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Oskarshamn site investigation

Calibration of 1D and 3D caliper data from core and percussion drilled boreholes

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Keywords: Calibration, Caliper1D, Caliper3D, Caliper mean.

Reading instruction

For revision no. 1 of this report a recalculation of the 1D and 3D caliper data has been done. The calibration procedure for caliper1D data has been changed. Chapter 5 is updated. All figures for each borehole in section 5-2 is removed and is replaced by one example for KLX04, see Figure 5-1. New values for accuracies for Caliper1D and Caliper3D are presented in Tables 5-1 and 5-2.

Abstract

This report presents the calibration of caliper1D and caliper3D data from the cored boreholes KSH01A, KSH01B, KSH02, KSH03A, KSH03B, KAV01, KAV04A, KAV04B, KLX01, KLX02, KLX03, KLX04, KLX05, KLX06, KLX07A, KLX07B, KLX08, KLX09, KLX09B, KLX09D, KLX09F, KLX09G, KLX10, KLX10B, KLX10C, KLX11A, KLX11B, KLX12A, KLX13A, KLX14A, KLX15A, KLX16A, KLX17A, KLX18A, KLX19A, KLX20A, KLX21B, KLX22A, KLX22B, KLX23A, KLX23B, KLX24A, KLX25A, KLX26A, KLX26B, KLX27A, KLX28A, KLX29A and the percussion drilled boreholes HSH01, HSH02, HSH03, HAV09, HAV10, HLX13, HLX15, HLX17, HLX18, HLX19, HLX20, HLX21, HLX22, HLX23, HLX24, HLX25, HLX26, HLX27, HLX28, HLX30, HLX31, HLX32, HLX33, HLX34, HLX35, HLX36, HLX37, HLX38, HLX39, HLX40, HLX41, HLX43.

The objective of the project was to generate calibrated caliper data by correction of the measured data with reference to technical borehole diameter information gained during the drilling activity.

Two different techniques were applied for the calibration procedure. The caliper mean data (average borehole diameter from the caliper3D measurement, acoustic televiewer) were calibrated by correcting the travel time of the ultra sonic pulse at the reference points with known diameter, and then recalculating the diameter along the entire borehole.

The one arm caliper data were filtered with a 15.1 m long median filter. The residual between the measured and filtered data were calculated and the residual data were then added to a linear function established from the technical borehole information.

The estimated accuracy after calibration is in average 0.08 mm for caliper1D and 0.24 mm for caliper mean in the core drilled boreholes. For percussion drilled boreholes the corresponding values after calibration are in average 0.16 mm for caliper1D and 0.35 mm for caliper3D. According to the method description the accuracy (absolute as well as relative) should be 0.5 mm or better.

Sammanfattning

Föreliggande rapport presenterar kalibreringen av caliper1D och caliper3D data från kärnborrhålen KSH01A, KSH01B, KSH02, KSH03A, KSH03B, KAV01, KAV04A, KAV04B, KLX01, KLX02, KLX03, KLX04, KLX05, KLX06, KLX07A, KLX07B, KLX08, KLX09, KLX09B, KLX09D, KLX09F, KLX09G, KLX10, KLX10B, KLX10C, KLX11A, KLX11B, KLX12A, KLX13A, KLX14A, KLX15A, KLX16A, KLX17A, KLX18A, KLX19A, KLX20A, KLX21B, KLX22A, KLX22B, KLX23A, KLX23B, KLX24A, KLX25A, KLX26A, KLX26B, KLX27A, KLX28A, KLX29A samt hammarborrhålen HSH01, HSH02, HSH03, HAV09, HAV10, HLX13, HLX15, HLX17, HLX18, HLX19, HLX20, HLX21, HLX22, HLX23, HLX24, HLX25, HLX26, HLX27, HLX28, HLX30, HLX31, HLX32, HLX33, HLX34, HLX35, HLX36, HLX37, HLX38, HLX39, HLX40, HLX41, HLX43.

Syftet med projektet var att skapa kalibrerade caliperdata genom att korrigera data mot uppmätta diametrar som erhållits i samband med utförandet av borrningarna.

