Julebæk Strand

– Effect full beach nourishment

Aim of Study

This study is a part of the COADAPT funding and the aim of the study is to analyze the effect of beach nourishment. In order to investigate the decay and effect of beach nourishment.

Area Description

Julebæk Strand is an exposed northeast faced beach on the north coast of Zealand, Denmark, Figure 1. The hydrodynamic processes and thereby the sediment transport are highly influenced by the predominant swells and waves coming from north-westerly directions, as oblique wave angles cause wave refraction and southeast directed longshore sediment transport. Secondly waves from the west-southwest may also cause high water levels as water is pushed from the North Sea into Kattegat causing a large wind and wave setup. Waves from the south-easterly directions are also frequent but the water exchange between the Baltic Sea through Øresund into Kattegat and the North Sea cause low water levels at Julebæk Strand. However these flows can potentially be strong changing the predominant sediment transport pattern. The water level varies roughly 20 cm daily taken the tidal action and water exchange between the North Sea and the Baltic Sea into consideration.

The beach is roughly 15-25 m wide and 1100 m long with a relatively flat slope. The profile steepens going offshore as a result of the abruption between the submerged headland and complex bathymetry between Denmark and Sweden. The beach is restricted inland by dunes, vegetation covered cliff faces and stone revetments. Old disintegrated groins of stones and concrete are present on the beach with 50 m spacing. For most areas between the groins the beach width extends all the way to the end of the groins. Additional attempts functions as coastal protection are also found. The yearly erosion rate is ranging from 0.25-0.9m and the groins may render some stability but are overall riddled and ineffective. The beach sediment consists of varies sizes ranging from sand, gravel and stones, with the most sandy beach area towards the northwest and increasing grain sizes towards the southeast.

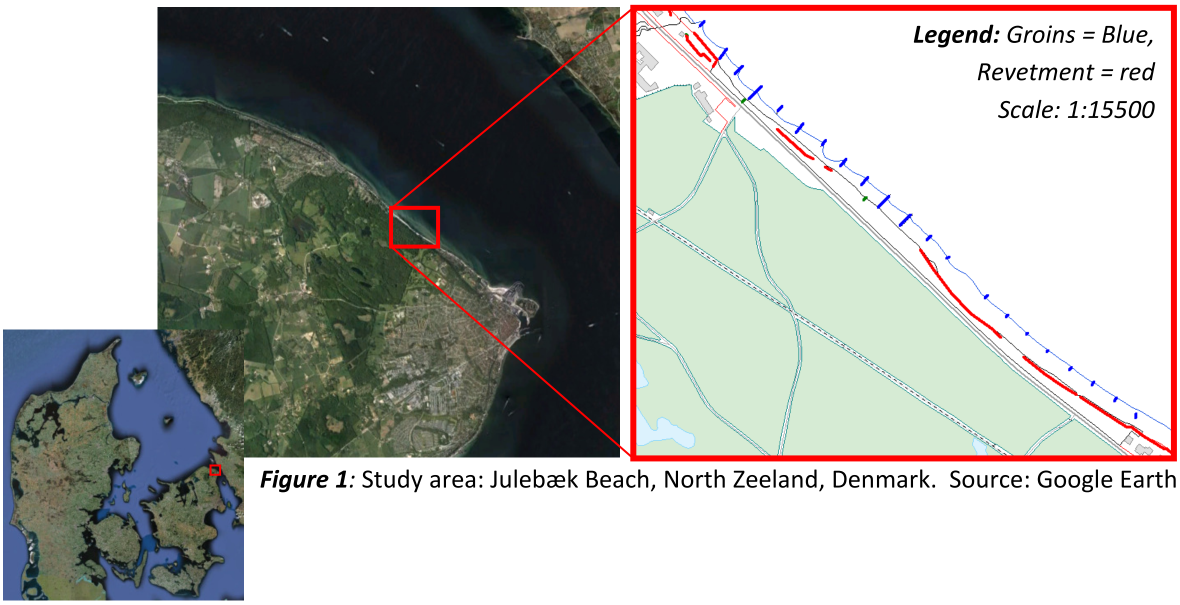
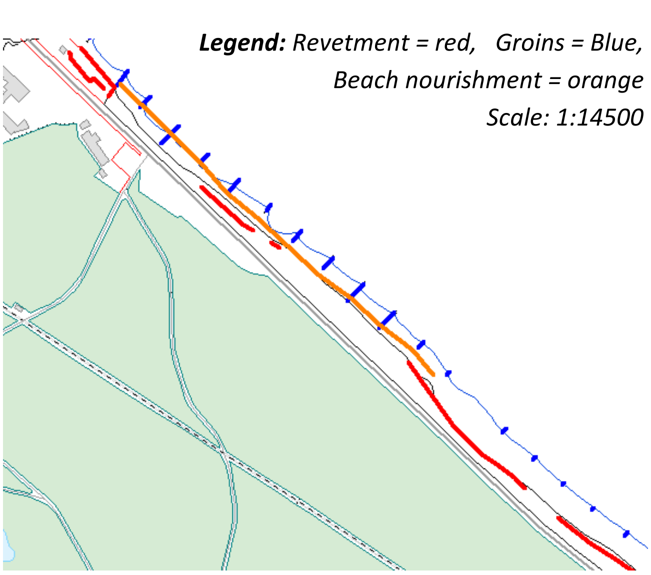


