Reconstructing the seascape at the mouth of the Oder
Elaboration of a DBM-model based on 1912-soundings

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Abstract: As an integral part of a 3-year research project financed by the Danish Research Foundation (DGF), the reconstruction of the early medieval seascape at the mouth of the Oder River represented a challenging task in an ever-changing environment. Besides nature-driven factors, the human factor ought be considered as one of the main agents of change active in the area, at least from the end of the 19th-century onwards. The data was processed on a GIS-based platform, and a digital model of the underwater area of the Oder Lagoon was generated from the digitising of more than 4000 soundings taken in the first half of the 20th-century. The digital bathymetric model (DBM) was used to elaborate aspect, slope, and hillshade maps of the Lagoon. Hydrological analysis was carried out on a TIN-based spatial model. The results show the potential of GIS-software in the reconstruction of past underwater areas, including the identification and matching of underwater anomalies with historical data from older cartographic sources.

Key words: Seascape, Oder Lagoon, DBM reconstruction, GIS-mapping, TIN-modeling

Introduction

During 1997 and 2000, a research project, involving institutions from Denmark, Germany, Poland, Sweden, and Norway, was carried out with the main goal of establishing a detailed view of the relationships between early medieval man, ships, and the marine environment at the mouth of the Oder River in that period. As an integral part of this project, financed by the Danish Research Foundation (DGF), the reconstruction of the early medieval seascape at the mouth of the Oder River represented one of the most challenging tasks in an ever-changing lagoon environment. Besides nature-driven factors, one had to consider, at least from the end of the 19th-century onwards, the human factor as one of the main agents of change active in the area. As a direct result of this intervention, the natural balance on both the sea side and the lagoon side of the two major islands, Usedom and Wolin, has changed drastically. Land-shaping through the building of artificial canals (the Piastowski/Kaiserfahrt canal, f. ex.), erecting protective obstacles against erosion, damming natural inlets of seawater, draining once-periodically flooded lowlands, etc. led to a radical change in the physical and geodynamic aspects of the region. Under these circumstances, the tedious work of reconstruction started as a race against all odds back in time using as much scientific knowledge as possible. Besides the use of modern prospective techniques such as seismic measurements, and geological analysis of bottom sediments, the collected data was aided by other research efforts that employed hydrodynamic modelling of water movements[1], and sediment mapping in the Oder Lagoon.[2]

A DBM-model of an early medieval landscape

The data from these sources of information help in building an approximate model of an early medieval landscape in the Oder mouth area. *ArcView* version 3.1 was the GIS-program used to construct the model. After securing the cartographic data, which varies from source to source, a digital map was constructed. The map shows the coastlines as they were measured at the beginning of the 20th c., thus before the massive anthropogenic impact on the region. Parallel with the landscape mapping, a digital bathymetric map was constructed for the Greater and the Lesser Lagoon, including the Dziwna, Swina, and the Peenestrom channels. The model took in consideration all the areas at the Oder mouth, including those heavily transformed by anthropogenic factors.[3] In this way, a complete picture was obtained by extrapolating the landscape from its actual shape back in time.

The bathymetric map is a DBM-model[4] based on floating points represented by 4232 digitized negative values (fig. 1). By comparison with modern navigation maps and with earlier models of bottom configuration in the Lagoon[5], the DBM model shows a more detailed delineation of offshore ledges both on the lagoon side and on the sea side. The Lagoon basin can be divided along the -4-3 meter isobaths into a ledge zone and the proper basin zone (fig. 2). The ellipsoidal shape of the basin strangled in the middle by the Repziner and Osiecka shoals defines the general outlook of the underwater part of the Oder mouth area.

The DBM model was used further in elaborating maps showing the underwater surfaces. The underwater surface map was produced in both monotonic and coloured versions in order to visually enhance bottom morphology (figs. 3 and 4). The comparison with modern charts shows little differentiation of bottom configuration in respect to main features such as the Wolin Shoal, the Krzecki Shoal, the Warpno Shoal, the Repzin Shoal, the Borken shoal, Göschenbrinks Flat, but the digital rendition of the underwater surface gives a more detailed overview of the bottom morphology. A reclassification of the generated surface illustrates visually that the underwater area at the Oder mouth area can be divided in nine major classes of different depth values with only four classes of depth in the Lagoon (fig. 5).

According to older cartographic sources, the Wolin Shoal (marked with the text *Das Schaar im grossen Haff ?? Fusstief?*) is known as a bottom obstruction at least since the middle of the 17th c. and this situation can be assumed for the other submerged geomorphic features. The model indicates also that the lagoon acts as a sink for heavier sediment with a higher settling velocity than that of the waterflow. This role is enhanced by the elevation in the discharge channels, which are shallower than the lagoon. Before the construction of the Piastowski/Kaiserfahrt navigational channel (that is after 1880), the mass of water had to push forward over the Wolin Shoal and into the Dziwna channel, over the Wicko Sill into the Old Swina channel, and over the Göschenbrinks shoal into the Peenestrom, in order to flow into the sea.

The analysis was carried further by calculating the aspect, the slope, and the hillshade of the underwater area. The aspect function determines the direction towards which a specific underwater slope faces. The direction is given in degrees, according to the position of the slope in relationship to cardinal points. Two aspect maps have been calculated:

- the first aspect map was calculated by using the spline interpolation method, with a cell resolution for 100 m
- the second aspect map was calculated by using the *IDW* (inverted distance weight) interpolation method, with a cell resolution of about 260-300 m
- an altered aspect was obtained by varying the brightness[6] of the second aspect map

The first aspect map shows the probable locations of underwater slopes in the Pomeranian Bay, in the lagoon and in the channels (fig. 6). The slopes, generally speaking, tend to be faced southward along the northern edge of the lagoon, while along the southern coastline, they are facing north, north-east or north-west. The Wolin shoal[7] is clearly outlined by a succession of slopes facing west on its left side, and east on its right side. A similar situation is present in the channels. On the Peenestrom and on the Dziwna, the east-facing ledges seem to cover more bottom than the west-oriented slopes from the other side of the channels. On the southern side of the lagoon, the Warpno and Repzin Shoals are shown as sloping eastward, while on the northern side, off the Karsibor Peninsula, the ledge of the Krzecki Shoal is oriented southward.

