Landeyjahöfn

Ferry harbour on the South Coast of Iceland

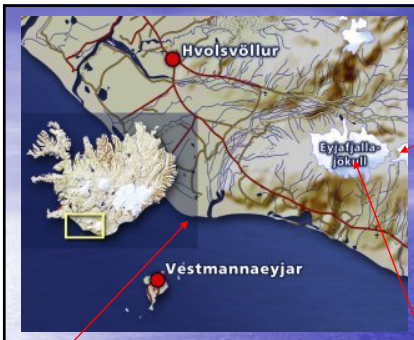
Research and Development of the Ferry Port and navigational criteria for the Ferry

Climate Change:
Global Change and Local Adaptation

6-9 June 2010
Hotel Rangá, Hella, Iceland

Presented by
Gísli Viggósson,
Director of Research and Development Icelandic Maritime Administration

SIGLINGASTOFNUN

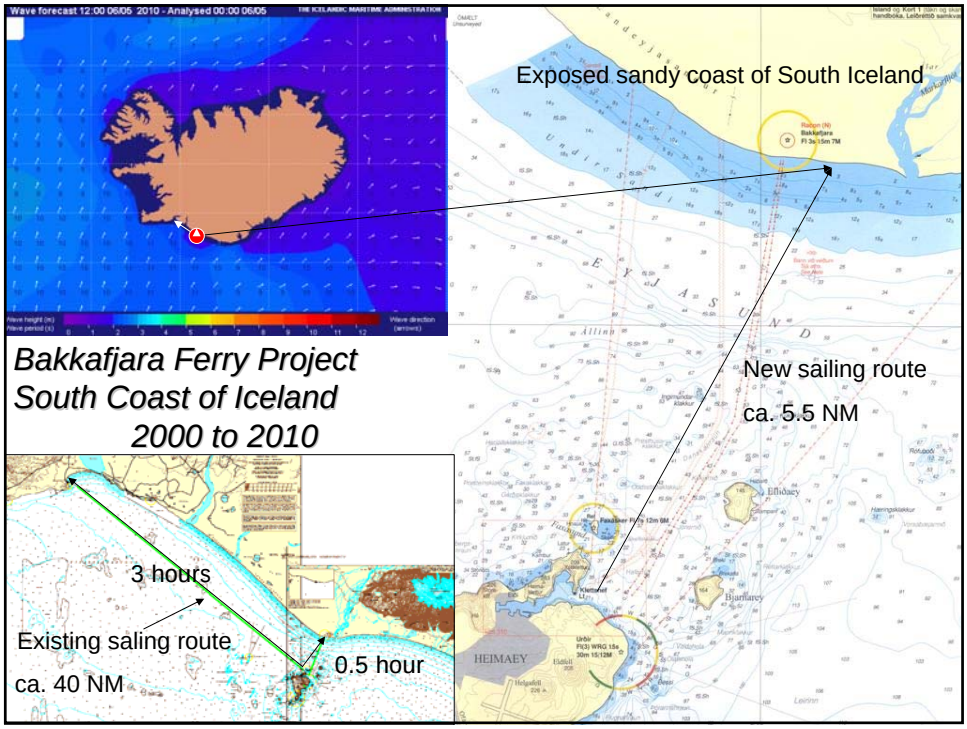


FIMMVÖRÐUHÁLS 20 March – 12 April 2010

LANDEYJAHÖFN

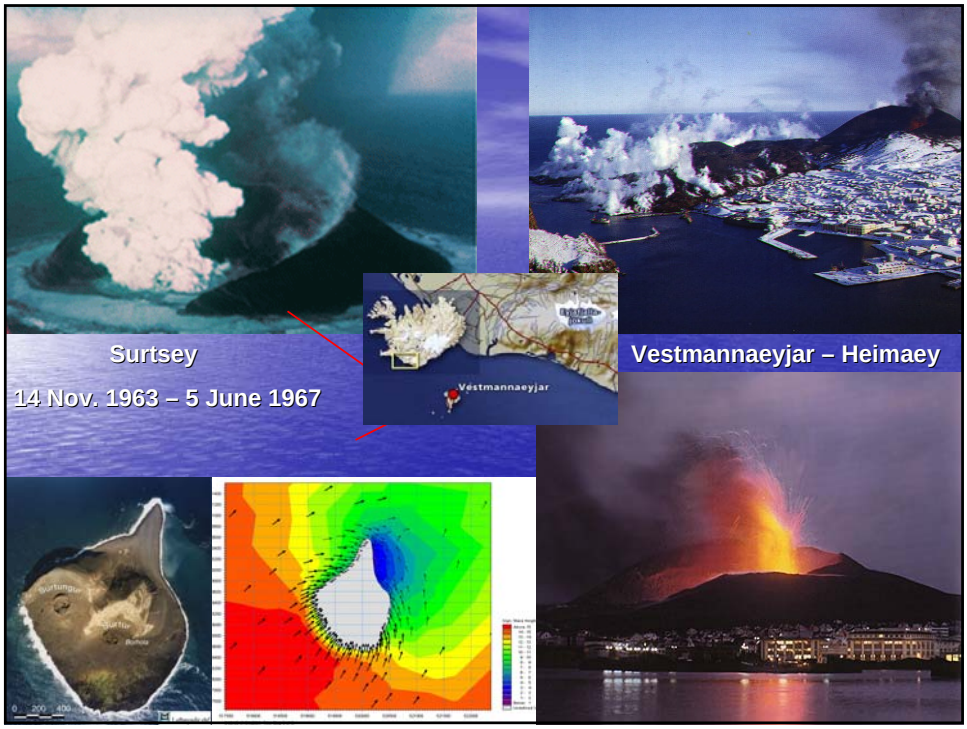
The new Ferry Harbour on the South Coast of Iceland

EYJAFJALLAJÖKULL 14 APRIL - ???

