P-06-05

Oskarshamn site investigation

Measurements of brook gradients

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December 2006

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Abstract

Surface water modelling is performed as part of SKB's Laxemar site investigation. The existing elevation model, in the form of a regular grid with a resolution of 10 m, does not describe the brooks and the lake thresholds with an adequate accuracy for this modelling. For this reason, measurements were made of the deepest part of the furrows and of the cross-sections along the brooks. Dense measurements were done in areas with large altitude gradients and sparse measurements in areas where the altitude gradient is gentle. The measurements were done with a DGPS, combined with a levelling instrument. The measurement method provides accuracy down to a few decimetres of the x- and y-coordinates and vertically more than one centimetre.

The field work was performed during five measurement campaigns. The first measurements were done in March 2005. At this occasion, the survey of the brook Mederhultsån was completed. The second field work was performed in April 2005, including surveys of the brooks Kåreviksån and Ekerumsån. Measurements along the brook Laxemarån were done in November 2005. The measurements were completed in April and July 2006, when eight tributaries to Laxemarån were surveyed.

Measurement points were transferred to a GIS program (ArcGIS) and delivered in ESRI shape format with coordinates in RT90 2.5 gon W and altitudes in the RHB 70 system for storage in SKB's GIS and SICADA data bases.

Sammanfattning

Ythydrologisk modellering utförs inom ramen för SKB's platsundersökning i Laxemar. Den befintliga höjdmodellen i form av en reguljär grid med 10 meters upplösning beskriver inte områdets bäckar och sjötrösklar med tillräcklig noggrannhet. Av den anledningen gjordes en inmätning av vattendragens djupfåror samt av tvärprofiler längs vattendragen. Tätare mätningar gjordes i områden där lutningen är större och glesare mätningar i områden där lutningen är mindre. Inmätningen utfördes med en DGPS kombinerad med ett avvägningsinstrument. Mätmetoden ger en noggranhet på några decimeter i x- och y-led och bättre än en centimeter i höjdled.

Fältarbetet utfördes under fem mätkampanjer. Den första inmätningen gjordes i mars 2005. Vid det tillfället avslutades mätningarna längs Mederhultsån. Kåreviksån och Ekerumsån mättes in i april 2005. I november 2005 gjordes mätningar längs Laxemarån. Mätningarna avslutades i april och juli 2006 när 8 av Laxemaråns biflöden mättes in.

Mätpunkterna överfördes till ett GIS-program (ArcGis) 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 as a part of SKB's Laxemar site investigation. The existing elevation model, in the form of a regular grid with a resolution of 10 m, does not describe the brooks and the lake thresholds with an adequate accuracy for this modelling. For this reason, measurements of the x- and y-coordinates and the altitude were made of the deepest part of the furrow and of the cross-sections along some of the brooks in the Laxemar subarea. Dense measurements were done in areas with large altitude gradients and sparse measurements in areas with gentle gradients.

The work was carried out in accordance with activity plan SKB AP PS 400-05-19 and Method Description 110.001. Table 1-1 lists the controlling documents for performing this activity. The activity plan is SKB's internal controlling document.

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

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

Activity Plan	**Number**	**Version**
Kartering och inmätning av vattendrag, Laxemar	AP PS 400-05-19	1.0
Kartering och inmätning av vattendrag, Laxemar	AP tillägg 1 (AP PS 400-05-019, 2006-02-01)	1.0
Method Description	**Number**	**Version**
Inmätning och avvägning av mätpunkter	MD 110.001	1.0

Table 1-2. Data references.

Sub-activity	**Database**
Kartering och inmätning av vattendrag, Laxemar	SICADA **GIS**

2 Objective and scope

According to activity plan AP PS 400-05-19 the geometry and altitude for the brooks in the catchments 6, 7, 10, 23, 24, 25 and 26 (the catchments is described in /Brunberg et al. 2004/) were of particular interest to be measured. However, later SKB only choose the following brooks (Figure 2-1):

(i) The brook Mederhultsån in catchment 6.

(ii) The brook Kåreviksån in catchment 7.

(iii) The brook Ekerumsån in catchment 9.

(iv) Parts of the brook Laxemarån in catchment 10 and 8 tributaries to Laxemarån in subcatchments 10:2–10:7, 10:10 and 10:11.

Figure 2-1. *Performed measurements of geometry and altitude of brook furrows in the Laxemar site investigation area.*

3 Equipment

3.1 Description of equipment

A DGPS (Differential Global Positioning System) in combination with an optical levelling instrument were used during the field work. The DGPS was a Trimble Pro XR, connected to a field computer (Trimble TSCe) using the ESRI ArcPad 6.0 real time GIS software. By measuring every two seconds for 1 minute at each location and using the mean value, the positions are calculated with a horizontal accuracy of a few decimetres (the result of test measurements towards fixed points in the area). The levelling instrument used was a CARL ZEISS JENA Ni 020 A. With this instrument, it is possible to produce a millimetre precision in the vertical direction for each measurement. The precision will, however, probably decrease after many successive measurements. This is due to an accumulation of measurement errors, since each new measurement proceeds from the previous measurement.