Figure 1*:* Study area: Julebæk Beach, North Zeeland, Denmark. Source: Google Earth & KDI

Beach Nourishment

In March 2010 the first beach nourishment was conducted at Julebæk Strand as a part of an initiative to re-establish the recreational value of Julebæk Strand. A four year permit for yearly beach nourishment with a maximum of 4000m^3 sand was given. Beach nourishment activities have been carried out in March ever since. For this analysis only the first beach nourishment in March 2010 is studied. The sediment used for to conduct the beach nourishments are dredged accumulated sediment west of Hornbæk Harbor.

In March 2010 4000m^3 of sand was offloaded with trucks onto the beach, for dumper trucks and bulldozers to evenly spread out the sand. The sand is deposited in the northwest end of the beach, on top of old groins and concrete seawalls, elevating the beach between 20-80 cm. The average deposit per square meter is 4,25m^3. The beach nourishment takes place in the northwest end of Julebæk Strand because of the large recreational activity here and to allow for the hydrodynamic and aeolian processes to re-suspend and transport the sand towards the southeast, increasing the value of the total stretch, Figure 2.



Beach nourishment quantity		
2010	**2011**	**2012**
4000m^3	4084m^3	4154 m^3

Figure 2: *Beach nourishment at Julebæk Strand: location, quantity, depiction during and after the beach nourishment. Picture source: Naturstyrelsen (top) and COWI (bottom)*

Cross-sectional profiles

45 cross-sectional profiles with a spacing of 25 m are surveyed along the 1100m of coastline. The length of the profiles varies, ranging from -0,9m to 6m with a maximum common area between -0,118m to 1,229m. The measurement uncertainty is with a standard deviation of 5 and an unequivocal of 2cm. This uncertainty may yield a significant error regarding the volume calculations which may be amplified when combined with small quantities spread over a relative large area, as changes can be critical to detect.

Four survey campaigns are conducted, but only three will be used in this study, as the second nourishment prevent studying the decay of the first beach nourishment even further and lack of measurements hinder an investigation of the second nourishment and the use of the fourth survey.

Survey campaigns			
2010.01	**2010.02**	**2010.03**	**2011.01**
4th March 2010	8th April 2010	7th July 2010	5th May 2011

Methodology

Defining the area of interest

In order to investigate the effect of beach nourishment a volume change analysis is made. In order to do so a common area representing the beach nourishment is selected. When investigating the cross-sectional profiles it is noted that the beach nourishment is deposited within 450m, from profile no. 7010075 to 7010500, which is in good agreements with the information given by Helsingør municipality who is in charge of the project, Figure 3 and Figure 4.