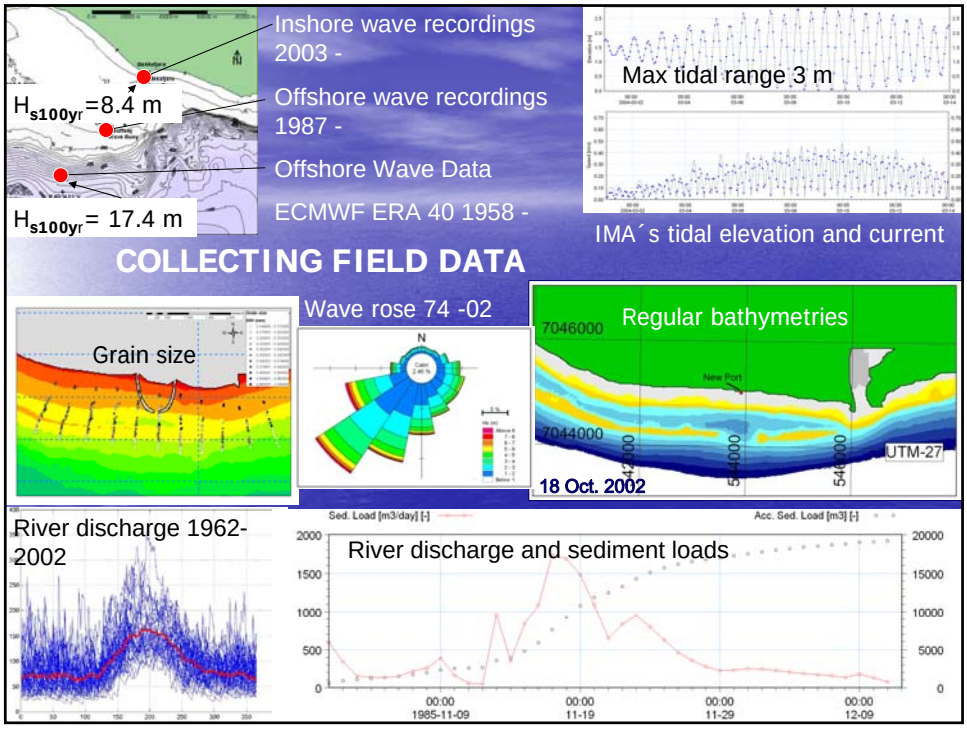


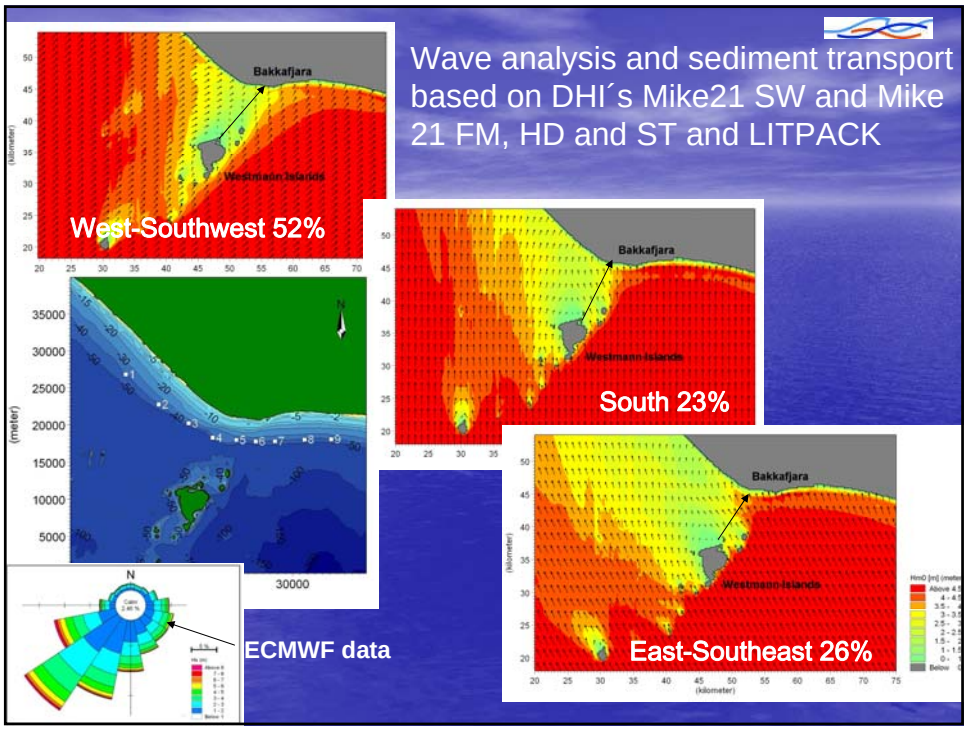
The aim of the Ferry Port project between Vestmannaeyjar and the mainland:

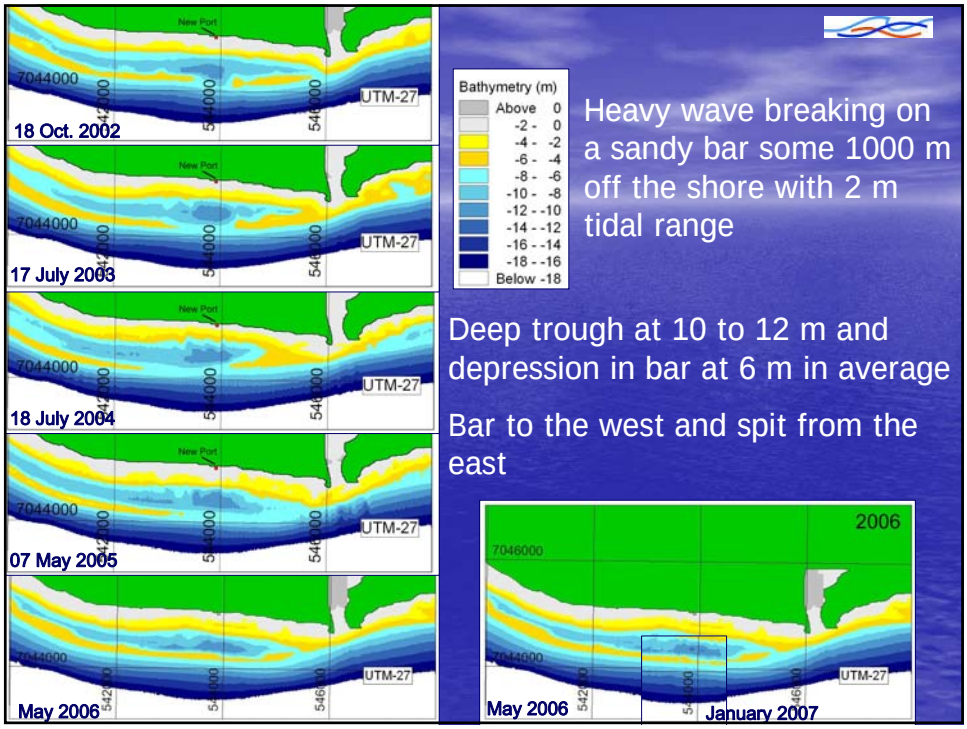
- Cut the sailing distance for the ferry from 3 hours to 0.5 hours by navigating safely through the breaking zone with intensive wave breaking and heavy littoral drift.
- Find a location on the coast with overall dynamic stable offshore sandbar with minimum acceptable depth for navigation and with minimum net littoral drift along the shore.
- Design a layout for the Ferry Port where minimum sedimentation into the Port and minimum equilibrium depth in front of the entrance is achieved.
- Find a rock quarry for building the Icelandic Berm Breakwaters for the Port.


