P-04-141

Forsmark site investigation

Measurements of brook gradients and lake thresholds

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ISSN 1651-4416
SKB P-04-141

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Keywords: Forsmark, AP PF 400-04-44, Brooks, Gradients, Cross-sections, Lake thresholds, RTK technique, Total station, DGPS, Levelling.

Abstract

Surface water modelling is performed for SKB's Forsmark site investigation. The existing elevation model, in the form of a regular grid with a resolution of 10 m, does however not describe the brooks and the lake thresholds with an adequate accuracy for this modelling. For this reason, measurements were made of the deepest furrow and cross-sections at regular distances along the brooks. This was planned to be done using the RTK technique and a total station; however, a DGPS combined with a levelling instrument was also used. The intended method provides accuracy down to a centimetre on the x- and y-coordinates and a few centimetres on the z-coordinates. The accuracy with the DGPS and the levelling instrument is a few decimetres on the x- and y-coordinates and better than one centimetre on the z-coordinates. Particularly precise measurements were performed in brooks at lake junctions in order to determine the lake threshold's position and level.

The fieldwork was performed during three periods. The first measurements were done in April 2004, before leafing, using the RTK technique and a total station. However, only about half of the measurements were finished. The second fieldwork was performed in November 2004. At this occasion almost all of the remaining measurements were finished. Since the terrain was extremely difficult in the remaining areas, measurements with the originally planned equipment had been almost impossible. A DGPS combined with a levelling instrument was used instead. Due to a lot of snow and ice some of the lake thresholds were not possible to measure at this time. Four of the six remaining lake thresholds were measured in April 2005. The last two lake thresholds were not possible to measure due to restricted access. It is not yet decided if or when the measurements will be completed.

Measurement points were transferred to a GIS program and delivered in ESRI shape format with coordinates in RT90 2.5 gon W and the levels in the RHB 70 system for storage in SKB's GIS and SICADA databases.

Sammanfattning

Ythydrologisk modellering utförs inom ramen för SKB's platsundersökning i Forsmark. Den befintliga höjdmodellen i form av en reguljär grid med 10 meters upplösning beskriver emellertid inte områdets bäckar och sjötrösklar med tillräcklig noggrannhet. Av den anledningen gjordes en inmätning av vattendragens djupfåror samt tvärprofiler med jämna avstånd längs vattendragen. Inmätningen var tänkt att utföras med RTK-teknik och totalstation, men även en DGPS kombinerad med ett avvägningsinstrument användes. Den tänkta metoden ger centimeter-upplösning i x- och y-led och en upplösning på några centimeter i y-led. Noggranheten med DGPS och avvägningsinstrument är några decimeter i x- och y-led och bättre än en centimeter i z-led. Speciellt noggranna mätningar gjordes vid bäckfåror i anslutning till sjöars utlopp med syfte att noggrant bestämma sjötrösklarnas läge och nivå.

Fältarbetet utfördes vid tre tillfällen. Den första inmätningen gjordes i april 2004, före lövsprickningen, med RTK-teknik och totalstation. Endast ungefär hälften av mätningarna blev dock klara vid det tillfället. Det andra fältarbetet utfördes i november samma år. Vid det tillfället kunde mätningarna nästan slutföras. Eftersom terrängen var mycket besvärlig i området där de återstående mätningarna skulle utföras, hade en mätning med den tänkta utrustningen varit näst intill omöjlig att genomföra där. Därför användes en DGPS kombinerad med ett avvägningsinstrument i stället. På grund av snö och is var det inte möjligt att mäta in några av sjötrösklarna. Fyra av de sex återstående sjötrösklarna mättes in i april 2005. De två sista sjötrösklarna var inte möjliga att mäta in på grund av att det då inte var tillåtet att beträda området där dessa sjöar är belägna. Det är ännu inte bestämt om och när mätningarna kommer att slutföras.

Mätpunkterna överfördes till ett GIS-program och levererades i ESRI shape-format med koordinaterna i RT90 2.5 gon W och nivåerna i RHB 70-systemet för lagring i SKB's GIS-databas och i SICADA.