Två olika tekniker användes för att kalibrera data från de två mätmetoderna. Data från caliper mean (medeldiameter från caliper3D, acoustic televiewer) kalibrerades genom att korrigera uppmätt gångtid för ultraljudspulsen vid referenspunkter med känd borrhålsdiameter. Därefter korrigerades samtliga mätpunkter längs borrhålet.

En arms caliperdata filtrerades med ett 15,1 m medianfilter. Residualen mellan uppmätta data och filtrerade data beräknades. Residualen adderades sedan till en linjär funktion beräknad med regressionsanalys från referenspunkter med känd borrhålsdiameter.

Den uppskattade noggrannheten efter kalibrering är i genomsnitt 0.08 mm för caliper1D och 0.24 för caliper mean i kärnborrhålen. För hammarborrhålen är motsvarande värden 0.16 mm för caliper1D samt 0.35 mm för caliper3D. Kraven i metodbeskrivningen avseende absolut och relativ noggrannhet är 0.5 mm.

Contents

1 Introduction

SKB performs site investigations for localization of a deep repository for high level radioactive waste in Oskarshamn. The performance of the investigations is controlled by a general program /1/ and a site specific program for Oskarshamn /2, 3/. An important part in the analysis of a borehole is the different geophysical loggings which provide information about the bedrocks physical qualities which are described in the method description (SKB internal controlling document). The diameter is one of the measured parameters in a borehole. The diameter is in one method measured mechanically with a one-armed caliper arm surveying in one direction clamping the logging tool towards the borehole wall. This logging method produces data called caliper1D. In the other logging method the diameter is logged with an Acoustic Televiewer tool. The probe generates a sound wave that propagates in the borehole water between the probe and the borehole wall. Determination of the diameter is based on the time it takes for the ultra wave to travel the distance between the probe and the borehole wall and back to the probe. The diameter is calculable since the velocity for the ultra wave in water is a known parameter. The Acoustic televiewer produces data called caliper3D. However it has been shown that caliper3D does not comply with the SKB accuracy demands. Therefore a calibration on both caliper1D and caliper3D data is performed.

This document reports the results gained from the calibration of caliper1D and caliper3D data from cored and percussion boreholes and is one of the activities performed within the site investigation at Oskarshamn. The following cored boreholes KSH01A, KSH01B, KSH02, KSH03A, KSH03B, KAV01, KAV04A, KAV04B, KLX01, KLX02, KLX03, KLX04, KLX05, KLX06, KLX07A, KLX07B, KLX08, KLX09, KLX09B, KLX09D, KLX09F, KLX09G, KLX10, KLX10B, KLX10C, KLX11A, KLX11B, KLX12A, KLX13A, KLX14A, KLX15A, KLX16A, KLX17A, KLX18A, KLX19A, KLX20A, KLX21B, KLX22A, KLX22B, KLX23A, KLX23B, KLX24A, KLX25A, KLX26A, KLX26B, KLX27A, KLX28A, KLX29A and the percussion drilled boreholes HSH01, HSH02, HSH03, HAV09, HAV10, HLX13, HLX15, HLX17, HLX18, HLX19, HLX20, HLX21, HLX22, HLX23, HLX24, HLX25, HLX26, HLX27, HLX28, HLX30, HLX31, HLX32, HLX33, HLX34, HLX35, HLX36, HLX37, HLX38, HLX39, HLX40, HLX41, HLX43 were included in this activity.

The work was carried out in accordance with activity plan AP PS 400-05-105. In Table 1-1 controlling documents for performing this activity are listed. The activity plan is a SKB internal controlling document. No method description (SKB internal controlling document) for this type of activity is available. A general discussion how the work was performed is discussed in Chapter 4.

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

Activity plan	Number	Version
Kalibrering av mätdata från caliper	AP PS 400-05-105	1.0

2 Objective and scope

The objective of this work was to calibrate the logging data obtained from measurements with one arm caliper and acoustic televiewer (caliper mean). The calibration was performed with reference to the diameters of calibre rings gained during the core drillings and measured diameter on cutter heads obtained during percussion drilling activities.

