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A Digital Terrain Model of the Korgen waterworks area, Lillehammer kommune

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REPORT

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Title:
A Digital Terrain Model of the Korgen waterworks area, Lillehammer kommune

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Summary:

This report has been prepared as part of NGUs contribution to the "Korgen vannverk" project being carried out by Berdal Strømme a.s.. This project forms part of the ENSIS VANN project connected with the 1994 Winter Olympic Games in Lillehammer. The report details the production of a Digital Terrain Model of the Korgen waterworks area. This terrain model forms the basis of a MODFLOW groundwater flow model and a pollution vulnerability assessment described in separate project reports.

Denne rapporten er utført som en del av NGUs bidrag til "Korgen vannverk"-prosjektet gjennomført av Berdal Strømme a.s.. Dette prosjektet utgjør en del av prosjektet ENSIS VANN som har sammenheng med 1994 Vinter OL på Lillehammer. Rapporten gir detaljer om produksjonen av en Digital TerrengModell for Korgen vannverksområde. Terrengmodellen utgjør basis for en MODFLOW grunnvannsstrøningsmodell og en vurdering av sårbarhet for forurensning beskrevet i egne prosjektrapporter.

Keywords: hydrogeologi	grunnvannsmagasin	grunnvann
vannverk	kvartær	fagrapport

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A DIGITAL TERRAIN MODEL OF THE KORGEN WATERWORKS AREA, LILLEHAMMER KOMMUNE

1. INTRODUCTION

1.1 Project background

The Korgen waterworks is the principal water source for Lillehammer kommune. The waterworks are being upgraded to cope with increased demand during the Winter Olympic Games staged at Lillehammer in February 1994. The upgrading is part of the ENSIS VANN project being carried out in close co-operation with Lillehammer kommune.

The digital terrain model described in this report forms the second part of the contribution of the Geological Survey of Norway (NGU) to the groundwater aspects of the ENSIS VANN project. This contribution included:

i) the collation of all existing data on the geology and hydrogeology of the Korgen and Hovemoen areas followed by the production of -
ii) a digital terrain model of the Korgen waterworks area and adjacent Hovemoen area,
iii) a groundwater flow model of the Korgen area and the southern part of Hovemoen and
iv) a groundwater vulnerability assessment of the Korgen waterworks.

Parts i), iii) and iv) are described in separate project reports.

The groundwater flow model and vulnerability assessment mentioned above consider the fate of pollutants after reaching the saturated zone; pollutant transport within the unsaturated zone has been considered in a seperate part of the ENSIS project carried out by Jordforsk. The results of this study are detailed in Jonasson (1994).

The location of the Korgen waterworks within the area of study is shown in Figure 1.

1.2 The objectives of the digital terrain model

The production of the digital terrain model of the Korgen area has two principal objectives:

i) the development of an understanding of the geological (and hydrogeological) conditions with the area,
ii) the terrain model is to form the basis for the production of the groundwater flow model developed as part of the later stages of the project.

1.3 Method

A number of distinct phases were involved in the production of the digital terrain model:

- definition of the major geological units within the area of study
- collation (where possible) of existing contoured elevation maps of the interfaces between the geological units and of the groundwater table

