In situ permeability measurement with the BAT Permeameter

Quick Manual
Inflow test

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Warranty details

BAT Geosystems AB (BAT) warrants all new BAT products against defects in materials and workmanship for a period of 6 months from the date of invoice. During the warranty period, we will repair or, at our option, replace at no charge a product that proves to be defective provided that it is returned, shipping cost prepaid, to BAT.

BAT´s liability and obligations in connection with any defects in materials and workmanship are expressly limited to repair or replacement, and the sole and exclusive remedy in the event of such defects shall be repair or replacement. BAT´s obligations under this warranty are conditional upon it receiving prompt written notice of claimed defects within the warranty period and it´s obligations are expressly limited to repair or replacement.

This warranty does not apply to products or parts thereof which have been altered or repaired outside of the BAT factory, or products damaged by improper installation or application, or subjected to misuse, abuse neglect or accident.

BAT Geosystems AB will not be liable for any incidental or consequential damage or expense incurred by the user due to partial or incomplete inoperability of it´s products for any reason whatsoever or due to inaccurate information generated by its products.

All warranty service will be completed as soon possible. If delays are inavoidable customers will be contacted immediately.

Contents

Pre-test measures

1) Installation of BAT MKIII Filter Tip

Install a BAT MKIII Filter Tip at desired depth and location. Follow the instructions from the "Installation of the BAT MKIII Filter Tip"-guide.

2) Measurement of pore pressure

Measure the actual pore pressure. Follow the instructions given in the "BAT Pore Pressure Guide".

Dissipation of disturbance effects

When the BAT Filter Tip is pushed into the soil, excess pore pressures will be generated due to disturbance effects. The time needed for dissipation of these disturbance effects varies with the type soil. In soft, plastic clays it may take several days until the original pore pressure is restored. On the contrary, in stiff clay, silt and fine sand the dissipation of the excess pressures goes much quicker. The process of dissipation of excess pore pressures can be logged by the BAT Sensor.
Make sure that the installation disturbance pore pressure has dissipated.before starting a permeability test. If unsure, leave the sensor connected to the BAT Filter Tip for 10 minutes. If , during this period, the he reading is stable (±0.01m H_2O) a permeability test can be performed.

3) Checking BAT Sensor

Make sure that the battery unit of the sensor contains a fresh, akaline battery. If unsure, change the battery. Normal life time of a battery when constant logging (1 minute interval) is about 3-4 weeks.

Introduction of BAT Permeameter

The BAT Permeameter can measure **permeabilites, *k*, in the range from $1*10^{-7}$m/s and lower.**

An example of typical *k*-values for different soil types:

Fine gravel:	$1 - 1*10^{-2}$m/s
Coarse sand:	$1*10^{-1}$m/s - $1*10^{-3}$m/s
Medium sand:	$1*10^{-2}$m/s - $1*10^{-4}$m/s
Fine sand:	$1*10^{-3}$m/s - $1*10^{-5}$m/s
Coarse silt:	$1*10^{-4}$m/s - $1*10^{-6}$m/s
Medium silt:	$1*10^{-6}$m/s - $1*10^{-7}$m/s
Fine silt:	$1*10^{-7}$m/s - $1*10^{-8}$m/s
Clay:	$<1*10^{-8}$m/s

Typical time of testing for different *k*-values:

$k \approx 10^{-7}$ m/s ; $t_{stab} \approx$ 10 minutes
$k \approx 10^{-8}$ m/s ; $t_{stab} \approx$ 30 - 60 minutes
$k \approx 10^{-9}$ m/s ; $t_{stab} \approx$ 3 - 4 hours
$k \approx 10^{-10}$ m/s ; $t_{stab} \approx$ 10 - 20 hours

Theory of the BAT Permeability Test

´The BAT Permeability Test is a type of ”falling head” test. The evaluation of the test is made by using Hvorslev´s equation *):

$$k = P_0 \cdot V_0/(F \cdot t \cdot 10^3) \cdot \{1/U_0 \cdot P_0 - 1/U_0 \cdot P_m + 1/U_0^2 \cdot \ln[(P_0 - U_0)/P_0 \cdot P_m/(P_m - U_0]\}$$