3 Equipment

3.1 Description of equipment/interpretation tools

The software used for the calibration are Grapher v6 (Golden Software), mainly used for plotting and some statistical analyses, and a number of in-house software developed by GeoVista AB on behalf of SKB.

4 Execution

4.1 General interpretation of caliper data

Before caliper data is calibrated some pre-processing is performed.

The general processing is performed in the following steps:

- Average filtering with a triangular 3-point filter.
- Noise levels are calculated.
- Re-sampling to even 0.1 m interval.

4.2 Calibration methods

The calibration of caliper data was performed with respect to borehole diameter information from the technical documents that originate from the drilling activities. For cored boreholes the technical document contains information about the diameter of the calibre-rings. For percussion boreholes it contains information about the diameter of the drill cutter and measured wear. The technical documents have been received from SKB in Microsoft Word format.

4.2.1 Calibration of one arm caliper data

The one arm caliper data were calibrated according to the following four steps:

1. Filtering of caliper data by use of 15.1 m long (151 points) median filter. The filtered data contain mainly long wave length (often stepwise) anomalies that are not related to physically reliable variations in borehole diameter.
2. The median filtered data is subtracted from the measured data (with the aim of removing all artificial long wavelength anomalies), which results in a residual log only showing high frequency diameter anomalies.
3. The technical data (usually 3 diameter readings at 3 section co-ordinates) are plotted in a diagram and a linear function ($y = kx + m$) is fitted to these data points by use of linear regression. The linear function represents some kind of “background” diameter along the borehole.
4. The residual data (from 2) is added to the linear function (from 3), and the result is the calibrated caliper log.

4.2.2 Calibration of caliper mean data

The caliper mean data originate from the acoustic televiewer measurements (average borehole diameter from the caliper3D measurement). An ultra sonic pulse is generated by the logging tool. The pulse is reflected at the borehole wall and returns to the logging tool and the travel time is measured. Since the velocity of the pulse in the borehole fluid can be estimated by use of other logging data, the travelling distance (and thus the borehole diameter) can easily be calculated. The calibration process for caliper mean data is performed in the following steps:

1. Calculation of the measured travel time of the ultrasonic pulse is performed on the caliper mean data. The ultra sound velocity is estimated from the mean temperature of the borehole fluid.

$$Measured\ time\ [s] = \frac{Logged\ caliper\ diameter\ [m] - Tool\ diameter\ [m]}{Ultrasound\ velocity\ [m/s]} \quad (1)$$

2. Calculation of "true" time in the calibration (reference) points with known diameters from technical documents.

$$True\ time\ [s] = \frac{Known\ \ caliper\ diameter\ [m] - Tool\ diameter\ [m]}{Ultrasound\ velocity\ [m/s]} \quad (2)$$

3. Calculation of the apparent velocity at the section co-ordinate of the calibration point.

$$Apparent\ velocity\ [m/s] = \frac{True\ time\ [s]}{Measured\ time\ [s]} \times Ultrasound\ velocity\ [m/s] \quad (3)$$

4. Establish the calibration relation between apparent velocity and borehole depth with linear regression analysis.

$$Ultrasound\ velocity = k \times depth + l \quad (4)$$

5. Calculation of the calibrated diameter

$$Diam = ((k \times borehole\ length + l) \times measured\ time) + Tool\ diameter \quad (5)$$

The tool diameter of the Acoustic televiewer is 45 mm. The ultrasound velocity in water is 1,403 *m/s* (0°*C*) and 1,529 *m/s* (40°*C*).

4.3 Preparations and data handling

All caliper1D, caliper3D data and technical documents have been ordered from SICADA and delivered as Microsoft Excel and Microsoft Word files on a CD from SKB. Then caliper data from each borehole has been saved separately as an ASCII-file. The data processing is performed on the ASCII-files.

Both calibrated caliper data and resampled caliper data are stored in the primary data base SICADA and are traceable by the activity plan number.