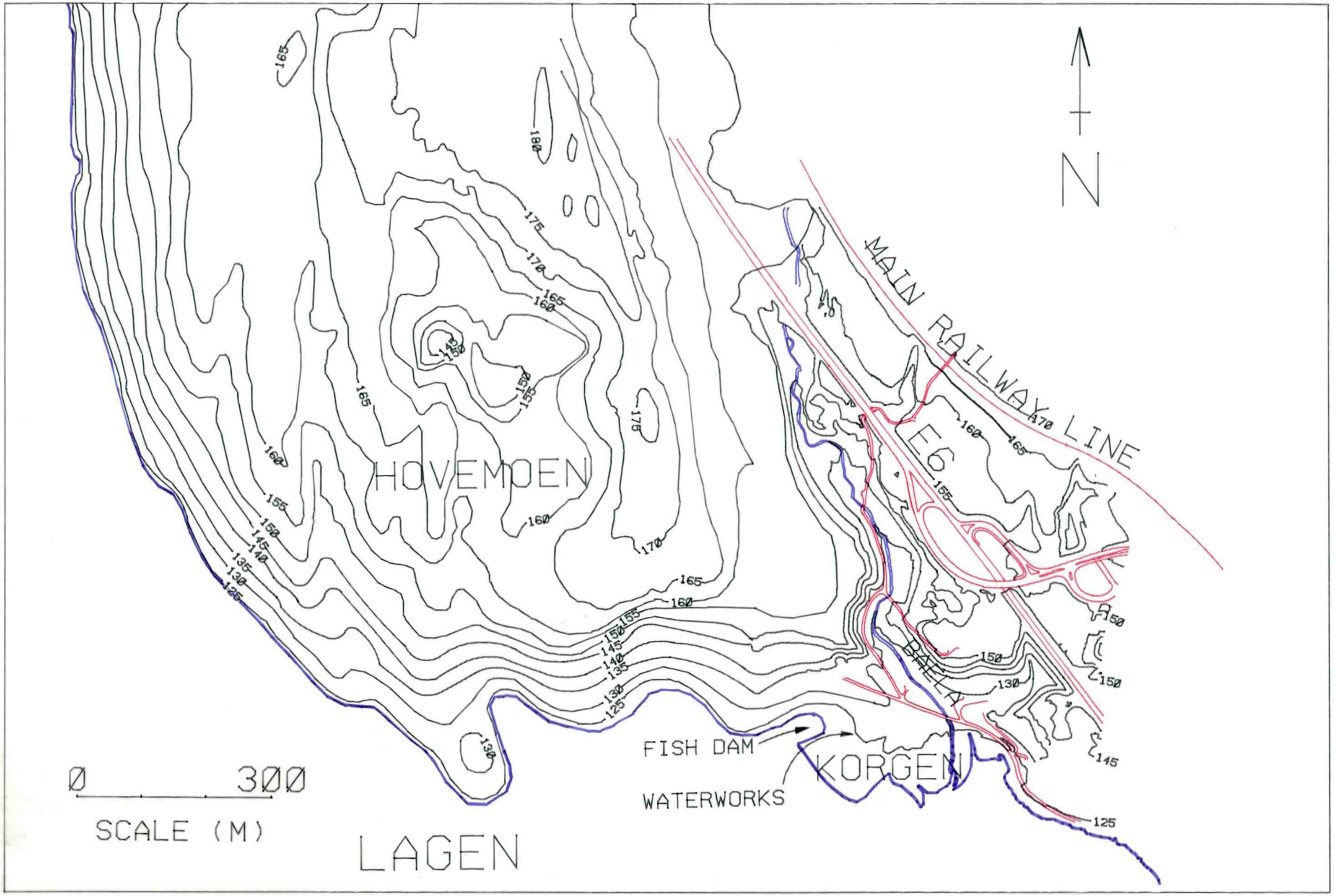

Figure 1. Location map of the study area showing the Korgen waterworks site on the Bæla fan.

- 'infilling' interpretation of any areas of missing data in the above maps
- digitising of the maps
- importing of the digitised sufaces into Intergraph's Microstation Modeller (MSM)
- production of the digital terrain model within MSM

2. GEOLOGY

2.1 Solid geology

Underlying the Korgen and Hovemoen areas are intercalated sandstones and shales of the Brøttum Formation. These sediments were deposited in a deep marine environment during the Late Precambrian era approximately 650Ma B.P.. The sediments probably represent a sequence of turbidite deposits deposited in a sub-marine fan lying offshore from a shallow coastal marine shelf.

The Brøttum Formation was considerably deformed during the Caledonian Orogeny. Regional north-south orientated compression led to the development of imbricated thrust sheets and complex folding.

2.2 Quaternary geology

2.2.1 The Hovemoen area

A total thickness of up to 130m of Quaternary sediments are present in the Hovemoen area.