The second aspect map edited in a monotonic colour range shows more clearly the underwater morphology (fig. 7). The ridge-like shape of the Wolin shoal is more pronounced on this map. The natural trough in which the Piastowski/Kaiserfahrt navigational canal was dug is visible on this map. The most interesting feature is the circular shape shown in the middle of the Lesser Lagoon, which represents the bottom sloping in that area. This feature is enhanced when the brightness of the aspect map is altered.

The slope map shows the areas on the sea/channel/lagoon floor where there is an abrupt change in the gradient of the slope (fig. 8). The colour range can be divided in three major zones:

- the undulated zone, represented by the blue colour range
- the trough zone, represented by the white colour
- the abrasive zone, represented by the red colour range

The 'blue' zone shows that prominent features, like the Wolin shoal, the Krzecki shoal, or the Göschenbrink flat are less visible, that is their slope seems to curve up gradually without pitfalls. The same seems valid on the seaside zone. The 'white' zone shows clearly the Piastowski/Kaiserfahrt navigational channel, but also an interesting pattern off the Baltic coast of the Wolin island. This feature is indicated on modern maps with the help of contour lines, and also on the 1709-navigational chart elaborated by Nicolaas De Vries.[8] The pattern of this feature suggests geomorphologic floor changes related to the Wolinian Stage of the retreating ice mass. Another interesting feature is the white feature at the Swiętoujście-Międzywodzie Height, which seems to be related to an older outlet of the Dziwna in this area.

The 'red' areas represent slopes with maximum gradient that are prone to erosion and sediment transport. The Borken Shoal seems to represent such an area, and also the underwater ledge off Miroszewo, east of the Warpno Shoal. This area was recognized on land as a retreating sector, where the cliff seems to be eroded intensively.[9] Two areas off the Warpno Shoal are shown as spots with an abrupt gradient. These spots are not easily seen on the bathymetric charts, and they seem to be prime candidates to erosion and sediment transport.

The hillshade map was calculated with an azimuth of 180° and a vertical altitude, in order to enhance all the geomorphological details of the floor in the Oder mouth area (fig. 9). The altitude chosen determined an equally distributed illumination over the floor surface. The previously mentioned details are visually enhanced and spatial relationships can be seen clearly:

- the sea floor inlet/Zinnowitz-Vineta-Kosserow banks/the *Rieck* inlet
- the geomorphic postglacial features off the coast of the Wolin Island
- the track of an older Dziwna outlet in the Swietoujscie-Miedzywodzie area
- the Wolin and the Krzecki Shoals
- the Piastowski/Kaiserfahrt navigational channel
- the Repzin and the Warpno Shoals with the two abrasive areas aforementioned
- the circular floor feature in the midst of the Lesser Lagoon.
- the Borken Shoal

- the geomorphic change which divides the Achterwasser basin in a northern and a southern part

The TIN-generated surface

The analysis continued with the elaboration of a TIN model that shows the steepest paths on the floor (sea, channels, lagoon) (fig. 10).[10] The direction of the steepest paths coincides with runoffs of water if the surface would have been dry land. Here one can observe that the major collector of drainage water is the basin located in the Zalew Szczeciński (Stettiner Haff).

Based on these results, it can be said, that the use of generated surfaces as analytic models depends to a great extent on the accuracy of the survey data. The generated model, can then be used to identify or highlight features or geophysical trends that otherwise remain hidden or overshadowed. The spatial analysis gives also the possibility to compare the generated model with older cartographic sources and seek matches of geomorphologic features. These results have been illustrated here with data from the Oder mouth area in order to show the potential brought by GIS-software to the research and reconstruction of underwater areas and past landscapes. GIS is a multifaceted research tool that can be used in different ways to visualize and analize spatially-related data sets.

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End notes

[1] Wolf, *et al.* 1998: 42-78; also, Robakiewicz, 1993.
[2] Osadczuk 1999: 175-188.
[3] Lock and Harris 1996: 219, mention that 'negative areas' known to have obliterated archaeological evidence need to be integrated since they are part of the reconstructed landscape, and most important, they contain information about land development. A similar position was taken here, with respect to the underwater environment.
[4] DEM is the acronym for three-dimensional digital elevation models built with the help of cartographic software. In this case, the input values are negative, thus the change from elevation to bathymetric.
[5] Osadczuk, 1997.
[6] Minimum cell brightness was set at 80 while maximum cell brightness was set at 20.
[7] On Polish navigational charts, the shoal is represented as a continuous feature running on a north-south axis but with three different names, depending on location: at the Rów peninsula height it is named the Wolin shoal, at the Smieć peninsula, it is the Pomeranian shoal, while off the Kopice cliff, it is named the Kopice shoal. In this work, the general name of Wolin shoal is used throughout to ease understanding, and also because the name represents one continuous geomorphological feature.
[8] Mingroot and Ermen 1987: 110.
[9] The erosional rate can be assessed by comparing 19[th]-century maps with modern maps. See Mielczarski 1987: 58-62.
[10] A TIN-based model (triangulated irregular networks) uses triangles in order to built a wire-frame representing adjoining, non-overlapping surfaces. This method minimizes the loss of information between input points, the type of surface rendering being closer to reality.

