along the East Coromandel-Western Bay of Plenty. The final paragraph provides an overview of the coastal hazard problems in Waihi Beach.

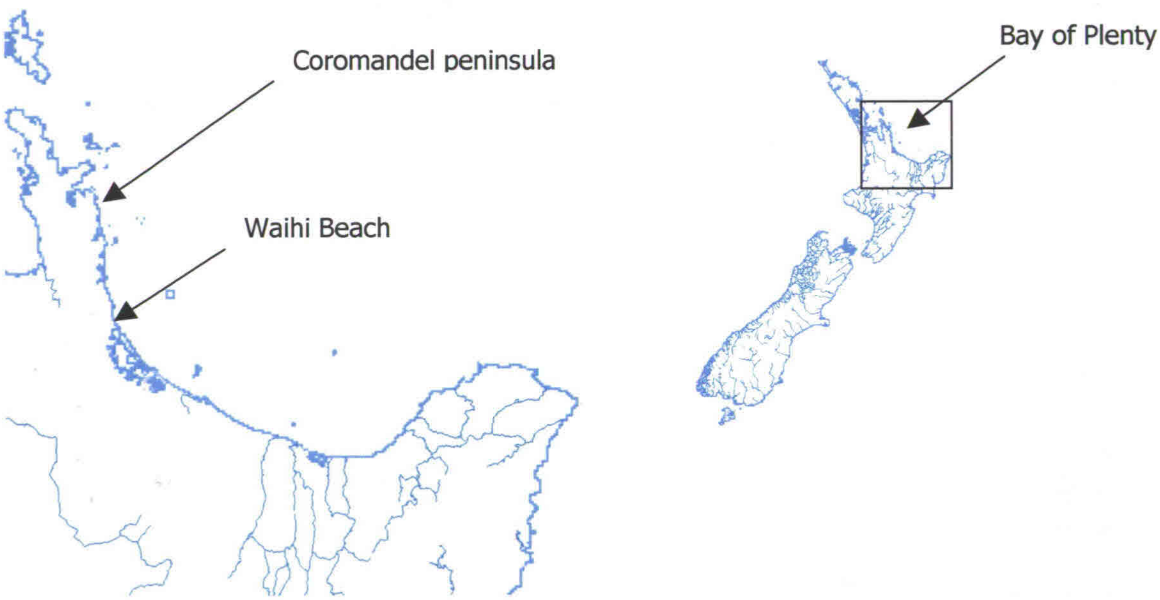

Figure 3-1 Bay Of Plenty, Coromandel and Waihi Beach

[1] Derived from: "Strategic options for sustainable management of the coastal interface along Waihi Beach, Western Bay of Plenty District", May 1997, Dr J.G. Gibb, with additions from Prof.T.R. Healy.

3.2. History of Waihi Beach

Waihi Beach is situated at the Northern Island of New Zealand in the Bay of Plenty. The town originally developed as a health resort for miners and gold battery workers from Waihi, a gold-mining town a few kilometers from Waihi Beach. In 1902 the Council surveyed the access road from Waihi to Waihi Beach. In 1930 the inhabitants opened Two Mile Creek and Three Mile Creek to drain the land further inshore.

Coastal development started earliest in 1948 with the subdivision of land in the Dillon street – Shaw Road area. Severe erosion and flooding problems in 1955 and 1962 forced the community to protect themselves against the sea.

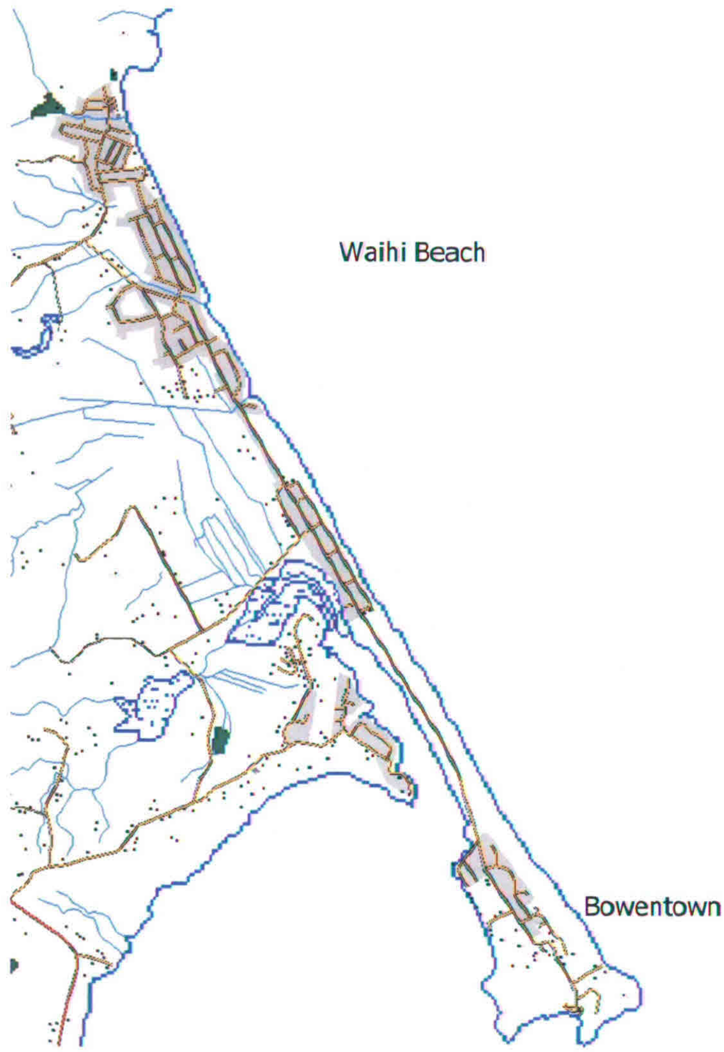

Figure 3-2 Waihi Beach

Between 1962 and 1980 seawalls were constructed at Seaforth Road and at The Loop (see figure 4-3). These protection works were built to protect the houses by preventing the natural recycling of sand. This wall is moderated many times since then.

Since 1989 the Western Bay of Plenty District Council is responsible for the administration of Waihi Beach. The Council initiated many research reports and policy plans since then, in order to create a sustainable solution for the coastal hazard problems. Paragraph 7.1.2 provides the process of decision-making of the Council until now and appendix A-I contains a time table, including the most important facts.

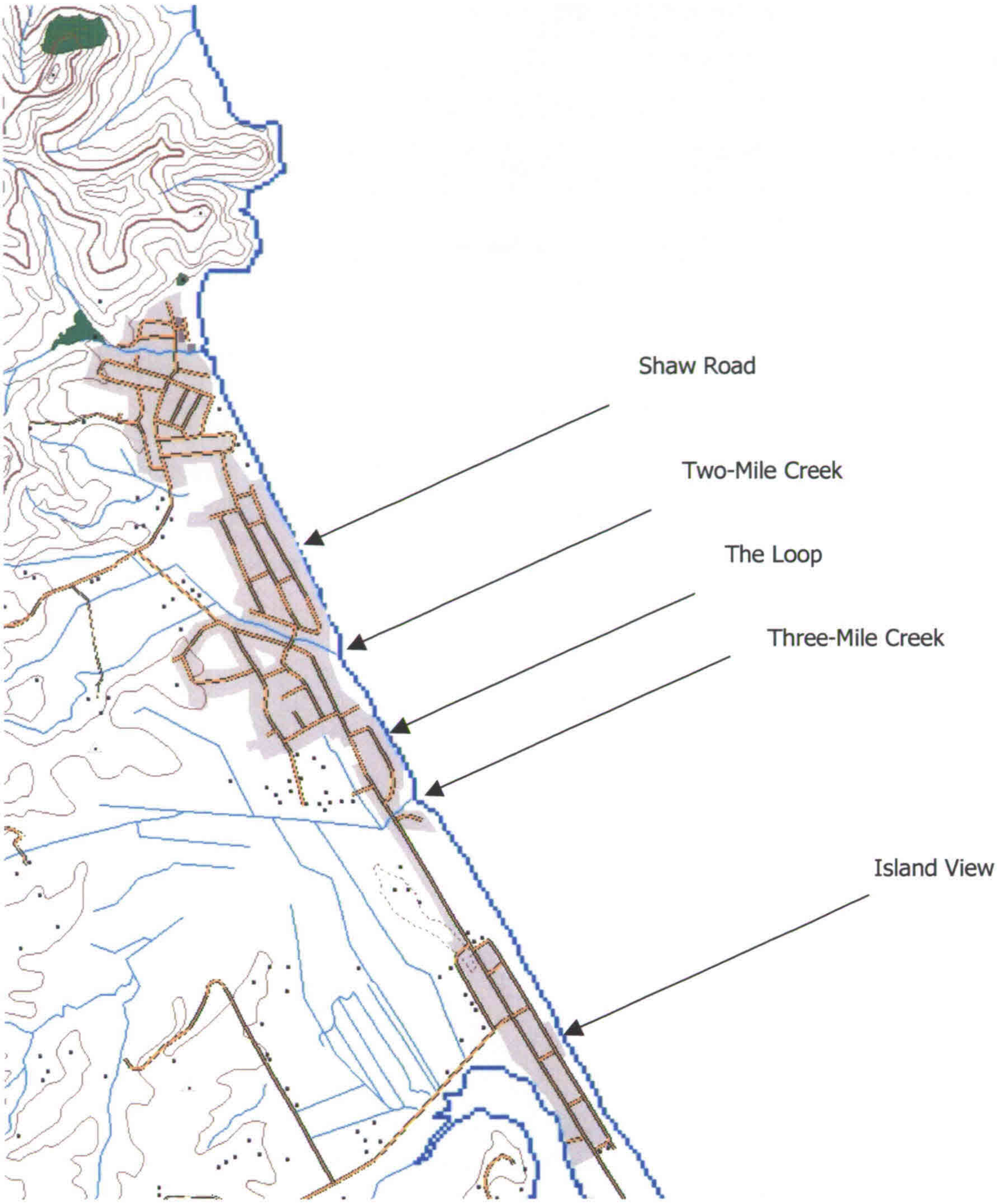

Figure 3-3 Close up of Waihi Beach

3.3. Geology

3.3.1. Geologic evolution

For a good interpretation of the processes in, and development of, a coastal area, the geologic evolution of coastal landforms needs to be analyzed. Waihi Beach, together with Matakana Island and Mount Maunganui, forms a unique combination of a tombolo - barrier island - tombolo. This formation has evolved over the last 6500 years with a relative stable sea-level. The primary sand sources are the large volcanic eruptions in the Taupo Volcanic Zone, the last about 20.000 years ago. The Taupo Volcanic Zone is located south of Waihi Beach. The Bay of Plenty is funnel shaped and at the time of the eruptions the sea-level was about 100 meters lower compared to present day sea level. During the sea-level rising (from 20.000 until 6.500 years ago) sediments were taken to the present-day shoreline. Waihi Beach is a subsiding coast with a net down-drop rate of approximately -0,1 m/1.000 year. This rate is typical for the areas in the Bay of Plenty.

3.3.2. Geomorphology

Waihi beach can be seen as a 9 km-long, straight barrier beach, attached as a tombolo to the Bowentown Heads in the south. This tombolo is situated between the relative stable strong points Bowentown Heads to the Southeast (SE) and the Coromandel Ranges to the Northwest (NW). The Bowentown Heads are a weathered remnant of volcanic lava dome of Minden Rhyolite of Pliocene age. The Coromandel Ranges in the NW of Waihi Beach are a combination of Mid Miocene Beeson's Island Volcanics overlain by Pliocene Minden Rhyolite.

Below Bowentown Heads the Katikati ebb-tide delta of Tauranga Harbour is situated followed by the barrier island Matakana Island.

North of The Coromandel Ranges the beach of Orakawa is located.

The duneline at Waihi Beach is characterized by large irregular embayments ranging from 800 to 2.500 meters in length and a depth averaging from 20 to 50 meter. These embayments are not dynamic in location as can be seen from aerial photographs taken through the years. The shoreline is composed out of foredunes, an upper shoreface from the beach down to about -8 m below MSL, a lower shoreface from about -8m to -20 m below MSL and an inner continental shelf from -20m to about -50m.

The upper shoreface is characterized by a subtle change in slope (about 1:58 in the current situation) and sediment composition. The diabethic length of the upper shoreface is about 300m in the south to 1000m in the north of Waihi Beach. Longshore bars with rip current channels can be seen migrating onshore and offshore in response to changes in the wave climate.

The lower shoreface is convex-up shaped overlain by the Katikati Inlet ebb-tide delta. The delta extends offshore for about 3 km length to -20m depth and stores approximately 30 million m^3 of sand. The main ebb-tidal channel is faced to SE, probably due to a net SE littoral drift.

The inner continental shelf is characterized by shore normal ridges,"submarine dunes", which are welded on the lower shoreface. The submarine dunes are asymmetric to the NW, are 0.2 m to 5.0 m high, spaced about 250 to 1,300m apart and are up to 2,000m long. A bottom current to the NW of sufficient velocity to transport bedload sediments in -20m to -50m water depth is suggested by the asymmetry and strike of the submarine dunes.

3.3.3. Sedimentology

Sand texture and mineral composition can be used to determine if a beach system has a renewable, partly renewable, or non-renewable resource. For the beach and barrier dune there is a progressive subtle fining of grain size northwards and improvement in sorting. Offshore, the beach out to -5m depth is characterized by Moderately Well Sorted Medium to Fine Sand. From -5m to about -20m depths, the seabed is composed of Well Sorted Fine to Very Fine Sand. At about -20m depth, there is an abrupt coarsening in sediment to Poorly Sorted Gravelly Coarse Sand that extends down to about -50m before abruptly grading into Mud.

About 95% of the beach sand is composed of the light minerals Quartz, Plagioclase Feldspar, Volcanic Glass and Shell Fragments. The remaining part, 5%, consists predominantly of heavy Hypersthene and Hornblende (black colored). The beach sands are relatively homogeneous in composition along the beach. For the lower shoreface, Glass-enriched Sands were identified in a continuous band along the nearshore seabed of Waihi Beach in depths of -5m to -25m. For the inner continental shelf, the fine-grained Felsic Sand overlies coarse-grained sand rich in rock and shell fragments.

3.4. Morphodynamics

3.4.1. Shoreline trends

The beachfront of Waihi Beach is irregular in shape and composition. From observations made in the past we know that the dunes in the north used to be about 30m high. The last 70 years these dunes have been taken away by people and have been eroded until a height of about 1 meter height above MSL. Due to a dune-care program initiated by the District Council these dunes are now redeveloping again. Further to the south houses are build about 10 meters from the beach. To protect these houses, seawalls composed out of rock have been constructed. The shoreline has prograded here to the seawall. The groundwater table is high at these locations as can be seen by the groundwater seeping into the sea during low-tide. South of the seawall from The Loop until The Bowentown Heads the beach is composed out of dunes with a width of about 200m. These areas are nowadays also part of the dune-care program.

The Waihi Beach barrier has a NNW-SSE orientation; so onshore dune building winds would blow from the sector N-SE. The direction of the winds in the study area is predominantly low speed west and southwest associated with the passage of mid-latitude anticyclones. This direction means an offshore wind along Waihi Beach and those winds inhibit the progradation of dune complexes.
Subtropical low-pressure systems referred to as Tasman Depressions with an infrequent passage (10-20 per annum) are accompanied by high-speed onshore-directed east and northeast winds. Decaying tropical cyclones also affect the study area to a greater or lesser degree depending on their track southeast over New Zealand. In the Western Bay of Plenty Cyclones Fergus and Drena produced onshore winds that backed anticlockwise from SE to W during SE passage of each cyclone. Whilst eroding the beach and foredune in places such onshore winds were observed to accelerate dune building.
Important long-term wind information may be inferred from the orientation of blowout and parabolic dunes.

In the early nineties "El Nino" determined partly the climate. During such a phase the wind tends to blow from the S-W quadrant, which is offshore in the study area. On the contrary, during a "La Nina" climate phase the wind tends to blow from the N-E quadrant.

During the measurement of wave and wind data these phenomena have to be taken into account.

Waihi Beach can be seen as a transgressive coast in the long term. Evidence of this is found in the steep profiles of the dunes and the relatively high concentration of the heavy Hypersthene and Hornblende (black colored) sand on the beach (more than 5%).

3.4.2. Waves and tides

The tides in the study area range from 1.27 to 1.65 m for mean, neap and spring tides. Relatively large Spring Tides exceeding 2.0m were predicted to occur in June, July, August, December (1996) and January, February, March. The large tides occurred over periods of 3 to 6 days following new moon and full moon. Coastal erosion along Waihi Beach has a higher probability of occurring during such high spring tides, especially if they are accompanied by onshore storm waves.

The western Bay of Plenty is sheltered by the North Island from deep-water waves approaching from SSE to NNW. Those deep-water waves are generally smaller at the east coast of New Zealand than elsewhere on the New Zealand coast. The prevailing deep-water waves approach the coast from N and E with wave heights of 0.5 m to 1.5m and periods of 5 to 7s. Long-period swells appear to originate from subtropical disturbances north of New Zealand whereas shorter period seas are generated by local weather patterns.

Wave records for the study area are limited, because there is no national organization that measures wave heights. In the period of 1991-1994 measurements of wave heights have been done 8km off the Katikati Entrance in 34 m deep water. These records are not representative for the long term period, because it is a short period of measuring and the measurements were made in an "El Nino" period. For the 3-year period of record, significant wave heights of less than 1m were recorded for about 70 % of the time and mean wave heights of about 0.8m. The wave heights were generally higher in winter (1.2m) compared to summer (0.7m). During the period of record 25 storm events were observed with peak significant wave heights (H_{sig}) ranging from 2.19 to 4.27m and mean periods (T_z) from 7.16 to 17.46s. The maximum wave height recorded was 6.7m.

In terms of wave direction 66 % of the 25 storms events came from directions E of (about 060°T, with respect to the north).

3.4.3. Sand Transport

From studies (Healy, 1993 and Gibb, 1997) it is clear that Waihi Beach is subject to erosion and therefore there is a net loss of sediment. Sediment transport is induced by waves and wind. Limited representative data of these phenomena as well as data of sediment transport are available. By analyzing the observations, interviewing local people and studying aerial photographs estimation is made of the sediment transport along and perpendicular to the beach.

The dominant wave direction of the deep water waves in the Bay of Plenty is from N to E. Waihi Beach is sheltered by Mayor Island (about 28 km offshore) but is opposed by the diffracted deep water waves. Refraction occurs near the coastline and wave focusing due to the irregularities in the inner shelf affects the direction of the incoming waves. In the surf zone the waves induce a longshore and crosshore sediment transport.

From the observations it can be concluded that there is a minor net longshore drift directed from NW to SE. Evidence for this statement is that the dunes in the north have been eroded. If the net longshore drift was directed to the north accretion had to be seen against The Coromandel Ranges. In the past the Local Council planned a road along the coastline from the northern part of the beach along the Coromandel Ranges to the beach of Orokawa. This road could not be constructed since the sea has taken the land. Other evidence is the accretion of the southern beach to Bowentown Heads and the erosion of Matakana Island behind Bowentown Heads.

Crosshore sediment transport to the beach occurs in calm wave conditions and offshore winds. These conditions occur during an "El Niňo" phase. During a "La Nina" phase the winds are predominantly N-E, onshore, which induce sediment transport offshore. The last phase in New Zealand was an El Niňo and the experts expect the next decades a La Nina (the time span of one phase is about 20 years). Therefore erosion is to be expected.

3.5. Coastal hazards at Waihi Beach

3.5.1. Erosion hazards

The following aspects have a role in the erosion of the beach at Waihi Beach:

Global sea level rise

The estimated global sea level rise is estimated to be 49cm/100 year. This number includes a 1cm/100 year subsidence of Waihi Beach. The raise of MSL will result in a transgressive shoreline.

Regional sea level effects

The wind direction is very important in coastal areas concerning a possible wind-setup. During "El Niňo" phases a low wind-setup is expected (offshore winds) and during a "La Nina" a large wind-setup (onshore winds).

Regional sand supply

Gradients in sediment transport induce erosion or accretion. Since the net drift is SE, the northern beaches erode. These beaches do not receive sand from the beaches of Orokawa because of The Coromandel Ranges. The only sand source is to be found from the inner shelf. Amounts of this transport are not available, though the presence of this transport can be seen by the shells from the inner shelf, which are found on the northern beaches.

Local wave focusing

Sand reefs at the inner shelf refract the incoming waves to the beach. These reefs are not stable since they migrate in response to the wave climate. Therefore in every storm, different refraction patterns occur and also different locations at the beach will erode faster. As a result of wave focusing embayments appear. The embayments are 800m to 2,500m in length with centers ranging from 400m to 3,000m apart.

Local creek mouths

Due to large rainfall the flow in the creeks can be significant. These flows increase the erosion near the outlets of the creeks.

Local property protection works

The 2.35km-long property protection works along Waihi Beach have exceeded their useful life by up to 15 years and are no longer providing sustainable protection of beachfront property and reserves. The rock revetment is poorly designed and constructed and is enhancing scour through wave reflection. The required sand reservoir for an unprotected coastal area is estimated as 400m^3/m beach. This is a generally accepted amount. At the seawall this reservoir is certainly not available.

Local groundwater effects

The groundwater table behind the seawall is high compared to the water table on the beach. This results in groundwater seeping onto the beach and low effective stresses in the sand because of the lack of a properly designed filter construction. At high tide the sand will become in suspension easy and erosion will occur.

3.5.2. Flooding hazards

The following aspects have a role in the flooding of low-lying areas in Waihi Beach:

Storm surge wave washover

The combination of barometric set-up, wind set-up, wave set up, predicted astronomic tide level and wave run-up contribute to a maximum level of storm wave run-up. For coasts with landforms at elevations less than storm wave run-up levels, overtopping and inundation of coastal hinterland will occur. Total design wave run-up for Waihi Beach is estimated as about 4m at the northern end, to about 5.4m at the Bowentown end.

Tsunami wave run-up

Long period waves (generally 20-30 minutes) are generated by large short duration disturbances of the sea-floor and may cause erosion of the coast and inundation of the low lying areas. The Bay of Plenty is not likely to suffer a very large Tsunami, based upon the present state of knowledge.

Flooding from creeks

Two Mile Creek and Three Mile Creek discharge along Waihi Beach. The presence of these local creeks causes the following flooding hazards:

- It allows storm surges to inundate low-lying land alongside both Creeks for several hundred meters inland.
- Flood flows are restricted by vegetation and accumulated sediment in the narrow channel leading to the ocean beach outfall.
- The peak flood flow of the creeks is rising. The causes of this are relative large areas of rural land discharging in the streams and drains and the further development of the urban area.

Part B

Coastal Zone Management

Property near the beach at Shaw Road 'protected' by the seawall

4 Problem definition

4.1. Introduction

In the previous chapters general information is given about New Zealand, the Bay of Plenty and in special the coastal problems in Waihi Beach. In solving those problems, one wants to engineer a solution, which solves the problem. However, an important factor is the implementation of that solution in a community. Within a community there are a lot of people with different functions (governing, living, working, recreating) and opinions. These people have to be addressed, before a decision can be made to implement a solution. Preferably this process is clear and carried out correctly and there's a lot of agreement. If not, this means a lot of consultation, meeting and probably discussions, which can sometimes take a lot of time.

In part B of this report the decision-making process is analysed and some recommendations are being made to improve the system. These recommendations are separated on central and local level.

4.2. Key issue

"The current solution for the coastal hazard problems in Waihi Beach seems not to satisfy any of the stakeholders, which are involved in the decision-making process."

In the Waihi Beach issue, the decision is now being made by the District Council to go for the long-term solution of diverting the Two and Three Mile Creek and reconstructing the seawall. Constructing the seawall is the first stage. This causes a lot of misunderstanding among the different stakeholders.

4.3. Main objective

The objective of this part is divided in two parts:

I: *"By describing and analyzing the institutional framework and the decision-making process of Integrated Coastal Zone Management projects in New Zealand, recommendations will be made to improve that decision-making process."*

The institutional framework and the policies on the different governmental levels will be described (chapter 5). In chapter 6 the policies will be sorted out by using an Integrated Coastal Zone Management Model. By analyzing the framework some recommendations will be made on the functioning of the decision-making system.

II: *"By describing the New Zealand decision-making process and the Waihi Beach decision-making history, recommendations will be made in order to improve the process through which a solution is developed in Waihi Beach."*

In chapter 7 a closer look will be taken at the Waihi Beach case. The decision-making process is described and after that recommendations will be made. We will compare the Waihi Beach situation with the general institutional system.

5 The New Zealand governmental framework

5.1. Introduction

When dealing with an issue in the coastal environment, one has to comply with a lot of policies and rules, made by different governmental organizations. In paragraph 5.2 those organisations and their functions and responsibilities are mentioned. The institutional system of New Zealand is divided in 3 levels: Central, Regional and Local government, as can be seen in the subparagraphs. Also the different levels of Courts are given, since they might play a role (amongst others) in a coastal management issue. Underneath this introduction, you can find a flow chart of the institutional system of New Zealand.

Paragraph 5.3 briefly sets out the statutory framework in New Zealand. In this paragraph all the important acts, policies and plans are mentioned in respect with the coastal zone.

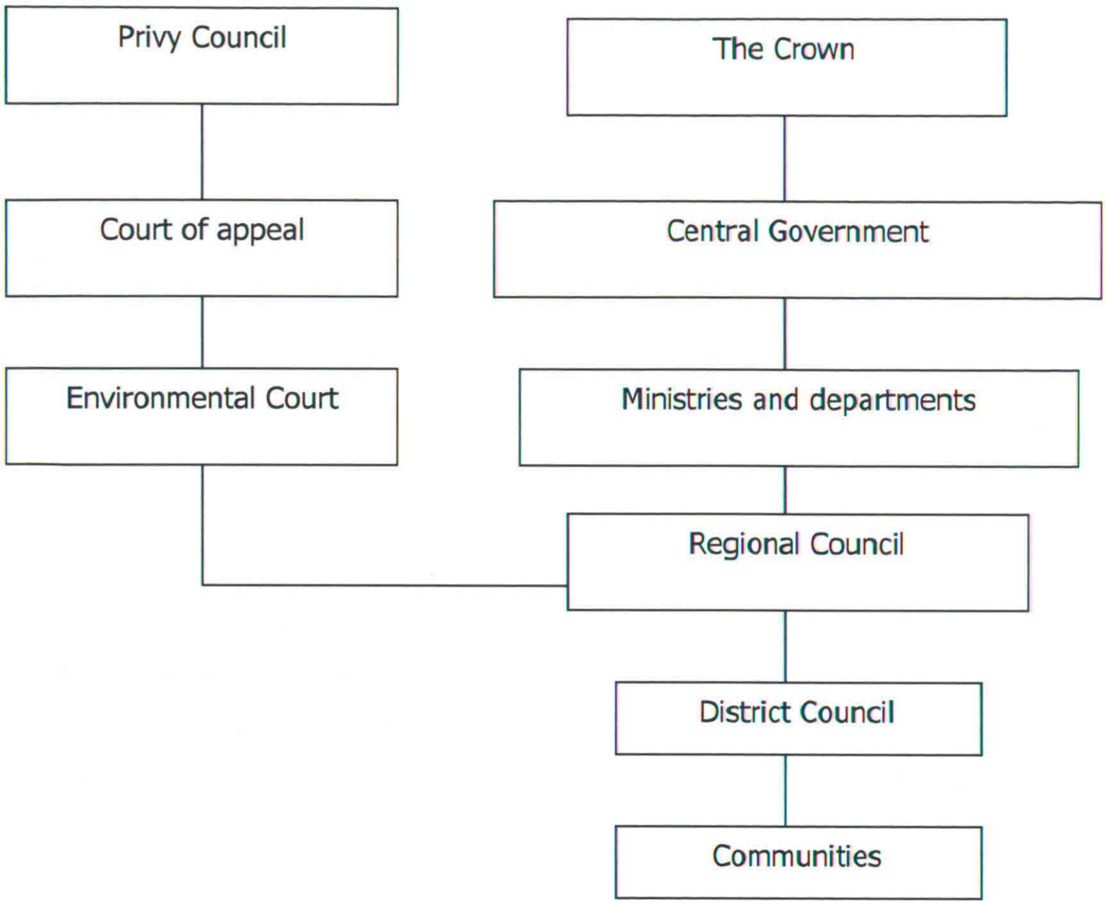

Figure 5-1 Overview of governmental system

5.2. The New Zealand institutional system

5.2.1. Central government

New Zealand is a constitutional monarchy. The Queen of Great Britain, Queen Elizabeth II, is the Head of State. The Queen's representative in this country is the Governor-General who has all the powers of the Queen in relation to New Zealand. The Queen and the Governor-General remain politically neutral and do not get involved in the political contest.

New Zealand has a single chamber of Parliament known as the House of Representatives. The Government is accountable to Parliament for its actions and policies. So Ministers are answerable to Parliament for their own actions and policies and for the actions and policies of the departments and state agencies under their jurisdiction.

Much of the governmental work is performed by ministries, government departments and other government agencies that are collectively known as the public sector. These ministries and departments carry out a total of 77 different portfolios. The portfolios of interest to our project are under the following Ministers:

- Minister of Conservation (Department of Conservation)
- Minister of Environment (Ministry of Environment)
- Minister of Economic Development (Ministry of Economic Development)
- Minister of Justice (Ministry of Justice)
- Minister of Courts (Department for Courts)
- Minister of Fisheries (Ministry of fisheries)

The relevant functions and responsibilities of the most important ministries or departments are stated here:

Department of Conservation

The Department of Conservation (DOC) administers most of the Crown land in New Zealand protected for scenic, scientific, historic or cultural reasons, or set aside for recreation. This is almost a third of New Zealand's land area, including national, forest and maritime parks, marine reserves, nearly 4000 reserves, river margins, some coastline and many offshore islands.

Functions: (stated in the 1991 Resource Management Act (RMA))

- The approval of the Regional Coastal Environment Plans;
- Approving applications for Restricted Coastal Activities (RCA, requirements can be found in the New Zealand Coastal Policy Statement);
- The monitoring of the effect and implementation of the Coastal Policy Statements and coastal permits;
- Establish and run a coastal tendering process where there is likely to be competition for occupying the Coastal Marine Area;
- Vesting legally reclaimed land.

Responsibilities:

- Advocacy of the Regional Policy and Plans and District Plans to the general public;
- Administrating the Coastal Marine Area, provided the Crown has vested ownership to that area;
- The protection of marine mammals and wildlife;
- Supervising the whale and dolphin rescue;
- Managing and caring for marine reserves.

Ministry of Environment

This Ministry reports to the Government on the state of New Zealand's environment and the way that environmental laws and policies work in practice. The most important policy is the Resource Management Act 1991.

Functions: (under the RMA)

- The recommendation (to the Governor-General, who has the right to approve statements) of the issue of National Policy Statements;
- The recommendation of the making of regulations concerning the environment;
- The monitoring of the effect and implementation of this Act, National Policy Statements and water conservation orders;
- The monitoring of the relationship between central and local government;
- The Minister of Environment also has the power to appoint other persons to take over the functions, powers and duties of a local government, when they don't function properly.

Responsibilities:

This ministry is responsible for the Coastal Marine Area, which is from Mean High Water Springs (MWHS) to the 12 Nautical Mile limit.

Ministry of Economic Development

The Ministry of Economic Development facilitates, leads and implements the Coalition Government's vision for economic development. One of the Government's key goals is to grow an inclusive, innovative economy for the benefit of all. Sustainable economic development is central to the achievement of this goal. This ministry also governs tourism.

5.2.1. Local government

The local government in New Zealand is divided into two levels:

- Region Council
- District Council

Region Council

New Zealand is divided into 16 different regions, which each have their own council. The councils manage environmental issues, resource management and public transport. They promote sustainable management for the natural and physical resources: land, air, coast and water. They monitor the effects of people's activities on the environment and can limit or control the use of resources.

Functions:

- The control of the use of land for the purpose of:
  - The maintenance of water quality and quantity;
  - The avoidance or mitigation of natural hazards (!);
- The preparation of objectives and policies in relation to effects of the use or development of land of regional significance and the Coastal Marine Area (Regional Policy Statement and Regional Coastal Environment Plan);
- In respect to any coastal marine area in the region, the control of:
  - The occupation of space of land vested in the Regional Council, i.e. foreshore or seabed, and the extraction of sand or other natural material;
  - Navigation and safety (also in harbours);
  - Oil pollution.
- The control of the taking, use, damming and diversion of water, the control of the quantity, level and flow of water in any water body, the construction of large earthworks and structures in rivers;
- In relation to any bed or water body, the control of planting of any plant for the purpose of the avoiding or mitigation of natural hazards.

Responsibilities:

The Region Council is responsible (in conjunction with the Minister of Conservation) for the area from Mean High Water Spring (MHWS) to the 12 nautical mile limit (the Coastal Marine Area) except where the District Council has bylaws.

District Council

The District Council is the local government, which discusses community issues with inhabitants of the towns in the district. The issues can be the state of the roads or sewerage system, the waste management, wastewater management, infrastructure planning, recreational and sporting facilities, safety, public health etc. The District Council provides services such as storm water outfalls, and pipelines, jetties, protection works and recreational facilities.

The Council consists of a number of councillors, who represent the community of his/ her Ward (a Ward is a subdivision of a district) and explicates and defends its point of view in a council meeting. The councillor communicates with the inhabitants of the Ward about the community issues.

In the Western Bay of Plenty District Council are 12 Ward Councillors. Councillors are elected by the resident electors; the number of councillors in the council for one Ward depends on the number of resident electors in that Ward. The Ward of Waihi Beach is represented by one councillor. That Councillor communicates with the community through the Community Board, which consists of inhabitants of the Ward.

Functions:

- The preparation and implementation of District Plans;
- The control of any actual or potential effects of the use, development or protection of land, including for the purpose of the avoidance or mitigation of natural hazards;
- The control of subdivision of land.

Responsibilities:

The District Council is responsible for the area from MHWS landwards and in harbours and estuaries.

5.2.2. Courts

When constructing a coastal protection work in New Zealand, consent must be granted, to clarify the environmental effects and the measures that are being taken to mitigate them. Consent can be lodged for at the Region Council. The Region Council also sorts out arguments between for instance a District Council decision and a person, who disagrees the District Council's decision.

If the Region Council can't make a decision or disagreement still exists, one can take the case to the Environmental Court, where a judge and two commissioners (often surveyors or engineers) will judge the subject. When still disagreement exists, one can successively go to the Court of Appeal and the Privy Council.

The different levels of Court are briefly explained here:

Environmental Court

The Environmental Court is constituted by the Resource Management Amendment Act 1996. The Court consists of Environmental Judges and Environmental Commissioners. Usually one Judge and two Commissioners constitute sittings of the Court. The parties before the Court are usually represented by lawyers, but anyone may appear in person.

Most of the Court's work involves public interest questions. Because of the gravity and complexity of the subject matter of the proceedings, oral decisions can seldom be given and decisions are usually reserved (a written judgement is delivered at later date).

Functions:

- Designations authorising public works (energy projects, hospitals, schools, sewerage works, major roads) and major private projects (tourist resorts, shopping centres);
- Classifications of waters, water permits for dams and diversions, taking of geothermal fluids, discharges from sewage works;
- Maximum and minimum levels of lakes and flows of rivers, and minimum quality standards and water conservation orders;
- Land subdivision approvals and conditions, development levies, car parking contributions, reserve contributions, road upgrading contributions, regional roads, limited access roads, and stopping roads;
- Environmental effects of prospecting, exploration, mining; including underground, open pit & alluvial mining;

- Enforcement proceedings (including interim enforcement orders), declarations about the legal status of environmental activities and instruments, existing and proposed.

Responsibilities:

The Court has jurisdiction under the following enactments:

- Resource Management Act;
- Regional and District statements and plans;
- Public Works Act (objections to compulsory taking of land);
- Historic Places Act (Appeals about archaeological sites);
- Forests Act (appeals about felling beech forests);
- Local Government Act (Objections to road stopping proposals);
- Transit NZ Act (Objections regarding access to limited access roads).

Court of Appeal

The Court of Appeal, located in Wellington, is the highest level of Court based in New Zealand. It has existed as a separate court since 1862. The head of the New Zealand Judiciary, the Chief Justice is a member of the Court and sits periodically. The President and six other permanent appellate Judges constitute the full-time working membership of the Court.