4 Execution

4.1 Execution of field work

The measurements were carried out with the following method:

(i) The measurements of the brooks were done with a combination of a DGPS and an optical levelling instrument. The x-, y-, and z-coordinates were recorded in the deepest part of the brook approximately every 50 m; shorter distances (down to approximately 10 m) were used where the altitude gradients were large, and distances were longer where the gradients were small. The measurements with the levelling instrument were started from fixed points or soil tubes with known altitudes.

(ii) The GPS-coordinates were given unique identification values and the same unique values were written for each level measured with the levelling instrument.

(iii) The cross-sections were measured every 200–300 m along the brooks with one measure made at the deepest part of the section (Figure 4-1 a)), two points at the edges of the brooks (Figure 4-1 b)), and two points at the top of the bank (Figure 4-1 c)). At each cross section, only one coordinate was measured with the DGPS. The rest of the coordinates were measured with a tape measure and the direction of the cross-sections was measured with a compass. The measuring points between the cross-sections measurements where thinner in areas where the furrow had a similar appearance and closer in areas where the appearance of the furrow changed markedly. The cross-sections were numbered according to the associated catchment area, as described in /Brunberg et al. 2004/.

(iv) At locations where the brook geometry was indistinct (i.e., through mires), the beginning and end of the indistinct part were recorded.

(v) If the water flows in underground pipes for longer distances, the beginning and end of these stretches were recorded.

(vi) In some sections of the brook Laxemarån only relative altitude values of "half" cross-sections (three coordinates) were measured. One coordinate at the top of the bank was measured with a DGPS and the other two coordinates were measured as described in (iii). The relative altitude from the top of the bank was measured with two levelling staffs and a spirit level.

(vii) Continuous quality controls were made towards fixed points and ground water pipes along the brooks, according to the quality plan.

(viii) The accuracy of the DGPS was controlled two times, at different times of the day, at every measurement campaign according to the quality plan.

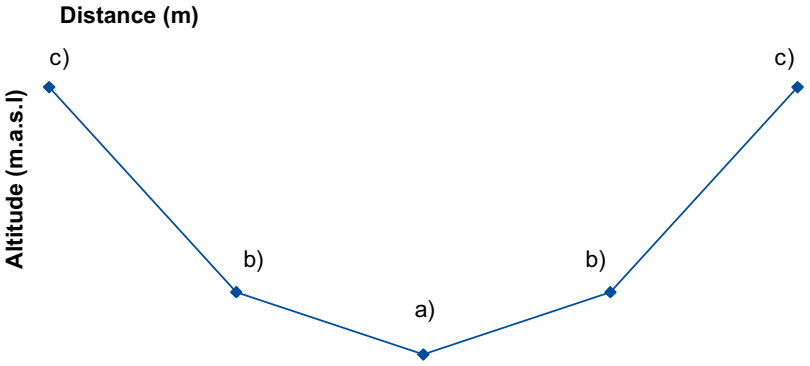

Figure 4-1. *A principle sketch of a cross-section of a brook furrow.*

4.2 Data handling after processing

Coordinates measured with the DGPS were stored according to the coordinate system RT90 2.5 gon W. Data from the levelling instrument were written to an Excel document, where it was converted to the elevation system RHB 70, using elevation values from fixed points or soil tubes with known altitude in the area. Attributes for indistinct brook geometry, piped brooks and cross-sections were written in different fields in excel document. The excel document was saved as a dBASE IV file.

All files were imported to ArcGis 9.1. The rest of the measured cross-section coordinates were digitized in the DGPS-file according to their direction and distance from the DGPS-coordinates. They were given the same unique identification numbers as the altitude values from the levelling instrument measurements. The altitude values were joined to the map with the measured and digitized coordinates. All files were finally merged into a single map. The map was stored in ESRI shape format. The data were quality checked before they were delivered to SKB.

The same method as described above was used for the coordinates from the measurements of the "half" cross-sections and the relative altitude values from the field measurements of the brook Laxemarån.

5 Results

Figure 5-1 shows the geometry and altitude measurements of brook furrows done during the field works in 2005 and 2006. The red dots illustrate parts measured with DGPS and levelling instrument and the yellow dots parts where only the coordinates and the relative altitude of half cross-sections were measured. The characteristics of these brooks are described in the coming sections. The nameless brooks have been named after the catchment they are located in. For instance, the brook in the catchment 10:2 is named the brook 10:2. Indistinct brook geometry or overflowed areas are illustrated with red dots in Figure 5-2 and the yellow dots illustrate water flow in pipes.

