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Description of hydrogeological data in SKB´s database GEOTAB. Version 2

Margareta Gerlach (ed.)

Mark Radon Miljö MRM Konsult AB, Luleå

December 1991

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

Information on SKB technical reports from 1977-1978 (TR 121), 1979 (TR 79-28), 1980 (TR 80-26), 1981 (TR 81-17), 1982 (TR 82-28), 1983 (TR 83-77), 1984 (TR 85-01), 1985 (TR 85-20), 1986 (TR 86-31), 1987 (TR 87-33), 1988 (TR 88-32), 1989 (TR 89-40) and 1990 (TR 90-46) is available through SKB.

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DESCRIPTION OF HYDROGEOLOGICAL DATA

IN SKB'S DATABASE GEOTAB

Version 2

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ABSTRACT

During the research and development program performed by SKB for the final disposal of spent nuclear fuel, a large quantity of geoscientific data was collected.
Most of this data was stored in a database called GEOTAB. The data is organized into eight groups (subjects) as follows:

- Background information
- Geological data
- Borehole geophysical measurements
- Ground surface geophysical measurements
- Hydrogeological and meteorological data
- Hydrochemical data
- Petrophysical measurements
- Tracer tests

Except for the case of borehole geophysical data, ground surface geophysical data and petrophysical data, described in the same report, the data in each group is described in a separate SKB report.

The present report describes data within the hydrogeological data group.

The hydrogeological data group (subject), called **HYDRO**, is divided into several subgroups (methods).

BHEQUIPE	**:**	**Equipments in Boreholes**
CONDINT	**:**	**Electrical Conductivity in Pumped Water**
FLOWMETE	**:**	**Flowmeter Tests**
GRWB	**:**	**Groundwater Level Registrations in Boreholes**
HUFZ	**:**	**Hydraulic Unit Fracture Zones**
HURM	**:**	**Hydraulic Unit Rock Mass**
HYCHEM	**:**	**Hydraulic Test during Chemical Sampling**
INTER	**:**	**Interference Tests**
METEOR	**:**	**Meteorological and Hydrological Measurements**
PIEZO	**:**	**Piezometric Measurements at Depths in Boreholes**
RECTES	**:**	**Recovery Tests**
ROCKRM	**:**	**Hydraulic Unit Rock Types in the Rock Mass**
SFHEAD	**:**	**Single Hole Falling Head Test**
SHBUP	**:**	**Single Hole Build Up Test**
SHSINJ	**:**	**Single Hole Steady State Tests**
SHTINJ	**:**	**Single Hole Transient Injection Tests**
SHTOLD	**:**	**Single Hole Transient Injection Tests - Old Data**

A method consists of one or several data tables. In each chapter a method and its data tables are described.

1 INTRODUCTION

Since 1977 Swedish Nuclear Fuel and Waste management Co., SKB, has been performing a research and development programme for final disposal of spent nuclear fuel. The purpose of the programme is to acquire knowledge and data for underground storage of radioactive waste. Measurement for the characterization of geological, geophysical, hydrogeological and hydrochemical conditions are performed in specific site investigations as well as for geoscientific projects.

Large data volumes have been produced since the start of the programme, both raw data and results. During the years these data were stored in various formats by the different institutions and companies that performed the investigations. It was therefore decided that all data from the research and development programme should be gathered in a database. The database, called GEOTAB, is a relational database. It is based on a concept from Mimer Information System, and have been further developed by Ergo-data. The hardware is a VAX 750 computer located at KRAB (Kraftverksbolagens Redovisningsavdelning AB) in Stockholm.

The database comprises eight main groups of data volumes. These are:

- **Background**
- **Geology**
- **Geophysical borehole logging**
- **Ground surface geophysical methods**
- **Geohydrological and meteorological measurements**
- **Chemical methods**
- **Tracer data**
- **Petrophysical measurements**

In the database background information about the investigations and results are stored on line in the VAX 750, while raw data files are stored on magnetic tapes at KRAB.

This report deals with hydrogeological data and describes the data flow from the measurements at the sites to the result tables in the database. Almost all the hydrogeological investigations were carried out by the Swedish Geological Survey, SGU, before 820701 and by Swedish Geological Co, SGAB, after that date. Thus hydrogeological data have been stored both at SGU and SGAB.

The results of the hydrogeological investigations have been divided into seventeen methods and each method is presented separately in the database.

Three of them comprise data that have been evaluated or calculated on the basis of the results from the other methods (i e HUFZ, HURM, ROCKRM).
In this case they constitute hydraulic conductivity values at different depths for defined hydraulic units of the bedrock.

One method is based on old calculations from Single Hole Transient Injection Test (SHTOLD) and one contains data about equipment in the borehole (BHEQUIPE). Rest (twelve methods) correspond to one type of measurement or a calculation.

BHEQUIPE	**:**	**Equipments in Boreholes**
CONDINT	**:**	**Electrical Conductivity in Pumped Water**
FLOWMETE	**:**	**Flowmeter Tests**
GRWB	**:**	**Groundwater Level Registrations in Boreholes**
HUFZ	**:**	**Hydraulic Unit Fracture Zones**
HURM	**:**	**Hydraulic Unit Rock Mass**
HYCHEM	**:**	**Hydraulic Test during Chemical Sampling**
INTER	**:**	**Interference Tests**
METEOR	**:**	**Meteorological and Hydrological Measurements**
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SHTINJ	**:**	**Single Hole Transient Injection Tests**
SHTOLD	**:**	**Single Hole Transient Injection Tests - Old Data**

At SGU/SGAB the hydrogeological data were stored on line on PRIME 750 computers, on magnetic tapes or in filed paper protocols. During 1985 and 1986 the data files were transferred from SGU and SGAB to data files on the VAX computer or to magnetic tapes at KRAB. The data from the protocols were punched to data files either on PRIME (before the transfer) or on VAX. Then the flyleafs (tables containing background data) and the result tables in the database were loaded with data from the transferred files. Some tables were loaded directly by means of punching of the protocol data.

The database is continuously updated. Methods, tables or columns may change. This report will be updated accordingly.

Several reports dealing with different data sets stored in the GEOTAB database have been published. These are:

TR86-22	Description of hydrogeological data in SKB's database GEOTAB Version 1. Bengt Gentzschein
TR91-01	Description of geological data in the SKB database GEOTAB; Version 2 Tomas Stark, Stefan Sehlstedt
TR91-02	Description of geophysical data in the SKB database GEOTAB; Version 2 Stefan Sehlstedt
TR91-05	Description of tracer data in the SKB database GEOTAB; Version 1 Peter Andersson, Margareta Gerlach
TR91-06	Description of background data in the SKB database GEOTAB; Version 2 Ebbe Eriksson, Stefan Sehlstedt
	Description of groundwater chemical data in the SKB database GEOTAB prior to 1990. Ann-Katrin Nilsson et al (to be published)

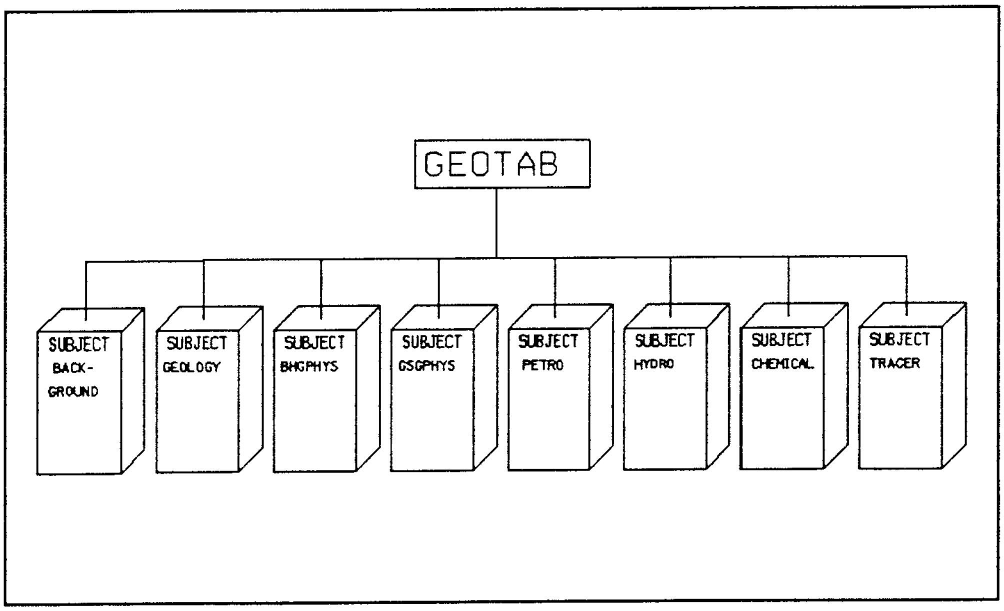


Figure 1-1 Structure of the GEOTAB database

2 SINGLE HOLE INJECTION TESTS

The purpose of single hole injection tests is to determine the hydraulic conductivity, skin factor, piezometric pressure and other hydraulic parameters of the bedrock in the vicinity of a test borehole. The single hole injection tests managed by SKB during the years 1977-91 have been performed in crystalline bedrock, most commonly in core drilled boreholes of the diameter 56 mm or 76 mm with a length varying between about 100 m to 1 000 m. However, tests in percussion drilled boreholes (diameters between 110 and 160 mm) have also been made. For further information about methods of hydraulic testing in the SKB-project it is referred to Almén et al (1986 b).

The fundamental idea of a hydraulic injection test is to inject water under controlled conditions into a borehole or part of a borehole and to record the response in the aquifer of the disturbance caused by the injected water. The tested section can include the entire borehole, but tests in delimited parts of a borehole have been much more frequent in the SKB-investigations. In the former case, a hydraulic or mechanic rubber packer installed high up in the borehole screens off the borehole from the atmosphere, and the water is injected below the inflated packer, a so called single packer test. Tests in delimited parts of the borehole can be single packer tests or double packer tests. In the latter case the water is injected between two inflated packers. The packer spacing can be just any, however in the SKB investigations a spacing of 2 m, 3 m, 5 m, 10 m, 20 m, 25 m or 30 m has been common. The length of the test section also in a single packer test can be anyone, but is in most cases rather long, i.e. several hundred meters.

A single hole water injection test can be performed either as a constant head or a constant flow test. In the SKB research program so far the most commonly performed tests have been constant head tests.

Single hole injection tests can be evaluated either as transient tests or as steady-state tests. In practice, also the performance usually differs between the two methods. The former method often comprises a rather long injection and pressure recovery period, whereas in steady-state tests the fall-off phase is excluded and the injection phase is short. The evaluation of hydraulic parameters from transient injection tests is based on the theories for transient flow and/or pressure changes. Steady-state tests are evaluated according to steady-state theory, where the momentary flow after between 10 and 15 min is used. The steady-state tests constitute a rapid and thus economical test method, well suited for tests en masse. The more time consuming transient tests are more expensive but are considered to admit a more accurate determination of hydraulic parameters. They are also valid for a larger volume of rock surrounding the test section. The transient respectively steady-state tests are separately treated in the sections below.

The two testing equipment systems used in the SKB-investigations for transient and steady-state single hole injection tests, the Steel Pipe Equipment

System and the Umbilical Hose Equipment System have both been modified in several steps, thereby increasing the degree of sophistication of the measurement instruments as well as of the accessory equipment such as hoisting rig and housing. The conversion of the Pipe String Equipment System from Version 2 to Version 3, which was performed during 1986, included installation of a new flow meter unit, a new control unit, a new computer with a test program permitting a semiautomatic operation control and the use of a new powerful plot program. The data was earlier processed by a Prime 750, but in Version 3 the data processing was transformed to PC medium.

The housing of Version 3 was modified in 1988. The previous test house, which had to be put together at every new test site and dismantled after testing, was replaced with a steel container, specially equipped for the purpose of storing the injection test equipment. With this solution the measurement equipment can be fixed permanently within the container and all instruments and other equipment can be transported as one single unit.

Also the Umbilical Hose System was modified during 1986 from Version 1 to Version 2. The most important difference between the two versions is the new flow meter system and the data processing, which as for the Pipe String Equipment System was transferred to PC environment.

The technical design of Version 3 of the Steel Pipe Equipment System and Version 2 of the Umbilical Hose Equipment System are thoroughly described by Almén et al (1986 a).

2.1 SINGLE HOLE TRANSIENT INJECTION TEST

In the SKB research program a rather standardized procedure has been developed for single hole injection tests. A single hole transient injection test, apart from type of equipment used during the test, is normally divided into nine different phases numbered from phase 0 to phase 8 as follows (Almén et al 1986 a):

Phase 0: Registration of pressure at the test level with packers deflated.

Phase 1: Selecting a reference pressure for the test.

Phase 2: Inflation of packers.

Phase 3: Closing the test valve. In this phase the pipe string or tube for injection water is evacuated from air bubbles and the tightness of the entire pipe string is controlled.

Phase 4: Injection phase. The injection starts when the test valve is opened to the test section. The pressure in the test section (normally 200 kPa above the reference pressure) is regulated with the injected water. During phase 4 pressure and flow rate are monitored and time indicated.

Phase 5: Fall-off phase. The pressure fall-off phase starts when the test valve is closed. During this phase pressure is monitored and time indicated.

Phase 6: Stop of fall-off phase.

Phase 7: Deflation of packers.

Phase 8: Stop of test. Comments on the test are punched in and the computer automatically prepares itself for the next test.

The duration of phase 2, 4 and 5 are normally 30 min, 120 min respectively 120 min, whereas the other phases claim much shorter time. During the complete test cycle, water flow rate, water temperature, water pressure in the test section and the packer pressure are registered and stored as data files in a Digital PC (DEC) 350 or 380 computer. As an option also the water pressure in neighbouring sections are registered. After data processing the single hole transient injection tests result in a number of plotted diagrams, which make possible the determination of the hydraulic parameters of the test section according to the theories for transient tests.

2.1.1 Steel Pipe Equipment System, Version 2

Single hole transient injection tests with the steel pipe system version 2 were performed during the period 1981-1983 at five sites.

2.1.1.1 Collecting, Processing and Evaluation of Data

Data flow is presented in the block diagram in figure 2-1.

The parameters measured during a test were pressure, temperature and injection flow rate. Two pressure transducers measured packer pressure and section pressure respectively. The section pressure value was suppressed just before the injection phase (Almén et al 1983). Air temperature in the measurement housing and temperature of the injected water were monitored by two temperature transducers. Pressures and temperatures were registered and stored automatically by the datalogger, while the injection flow values were manually registered. The datalogger also stored background data and reference pressures that were set on a thumb wheel device.

A single hole injection test with this equipment comprised eight stages, Table 2.1. During the whole measurement sequence datalogger values were recorded by a cassette recorder. The pressure values were also registered on a chart recorder and displayed on a multimeter. During the injection phase a constant injection pressure (c. 200 kPa) was maintained by regulating the water flow through the flow meter. The flow rate was noted in a protocol.

A test in one test section resulted in one flow protocol, one comment protocol and one chart from the chart-recorder. The cassette tape usually contained data from two tests, one on each side of the tape.

Table 2.1 Different stages of a single hole water injection test, steel pipe equipment, version 2.

Stage 0:	Section identifications are set on the thumb wheel
"	The section pressure stabilizes
" 1:	The stable absolute pressure is set on the thumb wheel Suppression of absolute section pressure t = 0
" 2:	Packer inflation starts
" 3:	The test valve is closed t = 25
" 4:	The test valve is opened, injection starts t = 30
" 5:	The test valve is closed, injection is stopped and the fall-off phase starts t = 150
" 6:	The fall-off phase ends and the packers are deflated t = 270
" 7:	Stable absolute pressure after the test is fed into the data logger via the thumb wheel t = minutes from test start

When a number of tests had been performed the measurement operators sent the resulting data for data processing and storing. A deliverance usually comprised 5-10 cassette tapes and the protocols and charts from the corresponding test sections.

The data on the cassette tape were read to a C-file on the PRIME 750-computer (at SGU before 830401, at SGAB after that date). The flow protocols were, after correction, punched to P-files. The C-file was then converted to a L-file, which besides the identification and the date contains the same data as the C-file. But in the L-file pressures and temperatures are in Pa and centigrades respectively and data from each scanning are on one line. The L-file was edited by the hydrogeologist. The P-file, the corresponding L-files and a file containing the inclination of the actual borehole were merged to M-files and
CO-files.

On the basis of the data in the M-file 11 graphs from each test section were plotted. The plots were sent to the hydrogeologist at SGU/SGAB who evaluated them and determined the hydraulic conductivity, skin factors and other parameters of the test sections. The results were noted in a result protocol and then punched to the result table SHTINJ in the GEOLIS database. GEOLIS was a database in SGU's PRIME 750. After 820701 GEOLIS was transferred to SGAB's PRIME 750 in Luleå.

During 1986 the result table SHTINJ was transferred to the VAX 750 computer at KRAB in Stockholm and the GEOTAB database, where the results of the transient injection tests can be found in the table SHTINJCD.

2.1.1.2 Data Volumes in the Block Diagram Figure 2-1

Section pressure and packer pressure

The output signals from the pressure transducers were received at ground level by an amplifier, amplifying the signal from 0.05 mV/kPa, to 0.1 mV/kPa and 1.0 mV/kPa, respectively for different purposes. The section pressure was registered by the data logger and the chart recorder in two channels respectively, see appendix 15.3, one registrating the absolute pressure the second registrating the suppressed absolute pressure, which was equal to the injection pressure. Also the packer pressure was registered by the data logger and the chart recorder.

Thumb wheel settings

A thumb wheel facility was connected to the data logger. The thumb wheel settings were registered by the data logger and stored on the tape at each scanning. The settings varied depending on the current stage of the injection test, appendix 15.2. Input data from the thumb wheel was test stage (see Table 2.1), stable absolute pressure in five digit resolution before and after the test in millibars and section identity. The section identity consists of borehole number, distance to the upper limit of the section and a section code, see appendix 15.2.

Air temperature and water temperature

Air temperature of the measurement housing and the temperature of the injection water were monitored during the whole injection test. The outsignal from the temperature sensors was 10 mV/°C.

Injection flow values

The flow meter unit consisted of five flow meters connected in parallel. The measurement operator read the flow values on the flow scales and the flow meter in question and noted them in the flow protocol. The flow values were read with increasing intervals during the injection, appendix 15.1.

Cassette tape

All the data registered by the channels of the data logger as well as the channel numbers, the thumb wheel settings and the time were stored on the cassette tape. The parameters stored were:

Absolute section pressure	from channel 0	(mV)
Suppressed - " -	" " 1	"
Packer pressure	" " 8	"
Air temperature	" " 9	"
Water temperature	" " 7	"
Date, time	" datalogger	DD, hhmmss
Test stage	" thumb wheel	one digit (0-7)
Borehole number	" " "	two digits
Distance to section	" " "	three digits
Section length code	" " "	one digit (1-4)
Stable pressure before test	" " "	(mbar) five digits
Stable pressure after test	" " "	" "

The resolution of the pressure values recorded on the cassette was 3 1/2 digit. For injection pressures less than 2 bars which was the normal, the resolution was 1 m bar recorded as suppressed section pressure. The suppressed section pressure was set to zero at the moment the stable pressure before test was set on the thumb wheel device with five digit resolution.
As a rule the cassette tape contained data from two injection tests, one on each side.

On the cassette the operator wrote the borehole name (site code + borehole number), upper and lower limit of the test section, the date of the test and his own signature.

When data from a cassette tape was processed and evaluated the content of the tape was aborted.

Record chart

On the chart from the chart recorder absolute section pressure, suppressed section pressure (= injection pressure) and packer pressure was registered during the entire test cycle. The resolution of the input signals, channels and pen-colour are shown in appendix 15.3. The paper feed varied according to a scheme, shown in appendix 15.1. On the chart the measurement operator noted section identification, change in paper feed, pressure values and time during the test, shift in test stages and other comments useful for the hydrogeologist. The pressure values, used for calibrating the drawings on the chart, were taken from the multimeter.

The chart was used when editing the C-file and in some few cases for evaluation when the logger registration failed. The charts are filed in the archive at SGAB, Uppsala.

Flow protocol

The flow protocol entails a table and a protocol head. The table consists of 4 columns. The first column gives time from injection start (min/sec), the second gives the flow meter number, the third shows the scale division on that flow meter and finally the fourth column shows the water flow (m^3/s) at the time given. The protocol head consists of borehole name, test section limits (m), date, signature of the measurement operator, distance (m) between section and pressure transducer (L_K), distance (m) to ground-water level from top of borehole casing, injection pressure in bars and the result of the flow test. If there was any flow during the flow test (injection when the test valve was closed) the operator noted corresponding flow meter number, scale division and the flow value in the protocol head.

The intervals between flow registrations are given in appendix 15.1.

Comment protocol

Two types of comments were written on the comment protocol: comments concerning registration and processing of data and comments concerning the evaluation of data. A protocol head comprises borehole name, section limits, signature, date, L_K-value and ground-water level, see flow protocol.

C-file and C-file name

The C-files were named according to the following convention:

CBHNR.k.n.ev (example: CGI12.1.3)

C = type of file; C = cassette file
BH = site code, two letters; GI for Gideå, KM for Kamlunge ...
NR = borehole number within the site; 1-99
k = number of deliverance, group of cassettes from one borehole
n = file number within the deliverance ev was seldom used and was assigned modified C-files

One C-files contains all data registered by the datalogger during one or more tests and stored on one cassette tape. Each scanning comprises three lines in the file. Stable pressures before and after the test are in millibars. The rest of the pressure values as well as the temperature values are in mV. Positions and formats of the C-file are presented in appendix 15.4.

The C-files are now (1986) stored on magnetic tapes at SGAB, Luleå.

C.DIR

C.DIR has five columns

		ofset	length
column 1:	File name	1	11
" 2:	Borehole name	12	9
" 3:	Upper limit of test section (m)	23	3
" 4:	Lower " " " " (m)	27	3
" 5:	Comments	29	79

In some cases columns 3 and 4 are longer.

The borehole names in column 2 were assigned according to a convention used in SGU's and SGAB's database GEOLIS. The borehole names comprise a GDA-code and a borehole number as follows

AKSSNRnnn (example: AKGI12000)

where

AKSS = See GDA-code below
NR = Borehole number. Two digits 1-99
nnn = Sample number, always = 000 for hydrogeological measurements

The C.DIR file is now (1986) stored in PRIME 750 (SGAB, Luleå).

L-FILE name, GDA-code and YYMM

Input data to the programme /INJFLAT are, with the exception of the C-file, L-file name, GDA-code and YYMM (year and month).

The L-file name is the same as the C-file name except that the first letter is a L (= loggerfile) instead of a C, e.g. LGI12.1.1

The GDA-code is a code describing boreholes, used in the GEOLIS-database at SGU/SGAB. The code has four letters:

AKSS (example: AKGI)

A = Engineering geology
K = Borehole type (K = cored drillhole, H = percussion drillhole)
SS = Site code, FJ for Fjällveden, GI for Gideå etc.

YYMM is year and month of the test in question.

L-FILE

The L-FILE is a converted C-file and contains the same data as the latter i.e. data from the datalogger. In the L-file data from each scanning are on the same line. The absolute section pressures before and after the test are expressed in Pascal. The other pressure values are expressed in Pa and the temperatures are expressed in centigrades. Format and positions of the L-file are described in appendix 15.4.

COMO-FILE

During the run of the program /INJFLAT a COMO-FILE is opened and closed. A COMO-FILE is a terminal file in the operating system of PRIME 750. It contains all the text displayed on the terminal during a session. An example of a COMO-FILE is shown in appendix 15.5. When the data processing was finished the COMO-FILE was deleted.

EDITED L-FILE

The original L-file was edited by the hydrogeologist. The result is an edited L-file, which contains the same data as the original L-file, apart from the adjustment made by the hydrogeologist. These are in general few and do not concern the data derived from the pressure- and temperature sensors.

The edited L-files are now (1986) stored on magnetic tapes at SGAB, Luleå.

LOG.DIR

LOG.DIR has five columns

		ofset	length
column 1:	File name	1	10
" 2:	Borehole name	12	9
" 3:	Upper limit of test section (m)	22	3
" 4:	Lower " " " " (m)	26	3
" 5:	Comments	30	79

The borehole names in column 2 were assigned according to a convention used in SGU's and SGAB's database GEOLIS, see C.DIR.

The comments of column 5 also includes notes about the corrections of the original L-file, made by the hydrogeologist.

LOG.DIR is now (1986) stored on magnetic tapes at

SGAB, Luleå.

Corrected protocols

Corrected protocols were the same as the flow- and comment protocols from the site. But the protocols were checked by the hydrogeologist and missing data were if necessary, completed.
Of special importance were dates and identities of the boreholes and test sections, since these data had to be equal to the identifications of the corresponding L-file(s).
The corrected flow- and comment protocols are now (1986) in the archive at SGAB, Uppsala.

P-FILE and P-FILE NAME

The P-file contains flow rate values and comments written on the protocols by the measurement operator and if necessary completed by the hydrogeologist. The P-file comprises three record types. The first record type contains data from the flow protocol head, the second record type shows water flow rate and finally the third record type contains comments from the comment protocols. The format of the P-files is presented in appendix 15.4.

The P-files are now (1986) stored on magnetic tapes at SGAB, Luleå.

The P-files were named according to the following convention:

PSSNR.k (example: PGI12.1)

P = File type, P = Protocol file
SS = Site code; GI = Gideå, KM = Kamlunge etc
NR = Borehole number within the site; 1-99
k = Number of deliverance, group of cassettes from one borehole

PROT.DIR

PROT.DIR has six columns

		ofset	length
column 1:	File name	1	10
" 2:	Borehole name	16	9
" 3:	Upper limit of test section (m)	26	3
" 4:	Lower " " " " (m)	30	3
" 5:	Date of test (YYMMDD)	34	6
" 6:	Comment	40	79

The borehole names were assigned according to a convention used by SGU/SGAB, see C.DIR.

PROT.DIR is now (1986) stored on magnetic tapes at SGAB, Luleå.

KROK-FILE

The KROK-files are the result of the borehole geophysical measurements, and they describe the inclination and the declination of the boreholes every tenth meter (Eriksson 1986).

The KROK-file has three columns:

Column 1: Depth along the borehole (m)
" 2: Angle against horizontal plane (degrees)
" 3: Angle against vertical north-south plane (degrees)

The KROK-file was named according to: KROK*SSNR, where SS = site code and NR = borehole number. The KROK-files are stored on magnetic tapes at SGAB, but the contents of them have been read into the table DEVANGLE in SKB's database GEOTAB.

M-FILE and M-FILE NAME

The M-FILE is a merged file. Its origin is one P-file, a number of L-files and data from the KROK-file. The P-file and the L-files comprise flow rate data and logger data, respectively, from the same test sections. Thus the M-file contains data from one deliverance from the measurement operators relevant for data evaluation.

The M-file name is the same as the P-file name with the exception that the first letter is a M (= merged file) instead of a P (example: MGI12.1).

In the M-file the absolute section pressure values were corrected for the distance between the test section and the pressure transducer (= the L_K-value). Apart from this the data of the M-file are the same as found in the L-files, P-file and KROK-file respectively, appendix 15.4.

The M-files are stored on magnetic tapes at SGAB and SGU. During 1986 copies of the M-files were transferred to magnetic tapes at KRAB in Stockholm.

CO-FILES

The CO-files have the same name as the corresponding M-files with the difference that the CO-file names begins with CO (=comment file) instead of M. The contents of the CO-files concern the same test sections as the corresponding M-files. The CO-files comprise data from the head of the flow protocol and comments written on the comment protocols. Unfortunately the comments are missing in many CO-files, since they were deleted during the data process. The CO-files also contain average inclination of the test sections calculated by the program

/TIMERG. The average inclination was used for the correction of the absolute section pressure in the M-file. The format of the CO-files is shown in appendix 15.4.

The CO-files are stored on magnetic tapes at SGAB, Luleå. During 1986 copies of the CO-files were transferred to magnetic tapes at KRAB in Stockholm.

MRG.DIR

MRG.DIR has six columns:

			ofset	length
column	1:	File name	1	9
"	2:	Borehole name	15	9
"	3:	Upper limit of test section (m)	25	3
"	4:	Lower limit of test section (m)	29	3
"	5:	Date of test (YYMMDD)	33	6
"	6:	Comments	40	40

The borehole names in column 2 were assigned according to a convention used in SGU's and SGAB's database GEOLIS, see C.DIR.

MRG.DIR is now (1986) stored on magnetic tapes at SGAB, Luleå. During 1986 a copy of MRG.DIR was transferred to magnetic tapes at KRAB in Stockholm.

PLOT-FILES

The programme PFLIMP generate 11 plot files for each injection test. The plotfiles are named as follows:

Plot_nsec_BHid (example: A1_0240_AKGI12000)
where

Plot = Name of graph; UT,A1-A4, B1-B4, C1 and C2
sec = Upper limit of test section (m)
n = serial number for sections with the same "sec" during one plot session.
BHid = Borehole name according to the GEOLIS' convention (see C.DIR)

When the plotting was finished the plotfiles were deleted.

GRAPHS

Eleven graphs were generated from each test. They were called UT,A1-A4, B1-B4, C1 and C2:

UT is a flyleaf presenting key values of flow and pressure and a preliminary value of hydraulic conductivity.

A1-A4 shows pressure-, flow- and temperature variations during the whole test cycle of an injection test in linear scale.

B1-B4 show pressure- and flow variations during the injection phase in logarithmic or semi-logarithmic scale.

C1, C2 show pressure variations during the fall-off phase in logarithmic or semi-logarithmic scale.

The graphs are filed in the archive at SGAB, Uppsala.

2.1.1.3 Processes in the Block Diagram, Figure 2-1

Pressure transducers, Amplifier unit with suppression device and Multimeter

The pressure transducer (Kistler 4043 A 100) that measured the section pressure was connected via coupling adapters and cannula tubes to the test section (Almén et al 1983). It was placed at a distance LnK from the test section. The difference between the pressure of the test section and the measured pressure was later corrected in the data processing.

The packer pressure monitoring transducer (Kistler 4043 A 50) was placed at ground surface in the measurement housing but connected to the packer pressurizing system (Almén et al 1983).

In the amplifier unit the signal from the pressure transducers were amplified from 0.05 mV/KPa to 0.1 mV/KPa and 1 mV/KPa respectively for different purposes. Due to the limited resolution of the datalogger, 3 1/2 digit, a suppression device was included in the amplifier unit. This facility was used to suppress the section pressure to zero before test start. The injection pressure was then recorded with the resolution of 1 mbar.

A digital multimeter was connected to the amplifier. With the help of a switch on the amplifier the measurement operators could read the absolute section pressure, the suppressed section pressure (= injection pressure) or the packer pressure on the multimeter display during the whole test cycle. The pressures were displayed with 5 1/2 digit which means the resolution of 1 mbar for pressures less than 200 bar. The stable pressures before and after the test were taken from the multimeter the moment they were set on the thumb wheel, Table 2.1. Readings from the multimeter were also used for the calibration of the chart recorder.

Measurement operators

There were two measurement operators at every borehole performing the tests. The operators lowered the measurement probe to the test section and commenced the test by starting up the monitoring and the data collecting instruments. They started and ended the water injection phase by opening and closing of the test valve. Another valve, also regulated by the operators, started and ended the packer inflation (Almén et al 1983). By aid of a thumb wheel device on the logger important data for the evaluation of the test were set, appendix 15.2. During the test cycle the operators changed the speed of the chart recorder and the scanning intervals of the logger, appendix 15.1.
Before a borehole was tested the flow meter units were calibrated by the measurement operators. During the injection phase they regulated the injection pressure by increasing or decreasing the flow through the flowmeter unit. The values of the flow meter scales were noted in the flow protocol. The operators also completed the flow protocol with other data and noted comments on the comment protocol.

When a number of tests were finished the operators sent data to the site hydrogeologist. A deliverance comprised record charts, cassette tapes and protocols from corresponding sections. Before the sending date and section identity were noted on the cassettes and on the charts.

The whole test as well as the work of the measurement operators were supervised by the site hydrogeologist.

Temperature transducers

The water temperature sensor was connected to the outflow of the flow meter unit, while the air temperature sensor was placed in the measurement housing (Almén et al 1983).

Flow meter unit

The flow meter unit, consists of five flow meters of type Brooks rotameter, connected in parallel (Almén et al 1983).
The flow meters are graded. The water flow is achieved by reading the graded scale and then transforming the scale values to water flow rate in accordance with a calibration made before the tests of each borehole. By increasing or decreasing the flow through the flow meter unit a constant pressure during the injection phase, read on the multimeter, was achieved. The flow

values were read and recorded (in the flow protocol) manually at stepwise increasing intervals, appendix 15.1.

Chart recorder

Parallel with the datalogger the measurement values were also registered (from the amplifier) on a chart recorder (Almén et al 1983). This was done primarily in order for the measurement operators to be in control of the progress of the test. The registration was also used for evaluation in case of datalogger breakdown and when editing the C-file. The chart recorder registered packer pressure, absolute- and suppressed section pressure, appendix 15.3. The paper feed varied during the test, appendix 15.1.

Datalogger

The control unit of the data collection system was a datalogger, type Minilogger ML 10-A (Almén et al, 1983). The data logger had 10 input channels for recording of analog signals and a parallel digital channel to which a thumb wheel device was connected. Moreover the logger included an internal clock and a tape recorder. Pressure and temperature values were assembled in the datalogger scanning being affected at stepwise increasing time intervals, appendix 15.1.

By aid of the suppression facility, earlier described, the injection pressure in the test section was registered. The thumb wheel device made it possible to register "external" data, such as stable pressure before test, section identity, the different stages of the injection test etc, appendix 15.2. Day of the month and time in hours, minutes and seconds were given by a clock in the data logger. These day/time values were registered on the tape at every scanning.

/ADDS, Tape recorder

/ADDS is an abbreviation of the programme SEG BBPRAV>CASSETTE> #ADDS on PRIME. The programme transferred data from the cassette tape to a C-file on the PRIME computer. Input data were data on the tape and the name of the C-file. Output of /ADDS was the C-file. The transfer was done by the data department at SGU before 830401 and then by SGAB.

The tape recorder used when reading data from the cassette tape to the PRIME computer was from A.D. Data Systems, Rochester N.Y. USA. The model was 817 and the serial number was 6322.

Cataloguing

The C-files, the L-files, the P-files and the M-files were catalogued in the catalogue files C.DIR, PROT.DIR, LOG.DIR and MRG.DIR respectively. The cataloguing was made by a data operator at SGU before 830401 and then by a data operator at SGAB. In LOG.DIR the hydrogeologist noted the corrections of the L-file he had done.

/INJFLAT

/INJFLAT is an abbreviation of the programme SEG BBPRAV>GEOLIS> #INJFLAT on PRIME. The programme convert a C-file to a L-file, which is a flat file and easy to read and edit. The programme also convert pressure and temperature values from mV in the C-file to Pa and °C respectively in the L-file. Input to the programme are C-file, C-file name, L-file name, GDA-code and year and month of the test. During the run of /INJFLAT key lines of the L-file, including section identity and date, and number of lines read and written are displayed on the terminal. Errors of the C-file are also displayed. Before starting of /INJFLAT a COMO-FILE, which stores text displayed on the terminal, is opened. The COMO-file was used during the editing of the L-file. /INJFLAT was run by a data operator at SGU before 830401 and then by a hydrogeologist at SGAB.

EDITING

The origin of the L-file is pressure- and temperature values from the transducers and the thumb wheel settings. In many cases the measurement operator made mistakes when he fed the datalogger via the thumb wheel. These errors were corrected by a hydrogeologist by editing the L-file. The most common errors were the wrong date, the wrong section limits, or incorrect stage number, Table 2.1. In some cases the datalogger failed and pressure values or time were taken from the record chart.

During the editing the hydrogeologist was helped by the flow- and comment protocols, the record chart, the COMO-file and his own knowledge of the stages of a water injection test.

The corrections of the L-file were catalogued in LOG.DIR.

Correction (of protocols)

When the site hydrogeologist had received the protocols from the measurement operators he checked that the protocols were correctly filled up and that they were ready for punching. If necessary he also completed the protocols with the water flow rate.

Punching

The corrected flow and comment protocols were punched to P-files by Pääjärvi stansbyrå, Uppsala before 830401. After that date the data division of SGAB (Luleå) did the punching. /TIMERG

/TIMERG is an abbreviation of the programme BBPRAV>GEOLIS>#-TIMERG on PRIME. The programme merges P-files, L-files and KROK-files to M-files and CO-files. During the run of the programme key data of the P-file and the L-file are displayed on the terminal. Key data are borehole name, section limits and data of the test section that the files contain. It is important that the key data of the L-files are the same as in the P-file. The merging procedure was handled by the data operator at SGU before 830401 and then by the hydrogeologist at SGAB.

The programme also correct the absolute section pressure of the L-file. The correction is necessary since the pressure transducer is placed a distance LnK from the test section. The correction is made with the aid of the LnK-value (from the P-file) and the inclination of the borehole (from the KROK-file).

PFLIMP

PFLIMP is an abbreviation of the programme SEG IGDUHY>PLOT>#INJ.MP on PRIME. The programme generates plot-files. Input is a M-file. Output are 11 plot-files. The plotting procedure was handled by the data department at SGU before 830401 and then by the data division at SGAB.

PLOT1, PTEX

Two plot programmes on PRIME were commonly used. They were PLOT1 (abbrev. for IGDUHY>PLOT>#PLOT_IGDUHY.1) and PTEX (abbrev. for IGDUHY>PLOT>#TEKPLT.A1_A4). 11 graphs were plotted, one for every plot file. The diagrams UT, A1-A4 were plotted on a Tectronix plotter, while the diagrams B1-B4, C1 and C2 were plotted on a Calcomp-plotter.

EVALUATION

By the aid of the graphs the test sections were evaluated and parameters such as hydraulic conductivity, skinfactors and natural section pressure were determined. Theory and evaluation methods are described in a number of reports, Ahlbom et al 1983, Andersson and Persson 1985. In some cases, when the data-logger failed, the record chart and the flow protocols were used for the evaluation.

2.1.2 Steel Pipe Equipment System, Version 3

Single hole transient injection tests with the Steel Pipe Equipment System, Version 3, which has existed since 1986, have been performed at two sites, the Finnsjön and Äspö test sites. The description below of technical data concerning this equipment is based on Almén et al (1986 a).

2.1.2.1 Collecting, Processing and Evaluation of Data

The data flow during and subsequent to a transient injection test performed with the Pipe String Equipment, Version 3, is presented in the block diagram in figure 2-7.

With this equipment, the measurement sequence is performed semiautomatically. The test is initiated by the operator, who starts the measurement program PST-86 (PIPE STRING TESTS - 86) on the measurement computer, a desk top Digital Equipment PC 350 or 380 with a 10 MByte Winchester hard disk unit and a floppy disk unit. The total program PST-86 is composed of several subprogram units. The PST-86 program can, from the functional point of view, be divided into four major parts:

1) Process control,
2) Data collecting,
3) Converting of raw data to calibrated data,
4) Plotting of graphs (this part of the program is called the ABC-plot program).

After the test program is started, the operator presses a button on the control unit (see figure 2-7). Thereby a periphery processor within the control unit activates the solenoid valves on the different pressure vessels which regulate e.g. the test valve and the packers. At the same time the processor sends a message to the computer indicating a certain phase in the test program. From the key signal lamps, which are turned on or off by the periphery processor on command from the computer, the operator becomes aware of the test phase, packer inflation/deflation and valve operations.

Once the measurement program is activated, the measurement process is running automatically, however with two exceptions. The injection flow rate is controlled manually by the operator. By regulating the valves on the flow meter unit versus the display for the injection pressure, the water pressure can be kept constant at c. 200 kPa above the hydrostatic pressure at (the top of) the test section with sufficient accuracy for a high test quality. (In very high-conductive test sections it may not be possible to reach 200 kPa. In these cases lower pressure values have to be selected for the injection.) Secondly, the operator has to press the buttons on the control unit in order to enable the test process to proceed.

The data collecting during a test is performed by the data collecting part of the PST-86-program, which is started automatically on the DEC PC when the test cycle is initiated by the operator. The program starts with some questions to the operator on background data such as calibration constants for the sensors, name of the test site, borehole location, test section identification, test crew and type of test as well as some technical data, e.g. the altitude of top of test section. After the operator has punched this data, the computer program collects values without effort from the operator. The program immediately converts raw data to calibrated data by applying the calibration constants, which results in a datafile with a so called Hydrofile format.

After phase 4 in the test cycle, i.e. the injection phase, the test is continuing automatically. The operator is however able to, at the end of the test, add comments on the test to the test file.

When the test cycle is completed, the test operator activates the part of the measurement program that produces diagrams from a menu on the DEC PC.

The complete Hydrofile from the test is saved on two floppy disks. One of these is mailed to the office, the other is a back-up disk. Data from the first disk is transferred to a DEC PC 350/380 at the office. This computer is by a telephone modem connected to the SKB VAX computer in Stockholm, the hard desks of which constitute the central part of the SKB database system, GEOTAB. Besides the hard disks on the VAX, GEOTAB consists also of magnetic tapes. After control on the DEC PC at the office of the Hydrofile data at the floppy disk, data is transferred by the telephone net to SKB VAX. When data has arrived safely to VAX, the back-up disk can be erased.

The Hydrofile is also used for producing a series of paper graphs from the test. These diagrams are described in section 2.1.2.2. This part of the program (the ABC-plot program) is activated by the operator, i.e. at the test site. The plots constitute the main tool for evaluation of the hydraulic parameters of the aquifer, and they are immediately mailed to the office for analysis by a geohydrologist. In practice, the plots from a specific test are produced during the performance of the next test, since in most cases several borehole sections are tested during one day. This way of working is time-saving. It also has the advantage that possible defects in the test performance are swiftly discovered and corrected.

The present procedure for evaluation of hydraulic parameters from the paper graphs is a two-step process: first a preliminary evaluation is performed and a preliminary report is written. Secondly, another geohydrologist, independently from the first evaluator, performs a final evaluation of hydraulic parameters, thereby using the paper graphs and the preliminary evaluation. The final data is presented in a SKB Report.

The finally evaluated hydraulic parameters are punched into a PC at the office and are, after control by the responsible geohydrologist, transferred by the telephone net to SKB VAX.

2.1.2.2 Data Volumes in the Block Diagram in figure 2-7

Injection Flow rate

The flow rate is in this equipment measured with two mass flow meters (Micromotion D 6 and D 25) connected in series. The flow rate is regulated manually as described above, but the flow values are registered automatically by the DEC PC. The flow rate signal is converted to a signal of 4-20 mA. The accuracy of the flow rate data is ± 0.4 % of rate for both flow meters. The flow meters have the following ranges:

D 6: 0 - 1 l/min
D 25: 0 - 40 l/min.

If the flow exceeds 1 l/min the D 6-meter is disconnected.

Section Pressure, Packer Pressure, Groundwater Level and Barometric Pressure

All pressures are measured with piezo resistive transducers, integrated by means of electronics to transmitters (Druck PTX). The transmitter supply power is 9-30 V dc (unregulated) and the current 4-20 mA is proportional to the measured pressure. Consequently, the cable length has no effect on the transmitter signal. The accuracy of the pressure sensors (combined linearity, hysteresis) is better than 0.1 % of full-scale.

The testing tool in the borehole is equipped with one or alternatively two or three transmitters (PTX 160, 13.5 MPa) just above the uppermost packer for recording of the pressure within and outside the test section (figure 2-7). The signals from these transmitters are received at the surface by the data collecting system. The pressures are displayed with 5 1/2 digits, giving a resolution of the pressure measurements of 0.1 kPa.

The packer pressure is measured with a transducer PTX 110, 4 MPa, installed at the pressure vessel for the packers.

The groundwater level in the borehole is registered indirectly by measuring the air pressure in a so called bubble pipe lowered to a distinct depth in the borehole a few meters below the groundwater level. The transducer used is a PTX 110, 200 kPa.

The barometric pressure is measured within the test container with a PTX 100 ABS, 120 kPa.

Water Temperature and Air Temperature

The system is equipped with four temperature sensors. One is recording the temperature of the water in the flow meter unit and two sensors are included in the pressure transmitters of the testing tool (figure 2-7). Finally, one registers the air temperature around the equipment.

All temperature sensors are of the semiconductor type with integrated electronics (temperature transmitters). As for the pressure transmitters, the power supply is 9-30 V dc (unregulated) and the current is proportional to the absolute temperature. The accuracy of the temperature data is 1° C and the resolution 0.5° C.

Scanner and Multimeter

All measuring sensors are connected to a scanner, Kiethly 705, multiplexing up to 20 different 2-pole channels. A multimeter, Kiethly 195, measures the current from the different sensors with up to 5 1/2 digits resolution. The multimeter and the scanner are connected to the computer through an IEEE interface. The scanning intervals and the resolution of the different measurements are different during the test program. These factors are controlled by the computer test program.

Control unit buttons and Display

The button function of the control unit is described in section 2.1.2.1. The display is controlled by the computer via a RS 232 interface and is showing time, phase number, injection pressure and absolute pressure in the test section. The pressures are shown with the resolution 0.1 kPa. Time is set at zero at every phase shift.

Plotter

A Hewlett Packard plotter, HP 7475 A, with six pens is used for drawing diagrams of processed data from the test. The plotter is operated from the DEC PC. Also a HP 7550-plotter with automatic paper feed can be used.

Hydrofile

The program PST-86 converts the raw data versus the calibration constants for the above mentioned variables to a so called Hydrofile. The Hydrofile is used for producing paper graphs of the tests. Since all Hydrofiles are stored on the SKB VAX, they are available for further analysis and treatment in the future.

Nyberg (1988) describes the convention for name giving of hydrofiles. The filename is written BHIDYDDDNNNNC.MMM where

BHID	: borehole name, e.g. AS02 (on DEC PC used as directory name)
Y	: one character representing the year A = 1981 B = 1982 • • Y = 2005
DDD	: day-number within the year, when the test started
NNNN	: nearest integer of borehole length (in meters) to top of the test section from top of casing
C	: one character used to separate two or more tests in the same section on the same day A = first test B = second test • •
MMM	: nearest integer of length of test section (in meters)

Paper graphs

Nineteen different graphs from each test can be generated with the ABC-plot program. The graphs are plotted on paper with a HP-plotter. The graphs are divided into three groups: A-, B- and C-plots. The A-plots, A0-A5, are all linear graphs. They preferably describe data used for judging of the technical quality of the test, e.g. packer pressure, water- and air temperature, groundwater level etc, factors of importance for the evaluation of hydraulic parameters.

The B-graphs, B1-B6, are semi logarithmic and logarithmic graphs from the injection phase, describing section pressure versus time and flow rate versus time in different transformations.

Finally, the C-graphs, C1-C7, illustrate the recovery phase. They all describe the section pressure versus time, however in different transformations.

In Appendix 15.14 a complete series of graphs with legend is presented.

Preliminary Report

The preliminary report is produced by the geohydrologist responsible for the field tests and includes a complete evaluation of hydraulic parameters. Attention is paid to technical aspects, e.g. possible instrument errors during the test. The preliminary report is not given the status of a SKB Report, but is used merely as a tool for the geohydrologist performing the final evaluation.

SKB Report

The final evaluation of hydraulic parameters results in a report of SKB status, most often a SKB Progress Report, where tests in several boreholes are presented.

SHTINJCD

The results of the transient single hole injection tests are stored in a table in GEOTAB. The table is called SHTINJCD and is described in Appendix 15.11.

2.1.2.3 Processes the Block Diagram in figure 2-7.

Measurement

The computer program used for performing a single hole transient injection test with the Pipe String Equipment System, Version 3, including process control, collection and presentation of data, is called PST-86 and was produced in 1986 at SGAB Uppsala. Programmer was Göran Nyberg. The program is thoroughly described by Nyberg (1988 a).

Normally a constant head injection test with a fall-off phase is divided into eight phases as described in section 2.1. When starting up the test program a selection is made in a menu: "INJECTION TEST AND/OR PLOT". This part of the program performs a complete injection test. There are certain prerequisites built into the program, e.g. scaninterval, sensor channels, sensor range etc. When this part of the program is started, another menu with six choices, the so called main-menu for injection tests, becomes visible on the screen. When the option "START OF INJECTION TEST" has been chosen, some questions are to be responded by the operator on background data of importance for the tests: name of the test site, borehole name, inclination of borehole, length to test section, test crew etc. as well as calibration constants for the sensors. Primarily, the program suggests the use of the same calibration constants as at the previous test. If these are still current, the operator is spared some punching, if not, new correct constants have to be entered into the measurement program.

After the above described initiating procedures, it is not necessary for the operator to communicate directly with the computer any more during the test. The equipment units that have to be handled are the flow meter unit and the control unit. It is however possible to plot graphs from previous tests during a new test. When plotting is performed during a test, a copy of the new measurement file being created during the test is produced. This file is designated "DOING.NOW". Also this file can be plotted. It is possible to enter new calibration constants for the sensors during a test and comments on the test (three lines) after its completion.

Converting

Entering new calibration constants can be performed in connection with the start of an injection test as described above. It is however possible to select this option also from the main-menu for injection tests. When this part of the program is started, the latest calibration constants together with the number of connected channels and scanner-card number for all sensors are shown on the screen. There are two calibration values for every sensor, C0 (offset) and C1 (gain). These constants can be changed if they are out of date. Until new constants are entered, the previous ones will be used in the program.

Also the background data is entered at the start of the test program or chosen from the main menu. Some of the background information, like distance from transducers to top of respective section, inclination of borehole, diameter of borehole, length of test section, is vital to the test results.

The converting part of the test program uses measured values (mA), calibration constants and relevant background data for converting raw data to calibrated data from which e.g. the K_{ss}-value of the test is calculated. The converting is performed simultaneously with the collection of data.

Plotting

The plotting part of the test program is designated the ABC-plot program. The program is described by Nyberg (1988 b). The ABC-plot program is able to produce graphs on the computer screen and on paper with the Hewlett Packard plotters 7475 A or 7550. When the HP-plotter 7550 is used, the program permits plotting of all A-, B- and C-plots automatically without the operator giving commands for every single plot. However, only the HP 7475 A-plotter has been used in the Pipe String Equipment System, Version 3, in the SKB-investigations. Data sent to the plotter is in HPGL. As mentioned before, previously performed tests can be plotted simultaneously with a new test being performed.

Collected values are stored either on the hard disk of the DEC PC or on a floppy disk. The file has to be created according to the so called Hydrofile format (see above).

The plotting is governed by three control files:

1) Test-phase file	specifies how different criteria for start of test phases are to be defined,
2) Definition file	specifies the definition of some reference values, e.g. P_i, P_0, P_p, P_f etc,
3) Plot-picture file	specifies the appearance of the A-, B- and C-plots such as the size of the diagrams, type of transformation of the measured values etc,

When the plot program is started, the operator has to make selections on a multichoice menu which leads to a new menu etc. In the first menu the actual datafile is selected. The name of the file defines the test section and the date of tests. In the next menu the type of plot is decided. In this case the A-, B- and C-diagram selection is made. In the following menus there are options between plotting directly on paper or first on the screen and, if required, later on paper. Other choices can be made between grids or no grids on the plot papers (and on the screen) and between lines or no lines between data points. The operator then uses a menu on the screen to command the diagrams to be plotted one by one. If the scaling of the diagram is not satisfactory, the operator has the possibility of changing it.