The Court deals with appeals of matter heard in the District Court, the High Court and the Employment Court, but most important in our situation is that the Court of appeal also deals with matters that come from the Environment Court.

Privy Council

The Judicial Committee of the Privy Council was formally established by the United Kingdom Judicial Committee Act in 1833. It consists of the Lord Chancellor, the Lords President of the Council, the Lords in Appeal Ordinary and judges of the superior courts of the Commonwealth countries as appointed by the Crown.

All the statutes and Orders in Council providing for appeals from New Zealand to the Judicial Committee are of United Kingdom origin but all have been declared to be in force in New Zealand. The Judicial Committee is regarded as a New Zealand Court when it sits on appeals from New Zealand. The Judicial Committee's decisions on appeals from this country, are binding on New Zealand Courts.

Appeals may be made to the Privy Council from the High Court or Court of Appeal of New Zealand.

5.3. New Zealand's coastal policy

The different governmental institutes all have policies and regulations. By this they can execute their functions and responsibilities. In this paragraph the most important (coastal) policies are stated. The levels of government are:

- Central government (5.3.1)
- Regional government (5.3.2)
- Local government (5.3.3)

5.3.1. Central Government

The Central Government has different policies, which are important to the coastal environment:

- Resource Management Act
- Coastal Policy Statement
- Building Act

Resource Management Act 1991 - Ministry of Environment

Introduction:

The Resource Management Act 1991 (RMA) is the core of the legislation intended to help achieve sustainability in New Zealand. By bringing together laws governing land, air and water resources and concentrating on the environmental effects of human activities, the RMA introduced a new approach to environmental management. The Act's purpose is to promote the sustainable management of natural and physical resources.

The RMA sets out how to manage the environment, including:

- Air
- Water
- Soil
- Biodiversity
- The coastal environment
- Noise
- Subdivision
- Land use planning in general

Purpose of the Act:

In general this is to promote the sustainable management of natural and physical resources.

The definition of "sustainable management" is managing the use, development and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural well being and for their health and safety while –

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

Relevant policy for the coastal environment:

- The preservation of the natural character of the coastal environment (including the coastal marine area) and the protection of it from inappropriate subdivision, use, and development;
- The maintenance and enhancement of public access to and along coastal marine area;
- Any finite characteristics of natural and physical resources

- The maintenance and enhancement of amenity values[1]

In achieving the purpose of this Act the *Treaty of Waitangi* shall also been taken into account. The *Treaty of Waitangi* is an agreement, which forms a compact or covenant between the Crown and Maori. It was signed in 1840 and recognized the prior occupation by Maori people of New Zealand. The treaty enabled the peaceful acquisition of land for settlement purposes and ensured that immigrants could come and live here in peace. It allowed the Crown to set up a government to establish laws. In return the Crown were to guarantee and actively protect Maori tribal authority over their lands, fisheries, forests, villages, treasures and culture and extend to them the status and rights of British citizens.

New Zealand Coastal Policy Statement - Department of Conservation

Introduction

The Resource Management Act 1991 established a new coastal management regime based on partnership between the Crown and the community through their regional and local authorities. The Act requires that at all times there shall be a New Zealand Coastal Policy Statement. This will guide local authorities in their day-to-day management of the coastal environment.

Purpose NZCPS

The purpose of the New Zealand Coastal Policy Statement is to state policies in order to achieve the purpose of the Resource Management Act 1991 in relation to the coastal environment of New Zealand.

Policy NZCPS

The stated policies in the New Zealand Coastal Policy Statement are subdivided in seven chapters. The content of these policies can be roughly summarized as:

- Identify and map areas sensitive to coastal hazards;

[1] "amenity value" is those natural or physical qualities and characteristics of an area that contribute to people's appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes.

- With respect to coastal hazards the precautionary principle would be effected through an 'avoidance' approach to those hazards;
- Where development has not occurred, avoid the hazards, by recognizing the buffers that natural features such as dunes can provide against the hazard (work with nature). Where development has occurred in a hazard prone area, use hard protection works only where they are the best practicable option; this will involve an evaluation of all options;
- Where development is subject to coastal hazards consider moving from the hazard prone area (retroactive avoidance).

The NZCPS also defines a range of activities that are classified as a RCA[1]. These activities have a significant or irreversible adverse impact on the coastal marine area. For example sea wall segments longer than 300m and groynes longer than 100m are each classed as an RCA.

Building Act 1991 - Building Industry Authority

Introduction

Building work is governed by one piece of legislation - the Building Act. It was assed as "an Act to consolidate and reform the law relating to building and to provide for better regulation and control of building". The Act is not involved with planning and resource management, the finish and appearance of a building, or protection of capital investment. These are the owner's responsibility. Gas and electrical work also are not covered by the Act.

The Building Act applies only to the physical aspects of building work. Other legislation may also apply to building proposals. For example, the Resource Management Act 1991 affects planning matters.

Purpose

- Necessary controls relating to building work and the use of buildings, and for ensuring that buildings are safe and sanitary and have means of escape from fire;
- The co-ordination of those controls with other controls relating to building use and the management of natural and physical resources.

[1] Restricted Coastal Activity: the Minister of Conservation is the consent authority

<u>Relevant policy for the coastal environment</u>

For buildings on land subject to erosion a districts council shall refuse to grant a building consent involving construction of a building or major alterations to a building if:

- The land on which the building work is to take place is subject to, or is likely to be subject to, erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage;
- The building work itself is likely to accelerate, worsen, or result in erosion, avulsion, alluvion, falling debris, subsidence, inundation, or slippage of that land or any other.

Unless the District Council is satisfied that adequate provision has been or will be made to protect the land or building work.

5.3.2. Regional Level

At the regional level there are two mechanisms for managing the coastal environment:

- The Regional Policy Statement;
- The Regional Coastal Environment Plan.

Regional Policy Statement

<u>Introduction</u>

The Regional Policy Statement has been prepared in accordance with the requirements of the Resource Management Act 1991. The Statement is subject to national level policy statements, standards, regulations and orders issued under the Act. It provides the overall principles for the promotion of sustainable management in the region. Day-to-day users of resources, controlled through the regional plan and district plan, exercise more detailed management.

<u>Purpose PRPS</u>

The purpose of a (proposed) regional policy statement is to achieve the purpose of the Act by providing an overview of the resource management issues of the region and policies and methods to achieve integrated management of the natural and physical resources of the whole region.

Policy PRPS

The Statement contains applicable policies relating to the following issues:

- Land;
- Fresh water;
- Coastal environment;
- Natural hazards;
- Physical resources/built environment;
- Natural character and ecosystems.

Relevant policies for the coastal environment:

- To ensure that, where natural character is already substantially compromised by development, all practicable steps are taken to avoid, remedy or mitigate adverse effects on remaining natural character, particularly when further subdivision, use or development is proposed;
- To enhance public usage and enjoyment of the coastal marine area.

Relevant policies for natural hazards:

- To promote community understanding of the risks associated with natural hazards;
- To recognize and protect the integrity of natural ecosystems that are natural defences against flooding, inundation or erosion, particularly where new subdivision, use and development is proposed;
- To recognise that some natural features may migrate inland as a result of dynamic coastal processes and to take into account of this in providing for the preservation of natural character when subdivision, use or development in the coastal environment is being assessed;
- To ensure that where existing hazard mitigation works are having adverse effects on ecological, cultural or natural character values, the adverse effects will be remedied or mitigated, to the extent practicable.

Regional Coastal Environment Plan

Introduction

Under the RMA a Regional Council is required to produce a Regional Coastal Plan. The issues, objectives and policies of this plan cover the coastal environment. Rules contained in this document apply only on the Coastal Marine Area (CMA). The rules are structured through the definition of zones. The Coastal Management Zone (CMZ) covers most of the open coast. Relevant rules for the research field cover:

- Maintenance of, or minor alteration to, existing structures in the Coastal Management Zone;
- New structures in the Coastal Management Zone;
- Structures which exceed the criteria for classification as RCA (Restricted Coastal Activity).

Purpose

The purpose of this plan is to enable Regional Council to promote the sustainable management of the natural and physical resources of the coastal environment.
The plan has as proposed objective for the coastal hazards field: "No increase in the total risk from coastal hazards."

Policy

For the policies of importance is referred to the policies of the New Zealand Coastal Policy Statement and the Regional Policy Statement.

5.3.3. Local level

District Plan

Introduction:

The District Plan is prepared by the District Council to meet its obligations under the provisions of the RMA. Generally speaking, the plan affects new development (i.e. new buildings) or new or changes in use of land or buildings. Many things can be done "as of right", while others require permission from Council.

Purpose:

The District Plan contains relevant objectives, policies and methods for addressing the resource management issues of the District for the next ten years. It also contains rules. This will help the District Council to carry out their functions in order to achieve the purpose of the Resource Management Act.

For this research field the most important objective in the Plan is the objective in relation to natural hazards:

- Minimisation of the threat of natural hazards to human life and the natural and physical environment;
- Protection of the existing natural character of the coastal environment and other natural features having recognised ecological, landscape or other significance to the District.

Policy:

The policies in the plan are in line with the Regional Policy Statement and the New Zealand Coastal Policy Statement. The following statements are included:

- The District Plan is based on the control of off-site effects. These are the effects that an activity may have on the immediate environment of the wider community. Exception is made for activities within a site, which fundamentally effects the sustainable management of natural/physical resources;
- The Council wishes to minimise unnecessary regulation while still ensuring that environmental standards are not compromised. This has resulted in zoning of the area. Zoning recognises that it is appropriate to have different environmental standards for different parts of the District;
- Activities, which are not provided for, can still become established, unless they are a prohibited activity.

6 Integrated Coastal Zone Management in New Zealand

6.1. Introduction

Coastal regions are among the most vulnerable areas in the world, due to severe pressures which may result from a variety of human activities and natural causes (high water and storm surges, erosion processes, tsunami over wash and inundation). Gradual large-scale processes, such as climate changes and sea level rise, are serious increasing these problems.

Integrated Coastal Zone Management (ICZM) is widely recognized as a matter to deal with these complex issues in the coastal area and is still developing. This is a long interactive process involving a number of cyclic steps. A clear methodology for ordering the complex issues in the coastal zone is developed; some sort of guideline. This methodology is developed by the National Institute for Coastal and Marine Management (in Dutch RIKZ) in the Netherlands. The result of the model aims to develop a practical procedure to the following issues.

- Judge the feasibility and the potential success of proposed actions at the coast;
- Identify obstacles in the way of continuation of the ICZM process;
- Identify the most feasible next action, as well the conditions to be met for these actions to be successful;
- Provide a framework for better exchange of information;
- Enhance the communication between the various disciplines and actors.

In paragraph 6.2 you can find the description of the methodology. In paragraph 6.3 a description of the stakeholders, the application of the model for the New Zealand situation and the recommendations can be found. Useful information for this paragraph about New Zealand in general and the New Zealand government can be found in chapter 2 and 5.

6.2. Description of the methodology

An ICZM project consists of different phases. In the first phase the measures that should be taken to solve short- and long-term coastal problems are put in a time schedule. This phase is divided in a *planning phase* and a *decision-making phase*.

The next phase is the implementation phase, in which the plan will be executed. This phase consists of the *technical implementation phase* and the *institutional implementation phase*. After this phase will follow monitoring and an evaluation.

The institutional setting in terms of the actor groups and specific actors and a description of the coast are also important for application of the methodology. It's important to keep this in mind before reading the next paragraph.

6.2.1. Implementation requirements categories

The main object of the methodology is to consider the status of the ICZM process and the role and position of the relevant actors. This consideration is based on four implementation requirement categories:

"Mandate" or: what actors are <u>allowed</u> (and expected) to do, in terms of the responsibility and executive powers available to actors in performing ICZM tasks, actions and decisions.

"Capacity" or: what actors are <u>capable</u> of doing in terms of knowledge and expertise, specific ICZM skills (analysis, design), human resources and facilities (various equipments).

"Commitment" or: the degree to which the relevant actors are actually <u>involved</u> with and committed to the successful application of ICZM.

"Financial potential" or: the extent of the <u>financial</u> resources available to actors, or the actor's possibilities to raise money, for financing ICZM related tasks and activities.

6.2.2. Implementation aspects

In order to assess the status on the implementation requirement categories a number of implementation aspects have been defined within each of these categories.

Implementation phases considered in specification of "mandate"

- Planning
  - Planning initiation: the authority to initiate an ICZM planning exercise;
  - Planning and assignment: the authority to execute or take part in ICZM planning and/or to assign other parties to execution of ICZM planning;
- Decision making
  - (Final) plan formulation: the authority to formulate the final plan (i.e. the preferred package of proposed technical and institutional measures) to be submitted for approval by a government (District or Regional Council, Environmental Court);
  - Plan adoption: the authority to formally approve of the ICZM plan including the related financial commitment associated with the approval of the plan;
- Technical and institutional implementation
  - Technical design: the authority to undertake (or assign other parties to undertake) feasibility and design studies for technical measures or projects;
  - Institutional 'design': the authority to undertake (or assign other parties to) feasibility and design studies for institutional measures (legal, administrative, and organizational changes with respect to rules, regulations responsibilities and executive powers);
  - Implementation and financing decision: the authority to approve of the actual implementation and financing of technical projects;
  - Enforcement decisions: the authority to approve of the actual enforcement of institutional measures and changes;
  - Jurisdiction in coastal zone: the authority to execute certain management tasks and to make certain management decisions with respect to the physical planning, use, and control of the coastal zone;

  - Land ownership: legal and economic ownership of parts of the coastal zone.

Implementation phases considered in specification of "capacity"

- Planning
  - Technical knowledge- and data facilities: the amount of expert knowledge and specialist staff related to the technical subjects. Data and information systems required for analysis;
  - Institutional analysis capacity: expert knowledge and specialist analysis staff related to the institutional subject of ICZM analysis;
  - Integrated analysis capacity: analysis experiences in the integrated approach of complex ICZM issues and analysis staff required to identify and analyze possible measures and packages of measures from a multi-problem and multi-actors perspective, and the development of comprehensive ICZM plans;
- Decision making
  - Decisions making capacity: experience, and staff required, to interpret and evaluate ICZM planning options and to select the preferred options based on objective judgment;
- Technical and institutional implementation
  - Technical design capacity: capabilities and technical staff required to make technically and economically feasible designs for specific technical measures and projects, which meet required objectives and criteria;
  - Institutional design capacity: capabilities and staff required to design institutional measures/ changes, which are operationally, administratively and legally feasible;
  - Technical implementation capacity: capabilities and staff required to realize (build) technical projects and structures;
  - Institutional implementation capacity: the organizational and management capabilities and staff to realize institutional changes and to enforce required rules and regulations;
  - Management/ operation capacity: capabilities, facilities and staff to properly operate and maintain technical projects and structures;

- Monitoring capacity: capabilities, facilities and staff for monitoring and inspection of coastal area and development of coastal problems and the effectiveness of implementation of technical and institutional measures.

Implementation phases considered in specification of "commitment"

- Actual involvement: limitations in the extent to which relevant parties are actually involved with, or can exert their influence on, the ICZM process;
- Co-operation potential: limitations in the extent to which an actual co-operation 'culture' (willingness to co-operate, co-operation experiences) and inter-sectoral contacts exists as well as in the extent to which actors are aware and convinced of the gravity of coastal problems and ICZM potentials to solve these problems, through strengthening of "vertical and horizontal" communication and co-ordination;
- Integration potential: limitations in the extent to which the existing institutional and hierarchical structures allow for an actual integration of interests, responsibilities and executive powers.

Implementation phases considered in specification of "financial potential"

- Structural existing financing capacity: the amounts actually available and used for ICZM tasks and activities based on firm budget allocations and financial commitments;
- Incidental existing financing capacity: the amounts actually available and used for ICZM tasks and activities based on temporary allocations and commitment;
- Potential financing capacity: the amounts which, in addition to existing financing capacity, could potentially be made available from national or regional financing resources, or could be raised from external sources (donor organizations).

6.2.3. Scores to implementation aspects

Scores in the table

All implementation aspects, which are mentioned above, need to be given qualitative scores. This should be done for each requirement category (mandate, capacity, commitment and financial potential). The left column of the table sums the actors involved in the different phases (with in it implementation aspects) of the ICZM process. The scores are generated as follows:

Scores on "mandate" are expressed as follows:

- ** Prime role (in terms of responsibility; executive powers; jurisdiction or ownership)
- * Secondary role (direct involvement following from partial responsibility; executive powers; jurisdiction or ownership)
- ++ Major (indirect) influence
- + Limited (indirect influence

Scores on "capacity" are expressed as follows:

- ** Substantial capacity
- * Limited capacity

Scores on "commitment" are expressed by indicating whether limitations exist by actor and implementation aspect, for each of the relevant phases in the ICZM process. When a limitation exists, it's indicated by a minus sign in the table.

Scores on "financial potential" are expressed as follows:

- ** Substantial financial potential
- * Limited financial potential

The scores per actor and implementation aspect are also expressed in reduction factors. These reduction factors are then applied to the "capacity" potential.

6.3. The Model for New Zealand

6.3.1. Description of the stakeholders

When we look at the model for New Zealand in general the following stakeholders can be summarized:

Central Government:

- The Governor-General represents the Queen of England in New Zealand. This person has only limited influence on the New Zealand government and policies;
- The different Ministries and Departments, which play a role in the model, are explained in paragraph 5.2. The Ministry of Environment and the Department of Conservation are the most important of that;
- The Environmental Court is important, because it makes decisions when there is disagreement about e.g. the appliance for resource consent;
- The Maori (Tangata Whenua) influence is of significant importance. That's mainly because of the treaty of Waitangi, which was signed in 1840. The treaty states that the Maori accept their sovereignty to the Crown, in exchange for the same citizenship rights, privileges and duties as the English civilians. The treaty also guarantees the Maori the possession of their land.

Local Government:

The duties and policies of the local governments are stated in paragraph 5.2.

- The Regional Council is the governmental organ, which has influence on regional level (consisting of different cities and districts);
- The District Council has influence on district level (mostly some villages or wards).

Non-governmental organizations:

- Consulting firms are mostly asked for advice by District or Regional Council. This includes as well technical as management advice;
- Universities and other research institutes, like NIWA, are asked to do scientific research or to collect data for further research;
- Design bureaus or engineering firms are asked when a decision for f.i. a construction is made and needs to be designed;

- Contractors will execute the design and sometimes can do the design their selves;
- Action groups are mostly raised when a large group of people doesn't agree a decision that's being made.

Local stakeholders:

- All the individual inhabitants of an area form the local population;
- A community board represents the local population in meetings with the District Council;
- Local interest groups are groups of inhabitants, who defend their statement;
- Tourists, if they are present in an area;
- Project developers, who might invest in a certain area;

The local stakeholders for the Waihi Beach case are stated in paragraph 7.2.2

6.3.2. The model

On the next pages the four tables (mandate, capacity, commitment and financial potential) of the model for the New Zealand situation are shown. The explanation and the comments on the fill in of the tables are stated in the next paragraph.

Mandate

Implementation phase / Actor groups and specific actors	Planning		Decision making		Technical and institutional implementation					
	Planning initiation	Planning and assignment	(Final) plan formulation	Plan adoption	Technical design	Institutional 'design'	Implemen-tation and financing decisions	Enforce-ment decisions	Jurisdiction in coastal zone	Land-ownership
Central government: Policy										
Governor-General										**
Prime minister and Cabinet of ministers				**	**	**			**	
Ministry of Environment			++	**	**	**			**	
Department of Conservation			++	**	**	**			**	
Ministry of Economic Development									**	
Other ministers/ ministries/ departments									**	
environmental court				**			**			
Maori tangata whenua			++	*						**
Regional government: Policy										
Region Council	*	*	++	**	**	**	**	**	**	
Local government: Policy										
District Council	**	**	**	++	**	**	++	**	**	
Non-government: study/analysis										
Consulting firms			+							
Universities			+							
NIWA e.a.			+							
Non-government: implementation										
Design bureaus/ Engineering firms										
Contractors										
(Local) stakeholders										
Local population	*		+	+	+	+	+			
Local community board	*		+	+	+	+	++			
Local interest groups	*		+	+	+	+	+			
Tourism	*		+							
Project developers	*									

Table 6-1 Mandate for ICZM in New Zealand

Capacity

Implementation phase / Actor groups and specific actors	Planning			Decision making	Technical and institutional implementation					
	Technical knowledge- and data facilities	Institutional analysis capacity	Integrated analysis capacity	Decision making capacity	Technical design capacity	Institutional design capacity	Technical implemen-tation capacity	Institutional implemen-tation capacity	Management/ operation capacity	Monitoring capacity
Central government: Policy										
Governor-General										
Prime minister and Cabinet of ministers										
Ministry of Environment		*	*	*		**		**		*
Department of Conservation		*	*	*		**		**		*
Ministry of Economic Development										
Other ministers/ ministries/ departments										
environmental court				**						
Maori tangata whenua										
Regional government: Policy										
Region Council	**	**	*	**	*	**	*	**	*	**
Local government: Policy										
District Council	*	**		*		**	*	**	*	**
Non-government: study/analysis										
Consulting firms	**	**	*		**	*				*
Universities	**	*			*					*
NIWA e.a.	**	*			*					*
Non-government: implementation										
Design bureaus/ Engineering firms					**	*	**		*	
Contractors					**		**		*	
(Local) stakeholders										
Local population	*									*
Local community board	*									*
Local interest groups	*									*
Tourism										*
Project developers										

Table 6-2 Capacity for ICZM in New Zealand

Commitment

Implementation phase / Actor groups and specific actors	Planning			Decision making			Technical implementation			Institutional implementation		
	Actual involve-ment	Co-operation potential	Integrated potential	Actual involve-ment	Co-operation potential	Integrated potential	Actual involve-ment	Co-operation potential	Integrated potential	Actual involve-ment	Co-operation potential	Integrated potential
Central government: Policy												
Governor-General												
Prime minister and Cabinet of ministers												
Ministry of Environment					-	-	-	-	-	-	-	-
Department of Conservation					-	-	-	-	-	-	-	-
Ministry of Economic Development				-	-	-	-	-	-	-	-	-
Other ministers/ ministries/ departments				-	-	-	-	-	-	-	-	-
environmental court												
Maori tangata whenua												
Regional government: Policy												
Region Council												
Local government: Policy												
District Council												
Non-government: study/analysis												
Consulting firms												
Universities												
NIWA e.a.												
Non-government: implementation												
Design bureaus/ Engineering firms												
Contractors												
(Local) stakeholders												
Local population		-							-			
Local community board									-			
Local interest groups									-			
Tourism		-										
Project developers												

Table 6-3 Commitment for ICZM in New Zealand

Financial potential

Implementation phase / **Actor groups and specific actors**	ICZM Planning/ decision-making			ICZM implementation		
	Existing financial capacity structural	Existing financial capacity incidental	Potential financing capacity	Existing financial capacity structural	Existing financial capacity incidental	Potential financing capacity
Central government: Policy						
Governor-General						
Prime minister and Cabinet of ministers						
Ministry of Environment	**					*
Department of Conservation	**					*
Ministry of Economic Development	*					*
Other ministers/ ministries/ departments	*					
environmental court						
Maori tangata whenua						
Regional government: Policy						
Region Council	**			*		
Local government: Policy						
District Council	**			*		
Non-government: study/analysis						
Consulting firms						
Universities						
NIWA e.a.						
Non-government: implementation						
Design bureaus/ Engineering firms						
Contractors						
(Local) stakeholders						
Local population		*		**		
Local community board						
Local interest groups						
Tourism					*	
Project developers					*	

Table 6-4 Financial potential for ICZM in New Zealand

6.3.3. Comments on tables

Comments on table Mandate

Comments in planning phase:

The District Council is usually the party that initiates new plans, but also the local population, tourists or project-developers are allowed to initiate a plan. For plans, which concern a greater interest, the Regional Council can be initiator. The Regional Council ought to initiate these plans in the 'Regional Policy Statement'. The National Government is involved in the planning process by making a Resource Management Act and the Coastal Policy Statement. In the RMA they can set rules and regulations concerning ICZM plans.

The District Council is the first party who takes action to execute a draft version of a plan. Mostly their knowledge is not sufficient to execute this plan themselves, so they assign another party to execute this task. Meanwhile the local population is also allowed to request consent for some work at the coast they want to execute, or to assign another party to execute some research.

Comments in the decision making phase:

The District Council formulates the plan, but this formulation has to satisfy the laws of the Regional Council and the Resource Management Act. In the plan formulation phase there is also an influence of all kinds of interest groups and individuals, because the District Council has to ask the opinion of the people involved with the problems. Due to the Treaty of Waitangi the Maori have got a huge influence on solutions, which concerns their landownership.

When a final plan is formulated and approved by the councilors in the District Council, the next step is an approval of the Regional Council. In this phase the District Council has influence in how they present their plan to the Regional Council. When the Regional Council can't decide (e.g. with an very extensive plan or when disagreement exists about the plan) the plan is taken to the Environmental. They only deliberate the laws in the RMA, for which ministries involved in the problem are responsible. It's also possible for the local population or an interest group to appeal to the Environmental Court, so they also have influence after the decision of the District Council. The *Treaty of Waitangi* gives the Maori influence on the decision making process, so they can appeal a decision, if it concerns their land or culture.

Comments on the technical and institutional implementation:

The District Council has the authority to initiate feasibility and design studies. When necessary the Regional Council has also got the authority to undertake feasibility and design studies. For the technical as well the institutional design there is a large influence of the local population and interest groups.

To enforce decisions different acts exist, e.g. the Resource Management Act, a Regional Coastal Environment Plan or a District Plan. These plans have to be updated. Respectively the Ministries, the Regions and the Districts have got the authority to formulate this management tasks.

The Maoris are important landowners in New Zealand. It makes them important stakeholders in the implementation phase.

The landward side of MHWS comes to the responsibility of the Districts, and the Coastal Marine Area from MHWS to the 12 nautical mile limit is the responsibility of the Regions

Comments on table Capacity

Comments on the planning phase:

In comparison to the District Council, the Regional Council has got more capacity on technical knowledge and data, by monitoring. The staff required for technical feasibility studies isn't available at the District Council, but they can receive those studies from consultancies. The District Council does have institutional knowledge available.

The District Council might have the possibility to collect the available knowledge, but they don't have the overview to use that knowledge, in a way to address an Integrated Coastal Zone Management problem. Such a problem often exceeds the physical and institutional borders of the District. From this can be concluded that a good integrated analysis of ICZM issues is merely available at the Regional Council or at higher governmental levels.

Comments on the planning phase:

The District Council as well as the Regional Council are capable of making decisions. The ministries have also got the capability but aren't involved in the decision making process.

Comments on technical and institutional implementation:

The Regional Council has enough staff with technical knowledge to make a technical design. For the institutional design both the District Council and the Ministries have knowledge because of their District Plan or Resource Management Act/ Building Act. They are also capable of implementing institutional measures. For implementation of technical designs the District and Regional Council are capable to a certain level, otherwise a contractor or engineering firm will do implementation.

For the maintenance and management of technical projects and structures the District Council can manage the maintenance but the technical work has to be done by a contractor or engineering firm.

The District Council and Regional Council do a lot of monitoring of coasts, dunes but also the roads, nature etc. The ministries control the councils by the Resource Management Act.

Comments on table Commitment

In New Zealand is a certain lack of awareness for the values of the coast among the population. At the moment the different Regions are executing education-campaigns to improve this awareness. The current behavior of the tourists doesn't contribute to a good conservation of the dune system.

In the decision making phase there is limited commitment of the Ministries, because they are only involved by law making.

For the same reason as above the ministries are also limited in the technical and institutional phase. The District and Regional Council manage the process with help of engineering firms, consultancies or universities. In this process there is limited executive power from the local interest groups and population, because they often have a lack of knowledge.

Comments on Financial Potential

In the planning and decision making phase of an Integrated Coastal Zone Management project most of the costs are paid from the rates. In New Zealand the population pays

rates to the Districts, Regions and also income taxes to the Central Government. The local population can do some individual research when they want.
For the implementation of an ICZM project it's mostly the local population who has to pay for it. They have to pay extra rates depending on their benefit of the project. The District Council decides what a relevant division of these rates is. Besides this the rates depend on the value of the properties. Some extra financing can come from tourism or a project developer who's interested in the area.

6.4. Recommendations of the model

In this paragraph you can find the recommendations, which result from the comments in the previous paragraph and the analyses of the tables (mandate, capacity, commitment and financial potential). The recommendations are divided in two categories (mandate and capacity), with limitation of commitment and the financial potential mentioned within this recommendation. After these recommendations follows the fact on which focus is required first, as final recommendation.

Planning

Mandate:

Initial leadership and executive powers are within de District Council. The fact the District Council is close to the local population causes a lot of commitment within the District Council and a lot of feedback from the local population.

Capacity:

The District Council has some data (by their own monitoring or from the Regional Council), institutional knowledge (by their own staff), technical knowledge (from consultancies or universities) and knowledge of the different interests in the problem area (because they are close to the community and communicate with the Community Board). But they don't have the capacity to take an integrated overall look at the problem, which has to be done to develop a proper Integrated Coastal Zone Management Plan. The main problems are shortage of money for a total solution and the fact that problems can exceed the District's borders.

The Regional Council has got a better total picture, but less contact with the community and also not the money and availability of enough data (e.g. wave data).

The Central Government does have the capacity and the money to deal with a complex problem, but they are not directly involved in the process. In the current situation they put demands on the districts, through the RMA and the Coastal Policy Statement, but give no financial contribution to help them fulfil these demands. If a solution can benefit more than the area of the District, the Central Government could also support financially.

Recommendation:

Support should focus on establishing a central organisation, which collects all the data, knowledge and experiences for ICZM projects in New Zealand. They have to deal with all the problems, which are too heavy for the Districts. This organisation can support the expected ICZM projects in the future, which reduces the costs.

Decision-making

Mandate:

The involvement of the population and interest groups in the decision making phase is very good. The District Council first formulates the plan and after this the plan will go to the Regional Council for approval. Because the approval depends on the decision of the Regional Council the District Council is limited in the decision-making phase. The Regional Council can give a better total view. The opinion of the Maori people is not always clear.

Capacity:

The institutional capabilities for a proper decision making process aren't available on District level. They have not the power to change regulations when necessary. Also a good overview is missing.

Recommendation:

Support should only be focused on a better dialogue with the Maori. They have a big influence on the decision making phase by the *Treaty of Waitangi* and are not enough involved in the decision making phase. This can lead to problems in a next phase of the process.

A National Committee for ICZM can also solve the lack of institutional capabilities.

Technical implementation

Mandate:

The District Council often uses external experts for technical solutions. The Regional Council has got more knowledge and staff themselves, but is not always involved in the technical design.

Capacity:

The District Council is very closely involved in the development of a solution and can enforce decisions. Unfortunately they don't have enough financial potential for implementation and maintenance the most preferable solution, most of the time. There is also a lack of experience, data and overview to solve complex ICZM problems.

Recommendation:

Support should focus on enhancing the financial potential of the District Council for such huge projects. Besides that the knowledge and data available in the Regional Council should be used better and longer for ICZM projects.

Institutional implementation

Mandate:

The system of plan approval with subsequently the District Council, the Regional Council and eventually the Environmental Court is very clear. Everybody should know his responsibilities. Only improvement could be increasing the involvement of the central government in ICZM issues, as well as the Maori communities, who are well-protected landowners in coastal areas.

The awareness of coastal hazards and values of the coastal system is insufficient in New Zealand. People would still like to live very close to the shoreline, presuming that they are safe. Another fact is that most tourists or visitors of the beach don't know how to treat the dunes and dune plants and thereby destroy nature's capability to recover its natural character and process. Education about these hazards could be given by Central Government and Regional government (they already have a dune care program and education program)

Capacity:

The New Zealand population is proud of the fact they live in harmony with each other. From this perspective they are experienced in talking about all different kind of problems and solve them.

Recommendation:

Support should focus on improving the awareness of the New Zealand population for the value of the coast. Enhancement of commitment will broaden the understanding of Integrated Coastal Zone Management and by that will facilitate a project in the future.

6.5. Conclusion

The fact that the District Council in New Zealand is close to the local population causes a lot of commitment with ICZM problems. The big executive power of the District Council provides that the population is involved narrowly in the dilemma and their opinion is well heard. This involvement is also caused by the rate paying system.
It's necessary too intensive the dialogue with the Maori people for ICZM problems.

A District Council often hasn't got the capacity to deal with such an extensive problem by himself. To ease the process for the District Councils it's useful to establish an organisation, which contains and collects all the knowledge about ICZM, call it a New Zealand Committee of Integrated Coastal Zone Management. On the next page there's a flow chart, which shows how information is given from and to the Committee (see Figure 6-1).

Possible tasks of a New Zealand Committee of Integrated Coastal Zone Management could be:

- Building a long-term plan for developing Integrated Coastal Zone Management in New Zealand;
- Collecting all the data, knowledge and experiences for ICZM projects in New Zealand;
- Participating in the planning phase of ICZM problems;
- Providing a better financial potential for ICZM problems;

- Providing the population of New Zealand is more aware of the ecological, economical and other values of the coast;
- Monitor all coastal activities;

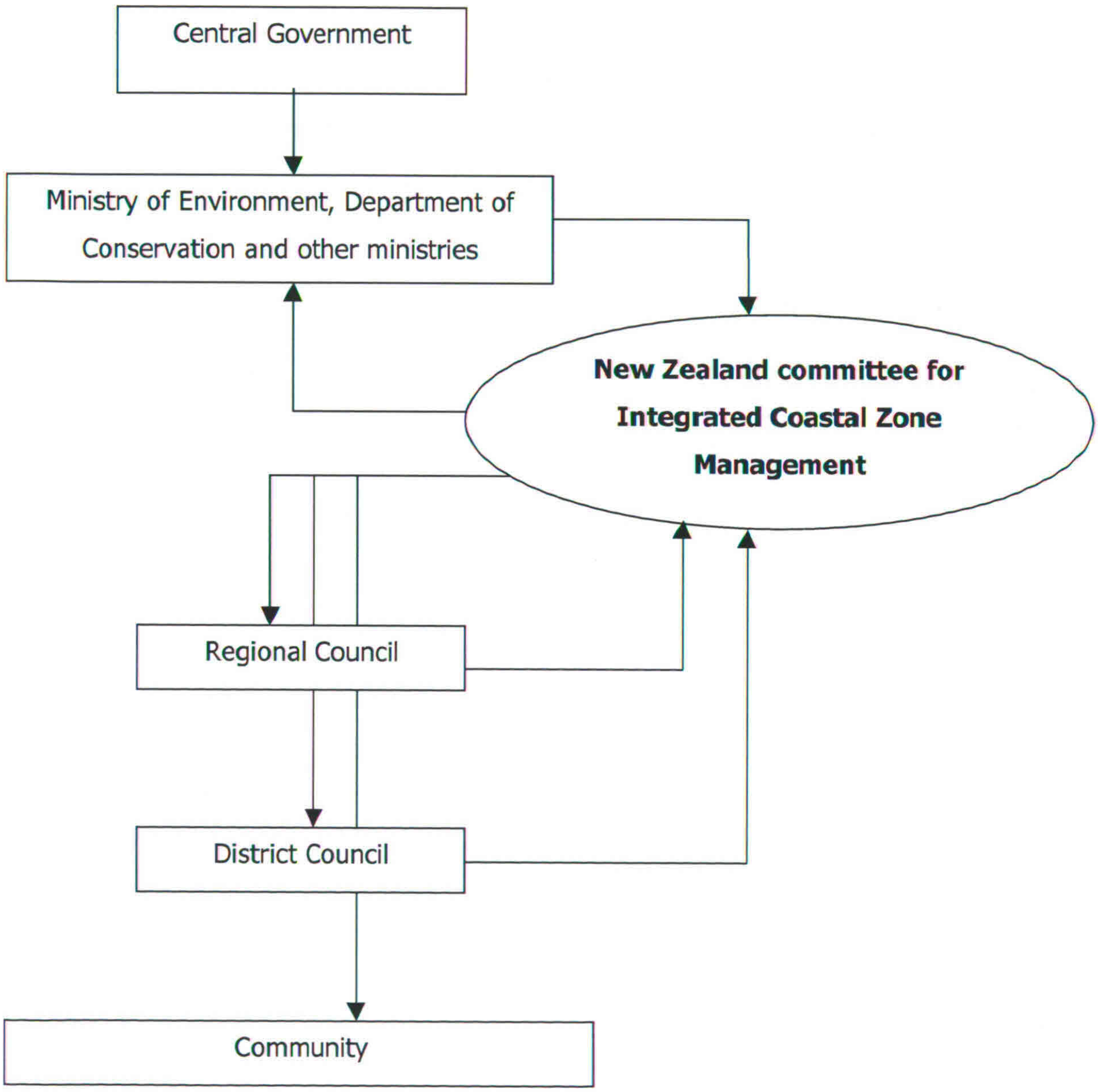

Figure 6-1 Flow chart of National Committee for ICZM

7 The Waihi Beach case

7.1. History of the coastal erosion problem

7.1.1. Introduction

In Chapter 3 the current problems with coastal hazards at Waihi Beach have been mentioned. Some problems have been there for a long time, some have occurred during (or even because of) the establishment of people in that area. In the following paragraph the process of reasoning and decision-making in the Waihi Beach issue is shown. This process resulted in the designing of the seawall at this moment. In Appendix A-I the timetable is shown, in which the detailed history can be seen. The Integrated Coastal Zone Model in Waihi Beach, recommendations and the conclusions are discussed in paragraph 7.2 - 7.4.