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Figures

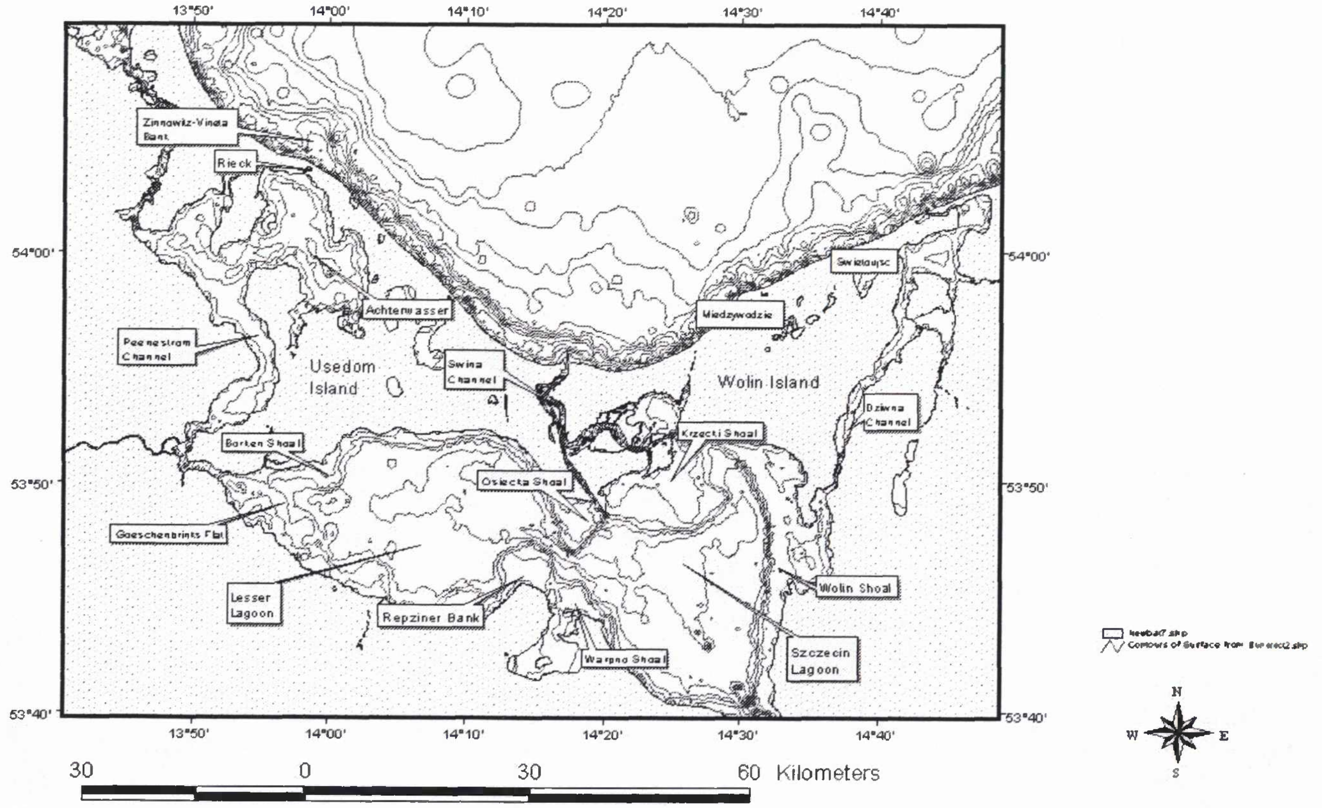

Figure 1. Isobath-contouring generated from 1912-bathymetric readings

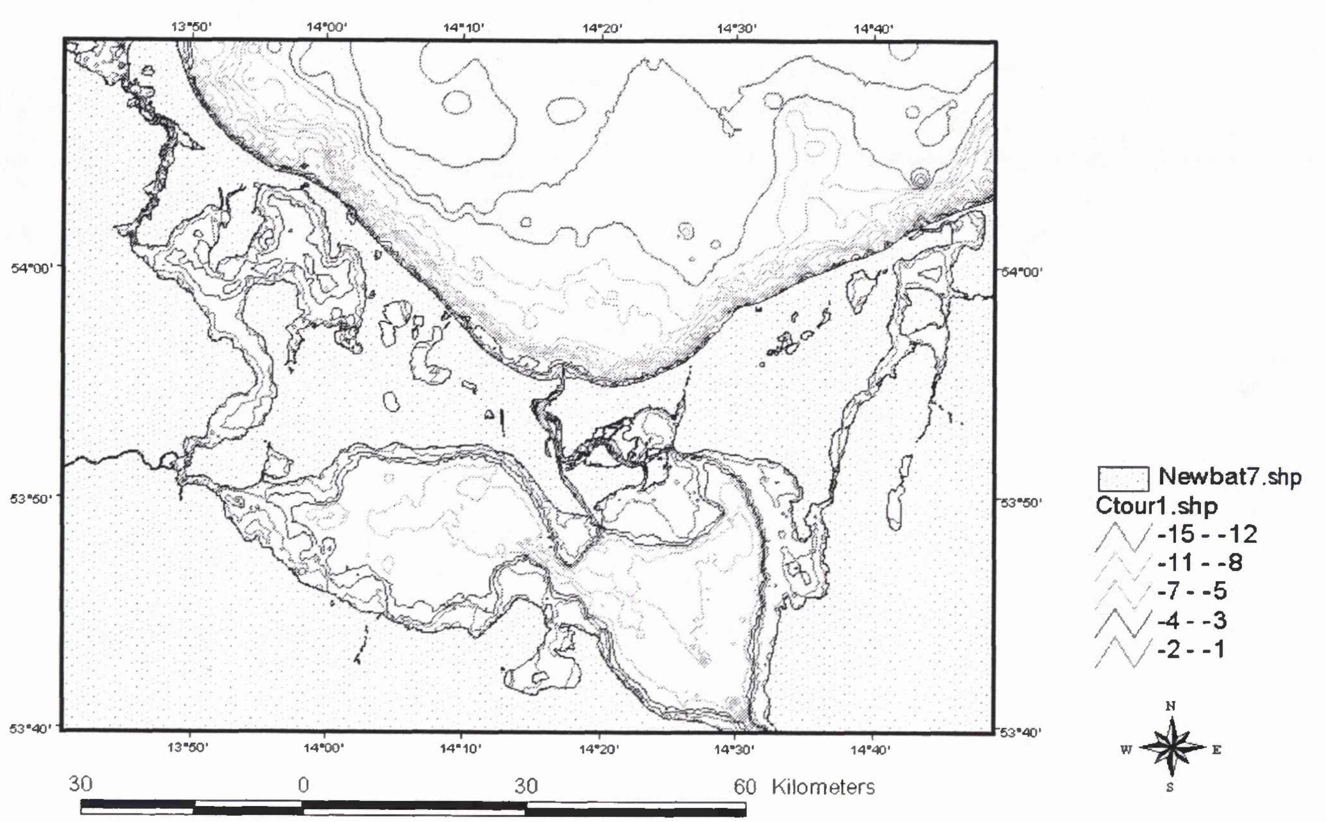

Figure 2. Graduated-colour isobath-contouring generated from 1912-bathymetric readings