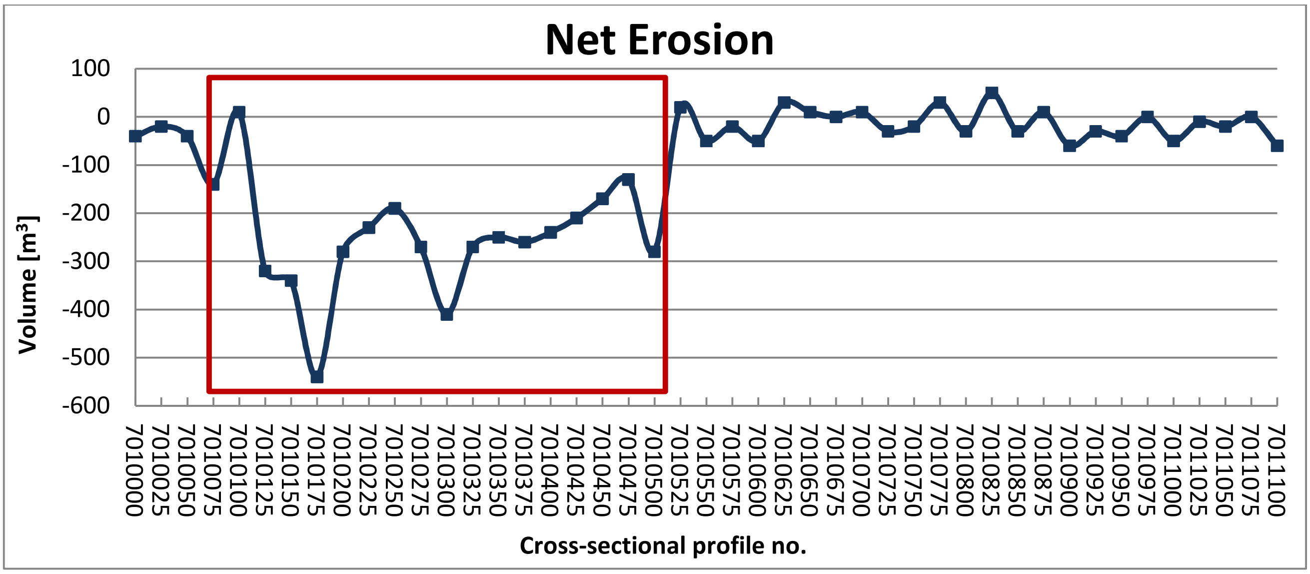


Figure 3: Net erosion on Julebæk Strand between the 4th March to 8th of April 2010

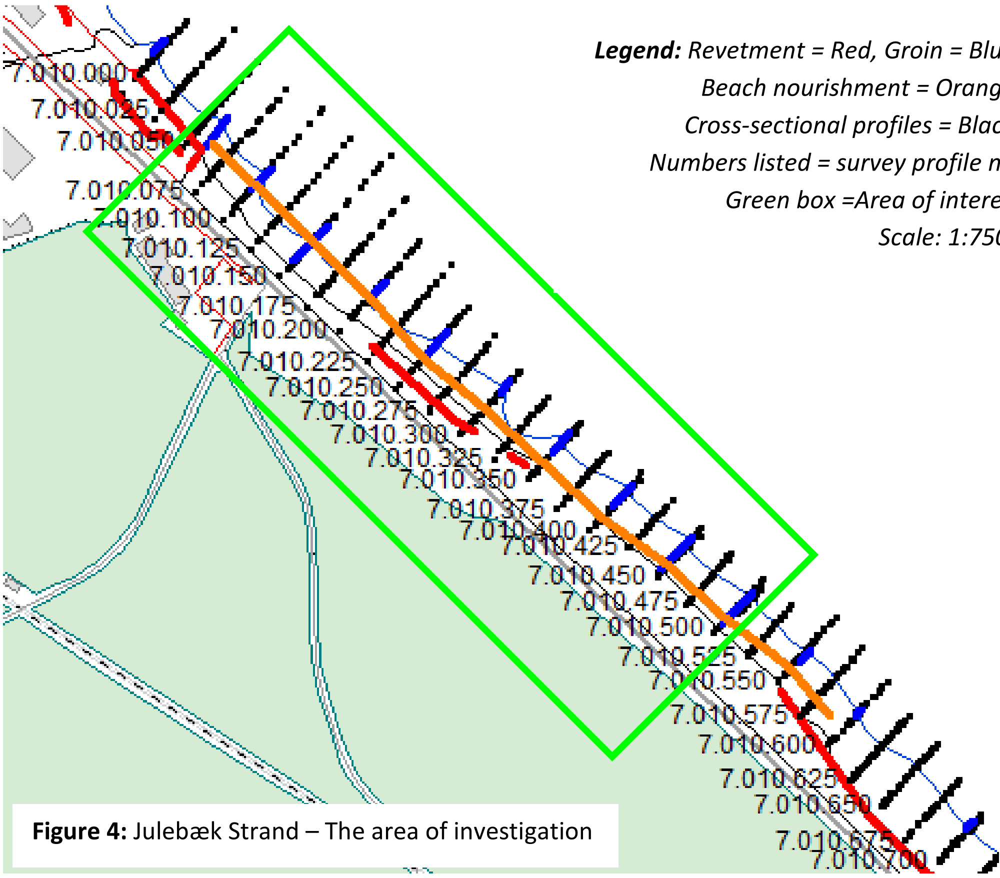


Figure 4: Julebæk Strand – The area of investigation

Envelope definition

Further investigation of the cross-sectional profiles shows that the common area of interest is rather narrow, ranging from -0,158 m to 1,459 m, Figure 5. The extent of this area is claimed to be insufficient for a volume change analysis as up to 34% of the beach nourishment is outside of the common area of interest and that the limited extent of several profiles will compel errors during computation of the volume, Figure 6.