Contents

1 Introduction

Surface water modelling is performed within SKB's Forsmark site investigation. The existing elevation model, in the form of a regular grid with a resolution of 10 m, does however not describe the brooks and the lake thresholds with an adequate accuracy for the surface water modelling. For this reason, the deep furrow and cross-sections were surveyed at regular distances along the brooks. Particularly precise measurements were performed in brooks at lake junctions in order to determine the lake threshold's position and level.

The work, except for the fieldworks in November 2004 and April 2005 when an alternative measurement technique was used, was carried out in accordance with activity plan SKB AP PF 400-04-44. Table 1-1 lists the controlling document for performing this activity. The activity plan is SKB's internal controlling document.

Table 1-1. Controlling document for the performance of the activity.

Activity plan	Number	Version
Inmätning av vattendrag och sjötrösklar	AP PF 400-04-44	1.0

The results of the measurements are stored in ESRI shape format (points) in the SICADA and GIS databases (Table 1-2).

Table 1-2. Data references.

Sub-activity	Database
Inmätning av vattendrag och sjötrösklar	SICADA
	GIS

2 Objective and scope

According to the activity plan AP PF 400-04-44 the following brooks and lake thresholds should be measured:

(i) Upstream Eckarfjärden, approximately the length that is marked in Figure 2-1.

(ii) From Eckarfjärden through Stocksjön, Bolundsfjärden, and Norra Bassängen to the Baltic Sea.

(iii) Upstream Gällsboträsket to the split of the brook.

(iv) From Gällsboträsket to the brook junction with the brook from Eckarfjärden.

(v) From Fiskarfjärden to the Baltic Sea.

(vi) From Gunnarsboträsket through Labboträsket, Gunnarsbo–Lillfjärden (södra) to the canal.

(vii) Lake thresholds for lakes in catchments 1:2, 2:2, 2:4–5, 2:5, 2:6, 2:7, 2:11, 3:1, 4:1–2, 4:2, 5:1, 6:1, 7:1–4, 7:2–4, 7:3, 7:4 and for the nine lakes mentioned above (Figure 2-1). For description of the catchments and the lakes, see /1/.