Preliminary and final evaluation of hydraulic parameters

The extensive set of graphs from every injection test permits a thorough evaluation of the technical standard of the test, especially from the A-graphs. Many external factors may have an influence on the results of an injection test: injection water temperature, air temperature surrounding the test equipment etc, and therefore the control system built into the test equipment is necessary. The control of the degree of technical success together with the set of B- and C-graphs with different transformations, provides a tool for very accurate evaluation of hydraulic parameters such as hydraulic conductivity, skin factor, storage capacity, different flow regimes, hydraulic boundaries etc. The fact that this evaluation is performed twice by two from each other independent hydrogeologists is aimed to raise the quality of the results further more.

2.1.3 Umbilical Hose Equipment System, Version 1

Single hole transient injection tests with the umbilical hose equipment version 1 were performed during the period 1981 -1986 at seven sites.

2.1.3.1 Collecting, Processing and Evaluation of Data

The data flow is presented in the block diagram in figure 2-2.

The pressures measured during a test were section pressure, packer pressure, barometer pressure and groundwater pressure just below the groundwater level. Three temperatures were measured: temperature of the injection water, temperature in the test section and outer air temperature. Finally the injection flow rate was monitored.

The test began with starting up the monitoring and data collecting units. The measurement probe, containing the packers and the sensors, was then lowered to the test section. Via the ABC 80 computer borehole data such as borehole name, the inclination of the borehole, length to test section and section length were fed into the datalogger. The data logger and the ABC 80 registered and monitored all the data necessary for evaluation during the entire test cycle. Data was stored on a cassette tape. The system also automatically regulated valves, packer pressure, injection pressure and injection flow during the measurement sequence in accordance with the demands of a constant head transient injection test. Comments could be entered on the data tape when the measurement cycle was completed. During the test measurement quantities could be graphically displayed on the screen of the ABC 80.

When the injection test was finished the data on the cassette tape was transferred to a diskette on a second ABC 80 unit. The same ABC 80 was used when 11 graphs from each test section were plotted on a plotter.

When a number of tests (generally 10-20) were completed the resulting data were sent to the site hydrogeologist for evaluation and storing. A deliverance comprised cassette tapes (two tests on each tape), diskettes (one for every test) and graphs (eleven graphs for every test).

Before April 1, 1983 the hydrogeologist sent the cassette tapes to the data department at SGU for reading to C-files on the host computer (PRIME). After 830401 the reading procedure was performed by the data division at SGAB to SGAB's PRIME 750.

Using the graphs the hydrogeologist determined the hydraulic parameters of the test sections. The results were noted in a result protocol and then punched to the result table SHTINJ in the GEOLIS database. GEOLIS is a database in SGU's PRIME 750. After August 1, 1982 GEOLIS was transferred o SGAB's PRIME 750 in Luleå.

During 1986 the result table SHTINJ was transferred to the VAX750 computer at KRAB in Stockholm and the GEOTAB database, where the results of the transient injection tests can be found in the table SHTINJCD.

2.1.3.2 Data Volumes in the Block Diagram Figure 2-2

Section Pressure

Section pressure was measured by two pressure sensors called P1 and P2, placed beneath the upper packer in the test section. Only data from one of the two sensors were stored on the cassette tape. In the beginning of the measurement sequence the stable absolute pressure of the test section, called P8, was stored. P8 was the reference pressure when the differential pressure (dP) of the test section was determined. During the injection phase dP was equal to the injection pressure in the measurement section.

Packer Pressure

The packer pressure was monitored by two pressure transducers, named P4 and P14. Pressure values from one of them (P4) were stored in the data file. They were placed at ground surface and were connected to the packer pressure system.

Barometer Pressure

The barometer pressure was measured by a pressure sensor B0 at ground surface.

Groundwater Pressure

The air drive pressure, that made the air pass through the bubble tube, corresponded to the groundwater pressure in the bubble tube. The air drive pressure was measured by the pressure sensor P7.

Temperatures

Three temperatures were measured during the entire measurement sequence: Temperature of the water in the test section, temperature of the injection water and outer air temperature.

Water Flow Rate

The injection water flow rate was measured by three flowmeters, covering the measuring range 0.005 - 117 ml/second. Before the injection phase, a reference measurement was made by opening a cannula tube in the system (Almén et al 1983).

Relay Values

The different valves of the pressurizing system of the umbilical hose equipment were regulated by means of relays (Almén et al 1983). The number of the relay and whether the relays functioned or were released (negative number) was registered and stored by the datalogger.

Borehole Data and Comments

Before the start of the injection test the measurement operators typed borehole data on the keyboard of the ABC 80 computer. The borehole data were registered by the datalogger and were as follows:

SSNN:	Borehole name, SS=site code NN=borehole number
Date:	Date of test; Year,Month,Day
IW:	Inclination of the borehole (degrees)
L:	Length of test section (m)
LO:	Length to upper limit of test section along the borehole (m)
LB:	Length of the bubble tube (m)
DW:	Diameter of the borehole (mm)

When the test sequence was completed the operators could feed comments via the ABC 80 unit.

Cassette Tape

The values regarding pressure, temperature, flow and relays as well as the borehole data registered by the datalogger were stored on the cassette tape, see C-file.

As a rule the cassette tape contained data from two injection tests, one on each side.

On the cassette the operator wrote the borehole name (site code + borehole number) upper and lower limit of the test section, the date of the test and his own signature.

When the processing and the evaluation of data from the tapes was finished the tape content was aborted.

C-FILE and C-File Name

The C-Files were named according to the following convention:

CBHNR.NL (example: CKM12.1A)

C: Type of file; C = cassette file
BH: Site code,two letters; GI for Gideå

KM for Kamlunge...

NR: Borehole number within the site; 1-99
N: Number of cassette from each borehole
L: Side of the cassette tape, A=A-side, B=B-side

One C-file contains the data registered by the datalogger and stored on the cassette tape during one test, including the borehole data fed in by the measurement operators, appendix 15.6 and 15.7. Pressure, temperature and flow rate are indicated in kPa, °C and ml/s respectively. The groundwater head is indicated in vertical distance between the top of the casing and the groundwater level. This value is calculated by the programme "WATER" from the bubble tube pressure, the length of the bubble tube and the inclination of the borehole. In the C-file the numbers of the relays used during a test sequence are stored, appendix 15.6 and 15.7.
The C-files were stored on magnetic tapes at SGAB and SGU. During 1986 the C-files were transferred to magnetic tapes at KRAB.

CAS.DIR

CAS.DIR has five columns:

Column 1: File name
Column 2: Borehole name
Column 3: Upper limit of section
Column 4: Lower limit of section
Column 5: Comments

The borehole names in column 2 were assigned according to a convention used in SGU's and SGAB's database GEOLIS, see chapter 2.1.1.2.

CAS.DIR is now (1986) stored on magnetic tapes at SGAB. During 1986 a copy of CAS.DIR was transferred to magnetic tapes at KRAB.

DAT.DTA, Diskette

The data stored on the cassette tape were transferred to a file named DATA.DTA on a diskette via the second ABC 80 computer. This was done when a test was finished or during the test by the program PLOT.

Thus, the diskette contains data from one test, the same data that can be found in the corresponding C-file, appendix 15.6 and 15.7. Section identity and date of test were written on the diskette.

The diskettes are currently (1986) in the archive at SGAB, Uppsala.

GRAPHS

Eleven graphs were generated from each test. With a few exceptions they look like the graphs obtained from transient injection tests with steel pipe equipment, chapter 2.1.2, and they were called A0, A1-A4, B1-B4, C1 and C2.

A0 is a flyleaf presenting key values of flow and pressure and a preliminary value of hydraulic conductivity.

A1-A4 show pressure, flow temperature and groundwater level variations during the whole measurement sequence in a linear scale.

B1-B4 show pressure and flow variations during the injection phase in a logarithmic or a semi-logarithmic scale.

C1, C2 show pressure variations during the fall-off phase in a logarithmic or a semi-logarithmic scale.

The graphs are filed in the archive at SGAB, Uppsala.

SHTINJCD

The results of the water injection tests were stored in the table SHTINJCD in SKBs database GEOTAB.

2.1.3.3 Processes in the Block Diagram, Figure 2-2

Pressure transducers

The different pressures were monitored by pressure transducers, type Kistler 4043A100. The section pressure meters, P1 and P2, were located in the test section just below the upper packer.
The packer pressure sensors, P4 and P14, were connected to the packer pressurizing system at ground surface. Also the barometric pressure sensor B0 was placed at ground surface.

Pressurized Bubble Tube

The groundwater head was determined by means of a steel pipe of length known (=LB) and air was made to pass through the pipe by means of a back pressure valve. The air drive pressure measured by the pressure sensor P7, corresponded to the water column height in the pipe.

From the drive pressure, LB and the inclination of the borehole the groundwater level in the borehole was determined. This was done by the programme "WATER".

Temperature sensors

The temperatures were measured by temperature sensors, type PT100, range 0-100 centigrades. They were placed in the test section (water temperature in the test section T2), in the measurement trailer (temperature of the injection water T3) and outside the measurement trailer (outer air temperature T4).

Flow Meter Unit

Three flow meters (Fisher and Porter, Minimag and OBF) measured the water flow rate. They represent three strictly delimited measurement ranges.

Q1 = 117-1.17 ml/s
Q2 = 1.7-0.08 ml/s
Q3 = 0.1-0.005 ml/s

Q1 was always connected. The other two flow meters were automatically switched on when the flow rate decreased. The flow meters measured a change in voltage applied across a measurement hole (Almén et al 1983).

From 1985 a new flow meter unit was utilized. This was a Micro-motion D 65-SJ within a maximum flow of 1455 l/min and a zero stability of ± 0.09 ml/min.

Measurement Operators

The measurement operators started the measurement sequence by executing the programme "WATER" on the ABC 80 computer. During the test they controlled the data flow on the display of the computer and intervened when necessary with corrections of measurement values or calculation routines. Via the ABC 80 they also fed borehole data to the datalogger. When a test was finished the operator plotted the graphs by means of a second ABC 80 and the program "PLOT" on the plotter. They also noted section identities and date of test on the cassettes and on the diskettes.

DATALOGGER

The datalogger used was a Monitor Lab. It registered the measurement values and sent them to the ABC 80 computer for processing. The datalogger was connected to a SIO card. The card holds two channels of which the datalogger uses one referred to as channel A

(Almén et al 1983).

ABC 80, CS3 Tape Recorder, WATER and PLOT

The heart of the system was an ABC 80 (I) computer comprising the programme "WATER". It controlled the measurement process and received measurement values from the datalogger. After processing the measurement values were stored by the data tape recorder.

A second computer, ABC 80 (II), was used for transferring measurement data from the cassette tape to a diskette and for plotting the graphs immediately after completion of the test.

When the registered data were processed by the ABC 80 (I) unit they were stored by the tape recorder. The tape recorder was a CS3 recorder, connected to the B-channel of the SIO card (Almén et al 1983).

The software of the system is divided into two main programmes:

"WATER" and "PLOT". "WATER" is used when collecting data whereas "PLOT" is used for transferring data from the cassette tapes to the diskettes and for plotting the graphs. Independent drive routines are used for the plotter, for the CS3 tape recorder and for handling of data received from the data-logger. These drive programmes are written in Assembler (machine language) and cannot be revised without special equipment.

Other drive routines are enclosed in the main programmes in the form of sub-routines and consequently written in BASIC. The Assembler routines are loaded by means of special BASIC programmes named "MON" and "PLOTDRIVE", resp. The programmes of the system are presented in Table 2.2.

Table 2.2 Programmes used for the umbilical hose equipment

Program	Purpose of Program
BOFA.BAC	Initiates the drive routine for the datalogger
MON.ASM	Drive routine for the datalogger, Assembler programme
MON.BAC	Basic programme, which loads the drive routine MON
CS3.ASM	Drive routine for the CS3-tape recorder
IECLINK.ASM	Automatic start routine. Loads from the CS3-tape recorder
WATER.BAC	Main programme for data collecting
PLOT.BAC	Initiates the drive routine of the plotter

PLOTDRIVE.BAC Basic programme, which loads the drive routine of the plotter

PLOTUT.BAC Main programme for plotting, manual

PLOTTA.BAC Main programme for plotting, automatic

The "WATER" programme simultaneously performs three different main tasks:

- Controls the measurement process
- Shows the operator what is going on
- Saves measurement data for subsequent evaluation

The control function has been included in the form of a sequence table where a complete measurement cycle is automatically run through once it has been initiated. A measurement cycle consists of a packer sealing phase, an injection phase, and a fall-off phase immediately afterwards. Below is a description of the activities stored in the sequence table . "T" signifies minutes after start of measurement.

T = 0 Certain input data, such as date, name of drillhole, length of measurement section, are stored in the tape recorder

T = 1 The relief valve opens. Measurement data begin to be stored on the tape

T = 2 Inflation of the packers. Adaption of the feed water tank pressure to the groundwater level. Initiating of rapid measurement value storage (every other second). The biggest flow meter is switched in to pressurize the hose.

T = 3 Stopping of rapid measurement value storing.

T = 22 Checking that flow = 0 (no leaks). The cannula test valve is opened. Automatic exchange of flow meters initiated.

T = 25 Saving of cannula flow for subsequent check. Closing of cannula test valve. Closing of the relief valve (after 821000).

T = 29 Repeat check that flow = 0. Closing of relief valve (before 821000). Switching in of the biggest flow meter.

T = 30 The now pressurized packers are cut off from their pressure tank. Supervision of packer pressure initiated. Rapid measurement value collection started. Test valve opened. This is the starting point of the injection phase.

T = 31 Rapid measurement value collection stopped. Automatic exchange of flow meters initiate. Regulation of overpressure in measurement section to 200 kPa is initiated.

T = 150 Regulation of the pressure in the measurement section discontinued. Rapid measurement value started. Test valve closes. This is the end of the injection phase and the initiation of the fall-off phase.

T = 151 Rapid measurement value collection stopped. Checking that flow = 0.

T = 170 Cannula test valve is opened.

T = 174 Checking that cannula flow = previous cannula flow. Flow meters disconnected. Test of change in pressure in measurement section initiated. Should the pressure decrease slowly enough the test can be discontinued, i e the computer jumps to T = 270.

T = 270 Packer pressure released. This is the end of the fall-off phase.

T = 300 One measurement cycle completed. The data storing is discontinued. Comments may be entered on the data tape.

During the injection phase (from T = 30 to T = 150) the programme aimed to maintain an injection pressure of 200 kPa. The time, however, that was required to reach a constant pressure was too long in many test sections, up to 10 minutes. Therefore the programme was modified. The "new" programme succeeded in reaching a constant injection head much faster, often before 60 seconds of injection. The "old" programme was used from 1981 to 1983 and the "new" programme from 1984 to 1986.

There were two plotting programmes: one automatic and one manual,Table 2.2. The automatic is ordinarily to be used for productional diagrams as soon as possible on preprinted forms. The manual programme makes it possible to plot random measurement values in order, e g to check transducer or a regulation device.

Of great importance in the automatic plotting programme was the criteria for the start of the injection phase and fall-off phase (t = 0 and t′ = 0 respectively). The criteria were as follows:

t = 0 the scanning that preceded the scanning when Q_{tot} > 500 ml or dp > 10 kPa

t′= 0 The scanning that preceded the scanning when dP2 > 2 kPa

where

t = Time from injection start in the B-graphs (s)
t′= Time from fall-off start in the C-graphs (s)
Qtot = Injection volume during injection phase (ml)
dp = Injection pressure during injection phase (kPa) dP2 = Pressure drop during fall-off phase (kPa)

MDS Tape Recorder

The data tape was read into the host computer by means of a MDS tape recorder and a programme named MDS. The host computer was SGU's PRIME before April 1, 1983 and then SGAB's PRIME 750.

Cataloguing

The C-files were catalogued by data operators at SGU before April 1, 1986 and then by a hydrogeologist at SGAB.

PLOTTER

The plotter used was for A4 and manufactured by Houston Instruments (model EDMP-2M). It was connected directly to the V:24 gate in the keyboard of the ABC 80.

EVALUATION

The graphs of the test sections were evaluated and parameters such as hydraulic conductivity, skinfactors and natural section pressure were determined. Theory and evaluation methods are described in a number of reports, Ahlbom et al 1983, Andersson and Persson 1985.

2.1.4 Umbilical Hose Equipment System, Version 2

Single hole transient injection tests with the Umbilical Hose Equipment System, Version 2, have been performed between 1986 and 1991 at one site in Sweden, the Ävrö test site, and also in Japan. As for the Pipe String Equipment System, Version 3, the technical data is thoroughly described by Almén et al (1986 a), to which report much of the description below is referred.

2.1.4.1 Collecting, Processing and Evaluation of Data

A single hole transient injection test performed with the Umbilical Hose Equipment, Version 2, is divided into the same test phases as described in section 2.1.

The data flow relevant for transient injection tests with the Umbilical Hose Equipment, Version 2, as well as a schematic design of the two trailer units constituting the system are presented in the block diagram in figure 2-8. A skeleton drawing of the testing tool with a two packer configuration is illustrated in figure 2-9. For instance, all transducers in the tool are shown in the figure. The signal cables from these are running inside the cover of the umbilical hose to the measurement and recording trailers on the ground surface.

In the Umbilical Hose Equipment System, Version 2, the measurement sequence is fully computer controlled. A transient injection test with this equipment is initiated by the operator. However, the operator only activates the measurement program WATER run by the measurement computer, which is of the same type as that of the Pipe String Equipment, Version 3, i.e. a desk top Digital Equipment PC 350 or 380 with a 10 MByte Winchester hard disk unit and a floppy disk unit. The task of the program is to run the test process, to collect, store and present measured data and to enable the operator to supervise and check the values during the test.

The computer program WATER is composed of several subprograms. As for the Pipe String Equipment, Version 3, the test program can be divided into four major parts:

1) Process control,
2) Data collecting,
3) Converting of raw data to calibrated data,
4) Plotting of graphs (this part of the program is called the ABC-plot program).

The result of the data collecting and converting by applying calibration constants is a datafile with Hydrofile format (see section 2.1.2.2).

When the test cycle is completed, the test operator activates the ABC-plot program via a menu on the DEC PC computer. This subprogram is identical with that used in the Pipe String Equipment System, Version 3 (see sections 2.1.2.1 and 2.1.2.3), the so called ABC-plot program.

The routines and data flow after a completed test cycle are identical with the corresponding processes for the Pipe String Equipment, Version 3, compare figures 2-7 and 2-8. For comments on this part it is therefore referred to sections 2.1.2.1, 2.1.2.2 and 2.1.2.3.

2.1.4.2 Data Volumes in the Block Diagram in Figure 2-8.

Injection Flow rate

The flow rate is in this equipment measured with two flow meters designated Q1 and Q2 connected in series. Q1 is a Minimag flow meter manufactured by Fisher and Porter. The range of this flowmeter is 0.09 - 7 l/min and the accuracy ± 1.0 % of rate. The Q2 meter is a Micromotion, model C6. The range is in this case 0 - 0.1 l/min and the accuracy ± 0.4 %. The flow meter Q1 is always connected during flow measurements. When the lower limit value 0.09 l/min for this flow meter is attained, the smaller flow meter Q2 is automatically switched on. The flow meters are controlled by the surface periphery processor PP:1.

Section Pressure, Packer Pressure, Groundwater Level and Barometric Pressure

The pressure in the test section is measured with two piezo resistive transducers, Kistler type 4043 with a pressure range of 10 MPa. The unlinearity and repeatability of the transducers are better than 0.3 % and 0.1 % of full scale, respectively. The transducers are installed within the processor housing below the packers (see figure 2-8) and are connected to the periphery processor PP:2.

Similar transducers are used for measuring the packer pressure. Like in the Pipe String Equipment, Version 3, the groundwater level is measured by means of a bubble pipe. The barometric pressure, finally, is measured with a barometric transducer. All surface pressure sensors are connected to the periphery microprocessor PP:1.

Water Temperature and Air Temperature

Temperatures are measured at three points. The injection water is measured in the measuring trailer before entering the umbilical hose but also in the test section, and the air temperature is measured in the measuring trailer. The temperature sensors are connected to PP:1 and PP:2.

Periphery processors

Two or more microprocessor cards, called periphery processors PP:1 and PP:2 are connected to the computer via a realtime interface RS 232/422. The processor cards include an A/D converter giving a resolution of 0.1 kPA for 1 000 kPa pressure range. It also contains a D/A converter for two analog signals and a relay function.

PP:1 controls all regulation units and measuring sensors situated at the surface and is installed in the measurement trailer (figure 2-8). Processor PP:2 is controlling valves, pressure- and temperature transducers and a moisture sensor. It is mounted within the testing tool inside a water-tight cover (figure 2-8).

Plotter and Printer

A Hewlett Packard plotter, HP 7550 A, with automatic paper feeding is used for drawing diagrams of processed data from the test. The plotter is operated from the DEC PC computer.

Also the printer, a Digital LA50, is connected directly to the DEC PC. The outprint is used merely for control of different functions during test and is not used for evaluation of hydraulic parameters.

Hydrofile, Preliminary Report, SKB Report and SHTINJCD

Concerning the data volumes in the headline above, it is referred to the corresponding description for the Pipe String Equipment System, Version 3. However, what is mentioned about the program PST-86 should be exchanged to the program WATER.

2.1.4.3 Processes in the Block Diagram in figure 2.-8

Measurement

The WATER program, produced in 1986 by Dan Stenberg, SGAB Malå, (except the ABC-plot program, which is identical to that used in the Pipe String Equipment System, Version 3) simultaneously performs three different main functions:

1) process control,
2) data collecting,
3) reporting the test process to the operator

Control functions are included in the form of a sequence table, where a complete hydraulic measurement cycle is run through, once it has been initiated. A transient injection test cycle is characterized by some introductory processes and controls. These are followed by the injection phase and the fall-off phase. The sequence table is shown below, where "T" represents minutes after test start. The number of minutes can easily be changed to other values, if desired.

T = 0	Certain background data, such as name of the test site, borehole name, date, length of measurement section etc are punched by the operator.
T = 1	Relief valve 1 opens. Storage of measured data is initiated.
T = 2	Inflation of packers. Control of the groundwater level system starts. Rapid storage of measured values starts (every other second). The large range flow meter is connected and the umbilical hose is pressurized.
T = 3	Rapid storage of data stops.
T = 10	Checking of the tightness of the flow system (flow should be = 0). Opening of the cannula test valve. Automatic exchange of flow meters initiated.
T = 15	Cannula test valve closes. The flow is stored for later check.
T = 25	Closing of relief valve. Repeated 0-flow check. The large range flow meter is connected.
T = 29	Rapid storage of data is started.
T = 30	Inflation of packers closes. Monitoring of packer pressure continues. The injection phase is started by opening of the test valve.
T = 31	Automatic change of flow meters initiated. Regulation of the injection pressure initiated.
T = 32	Rapid storage of data stops.
T = 149	Rapid storage of data starts.
T = 150	Regulation of the injection pressure stops. Test valve closes and the injection stops. Pressure fall-off phase starts.
T = 152	Rapid storage of data stopped. 0-flow check.
T = 170	Cannula test valve is opened.
T = 174	Checking that cannula flow rate is identical with the corresponding value before test. Flow meters disconnected. Test of pressure decrease in the test section initiated. If the pressure decrease is sufficiently slow, the test can be interrupted, i.e. the computer jumps to T = 270.
T = 270	Packer deflation. End of pressure fall-off phase.
T = 300	Test cycle completed. Data storage stops. Comments may be entered on the data file.

Normally the operator only initiates the test sequence. Acoustic signals warn if some error would occur and when the test sequence is completed. However, the operator is always able to intervene in the process, if necessary. A printer continuously prints out data from the test. The print-out is used only by the operator for control and does not have to be saved after the test.

Converting, Plotting, Preliminary and Final evaluation of hydraulic parameters

Concerning converting of raw data, plotting and evaluation of hydraulic parameters, it is referred to section 2.1.2.3. A minor difference between the two equipment systems is, that in the Umbilical Hose Equipment, Version 2, the plotter HP 7550 with automatic paper feeding is used, whereas the plotter HP 7475 A is employed in the Pipe String Equipment, Version 3.

2.1.5 Single Hole Transient Injection Tests in GEOTAB

The flyleaf data and result data from the single hole transient injection tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table SHTINJF1 - Flyleaf 1 Company, person(s) responsible, references

Table SHTINJF2 - Flyleaf 2 Equipment Table

Table SHTINJF3 - Flyleaf 3 Minimum K - table

Table SHTINJF4 - Flyleaf 4 Comment(s)

Table SHTINJF5 - Flyleaf 5 Flow Regimes Table

Table SHTINJD - Data Table

Table SHTINJCD - Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

2.2 SINGLE HOLE STEADY-STATE INJECTION TESTS

The main purpose of performing single hole steady-state tests is the same as for transient tests, to determine hydraulic parameters. The steady-state test-cycle is however much shorter and includes only the injection phase. The injection time is seldom longer than 15 min. Therefore this method is economically advantageous. The accuracy of evaluated test parameters is however not comparable with corresponding values from transient tests, i.e. the test quality does not quite reach the standard of the transient tests.

2.2.1 Steel Pipe Equipment System, Version 1

During 1977-1980 the single hole steady-state tests were performed by the aid of the steel pipe equipment, version 1. This equipment did not have any recording instrument. The measurement data were noted manually in protocols and only flow and pressure values at the end of the injection phase were taken in account when determining the hydraulic conductivity. The packers used were sealed against the borehole wall in a hydro-mechanical way, and their length were 0.3 m. The packer sealing phase varied between 10 and 30 minutes, while the injection phase varied from approx 3 minutes to approximately 30 minutes.

2.2.1.1 Collecting, Processing and Evaluation of Data

Data flow is presented in the block diagram in figure 2-3.

During a test section pressure, injection pressure and injection flow rate were measured. The section pressure was monitored by a pressure transducer connected to the test section and located just above the upper packer. The injection flow was measured by a flow meter unit in the measurement housing. Two manometers were connected to the outflow pipe of the flow meter unit. They measured the applied injection pressure during the injection phase.

The output signal from the pressure transducer was received at ground level by an amplifier unit. Before the injection phase the absolute pressure of the test section was suppressed and a reference pressure was stored by the aid of a suppression facility. The suppressed pressure value was equal to the injection pressure during the injection phase. On a digital display on the amplifier unit the pressure values could be read. The injection pressure at injection stop was noted in a measurement protocol. Unfortunately, the pressure transducers were out of order in many cases. Then the injection pressure was taken from the manometers instead.

During the injection phase a constant injection pressure was maintained by regulating the water flow passing through the flow meter unit. The regulation was done by the measurement operators. The flow value at injection stop was noted in the measurement protocol.

The test sections were tested several times consecutively with different pressures. The injection pressures used were 200 kPa, 400 kPa and sometimes 600 kPa or 800 kPa.

When a number of tests were completed the measurement protocols were sent to a hydrogeologist at SGU. The hydrogeologist calculated the hydraulic conductivity of the test sections.

The results of the steady-state tests with this equipment have been stored in the table SHSINJCD in SKBs database.

2.2.1.2 Data Volumes in the Block Diagram, Figure 2-3

Section Pressure

The section pressure was measured by a transducer placed above the upper packer of the test section. In the tests performed during 1977 (in eight boreholes) the transducer was connected to the test section through a plastic pipe. To eliminate deformations of this connection during the packer sealing phase the equipment was modified and from 1978 the transducer was connected to the test section through a telescope pipe made of stainless steel.
The output signal from the pressure transducer was received at ground level by an amplifier unit, amplifying the signal and presenting the section pressure on a display on the amplifier unit. By the aid of a suppression facility the absolute section pressure was suppressed before the injection phase. At the same time the absolute section pressure was stored as a reference. The suppressed pressure was equal to the injection pressure in the test section during the injection phase. A switch on the amplifier unit made it possible to read the absolute pressure, the suppressed pressure and the reference pressure on the display. The pressure values on the display were presented in bars with two decimals. When the pressure transducer malfunctioned the injection pressure was determined by subtracting the pressure losses in the pipe string from the manometer pressure.

Applied Injection Pressure

The two manometers measured the excess pressure caused by the injected water. Thus this pressure was equal to the applied injection pressure during the injection phase.

Injection Flow Value

The flow meter unit consisted of six flow meters connected in parallel. The measurement operator read the scale divisions on the flow scales and the flow meter in question. But only one flow value at the end of the injection phase was noted in the measurement protocol.

Measurement Protocol

The measurement protocol contained a protocol head and a table for measurement data. The protocol head comprised borehole name, date of test, identity of transducer, manometers and flow meter unit and occasionally the vertical distance between the top of the casing and the groundwater level.

The data table comprised section limits along the borehole, absolute pressure before packer sealing, constant injection pressure from transducer and/or the manometers, flow meter number and scale division corresponding to the water flow at the end of the injection phase and the signature of the measurement operators. Furthermore, there was a comment column, where the operators noted pressures during the test, duration of the packer sealing phase, water temperature and other data relevant for the evaluation of the test. The table contained data from 2-4 tests. The pressure values were expressed in bars with two decimals.

The measurement protocols are currently (1986) stored in the archive at SGAB, Uppsala.

Result Tables

The result from the steady-state injection tests were noted in tables. These tables vary. In general, they comprise 6 columns containing section limits, flow meter number, scale division, flow rate at the end of the injection phase, constant injection pressure in the test section and hydraulic conductivity (m/s) of the test section. The injection pressure value (expressed in meter water column) was taken either from the transducer or the manometer. In the latter case, pressure losses in the steel pipes were subtracted from the read value.

2.2.1.3 Processes in the Block Diagram, Figure 2-3

Pressure Transducer and Amplifier Unit

The pressure transducers were located above the upper packer in the borehole, see chapter 2.2.1.2. During 1977 two transducers from Entran Devices Inc, EPN 350 1000 AW and EPN 350 2000 AW, were used. They were coupled in parallel and had different measurement ranges, 0-1000 psi and 0-2000 psi respectively. From 1979 transducers from CJ Enterprises (CJ DC 60-23) were used. They had a measurement range between 0 and 99.99 bar.

Each pressure transducer was connected to a specific amplifier unit at ground level. The unit had a suppression facility and a digital display, which presented the measured pressure value in bars. A switch on the amplifier box enabled reading of the absolute pressure, the suppressed pressure and the stored reference pressure on the display. The amplifier unit was designed and produced by Studsvik Energiteknik AB, which also calibrated the unit together with the corresponding pressure transducer.

Manometers

The two manometers were connected to the outflow of the flowmeter unit. The measurement ranges were 0-0.6 MPa and 0-1.6 MPa respectively.

Flow Meter Unit

The flow meter unit consisted of 4-6 flow meters connected in parallel, type Brook's rotameters with mutually overlapping measurement sectors (Almén et al 1983). The measurement values read on the flow meters were later converted to flow rate values in accordance to calibration diagrams from the manufacturer. The lowest measurable flow rate varied between 1.42×10^{-8} m^3/s and 1.33×10^{-7} m^3/s depending on the flow meters used. Maximum measurable flow rate was 1.08×10^{-3} m^3/s.

Measurement Operators

There were two measurement operators at every borehole. They brought down the measurement probe to the test section and started the measurement sequence by expanding the rubber packers against the borehole wall. During the injection phase the operators maintained a constant injection pressure by regulating the water flow through the water flow meters. They wrote down the pressure and flow values as well as other data in the measurement protocol.

EVALUATION

On the basis of the measurement protocols a hydrogeologist at SGU evaluated the single hole steady-state tests. The water flow values of the protocols were converted into water flow rate (m^3/s) by means of calibration diagrams from the manufacturer of the flow meters. If the pressure transducer were out of order the injection pressure in the test section was taken from the manometers. Then the pressure losses in the infiltration pipe string were subtracted from the read value on the manometer. The pressure losses were determined earlier for different flow rates and different pipe string lengths in a calibration test performed on an airfield. When the pressure and flow values were determined the hydraulic conductivity of the test sections were determined according to the equation.

$$K = \frac{Q_p}{L \times H} \times \frac{1 + \ln (L/dw)}{2\pi} \qquad (2.1)$$

where

K = Hydraulic conductivity (m/s)
Q_p = Water flow rate at injection stop (m^3/s)
L = Length of the test section (m)
H = Constant injection head in the section (m water col)
dw = Diameter of the borehole (m)

2.2.2 Steel Pipe Equipment System, Version 2

Single hole steady-state injection test with steel pipe equipment version 2 were performed at four sites during the years 1982 and 1983.

2.2.2.1 Collecting, Processing and Evaluation of Data

Data flow is presented in the block diagram figure 2-4.

The data collecting routines and instruments were almost the same for steady-state test with this equipment as for the transient test with the same equipment, chapter 2.1.1. The difference between the two methods was that during the steady-state tests the measurement sequence was interrupted 15 minutes from the water injection start and as a consequence stage 4 (Table 2.1) became shorter and stage 5 was omitted.

The data of the cassette tapes were read into the host computer and filed in the catalogue file C.DIR. However, no L-files nor M-files were created. The protocols were checked and completed but they were not punched into P-files.

On the basis of the data from the record charts and the protocols the hydrogeologist at SGAB determined the hydraulic conductivity of the test sections. The results were during 1986 stored in the table SHSINJCD of the database GEOTAB.

2.2.2.2 Data Volumes in the Block Diagram in Figure 2-4

All the data volumes of figure 2-4 except one can also be found in figure 2-1 and they are described in chapter 2.1.1.2. The one that is not described in that chapter is

SHSINJCD

The results of the single hole steady-state test with the steel pipe equipment version 2 have been stored in the table SHSINJCD in SKBs database. SHSINJCD is described in Appendix 15.11.

2.2.2.3 Processes in the Block Diagram in Figure 2-4

Also the processes of figure 2-4 are described in chapter 2.1.1.2 with one exception, which is

EVALUATION

A hydrogeologist at SGAB determined the constant injection pressures in the test sections from the record charts. The flow rates at injection stop was taken from the corrected protocols.
The hydraulic conductivity was then calculated according to equation 2.1, chapter 2.2.1.3.

2.2.3 Steel Pipe Equipment System, Version 3

The performance of a steady-state test with this equipment system is in principle the same as the performance of a transient test. The differences are of a practical nature. The operator changes the length of the injection phase and excludes the fall-off phase manually by operating the buttons of the control unit (see section 2.1.2.1). He may also shorten the packer inflation time from 30 min to e.g. 10-15 min, depending on the specific demands relevant for the test. When plotting diagrams, the C-graphs are excluded and from the A- and B-graphs only those are selected which are regarded most interesting for the actual test. The reduced number of graphs from the test implies that the evaluation of hydraulic parameters is not quite as thorough as for transient tests. Concerning data flow as to the rest, it can be referred to the description in section 2.1.2.

2.2.4 Umbilical Hose Equipment System, Version 1

Single hole steady-state tests with the umbilical hose equipment version 1 have been performed at two sites (Kamlunge 1983 and Finnsjön 1986).

2.2.4.1 Collecting, Processing and Evaluation of Data

Data flow is presented in the block diagram in figure 2-5.

The routines for collecting and processing of data as well as the instruments were almost the same for steady-state tests with this equipment as for the transient tests with the same equipment, chapter 2.1.2. Also the programmes and the hardware were the same. The difference in performance between the two methods was that during the steady-state tests the water injection phase was interrupted 15 minutes from the injection start.
Thus the control functions were manually stepped forward from T = 45 to T = 270 in the sequence table, described in chapter 2.1.3.3. Another difference was that the steady-state test resulted in fewer graphs.

2.2.4.2 Data Volumes in the Block Diagram in Figure 2-5

Almost all the data volumes and processes of figure 2-5 are the same as in figure 2-2 and described in chapter 2.1.3.2. The ones that differ or are not described earlier are described below.

GRAPHS

When a steady-state injection test with the umbilical hose equipment was completed only the five A-plots were plotted, in the graphs A0, A1-A4, see chapter 2.1.3.2.

SHSINJCD

The results of the steady-state injection tests with the umbilical hose system have been stored in the table SHSINJCD in SKBs database. SHSINJCD is described in Appendix 15.11.

2.2.4.3 Processes in the Block diagram in Figure 2-5

Also the processes of figure 2-5 are described in chapter 2.1.3.3 with one exception, which is

EVALUATION

On the basis of the graphs from the steady-state tests the site hydrogeologist determined the hydraulic conductivity of the test sections according to the equation 2.1, chapter 2.2.1.3.

2.2.5 Umbilical Hose Equipment System, Version 2

Performing steady-state tests with the Umbilical Hose Equipment System, Version 2, demands a minor program change, where certain times set in the sequence table described in section 2.1.4.3 are changed. After this program modification, the operating routines are exactly the same as during transient tests, except that the test cycle is much shorter and the number of diagrams diminished.

2.2.6 Single Hole Steady-state Injection Tests in GEOTAB

The flyleaf data and result data from the single hole steady-state injection tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table SHSINJF1 - Flyleaf 1 Company, person(s) responsible, references

Table SHSINJF2 - Flyleaf 2 Minimum K - table

Table SHSINJF3 - Flyleaf 3 Comment(s)

Table SHSINJP - Pressure Data from Constant Head Test

Table SHSINJD - Data Table

Table SHSINJCD - Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

2.3 PRESSURE HEAD TEST

2.3.1 Principle

Water loss measurements or pressure head test is the conventional method of measuring a flow out into the rock at a constant applied pressure in a section of borehole delimited with packers. It is a simplified version of Single Hole Steady State Injection Tests used in Forsmark 1981 and 1983 (described in Swedish in report SFR 81 - 13).

2.3.2 Pressure head tests in GEOTAB

The flyleaf data and result data from the pressure head tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table SHSINJF1 - Flyleaf 1 Company, person(s) responsible, references

Table SHSINJF2 - Flyleaf 2 Minimum K - table

Table SHSINJF3 - Flyleaf 3 Comment(s)

Table SHSINJP - Pressure Data from Constant Head Test

Table SHSINJD - Data Table

Table SHSINJCD - Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

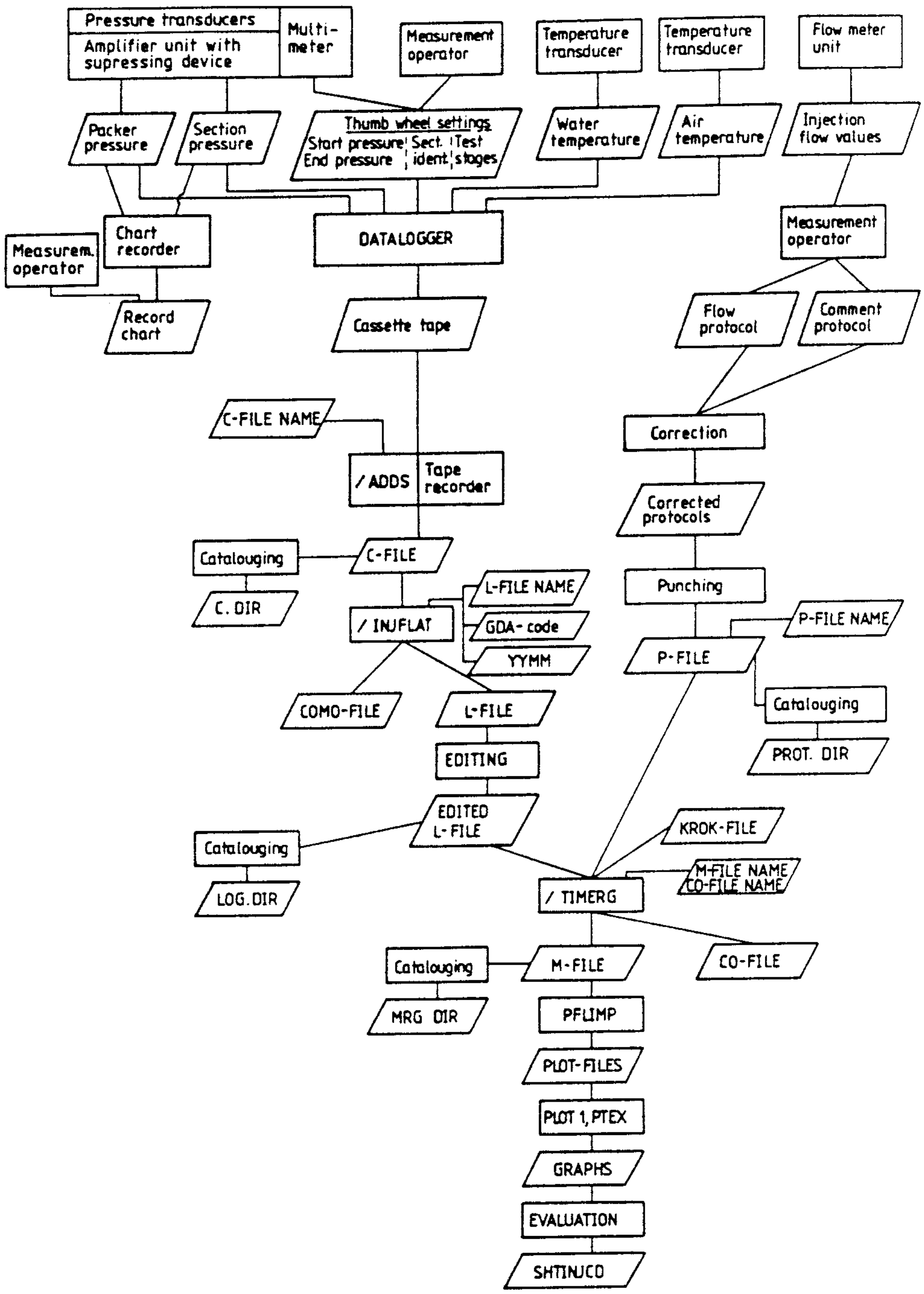


Figure 2-1 Data flow for data from single hole transient tests with the steel pipe equipment system, version 2.

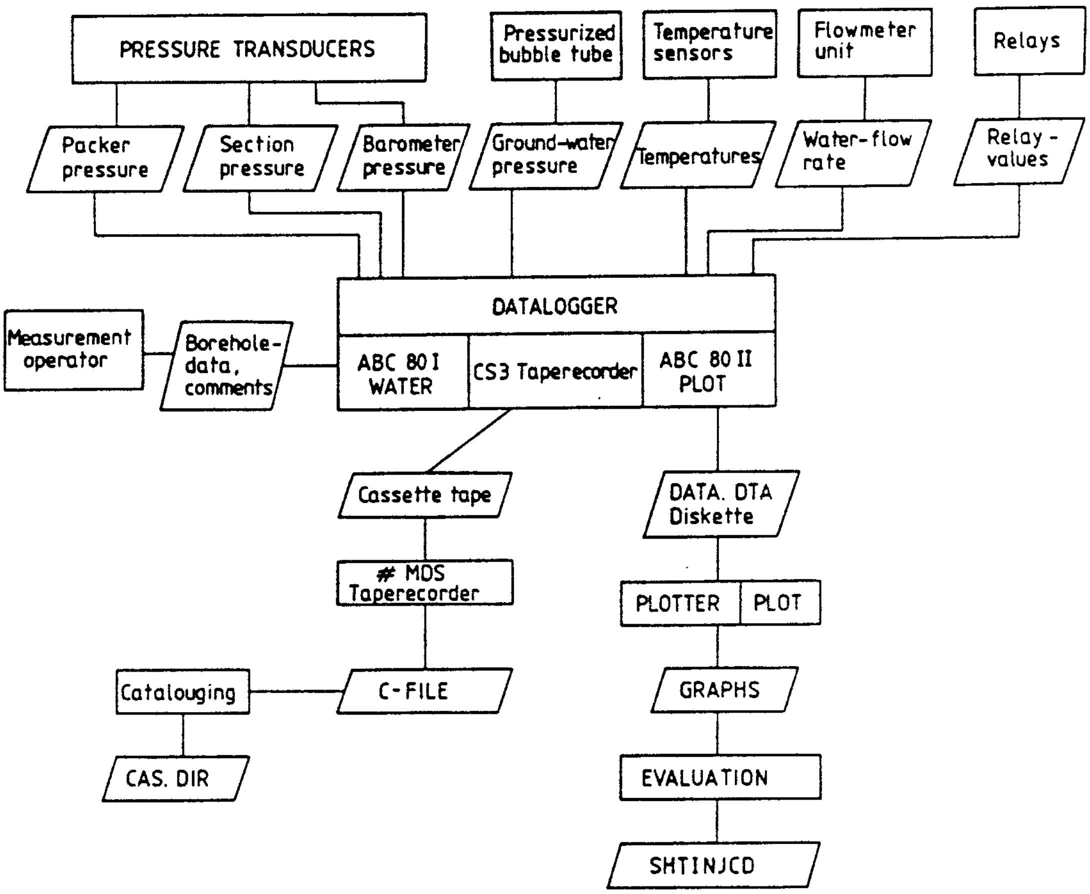


Figure 2-2 Data flow for data from single hole transient tests with the umbilical hose system, version 1.

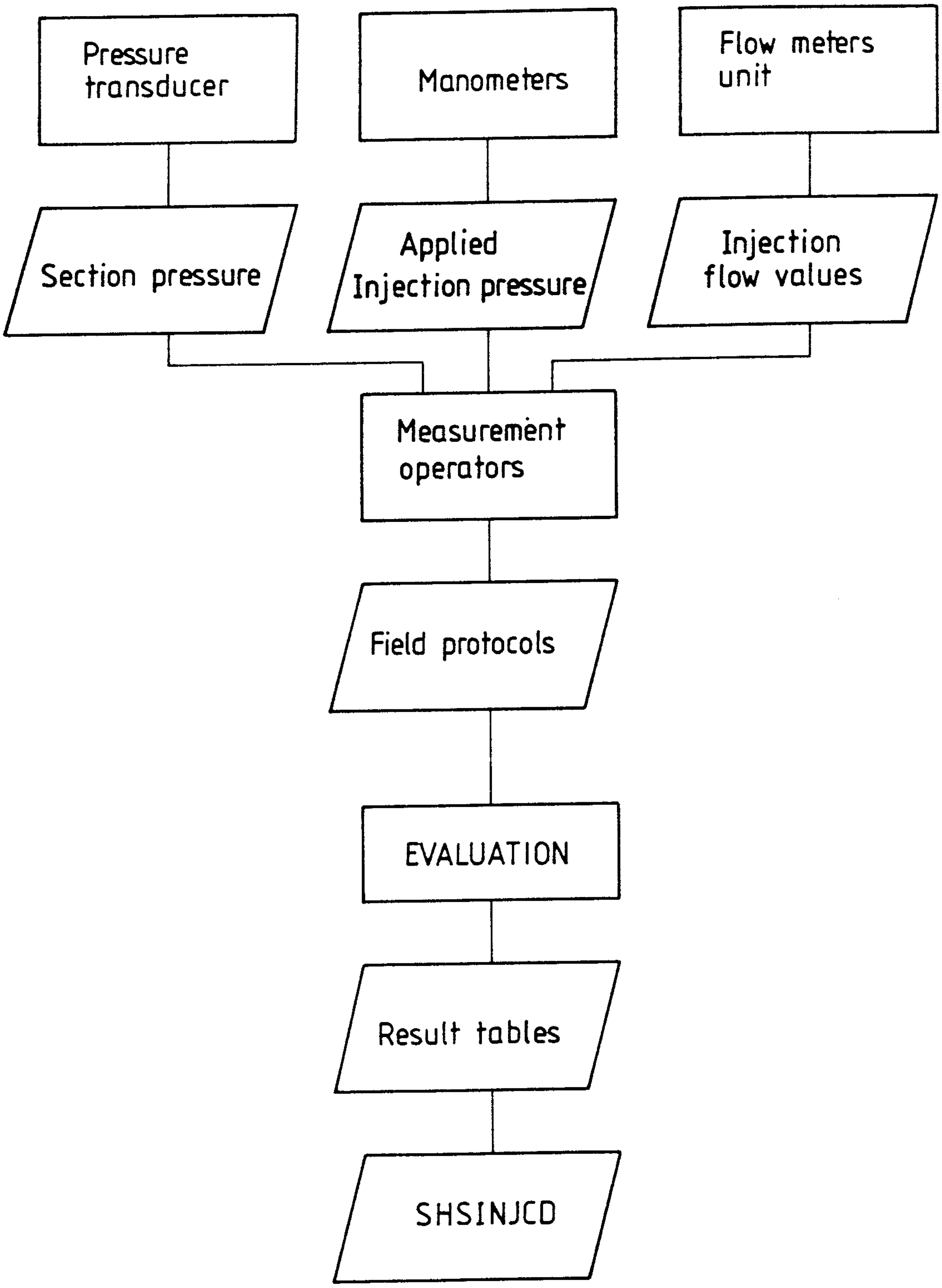


Figure 2-3 Data flow for data from single hole steady-state tests with the steel pipe equipment, version 1.

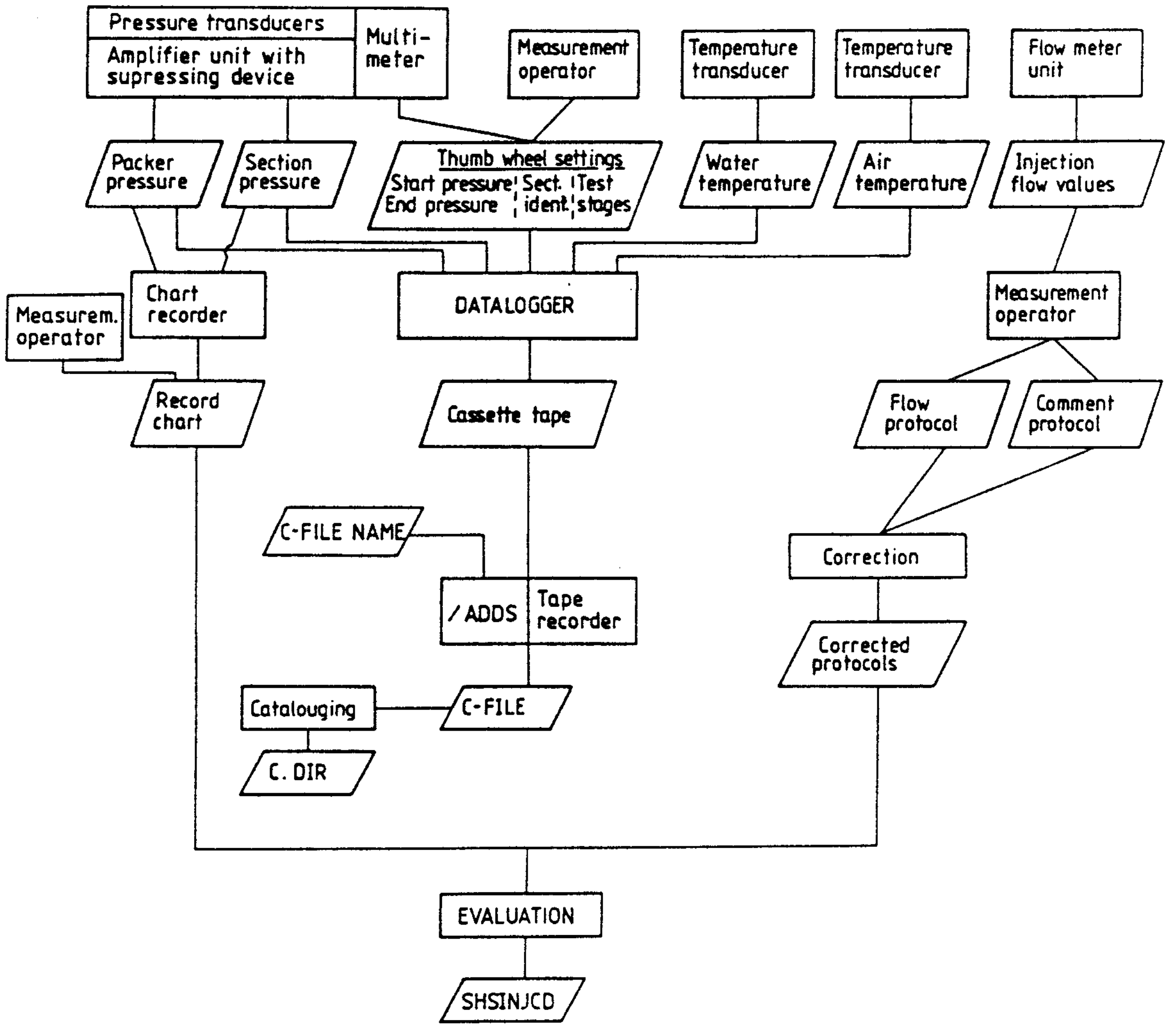


Figure 2-4 Data flow for data from single hole steady-state tests with steel pipe equipment, version 2.