Surtsey
14 Nov. 1963 – 5 June 1967
Vestmannaeyjar
Vestmannaeyjar – Heimaey


Markarfljót


Inshore wave recordings 2003 -
Offshore wave recordings 1987 -
Offshore Wave Data
ECMWF ERA 40 1958 -
H_{s100yr}=8.4 m
H_{s100yr}= 17.4 m
Max tidal range 3 m
IMA´s tidal elevation and current
COLLECTING FIELD DATA
Grain size
Wave rose 74 -02
Regular bathymetries
7046000
7044000
New Port
UTM-27
18 Oct. 2002
River discharge 1962-2002
River discharge and sediment loads
Sed. Load [m3/day] [-]
Acc. Sed. Load [m3] [-]


Wave analysis and sediment transport based on DHI´s Mike21 SW and Mike 21 FM, HD and ST and LITPACK
Bakkafjara
Westmann Islands
West-Southwest 52%
South 23%
East-Southeast 26%
ECMWF data


18 Oct. 2002
17 July 2003
18 July 2004
07 May 2005
May 2006
7044000
UTM-27
Bathymetry (m)
Above 0
-2 - 0
-4 - -2
-6 - -4
-8 - -6
-10 - -8
-12 - -10
-14 - -12
-16 - -14
-18 - -16
Below -18
Heavy wave breaking on a sandy bar some 1000 m off the shore with 2 m tidal range
Deep trough at 10 to 12 m and depression in bar at 6 m in average
Bar to the west and spit from the east
2006
7046000
May 2006
January 2007


The exposed sandy South Coast of Iceland is dangerous for seafarers. Hundreds of vessels have perished here and hundreds of seafarers have lost their lives.

Navigational tests over the sandbar for the ferry

Navigational criteria were established for the ferry over the sandbar into the ferry port by:

- sailing a remote-controlled model ferry,
- counting the number of breaking waves at the bar,
- wave measurements at 18 m, 15 m, 10 m and 6 m in front, at the top and at 10 m depth landward of the bar and in front of the ferry entrance.
- evaluation of the total depth based on wave height, tidal elevation and the draft of the ferry.

The navigation is regarded safe for the ferry when up to 10% of waves break on the bar between 10 m and 6 m which stretches about 250 m along the navigational line.

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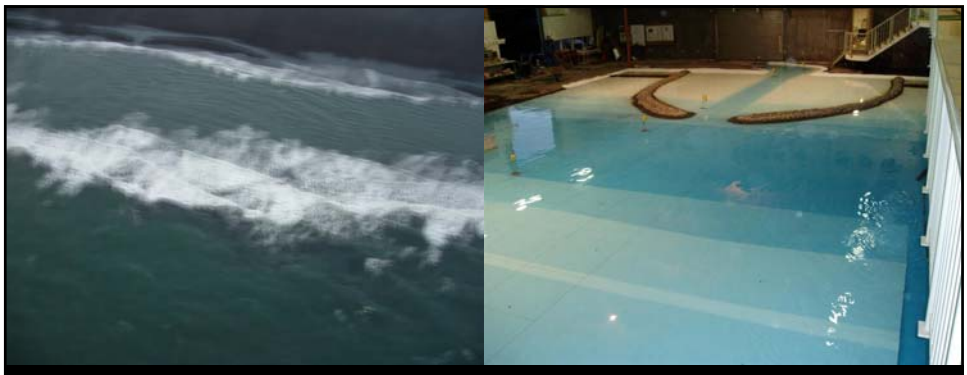
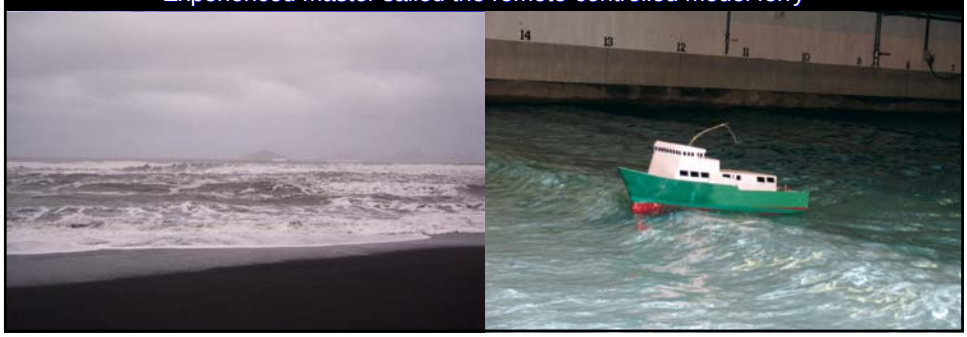


Experienced master sailed the remote-controlled model ferry



Safe Navigational Criteria for different ferries over the bar with 6 m water depth and 10% breaking waves