4.4 Analyses and interpretations

No analyses or interpretations were performed in this activity.

4.5 Nonconformities

The following boreholes have not been calibrated in this activity: KSH01B, KSH03B, KAV04B, KLX02, and KLX07B since no technical documents were obtained. Caliper3D data in KLX09 has not been calibrated since the log file is dominated by null-values.

5 Results

5.1 Results of the calibration

In Figure 5-1 below examples of the results of the calibration of caliper mean and caliper1D data are presented for KLX04. The linear increase in the raw caliper mean data is removed, though keep all anomalies and in the case of the caliper1D data the calibration procedure has removed the major stepwise variations (not related to true diameter variations) but kept the minor high frequency anomalies.

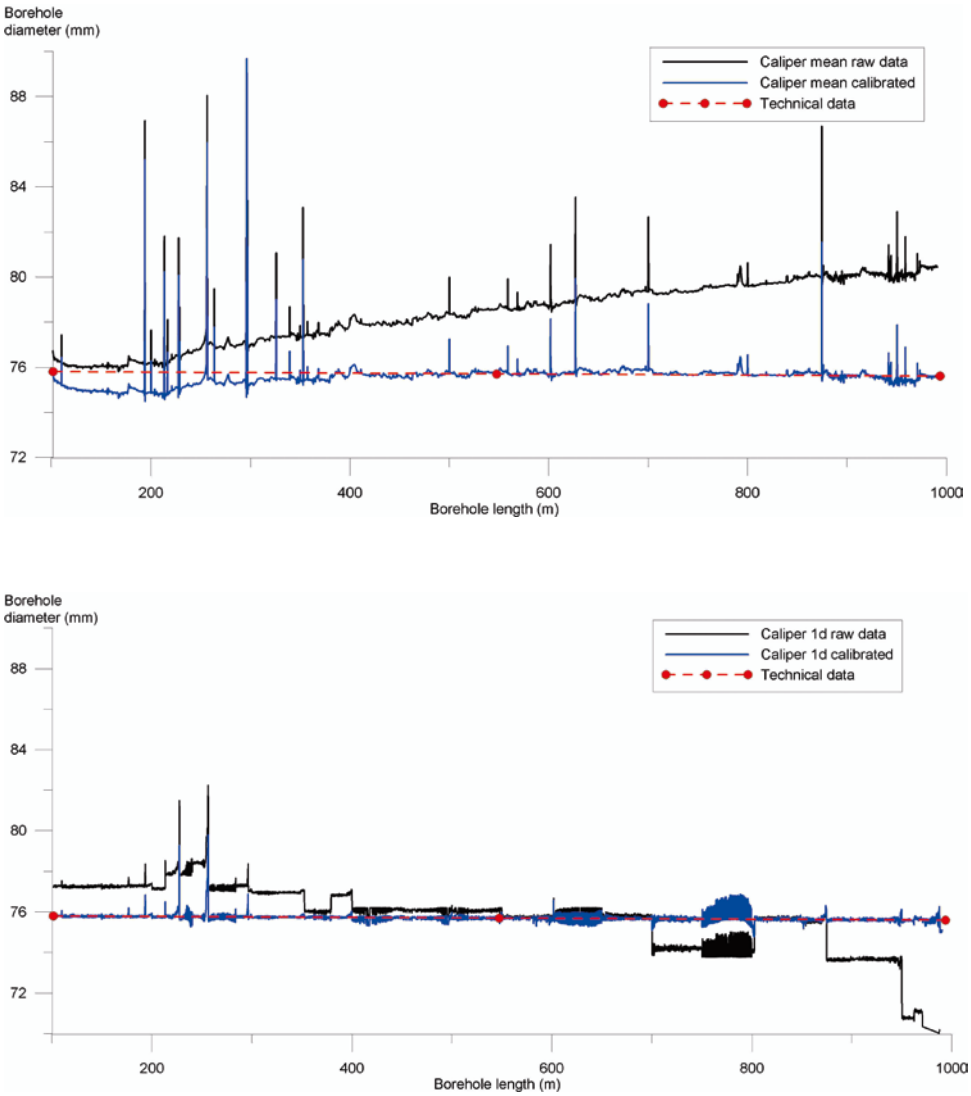

Figure 5-1. *Example showing caliper mean data (upper diagram) and caliper 1D data (lower diagram) before and after calibration (borehole KLX04).*

