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A method for construction of digital elevation models for site investigation program in Forsmark and Simpevarp

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1 Introduction

A digital elevation model (DEM) is a digital representation of a continuous variable over a two-dimensional surface by a regular array of z-values referenced to a common datum. Digital elevation models are typically used to represent terrain relief.

A DEM is required as input data for many types of surface models such as hydrological models, geomorphometrical models etc. The DEM resolution is the size of the cells in a DEM. The DEM is constructed by interpolation from irregular spaced elevation data. In both these models the Kriging interpolation method were used. Kriging is a geostatistical interpolation method based on statistical models that include autocorrelation (the statistical relationship among the measured points). Kriging weights the surrounding measured values to derive a prediction for an unmeasured location. Weights are based on the distance between the measured points, the prediction locations, and the overall spatial arrangement among the measured points.

Normally, a DEM have a constant value for sea surface (0 masl) and also constant values for lake surfaces. The DEM's for Forsmark and Simpevarp areas has negative values in the sea representing water depth, but constant positive values for lake surfaces representing the lake elevations. All lakes in both areas are depth sounded, so in future versions of the DEM's it is possible to let lakes be represented for the elevations of the lake bottoms instead of the lake surfaces.

Input data to the interpolation have many different sources, such as existing DEM's, elevation lines from paper topographical maps, paper charts and digital charts. All data are converted to point values with different techniques. The Kriging interpolation was performed in ArcGis 8 Geostatistical Analysis extension.

2 Methods

2.1 Data catch from land areas in both Forsmark and Simpevarp areas

Three sources has been used for collecting elevation point data for land areas, the existing DEM from the Swedish national land survey with a resolution of 50 meters (brown areas in figure 2-1 and 2-2), the SKB DEM with a resolution of 10 meters (red areas in figure 2-1 and 2-2) /Wiklund, 2002/, and elevation lines from the digital map with a scale of 1:10000 also from Swedish national land survey (brown areas in figure 2-1 and 2-2).

The lines were transformed to points with an Avenue script in the GIS software ArcView version 3.2. The existing DEM's were converted to point layers in shape-format using ArcToolbox in ArcGis 8. All three point-layers were merged into one single point layer. All point placed on the sea surface polygon from the digital localities maps were deleted from the datasets. These layers are in the Swedish national grid projection (RT 90 2.5 Gon W) and in the Swedish national height system 1970 (RH 70).