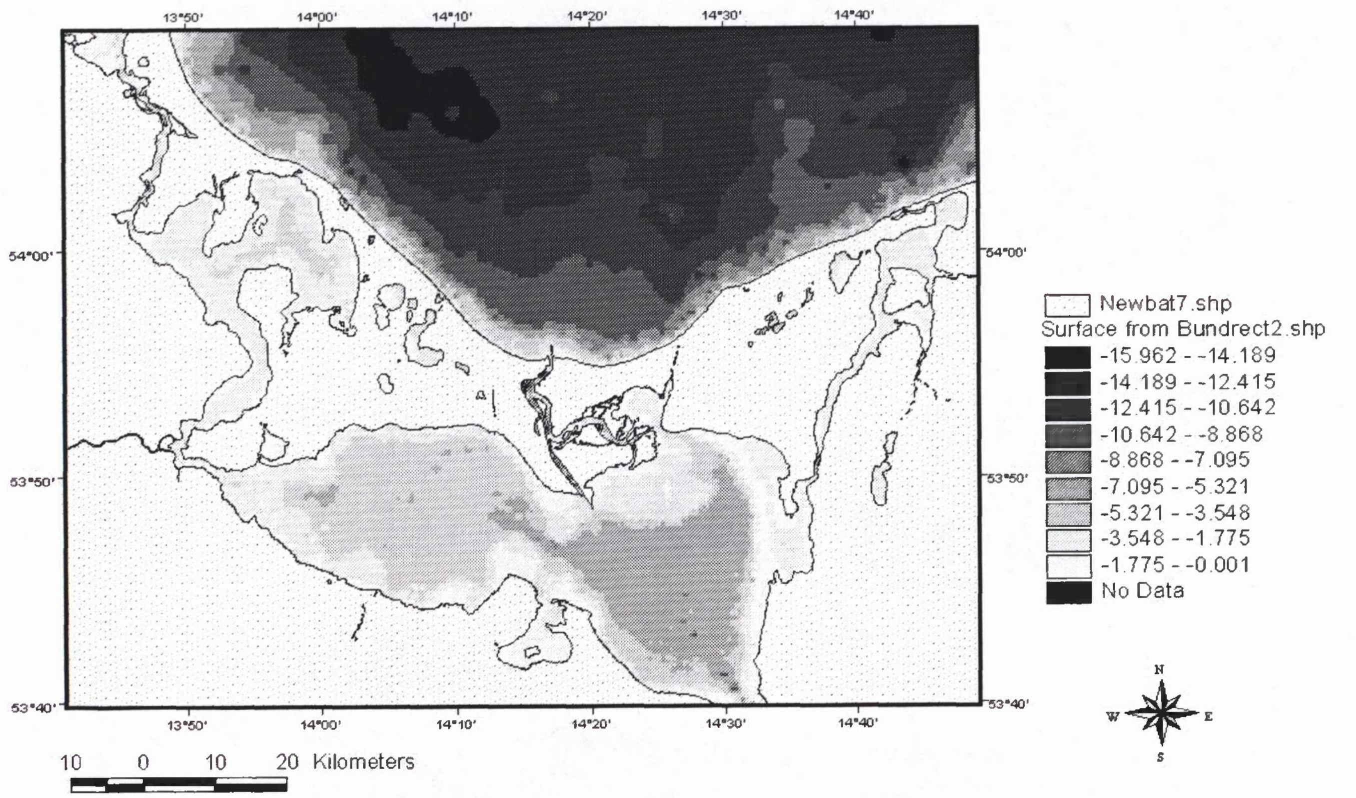

Figure 3. Underwater Surface generated from 1912-bathymetric readings

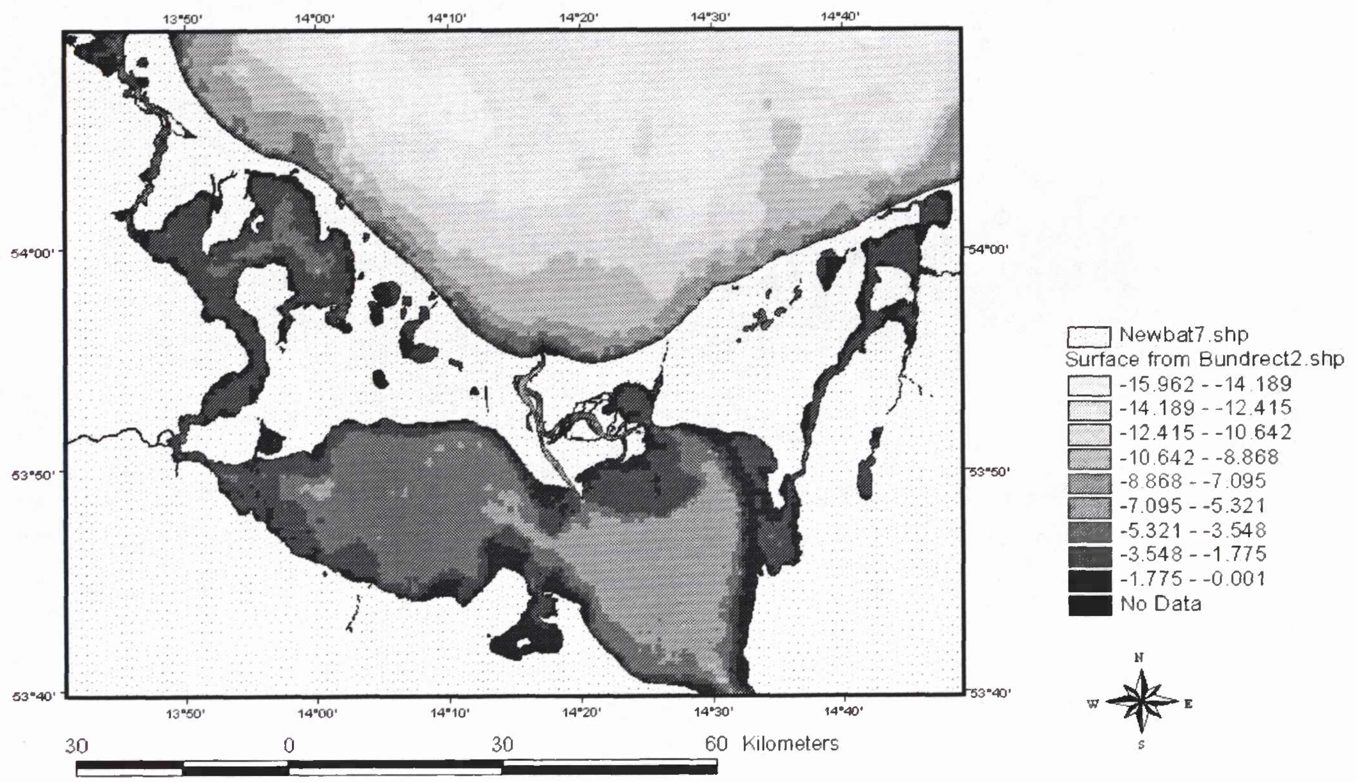

Figure 4. Graduated colour of underwater Surface generated from 1912-bathymetric readings