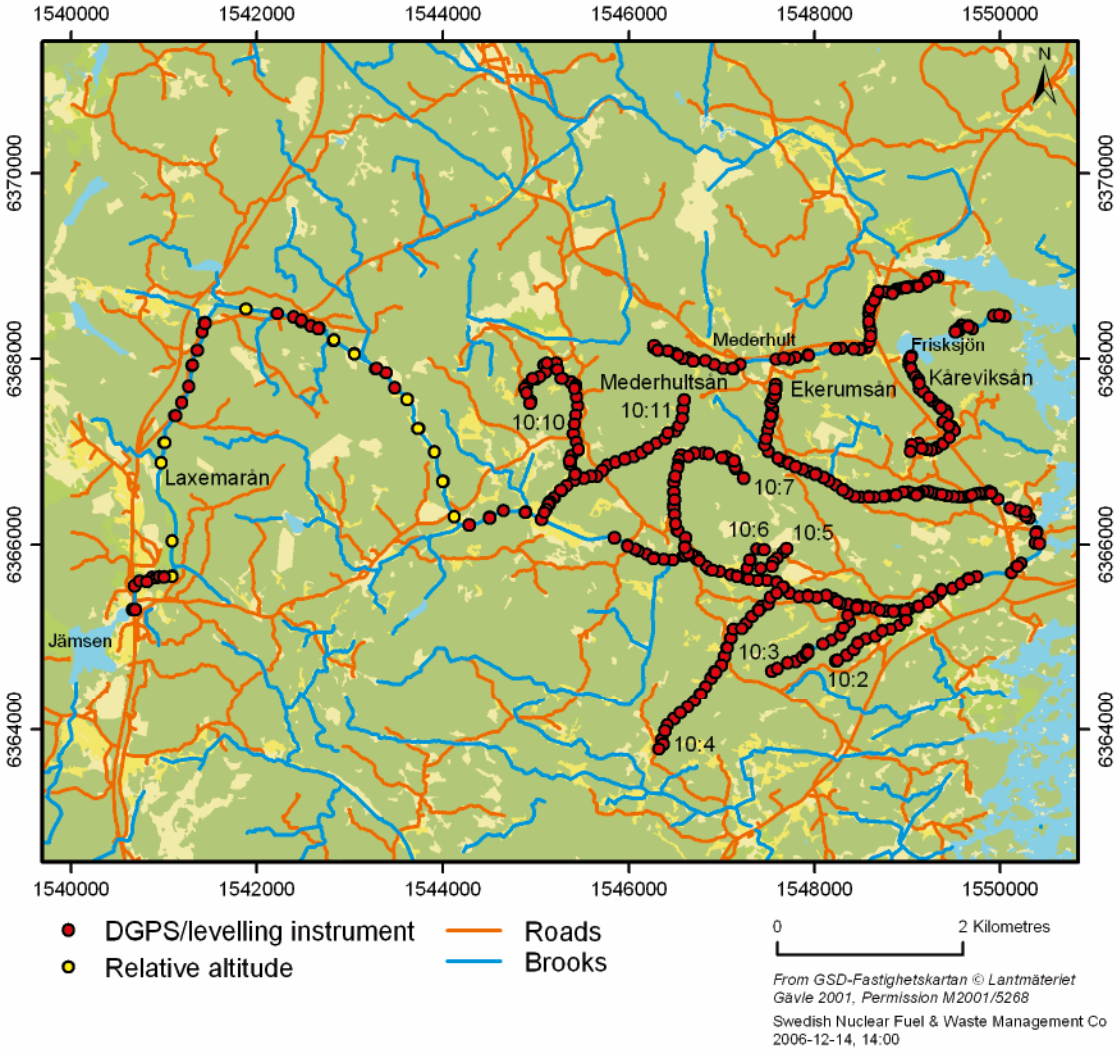

Figure 5-1. *The brooks in the Laxemar site investigation area measured in 2005 and 2006.*

Figure 5-2. *Indistinct brook geometry or overflowed areas and water flow in pipes along 12 brooks in the Laxemar site investigation area.*

5.1 The brook Mederhultsån

The brook Mederhultsån in catchment 6 begins around 1 km west of the village Mederhult, a little bit more than 3,700 m from the Baltic Proper (Figure 5-1). Mederhultsån starts at roughly 13 m above the sea level (Figure 5-3).

The altitude gradient is quite large at the beginning but becomes more moderate, and after about 2,300 m the gradient is very small. The gradient increases close to the outlet into the Baltic Proper. At some locations, the altitude increases downstream when comparing two altitude values. This can be seen, for example, around 1,000 and 2,500 m (Figure 5-3), illustrating thresholds along the brook.