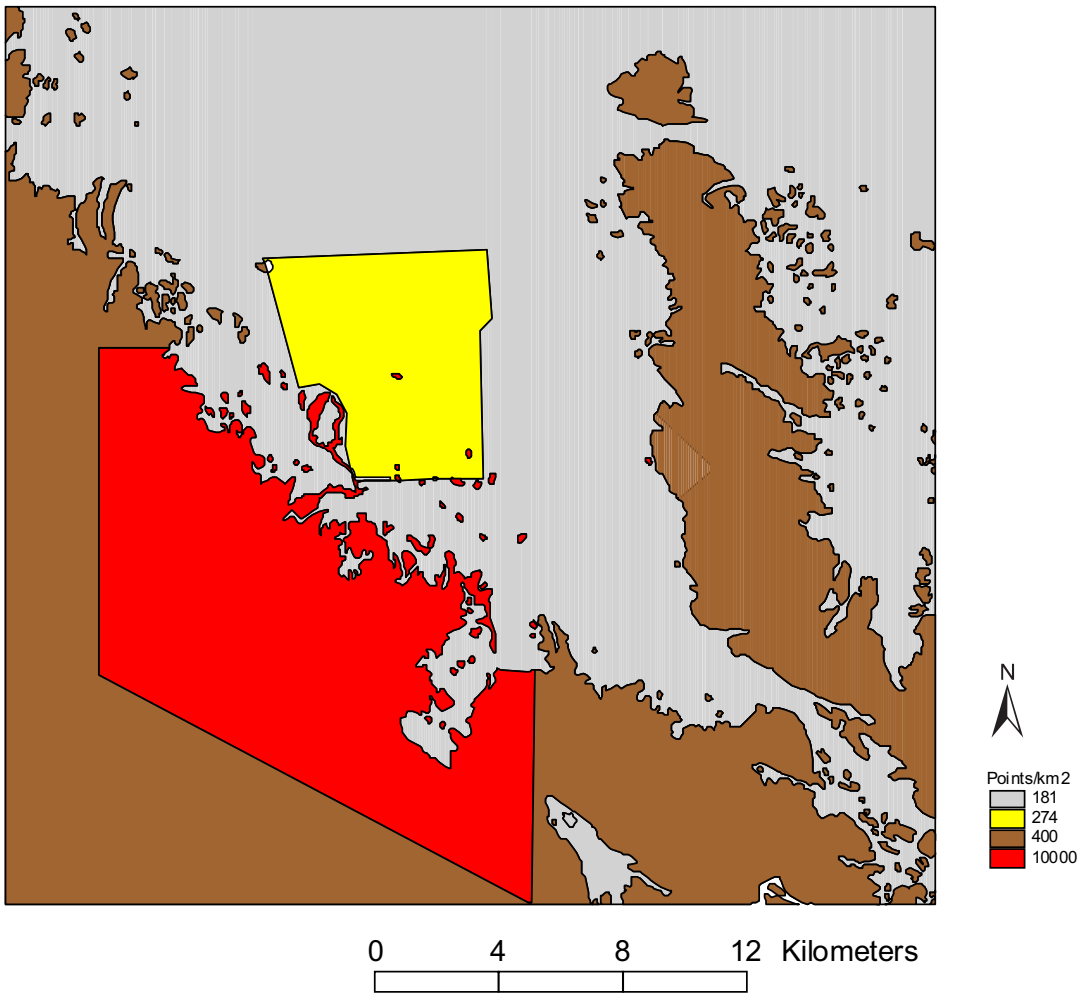

Figure 2-1. *Number of points per square kilometer in the input data to the interpolation for the Forsmark area.*

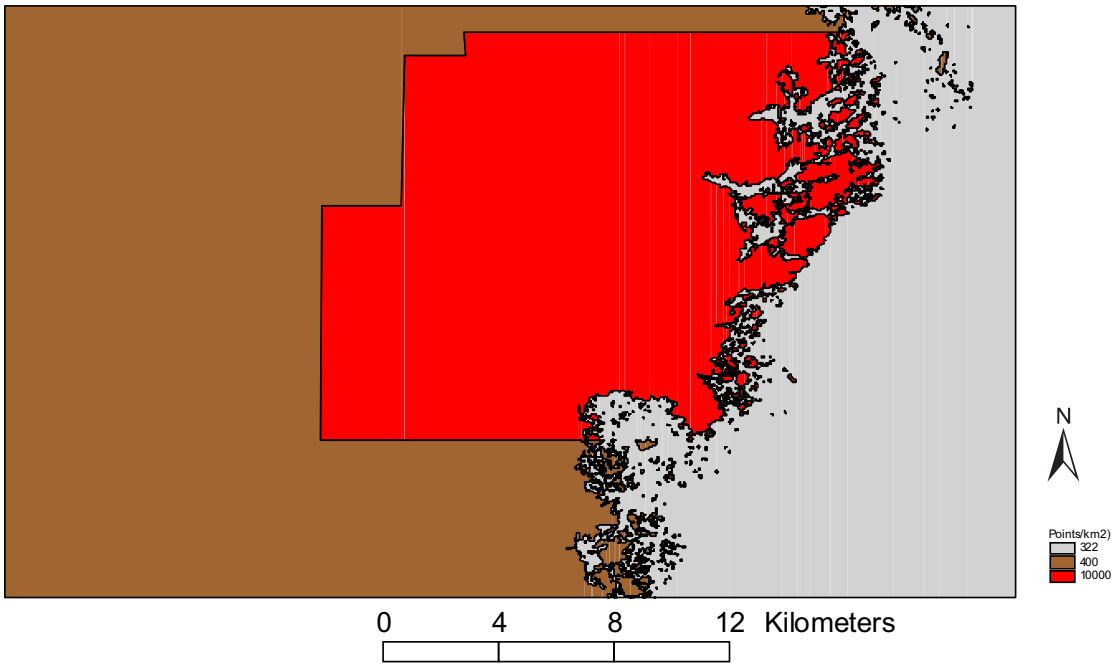

Figure 2-2. *Number of points per square kilometer in the input data to the interpolation for the Simpevarp area.*

