

## **Forsmark site investigation**

### **Drilling of groundwater monitoring wells SFM0006–SFM0008 in soil at drillsite DS3**

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*Keywords:* AP PF 400-02-36, percussion drilling, groundwater monitoring well, soil, DS3.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors and do not necessarily coincide with those of the client.

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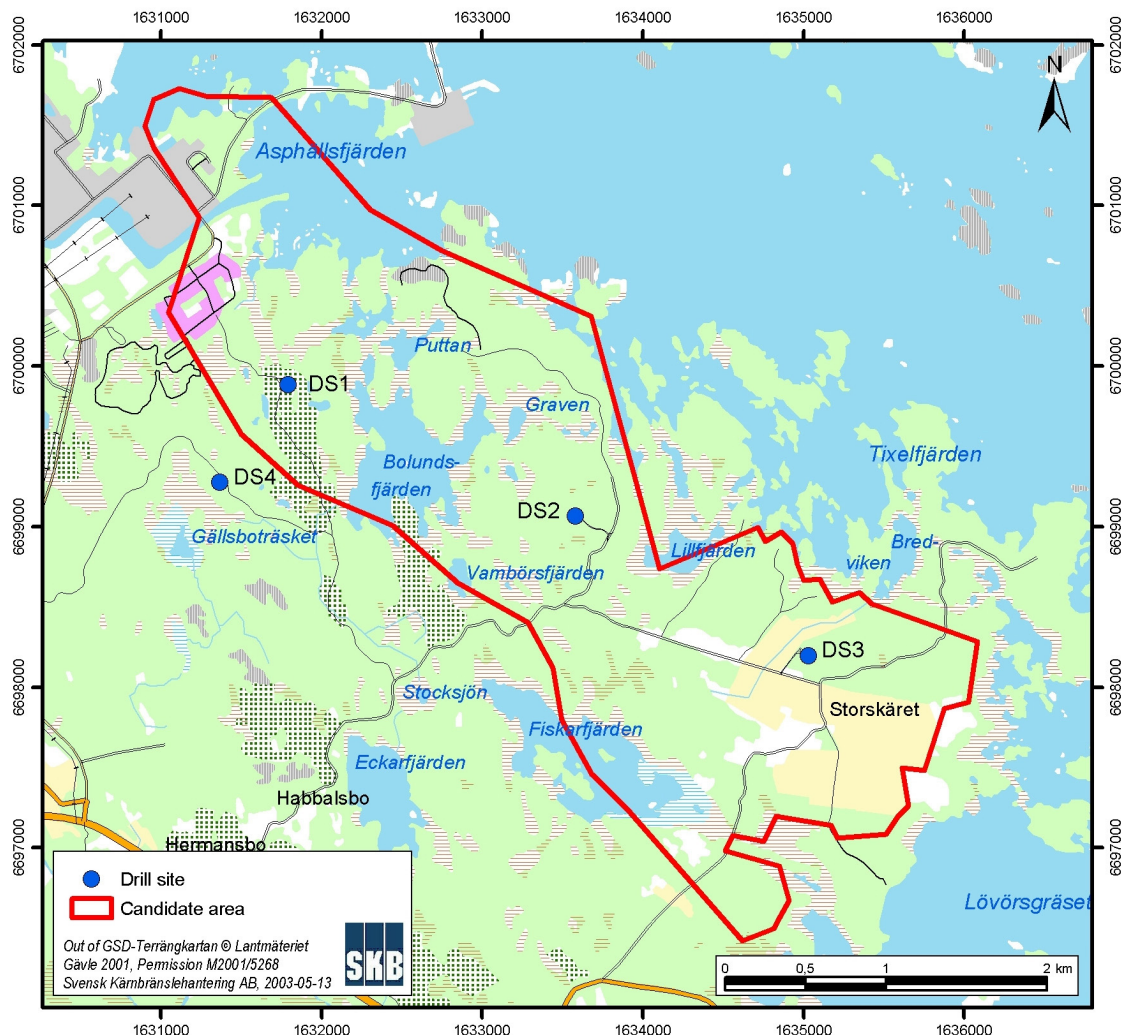
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# 1 Introduction

SKB performs site investigations to locate a deep repository for high level radioactive waste /1/. The investigations are performed in two Swedish municipalities, Östhammar and Oskarshamn. The investigation area in Östhammar is situated close to the nuclear power plant at Forsmark /2/, see Figure 1-1.