The lowermost Quaternary sediments in the Hovemoen area consist of fine-grained deposits of silt and clay. These deposits lie directly on the basement rock and were probably formed during an interstadial period (Soldal, 1988). Overlying these sediments are fine-grained sediments, probably of glacio-lacustrine origin. These deposits were probably formed during a period of deglaciation at a time when the ice-front was at Jørstadmoen (1km north of Hovemoen). These fine-grained sediments have a total thickness of approximately 100m.

These sediments are overlain by coarse fluvio-glacial sediments interpreted as being esker sediments deposited during an ice-advance. These sediment are approximately 30m thick. The sedimentary structure and petrographic texture of the sediments suggests that the ice-movement was from the direction of Gudbrandsdalen to the north of Hovemoen. Correlation with other work suggests that the esker was formed prior to 9000 years B.P..

In the southern part of Hovemoen, the esker sediment is absent. In this area, however, reworked coarse-grained sands and gravels are present. These sediments are interpreted by Soldal (1988) as being derived from the esker sediments further north. The processes involved in the reworking of the sediments are not clearly understood although fluvial erosion and deposition or marine reworking (at a time when the sea level was significantly higher than now) are two possibilities.

2.2.2 The Korgen area

The fine-grained interstadial sediments described above are also present in the Korgen area. As in the Hovemoen area, these sediments directly overlie the basement rock. These sediments have a thickness of approximately 50m in this area. The fine-grained glacio-lacustrine sediments, the coarse-grained esker sediments and the reworked esker sediments present in the Hovemoen area are, however, absent from the Korgen area. Overlying the interstadial sediments in the Korgen area is the alluvial fan of the Bæla stream. This fan is post-glacial in origin and is typically 20-30m thick. The fan consists of moderately to poorly sorted very coarse sands and gravels.

Within the fan deposits across the western and southern parts of Korgen is a fine-grained bimodal deposit consisting of cobble and boulder grade clasts in a matrix of clays and silts. According to Soldal (1988), this deposit is wedge shaped, being thickest in the southwestern part of Korgen (where it is at least 15m thick) and lensing out towards the central part of the area. Across the south-central part of Korgen it is typically 5m thick. Insufficient borehole data is available, however, to be certain of it's lateral extent and thickness away from the central part of the Bæla fan. This bimodal deposit is interpreted by Soldal (1988) as being the result of a landslide formed of material derived from the southern slopes of Hovemoen. Soldal (1988) suggests that the landslide may have been the result of the Bæla stream cutting into the fine-grained sediments in the south of Hovemoen. However, the origin of some of the material may be due to other processes such as fluvial deposition.

3. DEFINITION OF THE MAJOR GEOLOGICAL UNITS

A consideration of the above geological description leads to the division of the geology of the Korgen and Hovemoen area into five distinct geological units shown below in Table 1. These units are divided principally on the basis of grain size - the most important criterion in the hydrogeological studies to be based on the terrain model.

Unit	Description	Thickness(m)
1	Upper bimodal deposit extending across the southern and western parts of the Korgen fan only. Cobble and boulder grade clasts with a silt and clay matrix.	0-15
2	Very coarse-grained sand and gravel deposit formed by fluvial deposition from the Bæla stream. Present only in the Korgen area.	25-30
3	Coarse-grained sands and gravel deposits of variable origin extending across much of the Hovemoen area. Absent from the Korgen area.	0-30
4	Fine-grained silt deposits of variable origin underlying the Korgen and Hovemoen areas.	50-100
5	Solid geology (Brøttum Formation) - sandstones and shales	?

Table 1. The five distinct geological units present in the Korgen and Hovemoen areas. Classification based principally on grain-size.

4. DEFINITION OF THE TERRAIN MODEL

The terrain model was derived from the classification shown in Table 1 taking into account a number of hydrogeological considerations. It was decided to group Units 2 and 3 together as a single coarse grained unit. As the solid rocks were assumed to be impermeable and therefore eliminated from the hydrogeological studies, only the upper surface of the bedrock was considered. Furthermore, the uppermost bimodal deposit present in the southern and western parts of the Korgen area was considered insignificant in terms of the terrain model and so was not incorporated within the terrain model. It should be noted, however, that this layer was considered in the hydrogeological investigations.