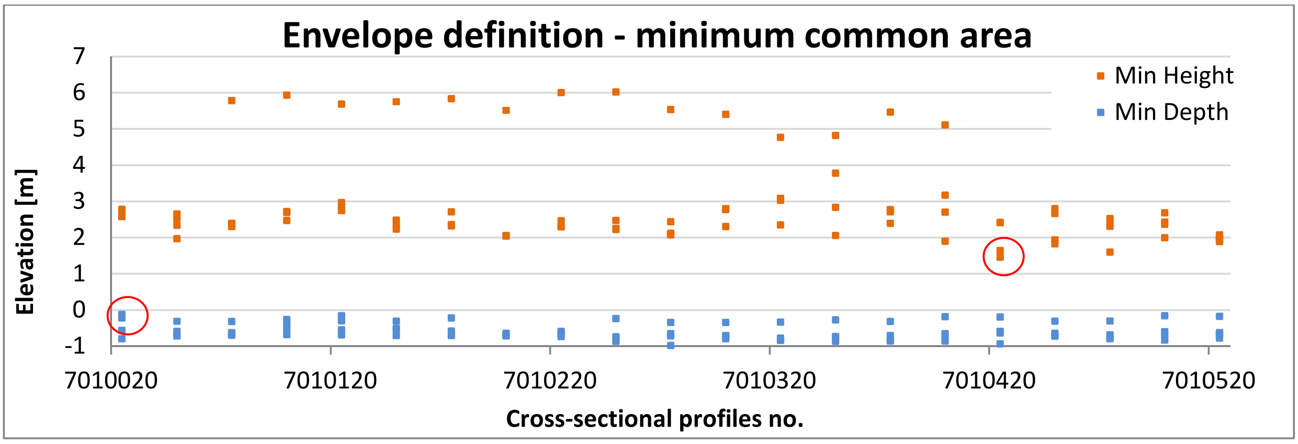


Figure 5: Minimum height and depth

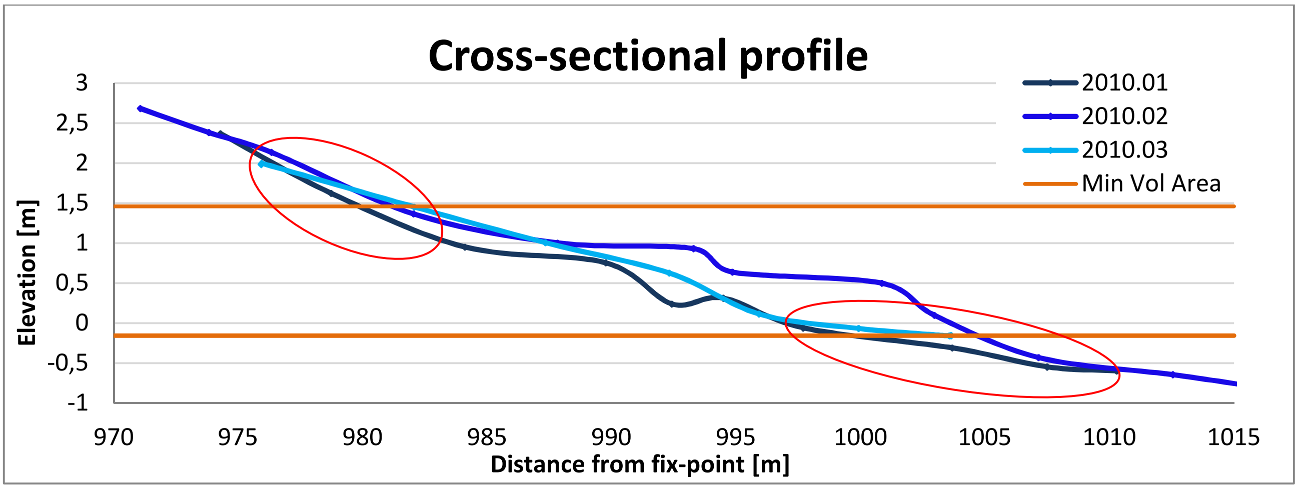


Figure 6: Survey differences – Potential complications highlighted in red

The envelope of the different cross-sectional profiles revealed that the area extent should truncate closer to -0.5 m and 2.3 m in order to enclose the beach nourishment. In order to extent the common area of interest additional elevations points were extrapolated within the selected cross-sectional profiles, Figure 7.