5.1.1 Comparison between calibrated and technical caliper data

A quality control of the calibrated caliper data was performed by comparing the calibrated caliper diameter to the caliper diameters in the technical data at the corresponding depths. This was done for each of the calibrated logs at three borehole lengths. In Figure 5-2 the calibrated caliper diameter is plotted versus caliper diameter of the technical data from KSH01A. A linear fit to the data (solid line in Figure 5-2) was used to calculate the accuracy of the calibration. The accuracy of each calibration is presented in Table 5-1 for core drilled boreholes and Table 5-2 for percussion drilled boreholes. Although the calculation of accuracy only is based on three comparison diameters, which is few, the accuracy parameter guides how well the performed calibration agrees with technical data at three borehole lengths for each borehole.

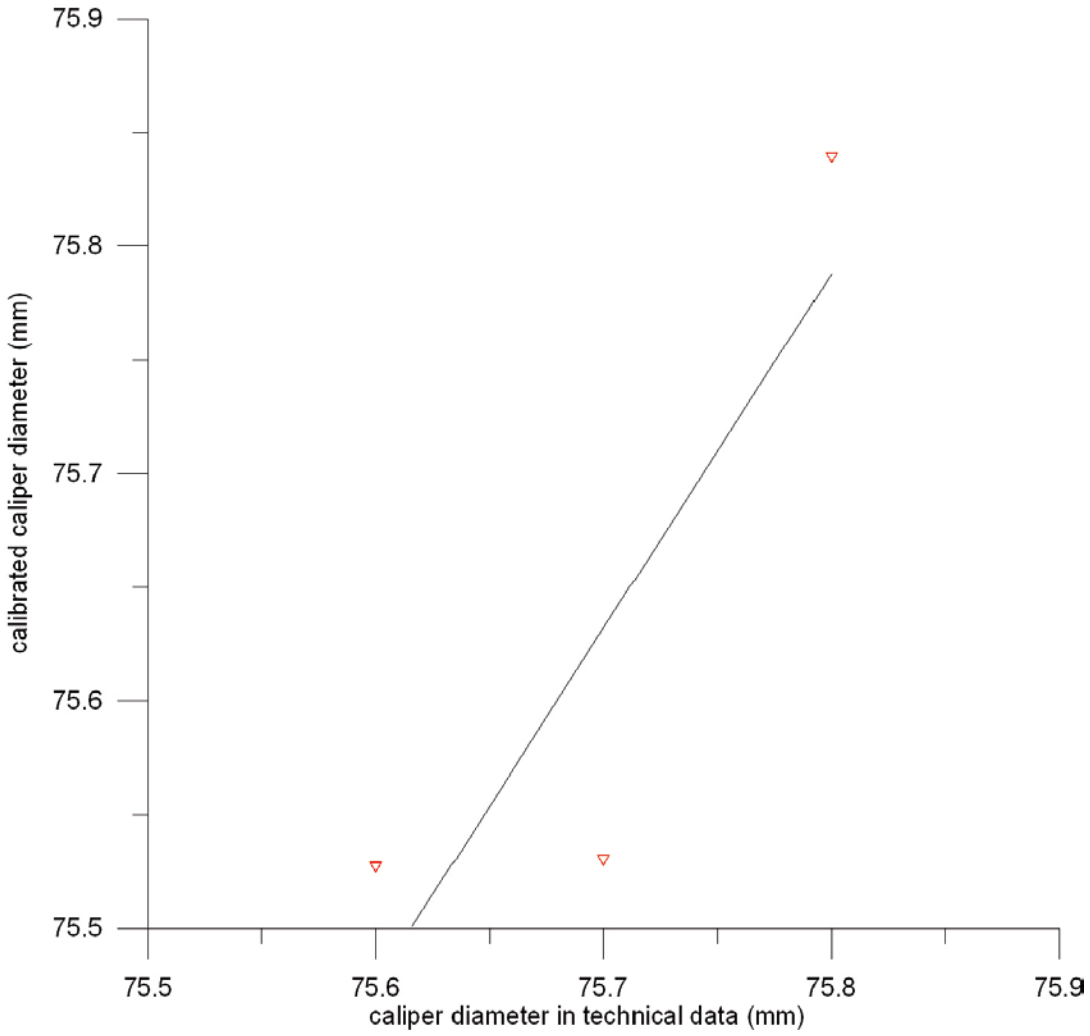

Figure 5-2. *Cross plot of calibrated caliper diameter versus caliper diameter from technical data from the core drilled borehole KSH01A.*

Table 5-1. Estimated accuracy for core drilled boreholes.

Borehole	Caliper 1D Accuracy [mm]	Caliper mean Accuracy [mm]
KSH01A	0.13	0.04
KSH01B	No data	No data
KSH02	0.09	0.02
KSH03A	0.13	0.29
KSH03B	No data	No data
KAV01	0.04	0.34
KAV04A	0.06	0.37
KAV04B	No data	No data
KLX01	0.13	No data
KLX02	No data	No data
KLX03	0.15	No data
KLX04	0.05	0.13
KLX05	0.01	0.33
KLX06	0.10	0.35
KLX07A	0.46	0.14
KLX07B	No data	No data
KLX08	0.02	0.57
