Along-Shore Sediment Transport at the Coast of Vík í Mýrdal

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2011

ALONG-SHORE SEDIMENT TRANSPORT AT THE COAST OF VÍK Í MÝRDAL

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30 ECTS thesis submitted in partial fulfillment of a
Magister Scientiarum degree in Sediment Transport

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Abstract

After the volcano eruption in Katla 1918 the coastline by the town of Vík í Mýrdal accreted about 500 to 600 m, until 1971. From then the coastline has erode about 350-450 m and is today about the same as it was prior the eruption. A part of the town is close to the today's coastline and a solution for the erosion is needed to prevent further erosion.

In this thesis the sediment transport is estimated with the Litpack model (by DHI-group). The directional equilibrium of Vík's coast is estimated and the water depth where the sediment transport occur is estimated.
The theories of spiral form coastline and equilibrium profile is introduced and possible coastline estimated.

To my family

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Special thanks go to my parents Anna and Gísli whose parenting skills and guidance let to the writing of the thesis.

I would also like to extend my gratitude to Icelandic Maritime Administration for the use of their facilities and documents related to the project.

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$\mathbf{w}$ Wave Frequency, page viii

$\mathbf{A}$ Wave amplitude , page viii

$\mathbf{d_w}$ Water depth , page viii

$\mathbf{Mm^3}$ Million cubic meeter , page viii

$\tau_\mathbf{b}$ Seabed shear stress generated from the Wave , page viii

$\tau_\mathbf{c}$ Seabed shear stress generated from the Current , page viii

$\mathbf{k_N}$ Roughness Factor , page viii

λ Wave Length , page viii

$\mathbf{d_{50}}$ Mean Grain Size Diameter , page viii

$\mathbf{q_t}$ Total Sediment Transport , page viii

$\mathbf{d_c}$ Depth of Closure , page viii

$\delta_\mathbf{w}$ Boundary Layer Thickness , page viii

$\mathbf{\Theta}$ Shield Number , page viii

$\mathbf{\Theta_c}$ Critical Shield Number , page viii

$\mathbf{\Phi}$ Dimensionless Sediment Transport , page viii

$\mathbf{Q}$ Bedload , page viii

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CHAPTER 1

Introduction

1.1 Background

The project site is Vík í Mýrdal, a small village on the South-Coast of Iceland. This study is a master degree project at the Civil Engineer Department of the University of Iceland and is done in cooperation with Icelandic Maritime Administration.
Iceland is located at the low pressure zone where the wind is strong resulting in high waves. The high waves makes the South-Coast one of the most exposed coasts in the world. With both the wave action, dominating from South-West direction, and the sediment transport, to east, the south coast of Iceland is constantly changing.
Most of the populated area on the South part are not located at the coast but Vík is the only village located next to the coastline.
After the volcano eruption in the volcano Katla in 1918 a huge volume of sand formed Kötlutangi which was a 2.8 km long sand area (see figure 2.3). The coastline emerged bout 600 m in front of the village Vík but since then it has retreated for about 350-450 m and the net sediment transport has been to East.

1.2 Objective

The goal of this study is to calibrate the net sediment transport model with the Vík's coast, evaluate the directional equilibrium of the beach and present a solution for the erosion problem. The theories of the equilibrium profile and the coastal spiral shape is applied to evaluate probable location of the future coastline.

The main chapters are six in total:

The second chapter covers the coastline history of the coast by Vík, it's characteristic and the waves which affect the coastline.

The third chapter covers the scientific part of alongshore sediment transport calculations, the theory of a coastal equilibrium profile, the theory of coastal spiral form and the measurements of the beach material is explained.

The fourth chapter is where the wave and sediment transport model Mike is introduced. The wave model Spectral waves and the sediment transport model Litpack is explained and the simulations for the coast explained.

The fifth chapter covers the result from the sediment transport by Litpack, the equilibrium profile and the spiral shape of Vík's coast.

The sixth chapter is a conclution about the study.

1.3 Literature Review

In the report: Sediment Transport and Morphology at Bakkafjara (DHI-Group 2006) the sediment transport model (litpack) which was used in the calculation of possible sediment transport in the harbor. The report was first published in 2006 where the sediment transport morphology were explained. The model calibrations were done at Vík's coast because its characteristics are similar to Landeyjarhöfn Beach. The environmental factors that could affect the sediment transport were analysed and possible accumulations in to the harbor area estimated per year.

The theory of coastal spiral form is explained in the book: Coastal Stabilization (Silvester & John R. C. Hsu 1997). Two main theories are explained, logarithmic shape and parabolic shape, and their history reviewed. Coastal protection is also introduced for sandy coasts.

Coastal profiles and beach definition are explained in K.Mangor 2004. Everything regarding the coastal zone is covered as well as the along shore sediment transport is introduced with the theory of equilibrium profile.

1. INTRODUCTION

CHAPTER 2

The Environmental condition at Vík

The South Coast of Iceland is a 400 km long sandy beach which is nourished from Glacier Rivers around. The heavy wave action makes the Iceland's South coast one of the most exposed coast in the world, South-West waves dominate both in frequency and energy.
The shape of the South Coast gives us information about in which direction the net sediment transport is. Figure 2.1 (I.M.A 2011) shows the West side of the headlands, Dyrhóley and Reynisfjall, the beach reaches to the tip of them, while there is a gap on their east side, especially at Reynisfjall where the gap is about 1400 m. These gaps are caused by erosion because of the net transportation to the East. The erosion, on an infinite long beach with a steady wave climate, would be steady along the coast. A headland, Reynisfjall and Dyrhólaey, causes accumulation on one side (West side with Reynisfjall) while it cause erosion on the other (East side with Reynisfjall).

2.1 Coastline history

Before the Katla eruption in 1918 the coastline was about the same as it is today. The beach in front of Vík was narrow and the erosion from 1904-1919

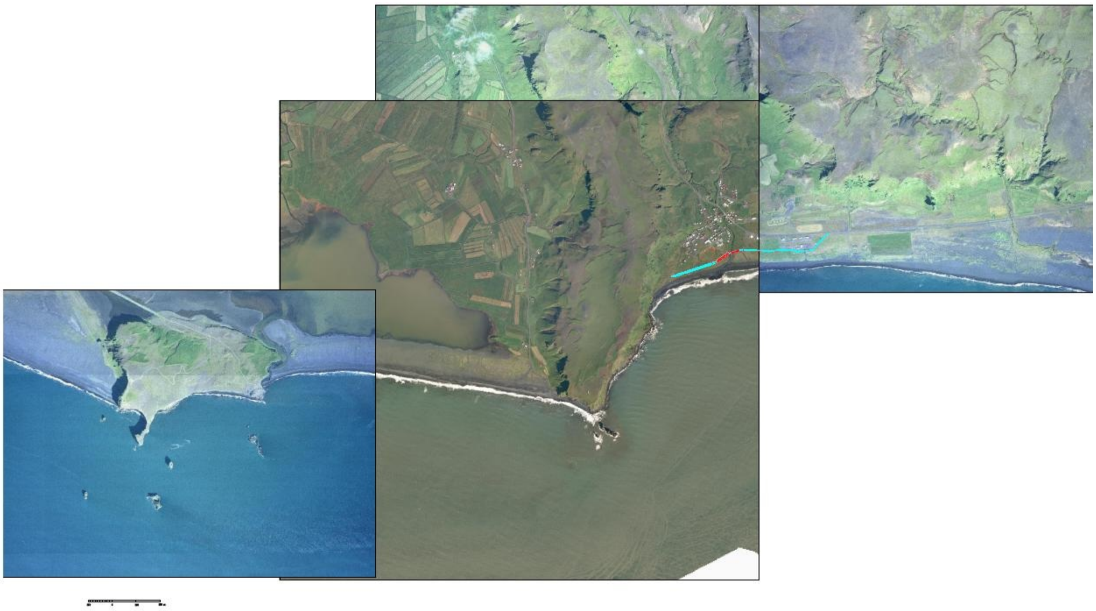


Figure 2.1: Overview - Vík í Mýrdal coast

was significant, Figure 2.2 (I.M.A 2011) shows how the coastline at Vik changes from 1904 to 2009. The flooding caused by the eruption brought huge volumes of material to the sea, mainly sand. The beach south of Hjörleifshöfði emerged about 2,8 km further out than it is today and formed Kötlutangi and 1.5km at the Múlakvísl River As a result of the wave action this material spread out, both to west and east as well as offshore. Figure 2.3 (I.M.A 2011) shows how the beach has emerged of about 500 to 600 m up to 1970. Since then there has been erosion at Vík of about 350 to 450 m. (S.Sigurðarson 2010)

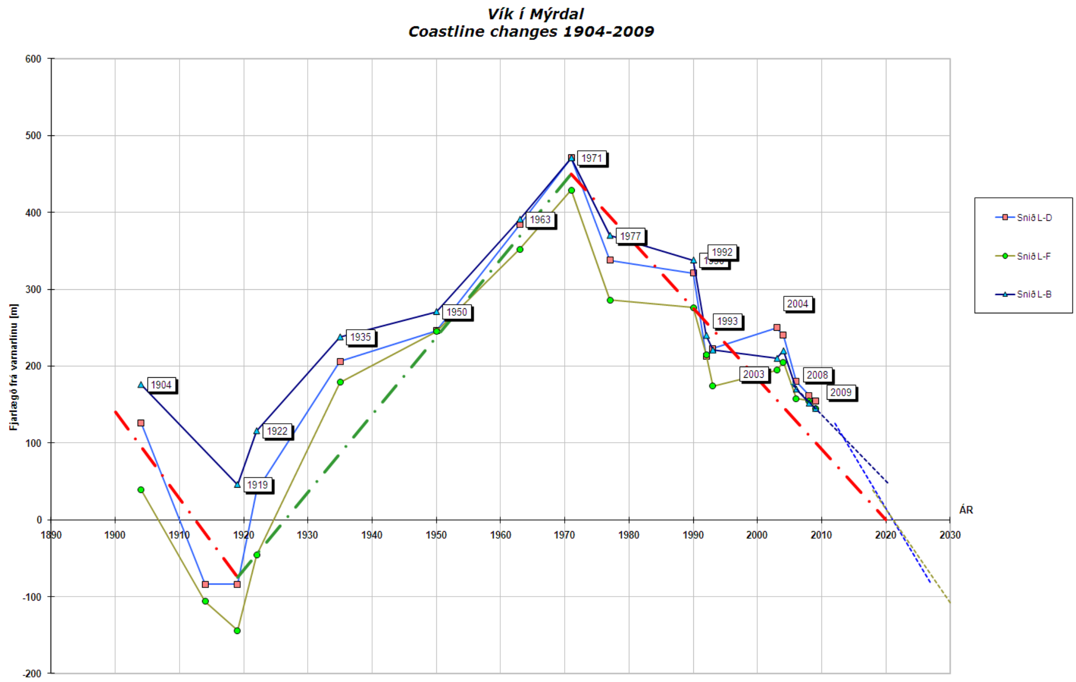


Figure 2.2: Coastline 1904-2009 - Coastline erosion/accretion from 1904

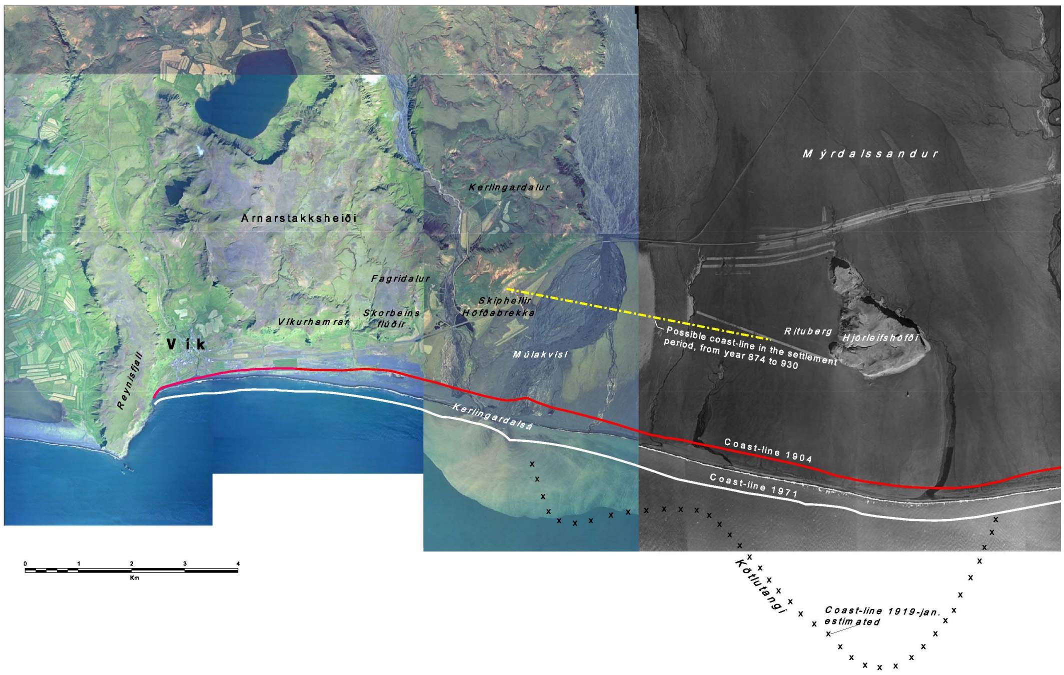
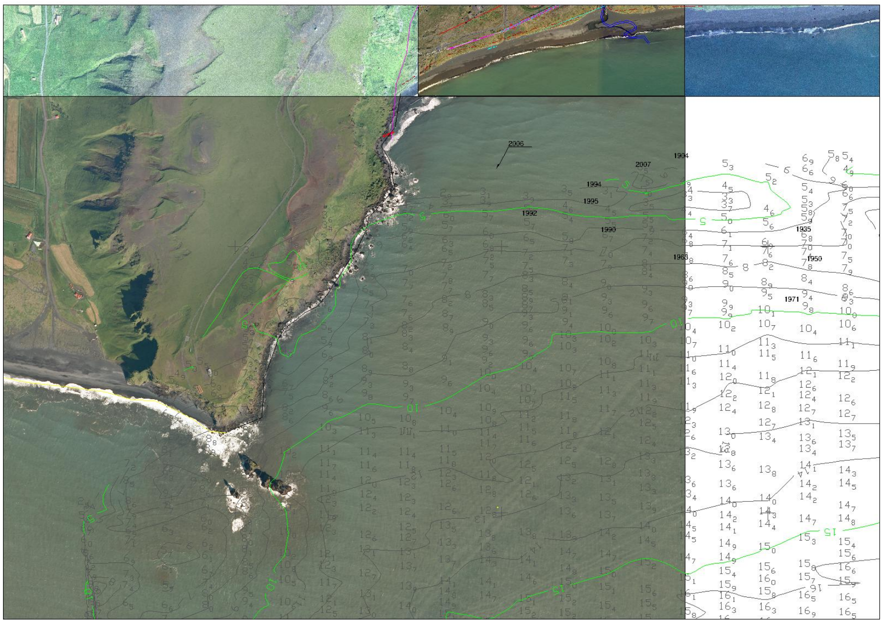


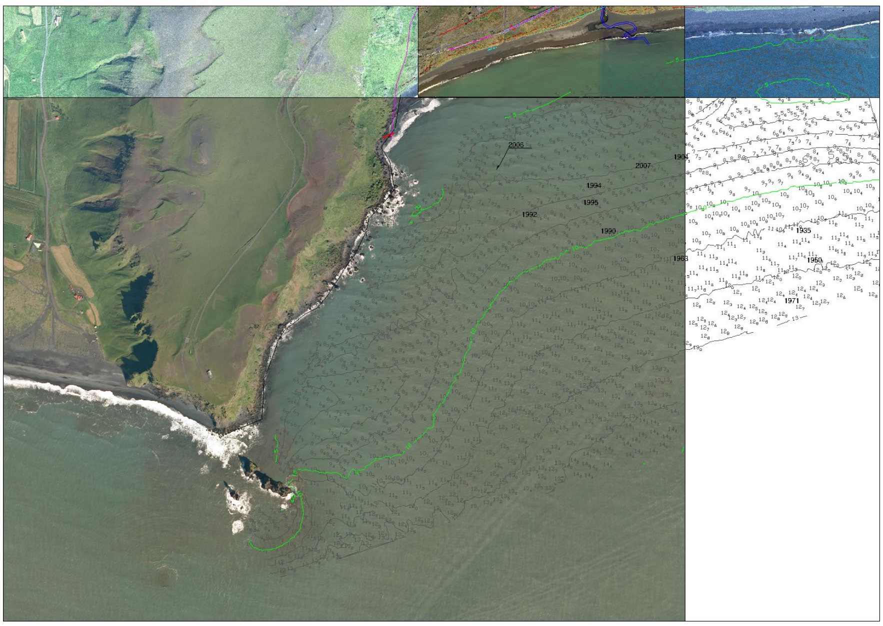
Figure 2.3: Coastline - The coastline changes after the eruption

2.2 Seabed

Seabed measurements were done in 2008 and 2010. The measurements done in 2010 reach -10 m water depth while the one 2008 reach -20 m water depth. Figures 2.4a and 2.4b (I.M.A 2011) shows the seabed from 2008 and 2010. The differences in the measurements are clear close to the Reynisfjall Mountain and the Reynisdrangar. In the measurements from 2010 accumulation, East of Reynisfjall and Reynisdrangar, was between the years. By that it can be assumed that the sediment transport is to East between the Reynifjall Mountain and Reynisdrangar. The rest of the area is similar to each other, normal erosion/accretion.



(a) 2008



(b) 2010

Figure 2.4: Measurements made in 2008 and 2010

2.3 Waves

Waves can be generated by earthquake (Tsunami), wind or by gravity. Waves can range between short waves, with periods about 0.1 s to long waves, with period of minutes to hours. Wave generated waves are waves with short periods which are measured in seconds. The waves at the South Coast of Iceland are generated by the wind and gravity where the highest wave height measured is about 25 m.

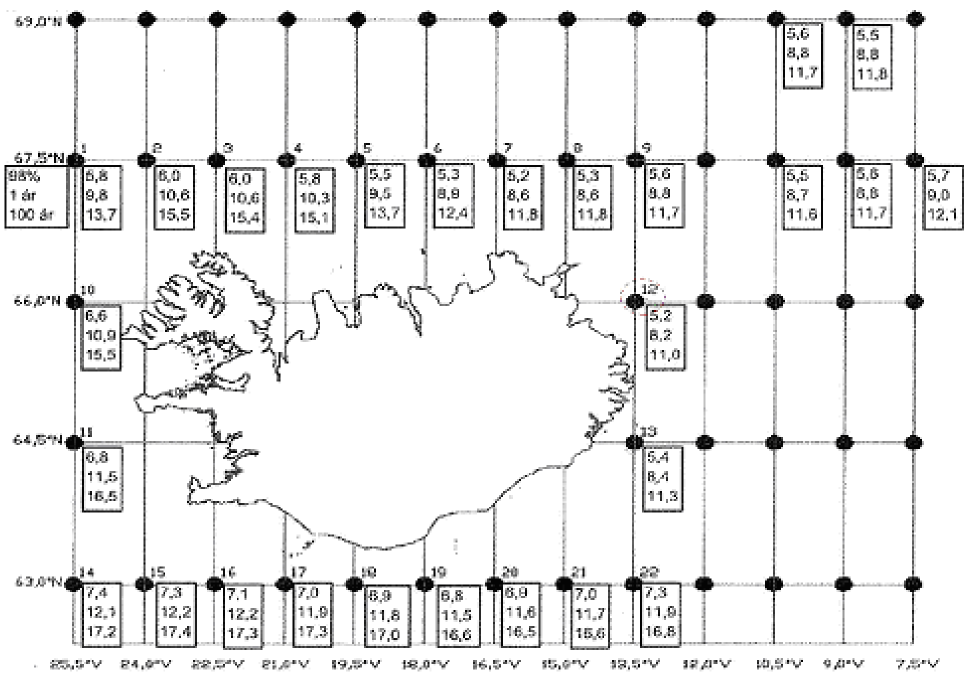
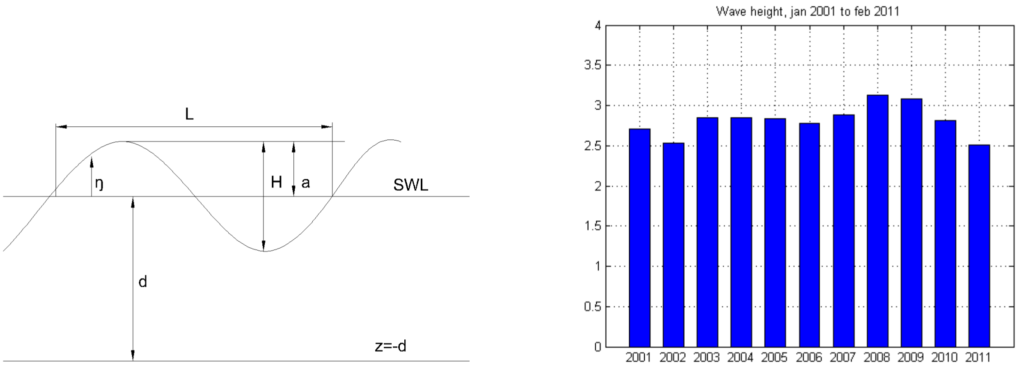


Figure 2.5: Wave Hindi Cast points - Wave hind cast points around Iceland

The wave force and its direction is the drive force in sediment transport. The European Centre for Mediourn-Range Weather Forecast, ECMWF, do a wave hind cast in 22 points around Iceland which can be seen in Figure 2.5 (ECMW 1975) where 1 year wave height, 100 year wave height and a wave with 98% variation is showed. The wave data used in this project are taken from hind cast point number 19 and are the points showed in 2.5.