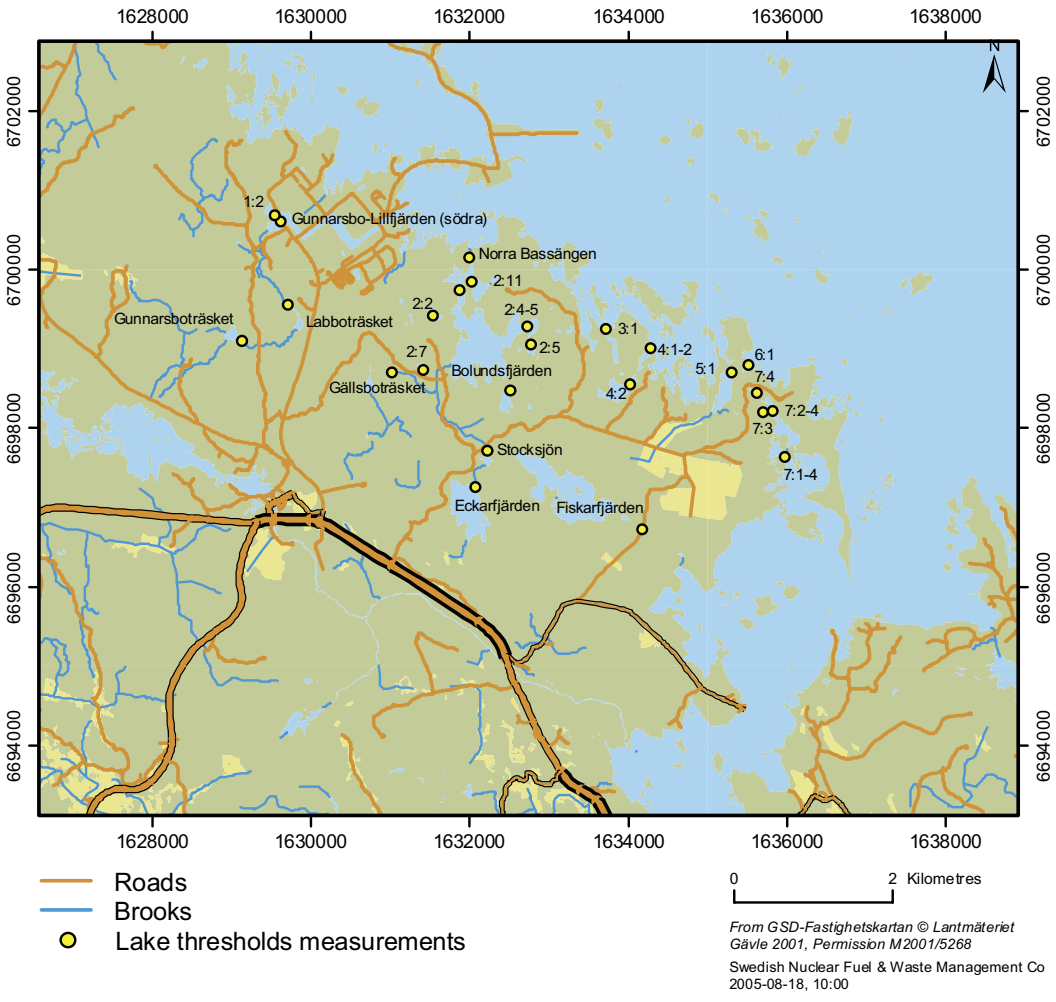

Figure 2-1. *Overview of the Forsmark site investigation area. The yellow dots mark positions for lake threshold measurements (see /1/ for description of catchments and lakes).*

3 Equipment

3.1 Description of equipment

RTK instruments and a total station were used to perform the measurements. The RTK technique (Real Time Kinematics) is a variant of the Global Positioning System (GPS). The RTK technique uses one stationary receiver (the base), placed over a known position, to send corrections to a mobile receiver (the rover). With access to these corrections, the rover can accurately calculate a position within centimetres if the distance between the base and the rover is shorter than approximately 20 km. Our choice of RTK was the Leica Skipro 500. A total station is an electronic instrument that measures length and horizontal and vertical directions where the angle measurements have an accuracy of at least 0.6 mgon and an accuracy in the length measurement of at least ± 5 mm + 5 ppm.

Measurements with RTK technique are faster than with the total station, so the RTK technique was used as a first choice. In places with dense vegetation close to the brook, it was however not possible to obtain contact with the satellites. At these locations, it was necessary to use the total station.

Because of the extremely difficult conditions, a DGPS in combination with an optical levelling instrument was used during the fieldworks in November 2004 and April 2005. The DGPS used was a Trimble Pro XR connected to a field computer Trimble TSCe with the ESRI ArcPad 6.0 real time GIS software. By measuring every other second for 1 minute at each location and by using the mean value, the positions are calculated with a horizontal accuracy of a few decimetres. With the levelling instrument, it is possible to produce a millimetre precision in the vertical direction for each measurement. Of course, the precision will decrease after many successive measurements.

4 Execution

4.1 Execution of field work

The measurements were carried out with the following method:

(i) The RTK base instrument was placed in a high central position in the area.

(ii) The measurements of the brooks were done with a RTK rover stick. The x-, y-, and z-coordinates were recorded in the deepest part of the brook approximately every 20 m; closer distances were used where gradients were large and in the measurements of lake thresholds.

(iii) The cross-sections were measured every 100 m along the brooks with one measurement made at the deepest part of the section, two points at each shoreline, and two points in the middle.

(iv) In places where the brook geometry was indistinct (i.e. through mires), the start and stop of the indistinct part were recorded.

(v) Where the rover was malfunctioning, a fix was placed at the last spot with an accurate position. The measurements were continued at the next location with an accurate position.

(vi) Along the brooks where RTK positions could not be recorded, the measurements were done with the total station.

(vii) At the second and third fieldwork the measurements were carried out with a combination of a DGPS and an optical levelling instrument. The GPS-coordinates were given unique identification values and the same unique values were written for each level measured with the levelling instrument.

4.2 Data handling after processing

Data recorded with the RTK technique were stored in RT90 2.5 gon W, whereas data recorded with the total station were stored in a local coordinate system. Using the fixed point measured with the RTK technique, the local coordinate system was transformed to RT90 2.5 gon W/RHB 70. Coordinates measured with the DGPS were saved in RT90 2.5 gon W, and data from the levelling instrument were converted to RHB 70 by using height values from earlier measurements of the levels of Labboträsket and Gunnarsbo Lillfjärden (södra).