Figure 7-1 shows the governmental structure of Waihi Beach.

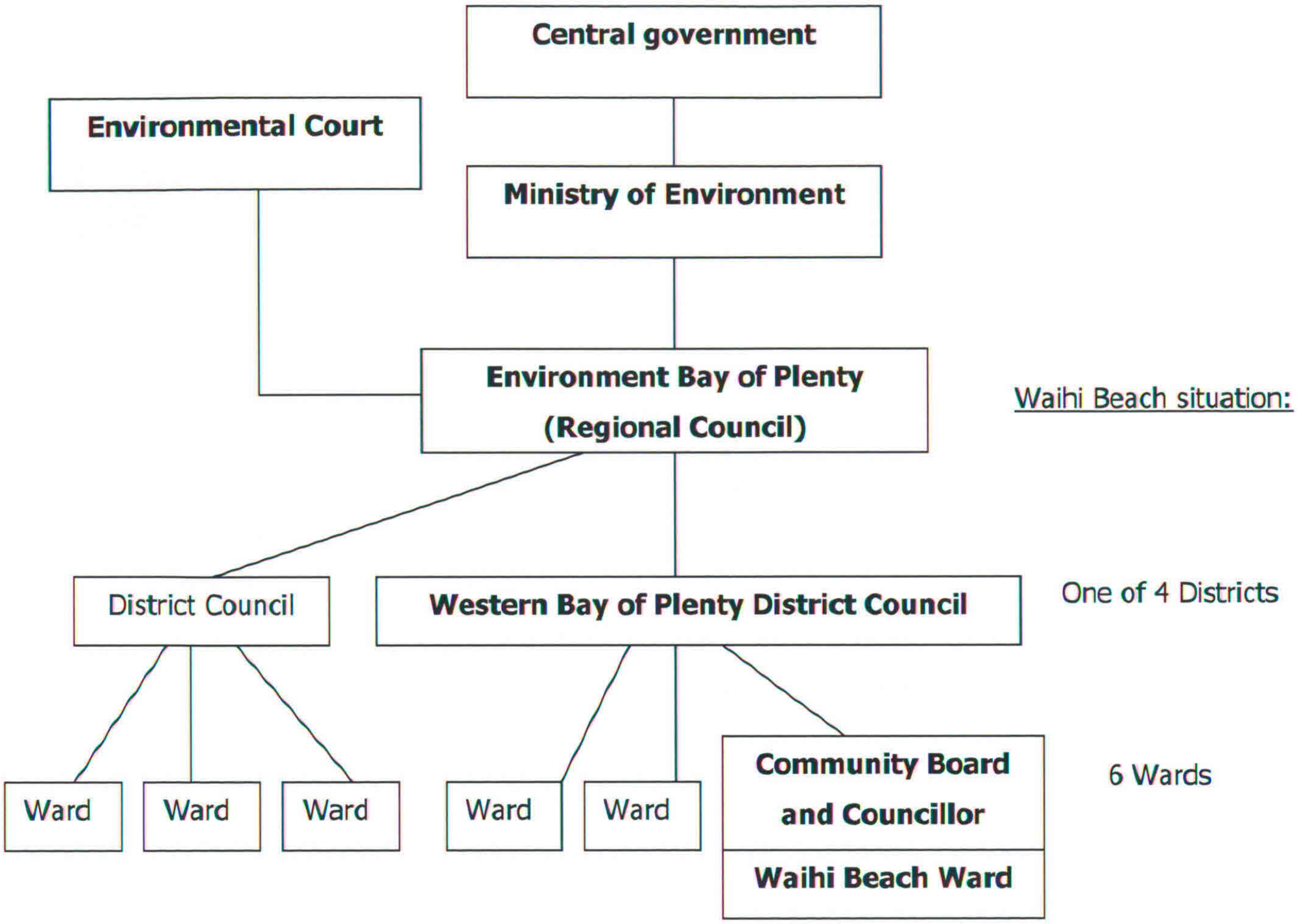

Figure 7-1 Waihi Beach governmental structure

7.1.2. Decision-making process

In 1996 the Western BOP District Council embarked on a programme to identify a long-term solution to the on-going coastal erosion. This was a response to community demand to repair the existing protection works. The Council considered options for managing future development within its Coastal Protection Area (Healy, 1993) as an interim measure until the outcomes from this programme had been identified.

Western Bay of Plenty District Council asked a consultant to assess the effects of the Waihi Beach seawalls on the coastal environment and the beachfront properties: "Assessment of the Effects of The Waihi Beach Seawalls" (Gibb, aug 1996). The following questions had to be answered: Is the wall causing any negative impact on the beach? Is the wall causing positive effects? Is the wall assisting in the protection of the private properties or does it increase the hazard to those properties?

Western BOP District Council and Waihi Beach Community Board desired to see the storm water control problems discussed. To achieve this Worley Consultants Limited carried out the Waihi Beach Storm water Development Plan (Mar 1997). A key objective of the study was to focus on issues of community concern and develop options for progressive development of an improvement storm water system.

Consultant Gibb and Tonkin & Taylor finished their report "Strategic options for sustainable management of the coastal interface along Waihi Beach, Western Bay of Plenty District" in May 1997. That report presented 15 options to manage the Waihi Beach coastal zone.

These options were presented to the community in public meetings and workshops around September and October 1997. In those workshops the District Council presented four key issues, which needed to be resolved in the best interest of the community and the environment:

- Future growth;
- Beach erosion management;
- Sewerage systems;
- Stormwater management.

With these key issues in mind everybody could say his or her advantages and disadvantages of every option. By this the 15 possible solutions were refined to three principal options: Stream management, Seawall protection and Managed retreat. These options were published to the community by a leaflet (dec 1997).

Engineering consultant Tonkin&Taylor presented their report 'Waihi Beach Management Evaluation of Options' in 1999. After the preliminary evaluation of the potential options (a multi-criteria assessment was carried out) nine options were left.
According to the District Council the Two and Three Mile Creek are the main causes of the problem. A pre-feasibility study has been carried out for the possibility of diversion

the two creeks in the upper catchment. After this, the study has been integrated in nine options.

From November 1999 to February 2000 the community was consulted to make a decision for one of the solutions, by filling out a response form. Also three open days were organised. After that there was discussion in the council and some council hearings were organised, to clarify what the final submission to the Regional Council should be. Finally the option of upper catchment diversion, dune care and maintenance of the existing seawall for health and safety was chosen. This option was further investigated, preliminary design was made and costs were estimated.

The total costs of diverting the Creeks were about $ 18 mln. The community wasn't willing to pay such an increase of rates. The District Council consulted the Community Board and they voted in favour of 'coastal protection works' in November 2002. Considering this decision and the present time scale and hazards, the council then made the decision to build just the seawall, because that was the cheapest option that provided direct safety to the nearby properties.

In 2003 the preliminary design for the seawall (or the rock revetment protection works) was started and measures were taken to change the proposed plan, so the seawall could be built.

7.2. The Integrated Coastal Zone Model in Waihi Beach

7.2.1. Introduction

In the previous chapter the method of the Integrated Coastal Zone Management Model is described and the model for New Zealand in general is made. In this model the stakeholders are not specified, so this will be done in paragraph 7.2.2. In paragraph 7.2.3, the same implementation aspects (planning, decision making, technical- and institutional implementation) as used on the national recommendations are mentioned. But now the experiences for the Waihi Beach case will be handled to make clear an ICZM problem is too proportional for the District Western Bay of Plenty.

7.2.2. Stakeholders

Community Board (4 members + 1 councilor):

Goal: The Community Board represents the opinion of the community of Waihi Beach to the District Council.

Ratepayers association (400-500 members):

Goal: They want a reasonable division of the rates among the inhabitants of Waihi Beach. Besides that they want to let the Community Board know what the their opinion is.

Friends of the Beach:

Goal: The FOB wants an environmental sustainable solution for the coastal hazard problems; Enhancement/ development of the beach; Protection of the beach more important then protection of the properties near the beach.

Beach Protection Society:

Goal: The BPS would like a solution, which protects the beach properties against the hazards of the sea. Besides that they prefer a solution that doesn't decrease the amenity value of the beach.

Beach Concern Society:

Goal: The BCS is concerned about the problem and thinks the rock wall is definitely not a good solution. Preservation of beach and dunes are important for them.

7.2.3. Comments on the implementation aspects

ICZM planning

For a good Integrated Coastal Zone Management project planning a **clear overview** of the situation is necessary. This includes the ecological system, the economic situation, social facts, future development, degree of welfare, recreational values, spatial planning etc. Besides that technical knowledge (data, data analyses experts, information systems and computational equipment) and institutional knowledge (rules, legislations and responsibilities) are needed. It's difficult to collect all this information within the District Council, whether from it's own staff or from other parties (consultancies, universities or engineering firms). Anyhow it will cost the D.C. (and thus the community) a lot of money. Because of these shortages **no good cost-benefit** analyses for the total range of solutions has been made.

Long-term plans (diverting the creeks) are made, but a short-term solution (seawall, which caused a lot of resistance) is carried out, because of the current **limited financial potential**. The feasibility of the long-term solution is uncertain and not clear to the community at this moment.

Decision-making

It seems that in the first stadium of the process not enough people were **committed to** the decision process. Only when the decision was (almost) made, people started to participate in the process.

The three-year period between new **elections** is very short for a good **continuation** of a decision process, which takes in general about eight years. Also the facts a lot of the residents don't actually live in Waihi Beach and the **fast movements of people** from one place to another don't make the decision process easier.

Technical implementation

For the technical implementation the District Council consults a **consultancy** or engineering firm. These firms often **don't know the optimal solution either**, because of the wideness of an Integrated Coastal Zone Management problem (e.g. they might not be aware of the social affairs, economic situation, history).

Implementing an ICZM project is a complex process that takes a lot of time. Using **experiences from other District Councils** with ICZM projects might reduce the costs of the technical implementation and maintenance of this ICZM project.

Institutional implementation

The **awareness and involvement of the people** during the process of implementation of an ICZM project is very important. This creates understanding and fastens the project. Clear and correct information, maybe presented by an expert, to communicate to the population is very important.

Policies and responsibilities should be observed and made clear to the community. This increases clearness and by that reliability. Clear regulations for granting permits are important. When these regulations are not obeyed, fair enforcement tools should be used.

Figure 7-2 shows how the opinion of the Waihi Beach residents is told to the District Council. It goes through the Community Board, but also through local action groups.
It also shows that the District Council has to comply with the central and regional policies (e.g. for lodging a consent), before it can execute its decisions or policies and communicate these to the community.

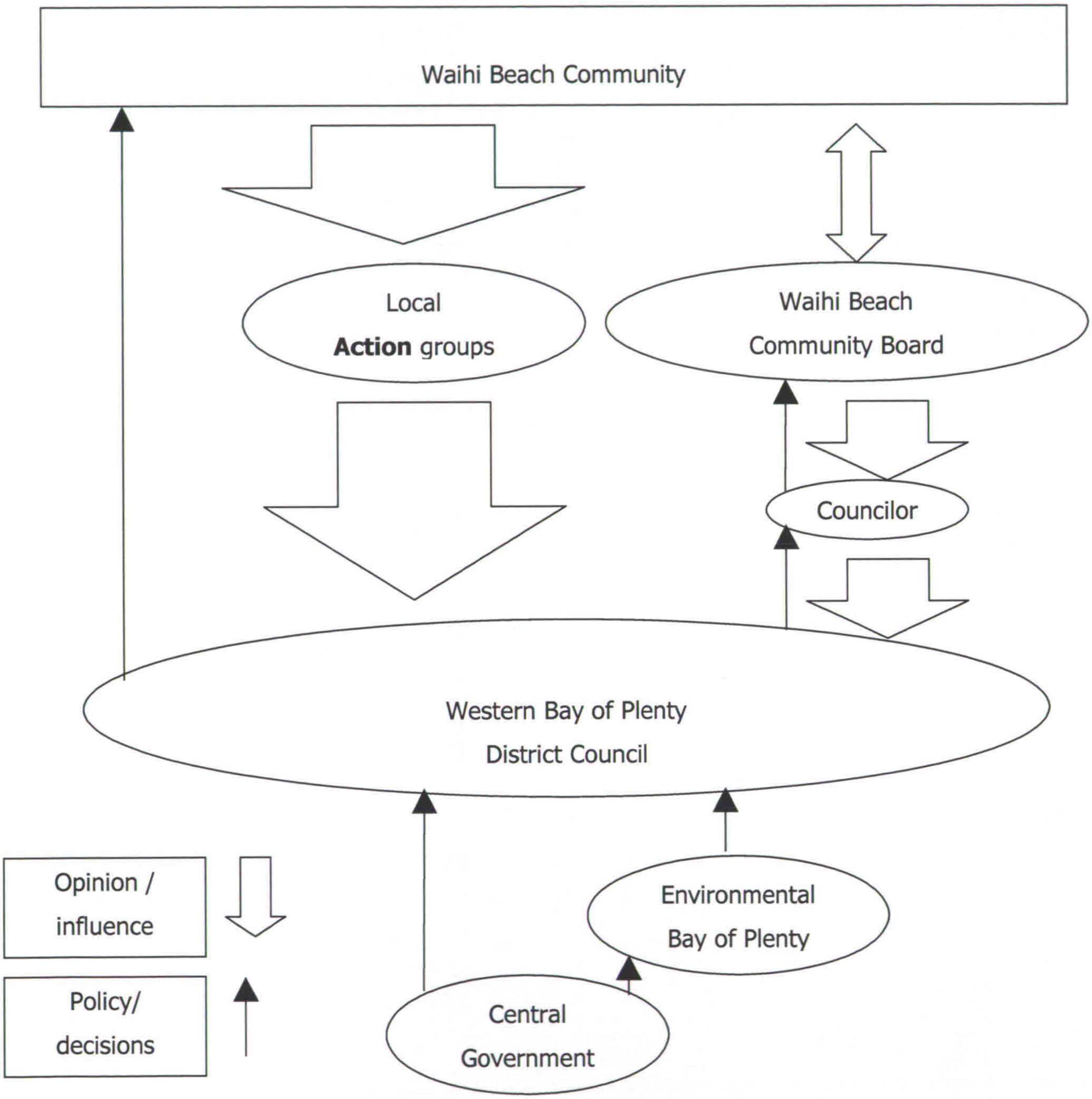

Figure 7-2 Flowchart of actual communication in Waihi Beach

7.3. Recommendations

As mentioned in the recommendations and conclusion on the national level (paragraph 6.4), an ICZM problem is too proportional for the District Western Bay of Plenty. This is the main reason that the decision process takes such a long time with finally not a satisfying result. Maybe it's possible for the District Council to initiate the idea of a **New Zealand Committee of Integrated Coastal Zone Management.**

On the other hand, for now you have to deal with this fact, because action in a short time-period is definitely necessary. In the short-term period the regional and local governmental system is observed, and the advantages and deficits of that can be seen. Besides that the opinion of all the stakeholders are obtained. With those things in our minds, the following recommendations arise, specifically for the Waihi Beach situation.

The following flow chart shows the ideal situation, where the Community Board mainly presents the opinion of the community. Direct communication of the Waihi Beach Community to the District Council is limited.

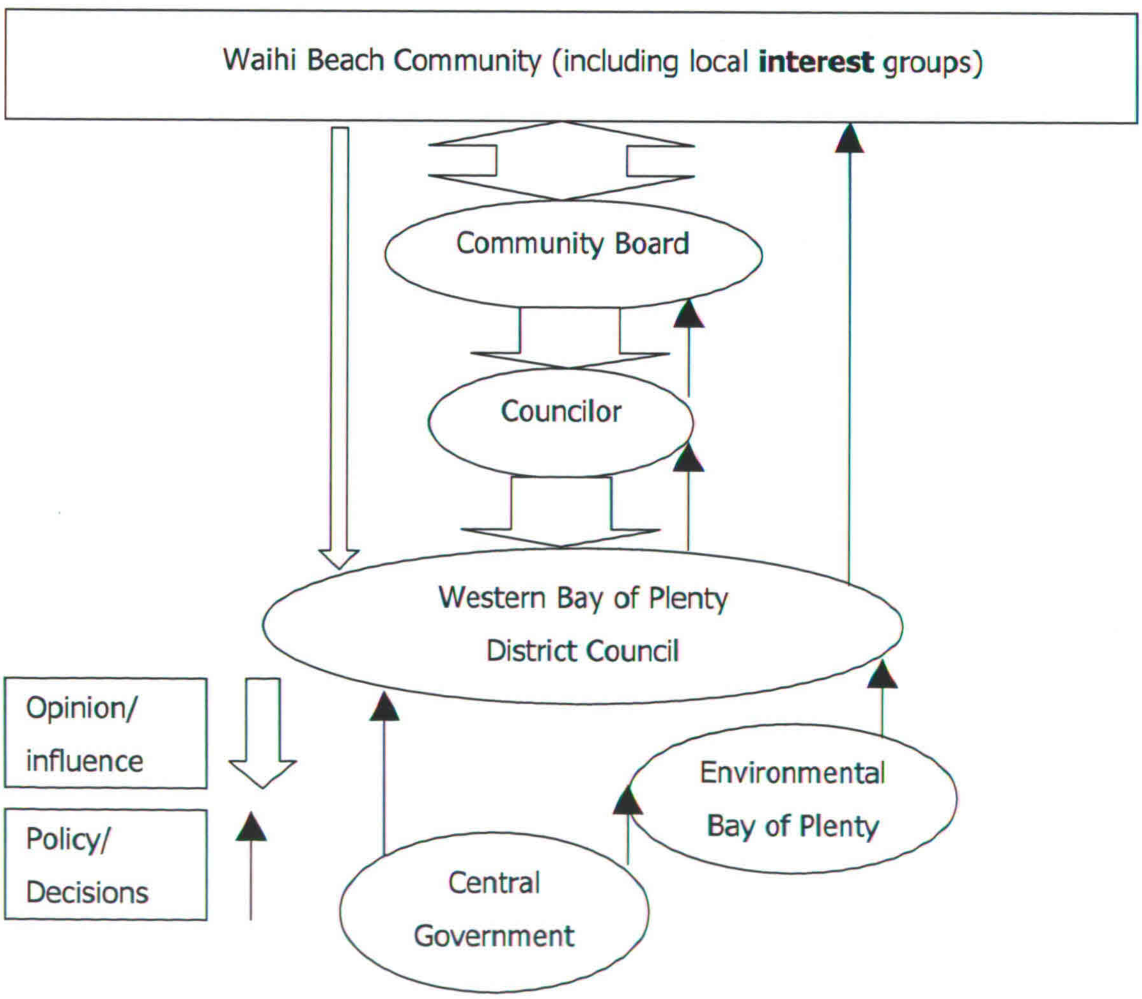

Figure 7-3 Flow chart of preferred communication

The **functions of the District Council and the Community Board** compared to the community must be clear to improve the planning- and decision-making phase (see Figure 7-2).

Some of these functions are:

- District Council: explain problem (with experts); make process clear; ask opinions (mainly through CB); present solution; justify solution;
- Community Board: Obtain opinion from community; formulate clear opinion; present opinion to DC; observe to it.

There are **no clear cost-benefit analyses** made by an objective expert for all the possible solutions. Some (initially more expensive) solutions could be interesting, because of the greater benefit they create. The population of Waihi Beach could also be interested in such a description of all the possible solutions.

More attention can be paid to the **financing of a solution**. For instance when more people benefit from a solution, more people can also pay for it. Project developers could also be interested in a certain solution, and would be willing to pay for it. These options could reduce the rates of the local residents of Waihi Beach.

To get people aware of the problems it's very important to **communicate with the population.** The process will go on faster, if people are participating earlier. A suggestion to keep the population up to date and let them pay attention for the situation is a weekly update about the situation at a certain page in one of the papers. Newspapers are read well, so everyone will receive the news. Important in such an article is to make a clear separation between objective views from experts and opinions written by journalists or local residents. Expert views are very important in order to **clarify the problem and create commitment and awareness** among the community. The dune care program for instance is a good signal to make people aware of the value, but also dangers, of the coast.

Another recommendation could be to present the complete **long-term solution** to the community and explain it. The community should understand the wideness of the problem and its solution, instead of only the (possibly negative) short-term solution.

The fact that a lot of inhabitants of Waihi Beach are **holiday residents** doesn't make the process easier. **Involvement** of these people is important and their opinion should be represented. This can be done by enquires, newspaper ads, workshops on different times and by the community board. Combining their opinions in an interest group would also help.

Because the short periods between elections, it's necessary to **formulate the process clear**. The process and decisions have to be stated very clearly, so no obscurity is caused. This will prevent disagreement afterwards, for instance with a next Community Board or councillor.

7.4. Conclusions

As mentioned in the recommendation on the national level, an Integrated Coastal Zone Management problem is to proportional for the District Western Bay of Plenty. It's hard to **overview** the wideness of the problems. A New Zealand Committee for Integrated Coastal Zone Management could combine the experiences of all the District Councils and by that ease the process.

Besides the overall committed work of the District Council, we have done some recommendations. Although the District Council **communicates** with the community to get their opinion, it is not always in an effective way. Clear and correct information, maybe presented by an expert could help. Besides that it's hard to create awareness and commitment with the community, particularly when a lot of residents are holiday residents. Another problem is that residents often only give their opinion at the end of a decision-making process, while their **commitment** is most needed in the planning-phase.

A good **cost-benefit** study for every solution could give a good view of the feasibility of a solution. Some solutions can benefit a greater area than the Waihi Beach Ward, or can interest some parties to invest more, which facilitates the financing of a solution.

Part C

Beach stabilization options

Beach in front of the seawall at Mean Sea Level at Shaw Road

8 Problem definition

8.1. Introduction

In chapter 3 of Part A the coastal hazards of Waihi Beach are discussed. The main hazards are coastal erosion, coastal flooding and stormwater flooding. Also the different areas, where those hazards might occur, were roughly shown in a map. This chapter discusses which problem occurs exactly in which area and what can be done to solve the problem (paragraph 8.2). After that will be decided what problem and what problem area will be looked at more closely (paragraph 8.3). The key issue (8.4) and the main objective (8.5) for this report can then be formulated. In paragraph 8.6 is explained in what direction the solution for the defined problem and the defined problem area will be looked for.

8.2. Coastal problem definition

8.2.1. Coastal erosion

The extent of coastal erosion depends on several factors, as shown in chapter 3. Some of these factors occur at the whole beach: global sea level rise, regional sea level effects and regional sand supply. Other factors are more dependent on the location at the beach: local wave focusing, local creek mouths, local property protection and local groundwater effects.
The wave focusing can be seen from an aerial view; embayments can be seen in the shoreline and in the dunes (near Glen Isla Place and opposite Athenree). The Creek outlets increase the local erosion; the area of influence is 400-500 m longshore of the beach for each Creek. The property protection work, which increases erosion, is the seawall. It is placed merely at Shaw road and The Loop (see figure 8-1). The local

groundwater effects take place in a large part of the beach, near the seawall, at Shaw Road (also because of the Opawe Swamp) and The Loop.

When looking at the global and local factors of erosion, one can discern different parts of the beach, which have different rates of erosion. The northern part of Waihi Beach (from the Terrace to Leo Street) has no increasing local factors of erosion. The part from Leo Street to Shaw Road, Two Mile Creek, The Loop and Three Mile Creek, has the most severe erosion. From Three Mile Creek to Bowentown, the only increasing local factor is the wave focussing. The unprotected dwellings at Island View Road may cause a problem, because they are very close to the coastline.

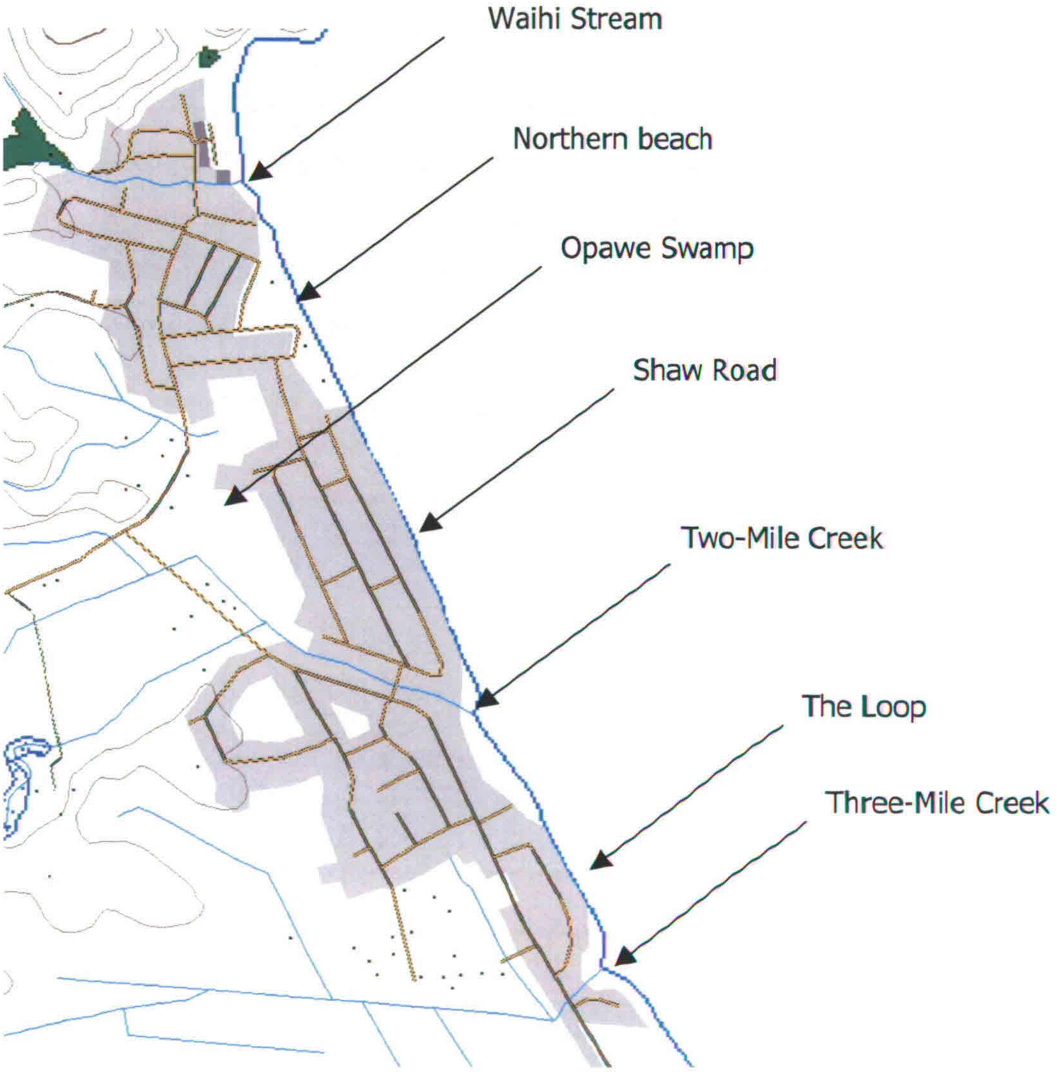

Figure 8-1 Sever erosion locations

There are measures, which have been taken to mitigate the erosion. In the north a dune care program has been started to establish new dunes, which provide safety by increasing the volume of sand that can be washed away during a storm. Also sand sausages have been placed to trail the Waihi Stream, which decrease the local erosion (figure 8-2). At Shaw Road a seawall has been built to protect the properties, but this seawall has actually increased the erosion.

Figure 8-2 Dune care in the north of Waihi Beach and a sand sausage to trail Waihi Beach Stream

8.2.2. Coastal flooding

Healy (1993) has examined the coastal flooding issue. He established the total design wave runup for Waihi Beach by summating factors from spring tide, barometric setup, wind setup, wave setup and wave runup onto the Mean High Water Level. For the northern part he found 4 m and for Bowentown 5,4 m.
The most crucial points where flooding problems occur, are the outlets of the Two and Three Mile Creek and the northern part of the beach because of a lack of dunes.

The dune care program in the North is also effective for protection against flooding hazards as it already developed small dunes in a short period. The Seawall protects the properties behind against flooding, although it was probably not constructed for that purpose.

8.2.3. Stormwater flooding

During large rainfall the Two and Three Mile Creek (and sometimes the Waihi Stream) cause a flooding problem. Because of their large catchments areas, the creeks accumulate a lot of water. The Creeks take the water to the sea, but when the amount of rainfall is larger than the creeks can transport, the areas close to the creeks will flood. Besides that, large volumes of water flow over the surface to the creeks, which also causes flooding. As developments in Waihi Beach go on, more surfaces are concealed and a larger volume of water flows directly to the creeks, instead of seeping into the ground. This causes a bigger flooding problem. An additional danger is the occasionally very low flow in the creeks, which enables the beach to block the creeks, causing a flooding problem upwards the stream.

The flooding problem has been subject of detailed studies (Tonkin & Taylor, 1999 and 2001). A solution proposed in one of these studies is the establishment of inundation areas. These areas are rural land, which can flood during large rainfall, to prevent (developed) areas from flooding. This decreases the problem, but doesn't prevent it. The most effective and preferable design to prevent the flooding problem is diversion of the creeks.

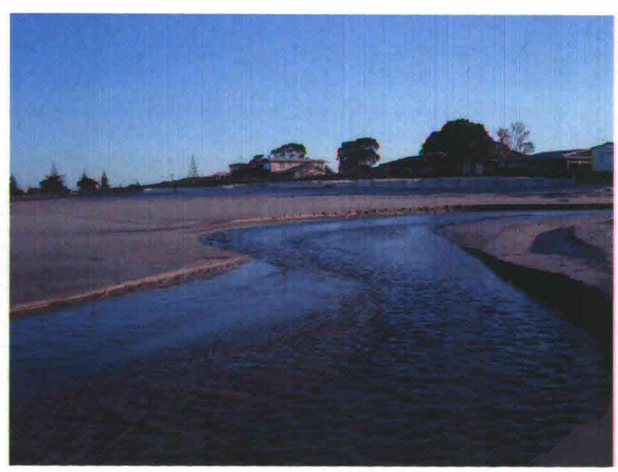

Figure 8-3 Left: Lack of drainage to creeks results in storm water flooding

Figure 8-4 Right: Two Mile Creek flows over the beach

8.3. Problem area definition

Waihi beach

The beach in Waihi Beach can be divided in the following zones with different characteristics (From NW to SE):

1. Northern Beach; extending from the rocklands between Waihi Beach and Orakawa to the begin of the timber seawall. The length is about 1250m. The properties are located about 50 m behind the small recently erected dunes.
2. Shaw Road; extending from the end of the northern beach to Three-Mile-Creek with a length of approximately 1175 m. This area is protected from the sea by a timber and rock seawall. The properties are located just 10 m behind the seawall.
3. Two-Mile-Creek; mouth of Two-Mile-Creek with an influence area of ca. 375m.

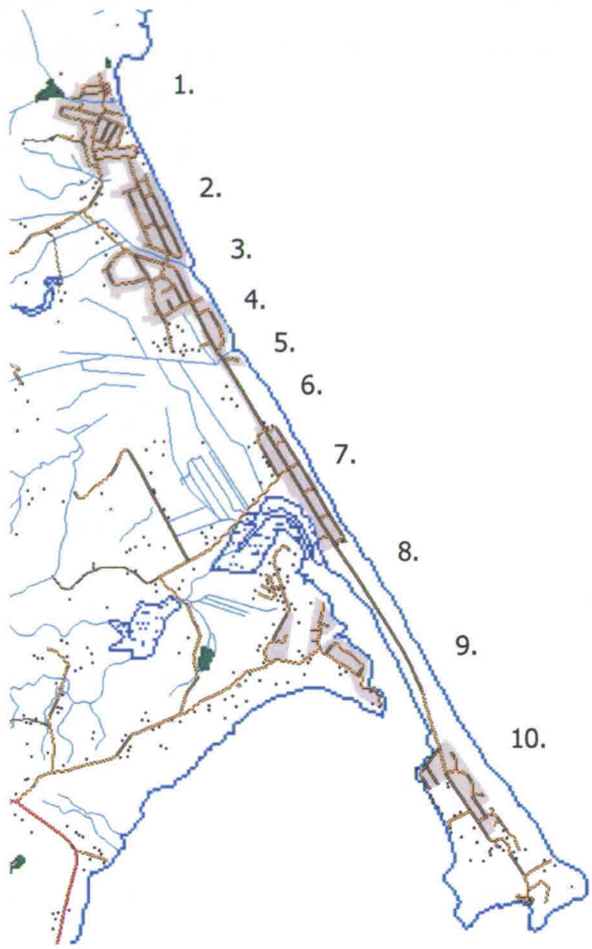

Figure 8-5 Zones in Waihi Beach

4. The Loop; Properties are just 10 m behind the protecting seawall, length ca.450m
5. Three-Mile-Creek; mouth of Three-Mile-Creek with an influence area of ca. 225m and southern located properties protected by a seawall with a length of 125 m.
6. Seaforth Road with houses, dunes (ca. 200m width) with a length of ca.1300 m.
7. Island View; Strip of houses of ca. 200m, some close (10m) behind the dunes.
8. Seaforth Road with houses, dunes (ca. 50m width) with a length of ca. 600m.
9. Southern Beach; Large strip of beach with dunes and no nearby houses, ca. 1950m
10. Bowentown dwellings and dunes, length ca. 1450m.

Project area definition

The stormwater flooding problem is best addressed by diverting the creeks, as is stated in many reports so it's not interesting to take another look at that at this stage. Of course it is still a very important part of the total solution for the Waihi Beach issue.

The coastal flooding problem is present at the whole beach, but most problematic near the creek outlets and in the North. We will not focus on this problem, because it's best addressed by the dune care program and the diversion of the creeks.

The erosion problem area, which is most interesting to look at is the area from Shaw Road to the Loop, with the two creeks and the seawall. Here almost all local factors, which increase the erosion, are present.

Project area motivation

The District Council has proposed the solution of refurbishing the seawall and at some locations construct a new seawall in combination with in the longer term rediversion of the creeks (The decision-making process, which led to this proposal, is described in Part B).

The proposed seawall can be seen as a not preferable solution for the erosion problem, because of the following reasons:

- Public access to the beach is restricted;
- Constructing the seawall will prevent development of the beach and foredunes;
- Seawalls influence the natural character and cyclic process of the coastal environment;
- Annual maintenance is required (about 2% of initial capital costs per year);
- The beach in front of the seawall will be subject to wave impact and therefore be eroded;
- This proposal can be seen as pragmatic, looking at the adverse effects compared with the objectives of the Resource Management Act (see part B);
- There are few people directly benefiting from the seawall.

Positive point of this solution is:

- The properties directly behind the seawall are protected against erosion and flooding;

The current solution for the problem in this area has many adverse effects. There are possibilities to design a proper solution, which satisfies more objectives. This fact and the interesting area of the seawall, from an erosional point of view, give possibilities for making this report.

8.4. Key issue

The key issue for this part of the report is:

"The proposed seawall in Waihi Beach is not a preferable option to solve the erosion problem. A proper design of a sustainable solution isn't yet available."