Two geological layers were therefore defined for the terrain model:

Layer	Description	Thickness (m)
1	Upper coarse-grained sediments extending across much of the Korgen and Hovemoen areas, incorporates the Bæla fan deposits.	25-60
2	Lower fine-grained deposits present throughout Korgen and Hovemoen areas	50-100

Consequently, the elevation of three geological interfaces have to be defined -

i) the upper surface of the coarse-grained sediments (equivalent to the surface topography),
ii) the interface between the coarse and fine grained sediments and
iii) the lower surface of the fine-grained sediments (equivalent to the bedrock surface).

In addition, the elevation of the groundwater table within the area of study was required.

Contoured elevation maps were available for the three geological interfaces across much of the study area. These maps were produced by Østmo (1972). Some extrapolation was required to produce a contour map of the fine/coarse sediment interface in the Korgen area. A reliable extrapolation was made possible through the use of borehole logs for the area. Extrapolation was also required for the base of the fine-grained sediments. This interface is generally gently sloping and appears to follow distinct trends; the extrapolation is therefore not considered to be a weakness of the terrain model.

The groundwater table is interpreted by a number of authors, notably Soldal (1988), to be coincident with the fine/coarse sediment interface across much of the study area. This assumption is used by the terrain model with the exception of the Bæla fan area where the groundwater table is gently sloping while the sediment interface decreases sharply in elevation by approximately 30m.

5. PRODUCTION OF THE TERRAIN MODEL

With the exception of the surface topography, the contour elevation maps described above were digitised by NGU. Digital surface topography data of the study area were obtained from Lillehammer kommune. Gaps in these surface topography data were found to be present in the forested areas. These gaps were filled in by combining these data with surface topography data obtained from digitising maps from Østmo (1972). This was carried out by Intergraph personnel. On completion of this work the terrain model interfaces were now in the form of digitised contour elevation files. The uppermost surface of the terrain model, equivalent to the topography, was shown in Figure 1. Contour elevation diagrams for the other three surfaces of the terrain model are shown in Figures 2 to 4.

These data were imported into Microstation Modeller (MSM) executed on an Intergraph 20/20 Workstation loaned by Intergraph. The contour data were then triangulated within MSM. The triangulated data were then converted to grid files containing 3-D representations of the terrain model interfaces.