The brook furrow is generally 3–6 m wide and 1.5–2 m deep (Figure 5-4). The brook furrow is considerably smaller the last part of Mederhultsån. At time of the survey, there were no overflowed areas along Mederhultsån. The water flows partly in underground pipes from around 400 m to almost 2,400 m, sometimes as long as several hundred metres (Figure 5-2).

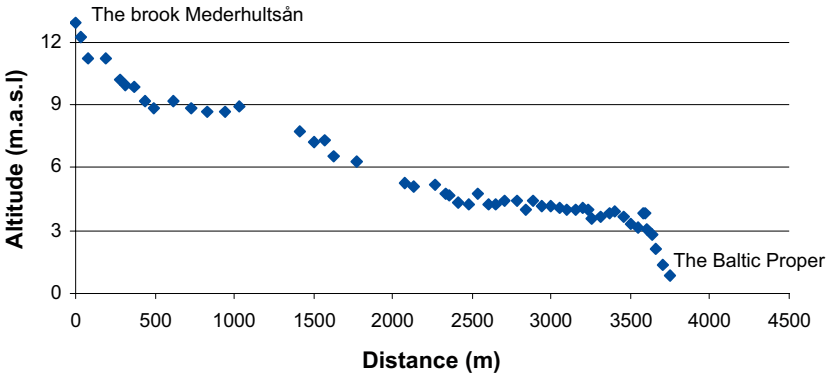

Figure 5-3. *The measured altitude values for the brook Mederhultsån from the starting point to the Baltic Proper.*

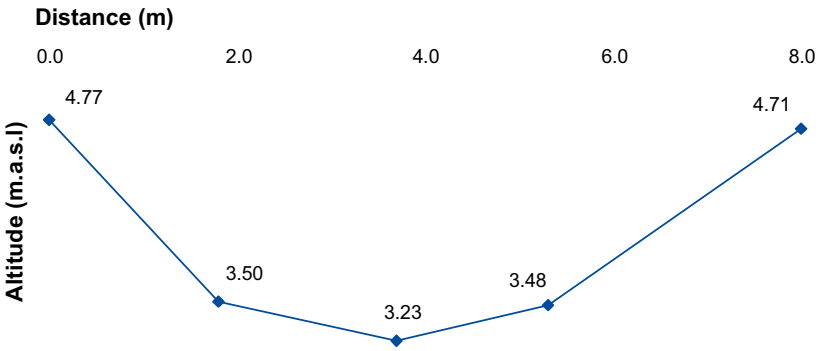

Figure 5-4. *The cross-section 6:4 in the brook Mederhultsån.*

5.2 The brook Kåreviksån

The brook Kåreviksån in catchment 7 begins approximately 1 km south of Lake Frisksjön (Figure 5-1). Kåreviksån starts around 10 m above the sea level and enters into the Baltic Proper after some 2,800 m (Figure 5-5).

Kåreviksån flows through Lake Frisksjön on its way down to the Baltic Proper. The slope is relatively gentle, except for a stretch after approximately 300 m, a stretch close to the inlet into Lake Frisksjön and a short stretch from the outlet of Lake Frisksjön.

The brook furrow is 2.5–5 m wide and 0.7–1.5 m deep. The geometry of the brook furrow is mostly clearly defined. The exception is a 300 m long section between Lake Frisksjön and the Baltic Proper, where the water overflowed the bank at time of the survey (Figure 5-2).

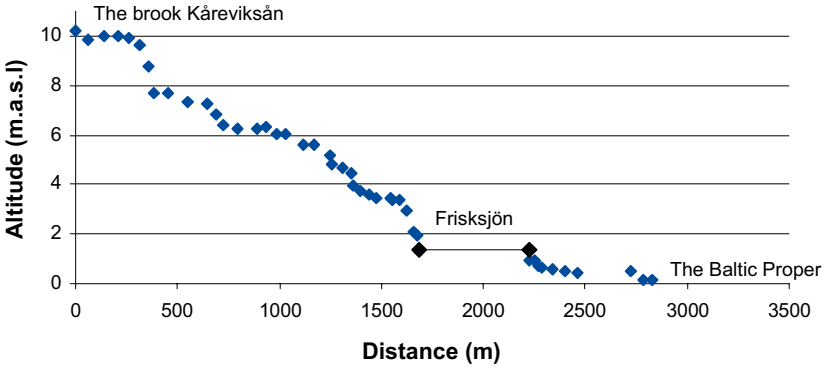

Figure 5-5. *The measured altitude values for the brook Kåreviksån from the starting point to the Baltic Proper.*

