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Äspö Hard Rock Laboratory

Large Scale Gas Injection Test

The LASGIT hole DA3147G01 Hydrogeology

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December 2004

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Abstract

As a part of the Lasgit project some hydrogeological tests have been performed in the large deposition hole DA3147G01 - the Lasgit hole and the anchor holes surrounding the large hole (TBM assembly hall, 420 m level at the Äspö HRL).

The inflow of water into the Lasgit hole has been measured. Water originating from the surrounding tunnel floor ("external water") but entering the deposition hole was sealed off at the top of the hole and measured separately. Ingressing water to the Lasgit hole, entering through the fractures and the rock mass of the hole wall and bottom ("internal water"), was measured by using a level indicator to study the rise of the water level per time unit.

During the period the measurements took place, the inflow of "external water" varied between 10-20 litres/day or 0.007-0.013 litres/minute.

The inflow of "internal water" was about 240 litres/day or 0.17 litres/minute if the theoretical evaporation was not considered and 266 litres/day or 0.2 litres/minute if it was.

To get an estimate of the evaporation in the TBM assembly hall an in situ test was performed in March 2004. It showed that the evaporation from a free water surface was 0.67 litres/day and square metre. This means that the evaporation from the free, circular water surface down in the deposition hole is 1.6 litres/day (possible evaporation from the hole wall not included). This corresponds to 0.7% of the "internal" inflow which is much less than the accuracy of the method used to measure the inflow (±2.5-3%). Thus, the evaporation from the free water surface down in the hole may be neglected.

At the time when the measurements of "internal water" inflow took place the theoretical evaporation from the hole wall could have been as much as about 24 litres/day. This is under the condition that the entire hole wall acts as a free water surface which is not the case since large parts of the wall was dry-damp. Therefore, also the evaporation from the hole wall may be regarded as negligible.

Hence, measured inflow of "internal water" is to be regarded as real inflow.

Other hydrogeological tests that have been performed are pressure build up and pressure drop tests and gas leakage tests. Pressure build up tests have been made not only in the anchor holes but also in pilot holes drilled in the planned centres of all the large deposition holes on the 420 m level prior to the drilling of the latter. These tests show a water pressure varying between 3-20 bars in the anchor holes and 0-27 bars in the pilot holes.

The pressure drop tests or pulse tests performed in the anchor holes gave varying results too. The calculated hydraulic conductivities and transmissivities varied between 1E-12 - 7E-10 m/sec. and 9E-12 - 3E-9 m^2/sec. respectively.

The idea of the gas leakage tests was to find out if there were any connections between the anchor holes themselves and the water filled Lasgit hole. The anchor holes were one by one put under pressure. Occurring gas leakage was seen as bubbles on the water surface in the Lasgit hole and in neighbouring anchor holes. By the help of a video camera the gas leakage was located on the wall of the Lasgit hole and registered on drawings. Without any doubt there are fractures connecting some of the anchor holes with each other as well as some of the anchor holes with the Lasgit hole.

The varying results of the respective pressure tests are likely to be due to variations in fracture patterns and how the boreholes are distributed among them. Leakage between packer and hole walls is, however, another possibility that cannot be ruled out.

Sammanfattning

Som en del av det s k Lasgit projektet har några hydrogeologiska tester utförts i deponeringshålet DA3147G01 (Lasgithålet) samt i de omgivande ankarhålen (TBM-monteringshallen, 420 m nivån i Äspölaboratoriets tunnel system).

Vatteninflödet i Lasgithålet har mätts. ”Externt vatten”, d v s sådant vatten som härrör från omgivningen (t ex inläckage i själva tunneln) men som delvis normalt rann ner i deponeringshålet avskärmades via ett dräneringssystem i toppen på hålet varefter vattenmängden mättes.

Det ”externa vattnet” varierade mellan 10-20 liter/dag eller 0.007-0.013 liter/minut.

Inläckage av vatten till deponeringshålet via sprickor och bergmassa i hålets vägg och botten (”internt vatten”), mättes genom att registrera stigningen av vattenytan i hålet med hjälp av ett vanligt ljuslod.

Inflödet av ”internt vatten” låg under mätperioden på ungefär 240 liter/dag eller 0.17 liter/minut om ingen hänsyn togs till den teoretiska avdunstningen och på 266 liter/dag eller 0.2 liter/minut om så gjordes.

För att uppskatta avdunstningen i TBM-monteringshallen gjordes en in situ test i mars 2004. Den visade att avdunstningen då var 0.67 liter/dag och kvadratmeter. Avdunstningen från den fria vattenytan nere i deponeringshålet blir då 1.6 liter/dag vilket motsvarar ca 0.7% av det ”interna” inflödet (ingen hänsyn har då tagits till eventuell avdunstning från hålväggen). Då avdunstning är så liten som den är och mindre än felet för mätningen (±2.5-3%) av vatteninläckaget, föreslås det att den negligeras.

Den teoretiska avdunstningen från hålväggen vid tiden för mätningarna av det ”interna vatteninflödet” skulle kunna ha varit så mycket som 24 liter/dag. Detta förutsätter att hela väggen agerar som en fri vattenyta. Detta är dock inte fallet då stora delar av väggen var torr-fuktig. Även avdunstningen från hålväggen är med all sannolikhet att betrakta som försumbar.

Sålunda, uppmätt inflöde av ”internt vatten” är att betrakta som verkligt inflöde.

Andra hydrogeologiska tester som utfördes var tryckuppbyggnads- resp tryckfallstester samt gasläckagetester.

Tryckuppbyggnadstesterna utfördes inte bara i ankarhålen utan även i de s k pilothålen, som borrades i de tänkta centrumpunkterna till alla de stora deponeringshålen på 420 m nivån innan de sistnämnda borrades. Testerna visade att vattentrycket varierade mellan 3-20 bar för ankarhålen och 0-27 bar för pilothålen.

Även tryckfallstesterna (pulstesterna) som utfördes i ankarhålen visade varierande resultat. Den hydrauliska konduktiviteten och transmissiviteten varierade mellan 1E-12 och 7E-10 m/sek respektive 9E-12 och 3E-9 m^2/sek.

Syftet med de s k gasläckagetesterna var att se om det fanns några samband mellan de olika ankarhålen och det vid detta tillfälle vattenfyllda Lasgithålet. Ett efter ett trycksattes ankarhålen med gas medan de övriga vattenfylldes. Befintligt gasläckage (bubblor) in till deponeringshålet registrerades med hjälp av en videokamera och läget noterades på en ritning. Gasbubblor registrerades även i ankarhål intill det trycksatta ankarhålet. Det råder ingen tvekan om att det finns sprickor som sammanbinder vissa av ankarhålen med varandra liksom med Lasgithålet.

De varierande resultaten för de olika trycktesterna beror med all sannolikhet bl a på variationer i sprickmönstret och hur borrhålen är placerade i förhållande till sprickorna. Utan tvekan kan även läckage via manschett och testhålets vägg orsaka variationer i resultaten.

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1 Introduction

The TBM assembly hall which is a part of the A-tunnel (TASA) is situated approximately on the 420m-level of the tunnel system at the Äspö Hard Rock Laboratory (Äspö HRL, Figures 1-1 and 1-2) will house the Lasgit project (Large Scale Gas Injection Test). A brief description of the project and the history of the TBM assembly hall, as well as information about the geology and water bearing fractures, are given in Hardenby & Lundin (2003).

For the tests to be performed, the Lasgit project will use the large deposition hole DA3147G01, often referred to as the Lasgit hole, which is situated in the assembly hall. As a part of the project some hydrogeological tests and measurements in and around the deposition have been performed and are described in this report.

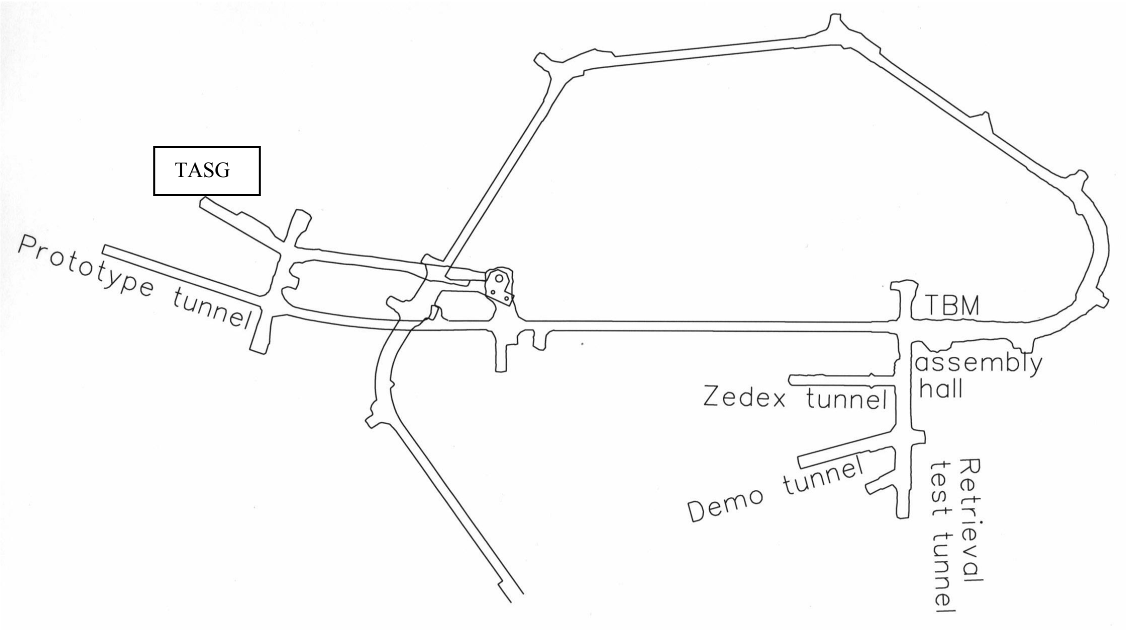


Figure 1-1. *Location of the TBM assembly hall on the 420 m level of the Äspö HRL*

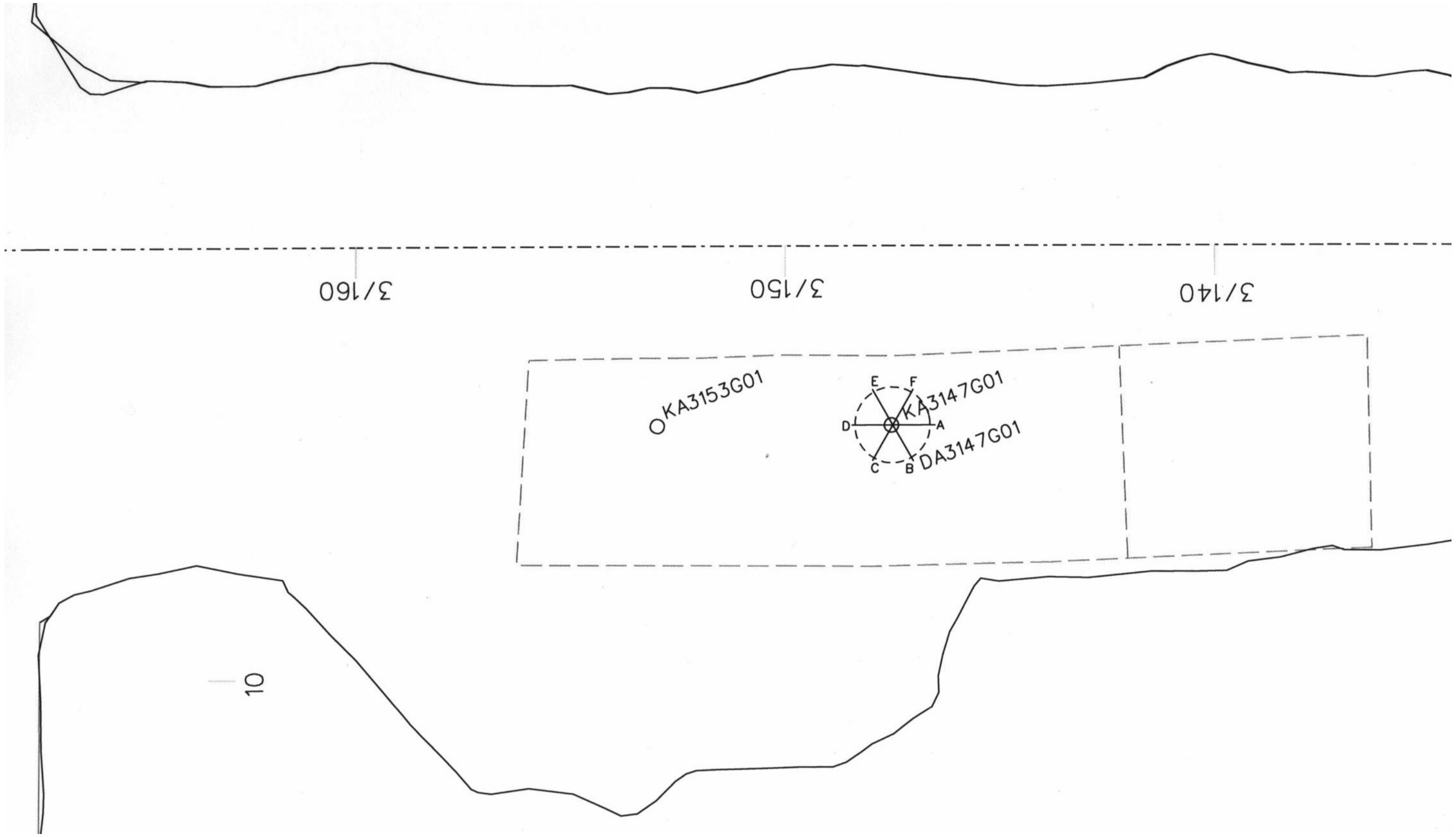


Figure 1-2. *Locations of the deposition hole DA3147G01 and two core (pilot) holes KA3147G01 and KA3153G01 in the TBM assembly hall at the Äspö HRL 420 m level.*
The letters A-F on the periphery of the deposition hole refer to vertical sections of the hole wall. Dashed line forming a rectangle refers to a previous pit in the paved floor of the assembly hall. The pit exposed at the time the underlying bedrock.

2 General conditions

Gravel and other fill material lies between the rock floor and the paved floor (asphalt) of the TBM Assembly Hall of the Äspö Hard Rock Laboratory. In a 5.2x15 m rectangular area surrounding the deposition hole, however, a concrete floor rests directly on top of the rock floor. Today most of the concrete is covered with fill material with asphalt on top. Only an approximately 3.0 x 2.8 m large "frame" of concrete added on top of the original concrete floor is visible. The deposition hole DA3147G01 is found almost in the centre of this frame. The present surface of the asphalt layer is 0.56 m above the concrete floor surface.

The floor of the TBM assembly hall, below the layer of asphalt, acts as an aquifer. Here, water not only originating from the assembly hall itself, but also water entering the hall from a few other parts of the tunnel system, is collected. In June 2004 the water level in the "aquifer" was found to be about 0.25 m below the top of the asphalt layer. It is only the narrow and 0.56 m high concrete frame/barrier that prevents this water from flowing into the deposition hole.