All files were imported to ArcGis 8. All files with brook geometry were merged into a single map, and measurements of lake thresholds were merged into one separate map. The two maps were stored in shape format.

4.3 Nonconformities

Because many places had dense vegetation close to both sides of the brooks, the RTK technique did not work everywhere. This made it necessary to use the total station. This implied that the fieldwork took much longer time than planned. In addition, not all brooks were measured before leafing, a situation that complicated the RTK measurements.

The fieldwork in November 2004 was problematical due to a great deal of snow and thick ice on some brooks and lakes. This made measurements of the thresholds for the lakes in the catchments 1:3–4, 2:2, 2:5, 2:7, 4:2 and 7:4 impossible. In April 2005 four of the remaining lake thresholds were measured. However, due to restricted access the lake thresholds in the catchments 2:5 and 7:4 could not be measured at this occasion.

5 Results

Figure 5-1 shows the brook sections measured during the fieldwork in 2004. The blue dots illustrate parts measured with RTK technique, the yellow dots parts measured with total station, and the red dots parts measured with DGPS and a levelling instrument.

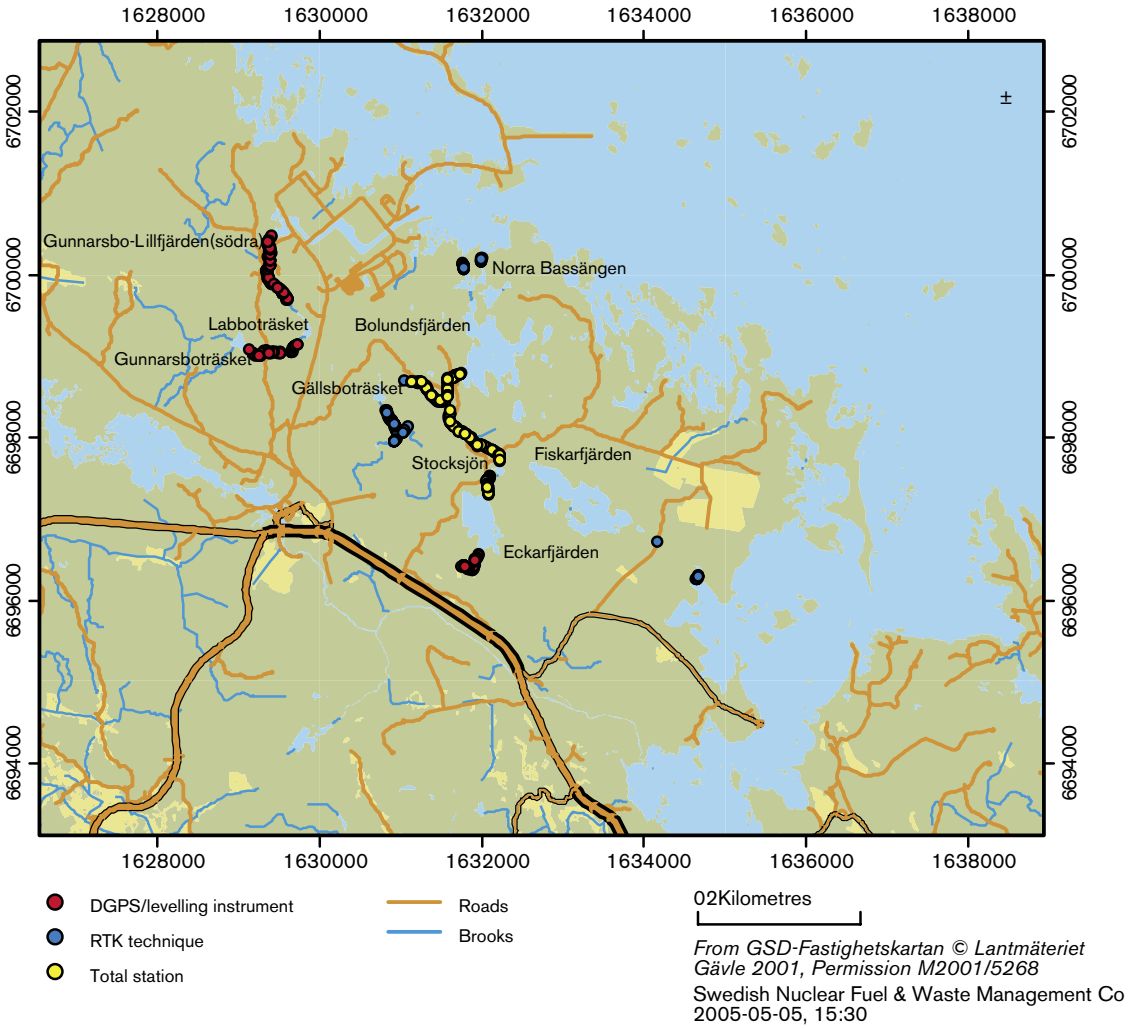

Figure 5-1. *The brook sections measured in 2004.*

5.1 The brook between Eckarfjärden and Stocksjön