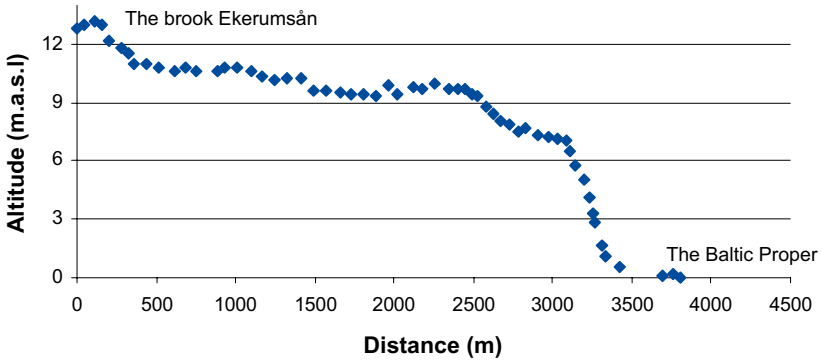

Figure 5-6. *The measured altitude values for the brook Ekerumsån from the starting point to the Baltic Proper.*

5.3 The brook Ekerumsån

The brook Ekerumsån in catchment 9 begins direct south of the village Mederhult, roughly 3,800 m from the Baltic Proper (Figure 5-1). Ekerumsån starts almost 13 m above the sea level (Figure 5-6).

The altitude gradient is small the first 3,000 m, except for some shorter stretches where it is steeper. At around 3,200 m, it becomes very steep when the vertical drop is more than 6 m along a distance of only 300 m. After this steep stretch, the terrain flattens out all the way down to the Baltic Proper.

The brook furrow is in most parts 4–5 m wide and 1–2 m deep. Ekerumsån is, however, as large as 7–8 m wide and 2–3 m deep in other parts.

There is an area where the geometry of the brook furrow is indistinct (close to the outlet in the Baltic Proper) and where the water overflows the banks at least parts of the year (Figure 5-2). This stretch is around 200 m long. Ekerumsån partly flows through pipes in the upper- and lowermost parts (Figure 5-2).

5.4 The brook Laxemarån

The brook Laxemarån in catchment 10 begins at Lake Jämsen around 25 m above the sea level (Figure 5-1). Laxemarån flows almost 15 km down to the Baltic Proper. The slope is steep the first 650 m and the altitude decreases almost 10 m (Figure 5-7). After this section, the slope becomes gentler. The exceptions are a 100 m long stretch between 3,300 and 3,400 m, where the altitude decreases 2.5 m, and a 1,000 m long stretch from around 8,000 m where the terrain is very flat.

The brook furrow varies between 5–7 m and the depth between 1–2 m in most parts (Figure 5-8). However, along a short stretch, at the village Lilla Basthult, the brook is between 8–9 m wide and 2–3 m deep. The geometry of the brook furrow is generally clearly defined. After around 600 m the brook flows through a 1 km long marsh area, where the geometry of the brook furrow is indistinct. The last kilometre is characterized by a very flat terrain where the brook overflowed the bank (Figure 5-2) at time of the survey. Laxemarån drains in pipes along two shorter stretches near the outflow from Lake Jämsen (Figure 5-2).

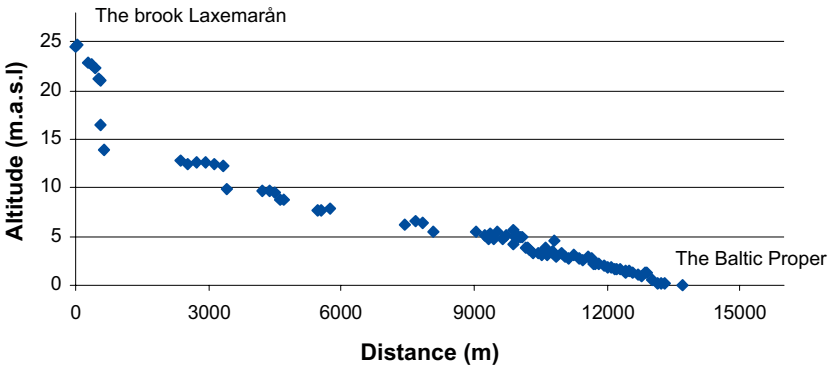

Figure 5-7. *The measured altitude values for the brook Laxemarån from the starting point to the Baltic Proper.*