Before the large deposition hole DA3147G01 was drilled an injection curtain was put in place to prevent more water than necessary to enter the hole while drilling progressed. The grout was injected from ten (10), 10 m long, Ø 64 mm percussion holes that according to G. Ramqvist (at Äspö HRL, pers. comm. 2004) were drilled about 0.5 m outside the periphery of the planned deposition hole. The water-cement ratio of the grout was 0.8 and the maximum end pressure during the injections was 60 bars. Only in two of the injection holes some grout could be injected, 3 and 5 litres respectively. Both holes situated in the D-E section of the periphery of the Lasgit hole (Figure 1-2),

In March 2004 ten, about 11 m long percussion holes were drilled around the large deposition hole. When the Lasgit canister and the buffer of bentonite is in place in the deposition hole the percussion holes will be used to anchor the cables that will hold the deposition hole lid in place. The ten holes with the Id HA3147G01 – HA3147G10 will further on be referred to as the anchor holes.

3 Hydrogeological tests

Five major tests or measurements have been performed: Evaporation test, water inflow test, pressure build up test, pressure drop test, and gas leakage test.

3.1 Evaporation

To get an estimate of the evaporation in the TBM assembly hall a simple and rather crude in situ test was carried out. Unfortunately the test was not performed at the same time as the water inflow measurements took place (December 2003) but during 9 days in March 2004.

Temperature and relative humidity was not registered in the TBM assembly hall during the measurements of water level nor during the test period for evaporation. It is acknowledged that the lack of these factors is a source of error. They will not only affect the degree of evaporation and but may also vary from the time the water measurements took place and when the evaporation test was performed. There is, however, some information available not only from some other parts of the tunnel system but also late information from the TBM assembly hall.

In the G-tunnel (TASG, Figure 1-1) continuous registrations of temperature and relative humidity have been made since the middle of February 2004. There, the temperature varied between 10-12ºC, mostly around 10ºC, and the relative humidity varied between 60-70% during last 1.5 weeks of February and the first 1.5 weeks of March. The rest of March and to the middle of April the temperature varied between 10-12ºC, mostly around 12ºC, and the relative humidity between 70-85%. During the evaporation test period the temperature was mostly about 12ºC and the relative humidity around 80%.

In December 2003 when the water level measurements in the deposition hole took place, the mean temperature was 13ºC on the 450 m level of TASA, almost between TASG and the TBM assembly hall, and in March 2004 it was 12ºC.

Measurements of temperature and relative humidity made on the 5th of May, 2004 in both the G-tunnel and the TBM assembly hall gave the following results: In the G-tunnel the temperature and relative humidity was 14.5ºC and 89% respectively and in the TBM assembly hall 15.1ºC and 95% respectively. At the same time the temperature on the 450 m level was 13.6ºC. Unfortunately information about relative humidity is missing from this locality.

For the evaporation test a small plastic container (253x276mm) was placed on the floor of the TMB assembly hall during March 22 and 31, 2004. The container was filled with water when the test commenced. After the 9 days, that the test lasted, the water level was 6 mm below the starting level. This means that the water level in the small container was sinking 0.67 mm/day which will give an evaporation rate of 0.67 litres/day and square metre.

Applied to the free, slowly rising water surface (2.41 m²) in the deposition hole these figures will give an evaporation of 1.6 litres/day. This corresponds to about 0.7% of the measured inflow of "internal water". Bearing in mind that the accuracy of those measurements is about ± 3%, the evaporation from the free water surface can be neglected.

If the surface of the hole wall is taken into account the evaporation may in theory be greater. The quantity of the evaporation from the wall depends not only on the exposed surface but also on how water-saturated the surface is. The part of the wall that was exposed for evaporation during the water level measurements was below the circular drain (Figure 3-1) and above the water surface, thus approximately between hole section 1.5 and 8 m (= 6.5 m hole length).

At the time the water level measurements took place, the surface of the exposed wall was about 36 m². If the entire hole wall acted as a free water surface the theoretical quantity of the evaporation from the wall was 24 litres/day (36 x 0.67 litres/day). The quantity of the evaporation from the hole wall will, however, decrease as the water level rises. When the hole is filled with water it will thus only be the free water surface that will contribute to the evaporation from the deposition hole. While the water level measurements took place, however, the total quantity of evaporation per day in theory may have been 25.6 litres (1.6 + 24 litres), assuming that the evaporation rate at that time was the same as when the evaporation test was performed and that the wall surface acted as a free water surface.

It is, however, not very likely that the hole wall will have much influence on the total quantity of evaporation since the wall in many parts was dry or at most damp and thus did not act as a free water surface. Another factor that will decrease the evaporation from the deposition hole is the low circulation of air in the hole which means that there will be very little exchange of air with the surroundings.

3.2 Water inflow

3.2.1 Conditions

The inflow of water into the deposition hole has two main sources. One of them is the ingress of water through the wall and bottom of the hole. Here called "internal water". The other source consists of water originating from leakage between the "concrete floor" and the original rock floor of the TBM assembly hall. This water is here referred to as "external water". Water from a drill hole connecting the tunnel floor with the interior of the deposition hole is also included in the external water.

To avoid interference, with "internal" and "external water", the water paths of the latter had to be sealed off. For the concrete/rock leakage this meant that a circular drain was attached to the rock wall at the top of the deposition hole (Figure 3-1). The drain was connected to a small plastic container from which collected water could be pumped away and measured. The drill hole ending in the deposition hole was sealed by a common packer which prevented any water from entering the deposition hole.

The injection curtain, mentioned earlier, means that the "internal water" enter the deposition hole via a, at least partially, sealed rock wall which of course will have an influence on the inflow rate.

Figure 3-1. *Deposition hole DA3147G01 with the circular drain and small plastic container (greyish)*

3.2.2 Leakage between rock and concrete floor

The measurements of the external water that was leaking through the rock floor and concrete floor (section 3.2.1) boundary took place between December 3 and 12, 2003. The quantity of the collected water that was pumped away was measured approximately once a day (Table 3-1). Measurements and also the construction of the circular drain (Figure 3-1) were performed by N-G. Myrén and G. Svensson of NCC.

As can be seen from Figure 3-2 and Table 3-1, the quantity of water that was prevented from entering the deposition hole by the circular drain was rather small, as an average 0.6 litres/hour or 0.01 litres/minute. It varied, however, a great deal during the time the measurements took place. The inflow rates for the measured intervals vary between about 0.4 litres/hour and 0.8 litres/hour. Thus, there is a difference of 0.4 litres/hour or 0.006 litres/minute between the lowest and highest inflow rate which means that the highest value is almost 1.9 times greater than the lowest one.

No leakage was observed from the now packer sealed drill hole that connects the deposition hole with the floor of the TBM assembly hall. Hence, all external water that is described here originates from the leakage between the rock floor and the concrete floor. The flow from the drill hole gave, however, about 30 litres of water per hour at the time when the deposition hole was mapped (Hardenby and Lundin, 2003).

Even if the leakage between rock floor and concrete floor had not been successfully sealed off, bearing in mind that it was small, the influence of that water would have had very little effect on the inflow rate of the ”internal water” (Section 3.2.3).

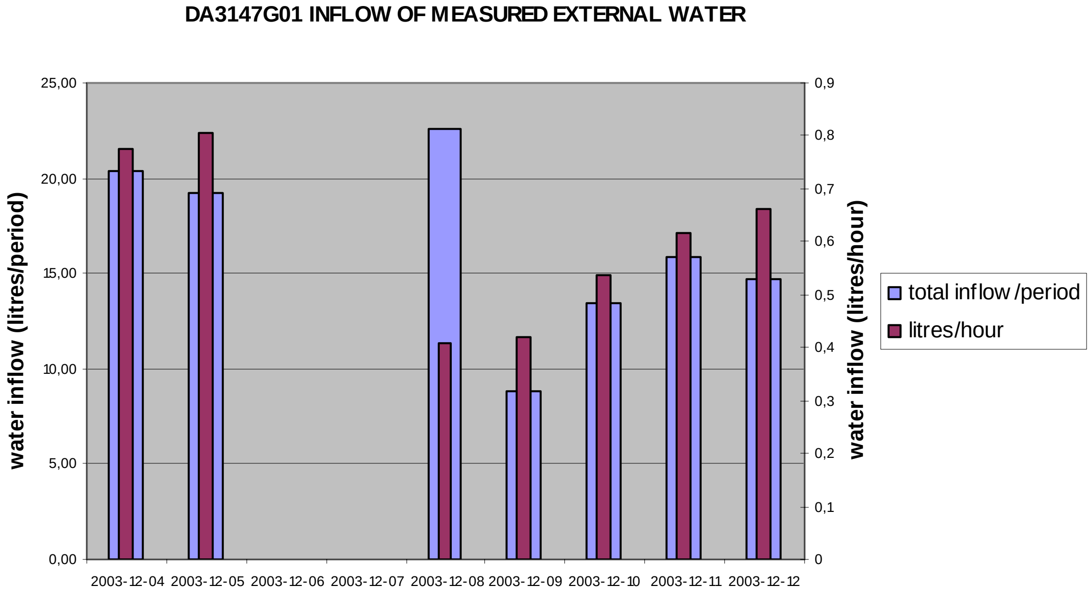


Figure 3-2. *DA3147G01, inflow of measured external water: total inflow and inflow rate (litres/hour) per measuring interval*

Table 3-1. DA3147G01, quantity (litres) of measured external water and inflow rate (l/day = litres/day, l/h = litres/hour and l/min = litres/minute) per measuring interval in December 2003

Interval				**No of hours**	**Quantity of water (litres)**	**Inflow rate**		
From		**To**				**(l/day)**	**(l/h)**	**(l/min)**
Day	**Time**	**Day**	**Time**					
3	7:50	4	10:03	26.22	20.35	19.9	0.776	0.013
4	10:12	5	10:05	23.88	19.20	19.3	0.804	0.013
5	10:15	8	10:21	48.10	22.60	11.3	0.470	0.008
8	10:37	9	7:36	21.18	8.85	10.0	0.418	0.007
9	7:40	10	8:35	24.91	13.40	12.9	0.538	0.009
10	8:38	11	10:17	25.65	15.85	14.8	0.618	0.010
11	10:20	12	8:35	22.25	14.70	15.9	0.661	0.011
Total:				192.19	114.95			
Mean:						14.4	0.6	0.01

3.2.3 Level indicator measurements

The water level in the deposition hole DA3147G01 was measured three times during a short period of time between December 12 and 17, 2003 (Figure 3-3 and Table 3-2). A simple water level indicator was used for the measurements.

Totally 116.7 hours elapsed between the first and the last measurement and the total change in water level was 0.485 m. The average rising rate of the water level in the hole was 0.0042 m/hour or about 0.1 m/day.

The theoretical diameter of the deposition hole is 1.75 m. A section across the hole will then have an area of 2.41 m². The total inflow of water during the period of measurements was calculated to be 1167 litres. This corresponds to an average inflow of about 240 litres/day, 10 litres/hour or 0.17 litres/minute (Table 3-2). Note that these figures do not take evaporation into account. When evaporation is considered the inflow rate will be slightly greater (Section 3.2.4).

For the time the measurements took place it appears to have been a stable inflow of water into the deposition hole (Figure 3-3). During the first interval the inflow rate was 10.2 litres/hour and during the second one 9.6 litres/hour. This means a difference of 0.6 litres/hour or 0.009 litres/minute between the lowest and highest recorded inflow rate. Thus, the highest value is less than 1.1 times the lowest one. This difference is negligible considering that the accuracy of the type of measuring instrument that was used commonly is about ±2.5-3%.

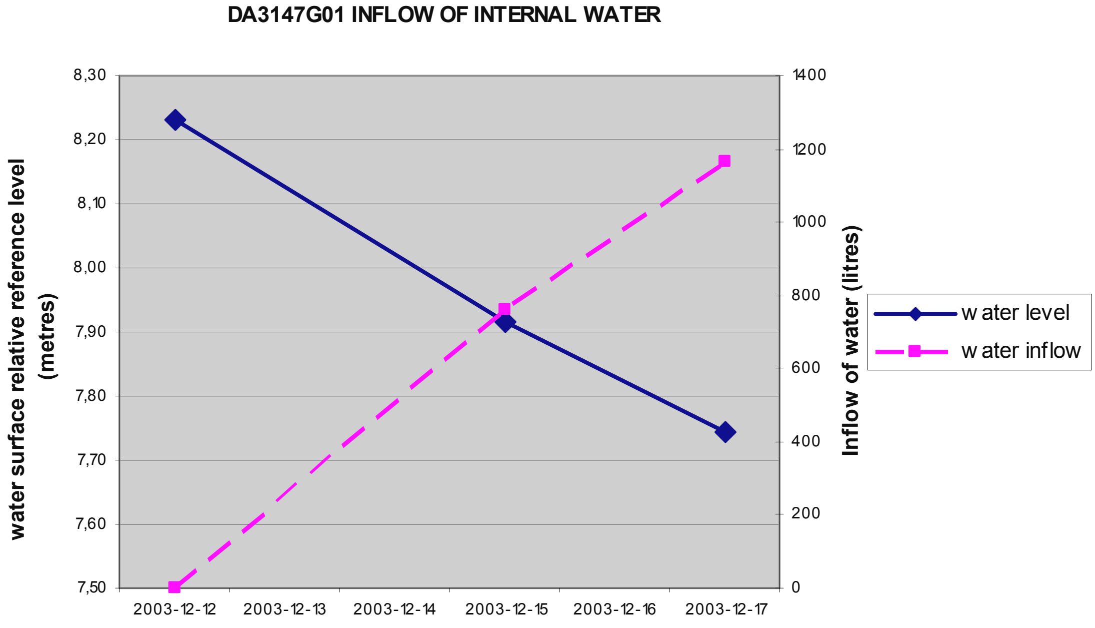


Figure 3-3. *The rise of the water level and accumulated inflow of internal water in deposition hole DA3147G01. The rising water level is shown as the decreasing distance between the water level and a reference level in the upper part of the hole.*

Table 3-2. Inflow of internal water into deposition hole DA3147G01 in December 2003 (water level refers to recorded level relative a reference level at the upper part of the hole at the end date of an interval, l/day = litres/day, l/h = litres/hour and l/min = litres/minute)

Interval				No of hours	Water level (m)	Change in water level (m)	Quantity of water (litres)	Inflow rate		
Start		End						(l/day)	(l/h)	(l/min)
Day	Time	Day	Time							
		12	13:50		8.230					
12	13:50	15	16:07	74.3	7.915	0.315	757.7	244.8	10.2	0.17
15	16:07	17	10:30	42.4	7.745	0.170	408.9	231.5	9.6	0.16
Total				116.7		0.485	1166.6			
Mean								239.9	10.0	0.17

3.2.4 Total inflow

When the theoretical total evaporation is taken into account the inflow rate of ”internal water” into the deposition hole will be about 266 litres/day (240 + 25.6 litres/day), 11 litres/hour or 0.2 litres/minute. Most likely, however, the effect of evaporation can be regarded as negligible due to the reasons described in section (3.1). Hence, the measured inflow of internal water is approximately the same as the real inflow.

3.3 Pressure build up tests

Pressure build up and flow tests and have been performed in a number of drill holes close to the Lasgit hole but also in other parts of the 420 m level at Äspö HRL. Besides the results from the tests around the Lasgit hole, some results from tests performed in pilot holes drilled prior to the drilling of other deposition holes on the 420 m level will be presented below (Table 3-3). Partially the results have been taken from the SKB Sicada database.