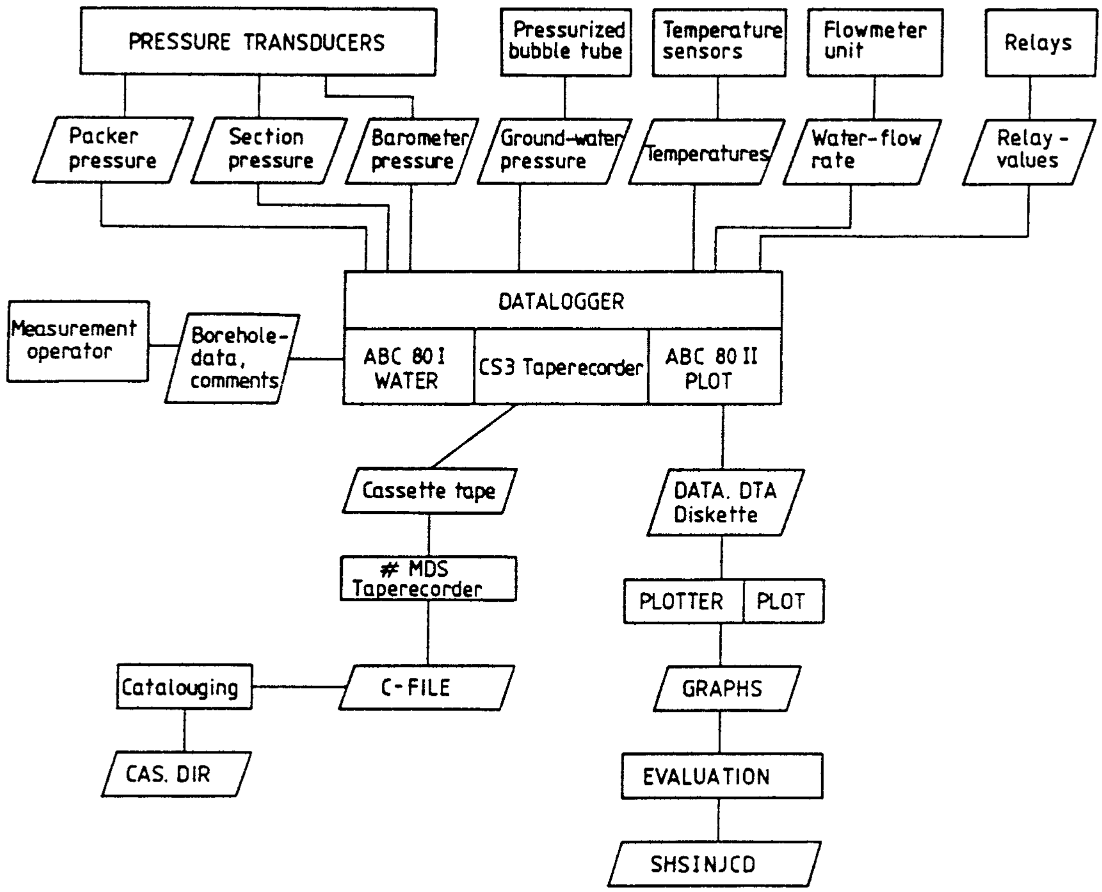
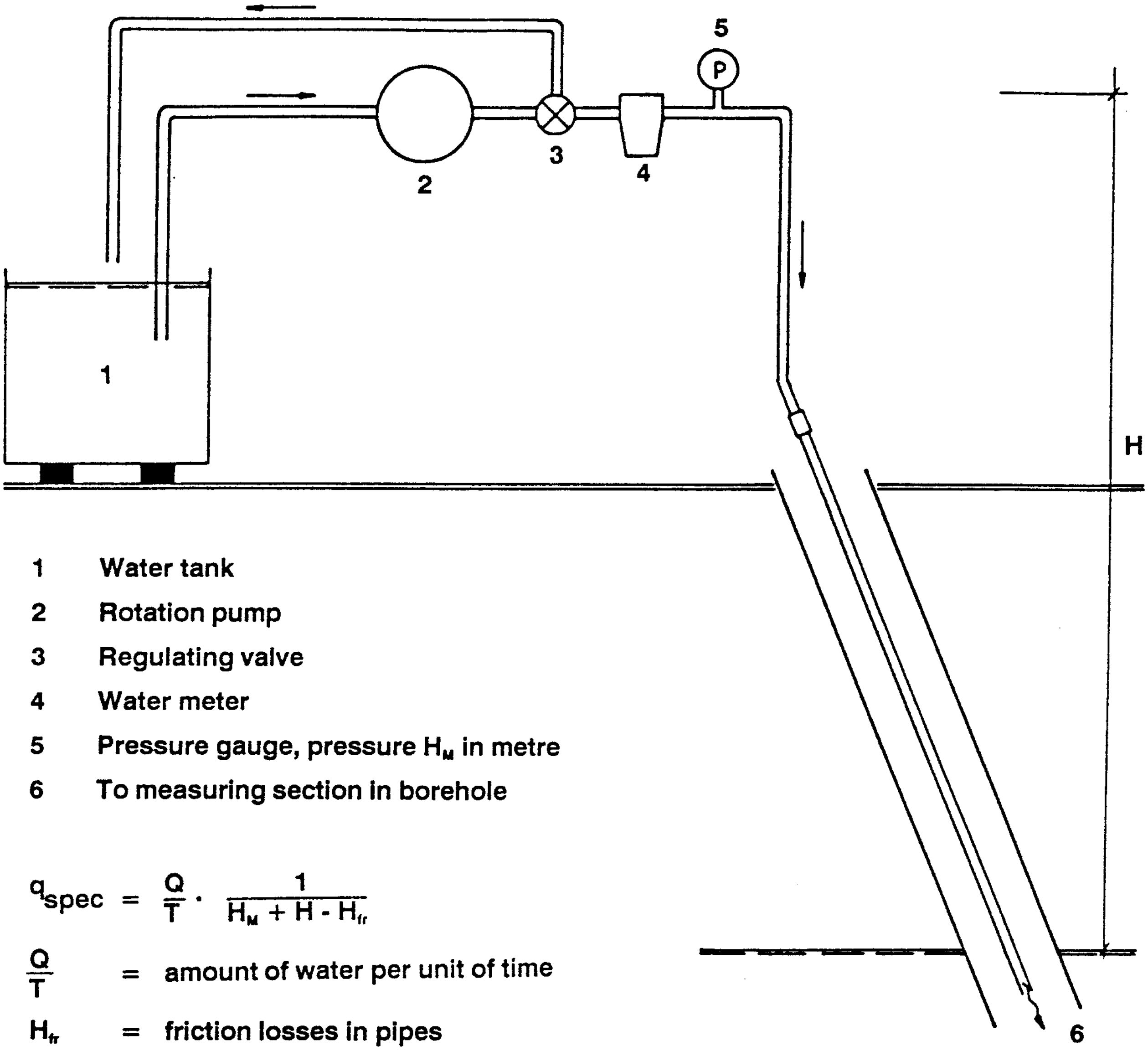


Figure 2-5 Data flow for data from single hole steady-state tests with the umbilical hose system, version 1.



1 Water tank
2 Rotation pump
3 Regulating valve
4 Water meter
5 Pressure gauge, pressure H_M in metre
6 To measuring section in borehole

$$q_{spec} = \frac{Q}{T} \cdot \frac{1}{H_M + H - H_{fr}}$$

$\frac{Q}{T}$ = amount of water per unit of time

H_{fr} = friction losses in pipes

q_{spec} = specific flow for measuring section

Figure 2-6 Measuring equipment for pressure head tests.

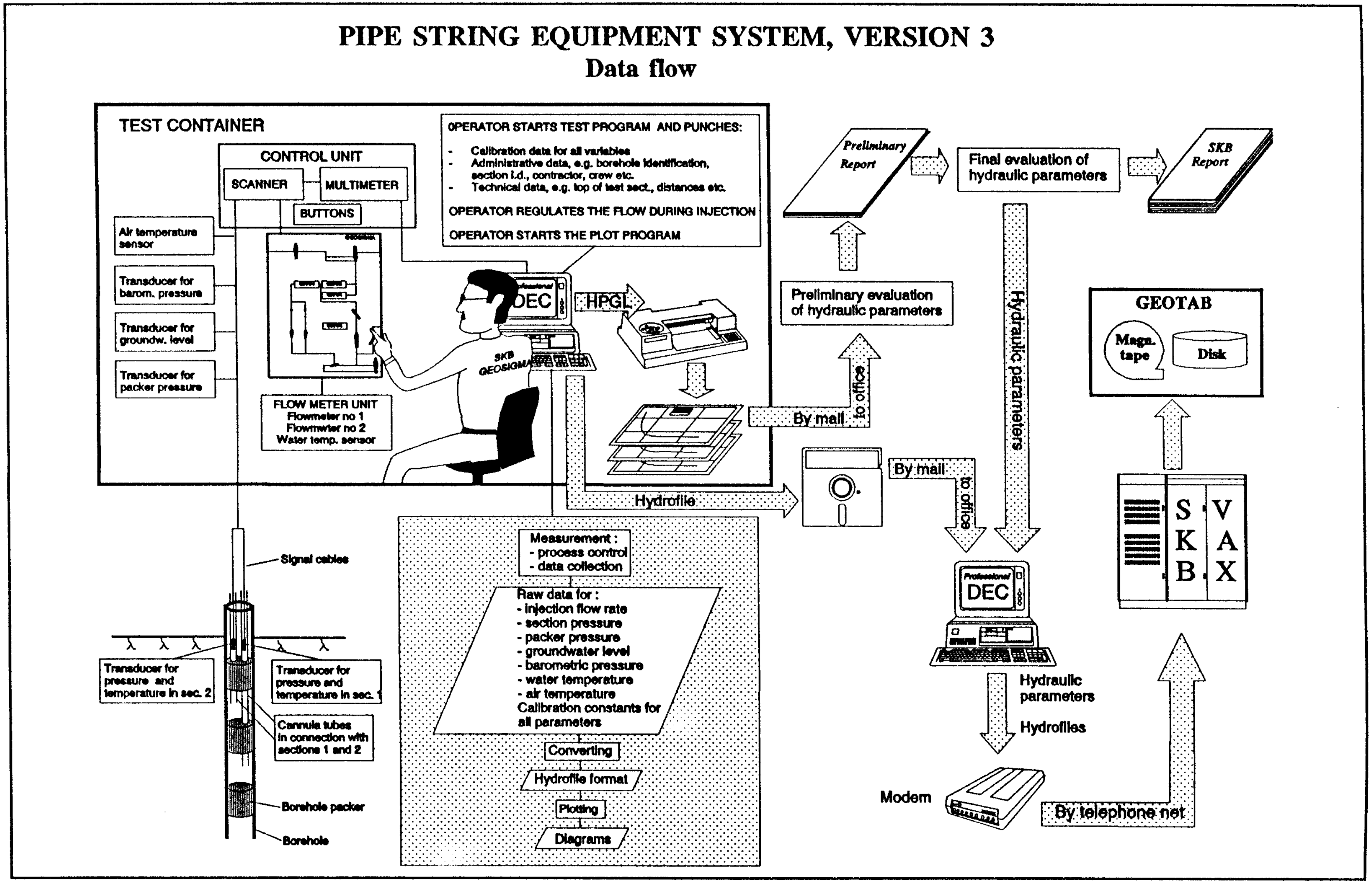


Figure 2-7 The Pipe string Equipment System, Version 3. Data flow for transient injection tests.

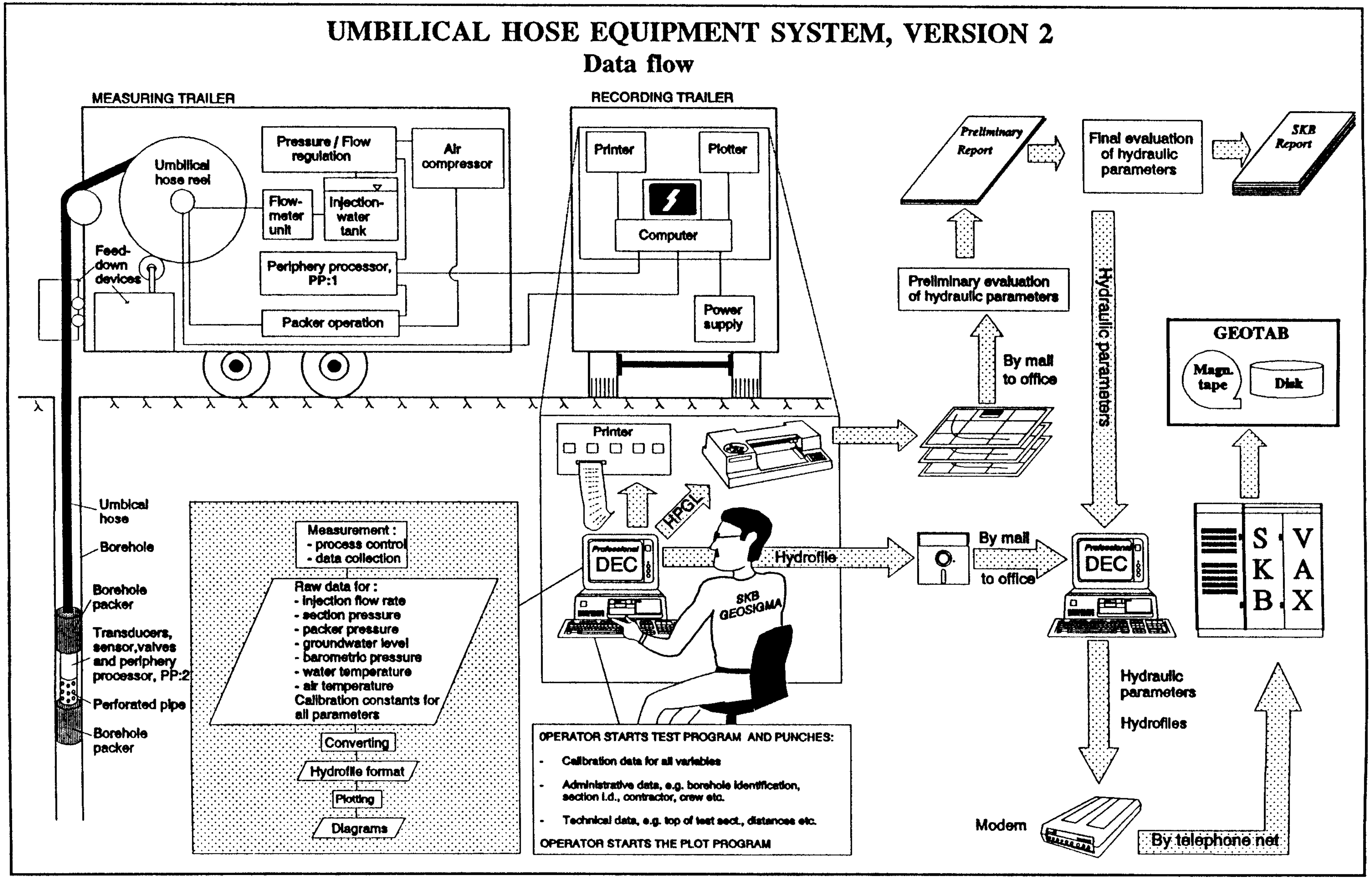


Figure 2-8 The Umbilical Hose Equipment System, Version 2. Data flow for transient injection tests

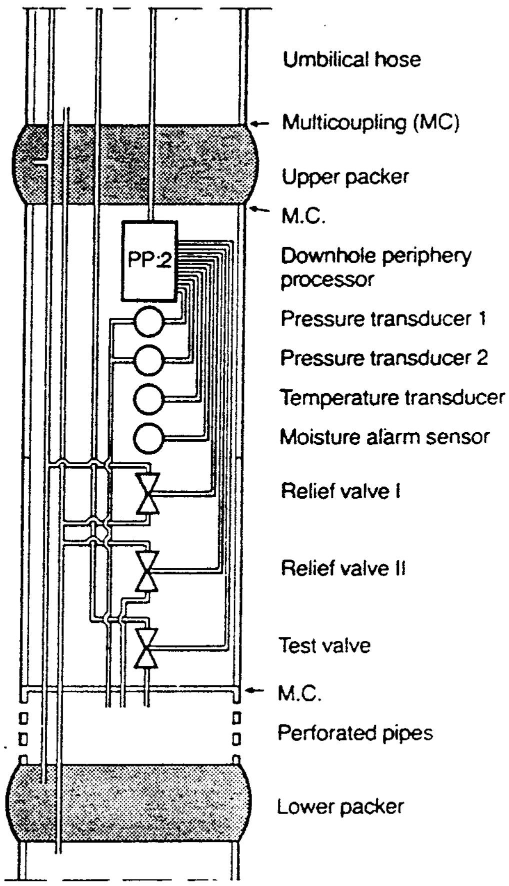


Figure 2-9 Principle design of the testing tool, two packer configuration (from Almén et al 1986 a).

3 GROUNDWATER LEVEL MEASUREMENTS IN BOREHOLES

One of the most important factors that influence the groundwater flow within an area is the level of the groundwater table. The position of the groundwater table have been determined by measurements of the groundwater levels in boreholes. The measurements have been carried out partly by manual level registrations with the help of sounding equipment, partly by continuous monitoring equipments. The latter were water-level gauges before 1984 and the GRUND-system from 1985. Some boreholes have been delimited by inflatable rubber packers and the groundwater table has been registered above and/or below the packers.

3.1 MANUAL GROUNDWATER LEVEL REGISTRATIONS

In up to c. 50 boreholes in each investigated area the position of the groundwater level was manually registered. This was carried out by soundings (before 1985). The registration frequency was in general 2-5 times/month. In between 5 to 15 boreholes in each site the boreholes were delimited into two sections by inflatable rubber packers. The groundwater head was then measured in both sections.

3.1.1 Data Collection and Data Flow

Data flow is presented in the block diagram in figure 3-1.

Groundwater level registrations

The measurement operator measured the distance from the top of the borehole casing to the groundwater head along the borehole. In case of delimiting packers the lower section was connected to the ground surface by a plastic tube through the packers. The distance to the groundwater level was then measured from the top of the tube to the water level in the tube.

Field protocol

The groundwater level values (in metres) were noted in a fieldprotocol - one value for each borehole/section and measurement occasion. When all the boreholes in an area (during one day) were sounded the field protocol were sent to the responsible hydrogeologist. The field protocols are now in the archive at SGAB, Uppsala.

Calculations and Borehole data

The responsible hydrogeologist calculated the level above the sea of the groundwater head for every registration occasion. The data used for this calculation were apart from the measured value the inclination of the boreholes and the altitudes of the top of the borehole casings.

Data files

The result of the hydrogeologists calculations were noted in a protocol and then punched into data files in the PRIME-computer at SGAB. In general it was one data file for each site. The data files comprise five columns containing borehole name, date of measurement, registered value (m), vertical length between the top of the casing and the ground surface (m) and the groundwater level in metres above the sea level. The datafiles are now (1986) stored on magnetic tapes at SGAB, Luleå.The protocols are in the archive at SGAB, Uppsala.

3.1.2 Manual groundwater measurements in GEOTAB

Table GRWBF1	- Flyleaf 1	Start/end, measuring equipment
Table GRWBF2	- Flyleaf 2	Packer position
Table GRWBD	- Data Table	No secup/seclow value indicated; only upper and lower section and no packer
Table GRWBSD	- Data Table	Secup and seclow values

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

3.2 CONTINUOUS GROUNDWATER LEVEL REGISTRATIONS BY RECORDING GAUGES

In three of the vertical boreholes of the investigated sites during the period 1982-1983 the groundwater level was monitored by recording gauges.

3.2.1 Data Collection and Data Flow

Data flow is presented in the block diagram in figure 3-2.

Recording gauges

The recording gauges used were SMHI-gauges type R 16.

Record charts

The groundwater level variations were registered by the pen carriage on the record chart, which was applied on a cylinder driven at a constant speed. The record chart was changed monthly.

Once a week or every fortnight the gauge was calibrated by sounding of the groundwater level. At these occasions the distance from the reference level to the groundwater level and the date and time of the calibration were noted on the record sheet.

The record sheets are (now) 1986 filed in the archive at SGAB,Uppsala.

Calculations and Borehole data

The record sheets were sent to the site hydrogeologist who from the groundwater level curve and borehole data calculated the average altitude of the groundwater level for every day during the actual month. This was done only for the two sites Fjällveden and Gideå. The borehole data used were the altitude of the top of the borehole casing and the vertical distance between the reference level and the top of the borehole casing.

Datafiles

The results of the calculations described above were punched into data files on the PRIME-computer, see chapter 3.1.1.

GRWBD

The data files were transferred to the VAX-computer at KRAB and their content were stored in the table GRWBD in SKBs database, see Appendix 15.11.

3.3 GROUNDWATER REGISTRATIONS BY THE MONITORING SYSTEM GRUND

Since 1985 the groundwater level in boreholes have been measured by the specially designed groundwater table monitoring system GRUND (Almén et al 1986). The system consists of the following parts:

- monitoring probe
- packer
- wire, hoses and cable to the surface
- portable computer

The monitoring probe is a microprocessor-controlled unit designed to measure and store the groundwater level in a borehole. In deep boreholes a packer is installed in order to isolate the upper part of the borehole. The probe and the packer are placed 5-10 m and c. 10 m respectively below the groundwater table. The GRUND system can be left for several months without maintenance. The portable computer is used only for initiating the registration and for collecting of data.

3.3.1 Collecting and Processing Data

Before the registration start a simple slug test is performed in the actual borehole to ensure that the surrounding rock is permeable enough to respond to the groundwater level variations of the bedrock. The slug tests are carried out with inflated packers. The measurements are initiated by the "start" programme of the portable computer (Epson HX-20). The measurement interval and the storage criteria can now be fed into the GRUND microprocessor unit. The communication with the GRUND unit is done with the help of hexadecimal codes.

Depending on the storage conditions the GRUND-system can be left without maintenance for several months or even years. In general, though, data is dumped after 2-3 months of registration.

The registered data in the memory of the GRUND unit are transferred to the Epson Hx-20 with the help of the programme "Fetch". Another programme saves data on the microcassette. It is also possible to list the registered values and to produce a simple plot. This is done on the built-in plotter of the HX-2 computer.

When the registrations from the boreholes of an area have been stored in the memory of the Epson HX-20 or on the microcassette tapes data are transferred to diskettes of a PC. A plotting programme enables the groundwater data to be presented as groundwater pressures, groundwater heads or levels related to any chosen reference level.

3.3.2 Data Volumes in the Block Diagram in Figure 3-3

Pressure values

The pressure transducer measures the groundwater pressure at the level of the measuring probe in mV. The output signal in mV represent different amounts of pressure for the individual pressure transducers. The pressure is measured and stored depending on preset conditions. Standard conditions are measurement every sixth minutes and storage of data every six hours or if the pressure change is greater than c. 20 mm of water column compared to the preceding stored value. These preset values can be changed via the GRUND micro processor unit. Until fetching of data the pressure values are stored in the memory of the GRUND unit. The pressure values are stored in hexadecimal characters. The 2096 most recently collected value scan be stored.

Borehole data I

When a measurement sequence is initiated the "start"-programme asks for a "Text". A message of maximum 15 characters comprising borehole name and depth to the pressure transducer can then be entered.

Borehole data II

In the beginning of the programme "HX-20 DATA" there is a table. Certain basic data are entered to this table. These data are unit number, scale constant (SC), of set constant (OF), and inclination of the borehole in degrees (IW). RAM FILE

By the help of the programme "Fetch" the stored data in the memory of the GRUND-unit is transferred to the RAM FILE of the HX-20 computer. The pressure values of the RAM FILE is still in mV and are expressed in hexadecimal characters.

Printer sheet

Via the built-in printer of the Epson HX-20 data from the RAMFILE are listed and simply plotted on a printer sheet. On the printer sheet basic data such as GRUND-unit number, borehole name, depth of the packer and date of print out are shown. A standard set-up in hexadecimal characters of the status of the GRUND unit is also presented. The listed pressure values are expressed in LSB (Least significant bits). One LSB represent different pressures for each GRUND-unit. A common value is 4 mm water column per LSB.

Cassette tape

By the help of the programme "Tape out" data stored in the RAMFILE is saved on a cassette tape. Data are not changed or converted during the saving procedure.

DATA FILE

The date files in the EPSON HX-20 is transferred to an ABC 80 diskette. In the future the ABC 80-computer will be replaced by a Digital Equipment PC 350. The transfer is done by the help of the programmes "Export data" and "HX-20 DATA". The data file is named as follows:

KSSNNddM.ymm   example: HKL1210M.609

where

K = Borehole type (K = cored borehole
H = percussion borehole)
SS = Site code, KL = Klipperås etc
NN = Borehole number (1-99)
dd = Distance to pressure transducer along borehole, integer (m)
M = Metres
y = Last digit in the year of dumping
mm = Month of dumping

The ten first lines of the data file contain borehole data and technical data. Then follows measurement date/time and pressure values. The pressure values in the data file are expressed in m water column above the transducer, see appendix 15.8. The datafiles are not stored in the database but stored on archive magnetic tape at SKB (Stockholm).

3.3.3 Processes in the Block Diagram Figure 3-3

GRUND unit

The GRUND unit is encapsulated in a water proof probe with accumulators and a pressure transducer. It is based on a CMOS processor and an integrating A/D converter. A 4 kByte RAM provides data storage and an EPROM circuits holds the program. The unit also contains a crystal controlled oscillator, a counter that can be fine tuned to a proper frequency and a DC/DC converter (Almén et al 1986).

The probe is vented via a hose to the surface, which means that the registered pressure values represent the groundwater head. For a pressure range of 10 m water column the resolution of the readings is 4 mm. The temperature range of the probe is 0 - 30 °C.

Programmes, EPSON HX-20

The stored data in the GRUND unit may be transferred to a portable computer Epson HX-20, which includes a built-in printer and a microcassette recorder.

The computer is also used for starting measurements and checking certain functions such as clocks and accumulator voltage. The communication with the GRUND unit is done with the help of hexadecimal characters. The software consists of seven self-instructing programs:

"Fetch"

Fetches the status message and all the data stored in the GRUND unit. The information is stored in the memory of the HX-20 together with the time of fetch operation. The RAM FILE of the computer will contain all the data.

"SIO"

The HX-20 acts as a terminal. The operator can use the GRUND commands. The characters are transmitted from the keyboard and the answers are displayed on the LCD display.

"Tape out"

Data stored in the RAM FILE is saved on a micro cassette.

"Printer"

Data from the RAM FILE is listed and simply plotted by means of the built-in printer.

"Read tape"

Data stored on a tape cassette is read to the RAM FILE.

"Start"

Enter the measurement interval, the interval between compulsory storage, and the limit value for conditional storage.

"Export data"

Data files can be exported to another computer.

"HX20 DATA"

Transfers data from the RAM FILE to the PC. "HX20 DATA" and "Export data" are run simultaneously. In the beginning of "HX20 DATA" there is a table, in which each line comprise unit number, scale constant (SC), ofset constant (OF) and borehole inclination (IW). Based on these facts the programme convert the pressure values from mV to m water column.

3.4 PIEZOMETRIC MEASUREMENTS WITH THE PIEZOMAC I SYSTEM

The purpose of the piezometric measurements is to determine the long-term natural piezometric pressure variations of the bedrock at different depths. This is done by delimiting deep boreholes into measurement sections by the aid of inflatable rubber packers and then monitor the groundwater head of the individual sections. The piezometric measurements are carried out using the Piezomac system. This system comprises a data collection and control unit (Piezomac), multipressure probe, analog probe, packers, pressure tubings and a data transfer and communication unit (Almén et al 1983). The equipment enables continuous and simultaneous registrations of the hydraulic head in the measurements sections for periods of 3-6 weeks or longer.

During 1985 and 1986 the PIEZOMAC System has been modified. The new equipment, called PIEZOMAC II, has an improved measurement probe, new hardwares and new plotprogrammes (Almén et al 1986). Since the new equipment is not yet completed, the data flow of the PIEZOMAC II system is not described in this report.

3.4.1 Collecting, processing and evaluation of data

Data flow is presented in the block diagram in figure 3-4.

The multipressure probe measures the groundwater head of the measurement sections and the analog probe measures alternative parameters, mostly the air pressure. The Piezomac-unit controls the measurement and stores the registered data. Scanning frequency, constants and date/time of measurement start are fed into the Piezomac-unit. Data are stored in the Piezomac-unit as a P-file which is transferred to the host computer at Malå either via radio and the telephone network or via a tape recorder.
In case of radio transfer the P-file is sent to a main computer at Malå and then to the PRIME 750 computer at Luleå. The cassette tape is sent to Luleå and the content is read into a P-file on PRIME 750. There is a third way of transferring data used in the piezometric measurement at the Fjällveden and Svartboberget sites. There the P-files were printed by a field printer and the print-out was sent to Luleå where it was punched to a P-file on PRIME 750. The measurement operator writes down basic data such as instrumental constants, packer configuration etc on a protocol. The protocol is punched to a S-file on the main computer at Malå and then sent to PRIME 750 via the telephone net. Via the radio/tele communication the measurement sequence can be supervised and the field instruments can be reprogrammed during the continuance of the measurement process.

The P-file and the S-file are merged to a D-file, which contain all registered measurement data and the relevant background data.

The D-files is input data for plotting programmes, which produce graphs that present the data from each individual section either as raw data or calculated groundwater pressures or groundwater heads.

3.4.2 Data volumes in the block diagram figure 3-4

Pressure values

The pressure is measured by the pressure transducer in the pressure measurement probe. The measured pressure represent the sum of the barometer pressure and the section pressure subtracted with the pressure difference between the level of the transducer and the level of the upper limit of the measurement section. The groundwater pressure of the measurement sections can thus be expressed as follows:

$$P_s = P_m - B + g \times (SECUP - LT) \times \sin(IW) \quad (3.1)$$

where

P_s	= Groundwater pressure in the measurement section at the level of the upper packer	(kPa)
P_m	= Measured pressure	(kPa)
B	= Barometer pressure	(kPa)
g	= gravity constant	(m^2/s)

SECUP = Length to upper limit of the section along the borehole from the top of the casing (m)

LT = Length to pressure transducer from the top of the casing along the borehole (m)

IW = Inclination of the borehole (degrees)

The measurement frequency differs depending on the mode that has been fed into the Piezomac-unit.

Analog values

The analog values are values measured by the analog probe. The analog probe can collect analog signals from any transmitter or transducer, but the analog values mostly represent barometer pressure when piezometric measurement is performed. The values from the analog probe are collected and processed in a similar way as for pressure values.

Date, time, modes, C_0 and K_0

Before the measurement start the measurement operator feed certain data into the Piezomac unit via the keyboard. These are data and time (DDhhmm) of measurement start and ofset constants for the multipressure probe (C_0) and the analog probe (K_0) respectively. Furthermore the scanning mode is set.

The different modes are as follows:

P = Pump mode, rapid scanning, c. 1 measurement per minute, only values from one borehole are accurate. This mode is usually not used in the piezometric measurements.

C = Continuous measurement, some minutes between every scanning

N = Normal measurement, the scanning interval is stored in PIEZOMAC

T = First scanning after packer inflation

Ö = First scanning after packer deflation

The modes T and Ö are not set by the measurement operator but by the conversion programme "CON" later in the data processing. The modes P, C, and N can be changed from the office via the radio/tele communication.

P-FILE (Piezomac)

The measurement values are stored in the memory of the Piezomac as a P-file (appendix 15.9). The values are expressed in mV. The file has 3 record types according to the following:

Record type 1: YYYY MM:DD hh:mm; Date/time of measurement period start

Record type 2: DD:MM hh:mm S; Date/time of measurement, S= scanning mode

Record type 3: $(n_b + n_a)$ x 5 x (sss vvvvvv); measurement values compensated for the ofset constant(C_o)
sss = seconds after time in record type 2.
vvvvvvv = stored value, one for each measurement section. The section values are in the same order as the corresponding section limits in the S-file. If there are less than five sections the data of the upper section is repeated. Record type 3 is repeated depending on the number of boreholes (n_b) and the number of analog probes (n_a). The order of the boreholes/probes is the same as in the S-file. Only the last scanning is valid for the values of the analog probe(s).
vvvvvvv = -32767 means bad value.

Cassette tape

The P-file of the Piezomac-unit can be recorded on a cassette tape by the aid of a tape recorder. The content of the cassette is the same as the corresponding P-file and has the same format.

If the radiotransfer do not function the cassette tape is read to a P-file on PRIME 750.

Print-out

The measurement data of the Piezomac-unit can be printed by the aid of a field printer. The print-out has the same format as the P-file.

If the data transfer via radio/telephone or the cassette recorder fails the print-out is punched to a P-file on PRIME 750.

Protocol

On a protocol the measurement operator writes down necessary background data. These are borehole name, date/time of packer inflation and packer deflation, length, diameter, inclination and azimuth of the borehole, x- y- and z-coordinates (local) of the borehole casing, measurement section limits, calibration constants(s) for the probe(s) and length from top of casing to the pressure transducer along the borehole.

S-FILE (PDP)

The protocol is punched into a S-file on the PDP 11-73 computer at SGAB, Malå. The S-file contains the background data necessary for evaluation of the piezometric measurement and has the following format:

Record 1: 3^{*} (YYMMDDhhmm)
Record 2-6: Ident, C_1, LB, DW, IW, AW, X, Y, Z, LT, n_s x (SECUP, SECLOW), n_s x r, K_o

where

3* (YYMMDDhhmm)	= Date/time for measurement start, packer inflation and packer deflation respectively
Ident	= Identification of borehole(s) or analog probe. The boreholes are named according to the GEOLIS-convention, see chapter 2.1.2.
C_1	= Calibration constants for the probes
LB	= Length of the borehole (m)
DW	= Diameter of the borehole (mm)
IW	= Inclination of the borehole (degrees)
AW	= Azimuth of the borehole (degrees)
X,Y,Z	= Local x- y- and z-coordinates for the top of the casing. z in m.a.s.l (m)
LT	= Length from top of the casing to the pressure transducer along the borehole (m)
n_s	= Number of measurement sections
SECUP	= Length to upper limit of section from top of casing (m)
SECLOW	= Length to lower limit of section from top of casing (m)
r	= Length from section to pumphole (only used in interference tests , chapter 6) (m)
K_o	= Ofset constant of the analog probe

P-FILE (PDP)

Via radio and the telephone net the P-file of the Piezomac-unit is transferred to a P-file on the PDP-computer at SGAB, Malå. Incorrect data are deleted, but apart from this the two P-files has the same content and format.

P-file (PRIME)

The P-file on the PRIME-computer originates either from the corresponding P-file on the PDP-computer or from the cassette tape or from the print-out from the Piezomac. In all three cases the format is the same as in the P-file of the Piezomac.

The P-files from PRIME 750 are now (1986) stored on magnetic tapes at SGAB, Luleå.

The P-files are named according to the following convention:

PBHNR.YYMMDD (example: PKM03.830324)

P = "Piezomac file"
BHNR = Borehole name
YYMMDD = Start date of measurement

S-file (PRIME)

The S-file from the PDP-computer is transferred to an identical S-file on the PRIME 750-computer at SGAB, Luleå. The S-file name is the same as the corresponding P-file except that the first letter is a S instead of a P (example: SKM03.830324).

D-FILE

The P-file and the S-file are merged to an D-file which contain all the data necessary for the evaluation of the piezometric measurement (appendix 15.9). A measurement with n probes (n or n-1 boreholes) have the following format:

Record 1-n : Ident., C, LB, DW, IW, AW, x, y, z, LT, n_s x (SEUP, SECLOW), n_s x r, K_0; explanations see the S-file
Record n+1: empty
Record n+2-...: YYMMDDhhmm,S, n x 5 x (sssvvvvvvvv)

where

YYMMDDhhmm = Date/time of measurement

S = Scanning mod P, N, S, T or Ö

n = Number of boreholes or probes

sss = Seconds after YYMMDDhhmm

vvvvvvvv = Measured pressure in the sections respectively (metres of water column)

The pressure values are in the same order as the corresponding section limits in records 1-n.

The D-file names are the same as the P-file names except that the first letter is a D instead of a P, e.g. DKM03.830324.

The D-files were stored on magnetic tapes at SGAB, Luleå. During 1986 copies of the D-files were transferred to magnetic tapes at KRAB in Stockholm.

GRAPHS

By the aid of the plot routine PIEZPLT various graphs can be generated. Input data is the D-file. The graphs present the data from each individual section either as raw data or calculated groundwater pressures or groundwater heads.

3.4.3 Processes in the block diagram in figure 3-4

Multipressure probe

The multipressure probe is placed c. 20 m below the groundwater level. I consists of a number of solenoid valves, a pressure transducer (Kistler 4043 500 kPa), a pressure amplifier and a A/D-converter. The measurement values are obtained at a resolution of 0.03 kPa. Pressure tubes connect all measurement sections with the multipressure probe. At the solenoid valves the pressure transducer is connected to the pressure tubes from the individual measurement sections, one at a time (Almén et al 1983).

Analog probe

During piezometric measurements it may sometimes be of interest to monitor other parameters. For this purpose an analog probe is used for measuring analog parameters in a similar way as for the multipressure probe. The most common parameter measured by the analog probe is the barometer pressure.

Measurement operators

The measurement operators lower the equipment in the borehole and connect all the cables and tubes. When starting up the measurement the operators feed the Piezomac-unit with certain background data. More background data is written down on a protocol. When necessary the measurement operators dump data either on a cassette tape or via a printer.

PIEZOMAC

The Piezomac data collection and control unit is a computer controlled unit for simultaneous operation of 1-5 measurement probes (Almén et al 1983). It also receives and stores data from the probes together with time data and transfers the data to other units. Piezomac consists of

- Microcomputer
- Semi- conductor storage (up to 74 kByte)
- Keyboard
- Display
- Serial inputs/outputs (9 pcs. 300 baude)

The Piezomac has low power-consumption during a measurement sequence and can measure for a couple of months on two batteries. The batteries can be recharged of a solar cell module.

Tape recorder

Data stored in the memory of the PIEZOMAC can be recorded by a tape recorder.

Printer

A printer type Epson MX-100 have been used for print-out of data from the Piezomac.

Radio transfer, Data control I

Data from the Piezomac may be transferred via radio, modems and the telephone network to the PDP-computer at SGAB, Malå. During the transfer data is checked and identified in order to be sub-sequently processed, and successively plotted on a monitor or on paper. In this way the measurement can be continuously supervised from the office. From the PDP-computer the field instrument can also be reprogrammed during the measuring process i.e.the scanning mode can be changed.

Data control II, Punching

If the data transfer via radio/telephone or via the tape recorder failed the corrected print-out from the field printer was punched to a P-file on PRIME 750. This was done by the data department at SGAB, Luleå.

Before the punching the print-out from the field printer was checked and incorrect data were excluded before punching. This was done by the responsible hydrogeologist.

The field protocol written by the measurement operators was punched to a S-file on the PDP-computer at SGAB, Malå.

"OVER"

"OVER" is a routine that transfer data (the P-file) from the PDP-computer in Malå to PRIME 750 in Luleå. The transfer is performed automatically every night. The routines calls for the programmes OVERS.SEG and CON.SEG. Principally OVERS is a transfer via SAFT-protocol but it can overlay a file or add data.

 # MDS

#MDS is a programme that reads data from the cassette tape to a P-file on PRIME 750.

"CON"

CON is the programme that creates the D-file. Input files are the P-file and the S-file. It also convert the mV-values to pressures with the help of the calibration constants in the S-file. In addition CON changes the scanning mode at the first scanning after packer inflation and packer deflation to T and Ö respectively. The format for reading up the P-file and printing of the D-file is given by the files DSC.P01 and D.DSG (on PRIME) respectively.

"PIEZPLT"

PIEZPLT is a routine on PRIME 750 for generating plots either on a terminal screen or on paper. The plotting routine is handled by the data department at SGAB. Input data is the D-file.

3.5 GROUND WATER LEVEL MEASUREMENTS AT THE ÄSPÖ HARD ROCK LABORATORY SINCE 1987

3.5.1 Manual ground water level measurements

Manual levelling has been made very irregularly, during some periods frequently but at times rarely. From the summer of 1989 and onwards, the manual levelling was made once every month. In those holes where one section is not registered by a logger, all the sections are checked once every week.

***.LOD - file**

Ground water level data are punched into a file on Digital Professional 350/380 computer. The file is described in G.Nyberg, June 1988 and comprises two parts; a head including borehole data (REF and IW) and a data part containing the measurements of the distance from the ground water to measuring point.

Plotfile

The plotfile or "hydraulic-file" is input file to the plot program. Its content and format are described in G. Nyberg, June 1988. Ground water level data are expressed in m.a.s.l.

Printfile

The printfile has 7 columns : Borehole idcode, upper test section limit, lower test section limit, date of measurement, time of measurement, distance from ground water to measuring point and ground water head (m.a.s.l.), see Nyberg June 1988.

Ground water level data to GEOTAB; see Chapter 3.1.2.

3.5.2 Logger-registered ground water level measurements

3.5.2.1 Mechanical equipment in boreholes

Most boreholes are divided into different sections by means of rubber packers.
The major parts of the core boreholes on Äspö are divided into 4-6 sections. Each section has a hydraulic connection to the ground surface via a bypass plastic tube through the packers. The tubes have an inner diameter of 4 to 6 mm at depth, whereas the uppermost 40-50 m of the tube connections consists of black polyethene with an inner diameter of 23 or 54 mm. In the upper wide part of each tube, a pressure transducer is installed. To achieve a rapid response to pressure changes in the actual borehole section, a small packer is installed in each tube at a depth of 25-30 m, a short distance below the pressure transducer. The latter is in connection with the borehole section via a thin tube through the small packer

One or two sections in the core boreholes mentioned above are equipped with a second tube between the section and the ground surface. This tube has an inner diameter of 6 mm all the way to the surface. In the upper enlarged part of the borehole, the tube is branched off, and a third tube (inner diameter 4 mm) leads up to the surface. The polyethene tube to these sections have the wider diameter 54 mm followed in the narrow part of the borehole by a plastic tube of 6 mm inner diameter. The purpose of this special equipment in some sections is to make possible circulation of section water in association with tracer injection tests.

3.5.2.2 Logger units

There are four different logger units used to collect pressure data. The most important components of these units are a multiplexer (except in GRUND), an A/D convertor, a data storing facility and a serial I/O port. They all have a battery power supply.

BORRE is a multichannel logger with a 16 bits A/D converter.

PIEZOMAC A is a multichannel logger with a 15 bits A/D converter.

PIEZOMAC D is a multichannel logger with a 15 bits A/D converter. The logger unit can also handle a multipressure probe.

GRUND is a single channel logger with a 13 bits A/D converter.

3.5.2.3 Pressure gauges

The **BORRE** logger is equipped with a DRUCK PDCR 830 differential pressure transducer with the pressure range 0-1, 0-3.5 or 0-10 bar.

The **PIEZOMAC** logger is equipped with a DRUCK PTX 160/D differential pressure transmitter with the pressure range 0-1, 0-3.5 or 0-10 bar.

The **multipressure probe** in KAV01 is provided with a DRUCK PTX 120/WL differential pressure transmitter with a pressure range of 0-700 kPa.

The **GRUND** logger has a CRL951 differential pressure transducer with pressure range 0-15 psi.

3.5.2.4 Calibration method

To calibrate the registrations from the data loggers, manual levelling for all sections has been performed.

3.5.2.5 Accuracy of groundwater level data

The results presented in the diagrams are the ground water levels for each section expressed as meters above sea level. The total error in these values, under disturbed conditions, consists of errors in the following measurements:

- Pressure gauge registrations
- Levelling of the borehole casing
- Levelling of the borehole ground water surface
- Borehole deviation measurements

When calculating the absolute pressure at the top of a packed off section, also an error due to uncertainty in the estimation of the density of water in the tube connecting the section with ground surface must be considered.

The magnitude of error in the ground water level or pressure data is to a large degree varying with time, depending mainly on two factors, the frequency of manual levelling and the influence of activities in the boreholes. As the pressure gauges are calibrated against series of manually levelled values, the error will in general be smaller than for one single measurement. The levelling frequency is increased during most pumping tests. During other tests, however, disturbances in the instrumentation may cause discontinuities in the data series. Some of these can be eliminated in the calibration process, while others are more difficult to identify and may remain for shorter periods.

Errors in determinations of the altitude of the borehole casing and of the borehole deviation are systematic and do not influence estimations of relative changes in ground water levels. Errors in pressure gauge registrations and in levelling of the ground water table, on the other hand, have a certain amount of randomness, while errors due to uncertainties in the density estimation can be of both types.

When making a rough estimate of the errors mentioned above, the total error in water-level elevation under undisturbed conditions has been estimated at ± 0.06 m for percussion boreholes and top sections in core boreholes, and ± 0.15-1.2 m for packed off sections. The value 1.2 m for the packed off sections stands for relatively short periods without manual levellings and with disturbances in the instrumentation.

3.5.2.6 Data flow of logger-registered groundwater level data

Data flow of ground water monitoring is described in the figures 3-6, 3-7, 3-8.

The hydraulic test files are transferred from DEC-PROFESSIONAL via communication program Kermit via DATEL to SKBs VAX 11/750 in Stockholm. The files are stored on archive magnetic tapes and are also condensed to one value for each day during measuring period.

3.5.2.7 Logger-registered ground water level data in GEOTAB

The flyleaf and result data from the automatic ground water level registrations are stored in the following table in the database (a detailed description of the data tables is found in Appendix 15.11).

The hydraulic data files are stored on archive magnetic tapes at SKB Stockholm. Condensed files with one value for each day are stored in table PIEZOLD.

Table PIEZOF1	Flyleaf 1 Start and End of Measurement, Responsible for Test
Table PIEZOF2	Flyleaf 2 Packer and Piezomac Information
Table PIEZOF3	Flyleaf 3 Constants
Table PIEZOF4	Flyleaf 4 Comment(s)
Table PIEZOF5	Flyleaf 5 Length/depth of Transducer
Table PIEZOF6	Flyleaf 6 Data File Names for Groundwater Monitoring
Table PIEZOPD	Groundwater Pressure in Sections (data from registrations at SFR).
Table PIEZOSPD	Start And End Groundwater Pressure Data

Table PIEZOSLD Start And End Groundwater Level Data

Table PIEZOLD Groundwater Level Data (monitoring at Äspö Hard Rock Laboratory)

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

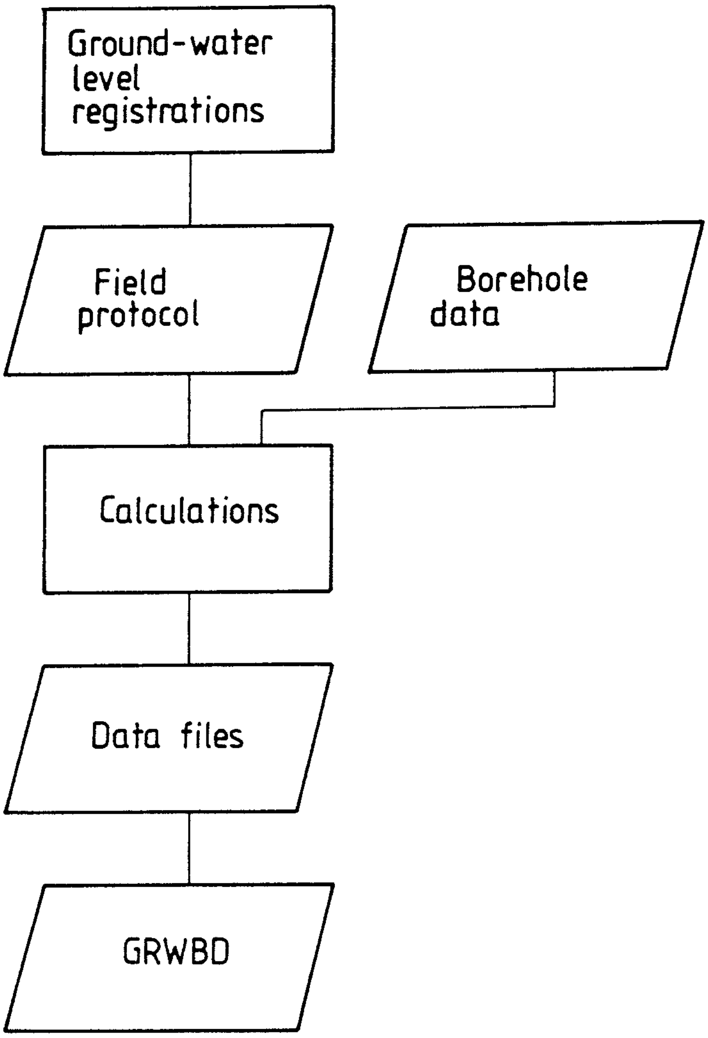


Figure 3-1 Data flow for data from manual groundwater registrations.

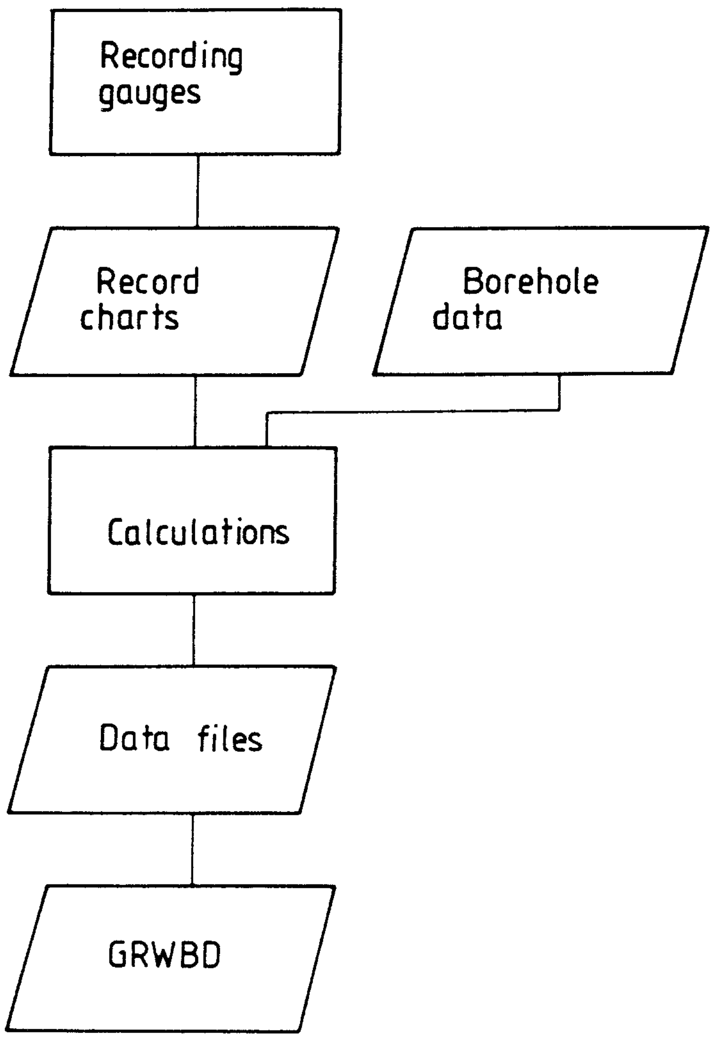


Figure 3-2 Data flow for data from groundwater level registrations by gauges.