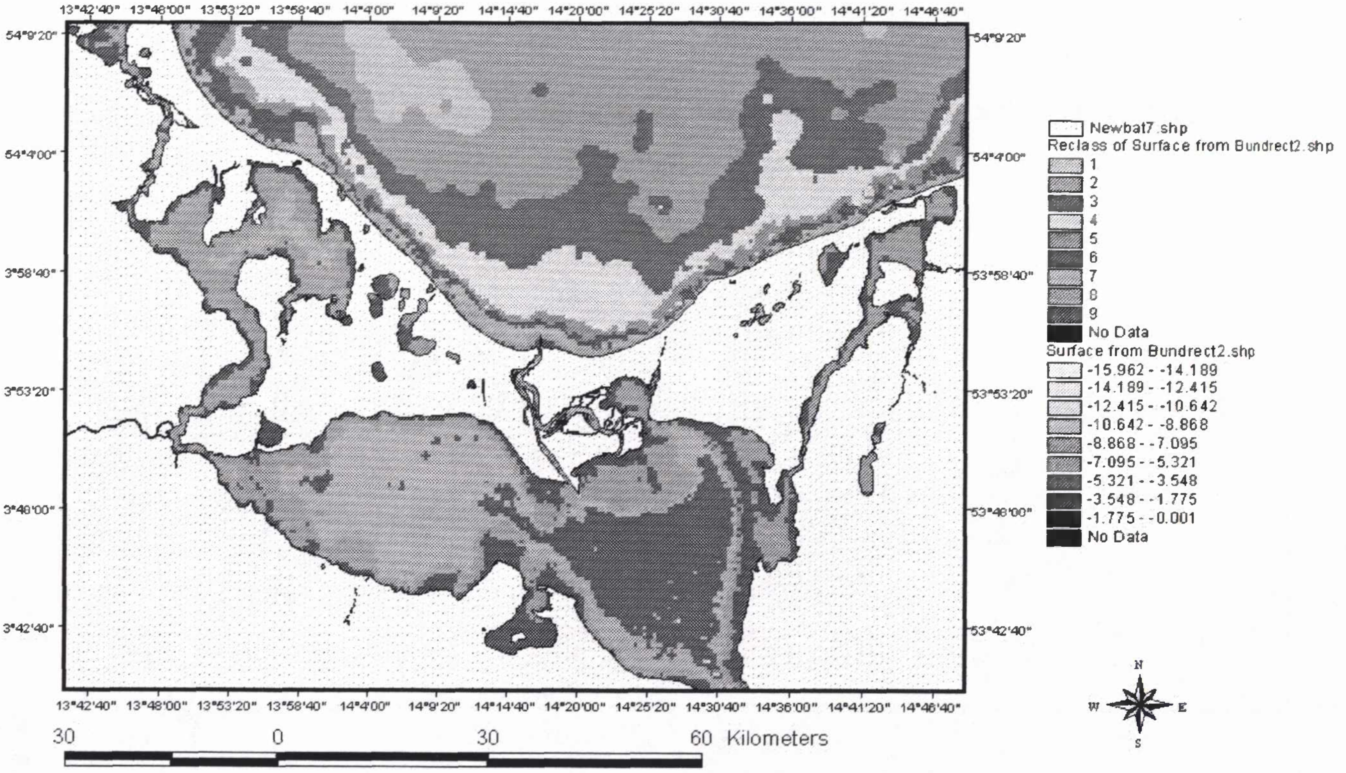

Figure 5. Reclassification of surface mapping

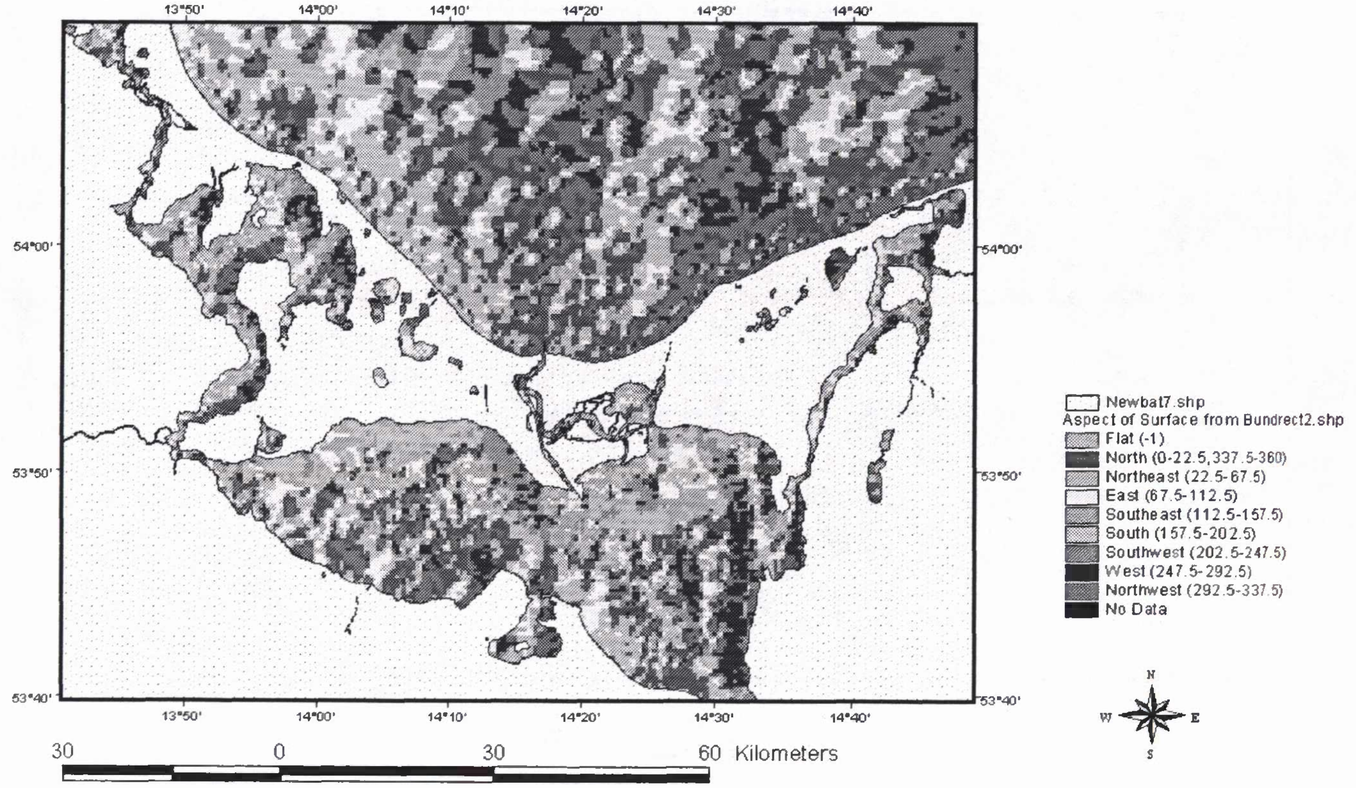