Drilling is one important activity performed within the frame of the site investigations. Three main types of boreholes are produced: core drilled boreholes, percussion drilled boreholes in solid rock and boreholes drilled through unconsolidated soil. The last type may be accomplished by different drilling techniques (percussion drilling, auger drilling etc) and may also be designed in various ways regarding geometrical characteristics etc.



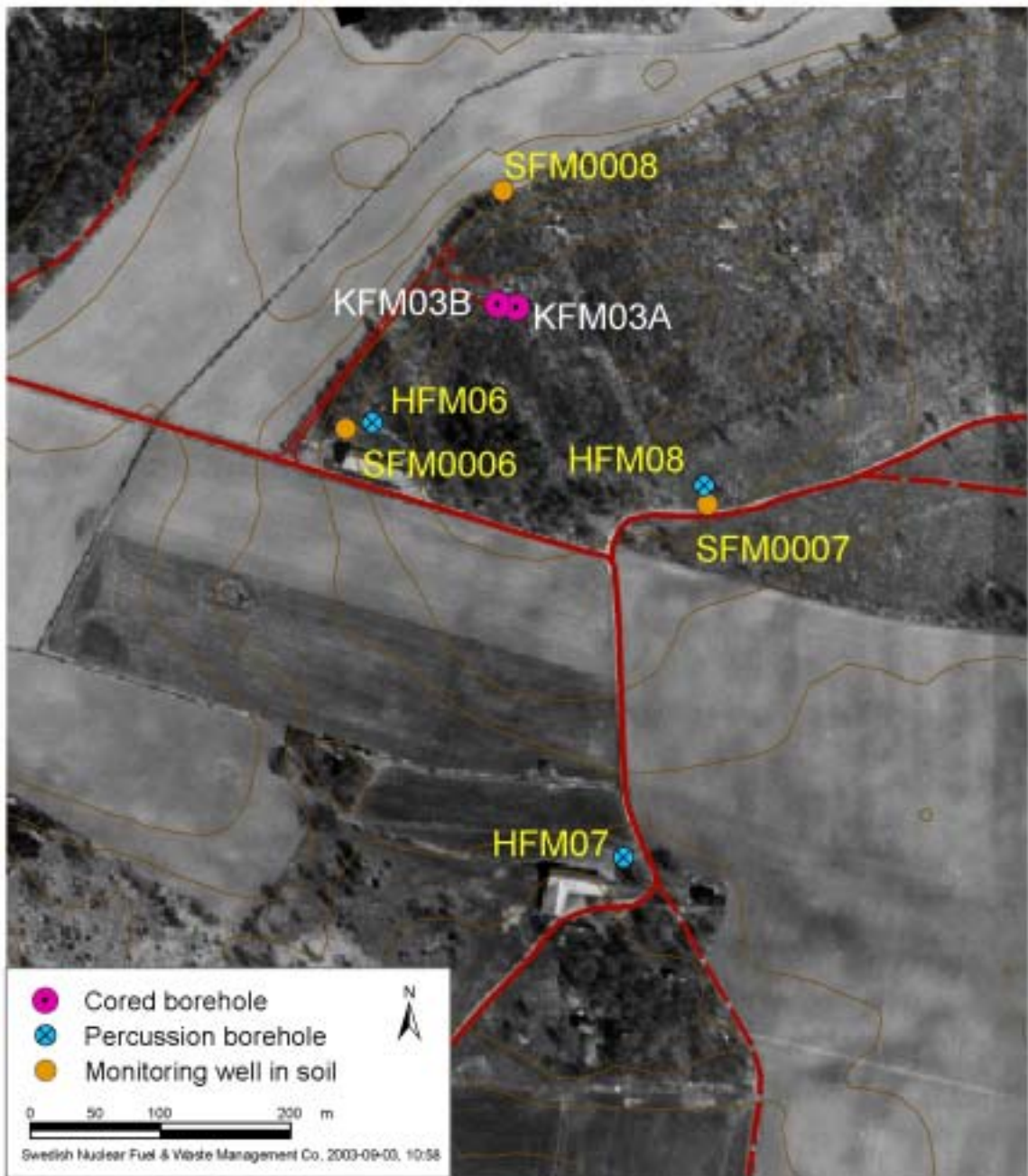
**Figure 1-1.** The investigation area at Forsmark including the candidate area selected for more detailed investigations. Drillsites DS1–4 are marked with blue dots.