The geometry of the brook is clearly defined along the whole section. The gradient is low in the beginning of the stretch (Figure 5-2) with fine-grained bottom sediment with large amounts of organic content. The gradient increases after approximately 250 m and the bottom sediments change to stony gravelly till. Because of bad satellite signals, the Eckarfjärden threshold was measured with the total station.

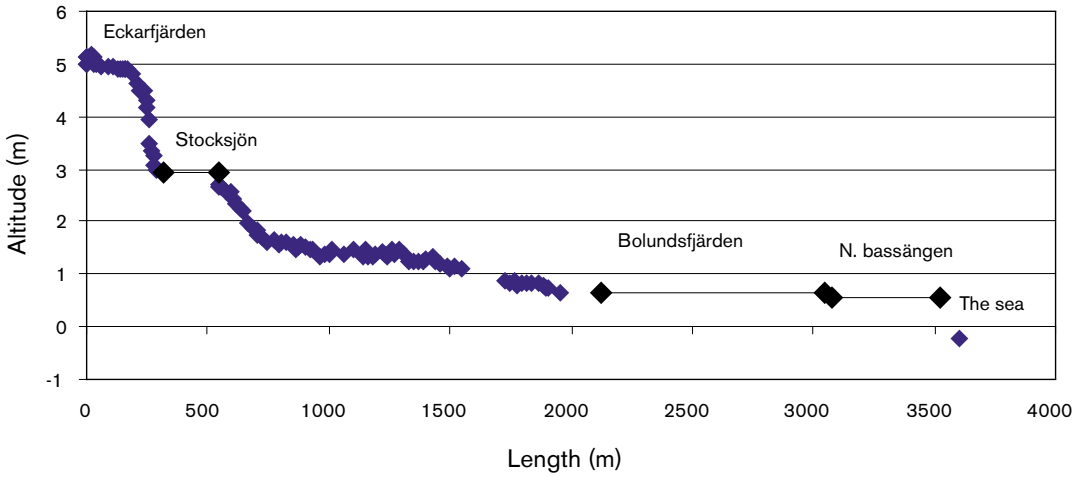

Figure 5-2. *The altitude of the brook between Eckarfjärden and the Baltic Sea.*

5.2 The brook between Stocksjön and Bolundsfjärden

Generally, the brook geometry is clearly defined from Stocksjön to Bolundsfjärden. In some parts, however, the water overflows the banks and the furrow is difficult to distinguish. At these parts of the brook, only the beginning and the end of the overflow area were measured.

The largest overflow area starts approximately 100 m upstream of the junction with the brook from Gällsboträsket and ends approximately 100 m downstream of the junction. Because of the dense vegetation closer to the brook, most of the measurements were made with the total station.

5.3 The brook between Bolundsfjärden and Norra bassängen

The water was flowing through a wide area with reed vegetation and stony bottom and without any clear furrow. The measurements were made using the RTK technique.

5.4 The brook between Norra bassängen and the Baltic Sea

This part of the brook does not have a clearly defined furrow. The bottom consists of stony till. All measurements were made using the RTK technique.