Briefly the tests have been carried out the following way: A manual or hydraulic packer is placed in the borehole. The packer rod is equipped with a pressure gauge, a valve and a tap connected to a 6/4 mm tecalan hose. The valve is closed to allow the pressure to build up in the borehole. When the pressure is found to have stabilized in the hole, which may take some days, a reading is made on the pressure gauge. The valve is then opened and the quantity of water is measured during a time span of a minute or two, it all depends on the water flow. The pressure build up is often registered by a logger. This was, however, mostly not done for the holes presented here.

3.3.1 Anchor holes

The most recent build up tests around the Lasgit hole are those performed in five (HA3147G01, HA3147G03, HA3147G05, HA3147G07, and HA3147G09) of the ten inclined (almost 70°downwards) anchor holes (Figure 3-4) by S. Grandin Svärdh and F. Rudklint of Skanska and Geosigma respectively. The tests took place in May 2004 and each test lasted between 2 and 7 days. No flow measurements were however performed and no logger was connected to the pressure gauge. Hence only the "end pressure" has been registered. The results that are presented in Table 3-3 show that the final pressures obtained in the tested holes vary between 3 bars (HA3147G03) and 19.5 bars (HA31447G07).

The length of the anchor holes varies between 10.98 and 11.07 m. The upper parts of the holes (from section 0.0 m to between 1.40-1.75 m) have been drilled through the concrete floor surrounding the Lasgit hole. The hole diameter is here 200 mm. Below, in the rock it varies between 162 and 169 mm. Information about lengths, diameters etc. for each separate hole is given in Appendix 1.

3.3.2 Pilot holes

Vertical core holes (pilot holes) were drilled in the approximate centre of the planned locations for large deposition holes to see if the rock condition was suitable. Pressure build up tests as well as flow tests were performed in each of the pilot holes by SKB personnel. These results too are presented in Table 3-3. Information about hole lengths, diameters etc. is given in Appendix 1.

In April 1998, two pilot holes were drilled in the TBM assembly hall, one (KA3147G01) in the centre of the present Lasgit hole and an alternative one (KA3153G01) some metres away (Figure 1-2). The results from these holes show that the pressure reaches 8-9 bars and 13-13.5 bars and the flow 1.5 l/min and 0.098 l/min respectively (Hardenby & Lundin (2003).

Although only four deposition holes were drilled in TASK (the Tunnel for demonstration of deposition technology, also called the Demo tunnel) five pilot holes (KK0025G01, KK0031G01, KK0037G01, KK0045G01, and KK0051G01) were drilled in March 1998. The smallest pressure and flow was found in KK0045G01 where no pressure was obtained and the flow was negative whereas in KK0051G01 the highest pressure and largest flow was found, 27 bars and 0.33 l/min respectively (Table 3-3).

In the Tunnel for the canister retrieval test (Retrieval test tunnel, TASD) two pilot holes and two deposition holes have been drilled. The two pilot holes (KD0086G01 and KD0092G01) were drilled in the end of March 1998. The test performed here gave a pressure of 0 bars for KD0086G01 and 5 bars for KD0092G01. The flow was 0.000071 l/min and 0.00032 l/min respectively (Hardenby 2002).

Table 3-3. Some pressure build up and flow tests on the 420 m level at Äspö HRL

Hole No	**Date/time** (year-month-day/hour:min)		**Flow**		**Pres-sure**
	Start	End and/or reading	l/min	m^3/sec	bars
HA3147G01	2004-05-05/14:43	2004-05-10/11:12	-	-	8.5
HA3147G03	2004-05-10/11:23	2004-05-14/10:53	-	-	3
HA3147G05	2004-05-14/11:29	2004-05-17/11:29	-	-	12
HA3147G07	2004-05-17/11:42	2004-05-24/14:45	-	-	19.5
HA3147G09	2004-05-24/15:04	2004-05-26/10:30	-	-	9
KA3147G01		1998-05-06/15:27	1.5	1.92E-005	9
KA3153G01		1998-04-06/15:21	0.098	1.63E-006	13.5
KK0025G01		1998-04-01/14:00	0.045	7.5E-007	12
KK0031G01		1998-04-01/14:08	0.0025	4.2E-008	6.5
KK0037G01		1998-04-01/14:22	0.0013	2.2E-008	10
KK0045G01		1998-04-01/14:30	Negative	-9.0E-008	0.0
KK0051G01		1998-04-01/14:36	0.325	5.4E-006	27
KD0086G01		1998-05-26/13:39	0.000071	1.18E-009	0.0
KD0092G01		1998-05-26/13:30	0.00032	5.32E-009	5

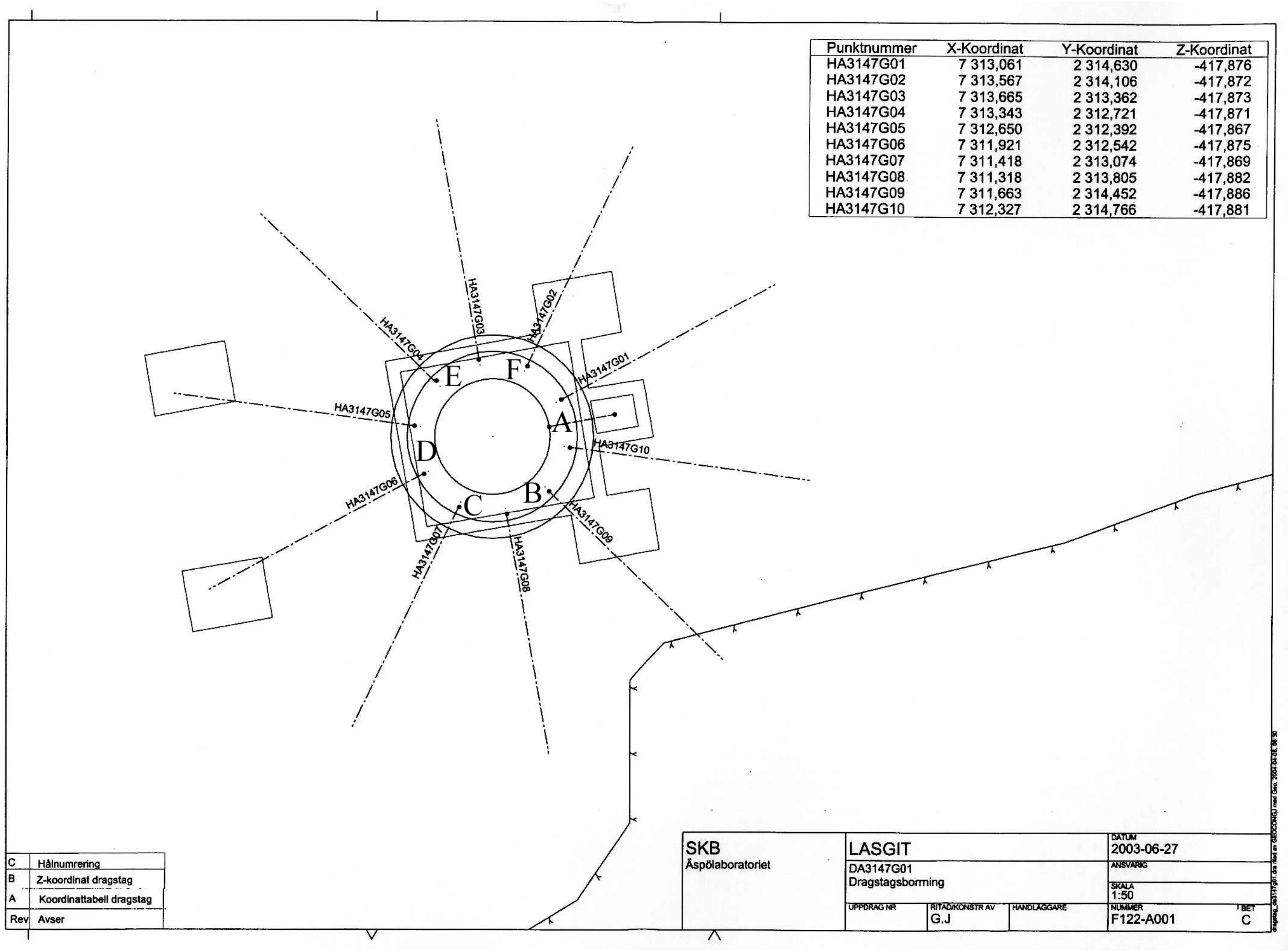
3.4 Pressure drop test/pulse test

The pressure drop test was performed in all of the ten anchor holes HA3147G01 – HA3147G10 (Figure 3-4) around the Lasgit hole on March 15-16, 2004 by U. Nilsson of Clay Technology. A hydraulic packer was placed in the holes with the lower end about 2 m down. After that the holes were pressurized one by one with water. The pressurized sections were between the packer end and the hole bottom (see Appendix 1 for some hole information). The change in pressure was then registered by a logger for about 10 minutes to 1.5 hours, depending on how fast the pressure dropped. Due to the limited time available for the test it was commonly interrupted before a stable pressure was reached. Thus the final (lowest) pressures of the drop test commonly do not reach the pressures obtained by the pressure build up tests as would have been expected. The results are presented in diagrams (modified from U. Nilsson, Figures 3-5 – 3-14) and in Table 3-4 (original logger data are stored at Äspö HRL). For comparison the readings from the pressure build up tests for the same anchor holes (Table 3-3) have been included in Table 3-4. The variations in the original logger readings, seen in the diagrams, are due to electric noise during the measurements.

Calculations to obtain permeability, conductivity, transmissibility and transmissivity values from the original test results have kindly been performed by Thomas Nowak of BGR (Bundesanstalt für Gewissenschaften und Rohstoffe/Federal Institute for Geosciences and Natural Resources, Germany) and are presented below in section 3.4.1 (Pulse test).

Table 3-4. Pressure drop tests in anchor holes HA3147G01-G10

Hole No	**Time consumption**	**Pressure trend line** (bars)		**Average speed of pressure decrease**		**Pressure build up test**
	(hour:min:sec)	Start	End	(bars/min)	(bars/sek)	(bars)
HA3147G01	01:23:55	20.8	13.5	0.087	0.0015	8.5
HA3147G02	00:13:10	17.2	11.2	0.456	0.0076	-
HA3147G03	00:09:40	19.5	8.5	1.138	0.0190	3.0
HA3147G04	00:10:14	17.1	3.5	1.329	0.0221	-
HA3147G05	00:26:40	19.8	17.6	0.083	0.0014	12
HA3147G06	00:14:40	20.6	17.9	0.184	0.0031	-
HA3147G07	00:20:40	19.1	14.8	0.208	0.0035	19.5
HA3147G08	00:31:55	19.1	13.2	0.185	0.0031	-
HA3147G09	00:25:09	21.3	14.6	0.266	0.0044	9.0
HA3147G10	00:30:40	21.2	17.4	0.124	0.0021	-



Punktnummer	X-Koordinat	Y-Koordinat	Z-Koordinat
HA3147G01	7 313,061	2 314,630	-417,876
HA3147G02	7 313,567	2 314,106	-417,872
HA3147G03	7 313,665	2 313,362	-417,873
HA3147G04	7 313,343	2 312,721	-417,871
HA3147G05	7 312,650	2 312,392	-417,867
HA3147G06	7 311,921	2 312,542	-417,875
HA3147G07	7 311,418	2 313,074	-417,869
HA3147G08	7 311,318	2 313,805	-417,882
HA3147G09	7 311,663	2 314,452	-417,886
HA3147G10	7 312,327	2 314,766	-417,881

Rev	Avser
C	Hålnumrering
B	Z-koordinat dragstag
A	Koordinattabell dragstag

SKB
Äspölaboratoriet

LASGIT
DA3147G01
Dragstagsborrning

DATUM 2003-06-27
ANSVARIG
SKALA 1:50
UPPDRAG NR
RITAD/KONSTR AV G.J
HANDLÄGGARE
NUMMER F122-A001
BET C

***Figure 3-4**. The Lasgit hole DA3147G01 and surrounding anchor holes HA3147G01-G10 (slightly modified after original by G. Johansson, Geocon). A-F refer to vertical line markings in Figures 3-26 – 3-31*

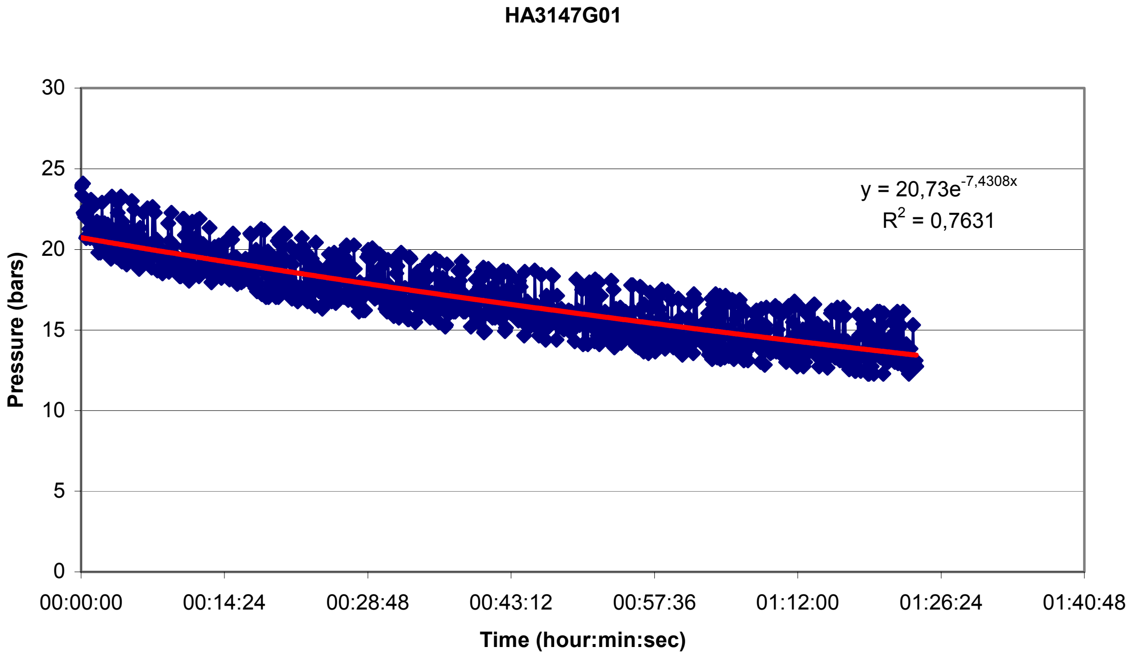


Figure 3-5. *Pressure drop test in HA3147G01 (individual readings and trend line)*