The boreholes described in this report are called groundwater monitoring wells in soil due to the main purpose of the boreholes, which is monitoring of groundwater levels and repeated water sampling for a long-term study of the groundwater-chemical composition. The boreholes were drilled using so called Tubex drilling technique, representing a form of percussion drilling with an excentric drill bit while simultaneously driving a steel casing through the unconsolidated soil layer, see details in Chapter 4.

The deepest boreholes drilled at the site investigation are core drilled boreholes. So far, four c 1000 m deep core boreholes have been or are currently being drilled. The locations of the four drillsites in question, DS1, DS2, DS3 and DS4, are illustrated in Figure 1-1. Close to the deep core boreholes also other, more shallow types of boreholes are drilled for different purposes. Regarding drillsite DS3, results from drilling of the c 1000 m deep borehole KFM03A will be reported in /3/, results from drilling of the c 100 m deep borehole KFM03B in /4/, and results from drilling of the three percussion drilled boreholes in solid rock, HFM06–08, in /5/.

In this document, data acquired from the drilling operations and from investigations made during drilling of three groundwater monitoring wells in soil, SFM0006–SFM0008, at drillsite DS3 (Figure 1-2) are reported. The drilling depths were 3.70 m, 5.70 m and 5.73 m respectively. Drilling was performed by Sven Andersson in Uppsala AB, with support from SKB-personnel regarding measurements and tests during drilling. A Nemek 407 RE percussion drilling machine was called in for the commission.

The percussion drilling of all three boreholes was performed according to the Activity Plan AP PF 400-02-36 (internal SKB controlling document), which refers to SKB MD 630.003, Version 1.0 (Method Description for Soil Drilling).



**Figure 1-2.** Borehole locations at drillsite DS3. Besides the monitoring wells in the overburden, also percussion drilled boreholes in solid rock have been produced, for the supply of flushing water, monitoring of groundwater levels and groundwater sampling.

## 2 Objective and scope

Drilling of a 1000 m deep core borehole is a time consuming operation associated with extensive operations regarding e.g. water handling. At the SKB site investigations, drilling of deep cored boreholes is performed using a so called telescopic drilling technique, implying that the upper 100 m of the borehole is percussion drilled with a large diameter ( $\geq 200$  mm), whereas the borehole section 100–1000 m is core drilled with a diameter of approximately 76–77 mm.

Core drilling demands injection of relatively large amounts of flushing water through the drill string and drill bit for the purpose of cooling down the drill bit and for transportation of drill cuttings from the borehole bottom to the ground surface. At the SKB site investigations, an air-lift pump is installed in the upper, large-diameter part of the telescopic drilled borehole in order to enhance the recovery of flushing water with suspended drill cuttings. During the entire drilling period (comprising several months), the air-lift pumping and, to a lesser extent, the injection of flushing water will involve some influence on the groundwater levels at least in the solid rock, and, possibly, on the groundwater-chemical composition in the near-surrounding of the deep borehole. To enable observation of this effect, monitoring wells in solid rock and in the soil layers are drilled.

The strategy for setting out the three monitoring wells, SFM0006, SFM0007 and SFM0008, at drillsite DS3, was to locate them within the expected radius of influence of groundwater draw-down due to air-lift pumping in borehole KFM03A during drilling.

Drilling of monitoring wells in the unconsolidated soil layers in connection with a deep core drilled borehole should normally be performed prior to the start of drilling operations at the deep borehole, since the objective of the monitoring wells is to make the study of undisturbed as well as of disturbed groundwater conditions in the soil layer possible. This logistics was applied in the actual case, and so undisturbed conditions regarding primary groundwater levels could be studied during a period before the start of drilling of KFM03A.