8.5. Main objective

The main objective is:

"Generate sustainable solutions for the erosion problem, and perform a cost-benefit study of the most preferred solution for Waihi Beach."

8.6. Possible solutions

Generating solutions

In 1997 Tonkin & Taylor and Dr. Gibb presented their report "Strategic options for sustainable management of the coastal interface along Waihi Beach, Western Bay of Plenty District", in which they elaborated 15 options to address the problems in Waihi Beach. These solutions can be divided in four main types:

- Land-Based Options;
- Soft Engineering Options;
- Hard Engineering Options;
- Combined Options.

The Land-Based Options include:

- Do-nothing;

- Remove property protection works;
- Managed retreat;
- Planning responses;
- Stream rediversion of the creeks.

The Soft Engineering Options include:

- Beach and dune replenishment;
- Beach face dewatering.

The Hard Engineering Options include:

- Seawalls (revetment);
- Reef breakwaters;
- Offshore breakwaters;
- Groynes;
- Artificial Headlands.

Combinations include:

- Land-Based and Soft Engineering approach;
- Reef/offshore breakwaters & replenishment;
- Artificial Headlands & replenishment.

In 2001 Tonkin & Taylor made more specific designs for the land based options and the seawall. The breakwater options (reefs, groynes, artificial headlands) and soft engineering options were rejected in the report of 1997. These options include the options, which stabilize and develop the beach (**beach stabilization options**). The main characteristic of these beach stabilization options is working with nature to realize a sustainable environment. They stabilize the shoreline, concentrating on the natural cyclic process of erosion and sedimentation, while developing the natural processes and human processes in harmony.

In our view these beach stabilization options were rejected at a premature stage, when only schematic designs were available. Besides that they might be rejected, because of the high estimated costs. Therefore, in this report a review is made on the feasibility of the beach stabilization options. They will be compared to the seawall-option.

Beach stabilization options include the following protection works:

- Renourishment of the beach;
- Combination of Breakwater & Renourishment.

Beach face dewatering is not looked at, because that would only be useful in a small part of the project area (Shaw road, where the Opawe swamp is located). Artificial headlands are not looked at, because of their large impact on this relatively small project area.

The preferred method to find a solution for the problem is executing a preliminary design for all alternatives, followed by a Multi Criteria Analysis on the basis of these designs. However, because of the limited time for this report a wider approach is used:

1. Formulating the constraints and objectives, which have to be satisfied (chapter 9);
2. Formulating the design data (chapter 10).

For each option (nourishment and breakwaters) separately: (resp. chapter 11-12)

3. Generate available alternatives;
4. Valuating alternatives;
5. Preliminary design with characteristics and effects of the most preferred alternative.

6. Executing a detailed MCA to the two beach stabilizing options (chapter 13);
7. Comparison of the preferred beach stabilization option to the proposed seawall by a cost-benefit analysis (chapter 14).

9 Constraints

9.1. General

The situation at Waihi Beach is described in part A. There are many constraints, which a possible solution, like a beach stabilization option, has to satisfy. These constraints are divided in:

- *Legislation;*, These are policies or regulations given by central, regional and local governments;
- *Objectives*, these are goals, which are defined for this report.

The legislations and objectives are divided in different categories:

- Social;
- Environmental;
- Financial;
- Functional;
- Technical.

In the following paragraphs these constraints are summed.

9.2. Legislation

The requirements are mostly imposed by the Resource Management Act 1991 (RMA). The following documents cannot be inconsistent with that Act: the New Zealand Coastal Policy Statement (CPS), the Bay of Plenty Regional Policy Statement (RPS), the Bay of Plenty Regional Coastal Environment Plan (RCEP) and the Western Bay of Plenty District Plan (DP). For a detailed description of these policies see chapter 5.

The requirements that are interesting for our study area are:

Social

- The natural character of the coastal environment should be preserved to the greatest extent possible;
- Public access to and enjoyment of the Coastal Marine Area (CMA) should be maintained and enhanced;
- The ability of natural features such as beaches and dunes to protect existing development should be recognized and enhanced;
- Further intensification of development in existing areas now known to be susceptible to natural hazards should be avoided.

Environmental

- The natural character of the coastal environment should be preserved to the greatest extent possible;
- Existing amenity values should be maintained and enhanced;
- A precautionary approach should be adopted where complete knowledge of natural processes is unavailable.

Technical

- Coastal protection works should be permitted only when they are clearly the best practicable option;
- Where coastal protection works are the best practicable option they should be designed so as to avoid adverse environmental effects.

Functional

- If a structure in the CMA is a Restricted Coastal Activity, consent needs to be requested with the department of Conservation.

9.3. Objectives

Social

- The properties protected by the seawall need to be maintained and protected;
- Amount of people benefiting should be maximized;
- Enlargement of possibilities for urban development, which includes infill and additional development in green field sites.

Environmental

- Development and maintenance of a wide beach and dune system;
- Maintain/ improve the marine ecology;
- Minimize negative effects on wider coastal environment.

Financial

- The total costs should be as low as possible;
- Value of the properties may not decrease.

Functional

- Reduce erosion at the locations where erosion is most severe;
- Reduce impact of coastal flooding of the two creeks;
- Reduce and guide the currents (crosshore and longshore).

Technical

- The lifetime of the construction should be about 50 years;
- Use of sustainable materials for the protection work

10 Design data

10.1. General

This chapter contains the design data for the beach stabilization options. These data consist of the hydrographic, geotechnical and meteorological data. An obstacle for gathering the right data is the lack of a long period of surveying and monitoring in this area. When data, like records of wave heights, are not available, indirect sources could be used to make a prediction of the local conditions at Waihi Beach. Meteorological stations could provide information about wind direction, wind speed, barometric pressure, and temperature that have been collected for a long period. Nowadays also satellites can give information about wave height and wave direction.

10.2. Hydrographic data

10.2.1. Waves

Before designing a protection structure short term and long term wave statistics are required. Several measurements of wave heights have been executed in the last decades by observations of ships and buoys.

Macky et al. (1995) studied the wave climate of Waihi Beach with an ENDECO Wave-track wave buoy stationed in 34-m water depth over a period of three years. They found out that for 70% of the time significant wave heights were less than 1m and the mean wave height was about 0.8m. The peak period of these waves was 10-11s. The highest significant wave height recorded during the three years was 4.3m. The data is gathered in an El Nino period, so the data could not be representative for a long-term prediction of the wave climate in this region. Although the data could be different in the future, in this case these will be used for the design of the stabilization options.

From these data the wave climate is determined according linear wave theory. See Appendix C-I for the results. The wave statistics will only be used for the Service Limit State. The data used for the Ultimate Limit State is included in paragraph 9.4 'Meteorological data'.

10.2.2. Bathymetry

To determine the dimensions of a protection work a detailed 3D display of the seabed is necessary. Hydrographic charts are not sufficient to develop a proper design, so the area has to be surveyed by survey equipment. These surveys are described in several reports (Beamsley, 1996 and Environment B.O.P., 1997). Recently no further research has been performed. The monitoring programmes of the Environmental B.O.P. will be used for the profile of the beach and nearshore and the results of Beamsley will be used for the offshore profile. The composed profile, which will be used, further on, is contained in Appendix C-II.

10.2.3. Tides

Tides in the Bay of Plenty are semidiurnal with range between 1.26m (neap) and 1.64m (spring) (Hume et al., 1995). Harris et al. (1983) found average tidal-current speeds of 0.13 m/s on the shelf. Therefore, it is thought that tidal currents are insufficient to initiate sediment transport (Hoban, 1993). The average tide range is taken as 1.46m.

10.3. *Geotechnical data*

10.3.1. Soil properties

Waihi Beach consists of quartzo-feldspathic fine to very fine sediments close to shore, with coarser sediment further offshore. For designing a protection structure the following soil properties must be known:

- grain size (D);
- permeability (k);
- density (ρ);
- shear strength (c, φ);
- compressibility (C_α, C_s);
- moduli of elasticity (G, E);
- in situ stress (σ).

These parameters must be known to check the following criteria:

- slip failure;
- liquefaction;
- dynamic failure;
- settlements;
- filter erosion.

To determine the soil properties mentioned above soil investigation is needed. These investigations may include the following methods:

- penetration test (CPT) to establish in-situ soil properties;
- borings to take samples from various depths for further analyses in laboratory;
- geophysical observations.

At this stage for Waihi Beach research has been done only to determine the texture and the mineralogy (Harray and Healy, 1978)

10.3.2. Groundwater data

The groundwater table in the area is quite high. This is due to groundwater drainage and constant recharge from the Opawe swamp located inland. On the other hand the seawall has induced scour, which initiated the lowering of the adjacent beach profile. This together has equalled the groundwater table and the beach surface. This process accelerates beach erosion in front of the seawall.

10.4. Meteorological data

10.4.1. Storm surges

Not only the tidal variation influences the sea level, but also meteorological effects can influence this level. If no direct observations are available, one may use records of wind velocities, barometric pressures and hurricane or cyclone paths to estimate the probability of extreme water levels. Bradshaw et al. (1991) stated that decaying tropical cyclones should also been taking into account in the area. These tropical depressions bring high rainfall and strong winds, with the direction dependent upon the path taken by the tropical depression.

Pickrill and Mitchel (1979) noted that quasi-cyclic rhythmic patterns with an interval of 5-11 days between successive troughs of low pressure can develop resulting in periods of strong onshore winds which generate local waves. Anticyclones between the low-pressure systems bring offshore wind to Waihi Beach. The most significant wave storms appear to be generated by cyclonic depressions migrating SE across northern New Zealand. During such storm waves there may be little or no wind at Waihi Beach. The most damaging wave storms approach from the Easterly quadrant and generate a north-westerly long shore drift along Waihi Beach.

10.4.2. Design storm wave

The highest 10% of the waves is analyzed to determine the design storm wave, which is used in the Ultimate Limit State (Frisby and Goldberg, 1981). From this research the design wave is taken as H_s = 12.6m. When constructing a protection work the total wave runup level above M.S.L. is an important data. This level is composed of the following components:

- spring tide 0.80m;
- barometric setup 0.35m;
- wind setup 0.23m (40 knot wind, fetch 25km);
- wave setup 1.39m.

Depending on the slope of the structure the wave runup can be calculated. According to Healy (1993) the total design wave runup for Waihi Beach varies between about 4m at the northern end to about 5.4m at the Bowentown end.

11 Nourishment

11.1. General

Before designing a beach stabilizing solution, a thorough research about the development of the beach and dune system has to be carried out. The sand transport along Waihi Beach is described in paragraph 11.2. The third paragraph holds the design of the required beach fill. In this paragraph two options are considered. Paragraph 11.4 provides a cost assessment of the most suitable option. The effects of this solution are listed in the final paragraph.

11.2. Sand transport

11.2.1. Longshore sediment transport

Various researchers have done research over the last decades. An overview of the results is given below.

A Harray and Healy (1978): Direction of littoral drift is clearly SE, for several reasons. See chapter 4.

B Macky (1995): Sand transport is calculated by 3 years of wave records.

To the Northwest	654,000	m^3/year
To the Southeast	582,000	m^3/year
Total gross transport	1,1236,000	m^3/year
Net NW transport	72,000	m^3/year

Highest transport rates occurring during significant wave storms.

C Hicks and Hume (in press): NW longshore transport of sand is 57,000 m^3/year

Next to the long-term trends, short-term trends are also available. A possible 3-year cycle in direction along Waihi Beach with a net NW longshore drift from January 1991 to may 1991, reversing to a net SE drift from may 1991 to July 1993, reversing to a net drift NW again from July 1993 to February 1995.

On the basis of available evidence it is concluded that over a very long period of time the longshore current drift along Waihi Beach is most oscillatory, with alternating phases of unknown duration of SE and NW longshore drift with a tendency for a minor net SE drift. See evidence in chapter 3.4.3.

11.2.2. Crosshore sediment transport

During storms parts of the beach and dunes are eroded by the waves and the sand is taken to offshore bars. In calm weather situations sand is being put by the waves on the beach again. Before calculating the amount of replenishment, estimation about the maximum storm cut has to be made. The maximum storm cut known in the Bay of Plenty is a sweep of $135m^3/m$ above MSL measured in Bowentown in 1978.

Maximum expected storm cut:	- *Gibb*:	150-175 m^3/m
	- *Healy*:	240 m^3/m (incl. safety factor 2)

11.2.3. Long term fluctuation of shoreline

Shoreline trends were quantified at 100m intervals by Gibb (1996b) for 36 sites extending from the northern boundary of Waihi Beach to about 300m south of Glen Isla Place over a distance of 3.5km. Rates of advance or retreat of the dune line were computed for each of the 36 sites for the survey intervals 1902-1942 (40y), 1942-1964 (22y), 1964-1996(32y) and for the entire 94-year-survey period.

Year	accretion/ erosion	rate	part of total monitored length
1902-1942	accretion	1.55±0.40m/year	2.0km N
	erosion	-3.43±0.40m/year	1.5km S
1942-1964	erosion	-1.91±1.0m/year	2.1km N
	accretion	3.95±1.0m/year	1.4km S

1964-1996	accretion	1.56±0.47m/year	2.0km N
	accretion	1.34±0.47m/year	1.5km S

From these rates can be seen that the long-term erosion rate for the study area fluctuates periodically. Because of the erosive character of Waihi Beach, this rate is assumed to be minor negative. This is similar to the minor net longshore sediment transport pattern, presented in paragraph 11.2.1.

11.3. Design of nourishment

11.3.1. General

In this paragraph a sustainable beach profile is designed by testing different lay-outs and nourishment intervals. Also the location of the sand source and the fill placement are dealt with in this paragraph.

11.3.2. Sand sources

The properties of the sand and the distance from the project area to the sediment source will determine which sand source is the most appropriate.

The following two requirements for the beach replenishment material are taken into account:

- Uncontaminated material;
- Grain sizes have to be comparable or larger than those of the native beach sand. Larger grains are more stable and have a larger angle of respose.

For this case two different sand sources are available:

- Sand of opportunity

  Sand can be used from projects, which primary purpose is not beach replenishment, e.g. dredging maintenance in the harbor of Tauranga or other operations in the Katikati ebb-tide delta. The medium to fine well sorted sands of the ebb-tide delta are slightly coarser in texture (D_{50}=0.28mm) than the fine to very fine sands (D_{50} =0.25mm) of the upper shoreface of the beach. In the

Katikati ebb-tide delta 30 million m^3 of sand are stored and the delta is located 10km from the problem area. Dredging over there will improve the possibilities for navigation in the ebb-tide delta. However the harbor maintenance in Tauranga could also be combined with the replenishment, the distance from Tauranga to Waihi is too long (32km) and additional measures should be taken to be sure the level of contamination is not too high.

- Offshore source

  The sand source lies offshore and dredging at that place may not influence the crosshore sediment transport. The coarse-grained gravelly shelly sands of the inner shelf are distinctly different in character to the native sands of the area requiring replenishment. The inner shelf sands form large sand dunes. These are located approximately 3km offshore from the replenishment area in water depths of 20-50m, so the transport cost are low for this case. The offshore borrow area is sited well seaward of active portion (below the depth of closure) of the beach profile, so the nourishment sand is not drained back. The coarse grained sand is overlain by about 0.5m of sand comparable with the native beach sand.

The offshore source is the most suitable option, because the distance between the problem area and the source is very short. A trailing suction hopper dredger can be used to dredge the sand.

11.3.3. Calculation of the required beach fill

The current beach profile in front of the seawall displays a few failures, like the lack of dunes, slope of the beach is too steep (compared to a healthy, stable beach) and scour near the seawall. To calculate a new healthy beach profile including the widening of the beach a proper display of the current situation is required. A healthy beach is a beach, where only the natural processes determine the beach profile. The following steps have to be followed:

1. Formulate features of the beach profile;
2. Construct a healthy beach profile;
3. Determine options for widening the beach/dunes;
4. Test new profiles on durability, resistance of stormcuts (Sbeach);
5. Multi-criteria assessment on the beach widening options;

6. Time schedule of renourishment (testing with Genesis).

1. Features of the beach profile

- mean grain size, $M_z = 2.0 \rightarrow D_{50} = 0.25$ mm;
- Function profile below MLW:

  $h = Ax^{2/3}$

  $A = 0.21 \cdot D_{50}^{0.48} = 0.108$

  $\frac{dh}{dx} = 0.0767x^{-1/3}$;
- The depth of closure (D_c) reaches from MLW to a depth where the cross shore sediment transport is negligible.

  The use of predictive formulas, input wave height should be determined at a near shore location, approximately 10m deep. In estimating D_c for beach-fill design, various time scales must be considered. A D_c based on a time scale on the order of a typical renourishment interval (approximately 5 years) is recommended for use in determining volume requirements of the design project.

  Birkemeier formula (1985):

  $$D_c = 1.75H_{s_{0.137}} - 57.9\left(\frac{H_{s_{0.137}}^2}{gT_s^2}\right) = 8.39\text{m MLW}.$$

  where,

  $H_{s_{0.137}} = H_s + 5.6 \times \sigma = 4.47 \times H_s = 6.26\text{m}$;

  $T_s = 9.5\text{s}$ from Macky ea, 1995;

  $\sigma = 0.62H_s$ (Shore Protection Manual);

  $H_s = 1.4\text{m}$ at 10m water depth.

  The depth of closure with regard to MD becomes:

  $D_c = 8.39 + 0.73 = 9.1\text{m}$

2. Design of a healthy beach profile

To change the current profile at the seawall into a healthy one, detailed drawings of both of them are necessary.

Current profile

The profile can be divided in different sections:

- Slope of the properties (1:10), "dunes" (1:3) and the seawall (1:1). The estimation of the slopes is based on photographs (see Figure 11-1 and 11-2);
- Upper foreshore, slope 1:80. (BOP Regional Council 1997, coastal monitoring programme 1992-1996);
- Foreshore, section from MHW to MLW, 1:32.5 (BOP Regional Council 1997, coastal monitoring programme 1992-1996);
- Nearshore, section from MLW to offshore, 1:58. (Stephens 1996)

Figure 11-1 Photograph taken at 16 October 2003 showing beach at Shaw Road

Figure 11-2 Photograph taken at 16 October 2003 showing seawall at Shaw Road

Healthy profile

The beach profile 100m south of three mile creek is an example of a healthy beach.

- Foreshore: 1:50 (BOP Regional Council 1997, coastal monitoring programme 1992-1996);
- Nearshore, profile adjusted to mean grain size with function $h = 0{,}109x^{2/3}$.

The influence of storm erosion on the current profile is concentrated in the surf zone. The storm conditions (25 storms in 3 years: $H_s = 2.7\text{m}$) determine the length of the surf zone → x = 280m from the shoreline at MSL. The intersection point between the line with slope 1:58 and the derivative of the function $h = 0.109x^{2/3}$ determines the area of scour and the path of the profile. With these variables and measurements of cross sections (Environment B.O.P. 1997) the two beach profile can be drawn, see Figure 11-3.

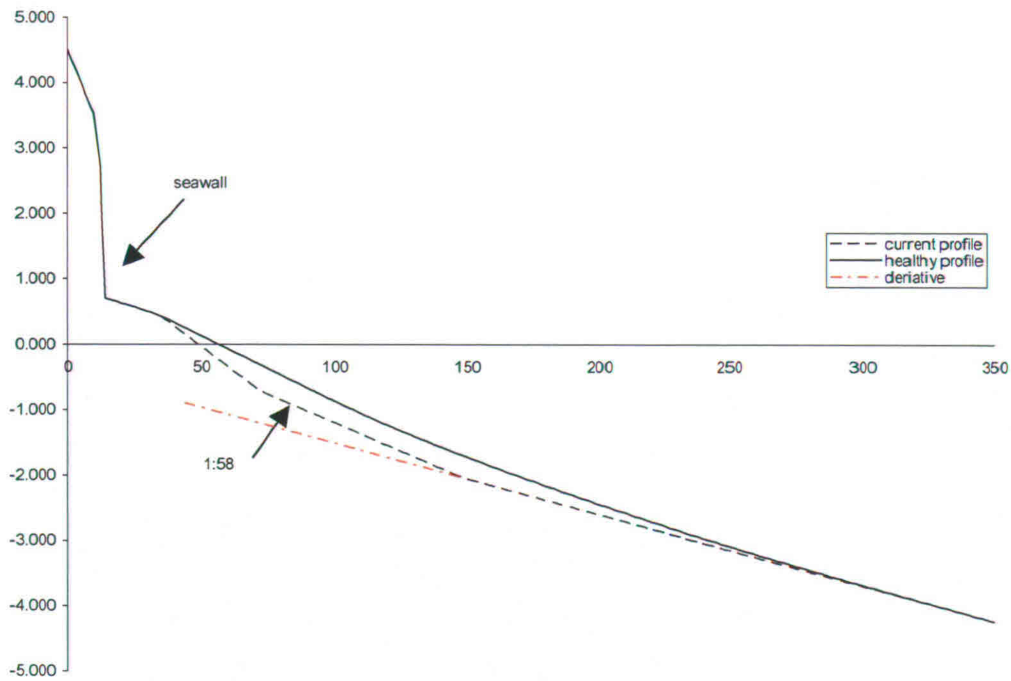

Figure 11-3 Profiles of current and healthy beach

By calculating the area between the healthy and the current profile an estimation of the volume of replenishment for the current profile is made: $52m^3/m$.

3. Widening of the beach

To make the right decision for the nourishment option two possibilities should be considered. The first version includes covering the current seawall with sand and the second version consists of building a whole dune system.

Version 1

The improvement of the current profile to the healthy beach profile doesn't provide a wider beach at high water, so extra replenishment is required. To provide public access at any time a widening of 10 meter beach at MHW is necessary. The foreshore of the beach is moved 20m offshore at MD, what results in a strip of 10m dry sand from the toe of the dune at MHW (see Appendix C-II). The amount of sand for this operation will be $100m^3/m$. The existing seawall will be covered by sand and will act as a small dune in the new system (see Figure 11-4)

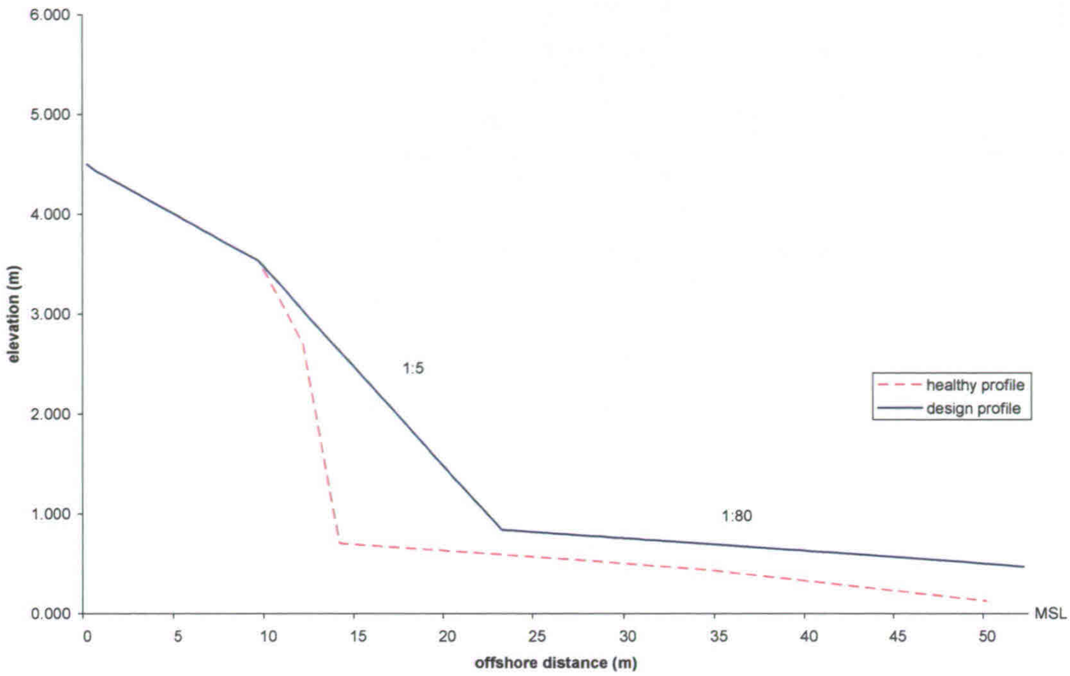

Figure 11-4 Close-up of dune and foreshore, version 1

Version 2

Building a new dune is another option, but requires more replenishment. In front of the current properties a dune with crest height of 5.5m MD will be developed and a beach with the same slopes as version 1 (see Figure 11-5 for a close-up and Appendix C-II for the whole profile). The foreshore will be translated 43m offshore at MD, what also results in a strip of 10m dry sand at MHW. The amount of sand for this operation will be 500 m^3/m.

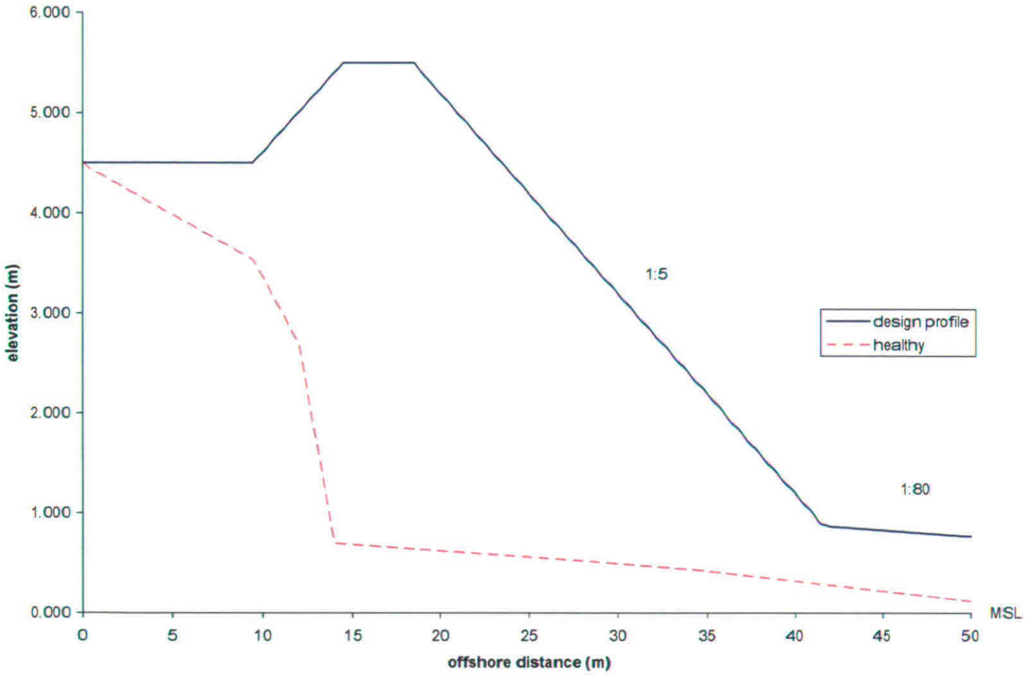

Figure 11-5 Close-up of dune and foreshore, version 1

4. Test new profile on durability, resistance of stormcuts

The protection of the beach properties depends on the resistance of the new profile against erosion in storm conditions. During severe storm conditions the waves cut away a part of the dune and displace it on the foreshore and offshore a bar formation develops. When this offshore bar is located within the reach of the closure depth the sand is not lost out of the system. The numerical computer program SBEACH can predict the affected area after a severe storm and the presence of washover. Another important parameter is the available sand reservoir. This reservoir provides a significant buffer for episodic storm cuts.

<u>SBEACH:</u>

- H_s=4.5m for a storm with occurrence once in 5 years (based on Macky 1995);
- h= 34m (depth at measurement point);
- T= 10s;
- H_b= 6.54m;
- h_b= 5.15m;
- Barometric setup: 0.35m;

- Tide: MHW = +0.73m MD;
- Wave setup:

$$h_s = 0.19\left(1 - 2.82\sqrt{\frac{h_b}{gT^2}}\right)H_b = 0.75\text{m} \qquad \text{Sorenson Formula}$$

- Wind speed: 40 knots, so wind setup = 0.23m (Erosion and hazard zone report, Healy 1993);
- Direction of wind and wave is perpendicular to the beach;
- Duration of storm: 36 hours.

After running the program SBEACH the new profile after a storm cut can be drawn. For both cases the pre-storm profile and the post-storm profile can be found in Appendix C-III. In Figures 11-6 and 11-7 a close-up of the "dunes" is shown. In Figure 11-6 the green line (dot dashed) represents the post-storm profile when the seawall has been removed.

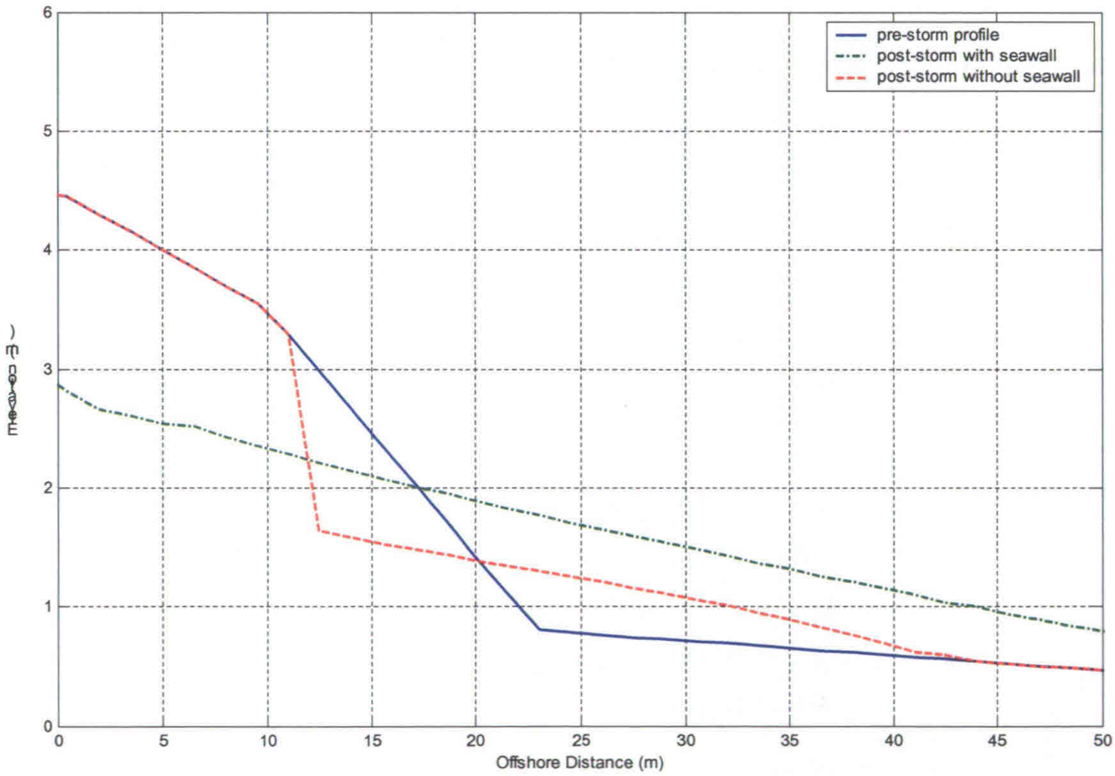

Figure 11-6 Close-up post-storm profile, version 1

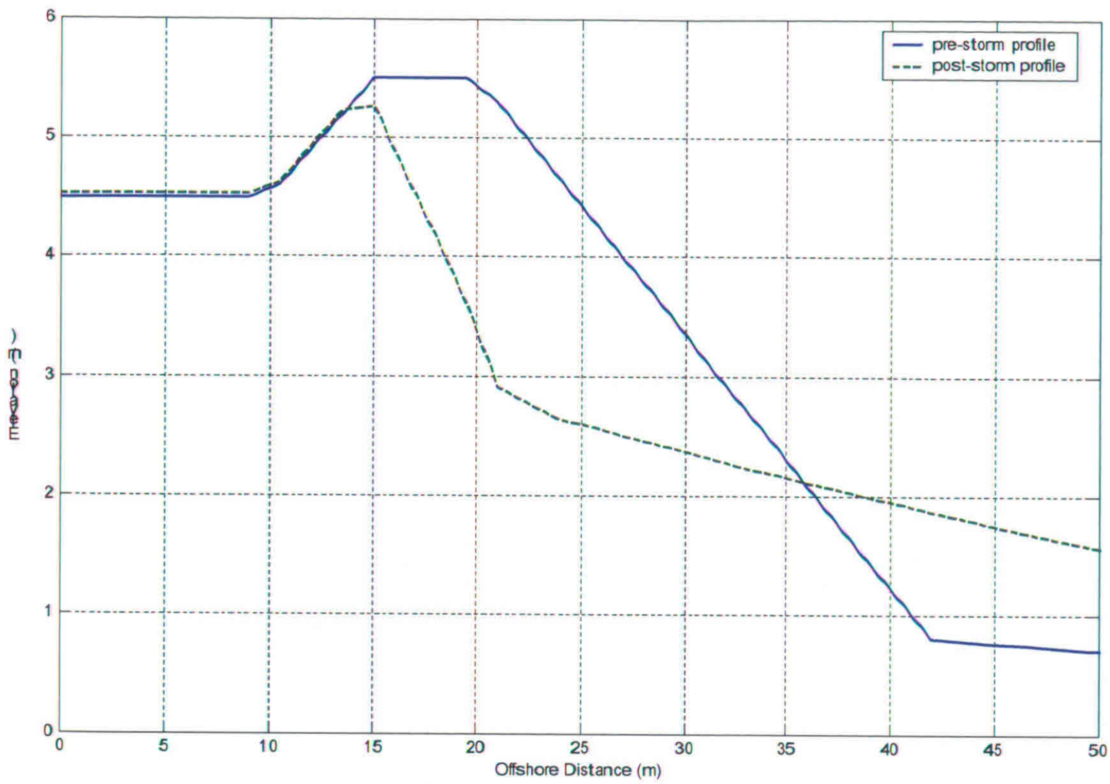

Figure 11-7 Close-up post-storm profile, version 2

Interpretation of the output of SBEACH

- Version 1

  During the storm event the seawall will be exposed to the wave forces, because the sand in front has been moved to the foreshore. From this one can conclude that the seawall is a necessary element during severe storm conditions to protect the properties from big storm cuts.

- Version 2

  The crest of the dune becomes 3.5m smaller and 0.3m lower. This implies the properties behind the dune are still protected against the waves, however washover will occur. To prevent this hazard, the dune should be 1m higher. For Waihi Beach it is not realistic to build such a high dune, because the properties are too close to the beach.

Available sand reservoir

In paragraph 12.2.2 the maximum storm cut has been described. From this data can be concluded that the available sand reservoir of version 1 is not sufficient to resist the maximum storm cut ever measured in the Bay of Plenty (135 m^3/m). The sand reservoir of version 1 consists of 45 m^3 sand between the crest of the covered wall and MSL.

During these storms the remaining seawall could provide the protection against flooding and erosion of the beach. Version 2 has a sand reservoir of 149 m^3/m; this will be sufficient to resist the maximum storm cut. To make a good choice between the two versions one has to evaluate them.

5. Preferable version for Waihi Beach

To evaluate the options a multi-criteria assessment is used. The criteria are already mentioned in chapter 9. The results of this assessment are shown in the table below:

	Version 1	Version 2
Social		
beach width	+	+
visibility effects	+	+
Environmental		
dune vegetation	+/-	+/-
Financial		
rough estimation costs	+	-
Functional		
coastal flooding	+/-	+/-
beach front properties	+	+
Technical		
disturbance execution	+/-	-
construction failure	+	+/-

Table 11-1 Multi-Criteria Assessment

Comments table:

- Social

  Both versions fulfill the social requirements, so this criterion does not a difference between the two versions;
- Environmental

  The two versions will perform the same, because the dunes are both artificially constructed. During severe storm the vegetation could vanish and human intervention is required;
- Financial

  The volume of sand required for version 1 is 20% of the volume required for version 2. This implies that version 1 will be 5 times less expensive, when no additional measures have to be taken. Taking into account the refurbishment of version 1, the difference between the two options still remain huge;

- Functional

  Both versions fulfill the functional requirements, so this criterion does not a difference between the two versions. ;
- Technical

  More maintenance is required for the second version, this will cause disturbance in the public area. The second version does not include the current seawall, so during severe the probability of failure is higher.