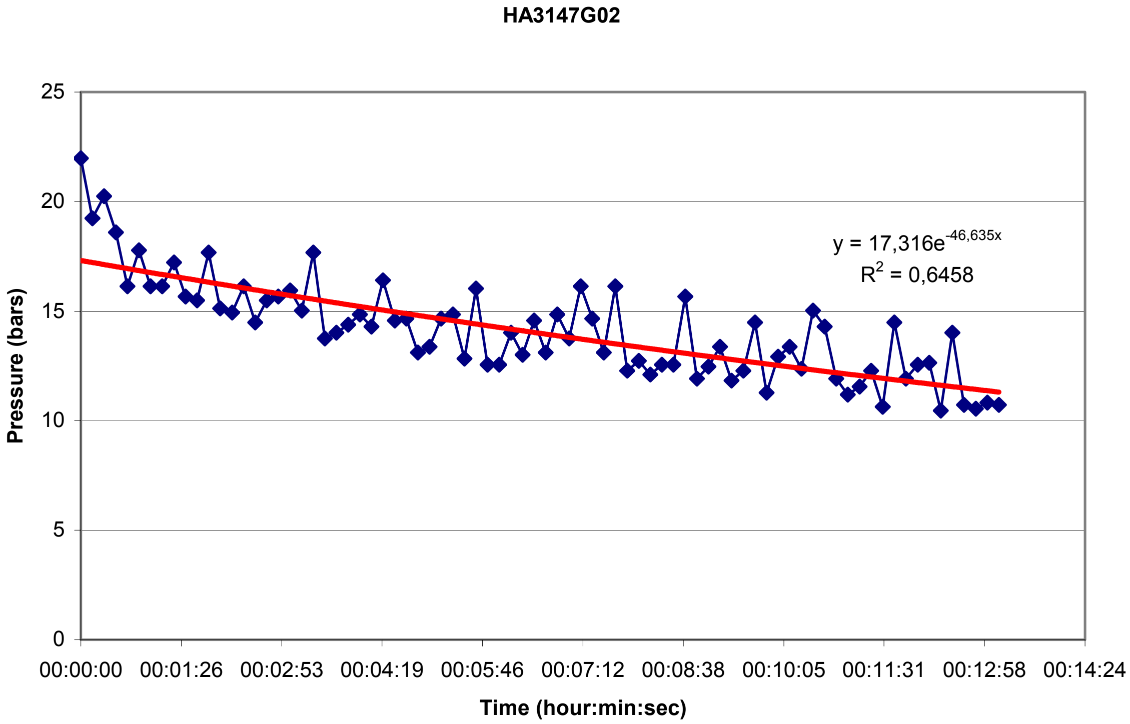


Figure 3-6. *Pressure drop test in HA3147G02 (individual readings and trend line)*

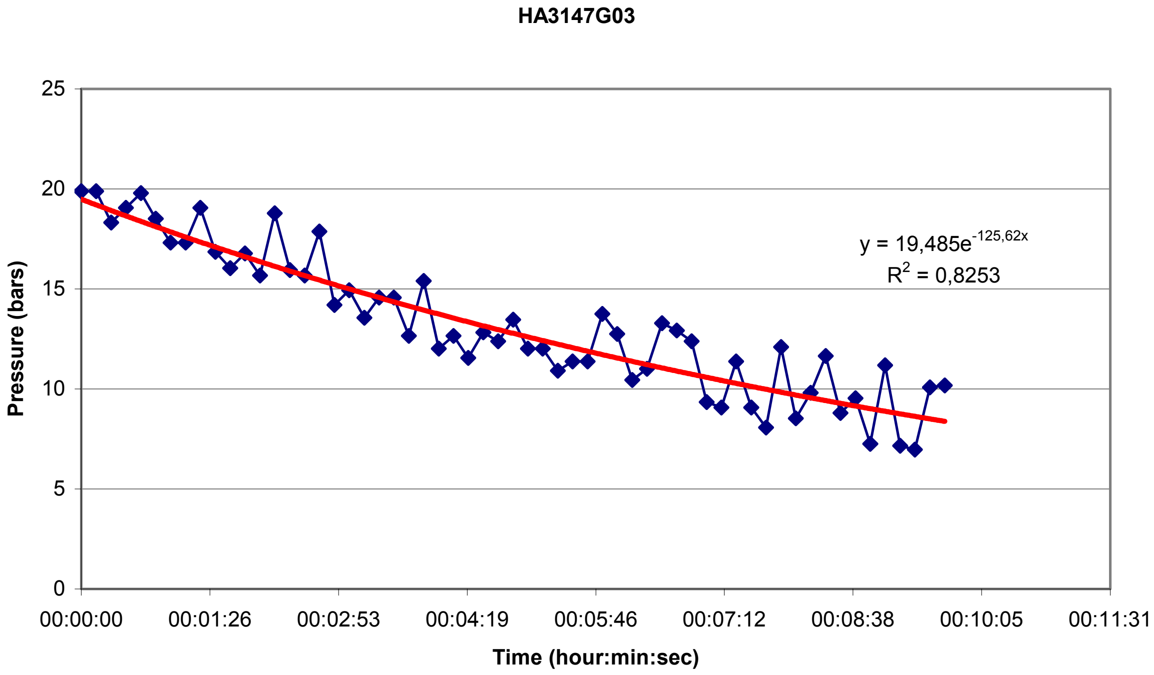


Figure 3-7. *Pressure drop test in HA3147G03 (individual readings and trend line)*

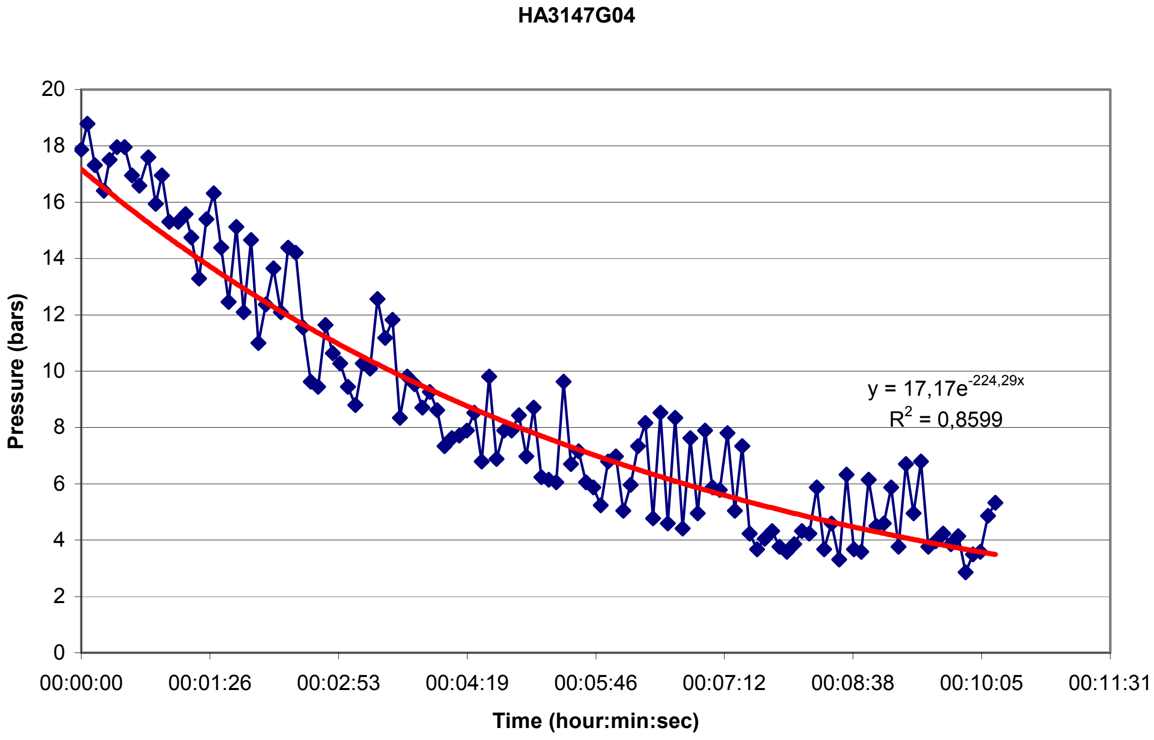


Figure 3-8. *Pressure drop test in HA3147G04 (individual readings and trend line)*

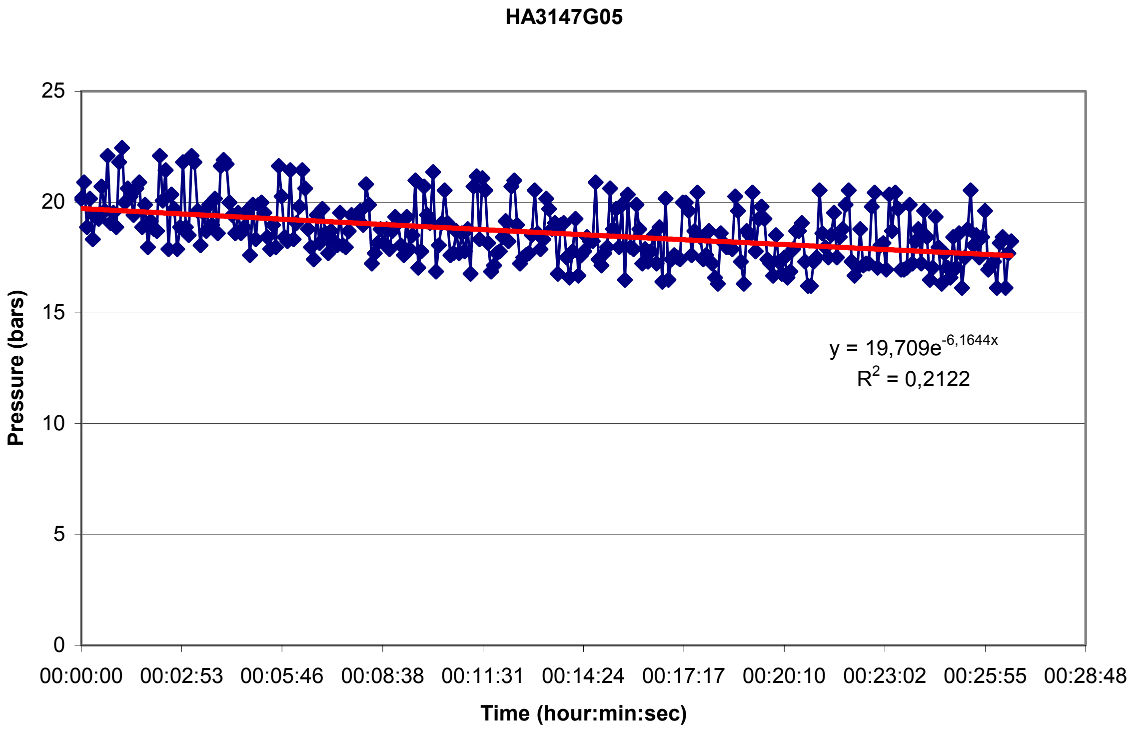


Figure 3-9. *Pressure drop test in HA3147G05 (individual readings and trend line)*

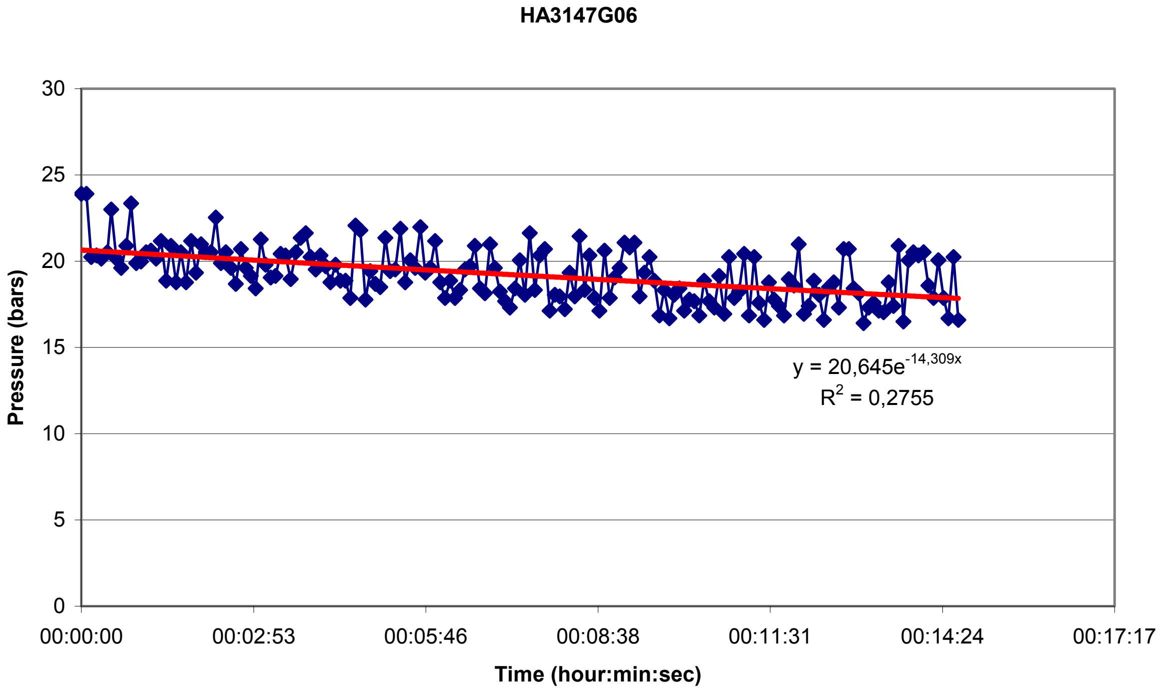


Figure 3-10. *Pressure drop test in HA3147G06 (individual readings and trend line)*

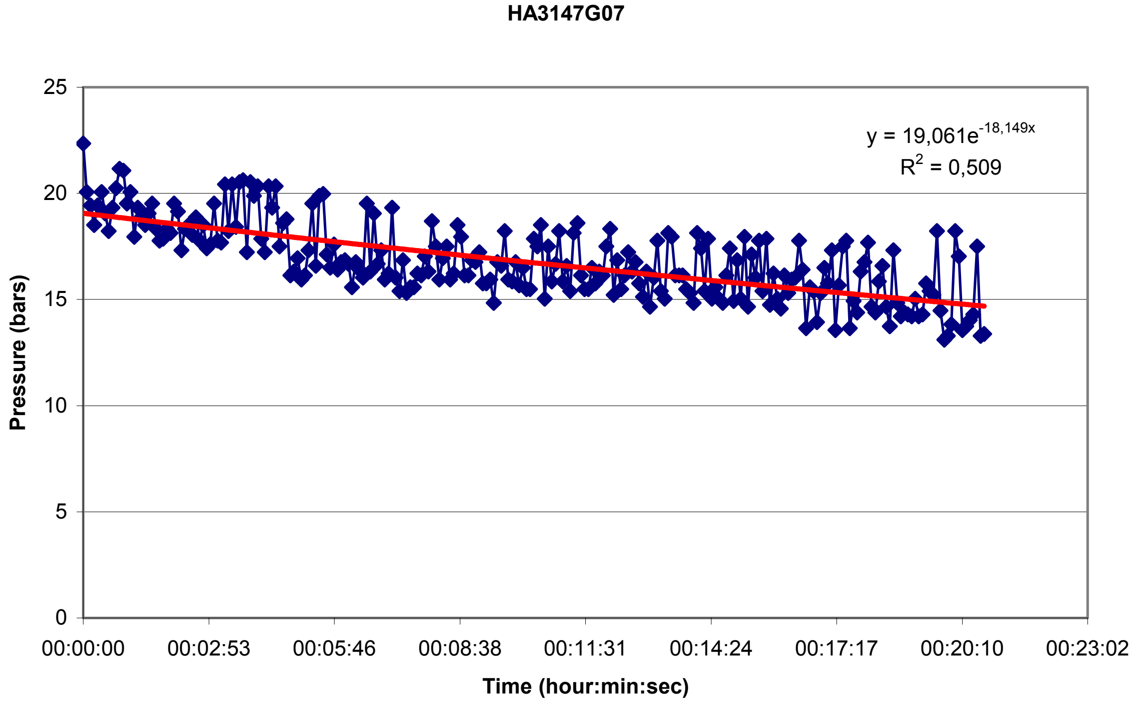


Figure 3-11. *Pressure drop test in HA3147G07 (individual readings and trend line)*