2.2 Data catch from sea areas in Forsmark

Elevation data for the sea area has been obtained from the digital chart (the Swedish National Administration of Shipping and Navigation), from the base map to the chart and from the paper chart (number 535 Öregrund – Grundkallen – Björn).

The digital chart has depth lines for 3, 6, 10, 15, 25 and 50 meters. These line objects have been transformed into point objects in the same way as for elevations lines in the digital map.

The digital chart lacks the point depths that are present in the paper chart, so these points where manually digitized from the paper chart. The paper chart was scanned and rectified to WGS-84 with ArcGis 8 and the point depths were manually digitized on screen.

For the yellow area in figure 2-3, the base map to the chart was used for digitizing point depths. These depth soundings were already performed in 1898 so it was necessary to convert these values from foot to meter and at the same time adjust the values for shore displacement since 1898. The adjustment for shore displacement (1898–1970) was calculated to +0.45 meter using equations presented in /Påsse, 1997/ with the following parameters:

As = 300, Bs = 7250, Af = 95 and Bf = 1000.

The base map was scanned and rectified to WGS-84 using the point depths from the paper chart. The point depths on the basemap were then manually digitized on screen.

The depth values in both the digital chart and the paper chart refer to mean sea level 1970, so no adjustment is needed for mixing soundings and land elevation data in RH70.

Elevation data from different sources was in different co-ordinate systems and therefore the data that was not in the Swedish national Cartesian system (RT90 2.5 Gon W) was transformed to RT90. This transformation was performed with the GIS software ArcGis 8.