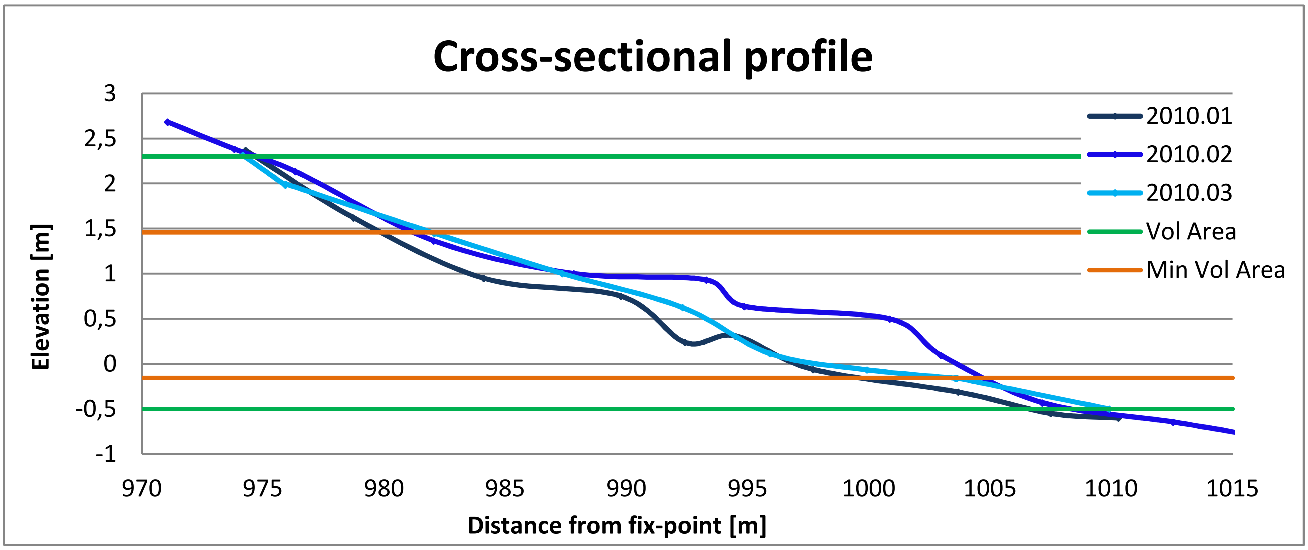


Figure 7: Cross-sectional profile incl. extrapolated points

Volume calculation
The volume is calculated by computing the changes defined by the different cross-sectional profile surveys. To estimate the volume an in-house developed tool, KI-Menu, is used. A KI-subfunction: KI-volume estimates the erosion and accumulation on the basis of the cross-sectional profile data, Figure 8.

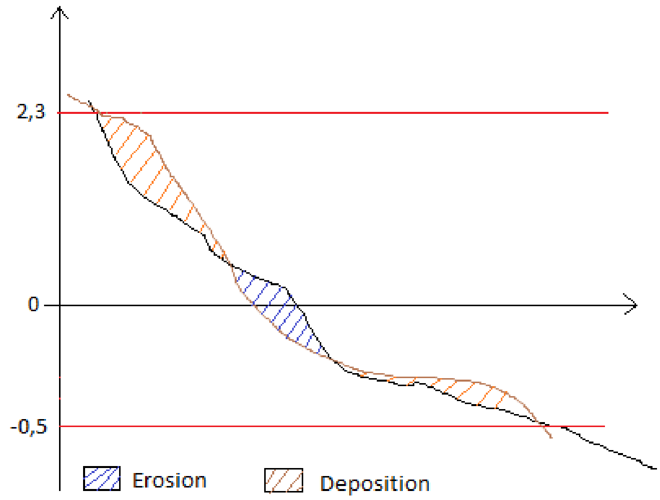


Figure 8: Volume calculation defined by elevation

When estimating the volume between the cross-sectional profiles a few assumptions are made as the tool connect each cross-sectional defined end point with a straight line and that the volume is determined by an area on both side defined by the bisecting line between the cross-sectional profiles, Figure 9.