2.3.1 Wave height

The average deep water wave height the past 10 years is showed in figure 2.6b where the highest average wave height was > 3 m in 2008.

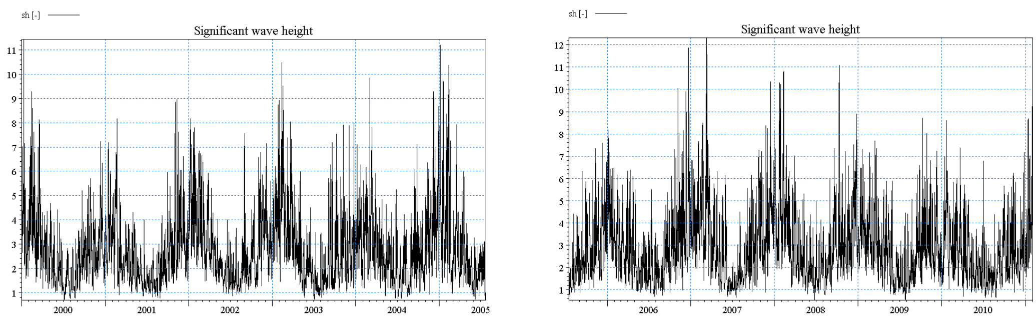


(a) Wave parameters

(b) Average wave height

Figure 2.6: Wave parameters and average wave height

The maximum wave height over these 10 years was calculated to be 12.1 m, in 2007 and can be seen on Figure 2.7.



(a) H_S 2001-2005

(b) H_S 2005-2011

Figure 2.7: H_S for 10 years

2.3.2 Wave Direction

The wave direction is dependent on the seabed depth because the wave transforms when the seabed is $\sim \frac{\lambda}{2}$. The deep water weighted average wave direction is showed in figure 2.8. The data's were weighted with the wave height in the power of 3. (Mangor 2004)

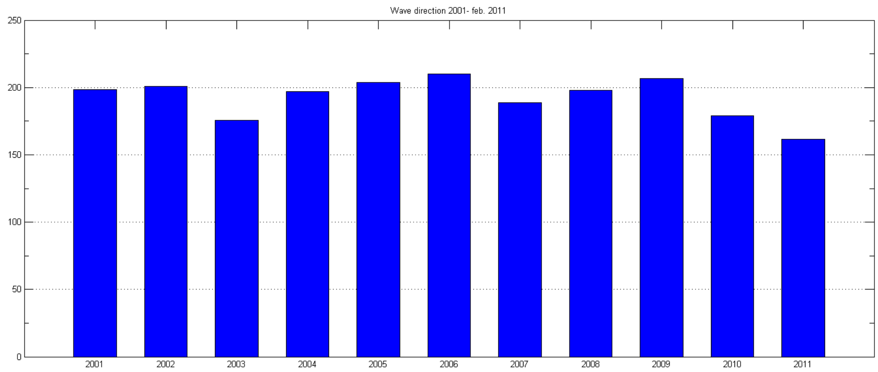


Figure 2.8: Wave direction - Weighted average wave direction for 2001-2011

Figure 2.8 shows that the wave direction varies from 170° to 220° but the highest weighted average wave height was the year 2006 where it was 219°. The lowest weighted average wave direction was 175° in 2003, pure South-West wave direction is 225°.

2.3.3 Wave refraction at Vík

Wave transformation analysis was done for three dominating wave direction, i.e. South-West, South-East and East, for the reason if a West going sediment transport is possible along Reynisfjall. Figure 2.9 (I.M.A 2011) shows the direction of the South-East wave at Vík. Because the wave transformation turns the wave, it will end up being parallel to the seabed, the wave current force is unable to move the sediment along the Reynisfjall Mountain. It can be assumed that the sediment transport to East stop at the Reynisfjall Mountain and form accumulation. (Figures from South-west and East can be seen in appendix)

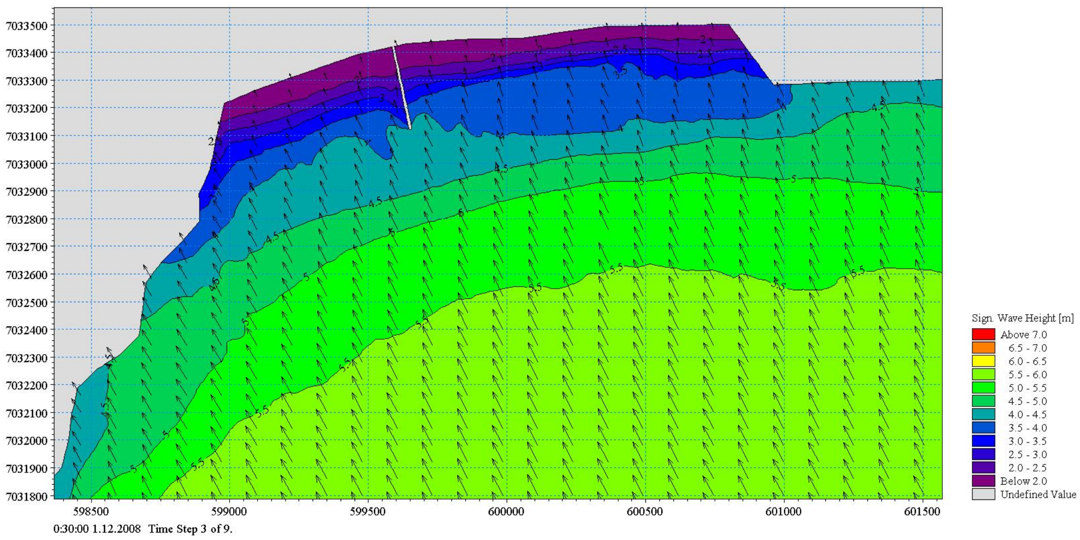


Figure 2.9: South-east wave - South east wave and its direction

2.4 Beach material

Knowing the size of a beach material when calculating sediment transport is important since the formulas for calculating the sediment transport are dependent on the grain size. A normal soil test should be made before the sediment calculations can start where the unit weight of the material is measured as well as the mean grain size diameter, d_{50}.

A Borro test shows how deep is to a hard bottom, i.e. the depth of the sand layer. It is done with a Borro hammer with a diameter of 3 cm. The hammer is dropped from 50 cm at the same location and the displacement measured between each drop. When the number of drops which takes the hammer to move 0.25 m, the case of Vík i Mýrdal, is increasing fast it state that the bottom of the sand layer is close.

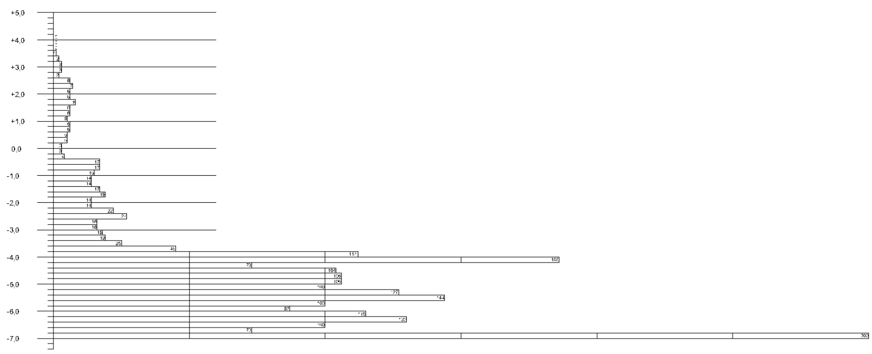


Figure 2.10: - Borro example, when the number of drop increases fast it is close to the hard bottom

The soil at the Vík's coast has been evaluated with soil tests. The results from the Borro test made in March 2010 can be seen in Figure 2.12 and an overview of Borro test points in Figure 2.11 (I.M.A 2011). The result shows that the beach closest to the Reynisfjall Mountain has hard bottom at the location about -6 m from the surface (zero line). The further from the Reynisfjall Mountain the deeper the hard bottom is because the hammer needs more drops to go through a layer of material, see figure 2.12 (I.M.A 2011).
Figure 2.13(I.M.A 2011) shows measurements on the sand grain size which were

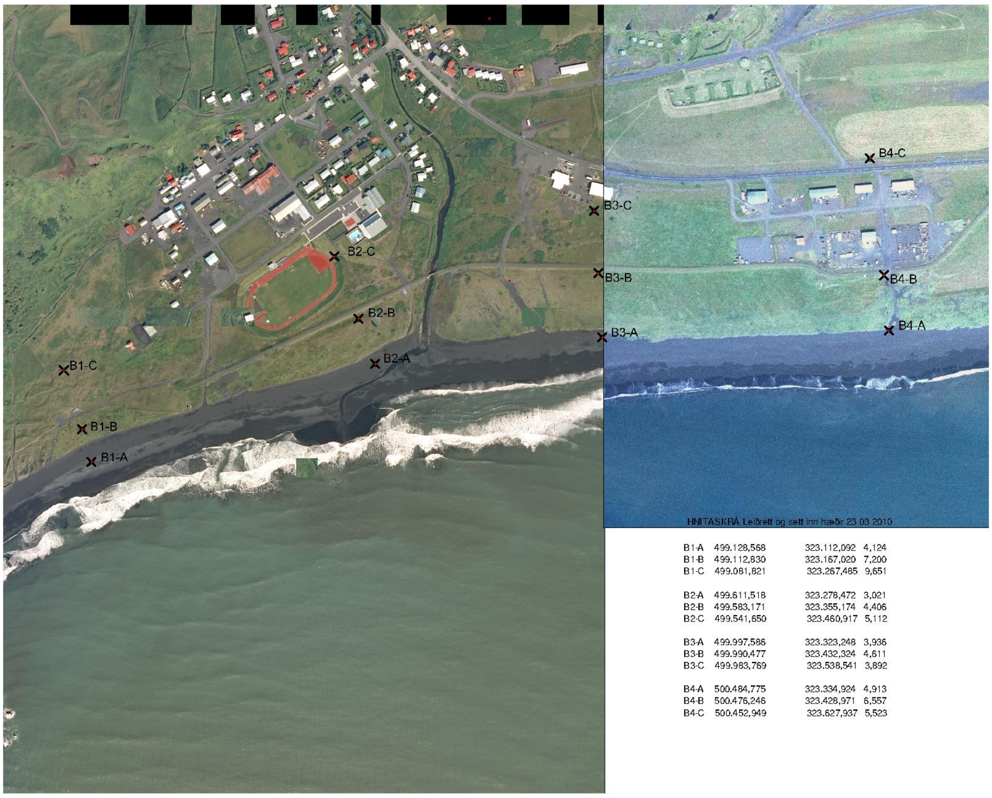


Figure 2.11: Overview of Vík - The placement of borro test

done in 2008 around the profiles 0-F in 0 to -5m water depth. The sediment size varies from 0.2mm, in deeper water, to 0.5 mm, in shallow water. The average sand grain size was estimated to be around d_{50}=0.25 mm.

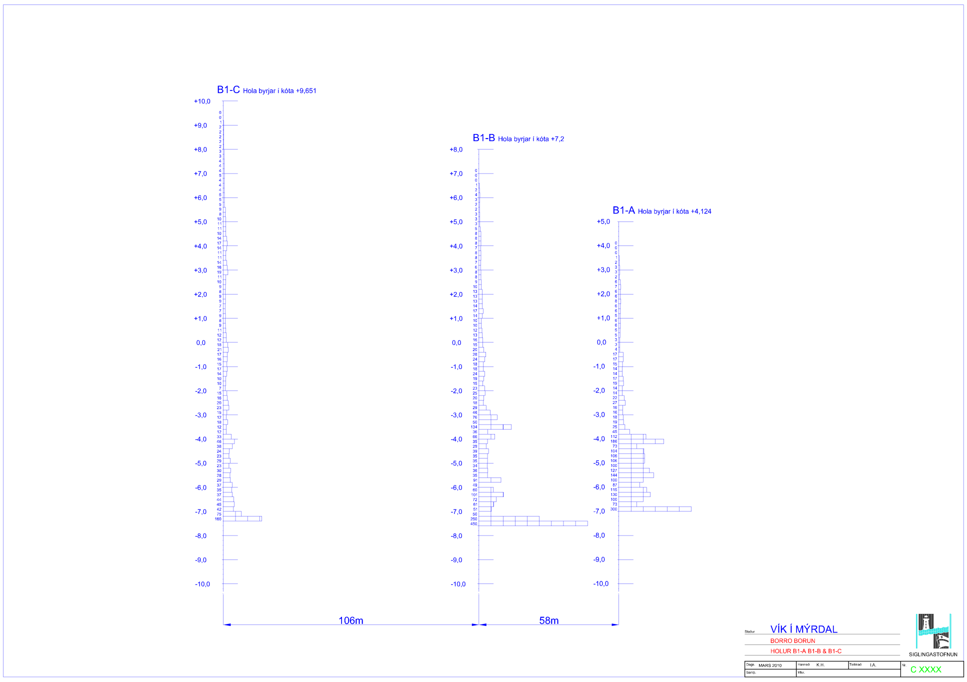


Figure 2.12: B1 to B3 - Results from a Borro test

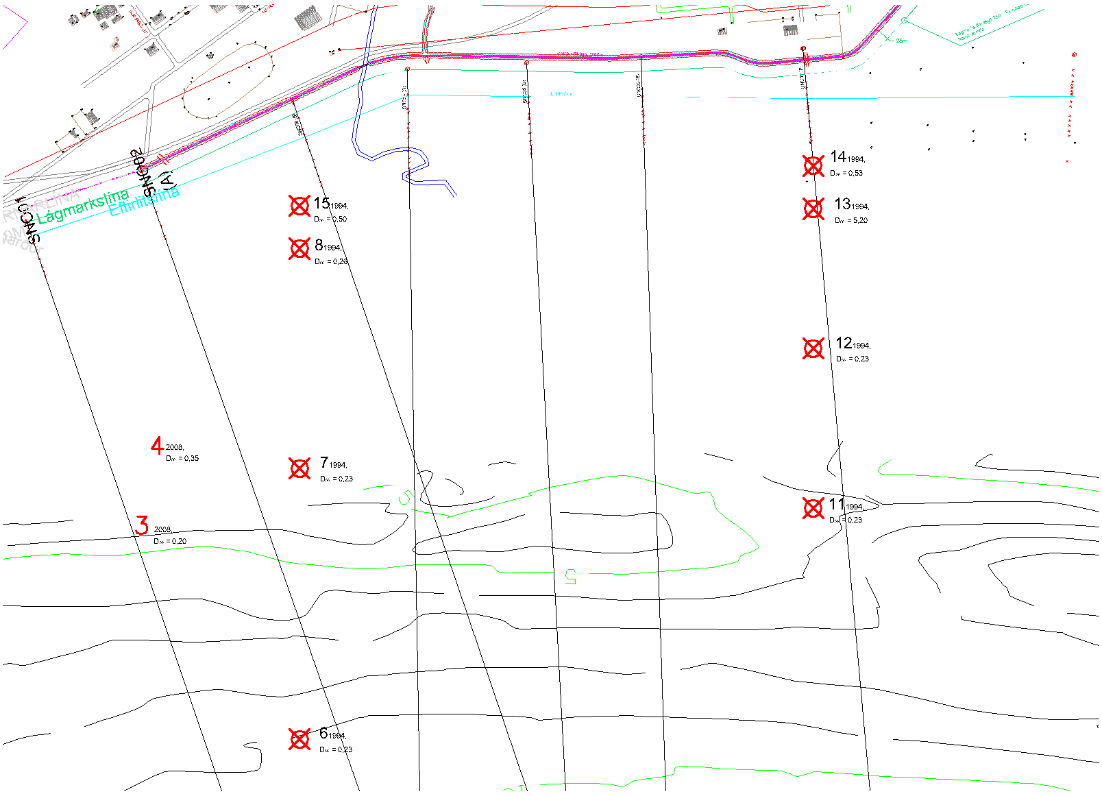


Figure 2.13: Sand size - d_{50} measurements on the coast

CHAPTER 3

Alongshore Sediment Transport

3.1 Coastal Sediment Transport

The shape of a coast is heavily dependent on the sediment transport. It is driven from the wind, the wave and the current. The environmental condition is the main factor of how much the erosion will be.

3.1.1 Types of sediment transport

Sediment transport is normally divided into 3 categories: Suspended sediments, bedload and sheet flow.
Suspended sediments is the sediments particles which mix with the water because of turbulent water flow, i.e. after the wave breaking. The sediments which are transported as suspended sediments are small, with stronger wave force bigger particles can be transported and more concentration will be in the water.
Bedload is a form of sediment transport and is when particles are dragged by the seabed. The wave force form a back and forward motion at the seabed which move bigger particles from place. Bedload is the particles which are to big to be suspended but small enough to be transported by the drag force.

Sheet flow is a form of sediment transport which occur under strong waves or strong current force. The sediments are moved in a thin layer, like a carpet, on the seabed. The difference between sheet flow and bedload is the transport in bedload is only bigger particle but sheet flow is a thin layer with both suspended sediments and bedload which are driven by a strong current. (Lars Erik Holmedal 2007)

3.1.2 Boundary layer

Boundary layer is a small layer just above the seabed. Before breaking the depth of the layer is much thinner than the water depth and can be seen in Figure 3.1. After the wave breaking the water flow is turbulent and the boundary layer can therefore be as hight as the water depth.
Boundary layer always exists and can be in either laminar form or turbulent form. It exists because of a friction from waves and current. Sediment transport equations are mostly depended on boundary layer condition where the velocity just outside the boundary layer is the drive force for sediment transport. Many sediment transport models assume that the sediment transport only takes place in the boundary layer. The thickness of the boundary layer in a rough turbulent wave flow is calculated as (DHI-group 2005*a*):

$$\frac{\delta_w}{k} = 0.072\left(\frac{A}{k}\right)^{\frac{3}{4}} \tag{3.1}$$

where k is the bed roughness in mm and A is the wave amplitude in m.

3.1.3 Cross-shore sediment transport

Cross-shore sediment transport, often called onshore and offshore transport, is when sediments travel along the profile (perpendicular to the coast). Normally the transport in cross-shore direction is not much, compared to alongshore transport, but in heavy winter storms it can be significant part of the sediment transport where the wave force, which works perpendicular to the beach, is the sediment transport drift. In a winter storm the sediments are transported out to a larger water depth where it forms a bar, the cross-shore profile will be steeper. This is called a winter profile which is explained in Chapter 3.3.

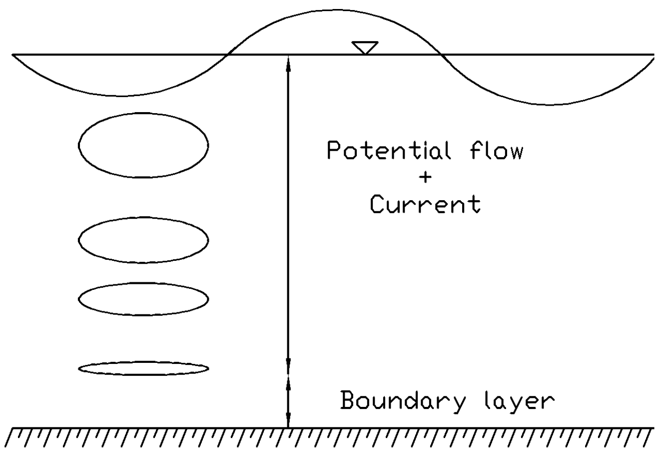


Figure 3.1: Ocean cross-section - Show how the movement of ocean particle change with depth

3.1.4 Littoral Transport

Littoral transport, often called alongshore sediment transport, is when a wave approaches the shoreline with an angle α, see figure 3.2 (Flanders Marine Institute (VLIZ) 2007). The wave diffraction starts to affect the wave and turn the wave crest parallel to the seabed contour. When the water depth becomes 0.8 times the wave height the wave starts to break and is that the start of the breaking zone. In the end of the breaking zone the waves break and form circular movement which cause the sediment to go into suspension sediment and travel in the direction of the wave driven current. The littoral zone starts immediately after the breaking zone.

Littoral transport is sediment transport with non-cohesive sediment, i.e. sand. When using littdrift equations it is important to keep in mind that they are approached with nearly straight coastline with parallel depth contours, see Chapter 3.3.

When calculating the magnitude of the littoral transport it is important that 3 main parameters are correctly evaluated, i.e. wave height, grain size and wave incident angle. If these 3 parameters are not measured accurately it can affect the result and give a wrong result.