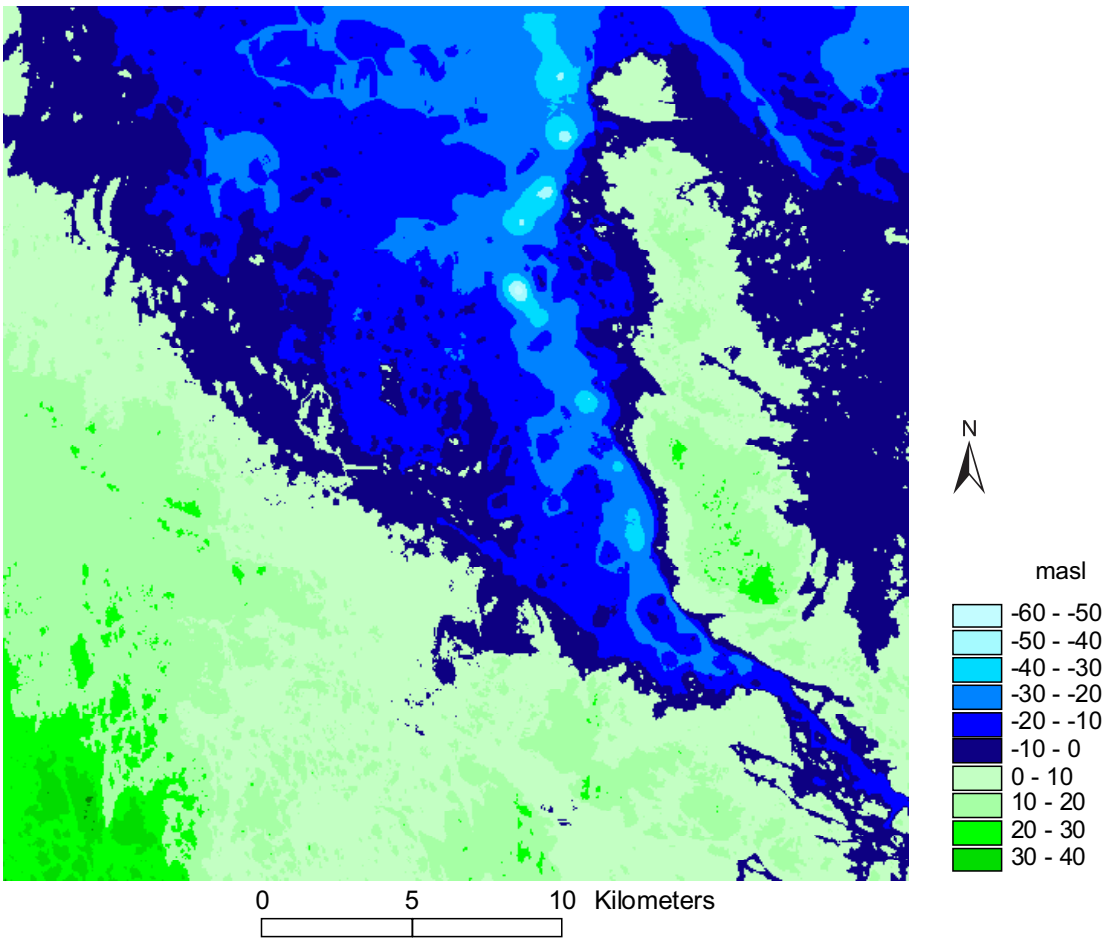

Figure 2-3. *The digital elevation model for Forsmark.*

2.3 Data catch from sea areas in Simpevarp

A digital chart for the Simpevarp archipelago was not available in September 2002 so to catch depths for the sea, the archipelago paper chart number 624 Kråkelund – Blå Jungfrun was used. The chart has a Gauss projection and the geographical grid refers to WGS-84 and was corrected 1997.

The chart was scanned and rectified to WGS-84 in the GIS-program ArcGis 8. The depth information on the rectified chart was digitized on the screen. The depth curves for 3, 6, 10, 15, 20 and 50 meters water depth was digitized as lines and then converted to points with an equidistance of approximately 10 meters. The point depths (single water depth values) and symbols for “Stone in water surface” (a plus sign with dots in each corner) and “Stone beneath water surface” (a plus sign) were digitized as points. The water depth for “Stone in water surface” was set to –0.1 meter and for “Stone beneath water surface” to –0.3 meter.

The sea shoreline was evaluated from the digital localities map (1:10000). The sea water polygon was converted to lines and the lines converted to points with an equidistance of approximately 10 meters and the depth values was set to zero.

The depth values in the chart are reduced to mean sea level 1985. Elevation data on land are in the Swedish national height system 1970 (RH 70) so it was necessary to adjust water depth values to mean sea water level at 1970. The shoreline displacement rate in this area is only approximately 0.1 cm per year so a constant of 0.015 meter was subtracted from the depth values.

All points with depth values were merged into one single point layer and the projection was changed from WGS-84 to RT90 2.5 Gon W using ArcToolbox in ArcGis 8. The total numbers of depth values in the Simpevarp area are 87500.

3 Results

3.1 Construction of the digital elevation models

All elevation point values were collected in two databases and with these databases new digital elevation models were created. The DEMs for both Forsmark and Simpevarp areas were created with a resolution of 10 meters. The interpolation from irregularly spaced point values to a regularly spaced DEM was done with the software ArcGis 8 Geostatistical Analysis extension. Kriging was chosen as the interpolation method /Davis, 1986; Isaaks and Srivastava, 1989/. The choosing of theoretical semivariogram model and the parameters scale, length and nugget effect was done with the extension.

The coordinates of the starting point (upper left corner) was chosen so that the values from the SKB 10 meters DEM was not changed by the Kriging interpolation process, i.e. the central points in the cells in the new DEM coincide with the central points in the SKB 10 meter DEM.