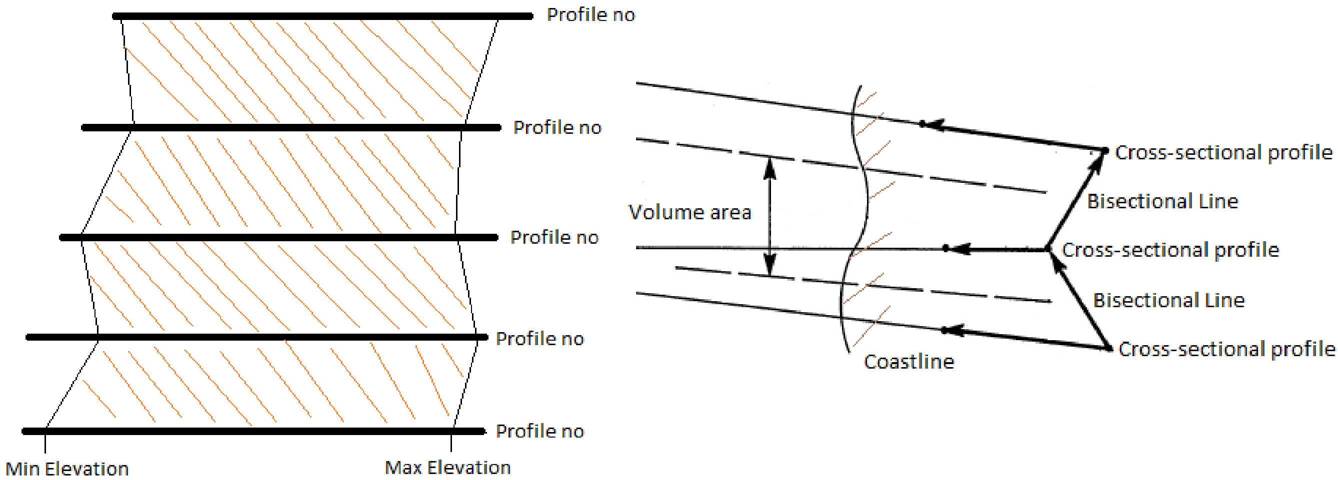


Figure 9: KI-menu: Volume computation and assumptions

The effect of the beach nourishment is investigated in relation to the theoretical exponential decay of beach nourishment defined by Silvester & Hsu: Coastal Stabilization, Advanced Series on Ocean Engineering – Vol. 14, World Scientific, 1997. The theoretical lifecycle and decay trend give an indication of beach nourishment behavior and when to re-nourish.

Decay of beach nourishment

The lifetime of beach nourishment is defined as followed:

$$t_{Beach\ nourishment\ lifecycle} = 0.2 * \frac{Y}{\alpha}$$

Where t is the time, Y is the width of the beach nourishment and α is the long-term erosion rate

The theoretical exponential decay of beach nourishment is defined:

$$Z(t) = \left(0.2 + \frac{0.8}{10^{k*t}}\right) * Y - t * \alpha$$

Where Z is the volume/height change and k is the rate of the exponential decrease

Another relation proposed by Dean states the following:

$$M(t) = e^{-k*t}$$

Where M is the volume, k is an empirical site specific factor and t is the time

Results and discussions

Studying the effect and decay of beach nourishment it can observed that 34,0 % is resuspended after a period of 91 days.