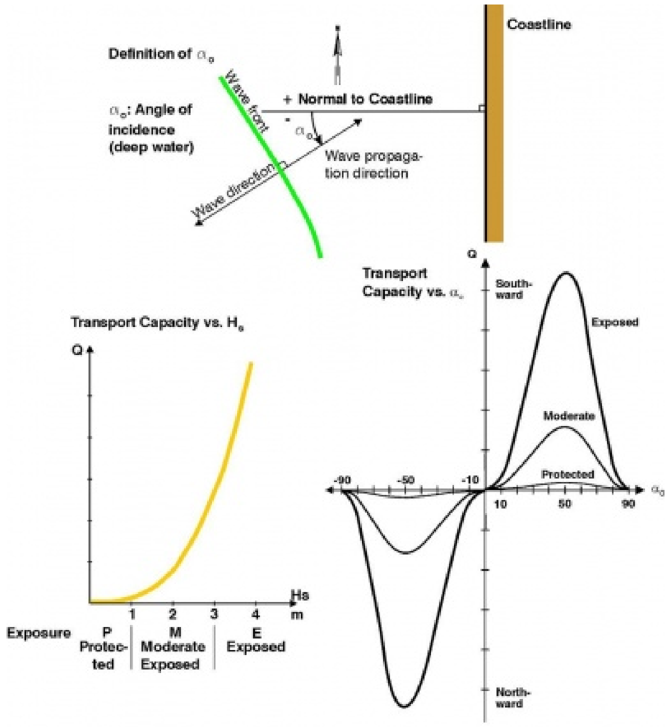


Figure 3.2: Basic of littoral transport - Shows how Littoral drift work

3.1.5 Calculation of sediment transport

The calculation of sediment transport is dependent on the boundary layer condition, as stated in boundary layer section. The important parameters for sediment transport can be seen in table 3.1.

Bottom roughness is an important factor in sediment transport and changes in the roughness alone can lead to an increase in net transport. For flat bottoms the roughness is related to the average sand grain diameter. (Lars Erik Holmedal 2007)

$$k_N = 2.5 d_{50} \Longleftrightarrow z_0 = \frac{d_{50}}{12} \tag{3.2}$$

For seabed with ripples with height η and length λ the seabed roughness can be calculated as:

$$z_o \sim \frac{\eta^2}{\lambda} \tag{3.3}$$

Table 3.1: Important parameters

Wave Velocity amplitude	V_0
Wave Frequency	ω
Wave Amplitude	A
Current Velocity	v_0
Bed roughness	z_0
Median sand diameter	d_{50}
Sea bed shear stress	τ_b
Shield number	Θ
Velocity in still water	w_s

The wave force is much stronger than the current force which causes the sediment transport driven by waves to be much larger than the transport by current. In Vík the sediment transport in mainly because of waves. Basic mechanism in sediment transport state that the waves stir up the sediments while the current transport them. Total sediment transport is calculated as:

$$q_t = q_b + q_s \tag{3.4}$$

where q_b is the bedload transportation and q_s is suspended sediment transport.

3.1.6 Bedload

Bedload sediment transport is dependent on the bottom shear stress from the current and from the wave. The wave shear stress is calculated from:(DHI-group 2005*a*)

$$\tau_b = \frac{1}{2}\rho f_w v_A^2 \tag{3.5}$$

Where τ_b is the bottom shear stress beneath waves, v_A^2 is the wave velocity just outside the boundary layer and f_w is the wave friction factor which is calculated as:

$$f_w = 1.39\frac{A}{k_N}^{-0.52} \tag{3.6}$$

where A is the amplitude just above the boundary layer.

The shear force from the current is much smaller than the current shear force but it is still important to calculated it to know the net bedload. (Silvester & John R. C. Hsu 1997)

$$\tau_c = d_d v_c^2 \tag{3.7}$$

where v_c is the current velocity and c_d is the current friction factor:

$$c_d = (\frac{0.4}{1 + \ln \frac{z_0}{h}})^2 \tag{3.8}$$

where h is the water depth and z_0 is the bottom roughness.
Shield number, the dimensionless bottom shear stress, is calculated as: (DHI-group 2005*b*)

$$\Theta = \frac{\tau_b}{\rho g (s-1) d_{50}} \quad ; \quad s = \frac{\rho_{sediment}}{\rho} \tag{3.9}$$

The critical Shield number is the value which is required to move the sediments, varies 0.04-0.08. If the calculated shield number is less than the critical then the shear force is not big enough to move the load. From the calculated shield number the bedload can be calculate from the dimensionless shear factor, Nielsen 1992:(DHI-group 2005*b*)

$$\Phi = 12\Theta^{\frac{1}{2}}(\Theta - \Theta_c)\frac{\Theta}{\mid \Theta \mid} \tag{3.10}$$

The bedload is then calculated separately, wave and current, with:

$$\Phi = \frac{Q}{\sqrt{gs - 1d_{50}^3}} \tag{3.11}$$

where Q is the bedload.

3.1.7 Suspended sediment

The formula for calculating the suspended sediment : (DHI-group 2005*b*)

$$Q_s = \int_{2d_{50}}^{z_{max}} v c_a (\frac{z}{z_a})^{-b} \, dz \tag{3.12}$$

where v is the velocity just outside the boundary layer, z_a is the water depth measured from the bottom, z_{max} is the thickness of boundary layer, b is calculated:

$$b = \frac{w_s}{v} \tag{3.13}$$

where w_s is the settling velocity, c_a can be calculated as: (DHI-group 2005*b*)

$$c_a = \frac{0.331(\Theta - \Theta_c)^{1.75}}{1 + 0.720(\Theta - \Theta_c)^{1.75}} \tag{3.14}$$

To find the calculated shield number equation 3.9 is used with the calculated shear stress, both for the current and the wave and then the value is inserted into equation 3.14 with $\Theta_c = 0.05$. the steps for the shear stress and shield number is used here to calculate c_a. Equation 3.12 assume that all the sediment transport takes place in the boundary layer.

3.2 Zones within the Coastal Area

The coastal area is the area which defines the zone offshore to the coast. It is divided into three different zones, i.e. Littoral zone, beach and coast, Figure 3.3 (Silvester & John R. C. Hsu 1997) shows the coastal zone.. Littoral zone is the area where the alongshore transport(littoral transport) takes place. Inside it, about 90% of it is the breaking zone. It starts from the depth of closure and end at the beach.

Beach is the zone of material that extend from mean low water to the line where nature vegetation is possible, the waves reach that point in storms.

The Coast is more or less vegetated and is normally not influenced by the coastal processes, but in the most extreme storms the waves can reach to the coast. The coast is often called the beach material budget so it can nourished to original form after a severe storm.

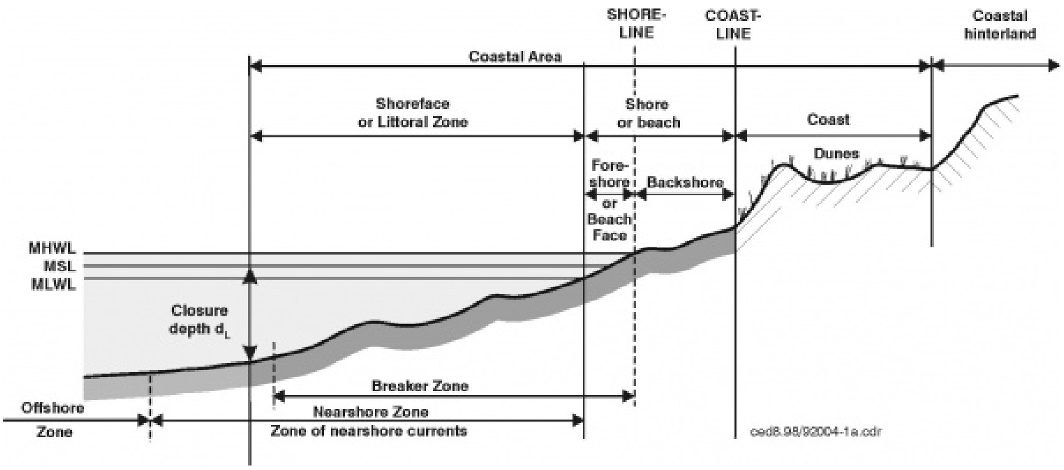


Figure 3.3: - Coastal Area

3.3 Coastal profile

The shape of a coastal profile is mainly dependent on the sediment size and the environmental conditions both offshore and at the beach. A profile has the attendance to reshape until it reaches equilibrium. After the equilibrium the only changes are because of the differences in the wave climate between summer and winter.

3.3.1 Depth of Closure

Depth of closure is the concept that describes the water depth where the wave force, on the seabed, is unable to move sediments because the bottom friction from the wave is small. The wave force decreases linearly from the surface to the seabed, Figure 3.1 shows how the wave force decreases. Beyond the depth of closure the profile is in equilibrium, the changes between years are small. Hallermaier(1978) proposed a formula to describe the depth of closure (Mangor 2004):

$$d_c = 2.28 * H_{s,12h/y} - \frac{68.5}{H_{s,12h/y}^2(g * T_s^2)} \tag{3.15}$$

where $H_{s,12h/y}$ is the wave height with a duration of 12 hours/year, T_s is the wave period and g is the gravity .
For $\mathrm{H}_{12hr/yr}$=9 m and $T_s = 15.1$ s the depth of closure, from eq. 3.15, is d_c=20.5 m. The equation is only dependent on the wave height and the wave period. The depth of closure at the coast by Vík varies by the distance from the Reynisfjall Mountain because it forms a shelter, wave shadow, over the area.

3.3.2 Seasonal profile

When comparing two profiles it is important to know when the measurements where taken because seasonal changes can affect the results. Two types of profile exists, i.e. summer profile and winter profile. The reason for the difference is that in the winter time the winter storms bring higher waves with more cross-shore sediment transport. Then a gravel/sand embankment build up a bar in the breaking zone. When larger waves approach, which happens mostly in the winter time, they break on the bars because waves breaks when $d_w < 0.8H_s$, Figure 3.4 (Department of conservation 2005) shows the difference between the profiles. Larger waves follows larger wave action but the bars prevent them to reach the coastline and therefore prevent the erosion of the beach significant. The winter profile is steeper because in the summer the material displacement is landward and cause the profile slope to be milder.

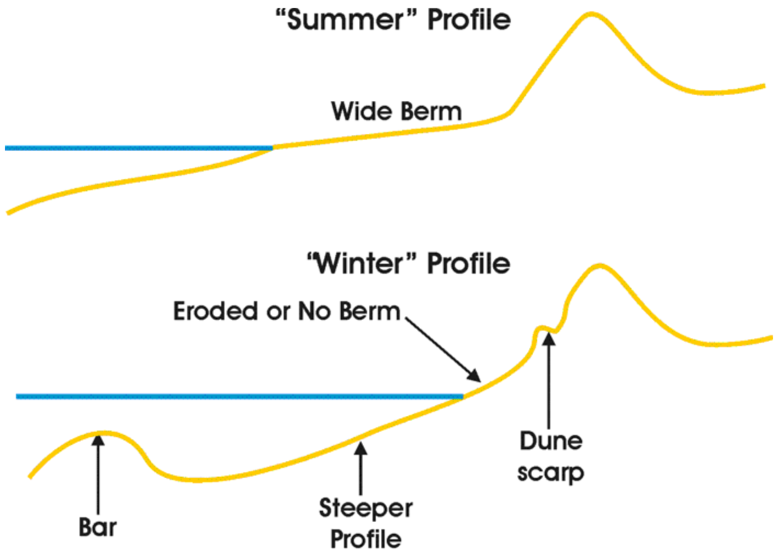


Figure 3.4: Winter- and summer profile - The difference between summer and winter profile

3.3.3 Equilibrium Profile

Equilibrium profile is a profile that does not vary over time, with only seasonal changes. When estimate if a profile is under equilibrium it is necessary to compare two profiles which have been measured in the same period off a year. After a profile has the shape of equilibrium it does not change much over the years, only seasonal changes will occur. Formula for calculating an equilibrium profile is (Dean) : (Mangor 2004)

$$d = Ax^m \tag{3.16}$$

where A is dimensionless steepness factor and m is dimensionless exponent. A is according to Dean : (Mangor 2004)

$$A = 0,067\omega_s^{0,44} \ [\omega_s \text{ in cm } s^{-1}] \tag{3.17}$$

where ω_s is sediment fall velocity. Fall velocity is dependent on the sediment size, see table: 3.2. (Table from Kamphius (Mangor 2004)).

The mean grain size diameter, d_{50}, of the beach material is measured to be around 0.25 mm in profile F therefor $A = 0.092$. It varies through the beach, from 0.2-0.3:

Table 3.2: Correlation beween d_{50} and A according to dean equation

d_{50}	0,10	0,15	0,20	0,25	0,3	0,5	1,00	2,00	5,00	10,00
A	0,043	0,062	0,080	0,092	0,103	0,132	0,178	0,234	0,318	0,390

The slope steepness of a equilibrium profile is depended on the grain size which makes the profile steeper with increased sediment size, the profile should be compared to summer profile when the profile is smooth.

3.4 Coastal spiral form

Where headland form a suddens change on a sandy beach a spiral bay is formed when a beach is under a equilibrium. The process for the beach to reach a static equilibrium can take a long time, if it will be reached. A beach will first reach a dynamic equilibrium before it reaches static equilibrium. Four main factors can be applied to prove the stability of the final shoreline.(Silvester & John R. C. Hsu 1997)

1. No further sand is deposited in the trap provided at the downcoast end.
2. The beach is not receding any further.
3. Waves are breaking simultaneously around the periphery.
4. Dye inserted in the surf zone does not move along the beach.

Two empirical equations have been proposed in deriving bay shaped beaches: Logarithmic Bay Shape and Parabolic Bay Shape.

3.4.1 Logarithmic shape

The equation used today was a result of Krumbein(1944) research when he examined beach processes of Half-Moon bay near California.:

$$\frac{R_2}{R_1} = \exp \theta \cot \alpha \tag{3.18}$$

The equation applies only to the curve part of the beach in the shadow zone. If the coast has only one fixed point, like Vík í Mýrdal, the formula does not apply. From figure 3.5 (Silvester & John R. C. Hsu 1997) the spiral is explained further. The Vík's coast has only one fixed point, Reynisfjall, and the shape of the bay is not like the figure shows.

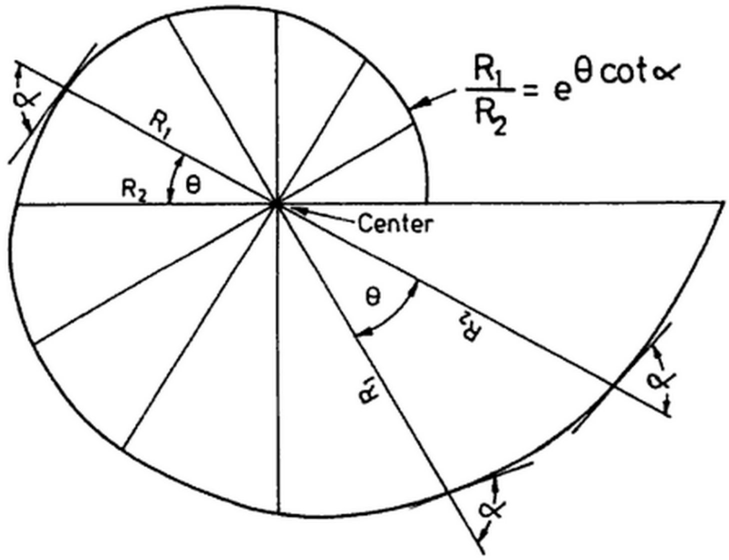


Figure 3.5: Logarithmic spiral - Definition of logarithmic spiral approach

3.4.2 Parabolic shape

The parabolic approach is the method which is used mostly today and was discovered by Silvester and Hsu, i.e. an equation which simulate a coast under equilibrium with a parabolic shape:

$$\frac{R}{R_0} = 0.81\frac{\beta^{0.83}}{\theta^{0.77}} \tag{3.19}$$

where β is the angle between the approaching wave and R_0 and θ is the angle between a radius R and the approaching wave angle.
The approach can be seen in figure 3.6(Silvester & John R. C. Hsu 1997) where R_0 is the radius from the diffraction point to a point on the coastline where the effects from the headlands doesn't valid, see figure3.6(Silvester & John R. C. Hsu 1997).

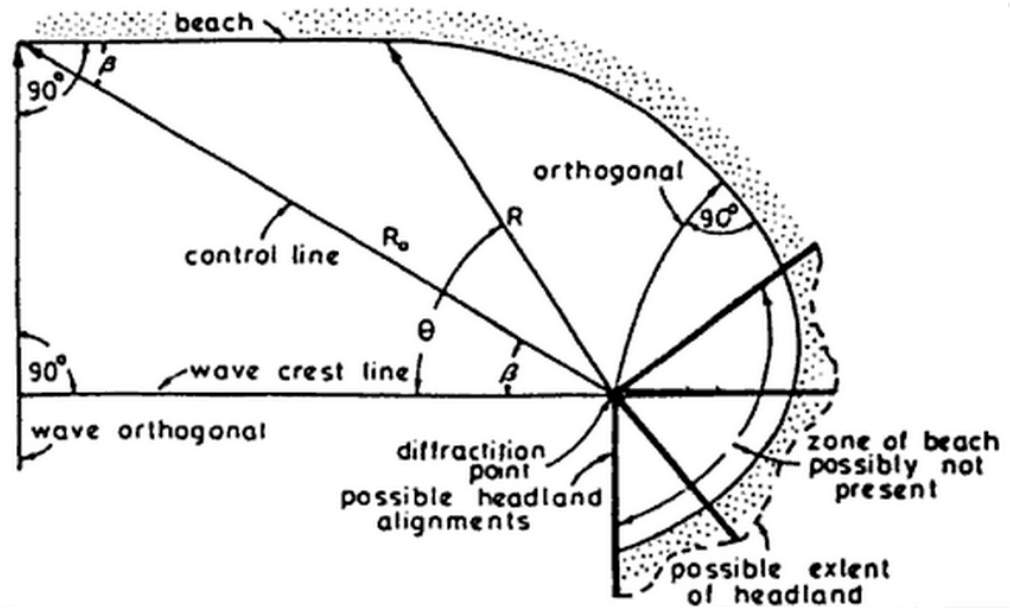


Figure 3.6: Parabolic spiral - Sketch of the parabolic approach by Hsu

3.5 Coastal Protection

There are several ways for preventing erosion but the two most used solutions are a groyne field or a detached breakwater. Both solutions are used widely over the world but are used in different scenario.

3.5.1 Groyne

A groyne is designed to capture the sediments, which prevent them moving along the coast and changes the direction of the coastal profile, it will reach equilibrium. It needs to be placed perpendicular to the dominating incoming wave angle which affects the sediment transport. Because a groyne prevent normal sediment transport an accumulation occur in the direction of the net sediment transport direction, i.e. if the net sediment transport is to the left an accumulation will

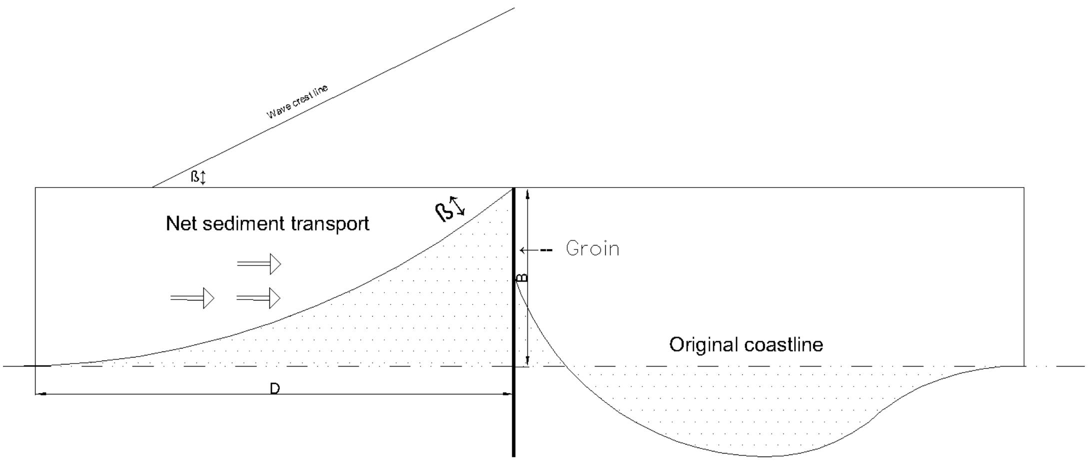


Figure 3.7: Groyne - The parameters needed for building a groyne

occur to the right side of the groyne(see Figure 3.7), and erosion on the other side. It is important when designing a groyne or groyne field to take into account that an erosion will happen.
The coastline that is affected by a groyne will have a spiral form and is the length of the new coastline same to the point not affected by it, same as R_0

when calculating a parabolic form bay. When placing more than one groyne it is important to place them in a distance D from each other where D is the distance from the groyne where it does not affect the wave.

3.5.2 Detatched breakwater

Detached breakwaters, near shore detached breakwaters, are used to reduce the incident wave energy on a coast which is affected by it (johnson, wilkens, Parsons & Chesher 2010) and therefore reduce the sediment transport on the beach. The breakwater form a salient or tombolo (see figure 3.8 (Flanders Marine Institute (VLIZ) 2007)) and the size of it is dependent of the length of the breakwater. When placing a detached breakwater fields the distance between them needs to be at a distance from it where the other breakwater does not affect the coastline. To calculate how the coastline behind a tombolo will form the parabolic shape of a coast is used.