Remote-controlled ferry, draft 4.0 m year 2003 - 2006

Hs = 3.4 + 0.2 x WL down time **3.9%**

Proposed Ferry, draft 3.3 m

Hs = 3.6 + 0.2 x WL down time **2.8%**

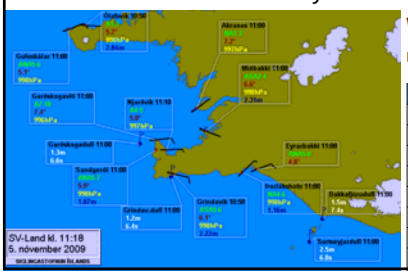
Existing Ferry, draft 4.3 m

Hs = 3.2 + 0.2 x WL down time **5.0 %**

Tides and storm surges
Vestmannaeyjar, 4.11.2009

Date	Time	Tides (m)	Storm surge (m)	Sea height (m)
3.11.2009	15:00	1,41	0,39	1,79
3.11.2009	16:00	2,03	0,35	2,38
3.11.2009	17:00	2,44	0,36	2,80
3.11.2009	18:00	2,60	0,36	2,96
3.11.2009	19:00	2,43	0,36	2,79
3.11.2009	20:00	1,98	0,35	2,33
3.11.2009	21:00	1,36	0,34	1,71
3.11.2009	22:00	0,75	0,34	1,09
3.11.2009	23:00	0,30	0,32	0,63
4.11.2009	00:00	0,12	0,32	0,44
4.11.2009	01:00	0,26	0,30	0,56

The Icelandic Information System on Weather and Sea State



Wave buoy - measurements

Bakkafjörudufl 63°30.62' N 20°08.60' W rv. 169°, 1.6 nm. from Bakkafjöruviti

Date	Time	Significant wave height (m)	Average wave period (s)	Wave length (m)
3.11.2009	14:00	1,6	8,4	111
3.11.2009	15:00	1,7	9,2	131
3.11.2009	16:00	1,5	8,1	101
3.11.2009	17:00	1,6	8,1	101
3.11.2009	18:00	1,5	8,6	115
3.11.2009	19:00	1,5	8,1	103
3.11.2009	20:00	1,5	8,1	102
3.11.2009	21:00	1,5	8,2	105

Sediment transport at the Port

The main natural forces

- Sandy coast
- Wave energy
- Vestmannaeyjar Islands
- River discharge from Markarfljot River
- Tide and tidal currents

The aim of the study was to investigate:

- And find the location with minimum net transport at the shore
- The overall stability of the bar and the depression in the bar
- Sedimentation rates into the Port
- Equilibrium depth in front of the entrance

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Jökulhlaup 14 April 2010

River discharge of sediments 200,000 m^3 after the flood

Jökulhlaup (Glacial flood) :

Max. discharge 2700 m^3/s

Total discharge 75 10^6 m^3

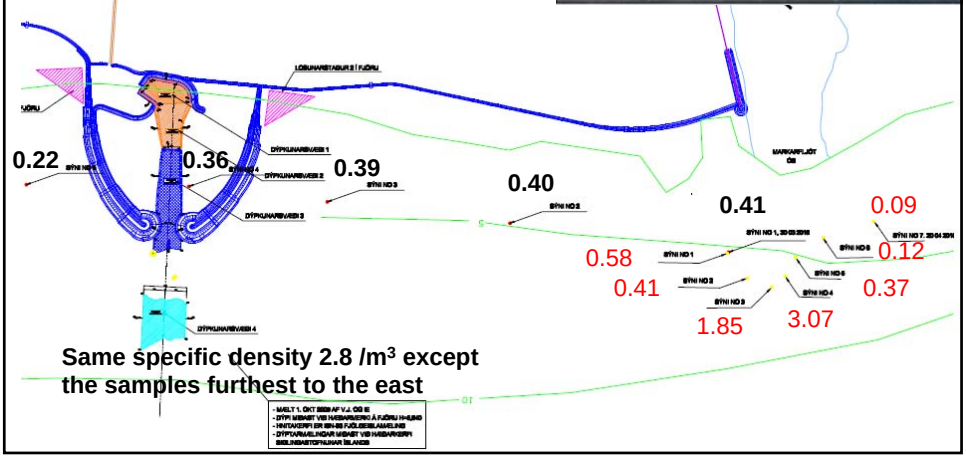
Annual discharge of sediments 100,000 m^3/yr

$Q_{100yr} = 1250\ m^3/s$

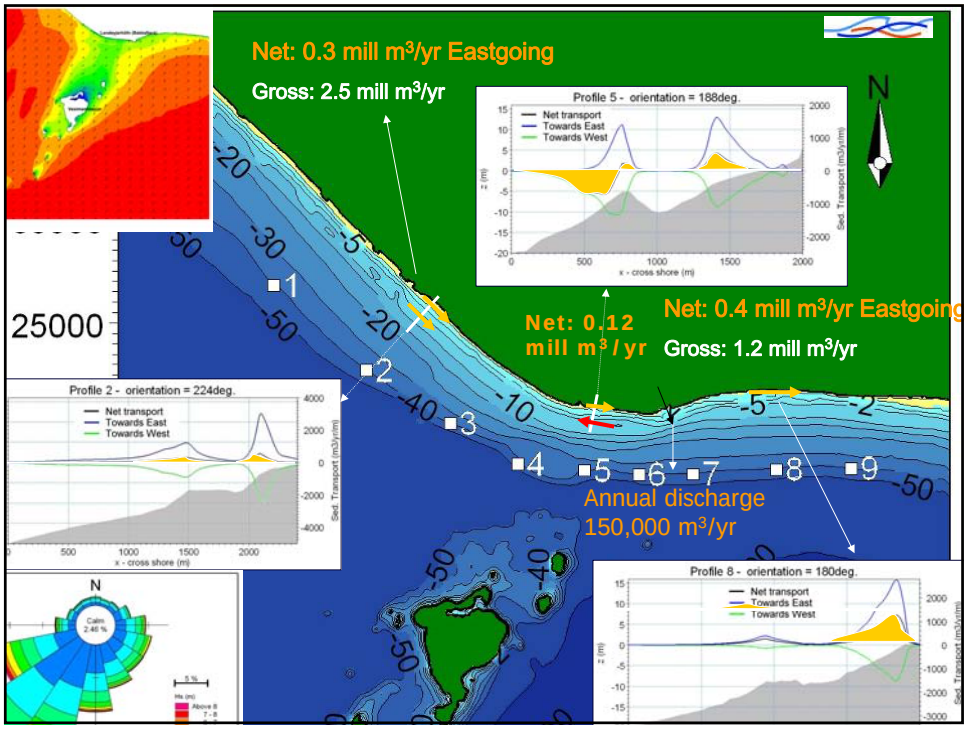
Glacial flood 14 April 2010
Grain size (mm)