5.5 The brook upstream Gällsboträsket

Measurements were made using the RTK technique in the westerly furrow from a point approximately 200 m downstream of a small tarn. The brook has a clearly defined furrow along the entire stretch (Figure 5-3). The brook is only 30–40 cm wide with approximately 1-metre high banks. In the upper part of the brook, the bottom consists of fine-grained sediments with high contents of organic material and low angle gradients. From a point approximately 200 m upstream of Gällsboträsket, the gradients are steeper and the bottom consists of till.

Measurements were also made in the easterly furrow approximately 150 m upstream Gällsboträsket until the brook was dried up. This furrow is not as clearly defined as the westerly furrow, but it appears more like a ditch with stationary water.

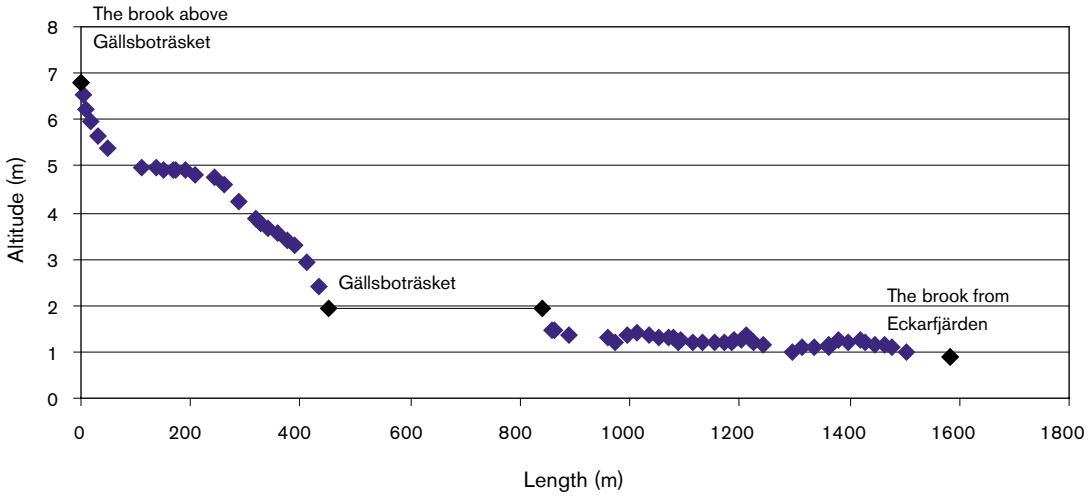

Figure 5-3. *The altitudes of the brook between a point 400 m upstream of Gällsboträsket and the junction with the brook from Eckarfjärden.*

5.6 The brook between Gällsboträsket and the junction with the brook from Eckarfjärden

The lake threshold for Gällsboträsket was measured using the RTK technique, while the rest of the brook was measured with the total station (Figure 5-3). The brook furrow is clearly defined down to approximately 30 m from the junction with the brook from Eckarfjärden, where the brook discharges its waters into a marsh. In some places, the brook banks are as high as 2 m.

5.7 The brook between Fiskarfjärden and the Baltic Sea

A concentrated water stream was only found in few places east of the road (Figure 5-4), but large areas were flooded down to 50 m from the outlet where the furrow is clearly defined. The altitudes were measured using the RTK technique.