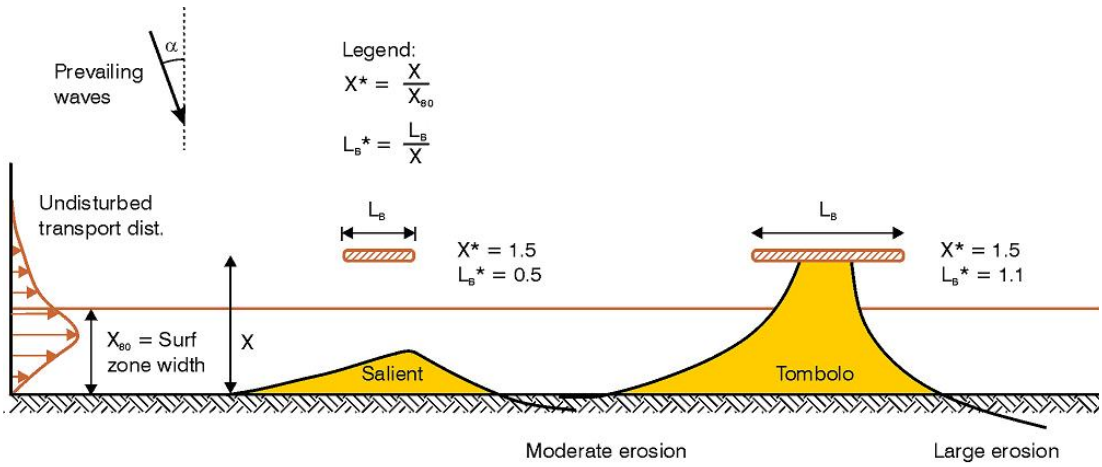


Figure 3.8: Detached Breakwater - Basic of a detached breakwater

CHAPTER 4

Modeling of Wave and Sediment Transport at Vík

4.1 Numerical model Mike

Mike can calculate wave hind cast and and sediment transport calculations. There are packages available where every single one is made for specific calculations. The packages used for wave analyses and sediment transport in this study are: Mike-SW and Mike-Litpack, Litdrift (it is designed by Danish Hydraulic Institute (DHI-group)).

4.1.1 Mike-SW (Spectral Waves)

Mike-SW is designed to calculate the wave parameters offshore to an area of interest. The measurements of the seabed are important because the wave transformation is dependent on it. It is important to have good measurements of the seabed so the wave transformation calculations in Mike-SW will be accurate, Figure 4.2 shows the seabed input for Mike-SW. A triangulated mesh is defined from the seabed measured points where the size, area, of the triangles is large in deep water while it is denser closer to the coastline, (varies from 900 m^2 to 500.000 m^2). The size of the triangles are important for the reason that the simulation

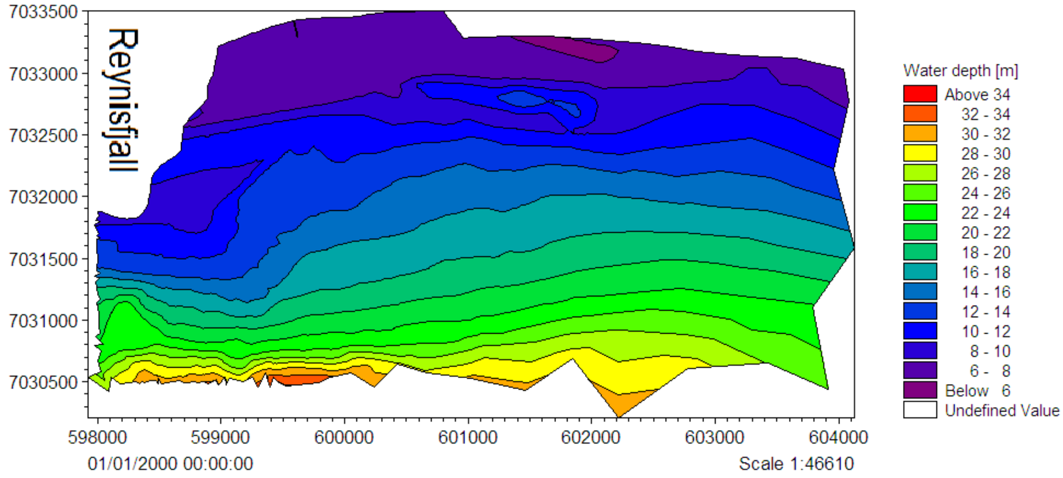


Figure 4.1: Seabed - Depth on the seabed

time is dependent on the size and the number of triangles, the more triangles the more time it takes to calculate the wave parameters for the area.

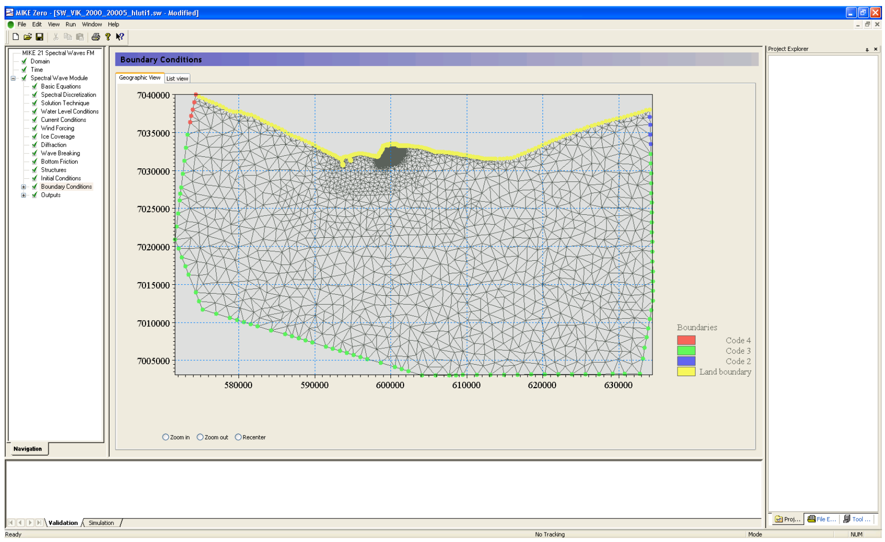


Figure 4.2: Mike-SW setup - Triangulated area with different triangle size

Many parameters needs to be modified before a simulation can start, see Table 4.2. The wave breaking constant is w_b=0.8 H_S and the bottom friction is estimated as k_N=4.5 mm, as average bottom friction. Mike uses Newton-Rapson iteration to calculate the wave parameters in every point from the original one.

Table 4.1: Parameters needed for Mike-SW

Wave parameters	Value
Wave height	From ECMWF
Wave period	From ECMWF
Wave direction	From ECMWF
Wind force	From ECMWF
Wave breaking constant	$H_b = 0.8H_S$
Mean water level	3 m above M.W.L
Bottom friction	Estimated 0.0045 m
Current	No current
Ice	No ice
Diffraction	Soothing factor=1
Fetch	Jonswap formula

For the simulation made for the years 2000-2011 the wave data were to heavy for the program that it was needed to divide them into two parts, 2000-2005 and 2005-2011 and took the simulation for each part approximately one week. The output file contains wave parameters H_s, T_p and wave direction only for the area closest to the coastline for every 6 hours. The wave parameters calculated in Mike-SW are used to make wave climate file, which is a input file for Litdrift. Profile file is also needed as a litdrift input.

4.2 Mike-Litpack,litdrift

Litpack is a package from Mike-zero which can calculate sediment transport. Litpack is divided into two packages, i.e. Litdrift and LitSTP, and is Litdrift used in this study because it can calculate the alongshore sediment transport. The formulas used in Litdrift assume that the coast is long with little variation in coastline direction and the seabed should we single sloped. Because these condition are not valid for the Vík's coast the model needs to be calibrate to give good results.
With measured irregular wave data's and a variance in profile shape it is recommended to use the model of Battjes and Janssen for the calculation. The model is based on occurring in a bore and the local probability of the wave breaking. The results are used as a sink in the energy balance equation, which is integrated to obtain the wave height, H_{rms}, as a function of distance from the coastline (on-shore distance). The basis for the statistical description of the wave heights is the Rayleigh distribution (DHI-group 2005a).
The wave energy balance equation for a stationary situation is

$$\frac{\delta}{\delta_x}(C_{gx}E) + E_{diss} = 0 \tag{4.1}$$

where

$E = \frac{1}{8}\rho g H_{rms}^2$	is the mean wave energy
$C_{gx} = \frac{1}{2}c(1+g)\cos\alpha$	is the group velocity in x-direction
E_{diss}	is the time-mean dissipated power per unit area.

Wave energy is dissipated due to wave breaking as:

$$E_{diss} = \frac{1}{4}\alpha\rho g\frac{1}{T}Q_b H_{max}^2 \tag{4.2}$$

where

x	Is an adjustable constant
Q_b	Is the fraction of breaking or broken waves
H_{rms}	Is the local maximum allowable wave height
α	Is the dissipation factor

Q_b is the key variable in the formulation, and controls the rate of dissipation.

The fraction, Q_b, of the waves that are broken is given by the number of waves which, according to the Rayleigh distribution, would have been larger than the maximum wave height. The Rayleigh distribution method is changed so that no wave heights exceed H_{max}. (Litdrift manual, (DHI-group 2005*a*))

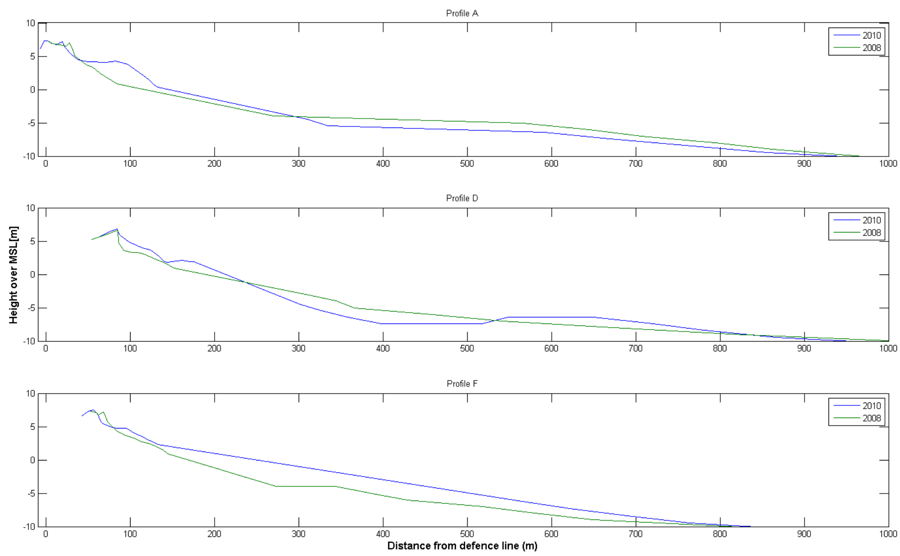


Figure 4.3: Profile A, D and F - Comparison of profile measured 2008 and 2010

A profile needs to be defined for Litdrift calculations and its length needs to span the coastal area. The profile used in this study were profile F and profile D as shown in Figure 4.3. The following table shows the variables needed as an input for the coastal profile F:

Table 4.2: Variables for coastal profile F

Mean grain size	0.25 mm
Fall velocity	0.02 m/s
Roughness	0.01 mm
Geometrical spread	1.4

Figure 4.4 shows a close up at the area of Vík. The location of the profiles and

the closest model points. Full overview of the model points and the profiles can be seen in appendix.

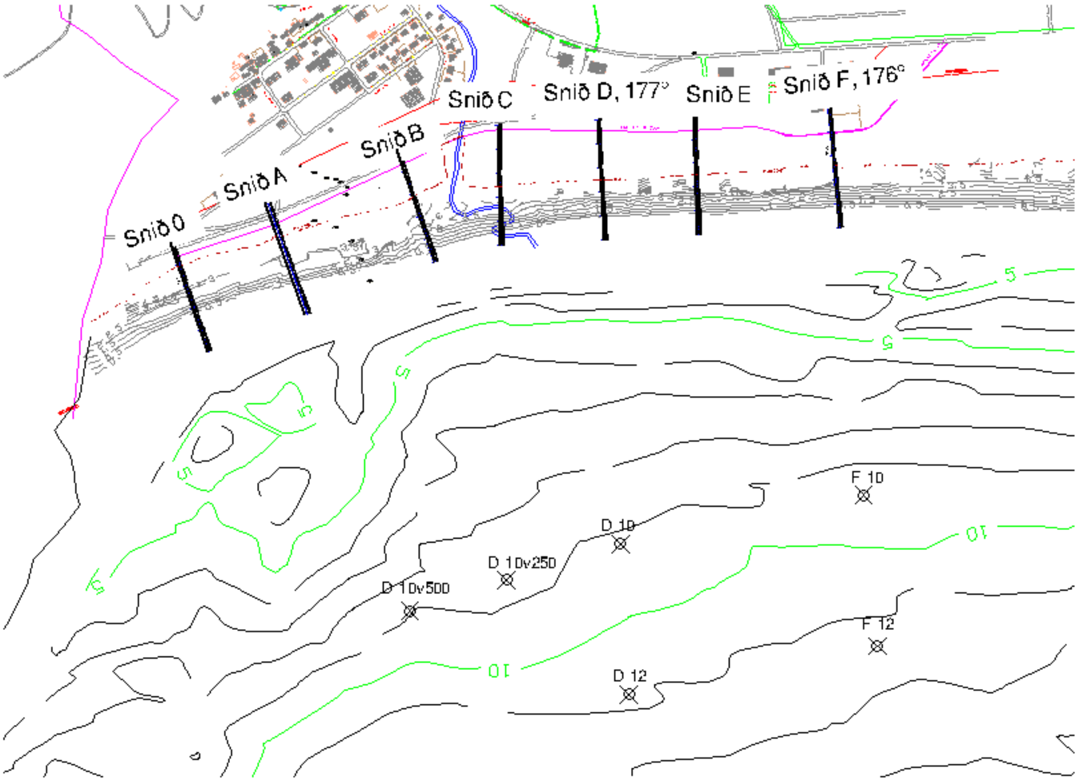


Figure 4.4: Profile overview - The location of the profiles and points

4.2.1 Litpack sensitivity analyze

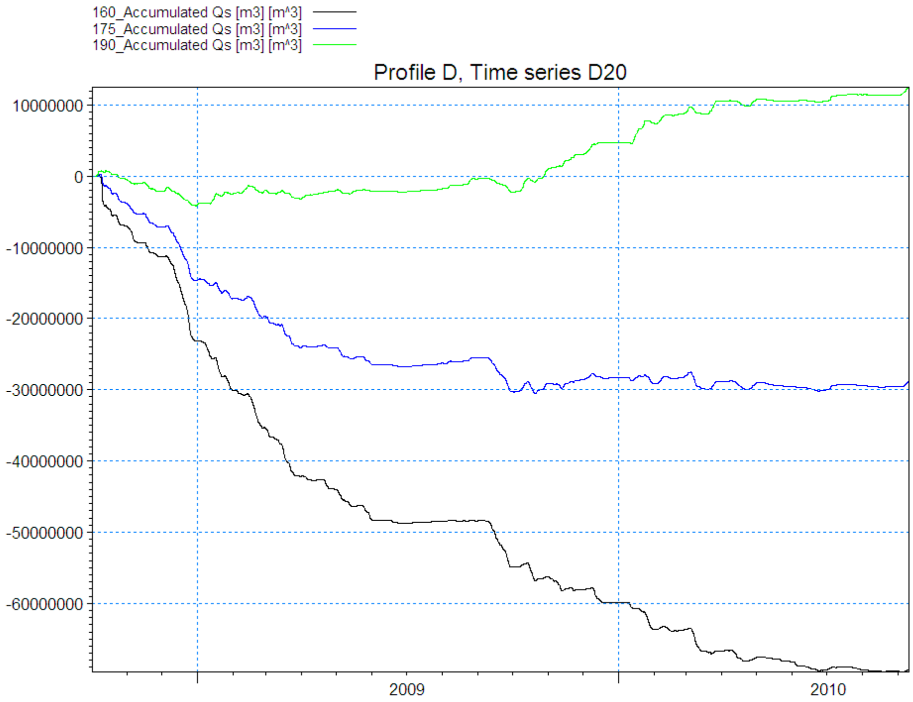


Figure 4.5: Profile D - Accumulated sediment transportation with different orientations 160° , 175° and 190°

The sensitivity analyses were done for wave data for the years 2008-2010 because that time interval is that what DHI-group used (DHI-Group 2006) , on the coast at Vík, to calibrate the model when calculate the sediment transport in Landeyjarhöfn project. The most important factors that need further analyses are: the profile direction, profile shape and the average sediment size.

If a wave approaches the coastline perpendicular to it the net sediment transport should be close to zero. During these two years the average wave direction was about 190° which state that when the profile orientation is about 190° the net sediment transport should be around zero. Profile F was run in litdrift with three profile orientation, i.e. 160°, 175° and 193°, with wave data from -20m water depth in a line from profile F. The result gave that 15° profile orientation change result in 40Mm^3 in difference, with profile direction of 175° the net sediment transport was -30mM^3 but with a direction of 190° the sediment transport was 10Mm^3. The net sediment transport is about zero when the profile direction is ∼190°.

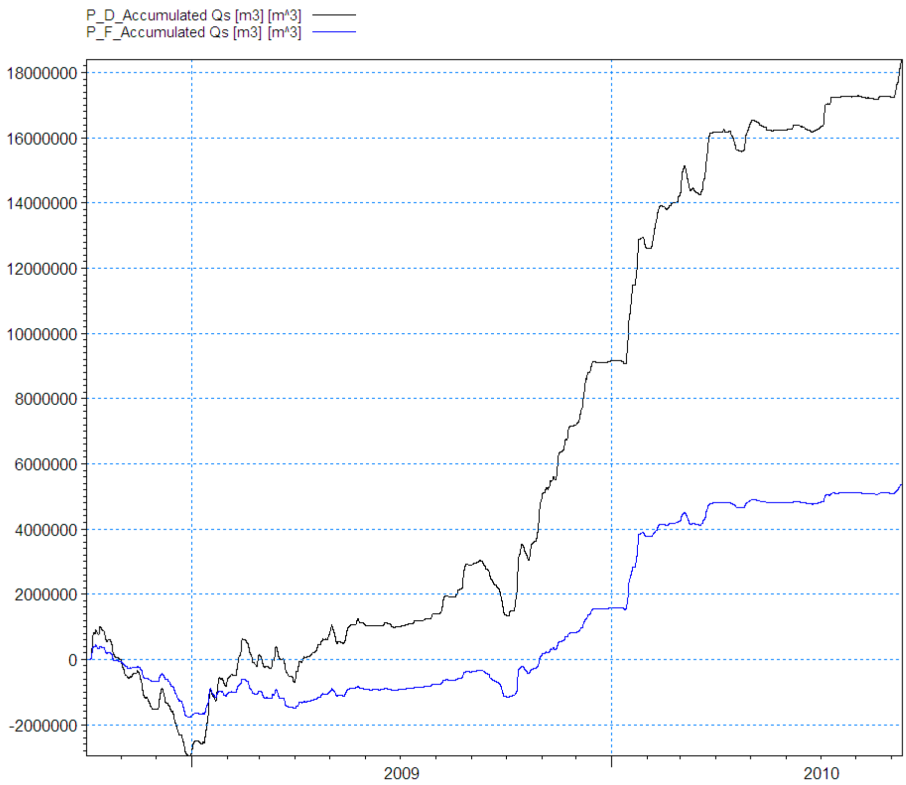


Figure 4.6: Profile D and F - Difference in sediment transportation with profile D and F with beach orientation of 193°

In 2008, when the measurements were done and this study is based on, the orientation of Profile A and B was 171°, D is 177° and F was 180° (from North). About 800 meters from east of profile F the beach reach directional equilibrium for couple of km east where its orientation is 193°. Based on the measurements the net sediment transport was to east over the period as shown in the Figure 4.3.

Net volume sediment transport was calculated when two profiles, profile D and profile F (measured 2008) were compared as shown in Figure 4.6. Its shape matters when calculate the net sediment transport. The sediment transport simulation with profile D was 18Mm^3 while simulation with profile F was 6Mm^3, 3 times more. The difference between the profiles is that, one is located in the shelter area from the Reynisfjall Mountain while the other isn't but it state that it is important to have good measurements of a coastal profile when simulate the sediment transport volume calculations.