KLX09	0.02	No data
KLX09B	0.02	No data
KLX09D	0.05	No data
KLX09F	0.1	No data
KLX09G	0.01	No data
KLX10	0.01	0.190
KLX10B	0.16	0.18
KLX10C	0.17	No data
KLX11A	0.01	0.54
KLX11B	0.01	0.07
KLX12A	0.05	0.06
KLX13A	0.19	0.33
KLX14A	0.49	0.31
KLX15A	0.02	No data
KLX16A	0.04	0.13
KLX17A	0.01	0.17
KLX18A	0.01	0.20
KLX19A	0.11	0.16
KLX20A	0.02	0.32
KLX21B	0.03	0.55
KLX22A	0.07	0.16
KLX22B	0.08	0.25
KLX23A	0.07	0.13
KLX23B	0.01	0.05
KLX24A	0.06	0.27
KLX25A	0.03	0.08
KLX26A	0.03	0.13
KLX26B	0.10	0.23
KLX27A	0.04	0.35
KLX28A	0.01	0.57
KLX29A	0.07	0.22
Average	0.08	0.24
Median	0.05	0.21

Table 5-2. Estimated accuracy for percussion drilled boreholes.

Borehole	Caliper 1D Accuracy [mm]	Caliper mean Accuracy [mm]
HSH01	0.03	No data
HSH02	0.42	No data
HSH03	0.06	No data
HAV09	0.06	0.24
HAV10	0.22	0.51
HLX13	0.22	0.20
HLX15	0.03	0.43
HLX17	0.11	No data
HLX18	0.32	No data
HLX19	0.16	No data
HLX20	0.06	No data
HLX21	0.15	0.47
HLX22	0.34	No data
HLX23	0.08	0.63
HLX24	0.09	0.53
HLX25	0.26	0.43
HLX26	0.23	0.25
HLX27	0.05	0.42
HLX28	0.22	No data
HLX30	0.33	No data
HLX31	0.15	0.46
HLX32	0.04	0.14
HLX33	0.28	No data
HLX34	0.09	No data
HLX35	0.14	No data
HLX36	0.13	0.05
HLX37	0.15	No data
HLX38	0.27	No data
HLX39	0.22	No data
HLX40	0.14	No data
HLX41	0.01	No data
HLX43	0.13	0.15
Average	0.16	0.35
Median	0.15	0.43

References

/1/ **SKB, 2001.** Platsundersökningar. Undersökningsmetoder och generellt genomförandeprogram. SKB R-01-10, Svensk Kärnbränslehantering AB.

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