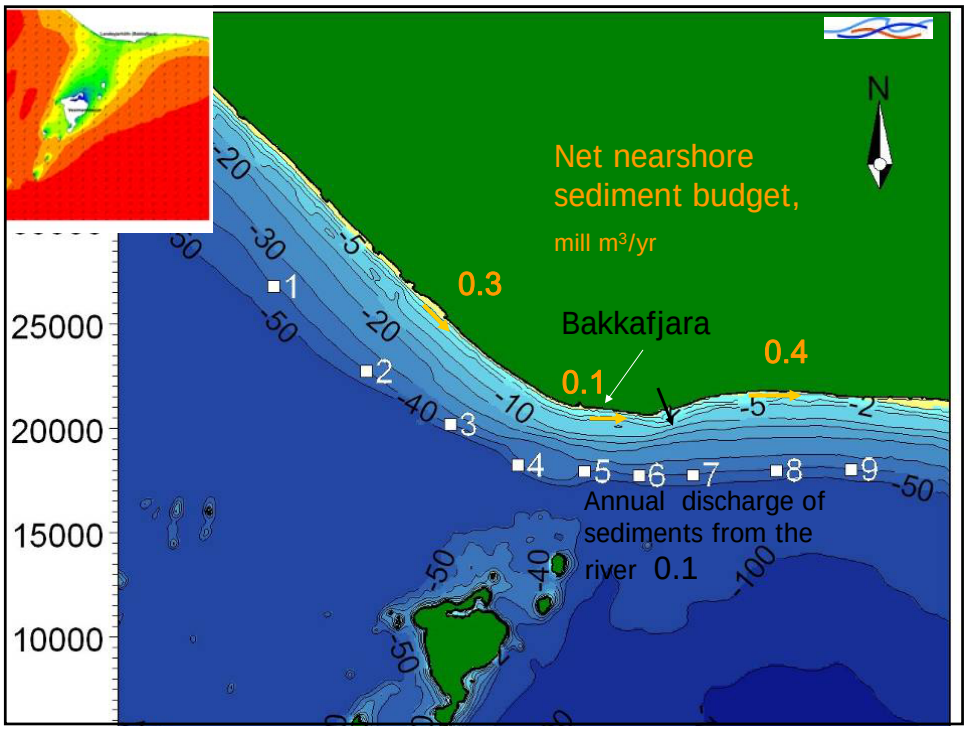
D_{60} measured 30 March

D_{60} measured 20 April 2010



Same specific density 2.8 /m^3 except the samples furthest to the east

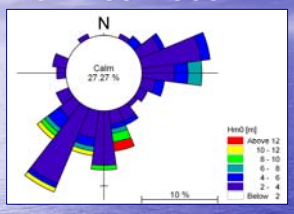

Net: 0.3 mill m³/yr Eastgoing
Gross: 2.5 mill m³/yr
Profile 5 - orientation = 188deg.
Net transport
Towards East
Towards West
Net: 0.12 mill m³/yr
Net: 0.4 mill m³/yr Eastgoing
Gross: 1.2 mill m³/yr
Profile 2 - orientation = 224deg.
Annual discharge 150,000 m³/yr
Profile 8 - orientation = 180deg.
N
25000

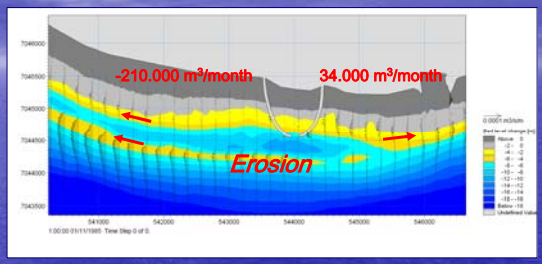

Net nearshore sediment budget,
mill m³/yr
0.3
Bakkafjara
0.1
0.4
Annual discharge of sediments from the river 0.1
N
25000
20000
15000
10000

Average sediment transport, selected periods

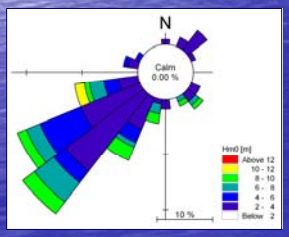
Sediment transport along the inner part of the profile
toward East for waves from W -SSE and toward West for SSE – E