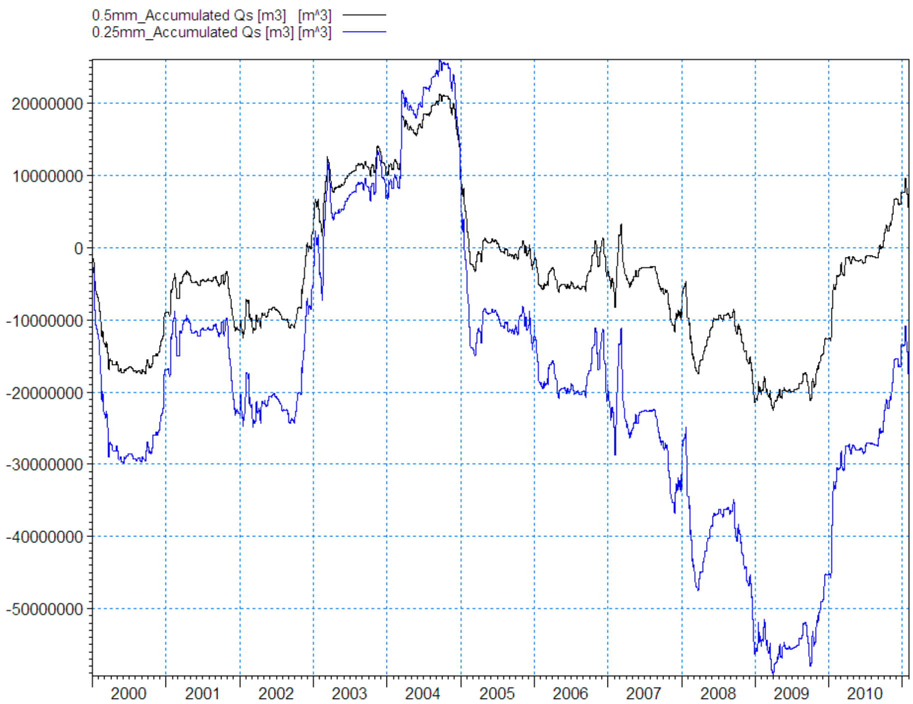


Figure 4.7: Profile F - Wave data's in 20m depth, profile orientation 193° d_{50}=0.25 mm (blue line) and d_{50}= 0.5 mm (dark line)

The grain size is important because bigger sediments needs bigger shear force to move, τ. It is essential to know if the net volume will change much with different sediment size. Figure 4.7 shows that the model isn't as sensible for diameter change as the beach orientation or the profile shape but it is important. The difference in sediment transport, according to Figure 4.7 is 2Mm^3 which is 10% error.

The sensitivity analyses showed that the profile orientation, the profile measurements and the grain size are the most important factors in sediment transportation. Another important factor is to determine where and how the shelter from the Reynsifjall Mountain influence the sediment transport capacity. This is done by using wave data from points which are outside the shadow area and points which are located inside it. To make this study easier to interpret it was decided to use the same beach profile for these simulations, profile F. It is important to keep in mind that the area of interest is 2km long but there are only four good profiles available which will result in not accurate measured sediment transport.

4.2.2 Litdrift simulations 2000-2005

The period 2008-2010 was unique for the reason the south west wave was stronger than the past decades. The wave directions were almost equal in all three directions (south-west, south east and east) and the sediment transport was positive, but the past decade the coast has retreat for about 350 m, from 1971. From the wave data's from F_{20} the dominating wave direction was south-west, which follows sediment transport to East.
The first simulations were run with profile F with wave data from D_{20}, $D_{12_W 250}$, $D_{12_W 500}$ and D_{12}, where D_{20} (see glossary) is located outside the shelter from The Reynisfjall Mountain but D_{12} is located inside the shelter as shown in Figure 4.8. The net sediment transport over these years, with a correct beach orientation (177°), result in east going sediment transport, about -300Mm^3 for wave datas from D_{20}. The sediment transport closest to the Reynisfjall Mountain and the beach should give the smallest net sediment transport to east because the effect from Reynisfjall should result in eastern wave data's but because the bottom is irregular the net sediment transport with the wave data from $D_{12_W 250}$ result in transport, about 170Mm^3.

4.2.3 Litdrift simulations 2000-2011

In the sediment transport simulation for the period 2000-2011 the wave data's points closer to the coastline was analysed to see where the affected wave on the beach, next to the Víkurá River, is located. The reason for the interest in the area around Vík is to find a good location for a coastal protection structure. The

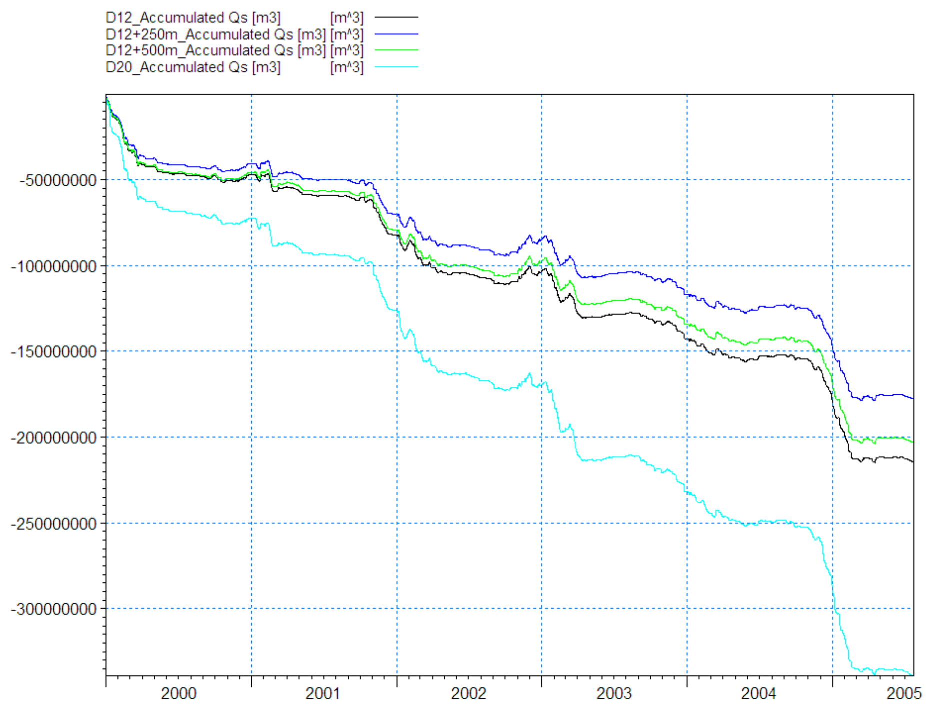


Figure 4.8: Profile F - Accumulated for 4 different time series (D_{20},D_{12},$D_{12+250m}$,D_{12500m}, profile F_{177})

wave data used in the first simulations are from D_{V250} for 6,7,8 and 10 m water depth and was it run with profile C as shown in Figure 4.9.
For the profile direction of 177° the net sediment transport was smallest for the 6m depth but highest for 10 m depth, east going. The orientation of the beach under equilibrium is more than 177°. The measured volume change during 2008-2010 at the profile D is measured to be $\sim$ 600.000m^3 and the wave data from 6 m depth gives a difference around that value as shown in Figure 4.10. The net sediment transport for wave data from a line from profile C at 8 m depth, with beach orientation of 182, was west going, positive, but east going, negative, for the other data. It can be estimated that the equilibrium of the profile at the location of profile C is $\sim$ 180°. The wave which affect the sediment transport is from 6 m depth and is under equilibrium when the profile direction is $\sim$ 180°. A net drift analyses needs to be done to estimate the depth of the main sediment transport, Figure 4.11 shows the net drift for the wave data's from -6 m depth at

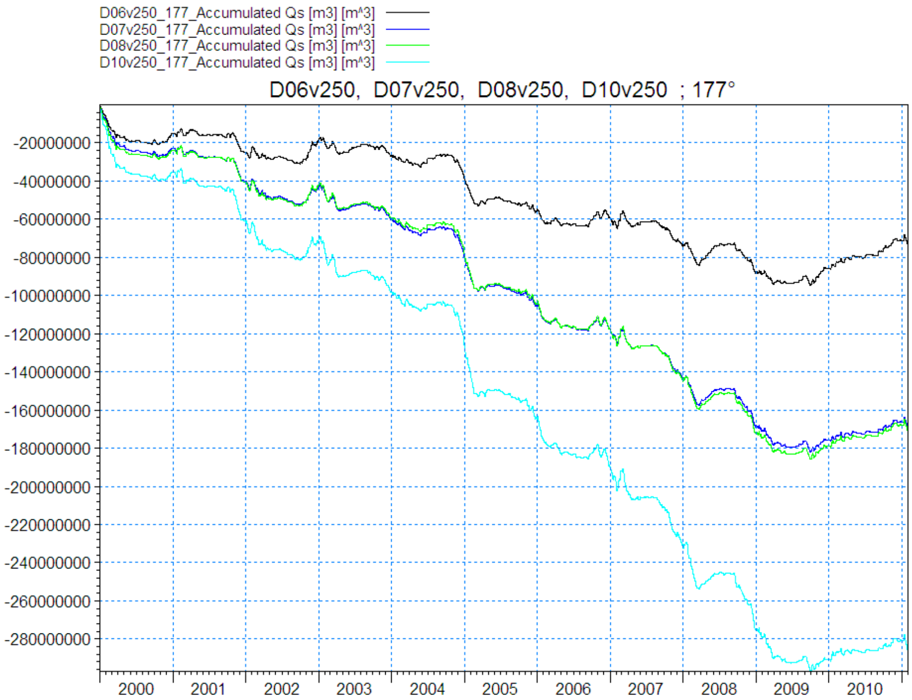


Figure 4.9: Profile C - Wave data's from 6,7,8 and 10 m water depth.

$D_{6_V 250}$. The net sediment transport starts at -7 m water depth, the SW-model was run with average water depth of 3 m, to -1 m water depth.

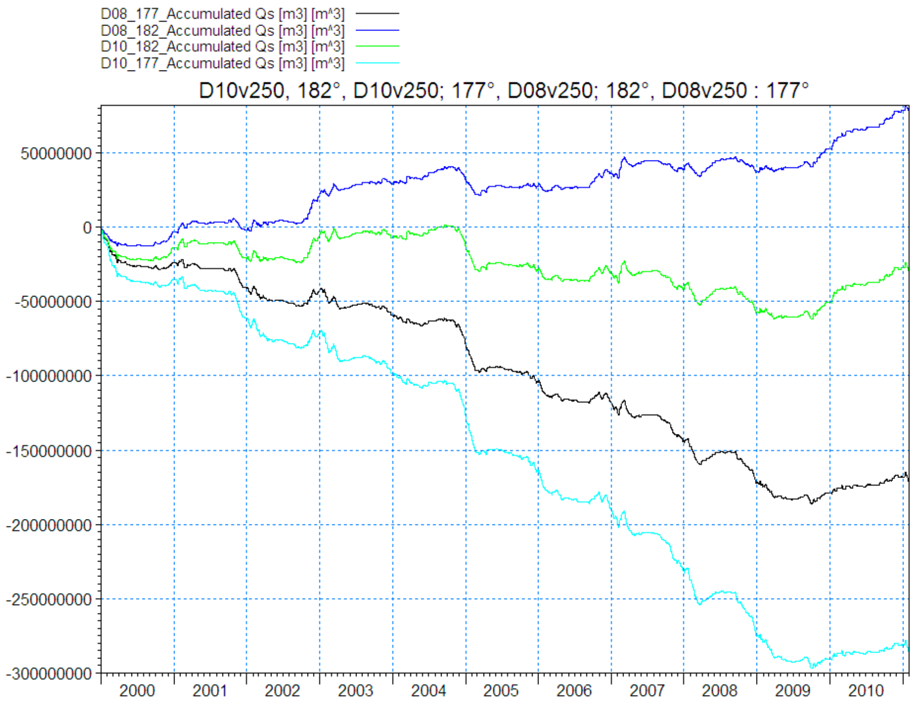


Figure 4.10: Profile C - Wave data's from 10m and 8m D_{V250} and profile orientation of 177° and 182°

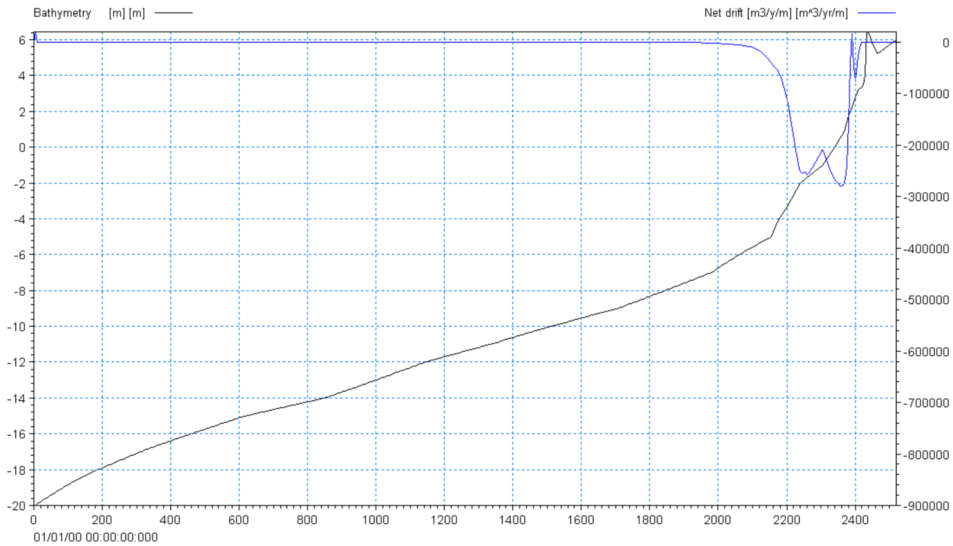


Figure 4.11: Net drift - The net drift for the area around profile C

How Reynisfjall affects the wave and transform is now clear, the wave which affect the wave at profile C is the one from 6 m depth. 1000 m further to east from the profile F the shadow effect from the Reynisfjall Mountain stop having influence on the wave data's. The wave data's which should be used there is the one taken from -20 m depth, because the depth of closure is -20 m and it is advisable to take the wave data's from that depth. The beach profile F was measured 2004 and 2008 and was the net volume change per meter about -2000 m^3. If it is given that the volume change per meter is the same along the beach it gives -6 Mm^3 in volume change along the coast, from 1000 m east of profile F to the Reynisfjall Mountain. Figure 4.12 shows the net sediment transport with wave data from three different depth with profile direction of 185°. The wave data from 10 and 12 m depth are not the affected wave because there weren't accumulation over these years. The wave data for 20 m depth gives -400 Mm^3 which is way to much sediment transport over these years. (for profile orientation of 193° see appendix)

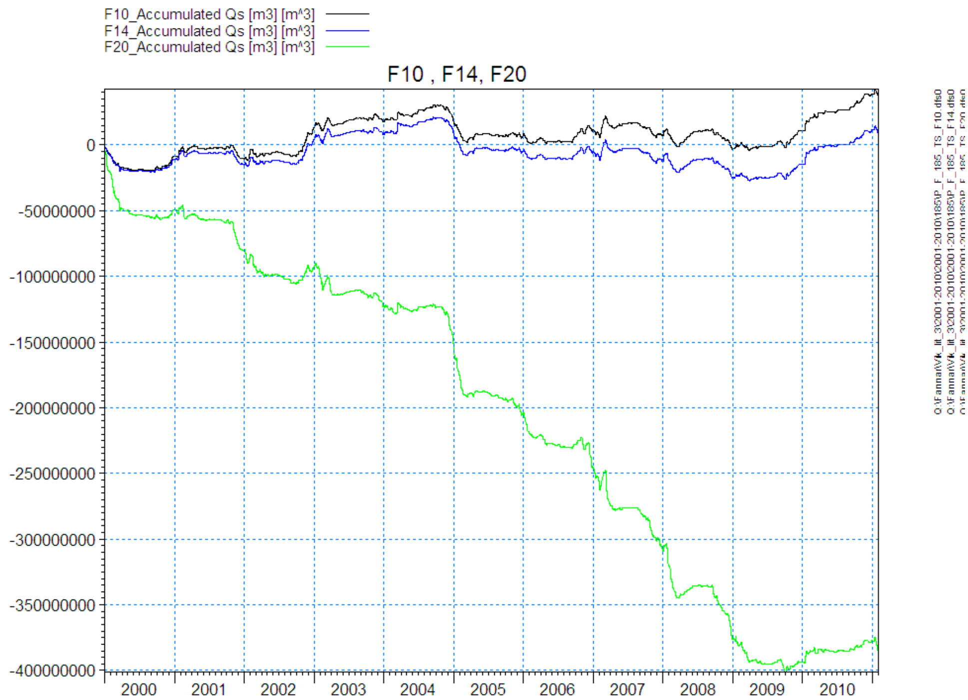


Figure 4.12: Profile F for 185° - Wave data's from , 10, 14 and 20 m depth

The accumulation with a profile orientation of 193°, the coastline direction 1000 m from profile F can be seen in Figure 4.13. Comparing the measured transport of -6 Mm^3 to the Figure the difference is ∼8 times more or about 50 Mm^3 with wave data's taken from 20 m depth in front of profile F. and ∼10x more for wave data 1000 m from profile F, at 20 m depth. Litpack is unable to calculate the correct sediment transport because of the shelter of Reynisfjall. The results that lipack gives is the possible accumulation and since the sediment transport to east starts from Reynsifjall it is 10x less than Litpack gives.

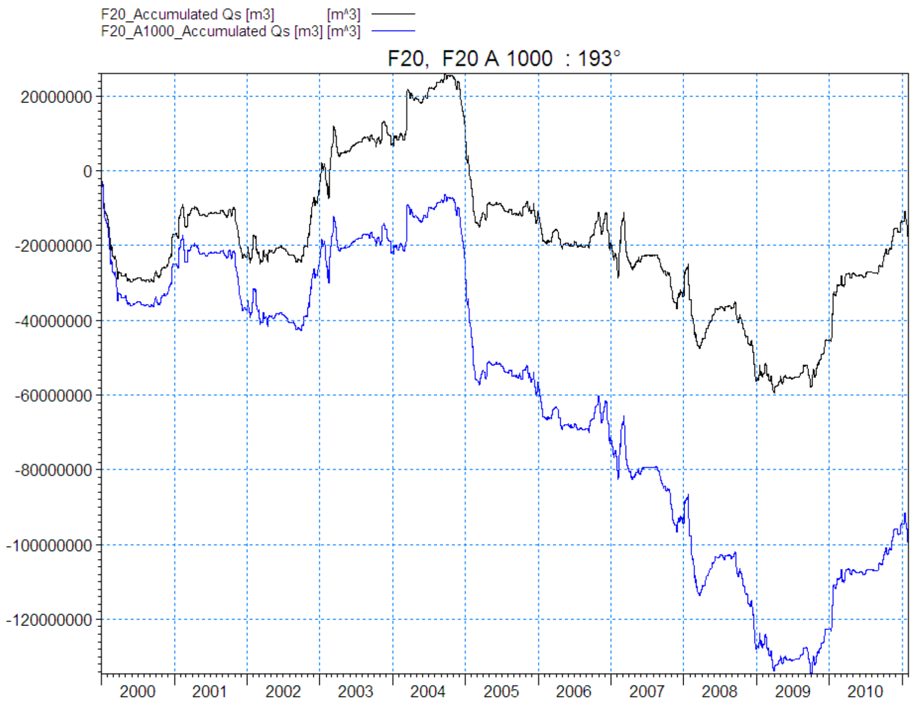


Figure 4.13: Profile F - Wave data's from 20 m depth in a line from profile F and 1000 m from profile F

CHAPTER 5

Results of the Sediment Transport at Vík

5.1 Sediment transport calculations result from Litdrift

The results from Litdrift gives possible accumulation on the area which makes it essential when calculate the actual sediment transport to calibrate the model correctly. The sediment transport to East starts immediately East of Reynisfjall and therefore the possible sediment transport is estimated to be 10 times less than Lipack gives. If the wave direction is more to West and therefore the sediment transport also to West the possible sediment transport is closer to the reality because the coast East of Vík is long. The calibration which DHI made for the coast was for the years 2008-2010 when the wave direction was more to West than for the period 2004-2008 which could affect their solution. It is important when using litdrift model to calibrate it with data that span more than one period.
Even though the volume calculations in Litpack aren't accurate they give good estimation for the directional equilibrium of the profile.

5.2 Equilibrium at the Vík's coast

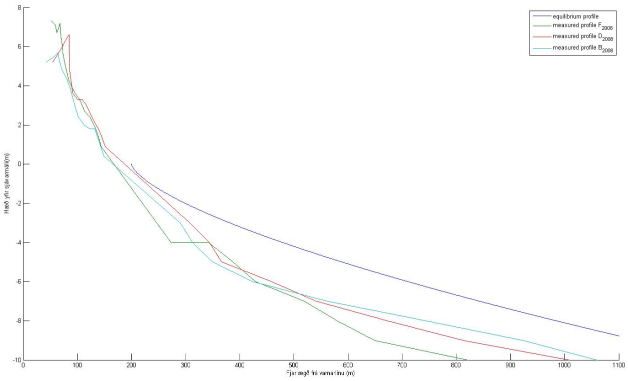
The shape of the coast by Vík í Mýrdal is affected by Reynisfjall. It reaches directional equilibrium 2.5km from Víkurá, 1000m east of profile F, river where the direction of the coastal profile is 193° from North.

5.2.1 Equilibrium profile

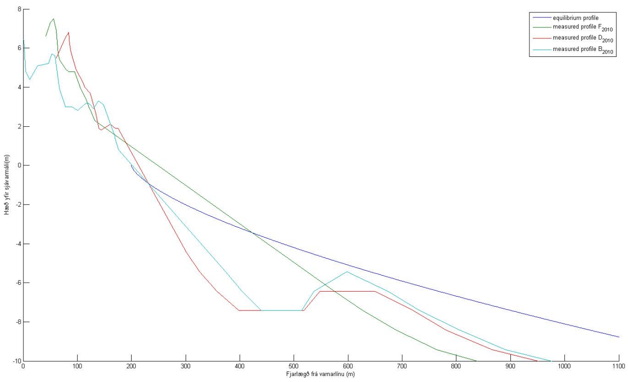
The coastal profile at the coast by Vík are changing between the years which state that the beach equilibrium is not obtained. In Figure 5.1 the profile is compared to profile B, D and F (measured 2010 and 2008 October). The profiles are far from being under equilibrium and therefore it can be estimated that the beach will change over the next years. It is important to take into account that equilibrium profile is only valid with depth less than d_c.