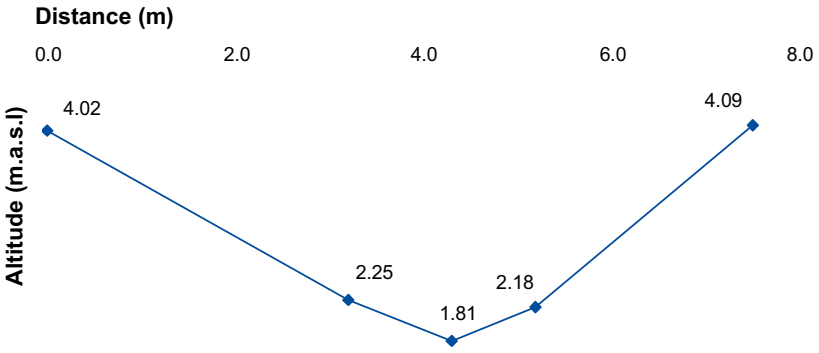

Figure 5-8. *The cross-section 10:6 in the brook Laxemarån.*

5.4.1 The brook in the subcatchment area 10:2 (a tributary to the brook Laxemarån)

The brook 10:2 is almost 1,000 m long. It begins at approximately 7 m above the sea level and enters in the brook Laxemarån at roughly 1 m above sea level (Figure 5-1). The altitude gradient is largest along the first 100 m and then becomes smaller (Figure 5-9).

The brook furrow is 1.5–3 m wide and 0.3–1 m deep. There are no areas with indistinct brook geometry.

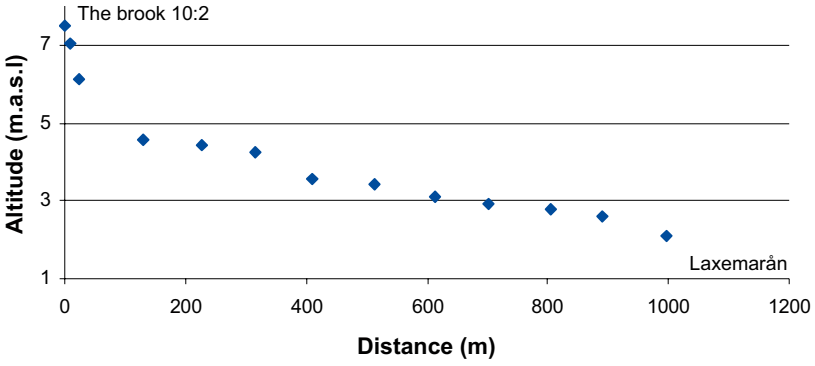

Figure 5-9. *The measured altitude values for the brook 10:2 from the starting point to the brook Laxemarån.*

5.4.2 The brook 10:3 (a tributary to the brook Laxemarån)

The brook 10:3 begins around 10 m above the sea level and enters in Laxemarån after more than 1,200 m, at around 2 m above the sea level (Figure 5-1 and Figure 5-10). The slope is mostly gentle, but along two shorter stretches it becomes much steeper. At time of the survey, there were no areas where the water overflows the bank. The water flows through underground pipes at around 500 m from the beginning and close to the outlet in Laxemarån (Figure 5-2).

5.4.3 The brook 10:4 (a tributary to the brook Laxemarån)

The brook 10:4 is almost 2,200 m long. It begins at roughly 9 m above the sea level and enters in the brook Laxemarån, at around 5 m above the sea level (Figure 5-1 and Figure 5-11).

The gradient is relatively flat along the entire brook. The brook furrow is 2–5.5 m wide and 0.5–2 m deep.

5.4.4 The brook 10:5 (a tributary to the brook Laxemarån)

The brook 10:5 begins at approximately 8 m above the sea level. After a little bit more than 500 m, the brook enters the brook Laxemarån, around 4 m above the sea level (Figure 5-1 and Figure 5-12). The slope is quite gentle along the entire brook. The brook furrow is generally 3 m wide and less than 1 m deep. At time of the survey, the water overflowed the bank a short stretch after around 150 m (Figure 5-2).

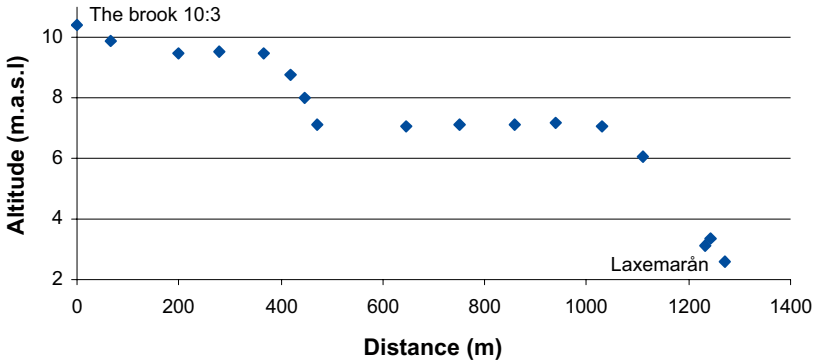

Figure 5-10. *The measured altitude values for the brook 10:3 from the starting point to the brook Laxemarån.*