In this case the greatest restriction is the limited budget. Using the current seawall as a back-up system is a way of keeping the costs as low as possible for the nourishment option. This means that version 1 is the preferable option for Waihi Beach.

6. Time schedule of renourishment

By translating the shoreline in offshore direction at the location of the seawall lateral spreading losses will exist. This is caused by creating a discontinuity of the position of the shoreline. The following parameters determine the lateral spreading:

- wave climate; this determines the wave-driven longshore sand transport;
- length of the nourishment project; local wave transformation patterns will occur where the beach fill switches over into the adjacent beaches;
- ambient background erosion; note that the historical shoreline erosion rate may underestimate the post-nourishment erosion rate.

It is possible to model the shoreline change in a numerical model, GENESIS[1]. The site that has to be replenished is shown in Figure 8-1 (Shaw Road 1175m, The Loop 450m and Three-Mile Creek 125m). So the total affected beach length is 2.35km (with creek outlets included). Within this stretch the outlets of the Two Mile Creek and the Three Mile Creek are located. There has to be taken some measurements to ensure the creeks won't be blocked. Paragraph 10.4 will present two options for this problem. In this paragraph only the lateral spreading losses at both ends will be considered to determine the most economic renourishment scheme.

[1] GENEralized model for SImulating Shoreline change model, Hanson and Kraus 1989

The following two parameters set the renourishment interval:

- Length of beach fill
  End losses from the main project (stretch of 2.35km) can be reduced by extending the design section past the limits of the reach where protection is required. A possibility to do this smoothly is tapering the beach fill into the adjacent beaches. These extensions of beach fills are called 'transition zones'.
- The volume of sand per meter longshore
  To maintain the design fill section during the renourishment intervals it is necessary to place more sand at the site than calculated before. The calculated amount ($100m^3/m$) is based on the minimum beach width to guarantee public access (10m at high tide). So directly after nourishment the beach should be wider to compensate lateral losses.

Selection of a renourishment cycle is made through an optimization process that optimizes the initial construction costs and the costs of periodic renourishment to minimize the net present value. For this case two intervals will be considered for a 50-year project life.

The input of GENESIS contains for all two renourishment cycles the following information:

- The current position of the shoreline at MSL is at x=48m;
- The pre-project sediment deficit ($52m^3/m$) in front of the seawalls translates the shoreline at MSL 8 meter to x=56m;
- The wave condition consists of two waves: H_s=1.4m, φ=21 and H_s=1.4m, φ=-20. This wave climate causes almost the same transport rates as Macky measured from a 3-year record in 1995 with a minor net littoral drift SE;
- The berm height is +0.85m MD and the closure depth is -9.1m MD;
- Effective grain size diameter is 0.28mm and the effective grain size of the native sand is 0.25mm;
- The northern end of the beach is modeled as a groin to prevent sand losses to the north;
- The boundary at the south is modeled as an open boundary.

In GENESIS four cases are evaluated:

- option 1A: 3-year renourishment cycle and length total transition zone 300m;

- option 1B: 3-year renourishment cycle and length total transition zone 800m;
- option 2A: 5-year renourishment cycle and length total transition zone 400m;
- option 2B: 5-year renourishment cycle and length total transition zone 900m.

Following are the results:

	Option 1A	Option 1B	Option 2A	Option 2B
interval (years)	3	3	5	5
width left transition zone (m)	100	300	0	200
width right transition zone (m)	200	500	400	700
length nourishment (m)	2,650	3,150	2,750	3,250
widening beach (m)	47	41	51	44
initial nourishment (m3)	976,922	973,193	1,123,238	1,101,100
length renourishment (m)	1,850	2,150	2,550	2,250
widening beach (m)	12	10	12	14
renourishment (m3)	220,890	213,925	304,470	313,425
net present value ($)	13,129,004	12,885,131	12,325,277	12,364,558

Table 11-2 Net present values of different options

The net present value is calculated by using an inflation rate of 2%, an interest rate of 7% and a lifetime of 50 years. The costs of sand are estimated on NZ$5.50 (current price level). This unit price includes dredging, transport and dumping of the material.

The most economic renourishment option is option 2A: a renourishment cycle of 5 years and a small transition zone at the southern end. Figure 11-8 shows plots of the initial rectangular fill section, and the calculated shoreline at 1-year intervals. In this figure the blue dashed line shows the required position of the shoreline at MSL. This corresponds to a dry beach width of 10 meter at MHW. Figure 11-9 shows the shoreline after 5 and after 10 years. From this plot can be concluded that the calculated volume of renourishment is sufficient to keep the shoreline in the required position. An assumption is made that the volume of sand needed for periodic renourishment is constant during the 50-year lifetime.

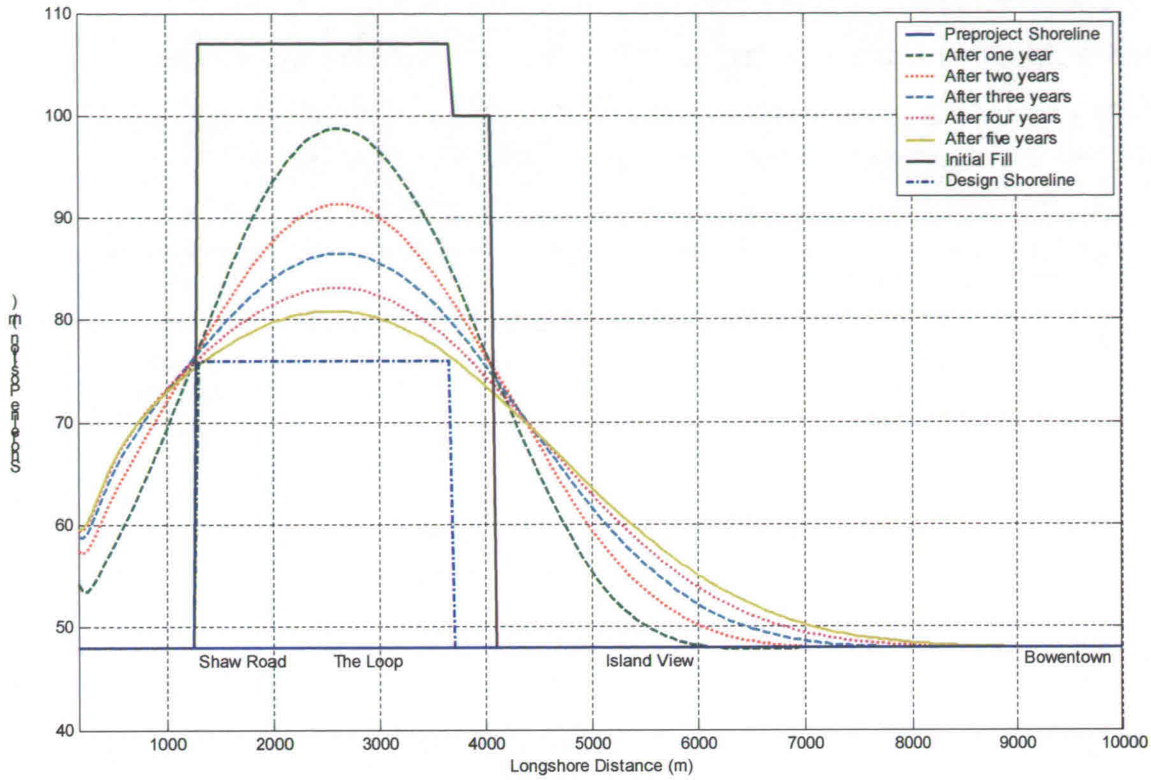

Figure 11-8 Position shoreline in the first cycle

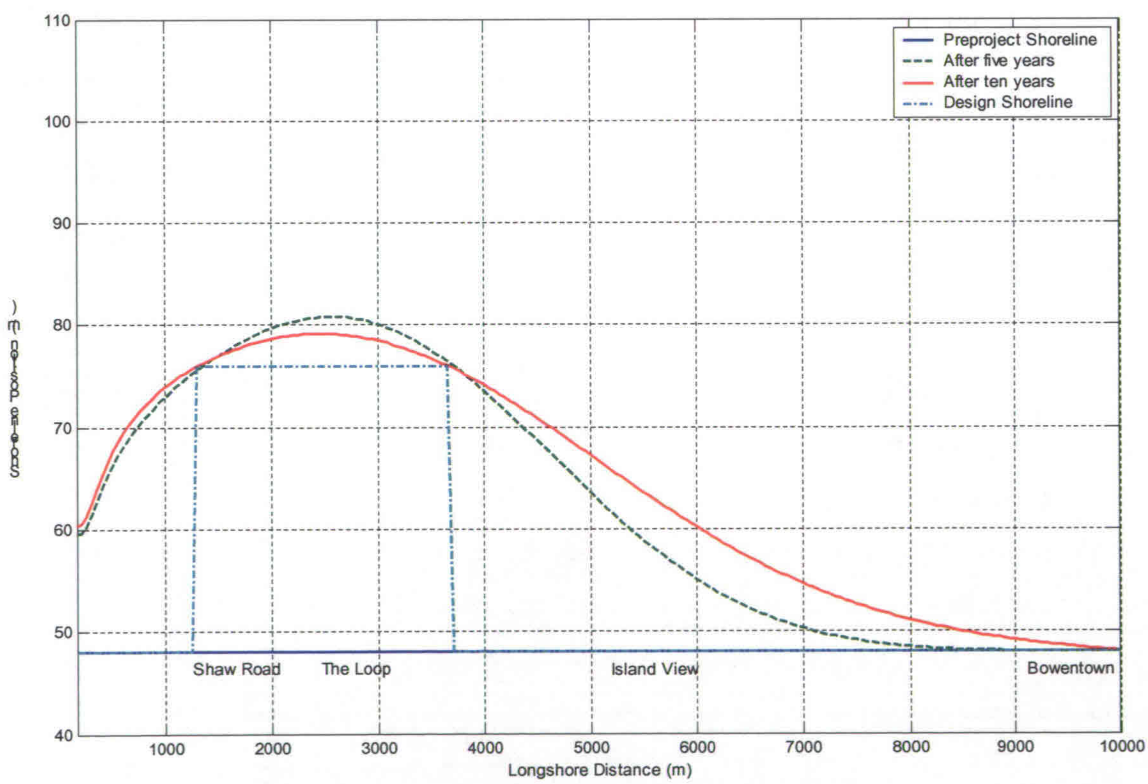

Figure 11-9 Position shoreline after first and second cycle

11.3.4. Fill placement

The replenishment operation can be divided in different stages. By using the new profile, one can determine the amounts of replenishment for the dunes, berm and foreshore. The possible locations where the sand can be dumped are listed below.

- Dune nourishment
  Dune nourishment is particularly effective in protecting upland development against storm waves;
- Dry beach nourishment
  Sand is placed on the dry portion of the beach and near the waterline and initiate an immediate increase in beach width. Sand will be redistributed offshore across the entire profile, until a stable configuration is established;
- Profile nourishment
  Profile nourishment involves placing the sand across the entire beach cross section, both above and below water, so an already-stable configuration will be build. Little offshore redistribution is expected, but this placement is difficult and provides less storm protection;
- Nearshore bar nourishment
  This method involves the placement of beach fill material in a sand bar just offshore of the surfzone with regard to the execution. To be successful the placement must be within the active portion of the beach profile. The sand will gradually move onshore under the influence of waves and currents and increasing the beach width.

The trailing suction hopper dredger dredges the sand from the location offshore so the most economic dumping location will be the foreshore bar. No extra equipment, like floating pipes, is required: this is an advantage.
The "dune" building operation will be operated after a few weeks by bulldozers when the sand from the bar has been displaced on the dry beach by the waves. The volume of sand necessary to cover the seawall is approximately 26 m^3/m. The total amount is 61,100 m^3.

11.4. *Costs assessment*

11.4.1. General

The nourishment operation will cause blockage of the Two and Three Mille Creek, so precautions have to be taken to prevent or minimize the blockage. Two options have been developed in the next two paragraphs to deal with this problem:

- Beach nourishment with trailing of the creeks (trailing devices on beach);
- Beach nourishment with 4 groynes at Two Mile and Three Mile Creek.

In paragraph 10.4.4 the net present value of both options will be calculated to choose the most economic renourishment option.

11.4.2. Trailing of the creeks

At the present situation the stream ends of the creeks are meandering across the beach and cover a lot of space of the beach. Trailing of the creek in a straight line with geotubes will prevent the meandering of the creek. After the nourishment operation in front of Shaw Road and the Loop, lateral spreading of the sand along the coast line will take place and the entrance of the creek will be blocked. This blockage could cause flooding problems upstream, so periodical maintenance is required.
The aspects of the total operation:

- Nourishment
  The initial nourishment operation consists of 1,12 million m^3 of sand along 2.75 km coastline based on the information in paragraph 12.3.2;
- Renourishment
  After a period of five year renourishment is required to maintain the 10m strip of dry sand during MHW. The renourishment operation consists of 0,30 million m^3 of sand along 2.55 km coastline based on the information in paragraph 12.3.2;
- Monitoring
  Monitoring activities consist of beach profile surveys (four times a year), beach sediment sampling (once a year) and aerial photography (once a year). For this option also data survey of the creeks is necessary because of the uncertainty in

the amount of sediment in the outlet of the creeks. To prevent total blockage of the creeks there has to be placed measuring equipment. This provides continuous data about the discharge and water level;

- Maintenance

  Maintenance costs are based on the period of filling up the outlet. To prevent blockage dredging of the outlet of the creek with appropriate equipment is estimated once a month. This maintenance cycle will be based on the results of monitoring;

- Stream Jetties

  The purpose of a stream jetty is to limit the erosion hazard by controlling the outlet locations of Two Mile Creek and Three Mile Creek. The structures are located either side of the stream outfall to guide the flow to the beach. A minimum channel width of 25m is sufficient to maintain catchment flood levels to the existing situation. The four stream jetties are composed out of geotubes filled with sand and they have a length of 55m each. The total required volume of sand to fill the bags is estimated to be 560m^3.

11.4.3. Groynes at both sides of the creeks

Another way of minimizing the blockage of the creeks is the construction of groynes, which reach from the shoreline to the end of the surfzone. These groynes also reduce the lateral spreading of the sand after a nourishment operation. The groynes can be seen as extensions of the trailing devices on the beach.
The aspects of the total operation:

- Nourishment

  In this option it is impossible to realize a widening of the beach at the south of Three Mile Creek. The length of this stretch is 125 meter. Groynes southwards will be necessary to hold the sand in place. A beach stabilization option with groynes is not included in this nourishment design.

  The initial nourishment operation consists of 0.54 million m^3 of sand along 3.25 km coastline. This amount is much lower than the previous option. Figure 11-10 shows plots of the calculated shoreline at 2-year intervals.

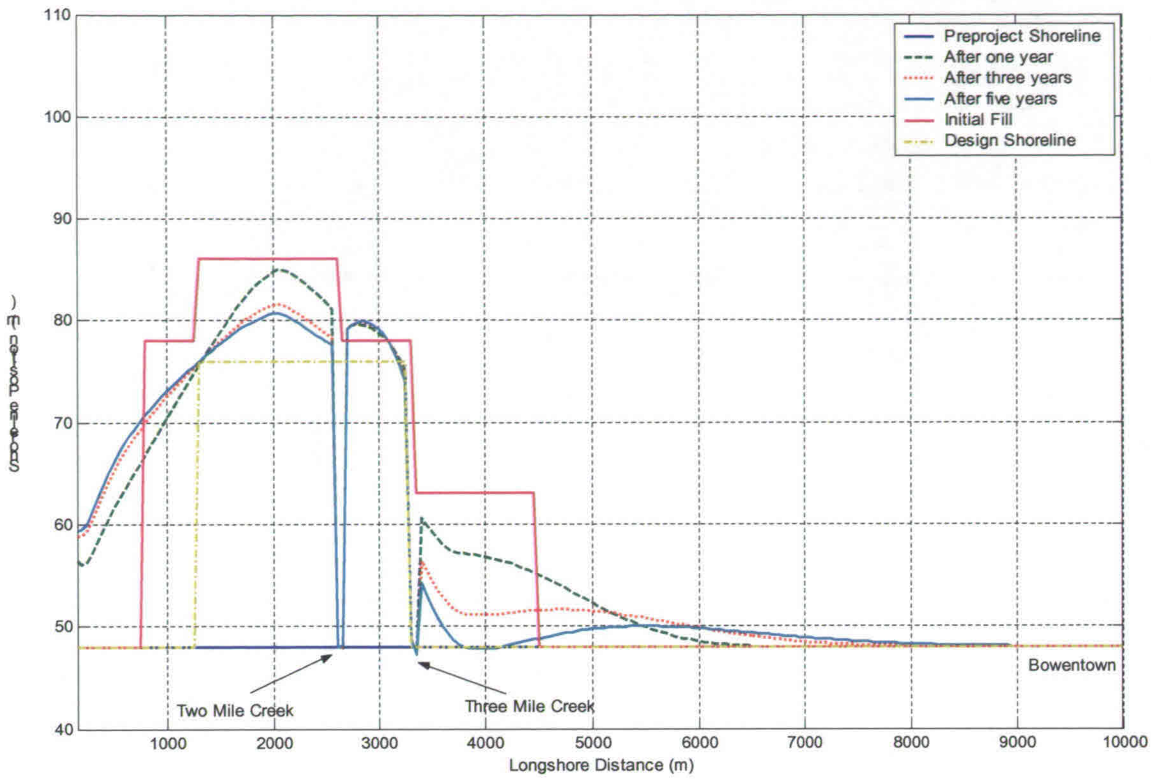

Figure 11-10 Position shoreline in the first cycle

- Renourishment

  After a period of five year renourishment is required to maintain the 10m strip of dry sand during MHW. The renourishment operation consists of 0,12 million m^3 of sand along 3.25 km coastline. Figure 11-11 shows the shoreline after 5 and after 10 years. From this plot can be concluded that the volume of renourishment is sufficient to keep the shoreline in the required position. Note that the creek outlets stay open.

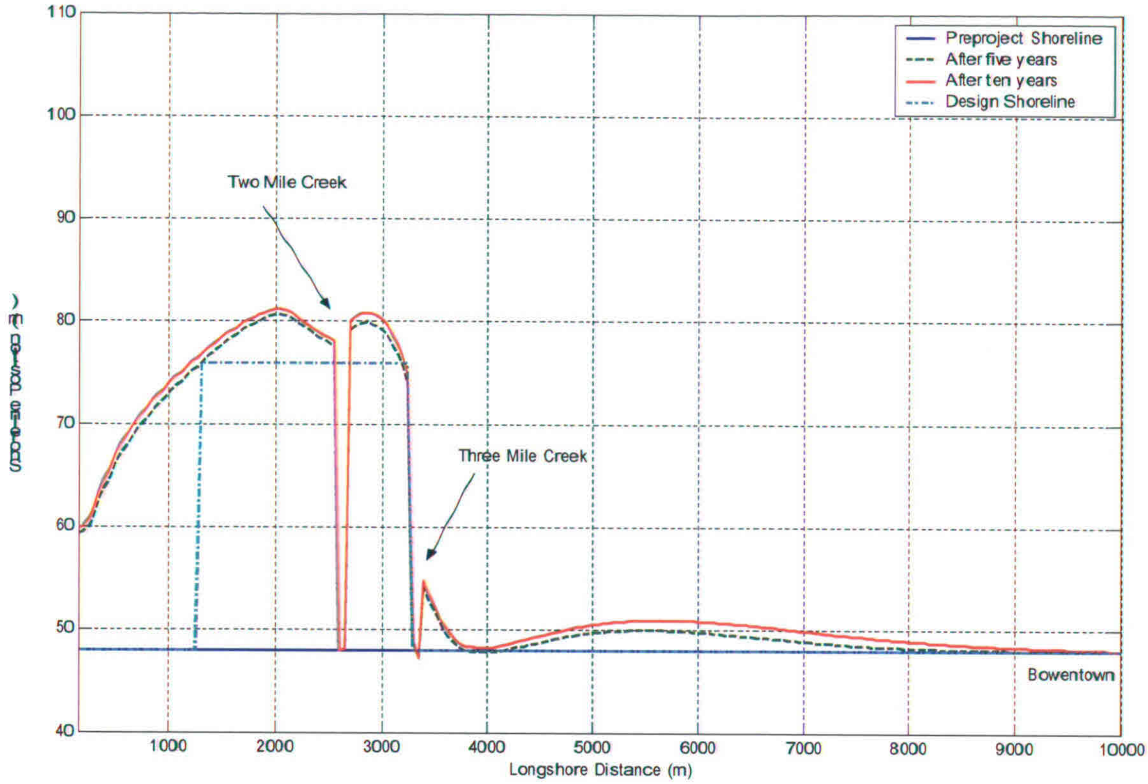

Figure 11-11 Position shoreline after first and second cycle

- Monitoring

  Monitoring activities consist of beach profile surveys (four times a year), beach sediment sampling (once a year) and aerial photography (once a year). For this option data survey of the creeks is not necessary because of the protection by the groynes;
- Maintenance

  No extra maintenance required;
- Groynes

  The four groynes provide a continuous flow out of the creeks. The groynes have to be extended through a great part of the surf zone to realize this. From the output of GENESIS can be concluded that the length of the groynes have to be 225m. The four groynes are composed out of geotubes filled with sand. The design of the groynes is an extension of the design of the stream jetties. The total required volume of sand to fill the bags is estimated to be 15,000m^3.

11.4.4. Financial evaluation

The cost aspects of both options have to be viewed, because the most economic option will be chosen. The costs of the nourishment, renourishment, monitoring, maintenance and the hard structures will be described in the tables below.

Costs of Nourishment - option stream jetties

Renourishment							
Initial			Volume m^3	Price/unit $/m^3	Costs		
	Nourishment		1,245,000	$ 5.50	$ 6,847,500	$ 6,850,000	$ 6,850,000
Maintenance			Volume m^3	Price/unit $/m^3	Costs		
	After 5 year		300,000	$ 6.07	$ 1,821,733	$ 1,820,000	$ 1,300,000
	After 10 year		300,000	$ 6.70	$ 2,011,341	$ 2,010,000	$ 1,020,000
	After 15 year		300,000	$ 7.40	$ 2,220,683	$ 2,220,000	$ 800,000
	After 20 year		300,000	$ 8.17	$ 2,451,813	$ 2,450,000	$ 630,000
	After 25 year		300,000	$ 9.02	$ 2,707,000	$ 2,710,000	$ 500,000
	After 30 year		300,000	$ 9.96	$ 2,988,747	$ 2,990,000	$ 390,000
	After 35 year		300,000	$ 11.00	$ 3,299,818	$ 3,300,000	$ 310,000
	After 40 year		300,000	$ 12.14	$ 3,643,265	$ 3,640,000	$ 240,000
	After 45 year		300,000	$ 13.41	$ 4,022,459	$ 4,020,000	$ 190,000
	Monitoring				$ 1,380,336	$ 1,380,000	$ 300,000
					Subtotal	**$ 33,390,000**	**$ 12,530,000**
Geotubes							
Initial		Number -	Volume m^3	Price/unit $/m^3	Costs		
	Stream jetties	4	140	$ 70.00	$ 39,200	$ 40,000	$ 40,000
	replacement after 25 years	4	140	$ 70.00	$ 39,200	$ 60,000	$ 10,000
					Subtotal	**$ 100,000**	**$ 50,000**
Creeks							
	Maintenance of the creeks	12		1500	$ 1,550,000.00	$ 1,550,000	$ 330,000
					Total	**$ 35,040,000**	**$ 12,910,000**

Table 11-3 Costs of option with stream jetties

Costs of Nourishment - option groynes

(Re)nourishment							
Initial			Volume m³	Price/unit $/m³	Costs		
	Nourishment		659,000	$ 5.50	$ 3,624,500	$ 3,620,000	$ 3,620,000
Maintenance			Volume m³	Price/unit $/m³	Costs		
	After 5 year		120,000	$ 6.07	$ 728,693	$ 730,000	$ 520,000
	After 10 year		120,000	$ 6.70	$ 804,536	$ 800,000	$ 410,000
	After 15 year		120,000	$ 7.40	$ 888,273	$ 890,000	$ 320,000
	After 20 year		120,000	$ 8.17	$ 980,725	$ 980,000	$ 250,000
	After 25 year		120,000	$ 9.02	$ 1,082,800	$ 1,080,000	$ 200,000
	After 30 year		120,000	$ 9.96	$ 1,195,499	$ 1,200,000	$ 160,000
	After 35 year		120,000	$ 11.00	$ 1,319,927	$ 1,320,000	$ 120,000
	After 40 year		120,000	$ 12.14	$ 1,457,306	$ 1,460,000	$ 100,000
	After 45 year		120,000	$ 13.41	$ 1,608,984	$ 1,610,000	$ 80,000
	Monitoring				$ 862,710	$ 860,000	$ 300,000
					Subtotal	**$ 14,550,000**	**$ 6,080,000**
Geotubes							
Initial		Number -	Volume m³	Price/unit $/m³	Costs		
	Groynes	4	3,750	$ 70.00	$ 1,050,000	$ 1,050,000	$ 1,050,000
	replacement after 25 years	4	3,750	$ 70.00	$ 1,050,000	$ 1,720,000	$ 320,000
					Subtotal	**$ 2,770,000**	**$ 1,370,000**
					Total	**$ 17,320,000**	**$ 7,450,000**

Table 11-4 Costs of option with additional groynes

Remarks on tables

- Unit price stream jetties and groynes: This price includes the sand, geotextile and placement of the structures at current price level;
- Maintenance hard structures: No maintenance costs are calculated, because the structures will be completely replaced after 25 years.
- NPV: Nett present value based on construction in year 1 with interest rate of 7% and inflation rate of 2%.

This financial evaluation shows that the option of groynes at both sides of the creek is the most economical one. Note that this option does not include beach protection at the most southern part of the current seawall. The length of this stretch is 125m.

Figure 11-12 shows the current status of the profile. The beach profile at this section looks healthier in comparison with the other two parts of the seawall.

Figure 11-12 Photograph taken at 16 October 2003 showing seawall at south of the Three Mile Creek.

11.5. Effects

The beach fill and the construction of the additional groynes will have effects on the coastal environment:

Positive effects

- The beach-dune system is restored;
- The natural character in the centre of Waihi Beach is guaranteed;
- All-tide public access along the fore shore is restored;
- The amenity values of the area to the general public are restored;
- The beachfront properties are protected during severe storms;
- Development of the beach induces tourism and more usage of the beach;
- The beach will be raised; therefore the groundwater at the seawall at Shaw Road will be of less influence to the erosion process then before;
- Lateral spreading processes cause a widening of the adjacent beaches;
- Trailing of the creeks mitigates the local erosion at the creek outlets.

Adverse effects

- Construction and maintenance activities do have a negative impact on the beach;
- The groynes diminish the positive effects of the nourishment at the creek outlets like natural character, amenity values and public access;
- Though the storm impact is reduced wave overtopping of the existing seawall is a potential hazard at very severe storms;
- After severe storms the current seawall is exposed, which could cause dangerous situations for safety and public health;
- Strong rip currents will occur adjacent to the groynes.

12 Breakwaters

12.1. *General*

This chapter holds a preliminary design of a breakwater. Breakwaters have a specific layout and composition. In paragraph 13.2 the different layout options and the different types of breakwaters are presented. Together they will form the available options in Waihi Beach. The most preferable breakwater is chosen from a Multi Criteria Assessment in paragraph 13.3. In paragraph 13.4 a preliminary design is presented of the most preferred breakwater resulting from the MCA. Paragraph 13.5 holds the execution and maintenance of the breakwater followed by the estimated costs in paragraph 13.6. Paragraph 13.7 holds the effects of the breakwaters. Finally some remarks are presented in paragraph 13.8.

12.2. *Available breakwaters*

12.2.1. Lay out options

Different lay out options are possible, each with its typical effects. These layout options are:

Perpendicular or parallel to the coast

Sediment transport can be divided in crosshore direction and in longshore direction. Breakwaters should prevent erosion in the dominant direction (crosshore at Waihi Beach).

Overtopped or non-overtopped breakwaters

Overtopping is defined as the quantity of water passing over the crest of a structure per unit of time. Overtopped breakwaters only allow larger waves to wash across the crest.

Crest elevation determines the amount of wave overtopping. The optimum crest elevation is determined by the minimum height, which provides the needed protection. Non-overtopped breakwaters always prevent wave energy passing across the crest.

Submerged breakwater

Submerged breakwaters are fully overtopped breakwaters. They are designed to dissipate sufficient wave energy to eliminate or reduce shoreline erosion.

Single or multiple breakwaters

Choice of single or multiple breakwaters will depend on the coastline geometry and predominant wave direction. Special attention is required to the change of currents and flow patterns caused by the structure.

12.2.2. Types

Different types of breakwaters are possible. The available types are:

Rubble Mound Breakwater

This type of breakwaters consists of interior graded layers of stones. An outer armor layer, composed out of rock or concrete blocks, will resist the wave attack, but allow high wave energy transmission. Graded layers below the armor layer absorb wave energy and prevent the finer soil in the foundation from being undermined. This type is adaptable for a wide range of water depths, suitable on nearly all foundations and is readily repairable. A disadvantage of this construction is the rapid increase of material with increasing depth.

Composite or Wall-Type Breakwater

Consists often of caissons (a concrete or steel shell filled with sand or gravel) sitting on a gravel base. An assessment has to be made to the reflection of wave energy and scour at the toe of the structure, which are important aspects for the sustainability of the structure. This construction is applicable on a firm to less firm soil, depending on the mound. A high mound will require more material, compared to a caisson.

Floating Breakwater

Floating breakwaters are special constructions and relatively new compared to the traditional appearances of breakwaters. The main characteristic of floating breakwaters is the wave energy reducing capacity while enhancing the crosshore sediment transport. This transport will be more regulated as the wave energy is reduced. The uplift can be achieved by e.g. pneumatic constructions, foam or tires. These breakwaters require a stable and special foundation since they are dynamic in their behavior. The behavior of this kind of construction in a rough wave climate has to be analyzed and tested before applicable in a coastal environment.

Breakwater composed out of geotubes/containers

A special type of breakwaters is composed out of geotubes/containers, possibly protected by an armor layer. The tubes are filled with sand for about 70-90%. This will result in a flexible "sausage" which will form the breakwater with surrounding "sausages". Wave transmission depends on the amount of and distances between the tubes.

12.2.3. Combinations

By combining available layout options and typical breakwaters different options can be derived. Some of the combinations are not realistic and are marked with an X in the table. Those will not be assessed in the Multi-Criteria Assessment in the next paragraph.

		Parallel	Perpendicular	(Non)-Overtopped	Submerged	Single	Series
Rubble Mound	Rock		X			X	
	Concrete		X			X	
Composite	Caisson		X			X	
	High Mound		X			X	
Floating			X	X		X	
Geotubes			X	X		X	

Table 12-1 Combinations of layout and types of breakwaters

In Waihi Beach the prevailing sediment transport direction is crosshore. The littoral drift induces long shore sediment transport but according recent studies the net long shore sediment transport is negligible. To reduce the crosshore sediment transport, the structure has to reduce the wave impact. Structures only perpendicular to the coast do not have this ability and are not analysed. Combinations of perpendicular and parallel structures are possible, e.g. T-groynes.

The locations where protection is required are limited in length and number. These critical locations are at Shaw Road with a length of about 1175m, at the Loop about 450m and south of 3 Mile Creek about 125m. Constructing single breakwaters will therefore be inefficient and very expensive, with regard to the ratio of the affected beach length and breakwater length. If a breakwater is constructed in front of the creeks a salient will develop, which will block them. Therefore, a single breakwater is not preferred with regard to the influence of the creeks. Therefore all breakwaters will be constructed in serie.

From this assessment the following options can be derived:

Rubble Mound Breakwater, (Non-) Overtopped, armor layer of rock.
Rubble Mound Breakwater, Submerged, armor layer of rock.
Rubble Mound Breakwater, (Non-) Overtopped, armor layer of concrete blocks.
Rubble Mound Breakwater, Submerged, armor layer of concrete blocks.
Composite Breakwater, (Non-) Overtopped, caisson.
Composite Breakwater, Submerged, caisson.
Composite Breakwater, (Non-) Overtopped, High Mound.
Composite Breakwater, Submerged, High Mound.
Breakwater composed out of geo-containers, Submerged.
Floating breakwater
T-groynes

12.3. *Global Multi Criteria Assessment*

In the Multi Criteria Assessment the options for the protection work are valued by the objectives mentioned in chapter 9. The objectives are divided into five groups (social, environmental, financial, functional and technical). For each group the options will get a score from 1 to 5. The score 1 equals to a negative influence of the option with regard to the objective, the score 5 to a positive influence. The scores are based upon the characteristics mentioned in paragraph 12.2.

Each group has a contribution to the final score of an alternative. By applying a scale factor to the contribution, a sensitivity analysis can be executed. For each sensitivity analysis the preferred solutions will be pointed out.

Options		Criteria	Social	Environmental	Financial	Functional	Technical	Total	
Rubble Mound	Rock	(Non-)Overtopped	2	5	2	5	2	16	
		Submerged	4	4	3	4	3	18	
	Concrete blocks	(Non-)Overtopped	2	4	1	5	2	14	
		Submerged	4	3	2	4	3	16	
Composite	Caison	(Non-)Overtopped	2	3	1	5	1	12	
		Submerged	4	2	2	4	2	14	
	High Mound	(Non-)Overtopped	2	4	1	5	2	14	
		Submerged	4	3	1	4	3	15	
Geotubes		Submerged	4	5	4	4	5	22	1
Floating			4	3	5	2	2	16	
T-groynes			4	4	2	4	3	17	

Scale factors: Social 1.0 Functional 1.0
Environmental 1.0 Technical 1.0
Financial 1.0

Table 12-2 Global MCA – Neutral

From the Global MCA and the sensitivity assessments follows the preferred option. As can be seen in Table 12-2 and Appendix C-IV, the submerged breakwater composed out of geotubes is the most preferable beach stabilization option for all sensitivity assesments.

12.4. Preliminary design

12.4.1. General

Geotextiles have been utilized for over 5 decades and great advances have been made in the last 10 years. Recently these geotextiles have been used in the marine environment as construction material for Artificial Surfing Reefs (ASR). Typical dimensions of geotubes are 20m in length and 3-5m in diameter. These tubes are filled with sand for about 70-90%. Placed together they will form a submerged breakwater.

Shoreline response to a submerged breakwater is controlled by at least 14 variables (Hanson and Kraus, 1989, 1990, 1991), of which eight are considered primary; (1) distance offshore; (2) length of the structure; (3) transmission characteristics of the structure; (4) beach slope and/or depth at the structure (controlled in part by the sand grain size); (5) mean wave height; (6) mean wave period; (7) orientation angle of the structure; and (8) predominant wave direction. For segmented detached breakwaters and artificial reefs, the gap between segments becomes another primary variable.
The efficiency of submerged structures (reefs) and the resulting shoreline response mainly depends on the diffraction of the waves around the breakwater. Diffraction currents induce sediment transport into the lee side of the structure and depend on the transmission characteristics (crest elevation) and the layout of the structure (length of the structure compared to the wavelength) (see Figure 12-1).

A number of engineering procedures to estimate combined wave transmission through a breakwater and wave overtopping are available, but still not very reliable (Tanaka, 1976, Ahrens, 1987, Uda, 1988, Van der Meer, 1990, d'Angremond & Van der Meer & De Jong, 1996, Seabrook et al, 1998, etc). Also, the shoreline response to exposed offshore breakwaters has been studied considerably. However, little work has been done on the effect of submerged offshore reefs, particularly outside the laboratory.