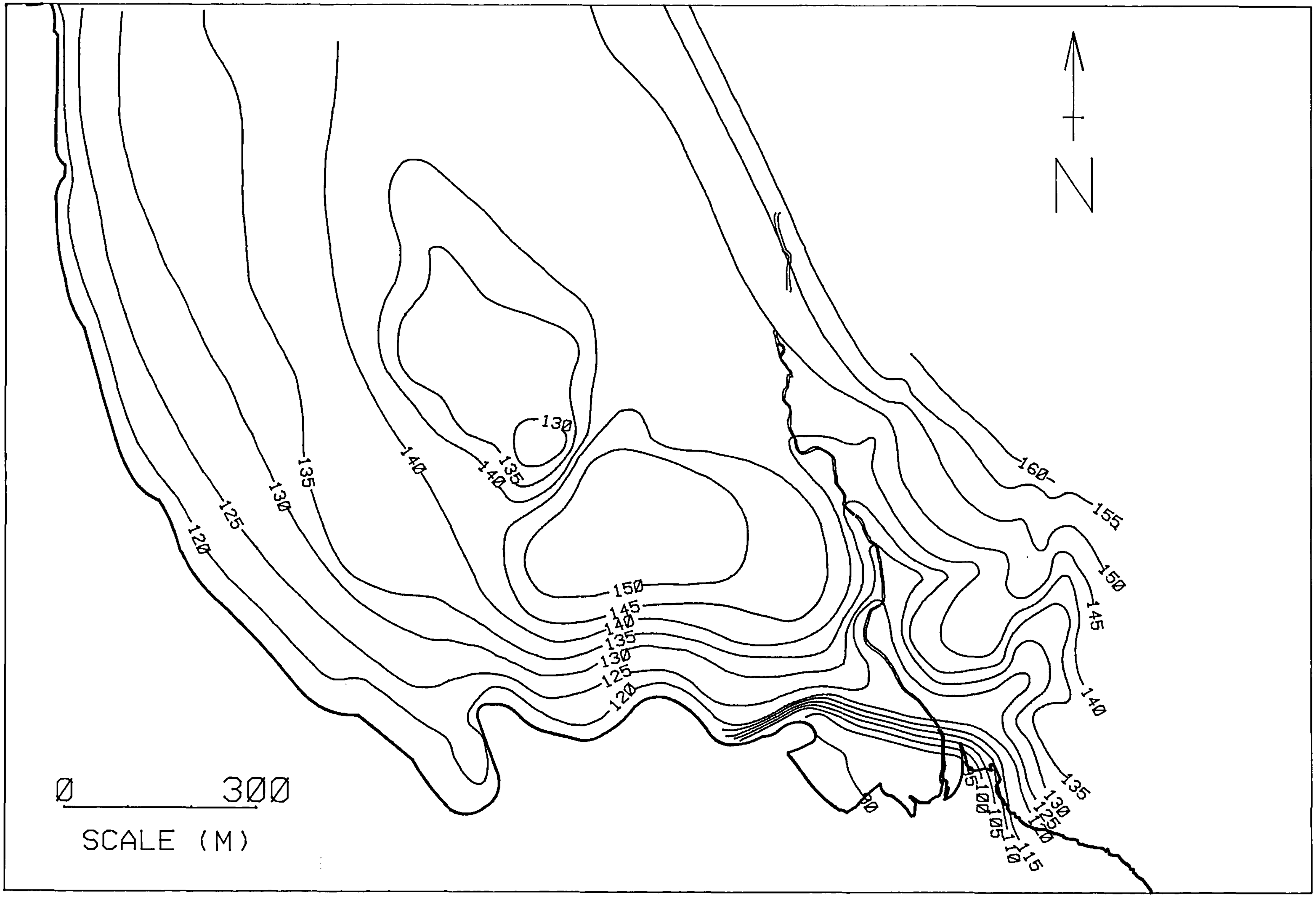

Figure 2. Contour elevation map of the fine-grained/coarse-grained sediment interface representing the interface between Layers 1 and 2 of the terain model.