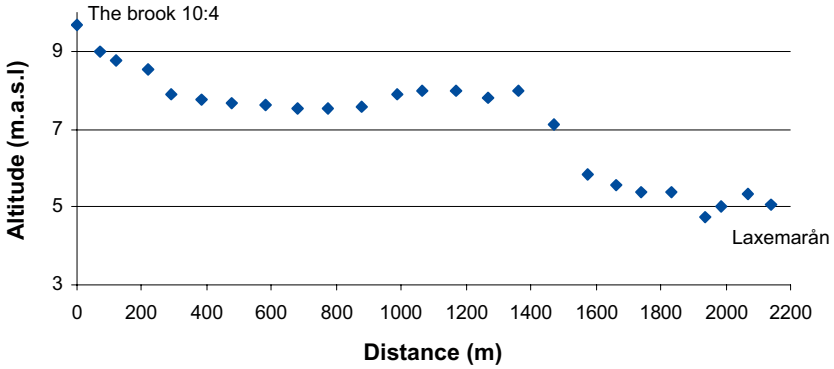

Figure 5-11. *The measured altitude values for the brook 10:4 from the starting point to the brook Laxemarån.*

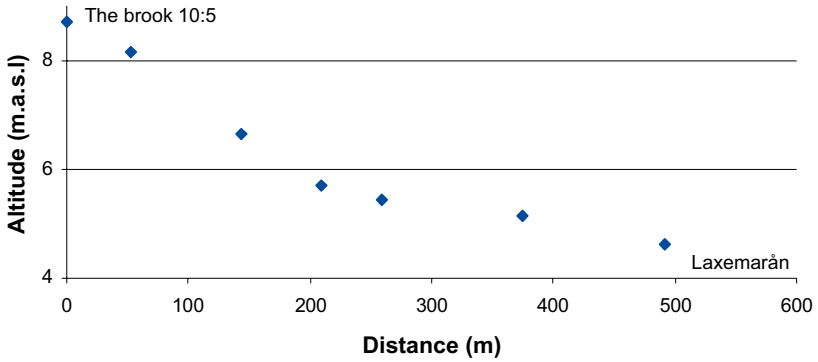

Figure 5-12. *The measured altitude values for the brook 10:5 from the starting point to the brook Laxemarån.*

5.4.5 The brook 10:6 (a tributary to the brook Laxemarån)

The brook 10:6 begins around 5 m above the sea level and ends after roughly 400 m in the brook Laxemarån, a little more than 1 m lower (Figure 5-1 and Figure 5-13). The altitude gradient is small along the entire brook.

The geometry of the brook furrow varies a lot. The brook is generally 3–4 m wide and less than 1 m deep, but along a 30 m short stretch near the end of the brook it is around 8 m wide and 2 m deep. There are no areas with indistinct brook geometry.

5.4.6 The brook 10:7 (a tributary to the brook Laxemarån)

The brook 10:7 begins at approximately 17 m above the sea level and ends after around 2,000 m in the brook Laxemarån, a little less than 6 m above the sea level (Figure 5-1 and Figure 5-14). The slope is very gentle, except for two shorter stretches with steeper slopes (after around 100 m and at the end of the brook). The geometry of the brook furrow is not clearly defined in some shorter stretches between roughly 900–1,300 m from the beginning (Figure 5-2). The water drains in pipes along two shorter stretches at around 1,360 m and 1,640 m from the beginning of the brook (Figure 5-2).

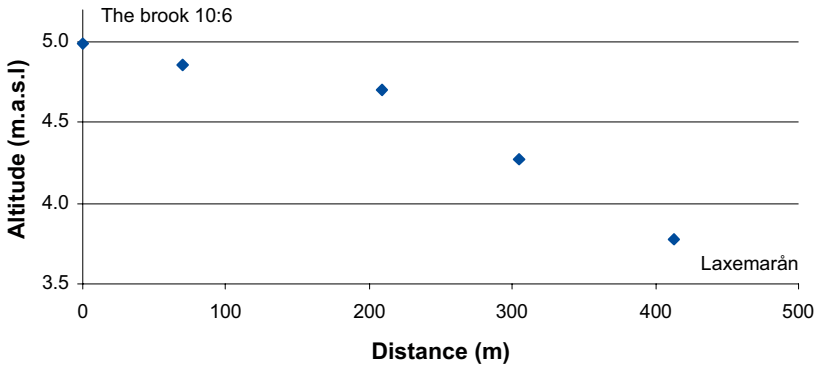

Figure 5-13. *The measured altitude values for the brook 10:6 from the starting point to the brook Laxemarån.*