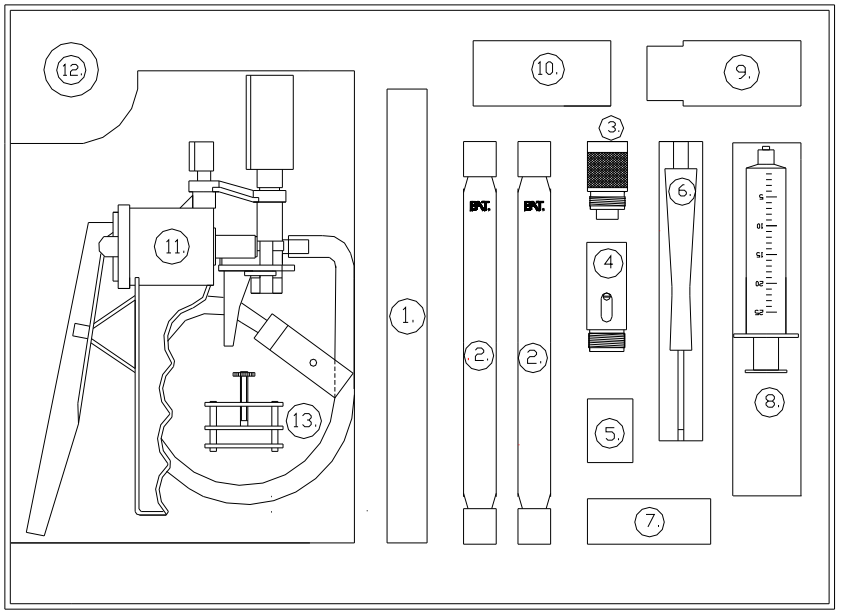
Parameters:

F	=	Hvorslev´s flow factor BAT MKIII Standard: 230 mm BAT MKIII Vadose: 194 mm	mm
k	=	coefficient of permeability	m/s
U_0	=	equilibrium pore pressure in-situ (absolute)	m H_2O
P_0	=	initial system pressure (absolute)	m H_2O
P_m	=	system pressure at time *t* (absolute)	m H_2O
V_0	=	initial system volume of air	ml
t	=	time for the test	s

At any time ***t*** the corresponding coefficient of permeability ***k*** can be calculated using Hvorslev´s equation.

*) Hvorslev, M.J. 1951. ”Time lag and soil permeability in ground water observations”. Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, pp.1-50.

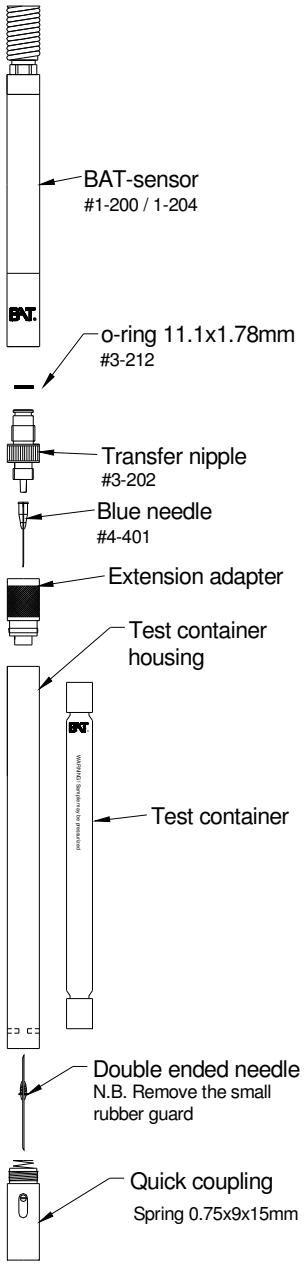
BAT Permeameter Equipment



Contents:

1. Test container housing
2. Test container (35 ml)
3. Extension adapter
4. Quick coupling sleeve
5. Spare screws and springs
6. Screwdriver for mounting of double ended needle
7. Spare septas
8. Syringes (25 ml & 35 ml)
9. Container for used needles
10. Double ended needles
11. Vacuum pump with Manometer
12. Blue needles
13. Cable Clamp

Equipment Parts



PRECAUTIONS

- Handle all parts carefully, especially the glass containers.
- Use only sharp needles. Do not re-use needles.
- Store the set in a dry environment.
- Do not use any tools to assemble the set. Finger tight is enough.

Assembly of equipment - Stepwise

Transfer nipple & extension adapter

- Screw the transfer nipple until it seats in the sensor cavity. Firstly, make sure the parts all are dry.
- Attach a blue needle onto the transfer nipple.
- Mount the extension adapter onto the transfer nipple.

Test Container

Container housing assembly and connection of Pressure Sensor and IS Field Unit

- Carefully insert the test container into the container housing.
- Screw the extension adapter onto the open end of the container housing . The Pressure Sensor is now connected to the Test Container.
- Connect the IS Field Unit, choose Display Mode.
- The pressure in the test container can now be measured with the IS Field Unit .

Application of initial system pressure P_0

Inflow Test

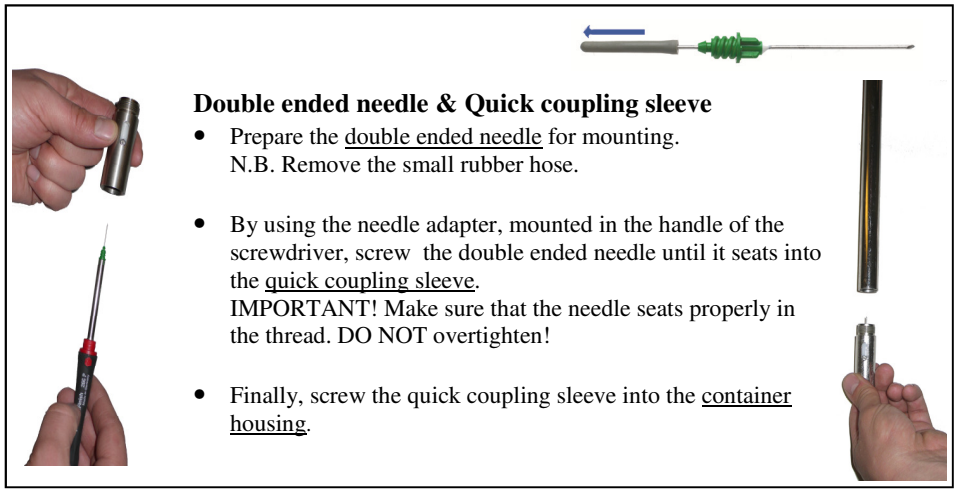
The initial system pressure P_0 in the Test Container is applied by either by extracting or injecting a volume of air by using either the 25 ml or the 35 ml syringe.

The volume of air to be extracted or injected is a function of the actual pore pressure U_0.

See page 7 for instructions regarding the application of the initial system P_0 in the test container.

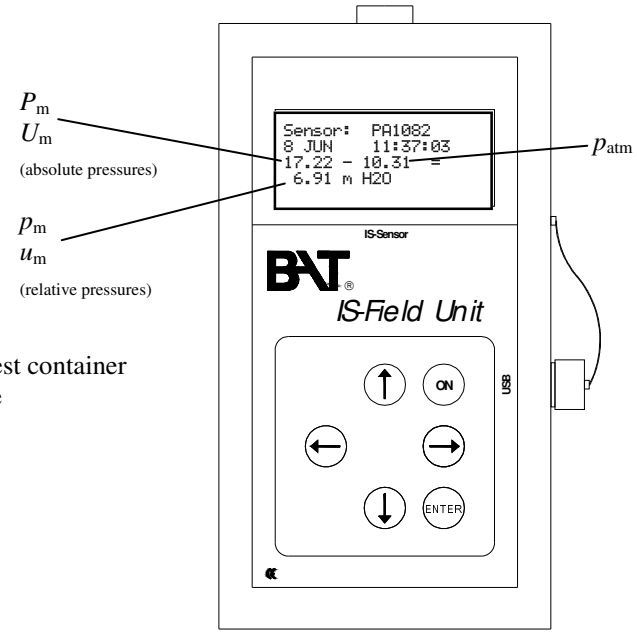
Use the IS Field Unit for checking The actual pressure in the Test Container.