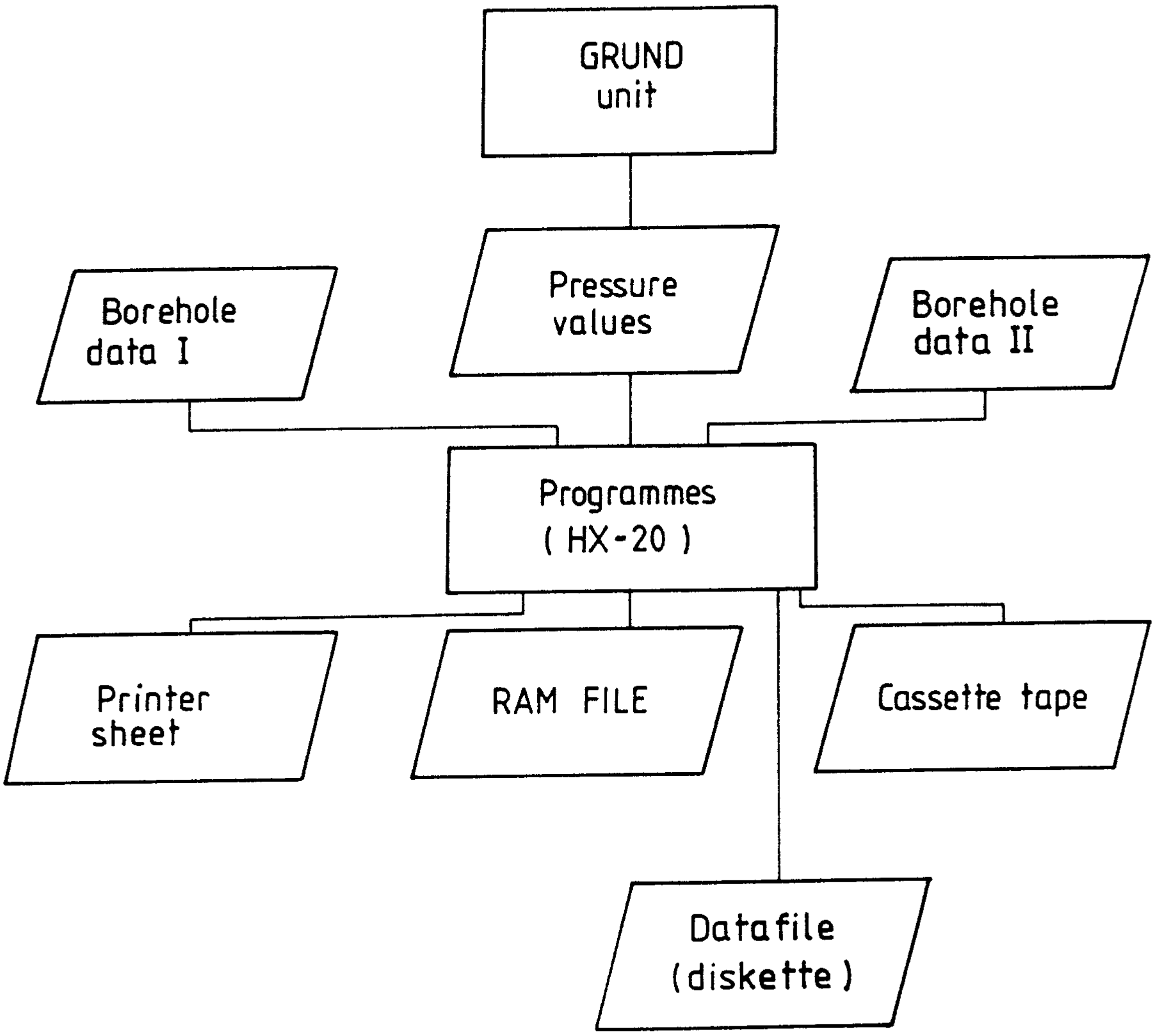


Figure 3-3 Data flow for data from groundwater pressure egistrations by the GRUND system.

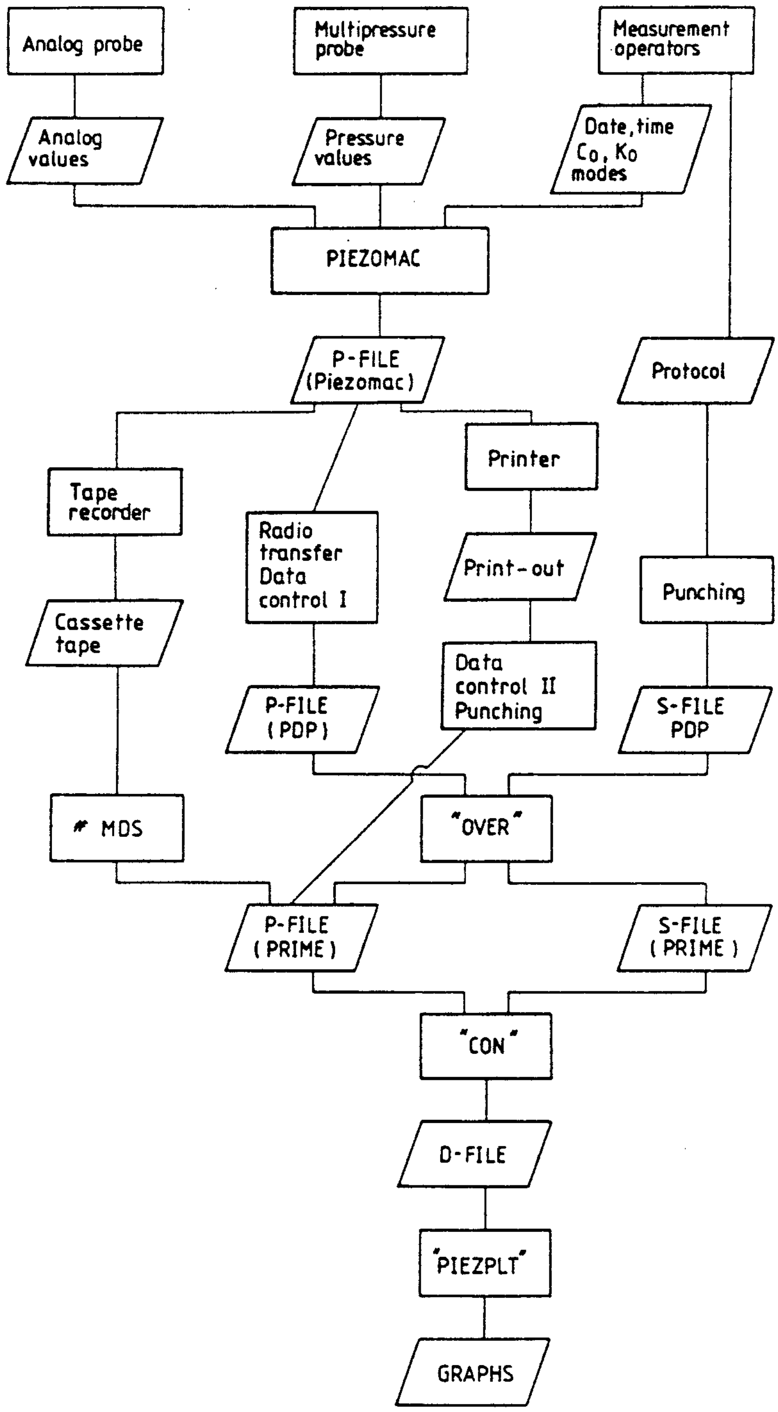


Figure 3-4 Data flow for data from piezometric measurements with the PIEZOMAC I system.

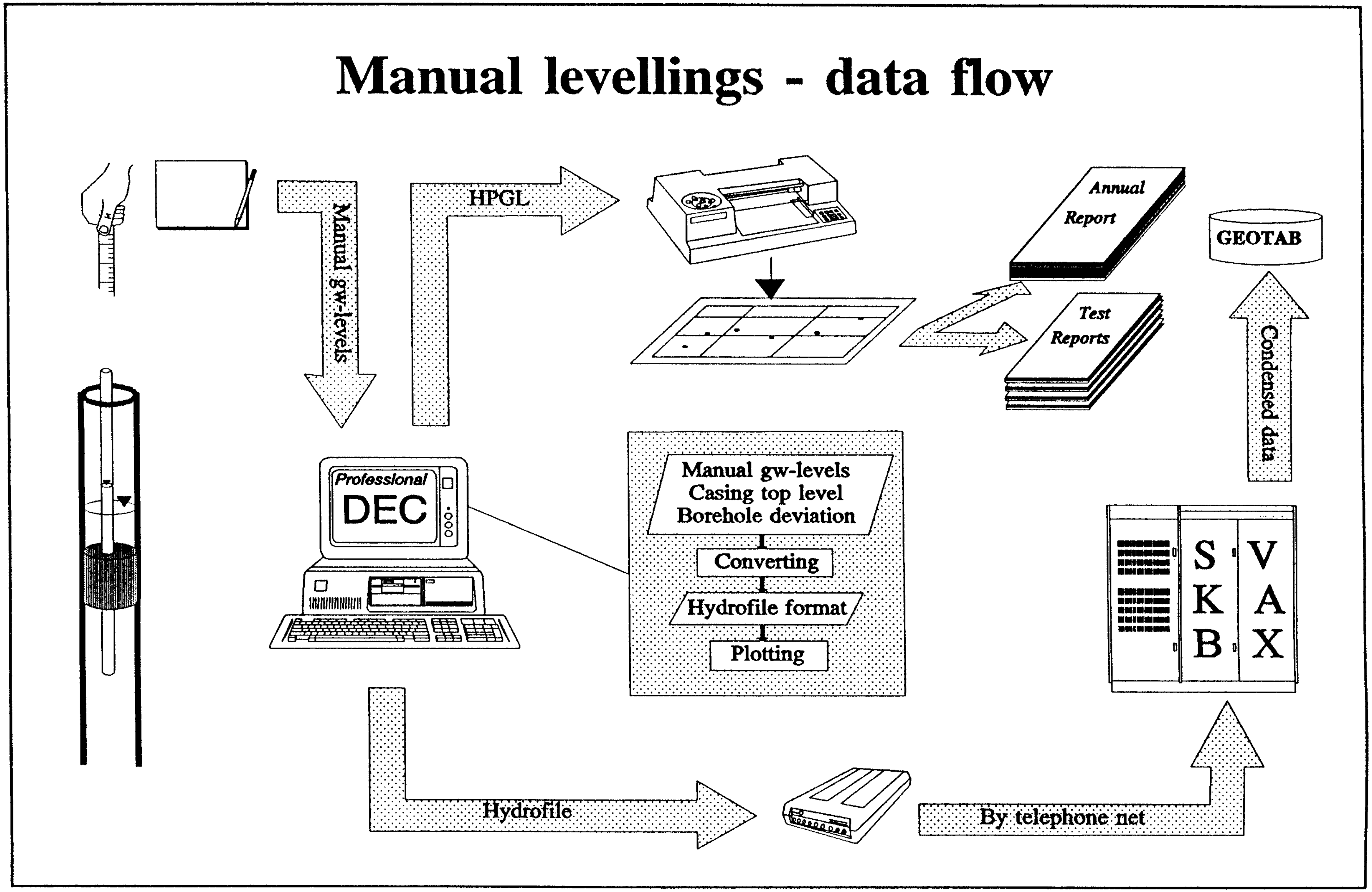


Figure 3-5 Data flow for manual levelling to GEOTAB.

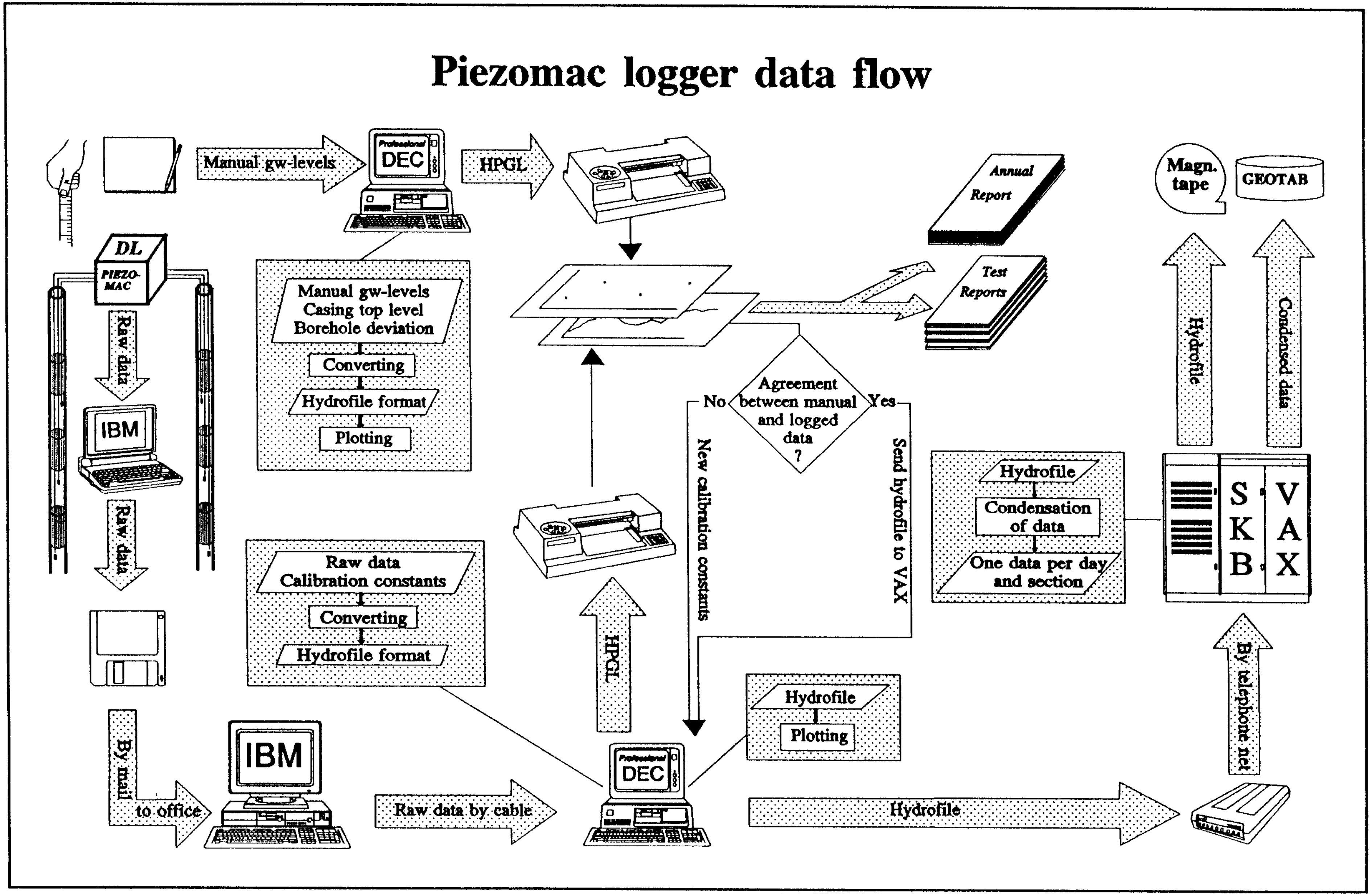


Figure 3-6 Data flow for data from PIEZOMAC A and D to GEOTAB.

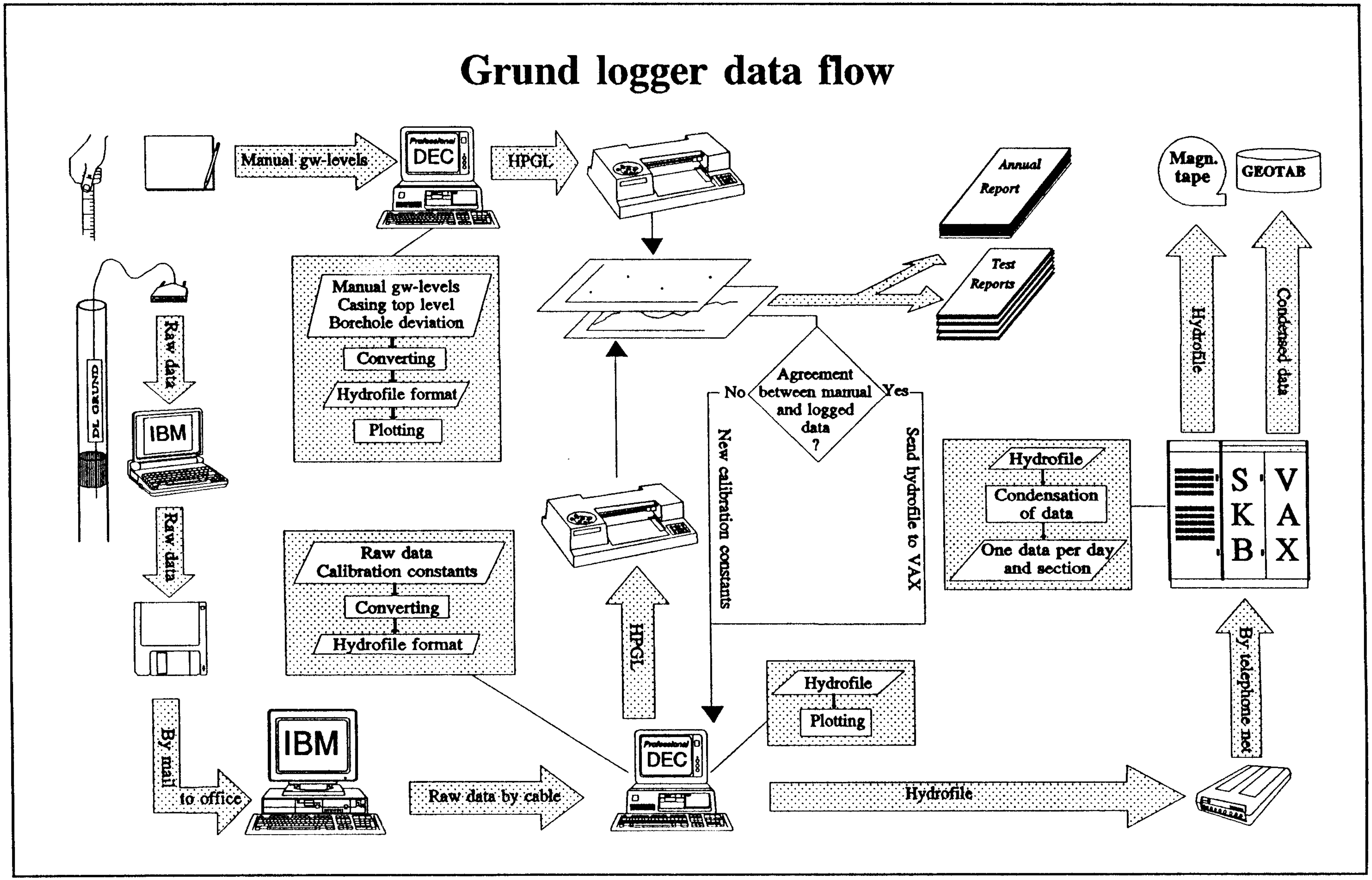


Figure 3-7 Data flow for data from GRUND to GEOTAB

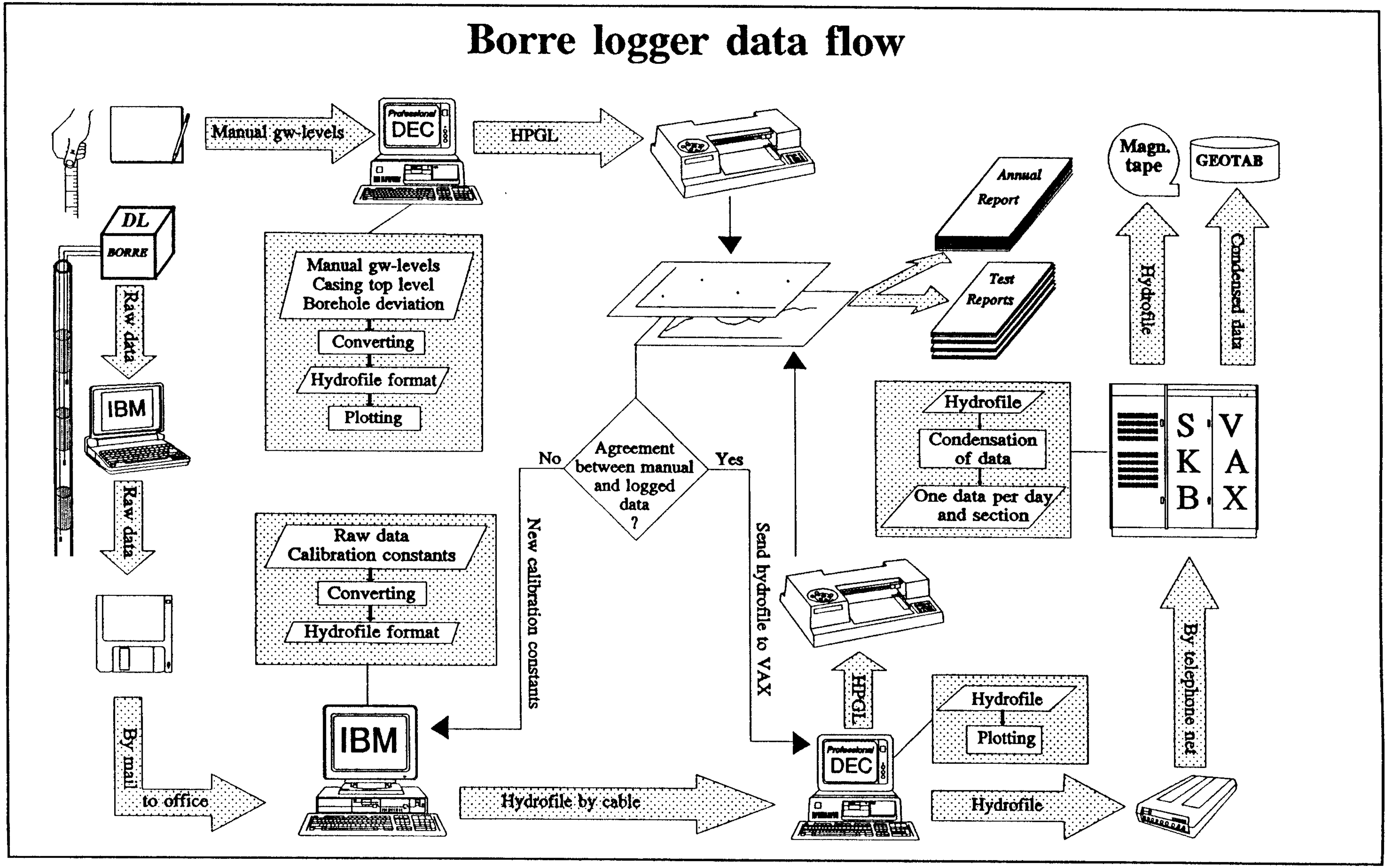


Figure 3-8 Data flow for data from BORRE to GEOTAB.

4 PUMP TESTS

4.1 TEST AND CLEANING PUMPING

The aim of test and cleaning pumping is to clean the borehole from cuttings and flushing water, to decide hydraulic properties of the rock and its surroundings and to investigate if there are any hydraulic connections between the other boreholes in the area.

The equipment used for pump test in the Äspö Laboratory project is the Steel Pipe Equipment System.

A test starts with a "pump phase", when water is pumped at constant flow capacity from a borehole. After a period, varying between some hours to some weeks, the pumping is stopped and a "recovery phase" starts, when the disturbed groundwater head recovers to its natural level. During the whole test period the variations of the groundwater level or the groundwater pressure is registered in all the influenced boreholes and measurement sections. The registration frequency is high in the beginning of the two phases but it decreases with increasing time.

4.1.1 Collecting, processing and evaluation of data

Collecting, processing and evaluation of data follows the schedule as for interference tests; manual registrations (Chapter 4.2) and automatic registrations (Chapter 4.3) and automatic groundwater level measurements with GRUND, BORRE, PIEZOMAC or manual registrations (Chapter 3.5).

4.2 INTERFERENCE TESTS WITH MANUAL REGISTRATION OF THE GROUNDWATER LEVEL

By means of interference tests hydraulic properties such as hydraulic conductivity, storage coefficient and skin factor can be determined. The difference compared with the single hole injection tests (chapters 2) is that the parameters obtained from interference tests represent a larger rock volume. The purpose of the interference test is often to decide the hydraulic properties of a fracture zone.

An interference test starts with a "pump phase", when water is pumped at constant flow capacity from or to a borehole. After a period, varying between some hours to some weeks, the pumping is stopped and a "recovery phase" starts, when the disturbed groundwater head recovers to its natural level. The pump well and adjacent observation boreholes can be delimited by inflatable rubber packers. During the whole test period the variations of the groundwater level or the groundwater pressure is registered in all the influenced boreholes and measurement sections. The registration frequency is high in the beginning of the two phases but it decreases with increasing time.

4.2.1 Collecting, processing and evaluation of data

Data flow is presented in the block diagram in figure 4-1.

The parameters measured during an interference test is groundwater levels of the measurement sections/boreholes and the flow rate of the pump. The groundwater levels are measured by means of soundings. The flow rate is measured either by a flow meter or by measuring flow volumes during a delimited time.

For the test pumping a submersible pump is most often used. But the groundwater head of the pump hole has also been lowered by means of gas-lift pumping.
When the equipment have been installed in the boreholes the field personnel measure the groundwater levels in the measurements sections before the packer inflation and just before the pump start. In the beginning of the pumping- and recovery periods respectively the measuring frequency is high but it decreases with increasing time. The flow is regulated to a constant rate by the flow meter. During the pump test the flow is checked and sometimes corrected.

The measurement data are noted in field protocols. With the help of these the responsible hydrogeologist calculate the draw-down or recovery of the groundwater level at every measurement occasion. The results are noted in a data tables. The data tables are punched to datafiles, which now are stored on magnetic tapes at KRAB, Stockholm.

The data of the data table is plotted on a number of diagrams. The diagrams show the groundwater level draw-down or recovery versus the time in a logarithmic or semi-logarithmic scale.

By the aid of the diagrams the interference test is evaluated and parameters such as hydraulic conductivity, skinfactor and storage coefficient are evaluated.

The results of the interference tests are stored in the table INTRCD in SKBs database GEOTAB.

4.2.2 Data Volumes in the Block Diagram in Figure 4-1

Groundwater level values

The measured values are the distance (in metres) between the top of the borehole casing and the groundwater level along the borehole. The measurement frequency differ for different interference tests but as a rule the measurement frequency in the pump well and in the observation holes close to the pump well is 2-3 measurements/minute during the first 5 minutes of the pumping phase and the recovery phase. Successively the time intervals between the registrations increase and after five days the frequency is 1-2 measurement per day. Observation holes at a greater distance from the pump hole are measured at a lower frequency.

Flow values

When a submersible pump is used the flow is generally measured by a flow meter (type Brooks rotameter) and the flow values are read on the scale of the flow meter.

During interference test carried out by means of air lift pumping the flow is usually determined by measuring flow volumes during a delimited time.

Field protocols

The measurement data are written down in the field protocols (one for each borehole) by the measurement operators. The columns of the protocols comprise date and time of measurement, groundwater level value or flow scale value (alternatively flow volume per unit of time).

The field protocols are now (1986) filed in the archive at SGAB, Uppsala.

Borehole data

The responsible hydrogeologist needs certain borehole data to convert the field protocols to data tables. These data are inclination of the boreholes and altitude of the tops of the borehole casings.

Data tables

The results of the calculations of field data are written down in data tables. The respective columns of the tables contain the following data: borehole name, date/time of measurement, minutes from the pump start or recovery start, vertical draw-down or recovery after the pump start or recovery start respectively for the measurement sections. The data tables are now filed in the archive at SGAB, Uppsala.

Data files

The data of the data tables is punched to data files. The 100 first lines of the data files contain a description of the actual data file. The rest of the lines have the following format.

column 1: Borehole idcode TSSNN:
T = borehole type,
K= cored borehole
H= percussion borehole
SS= site code
NN=borehole number

column 2: Date/time of measurement (YYMMDDhhmmss)

column 3: Time from pumpstart or time from recovery start (min)

column 4: Vertical distance from the top of the casing to the groundwater level for the upper measurement section (m)

column 5: Vertical distance from the top of the casing to the groundwater level for the second measurement section from the ground surface (m)

column 6: Vertical distance from the top of the casing to the groundwater level for the third measurement section from the ground surface (m)

Section limits of the measurement sections are noted in the beginning of the data file. The data files are stored on magnetic tapes at KRAB.

GRAPHS

The data in the data files are plotted in a number of graphs. In the graphs the following parameters are plotted.

s against $\log t$ (or $\log t'$)
$\log s$ against $\log t$ (or $\log t'$)
s against $\log(t/r^2)$ (or $\log(t'/r^2)$)
s_p against $\log r$
s_p against $\log(t'/(t+t'))$
Q against $\log t$

where

s = Draw-down during the pump phase or recovery during the recovery phase for each section respectively (m)

t = Time from pumpstart during pump phase (s)

t' = Time from pump stop (s)

t_p = Duration of the pump phase (s)

s_p = Draw-down at pump stop

r = Distance between the measurement sections of the observation holes and the pump well (m)

Q = Water flow rate (m^3/s)

The graphs are now in the archive at SGAB, Uppsala.

4.2.3 Processes in the Block Diagram in Figure 4-1

Groundwater level measurements

The groundwater heads of the boreholes and the measurement sections are measured by means of soundings. The sections below the packers are measured via tubes leading from the ground surface through the packers to the actual section.

Flow measurements

When the interference test is performed with a submersible pump the water flow is in general regulated and monitored by the same flow meter used in the water injection tests with the steel pipe equipment (sections 2.1.1.3 and 2.2.1.3).

In the case of air lift pumping the water flow is usually determined by measuring flow volumes from the pump well during delimited time periods.

Measurement operators

The measurement operators install the equipment in the boreholes and on the ground surface. They start the test and registrate groundwater levels and the water flow and note the measurement data in protocols. They also keep the pump flow at a constant level.

Calculations

The responsible hydrogeologist calculate the draw-down during the pump period and the recovery during the recovery period for each measurement. He also transform the time of measurement to minutes after pump start and pump stop respectively. The results are written down in data tables.

Plotting

The graphs are plotted either manually or by the help of standard programmes on a PC.

Punching

The data tables are punched to data files either directly to the host computer (PRIME 750 at SGAB or VAX 750 at KRAB) or via an ABC 800 PC.

Evaluation

The tests have been evaluated according to the theories for interference tests in single-porous media or double-porous media (Andersson and Hansson 1986, Carlsson and Gustavsson 1984).

4.3 INTERFERENCE TESTS WITH AUTOMATIC REGISTRATION OF THE GROUNDWATER PRESSURE BY THE PIEZOMAC I SYSTEM

4.3.1 Collecting, Processing and Evaluation of Data

Data flow is presented in the block diagram in figure 4-2.

The data collecting routines and instruments are almost the same for interference tests with the PIEZOMAC I system as for piezometric measurements performed with the same equipment (chapter 3.4). In the interference tests, though , two or more multipressure probes are connected to the Piezomac-unit, which is not always the case during the piezometric measurements. Furthermore pump or injection flow from or to the pump well is measured and regulated in the interference tests. The water flow is measured by same type of flow meter that is described in section 4.2.

The routines for data processing of the measurement values of the probes are identical(all the way from

the probes to the D-file) to the piezometric measurements described in chapter 3.4.
The flow values from the manual flow meter is noted in a protocol and the average flow rate of the pumping period is calculated.

On the basis of the D-file 14 graphs can be plotted. The graphs are evaluated and hydraulic parameters such as hydraulic conductivity, skinfactor and storage coefficient are determined. The results of the interference tests are stored in the table INTRCD in the GEOTAB database.

During 1985 and 1986 the PIEZOMAC system has been modified. The new equipment, called PIEZOMAC II, has an improved measurement probe, new hardwares and new plot programmes (Almén et al 1986). Since the new equipment is not yet completed the data flow of the PIEZOMAC II system is not described in this report.

4.3.2 Data Volumes in the Block Diagram in Figure 4-2

Most of the data volumes in figure 4-2 are identical or almost identical to the data volumes of figure 3-4 and they are described in section 3.4.2. The data volumes that differ or are not described earlier are completed below.

P-FILES AND D-FILES

The P-files and the D-files have the same format as described in section 3.4.2, but there are small differences in the content that are worth noticing.

In the record type 3 the five first stored pressure values always come from the pump well in the interference tests. If there are less than 5 sections in the well the data are repeated. If the scanning mode is P (in record type 2) only measurement data from the pump well are valid. Apart from this the P-files and the D-files have the same format as described in chapter 3.4.

S-FILE

The format of the S-file is the same as described in section 3.4, but the second record always correspond to the pump well.

Flow protocol

The flow values read on the scale of the flow meter are noted in a flow protocol.

Flow rate

The responsible hydrogeologist calculate the average flow rate during the pumping period in (m^3/s). This value is later used in the evaluation of the interference test.

GRAPHS

By the aid of the plot routine INTFPLT one flyleaf, called AO, and 14 different graphs can be plotted. The flyleaf show relevant borehole data such as borehole-length, inclination of the boreholes , limits of the measurement sections, distances between the pump hole and the measurement sections, length to the pressure transducer from the top of the casing and pressure values (kPa) at the beginning and the end of the pumping phase. The graphs are called A1, B1 - B7, C1 - C5 and D1. They show pressure and flow variations before pump start(A1), during the pump phase (B1 - B7), during the recovery phase (C1 -C5) or after the recovery according to the following:

A1: P	vs	t_{abs}	
B1: dP_1	vs	$\log t$	
B2: $\log dP_1$	vs	$\log t$	
B3: $\log dP_1$	vs	$\log(t/r^2)$	
B4: Q	vs	$\log t$	
B5: dP_1	vs	$(t)^{1/4}$	
B6: dP_1	vs	$\log r$	(at pump stop)
B7: $\log dP_1$	vs	$\log r^2$	(at pump stop)
C1: dP_3	vs	$\log(t'/(t_p+t'))$	
C2: $\log dP_2$	vs	$\log t'$	
C3: dP_2	vs	$(t')^{1/4}$	
C4: dP_2	vs	$\log r$	(when $t+t'=2t_p$)
C5: $\log dP_2$	vs	$\log r^2$	(" " "
D1: P	vs	t_{abs}	

where

P = absolute pressure
t_{abs} = absolute time
t = time from pump start
dP_1 = pressure draw-down
r = distance from measurement section to pump well
Q = Water flow rate
dP_2 = pressure recovery
dP_3 = residual pressure recovery
t' = time from pump stop
t_p = duration of pump phase

INTRCD

The results of the interference tests are stored in the table INTRCD in the GEOTAB database. INTRCD is described in appendix 15.

4.3.3 Processes in the Block Diagram in Figure 4-2

Most of the data processes in figure 4-2 are identical to those in figure 3-4 and are consequently described in section 3.4.3. The ones not defined earlier are described below.

Flow measurements

The water flow from or to the pump well is measured by the same type of flow meter used in the interference tests with manual registrations, section 4.2.3. The flow is in some cases maintained at preset constant capacity by means of an automatic regulation unit (Almén et al 1983). The regulation unit keeps the flow constant within 1%. The flow values read on the scale of the flow meter are registered at intervals that vary depending on if they differ from the preset value.

Flow calculation

Data from the flow protocol are converted to flow rates and the average flow rate (in m^3/s) of the pumping sequence is calculated by the responsible hydrogeologist.

"INTFPLT"

INTFPLT is a plot routine on PRIME 750 for generating plots either on a terminal screen or on paper. The plotting routine is handled by the data department at SGAB.

Evaluation

The tests have been evaluated according to the theories for interference tests in single-porous or double-porous media (Andersson and Hansson 1986, Carlsson and Gustavsson 1984).

4.4 PUMP TESTS IN GEOTAB

The flyleaf data and result data from both the test and cleaning pumpings and interference tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table INTRF1	- Flyleaf 1 Company, person(s) responsible, references
Table INTRF2	- Flyleaf 2 Start/stop of pump and recovery phase, flows, datafiles
Table INTRF3	- Flyleaf 3 Equipment In Pumpwell and Obsholes
Table INTRF4	- Flyleaf 4 Comments From Pumpwell and Obsholes
Table INTRF5	- Flyleaf 5 Constants From Pumpwell And Obsholes
Table INTRGEOM	- Geometry Of The Pumpwell
Table INTERQD	- Water Flow Data in Pumpwell
Table INTERVD	- Water Volume Data in Pumpwell
Table INTRD	- Packer Data from Pumpwell and Obsholes
Table INTRPSEC	- Groundwater Pressure Data from Test Sections in Pumpwell and Obsholes
Table INTRLSEC	- Groundwater Level Data from Test Sections in Pumpwell and Obsholes
Table INTRCD	- Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

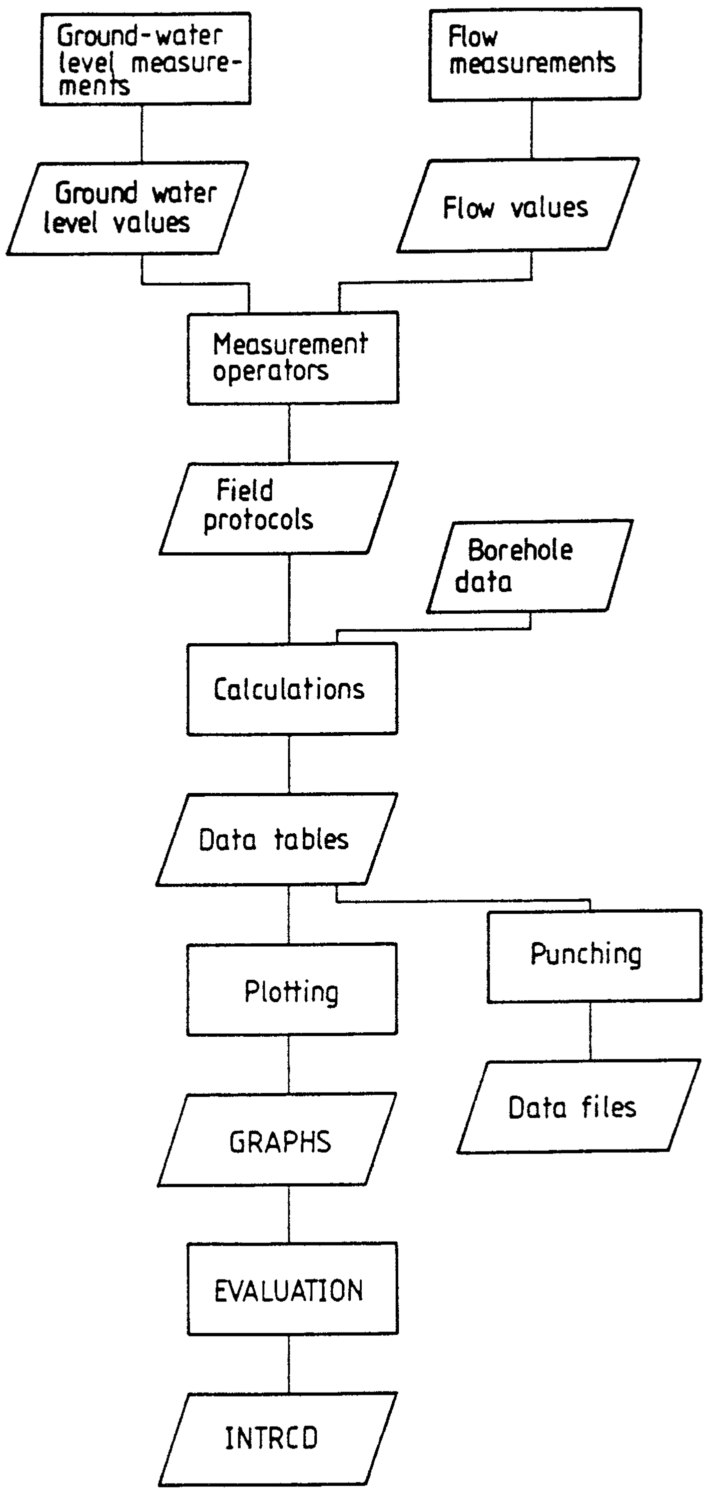


Figure 4-1 Data flow for data from interference tests with manual groundwater registrations

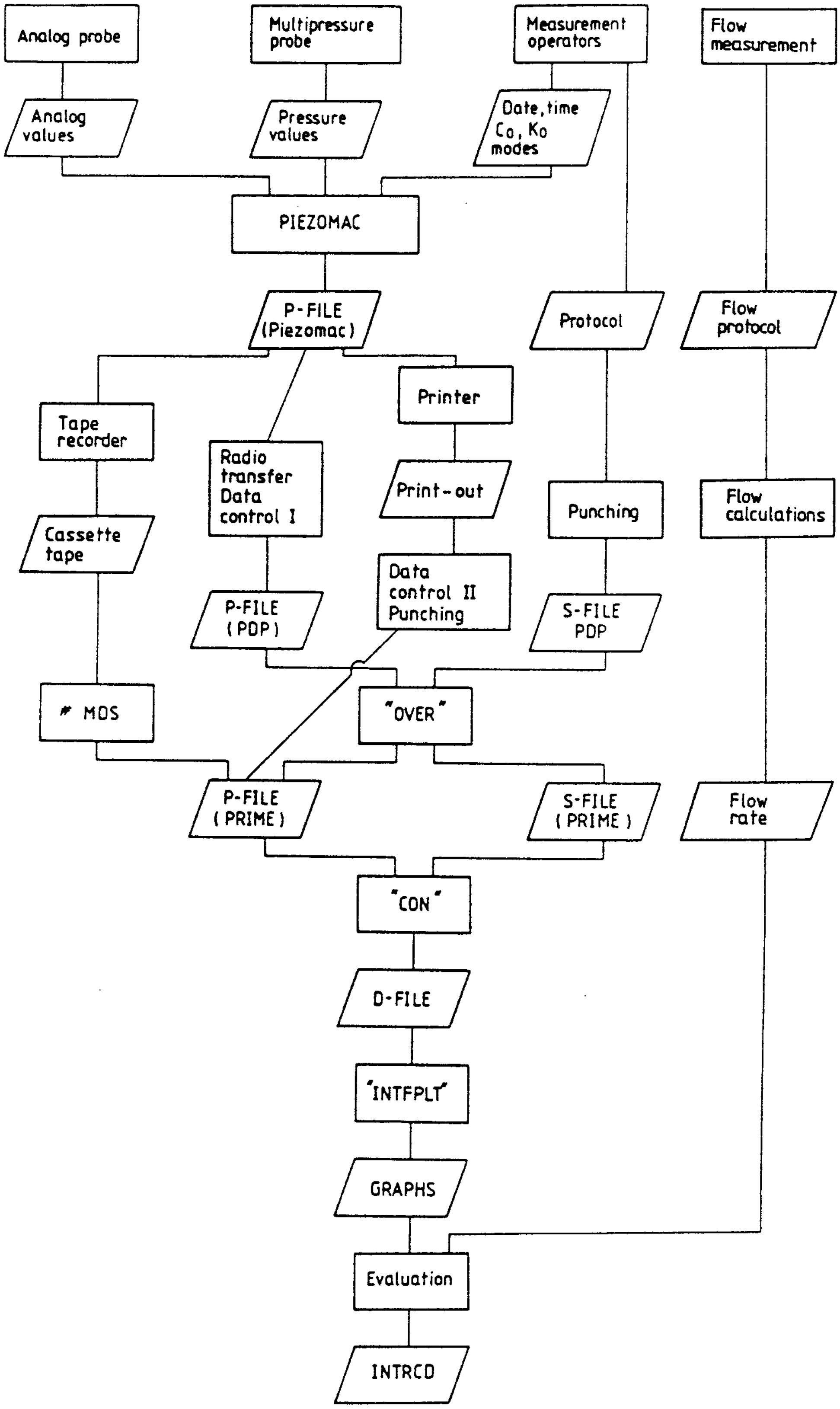


Figure 4-2 Data flow for data from interference tests with the PIEZOMAC I system.

5 HYDRAULIC UNITS

The bedrock in some of the investigated study sites have been subdivided into hydraulic units according to their hydraulic properties, i.e. their hydraulic conductivity at depths. This division is basic to the construction of a descriptive model of the sites respectively. The following three main units have been identified:

- rock mass
- local fracture zones
- regional fracture zones

This classification is based on the results from the geological and tectonic investigations which indicate the location and extension of existing regional and local fracture zones. The fracture zones located on the ground surface are correlated to intervals in the boreholes by means of core mapping and geophysical measurements. The hydraulic conductivity values of the borehole intervals that intersect the fracture zones are determined from the results of the transient injection tests, chapter 2. In the database local fracture zones and regional fracture zones are brought together to one method called fracture zones. The hydraulic conductivity values of the measurement sections that do not intersect the fracture zones represent the hydraulic unit rock mass. In some study sites differences in hydraulic conductivity between different rock types in the rock mass have been confirmed. In these cases the rock mass has been divided into sub units. Accordingly there are three methods in the data base, which correspond to a hydraulic unit respectively. The methods are:

- Hydraulic unit fracture zones
- Hydraulic unit rock mass
- hydraulic unit rock types in the rock mass

The data flow of the methods are described separately in the following sections.

5.1 DATA FLOW OF THE METHOD HYDRAULIC UNIT FRACTURE ZONES

Data flow is presented in figure 5-1

SHTINJCD

The table SHTINJCD in the GEOTAB database contains the results of the single hole transient injection tests, see appendix 15.

Selection

The widths of the fracture zones in the boreholes are determined from the geologic and tectonic investigations of the core and from borehole geophysical measurements. The measurement sections that cover the fracture zones in the boreholes are initially selected. The section lengths are depending on the performance of the tests and the width of the zone.

Hydraulic conductivity values

After the selection the result is a number of hydraulic conductivity values from sections that entirely or partially are penetrated by the fracture zones.

Borehole data

The borehole data needed for the calculations are the initial inclinations (IW) of the boreholes.

Calculations

If the measurement section is entirely covered by the fracture zone the hydraulic conductivity (K) of the zone is equal to the measured value. The depth of the K-value is then calculated according to equation 5.1.

$$d_z = (L_0 + L/2) \times \sin(IW) \qquad (5.1)$$

where

d_z = Vertical depth of the fracture zone (m)
L_0 = Length to upper limit of the measurement section (m)
L = Length of the measurement section (m)
IW = Inclination of the borehole (degrees)

If the section is only partially penetrated by the zone the K-value is calculated according to equation 5.2

$$K_z = (K \times L)/L_z \qquad (5.2)$$

where

K_z = Hydraulic conductivity of the fracture zone (m/s)
K = Measured K-value (m/s)

L_z = Width of the zone in the borehole (m)

The vertical depth is in the case of a partially penetrated section calculated as follows:

$$d_z = (L_{z0} + L_z/2) \times \sin(IW) \qquad (5.3)$$

where

L_{z0} = Borehole length to upper limit of the fracture zone (m)

If the fracture zone covers a section limit the zone is divided into two parts each one represented by a K-value.

5.2 DATA FLOW OF THE METHOD HYDRAULIC UNIT ROCK MASS

Data flow is presented in figure 5-2.

SHTINJCD

The table SHTINJCD in the GEOTAB database contains the results of the single hole transient injection tests, see appendix 15.

Selection

The 25 m or 20 m measurement sections that do not intersect the fracture zones are selected. In addition single packer tested sections of deviating lengths can be selected.

Hydraulic conductivity values

The result of the selection is a large number of hydraulic conductivity values representing the hydraulic unit rock mass.

Borehole data

The borehole data needed for the calculations are the initial inclinations (IW) of the boreholes.

Calculations

The vertical depth of the selected K-values are calculated according to equation 5.1. Many measurement section from single packer tests have approximately twice the length of the rest of the sections. These sections are represented by two K-values, equal to the measured value, but with separate depths.

5.3 DATA FLOW FOR DATA FROM THE METHOD ROCK TYPES IN THE ROCK MASS

Data flow is presented in figure 5-3.

HURMCD

The content of HURMCD is described in the preceding section 5.2.

Selection

In some investigated study sites layers of subordinate rock types have higher K- values than the host rock. In these cases the measurement sections, which represent the rock mass and are intersected by the subordinate rock type, are selected to a sub unit of the rock mass.

Hydraulic conductivity values

The selection results in hydraulic conductivity values from sections of the rock mass that contain the subordinate rock type.

Calculations

If the measurement section is entirely covered by the subordinate rock type the hydraulic conductivity of the subordinate rock type is equal to the measured value. The depth of the K-value is then calculated according to equation 5.4.

$$d_s = (L_0 + L/2) \times \sin(IW) \qquad (5.4)$$

where

d_s = Vertical depth of the subordinate rock type (m)
L_0 = Length to upper limit of the measurement section (m)
L = Length of the measurement section (m)
IW = Inclination of the borehole (degrees)

If the section is only partially penetrated by the subordinate rock type the K-value is calculated according to equation 5.5

$$K_s = \frac{K \times L - K_r \times L_r}{L_s} \qquad (5.5)$$

where

K_s = Hydraulic conductivity of the subordinate rock type (m/s)

K = Hydraulic conductivity of the section concerned (m/s)

K_r = Hydraulic conductivity of the main rock type, at the actual depth obtained from regression analysis (m/s)

L_s = Length of the subordinate rock type in the section (m)

L = Length of the section concerned (m)

L_r = Length of the main rock type in the section (m)

The regression analysis mentioned above is a Power curve analysis of the form $K(z) = a z^b$ (a,b = constants, z = depth) with the K- values from the rock mass as input data.

The corresponding depths for the K- values from eq. 5.5 are calculated according to the following:

$$d_s = (L_{s0} + L_s/2) \times \sin(IW) \qquad (5.6)$$

where

L_{s0} = Borehole length to upper limit of the subordinate rock type (m)

5.4 HYDRAULIC UNIT DATA IN GEOTAB

The hydraulic unit data are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Method HUFZ - Hydraulic Unit Fracture Zones

Table HUFZF - Flyleaf

Table HUFZCD - Calculated Data

Method HURM - Hydraulic Unit Rockmass

Table HURMF - Flyleaf

Table HURMCD - Calculated Data

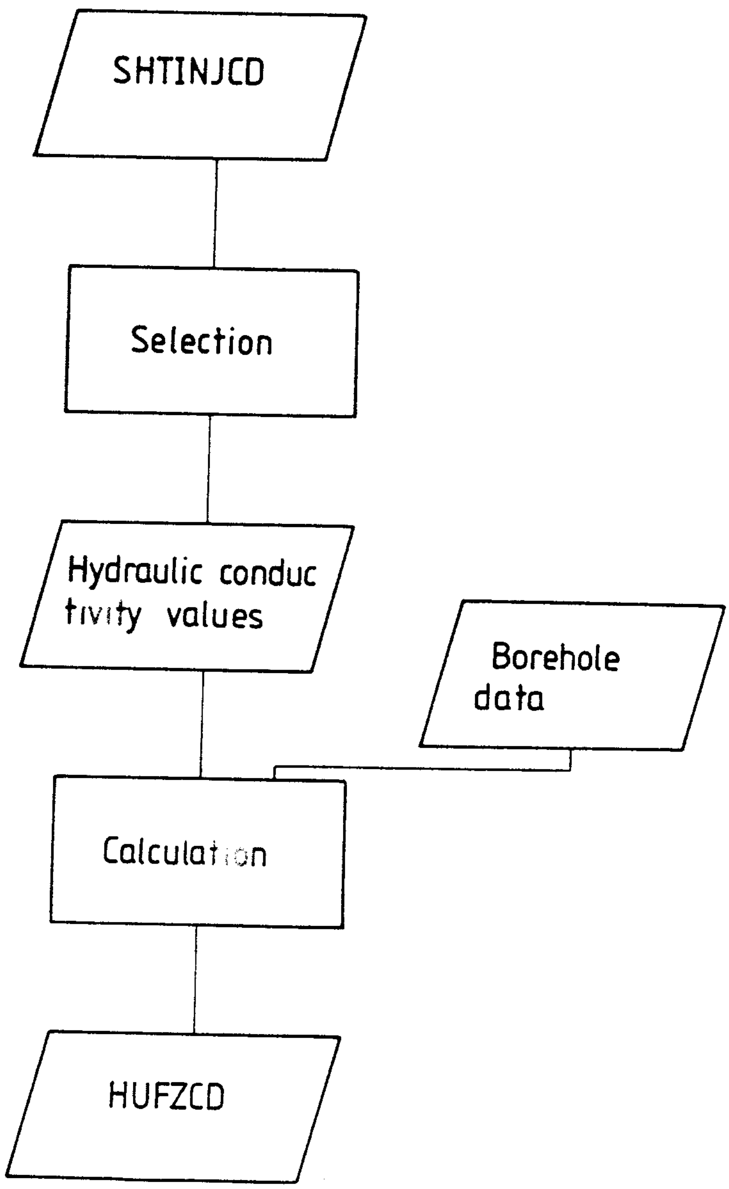
Method ROCKRM - Rocktypes In Rockmass

Table ROCKRMF - Flyleaf

Table ROCKRMCD - Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

Figure 5-1 Data flow of the method "hydraulic unit fracture zones".