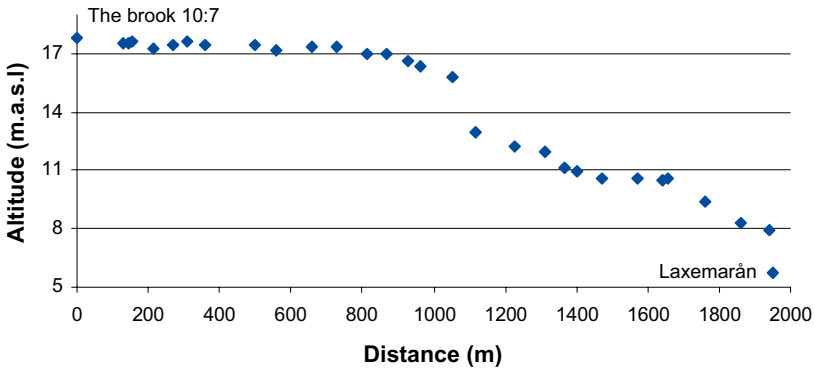

Figure 5-14. *The measured altitude values for the brook 10:7 from the starting point to the brook Laxemarån.*

5.4.7 The brook 10:10 (a tributary to the brook Laxemarån)

The brook 10:10 begins around 16 m above the sea level and ends after approximately 2,700 m in the brook Laxemarån, less than 6 m above the sea level (Figure 5-1 and Figure 5-15). The altitude gradient is very small the first 2,500 m. Then the brook becomes steeper and the altitude decreases 4 m in 200 m. Generally, the brook furrow is clearly defined. The width varies between 4.5 m and a little bit more than 2 m. The depth is 0.6–1.5 m. At time of the survey, the water overflowed the bank along 3 shorter stretches (Figure 5-2). The brook drains in underground pipes in 3 sections along the first 500 m from the beginning (Figure 5-2).

5.4.8 The brook 10:11 (a tributary to the brook Laxemarån)

The brook 10:11 begins more than 16 m above the sea level and ends in the brook Laxemarån after roughly 1,600 m, at approximately 11 m above the sea level (Figure 5-1 and Figure 5-16). The slope is very small. The exception is a section around 800 m, where the slope is larger. The brook furrow is 2–4 m wide and 0.2–2 m deep. There are no areas with indistinct brook geometry.The water flows in pipes in only one short part of the brook at around 1,000 m from the beginning (Figure 5-2).

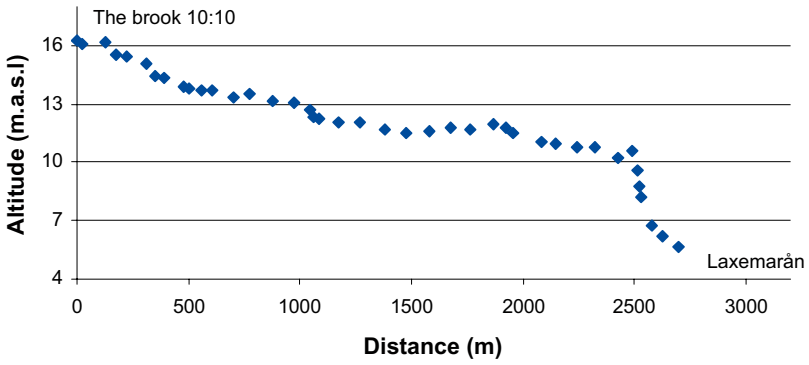

Figure 5-15. *The measured altitude values for the brook 10:10 from the starting point to the brook Laxemarån.*

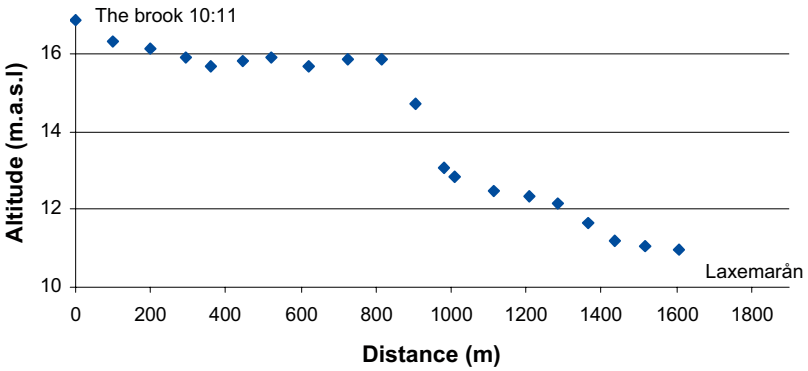

Figure 5-16. *The measured altitude values for the brook 10:11 from the starting point to the brook Laxemarån.*

5.5 Data files delivered to SKB

The following data files are delivered to SKB and stored in the SICADA-GIS-database:

Laxemar_vattendrag_mätpunkter	ESRI shape format, geometry and altitude of brooks. Excel file with metadata.
Laxemar_halva_tvärsnitt	ESRI shape format, geometry and relative altitude of parts of the brook Laxemarån. Excel file with metadata.

6 References

Brunberg K, Carlsson T, Brydsten L, Strömgren M, 2004. Oskarshamn site investigation, Identification of catchments, lake-related drainage parameters and lake habitats. SKB P-04-242, Svensk Kärnbränslehantering AB.