The two digital elevation models are illustrated in figure 3-1 and 3-2.

Finally, the DEM was transformed from ESRI Grid format to ArcInfo ASCII Grid format, a data format that most GIS software can read.

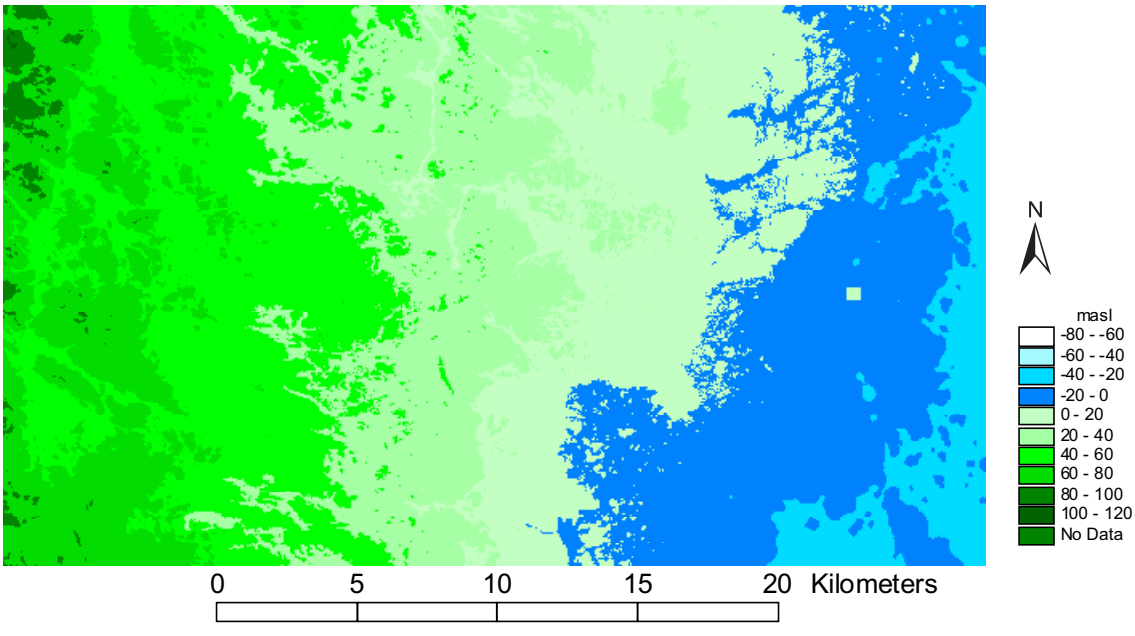

Figure 3-1. *The digital elevation model for Simpevarp.*

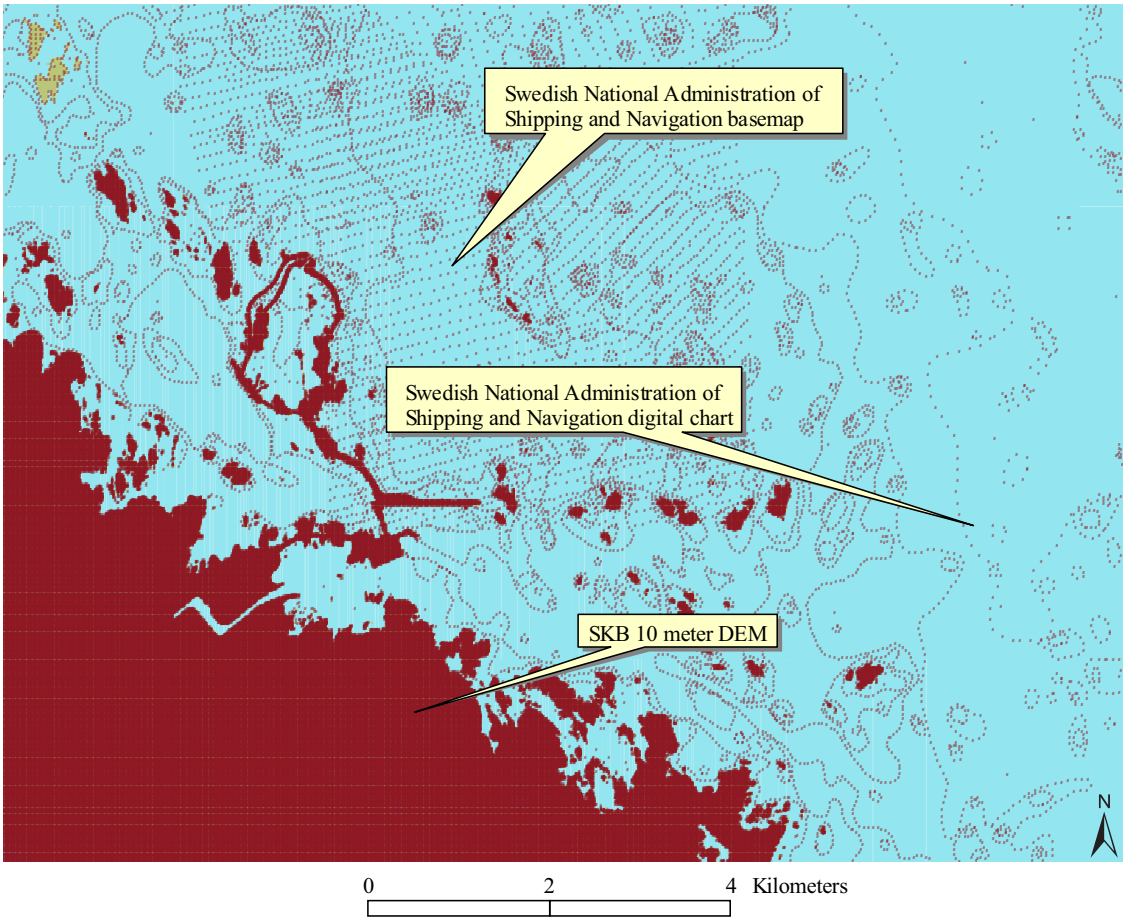

Figure 3-2. *Examples of variation in point elevation densities due to different data sources.*

3.2 Quality of the digital elevation models

Different parts of the DEM area have different data density of the irregular point elevation values. In general, land areas have higher data density compared to sea areas, particularly in sea areas with great water depths. This implies that different parts of the DEM also have different quality.

Figure 3-1 illustrate the great differences in point densities depending on which data source the values belong to. The best quality is within the area of the SKB 10 meter DEM, much lower quality within the base map area and poor quality within the digital chart area.
The lowest data quality in the DEM is the area on the east side of the island Gräsö where soundings are rare due to military restrictions.

A digital polygon map is delivered with the DEM which shows the density of the irregular points over the DEM area (se figure 2-1 and 2-2).

3.3 Data files delivered to SKB

Following data files are delivered to SKB:

Forsmark_DEM	DEM with 10 meter resolution in ESRI grid format
Forsmark_DEM.asc	DEM with 10 meter resolution in ArcInfo ASCII grid format
Forsmark_points.shp	Elevation points used for producing the DEM in shape-format
Forsmark_quality.shp	Polygon map showing variations in point densities in shape-format
Simpevarp_DEM	DEM with 10 meter resolution in ESRI grid format
Simpevarp _DEM.asc	DEM with 10 meter resolution in ArcInfo ASCII grid format
Simpevarp _points.shp	Elevation points used for producing the DEM in shape-format
Simpevarp _quality.shp	Polygon map showing variations in point densities in shape-format

4 References

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Isaaks Edward H, Srivastava R Mohan, 1989. An introduction to applied geostatistics, Oxford University Press, NY, Oxford. ISBN 0-19-505013-4.

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Wiklund S, 2002. Digitala ortofoton och höjdmodeller. Redovisning av metodik för platsundersökningsområdena Oskarshamn och Forsmark samt förstudieområdet Tierp Norra. SKB P-02-02.