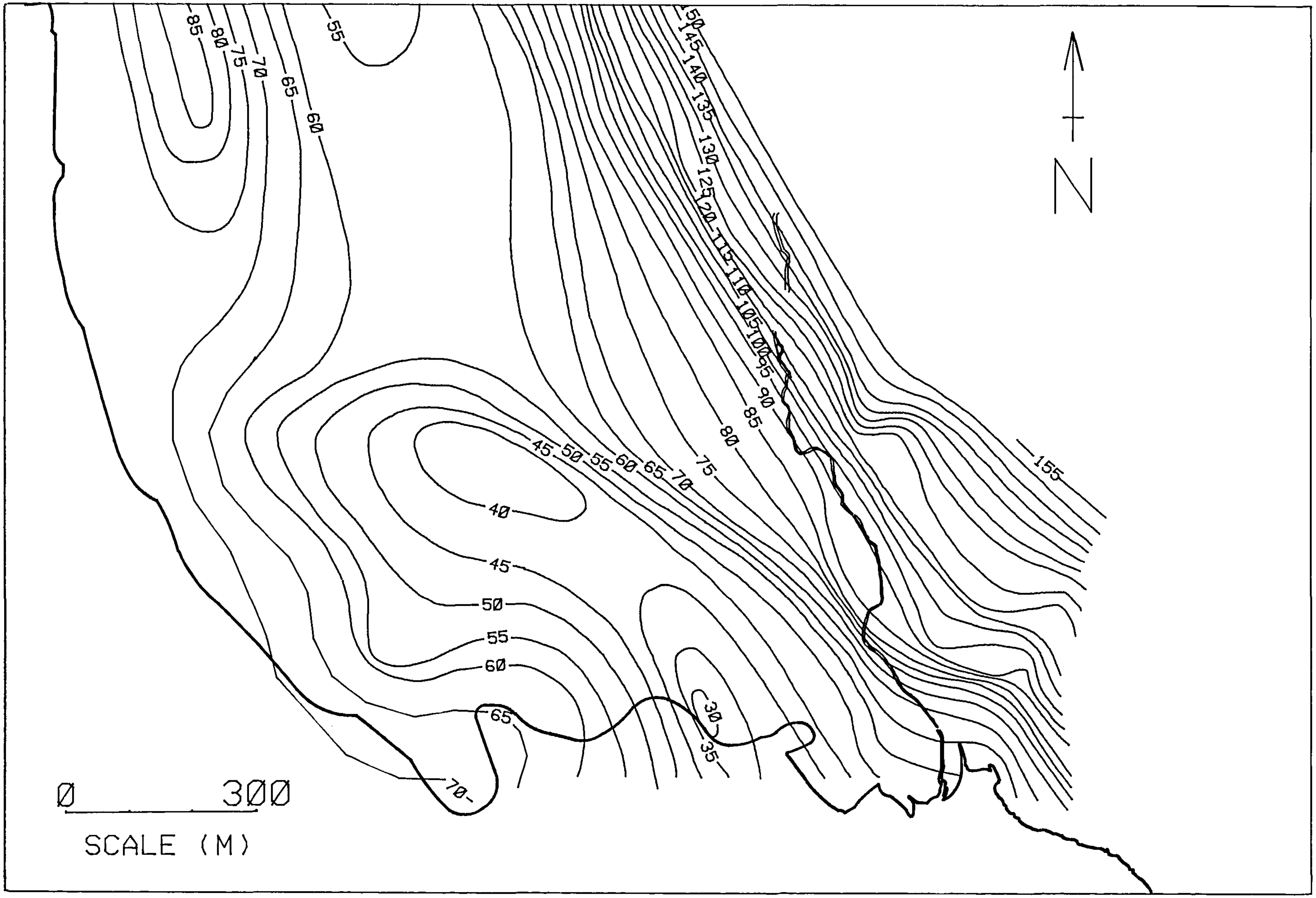

Figure 3. Contour elevation map of the base of the basal fine-grained sediment present throughout the terrain model area. This surface forms the base of Layer 2 of the terrain model.