Figure 6. Aspect Mapping of generated surface

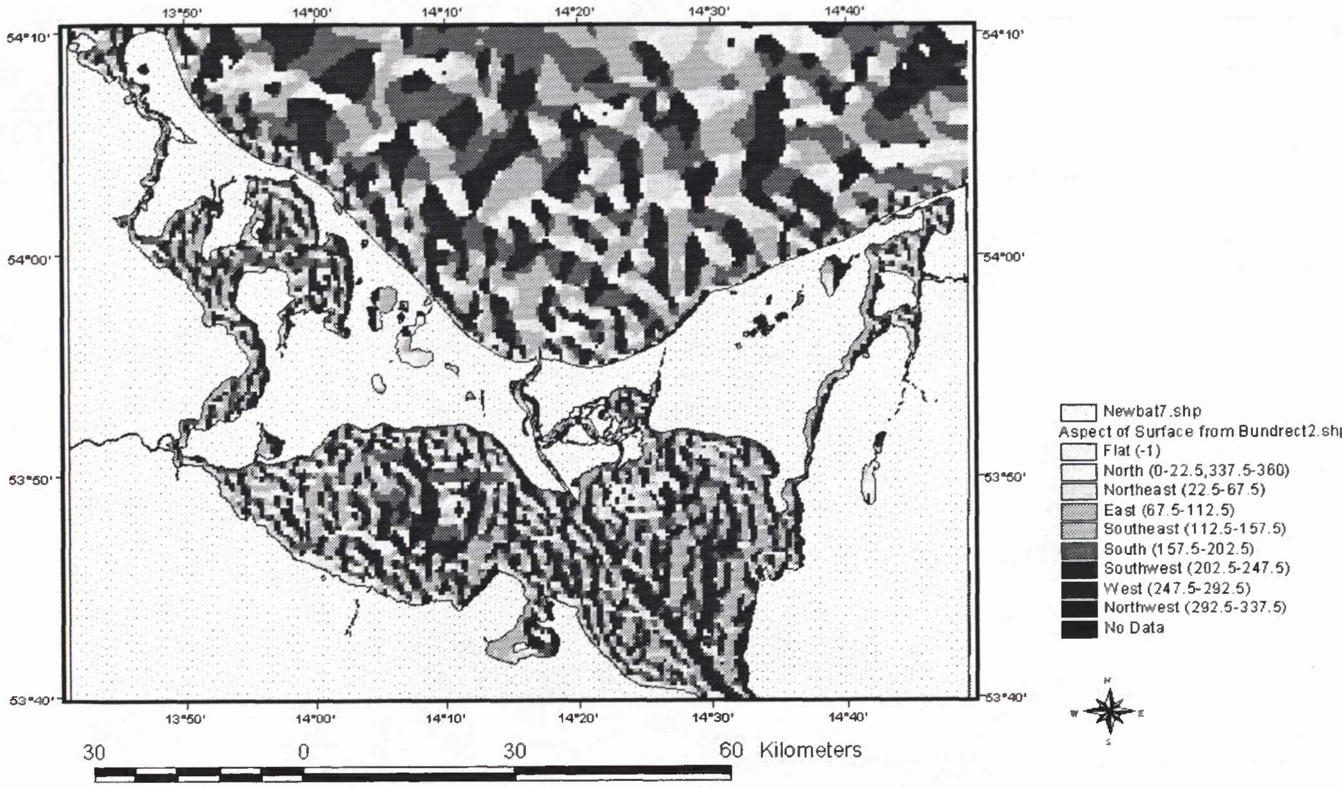

Figure 7. Second Aspect map of generated surface