Measurements made 2010 are not good for the reason that the distance between each measure point is long which could affect the sediment transport results, profile from 2008 was picked to run Litpack because it is more accurate than 2010 profile. On figure 5.2b profile F_{2008} is compared with equilibrium profile with $d_{50} = 0.25$ mm and $d_{50} = 0.30$ mm, $d_{50} = 0.25$ mm is average size along the profile.

On figure 5.2b the equilibrium profile is offset by 170 m towards to the land. The profile after -4 m is close to be in equilibrium but the profile above -4 m is not in equilibrium which can result that the coast will need to retreat about 170 m in the next years to reach equilibrium.

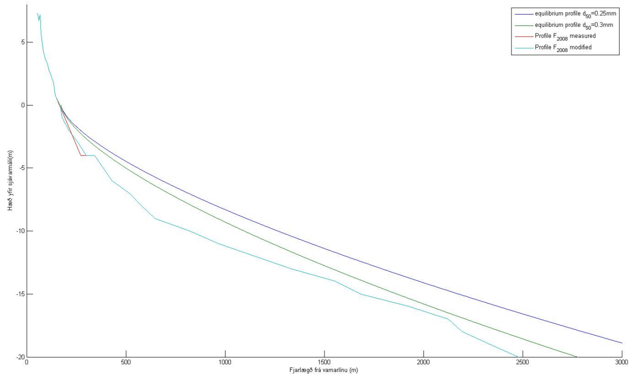


(a) 2008

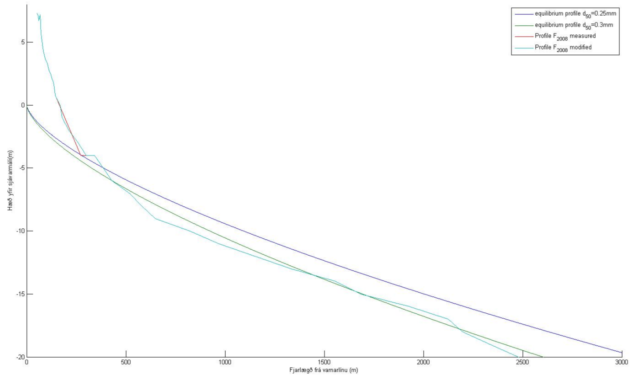


(b) 2010

Figure 5.1: Equilibrium profile vs profile B,D and F



(a) Modified F profile compared to equilibrium profile



(b) Modified F profile compared to equilibrium profile. Equilibrium profile offset by 150 m

Figure 5.2: Figure shows modified profile F compared by different equilibrium profile

5.2.2 Spiral Form of Vík's coast

The shape of Vík's coastline makes the parabolic shape better approach for Vík than the Logarithmic shape, because the Reynisfjall Mountain is the only fixed

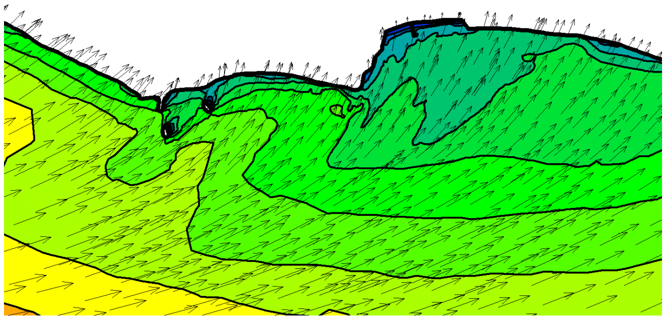


Figure 5.3: South west wave - Diffraction point estimated

point at the coast. As stated earlier the formula for calculate parabolic form is only valid under beach equilibrium. To find the diffraction point wave data from the dominating wave direction is needed, i.e. SW-direction (190-200°). From figure 5.3 the diffraction point is estimated to be close to the end of the Reynisfjall Mountain (1.5km from it in both direction), where the SW-wave starts to turn. Given the directional equilibrium of the beach is around 190° and the location of the beach directional equilibrium is ∼1000m east of Profile F, $\beta = 60°$ and $R_0 = 4360m$ (see figure in appendix, A.4) the spiral shape can be calculated.
According to the figure the beach will retreat the next years and form a spiral shape. The coastline at the profile F will retreat to the Ring road and east of the profile the coast will reach directional equilibrium, i.e. 193°.
By comparing the spiral form with the equilibrium profile from the location of profile F, see figure 5.4, the beach erosion is estimated to be similar. The spiral reach 160 m behind the coastline from 2008 and profile F would reach equilibrium 150 m from the coastline from 2008.

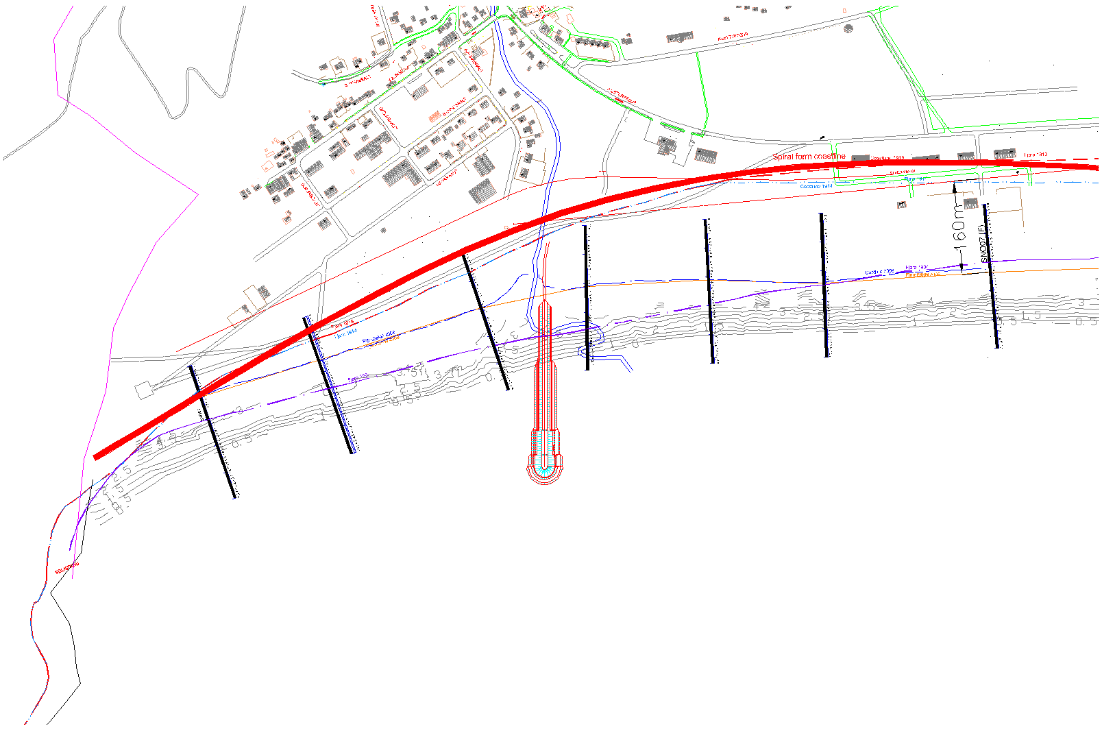


Figure 5.4: Vík's Coast - Spiral coastline form compared with the measured coastline

5.3 Erosion solution

A groyne next to Víkurá River will be placed the year 2011 and will reach to -6 m water depth, because the net drift is from -2 m to -7 m water depth (see Chapter 4.2.3). It was decided to pick that solution for the reason it is more efficiency in the area by Vík because the sediment transport is along a curved coast and the area where the groyne will be placed is under the shadow effect from Reynisfjall. A detached breakwaters would not work properly in the shadow area of the Reynisfjall Mountain. The reason that the groyne was placed next to the Víkurá River was because the possible formation of the coast will be about 600m long if the groyne is fully functional and the distance from the Víkurá River to the Reynisfjall Mountain is about 600 m. The groyne should be placed in the direction of 180° because that's the direction when the net sediment transport with affected wave is zero, the direction which is perpendicular to the affected incoming wave.

The groyne will prevent further erosion West of the Víkurá River and the beach will get a spiral form according to the size of the groyne as is shown in Figure 5.5. Because the sediment transport increases with a distance from the Reynissfjall Mountain and the location of the groyne is 600 m from the mountain it is possible that the accumulation will not fill the groyne, its west side, which follows that the erosion will not be as much on the other side, east side. The beach east of the Víkurá River will retreat for the next years, at profile F it will reach the ring road. It is possible to place another groyne in the near future in a distance east from the groyne, next to the Víkurá river, to save the area from further erosion next to the village. Figure 5.6 shows a possible solution of a groyne field. The coastline east of the groyne is compared with today's coastline but it can be assumed that it will retreat more than showed on the Figure.

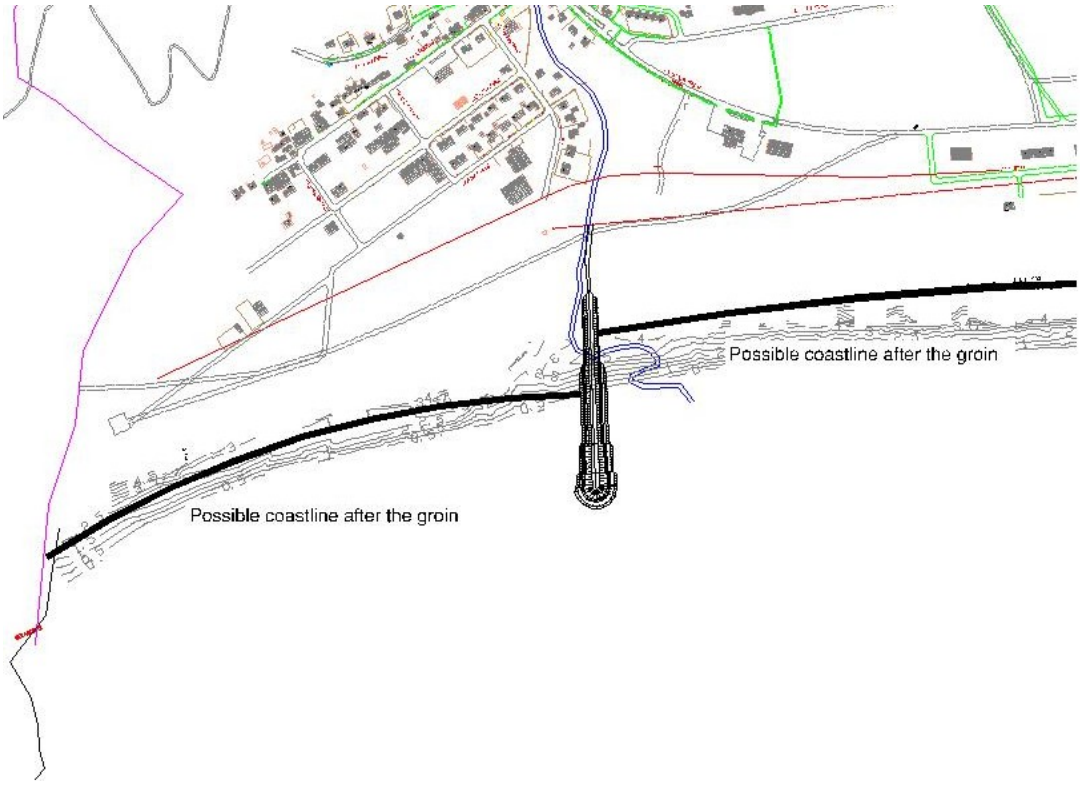


Figure 5.5: Groyne - The coast in the equilibrium at the groyne

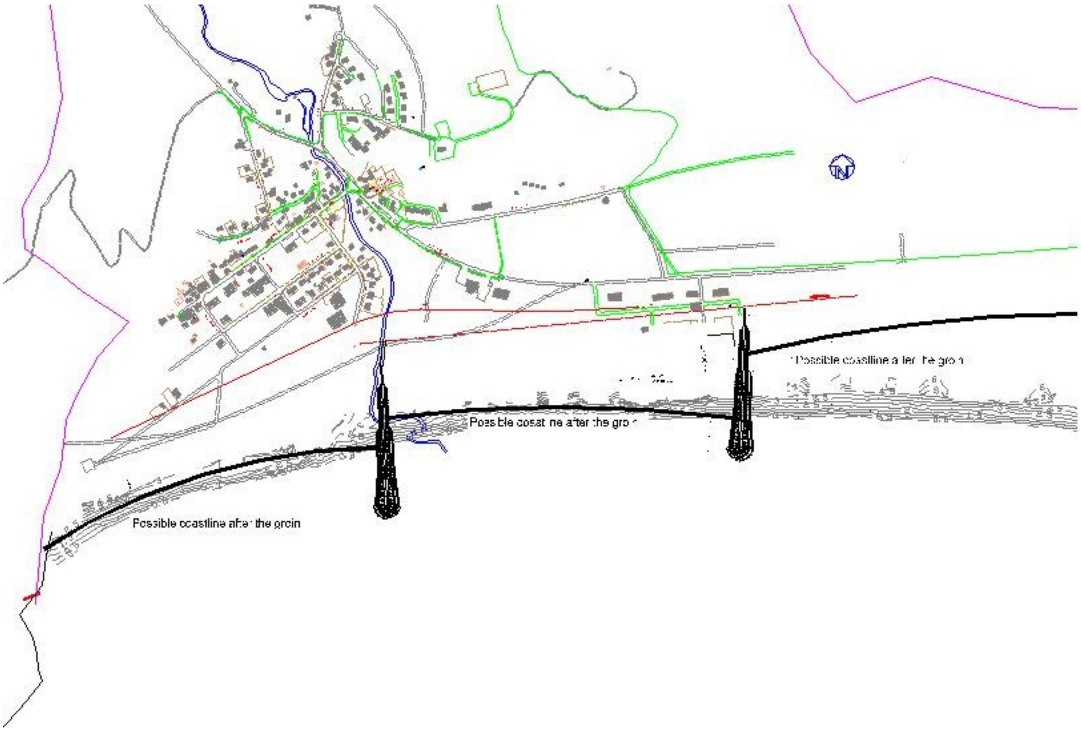


Figure 5.6: Groyne Field - Possible shape of a groyne field by Vík

CHAPTER 6

Conclusion

To estimate how the sediment transport will be in the future it is essential to have a knowledge of the coastal history of the area in order to calibrate a sediment transport model. The Litpack sediment transport model is accurate when the conditions are right, i.e. a long beach with a single sloped beach profile. The drive force of sediment transport is the angle between the wave direction and the angle normal to the beach. In this study the calibration of the coast at Vík was very much depended on the wave direction directly in front of the town and in the lea of Reynisfjall. For the years 2004-2008, when East going wave direction was dominating, Litpack gives 10 times more sediment transport to East than in prototype but for the years 2008-2010, when West going wave direction was dominating, it gives approximately the same West going sediment transport as the prototype.

The parabolic shape and the equilibrium profile theories estimate that the beach equilibrium is about 150 m landward from the 2008 coastline, with the assumption that the todays coastline East of Vík is under equilibrium when its direction is about 193°. Without nourishment of new beach material, e.g. eruption of Katla, the coastline East of Vík will in the long term most likely retreat to Hjörleifshöfði which connect the beach with two headlands, the coastline will have spiral shape form between the headlands. It will takes the nature decades or centuries to reach the beach equilibrium, if it is any, and meanwhile it is possible that Katla will erupt again bringing huge amount of material to the ocean so the beach will emerge.

The coastline stabilization because of the groyne will be significant the first years and will be close to equilibrium. From that time it can take the coastline, East of the groyne, years/decade to reach static equilibrium. If the town will expand to East in the future a groyne field would solve the erosion problem for the area under affect of them.

Analysis of the groyne efficiency is important the first years for better understanding of if the solution is working properly under these conditions. A knowledge of how a groyne solution will affect the area is limited in Iceland and is a further study on how it works essential for deciding if another groyne would be a feasible solution.

APPENDIX A

Figures of Vík

A.1 overview of points

The wave data which were used in the simulations.

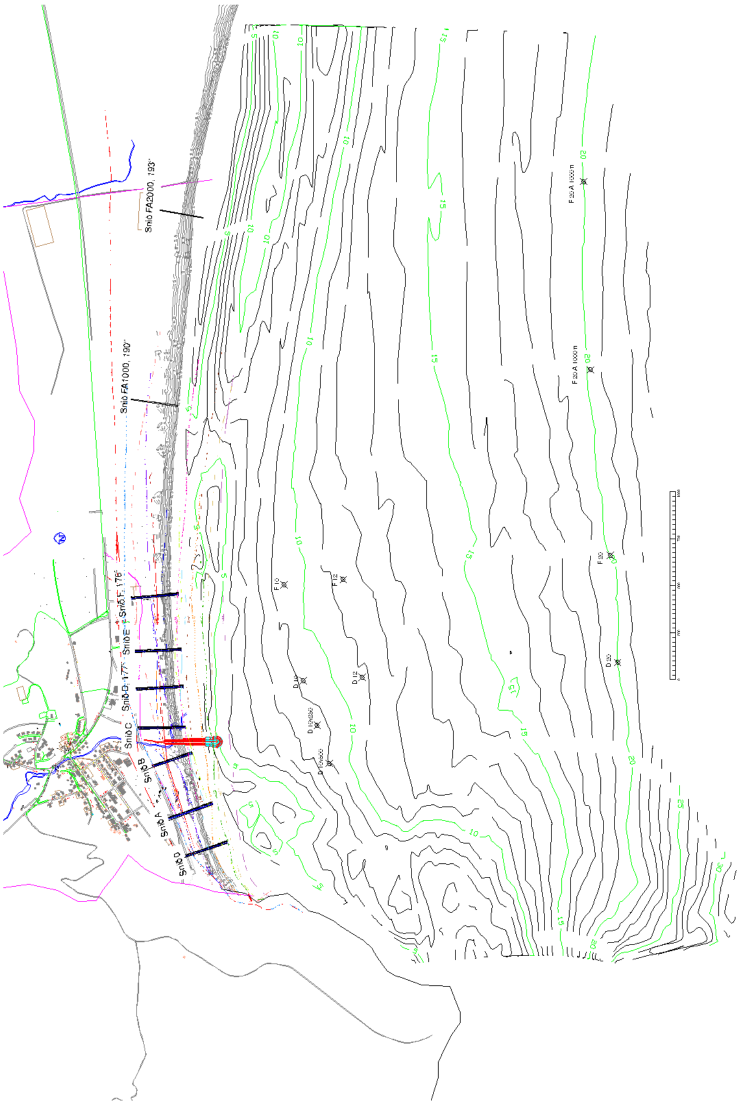


Figure A.1: The model points - points which where ran in litpack

A.2 Wave Transformation

Wave transformation from South wave. The wave current is unable to make a west going sediment transport current.

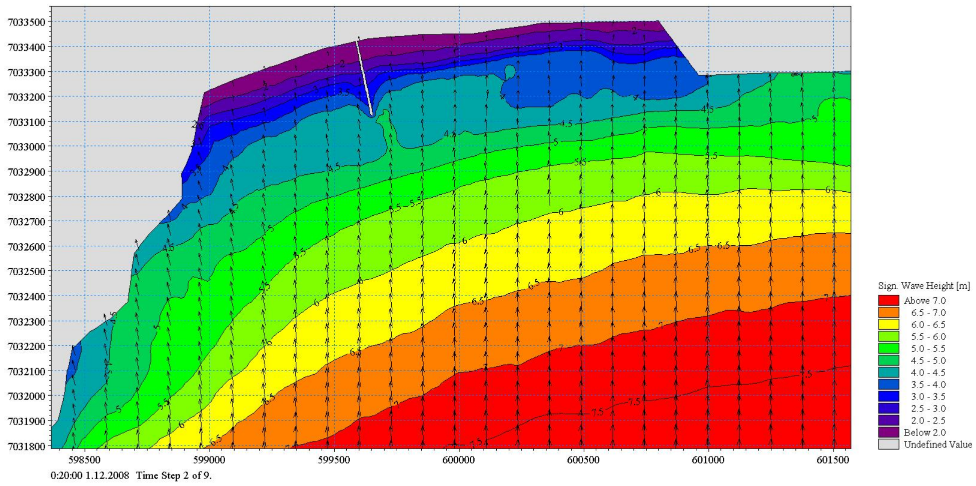


Figure A.2: South wave - Wave transformation from South wave.