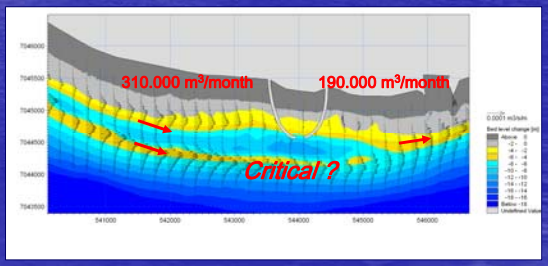
Nov-Dec. 1985

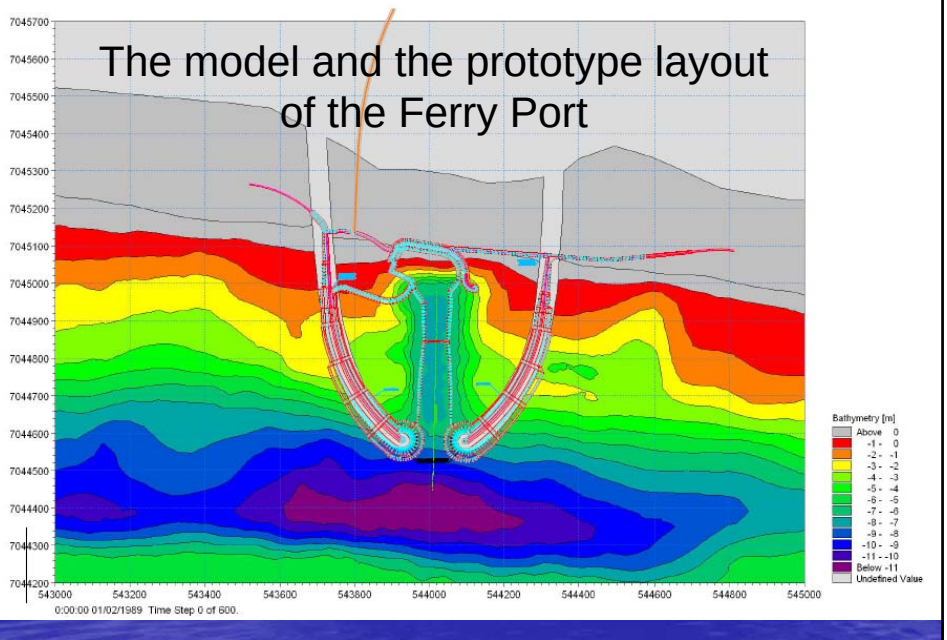


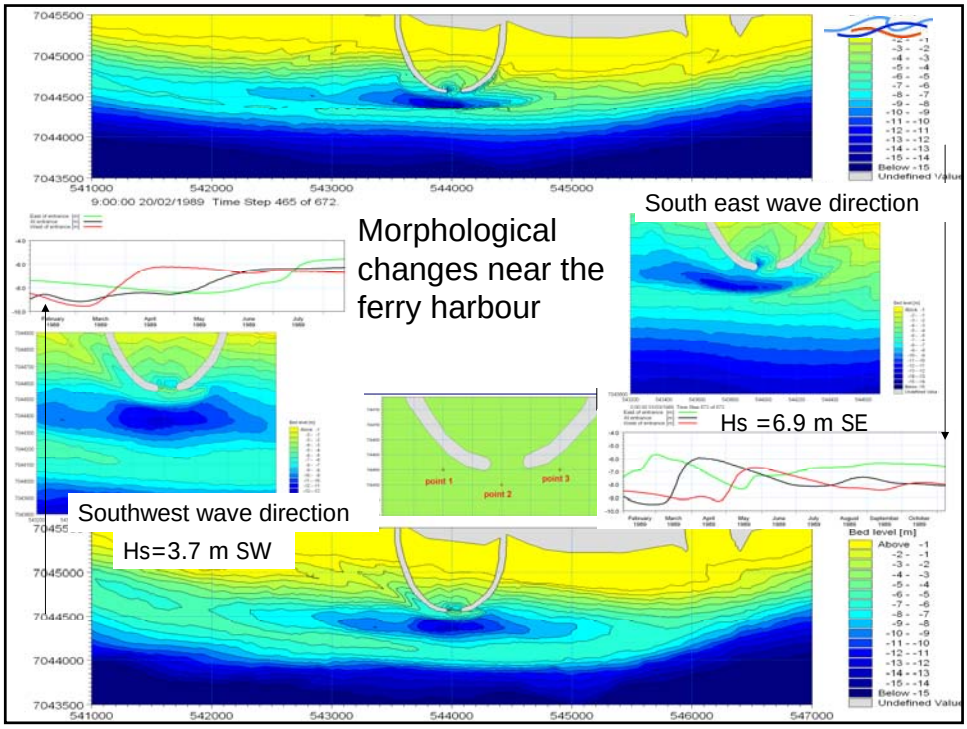


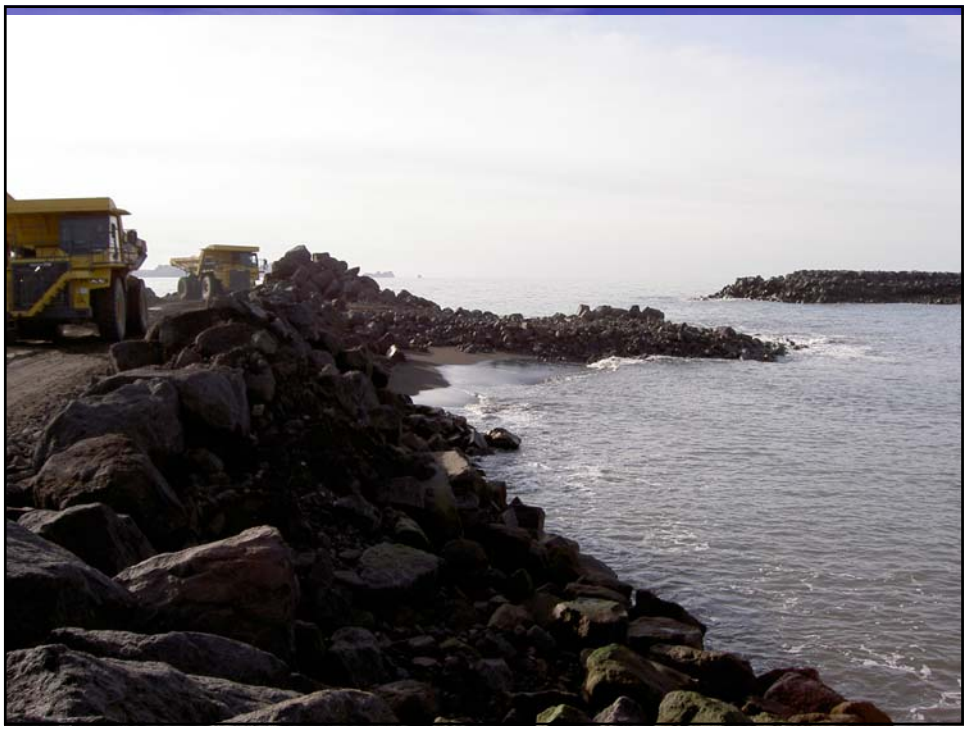
Feb. 1989

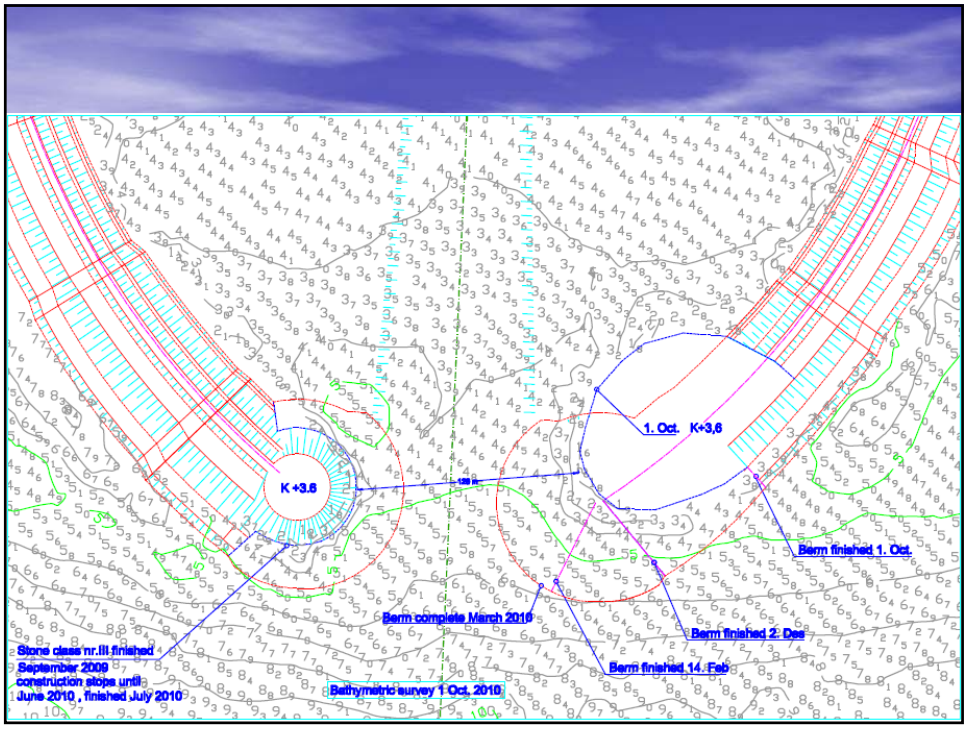


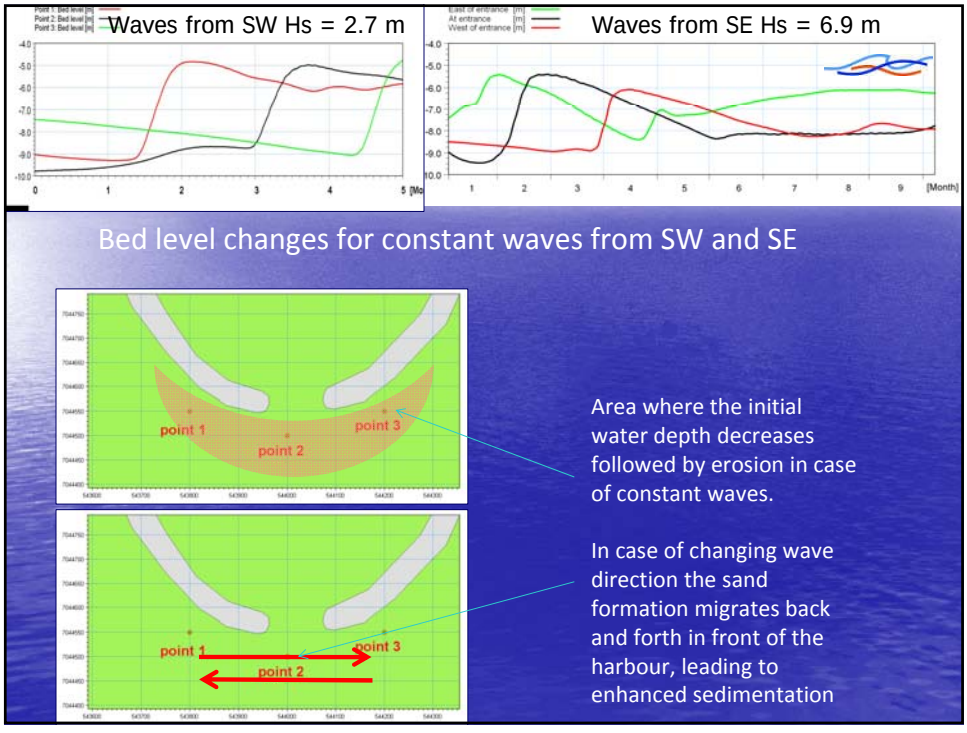





Morphological changes near the ferry harbour
South east wave direction
Hs =6.9 m SE
Southwest wave direction
Hs=3.7 m SW
point 1
point 2
point 3
9:00:00 20/02/1989 Time Step 465 of 672.
Bed level [m]
Above -1
Below -15
Undefined Value

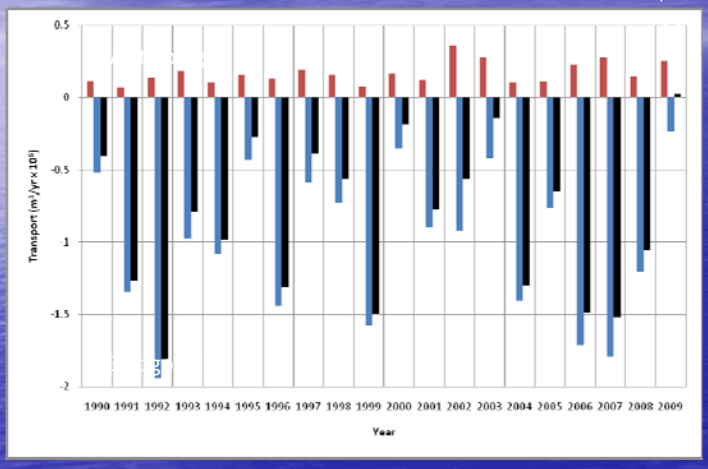



1. Oct. K+3,6
K +3.6
Berm finished 1. Oct.
Berm complete March 2010
Berm finished 2. Dec
Berm finished 14. Feb
Stone class nr.III finished September 2009 construction stops until June 2010 , finished July 2010
Bathymetric survey 1 Oct. 2010

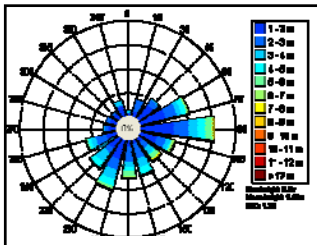

Waves from SW Hs = 2.7 m
Waves from SE Hs = 6.9 m
[Month]
Bed level changes for constant waves from SW and SE
point 1
point 2
point 3
point 1
point 2
point 3
Area where the initial water depth decreases followed by erosion in case of constant waves.
In case of changing wave direction the sand formation migrates back and forth in front of the harbour, leading to enhanced sedimentation

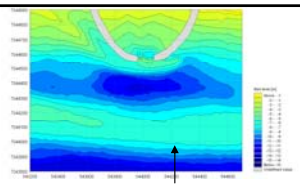
Rough estimate of long shore transport (based on offshore wave climate)