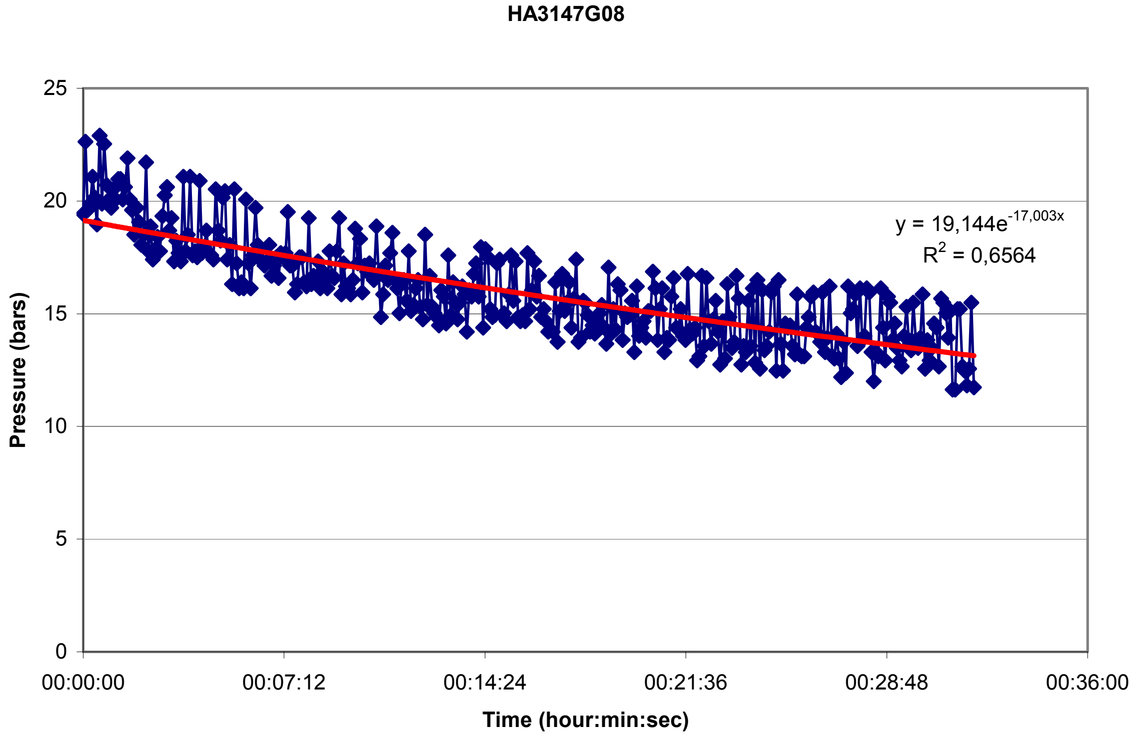


Figure 3-12. *Pressure drop test in HA3147G08 (individual readings and trend line)*

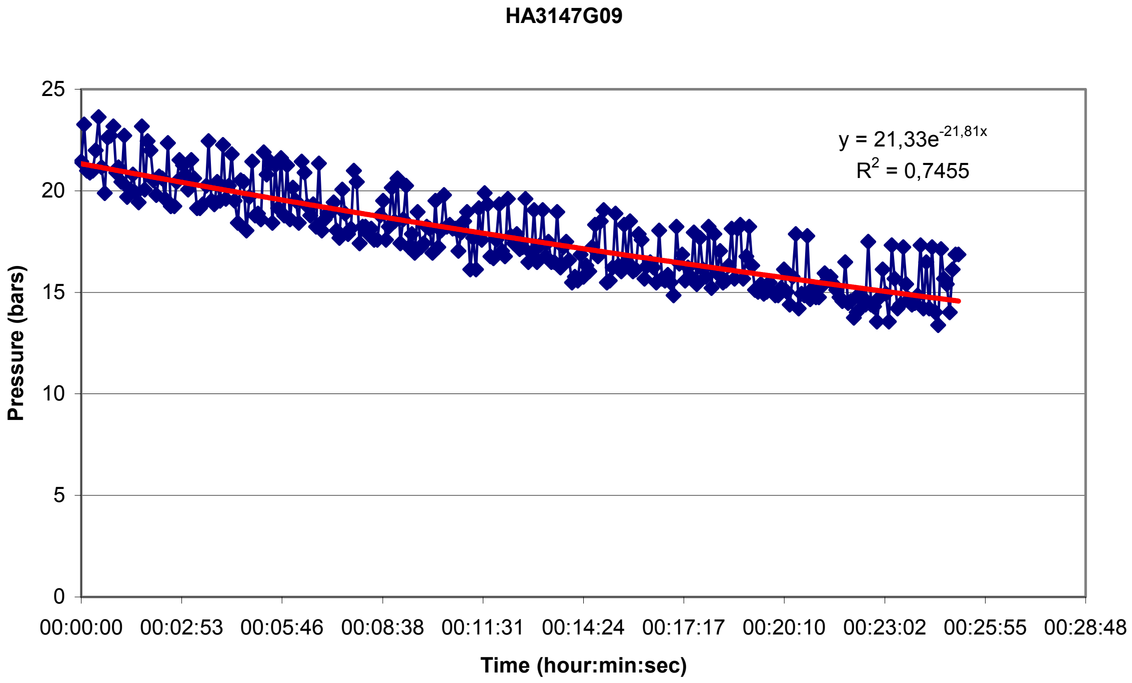


Figure 3-13. *Pressure drop test in HA3147G09 (individual readings and trend line)*

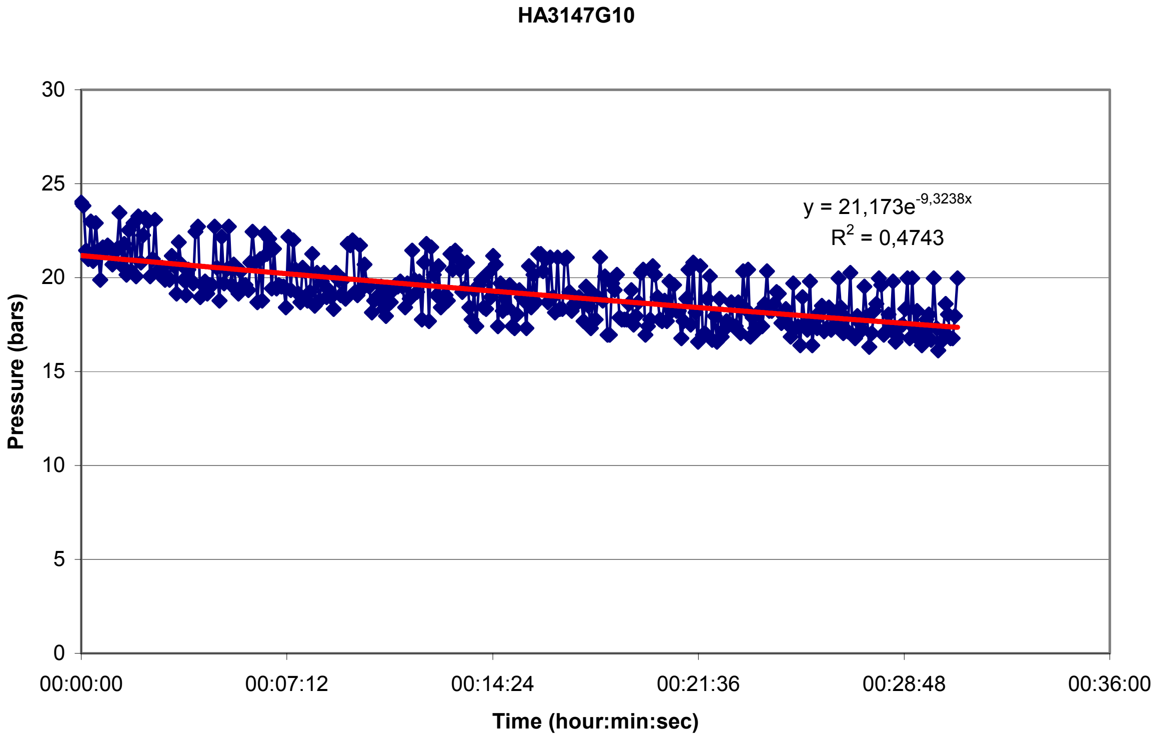


Figure 3-14. *Pressure drop test in HA3147G10 (individual readings and trend line)*

3.4.1 Pulse test

This section has been written by Thomas Nowak of BGR. Only minor changes involving figure and table numbers (to fit the present report) and minor adjustments of the figures have been made.

The purpose of well testing is the determination of the permeability of the rock. The principle of testing is the monitoring of the pressure response while a test fluid with known viscosity and compressibility is extracted from or injected into a test interval of a borehole. The permeability can be determined from the relationship between flow rate and pressure response.

In the anchor boreholes around the deposition hole DA3147G01 pulse tests have been performed which are well suited for the measurement of low permeabilities. In an interval of the borehole which has been hydraulically separated an initial pressure has been generated and then the borehole interval has been closed. The pressure gradient between the closed interval and the pore space of the tested rock causes a fluid flow and therefore a pressure equalization. The evolution of pressure is determined by the permeability of the rock.

The relationship between pressure evolution and permeability is described with the diffusivity equation:

$$\frac{\partial^2 p}{\partial r^2} + \frac{1}{r}\frac{\partial p}{\partial r} = \frac{\phi c_t \mu}{k}\frac{\partial p}{\partial t} \qquad (1)$$

with	p	pressure in the borehole
	c_t	compressibility
	r	distance to the borehole axis
	k	permeability
	ϕ	porosity
	μ	viscosity.

The pressure can be solved analytically as function of distance r and time t:

$$p_D = \frac{8\alpha}{\pi^2}\int_0^\infty \frac{\exp\left(\frac{-\beta u^2}{\alpha}\right)}{u\left[\left(uJ_0(u)-2\alpha J_1(u)\right)^2+\left(uY_0(u)-2\alpha Y_1(u)\right)^2\right]}du \tag{2}$$

with $\beta = \frac{kht\pi}{V_w c_t \mu}$ and $\alpha = \frac{\pi r_w{}^2 \phi c_t h}{V_w c_t}$

and	J_0	Bessel function first type order null
	J_1	Bessel function first type first order
	Y_0	Weber function order null
	Y_1	Weber function first order
	c_t	compressibility
	h	length of the tested borehole interval
	r_w	borehole radius
	V_w	fluid volume in the tested borehole interval.

The solution for the diffusivity equation has been introduced by COOPER et al. (1967) for an open borehole and BREDEHOEFT & PAPADOPULOS (1980) transferred this solution to a closed borehole. Opposite to the notation of the cited authors instead of the head difference as function of storage capacity and transmissibility in equation 2 the dimensionless pressure as function of porosity and permeability is used in the following. The dimensionless pressure p_D can be converted into the pressure in the borehole using the following equation:

$$p_D = \frac{p_i - p_w}{p_i - p_0} \tag{3}$$

with	p_D	dimensionless pressure
	p_i	initial formation pressure
	p_0	initial pressure in the borehole
	p_w	pressure in the borehole at the considered point in time

With equation 2 and 3 the necessary equations to calculate the pressure evolution for a pulse test are available. Pressure evolutions for different permeabilities are calculated with these equations and then compared to a measured pressure evolution. The permeability of the rock is found when measured and calculated pressure evolutions agree well.

In equation 2 there is beneath the permeability the porosity as a parameter that is not determined by the boundary conditions of the test. Permeability and porosity affect the pressure evolution in different ways, compare Figure 3-15.

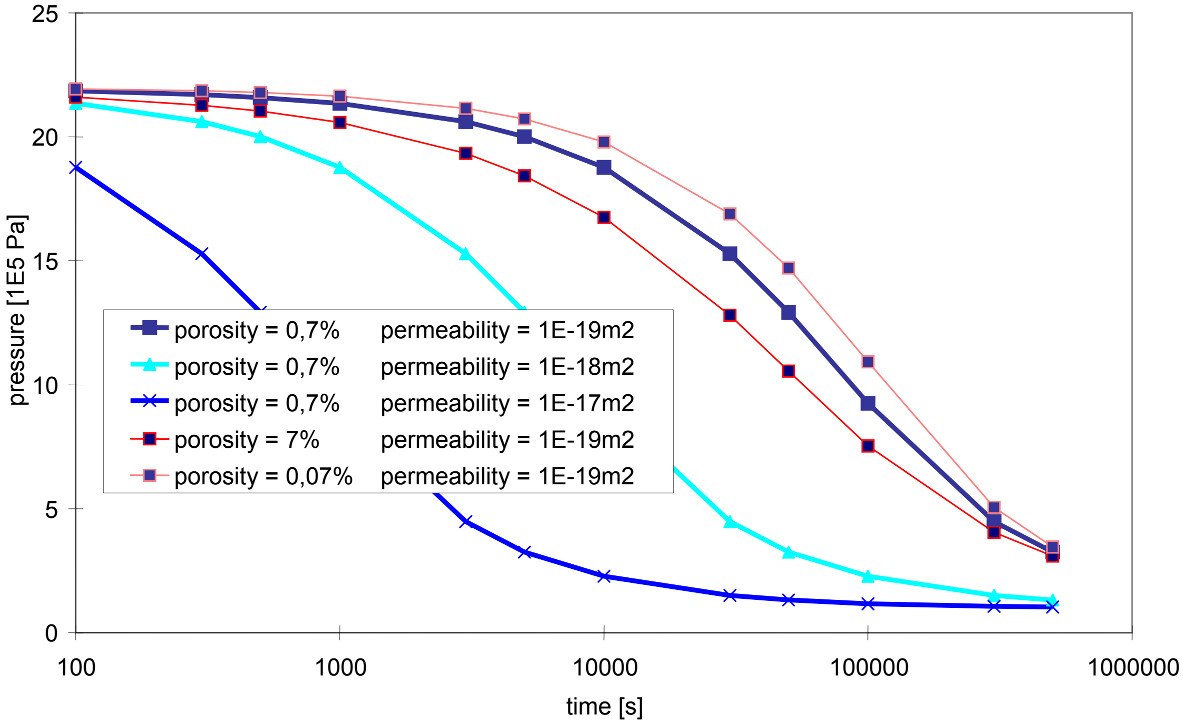


Figure 3-15. *Effect of porosity and permeability on the pressure evolution in a pulse test*

Figure 3-15 shows the influence of different values of porosity and permeability on the pressure evolution in a virtual pulse test. Porosity has an influence on the *shape* of the pressure evolution (red curves). Alteration of permeability leads to a *shift* of the pressure evolution with respect to the (logarithmic) time axis without alteration of the shape. For this reason the determination of permeability from a pulse test is hardly influenced by the porosity. For the analysis of the pulse tests in the anchor boreholes the porosity has been set to 0.7% and the compressibility of the test fluid has been set to $4{\cdot}10^{-10}$ Pa^{-1}.