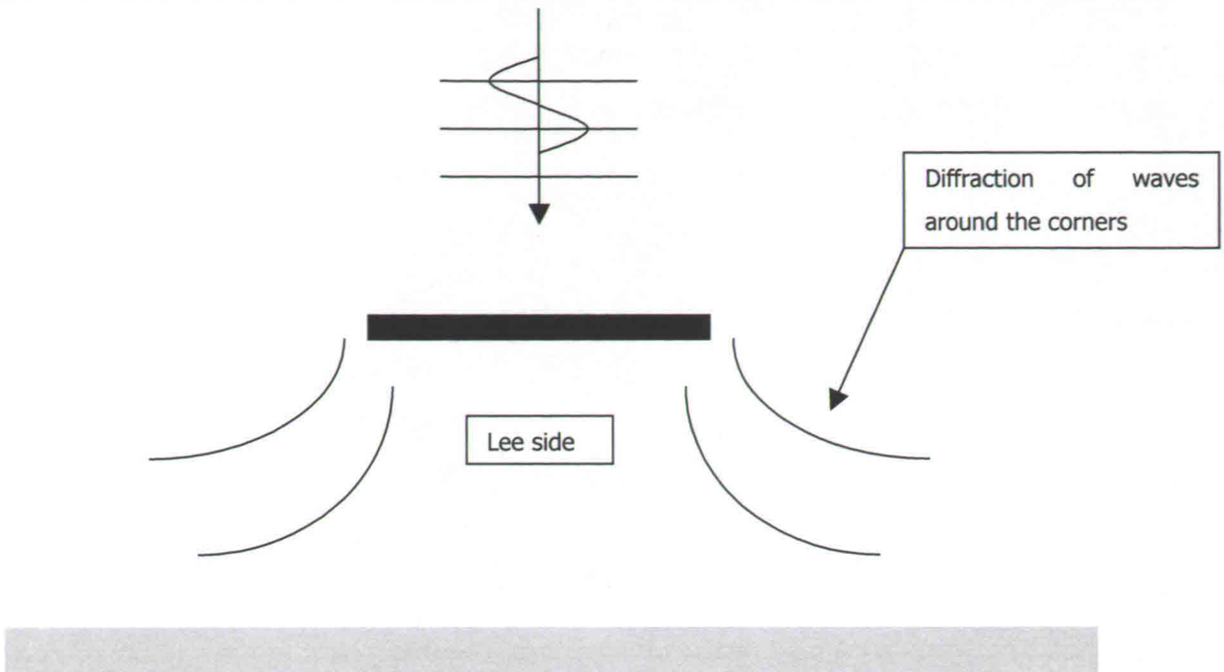

Figure 12-1 Diffraction of waves at breakwater

In the next paragraphs the preliminary design is made for a series of detached breakwaters. First the global dimensions and location are estimated (12.4.2-3-4) and the current beach characteristics are shown (12.4.5). The global salient development and estimated number of breakwaters are first estimated with the method of Black, Mead and Andrews. After that the shoreline response is calculated in more detail with the software program GENESIS (12.4.6).

12.4.2. Offshore distance of the breakwater

The offshore distance of the breakwater mainly depends on the length of the surfzone. The breakwater should be placed about 1.5 times the length of the surfzone from the undisturbed shoreline. At this distance larger waves will break and dissipate energy, which contributes to the salient development. Salient development occurs at calm wave conditions. Therefore, the breakwater should be designed according these conditions. At storm conditions the salient will be eroded.

From the wave data it is known that the surf zone for calm wave conditions (angle of incidence is 0 degrees) is equal to 130 m (H_s=1.8 m, h = 2.20 m). The angle of incidence is defined as the angle between the line perpendicular to the coast and the wave ray. See Appendix C-I for the refraction patterns and shoaling characteristics at

Waihi Beach for calm wave and storm wave conditions. From these data the offshore distance should be about 200 m offshore.

12.4.3. Crest-elevation

The wave climate at, the tidal range at and the crest-elevation of the breakwater determine the wave energy reducing capacity. A large crest-elevation corresponds with a higher wave reducing capacity, which will be more favorable for the beach development. A rule of thumb for the crest-elevation is about 0.5 m below LLW. At this height the crest will always be submerged and small boats are able to pass the breakwater at low tide.
The transmission coefficient of breakwaters is (d'Angremond & Van der Meer & De Jong, 1996) See Figure 12-2 :

$$K_t = \frac{H_i}{H_t} = -0.4\frac{F}{H_i} + \left(\frac{B}{H_i}\right)^{-0.31}\left(1 - e^{-0.5\xi}\right)C = 0.36$$

where,

F	=	Freeboard (equal to 3.1 - 1.8 = −1.3m)
H_i	=	Incoming wave height (equal to 1.6 m at breakwater)
H_t	=	Transmitted wave height
B	=	Width of breakwater (estimated to be 15m)
C	=	numerical coefficient (equal to 0.64 for permeable and 0.80 for impermeable structures)
ξ	=	Irribarren number, equal to:

$$\xi = \frac{\tan\alpha}{\sqrt{H_s/L_0}} = \frac{1/58}{\sqrt{1.4/127}} = 0.16$$

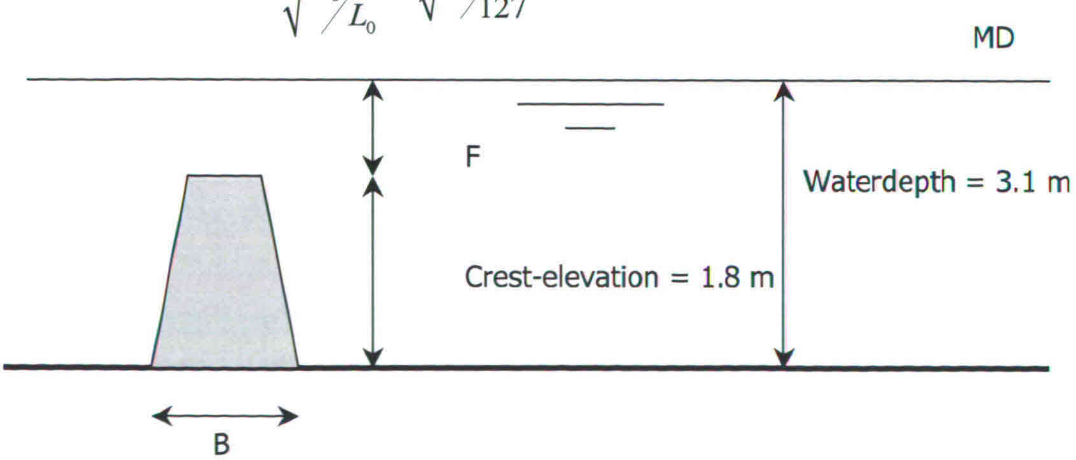

Figure 12-2 Geometrical measures for breakwater

12.4.4. Length of the breakwater

The development of a salient is possible by energy dissipation and by the diffraction of the waves around the breakwater. In this situation diffraction currents induce sediment transport from the adjacent area to the lee side of the structure. The length of the structure at, the wavelength at and the transmission coefficient of the breakwater determine the diffraction pattern of the waves. The diffraction pattern of various lengths of breakwaters can be seen in the Figures 12-3 to 12-5. Its influence area determines the efficiency of a breakwater. The graphs show the diffraction coefficient, which is defined by the ratio between the local wave height and the incident wave height, for reef lengths of 50m, 100m and 150m.

Calm wave conditions (offshore distance 200m, h=3.1m, T=9s)

The wavelength at the breakwater is equal to (following from linear wave theory):

$$\frac{h}{L} = 0.064$$

$$L = \frac{h}{0.064} = 48 \text{ m}$$

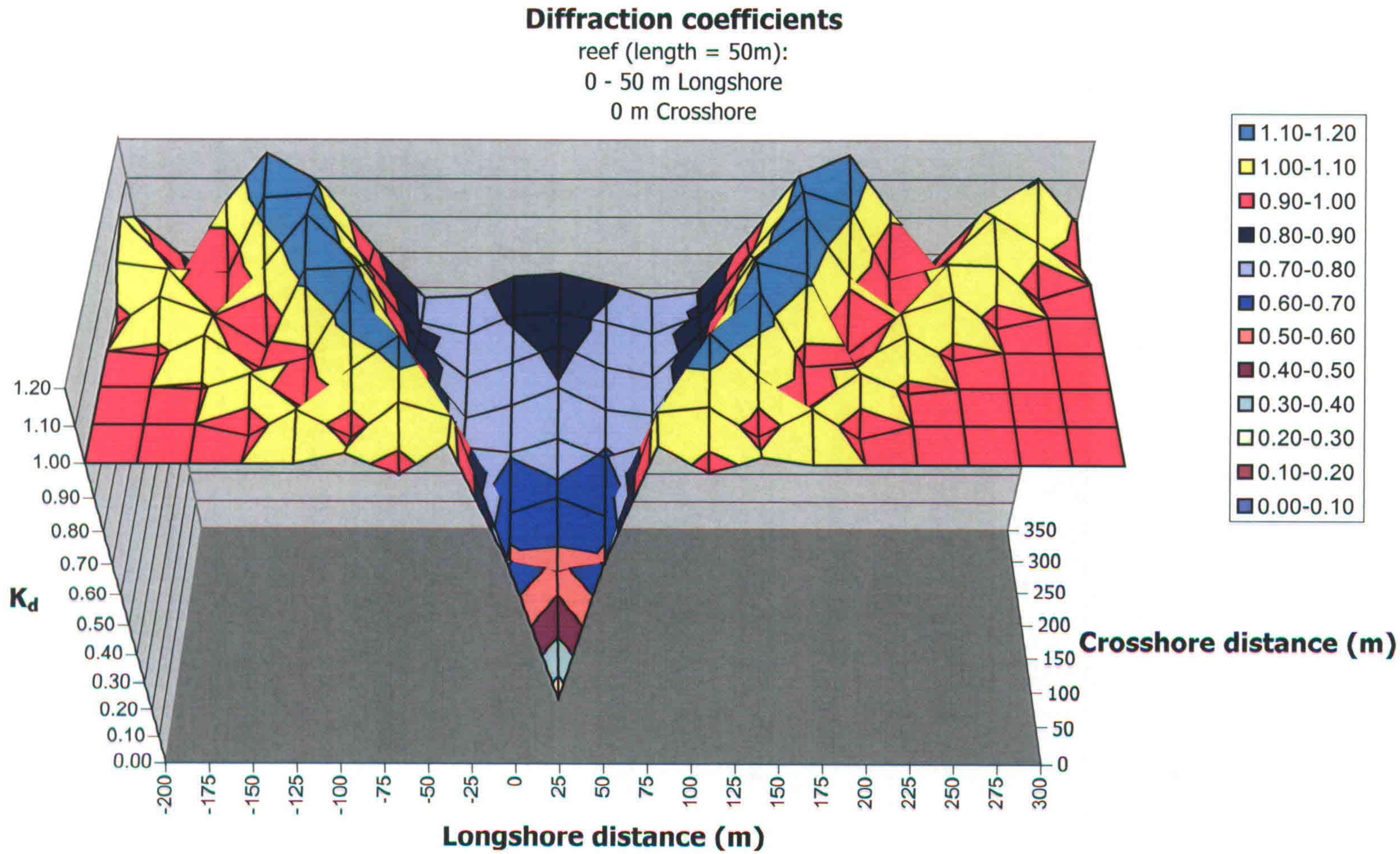

Figure 12-3 Diffraction pattern for reef of 50m length

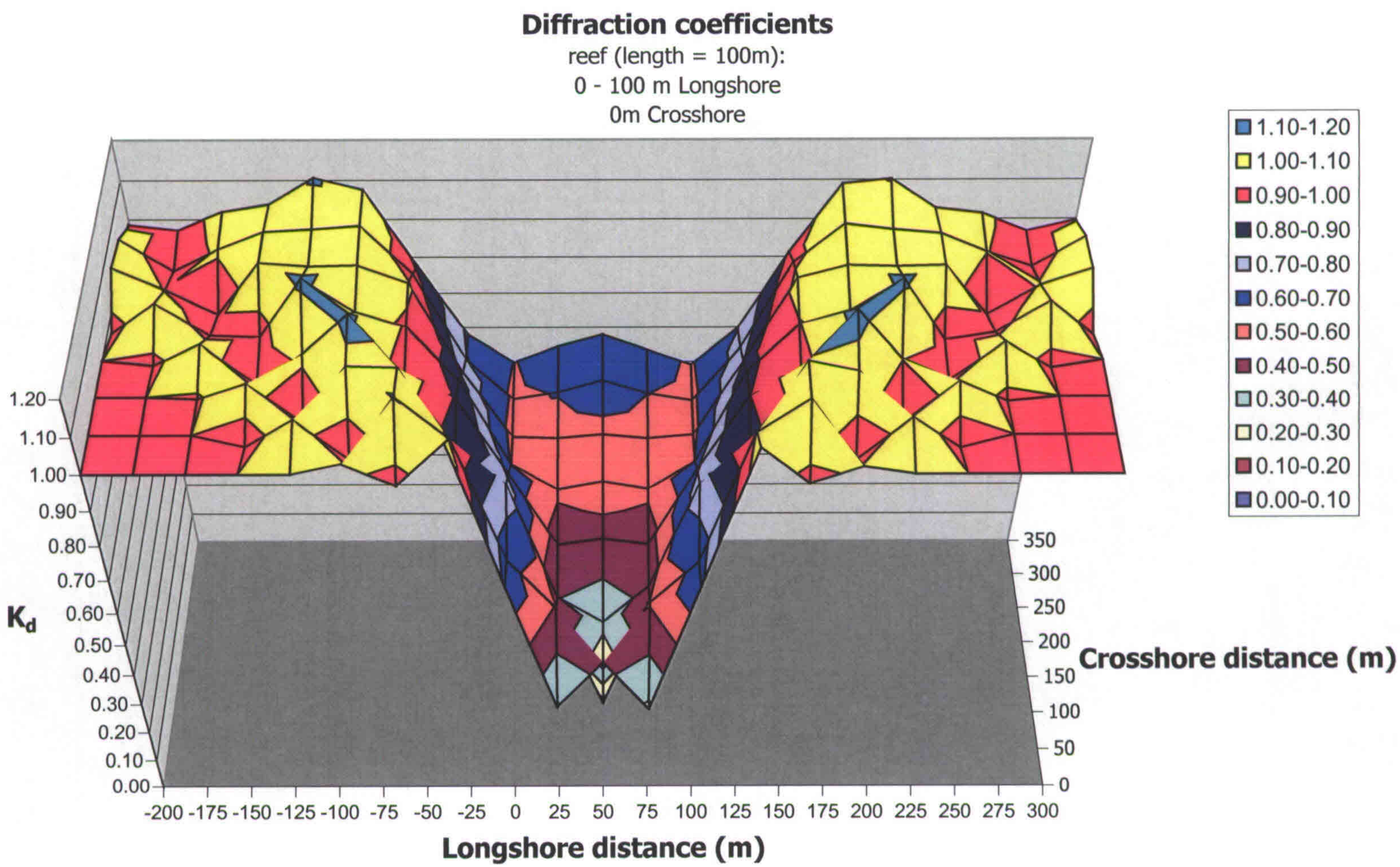

Figure 12-4 Diffraction pattern for reef of 100m length

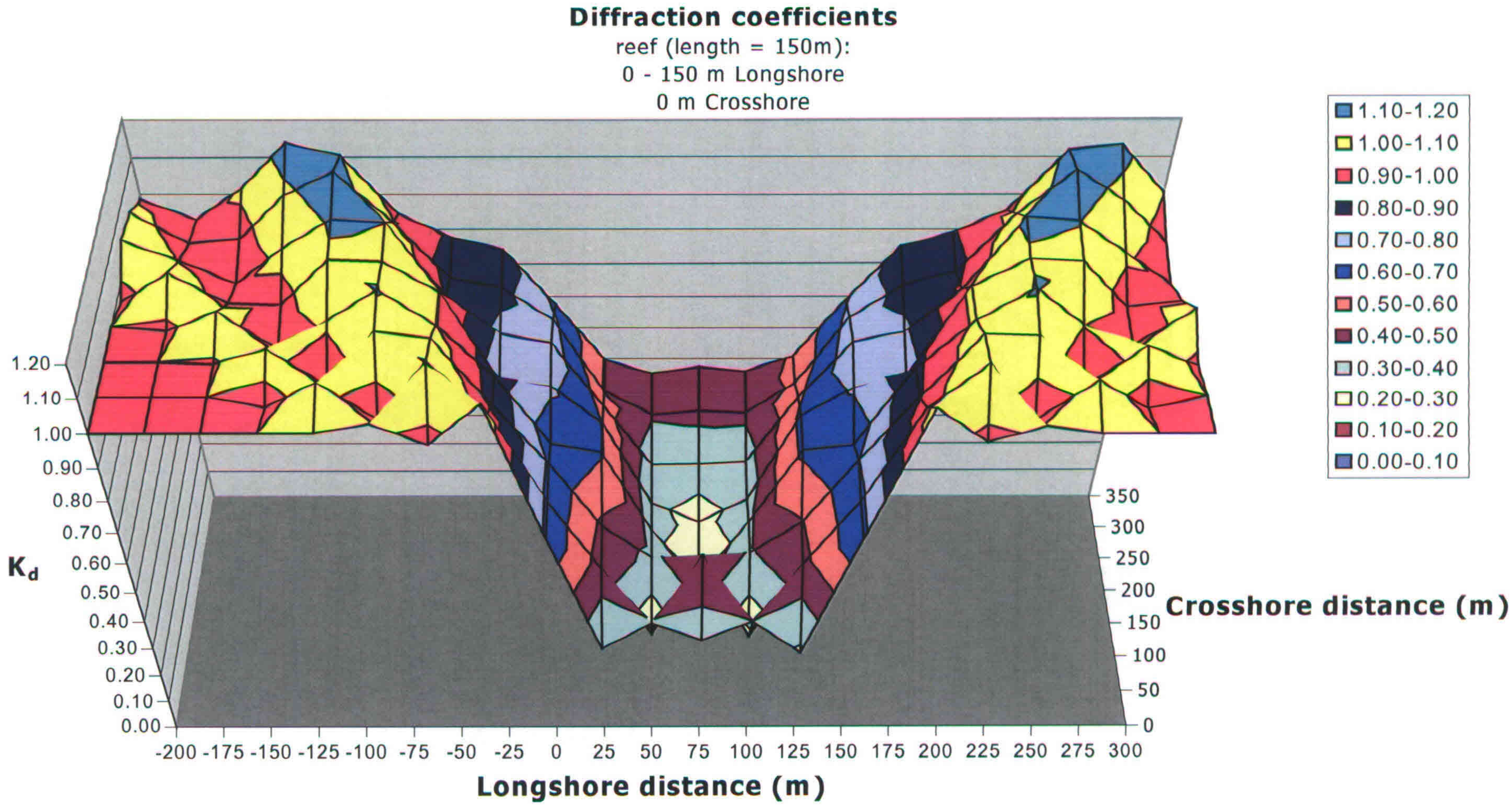

Figure 12-5 Diffraction pattern for reef of 150m length

From the graphs it can be seen that the breakwater of 50 m length is not efficient (high K_d –values and small influence area). The 100m and 150m breakwaters have a larger influence area and small K_d – values, which is preferred. Therefore these lengths will be used as dimensions of the breakwaters.

12.4.5. Beach characteristics

Nourishment

Requirements of this project are a healthy beach and a 10 m wide beach everywhere at high tide (including in front of the seawall). There's not enough sand budget in the system to create this situation, so nourishment is required.

Waves induce longshore sediment transport. Breakwaters decrease the wave height (by transmission and diffraction) behind the breakwater. This decrease of wave height behind the breakwater results in a gradient in longshore sediment transport. This causes accretion of sediment behind the breakwater and erosion adjacent to it. To mitigate the erosion in these adjacent areas extra nourishment is required. The breakwater will redistribute this nourished sand to an equilibrium profile (salient development).

During a storm the beach will be eroded. At calm wave conditions the beach can recover from these storm impacts. The recovering capacity needs to be monitored and if necessary adjusted by periodically maintenance.

Creeks

The Two and Three Mile Creek flow over the beach into the sea. When there's little rainfall (and calm weather at sea), a lot of sand accumulates on the beach and blocks both of the creek outlets. This causes flooding problems upstream of the creek outlets. To prevent these floodings, the creek should always be open. This can be realised by trailing them with geotextile bags until the shoreline or by bulldozers.

Seawall

The seawall is very close to the shoreline and prevents the beach to develop in a natural way. The requirement of 10 m of beach everywhere is most difficult to realize here. By nourishment and a breakwater more beach (sand budget) will develop in front of the seawall. Even small "dunes" can rise on top of the seawall. The natural process can take place, and a storm can take the sand from the beach and even from the "dunes" on top of the seawall.

12.4.6. Shoreline response

The shoreline response will be estimated with the method of Black, Mead and Andrews and will be calculated with software program GENESIS. First the three regimes of shoreline response are shown:

Tombolo formation

A tombolo is a fully developed beach, which extends to the breakwater. The tombolo can be seen as a sandy groin, which interrupts the longshore transport. This will induce erosion and accretion in the adjacent areas. To mitigate these effects, nourishment is required.

Salient formation

A salient develops by sedimentation of sand in the leeside of the breakwater. This salient does not reach the reef. Therefore, long shore transport is not interrupted. The adjacent area will provide the sediment required to form the salients. To mitigate the erosion effects in these areas replenishment is also required.

Limited response

The influence of the reef to the environment decreases when the offshore distance between the reef and the undisturbed shoreline increases. Also with a decreasing crest-elevation this influence is decreasing. This situation must be avoided.

In the current situation, the shoreline is at the toe of the seawall at high tide, inducing scour and erosion. To prevent this and to maintain public access to the beach, the required salient development has to be sufficient. The salient development is determined at normal wave conditions at MSL Moturiki Datum (MD).

The zones that will be protected by the breakwaters are Shaw Road (1175 m), The Loop (450 m), and 125 m south of Three-Mile Creek.

A minimum beach width of 10 m is estimated as a requirement. Therefore, with a total tidal range of 1.6 m and an average slope of 1:58, the minimum beach width at the edges of the zones is estimated to be:

$$10 + \frac{1.6}{2} \cdot 58 \sim 55 \text{ m}$$

Estimation with Black, Mead and Andrews-method

To estimate the shoreline response and the number of breakwaters, the following method is used. This method is very indicative and does not take into account all 8 variables mentioned in paragraph 12.4.1. Black & Mead, (1999) and Andrews (1997) examined aerial photographs seeking cases of shoreline adjustment to offshore reefs and islands. All relevant shoreline features in New Zealand and eastern Australia were scanned and digitalized, providing 123 different cases. From these cases the relations between the offshore distance, length of the breakwater and the salient/ tombolo development were distilled:

Tombolo development: $\frac{L_s}{X} \geq 0.6$

Salient development: $\frac{L_s}{X} \leq 2.0$

Limited response: $\frac{L_s}{X} \geq 0.1$

See figure 12-5 for the geometric measurements.

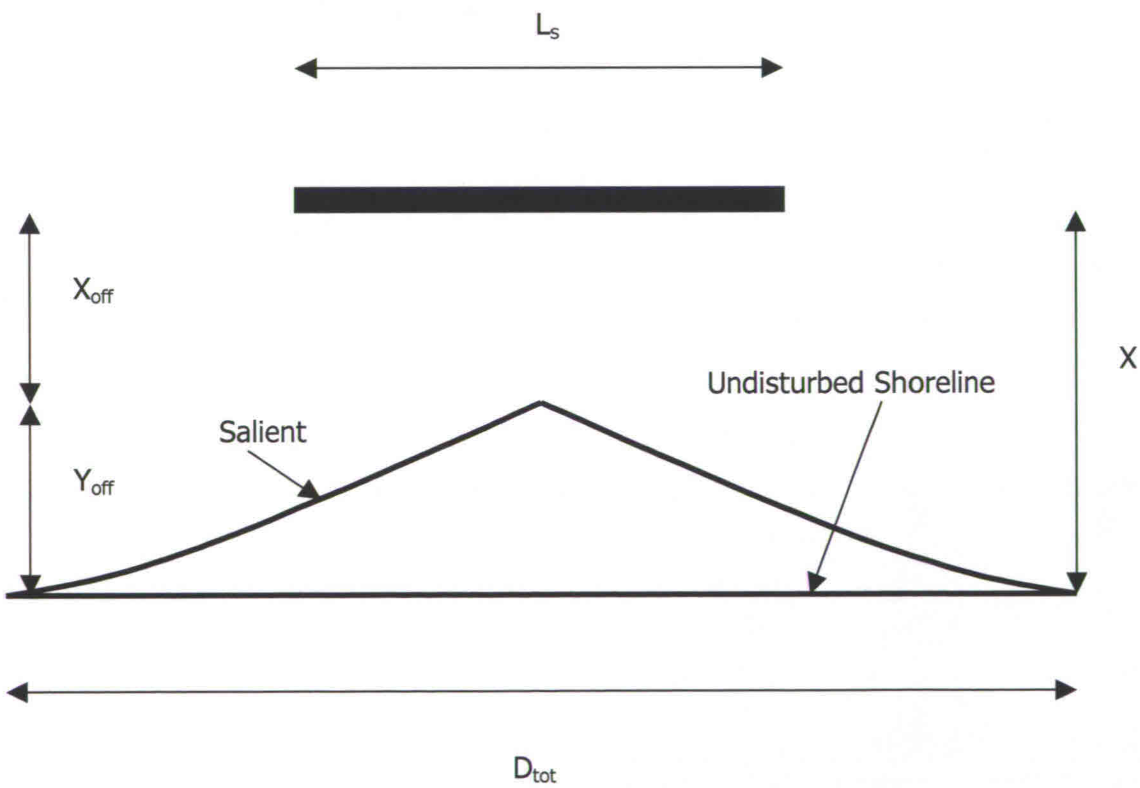

Figure 12-6 Geometric measurements for shoreline response

The salient development can be described by the following equation:

$$\frac{X_{off}}{L_s} = 0.5\left(\frac{L_s}{X}\right)^{-1.27}$$

The affected beach length (D_{tot}) is decribed with:

$$\frac{Y_{off}}{D_{tot}} = 0.125 \pm 0.020$$

These relations result in the following graph:

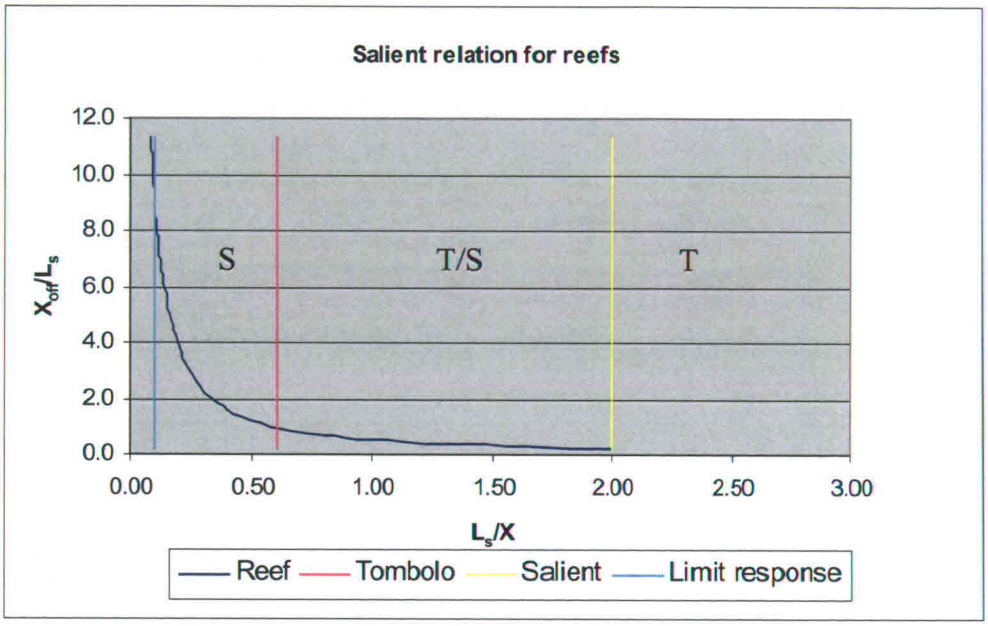

Figure 12-7 Salient relation for submerged breakwaters

From the ranges described in the previous paragraphs, the length of the breakwater and offshore distance are chosen as 100-150m and 200m respectively. From these dimensions the affected beach length of one breakwater is about 690 m. A salient with amplitude of 92m is developed. At Shaw Road two breakwaters will be required protecting about 1175 m. At the Loop one breakwater will sustain protecting about 460 m.

Note: because of a 45m-beach difference in high tide and mean sea level the offshore distance of the reefs in the chart is about 250 m.

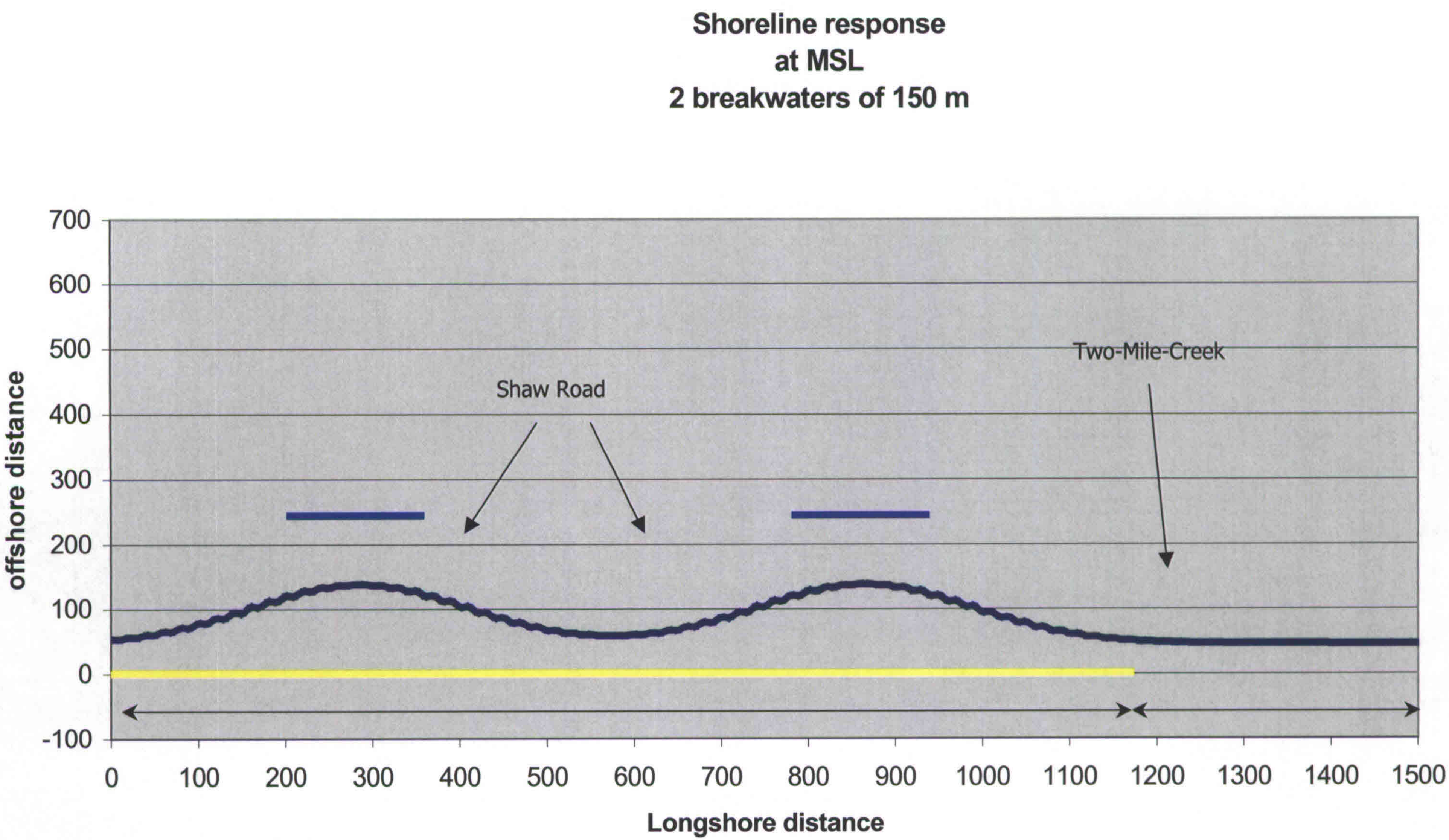

Figure 12-8 Shoreline response at Shaw Road

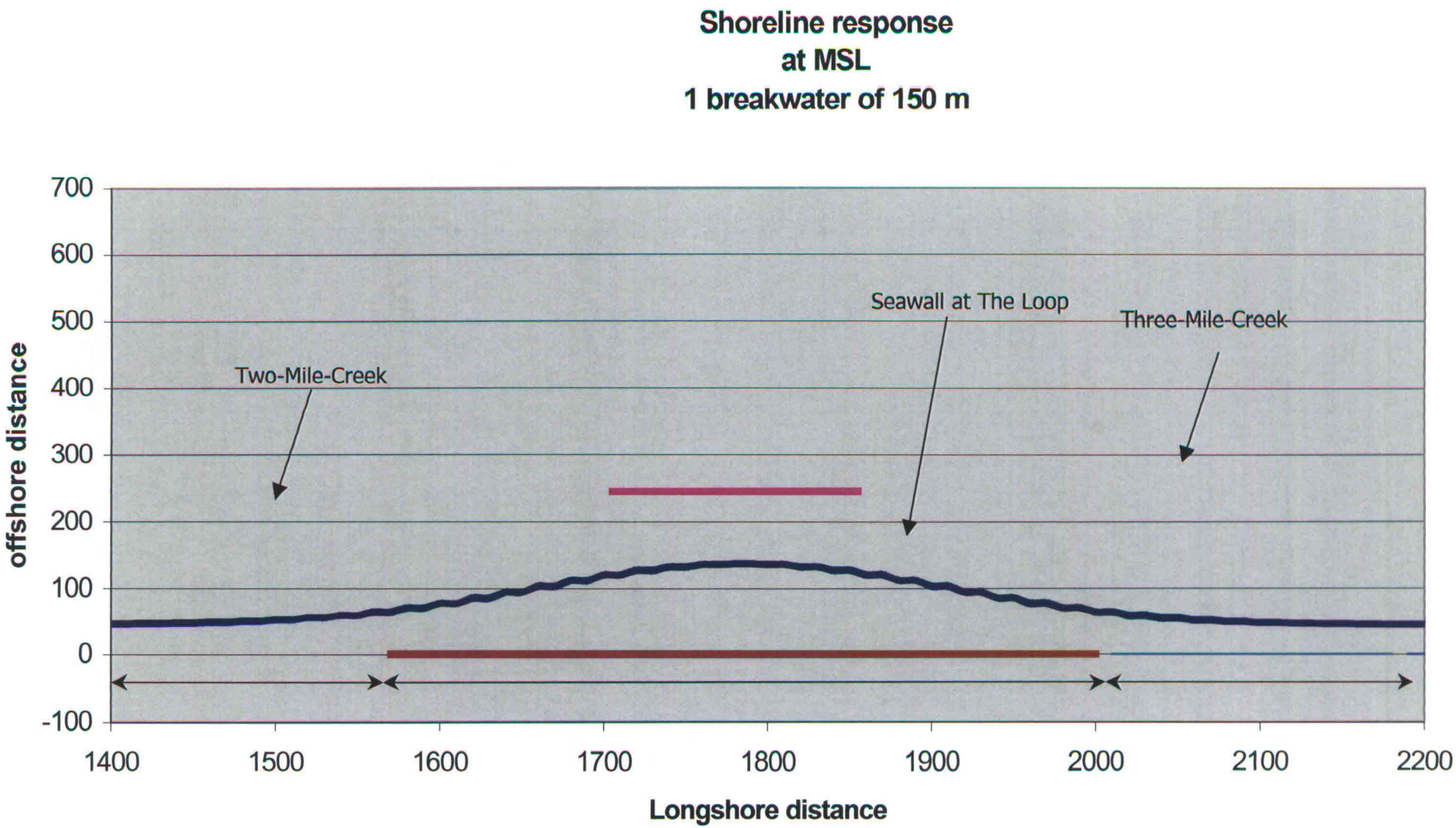

Figure 12-9 Shoreline response at The Loop

Concerning shoreline response the following (important) aspects weren't taken into account with this method:

- Wave height and period;
- Wave directions and duration;
- Transmission of the breakwater;
- Beach slope;
- Orientation angle of the structure.

Calculation with GENESIS

The results from the previous method were used as first input for the numerical shoreline response model GENESIS Version 3.0. This program can be used to determine the shoreline response. This program takes into account all eight variables mentioned in paragraph 12.4.1.