Data gained during monitoring of undisturbed conditions will be part of the basic characterization of the groundwater conditions of the soil layers. Monitoring during the percussion and core drilling operations in KFM03A is primarily part of the environmental control program for these drilling operations. However, also these data may be used for basic characterization purposes. After completion of drilling and borehole loggings at drillsite DS3, the monitoring wells in solid rock as well as in soil will be used for long-term hydraulic and hydrochemical groundwater monitoring.



## 3 Equipment

Drilling of the three monitoring wells was performed using a Nemek 407 RE DTH (Down The Hole-equipment) percussion drilling machine (Figure 3-1) supplied with various accessory equipment.

### 3.1 Drilling equipment

The drilling machine was equipped with separate engines for transportation and power supplies. For discharging water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 455 Md was used. The DTH drillhammer was of type Secoroc 5", lowered into the borehole by a Driconeq 76 mm pipe string. Drilling was performed with the Ejector-Tubex technique, whereby a 168/160 mm steel tube was driven through the soil layer (Figure 3-2).

Cleaning of all DTH-equipment was carried out with a high-capacity steam cleaner of type Kärcher HDS 1195.



**Figure 3-1.** The Nemek 407 percussion drill machine engaged for drilling the monitoring wells in unconsolidated soil layers. Note the fluidproof cover beneath the drill rig used for protection of the ground in case of unintentional oil spillage. Photo Alf Sevastik.



### 3.2 Equipment for measurements and sampling during drilling

Flow measurements during drilling were performed using measuring vessels of different sizes and a stop watch. Measurements of drilling penetration rate were accomplished with a carpenter's rule and a stop watch.

Samples of soil and drill cuttings were collected in sampling pots and groundwater in small bottles. A field measuring device was used for measurements of electrical conductivity of the groundwater.



*Figure 3-2. The Nemek 407 percussion drill machine with a 168/160 mm temporary steel casing simultaneously driven through the overburden and approximately one metre into the bedrock while drilling at DS3. Photo Alf Sevastik.*

## 4 Execution

The performance of the work followed SKB MD 630.003, Version 1.0 (Method Description for Soil Drilling) and included the following parts:

- preparations,
- mobilisation, including lining up the machine and measuring the position,
- drilling, measurements, and sampling during drilling,
- installation of well screen and screen filter,
- finishing off work,
- data handling,
- environmental control.

### 4.1 Preparations

The preparation stage included the Contractor's service and function control of his equipment. The machinery was obliged to be supplied with fuel, oil and grease exclusively of the types stated in SKB MD 600.006, Version 1.0 (Method Instruction for Chemical Products and Materials). Finally, the equipment was cleaned in accordance with SKB MD 600.004, Version 1.0 (Method Instruction for Cleaning of Borehole Equipment and certain Ground-based Equipment) at level two used for boreholes prioritized for hydro-geochemical investigations.

Well screens and riser pipes of HDPE-material (High Density PolyEthylene) were delivered in tight-fitting packages. Before delivery to the drillsite, the pipes etc had been treated by acid leaching followed by rinsing with deionized water, see procedure in /6/, Section 4.1. At the drillsite, the screens and pipes aimed for boreholes SFM0006, SFM0007 and SFM0008 were prepared by steam-cleaning.

### 4.2 Mobilisation

Mobilisation onto and at the site included first of all transport of drilling equipment, well screens and well pipes, sand, bentonite, sampling pots for soil and drill cuttings, hand tools and other necessary equipment. Furthermore, the mobilisation comprised cleaning of all DTH-equipment, preparation of the drill site, lining up the machine, and final function control.