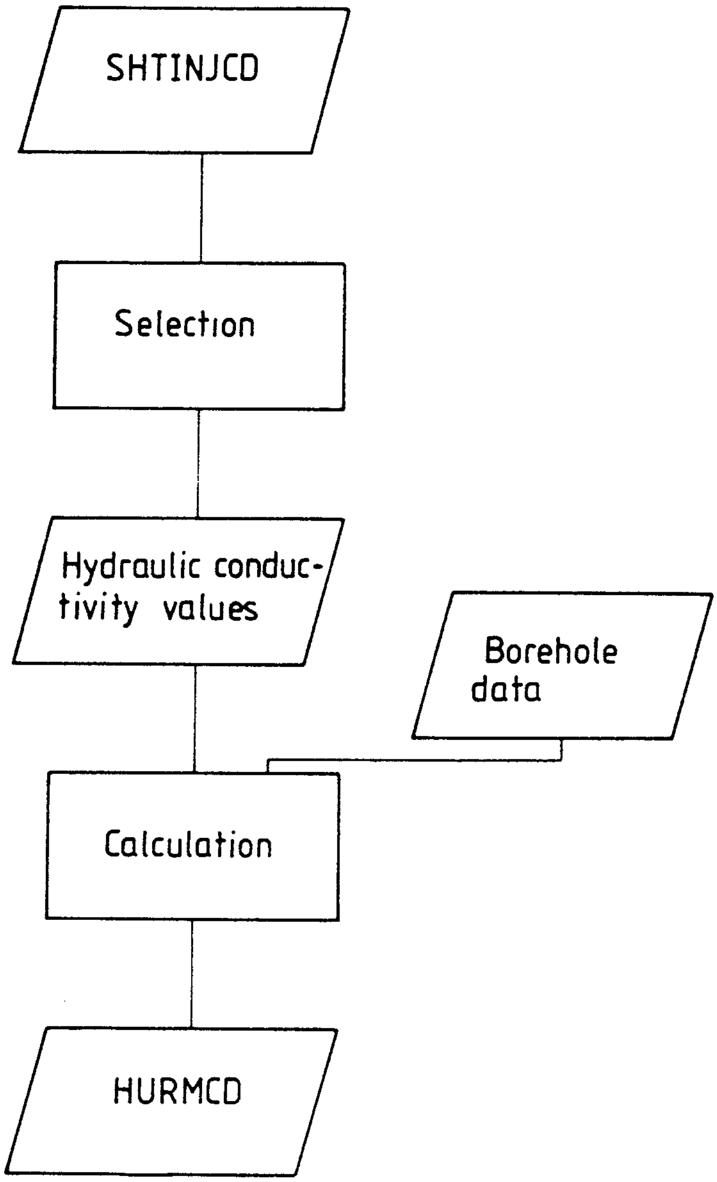


Figure 5-2 Data flow of the method "hydraulic unit rock mass".

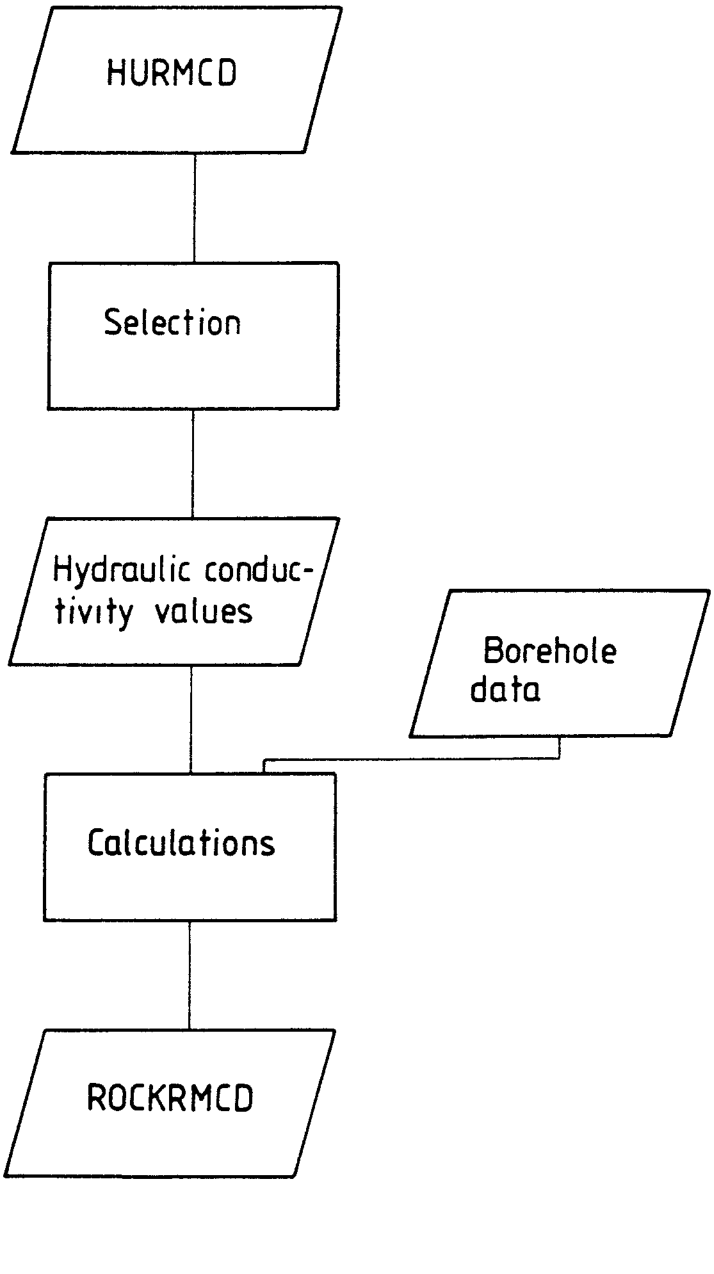


Figure 5-3 Data flow of the method "hydraulic unit rock types in the rock mass".

6 FALLING HEAD TESTS

6.1 PRINCIPLE AND THEORY

The falling head method used in a laboratory situation applied to soil samples have been reported (Tell 1961, de Wiest 1966). The falling head method applied as a preinvestigation tool on a field scale has been discussed by ISRM (1974), Bell (1980) and Hoek and Bray (1977). Few examples of actual field application of the method has been reported. Raven (1980) reports the use of falling head tests at Chalk River, Ont., Canada. In Sweden, Hagconsult AB (Lindblom, Adolfsson and Norlén 1981) reports results from falling head tests performed in conjunction with underground experiments with electrokinetic injection at Forsmark. The following description of equipment and measurement technique is adopted from the reporting of falling head tests performed by Hagconsult AB in conjunction with preinvestigations for the Swedish Storage for Reactor Waste (SFR) located offshore, at Forsmark (SFR 1981).
An excess head is applied to a packed off section in a borehole by filling up a measurement vessel attached to the top of a stand pipe connected to the downhole measurement section. After initiating the test, water is flowing into the formation, monitored by the sinking water level in the measurement vessel. The decline in the water level is monitored as a function of time as long as a decreasing flow can be calculated from the successively lowered head.

By keeping the applied excess head below 5 metres of water column, most of the common disturbances associated with injection tests , eg. rock heaving, flushing of fracture infillings and turbulent flow, can be eliminated. In addition, water consumption and pressure losses during the test are significantly reduced.

Input data to evaluation of the formation hydraulic conductivity or the specific flow are:

1) data on the descending water level in the measurement vessel as a function of time.

2) calculated flows associated with, and discretized in accordance with the time/space resolution in the level readings.

By extrapolating the flow vs. head relation to a flow equal to zero, the piezometric head level in the measurement section is obtained.

The flow from the section into the rock may be written:

$$q = k * H(t)\,\frac{1}{C}$$

where

q = volumetric flow (m^3/s)

K = hydraulic conductivity (m/s)

C = geometric constant (m^{-1})

For reasons of continuity, the same value of the flow q must also apply to the reduction of the volume of water in the measurement vessel, ie:

$$q = -\frac{dh(t)}{dt} * A_s$$

where

A_s = area of crossection of the measurement vessel

h(t) = water level (hydraulic head) in the measurement vessel as a function of time.

Integration and evaluation yields;

$$K = C * A_s * (t_1 - t_o) * \ln(\frac{h_o}{h_1})$$

where

h_o = head at time t = t_o = time of initiation of test

h_1 = head at time t = t_1

Another means of presenting the material property is in the form of the specific flow ρ defined as;

$$\rho = \frac{q(h)}{h(t)}$$

Examples of calculation algorithms and plotting of results are provided in Figure 6-1.

6.2 EQUIPMENT

The equipment may be subdivided into a downhole packer assembly, a surface arrangement for flow measurement and a field computer which facilitates on-site evaluation and control of collected data and results.

6.2.1 Down-hole packer assembly

The down-hole packer assembly used consists of three packers. The periphery packers T1 and T3, cf. Figure 6-2, are connected with the central packer in order to provide two 3m test sections. The central packer is 3m long and thus with the latter deflated a measurement section of 9m is obtained.

The packers are manufactured of rubber and are pneumatically inflated with compressed air. The periphery packers are operated with one single airline (ϕ_i = 0.004m), whereas the packer T2 is operated independently.

Water is supplied to the measurement section through a column of soldered brass pipes (the stand pipe). The individual pipes are 3m long and have an inner diameter of 0.019m.

Apart from air lines and the brass stand pipe, the packer assembly is also secured with a steel wire, also used for lowering and hoisting the packer system in the borehole.

6.2.2 Equipment for flow measurement

The equipment for flow measurement consists of four measurement vessels with different diameters, cf. Figure 6-3. Each measurement vessel is 1.8 m high. The standpipes with the largest diameter, K1 -K3, are made of steel and are equipped with separate glass scales (N1-N3). The individual measurement vessels are connected to a main pipe. The measurement vessels can be disconnected from the main pipe with valves. A pipe for filling up the brass standpipe with water is also connected to the main pipe.

6.2.3 Field computer

An important integral part of the equipment is a personal computer ABC 801 with a cassette memory and a matrix printer. The computer is used to evaluate the manually inputed readings of head (h) and time (t). Each measurement point is plotted in a flow-head diagram, cf. Figure 6-1, on the screen. The original measurement data are stored on cassette for later reinterpretation and/or presentation.

6.3 FIELD PERFORMANCE

The packer assembly is lowered into the borehole and the brass pipes are successively soldered together to form the standpipe. When the packers has been emplaced at the desired depth the packers are inflated according to choice of measurement section length.

Water is supplied to the measurement section and the standpipe is filled to a desired level in the assembly of measurement vessels. Some short time tests are used to select the vessel to be used during the test. During the test, the time for each 0.05 or 0.10 m decline in water level will be read and noted. The decline in water level in the measurement vessel is monitored for as long as the (calculated) flow decreases proportionally with decreasing head, ie. for as long as laminar flow prevails. Laminar flow conditions is a prerequisite for the subsequent calculations of material properties. The on-site computer processing facilitates rapid means to check that the prerequisites are met and also provides an overall check of the test.

The piezometric head in the test section can be evaluated from the flow-pressure plot by extrapolating the linear relation to a flow equal to zero, cf. Figure 6-1.

6.4 DATA FLOW

The readings of declining head (h) as a function of time (t) are inputed in the computer. These data are used to compute the mean flow (q) between two consecutive readings of h. The flow-head q(h) relation is stored on cassette as is the h(t) relation.

The output from the subsequent calculations are;

Material properties

1) Specific flow ρ
2) Hydraulic conductivity K
3) Transmissivity T

Pressure information

4) Piezometric level of the test section
5) Piezometric level corrected for density differences

Quality measures related to the evaluation

6) Regression coefficient of the q(h) relation
7) Extrapolation factor, ie. ratio between the length of the segment which has been extrapolated to obtain the piezometric level and the total length of the q(h) relation.
8) distance to start level from top of standpipe

other data

9) number of data used in the calculation, ie. the discretization in the monitoring of the decline in the water level.

A complete list of data inputed in GEOTAB are provided in Table 8.1 (SFHEADCD).

6.5 ACCURACY AND SOURCES OF ERROR

When assessing the accuracy and the sources of error associated with the falling head test, three subheadings may be identified;

1) Accuracy and errors in readings of the descending water level.

2) Random and systematic disturbances affecting the measurements.

3) Accuracy in the subsequent calculation procedure.

6.5.1 Accuracy and errors in the water level readings

The accuracy in level readings is assumed to be ±0.001 m. Individual errors in readings of the water level will show up as deviations in relation to the otherwise straight q(h) relation. Isolated erroneous readings will be balanced out with the procedure of readings of total elapsed time and total sinking of the water level from set starting points.

6.5.2 Disturbances affecting the measurements

Random disturbances affecting measurements, eg. transients in the ambient air pressure due to changing wind conditions, will be discovered during the calculation and plotting, and may be excluded before regression calculation. To the potential errors and disturbances also belong air leakages in the equipment, density differences due to temperature differences and errors in the determination of the inclination of the brass standpipe. Analysis of these sources of error show that they may be regarded as insignificant. However, a leakage between the two columns of water in the U-tube could imply larger errors. Errors on the order of 5% has been noted during some tests. These types of error are difficult to detect and may in part be avoided by regular checks of valve and tubing connections during measurements. An estimation of the maximum systematic error is 10%.

6.5.3 Accuracy in calculations

The type of calculations performed during and subsequent to falling head tests are not theoretically correct since no consideration is taken to the sinking (pressure) level (pseudo-stationary conditions). In order to control the accuracy of the calculations associated with the falling head tests, the following calculations have been performed;

1) Calculation of specific flow and piezometric level according to the previously described calculation procedure, cf. Section 8.1.

2) Iterative fitting calculation of specific flow with the piezometric level calculated according to 1) as input value.

3) Analysis of spread of specific flows obtained from the fitting calculation.

4) Calculation of the accuracy in the presented piezometric level.

The accuracy of the determination of the specific flow can expressed as a relative standard deviation. The piezometric level can be stated with an accuracy of c. ±0.1m.

6.6 FALLING HEAD TESTS IN GEOTAB

The flyleaf data and result data from the falling head tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

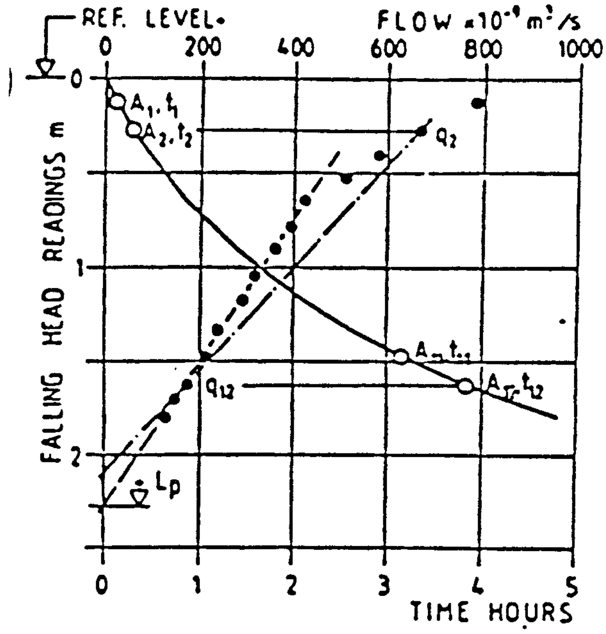
Table SFHEADF1 - Flyleaf 1 Company, person(s) responsible, references

Table SFHEADF2 - Flyleaf 2 Number of sections,

Table SFHEADF3 - Flyleaf 3 Comment(s)

Table SFHEADCD - Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).



CALLCULATIONS

$q_2 = ((A_2\text{-}A_1) \times A_S)/(t_2\text{-}t_1)$

$q_{12} = ((A_{12}\text{-}A_{11}) \times A_S)/(t_{12}\text{-}t_{11})$

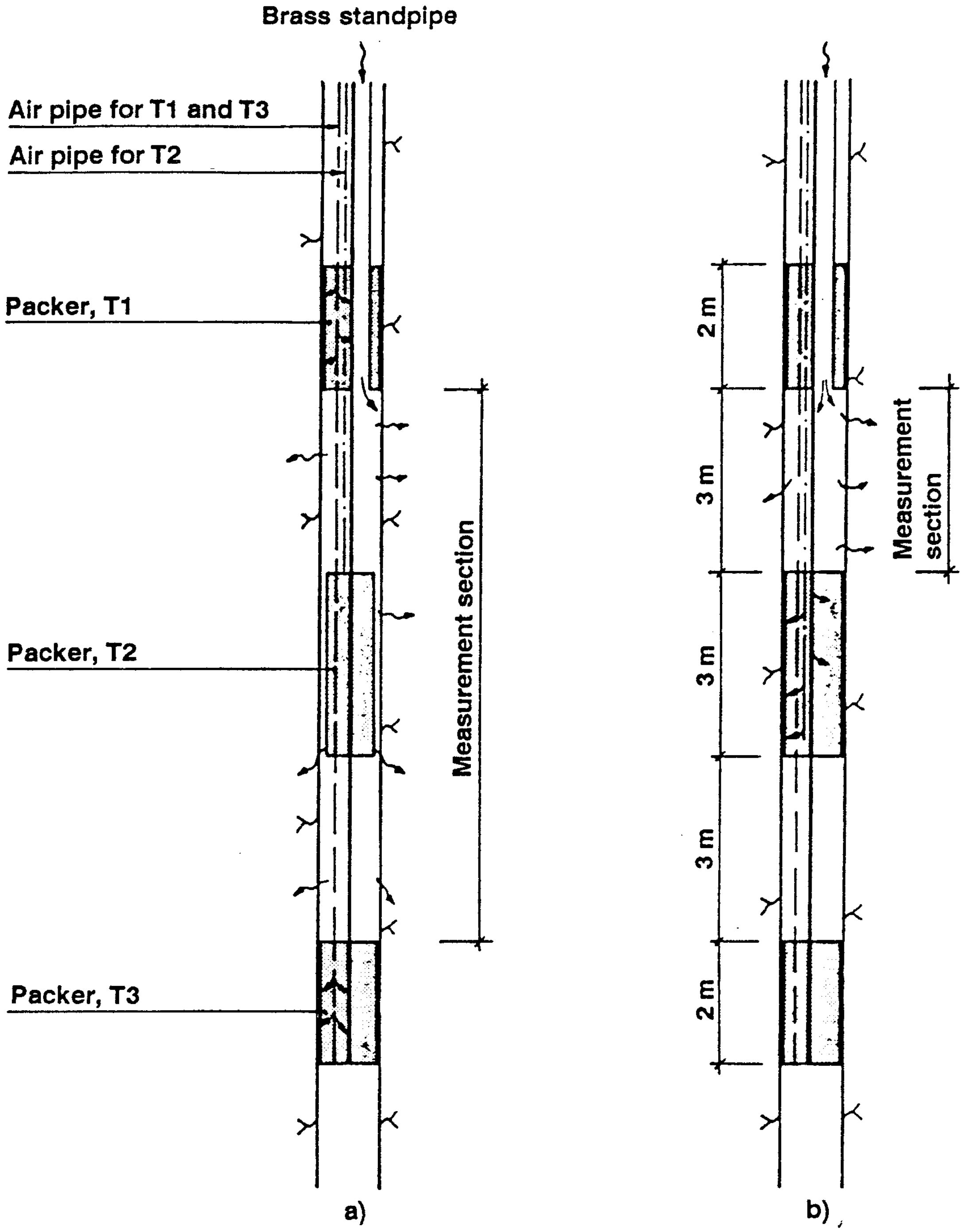
$\rho = [(q_2\text{-}q_{12})/(A_{12}\text{-}A_2)] \times 10^{-2}$

$L_P = L_R - A_{12} - (q_{12}/e) \times 10_{\cdot 2}$

where q flow (m^3/s)
A reading from reference level (m)
t time (s)
A_S area, reading column (m^2)
P specific flow (MPa)

L_P piezometric level
L_R reference level

Figure 6-1 Interpretation of Falling Head Tests.



a) Central packer, T2 deflated, 9 m measurement section

b) Middle packer inflated, 3 m measurement section

Figure 6-2 Packer assembly used in falling head tests

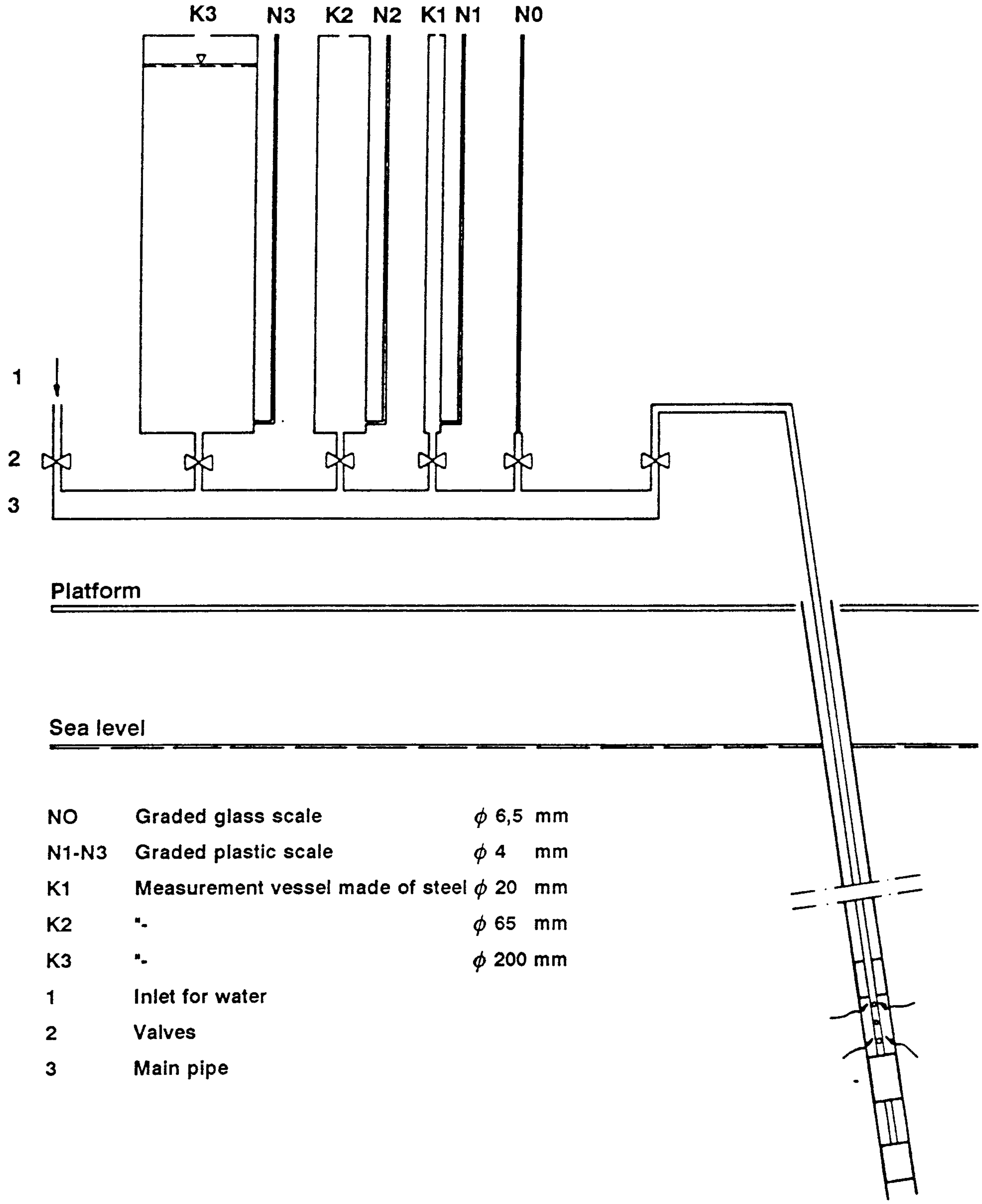


Figure 6-3 Measurement equipment for flow.

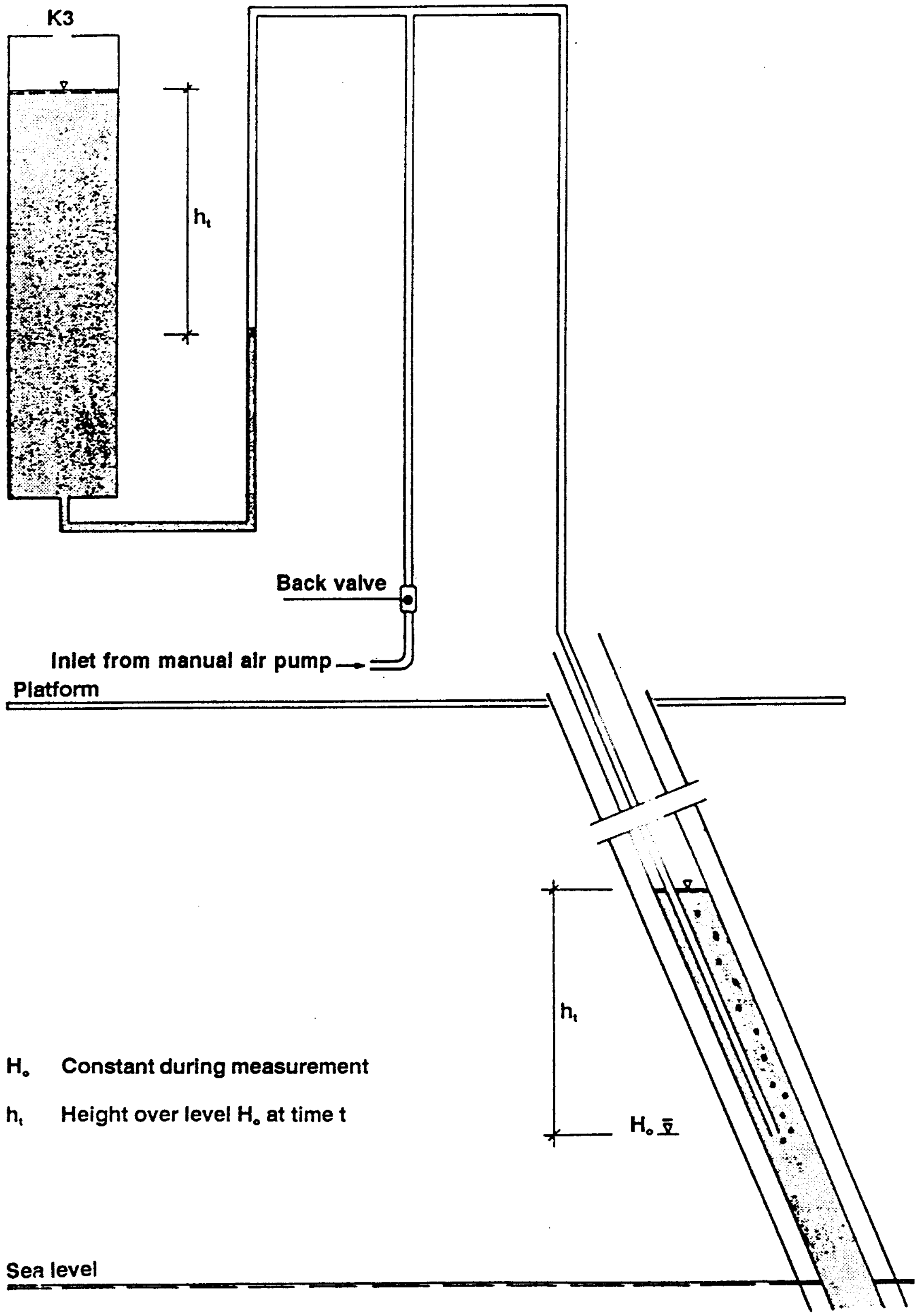


Figure 6-4 Modified measurement equipment for falling head tests.

7 BUILD-UP TESTS

7.1 PRINCIPLE

The hydraulic properties of a groundwater bearing medium can be determined with hydraulic tests. The aim with the build-up tests is to determine the hydraulic conductivity of the rock.
Higher water pressure exists in the sealed sections in the boreholes than it should be at actual level in tunnels and underground facilities at respective borehole. Water will flow, due to this, from a section when it is opened.
During build-up tests, a certain section has been opened and the flow is registered. The flow will stabilize after a while and a equilibrium state between pressure in section and pressure in tunnel is reached. The last registration of flow, i e immediately before start of build up phase, will be the flow value for calculating hydraulic conductivity of the section. During the build up phase the groundwater pressure is registered as a function of time after the flow stops. When the stable pressure of section has reached, the test is over.

7.2 EQUIPMENT

Packers, which delimit different sections for groundwater pressure measurements have been installed in selected boreholes. The packers have sealing devices, 1m, which are stretched against the borehole wall with water pressure. The packers are equipped with up to five through passing pressure pipes. Between the packers these pipes are connected with pressure tubes made of polyamide with an inside diameter of 4 mm.

The sections in one borehole are connected through pressure tubes with a registration equipment placed at every borehole. Flow and pressure can be registered through these tubes. In order to make the measurements and equipment easier, the box with cocks and electronic pressure transducer have been placed direct in connection with respective borehole. The pressure transducers, Druck PDCR 10, admit pressure registrations up to 10, 15 or 20 bar and the accuracy are ca 0.01 m water column. A data logger and a printer are connected to the pressure registration system. The logger can automatic register at most nine delimited sections at the same time. Rest of the sections in boreholes can be registered with manual displays.

Manual registrations has been carried out during build-up tests. The water flow from tested sections have been measured with a graduated glass and time-keeping.

7.3 CARRYING OUT

Build-up tests in the boreholes in the project SFR have been performed in two ways:

A.

A selected section in the boreholes KFR01, KFR04, KFR05, KFR19, KFR20, KFR53, KFR54 and KFR55 have been opened and flow registered. After some time the section is closed and build-up phase is registered.

B.

The build-up tests in boreholes KFR02, KFR7A, KFR7B, KFR7C, KFR08, KFR09, KFR10, KFR11, KFR12, KFR13, KFR56 and KFR83 have been carried out combined with the installation of the packer system in the boreholes. The packers have been sealed during ca 24 hours, which water from the measuring sections is flowing through the connection tubes. Thereafter the measuring sections successively have been closed and the build up phase has been registered. Before closing a measuring section, the flow has been read. The pressure values in the test sections are plotted as a function of time and the hydraulic conductivity has been calculated.

The flow period has ranged over 52 up to 458 hours and was accompanied of a build up phase, which was registered at least 23 hours. The water pressure has been registered during both flow and build up phases. Registration of build up phase has ranged over between ca 2 and 22 hours.

7.4 SINGLE HOLE BUILD-UP TEST IN GEOTAB

The flyleaf data and result data from the single hole build-up tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table SHBUPF1 - Flyleaf 1 Company, person(s) responsible, references

Table SHBUPF2 - Flyleaf 2 Number of sections

Table SHBUPD - Data Table

Table SHBUPCD - Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

8 FLOWMETER TESTS

8.1 DESCRIPTION OF THE MEASURING DEVICES

8.1.2 Equipment for borehole measurements

The borehole part of the flowmeter tool consists of a probe attached to a logging cable (steel armoured 3/16" diameter) by a cable head type Gerhart- Owen. The probe can be centralized in large diameter boreholes by means of blade assays of different diameters. During these works no centralizing has been done as most of the works have been carried out in 56 or 76 mm diameter boreholes.

The working principle is as follows:

Fluid passing the probe at a specific velocity forces a propeller located at the bottom end of the probe into a revolving movement. This movement is registered in the probe as electric pulses at a rate of four pulses/revolution. The signals are transferred through the logging cable and appear as positive voltage pulses at the surface module.

8.1.3 Surface equipment

The surface system used is based on digital data recording on a Compaq II portable computer. The surface equipment consists of the following parts;

- Compaq II portable computer with data acquisition unit
- Measuring wheel with digital counter
- Winch with cable
- Power supply 300 Volt for probe
- Pulse counter

The electric pulses generated by the probe are transferred by the logging cable to the surface unit. There the pulses are registered by a frequency counter at the data acquisition unit and stored together with the measuring depth on the computer hard disk.

Data can also be recorded manually on protocol and afterwards together with depth information entered into a data file by a suitable word processor.

Data on the borehole probe are found in Table 1.

Table 1. Data on MLS Flowmeter Tool

Tool diameter:	36.5 mm
Length:	68.5 mm
Weight:	2.5 kg
Conductors:	Single
Maximum pressure:	680 atm
Maximum temperature:	175 °C
Operating voltage:	+300 VDC
Operating current:	0.5 mA
Output signals:	Positive pulses
Pulses/revolution:	Four

8.1.4 Data processing and presentation

The recorded data from the flowmeter can be converted into flow units (liters/minute) through a calibration data table. This table has been obtained by taking measurements at different flow rates under controlled conditions. Such a calibration is performed at every logging occasion.

Data are stored on ASCII- format and can then be plotted versus depth with standard plotting routines.

8.2 MEASUREMENTS

The performance of a field measurement can be described as follows;

* The water pump is lowered into its planned location in the borehole.

* Pumping is started and carried out until a constant water table is registered.

* The probe is lowered into the measuring borehole to a depth below the pump and where measurements are to be started.

* Measurements are taken at even intervals in the borehole by measuring during a specific time and calculating the mean value of the registered counts/sec.

* The probe is the lowered to the next measuring position.

Measurements are normally taken by lowering the probe into the borehole thereby minimizing disturbing effects of i.e. turbulence.

When the last measurement is taken the probe is hauled up from the borehole.

8.3 DATA QUALITY

8.3.1 Measurement accuracy

The minimum force that has to be overcome in order to get the propeller into a revolving movement determines the smallest flow detected by the probe without any pumping.

Practical experience has shown that this corresponds to a flow of approx. 15 litres/minute in a 56 mm diameter borehole.

This threshold level has then to be overcome while logging. It is normally achieved by creating a flow in the borehole through pumping. The pumped amount of water is measured during a finite time interval resulting in an average measure of the flow. Variations in the pumped amount of water may therefore cause variations in the flow that can wrongly be interpreted as anomalous flow from the bedrock. This can be overcome by averaging the measurements for some time.

8.3.2 Sources of error

The rotation of the propeller is sensed by four elements placed around the axis of the propeller. If any of the elements are defect during logging a wrong number of pulses will be registered resulting in erroneous flow data. This effect has been observed some times during logging.

An accurate calibration is necessary in order to obtain accurate flow data during logging. This finally determines the measured flow in the borehole.

Variations in borehole diameter may result in erroneous flow data as the calibration is generally carried out in a tube of a specific diameter.

8.4 FLOWMETER TESTS IN GEOTAB

The flyleaf data and result data from the flowmeter tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table FLOWMEF1	- Flyleaf 1 Company, person(s) responsible, references
Table FLOWMEF2	- Flyleaf 2 Pump data
Table FLOWMEF3	- Flyleaf 3 Comment(s)
Table FLOWCAL	- Calibration Data
Table FLOWMED	- Count Data
Table FLOWMECD	- Calculated Flow
Table FLOWMELD	- Groundwater Head

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

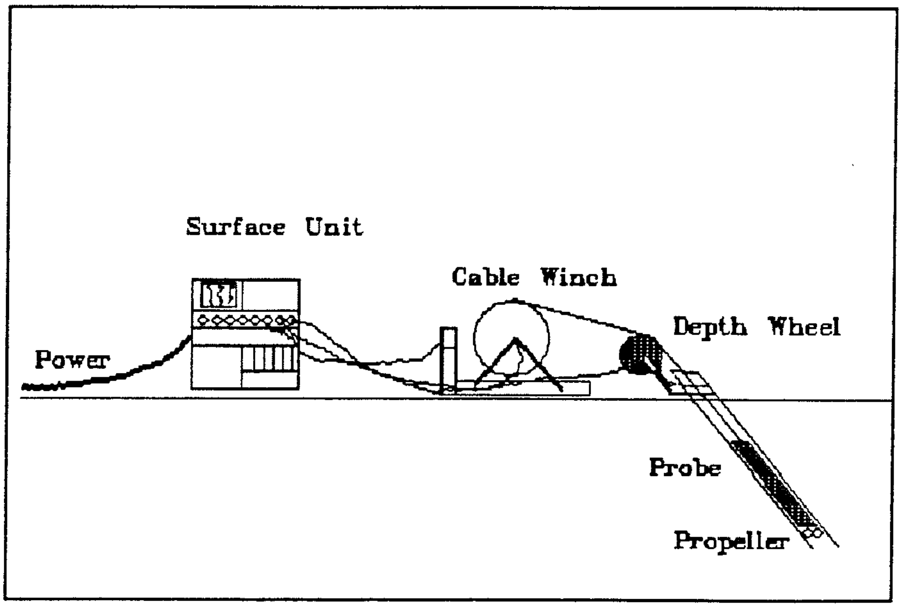


Figure 8-2 Measurement equipment for flowmeter tool

9 ELECTRICAL CONDUCTIVITY IN PUMPED WATER

During 1987, eleven test pumpings were made at Ävrö, Äspö and Laxemar with manual measurement of electrical conductivity of pumped water.

During the pumping phase the electrical conductivity of the pumped water is measured at intervals during the pumping phase.

9.1 ELECTRICAL CONDUCTIVITY IN PUMPED WATER IN GEOTAB

The flyleaf data and result data from the electrical conductivity in pumped water measurements are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table CONDINF1 - Flyleaf 1 Company, person(s) responsible, references

Table CONDINF2 - Flyleaf 2 Measuring Equipment

Table CONDINTD - Data Table

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

10 RECOVERY TESTS

The purpose of the recovery tests is to determine hydraulic parameters of boreholes during or immediately after drilling. The tests are carried out partly in percussion boreholes and partly in connection with water sampling in sealed sections of core drilled boreholes. The performance of the tests in the core drilled sections differs from the tests in the percussion boreholes. In general the data collecting is more comprehensive and especially flow data are more accurate. In the upper reamed part of core drilled holes the tests are executed as in the percussion boreholes.

10.1 TESTS IN DELIMITED SECTIONS OF CORE DRILLED BOREHOLES

10.1.1 Routines of collecting and processing data.

Data flow is showed in the block diagram figure 10.1

A specially made valve and a packer are mounted on the drilling rod and lowered to a depth, approximately 100 m from the borehole bottom. The packer is expanded against the borehole wall by the drilling water. By rotating the drilling pipe and lowering the valve hydraulic connection between the test section and the drilling rod is achieved.
Two plastic pipes are placed inside the drilling pipes. One of them is used when measuring the ground water level, the second is connected to a compressor. The test commences by starting the compressor. Water is air-lifted from the test section via the drilling pipes and an out-let on top to a calibrated water tank, which is used for water volume measurements. The draw-down in the test section is manually measured by an electric water level indicator and the discharged water volume is determined by reading the scale of the water tank. One litre of water is sampled when a volume equal to the test section volume plus the drill pipe volume has been discharged. When twice that volume or more has been discharged a second sampling of water occur. Shortly after the second water sampling the air-lift pumping is stopped and the recovery of the ground water level is manually monitored for two hours.

The field geohydrologist participate in and/or supervise the whole test sequence. He also writes down all the relevant borehole-, level- and flow data in a

protocol.
Ground water level data from the protocol is punched to a file on a DEC Professional Computer. This file is input file to a conversion program. Output files are a "Printfile" and a "Plotfile". Three plots are produced with the help of a plot program. They show the ground water head change during the test in linear, logarithmic and semi-logarithmic scale. The Printfile is together with the protocol and the graphs compiled to a report, which is sent to the geohydrologist responsible for evaluation. After evaluation values of the hydraulic parameters are sent to the data base engineer who store them in the table RECTESCD in GEOTAB. The data base engineer also receive the Printfile and the report. The printfile is transferred to the table RECTESLD and data from the report are stored in the flyleafs and in the table RECTESQD.

After storing in GEOTAB the geohydrologist receive an outprint to confirm the accuracy of data and necessary corrections are made.

10.1.2 Data volumes in the block diagram Figure 10-1

Borehole- and test data

Important data are borehole idcode, borehole length, altitude of the borehole casing, packer depth, dimensions of the plastic pipes, date/time of pump start and pumpstop and the angle between the borehole and the horizontal plane. In addition the distance from top of casing to the measuring point, from which the distance to the ground water is measured, is determined.

Ground water level data

The distance between the measuring point and the ground water level is manually determined by means of an electric water level indicator. During the air-lift pumping period the measuring interval is 15 minutes. After pump stop measurements are made every minute or 1/2 minute during the first 10 minutes; then every 2 minutes for 10 minutes; then every 5 minutes for 40 minutes. From this point readings are taken at 10 minutes interval for an hour.

Water volume data

Water from the test section is pumped to two 1 m3 water tanks which are graded every 100 litre. The cumulative discharged volume is read every 15 minutes.

Protocol

The protocol have two pages. On the first one volume data and level data from the pump phase are noted. On the second page level data of the recovery is written down. Both pages have a head where borehole data and test data are noted.

REF

REF is an important factor in the data process. It is equal to the altitude (m.a.s.l.) of the measuring point, from which the distance to the ground water is measured.

$$\mathbf{REF = d \times \sin(IW) + Talt}$$

d = distance from top of casing to measuring point (m)
IW = angle between bore hole and horizontal plane (°)
Talt = altitude of top of casing (m.a.s.l.)

***.LOD - file**

Ground water level data are punched into a file on Digital Professional 350/380 computer. The file is described by G.Nyberg (June 1988) and comprises two parts; a head including borehole data (REF and IW) and a data part containing the measurements of the distance from the ground water to measuring point. See also appendix...?

Plotfile

The plotfile or "hydraulic-file" is inputfile to the plot program. Its content and format are described by G. Nyberg (June 1988). Ground water level data are expressed in m.a.s.l.

Printfile

The printfile has 7 columns : Borehole idcode, upper test section limit, lower test section limit, date of measurement, time of measurement, distance from ground water to measuring point and ground water head (m.a.s.l.), see Nyberg June 1988.

Graphs

Three diagrams are produced. One describes the variation of the ground water level during the whole test sequence in linear scale. The two other graphs show in logarithmic and semi-logarithmic scale respectively the recovery of the ground water after pump stop. On the X-axis the following time-transformation is used.

$$dte = \frac{dt \cdot tp}{dt + tp}$$

tp = duration of the pump phase (minutes)
dt = time from pump stop (minutes)

Report

Data from the protocol, the printfile and the ground water level diagrams are compiled to a report, comprising all the data necessary for evaluation of the test. The report text contains tables listing cumulative water volume data and ground water level data. The report is sent to SKB and included in the borehole report of the borehole in question. A copy is also sent to the responsible geohydrologist for evaluation.

10.1.3 Processes in the block diagram Figure 10-1

Field crew

The field crew manually collects borehole- and test data, ground water level data and water volume data. Data are written down in the protocol. The field crew consists of two drillers and always of the site geologist or site geohydrologist. The latter surveys the test sequence and is responsible of the data quality.

Punching

The site geohydrologist punches ground water level data into a "*.LOD-file" on a DEC Professional Computer. He also includes REF and borehole data in the head of the file.

Conversion program

The program exists at present only in DEC-PC. Input file is the *.LOD-file. Output files are the plotfile and the printfile. Using data in the head of the *.LOD-file the conversion program transforms measured distance to ground water into ground water head in m.a.s.l., see G. Nyberg june 1988.

Plotprogram

Inputfile is the plotfile. Three diagrams are produced. When plotting the diagrams describing the recovery the time of and the ground water level at pumpstop are needed. These data are taken from the protocol and the plotfile respectively. The plotprogram is described by G. Nyberg 1987.

Data transfer, Editing

The printfile is transferred to an IBM-compatible PC and together with data from the protocol a test report is edited (Word Perfect).

The printfile is also transferred to the data engineer, via diskette or via the SKB-VAX. The file is stored in GEOTAB as the table RECTESLD.

Evaluation

After receiving the report the responsible geohydrologist evaluate the diagrams and determine the hydraulic properties of the test section.

10.2 RECOVERY TESTS IN PERCUSSION BOREHOLES AND IN THE UPPER REAMED PART OF CORE DRILLED BOREHOLES

10.2.1 Routines of collecting and processing data

The data flow in the block diagram figure 10.1 is valid also for recovery tests in percussion boreholes.

The performance of the tests has varied but as a rule the drilling pipes has been replaced by a plastic pipe connected to a compressor. A watertight well-head is mounted on the borehole casing. No packers are used. The test commence by starting the compressor. Water is air-lifted from the borehole outside the plastic pipes to an out-let through the well-head. The pumped volume is in general determined by measuring the time needed to fill up a calibrated bucket or barrel. After one hour the compressor is switched off and the recovery of the ground water level is manually measured by an electric water level indicator during one hour.

Often the field geohydrologist participate in and/or supervise the whole test sequence but in numerous cases the drillers themselves have been carried through the tests.

In some tests the drilling pipes have been used as flushing pipes. Then the recovery measurements can't be started until the drilling pipes have been removed from the borehole. The water flow measurements have sometimes been of varying quality. In some cases the flow has been estimated, not measured.
Anyway, a protocol is written during the test. When the field hydrologist has received the protocol the data flow and the data processes are much the same as described in chapter 10.1.

10.2.2 Data volumes in the block diagram Figure 10-1, recovery tests in percussion boreholes

Borehole- and test data

Important data are borehole idcode, borehole length, altitude of the borehole casing, dimensions of the plastic pipe, date/time of pump start and pumpstop and the angle between the borehole and the horizontal plane. In addition the distance from top of casing to the measuring point, from which the distance to the ground water is measured, is determined.

Ground water level data

The distance between the measuring point and the ground water level is manually determined by means of an electric water level indicator. During the air-lift pumping period no measurements are carried out. After pumpstop, as a rule, the measurements are made every minute during the first 10 minutes; then every 2 minutes for 10 minutes; then every 5 minutes for 40 minutes.

Water volume data

The methods to determine pumped water volume during recovery tests in percussion boreholes varies. In general the pumped volume is obtained by measuring the time needed to fill up a calibrated bucket or barrel, 2 - 3 times during the pumping.
However in some cases the flow has not been measured but only estimated.

Protocol

In the protocol borehole data, ground water level data and flow data are noted.

REF

REF is an important factor in the data process. It is equal to the altitude (m.a.s.l.) of the measuring point, from which the distance to the ground water is measured.

$$\mathbf{REF = d \times \sin(IW) + Talt}$$

d = distance from top of casing to measuring point (m)
IW = angle between bore hole and horizontal plane (°)
Talt = altitude of top of casing (m.a.s.l.)

***.LOD - file**

Ground water level data are punched into a file on Digital Professional 350/380 computer. The file is described by G.Nyberg (June 1988) and comprises two parts; a head including borehole data (REF and IW) and a data part containing the measurements of the distance from the ground water to measuring point.

Plotfile

The plotfile or "hydraulic-file" is inputfile to the plot program. Its content and format are described by G. Nyberg (June 1988). Ground water level data are expressed in m.a.s.l. See also appendix.

Printfile

The printfile has 7 columns : Borehole idcode, upper test section limit, lower test section limit, date of measurement, time of measurement, distance from ground water to measuring point and ground water head (m.a.s.l.), see Nyberg June 1988.

Graphs

Three diagrams are produced. One describes the variation of the ground water level during the whole test sequence in linear scale. The two other graphs show in logarithmic and semi-logarithmic scale, respectively the recovery of the ground water after pump stop. On the X-axis the following time-transformation is used.

$$dte = \frac{dt \cdot tp}{dt + tp}$$

tp = duration of the pump phase (minutes)
dt = time from pump stop (minutes)

Report

Data from the protocol, the printfile and the ground water level diagrams are compiled to a report, comprising all the data necessary for evaluation of the test. The report text contains tables listing water flow rate data and ground water level data. The report is sent to SKB and included in the borehole report of the borehole in question. A copy is also sent to the responsible geohydrologist for evaluation.

10.2.3 Processes in the block diagram Figure 10-1, recovery tests in percussion boreholes

Field crew

The field crew manually collects borehole- and test data, ground water level data and water volume data. Data are written down in the protocol. The field crew consists as a rule of two drillers and sometimes but not always of the site geologist or site geohydrologist.

Punching

The site geohydrologist punches ground water level data into a "*.LOD-file" on a DEC Professional Computer. He also includes REF and borehole data in the head of the file.

Conversion program

The program exists at present only in DEC PC. Input file is the *.LOD-file. Output files are the plotfile and the printfile. Using data in the head of the *.LOD-file the conversion program transforms measured distance to ground water into ground water head in m.a.s.l., see G. Nyberg june 1988.

Plotprogram

Inputfile is the plotfile. Three diagrams are produced. When plotting the diagrams describing the recovery the time off and the ground water level at pumpstop are needed. These data are taken from the protocol and the plotfile respectively. The plotprogram is described by G. Nyberg 1987.

Data transfer, Editing

The printfile is transferred to an IBM-compatible PC and together with data from the protocol a test report is edited (Word Perfect).

The printfile is also transferred to the data engineer, via diskette or via the SKB-VAX. The file is stored in GEOTAB as the table RECTESLD.

Evaluation

After receiving the report the responsible geohydrologist evaluate the diagrams and determine the hydraulic properties of the test section.