Do also check that the system is leakproof by reading the displayed pressure.



Double ended needle & Quick coupling sleeve

- Prepare the double ended needle for mounting.
  N.B. Remove the small rubber hose.
- By using the needle adapter, mounted in the handle of the screwdriver, screw the double ended needle until it seats into the quick coupling sleeve.
  IMPORTANT! Make sure that the needle seats properly in the thread. DO NOT overtighten!
- Finally, screw the quick coupling sleeve into the container housing.



P_m = pressure in test container
U_m = pore pressure

Saturated soil conditions & positive pore pressure situation
INFLOW TEST

For saturated soil conditions it is recommended to carry out the BAT Permeability test as an inflow test. It is also assumed that a positive pore pressure situation is prevailing, i.e.:

$U_0 > p_{atm}$

in which U_0 = equilibrium pore pressure (absolute pressure) (m H_2O)
p_{atm} = atmospheric pressure (m H_2O)

The inflow test starts with an **empty** Test container.

For the inflow test it is recommended to use either the BAT MkIII Std Filter Tip or the BAT MkIII HD Filter Tip.

Recommended procedure

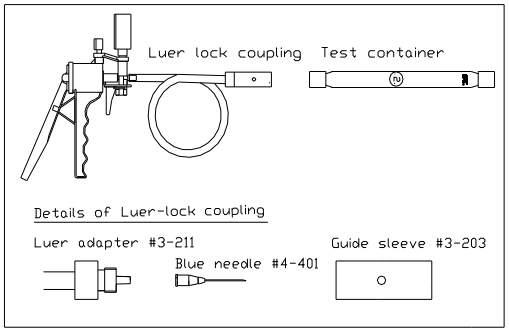
When conducting the Inflow Test it is recommended to adjust the initial pressure $\boldsymbol{P_0}$ so that at 80% pressure recovery, i.e. at $\boldsymbol{P_{80}}$, the water volume in the Test container, $\boldsymbol{\Delta W_{80}}$, will be in the order of 15 ml.
Depending on the magnitude of $\boldsymbol{U_0}$ the initial pressure in the Test container $\boldsymbol{P_0}$ can be adjusted either **by extracting or injecting** a volume of air, $\boldsymbol{\Delta V}$air from/to the Test Container.

in which:
$\boldsymbol{P_0}$ = initial pressure in Test container
$\boldsymbol{\Delta V_{air}}$ = extracted or injected volume of air out of or into the Test container
$\boldsymbol{P_{80}}$ = pressure in Test container at 80% pressure recovery
$\boldsymbol{\Delta W_{80}}$ = volume of water in Test container at $\boldsymbol{P_{80}}$
See **APPENDIX 2** for more details about this recommended procedure.

Combined discrete sampling of porewater and permeability testing

The BAT Permeability test can be combined with a simultaneous collection of a porewater sample for chemical analysis. In this case, it is recommended to evacuate the test container by using the hand vacuum pump for creating highest possible vacuum. Maximum achievable vacuum using the hand pump is in the order of 90% .

The logged pressure/time data from the filling of the Test container can readily be used for evaluation of the *k*-value for the tested soil.



Hand-vacuum pump for evacuation of the Test container.