### **4.3 Drilling, measurements, and sampling during drilling**

Drilling through the overburden was performed using a variant of the Tubex system, called Ejector-Tubex. Tubex is a system for simultaneous drilling and casing driving. The method is based on a pilot bit and an eccentric reamer, which together produce a borehole slightly larger than the external diameter of the casing tube. This enables the casing tube to follow the drill bit down the hole. In the Ejector-Tubex system, the design of the discharge channels for the flushing medium, in this case compressed air, is such that the oxygen and oil contamination of the penetrated soil layers is reduced compared to conventional systems. During drilling, a temporary steel casing with the dimension 168.3 mm external and 160 mm internal diameter was simultaneously driven through the soil. When solid rock was indicated, drilling was continued approximately a couple of decimetres further, to ensure that the bedrock surface had been reached and not only compact till or a large boulder.

During drilling, a sampling and measurement program was performed, which included:

- One soil sample per metre. Analysis and results are reported in /7/.
- One sample of drill cuttings from the bedrock. Rock samples collected during drilling of monitoring wells in soil will be analysed and the results reported within the frame of the Activity Plan AP PF 400-03-51 (internal SKB controlling document).
- One observation of groundwater flow (if any) and water colour per 20 cm and a measurement of the flow rate at each major flow change observed.
- Measurement of the electrical conductivity of the sampled groundwater (if any) at each 3 m.

The results from the last two items, preserved as field records, were used exclusively for the on-site decision of the design of the well screen and filter installation in each borehole.

### **4.4 Installation of well screen and screen filter**

At completion of drilling, the temporary casing was driven approximately one metre into the bedrock. The results observed during drilling regarding soil depth and type, groundwater inflow etc were analysed on-site and a decision was made about the design of the borehole installation. The well screen and screen filter was then installed, see Figure 4-1, and the installation documented. The installation was performed uniquely for each well, according to the designs illustrated in Chapter 5.

The first part of the installation was to fill up a suitable amount of filter sand into the borehole, in order to cover the bedrock. The screen, connected to the riser pipes, was then lowered into the borehole, all the way down to the sand bed and was centralized in the borehole. During simultaneous lifting of the steel casing, the space between the



*Figure 4-1. Installation of the HDPE well screen, riser pipes, sand filter and bentonite sealings in a groundwater monitoring well inside a temporary steel casing. The snapshot illustrates filling with bentonite pellets. Photo Göran Nilsson.*

plastic pipe and the inner casing wall was filled up with filter sand. In order to prevent surface water to infiltrate along the borehole, a bentonite sealing was installed at an appropriate level in the borehole. In the actual monitoring wells, dry bentonite pellets were used (Figure 4-1). However, also a bentonite slurry may be suitable for this purpose.

#### **4.5 Finishing off work**

After installation of the screen, sand filter and sealing, the temporary casing was removed and the monitoring well secured with a stainless steel protective casing, which was driven a short distance into the ground around the upper part of the HDPE riser pipe. The casing was moulded firmly to the ground. Supplied with a lockable stainless steel cover, this construction offers an effective protection against damage of the monitoring well.

Finally, the drilling machine was removed, the site cleaned, and a joint inspection of the drill site made by SKB and the Contractor.

## **4.6 Data handling**

Minutes for the following items: Activities, Cleaning of equipment, Drilling, Drillhole, Deliverance of field material, and Discrepancy report were collected by the Activity Leader, who made a control of the information and had it stored in the SKB database SICADA /8/.

## **4.7 Environmental control**

A program according to SKB's routine for environmental control was followed throughout the activity. A checklist was filled in and signed by the Activity Leader, and was filed in the SKB archive.

## 5 Results

All data were stored in the SICADA database for Forsmark. Field note numbers are 80, 81 and 82.

### 5.1 Design of the groundwater monitoring wells SFM0006, SFM0007 and SFM0008

The design of the groundwater monitoring wells SFM0006, SFM0007 and SFM0008 is illustrated in Figures 5-1, 5-2 and 5-3. Table 5-1 displays the geometric characteristics of the wells.