10.3 RECOVERY TESTS IN GEOTAB

The flyleaf data and result data from the recovery tests are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table RECTESF1	- Flyleaf 1 Company, person(s) responsible, references
Table RECTESF2	- Flyleaf 2 Draw-down data
Table RECTESF3	- Flyleaf 3 Comment(s)
Table RECTESQD	- Water Flow
Table RECTESVD	- Water Volume Data
Table RECTESLD	- Groundwater Level Data
Table RECTESCD	- Calculated Data

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

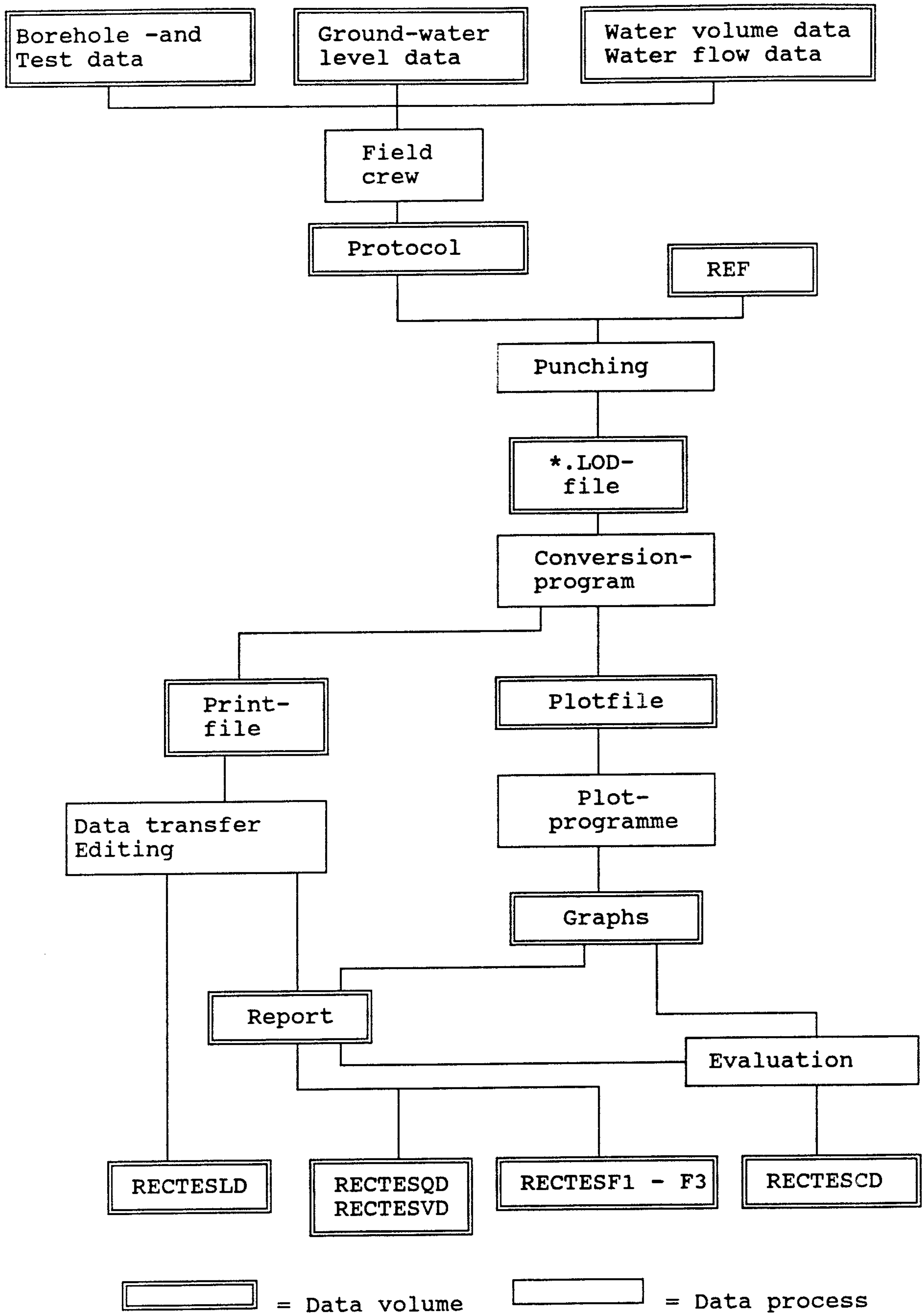


Figure 10-1 Data flow for data from recovery tests

11 METEOROLOGICAL AND HYDROLOGICAL MEASUREMENTS

11.1 PRECIPITATION

11.1.1 Measurement

Precipitation from two stations is stored in GEOTAB so far. Oskarshamn is an ordinary weather station belonging to Swedish Meteorological and Hydrological Institute (SMHI), where the precipitation gauge with a wind shield (SMHI-type) is emptied at 0700 hours every day. Precipitation amount is always referred to the day before. In Simpevarp a gauge of the same type, but installed in a non-standard manner, is usually emptied at 0800 hours on days after rain.
Sometimes the gauge is also emptied later on the day, but this record is still included in the notation for that same day. On Saturdays and Sundays the gauge is usually not emptied at all, and precipitation will then be noted on Mondays. Unfortunately this lack of regularity reduces the valued of the Simpevarp data. Data is transferred to GEOTAB from a floppy disk via PC and Kermit.

11.1.2 Accuracy

The most important error in point measurements of precipitation is due to the wind. The wind error varies with type of precipitation, windspeed and site, but always results in a deficiency of catch. The error due to evaporation from the gauge is largest during warm summer days with showers. The loss is estimated to some 1.5 mm/month as a mean, however much depending on meteorological factors. For the Oskarshamn station the correction for all types of errors have been estimated to +18% of the annual precipitation.

A much more difficult problem when dealing with precipitation data is the poor areal representativeness of precipitation measurements, especially during showery conditions in the summer.

11.2 TEMPERATURE

11.2.1 Measurements

Daily mean temperatures from SMHI are evaluated as a weighted mean of: temperature measured at 0700, 1300 and 1900 hours as well as maximum and minimum temperature. Temperature is an easier variable to measure than precipitation, and the areal representativeness is normally much better.
Data is transferred to GEOTAB from a floppy disk via PC and Kermit.

11.3 POTENTIAL EVAPOTRANSPIRATION

11.3.1 Calculations

The theoretical evapotranspiration from a surface completely covered by a homogenous surface of green vegetation (crop) experiencing no lack of soil water. The potential evapotranspiration is calculated with the Penman formula. This demands meteorological data available only on some synoptical stations.
Although **actual** evapotranspiration can show a rather great areal variation on the local scale, the **potential** evapotranspiration, depending mainly upon meteorological factors, does not vary that much. Normally the actual evapotranspiration is almost the same as the potential, except for the summer months, when it does not reach the potential rate. This difference very much depends upon vegetation, ground and wetness conditions in an area.
Data is transferred to GEOTAB from a floppy disk via PC and Kermit.

11.4 SEA LEVEL MEASUREMENTS

11.4.1 Measurements

Sea level is recorded by the Swedish Meteorological and Hydrological Institute (SMHI). A writing recorder is connected to a float in a gauge well. Data is

digitized and transferred to computer media (by SMHI) on an hourly basis. The influence of oscillations with short frequency (waves) are filtered, both by the gauge well and the digitizing. Sea levels are adjusted to the national elevation system, RH70.
Data is transferred to GEOTAB from a floppy disk via PC and Kermit.

11.4.2 Accuracy

According to SMHI, the error in time notation is less then an hour and the error in elevation is not greater than a few centimetres.

11.5 METEOROLOGICAL AND HYDROLOGICAL MEASUREMENTS IN GEOTAB

The flyleaf data and result data from the meteorological and hydrological measurements are stored in the following tables in the database (a detailed description of the data tables is found in Appendix 15.11):

Table METEORF1	- Flyleaf 1 Station name, station number
Table METEORF2	- Flyleaf 2 Comment(s)
Table METETEMP	- Temperature Measurement
Table METEPREC	- Precipitation Measurement
Table METEVAPO	- Evaporation Measurement
Table MESEALEV	- Sea Level Measurement

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

12 HYDRAULIC TEST DURING CHEMICAL SAMPLING

12.1 PRINCIPLE

A special type of hydraulic test is performed at the same time as sampling of ground water for chemical analysis is carried out in the field laboratory (KEMILAB 1 or KEMILAB 2) for chemical analysises. The packer sealed section in a borehole is pumped during one week and after that follows a recovery period of at least 7-8 hours. Then the hydraulic test is finished. At every measurement the pressure is registered and the medium flow since last measurement is calculated. Time between measurement varies between one minute and one hour. One minute is the shortest interval and is used during pumping start and pumping stop and one hour interval is used during pumping time. After measurement period the pressure and flow are collected in a data file which is used for plotting and calculating hydraulic parameters.

12.2 DATA FLOW

Flow and pressure values are registered both in KEMILAB 1 and KEMILAB 2, but in different ways. KEMILAB 2 registers both pressure and flow values among all the other variables. KEMILAB 1 collects only flow values but a multichannel data logger BORRE, which registers pressure values, is connected.

12.3 HYDRAULIC TEST DURING CHEMICAL SAMPLING IN GEOTAB

The flyleaf data from the hydraulic test during chemical sampling are stored in the following tables in the database (a detailed description of the data tables are found in Appendix 15.11).

Table HYCHEMF1 - Flyleaf 1 Company, person(s) responsible, references

Table HYCHEMF2 - Flyleaf 2 Pump data

Table HYCHEMF3 - Flyleaf 3 Comment(s)

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

13 EQUIPMENTS IN BOREHOLES

Different types of instrumental background data for hydrogeological tests are stored in the SKB database GEOTAB:

* the equipments in a borehole, i a packers, pressure transducers, data loggers, conductivity loggers
* calibrations constants
* data from injection tests are recorded on cassettes and transferred to data files, which were transferred to the SKB VAX750 computer
* the geometry of borehole, i e diameters of borehole, rising main, pump cable, transducer cable, wire, flowmeter cable, inside and outside diameter of measurement pipe

In earlier tests (before 1991) these data for packers, transducers, loggers, constants and geometry of borehole were stored in flyleaves beneath each measuring method with a start and end date. The coupling of cassettes and data files from injection tests were only archived in paper folders.

A new method called BHEQUIPE was created, which contains the overall information of downhole equipments and the coupling between cassettes and data files.

13.1 EQUIPMENTS IN BOREHOLES IN GEOTAB

The downhole equipment data are stored in the following tables in the database (a detailed description of the data tables are found in Appendix 15.11).

Table BHEQLOGG Data Loggers In Boreholes

Table BHEQTRAN Pressure Transducers In Boreholes

Table BHEQCONS Calibration Constants For Transducers

Table BHEQPACK Packers In Boreholes

Table BHEQGEOM Borehole Equipment - Geometry In Borehole

Table BHEQCOND	Conductivity Loggers In Boreholes
Table CASSETTE	Name Of Cassette Files From Injection Tests

Several quality assurance controls during and after storing data in GEOTAB are performed (Sehlstedt,1991).

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15 APPENDICES

15.1 APPENDIX 1

MANUAL OF THE DATACOLLECTING UNITS DURING A TRANSIENT INJECTION TEST WITH STEEL PIPE EQUIPMENT VERS. 2 , A COMPILATION

Item	Chart recorder Paper feed	Datalogger Scanning interval	Thumb wheel settings	Flowmeter Reading interval	Remarks
1	-	-	10NNPQQQ	-	
2	-	1 min	"	-	
3	-	"	110RRSSS	-	When pressure is stable
4	-	5 min	"	-	1 minute after item 3
5	20 cm/h	"	"	-	When recorder is adjusted
6	"	"	120RRSSS	-	Packer inflation
7	"	1 min	130RRSSS	-	The test valve is closed at least 30 min after item 6
8	10 cm/min	10 sec	"	-	Immediatly before item 9
9	"	"	140RRSSS	-	The test valve is opened (Injection phase starts)
10	"	"	"	20 sek	0- 2 min injection time
11	1 cm/min	30 sec	"	30 sek	2- 5 min "
12	"	1 min	"	60 sek	5- 30 min "
13	20 cm/h	5 min	"	5 min	30-119 min "
14	10 cm/min	10 sec	"	5 min	119-120 min "
15	"	"	150RRSSS	-	The test valve is closed (Injection phase ends, Fall-off phase starts)
16	"	"	"	-	0- 2 min Fall-off phase time
17	1 cm/min	30 sec	"	-	2- 5 min "
18	"	1 min	"	-	5-30 min "
19	20 cm/h	5 min	"	-	30- min "
20	"	1 min			1 min before item 21
21	"	"	160RRSSS	-	Packer deflation
22	"	"	170TTUUU	-	When pressure is stable
23	"	"	"	-	Wait at least 1 min before the logger is switched-off!
24	0	0		-	Note the zero-points of the chart recorder !

15.2 APPENDIX 2

THUMB WHEEL SETTINGS DURING A TRANSIENT INJECTON TEST WITH STEEL PIPE EQUIPMENT, VERS. 2

Thumb wheel settings	Remarks
0XXX XXXX	Invalid data
1XXX XXXX	Valid data
10NN PQQQ	Section identity
	NN: Borehole number (01-99)
	P: Section length code (1 = 1 m, 2 = 5 m, 3 = 25 m, 4 = 10 m)
	QQQ: Borehole length to upper limit of test section (m)
110R RSSS	Absolute section pressure before test (from multimeter)
	RR: Absolute pressure, bars (integers)
	SSS: " " " (decimals)
120R RSSS	Packer inflation, test valve open
130R RSSS	Test-valve is closed
140R RSSS	Injection starts, test valve is opened
150R RSSS	Injection ends, Fall-off phase starts, the test valve is closed
160R RSSS	Fall-off phase is stopped, packer deflation
170T TUUU	Absolute section pressure after test (from multimeter)
	TT: Absolute pressure bars (integers)
	UUU: " " " (decimals)

The second digit of the thumb wheel settings is the code for the different stages of a transient injection test, Table 2.1.

15.3 APPENDIX 3

INPUT SIGNALS TO THE DATA LOGGER AND THE CHART RECORDER DURING A INJECTION TEST WITH STEEL PIPE EQUIPMENT, VERS. 2

Datalogger

Channel	Input signal	
0	Absolute section pressure	100 mV/bar
1	Supressed section pressure	100 mV/bar
2-6	Not used	
7	Temperature of the measurement housing	
8	Absolute packer pressure	100 mV/bar
9	Temperature of the injection water	

Chart recorder

Channel	Input signal	Range of measurement	Pen colour	Pressure/10 scale divisions
1	Absolute section pressure 10 mV/bar	100 mV	black	1 bar
2	Supressed section pressure 100 mV/bar	50 mV	red	0.05 bar
3	Not used			
4	Packer pressure 10 mV/bar	50 mV	blue	0.5 bar

15.4 APPENDIX 4

DESCRIPTION OF DATA FILES FROM SINGLE HOLE TRANSIENT INJECTION TESTS, STEEL PIPE EQUIPMENT VERS. 2

I C-FILE (cassette file)

Three lines/scanning

```
Line no 1: Position 1-2: Date (DD)
             "      3-8: TIME (hhmmss)
Line no 2: Position 1:   0 = invalid data, 1 = test data
             "      2:   Stage of the injection test
                         0 = Section identifications are set on the thumb wheel.
                         1 = Supression of section pressure.
                             Stable absolute section pressure is set on the thumb wheel.
                         2 = Packer inflation starts
                         3 = The test valve is closed
                         4 = The test valve is opened, injection starts.
                         5 = The test valve is closed, the injection is stopped and the
                             fall-off phase is started
                         6 = The fall-off phase is ended, packer deflation
                         7 = Stable absolute section pressure is set on the thumb wheel
           Position 3-8: If stage (position 2) = 0:
                       pos. 3-4:  Borehole number (01 - 99)
                       pos. 5  :  Section length code (1=5 m, 2=10 m, 3=25 m, 4 =10 m)
                       pos. 6-8:  Length to upper limit of test section (m)
                       If stage (position 2) = 1-6
                       pos. 3-8:  Stable absolute section pressure before test (mb).
                       If stage (position 2) = 7
                       pos. 3-8:  Stable absolute section pressure after test (mb).

Line no 3: Position 1:      Channel number (= 0)
           Position 2-7:    Absolute section pressure value (mV)
           Position 9:      Channel number (= 1)
           Position 10-15:  Supressed section pressure value (mV)
           Position 17:     Channel number (= 7)
           Position 18-23:  Temperature value of the measurement housing
           Position 25:     Channel number (= 8)
           Position 26-31:  Packer pressure (mV)
           Position 33:     Channel number (= 9)
           Position 34-39:  Injection water temperature value
```

II P-FILE (protocol file)

The file has three Record types

Record type 1; Protocol head, H in position 5

Position 1-3: Number of protocol (section) in the file
Position 5: H
Position 7-15: Borehole code; GDA-code and borehole number
Position 17-19: Borehole length to upper limit of test section (m)
Position 21-23: Borehole length to lower limit of test section (m)
Position 25-30: Date (YY MM DD)
Position 33-37: Signatures of the measurement operator(s)
Position 39-43: Applied injection pressure (bars)
Position 45-54: Result of flow test, 2-3 digits. The first digit is always flow meter number, the second and third are scale values on that flow meter.
Position 56-61: L_K = distance between test section and pressure transducer (m)
Position 63-68: Borehole length between groundwater level and top of casing (m)

Record type 2; Water flow data, D in position 5

Position 1-3: Number of protocol (section) in the file
Position 5: D
Position 7-11: Time from injection start (mmmss)

Position 13-22: Injection water flow rate (m^3/s)

Record type 3; Comments, C in position 5

Position 1-3: Number of protocol (section) in the file
Position 5: C
Position 13-72: Comments on the test

III L-FILE (logger file)

Position 1-9: Borehole code, GDA-code and borehole number
Position 11-13: Borehole length to upper limit of test section (m)
Position 15-17: Borehole length to lower limit of test section (m)
Position 19-24: Date (YY MM DD)
Position 26-31: Time (hh mm ss)
Position 33: Stage of the injection test, see C-FILE
Position 35-42: Stable absolute section pressure before and after the test (Pa).
The pressure value is not corrected for the effect of L_K

Position 46-53: Supressed section pressure = Injection pressure (Pa)
Position 57-64: Absolute section pressure (Pa)
The pressure value is not corrected for the effect of L_K

Position 68-75: Packer pressure (Pa)
Position 79-86: Temperature of the injected water (°C)
Position 90-97: Air temperature of the measurement housing (°C)

IV M-FILE (merge file)

Position 1-33: See L-FILE
Position 35-42: Stable absolute section pressure before and after test (Pa).
The pressure value is corrected for the effect of L_K
Position 46-53: See L-FILE
Position 57-64: Absolute section pressure (Pa). The pressure value is corrected for the effect of L_K.
Position 68-97: See L-FILE
Position 102-110: Injection flow rate (m^3/s)
Position 113-121: Distance between test section and pressure transducer = L_K (m)
Position 123-132: The inclination of the borehole (degrees)

V CO-FILE (comment file)

Position 1-24: See L-FILE
Position 26-30: Signatures of the measurement operators
Position 32-36: Applied injection pressure (bars)
Position 38-41: Result of flow test, 2-3 digits. The first digit is always the flow meter number, the second and third are the scale values on that flowmeter.
Position 42-46: Distance to groundwater level from top of casing (m)
Position 48-52: L_k = distance between test section and pressure transducer (m)
Position 55-122: Comment
Position 123-129: The inclination of the borehole at the depth of the section (degrees)
Position 131-162: Comment

15.5 APPENDIX 5

EXAMPLE OF A COMO-FILE FROM TRANSIENT INJECTION TEST WITH STEEL PIPE EQUIPMENT, VERSION 2.

```
OK, /INJFLAT
INPUT FILE: CGI5.1.4
OUTPUT FILE: LGI5.1.4
GIVE BOREHOLE GDA-CODE (4 LETTERS): AKGI
GIVE YEAR AND MONTH OF TEST (YYMM): 8209

AKGI05000 145 - 170 820926
ILLEGAL SEQUENCE OF THUMBWHEEL SETTINGS
OUTPUT  RECORDS 28

AKGI05000 170 - 195 820926
ILLEGAL SEQUENCE OF THUMBWHEEL SETTINGS
OUTPUT RECORD 72
FINISHED!
  673 RECORDS READ
  224 RECORDS WRITTEN
OK, /INJFLAT
INPUT FILE: CGI5.1.1H5
OUTPUT FILE: LGI5.1.5
GIVE BOREHOLE GDA-CODE (4 LETTERS): AKGI
GIVE YEAR AND MONTH OF TEST (YYMM): 8209

AKGI05000 195 - 220 820927

AKGI05000 220 - 245 820927
FINNISHED!
  1214 RECORDS READ
   404 RECORDS WRITTEN
OK, /INJFLAT
INPUT FILE:CGI5.1.6
OUTPUT FILE: LGI5.1.6
GIVE BOREHOLE GDA-CODE (4 LETTERS): AKGI
GIVE YEAR AND MONTH OF TEST (YYMM): 8209

AKGI05000 245 - 270 820928

AKGI05000 270 - 295 820929
ILLEGAL SEQUENCE OF THUMBWHEEL SETTINGS
OUTPUT RECORD 181
FINNISHED!
  1035 RECORDS READ
   345 RECORDS WRITTEN

OK, COMO -END
```

15.6 APPENDIX 6

EXAMPLE OF AN DATAFILE FROM TRANSIENT INJECTION TEST WITH UMBILICAL HOSE EQUIPMENT, VERSION 1.

```
TRANSIENT INJEKTIONSTEST; KONSTANT TRYCK
FJ8
DATUM 820715
IW, 60 grader
L,  25,m
LB, 6,m
000:20:12:17                0
RÄ, 2,nr
T,  1,min
000:20:12:48                1
LO, 70,m
T4, 22.22, oC
P1, 53.2 kPa
P8, 600,kPa
dP, 0,kPa
P2, 600,kPa
Q,  0,ml/s
P0, 287.2,kPa
G0,-3.05441,m
P4, 76,kPa
B0, 101.08,kpa
T2, 7.22,oC
T3, 28.9,oC
000:20:13:17                1
LO, 70,m
P1, 53,kPa
P8, 600,kPa
dP, 0,kPa
P2, 600,kPa
Q,  0,ml/s
P0, 287,kPa
G0,-3.05543,m
T2, 7.21,oC
T3, 28.9,oC
RÄ, 12,nr
RÄ, 11,nr
RÄ, 5,nr
RÄ, 6,nr
T,  2,min
000:20:13:30                2
dP, 0,kpa
P2, 600,kPa
Q,  0,ml/s
000:20:13:32                2
dP, 0,kPa
P2, 600,kPa
Q,  0,ml/s
000:20:13:38   2
dP, .2,kPa
P2, 600.2,kPa
     .
001:00:04:36                299
P1, 53.2,kPa
dP, .2,kPa
P2, 600.2,kpa
Q,  0,ml/s
P0, 262.2,kpa
G0,-3.10945,m
T2, 7.21,oC
T3, 28.84,oC
001:00:05:08                299
P1, 53.2,kPa
dP, 0,kPa
P2, 600,kpa
Q,  0,ml/s
P0, 262,kpa
G0,-3.11047,m
T2, 7.21,oC
T3, 24.83,oC
DATA SLUT
$
```

15.7 APPENDIX 7

DESCRIPTION OF DATA FILE (C-FILE) FROM SINGLE HOLE TRANSIENT INJECTION TEST, UMBILICAL HOSE EQUIPMENT VERSION 1

Line 1: Headline; Transient injection test; constant pressure
Line 2: Borehole name; SSNN (SS = Site code, NN = borehole number)
Line 3: Date of test (YYMMDD)

The following lines are either technical data/measurement values or scanning time. The scanning time has the following format:

ddd : hh : mm : ss MMM

where ddd = Day number after start date of test
hh : mm : ss = time of day (HH MM SS)
MMM = Commenced minutes from test start

The technical data and measurement values have the following format:

Technical data or measurement parameter, value, dimension

The technical data or measurement parameters are

IW :	Inclination of the borehole	(degrees)
L :	Length of test section	(m)
LB :	Length of bubble tube	(m)
DW :	Diameter of the borehole	(mm)
T :	Commenced minutes from test start	(min)
LO :	Length to upper limit of test section	(m)
Q :	Water flow rate	(ml/s)
GO :	Vertical distance from groundwater level from top of casing, negative	(m)
BO :	Barometer pressure	(kPa)
PO :	Injection drive pressure	(kPa)
P1 :	Absolute section pressure from pressure transducer P1	(kPa)
P2 :	Absolute section pressure from pressure transducer P2	(kPa)
P8 :	Absolute pressure in test section before packer inflation	(kPa)
dP :	Differential section pressure, P1-P8 or P2-P8	(kPa)
P4 :	Packer pressure	(kPa)
T2 :	Temperature in the test section	(centigrades)
T3 :	Temperature in the measurement trailer	(centigrades)
T4 :	Outer air temperature	(centigrades)
RÄ :	Relay numbers - positive if the relays functioned, negative if the relays were released, see table A.1.	

Table A.1 Relay values used in the umbilical hose system, version 1

Relay values on	off	Type, function
0	-16	Cannula test
1	-1	Test valve
2	-2	Relief valve
3	-3	Flow meter 3
4	-4	Flow meter 2
5	-5	Flow meter 1
6	-6	Pressure regulation
7	-7	Upper measurement range flow meter 1
8	-8	Reserve
9	-9	Reserve
10	-10	Reserve
11	-11	Packer deflation
12	-12	Packer inflation
13	-13	Reserve
14	-14	Reserve
15	-15	Rapid scanning
16	-16	See relay number 1

The measurement time for the measurement values is the time showed on the preceeding "scanning line" respectively.

15.8 APPENDIX 8

EXAMPLE AND DESCRIPTION OF DATA FILE FROM GROUNDWATER REGISTRATION BY THE GRUND SYSTEM.

FILE: HKL0810M.609

LINE NUMBER	LINE TEXT
1	GRUND 2.0 nr 022
2	HKL08 10M
3	09/08/86 13:25:32
4	001001FOFB35C7176281
5	00080600033B005A
6	CN, 22, nr
7	SC, 16.943, bar/volt
8	OF, -132, LSB
9	IW, 50, grader
10	IN, 360, S
11	19860104011332
12	GO, -1.16493, m
13	19860104131332
14	GO, -1.16826, m
.	
.	
.	
2017	19860907080132
2018	GO, -1.78324, m
2019	$

Description of the content of the data file

LINE 1: Version number of the GRUND system and serial number of the unit.

LINE 2: Borehole name and Length from top of casing to pressure transducer (m),, M = metres

LINE 3: Date and time of dumping of data MMDDYY HHMMSS

LINE 4-5: 36 hexadecimal characters with the following meaning:

0010 Four characters which give the hexadecimal starting address of the parameter area. Here the address is 10H.

01FDFB The number of measurements performed since the previous reset of the cells. The number is incremented by one for each measurement.

35 The number of measurement values not stored since the last stored measurement. Refers to conditionally stored measurements.

C7 Always equal to C7.

1762 The memory address of the next data word to be stored. The data storage takes up the hexadecimal addresses 0800 to 17FF. Data will be stored starting at 0800 with two byte per data word. When the area is full, data will be stored from the starting address again.The memory will thus contain the 2048 latest stored data words.

81 Always equal to 81.

00 Not used by the GRUND unit. Can for instance contain the offset voltage of the pressure gauge or the serial number.

08 The limit value for conditional data storage. A measurement value will be stored if it differs from the latest stored value by the given number of LSB (least significant bits). A zero will cause all values to be stored.

06 The number of conditional data values to be measured before the next compulsory data storage.

0003 The number of four seconds periods to the next measurement. The clock of the GRUND unit is incremented once every four seconds. This is the shortest time interval measured.

3B The total number of conditional data storages between two consecutive compulsory data storages.

005A The interval between measurements expressed as a number of four seconds periods. 5AH means one measurement every 6 minutes.

LINE 6: Circuit card number nr = number

LINE 7: Scale Constant

LINE 8: Ofset constant, LSB = Least significant bits

LINE 9: Inclination of the borehole in degrees (= grader).
IW = 90 for vertical boreholes

LINE 10: Measurement interval in seconds (s)

LINES 11, 13, 15 .... (uneven line numbers): Date and time of stored measurement
(YYYY MM DD HH MM SS)

LINES 12, 14, 16 .... (even line numbers): Stored measurement value expressed in m water column below top of casing.

LINE 2019: $ = END OF FILE

15.9.1 APPENDIX 9(1)

EXAMPLE OF A P-FILE FROM AN INTERFERENCE TEST WITH THE PIEZOMAC I SYSTEM

```
Ident  C1  LB DW IW AW  X       Y      Z      LT     SECUP      SECLOW                                    3 x r
AH612400062176E-3  40150 90      902.0   1224.0 106.31  30.95
AH6120000306355E-3 100110 90  0   740.0   1238.0 107.58  40.98  0.00 42.70 43.70 53.70 54.70100.00          125.0125.01
25.0
AH612300035787E-3  90150 90  0    870.0   1266.0 116.92  29.15  0.00 30.00 31.00 90.00                        45.0 45.0
AH6105000332256E-3 115110 55210   886.0   1268.0 115.09  43.72  0.00 44.00 45.00 57.00 58.00115.00           32.0 12.0
24.0
AH6101000306355E-3 153115 55210   902.0   1224.0 106.35  16.98  0.00 18.00 19.00 26.00 27.00 53.00            10.0 10.0
60.0
Day/Time Mode                                  Seconds/Measurement values
8212091234T       27409304.6 60409304.6 94409242.4127409242.4160409242.4 29416329.6 62416574.7 95415931.3129416268.3162416207.1 3
030075
9 64300861.3 97301934.9130301505.4164300431.8 32386102.1 65386035.6 99386368.1132386068.8165386168.6 34250196.0 67250196.0100250716.8
134250
.7167251176.3
8212091318P       5408061.0 17408061.0 27407625.8 38407501.4 49407377.1  7416207.1 18416605.3 29416421.5 40416452.1 50416452.1
830086
 19300753.9 30301970.6 41301505.4162300503.4 10385071.1 21384971.4 32385303.9 42385004.6 53385037.9 11249552.7 22249460.8 33249705.8
442494
8 54249215.7
8212091319P       6407252.8 16407128.4 27407066.2 38407004.0 49406879.7  7416390.9 18416574.7 29415962.0 39416329.6 50416329.6
830089
 19300753.9 30301934.9 41301612.8 51300467.6 10384938.1 20384871.6 31385137.7 42384805.1 53384838.4 11248878.7 22248848.1 33249062.5
432489
6 54248817.4
8212091320P       5406817.5 16406755.3 27406693.1 38406568.8 48406506.6  7416268.3 17416452.1 28415808.8 39416207.1 50416176.4
830086
 19300825.4 30300682.3 40301720.1 51300467.6  9384738.6 20384638.8 31384938.1 42384572.3 53384638.8 11248235.4 22248327.3 32248694.9
432485
4 54248388.6
8212091321P       5406444.4 16406382.3 27406382.3 37406320.1 48406257.9  6416115.1 17416329.6 28415716.9 39416084.5 50416053.9
830086
 19300718.1 29300682.3 40301791.7 51300789.7  9384505.8 20384439.3 31384771.9 42384339.5 52384439.3 11248020.9 21247990.3 32248357.9
432481
5 54248051.6
8212091322P       5406133.6 16406071.4 26406009.2 37406009.2 48405947.1  6416023.3 17416237.7 28415625.0 39415992.6 49415962.0
830078
 18300646.5 29300789.7 40301612.8 51300646.5  9384306.3 20384239.8 31384505.8 41384173.3 52384239.8 10247653.3 21247622.7 32248112.8
432479
7 53247837.1
8212091322P       65405884.9 75405822.7 86405822.7 97405698.3108405698.3 66415962.0 77416145.8 87415563.8 98415900.7109415900.7 6
730082
4 78300789.7 89300718.1100301684.3110300610.8 69384140.0 79384040.2 90384372.8101383973.7112384073.5 70247469.5 81247438.9 92247867.8
102247
.6113247622.7
8212091323C       82405574.0111405449.6140405387.4169405263.1198405200.9 83415747.5112415931.3142415349.3171415747.5200415747.5 8
530078
7114300646.5143300682.3172301827.5201300753.9 87383907.2116383774.2145384040.2174383607.9203383641.1 88247163.2117247101.9146247438.9
175247
.3204247132.5
8212091326C       48405076.6 77405076.6106404952.3135404827.9164404765.7 49415716.9 78415962.0108415379.9137415747.5166415747.5 5
130078
7 80300610.8109300718.1138301791.7167300753.9 53383474.9 82383375.1111383641.1140383208.8169383242.1 54246642.3 83246642.3112247101.9
141246
.4170246734.3
8212091328C       73404703.5102404703.5131404579.2160404517.0189404392.6 74415747.5103415962.0133415349.3162415778.2191415747.5 7
630082
4105300789.7134300610.8163301791.7192300789.7 78383075.8107382976.0136383242.1165382843.0194382876.3 79246213.5108246182.8137246703.6
166246
.3195246336.0
```

15.9.2 APPENDIX 9(2)

EXAMPLE OF A D-FILE FROM AN INTERFERENCE TEST WITH THE PIEZOMAC I SYSTEM

```
Month Hour
 Day  Minute Mode
12:09 12:34 N
027 +06583 060 +06583 094 +06582 127 +06582 160 +06582
029 +13590 062 +13598 095 +13577 129 +13588 162 +13586
030 +08404 064 +08407 097 +08437 130 +08425 164 +08395
032 +11610 065 +11608 099 +11618 132 +11609 165 +11612
034 +08167 067 +08167 100 +08184 134 +08187 167 +08199
12:09 13:18 P    Number of seconds after absolute time
005 +06563 017 +06563 027 +06556 038 +06554 049 +06552
007 +135[illegible] 018 +135[illegible]9 029 +13[illegible]73 040 +1[illegible]594 050 +[illegible]594
008 +08407 019 +0840[illegible] 030 +08438 041 +08425 05[illegible] +08397
010 +11579 021 +11576 032 +11586 042 +11577 053 +11578
011 +08146 022 +08143 033 +08151 044 +08143 054 +08135
12:09 13:19 P    Measurement values at the time given
006 +06550 016 +06548 027 +06547 038 +06546 049 +06544
007 +13592 018 +13598 029 +13578 039 +13590 050 +13590
008 +08408 019 +08404 030 +08437 041 +08428 051 +08396
010 +11575 020 +11573 031 +11581 042 +11571 053 +11572
011 +08124 022 +08123 033 +08130 043 +08127 054 +08122
12:09 13:20 P
005 +06543 016 +06542 027 +06541 038 +06539 048 +06538  Probe 1
007 +13588 017 +13594 028 +13573 039 +13586 050 +13585    ..  2
008 +08407 019 +08406 030 +08402 040 +08431 051 +08396    ..  3
009 +11569 020 +11566 031 +11575 042 +11564 053 +11566    ..  4
011 +08103 022 +08106 032 +08118 043 +08114 054 +08108    ..  5
12:09 13:21 P
005 +06537 016 +06536 027 +06536 037 +06535 048 +06534
006 +13583 017 +13590 028 +13570 039 +13582 050 +13581
008 +08407 019 +08403 029 +08402 040 +08433 051 +08405
009 +11562 020 +11560 031 +11570 042 +11557 052 +11560
011 +08096 021 +08095 032 +08107 043 +08100 054 +08097
12:09 13:22 P
005 +06532 016 +06531 026 +06530 037 +06530 048 +06529
006 +13580 017 +13587 028 +13567 039 +13579 049 +13578
008 +08405 018 +08401 029 +08405 040 +08428 051 +08401
009 +11556 020 +11554 031 +11562 041 +11552 052 +11554
010 +08084 021 +08083 032 +08099 043 +08094 053 +08090
12:09 13:22 P
006 +06528 016 +06527 027 +06527 038 +06525 049 +06525
007 +13578 018 +13584 028 +13565 039 +13576 050 +13576
008 +08406 019 +08405 030 +08403 041 +08430 051 +08400
010 +11551 020 +11548 031 +11558 042 +11546 053 +11549
011 +08078 022 +08077 033 +08091 043 +08086 054 +08083
12:09 13:23 C
023 +06523 052 +06521 081 +06520 110 +06518 139 +06517
024 +13571 053 +13577 083 +13558 112 +13571 141 +13571
026 +08405 055 +08401 084 +08402 113 +08434 142 +08404
028 +11544 057 +11540 086 +11548 115 +11535 144 +11536
029 +08068 058 +08066 087 +08077 116 +08073 145 +08067
12:09 13:26 C
023 +06515 052 +06515 081 +06513 110 +06511 139 +06510
024 +13570 053 +13578 083 +13559 112 +13571 141 +13571
026 +08405 055 +08400 084 +08403 113 +08433 142 +08404
028 +11531 057 +11528 086 +11536 115 +11523 144 +11524
029 +08051 058 +08051 087 +08066 116 +08059 145 +08054
12:09 13:28 C
023 +06509 052 +06509 081 +06507 110 +06506 139 +06504
024 +13571 053 +13578 083 +13558 112 +13572 141 +13571
026 +08406 055 +08405 084 +08400 113 +08433 142 +08405
028 +11519 057 +11516 086 +11524 115 +11512 144 +11513
029 +08037 058 +08036 087 +08053 116 +08043 145 +08041
033 +08242 067 +08242 100 +08255 133 +08263 166 +08265
```

15.10 APPENDIX 10

EXAMPLE OF A DATA FILE FROM UMBILICAL HOSE EQUIPMENT SYSTEM, VERSION 2.

File description:

A data file consists of three parts; head, definition part and a data part.

File part 1: Head

All posts in this section are treated as strings during reading and the format for the posts are relatively free.

Post 1: Headline This post is always the same for the same type of measurement. The content in this post will always be situated at the top of printings. The headline also confirms to the calculation program that a correct data file has been opened. For example "TT,BORRE MEASUREMENT". Automatic plot programmes will not read files with the "wrong" headline.

Post 2: Measuring object When umbilical hose equipment is used, the borehole idcode will be written. For example KAS02

Post 3 and forward: Unchanged data. A number of measuring magnitudes, which will not be changed during measurement and perhaps not even will be measured but can be written by the operator or are fixed in the measuring program. Perhaps they will be needed in certain calculations or only written on reports. For example IW,84.0,DEGREES which is the inclination of the borehole

File part 2: Definition part

Here are all magnitudes defined which exist in the data part. It must be one post for each magnitude. A reading part of a plot program can here reserve a work area to each variable which is found in this file part 2.

Post 1 and forward: Definition Every quantity which will be measured are written as follows: <quantity>,,<unit>. A post will look like this: "BX,,mS/m" or: "Q ,,m3/s". Observe the space after Q! Commas separate the terms. The empty middle term shows that it's a definition post and no measuring value.

> **Term 1: <quantity>** Quantity has up till now always consist of two sign, where the first sign is a letter and the other is a letter, number or a space.
> Example: "T4", "Q ", "dP", "RÄ".
> **Term 2:** not used

Term 3: <unit> Unit can for example be "kPa", "m", "m3". Max post length 80 signs. The unit stated here is valid for all measurements values in file part 3 (the data part). Space is significant and allowed. Raised and lowered indices cannot be written in ISO-code.

File part 3: Data part

The measurement values are stored here.Two types of posts are mixed: time post which always begins with a number (0,1,2,.....,9) and measurement post which always begins with a letter (A,B,...,Ö,a,b,...,ö). The data part always starts with a time post with 12 signs length. First date will be written on all lists and diagrams.

Post type 1: Time post The time for following measurement post will be written in the format: "<year><month><day><hour><min><sec>". Fixed term length is 2 numbers. For example 900221110400 means 1990-02-21 11:04:00.

Term 1-3: <year><month><day> Date. Year 00-99, month 01-12 and day 01-31.

Term 4-6: <hh><mm><ss> Hour 00-23, minute 00-60, second 00-60. If parts of seconds will bee needed in the future, just add a decimal point and more numbers. Input program should be able to read decimal point and more numbers.

Time post may and shall be shortened in order to only changed terms are written. Two numbers time post is read as seconds during the minute as preceding time post, a four number time post is read as minutes and seconds during the same hour as preceding time post and so on. The post length will be varying between 2 and 12 numbers. Number of terms: 1-6.

Post type 2: Measurement post Measuring value for each quantity which has been measured at the time in preceding time post. Format "<quantity>,<measuring value>". For example: "G0-2.2534" or "Q 5.78E4". Observe the space after Q!

Term 1: <quantity> Same quantity as in definition part above. Fixed term length two figures.

Term 2: <measuring value> Measuring value in a free format according to "computer convention", that is possible sign, possible integer, possible decimal point and decimal part, possible E and exponent. Permitted signs: "1234567890.+-E". All spaces are unnecessary and should be avoided, but they should be accepted by input routines. Flexible term length 1 - 20 figures.

End post

If you want to store or send several measuring sequences, it's necessary to have a special end post in the file. Also in order to see that the measurement is finished in the right way and no data is lost, the end post is necessary.
After the measuring sequence a dollar sign ($) is written, it's end post and not file end. Several measuring sequences can be stored in the same file.

Comment post

Comment lines are allowed any where in the file if they start with a asterisk (*). Example:

```
* Free text with any sign 12345!"£/;%
```

Example of a data file

```
TT,BORRE MEASUREMENT
BH,KAS02
IW,84.0,DEGREES
*          Here the definitions start
BT,,degrees
BX,,mS/m
B1,,m
B2,,m
B3,,m
B4,,m
B5,,m
B6,,m
*          The data part begins with a 12 number time
890709172847
BT9.701831
48
BX1253.708
49
B1-3.7451
50
B2-1.814304
51
B3-.4956951
52
B4-.8124924
53
B5-.4179688
54
B61.216299
5847
B4-2.914619E-02
12
B5.1232052
13
B6.9168396
$          End sign
```

15.11 APPENDIX 11

BHEQUIPE - Equipments In Boreholes

Table BHEQLOGG Data Loggers In Boreholes

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
SDATE	*	CHAR(6)	DATE	start date of logger (yymmdd)
STIME		CHAR(6)	TIME	start time of logger (hhmmss)
EDATE		CHAR(6)	DATE	end date of logger (yymmdd)
ETIME		CHAR(6)	TIME	end time of logger (hhmmss)
LOGGER		CHAR(25)	EQPMX	datalogger or data collecting unit
LOGGERID		CHAR(10)	SNUMBERX	serial number of data collecting unit
PLACE		CHAR(10)	PLACE	
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table BHEQTRAN Pressure Transducers In Boreholes

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
SDATE	*	CHAR(6)	DATE	start date of transducer (yymmdd)
STIME		CHAR(6)	TIME	start time of transducer (yymmdd)
EDATE		CHAR(6)	DATE	end date of transducedr (yymmdd)
ETIME		CHAR(6)	TIME	end time of transducer (hhmmss)
TGAUGE		CHAR(25)	EQPMX	type of measurement gauge, probe or transducer
TGAUGEID		CHAR(10)	SNUMBERX	serial number of measurement gauge
CLASS		NUM (5,2)	CLASS	class (bar)
LT		NUM (6,2)	LENGTH	length to measurement gauge from top of casing (m)
CHANNEL		CHAR(4)	CHANNEL	logger channel
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table BHEQCONS Calibration Constants For Transducers

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
SDATE	*	CHAR(6)	DATE	start date of constant (yymmdd)
STIME	*	CHAR(6)	TIME	start time of constant (hhmmss)
EDATE		CHAR(6)	DATE	end date of constant (yymmdd)
ETIME		CHAR(6)	TIME	end time of constant (hhmmss)
C0		NUM (4,*)	CONST	calibration constant Co
C1		NUM (4,*)	CONST	calibration constant C1
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table BHEQPACK Packers in Boreholes

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SDATE	*	CHAR(6)	DATE	date of packer inflation (yymmdd)
STIME	*	CHAR(6)	TIME	time of packer inflation (hhmmss)
EDATE		CHAR(6)	DATE	date of packer deflation (yymmdd)
ETIME		CHAR(6)	TIME	time of packer deflation (hhmmss)
PSECUP		NUM (6,2)	LENGTH	length to packer, upper limit (m)
PLENGTH		NUM (6,2)	LENGTH	length of packer (m)
PTYPE		CHAR(25)	EQPMX	type of packer
PACKID		CHAR(10)	SNUMBERX	serial number of packer
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table BHEQCOND Conductivity Loggers In Boreholes

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
SDATE	*	CHAR(6)	DATE	start date of logger (yymmdd)
STIME		CHAR(6)	TIME	start time of logger (hhmmss)
EDATE		CHAR(6)	DATE	end date of logger (yymmdd)
ETIME		CHAR(6)	TIME	end time of logger (hhmmss)
LOGGER		CHAR(25)	EQPMX	datalogger or data collecting unit
LOGGERID		CHAR(10)	SNUMBERX	serial number of data collecting unit
PLACE		CHAR(10)	PLACE	
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table CASSETTE Name Of Cassette Files From Injection Tests

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
DATE	*	CHAR(6)	DATE	date of test (yymmdd)
SECLEN	*	NUM (6,2)	SECLEN	section length (m)
CFILE		CHAR(15)	FIL	name of cassette file
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table BHEQGEOM Borehole Equipment - Geometry In Borehole

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	idcode of the borehole
START	*	CHAR(6)	DATE	start date of the test (yymmdd)
HOLDIAM		NUM (4,3)	DIAM	borehole diameter (m)
RMAIDIAM		NUM (4,4)	DIAMET	diameter of the rising main (m)
DDUMMY		NUM (4,4)	DIAMET	diameter of dummy (m)
LDUMMY		NUM (4,4)	LDUMMY	length of dummy (m)
COPCDIAM		NUM (4,4)	DIAMET	diameter of the conductivity probe cable (m)
OWTUDIAM		NUM (4,4)	DIAMET	outside diameter of the withdrawal tube (m)
IWTUDIAM		NUM (4,4)	DIAMET	inside diameter of the withdrawal tube (m)
OOTUDIAM		NUM (4,4)	DIAMET	outside diameter of the outlet tube (m)
IOTUDIAM		NUM (4,4)	DIAMET	inside diameter of the outlet tube (m)
LOUTLET		NUM (4,4)	LOUTLET	length to outlet (m)
OTHT1		NUM (4,4)	DIAMET	outside diameter of through tube # 1 (m)
OTHT2		NUM (4,4)	DIAMET	outside diameter of through tube # 2 (m)
OTHT3		NUM (4,4)	DIAMET	outside diameter of through tube # 3 (m)
OTHT4		NUM (4,4)	DIAMET	outside diameter of through tube # 4 (m)
OTHT5		NUM (4,4)	DIAMET	outside diameter of through tube # 5 (m)
OTHT6		NUM (4,4)	DIAMET	outside diameter of through tube # 6 (m)
COM50		CHAR(50)	COM50	comment text
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Method CONDINT - Electrical Conductivity in Pumped Water

Table CONDINF1 Electrical Conductivity In Pumped Water - Flyleaf 1

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode of the pumpwell
START	*	CHAR(6)	DATE	start date of interference test (yymmdd)
COMPANY		CHAR(30)	COMP	logging company
RESP1		CHAR(20)	PERSON	person responsible for measurement
RESP2		CHAR(20)	PERSON	person responsible for evaluation of data
REPORT		CHAR(30)	REPORT	reference to report
ARCHIVE		CHAR(50)	ARCHIVE	reference to archive
DATASTO		CHAR(79)	DATASTO	data storage
COM50		CHAR(50)	COM50	comments
SIGN		CHAR(5)	SIGN	signature of person responsible for input of data
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table CONDINF2 Electrical Conductivity In Pumped Water - Flyleaf 2

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode of the pumpwell
START	*	CHAR(6)	DATE	start date of interference test (yymmdd)
MEQUIPE		CHAR(50)	EQPM	measuring equipment
COMMENT		CHAR(50)	COM50	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table CONDINTD Electrical Conductivity In Pumped Water - Data Table

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode of the pumpwell
START	*	CHAR(6)	DATE	start date of interference test (yymmdd)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
ECOND		NUM (5,1)	ECOND	electrical conductivity in pumped water (mSiemens/m)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method FLOWMETE - Flowmeter Test

Table FLOWMEF1 Flowmeter Test - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
END		CHAR(6)	DATE	end date of test (yymmdd)
COMP		CHAR(30)	COMP	loggin company
RESP		CHAR(20)	PERSON	person evaluating data
REPORT		CHAR(30)	REPORT	reference to report
ARCHIVE		CHAR(50)	ARCHIVE	reference to archive
DATASTO		CHAR(79)	DATASTO	data storage
COM50		CHAR(50)	COM50	comment text
SIGN		CHAR(5)	SIGN	signature of person responsible for input of data
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table FLOWMEF2 Flowmeter Test - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
END		CHAR(6)	DATE	end data of test (yymmdd)
PSTART		CHAR(6)	DATE	start date of pumping (yymmdd)
PTIME		CHAR(6)	TIME	start time of pumping (hhmmss)
EPDATE		CHAR(6)	DATE	end date of pumping (yymmdd)
EPTIME		CHAR(6)	TIME	end time of pumping (hhmmss)
PSECUP		NUM (6,2)	LENGTH	length from top of casing to pump (m)
PRATE		NUM (4,*)	FLOW	pump rate (m**3/s)
VOL		NUM (8,4)	RVOL	total amount of pumped water (m**3)
EQUIP		CHAR(79)	COMMENT	equipment
TCOUNT		NUM (6)	TCOUNT	number of seconds per registration window
COM50		CHAR(50)	COM50	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table FLOWMEF3 Flowmeter Test - Flyleaf 3

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table FLOWCAL Flowmeter Test - Calibration Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
CDATE	*	CHAR(6)	DATE	date of calibration (yymmdd)
CTIME	*	CHAR(6)	TIME	time of calibration (hhmmss)
COUNT		NUM (6,*)	COUNTS	number of counts
FLOW		NUM (4,*)	CFLOW	calculated water flow (m**3/s)
COM50		CHAR(50)	COM50	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table FLOWMED Flowmeter Test - Count Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLEN	*	NUM (6,2)	LENGTH	length of tested section (m)
DIRECT	*	CHAR(1)	DIRECTIO	measurements upwards (U) or downwards (D)
COUNTS		NUM (6,*)	COUNTS	counts/s
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table FLOWMECD Flowmeter Test - Calculated Flow

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLEN	*	NUM (6,2)	LENGTH	length of tested section (m)
FLOW		NUM (4,*)	FLOW	calibrated flow in borehole (m**3/s)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table FLOWMELD Flowmeter Test - Groundwater Head

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
GRWD		NUM (5,2)	GRWD	groundwater
GRWHEAD		NUM (6,2)	GRWHEAD	groundwater head (m.a.s.l.)
COM30		CHAR(30)	COM30	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method GRWB - Measurements of Groundwater Level in Boreholes

Table GRWBF1 Measurements Of Groundwater Level In Boreholes - Flyleaf 1

Column	Key	Type	Domain	Text
AREAC	*	CHAR(2)	AREACODE	idcode for area
START	*	CHAR(6)	DATE	start date of measurement (yymmdd)
END	*	CHAR(6)	DATE	end date of measurement (yymmdd)
MEQUIP		CHAR(2)	MEQUIP	measuring equipment; as S = sounding G = water level gauge P = pressure transducer
MEASFRQ		CHAR(50)	MEASFREQ	measuring frequency
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table GRWBF2 Measurements of Groundwater Level In Boreholes - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
BHPART	*	CHAR(1)	BHPART	part of borehole U = upper section L = lower section N = borehole without packer
START	*	CHAR(6)	DATE	measuring start date (yymmdd)
END		CHAR(6)	DATE	measuring end date (yymmdd)
MEQUIP		CHAR(2)	MEQUIP	measuring equipment as S = sounding G = water level gauge P = pressure depth of packer (m)
PACKERD		NUM (6,2)	DEPTH	vertical depth of packer (m) (corrected for deviation measurements)
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table GRWBD Measurements Of Groundwater Level In Boreholes - Data Table

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
BHPART	*	CHAR(1)	BHPART	part of borehole U = upper section L = lower section N = borehole without packer
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurment (yymmdd)
GRWHEAD		NUM (6,2)	GRWHEAD	groundwater head above sealevel (m.a.s.l.)
COM30		CHAR(30)	COM30	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table GRWBSD Measurement Of Groundwater Level In Boreholes - Data Table

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to measurement section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to measurement section, lower limit (m)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
GRWHEAD		NUM (6,2)	GRWHEAD	groundwater head above sea level (m.a.s.l.)
COM30		CHAR(30)	COM30	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method HUFZ - Hydraulic Unit Fracture Zones