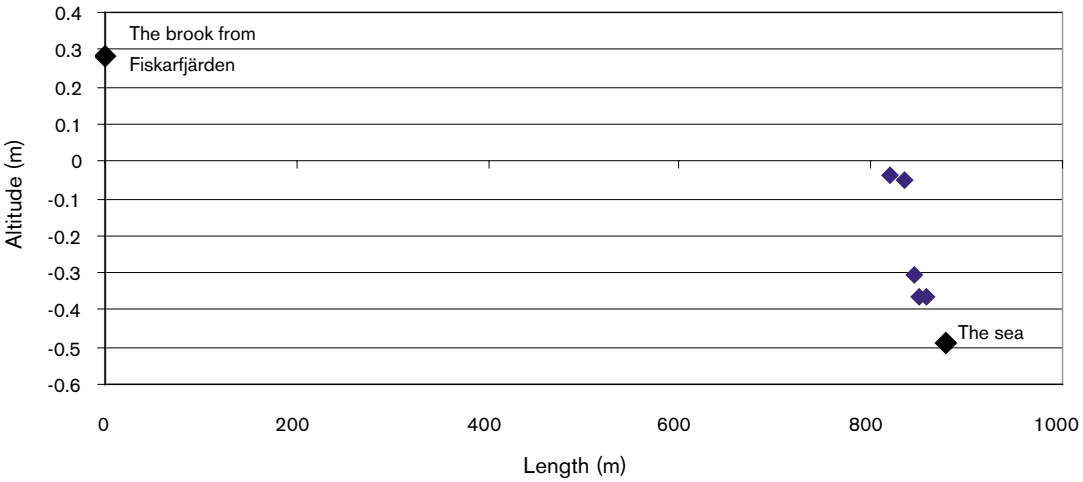

Figure 5-4. *The altitudes for the brook from Fiskarfjärden to the Baltic Sea.*

5.8 The brook between Gunnarsboträsket and Labboträsket

The geometry of the brook is clearly defined all the way to Labboträsket, except for a section at the outlet from Gunnarsboträsket and a part approximately 500 m from the outlet where the water overflows the banks of the brooks. The gradient is very low at first (Figure 5-5) with fine-grained bottom sediment with large amounts of organic content. Downstream of the road (see Figure 5-1), the gradient increases. Since the brook cuts through a coarse till, the bottom consists of a lot of stones and gravels. From the second overflow area and down to Labboträsket, the bottom substrate is fine-grained. The vegetation, which is mostly deciduous, is sometimes very dense, especially the part downstream of the road.

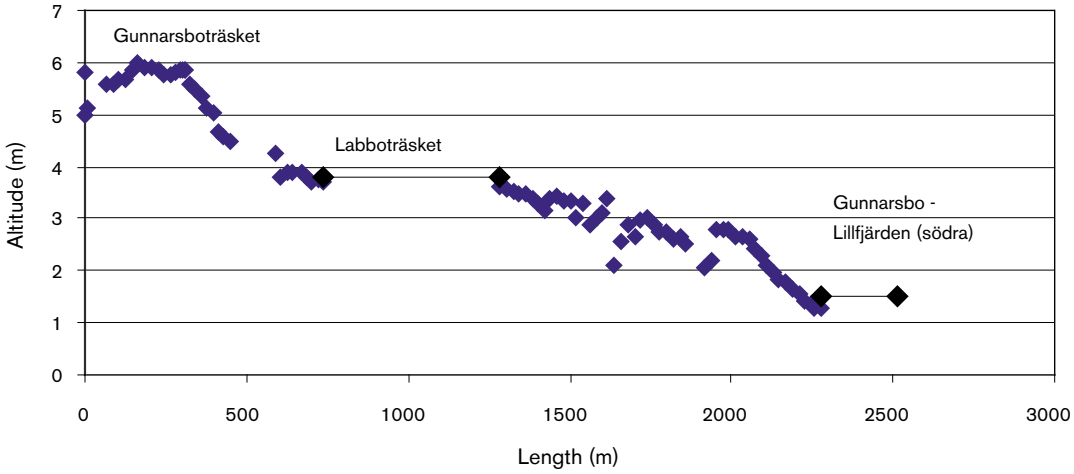

Figure 5-5. *The altitude for the brook from Gunnarsboträsket to Gunnarsbo-Lillfjärden (södra).*

5.9 The brook between Labboträsket and Gunnarsbo–Lillfjärden (södra)

In the upper part the brook has a well-defined geometry. At some locations the bank is several metres high. Further downstream the brook flows into a swampy area where a distinguished furrow is hard to see. The bottom substrate varies from very thick organic sediment to stony till. The slope is mostly very gentle except for the last 200 m where it is steeper (Figure 5-5).

5.10 Measurements of altitude for lake thresholds

Figure 5-6 shows results from the measurement of the lake threshold of Norra bassängen. The distances between the survey points are 3–5 m. The altitudes were plotted versus distance; the first survey point and the threshold altitude were determined using the plot.

Table 5-1 presents the positions and altitudes for lake thresholds and which thresholds that remain to be measured.