The assumptions in this program are:

1. The beach profile shape is constant and is dependent on the particular coastal parameters (depth of closure, berm height and grain size);
2. The shoreward and seaward limits of the profile are constant and modelled as one line. In this model the shoreline corresponds with MSL;
3. Sand is transported alongshore by the action of breaking waves. This is modelled using the CERC-formula with an extra term to take into account the gradient of the wave height in longshore direction:

$$Q = (H^2 c_g)_b [\mathrm{a}_1 \sin 2\theta_{\mathrm{bs}} - \mathrm{a}_2 \cos\theta_{bs} \frac{\partial \mathrm{H}}{\partial \mathrm{x}}]_\mathrm{b}$$

where,

H	=	wave height
c_g	=	group speed given by linear wave theory
b	=	subscript denoting wave breaking condition
θ_{bs}	=	angle of breaking waves to the local shoreline
a_1, a_2	=	non dimensional parameters

The contribution arising from the longshore gradient in wave height is usually much smaller than that from oblique wave incidence in an open-coast situation (just CERC-formula). However, in the vicinity of structures, where diffraction produces a substantial change in breaking wave height over a considerable length of beach, inclusion of the second term provides an improved modelling result, accounting for the diffraction current;

4. The detailed structure of the near shore circulation (in the surf zone) is ignored;
5. There is a long-term trend in shoreline evolution.

In this method the following input constants are used, to represent the current situation in Waihi Beach as accurate as possible:

- Simulation time (= 1 or 10 years);
- Numerical coefficients:
  - a_1 : 0.014;
  - a_2 : 0.074;
- Wave data
  - H=1.4m;
  - T=9s;
  - Angle of incidence is -21 or +20 degrees, changing with a period of 3 days to realize a gross longshore transport of about 1.2 mln m^3 and a minor net transport to the South, which represents the situation in Waihi Beach;
- Beach data
  - An impermeable groin is modelled on the North boundary, to represent the rock lands between Waihi Beach and Orakawa;
  - Beach profile of a healthy beach (after renourishment, see previous chapter). Closure depth is 9.1m and bermheight is 0.85 m;
  - The seawall is modelled as a construction, which cannot be eroded;
  - Groins of 55 m length model the trailing works of the creeks.

The variables in the model are:

- Breakwater length;
- Gap width;
- Number of breakwaters;
- Amount of renourishment.

With the input from the previous method (2 breakwaters of 150 m at Shaw Road and 1 breakwater of 150m at The Loop) the requirements were not met. As said before, the method was indicative and used to determine the global dimensions.
After several iterations, we found the following solution, which best matched the requirements (this solution can be seen in figure 12-10 on the next page):

- Nourishment is executed at Shaw Road (1175 m), The Loop (450 m), and south of Three-Mile Creek (125 m):
    - Nourishment required for a healthy beach profile: 52 m^3/m (previous chapter);
    - Extra nourishment in front of seawalls:
        - shoreline advance * (berm height + closure depth) =
        - 30 m * (0,85 m + 9,1 m) = 300m^3/m;
    - Extra Renourishment after 10 years: 150.000 m^3
    - This has to be done, because there is a net transport to the south and a redistribution of sand. This causes the shoreline to retreat in 10 years (yellow line), compared to the shoreline after 1 year (green line). The renourished sand should be deposited in the north. This causes an accretion of the beach of 11 m;
    - After 10 year a 10-year periodically renourishment of about 50.000 m^3 is required to mitigate the longshore loss of sediment;
    - Breakwaters are constructed at:
    - Shaw Road: 4 breakwaters of 150 m wide, with a gap width between them of 175 m;
    - The Loop, 2 breakwaters of 150 m with a gap width of 75 m;
    - Three-Mile Creek, 1 breakwater of 100 m.

Other configurations are possible as well and need to be looked at in a detailed design.

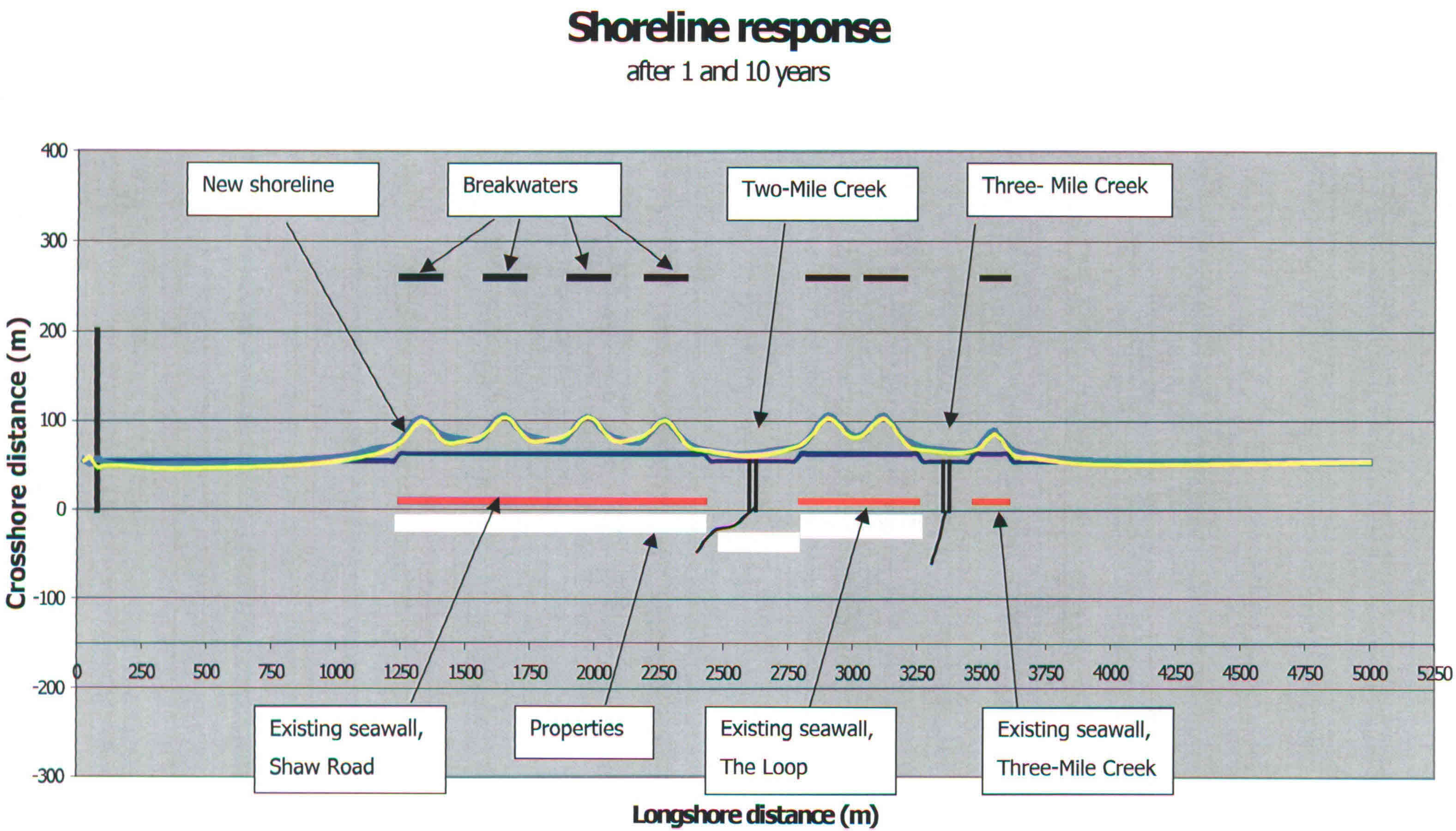

Figure 12-10 Shoreline response over total study area

12.5. Execution/ Maintenance

Geotubes

The submerged breakwaters (artificial surfing reefs) are constructed out of geotubes. These are geotextile bags filled with sand for about 70%-90%, to obtain a flexible geotube. This will prevent failing during construction and in service.

Some characteristics of geotubes are:

- The capacities of the geotube vary from 200m^3 to 500m^3;
- Geotubes are chemically inert to alkalis and acids, providing long term strong and reliable solutions;
- The yarns have been treated with special long life additives to ensure a life time expectancy in seawater environments of over 200 years;
- The Geotubes are very robust and have a high resistance against possible mechanical damage during and after installation, for instance anchor impacts.
- The geotubes can be filled and dropped by a spit-hull barge, or located on their final location and then filled by pumping sand-slurry into the bag. The used method depends on the crest-elevation of the breakwater and the maximum draught of a split-hull barge.

The tidal range at Waihi Beach is from 1,26m (neap) to 1,64m (spring). The available water depth above the construction is approximately 1,8m - 2,1m at high tide. This is less than the draught of a split-hull barge, so that this execution method cannot be used. Pumping the sand into the bags, which are located on their final position, from a vessel on deeper water is possible.

Sand

Geotubes are filled with locally available materials. Sand is available near Waihi Beach from the Tauranga harbour (about 32 km from Waihi Beach), the Katikati delta (about 10km from Waihi Beach) or from the large sand dunes on the inner shelf (about 2-3 km offshore from Waihi Beach). The most cost-effective option seems to be to dredge the sand from the offshore sand dunes in a vessel. It can easily be transported to the location of the breakwaters, where the bags can be filled.

Renourishment

The sand from the sand dunes can also be used for renourishment. As well for creating an healthy beach profile as for the renourishment, required for the extra beach width of 10 m.

Execution process

The installation phases are:

- Installation of the scour apron. This apron will prevent scour at the toe and settlement of the geotubes;
- Deployment of the geotextile bag on the seabed and filling it with water. Now the bags can be triggered to their preferred location;
- Pumping sand into the bags, displacing the water. The sand/water ratio of the fluid during pumping is 10/90%;
- Renourishment to create the required beach profile;
- Construction of the trailing works in the creeks.

Maintenance

Due to a loss of sediment in crosshore direction and a minor amount in longshore direction, maintenance of the renourishment is required. From GENESIS follows a 10-yearly renourishment of 150.000 m^3 is needed. Monitoring of the shoreline fluctuation and the beach profile is required to determine the coastal processes at Waihi Beach.
The status of the creek outlets should be part of the maintenance program. The creeks should be prevented from blocking. The trailing works will minimise the blocking, but periodically bulldozers can execute the maintenance of the creeks.
The lifetime of the geotubes is guaranteed to be 25 years. For the trailing works special geotextiles are required to protect them against vandalism.

12.6. Costs assessment

The costs of these beach stabilisation works are calculated over a 50-year period. In this calculation an inflation rate of 2% is taken into account, which is representative for New Zealand, considering the last 15 years[1]. Each year a monitoring cost of NZD 10,000 is required. This is based upon 2-monthly monitoring of the beachprofile and shoreline position. The maintenance costs for the creeks are estimated to be NZD 10,000. This is based upon a 10-times per year clearing operation of the creek outlets with bulldozers.
The current price per unit volume of renourishment is estimated to be NZD 5,50 on basis of a NZD 4,50 price/unit in 1993[2] and a 2% inflation rate.
The current price per unit volume for the geotubes is estimated to be NZD 35,00, based upon reference projects in the USA. The price for the trailing works is estimated to be twice as high (per volume) as for the breakwaters as these structures are constructed on land. At this location sand has to be transported in a more expensive way.
The minimum guaranteed lifetime of the geotubes is equal to 25 years. The time span looked at in this costs assessment is set to 50 years. Therefore the geotubes need to be constructed after 25 years inducing new construction costs.
In the costs assessment two values to determine the costs are used. First. The first column states the value of the works when they have to be paid (total over 50 year), taking into account the inflation (set to 2%). In the second column the Net Present Value (NPV) is presented. The NPV represents the value needed now to finance an expenditure in the future. The transition in time of money is calculated with the inflation rate and the interest rate (7%). In formula form:

$$V = \sum PV\left(1+2\%\right)^{t}$$

$$NPV = \sum PV\left(\frac{1+2\%}{1+7\%}\right)^{t}$$

where,

V	=	Value of expenditure at time of expenditure;
PV	=	Present Value, price you have to pay now;
NPV	=	Net Present Value;
t	=	number of years difference between now and the expenditure.

[1] Derived from the Reserve Bank of New Zealand

[2] From T. Healy, 1993

Costs of Breakwater

									Total over 50 years	NPV
Renourishment										
				Area	Length	Volume	Price/unit	Costs		
Initial				m^3/m	m	m^3	$\$/m^3$			
	To "healthy" beach profile			50	1775	88,750	$ 5.50	$ 488,125	$ 490,000	$ 490,000
	Extra renourishment			300	1775	532,500	$ 5.50	$ 2,928,750	$ 2,930,000	$ 2,930,000
						Volume	Price/unit	Costs		
Maintenance						m^3	$\$/m^3$			
	After 10 year					150,000	$ 6.70	$ 1,005,670	$ 1,010,000	$ 510,000
	After 20 year					50,000	$ 8.17	$ 408,636	$ 410,000	$ 110,000
	After 30 year					50,000	$ 9.96	$ 498,124	$ 500,000	$ 70,000
	After 40 year					50,000	$ 12.14	$ 607,211	$ 610,000	$ 40,000
	Monitoring							$ 862,710	$ 860,000	$ 190,000
								Subtotal	**$ 6,810,000**	**$ 4,340,000**
Geotubes										
		Number	Width	Height	Length	Volume	Price/unit	Costs		
Initial		-	m	m	m	m^3	$\$/m^3$			
	Design costs							$ 250,000	$ 250,000	$ 250,000
	Geotubes 150 m	5	10	1.8	150	10,603	$ 35.00	$ 371,101	$ 370,000	$ 370,000
	Geotubes 100 m	2	10	1.8	100	2,827	$ 35.00	$ 98,960	$ 100,000	$ 100,000
	Trailing tubes	4	1.8	1.8	55	560	$ 70.00	$ 39,188	$ 40,000	$ 40,000
Second construction (after 25 years)							*Subtotal*	*$ 1,250,000*	$ 1,250,000	$ 230,000
								Subtotal	**$ 2,010,000**	**$ 990,000**
Creeks										
	Maintenance of the creeks						*Subtotal*	*$ 860,000.00*	**$ 860,000**	**$ 190,000**
								Total	**$ 9,680,000**	**$ 5,520,000**

Table 12-3 Costs of breakwater

12.7. Effects

The construction of the breakwaters and the renourishment will have effects on the coastal environment:

Positive effects

- Breakwaters reduce the impact of the waves and will therefore create an area behind the breakwater of low wave energy. Sediment transport is lower in this area and a gradient in this transport will occur in longshore direction. This results in sedimentation in the leeside of the structure and the development of a salient;
- Recreational activities are stimulated. Not only in the lee side of the structure where the wave heights are lower. Also on the reef surfers meet the breaking waves;
- Maintenance costs are minimised by the "holding" capacity of the structure to stabilize the sand in the leeside;
- Structural erosion is prevented by the reduced impact of storms and waves;
- Marine development at the reefs will occur;
- A new natural beach-dune system can be developed in harmony with human activities;
- The breakwaters protect the properties in moderate storms;
- Development of the beach induces tourism and more usage of the beach;
- The beach will be raised; therefore the groundwater at the seawall at Shaw Road will be of less influence to the erosion process than before.

Adverse effects

- Breakwaters alone do not provide the sand required for the protection of the beach, they redistribute the available sand. Accretion in one area (the leeside) will be balanced by erosion in an adjacent area. Replenishment will balance this erosion to the desired shoreline position;
- Periodically replenishment is required due to a loss of sediment crosshore and longshore (minor influence). Periodically monitoring of the beachprofile and shoreline fluctuations is required to determine the scale of this replenishment;
- The creeks shouldn't be blocked; otherwise storm water flooding will become a major risk. The trailing works will stop the creek meandering over the beach and

force the creek to flow between them and therefore the bed of the creek will be lower than that of the beach. Blocking will be prevented, as the flow through the creeks is sufficient. Monitoring and maintenance is required;

- Though the storm impact is reduced wave overtopping of the existing seawall is a potential hazard at very severe storms.

13 Evaluation of beach stabilization options

13.1. General

In this chapter a Multi Criteria Assessment is executed to the following beach stabilization options:

- Nourishment
- Nourishment in combination with breakwaters

The criteria used are described in paragraph 13.2. Paragraph 13.3 provides the results of the MCA using weights to the different criteria that determine which beach stabilisation option is the most preferable for Waihi Beach. The final paragraph holds the remarks on the assumptions, which have been used for the design.

13.2. Criteria

To make a choice between the two options, criteria are required to execute the Multi Criteria Assessment. These criteria are distilled from the objectives mentioned in chapter 9.3. The criteria are divided in the same groups as the objectives:

Social

- Potential for rip current formations;
- Area of dry beach that is created;
- The rate of disturbance of the ocean/beach view.

Environmental

- The ability to create new marine ecology systems;

- The ability to improve natural processes of the beach system (sediment transport and current patterns);
- The ability to restore the natural character of the beach and dune system.

Financial

- Net present value of the option.

Functional

- The number of beachfront properties that are protected against coastal hazards;
- Potential for inland flooding problems caused by blockage of the creek outlets;
- Is the design classed as a Restricted Coastal Activity?

Technical

- The level of disturbance during the execution and maintenance periods;
- The risk of possible failure of the construction (caused by lack of knowledge);
- The usage of sustainable construction materials.

The groups do not contain the same number of criteria. To realize that each group has the same contribution to the final score, the weight of every group should be the same; for this case: 0.2. Afterwards the importance of a group can be adjusted by applying a scale factor to the contribution to the final score. This makes it possible to compare different scenarios.

13.3. Multi Criteria Assessment

13.3.1. Neutral scenario

The options will get on each criterion a score from 1 to 5. The score 1 implies a negative impact of the option; score 5 implies a positive impact. Every group of criteria has the same weight; this implies that the financial criterion has a weight of three comparing to the other criteria (the other groups have three criteria each). The scores of the two options are shown in table 13.1

	Option 1 Beach fill	Option 2 Breakwaters
Social		
rip currents	2	4
beach area	3	4
disturbance view	3	5
Environmental		
marine ecology	2	4
natural processes	3	3
natural character	2	4
Financial		
NPV	2	3
Functional		
beach front properties	3	4
inland flooding	4	2
RCA	1	1
Technical		
disturbance execution	3	4
construction failure	4	2
sustainable materials	3	3
	39	49

Table 13-1 Scores multi criteria assessment

Comment table

- Social
  - Rip currents can occur along the groynes and could cause a hazard to swimmers. The breakwaters are positioned offshore (200m);
  - Option 1 does not provide a wider beach southwards of the Three Mile Creek. Option 2 creates larger salients;
  - The groynes in option 1 disturb the view on the ocean; the breakwaters in option 2 are submerged.
- Environmental
  - Option 2 provides development of new marine ecology on top of the geotextile tubes;
  - Both options contribute at the same level to enhancement of the natural processes;
  - The groynes in option 1 are an artificial element, which do not contribute to the natural character of the beach.

- Financial
  - The costs of option 1 are approximately 20% higher than the costs of option 2.
- Functional
  - Option 1 does not protect the beachfront properties southwards of the Three Mile Creek;
  - The groynes will prevent blockage of the creeks, which reduce the risk of inland flooding;
  - Both options require consent of the Minister of Conservation because of the dimensions of the structures.
- Technical
  - The maintenance period of option 1 is two times shorter than the period of option 2;
  - The technique of designing reefs is relatively new and still in development;
  - Both designs use the same construction materials.

Option 2 including the breakwater system has a significantly higher score than option 1. Out of a neutral perspective option 2 is the best beach stabilization option.

13.3.2. Scenarios from different perspectives

It is possible to analyze this evaluation from different views. For this multi criteria assessment the perspective coincide with the five groups of criteria. This will result in different scores for the two options. In the first four of criteria option 2 including the breakwater system do score higher than option 1 including the beach fill. Option 1 do only perform slightly better on the technically criteria. This implies that a detailed analysis of the five scenarios is not necessary for this evaluation: option 2 is the preferable beach stabilization option.

13.4. Remarks

Option 2 has been made with data available and assumptions. For a detailed design the following aspects need to be looked at:

- The wave data used are distilled from a survey of only 3-years during an El Nino period.
  - The known wave data are derived from this period. Measurements during a La Nina period should be done to collect the correct wave data;
  - In this period moderate waves and storms occur. During a La Nina period more severe waves and storms can be expected;
  - From this wave data the scale of sediment transport is calculated. This might be not the correct value.
- The net longshore direction seems to be to SE, while some people argue that.
- This method of beach stabilization construction works is a relative new technique. In nature multiple examples can be seen like coral reefs and islands near shore. Though a lot of research has been carried out to submerged breakwaters, the application in practice is not widely recognized;
- The foundation of the breakwaters has not been looked at in this preliminary design. Further studies have to look at the stability to prevent scour at the breakwater, settlement or failing of the soil. Overturning and sliding seems not to be a real problem since the geotube has a major mass compared to the (wave) forces acting on it;
- The equilibrium beach profile used in the calculations is based only on the grain size of the sand. This is a simplistic representation of the real profile.
- The influence of the creeks has not been taken into account in the calculations. Trailing of the creeks is a good option, as long maintenance will be done, to prevent blocking by the natural processes.

14 Cost-benefit analysis

14.1. General

In this chapter a cost-benefit analysis is made between the most preferable beach stabilization option, breakwaters with nourishment, and the proposed option of the District Council, the seawall. The objective of a cost-benefit analysis is to determine whether society, as a whole, will be better off if the policy or action is implemented. In this case the analysis is divided in four steps:

1. Specification and description of the two options (paragraph 14.2).
2. Description of the effects of both options (paragraph 14.3).
3. Estimation of social costs and benefits (paragraph 14.4).
4. Final cost-benefit analysis (paragraph 14.5).

14.2. Description of the options

Seawall

The design of the seawall is in a preliminary stage; it's up to the District Council to make a decision about the final design. The seawall option is primarily to protect private development landward of the beach system. The crest level of the wall is similar to the maximum natural dune crest. The refurbished seawall is located on the place of the current seawall, but will not replace the whole current seawall, but a stretch of 1.5km. Public access to the foreshore has been provided at all reserves with a walkway, only during storms the walkway is closed. The seawall is positioned in the area of the creeks to protect the most threatened properties against erosion. The seawall will be composed out of the reuse of existing rock fill and material from the quarry at Waihi Beach. The costs of the seawall will be approximately 3 million dollar.

Breakwater

In chapter 12 an elaborately description of the submerged reefs can be found.

14.3. Effects

This paragraph provides a description of the effects of the seawall and the breakwater that will lead to benefits and costs to society.

Seawall

- Effects on the beach

The seawall is composed out of large boulders placed at a controlled slope, so that wave energy is to some extent dissipated rather than reflected back onto the beach as erosive energy. The seawall is effective in his main task of isolating the dune reservoir from the beach and protecting the land immediately behind the beach. Erosion may be exacerbated at the ends of the wall due to the groyning effect of the seawall, although this effect is expected to be minor.

- Effects on the users of the beach

The wall will disturb the beach landscape, because it restricts the recreation activities at this stretch of beach. At high tide it not possible to walk on the beach, because the only walkway is the path of the seawall.

The wall will offer some hazard to people, particularly young children, who choose to clamber over them instead of using the provided walkways. The wall will contain many spaces between the rocks, which will attract and trap litter.

Breakwater

- Effects on the beach

The submerged reef will reduce the impact of the waves and will create a salient behind the reef, so structural erosion is avoided. The beach will be raised; therefore the groundwater at the seawall at Shaw Road will be of less influence to the erosion process. A new natural beach-dune system can be developed in harmony with human activities. After severe storms erosion at parts of the beach adjacent to the salient will occur.

- Effects on the users of the beach

Tourism is stimulated by the widening of the beach and developing marine life at the reefs. The annual increase of value of the properties along the beach and behind will be bigger, because the properties will be protected against coastal erosion and the beach in front of the properties is widened. Also the other properties in Waihi Beach will increase in value.

14.4. Techniques for valuing environmental services[1]

14.4.1. General

It is very difficult to quantify the value of goods and services which are not subject to the market price mechanism. Alternative techniques have been developed to assist in the evaluation of these benefits. Some of these techniques rely on market prices of related goods and services while others rely on survey-based approaches to determine values. This results in three approaches to estimate the value of the environmental services:

- Revealed willingness to pay (market price)
  The value of some ecosystem goods or services can be measured using market prices. The prices people are willing to pay in markets for related goods can be used to estimate the values of the environmental services.
- Imputed willingness to pay (circumstantial evidence)
  The value of some environmental services can be measured by estimating what people are willing to pay, or the cost of actions they are willing to take, to avoid the adverse effects that would occur if these services were lost.
- Expressed willingness to pay (surveys)
  Surveys can be used to ask people directly what they are willing to pay for hypothetical scenarios. Alternatively, people can be asked to make tradeoffs among different alternatives, from which their willingness to pay can be estimated.

[1] Environmental services are the beneficial outcomes that result from ecosystem functions for the natural environment or people. Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of an ecosystem.

The two solutions for this particular case will create different environmental services. The breakwater-option will maintain and enhance the environmental amenities much better than the seawall-option. To estimate how much people are willing to pay for these offered environmental services two useful criteria are:

- Residential housing prices → hedonic pricing method
- Recreation → travel cost method


Figure 14-1 Amenity Values

Both methods belong to the approach of 'revealed willingness to pay'. A short description of each method will assist in choosing the best method for Waihi Beach.

14.4.2. Hedonic pricing method

The hedonic pricing method is used to estimate economic values for environmental amenities that directly affect market prices. The basic premise of the hedonic pricing method is that the price of the marketed good (in this case: residential properties) is related to its characteristics. Therefore, one can value the individual characteristics of a property by looking at how the price people are willing to pay for it changes when the characteristics change.

To apply this method for Waihi Beach the following steps have to been taken:

1. collect data on residential property sales in the area;
2. estimate a function that relates property values to the distance to the beach based on the same beach characteristics; this function will represent the seawall-option;

3. estimate a function that relates property values to the distance to the beach based on the improved beach characteristics initiated by the breakwaters; this hedonic value function can be used to determine the extra benefits of the created beach;
4. compare the benefits calculated in step 3 to the extra costs to realize the breakwater-option;

Note that the scope of environmental benefits that can be measured is limited to things that are related to the housing prices. This result can be used to place a lower bound on the value of the beach.

14.4.3. Travel cost method

The travel cost method is used to estimate economic use values associated with ecosystems or sites that are used for recreation. The basic premise of the travel cost method is that the time and travel cost expenses that people accept to visit a site represent the "price" of access to the site. Thus, peoples' willingness to pay to visit the site can be estimated based on the number of trips that they make at different travel costs. This is analogous to estimating peoples' willingness to pay for a marketed good based on the quantity demanded at different prices.

The method consists of the following steps:

- define a set of zones surrounding the beach of Waihi Beach;
- collect information on the number of visitors from each zone, and the number of visits made in the last year;
- calculate the visitation rates per 1,000 population in each zone;
- calculate the average round-trip travel time to the site for each zone;
- estimate the equation that relates visits per capita to travel costs; one can estimate the demand function for an average visitor.

The result of the final step is an indication for the current value of the beach. This is used to estimate the benefits of the seawall-option. To determine the extra benefits for the breakwater-option the following steps have to been taken:

- estimate the number of visitors when the characteristics of the beach has changed through the construction of the breakwaters;

- estimate the number of visitors for the following cases: travel costs+$5, travel costs+$10.....;
- construct the demand curve, using the results of the previous steps;
- estimate the total economic benefit of the site to visitors by calculating the consumer surplus (area under the demand curve);
- compare the created benefits to the extra costs to realize the breakwater option.

14.4.4. Evaluation best valuation method

Both valuation methods have their pros and cons. The most important effects are listed below:

Hedonic pricing method:

- required data readily available;
- the scope of benefits that can be measured is limited to things that are related to housing prices.

Travel cost method:

- it takes a lot of time to do on-site surveys;
- only a small stretch of the beach will change, so it is difficult to predict the changes in tourism rates.

For Waihi Beach is chosen to use the hedonic pricing method. The outcome of this analysis will show the required value increase of the beachfront properties to justify building the breakwaters. This is not completely true because the expected increase of tourism is neglected in this method. This will definitely have a positive effect on the local economy. So this method is a lower bound estimation of the value of the beach.

14.5. Estimation of the benefits

The following data are important to apply the hedonic pricing method:

- Quantity of properties;
- Value of the current properties;
- Increase of value of the properties.

Quantity of properties

The main reason of living in Waihi Beach is the beach and the ocean. In this analysis the first three streets adjacent to the beach in the study area are taken into account. A division has been made between the properties next to the beach (Shaw Road and The Loop) and the two rows of properties right behind them.

- First Row: 79 properties;
- Second Row: 169 properties.

Value of the current properties

First Row: $NZ 1,000,000 (mean value)

Second row: $NZ 500,000 (mean value)

Total value of properties: 79 + 84.5 = $NZ 163,5 million

Increase of value of the properties

The last years the New Zealand economy is doing reasonably well and the interest rate has been lowered to 7 %. Next to the fact that New Zealanders love the beach, the previous reasons determine the increase of value of properties in Waihi Beach (demand>supply). Properties along the beach (first row) cost approximately $NZ 125,000 13 years ago, $NZ 410,000 2 years ago and $1.000.000 nowadays.

For this cost-benefit analysis the following parameters are considered:

- The width of the beach;
- Ocean view;
- Protection of coastal hazards;
- Distance from property to beach.

The influence of other parameters, like growth of population, inflation, which also cause increase of value, is set aside (ceteris paribus). A period of 5 years is viewed in this analysis. After 5 years the results of the benefits are compared with the cost at t=0, because the other influence parameters are excluded.

Figure 14-2 Lovely ocean view in Waihi Beach

Seawall: Although the seawall will protect the properties against coastal hazards, the beach width in front of the properties is minimal. An assumption has been made for the increase of value for the first row 1.0% and for the second row 0.5 %.

Total increase of value: 169.6 -163.5 = $NZ 6.1 million.

Breakwater: The widening of the beach will increase the demand for properties near the beach, which will cause an increase of value of the properties after one year (development time of salient). To be a competitive alternative to the seawall the increase of value should be at least $NZ 2.5 million. This amount is the difference between the cost of the seawall and the cost of the breakwater (5.5 – 3 = $NZ 2.5 million). The minimum annual growth rate should be: The first year the same as the seawall (beach not in equilibrium state), but the next four years an extra increase of value of 1.6% compared to the seawall scenario (annual rate 0.4%).

The difference in benefit between the seawall and the breakwater is $NZ 2.6 million. This could compensate the difference of cost of $NZ 2.5 million between the two options. The number of beach properties and their value represent a capital, which could be applied to finance a sustainable solution. Even a minor increase in growth percentage of the value of the properties will result in a reasonable increase of benefits. Due to this capital power more money could be spent on a solution which enhances the social and environmental amenities. Notwithstanding this chapter does not deal with the way of financing a sustainable solution, but it emphasize the increase of benefits initiated by the solution. The way of financing is out of scope of our study, but a detailed study of way of financing is recommended.

15 Recommendations and conclusions

15.1. Recommendations

From the remarks, made in chapter 13, and findings in the following recommendations can be made:

- A monitoring program should be started to obtain better information about wave and storm data.
- The theory of sediment transport should be verified by measuring the sediment transport (crossshore and longshore); This could result in an correction of the maintenance scheme of the nourishment;
- More experience could be obtained in designing submerged breakwaters:
  - A detailed design of the breakwaters should be made, to know their exact size, number and foundation;
  - The exact development of the salient should be determined;
- The equilibrium beach profile used in the calculations is based only on the grain size of the sand. Monitoring of the seabed and 3D modelling is required to get the correct beach profile and make a detailed design;
- The exact influence of the creeks is unknown, trailing works are designed to prevent them from blocking. More information is needed from:
  - The rate of sediment transported into the creeks by the coastal processes;
  - A detailed model of the discharge of the creeks and in what extent the discharge will prevent the creeks from blocking;
  - The effectiveness of the geotube trailing works in controlling the outlets.
- A cost-benefit study has been executed to the seawall and breakwater options. The financing model has not been treated in this report but should be based on a more specific cost-benefit analysis presented in this report (taking into account more criteria than property value only).

15.2. Conclusions

For addressing the erosion problems in Waihi Beach, solutions have been sought, which could be more sustainable than the current proposed solution of the seawall:

- Nourishment (optional with groynes);
- Nourishment in combination with breakwaters;

Preliminary designs for these alternatives have been presented. The main characteristics and effects are repeated here.

An important function of as well the seawall as only nourishment and nourishment in combination with breakwaters is protection of the beachfront properties. Adverse effect in the design of the seawall is erosion of the beach.

The beach stabilization options have, compared to the seawall, the advantage of improving the amenity values. The beach will be widened and public access on a strip of 10m of beach during high tide is guaranteed. This will increase recreational activities and usage of the beach by Waihi Beach residents and tourists from a greater area.

The natural character of the beach is also restored; the natural process of accretion and erosion (even during heavy storms) can take place. Besides that the breakwater option reduces the wave-impact during a storm.

Adverse effect of the beach stabilization options is that periodically renourishment is needed to maintain the preferred shoreline. With the construction of breakwaters, which decrease the sediment transport, the number and volume of renourishment is reduced. Nevertheless this renourishment and the construction of breakwaters, trailing works or groynes will cause some nuisance on the beach. Besides that the groynes will remain visible after construction.

The current seawall will remain part of the beach stabilization options. It will withstand flooding and will be visible after severe storms. Maintenance is needed to prevent dangerous situations.

The blocking of the creeks should be avoided. This is partly done by realising groynes or by trailing the creeks on the beach. Nevertheless, periodical removal of the sediment that blocks the creeks could be needed.

The costs of the nourishment option ($ NZ 7,4 mln Net Present Value) are higher than those of the breakwater option ($ NZ 5,5 mln NPV). Because of the comparable effects and the lower costs, the breakwater option is the most preferable beach stabilization option for Waihi Beach.

The Net Present Value for the seawall is $ NZ 3.0 million. Despite of the higher costs of the breakwater option, the breakwater option could be a better solution. Important are the *benefits* of the two solutions. The benefits can be quantified through several methods. By quantifying the benefits the feasibility of such an alternative is more realistic, compared to only consider the costs. In the costs-benefit analysis the value of the properties have been taken into account to valuate the benefits. More criteria should be used, but data are not available (e.g. tourism, growth of Waihi Beach).
To realise a net comparable value between the seawall and the breakwater option the value of the properties need to increase with a difference of 1.6% in a time span of 5 years. This percentage seems to be feasible.
From this it follows that the nourishment in combination with the breakwaters is preferable above the current proposal of refurbishing the seawall.

Nourishment in combination with breakwaters is a sustainable solution, regarding to the coastal erosion and coastal flooding problems. From previous studies, diversion of the creeks is the best way to deal with the storm water flooding problem.

These two designs together, integrated in a long-term strategy, will contribute to a sustainable growth of Waihi Beach.

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Appendix A-I. History of Waihi Beach

History and process of the coastal erosion problem at Waihi Beach

<u>1948</u>

Coastal development started earliest in 1948 with the subdivision of land in Dillon Street-Shaw Road area. Further extension down to Two Mile Creek occurred in 1951. In the late 50's Island View and The Loop was beginning to develop.

<u>1955</u>

Sea flooded through creek entrances inundating properties at rear of dunes and main street. On the open coast there was to 10m erosion of the dune leaving an erosion scarp up to 4,6m high. Erosion threatened 23 properties resulting in relocation of properties further back on sections.

<u>1962</u>

Very high North East seas eroded up to 8m along the South East length of Shaw Road over a distance of 160m, contributing to a net loss of 12 to 25m of residential property in the Edinburgh Street-Shaw Road area.

<u>1966</u>

People first started looking at coastal erosion/ town planning and the flooding problem in Waihi Beach. The sea was threatening the houses very near to the beach. The owners of those houses started (on their own initiative) putting large rocks (a rock revetment) between the houses and the beach.

<u>1968</u>

In this year sea erosion is getting worse: in May high seas eroded up to 9m of dune with up to 12m erosion being observed to occur in one night. In June sea erosion is threatening 44 beachfront dwellings and 26 acres of public domain. In the last months a further 9m erosion occurred and high seas flooded Brighton Road, entering some buildings.

Cabinet approve a 1:1 Government subsidy to construct a vertical permeable timber seawall with short spur groynes from Two Mile Creek to Coronation Park. This was designed and promoted by a Ohinemuri County engineer.