Table HUFZF Hydraulic Unit Fracture Zones - Flyleaf

Column	Key	Type	Domain	Text
AREAC	*	CHAR(2)	AREACODE	areacode
IDCZON	*	CHAR(6)	IDCZON	idcode for fracture zone
IDCODE	*	CHAR(5)	IDCODE	idcode for borehole
ZONDIR		CHAR(2)	ZONDIR	zon orientation
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table HUFZCD Hydraulic Unit Fracture Zones - Calculated Data

Column	Key	Type	Domain	Text
IDCZON	*	CHAR(6)	IDCZON	idcode for fracture zone
IDCODE	*	CHAR(5)	IDCODE	idcode for borehole
ZONUP	*	NUM (6,2)	LENGTH	length to measuring section, upper limit (m)
ZONLOW	*	NUM (6,2)	LENGTH	length to measuring section, lower limit (m)
VERTDEP		NUM (6,2)	DEPTH	vertical depth corrected for deviation measurements
TW		NUM (5,2)	WIDTH	true width of the zone
DIP		CHAR(4)	DIP	dip of zon (degrees)
CL		NUM (6,2)	LENGTH	length of crushed bedrock (m)
KU		NUM (3,*)	HCOND	hydraulic conductivity (m/s)
COM30		CHAR(30)	COM30	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method HURM - Hydraulic Unit Rockmass

Table HURMF Hydraulic Unit Rockmass - Flyleaf

Column	Key	Type	Domain	Text
AREAC	*	CHAR(2)	AREACODE	areacode
IDCODE	*	CHAR(5)	IDCODE	idcode for borehole
SECLEN	*	NUM (6,2)	SECLEN	section length (m)
NUMTSEC		NUM (3)	NUMTSEC	number of test sections
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table HURMCD Hydraulic Unit Rockmass - Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	idcode for borehole
SECUP	*	NUM (6,2)	LENGTH	length to measuring section, upper limit (m)
SECLEN	*	NUM (6,2)	SECLEN	section length (m)
VERTDEP	*	NUM (6,2)	DEPTH	vertical depth to middle of measuring section (m) corrected for deviation measurements
K		NUM (3,*)	HCOND	best fitted hydraulic conductivity, of test section
ROCKT		CHAR(2)	ROCKT	H = if the test section intersect the main rock type S = if the test section intersect the subordinate rock type
COM30		CHAR(30)	COM30	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method HYCHEM - Hydraulic Test During Chemical Sampling

Table HYCHEMF1 Hydraulic Test During Chemical Sampling - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
COMPANY		CHAR(30)	COMP	company performing test
RESP1		CHAR(20)	PERSON	person responsible for measurement
RESP2		CHAR(20)	PERSON	person responsible for evaluation
REPORT		CHAR(30)	REPORT	reference to report
ARCHIVE		CHAR(50)	ARCHIVE	reference to archive
DATASTO		CHAR(79)	DATASTO	data storage
COM50		CHAR(50)	COM50	comments
SIGN		CHAR(5)	SIGN	signature of person responsible for input of data
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table HYCHEMF2 Hydraulic Test During Chemical Sampling - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
END		CHAR(6)	DATE	end date of test (yymmdd)
SPDATE		CHAR(6)	DATE	start of pumping period date (yymmdd)
SPTIME		CHAR(6)	TIME	start of pumping period time (hhmmss)
EPDATE		CHAR(6)	DATE	end of pumping period date and start of recovery period date (yymmdd)
EPTIME		CHAR(6)	TIME	end of pumping period time and start of recovery period time (hhmmss)
ERDATE		CHAR(6)	DATE	end of recovery period date (yymmdd)
ERTIME		CHAR(6)	TIME	end of recovery period time (hhmmss)
TP		NUM (8,*)	TP	duration of pumping period (s)
TREC		NUM (8,*)	TREC	duration of recovery period (s)
PSECUP		NUM (6,2)	LENGTH	length from top of casing to pump section, upper limit (m)
PSECLOW		NUM (6,2)	LENGTH	length from top of casing to pump section, lower limit (m)
TEQUIP		CHAR(79)	TEQUIP	test equipment
DATAFIL		CHAR(79)	DATAFIL	data files
PROGPLT		CHAR(50)	PROGPLOT	plot program
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table HYCHEMF3 Hydraulic Test During Chemical Sampling - Flyleaf 3

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
END	*	CHAR(6)	DATE	end date of test (yymmdd)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Method INTER - Interference Test and Test Pumping

Table INTRF1 Interference Test and Test Pumping - Flyleaf 1

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode for borehole as pumping/injection well
START	*	CHAR(6)	DATE	start date of test (yymmdd)
COMP		CHAR(30)	COMP	logging company
RESP1		CHAR(20)	PERSON	person responsible for test
RESP2		CHAR(20)	PERSON	person responsible for evaluation
REPORT		CHAR(30)	REPORT	reference to report
ARCHIVE		CHAR(50)	ARCHIVE	reference to archive
DATASTO		CHAR(79)	DATASTO	data storage
COM50		CHAR(50)	COM50	comments
SIGN		CHAR(5)	SIGN	signature of person responsible for input of data
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRF2 Interference Test and Test Pumping - Flyleaf 2

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode for borehole as pumping/injection well
START	*	CHAR(6)	DATE	start date of test (yymmdd)
END		CHAR(6)	DATE	end date of test (yymmdd)
SPDATE		CHAR(6)	DATE	start of pumping period date (yymmdd)
SPTIME		CHAR(6)	TIME	start of pumping period time (hhmmss)
EPDATE		CHAR(6)	DATE	end of pumping period and start of recovery period date (yymmdd)
EPTIME		CHAR(6)	TIME	end of pumping period and start of recovery period time (hhmmss)
ERDATE		CHAR(6)	DATE	end of recovery period date in pumpwell (yymmdd)
ERTIME		CHAR(6)	TIME	end of recovery period time in pumpwell (hhmmss)
TP		NUM (8,*)	TP	duration of pumping period (s)
TREC		NUM (8,*)	TREC	duration of measured recovery period (s)
PSECUP		NUM (6,2)	LENGTH	lenght from top of casing to pump/injection section, upper limit (m)
PSECLOW		NUM (6,2)	LENGTH	length from top of casing to pump/injection section, lower limit (m)
VTOT		NUM (5,*)	VOL	total pumped volume (m**3)
QP		NUM (4,*)	FLOW	flow rate at pumpstop (m**3/s)
QMEAN		NUM (5,*)	MFLOW	mean flow rate during pumping phase (m**3/s)
TTYPE		CHAR(8)	TTYPE	testttype: injection or testpumping constant Q or constant P
PUMP		CHAR(50)	EQPM	pump
PUMPID		CHAR(15)	SNUMBER	serial number of the pump
PUMPL		NUM (6,2)	LENGTH	length to pump intake along the borehole (m)
TEQUIP		CHAR(79)	TEQUIP	test equipment
DATAFIL		CHAR(79)	DATAFIL	datafiles
PROGPLT		CHAR(50)	PROGPLOT	program for plots
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRF3 Interference Test and Test Pumping: Equipment In Pumpwell and Obsholes - Flyleaf 3

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode for borehole as pumping/injection well
OBSHOLE	*	CHAR(5)	IDCODE	idcode for obshole
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
START	*	CHAR(6)	DATE	start date for test (yymmdd)
LT	*	NUM (6,2)	LENGTH	length to measurement gauge from top of casing (m)
TGAUGE		CHAR(50)	EQPM	type of measurement gauge, probe or transducer
TGAUGEID		CHAR(15)	SNUMBER	serial number of measurement gauge
LOGGER		CHAR(50)	EQPM	datalogger or data collecting unit
LOGGERID		CHAR(15)	SNUMBER	serial number of data collecting unit
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRF4 Interference Test and Test Pumping: Comments From Pumpwell and Obsholes - Flyleaf 4

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode for borehole as pumping/injection well
OBSHOLE	*	CHAR(5)	IDCODE	idcode for obshole
START	*	CHAR(6)	DATE	start date for test (yymmdd)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRF5 Interference Tests and Test Pumping: Constants From Pumpwell And Obsholes - Flyleaf 5

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	borehole idcode, pump well/injection well
OBSHOLE	*	CHAR(5)	IDCODE	idcode for obshole
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
START	*	CHAR(6)	DATE	start date for test (yymmdd)
CONSNO	*	NUM (2)	CONSNO	constant number
CO		NUM (4,*)	CONST	calibration constant Co
C1		NUM (4,*)	CONST	calibration constant C1
COM50		CHAR(50)	COM50	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRGEOM Interference Tests and Test Pumping - Geometry Of The Pumpwell

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	idcode of the pumpwell
START	*	CHAR(6)	DATE	start date of the test (yymmdd)
HOLDIAM		NUM (4,3)	DIAM	borehole diameter (m)
RMAIDIAM		NUM (4,4)	DIAMET	diameter of the rising main (m)
OMPIDIAM		NUM (4,4)	DIAMET	outside diameter of the measurement pipe (m)
IMPIDIAM		NUM (4,4)	DIAMET	inside diameter of the measurement pipe (m)
PCABDIAM		NUM (4,4)	DIAMET	diameter of the pump cable (m)
TCABDIAM		NUM (4,4)	DIAMET	diameter of the transducer cable (m)
WIREDIAM		NUM (4,4)	DIAMET	diameter of the wire (m)
FLOWDIAM		NUM (4,4)	DIAMET	diameter of flowmeter cable (m)
COM50		CHAR(50)	COM50	comment text
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table INTERQD Interference Test and Test Pumping - Water Flow Data in Pumpwell

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to pump section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to pump section, lower limit (m)
START	*	CHAR(6)	DATE	start date of test (yymmdd)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
TIMEINT		NUM (6)	TIMEINT	time interval when water volume was measured (min)
VOLUME		NUM (6,4)	LVOL	water volume measured during the time interval (m**3)
FLOW		NUM (4,*)	CFLOW	calculated water flow rate (m**3/s)
COM50		CHAR(50)	COM50	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTERVD Interference Test and Test Pumping - Water Volume Data in Pumpwell

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to pump section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to pump section, lower limit (m)
START	*	CHAR(6)	DATE	start date of test (yymmdd)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
VOL		NUM (5,*)	VOL	read water volume on water meter (m**3)
MEANFLOW		NUM (4,*)	CFLOW	mean flow between two readings (m**3/s)
COM50		CHAR(50)	COM50	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRD Interference Test and Test Pumping - Packer Data from Pumpwell and Obsholes

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	borehole idcode, pump well/injection well
OBSHOLE	*	CHAR(5)	IDCODE	idcode for obshole
START	*	CHAR(6)	DATE	start date for test (yymmdd)
PISDATE		CHAR(6)	DATE	date of packer inflation start (yymmdd)
PISTIME		CHAR(6)	TIME	time of packer inflation start (yymmdd)
PDDATE		CHAR(6)	DATE	date of packer deflation (yymmdd)
PDTIME		CHAR(6)	TIME	time of packer deflation (yymmdd)
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRPSEC Interference Tests and Test Pumping - Groundwater Pressure Data from Test Sections in Pumpwell and Obsholes

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	borehole idcode, pump well/injection well
OBSHOLE	*	CHAR(5)	IDCODE	idcode for obshole
START	*	CHAR(6)	DATE	start date for test (yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to test section , upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section , lower limit (m)
RADSEC		NUM (5,1)	RADSEC	horisontal radius from centre of section to centre of pumphole
PI		NUM (7,2)	PRESS	absolute pressure before packer inflation (kPa)
PO		NUM (7,2)	PRESS	absolute pressure immediately before pumpstart (kPa)
DPOPP		NUM (6,2)	DPRESS	difference between pressure before pumpstart and pressure at pumpstop in resp. section(kPa)
DPOPR		NUM (6,2)	DPRESS	difference between pressure before pumpstart and pressure at recovery stop (kPa)
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRLSEC Interference Tests and Test Pumping - Groundwater Level Data from Test Sections in Pumpwell and Obsholes

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	borehole idcode, pump well/injection well
OBSHOLE	*	CHAR(5)	IDCODE	idcode for obshole
START	*	CHAR(6)	DATE	start date for test (yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to test section , upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section , lower limit (m)
HI		NUM (6,2)	GRWHEAD	groundwater head above sealevel before packer inflation (m.a.s.l.)
HO		NUM (6,2)	GRWHEAD	groundwater head above sealevel at pumpstart (m.a.s.l.)
DHOHP		NUM (5,2)	DGRWH	difference in groundwater head between pumpstart and pumpstop (m)
DHOHR		NUM (5,2)	DGRWH	difference in groundwater head between pumpstart and recoverystop (m)
RADSEC		NUM (5,1)		space distance from centre of section to centre of pumphole (m)
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table INTRCD Interference Tests and Test Pumping - Calculated Data

Column	Key	Type	Domain	Text
PUMPWELL	*	CHAR(5)	IDCODE	borehole idcode, pump well/injection well
OBSHOLE	*	CHAR(5)	IDCODE	idcode for obshole
START	*	CHAR(6)	DATE	start date of test (yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
SEQNO	*	NUM (3)	SEQNO	sequence number
K		NUM (3,*)	HCOND	hydraulic conductivity (m/s)
T		NUM (3,*)	TRANSM	transmissivity (m**2/s)
S		NUM (3,*)	STORCO	storage coefficient (dim.less)
SS		NUM (3,*)	STORCO	specific storage coefficient (1/m)
SKINFAC		NUM (4,2)	SKINFAC	skin factor
LEAKFAC		NUM (3,*)	LEAKFAC	leakage factor
LEAKCOEF		NUM (4,*)	LEAKCOEF	leakage coefficient
RWF		NUM (4,2)	RWF	effective borehole radius (m)
HUNIT		CHAR(20)	HUNIT	hydraulic unit
COMMENT		CHAR(79)	COMMENT	comments
COM50		CHAR(50)	COM50	more comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method METEOR - Meteorologic and Hydrologic Data

Table METEORF1 Meteorologic and Hydrologic Data - Flyleaf 1

Column	Key	Type	Domain	Text
STACODE	*	CHAR(4)	STACODE	station number
AREANAME		CHAR(20)	AREANAME	station name
COMMENT		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table METEORF2 Meteorologic and Hydrologic Data - Flyleaf 2

Column	Key	Type	Domain	Text
STACODE	*	CHAR(4)	STACODE	station number
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table METETEMP Meteorologic and Hydrologic Data - Temperature Measurement

Column	Key	Type	Domain	Text
STACODE	*	CHAR(4)	STACODE	station number
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TEMP		NUM (6,1)	TEMP	temperature (oC)
INDAT		CHAR(6)	DATE	date of input of data to geodatabase (yymmdd)

Table METEPREC Meteorologic and Hydrologic Data - Precipitation Measurement

Column	Key	Type	Domain	Text
STACODE	*	CHAR(4)	STACODE	station number
DATE	*	CHAR(6)	DATE	date of measurement
PRECIP		NUM (6,1)	PRECIPA	precipitation (mm)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table METEVAPO Meteorologic and Hydrologic Data - Evaporation Measurement

Column	Key	Type	Domain	Text
STACODE	*	CHAR(4)	STACODE	station number
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
EVAPORAT		NUM (6,1)	EVAPO	potentiell evaporation (mm)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table MESEALEV Meteorologic and Hydrologic Data - Sea Level Measurement

Column	Key	Type	Domain	Text
STACODE	*	CHAR(4)	STACODE	station number
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
LEVEL		NUM (6,2)	LEVEL	sea level in local height system (m)
RH70		NUM (6,2)	LEVEL	sea level in height system RH70 (m)
RH00		NUM (6,2)	LEVEL	sea level in height system RH00 (m)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method PIEZO - Piezometric Measurements

Table PIEZOF1 Piezometric Measurements - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	idcode for boreholes
START	*	CHAR(6)	DATE	start of measurement period, date (yymmdd)
END		CHAR(6)	DATE	end of measurement period, date (yymmdd)
COMP		CHAR(30)	COMP	company performing test
RESP1		CHAR(20)	PERSON	responsible for the test
RESP2		CHAR(20)	PERSON	responsible for the evaluation of data
PRGPLOT		CHAR(50)	PROGPLOT	program for plot generation
REPORT		CHAR(30)	REPORT	reference to report
CTHOLES		CHAR(50)	CTHOLES	contemporary test holes
ARCHIVE		CAHR(50)	ARCHIVE	reference to archive
DATASTO		CHAR(79)	DATASTO	data storage
COMMENT		CHAR(79)	COMMENT	comment
SIGN		CHAR(5)	SIGN	signature of person responsible for input of data
INDAT		CHAR(6)	DATE	

Table PIEZOF2 Piezometric Measurements - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	idcode for borehole
START	*	CHAR(6)	DATE	start of measurement period, date (yymmdd)
END		CHAR(6)	DATE	end of measurement period, date (yymmdd)
PMSTART		CHAR(6)	DATE	start date of piezomac (yymmdd)
PMSTIME		CHAR(6)	TIME	start time of piezomac (hhmmss)
PMEND		CHAR(6)	DATE	end date of piezomac (yymmdd)
PMETIME		CHAR(6)	TIME	end time of piezomac (hhmmss)
PISDATE		CHAR(6)	DATE	start of packer inflation, date (yymmdd)
PISTIME		CHAR(6)	TIME	start of packer inflation, time (hhmmss)
PDDATE		CHAR(6)	DATE	start of packer deflation, date (yymmdd)
PDTIME		CHAR(6)	TIME	start of packer deflation, time (hhmmss)
PMETER		CHAR(50)	EQPM	pressure transducer, name and/or id
PIEZOM		CHAR(50)	EQPM	piezomacnumber
DATAFIL		CHAR(79)	DATAFIL	datafiles such as D - files
COMMENT		CHAR(30)	COM30	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table PIEZOF3 Piezometric Measurements - Flyleaf 3

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date for test (yymmdd)
CONSNO	*	NUM (2)	CONSNO	constant number
CONST		NUM (4,*)	CONST	calibration constant
CONSCOM		CHAR(50)	COM50	comments concerning the calibration constant
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table PIEZOF4 Piezometric Measurements - Flyleaf 4

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date for test (yymmdd)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table PIEZOF5 Piezometric Measurements - Flyleaf 5 Length/depth of Transducer

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	Borehole idcode
START	*	CHAR(6)	DATE	Start of measurement (yymmdd)
MEQUIP		CHAR(50)	EQPM	equipment
LT		NUM (6,2)	LENGTH	Length from transducer to top of casing (m)
LTZ		NUM (6,2)	DEPTH	Depth of transducer
COM50		CHAR(50)	COM50	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table PIEZOF6 Piezometric Measurements - Flyleaf 6 Data File Names for Groundwater Monitoring

Column	Key	Type	Domain	Text
AREA	*	CHAR(2)	AREACODE	Area code
START	*	CHAR(6)	DATE	start date of monitoring (yymmdd)
SEQNO	*	NUM(3)	SEQNO	sequence number
DATASTO		CHAR(79)	DATASTO	data files
INDAT		CHAR(6)	DATE	input date of data to geodata base (yymmdd)

Table PIEZOPD Piezometric Measurements - Groundwater Pressure in Sections

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start of measurement period (yymmdd)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
P1		NUM (8,3)	PPRESS	groundwater pressure in section P1 (kPa)
P2		NUM (8,3)	PPRESS	groundwater pressure in section P2 (kPa)
P3		NUM (8,3)	PPRESS	groundwater pressure in section P3 (kpa)
P4		NUM (8,3)	PPRESS	groundwater pressure in section P4 (kPa)
COM50		CHAR(50)	COM50	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table PIEZOSPD Piezometric Measurements - Start And End Groundwater Pressure Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start of measuring period (yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to measurement section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to measurement section, lower limit (m)
END		CHAR(6)	DATE	end of measuring period (yymmdd)
PI		NUM (7,2)	PRESS	absolute pressure in section before packer inflation (kPa)
PP		NUM (7,2)	PRESS	absolute pressure in section at the end of the measurement (kPa)
DPPPI		NUM (7,2)	PRESS	difference between pressure before packer inflation and pressure at the end of the measurement (PI-PP) (kPa)
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table PIEZOSLD Piezometric Measurements - Start And End Groundwater Level Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start of measurement period, date (yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to measuring section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to measuring section, lower limit (m)
END		CHAR(6)	DATE	end of measurement period, date (yymmdd)
HI		NUM (6,2)	GRWHEAD	groundwater head above sea level before packer inflation (m.a.s.l.)
HO		NUM (6,2)	GRWHEAD	groundwater head above sea level after packer inflation (m.a.s.l.)
HP		NUM (6,2)	GRWHEAD	groundwater head above sea level at the end of the measurement period (m.a.s.l.)
COMMENT		CHAR(79)	COMMENT	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table PIEZOLD Piezometric Measurements - Groundwater Level Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to tested section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to tested section, lower limit (m)
START	*	CHAR(6)	DATE	start date of test (yymmdd)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
GRWHEAD		NUM (6,2)	GRWHEAD	groundwater head (m a s l)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method RECTES - Recovery Tests

Table RECTESF1 Recovery Test - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SDDDATE	*	CHAR(6)	DATE	start date of draw-down (yymmdd)
SDDTIME	*	CHAR(6)	DATE	start time of draw-down (hhmmss)
COMP		CHAR(30)	COMP	loggin company
RESP		CHAR(20)	PERSON	person evaluating data
REPORT		CHAR(30)	REPORT	reference to report
ARCHIVE		CHAR(50)	ARCHIVE	reference to archive
DATASTO		CHAR(79)	DATASTO	data storage
COM50		CHAR(50)	COM50	comments
SIGN		CHAR(5)	SIGN	signature of person responsible for input of data
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table RECTESF2 Recovery Test - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SDDDATE	*	CHAR(6)	DATE	start date of draw-down (yymmdd)
SDDTIME	*	CHAR(6)	TIME	start time of draw-down (hhmmss)
EDDDATE		CHAR(6)	DATE	end date of draw-down and start of recovery (yymmdd)
EDDTIME		CHAR(6)	TIME	end time of draw-down and start of recovery (hhmmss)
TD		NUM (6,2)	LENGTH	borehole length when the test was performed (m)
DDMETH		CHAR(79)	COMMENT	method of draw-down
TUBED		NUM (6,2)	LENGTH	length of flushing pipe along the borehole from the top of casing (m)
PACKER		CHAR(20)	EQUIPM	packer name and/or id
PACKERD		NUM (6,2)	LENGTH	length to lower limit of packer in borehole (m)
FLOWMEAS		CHAR(79)	COMMENT	method of determining the water flow or water volume during the draw-down
REFLEV		NUM (6,2)	REFLEV	reference level from which the distance to groundwater level i measured (m.a.s.l.)
COMMENT		CHAR(79)	COMMENT	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table RECTESF3 Recovery Test - Flyleaf 3

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SDDDATE	*	CHAR(6)	DATE	start date of draw-down (yymmdd)
SDDTIME	*	CHAR(6)	TIME	start time of draw-down (hhmmss)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table RECTESQD Recovery Test - Water Flow

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SDDDATE	*	CHAR(6)	DATE	start date of draw-down (yymmdd)
SDDTIME	*	CHAR(6)	TIME	start time of draw-down (hhmmss)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
SECUP		NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW		NUM (6,2)	LENGTH	lenght to test section, lower limit (m)
TIMEINT		NUM (6)	TIMEINT	time interval when water volume was measured (s)
VOLUME		NUM (6,4)	LVOL	water volume measured during the time interval (m**3)
FLOW		NUM (4,*)	CFLOW	calculated water flow rate (m**3/s)
COMMENT		CHAR(79)	COMMENT	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

<u>Table</u> RECTESVD Water Volume Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	Borehole idcode
SDDDATE	*	CHAR(6)	DATE	start date of draw-down (yymmdd)
SDDTIME	*	CHAR(6)	TIME	start time of draw-down (hhmmss)
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, lower limit (m)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
VOL		NUM (5,*)	VOL	water volume drawn up measured from start of the draw-down (m**3)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

<u>Table</u> RECTESLD Recovery Test - Groundwater Level Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SDDDATE	*	CHAR(6)	DATE	start date of draw-down (yymmdd)
SDDTIME	*	CHAR(6)	TIME	start time of draw-down (hhmmss)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
SECUP		NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW		NUM (6,2)	LENGTH	length to test section, lower limit (m)
GRWHEAD		NUM (6,2)	GRWHEAD	groundwater head above sea level (m.a.s.l.)
GRWD		NUM (6,2)	LENGTH	distance along the borehole to groundwater level from Reference level (m)
COM50		CHAR(50)	COM50	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

<u>Table</u> RECTESCD Recovery Test - Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to test section, upper limit (m)
SDDDATE	*	CHAR(6)	DATE	start date of draw-down (yymmdd)
SDDTIME	*	CHAR(6)	TIME	start time of draw-down (hhmmss)
T		NUM (3,*)	TRANSM	transmissivity (m**2/s)
Z		NUM (4,2)	SKINFAC	skinfactor
SPCAP		NUM (3,*)	SPCAP	specific capacity (m**2/s)
COM50		CHAR(50)	COM50	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method ROCKRM - Rocktypes In Rockmass

<u>Table</u> ROCKRMF Rocktypes In Rockmass - Flyleaf

Column	Key	Type	Domain	Text
AREAC	*	CHAR(2)	AREACODE	areacode
IDCODE	*	CHAR(5)	IDCODE	idcode for borehole
MROCKT		CHAR(20)	MROCKT	main rocktype of the rockmass
SROCKT		CHAR(20)	SROCKT	subordinate rocktype of the rockmass
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

<u>Table</u> ROCKRMCD Rocktypes In Rockmass - Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	idcode for borehole
SUBUP	*	NUM (6,2)	LENGTH	length along borehole to upper limit of subordinate rock in borehole
SUBLOW	*	NUM (6,2)	LENGTH	length along borehole to lower limit of subordinate rock in borehole
SECUP	*	NUM (6,2)	LENGTH	length to measuring section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length to measuring section, lower limit (m)
VERTDEP		NUM (6,2)	DEPTH	vertical depth corrected for deviation measurements
KSUB		NUM (3,*)	HCOND	hydraulic conductivity of divergent rock
KREG		NUM (3,*)	HCOND	hydraulic conductivity of divergent rock calculated from regressioncurve
COM30		CHAR(30)	COM30	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method SFHEAD - Single Hole Falling Head Tests

Table SFHEADF1 Single Hole Falling Head Tests - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurements in the borehole (yymmdd)
END		CHAR(6)	DATE	end date of measurements in the borehole (yymmdd)
RESP1		CHAR(20)	PERSON	responsible for the test
RESP2		CHAR(20)	PERSON	responsible for the evaluation of the test
REGMET		CHAR(50)	REGMET	flow rate registration method
PACKER		CHAR(50)	EQPM	packer name and/or id
DATAFIL		CHAR(79)	DATAFIL	datafiles containing measurement data
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SFHEADF2 Single Hole Falling Head Tests - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurements in the borehole (yymmdd)
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
END		CHAR(6)	DATE	end date of measurement in the borehole (yymmdd)
NUMSEC		NUM (3)	NUMSEC	number of sections measured
KMIN		NUM (3,*)	COND	lower measurement limit of the hydraulic conductivity (m/s)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SFHEADF3 Single Hole Falling Head Tests - Flyleaf 3

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurements in the borehole (yymmdd)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SFHEADCD Single Hole Falling Head Tests - Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurements in the borehole (yymmdd)
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECUP	*	NUM (6,2)	LENGTH	length to measurement section, upper limit (m)
TSDATE		CHAR(6)	DATE	test start date of the test section
K		NUM (3,*)	COND	hydraulic conductivity (m/s)
T		NUM (3,*)	TRANSM	transmissivity (m**2/s)
QSPEC		NUM (5,*)	SPFLOW	specific flow rate (m**3)/(m*s)
PLEVEL		NUM (6,2)	PLEVEL	piezometric level of the section(m.a.s.l.)
CPLEVEL		NUM (6,2)	PLEVEL	piezometric level of the section,corrected for the density of the fracture water(m.a.s.l.)
REGCOEF		NUM (3,3)	REGCOEF	regression coefficient
XPOLFACT		NUM (3,3)	XPOLFAC	
NUMDAT		NUM (3)	NUMDAT	number of data used in the evaluation
STLEVEL		NUM (4,2)	STLEVEL	distance to start level from top of casing(m)
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method SHBUP - Single Hole Build-Up Test

Table SHBUPF1 Single Hole Build-Up Test - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurement(yymmdd)
END		CHAR(6)	DATE	end date of measurement(yymmdd)
RESP1		CHAR(20)	PERSON	responsible for the test
RESP2		CHAR(20)	PERSON	responsible for the evaluation of the test
REGMET		CHAR(50)	REGMET	registration method;manual or data logger,transducer or sounding
PACKER		CHAR(50)	EQPM	packer name and/or id
PMETER		CHAR(5)	EQUIP	pressure meter name and/or id
LOGGER		CHAR(50)	EQPM	data logger name and/or id
LPM		CHAR(50)	EQPM	location of the pressure transducer
CONST		NUM (4,*)	CONST	instrumental constant(s)
DATAFIL		CHAR(79)	DATAFIL	datafile containing measurement data
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHBUPF2 Single Hole Build-Up Tests - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurement(yymmdd)
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
END		CHAR(6)	DATE	end date of measurement(yymmdd)
NUMSEC		NUM (3)	NUMSEC	number of sections measured
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHBUPD Single Hole Build-Up Tests - Data Table

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurement(yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to measurement section, upper limit
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECLOW		NUM (6,2)	LENGTH	length to measurement section, lower limit
END		CHAR(6)	DATE	end date of measurement(yymmdd)
TSDATE		CHAR(6)	DATE	test start date, i.e. when the test section is shut in (yymmdd)
TSTIME		CHAR(6)	TIME	test start time, i.e. when the test section is shut in (hhmmss)
PISDATE		CHAR(6)	DATE	start of packer inflation, date(yymmdd)
PISTIME		CHAR(6)	TIME	start of packer inflation, time(hhmmss)
FTIME		NUM (8)	FTIME	flow time (s)
QP		NUM (4,*)	FLOW	water flow rate when the test section is shut in
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHBUPCD Single Hole Build-Up Tests - Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of measurement(yymmdd)
SECUP	*	NUM (6,2)	LENGTH	length to measurement section, upper limit
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECLOW		NUM (6,2)	LENGTH	length to measurement section, lower limit
END		CHAR(6)	DATE	end date of measurement(yymmdd)
TSDATE		CHAR(6)	DATE	test start date, i.e. when the test section is shut in
K		NUM (3,*)	COND	hydraulic conductivity (m/s)
T		NUM (3,*)	TRANSM	transmissivity (m**2/s)
COMMENT		CHAR(79)	COMMENT	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method SHSINJ - Single Hole Steady State Injection Tests

Table SHSINJF1 Single Hole Steady State Injection Tests - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
END	*	CHAR(6)	DATE	end date of tests (yymmdd)
RESP1		CHAR(20)	PERSON	responsible for the tests
RESP2		CHAR(20)	PERSON	responsible for the evaluation of data
UNIT		CHAR(5)	EQUIP	main id for used equipment: MV = umbilical hose system RG = steel pipe system
GRWD		NUM (5,2)	GRWD	vertical distance (approx) between top of casing and groundwater head (m)
FLOWM		CHAR(50)	EQPM	flowmeter name and/or id
FLOWMAX		NUM (4,*)	FLOWB	maximum recordable flow rate (m**3/s)
FLOWMIN		NUM (4,*)	FLOWB	minimum recordable flow rate (m**3/s)
INJP		CHAR(30)	INJP	most frequent injection pressures (kPa)
PMMETER		CHAR(50)	EQPM	pressure meter name and/or id
PACKER		CHAR(50)	EQPM	packer name and/or id
LOGGER		CHAR(50)	EQPM	data logger
CHARTR		CHAR(50)	EQPM	chart recorder
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHSINJF2 Single Hole Steady State Injection Tests - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECLEN	*	NUM (6,2)	SECLEN	section length (m)
START	*	CHAR(6)	DATE	start date of test (yymmdd)
END	*	CHAR(6)	DATE	end date of test (yymmdd)
NUMSEC		NUM (3)	NUMSEC	number of sections recorded
KMIN		NUM (3,*)	HCOND	minimum measurable K-value (m/s)
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHSINJF3 Single Hole Steady State Injection Tests - Flyleaf 3

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of test (yymmdd)
END	*	CHAR(6)	DATE	end date of test (yymmdd)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHSINJP Single Hole Steady State Injection Test - Pressure Data from Constant Head Test

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECUP	*	NUM (6,2)	LENGTH	length of tested section, upper limit (m)
SECLOW	*	NUM (6,2)	LENGTH	length of tested section, lower limit (m)
START	*	CHAR(6)	DATE	start date of test (yymmdd)
DATE	*	CHAR(6)	DATE	date of measurement (yymmdd)
TIME	*	CHAR(6)	TIME	time of measurement (hhmmss)
PRESSURE		NUM (8,2)	SECPRESS	section pressure (kPa)
COMMENT		CHAR(30)	COM30	comments
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHSINJD Single Hole Steady State Injection Tests - Data Table

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECUP	*	NUM (6,2)	LENGTH	borehole length to test section, upper limit (m)
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
TYPE		CHAR(3)	TYPECODE	measuring equipment MV = umbilical hose system RG = steel pipe system
TP		NUM (6)	TPH	duration of injection phase (s)
DP		NUM (7,2)	PRESS	injection pressure in section during injection phase (kPa)
DP0		NUM (7,2)	PRESS	injection pressure in test section related to P0 where P0 is hydrostatic pressure in section immediately before injection start
DP0PI		NUM (7,2)	PRESS	hydrostatic pressure in section immediately before injection start related to PI (P0-PI) (kPa)
TIVOL		NUM (3,*)		total injected volume (m**3)
QP		NUM (4,*)	FLOW	water flow rate at injection stop (m**3/s)
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHSINJCD Single Hole Steady State Injection Tests - Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECLEN	*	NUM (6,2)	SECLEN	section length (m)
SECUP	*	NUM (6,2)	LENGTH	length to measuring section, upper limit (m)
START	*	CHAR(6)	DATE	start date of test (yymmdd)
TP		NUM (6)	TPH	duration of injection phase (s)
K		NUM (3,*)	HCOND	steady state hydraulic conductivity (m/s)
T		NUM (3,*)	TRANSM	transmissivity (= K*L) (m**2/s) K = hydraulic conductivity L = section length
DP		NUM (7,2)	PRESS	injection pressure in section during injection phase (kPa)
QP		NUM (4,*)	FLOW	waterflow rate at injection stop (m**3/s)
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method SHTINJ - Single Hole Transient Injection Tests

Table SHTINJF1 Single Hole Transient Injection Tests - Flyleaf 1

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
END	*	CHAR(6)	DATE	end date of tests (yymmdd)
COMP		CHAR(30)	COMP	company
RESP1		CHAR(20)	PERSON	responsible for the tests
RESP2		CHAR(20)	PERSON	responsible for the tests
RESP3		CHAR(20)	PERSON	responsible for the evaluation of data
REPORT		CHAR(30)	REPORT	reference to report
ARCHIVE		CHAR(50)	ARCHIVE	reference to archive
DATASTO		CHAR(79)	DATASTO	data storage
COM50		CHAR(50)	COM50	comments
SIGN		CHAR(5)	SIGN	signature of person responsible for input of data
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHTINJF2 Single Hole Transient Injection Tests - Flyleaf 2

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
END	*	CHAR(6)	DATE	end date of tests (yymmdd)
UNIT		CHAR(5)	EQUIP	main id for used equipment, MV = umbilical hose system, RG = steel pipe system
FLOWM		CHAR(50)	EQPM	flowmeter name and/or id,
FLOWMAX		NUM (4,*)	FLOWB	maximum recordable flow rate (m**3/s)
FLOWMIN		NUM (4,*)	FLOWB	minimum recordable flow rate (m**3/s)
PMETER		CHAR(50)	EQPM	pressure meter name and/or id
PACKER		CHAR(50)	EQPM	packer name and/or id
LOGGER		CHAR(50)	EQPM	data logger name and/or id
CHARTR		CHAR(50)	EQPM	chart recorder name and/or id
GRWD		NUM (5,2)	GRWD	vertical distance (approx.) between top of casing and groundwater head (m)
DATAFIL		CHAR(79)	DATAFIL	datafiles such as M, C - files
PRGPLOT		CHAR(50)	PROGPLOT	program for plot generation
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHTINJF3 Single Hole Transient Injection Test - Flyleaf 3

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
NUMSEC		NUM (3)	NUMSEC	number of sections recorded
KMINMEAS		NUM (3,*)	HCOND	minimum measurable K-value (K and KPREL) m/s
KMINCAL		NUM (3,*)	HCOND	minimum calculated K-value (KJACOB) m/s
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHTINJF4 Single Hole Transient Injection Tests - Flyleaf 4

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECLEN	*	NUM (6,2)	LENGTH	length of tested section (m)
SECUP	*	NUM (6,2)	LENGTH	length to tested section, upper limit (m)
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
LINENO	*	NUM (4)	LINENO	line number
COMMENT		CHAR(79)	COMMENT	comment text
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHTINJF5 Single Hole Transient Injection Tests - Flyleaf 5

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECUP	*	NUM (6,2)	LENGTH	borehole length to test section, upper limit (m)
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
SEQNO	*	NUM (3)	SEQNO	sequence number
FLOWREG		CHAR(2)	FLOWREG	flow regime: R = radial, SP = spherical, L = linear and SS = steady state
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHTINJD Single Hole Transient Injection Tests - Data Table

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECUP	*	NUM (6,2)	LENGTH	borehole length to test section, upper limit (m)
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
TYPE		CHAR(3)	TYPECODE	measuring equipment MV = umbilical hose system RG = steel pipe system
TP		NUM (6)	TPH	duration of injection phase (s)
DTF		NUM (6)	TPH	duration of recovery phase (s)
PI		NUM (7,2)	PRESS	hydrostatic pressure in section before packer sealing (kPa)
DPO		NUM (7,2)	PRESS	injection pressure in test section related to PO where PO is hydro static pressure in section immediately before injection start
DPFPI		NUM (7,2)	PRESS	calculated hydrostatic pressure in section related to pressure before packer sealing (PS-PI) (kPa)
DPOPI		NUM (7,2)	PRESS	hydrostatic pressure in section immediately before injection start related to PI (PO-PI) (kPa)
TIVOL		NUM (3,*)		total injected volume (m**3)
QP		NUM (4,*)	FLOW	water flow rate at injection stop (m**3/s)
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Table SHTINJCD Single Hole Transient Injection Tests - Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECUP	*	NUM (6,2)	LENGTH	borehole length to test section, upper limit (m)
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
BC		CHAR(3)	BC	hydralic boundary conditions: PB = positive boundary, NB = negative boundary
KSS		NUM (3,*)	HCOND	steady state hydraulic conductivity, preliminary (m/s)
KI		NUM (3,*)	HCOND	hydraulic conductivity, calculated from injection phase (m/s)
KT		NUM (3,*)	HCOND	hydraulic conductivity, from fall-off phase (m/s)
KJACOB		NUM (3,*)	HCOND	representative hydraulic conductivity according to Jacob /m/s)
KPREL		NUM (3,*)	HCOND	preliminary best fitted hydraulic conductivity value, one of KSS, KI or KT (m/s)
K		NUM (3,*)	HCOND	representative hydraulic conductivity (m/s)
ZI		NUM (4,2)	SKINFAC	skinfactor calculated from injection phase
ZT		NUM (4,2)	SKINFAC	skinfactor calculated from recovery phase
GOODNES		CHAR(2)	GOODNESS	judgement of data quality, G = good, N = normal or B = bad
TDATE		CHAR(6)	DATE	test date (yymmdd)
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

Method SHTINJOD - Single Hole Transient Injection Tests, Old Calculated Data

Table SHTINJOD Single Hole Transient Injection Tests, Old Calculated Data

Column	Key	Type	Domain	Text
IDCODE	*	CHAR(5)	IDCODE	borehole idcode
START	*	CHAR(6)	DATE	start date of tests (yymmdd)
SECLEN	*	NUM (6,2)	LENGTH	section length (m)
SECUP	*	NUM (6,2)	LENGTH	borehole length to test section, upper limit (m)
TYPE		CHAR(3)	TYPECODE	measuring equipment: MV = umbilical hose system, RG = steel pipe system
BC		CHAR(3)	BC	hydralic boundary conditions: PB = positive boundary,NB = negative boundary
TP		NUM (6)	TPH	duration of injection phase (s)
DTF		NUM (6)	TPH	duration of fall-off phase (s)
KSS		NUM (3,*)	HCOND	steady state hydraulic conductivity, preliminary (m/s)
KI		NUM (3,*)	HCOND	hydraulic conductivity, calculated from injection phase (m/s)
KT		NUM (3,*)	HCOND	hydraulic conductivity, from fall-off phase (m/s)
K		NUM (3,*)	HCOND	K = representative hydraulic conductivity (m/s)
T		NUM (3,*)	TRANSM	transmissivity (= K*L) (m**2/s) K = representative hydraulic conductivity, L = section length
ZI		NUM (4,2)	SKINFAC	skinfactor calculated from injection phase
ZT		NUM (4,2)	SKINFAC	skinfactor calculated from fall off phase
PI		NUM (7,2)	PRESS	abs. pressure in section before packer sealing (kPa)
DPFPI		NUM (6,2)	DPRESS	difference in hydrostatic section pressure and long time after packer inflation (kPa) PF - PI, PF = abs. hydrostatic pressure of the section, obtained from fall-off phase
DPOPI		NUM (6,2)	DPRESS	difference in hydrostatic pressure before and after packer inflation (kPa) PO - PI, PO = abs pressure in section at injection start
FLOWREG		CHAR(2)	FLOWREG	flow regime: R = radial, SP = spherical, L = linear and SS = steady state
GOODNES		CHAR(2)	GOODNESS	judgement of data quality, G = good, N = normal or B = bad
COM50		CHAR(50)	COM50	comment
INDAT		CHAR(6)	DATE	input date of data to geodatabase (yymmdd)

15.12 APPENDIX 12

GRAPHS FROM THE STEEL PIPE EQUIPMENT SYSTEM, VERSION 3, AND THE UMBILICAL HOSE EQUIOPMENT SYSTEM, VERSION 2

<u>Legend</u>

P	= absolute pressure in test section (kPa)
P_i	= absolute pressure in test section before packer inflation (kPa)
P_o	= absolute pressure in test section immediately before start of injection (kPa)
P_p	= absolute pressure in test section immediately before stop of injection (kPa)
P_e	= absolute pressure in test section at the end of the test after packer deflation (kPa)
P_f	= absolute pressure in test section at the end of recovery phase (kPa)
P_b	= absolute pressure in test section measured at the time t_b (for calibration purposes) (kPa)
dP_i	= differential pressure, $P-P_i$ (kPa)
dP_o	= differential pressure, $P-P_o$ (kPa)
dP_p	= differential pressure in test section during recovery phase = P_p-P (kPa)
dP_{im}	= average value of dP_i during injection phase (kPa)
dP_{om}	= average value of dP_o during injection phase (kPa)
P3	= absolute pressure in a section outside the test section (kPa)
P4	= absolute packer pressure (kPa)
P5	= absolute pressure in another section outside the test section (kPa)
B	= barometric pressure (kPa)
B_b	= barometric pressure measured at time t_b (for calibration purposes) (kPa)
W	= groundwater level below top of casing (m)
W_i	= groundwater level at start of test, before packer inflation (m)
W_o	= groundwater level at start of injection (m)
T2	= temperature of water in test section (° C)
T3	= temperature of injection water at the ground (° C)
T4	= air temperature in the measurement container (° C)
Q	= injection flow rate (m^3/s)
Q_p	= injection flow rate immediately before stop of injection (m^3/s)
Q_m	= average flow rate during the total time of injection (m^3/s)
V_{tot}	= totally injected volume of water during the injection (m^3)
t	= time since start of injection (s)
dt	= time since stop of injection (s)
t_p	= total injection time (s)
t_{pp}	= corrected injection time ($t_{pp}=V_{tot}/Q_p$) (s)
t_b	= point of time for measurement of P_b and B_b
dte	= equivalent time since stop of injection = t_{pp} x $dt/(t_{pp} + dt)$ (s)
dtf	= total pressure recovery time (s)
K_{ss}	= K-value calculated according to steady-state theory (m/s)
K_{iss}	= as above, however calculated from dP_{im} (m/s)
K_{oss}	= as above, however calculated from dP_{om} (m/s)
L	= section length (m)
LK	= distance between pressure transducer for test section and upper limit of test section (m)
LL	= distance between pressure transducer for lower section and upper limit of test section (m)
LB	= length of bubble pipe (m)
AW	= borehole declination (azimut, direction towards N = 0°) (°)
IW	= borehole inclination (vertical borehole = 90°) (°)
DW	= borehole diameter (m)
X Y Z	= coordinates for top of casing (m)
EC	= equipment code

15.13 APPENDIX 13

STANDARD GRAPHS FROM THE STEEL PIPE EQUIPMENT SYSTEM, VERSION 3, AND THE UMBILICAL HOSE EQUIPMENT SYSTEM, VERSION 2

A0:	Epitome of some borehole data and measured values
A1:	P - t before start of injection
A2:	Q - t
A3:	P - t
	P3 - t
	P5 - t
A4:	T2 - t
	T3 - t
	T4 - t
A5:	P4 - t
	W - t
	B - t
B1:	P - log (t)
	[T2 - log (t)]
B2:	1/Q - $\sqrt[4]{t}$
B3:	1/Q - $\sqrt{t}$
B4:	1/Q - log (t)
B5:	log (Q) - log (t)
	log (1/Q) - log (t)
B6:	Q - $\sqrt{1/t}$
C1:	P - $\sqrt[4]{dte}$
C2:	P - $\sqrt{dte}$
C3:	P - $\sqrt{t_{pp} + dt} - \sqrt{dt}$
C4:	P - log (dte)
	[Q - log (dte)]
C5:	P - log (dt)/(t_p + dt)
	[T2 - log (dt)/(t_p + dt)]
C6:	log ($dP_{p)}$ - log (dte)
C7:	P - $\sqrt{1/dt} - \sqrt{1/(t_{pp} + dt)}$

15.14 APPENDIX 14

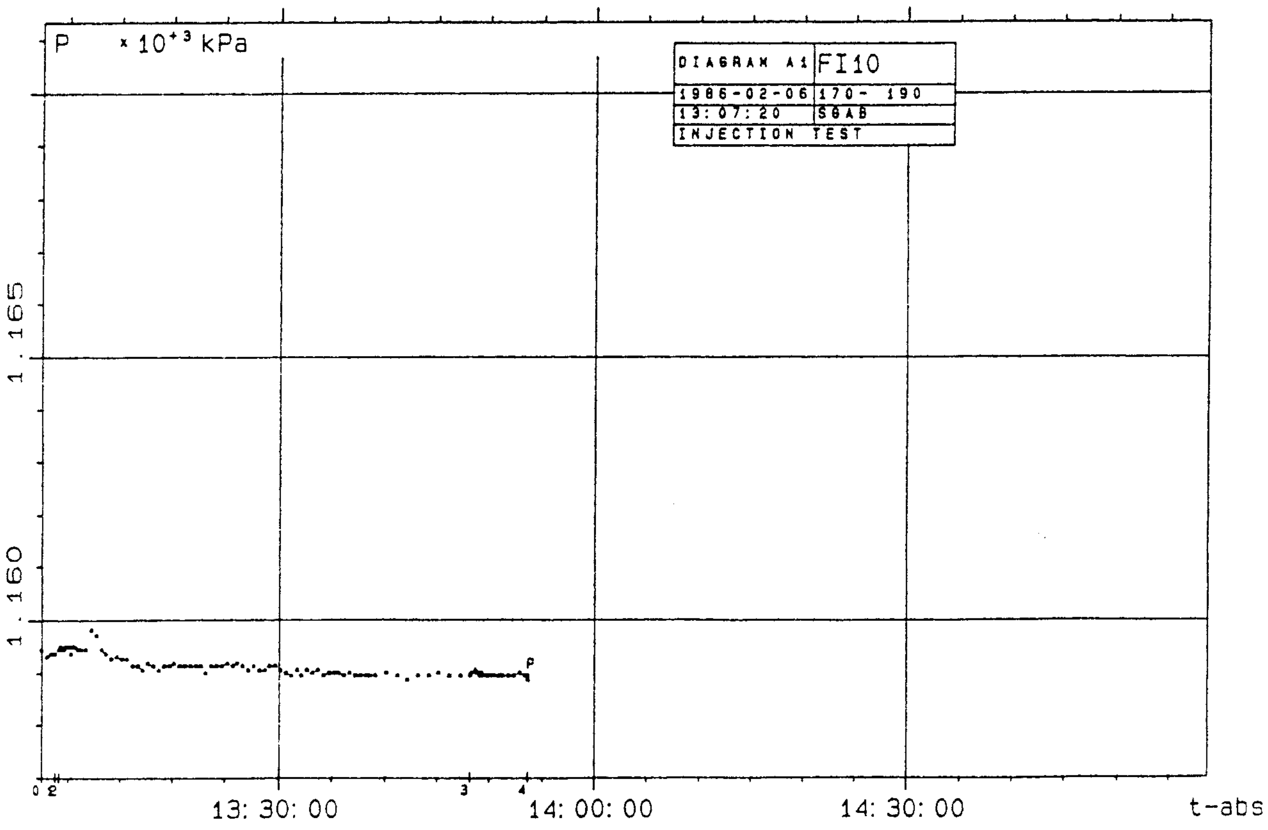
GRAPHS

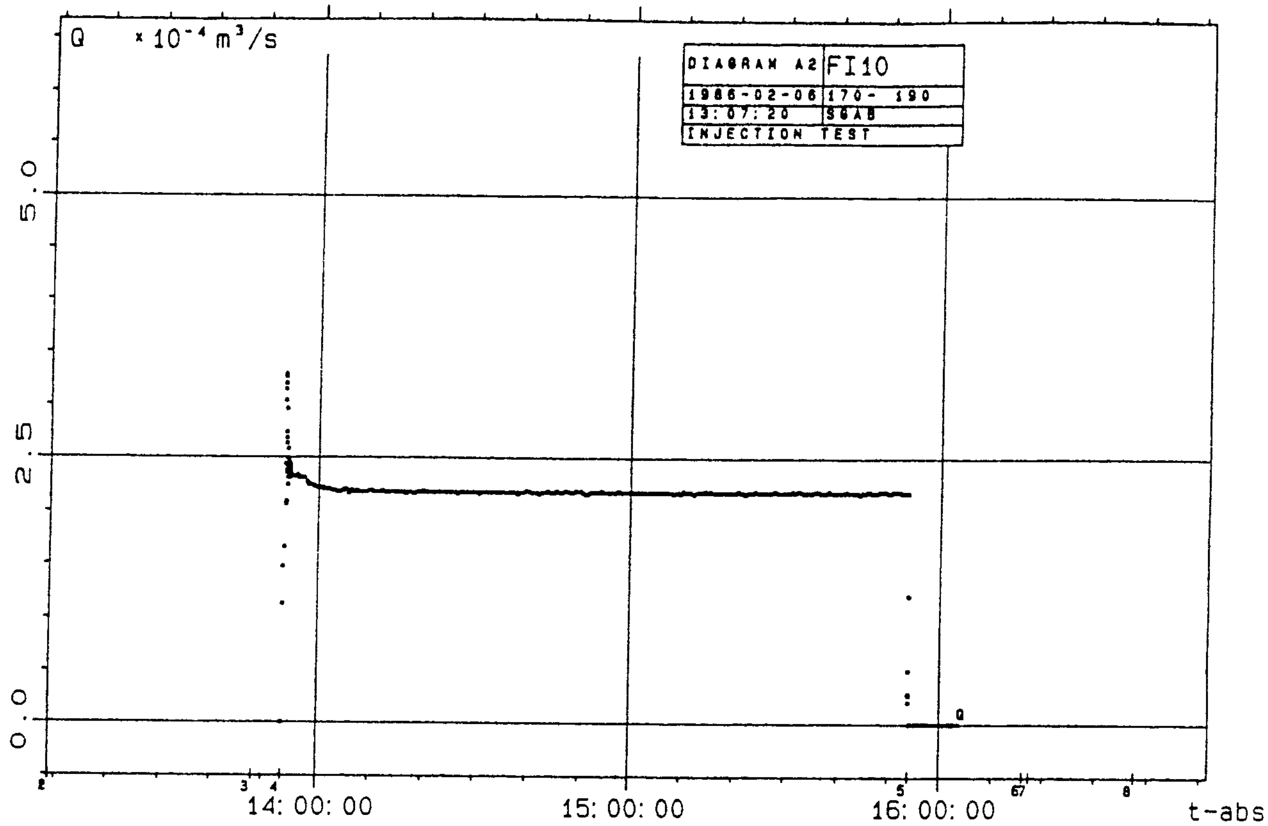
P_i	1159.4	kPa
P_0	1158.9	kPa
$P_0 - P_i$	-0.4	kPa
P_p	1359.6	kPa
$P_p - P_i$	200.3	kPa
P_f	1159.4	kPa
$P_f - P_i$	0.0	kPa
P_s	1159.6	kPa
P_b	18.6	kPa
B_b	98.2	kPa
t_b	8601141200	
W_i	4.10	m
$W_0 - W_i$	0.00	m
t_p	7218	s
t_{pp}	7237	s
dt_f	1335	s
Q_p	2.184E-04	m^3/s
V_{tot}	1.58	m^3
dP_{is}	199.9	kPa
dP_{0s}	200.3	kPa