**Table 5-1. Geometric data for groundwater monitoring wells SFM0006, SFM0007 and SFM0008.**

Drillhole ID	Inclination	Northing	Easting	Elevation m a s l (top of HDPE-pipe)	Total depth from ground level (m)	Screen length (m)	Screen pipe length (m)	Screen pipe diameter ( $\varnothing_o/\varnothing_i$ , mm)
SFM0006	90°	6697747.161	1634501.930	6.285	3.70	1.00	4.10	90/75
SFM0007	90°	6697688.659	1634780.076	7.002	5.70	1.00	6.10	63/50
SFM0008	90°	6697930.561	1634622.986	3.769	5.75	1.00	6.15	63/50

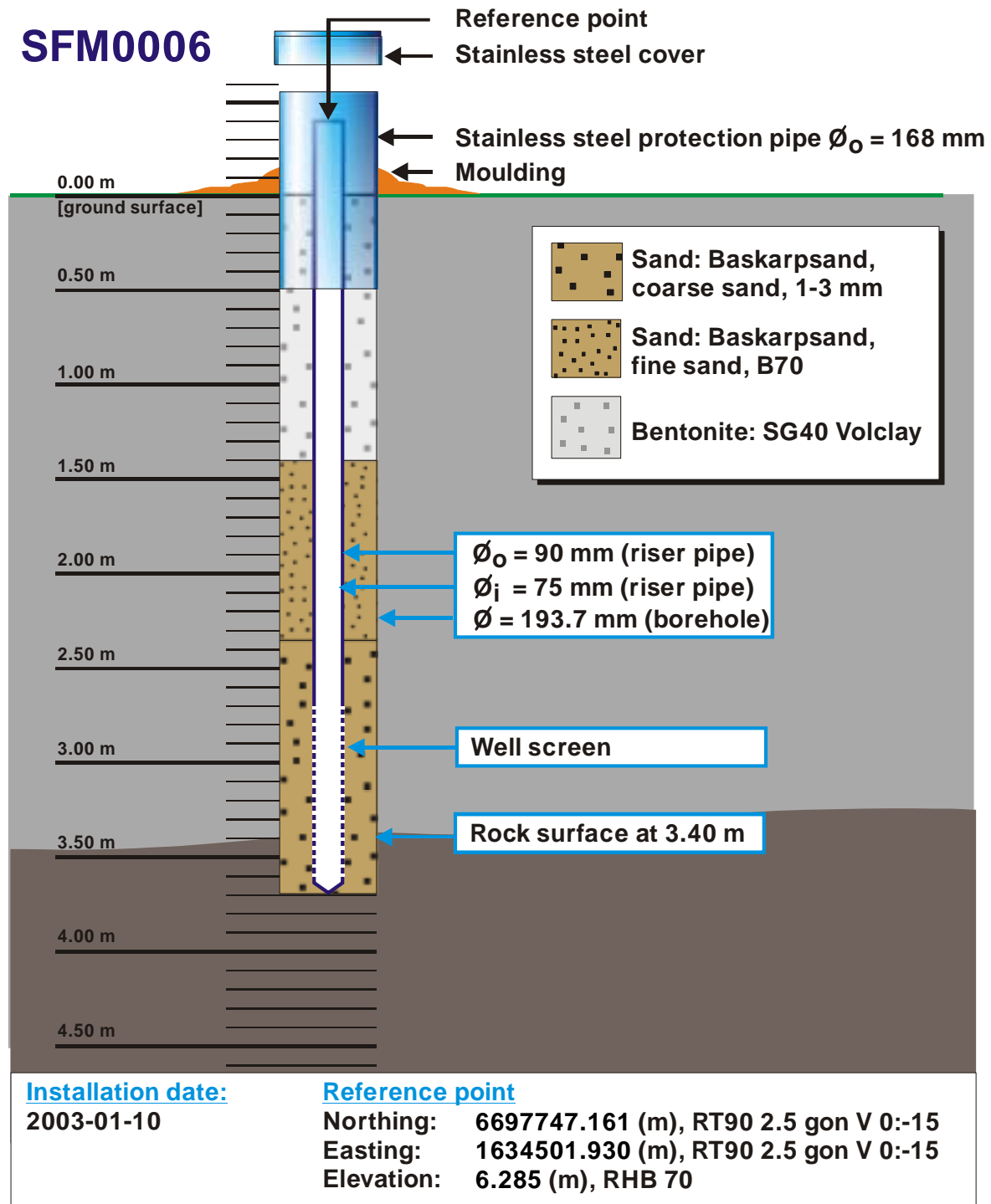


Figure 5-1. The groundwater monitoring well installation in borehole SFM0006.