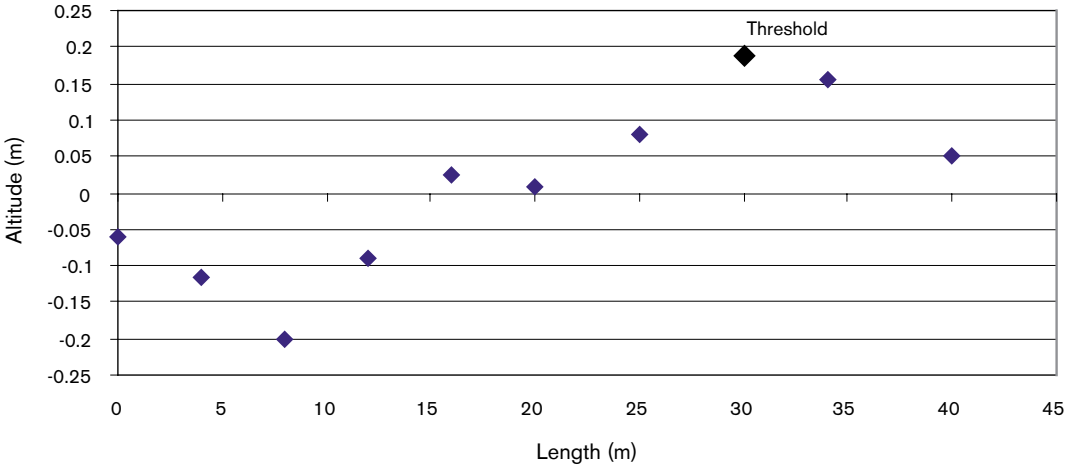

Figure 5-6. *Measurement of altitudes for determining lake threshold altitude for Norra bassängen.*

Table 5-1. Positions and altitudes for lake thresholds.

Catchment	Lake	X (RT 90 2.5g W)	Y (RT 90 2.5g W)	Z (m.a. RHB 70)
1:1–4	Gunnarsbo–Lillfjärden (södra)	1629623.97	6700604.20	1.92
1:2	Gunnarsbo–Lillfjärden (norra)	1629534.68	6700681.01	1.07
1:3–4	Labboträsket	1629716.85	6699551.64	2.65
1:4	Gunnarsboträsket	1629131.67	6699090.02	5.68
2:1–10	Norra bassängen	1631991.42	6700149.26	0.19
2:2	Lake 2:2	1631537.55	6699413.63	1.77
2:3–10	Bolundsfjärden	1631867.13	6699728.88	0.28
2:4–5	Graven	1632726.61	6699285.18	0.44
2:5	Fräkengropen			Not determined
2:6	Vambörsfjärden	1632508.26	6698470.73	1.02
2:7	Kungsträsket	1631420.49	6698731.68	2.31

Catchment	Lake	X (RT 90 2.5g W)	Y (RT 90 2.5g W)	Z (m.a. RHB 70)
2:8	Gällsboträsket	1631020.24	6698699.34	1.47
2:9–10	Stocksjön	1632223.78	6697710.14	2.70
2:10	Eckarfjärden	1632072.76	6697245.72	5.15
2:11	Puttan (towards Norra bassängen)	1632024.36	6699841.52	0.48
2:11	Puttan ((towards Bolundsfjärden)	1632071.12	6699558.27	0.69
2:11	Puttan (towards Bolundsfjärden)	1631954.36	6699703.04	0.72
3:1	Tallsundet	1633711.15	6699250.23	–0.23
4:1–2	Lake 4:1	1634277.37	6699003.68	–0.34
4:2	Lillfjärden	1634023.33	6698549.25	–0.35
5:1	Bredviken	1635295.63	6698702.83	–0.26
6:1	Simpviken	1635512.37	6698794.73	–0.32
7:1–4	Lake 7:1	1635963.90	6697633.22	–0.47
7:2–4	Märrbadet	1635823.32	6698209.56	–0.29
7:3	Lake 7:3	1635691.69	6698198.23	0.17
7:4	Lake 7:4			Not determined
8:1	Fiskarfjärden	1634171.56	6696712.55	0.28

6 References

/1/ **Brunberg K, Carlsson T, Blomqvist P, Brydsten L, Strömgren M, 2004.** Forsmark site investigation. Identification of catchments, lake-related drainage parameters and lake habitats. SKB P-04-25. Svensk Kärnbränslehantering AB.