Table 3-5 summarizes the results of the pulse tests in the anchor boreholes. The recorded pressure evolutions provide just a short period for analysis. Together with the oscillation of the recorded pressure values the analysis yields in a bandwidth of permeability values. Another uncertainty in the analysis arises from the measurements of initial pressure in the rock. In five of the ten anchor boreholes the initial pressure in the rock has been measured. For the remaining five boreholes the initial pressure has been assumed to be the medium value between the measured values in the neighboring boreholes. The recorded initial pressure in anchor borehole G07 of 1.95 MPa does not match with the measured pressure evolution in the pulse test in G07. For this reason the tests in the boreholes G06, G07, and G08 have not been analyzed. In borehole G04 the initial pressure in the borehole has not been measured. The medium value from the neighboring boreholes G03 and G05 does not match with the recorded pressure evolution in the pulse test, for this reason a value of 0.1 MPa was assumed for analysis. The permeability values that seem to be most reliable are printed bold. The Figures 3-16 - 3-20 shows the measured data together with the calculated pressure evolutions for the upper and lower boundary of permeability in these tests.

Table 3-5: Results from pulse tests in the anchor boreholes around deposition hole DA3147G01

name of anchor borehole	interval		interval radius [mm]	interval length [m]	initial pressure		(equivalent) permeability [m2]		(equivalent) hydraulic conductivity [m/s]		transmissibility [m3]		transmissivity [m2/s]		pulse test duration [s]
	from [m]	till [m]			value [1E5 Pa]	duration [h]	from	till	from	till	from	till	from	till	
G01	1.50	11.05	81	9.05	8.50 m	164	**5.E-19**	**2.E-18**	**5.E-12**	**2.E-11**	**4.5E-18**	**1.8E-17**	**4.4E-11**	**1.8E-10**	**5035**
G02	1.45	11.07	81	9.07	5.75 c		3.E-18	2.E-17	3.E-11	2.E-10	2.7E-17	1.8E-16	2.7E-10	1.8E-09	790
G03	1.35	11.06	81	9.06	3.00 m	95	**8.E-18**	**3.E-17**	**8.E-11**	**3.E-10**	**7.2E-17**	**2.7E-16**	**7.1E-10**	**2.7E-09**	**580**
G04	1.60	10.98	81	8.98	1.00 a		2.E-17	7.E-17	2.E-10	7.E-10	1.8E-16	6.3E-16	1.8E-09	6.2E-09	614
G05	1.75	11.04	81.5	9.04	12.00 m	72	**1.E-19**	**3.E-18**	**1.E-12**	**3.E-11**	**9.0E-19**	**2.7E-17**	**8.9E-12**	**2.7E-10**	**1600**
G06	1.75	11.03	81.5	9.03			no analysis								880
G07	1.70	11.09	81	9.09	19.50 m	171	no analysis								1240
G08	1.40	11.07	81	9.07			no analysis								1915
G09	1.60	11.07	81	9.07	9.00 m	43	**1.E-18**	**5.E-18**	**1.E-11**	**5.E-11**	**9.1E-18**	**4.5E-17**	**8.9E-11**	**4.4E-10**	**1509**
G10	1.40	11.05	81	9.05	8.75 c		**5.E-19**	**2.E-18**	**5.E-12**	**2.E-11**	**4.5E-18**	**1.8E-17**	**4.4E-11**	**1.8E-10**	**1840**

note (to initial pressure): m measured, c calculated, a assumption

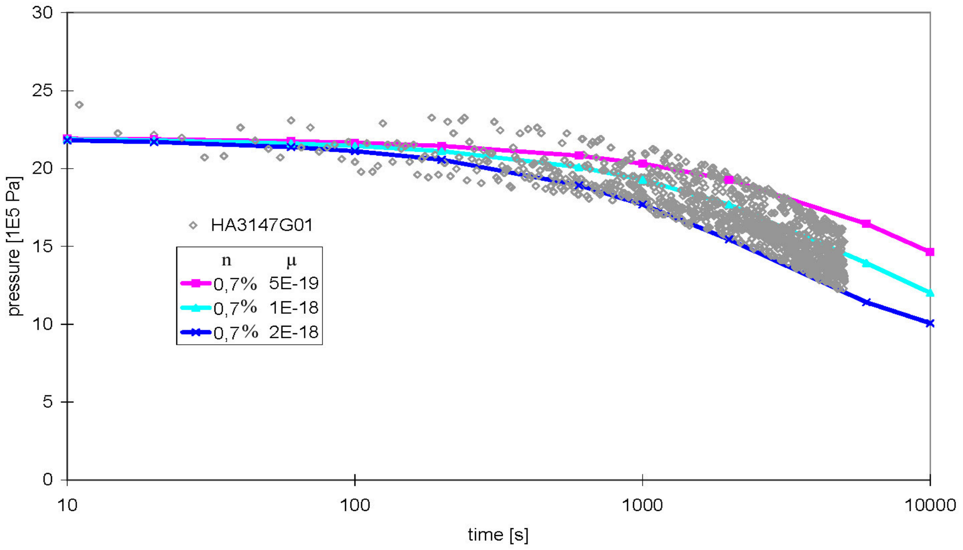


Figure 3-16. *Measured and calculated pressure evolutions for pulse test in the anchor borehole HA3147G01. n=porosity, μ=permeability*

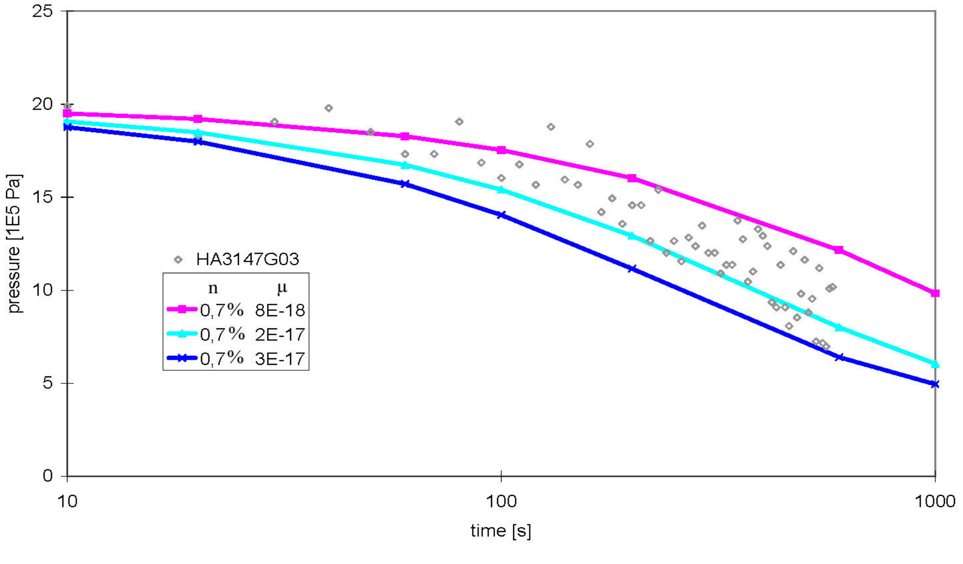


Figure 3-17. *Measured and calculated pressure evolutions for pulse test in the anchor borehole HA3147G03. n=porosity, μ=permeability*

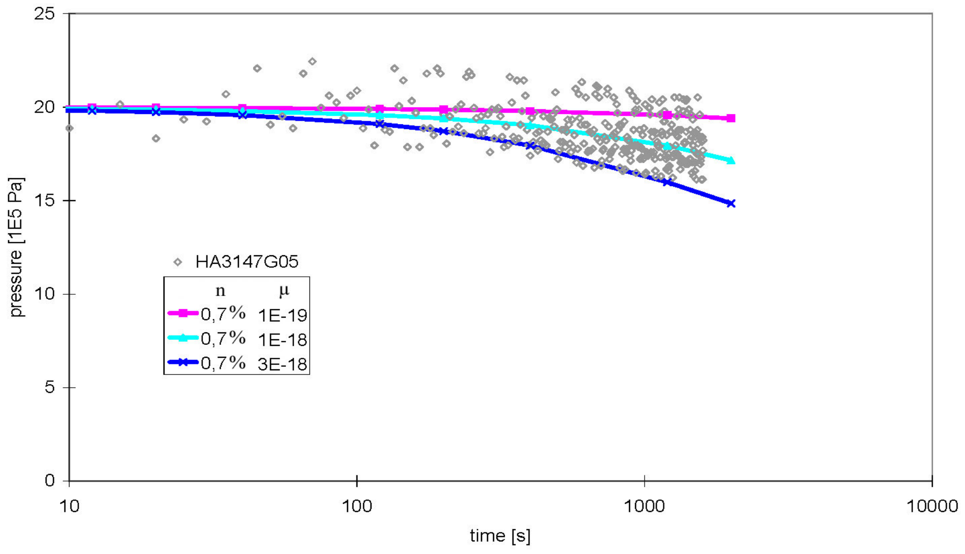


Figure 3-18. *Measured and calculated pressure evolutions for pulse test in the anchor borehole HA3147G05. n=porosity, µ=permeability*

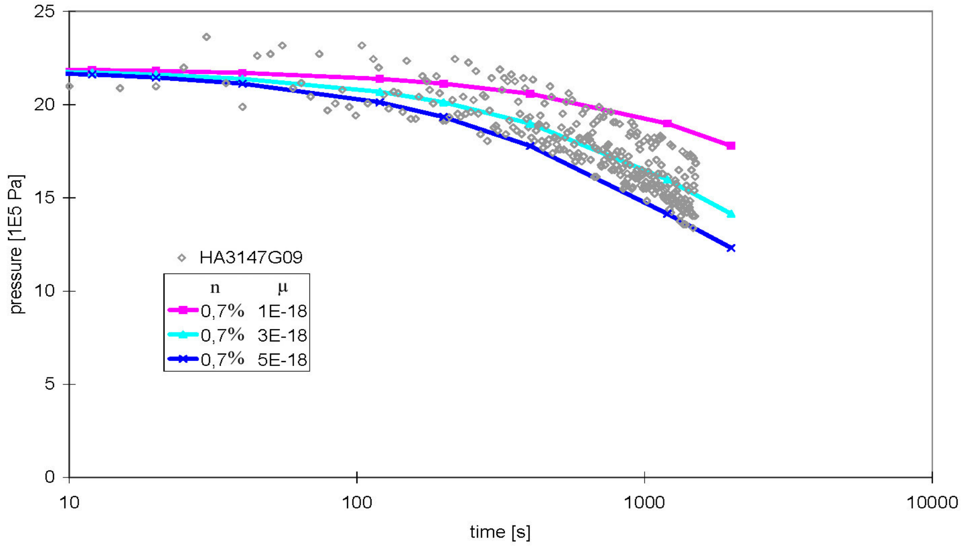


Figure 3-19. *Measured and calculated pressure evolutions for pulse test in the anchor borehole HA3147G09. n=porosity, µ=permeability*

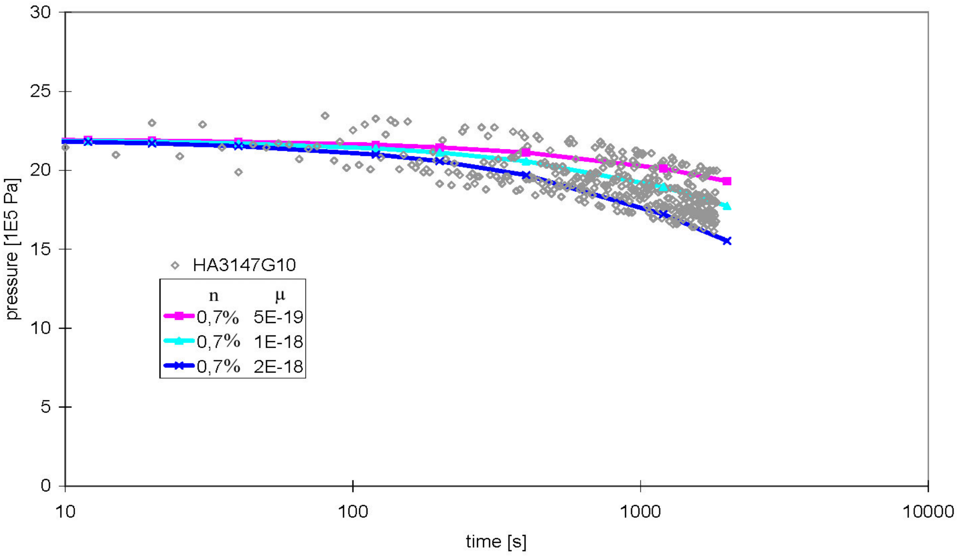


Figure 3-20. *Measured and calculated pressure evolutions for pulse test in the anchor borehole HA3147G10. n=porosity, µ=permeability*

Because the anchor boreholes run across fractures the given permeability values have to be understood as equivalent permeability, i.e. a combined value for matrix and fractures. The transmissibility is calculated by multiplication of permeability with the length of the test interval. The conversion from permeability k [m^2] to hydraulic conductivity k_f [m/s] is as given in equation 4. Transmissivity is calculated by multiplication of hydraulic conductivity with the length of the test interval (compare transmissibility).

$$k_f = \rho_w * g * (k/\eta) \qquad (4)$$

with ρ_w water density

g gravity

η dynamic viscosity [Pa * s]

3.5 Gas leakage test

A gas leakage test was executed in six of the ten the anchor holes (HA3147G01, HA3147G02, HA3147G04, HA3147G06, HA3147G08, and HA3147G10, Figure 3-4). The purpose was to see if there were any leakage paths between the anchor holes and the large Lasgit hole. The test was performed by S. Grandin Svärdh (Skanska), F. Rudklint (Geosigma), personnel from Jan Andersson's Dykeri AB, and C. Hardenby (SwedPower) between April 16 and 21 in 2004.

The large deposit hole had been filled with water in advance. The anchor holes were one at the time emptied of water, sealed with a hydraulic packer and pressurized to about 20 bars with nitrogen gas. When some time had elapsed (half an hour or so) gas bubbles were commonly visible in the Lasgit hole. By the use of a black and white video camera attached to a metal rod the leakages were localized. They were marked on copies of the drawing that was the result of the geological mapping of the Lasgit hole (Hardenby and Lundin, 2003). Unfortunately it was difficult to pin point the location of a leakage to a specific fracture on the drawings. If gas bubbles were found in any the neighbouring anchor holes this was recorded too. When the test was finished for an anchor hole notes were taken on time and gas pressure and the process was repeated for the next anchor hole to be emptied of water and to be pressurized.

The notes from the gas leakage test have been summarized in Table 3-6. Figures 3-21 – 3-25 show parts of the environment and equipment and Figures 3-26 – 3-31 present the gas leakage drawings. These drawings show the hole wall in an unfolded state. Figure 3-4 shows how the vertical lines marked A-F in the drawings are located on the circumference of the Lasgit hole.

The gas test had been preceded by a similar test, which failed, where Rhodamine WT coloured water had been used instead of gas. This time the Lasgit hole was empty of water. Besides this the principal set up was basically the same as for the gas leakage test (Figure 3-32). The coloured water was hoped to seep out along fractures in the Lasgit hole wall if there was a leakage. Nothing happened, however, may be due to shortage of time for the experiment.