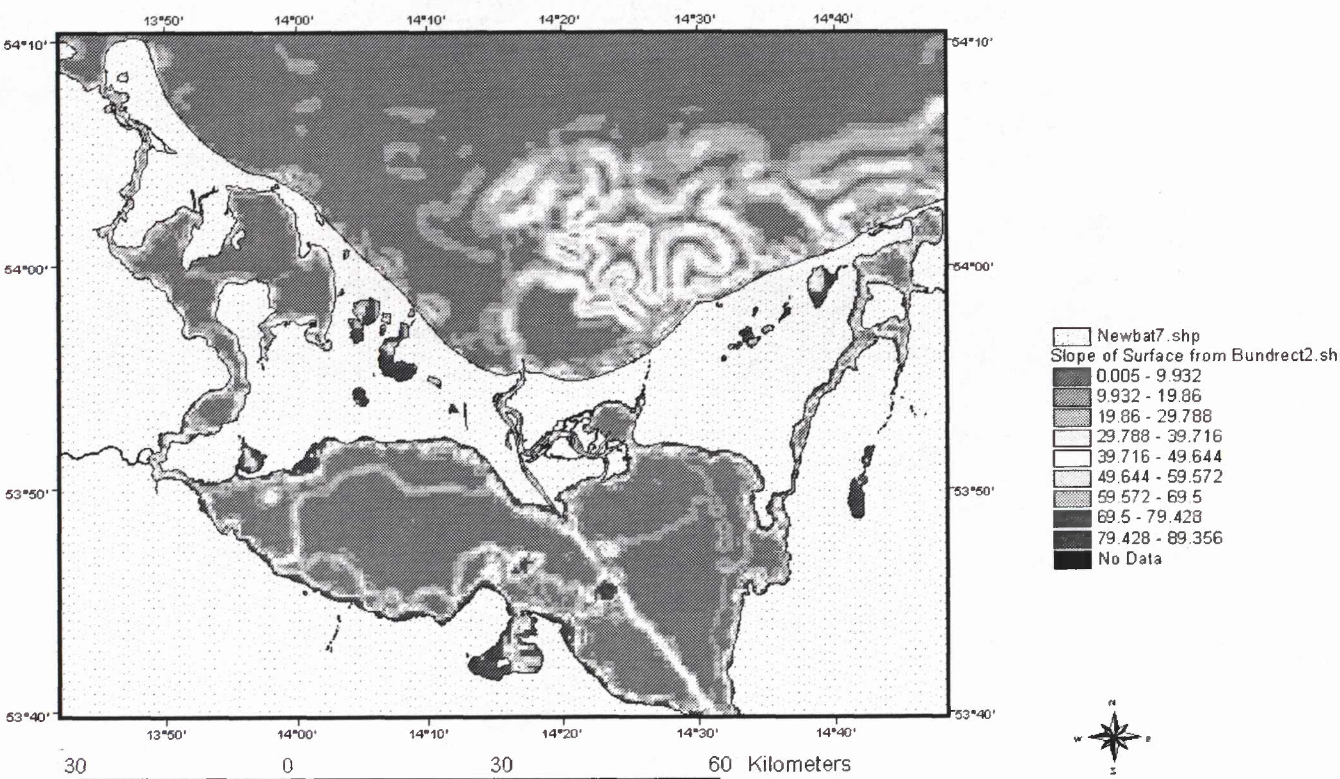

Figure 8. Slope map of generated surface

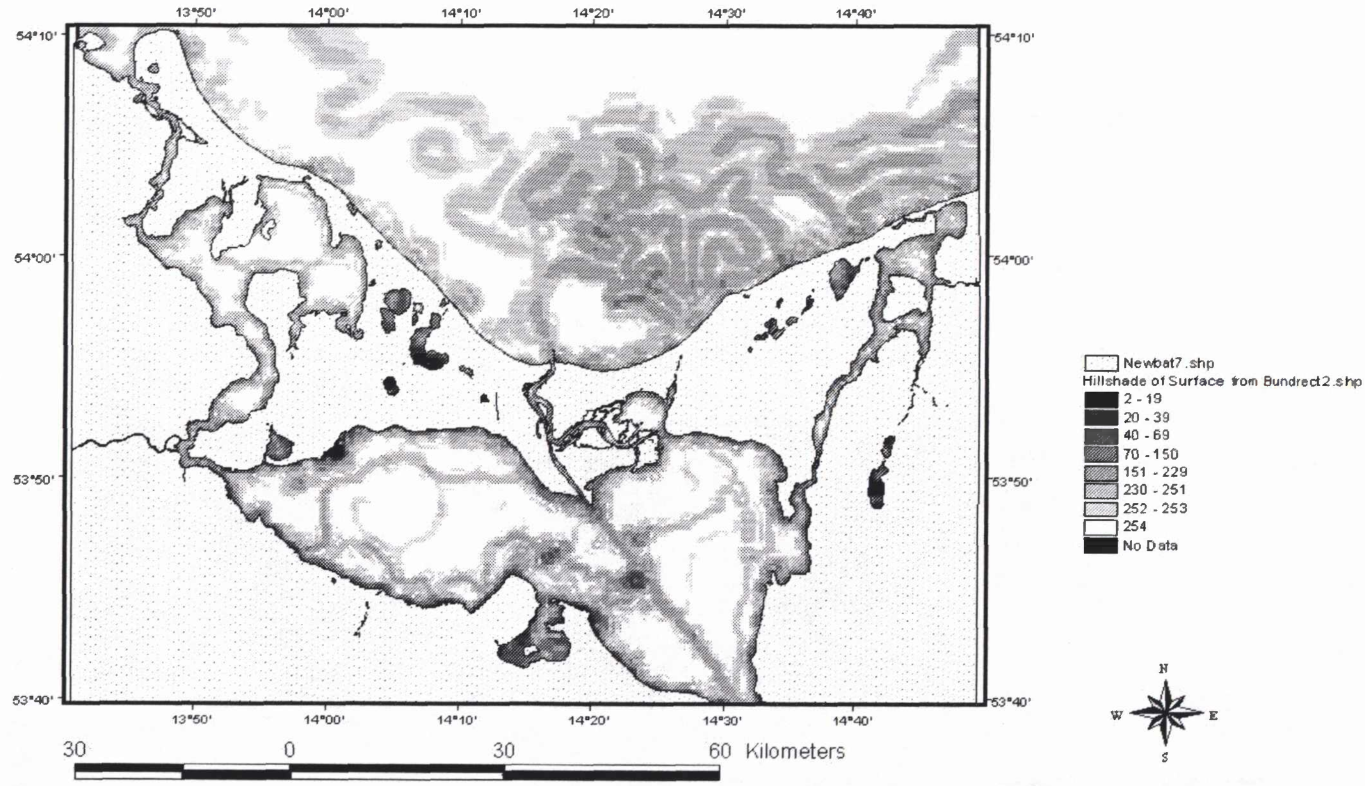