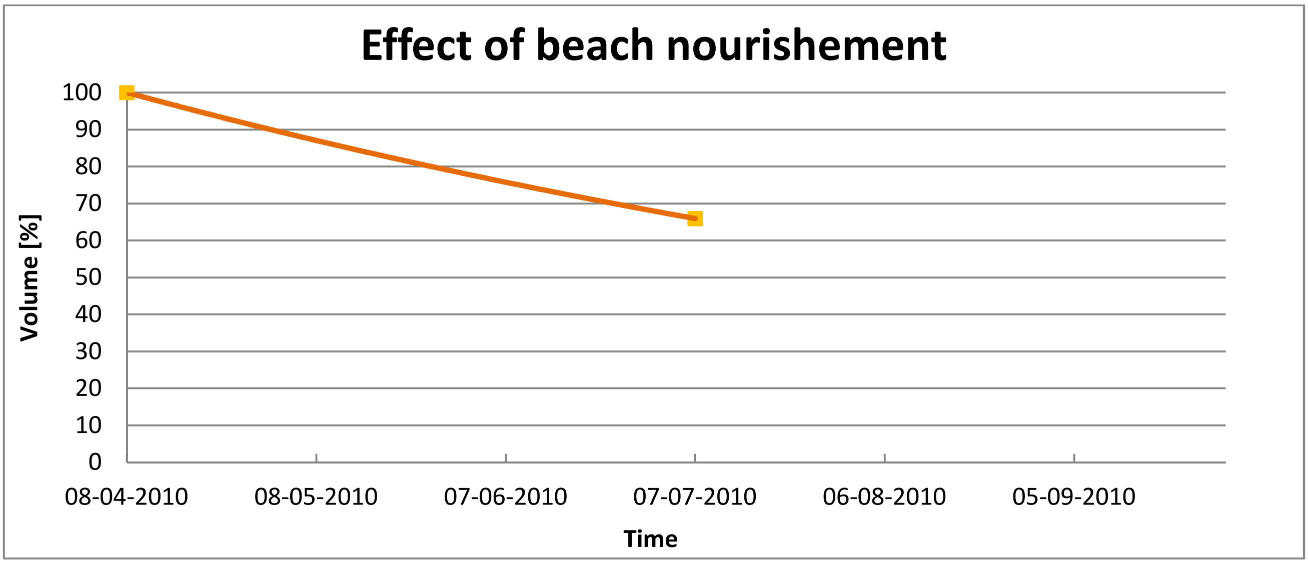


Figure 10: Decay of beach nourishment, Julebæk Strand

Decay of beach nourishment		
Measured	Silvester & Hsu	Dean
34,0%	24,6%	20,2%

Accordingly to Silvester & Hsu the lifecycle of Julebæk Strand beach nourishment material is estimated to 24 years and according to the theoretical exponential decay of beach nourishment material 24,6% of the nourished volume should be re-suspended by 91 days. Dean depicts that 20,2% is re-suspended after 91 days, Figure 11.

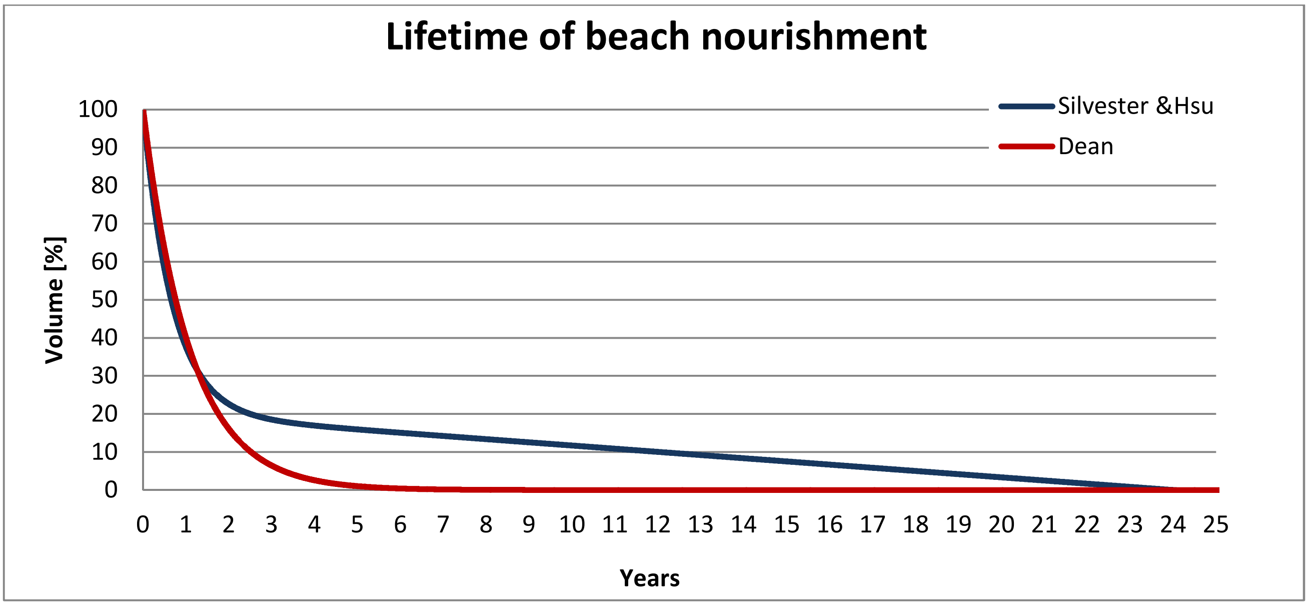


Figure 11: Theoretical decay of Beach Nourishment

When comparing with Silvester & Hsu and Dean's proposed theoretical decay of beach nourishment, it can be seen that it slightly underestimate the decay at Julebæk Strand in the investigated time frame, Figure 12. Additional surveys, enabling extension of the measured curve would have been interesting.