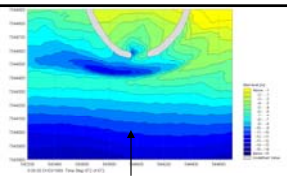
1/7 09 – 15/3 2010



Normally: east going >> west going. This year: east going approx. = west going



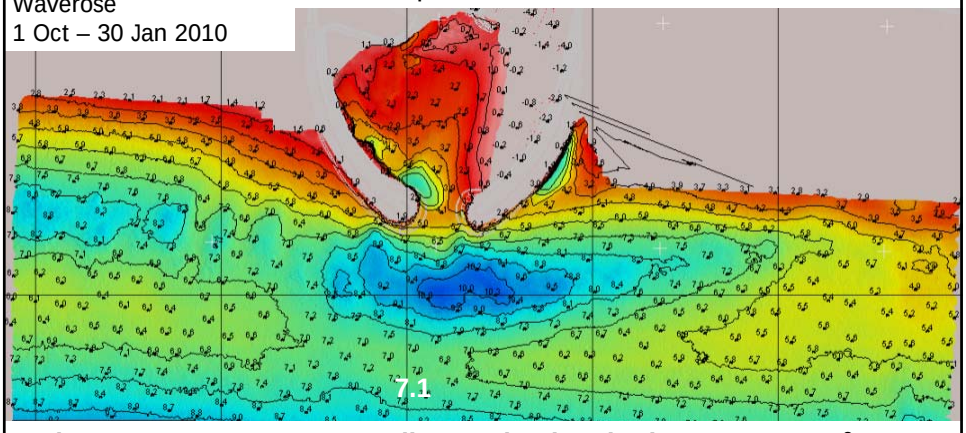




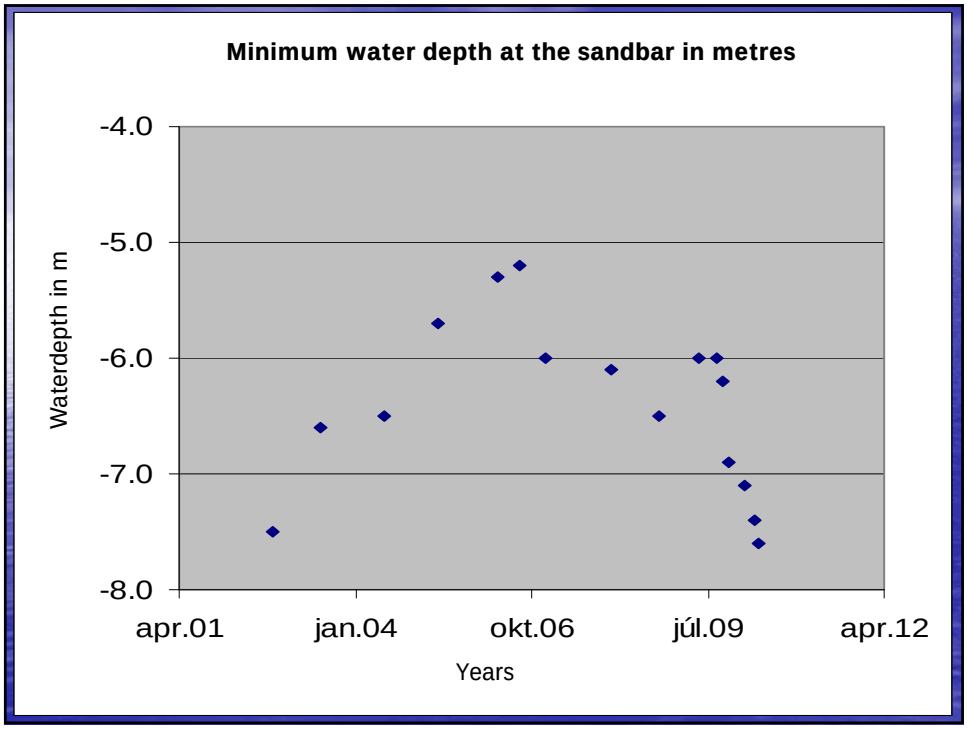
Transport toward East and West

Comparison between nature and simulations

Waverose
1 Oct – 30 Jan 2010



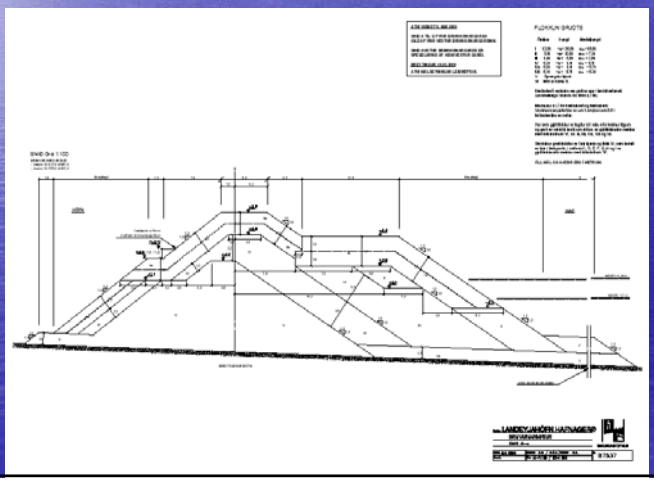
Bathymetry 31 Jan 2010 **Sedimentation into harbour 161,000 m³**


Minimum water depth at the sandbar in metres
Waterdepth in m
-4.0
-5.0
-6.0
-7.0
-8.0
apr.01
jan.04
okt.06
júl.09
apr.12
Years


Quarry run in March 2009

Breakwater section

- Significant wave height Hs = 6.1m
- Necessary stone size for Ice BB up to 30 tons
- Availability of armour stones at Quarry site, 25 km distance.
- Quarry yield predicted 27-37%> 1t and 8-12%> 10t.



Landeyjahöfn October 2009

Landeyjahöfn October 2009

Landeyjahöfn October 2009

Ferry Port project between Vestmannaeyjar and the mainland in conclusion:

- Technically and economically feasible to build a Ferry Port on the South Coast by navigating safely through the breaking zone in front of the Port.
- Only one location at the coast is with a dynamic stable bar with minimum acceptable depth for navigation and with minimum net littoral drift along the shore.
- Design the layout of the Ferry Port with minimum sedimentation into the Port and minimum equilibrium depth in front of the entrance is achieved.
- High quality rock quarry is available for building Icelandic Berm Breakwaters at the Port.
- The whole project fulfilled all international standards regarding design and safety.

Landeyjahofn Ferry Harbour April 2010

Open for service on 21. July 2010

Thank you