Figure 9. Hillshade map of generated surface

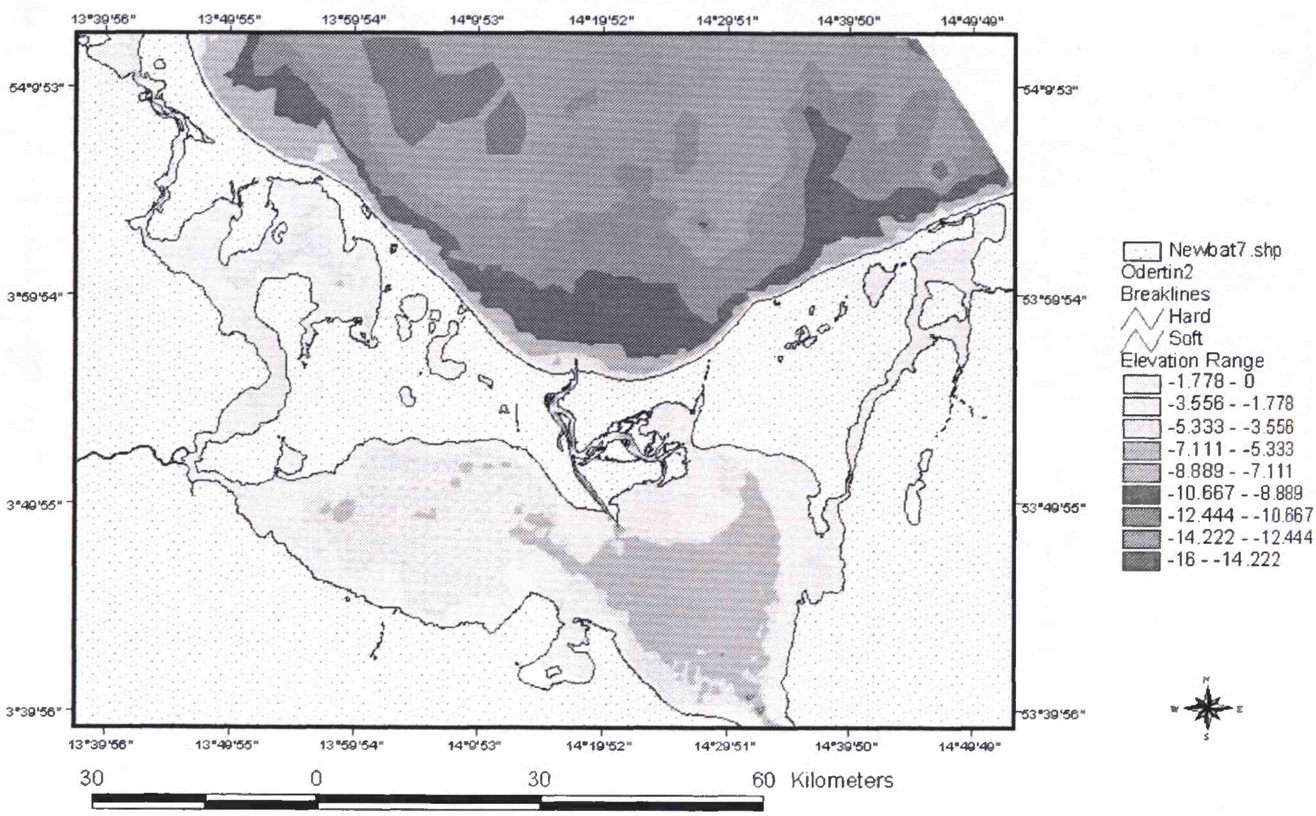

Figure 10. A TIN-based model of the Oder Mouth area