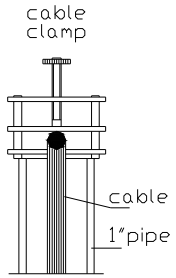
- Assemble the Luer lock coupling

- Insert the Test container into the Guide sleeve

- Evacuate the test container

See APPENDIX 2 for setting of the recommended value system pressure P_0.
With the system pressure P_0 set correctly the next steps are as follows:

Temperature equilibrium
With knowledgde of the installation depth, use the cable clamp to fix the cable and let the BAT Permeameter rest some 0.5 meter above the filter tip before starting the test.
With the BAT/IS-Field Unit connected you can now monitor the pressure change that occurs in the Test container due to change of temperature. Temperature equilibrium is normally reached after about 15 to 20 minutes. When the system pressure P_0 is stable **note the P_0** value in the Test Protocol., see APPENDIX 1.



Cable clamp to fix the cable during temperature equalization.

Starting the test

1) Prior to the start of the test, prepare the Field Unit by opening the "Start Measure" menu. Select both *sensor* and *temperature* logging (sensor+temp) and a suitable time interval.

2) To start with it is recommended to use 1 min logging interval. At a later stage of the test, the logging interval can be increased, without any inteferece with the ongoing logging of test data, see paragraph **6)** below.

3) Thereafter, return once more to the "Start Measure" menu and just place the marker on the OK-option, **without** starting the logging.

4) The next step is to connect the test equipment to the BAT Filter Tip. Thus, remove the cable clamp and gently lower the equipment the remaining distance down to the Filter Tip. **At the same moment** the equipment connects to the Filter Tip, **press** OK on the Field Unit and the test is running. **Open the "Display" menu** of the Field Unit to have a visual check that the test is running, i.e the pressure shall gradually change.

5) Depending on soil type the time of testing may vary from about 5 minutes up to 24 hours or more.

6) After about one hour of logging it is recommended to increase the measuring interval of the sensor to 10 minutes or more. This is simply done by activating the "Start measure" function of the BAT/IS-Field Unit and select a new logging interval.

7) **Finalizing the permeability test**
It is recommended to evaluate the permeability of the tested soil at a **pressure equalization 80% , i.e at pressure level P_{80}.**

When finalizing the test the by following the following steps shall be taken:

A) Note the values of system pressure P_{end} and atmospheric pressure p_{atm} in the Test Protocol, APPENDIX 1.
NB. In case a substantial change of the atmospheric pressure p_{atm} has occurred during the test this has to be taken into account when evaluating the test results.

B) Gently pull up the equipment and measure the volume of water W_{end} in the test container. The W_{end}-value shall be noted in the Test Protocol. The volume can be meaured by pouring the liquid into a syringe sealed with a rubber septa to the needle. It can also be measured more accurately using a scale at the office at a later stage.

C) Now the field part of the test is completed.
Processing of test data and evaluation of the coefficient of permeability k_{80} can be done by using an Excel sheet shown in APPENDIX 3.

NB. If running more tests before downloading the data to a PC, just remember **do not clear the data between the tests**. Keep notes on the starting time and starting pressures of each test and each set of test data so that the tests can be is easily separated when processing it on a PC.

An Output Excel sheet with evaluated test data and diagrams is shown in APPENDIX 4.

D) Checking the quality of the permeability test
The quality of permeability can be checked by calculation of the water volume ratio:

W_{end}/W_{calc}

in which W_{end} = measured water volume in the Test container (ml)
W_{calc} = calculated water volume in the Test container (ml)

For approval of the test the water volume ratio shall fulfil the following requirement: :

$$W_{end}/W_{calc} > 0{,}9$$

NB. In case the soil contains free gas the water volume ratio will normally be: $W_{end}/W_{calc} < 0{,}9$

Site:…… Date:……..

Measuring point.: …….. BAT/IS sensor nr.: ……

Installation depth of filter tip:…… Test performed by :…….

Initial atmospheric pressure : ……m H_2O time: ……...

Final atmospheric pressure : ……m H_2O time: ...…….