1969

Construction of seawall along Shaw Road consisting of steel columns at 2.4m intervals with 5 rows of planks at about 8cm of spacing. This was set 1.2m above beach level and backfilled with rock chips boulders and clay. The groynes consisted of 2m wide by 1m deep by 12m long plastic Gabion baskets filled with loose rock, spaced every 40m at right angels to the timber seawall.

Soil Conservation and Rivers Control Council through Hauraki Catchment Board approve 1:1 Government subsidy to protect residential properties along The Loop and stabilize Three Mile Creek.

1970

Completion of seawall along The Loop and training walls for Three Mile Creek.

1971

Sustained wave attack between July and August 1971 resulted in the groynes settling 1.4m lower than normal beach levels and about 610m of the timber seawall being underlined causing it to lean seawards (especially at The Loop) and 120 m being demolished by the sea.

1975

Soil Conservation and Rivers Control Council approve a 1:1 subsidy to extend the timber seawall to Hinemoa Street and stabilise the Town Creek outlet on to the beach.

1976

Ohinemuri County Council states that the life of the vertical timber seawall is not expected to extend beyond a further 7 years (1983) after which time beachfront property owners will be expected to meet the full capital costs of replacement.

1978

Wave storm damage to seawall along Shaw Road resulting in the replacement of timber planks and back filling with large boulders

1980

Large quantities of rock placed behind seawall at The Loop following severe storm damage in January.

1981

Large quantities of rock placed behind seawall at Shaw Road following storm damage

1985

Wave storms breached the seawall at The Loop and cut off public access to the beach from Ayr Street by demolishing the access way.

1993

In order of Western BOP District council Professor Terry Healy presented his report "Coastal erosion, setback determination and recommendations for the management of the Waihi-Bowentown and Pukehina beaches and dunes". In this study he produces a coastal hazard zone defining the minimum setback and the minimum floor level of any building adjacent to the coast and the controls required for development of the coastal dunes.

1996

Various beachfront property owners undertake unauthorised rock emplacement works on the beach in front of their sites.

Western BOP District Council embarked on a programme to identify a long-term solution to the on-going coastal erosion. This was a response to community demand to repair the existing protection works.

The Council considered options for managing future development within its Coastal Protection Area (Healy, 1993) as an interim measure until the outcomes from this programme had been identified.

Dr Jeremy Gibb was commissioned by Western BOP to assess the effects of the Waihi Beach seawalls on both the coastal environment and its amenity values and on the beachfront property and assets protected by the structures: "Assessment of the Effects of The Waihi Beach Seawalls".

Western BOP Districts Council asked Tonkin&Taylor to consider the reports on coastal erosion from Professor Terry Healy and from Jeremy Gibb and inspect the seawall or revetment with Dr Gibb. Using this information the objective of the report under the heading "Waihi Beach Seawall" was to provide the preliminary design and costs for a replacement seawall or revetment, as one possible option currently being considered by the Council, to address the long-term management of Waihi Beach.

1997

Western BOP District Council commissioned a further report from Dr Gibb, which was finished in May under the heading "Strategic options for sustainable management of the coastal interface along Waihi Beach, Western Bay of Plenty District".
Fifteen options were reviewed and assessed in terms of success probability.

Western BOP District Council and Waihi Beach Community Board asked Worley Consultants Limited to carry out the Waihi Beach Stormwater Development Plan.

1999

Tonkin&Taylor was commissioned to investigate the range of potential options of managing coastal erosion and catchment flooding with respect to technical feasibility, ability to address the issues of urban growth, coastal erosion, catchment flooding, environmental impact and sustainable management. After the preliminary evaluation of the potential options nine options were left.

2000

From November 1999 to February 2000 the community was consulted to make a decision for one of the solutions, by filling out a response form. The option of Upper catchment diversion, dune care and maintenance of the existing seawall was further investigated, preliminary design was made and costs were estimated.

<u>2002</u>

The high costs of this alternative (14mln dollar) were presented to the community. Looking at the present time scale and the hazards, the council then made the decision to build just the seawall.

<u>2003</u>

In 2003 the tendering for the construction of the seawall (or the rock revetment protection works) started, and measures were taken to change the proposed plan, so the seawall could be built.

Appendix C-I. Wave climate

Calm wave conditions

From the short-term wave statistics the probability of exceeding wave height H by wave height $\underline{H}$ is equal to:

$$Q_{\underline{H}}(H) = \Pr\left[\underline{H} \geq H\right] = e^{-\frac{H^2}{8m_0}}$$

From the wave data it is known that the wave height at calm wave conditions, which is exceeded 30% of the time, is equal to 1.0m at a 34m waterdepth:

$$Q_{\underline{H}}(1.0) = \Pr\left[\underline{H} \geq 1.0\right] = e^{-\frac{1.0^2}{8m_0}} = 0.3$$

$$\rightarrow m_0 = 0.103$$

The corresponding PDF is:

$$p_{\underline{H}}(H) = \frac{H}{4m_0} e^{-\frac{H^2}{8m_0}}$$

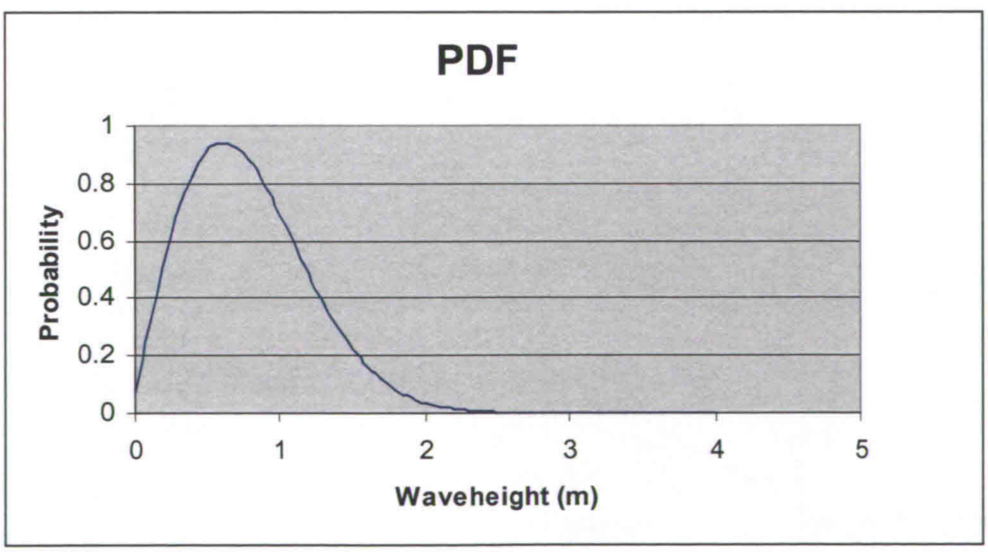

Figure C-I-1 PDF of wave height at Waihi Beach

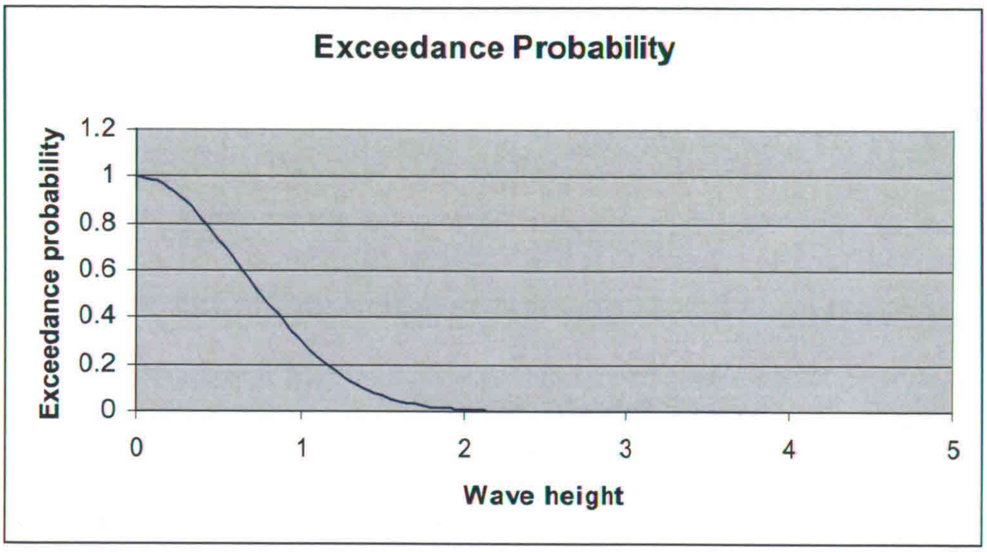

Figure C-I.1. Exceedance probably of wave heights at Waihi Beach

From these data the significant wave height (exceedance probability of 13,5 %) at 34m water depth can be determined. The significant wave height is defined as the wave with a height which is exceeded 13,5 % of the time and is equal to:

$$H_s = 1.29 \text{ m}$$

At deep water the waveheight is equal to 1.4m. The peak period, defined as the wave period where the energy density has a maximum, is equal to 10-11s. The significant wave period can be estimated as:

$$T_s \approx 0.9T_p \approx 9 \text{ s}$$

Storm wave conditions

For storm wave conditions it is known that the significant wave height is 2,7m at deep water with a period of 7s.

To determine the waveclimate at a certain waterdepth linear wave theory has been used. The beach profile is assumed to be a function of the grain size:

$$h(X) = AX^{\frac{2}{3}}$$

$$A = 0.21D^{0.48}$$

where,

D = mean grain size (mm)

X = offshore distance (m)

h = waterdepth (m)

Breaking of waves will occur if:

$$\frac{H_s}{h_d} \geq 0.78$$

Where,

H_s = Wave height (m)

h_d = water depth (m)

From measurements it is known that the angle of incidence of the waves is between -10 and 30 degrees. See the next pages for the waveheight distribution and refraction patterns of the wave rays.

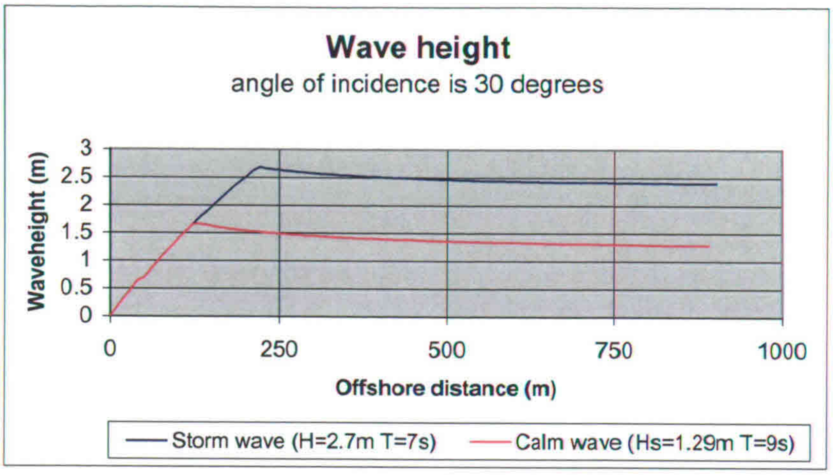

Figure C-I.2. Wave height offshore, angle of incidence is 30 degrees

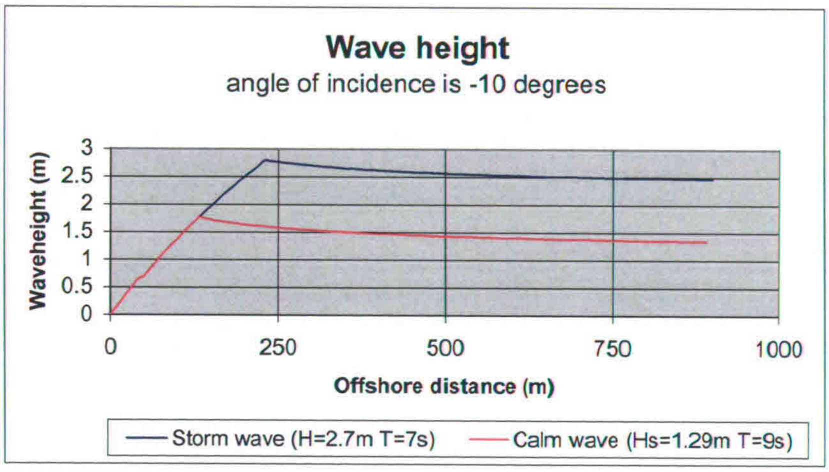

Figure C-I.2. Wave height offshore, angle of incidence is -10 degrees

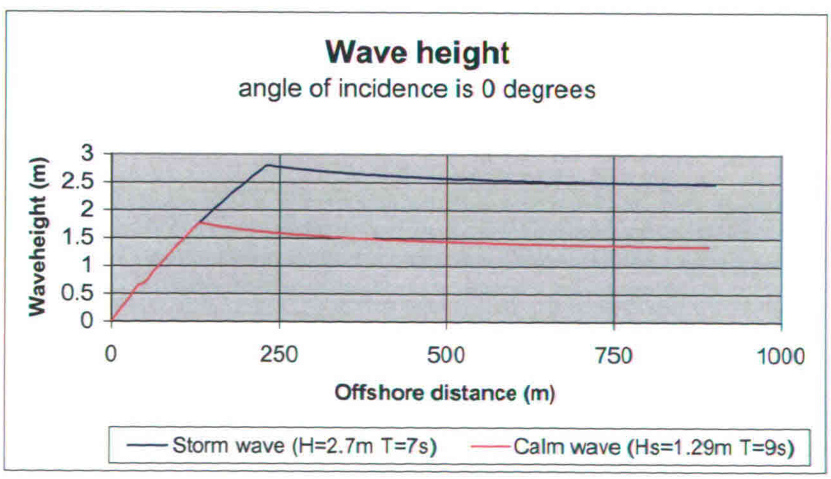

Figure C-I.3. Wave height offshore, angle of incidence is 0 degrees

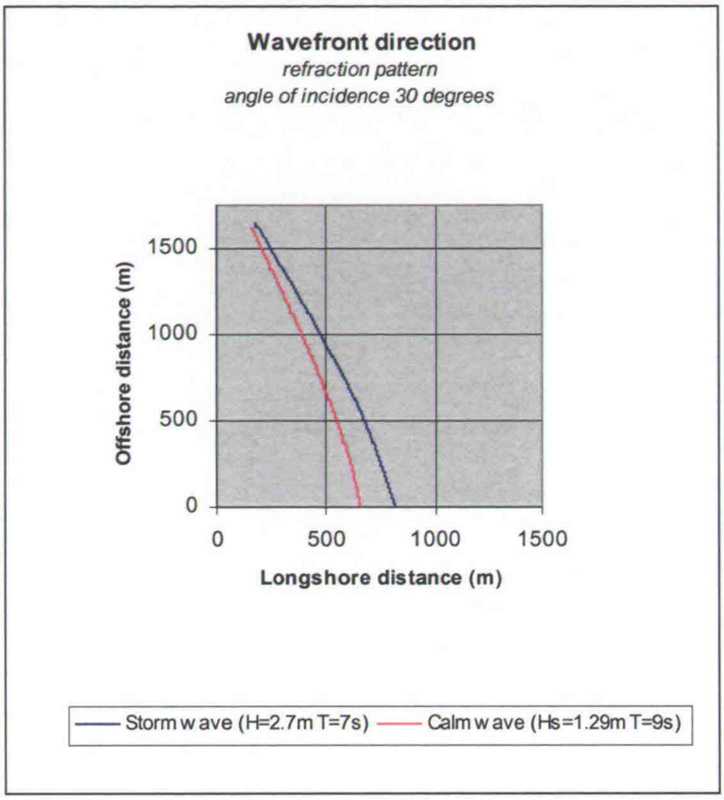

Figure C-I.4. Refraction pattern, angle of incidence is 30 degrees

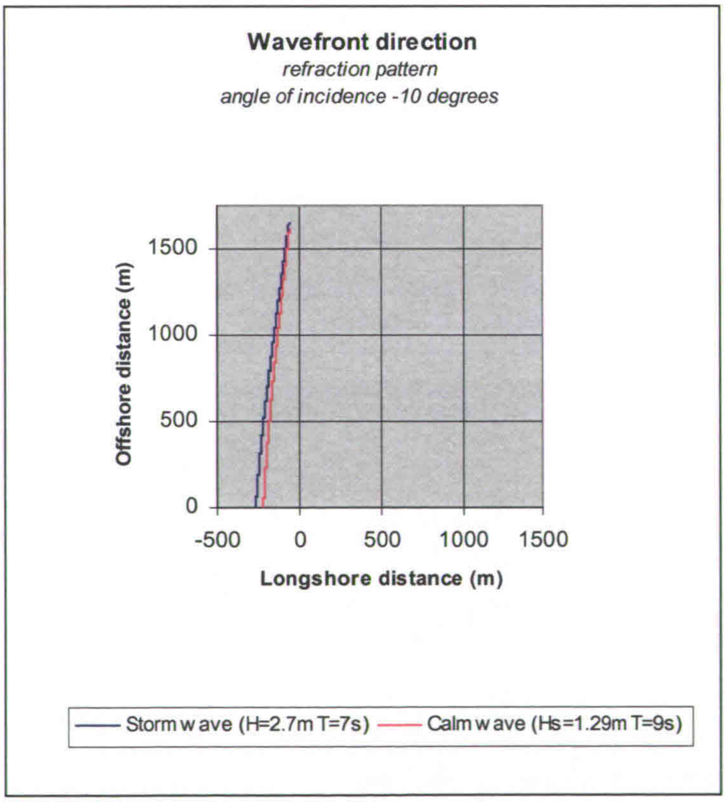

Figure C-I.5. Refraction pattern, angle of incidence is 30 degrees

Appendix C-II. Current beach profile

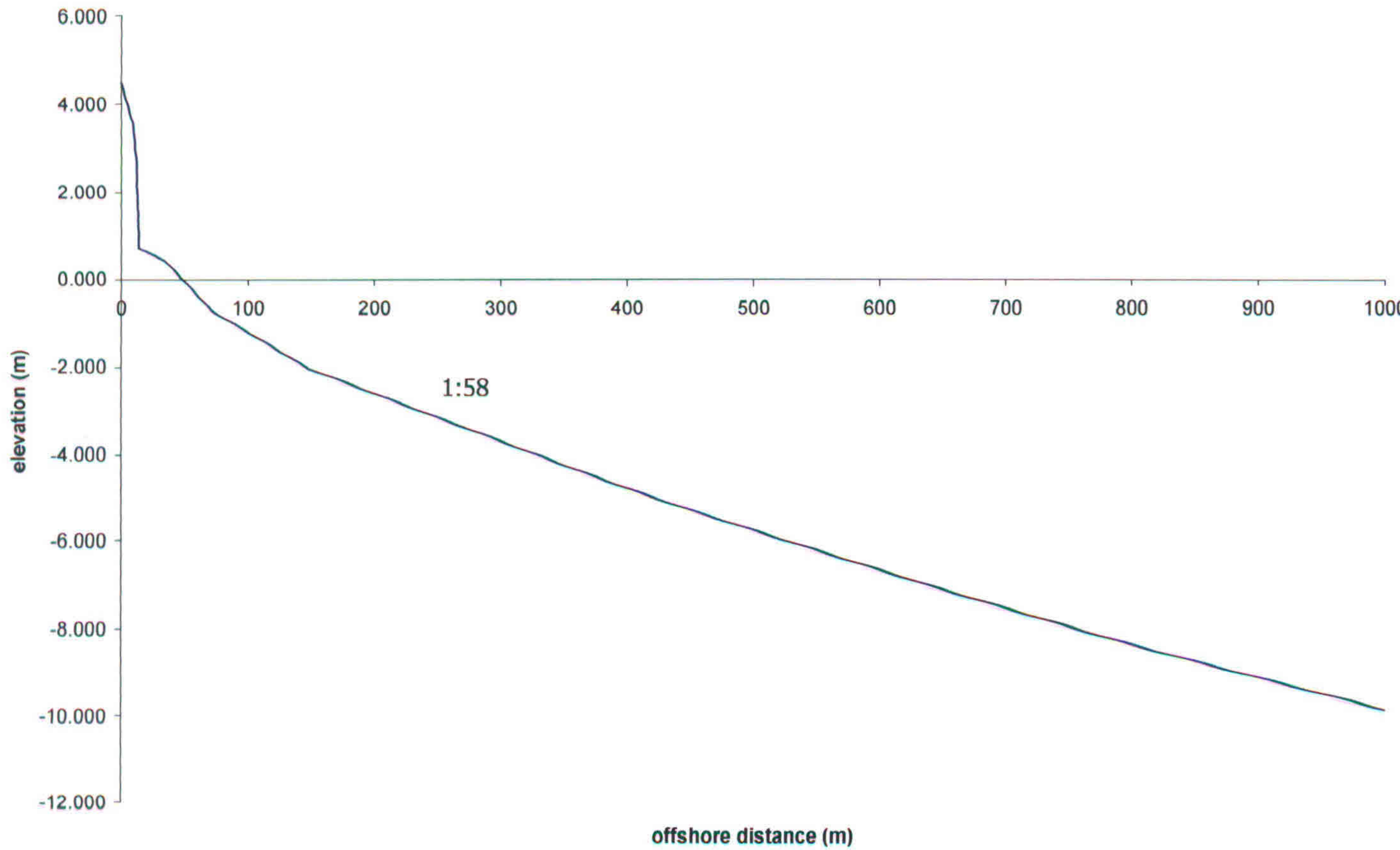

Figure C-II.1. Current beach profile

Appendix C-III. Design beach profiles

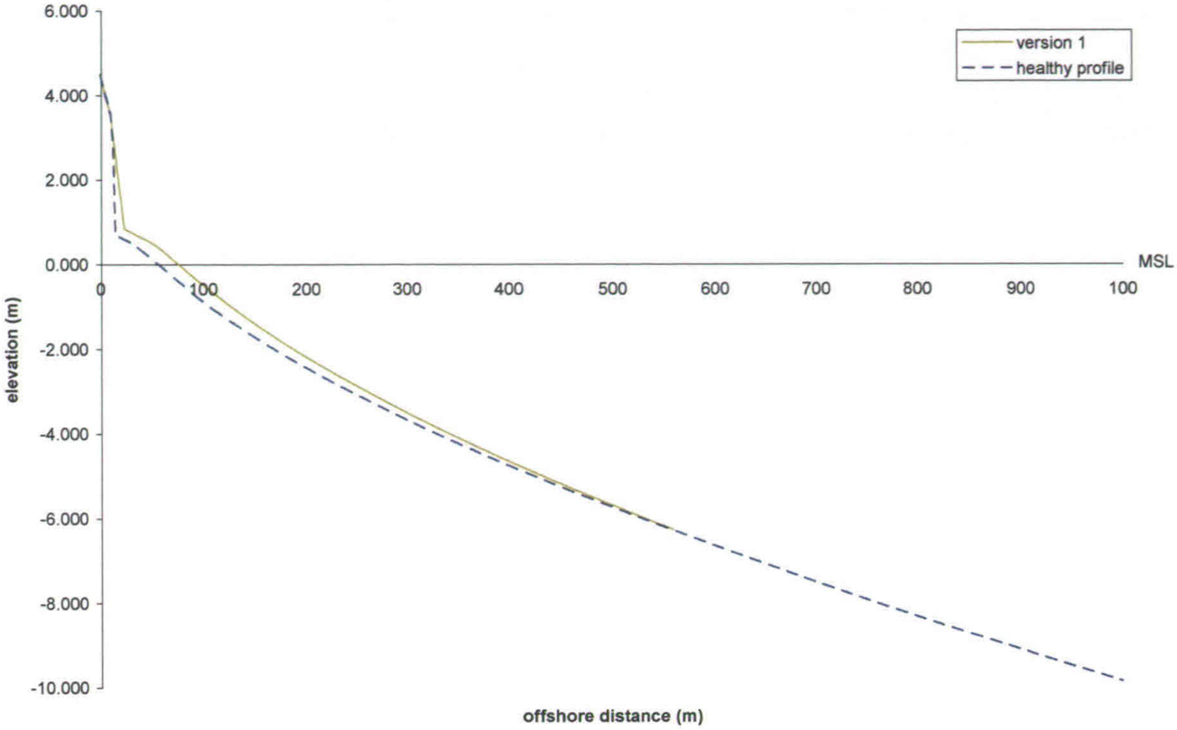

Figure C-III.1. Design beach profile version 1

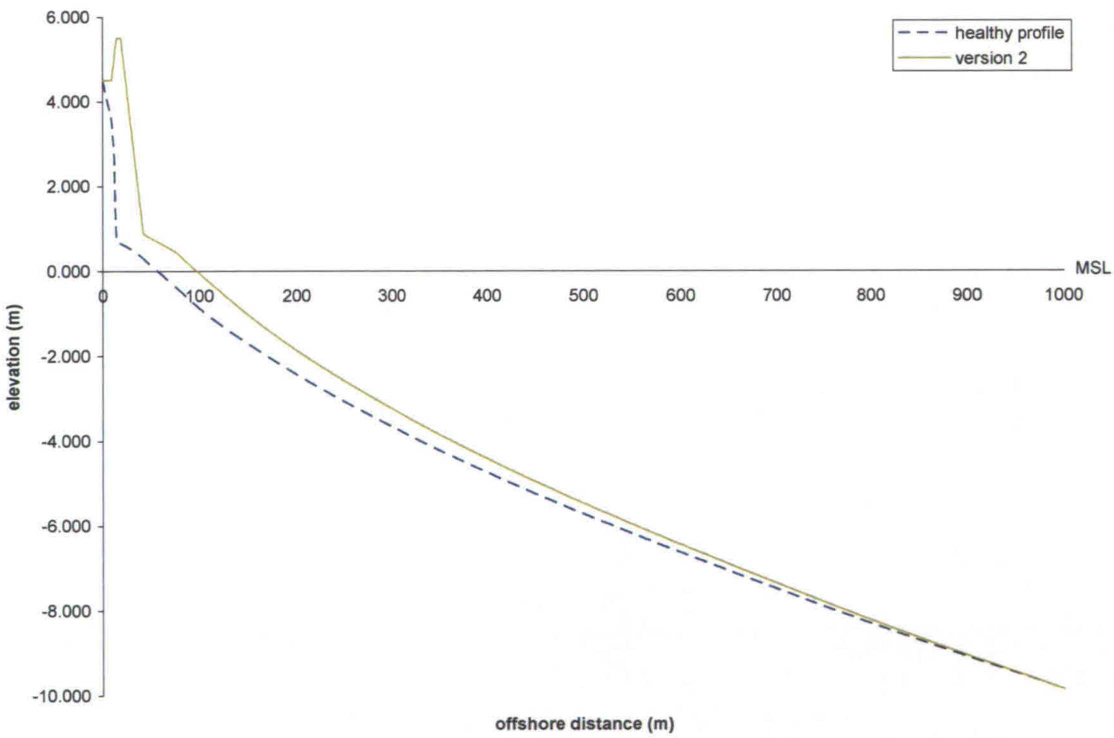

Figure C-III.2. Design beach profile version 2

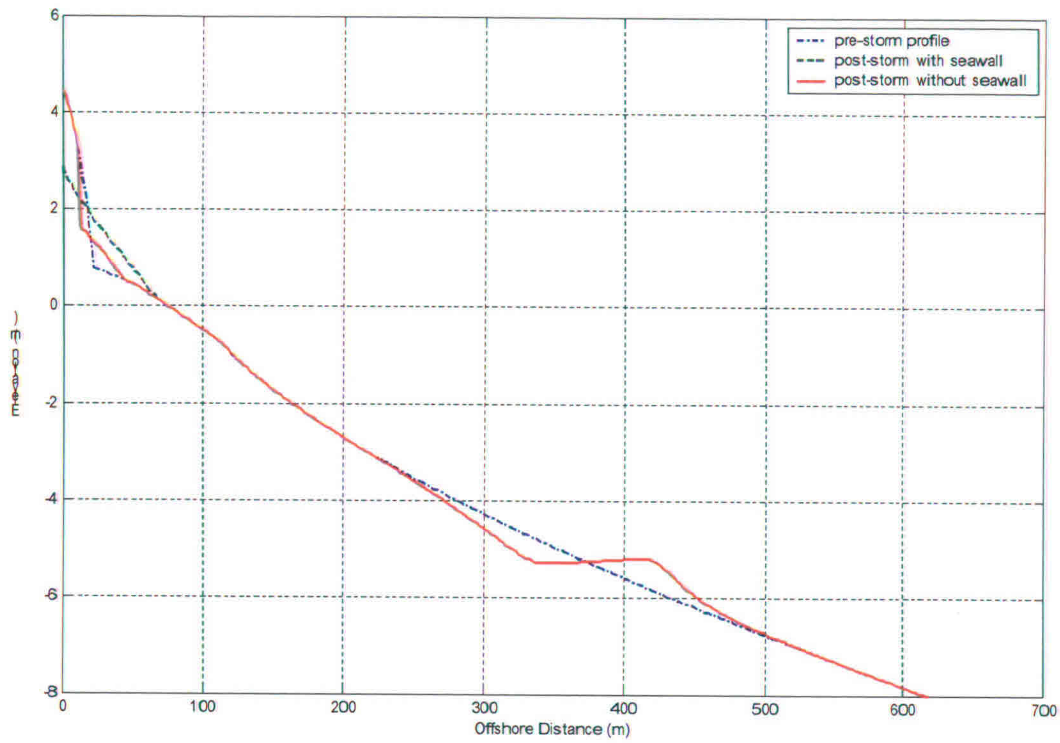

Figure C-III.3. Post-storm profile version 1

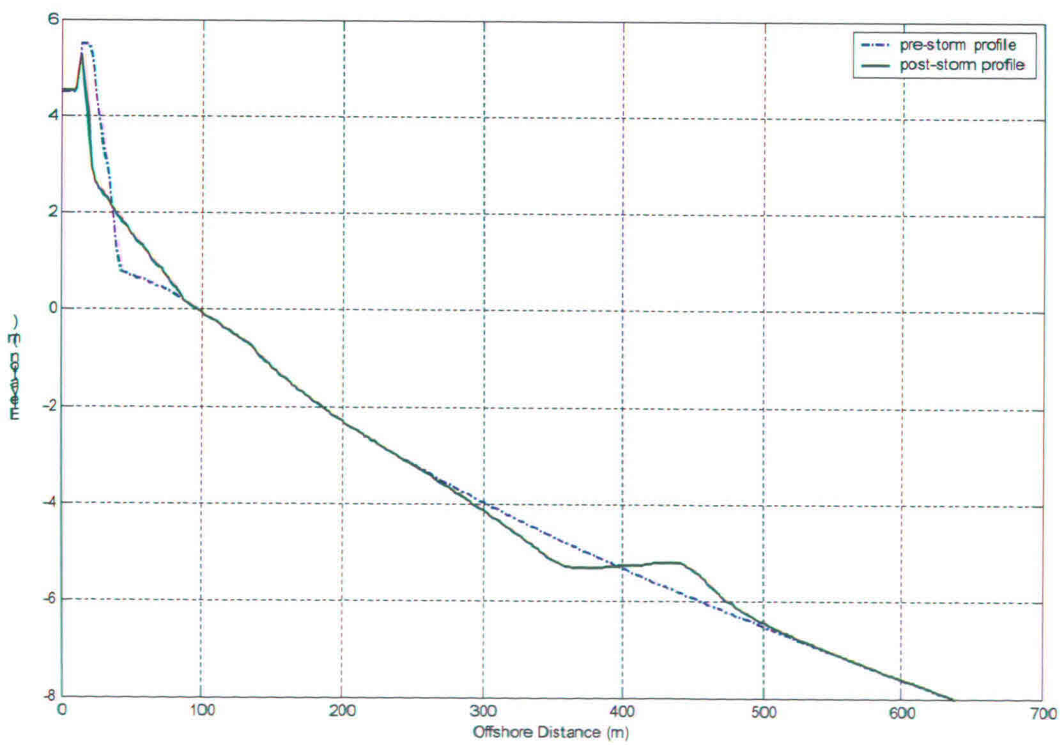

Figure C-III.4. Post-storm profile version 2

Appendix C-IV. Sensitivity analysis MCA for breakwaters

Options			Social	Environmental	Financial	Functional	Technical	Total
Rubble Mound	Rock	(Non-)Overtopped	2	5	2	5	2	18
		Submerged	4	4	3	4	3	22
	Concrete blocks	(Non-)Overtopped	2	4	1	5	2	16
		Submerged	4	3	2	4	3	20
Composite	Caison	(Non-)Overtopped	2	3	1	5	1	14
		Submerged	4	2	2	4	2	18
	High Mound	(Non-)Overtopped	2	4	1	5	2	16
		Submerged	4	3	1	4	3	19
Geotubes		Submerged	4	5	4	4	5	26
Floating			4	3	5	2	2	20
T-groynes			4	4	2	4	3	21

1

Scale factors: Social 2.0, Environmental 1.0, Financial 1.0, Functional 1.0, Technical 1.0

Table C-IV.1. Global MCA- Social

Options			Social	Environmental	Financial	Functional	Technical	Total
Rubble Mound	Rock	(Non-)Overtopped	2	5	2	5	2	21
		Submerged	4	4	3	4	3	22
	Concrete blocks	(Non-)Overtopped	2	4	1	5	2	18
		Submerged	4	3	2	4	3	19
Composite	Caison	(Non-)Overtopped	2	3	1	5	1	15
		Submerged	4	2	2	4	2	16
	High Mound	(Non-)Overtopped	2	4	1	5	2	18
		Submerged	4	3	1	4	3	18
Geotubes		Submerged	4	5	4	4	5	27
Floating			4	3	5	2	2	19
T-groynes			4	4	2	4	3	21

1

Scale factors: Social 1.0, Environmental 2.0, Financial 1.0, Functional 1.0, Technical 1.0

Table C-IV.2. Global MCA - Environmental

Options		Criteria	Social	Environmental	Financial	Functional	Technical	Total	
Rubble Mound	Rock	(Non-)Overtopped	2	5	2	5	2	18	
		Submerged	4	4	3	4	3	21	
	Concrete blocks	(Non-)Overtopped	2	4	1	5	2	15	
		Submerged	4	3	2	4	3	18	
Composite	Caison	(Non-)Overtopped	2	3	1	5	1	13	
		Submerged	4	2	2	4	2	16	
	High Mound	(Non-)Overtopped	2	4	1	5	2	15	
		Submerged	4	3	1	4	3	16	
Geotubes		Submerged	4	5	4	4	5	26	1
Floating			4	3	5	2	2	21	
T-groynes			4	4	2	4	3	19	

Scale factors:

Social	1.0		Functional	1.0
Environmental	1.0		Technical	1.0
Financial	2.0			

Table C-IV.3. Global MCA - Financial

Options		Criteria	Social	Environmental	Financial	Functional	Technical	Total	
Rubble Mound	Rock	(Non-)Overtopped	2	5	2	5	2	21	
		Submerged	4	4	3	4	3	22	
	Concrete blocks	(Non-)Overtopped	2	4	1	5	2	19	
		Submerged	4	3	2	4	3	20	
Composite	Caison	(Non-)Overtopped	2	3	1	5	1	17	
		Submerged	4	2	2	4	2	18	
	High Mound	(Non-)Overtopped	2	4	1	5	2	19	
		Submerged	4	3	1	4	3	19	
Geotubes		Submerged	4	5	4	4	5	26	1
Floating			4	3	5	2	2	18	
T-groynes			4	4	2	4	3	21	

Scale factors:

Social	1.0		Functional	2.0
Environmental	1.0		Technical	1.0
Financial	1.0			

Table C-IV.4. Global MCA - Functional

Options			Social	Environmental	Financial	Functional	Technical	Total	
Rubble Mound	Rock	(Non-)Overtopped	2	5	2	5	2	18	
		Submerged	4	4	3	4	3	21	
	Concrete blocks	(Non-)Overtopped	2	4	1	5	2	16	
		Submerged	4	3	2	4	3	19	
Composite	Caison	(Non-)Overtopped	2	3	1	5	1	13	
		Submerged	4	2	2	4	2	16	
	High Mound	(Non-)Overtopped	2	4	1	5	2	16	
		Submerged	4	3	1	4	3	18	
Geotubes		Submerged	4	5	4	4	5	27	1
Floating			4	3	5	2	2	18	
T-groynes			4	4	2	4	3	20	

Criteria

Scale factors:				
Social	1.0		Functional	1.0
Environmental	1.0		Technical	2.0
Financial	1.0			

Table C-IV.5. Global MCA – Technical