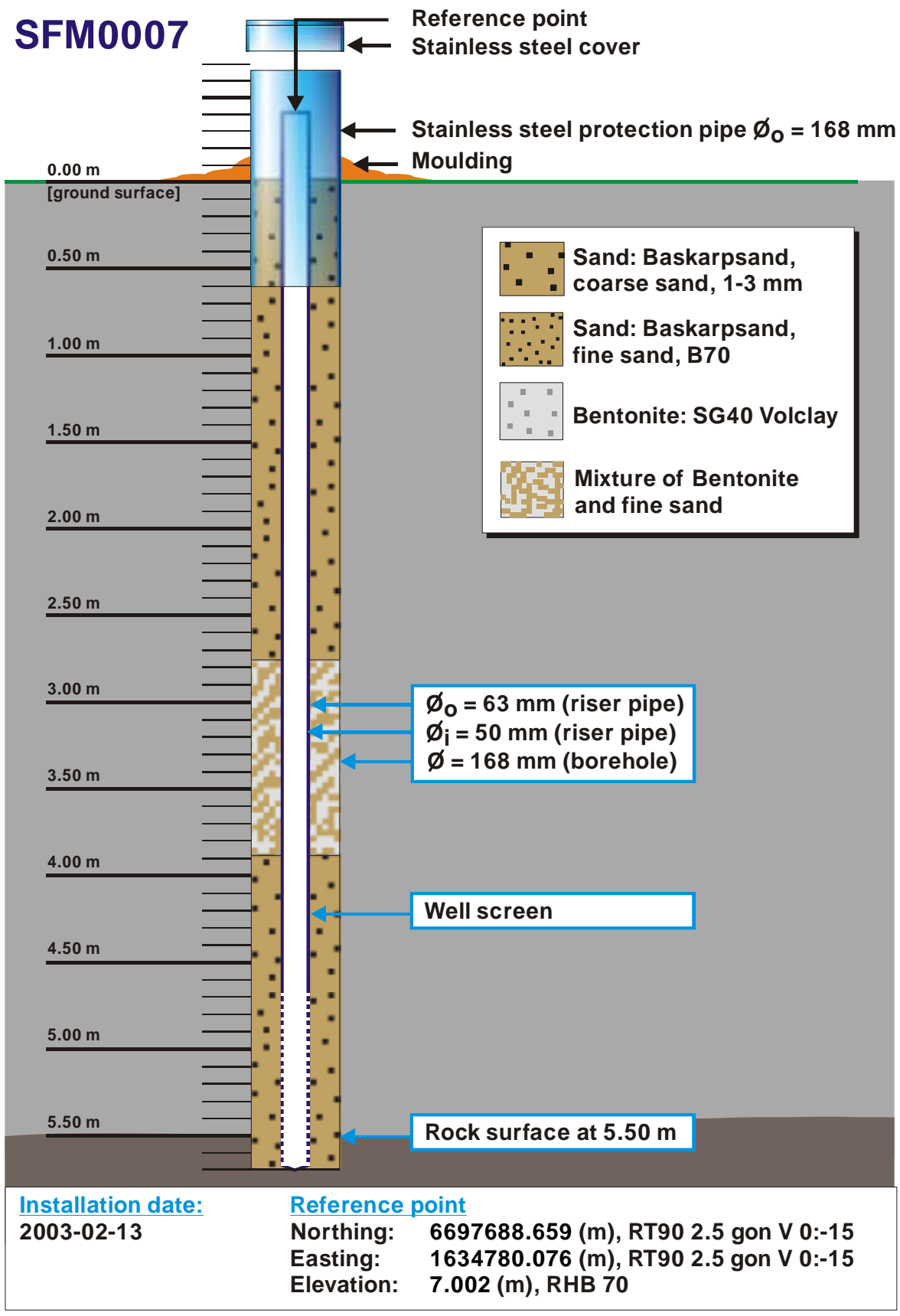


Figure 5-2. The groundwater monitoring well installation in borehole SFM0007.