Form factor *F*, BAT MkIII Standard Filter Tip: F = 230 mm
BAT MKIII HD: F = 213 mm

NOTE! ALL PRESSURES ARE IN ABSOLUTE VALUES!

U_0, pore pressure at equilibrium, m H_2O:……..
($U_0 = U_m + 0.2$ mH_2O)

P_0, system pressure at start of test (at temperature equilibrium), m H_2O:……...
(displayed P_m value)

P_{80}, system pressure at 80% pressure recovery, m H_2O: …….
$P_{80} = P_0 + 0{,}8(U_0 - P_0)$

P_{end}, final system pressure, m H_2O:…….

W_{calc}, calculated volume liquid in system at end of test, ml:……

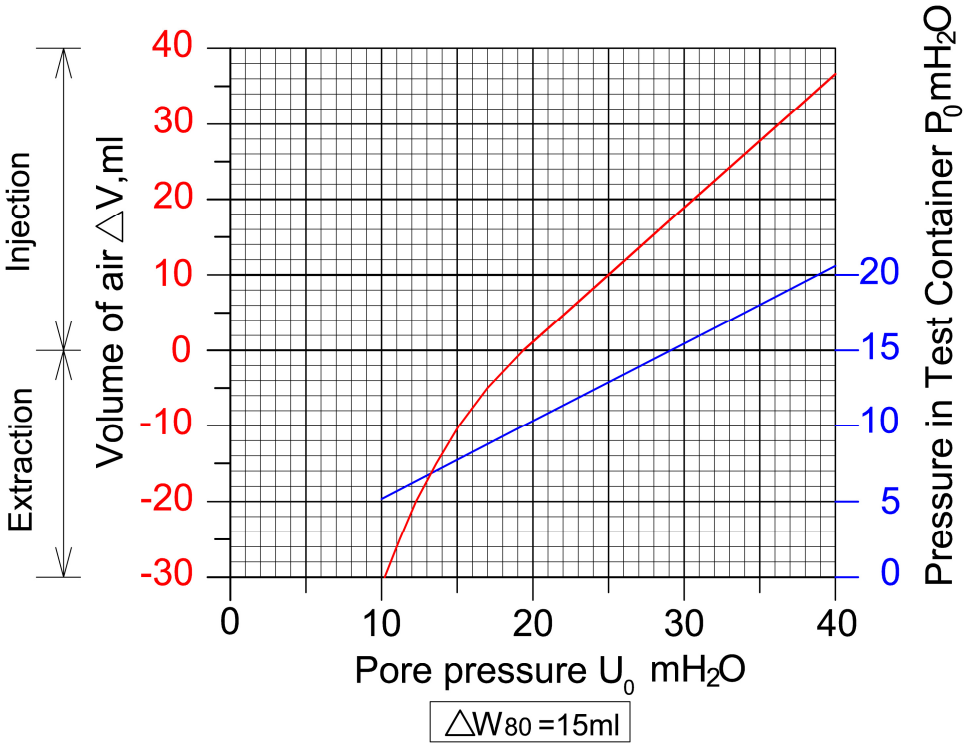
$W_{calc} = 35 - (P_0 * 35)/ P_{end}$

W_{end}, measured volume liquid in sample container at end of test, ml: ……...

Coefficient of permeability, *k* = ……*10^{-} m/s, calculated at …….% pressure equalization

Notes:_____

_____



Parameters

ΔV_{air}	= **extracted** or **injected** volume of air <u>out of</u> or <u>into</u> the Test Container		ml
U_0	= equilibrium pore pressure (absolute pressure)		m H_2O
ΔW_{80}	= volume of water in Test container at 80% pressure recovery		ml
P_0	= initial pressure in Test container (absolute pressure)		m H_2O
P_{80}	= pressure in Test container at 80% pressure recovery		m H_2***Di***

Evaluation of ΔV_{air} as a function of U_0 at ΔW_{80} =15 ml

The above diagram enables evaluation of ΔV_{air} as a function of U_0 valid for a volume of water in the Test container of ΔW_{80} *=15 ml* .