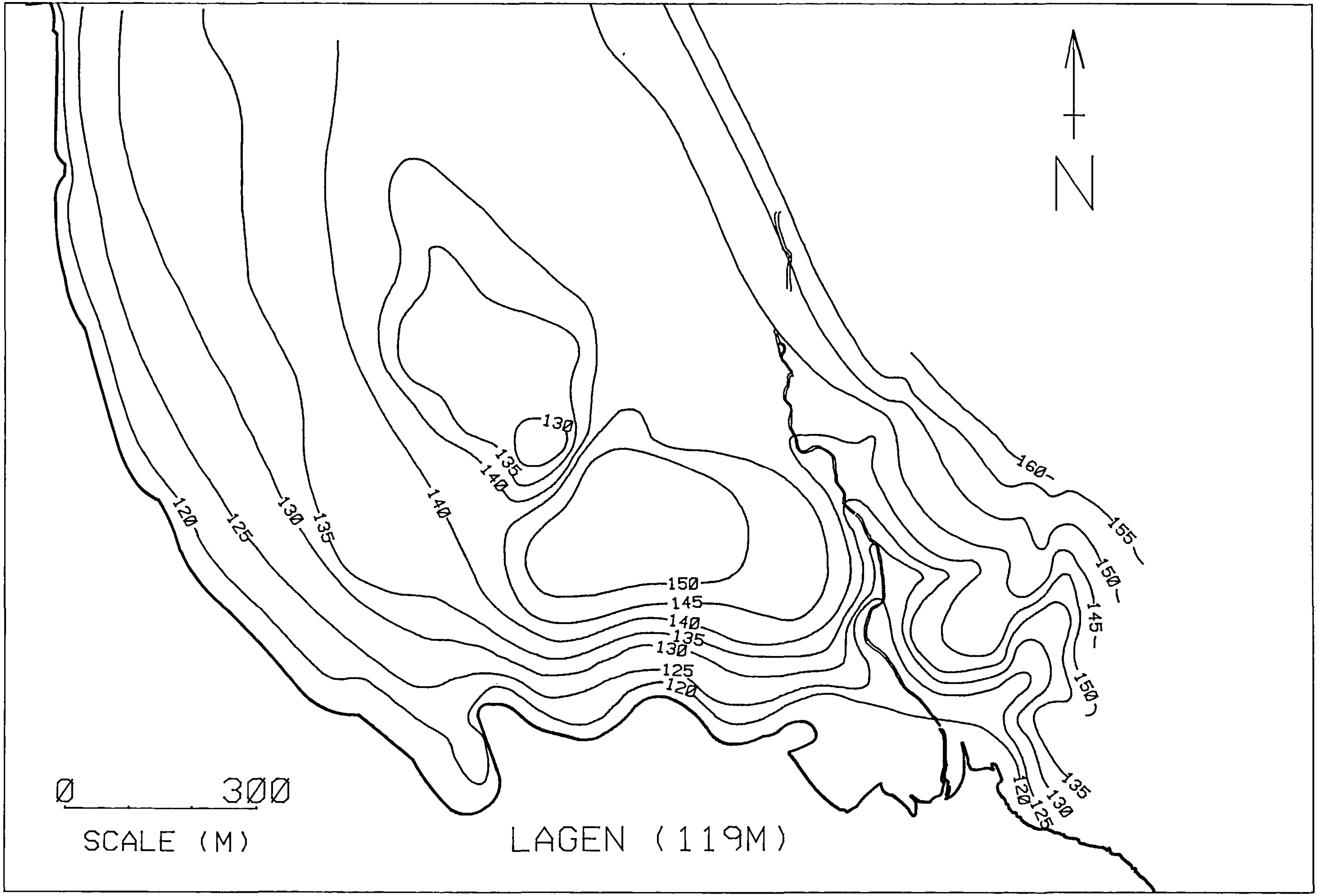

Figure 4. Contour elevation map of the groundwater table.

6. CONCLUSIONS

1). A digital terrain model of the Korgen and Hovemoen areas has been produced. This terrain model enables a visualisation of the 3-D geology of the area. This is an invaluable tool in the understanding of the geological and hydrogeological factors which influence the vulnerability to groundwater pollution of the Korgen waterworks.

2). The terrain model is defined by two distinct geological units; an upper coarse-grained layer of sands and gravels incorporating the Bæla fan deposits and a lower, fine-grained layer predominantly consisting of silt grade material. Three surfaces were therefore required to define the geological terrain model: i) the upper surface of the coarse-grained sediments (equivalent to the surface topography), ii) the interface between the fine and coarse grained sediments and iii) the lower surface of the fine-grained sediments. The groundwater table was also defined as part of the terrain model.

3). Contour elevation maps of these surfaces were digitised and imported into the Intergraph MSM software. MSM was then used to convert these data into 3-D design files which form the terrain model.

4). The terrain model was completed in a way which enabled it to be used as a basis for the further hydrogeological investigations being carried out as part of the ENSIS VANN project. The terrain model enabled a visualisation of the 3-D geology and hydrogeology of the area. Furthermore, the design files forming the terrain model were imported into Intergraphs' ERMA software and used directly in the production of the MODFLOW finite-difference groundwater flow model of the area. The ERMA package facilitated the direct interpolation of the geological surfaces and groundwater table stored as 3-D design files directly onto the MODFLOW finite-difference grid. This considerably reduced the amount of time involved in the preparation of the model.

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