South-West waves generates South-West current

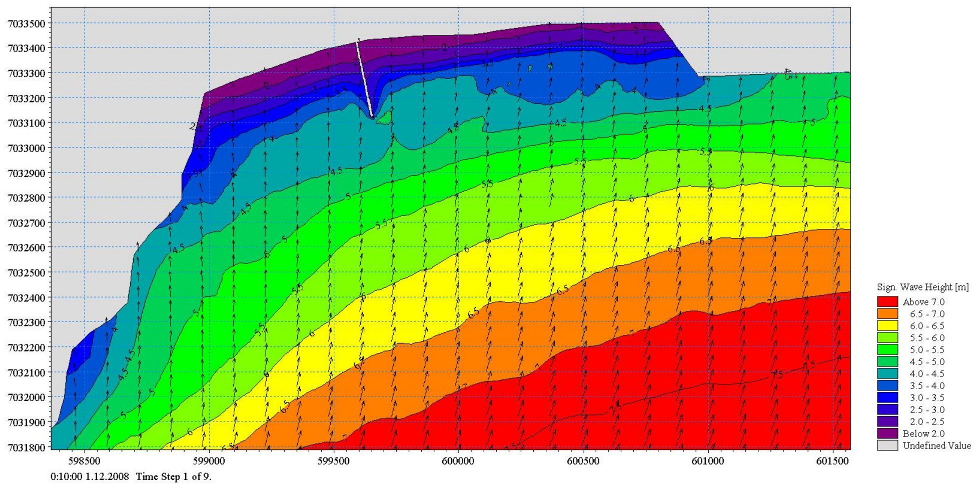


Figure A.3: South-West wave - Wave transformation from South-west wave.

A.3 Spiral Shape

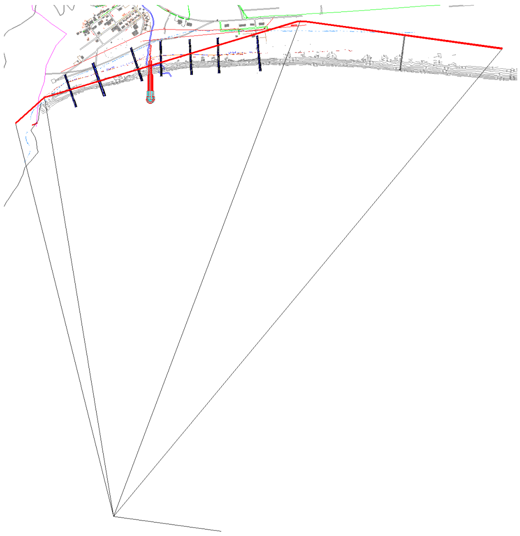


Figure A.4: Spiral shape - How the spiral was estimated in Vík's coast

The figure shows how the spiral was done. The start of the spiral is the diffraction point which was estimated to be around 1500m from the end of the Reynsifjall Mountain.

APPENDIX B

Profiles Measurements

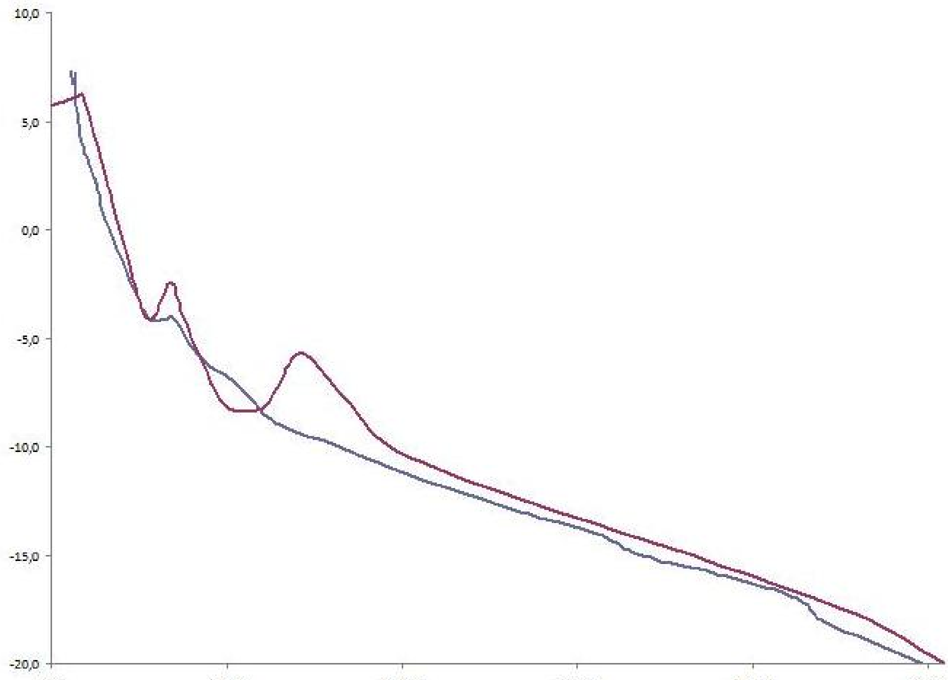


Figure B.1: Profile F - Measurements from 2004 and 2008

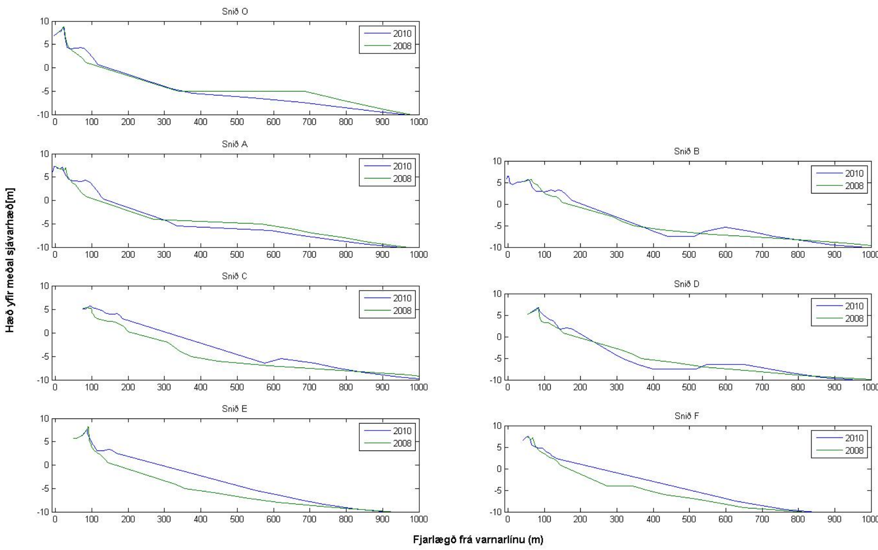


Figure B.2: Profiles Measurements - 2008 and 2010 profile measurements

APPENDIX C

Litdrift results

C.1 points explanations in Icelandic

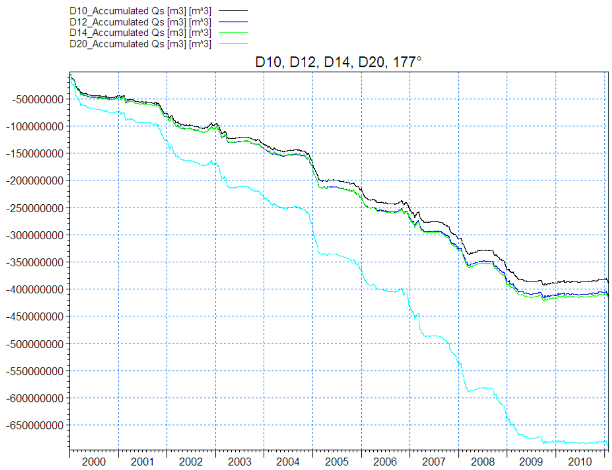


Figure C.1: Snið D fyrir 177°: 10 vs 12 vs 14 og 20m dýpi - Samanburður á flutningsgetu í sniði D með 177° sniðstefnu fyrir öldugögn af mismunandi dýpi ; 10,12,14 og 20m. Prófíll F_{mod}

Samanburðurinn sýnir að flutningsgetan er mest fyrir öldugögn af 20m dýpi, um

-680Mm^3, en nokkuð svipuð fyrir öldugögn af 10,12 og 14m dýpi eða um -380 til -410 Mm^3, þar sem neikvæð flutningsgeta vísar til austurs.
Þannig minnkar flutningsgetan þegar öldugögnin eru tekin af minna dýpi. Þetta verður að skýrast með því að öldureikningar í $MIKE_{21,SW}$ Sveigja ölduna meira í átt að þvi að vera þvert á ströndina heldur en innbyggð öldusveigja í $Mike_{LITTPACK,LITDRIFT}$ reiknilíkaninu.

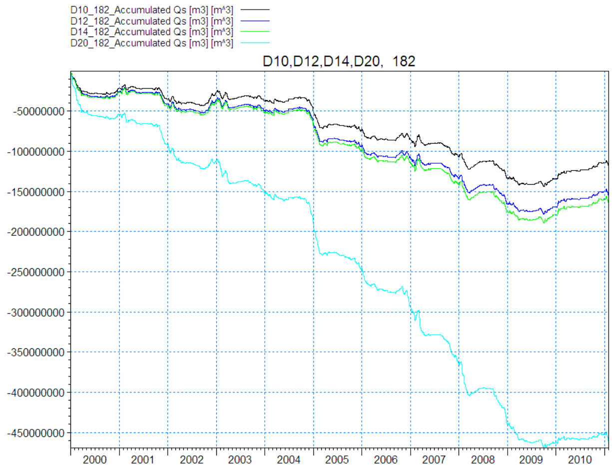


Figure C.2: Snið D fyrir 182°: 10 vs. 12 vs. 14 og 20m dýpi - Samanburður á flutningsgetu í sniði D með 182° sniðstefnu fyrir öldugögn af mismunandi dýpi ; 10,12, 14 og 20m

Flutningsgeta í sniði D með 182° sniðstefnu er nokkuð minni en í sniði með 177° sniðstefnu, sbr mynd C.1. Að öðru leiti er niðurstöðurnar svipaðar, þ.e. flutningsgeta fyrir öldugögn af 20m dýpi er mest -450Mm^3, en er svipaður fyrir öldugögn af 10, 12 og 14 m dypi, -110 til -160 Mm^3. Flutningsgetan minnkar þegar öldugögnin eru tekin af minna dýpi.

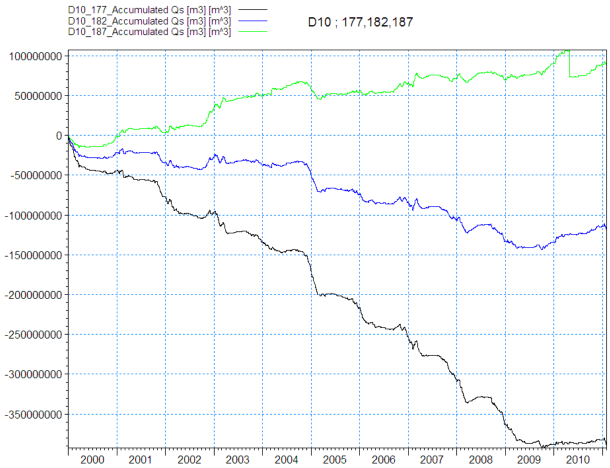


Figure C.3: Snið D fyrir 177°, 182° og 187°; 10m Dýpi - Samanburður á flutningsgetu í sniði D fyrir öldugögn á 10m dýpi, fyrir mismunandi stefnu strandar. Upphafsstefnu 177° með 5° og 10° stefnubreytingu, Prófíll F_{mod}

Samanburðurinn sýnir að með 5° stefnubreytingu, 182°, breytist flutningsgetan úr -380Mm^3 í -110Mm^3 og með 10° stefnubreytingu, 187°, hefur flutningsgeta snúist til vesturs, +90Mm^3. Því má búast við að jafnvægi í sandflutningi til austurs og vesturs náist fyrir 184° sniðsstefnu, í sniði D.

Raunveruleg stefna strandarinnar í sniði D snýr i 177°.

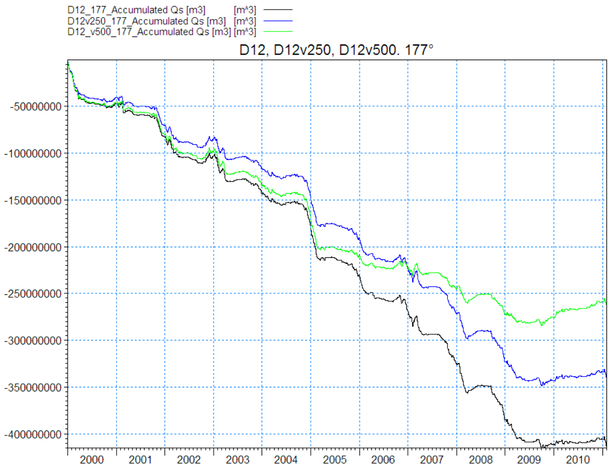


Figure C.4: Snið D, D$_{v250}$ og D$_{v500}$ fyrir 177°, 12m - Samanburður á flutningsgetu í sniðum D, D$_{v250}$ og D$_{v500}$ fyrir 177° stefnu sniðs og öldugögn af 12m dýpi. Fyrir Prófíl F_{mod}

Samanburðurinn sýnir að flutningsgetan til austurs minnkar þegar farið er til vestur frá sniði D annars vegar 250m og hins vegar 500m.
Miðað við öldugögn af 12m dýpi er flutningsgetan um -340Mm^3 í sniði D$_{v500}$ og um -260Mm^{3}" í sniði D$_{v500}$
Þettaer nokkuð meiri flutningsgeta en fyrir öldugögn af 10m dýpi, sjá mynd C.5.
Stefna strandarinnar í sniðunum 3. (þ.e. D, D_{v250}, D_{v500}) er:
$D = 177°$, $\qquad D_{v250} = 163°$, $\qquad D_{v500} = 160°$

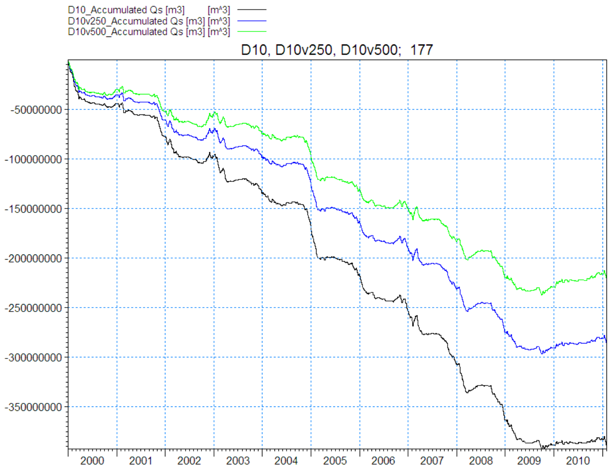


Figure C.5: Snið D, D$_{v250}$ og D$_{v500}$, 177°,10m - Samanburður á flutningsgetu í sniðum D, D$_{v250}$ og D$_{v500}$ fyrir 177° stefnu sniðs og öldugögn af 10m dýpi.

Samanburðurinn sýnir að flutningsgetan til austurs minnkar þegar farið er til vestur frá sniði D, 250 og 500m. Miðað við öldugögn af 10m dýpi er flutningsgetan -350Mm^3 í sniði D, -250Mm^3 í sniði D$_{v250}$ og -210Mm^3 í sniði D$_{v500}$.
Þetta er heldur minni flutningsgeta en fyrir öldugögn af 12m dýpi, sjá mynd C.4.
Stefna strandarinnar í sniðunum 3. (þ.e. D, D_{v250}, D_{v500}) er:
$D = 177°$, $\quad D_{v250} = 163°$, $\quad D_{v500} = 160°$

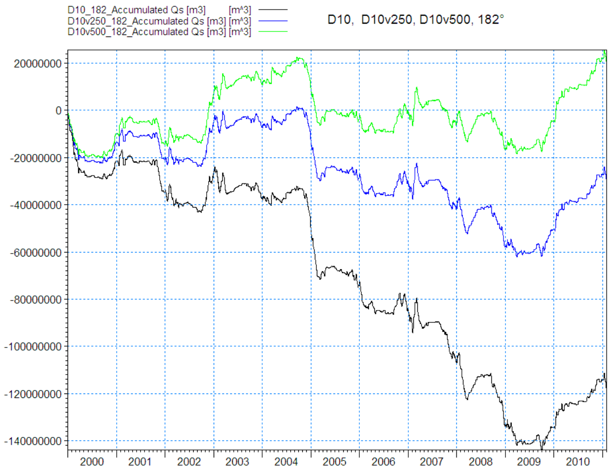


Figure C.6: Snið D, D_{v250} og D_{v500}, 182°, 10m - Samanburður á flutningsgetu í sniðum D, D_{v250} og D_{v500} fyrir 182° stefnu sniðs og öldugögn af 10m dýpi.

Eins og á mynd C.5, sýnir samanburðurinn að eftir 5° snúning (úr 177° í 182°) er flutningsgeta til austurs mest á austasta sniðinu en minnkar eftir því sem farið er vestur eftir 10m dýptarlínunni. Miðað við öldugögn af 10m dýpi er flutningsgetan +20Mm^3 í sniði D, -25Mm^3 í sniði D_{v250} og -110Mm^3 í sniði D_{v500}

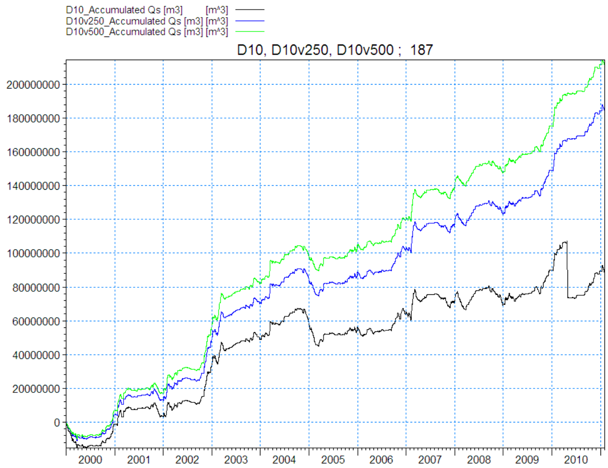


Figure C.7: Snið D, D_{v250} og D_{v500},187°, 10m - Samanburður á flutningsgetu í sniðum D, D_{v250} og D_{v500} fyrir 187° stefnu sniðs og öldugögn af 10m dýpi.

Miðað við fasta stefnu strandarinnar í 187° þá eykst flutningsgetan til vesturs. Þetta er fyrir öldugögn á 10m dýpi fyrir snið D_{v250} og D_{v500} (250 og 500m vestur við snið D). Í samræmi við myndir C.5 og C.6 er flutningsgeta til vestur minnst í punkti D eftir snúning um 10° en eykst eftir því sem farið er vestur eftir 10m jafn dýpislínunni.

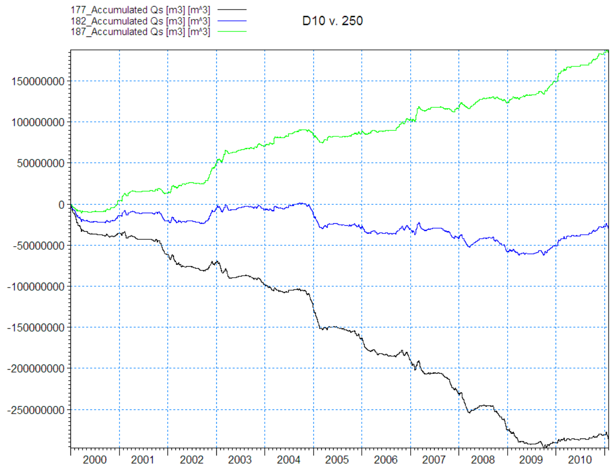


Figure C.8: D$_{v250}$, 177°,182°,187° fyrir 10m - Samanburður á flutningsgetu á sniði D$_{v250}$ á 10m dýpi fyrir mismunandi stefnu strandar, upphafsstefnu 177° og með 5° og 10° stefnubreytingu

Samanburðurinn sýnir að með 5° stefnubreytingu frá upphafsstefnunni 177° í 182° þá minnkar flutningsgetan til austurs, úr -280Mm^3 með -30Mm^3 og með 10° stefnubreytingu í +180Mm^3. Búast má við að jafnvægi í flutningi til austurs og vesturs náist fyrir 183° normalstefnu strandar. Mæld stefna strandarinnar í sniði D_{v250} er 163°

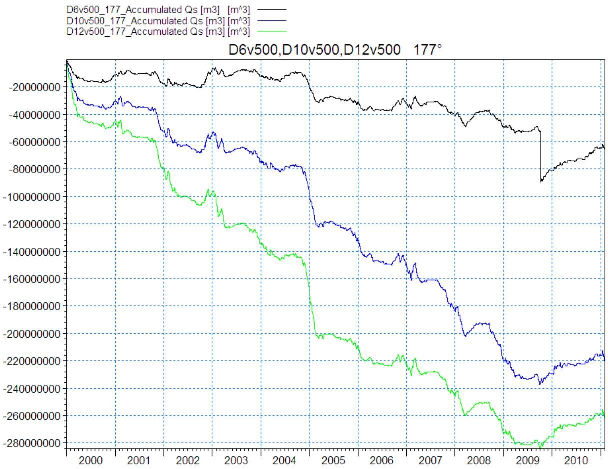


Figure C.9: Snið D_{V500}, 177° , 6, 10 og 12m dýpi - Samanburður á flutningsgetu í sniði D með öldugögn úr punktum á 6,10 og 12m dýpi. Sniðstefna í 177°

Samanburður fyrir 3 mismunandi tímaraðir fyrir snið D_{V500} með sniðstefnu 177°. Mæld stefna sniðs D_{V500} er 160°. Fyrir tímaröðina í 12m dýpi er flutningsgetan -280Mm^3, fyrir 10m dýpi er hún -240Mm^3 en fyrir 6m dypi er hún -60Mm^3. Þannig minnkar flutningsgetan með minna dýpi.