**SFM0008**

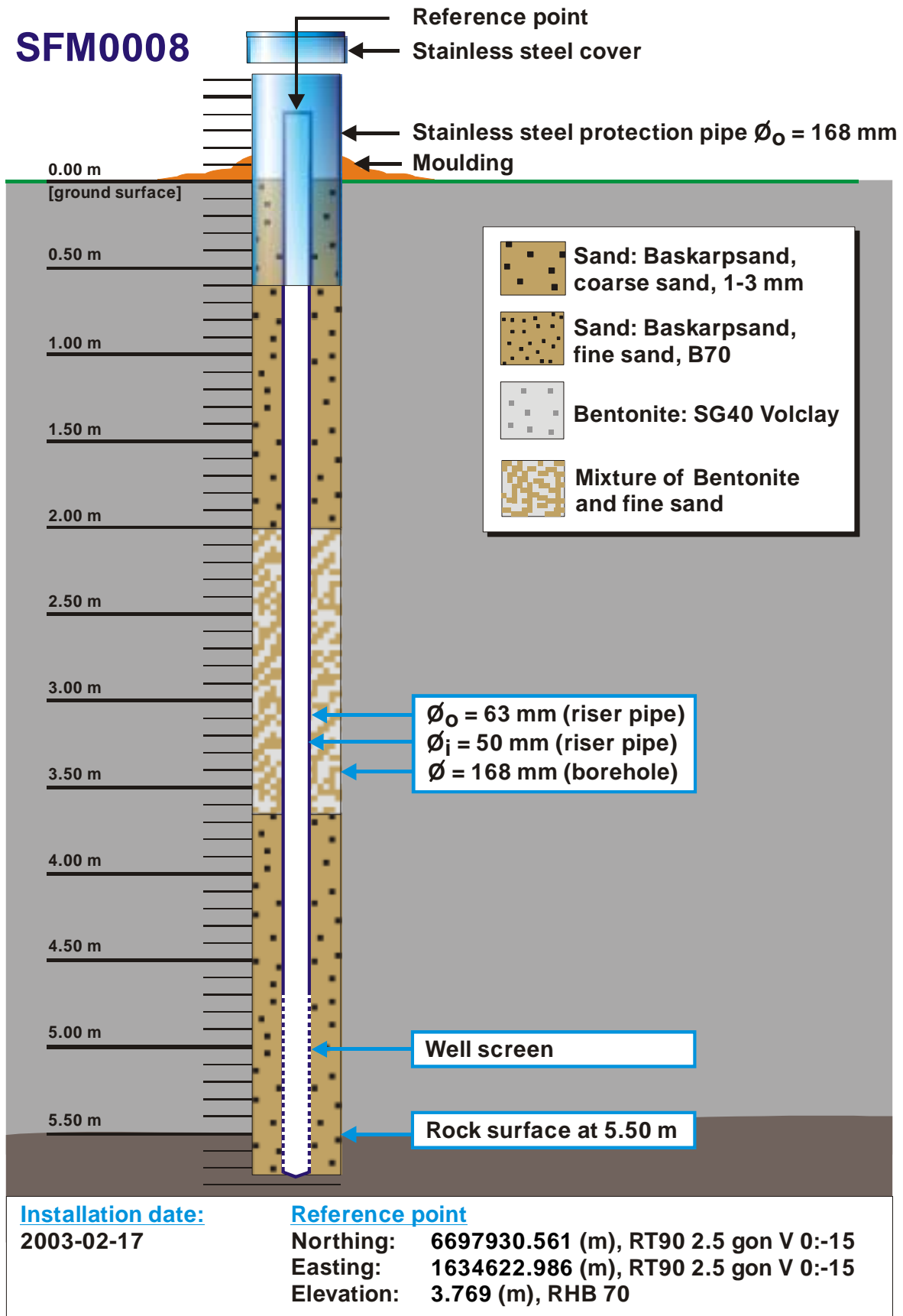


Figure 5-3. The groundwater monitoring well installation in borehole SFM0008.

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