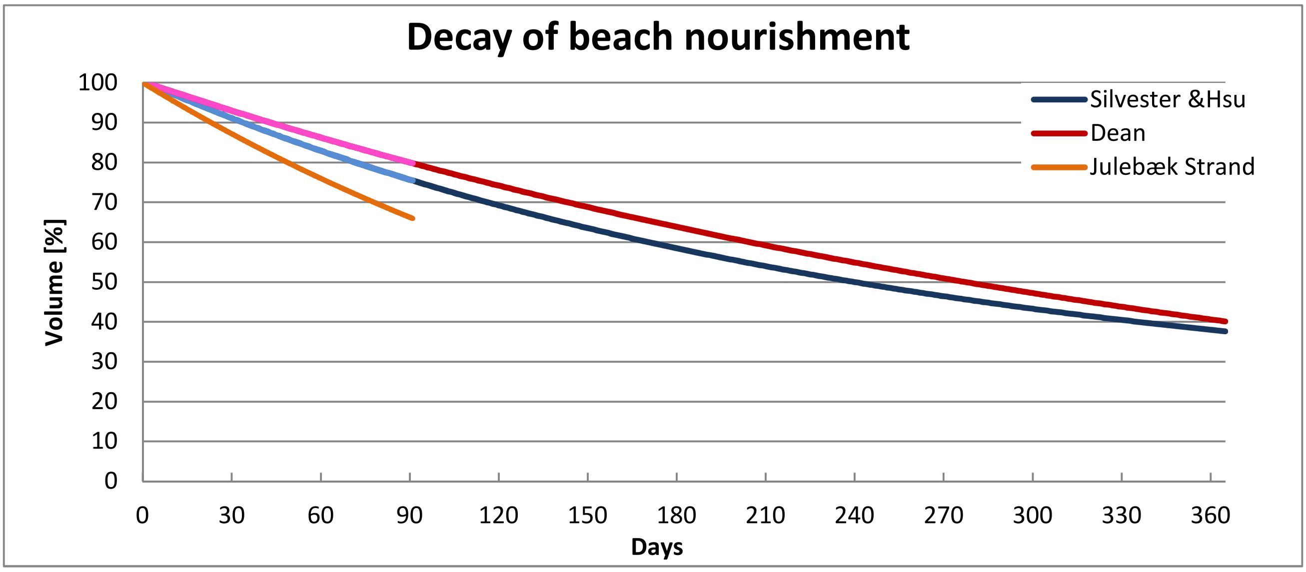


Figure 12: Decay of Beach nourishment

The decay is related to the coastal processes. Not only will the natural processes continue change the beach, but also the newly introduced beach nourishment material will in terms of the increased elevation and profile changes cause instability in the equilibrium profile, causing increased erosion and re-suspension after implementation nourishment activities.

It should be noted that nourishment actions is still effective and needed as coastal protection, as sediment deposited in the active zone of the beach profile keep building the beach up and acts as a buffer. On the long term basis adjacent beaches will benefit from the nourishment action upstream as longshore processes will transport sediment downstream. Re-nourishment is therefore an important element in coastal protection schemes.

In order to determine the direction of the sediment transport, an offshore, downstream and diagonal test sites were defined with the following dimensions listed in Figure 13. It can be seen, that beach nourishment material is re-suspended offshore and slightly downstream, as net accretion is detected. The total volume is not account for but a trend is outlined and a further investigation is needed covering a larger area.

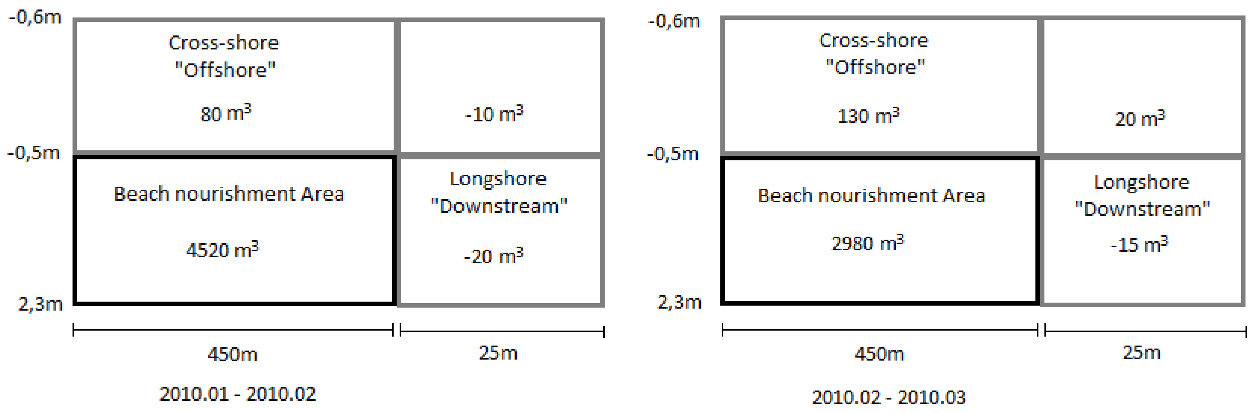


Figure 13: Sediment transport pattern

Conclusion

The decay of beach nourishment is 34% after just 3 months. The nourished material is re-suspended offshore and slightly downstream. Despite the large decay of beach nourishment material, nourishment actions are still important in relation to coastal protection and establishing recreational environments, as material is deposited in the active zone for hydrodynamics to continuously re-suspend it.