<u>*Example 1.*</u>

U_0 = 15 m H_2O gives **ΔV_{air} = -10 ml** (**extraction**) and a corresponding P_0 equal to about **7,8 m** H_2O.

<u>*Example 2.*</u>

U_0 = **25 m** H_2O gives **ΔV_{air} = 10 ml** (**injection**) and a corresponding P_0 equal to about **13m** H_2O.

Input sheet data sheet
INFLOW TEST

APPENDIX 3

Note! All pressures are absolute pressures in Pa resp mH_2O

Site	Office	Fill these cells with the starting	In these columns you paste data
Point	3	parameters before calculation	from the IS-sensor. If needed,
Date	2012-01-15		replace all dots with commas.
Installation depth of filtertip	3m		
BAT/IS sensor no.	PA3221		
Operator	ST		
Length of filter, mm	35		(Standard Mk III = 35 mm) (Cheramic filter =35 mm)
Diameter of filter, mm	31,5		(Standard Mk III =31,5 mm) (Cheramic filter =25 mm)
Flow factor, mm	229,6		
P_0, m H_2O	8,22	Initial system pressure	
h_{vnd} mH_2O	0,3	Final water column in test container	k_{80}= 2,34E-10 t_{80}= 4:40:00
V_0, ml	35	Initial air volume	
U_0, m H_2O	51,00	Static pore pressure	
Air pressure, Pa	95230		
P_{end} mH_2O	50,87		
W_{calc}, ml	29,30	Calculated volume of water after test	
W_{end}, ml	26,83	Measured volume water after test	
P_{80}	42,44	P80 = System pressure at 80% pressure equalization. It is **recommended** to evaluate k-value at this pressure level	
P_{50}	29,61	P50: System pressure at 50% equalization.	

Date	Time	Pressure Pa	Time elapsed	Time elapsed seconds		System pressure m H2O		Water volume in test container,ml	Permeability k [m/s]
1	2	3	5	6		8		10	11
2011-11-10	09:10:00	80677,5	0:00:00	0		8,22		0,00	
2011-11-10	09:20:00	88661,2	0:10:00	600		9,24		3,15	6,63E-10
2011-11-10	09:30:00	95929,5	0:20:00	1200		10,00		5,56	5,37E-10
2011-11-10	09:40:00	103448	0:30:00	1800		10,78		7,70	4,82E-10
2011-11-10	09:50:00	110989	0:40:00	2400		11,55		9,56	4,44E-10
2011-11-10	10:00:00	118671	0:50:00	3000		12,35		11,21	4,14E-10

Downloading of and processing of measurement data

The procedure for downloading and processing of measurement data is described in BAT´s manual for pore pressure measurement ”BAT/IS– system for Pore pressure measurement. Make sure macros are activated.

Insertion of measurement data in Excel calculation sheet

1) Insert the the data from the Test Protocol into Input sheet.

2) Paste the downloaded data in the columns 1, 2 and 3.

If present, change the ”dots” to ”commas” in the pressure column.

Output sheet
from PC-calculation
INFLOW TEST

APPENDIX 4

Site	Office	Filter Type	BAT MKIII Standard
Point	3	Sensor #	PA3221
Installation depth	43m		BAT Permeameter test
Date	2012-01-15		info@bat-gms.com
Operator	ST		www.bat-gms.com

Initial pore pressure	U_0	51	mH_2O	
Initial system pressure	P_0	8,22	mH_2O	
Final water volume (measured)	Wend	26,83	ml	
Final water volume (calculated)	Wcalc	29,3	ml	
Water volume ratio	Wend/Wcalc	0,92		
Final pressure	P_{end}	50,87	mH_2O	
Pressure equalization		99,7%		Pressure equalization
Calculated permeability:	k_{80}	**2,34E-10**	**m/s @**	**4:40:00 hrs**
at system pressure:	P_{80}	42,44	mH_2O