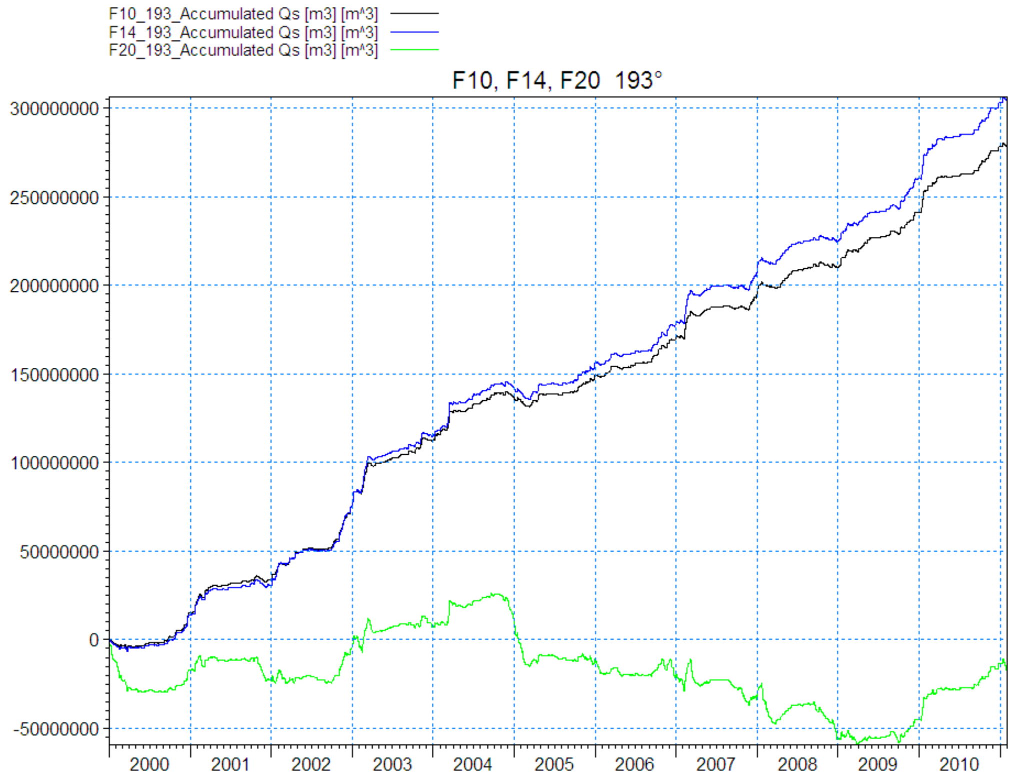


Figure C.10: Snið F fyrir 193°, 10, 14 og 20m - fyrir 193°

Samanburðurinn sýnir að fyrir sniðstefnu 193° og öldugögn tekin í 20m dýpi er flutningsgetan í jafnvægi, en fyrir öldugögn miðað við 10m og 14 m dýpi er flutningsgetan +300Mm^3 til vesturs. Samanber mynd 4.12 er flutningsgetan til vesturs en ekki austurs. Sniðstefna strandarinnar í sniði F er 179°.

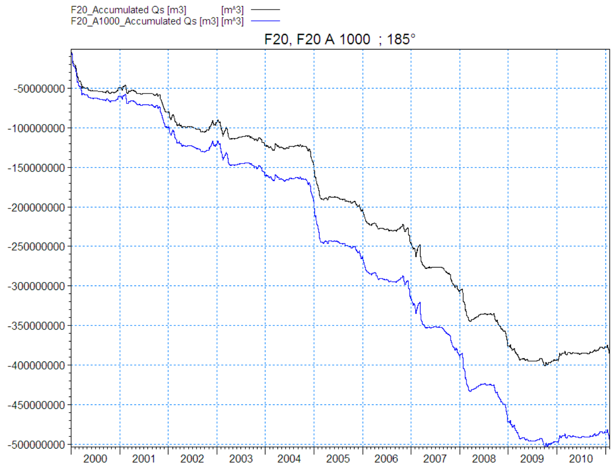


Figure C.11: Snið F og F_{A1000} fyrir 185° og 20m dýpi - 185

Samanburður á sniðum F og F_{A1000} miðað við sniðstefnu 185° á 20m dýpi. Fyrir snið F er flutningsgetan -400 Mm^3 en og -500Mm^3 fyrir F_{A1000}. Sniðstefna strandarinnar í sniði F er 179° og 185° í F_{A1000}

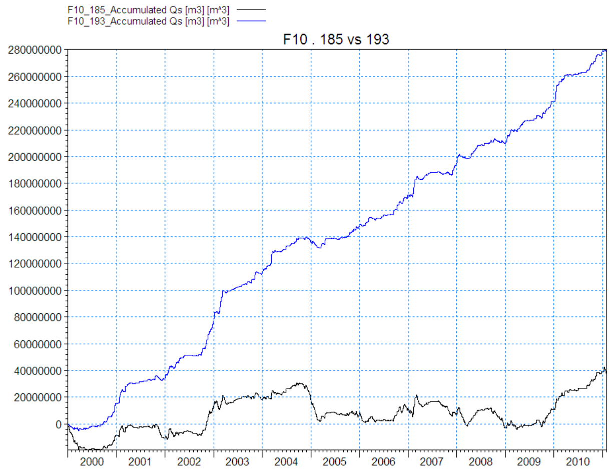


Figure C.12: Snið F, 185° og 193° , 10m dýpi - 185° vs. 193°

Samanburður á sniði F fyrir sniðstefnu 185° og 193° og 10 m dýpi. Sjáum að miðað við öldugögn frá sniði F úr 10m dýpi er sandflutningurinn í jafnvægi þegar sniðsstefnan er í 185° og rétt jákvæð flutningsgeta , 40Mm^3. Þegar sniðstefnan er 193° hækkar flutningsgetan til vesturs margfallt og er 280Mm. Ef borið er saman mynd **??** má sjá að áhrifa öldusveigju skekkju milli Mike$_{SW}$ og Mike$_{Litpack_{Litdrift}}$ er farið að hafa áhrif á niðurstöðuna fyrir öldugögn á 10m dýpi. SV-aldan er ekki jafn mikil og hún er í á 20m dypi

C.2 Analysis points

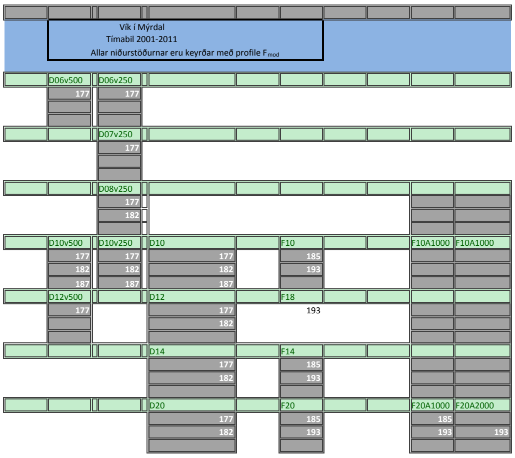


Figure C.13: Points which were tested in Litdrift

An excel sheet showing which wave data's have been modeled in Litpack.

APPENDIX D

Matlab code

D.1 equilibrium proflie

```
 clear all
clc
close all

% F 2010 Okt
X_F10=[42 50 56 61 65 67 79 84 95 105 116 121 125 132 575 627 ...
    689 764 892];
Y_F10=[6.6 7.3 7.5 6.9 5.7 5.4 4.9 4.8 4.8 4.0 3.4 3.0 2.8 2.3 ...
    -6.43 -7.43 -8.43 -9.43 -10.43];

X_F08=[52.1 59.7 62.0 64.4 68 70 71 73 77 84 94 104 114 123 127 ...
    134 139 144 273 343 387 429 519 580 649 822];
Y_F08=[7.3 7.1 6.7 6.9 7.2 6.5 6.3 5.7 5.1 4.3 3.7 3.3 2.7 2.4 ...
    2.2 1.8 1.4 0.9 -4 -4 -5 -6 -7 -8 -9 -10];

% D 2010 Okt
X_D10=[61 77 84 86 88 98 111 114 124 134 140 144 161 161 170 175 ...
    301 326 358 398 518 548 650 720 781 866 1013];
```

```
Y_D10=[5.5 6.5 6.8 6.2 5.8 4.9 4.2 4.0 3.7 2.7 1.9 1.8 2.1 2.1 ...
    1.9 1.9 -4.43 -5.43 -6.43 -7.43 -7.43 -6.43 -6.43 -7.43 -8.43 ...
    -9.43 -10.43];

X_D08=[54.2 70.5 78.5 80.0 84.9 86 92 101 109 117 129 141 152 ...
    308 344 366 458 541 673 813 1009];
Y_D08=[5.2 5.9 6.3 6.4 6.6 4.8 3.6 3.3 3.3 3.0 2.3 1.7 0.9 -3 -4 ...
    -5 -6 -7 -8 -9 -10];

%B 2010 Okt
X_B10=[-4 -2 1 5 12 27 47 53 59 67 78 90 101 113 119 124 130 139 ...
    148 160 169 169 176 374 404 440 453 469 514 537 598 674 732 ...
    806 891 1038];
Y_B10=[5.8 6.5 6.4 4.8 4.4 5.1 5.2 5.7 5.6 3.9 3.0 3.0 2.8 3.1 ...
    3.2 3.1 2.9 3.3 3.1 2.2 1.5 1.4 0.8 -5.43 -6.43 -7.43 -7.43 ...
    -7.43 -7.43 -6.43 -5.43 -6.43 -7.43 -8.43 -9.43 -10.43];

X_B08=[43 57 65 66 72 80 87 94 102 113 123 132 141 149 290 313 ...
    349 424 561 744 924 1060];
Y_B08=[5.2 5.5 5.7 5.3 4.8 4.4 3.9 3.1 2.4 2.0 1.8 1.8 1.1 0.4 ...
    -3 -4 -5 -6 -7 -8 -9 -10];

% C 2008 okt
X_C08=[77.5 86.7 93.0 98.6 99.7 101 103 106 108 114 143 153 163 ...
    178 188 201 309 326 343 375 447 589 782 974 1103 1193 1349 ...
    1627.0 1782.0 2004.0 2123.0 2267.0 2375.0 2492 2567];
Y_C08=[5.2 5.3 5.2 5.2 4.9 4.3 4.1 3.8 3.4 3.0 2.4 2.5 2.3 1.7 ...
    1.3 0.2 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 -13 -14 -15 -16 ...
    -17 -18 -19 -20];
%1193 1349 1627.0 1782.0 2004.0 2123.0 2267.0 2375.0 2492 2567
% -11 -12 -13 -14 -15 -16 -17 -18 -19 -20

x=[0:1:4000];
%d=[0:-0.1:-10];
A=0.092;
m=0.67;
%x=(d./A).^(1./m);
d=-1.*A.*x.^m;
for i=1:length(x)
x(i)=x(i)+200;
end
```

```
figure('color','w')
plot(x,d,X_F10,Y_F10,X_D10,Y_D10,X_B10,Y_B10)
axis([0 1100 -10 8])
legend('equilibrium profile','measured profile ...
    F_{2010}','measured profile D_{2010}','measured profile ...
    B_{2010}')
box off
figure('color','w')
plot(x,d,X_F08,Y_F08,X_D08,Y_D08,X_B08,Y_B08)
axis([0 1100 -10 8])

legend('equilibrium profile','measured profile ...
    F_{2008}','measured profile D_{2008}','measured profile ...
    B_{2008}')
box off
figure('color','w')
plot(x,d,X_C08,Y_C08)

legend('equilibrium profile','Profile C_{2008}')
axis([0 3000 -20 8])
box off
```

D.2 Wave Height

```
close all
clear all
clc

A=load('63_19_2001_2010_hluti1.txt');
h=A(:,1);

ibeg=datenum(2000,01,01,00,00,00);
end=datenum(2011,02,02,00,00,00);
i1=datenum(2001,01,01,00,00,00);
i2=datenum(2002,01,01,00,00,00);
i3=datenum(2003,01,01,00,00,00);
i4=datenum(2004,01,01,00,00,00);
i5=datenum(2005,01,01,00,00,00);
i6=datenum(2006,01,01,00,00,00);
```

```
i7=datenum(2007,01,01,00,00,00);
i8=datenum(2008,01,01,00,00,00);
i9=datenum(2009,01,01,00,00,00);
i10=datenum(2010,01,01,00,00,00);
i11=datenum(2011,01,01,00,00,00);


date=[ibeg:0.25:end];
c1=[];c2=[];c3=[];c4=[];c5=[];c6=[];c7=[];c8=[];c9=[];c10=[];c11=[];
for i=1:length(h)
    if date(i) ≥ ibeg && date(i) < i1
        c1=[c1 h(i)];
    end

    if date(i)≥i1 && date(i)<i2
        c2=[c2 h(i)];
    end

    if date(i)≥i2 && date(i)<i3
        c3=[c3 h(i)];
    end

    if date(i)≥i3 && date(i)<i4
        c4=[c4 h(i)];
    end

    if date(i)≥i4 && date(i)<i5
        c5=[c5 h(i)];
    end

    if date(i)≥i5 && date(i)<i6
        c6=[c6 h(i)];
    end

    if date(i)≥i6 && date(i)<i7
        c7=[c7 h(i)];
    end

    if date(i)≥i7 && date(i)<i8
        c8=[c8 h(i)];
    end
```

```

    if date(i)≥i8 && date(i)<i9
        c9=[c9 h(i)];
    end

    if date(i)≥i9 && date(i)<i10
        c10=[c10 h(i)];
    end

    if date(i)≥i10 && date(i)<i11
        c11=[c11 h(i)];
    end
end
dagur=[2001:1:2011];
ca1=mean(c1);
ca2=mean(c2);
ca3=mean(c3);
ca4=mean(c4);
ca5=mean(c5);
ca6=mean(c6);
ca7=mean(c7);
ca8=mean(c8);
ca9=mean(c9);
ca10=mean(c10);
ca11=mean(c11);
Ca=[ca1 ca2 ca3 ca4 ca5 ca6 ca7 ca8 ca9 ca10 ca11];

figure('color','w')
bar(dagur,Ca,0.8,'r')
axis([2000 2012 0 5])

cmin1=[];cmin2=[];cmin3=[];cmin4=[];cmin5=[];cmin6=[];cmin7=[];cmin8=[];
cmin9=[];cmin10=[];cmin11=[];
for i=1:length(c1)
    if c1(i)>2.2
        cmin1=[cmin1 c1(i)];
    end
    if c5(i)>2.2
        cmin5=[cmin5 c5(i)];
    end
     if c9(i)>2.2
```

```
        cmin9=[cmin9 c9(i)];
    end
end
for i=1:length(c2)
    if c2(i)>2.2
        cmin2=[cmin2 c2(i)];
    end
    if c3(i)>2.2
        cmin3=[cmin3 c3(i)];
    end
    if c4(i)>2.2
        cmin4=[cmin4 c4(i)];
    end
    if c6(i)>2.2
        cmin6=[cmin6 c6(i)];
    end
    if c7(i)>2.2
        cmin7=[cmin7 c7(i)];
    end
    if c8(i)>2.2
        cmin8=[cmin8 c8(i)];
    end
    if c10(i)>2.2
        cmin10=[cmin10 c10(i)];
    end
     if c11(i)>2.2
        cmin11=[cmin11 c11(i)];
     end
end

ca1=mean(cmin1);
ca2=mean(cmin2);
ca3=mean(cmin3);
ca4=mean(cmin4);
ca5=mean(cmin5);
ca6=mean(cmin6);
ca7=mean(cmin7);
ca8=mean(cmin8);
ca9=mean(cmin9);
ca10=mean(cmin10);
ca11=mean(cmin11);
```

```
Ca=[ca1 ca2 ca3 ca4 ca5 ca6 ca7 ca8 ca9 ca10 ca11];

figure('color','w')
bar(dagur,Ca,0.8,'r')
axis([2000 2012 0 5])
```

D.3 Direction

```
close all
clear all
clc

A=load('63_19_2001_2010_hluti1.txt');
h=A(:,1);
d=A(:,3);

k=[];
kn=[2000:1:2010];
n=[1 5 9];

for j=1:length(kn)
    for i=1:3
        k(j,i)=datenum(kn(j),n(i),1,0,0,0);
    end
end


 ibeg=datenum(2000,01,01,00,00,00);
i1=datenum(2000,05,01,00,00,00);
i2=datenum(2000,9,1,00,00,00);

i3=datenum(2001,1,1,00,00,00);
i4=datenum(2001,5,01,00,00,00);
i5=datenum(2001,09,01,00,00,00);

i6=datenum(2002,1,01,00,00,00);
i7=datenum(2002,05,01,00,00,00);
i8=datenum(2002,09,01,00,00,00);

i9=datenum(2003,01,01,00,00,00);
i10=datenum(2003,05,01,00,00,00);
i11=datenum(2003,09,01,00,00,00);

i12=datenum(2004,01,01,00,00,00);
i13=datenum(2004,05,01,00,00,00);
```

```
i14=datenum(2004,09,01,00,00,00);


i15=datenum(2005,01,01,00,00,00);
i16=datenum(2005,05,01,00,00,00);
i17=datenum(2005,09,01,00,00,00);

i18=datenum(2006,01,01,00,00,00);
i19=datenum(2006,05,01,00,00,00);
i20=datenum(2006,06,01,00,00,00);

i21=datenum(2007,01,01,00,00,00);
i22=datenum(2007,05,01,00,00,00);
i23=datenum(2007,09,01,00,00,00);

i24=datenum(2008,01,01,00,00,00);
i25=datenum(2008,05,01,00,00,00);
i26=datenum(2008,09,01,00,00,00);

i27=datenum(2009,01,01,00,00,00);
i28=datenum(2009,05,01,00,00,00);
i29=datenum(2009,09,01,00,00,00);

i30=datenum(2010,01,01,00,00,00);
i31=datenum(2010,05,01,00,00,00);
i32=datenum(2010,09,01,00,00,00);

i33=datenum(2011,01,01,00,00,00);
 end=datenum(2011,02,02,00,00,00);



date=[ibeg:0.25:end];
c1=[];c2=[];c3=[];c4=[];c5=[];c6=[];c7=[];c8=[];c9=[];c10=[];c11=[];
d1=[];d2=[];d3=[];d4=[];d5=[];d6=[];d7=[];d8=[];d9=[];d10=[];d11=[];





for i=1:length(h)
```

```
    if (date(i) ≥ ibeg && date(i) < i1) || (date(i) ≥ i2 && ...
       date(i) < i3)
        c1=[c1 h(i)];
        d1=[d1 d(i)];
    end

    if (date(i)≥i3 && date(i)<i4) || (date(i)≥i5 && date(i)<i6)
        c2=[c2 h(i)];
        d2=[d2 d(i)];
    end

    if (date(i)≥i6 && date(i)<i7) || (date(i)≥i18 && date(i)<i9)
        c3=[c3 h(i)];
        d3=[d3 d(i)];
    end

    if (date(i)≥i9 && date(i)<i10) || (date(i)≥i11 && date(i)<i12)
        c4=[c4 h(i)];
        d4=[d4 d(i)];
    end

    if (date(i)≥i12 && date(i)<i13) || (date(i)≥i14 && date(i)<i15)
        c5=[c5 h(i)];
        d5=[d5 d(i)];
    end

    if (date(i)≥i15 && date(i)<i16) || (date(i)≥i17 && date(i)<i18)
        c6=[c6 h(i)];
        d6=[d6 d(i)];
    end
      if (date(i)≥i18 && date(i)<i19) || (date(i)≥i20 && ...
         date(i)<i21)
        c7=[c7 h(i)];
        d7=[d7 d(i)];
      end
     if (date(i)≥i21 && date(i)<i22) || (date(i)≥i23 && date(i)<i24)
        c8=[c8 h(i)];
        d8=[d8 d(i)];
     end
     if (date(i)≥i24 && date(i)<i25) || (date(i)≥i26 && date(i)<i27)
        c9=[c9 h(i)];
```

```
        d9=[d9 d(i)];
     end

      if (date(i)≥i27 && date(i)<i28) || (date(i)≥i29 && ...
         date(i)<i30)
        c10=[c10 h(i)];
        d10=[d10 d(i)];
      end

       if (date(i)≥i30 && date(i)<i31) || (date(i)≥i32 && ...
          date(i)<i33)
        c11=[c11 h(i)];
        d11=[d11 d(i)];
       end

end

dagur=[2000:1:2010];
ca1=mean(c1);
ca2=mean(c2);
ca3=mean(c3);
ca4=mean(c4);
ca5=mean(c5);
ca6=mean(c6);
ca7=mean(c7);
ca8=mean(c8);
ca9=mean(c9);
ca10=mean(c10);
ca11=mean(c11);
Ca=[ca1 ca2 ca3 ca4 ca5 ca6 ca7 ca8 ca9 ca10 ca11];

da1=mean(d1);
da2=mean(d2);
da3=mean(d3);
da4=mean(d4);
da5=mean(d5);
da6=mean(d6);
da7=mean(d7);
da8=mean(d8);
da9=mean(d9);
da10=mean(d10);
```

```
da11=mean(d11);
Da=[da1 da2 da3 da4 da5 da6 da7 da8 da9 da10 da11];


figure('color','w')
bar(dagur,Ca,0.8,'r')
%axis([1999 2011 0 200])
box off

figure('color','w')
bar(dagur,Da,0.8,'r')
axis([1999 2011 0 200])
```

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