Table 3-6. Notes from the gas leakage test in the Lasgit hole DA3147G01 and some of the anchor holes

Pressurized Anchor Hole	**Start** April 2004	**Max pressure**		**End** April 2004	**End pressure**	**Notes**
No	Day/time (d/h:min)	Time (h:min)	Pressure (bars)	Day/time (d/h:min)	(bars)	G01-G10 refer to the anchor holes. For leakage into the Lasgit hole see Figures 3-26 – 3-31
HA3147G01	21/13:37	13:41	20	21/15:26	16.5	G01: some bubbles observed above the packer, G10: bubbles, G02 and G09: a few bubbles.
HA3147G02	20/13:22	13:32	20	20/15:24	16	G02: lots of bubbles observed above the packer, G03: lots of bubbles, G01 and G10: bubbles and G05: a few bubbles.
HA3147G04	20/10:26	10:35	20	20/11:45	16	G04: bubbles observed above the packer and G05: bubbles.
HA3147G06	--/10:39	10:55	20	--/11:21	20	G06: some bubbles above the packer.
HA3147G08	21/10:59	11:11	20	21/12:11	19.5	G08: a few bubbles above the packer.
HA3147G10	21/08:48	09:00	20	21/09:40	19	G10: a few bubbles above the packer, G01 and G09: a few bubbles.

Figure 3-21. *The TBM assembly hall/ the Lasgit site*

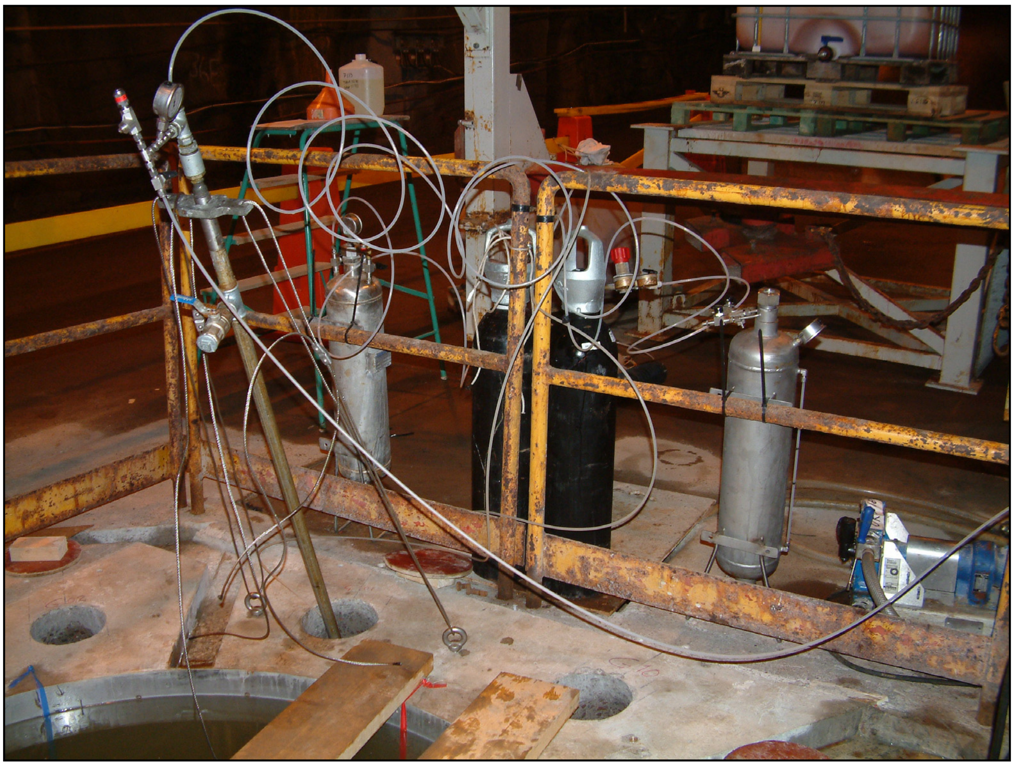


Figure 3-22. *Part of the Lasgit hole, some of the anchor holes (one with a packer installed) and gas tubes*

Figure 3-23. *The video camera*

Figure 3-24. *Video recording equipment*

Figure 3-25. *Gas bubbles on the water surface in the Lasgit hole*

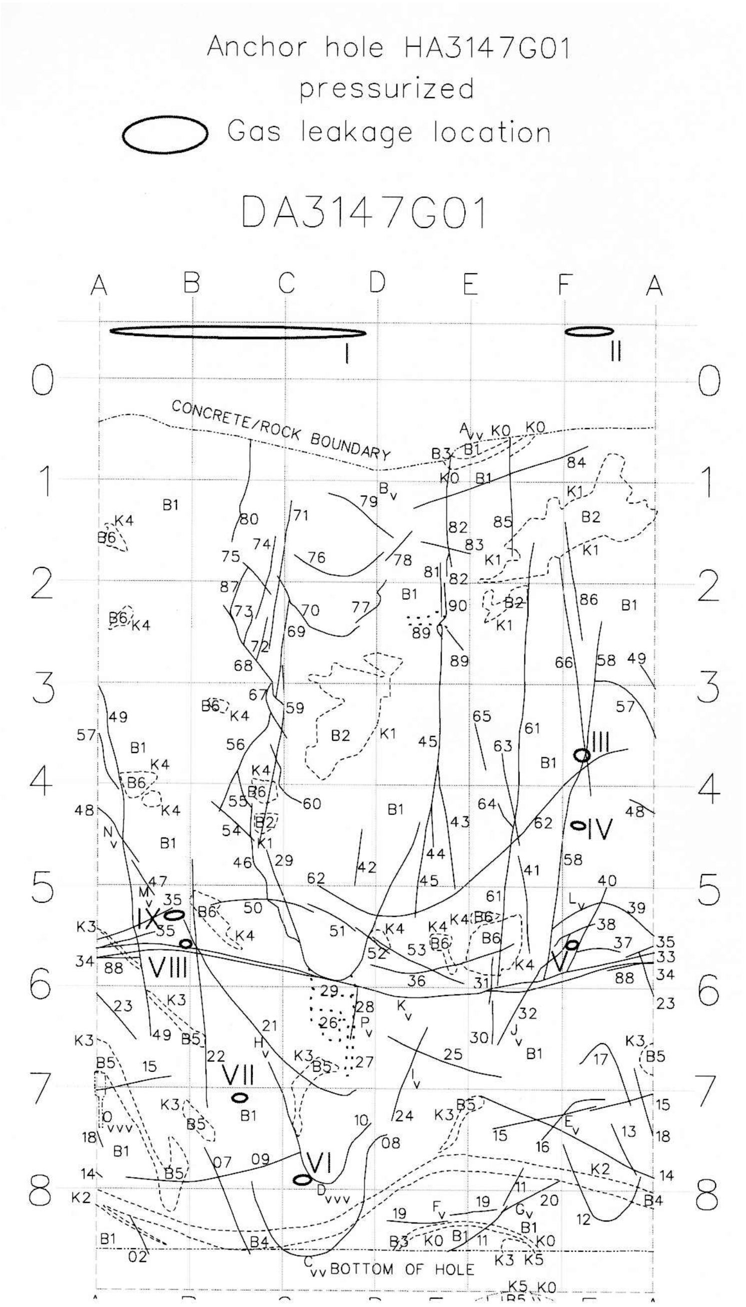


Figure 3-26. *Gas leakage locations in DA3147G01 when Anchor hole HA3147G01 was pressurized.*
I. Bubbles on the surface
II. Some bubbles on the surface
III - V. Bubbles from one spot
VI. Bubbles
VII. Some bubbles, one spot
VIII. Bubbles, one spot, top of slot
IX. Bubbles from three spots on a row

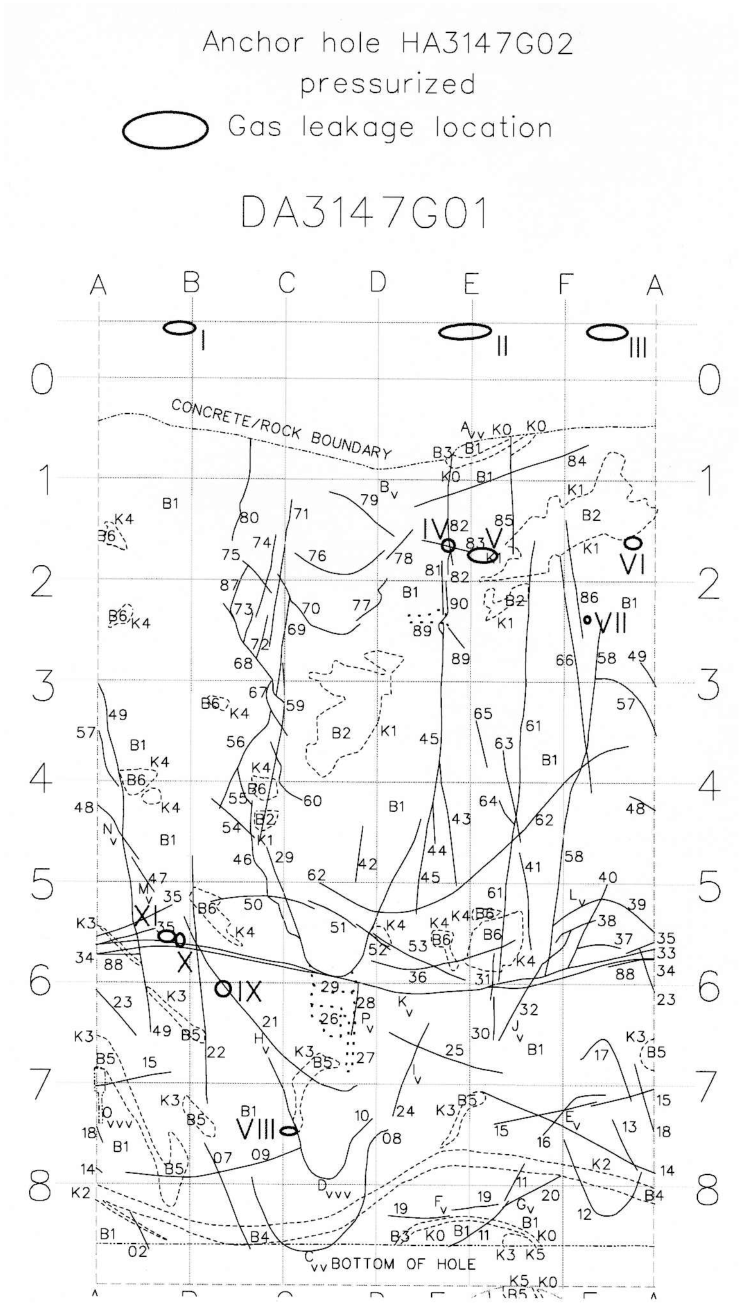


Figure 3-27. *Gas leakage locations in DA3147G01 when Anchor hole HA3147G02 was pressurized.*

I & III. Some bubbles on the surface

II. Lots of bubbles on the surface

IV. Bubbles from fracture intersection

V. Lots of bubbles from small holes on a row

VI & VII. Bubbles from small hole

VIII & IX. No comments

X. Top of vertical slot

XI. Small holes on a row

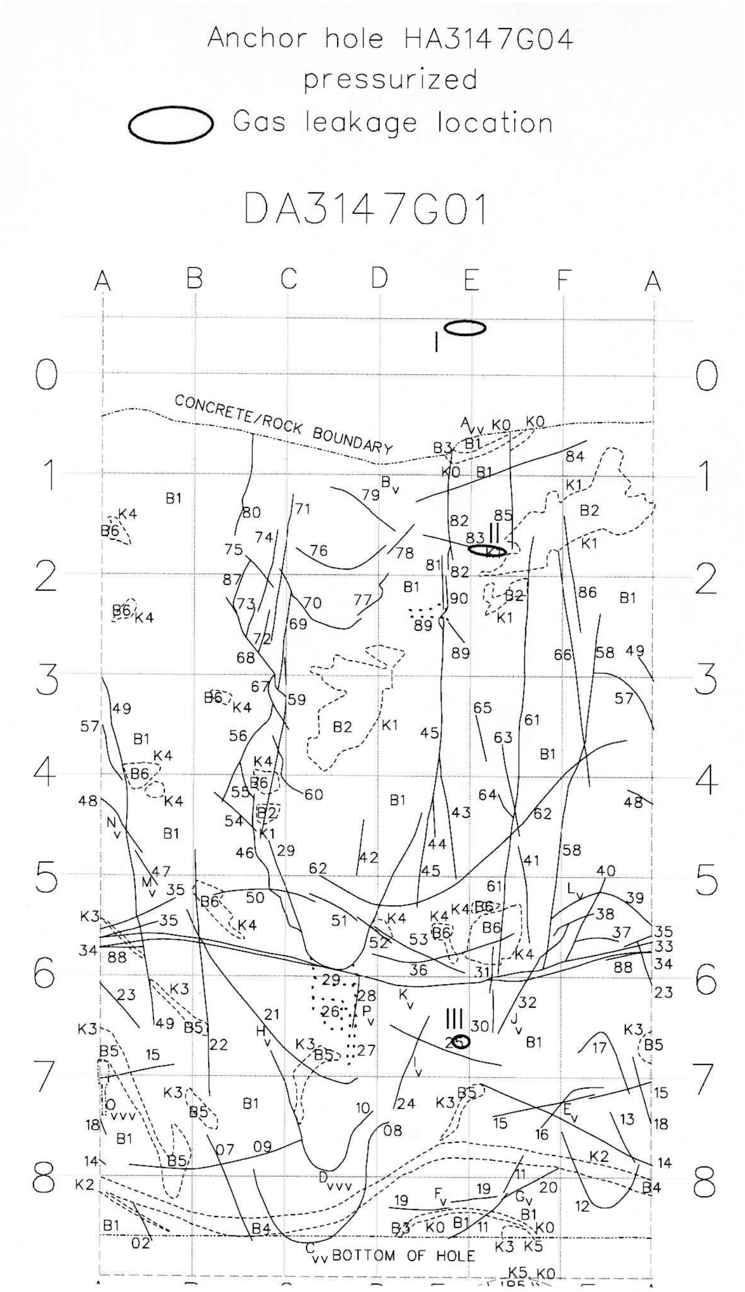


Figure 3-28. *Gas leakage locations in DA3147G01 when Anchor hole HA3147G04 was pressurized.*
I. Lots of bubbles on the surface
II. Bubbles from a possible fracture
III. Top of slot

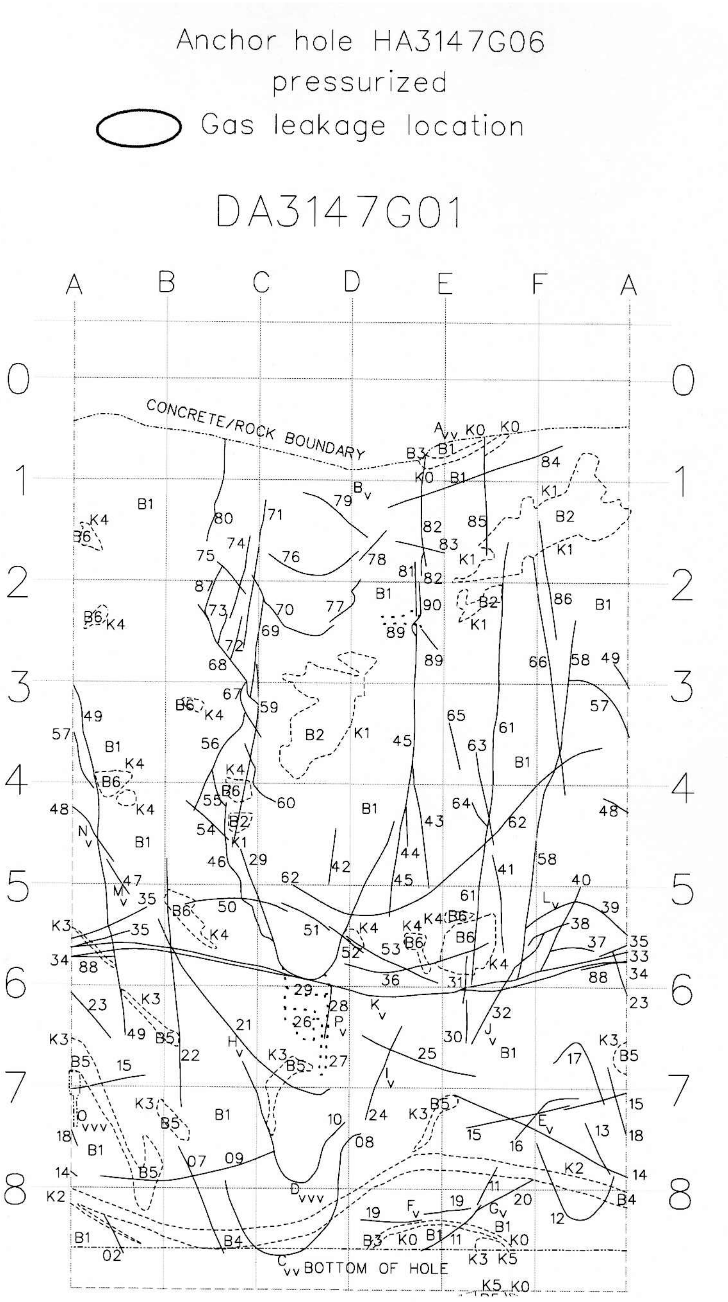


Figure 3-29. *Gas leakage locations in DA3147G01 when Anchor hole HA3147G06 was pressurized.*
No leakage observed in the Lasgit hole

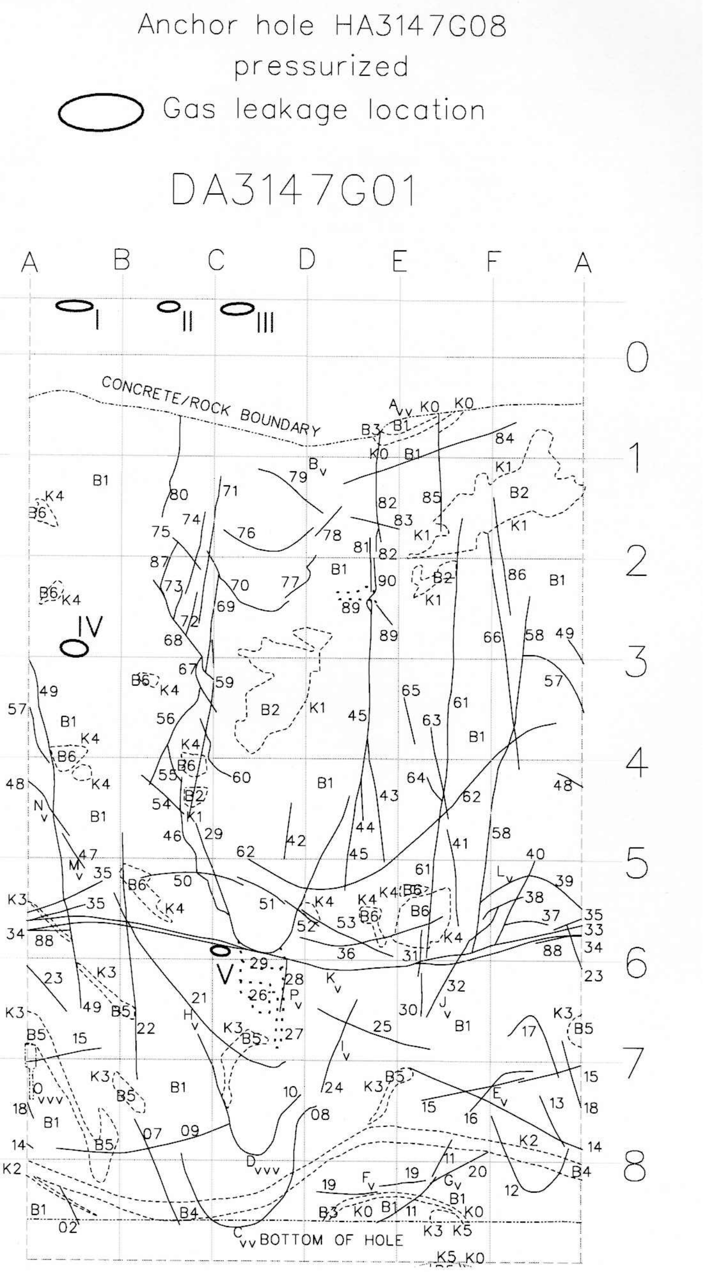


Figure 3-30. *Gas leakage locations in DA3147G01 when Anchor hole HA3147G08 was pressurized.*
I - III. Few bubbles on the surface
IV. Single sporadic bubbles
V. A few bubbles from one spot

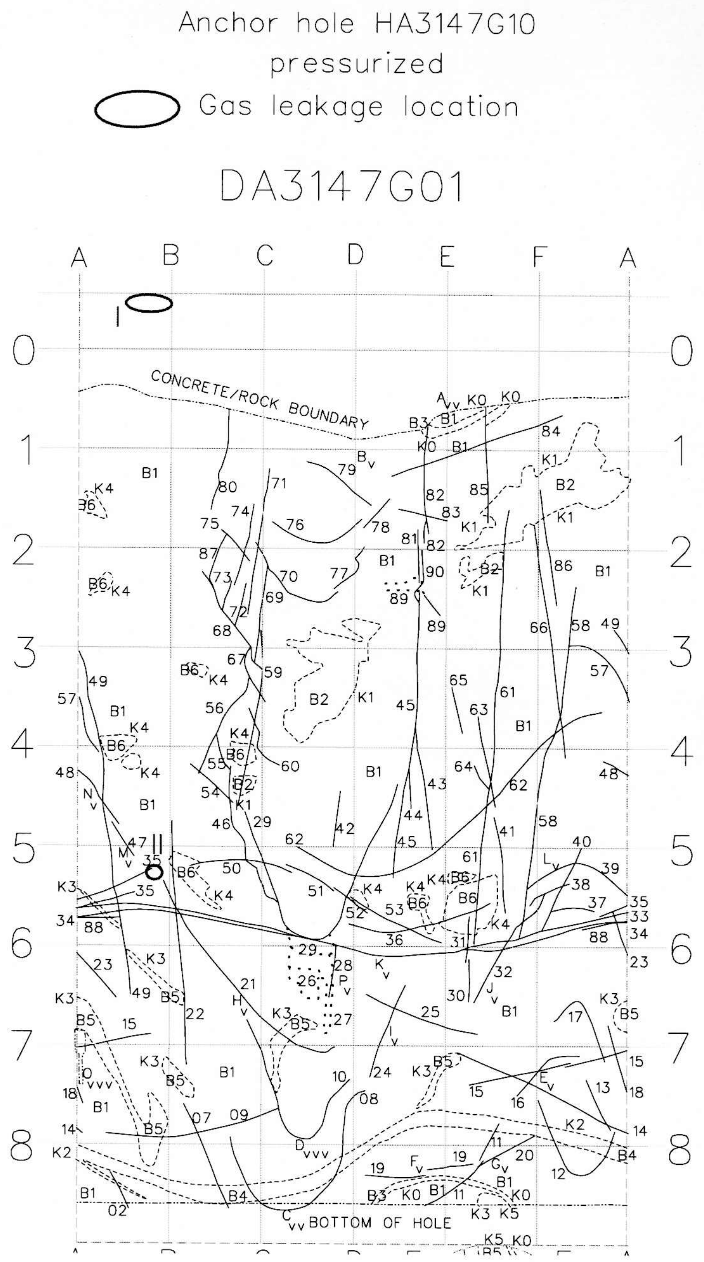


Figure 3-31. *Gas leakage locations in DA3147G01 when Anchor hole HA3147G10 was pressurized.*
I. Some bubbles on the surface
II. Two holes

Figure 3-32*. The Lasgit hole, the coloured water test. One of the anchor holes with a packer inserted (to the left), the empty Lasgit hole and in the background the container with Rhodamine WT coloured water.*

4 Concluding remarks

As has been demonstrated above there appear to be a rather slow steady “internal” inflow of water into the “Lasgit” hole via visible fractures and the rock mass. The obtained inflow rate was 240 litres/day or 0.17 litres/minute if the theoretical evaporation was not considered and 266 litres/day or 0.2 litres/minute if it was.

This means, that to fill the deposition hole with water up to the lowest point of the rock/concrete boundary at the top of the hole (a 7.93 m long section) will take approximately 79 days if the theoretical evaporation is not considered and 72 days if it is and the possibly evaporated water is prevented from escaping the Lasgit hole. This would mean a difference of 7 days.

The water pressure situation around the Lasgit hole and its possible influence on the inflow rate has been neglected. The hydraulic gradient may, however, decrease as the water level rises in the hole which in turn will decrease the inflow rate.

The effect of the actual evaporation will be a lot less than what the theoretical evaporation indicates since the latter is based on the hole wall acting as a free water surface. The hole wall was, at the time when the measurements took place, in many parts dry or at most damp and could therefore not act as a free water surface. Since the evaporation from the rising free water surface in the deposition hole was very small (1.6 litres/day) it may be neglected. Measured inflow of internal water can thus, as an approximation, be regarded as being the same as the real inflow.

The injection curtain, made around the deposition hole prior the drilling of the hole, most probably have a greater influence on the inflow rate of the ”internal water” than the evaporation has. A greater inflow may be expected if the curtain is damaged. This may have happened and being the cause of the small beam of water that recently has been discovered close to the E section (Figures 1-2 and 3-4) and about 0.35 m above the present concrete floor of the deposition hole. The “new” water beam gives about 0.1 litres/minute (105 ml/min).

The “external” inflow varied over the time of measurement (10-20 litres/day or 0.007-0.013 litres/minute) and is much less than the inflow of ”internal water” (about 240 litres/day or 0.2 litres/minute). Even if the “external” water had not been sealed off by the circular drain, it would have had very little effect on the inflow rate of the “internal water”.

The variation of external inflow is likely to be due to what kind of activities that have taken place in the tunnel section above the TBM assembly hall. The nearest water measuring ditch/weir above the TBM assembly hall is situated across the floor in the 2994 m section of the tunnel which is 153 m before the deposition hole at the 3147 m section. All water entering the tunnel after the 2994 m ditch and before the rock floor threshold in front of the TBM-tunnel at about section 3168 m will affect the gravel bed which acts as an aquifer surrounding deposition hole. The higher water table in the gravel bed/aquifer the more water is likely to seep through the rock/concrete floor boundary and eventually entering the deposition hole as external water.

A comparison between notes on water inflow in the report by Hardenby and Lundin (2003) indicates that the "external" inflow between concrete and rock floor has decreased from about 0.3 to 0.01 litres/minute since that report was written. The reason for this is for the time being uncertain. The drainage system of the TBM assembly hall was, however, improved in connection with the drilling of the deposition hole. Later, the drainage system in the tunnels has been rinsed and besides that the total inflow of water in the Äspö tunnel system is less today.

The anchor holes that were drilled around the deposition hole (the Lasgit hole) have been subject to a number of hydrogeological tests such as pressure build up as well as pressure drop tests and gas leakage tests.

To get a better picture of the water pressure in the disturbed hydraulic environment, which the Lasgit hole is a part of, the water pressure build up tests in some bore holes in the neighbouring tunnels have been taken into account. The pressures vary between 3-19.5 bars in the anchor holes and 0-27 bars in the other considered holes. These variations in pressure are likely to depend on the fracture pattern which may cause interference between boreholes as well as between boreholes and tunnels. The variations may also depend on how effective the packers have sealed off the holes during the tests.

During the pressure drop test performed in HA3147G07 the pressure went down below the pressure obtained by the pressure build up test. The reason for this is most likely due to leakage via the packer during the drop test.

For the anchor holes HA3147G01, G03 and G05 there appear to be a tentative relationship between the stabilized pressure in the build up test and the speed of the pressure drop fall. The higher pressure obtained during the pressure build up test the slower the pressure drop was during the drop test.

Considering all the holes where the pressure drop test was performed, the calculated hydraulic conductivity must be regarded as low 1E-12 to 7E-10 m/sec. For comparison it will be mentioned that the hydraulic conductivity outside more fractured sections in core borehole KAS03 (northern part of Äspö island) varied between 1E-10 to 1E-8.5 m/sec and in five core boreholes in southern part of Äspö between about 1E-11 to 1E-8 m/sec (Rhén et al. 1997).

The gas leakage test showed that there in many cases was interference between fractures, anchor holes and the Lasgit hole. The gas bubbles found in a hole with a packer inserted are believed to be due to a fracture pattern around the hole that allows the gas to escape into the hole above the packer. Another possibility for the latter is a simple leakage between the packer and the anchor hole wall.

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Appendices

Appendix 1. Anchor hole information – lengths, diameters and orientation

Appendix 1.

Hole information – lengths, diameters, measured sections and orientation

Borehole No	Diameter			Measured section (m)		Orientation (Äspö 96, º)	
	Section (m)		Ø				
	From	To	(mm)	From	To	Bearing	Inclination
HA3147G01	0.00	1.50	200	1) 2.00	11.05	64.7	-68.7
	1.50	11.05	162				
HA3147G02	0.00	1.45	200	1) 2.00	11.07	25.7	-68.8
	1.45	11.07	162				
HA3147G03	0.00	1.35	200	1) 2.00	11.06	350.0	-68.3
	1.35	11.06	162				
HA3147G04	0.00	1.60	200	1) 2.00	10.98	315.0	-68.1
	1.60	10.98	169				
HA3147G05	0.00	1.75	200	1) 2.00	11.04	277.8	-68.8
	1.75	11.04	163				
HA3147G06	0.00	1.75	200	1) 2.00	11.03	240.8	-68.3
	1.75	11.03	163				
HA3147G07	0.00	1.70	200	1) 2.00	11.03	207.1	-68.8
	1.70	11.03	162				
HA3147G08	0.00	1.40	200	1) 2.00	11.07	170.6	-68.8
	1.40	11.07	162				
HA3147G09	0.00	1.60	200	1) 2.00	11.07	134.8	-68.9
	1.60	11.07	162				
HA3147G10	0.00	1.40	200	1) 2.00	11.05	98.4	-69.0
	1.40	11.05	162				
KA3147G01	0.00	8.00	76	2)	8.00	253.7	-88.6
KA3153G01	0.00	8.00	76	2)	8.00	206.6	-89.7
KK0025G01	0.00	8.00	76	3) 0.50	8.00	180.0	-89.8
KK0031G01	0.00	8.00	76	3) 0.50	8.00	123.7	-89.6
KK0037G01	0.00	8.00	76	3) 0.50	8.00	191.3	-89.7
KK0045G01	0.00	8.50	76	3) 0.50	8.50	135.0	-89.8
KK0051G01	0.00	8.00	76	3) 0.50	8.00	108.4	89.6
KD0086G01	0.00	8.00	76	3) 0.30	8.00	270.0	89.9
KD0092G01	0.00	8.00	76	3) 0.30	8.00	135.0	89.7

Note: Negative (-) inclination = the hole is directed downwards
1) Approximate location of packer end according to personnel involved
2) No information
3) According to the Sicada database