COMMENTS

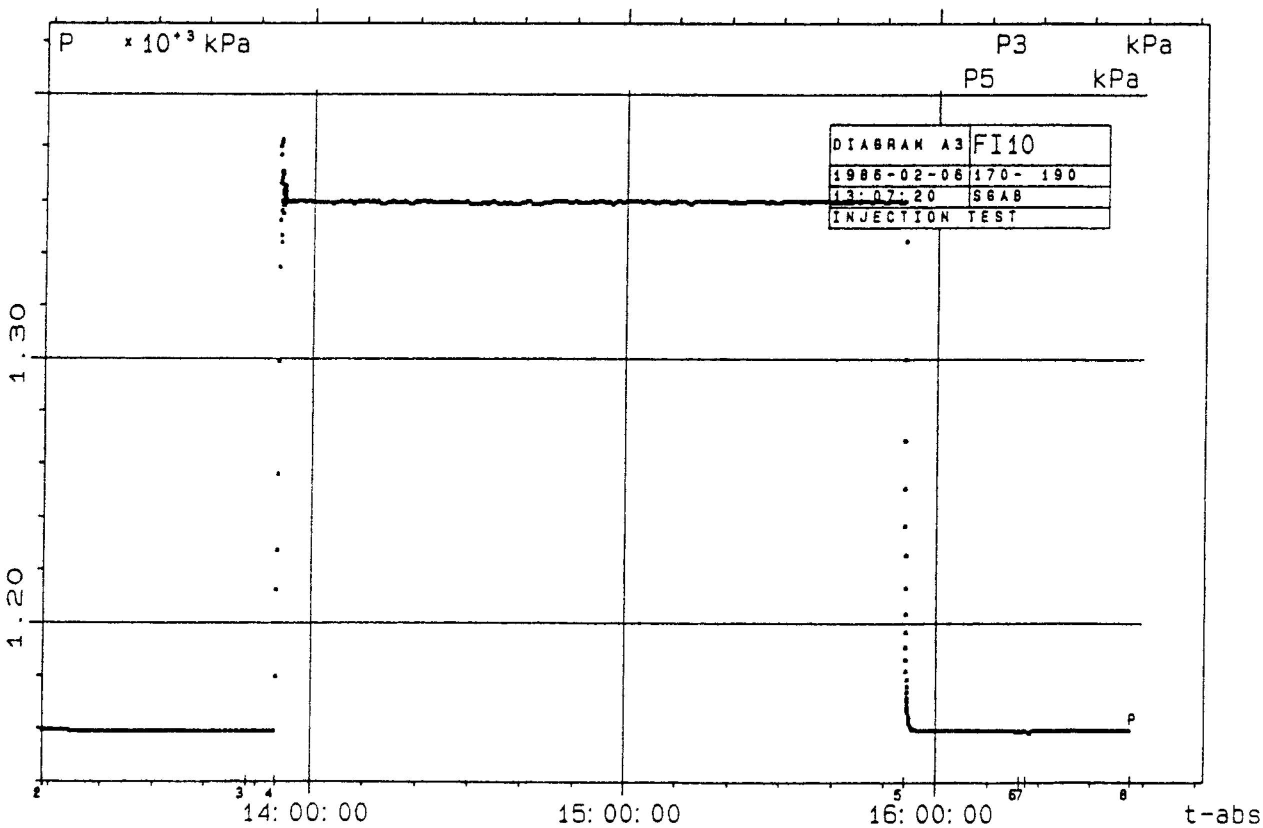
DIAGRAM A0	FI10
DATE : 1986-02-06	SECTION : 170- 190
START TIME: 13:07:20	CONSULTANT: SGAB
FIELD CREW: HERR OLAUS	CLIENT : SKB
TEST TYPE : INJECTION TEST	

K_{iss}	5.86E-07	m/s
K_{0ss}	5.85E-07	m/s
X	6696359	m
Y	1616442	m
Z	30.46	m
AW	276	deg
IW	50	deg
DW	56	mm
LK	0.81	m
LL	0.00	m
LB	7.00	m
EC	NEW RG-1	





Q ×10⁻⁴ m³/s
DIAGRAM A2 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
5.0
2.5
0.0
14:00:00
15:00:00
16:00:00
t-abs



P ×10⁺³ kPa
P3 kPa
P5 kPa
DIAGRAM A3 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
1.30
1.20
14:00:00
15:00:00
16:00:00
t-abs

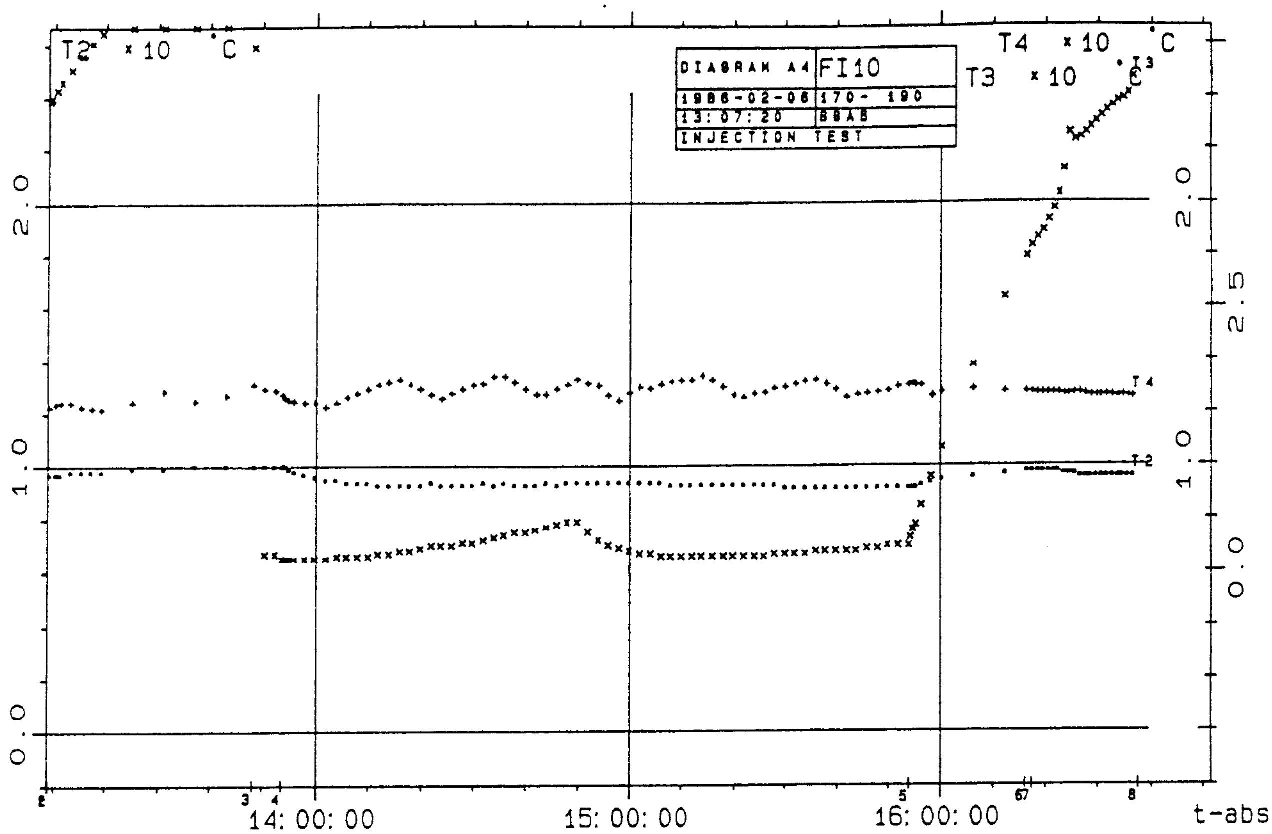


DIAGRAM A4
FI10
1986-02-06
170- 190
13:07:20
SGAB
INJECTION TEST
T2 × 10 °C
T4 × 10 °C
T3 × 10 °C
14:00:00
15:00:00
16:00:00
t-abs

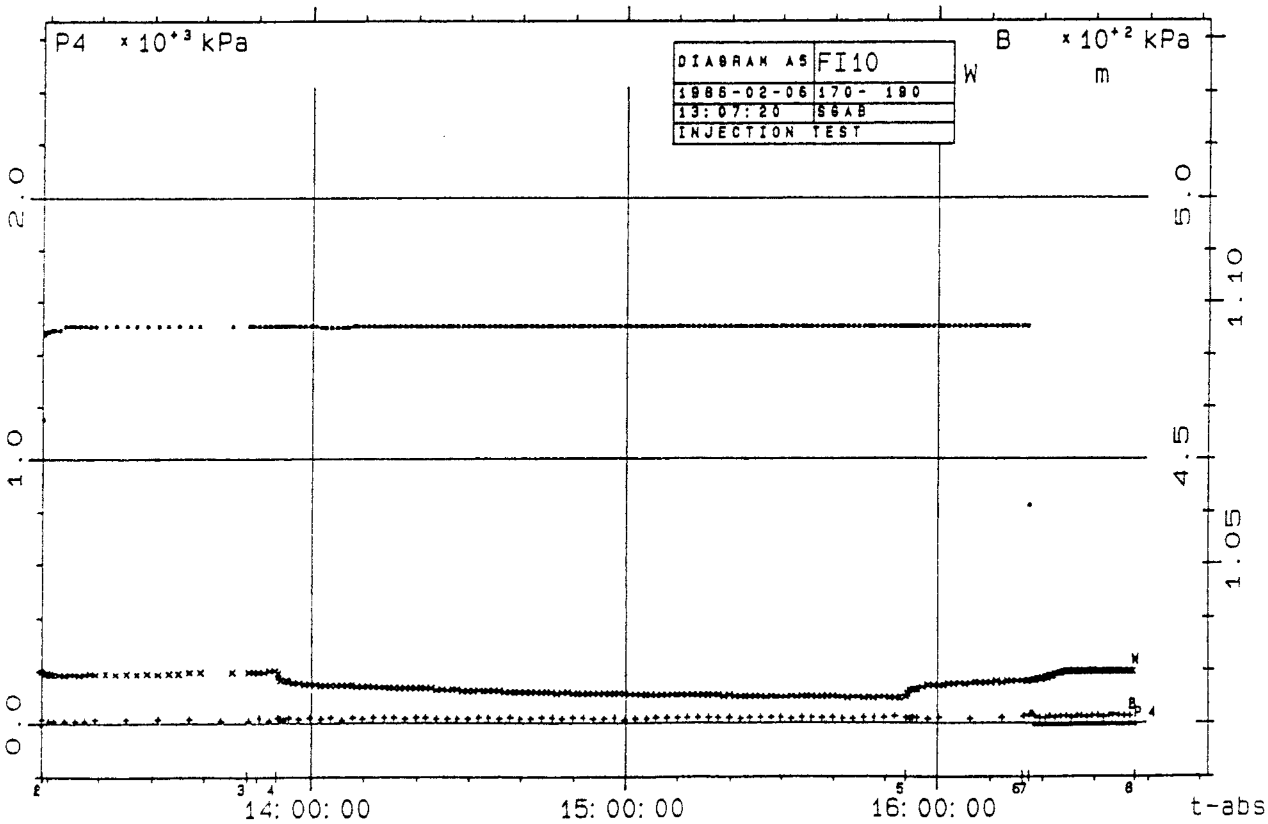
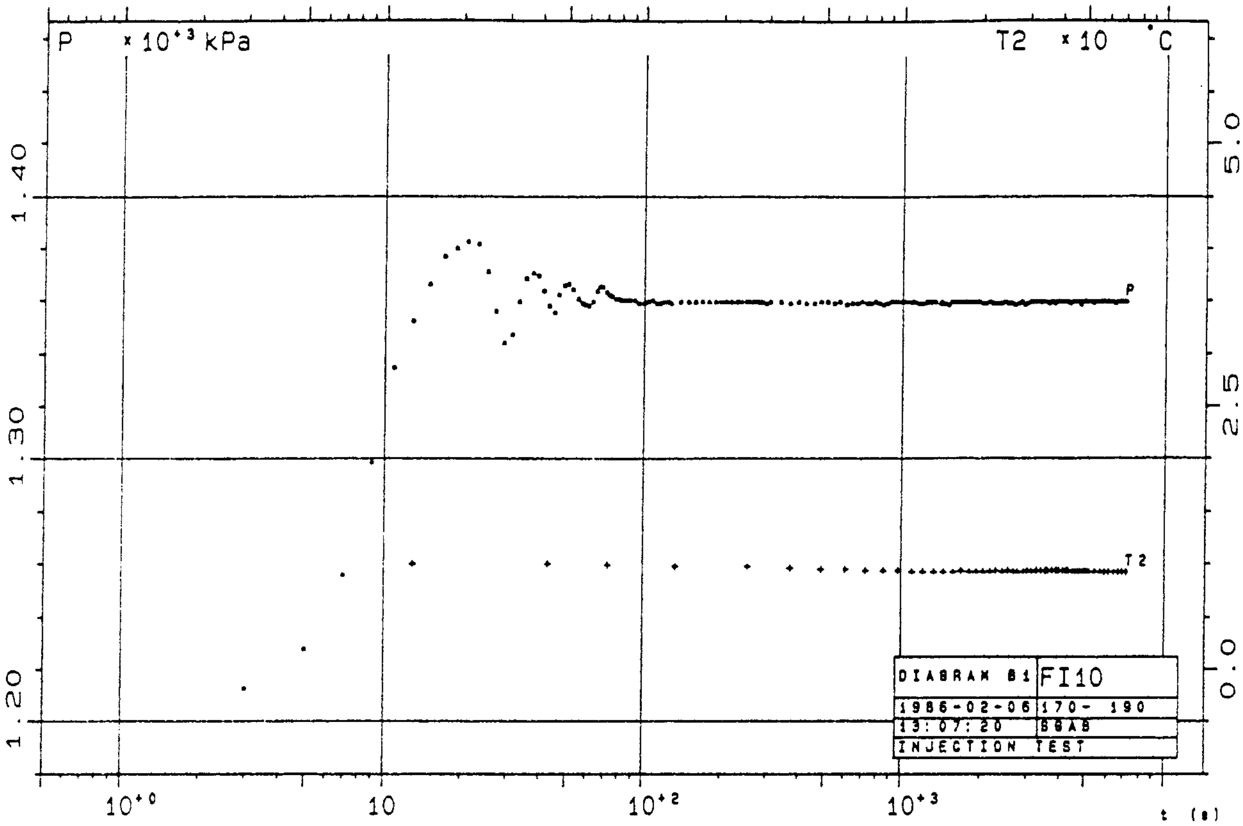
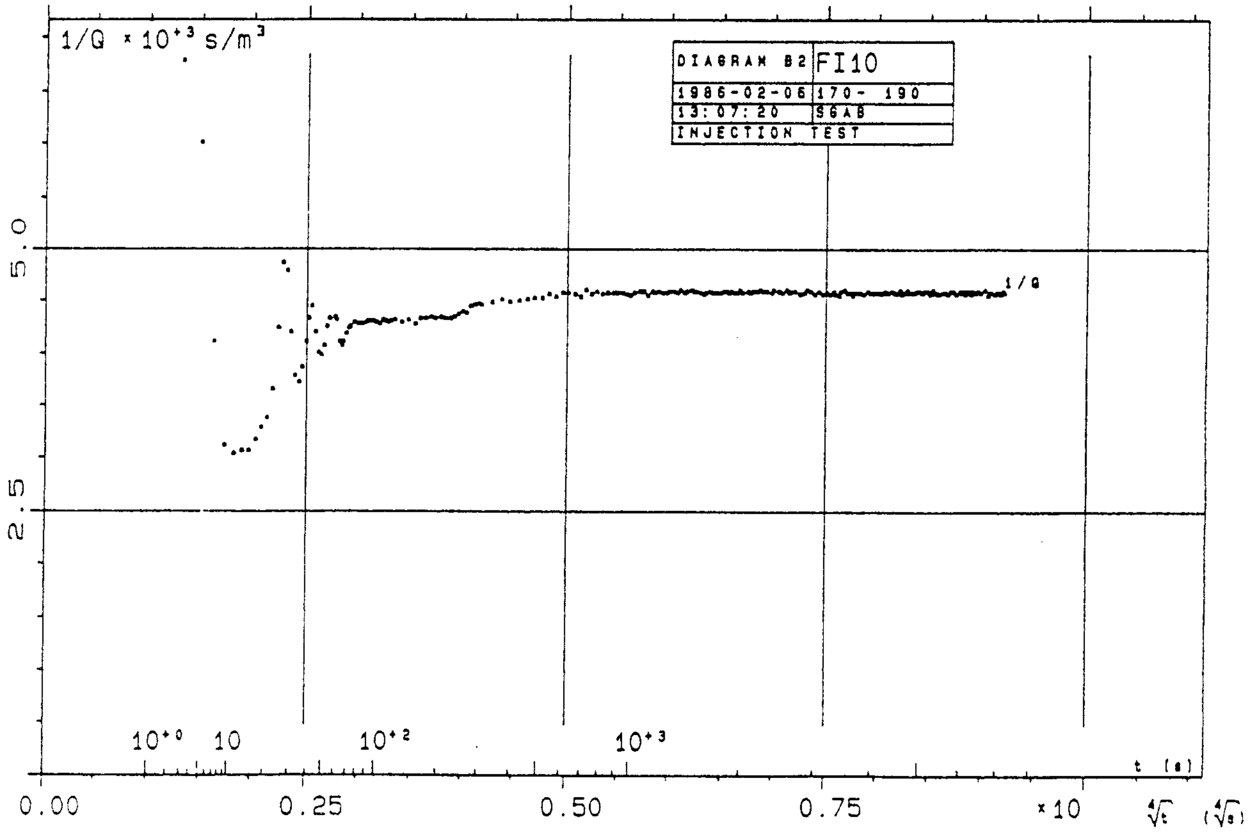


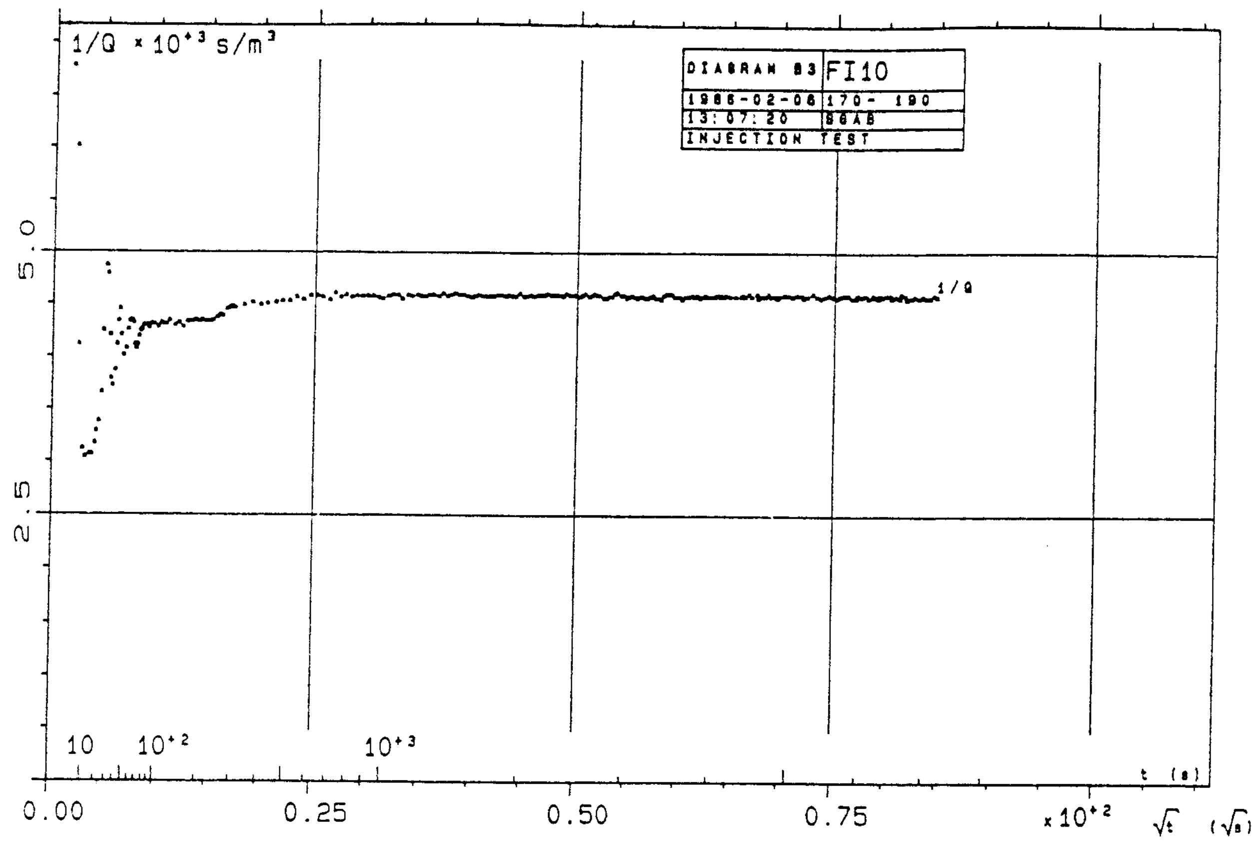
DIAGRAM A5
FI10
1986-02-06
170- 190
13:07:20
SGAB
INJECTION TEST
P4 × 10⁺³ kPa
B × 10⁺² kPa
W m
14:00:00
15:00:00
16:00:00
t-abs



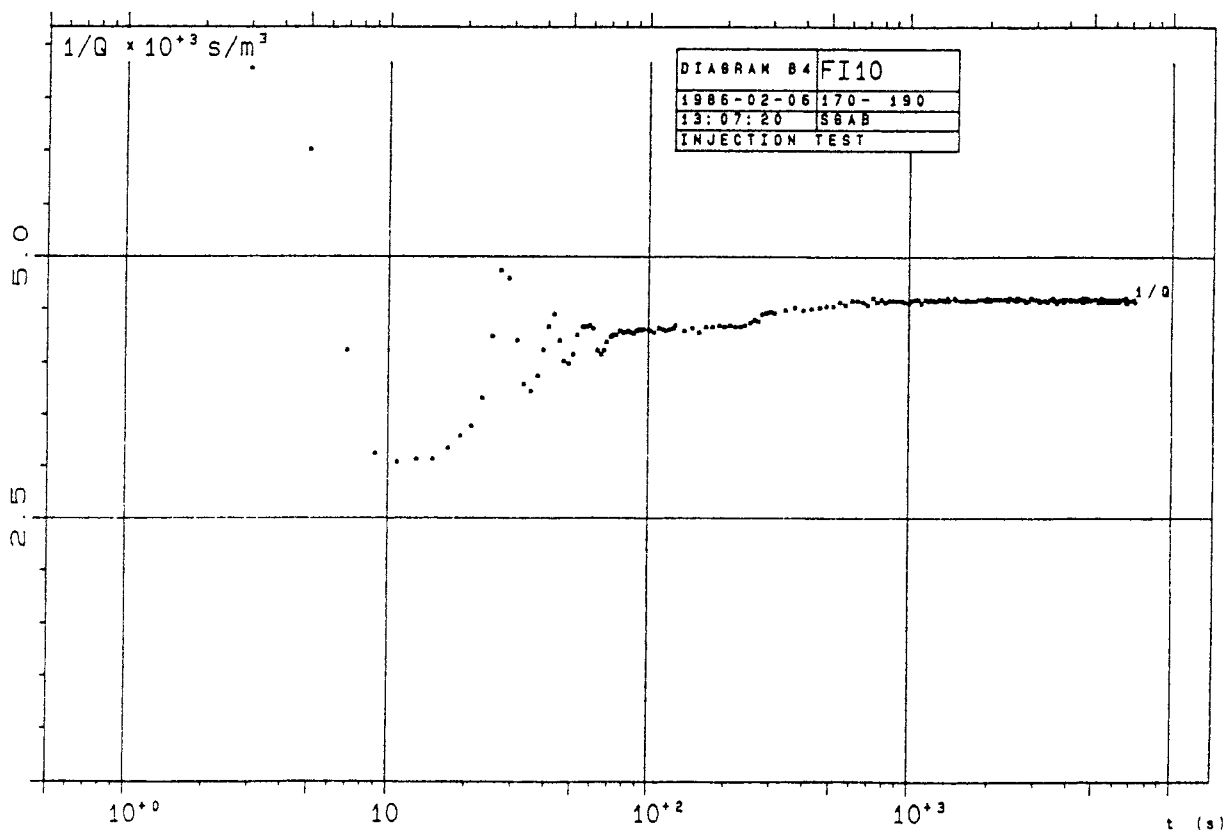
P ×10^+3 kPa
T2 ×10 °C
1.40
1.30
1.20
5.0
2.5
0.0
P
T2
DIAGRAM B1 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
10^+0
10
10^+2
10^+3
t (s)



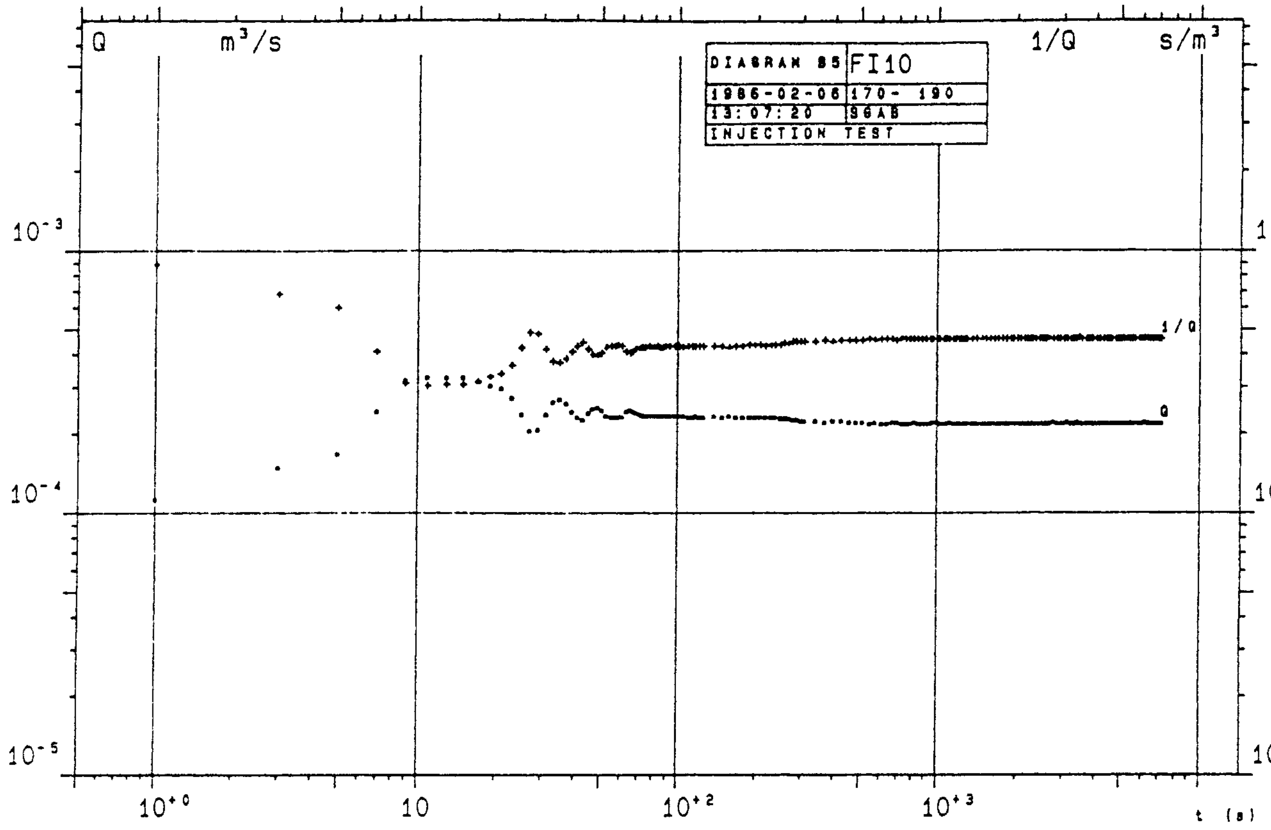
1/Q ×10^+3 s/m^3
DIAGRAM B2 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
5.0
2.5
1/Q
10^+0 10
10^+2
10^+3
t (s)
0.00
0.25
0.50
0.75
×10
∜t (∜s)



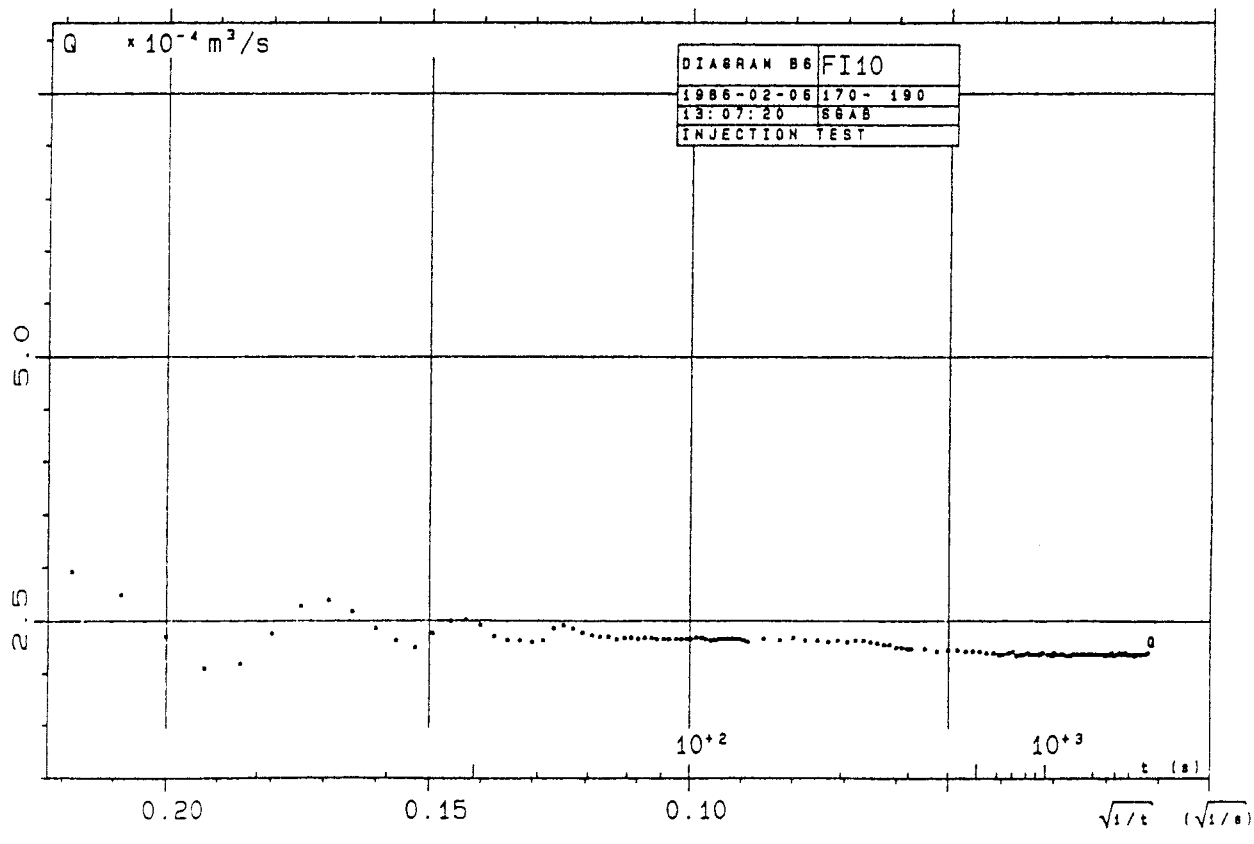
1/Q × 10+3 s/m3
DIAGRAM 83
FI10
1986-02-06
170- 190
13:07:20
SGAB
INJECTION TEST
5.0
2.5
1/Q
10
10+2
10+3
t (s)
0.00
0.25
0.50
0.75
×10+2
√t (√s)



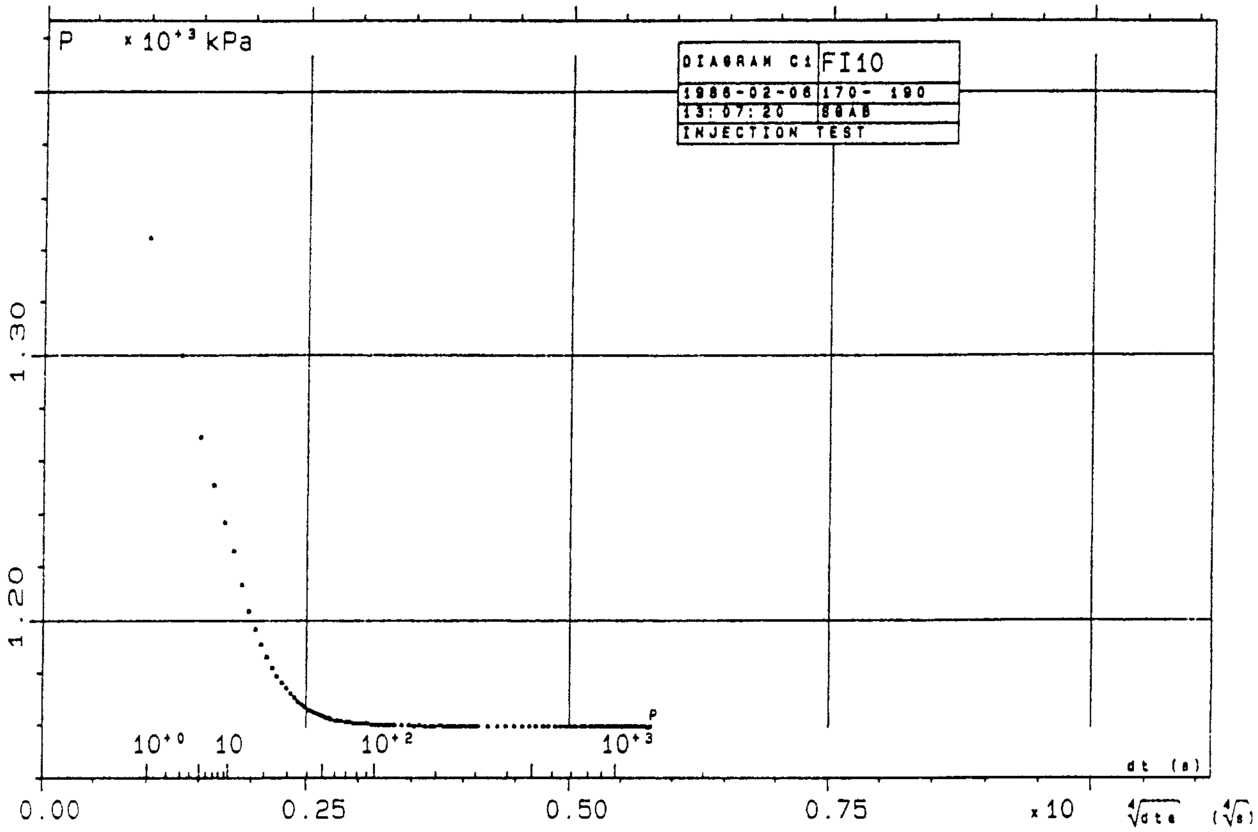
1/Q × 10+3 s/m3
DIAGRAM 84
FI10
1986-02-06
170- 190
13:07:20
SGAB
INJECTION TEST
5.0
2.5
1/Q
10+0
10
10+2
10+3
t (s)

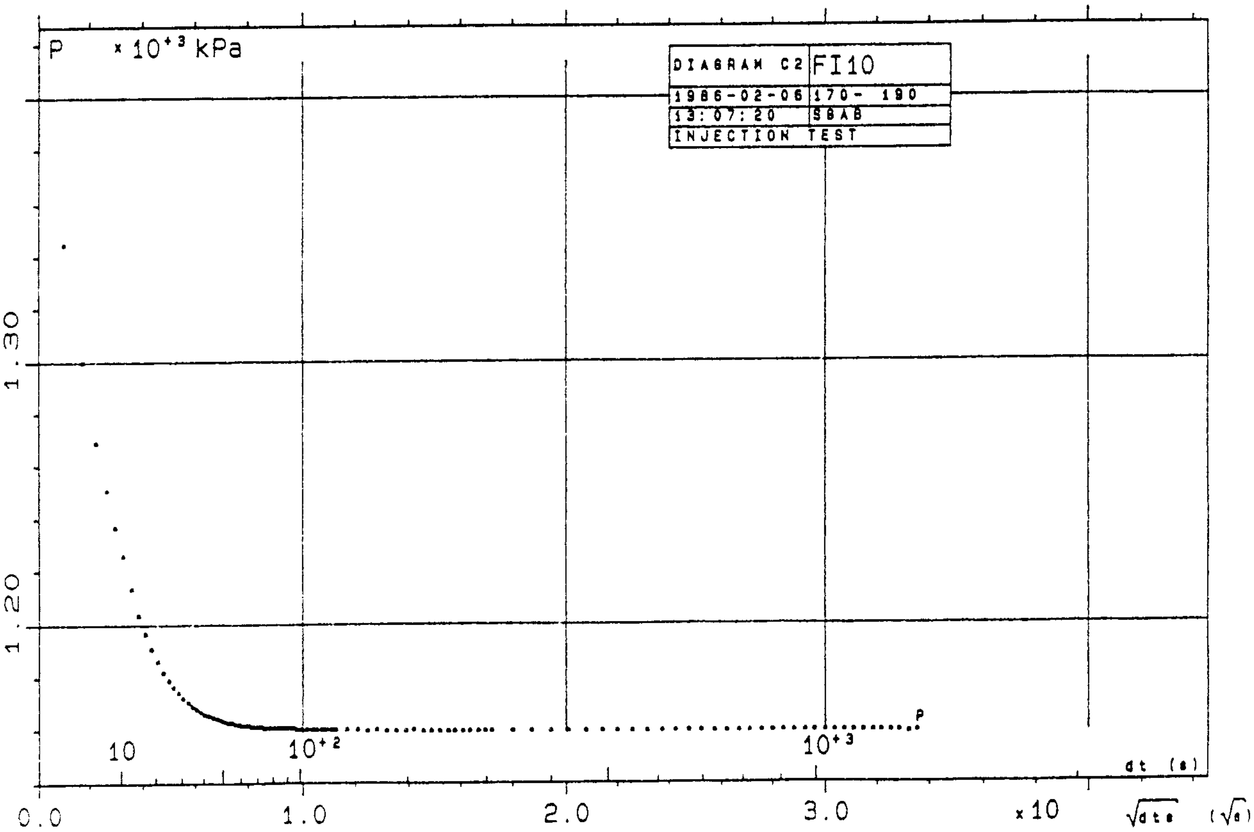


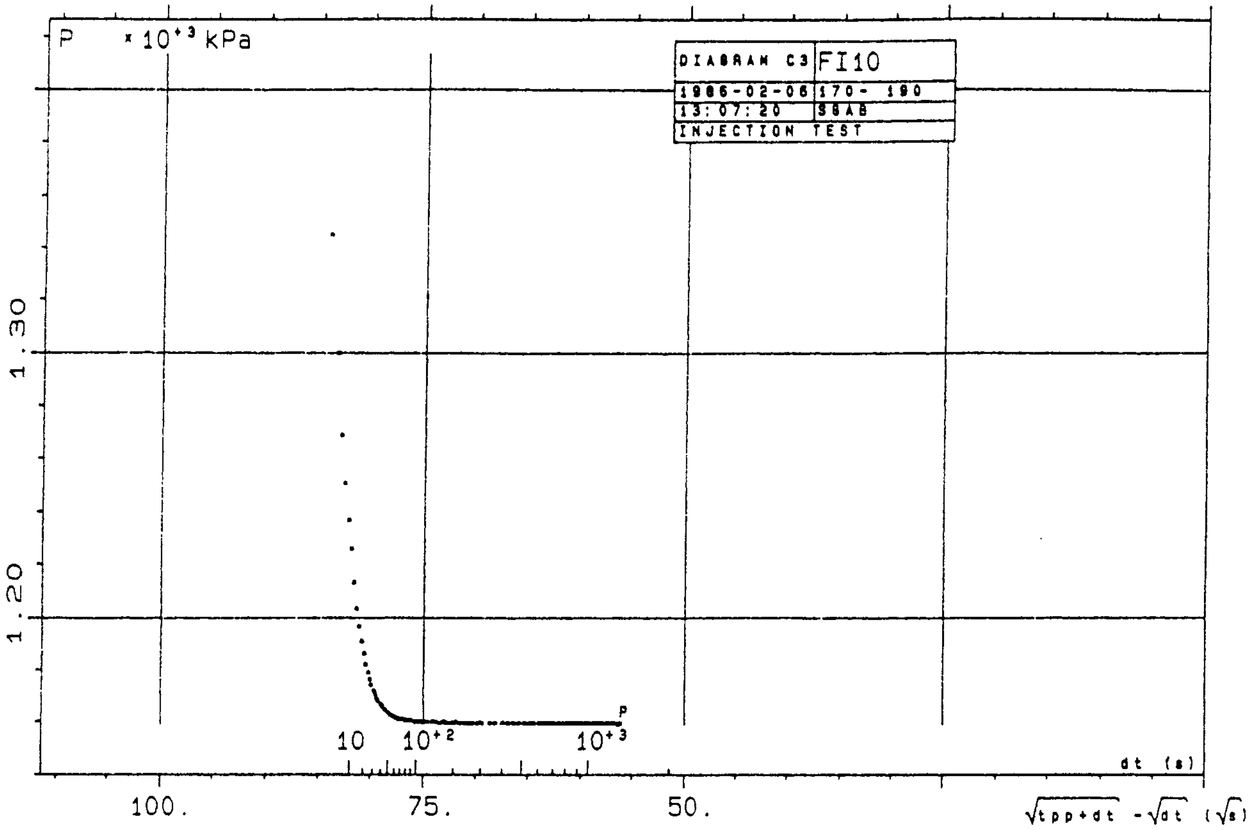
Q m³/s
1/Q s/m³
DIAGRAM B5 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
10⁻³
10⁻⁴
10⁻⁵
10⁺⁴
10⁺³
10⁺²
1/Q
Q
10⁺⁰
10
10⁺²
10⁺³
t (s)

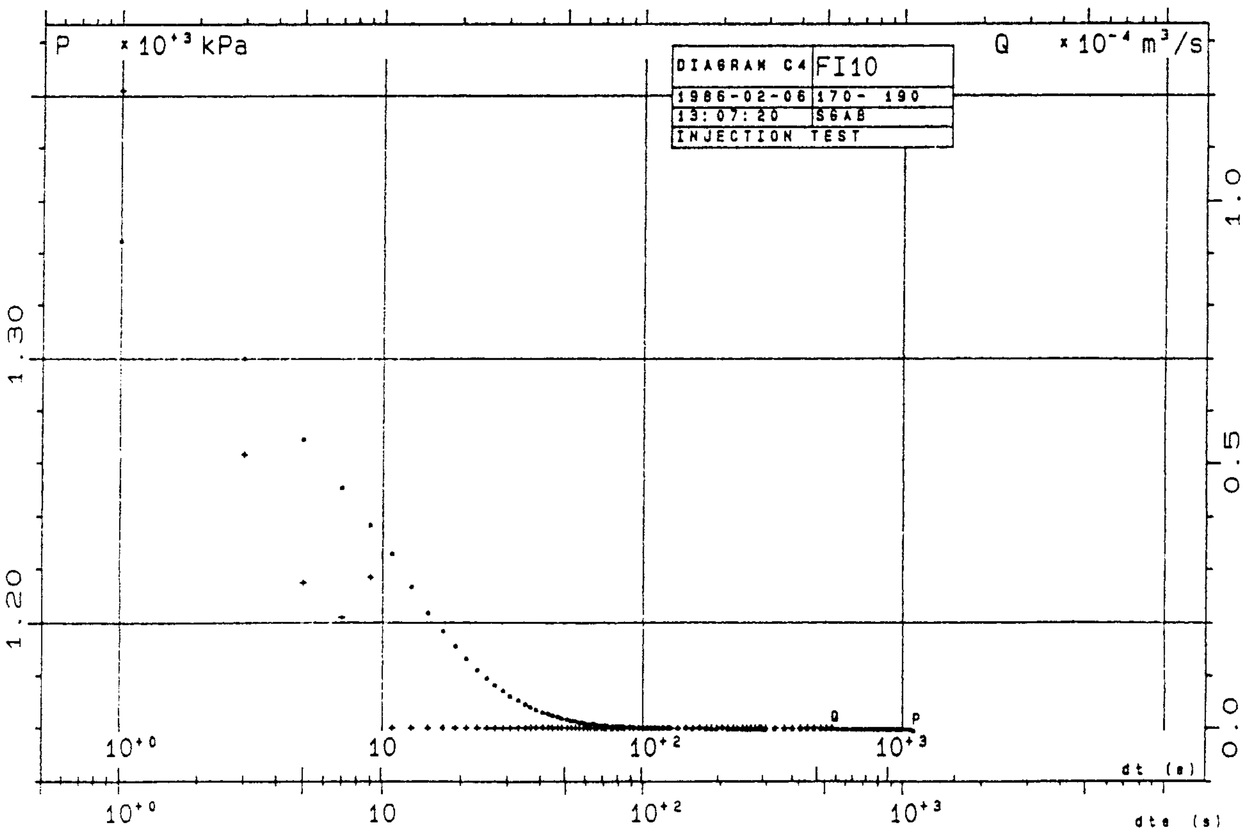


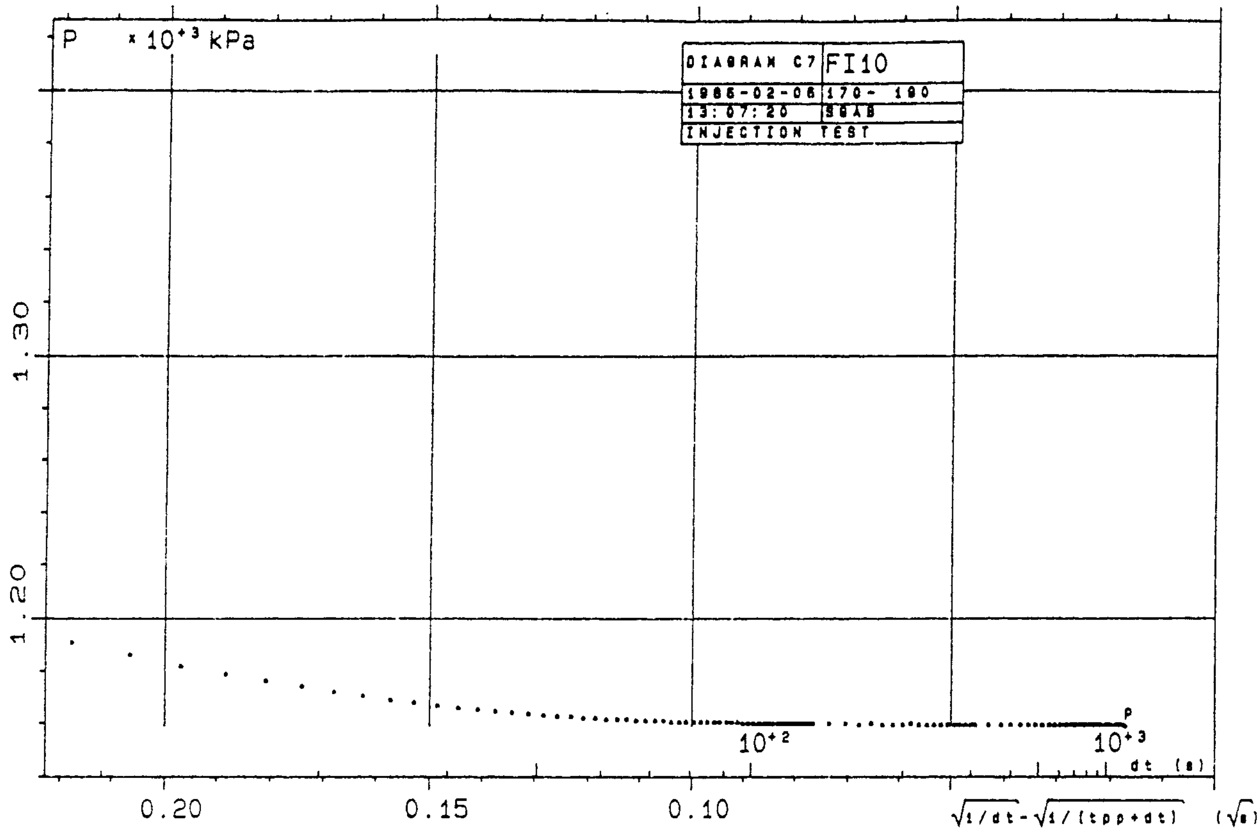
Q ×10⁻⁴ m³/s
DIAGRAM B6 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
5.0
2.5
Q
10⁺²
10⁺³
t (s)
0.20
0.15
0.10
√1/t (√1/s)


P ×10⁺³ kPa
DIAGRAM C1 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
1.30
1.20
10⁺⁰ 10 10⁺² 10⁺³
dt (s)
0.00 0.25 0.50 0.75 ×10
∜dte (∜s)


P ×10⁺³ kPa
DIAGRAM C2 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
1.30
1.20
10 10⁺² 10⁺³
dt (s)
0.0 1.0 2.0 3.0 ×10
√dte (√s)


P ×10⁺³ kPa
DIAGRAM C3
FI10
1986-02-06
170- 190
13:07:20
SGAB
INJECTION TEST
1.30
1.20
10
10⁺²
10⁺³
dt (s)
100.
75.
50.
√(tpp+dt) - √dt (√s)


P ×10⁺³ kPa
Q ×10⁻⁴ m³/s
DIAGRAM C4
FI10
1986-02-06
170- 190
13:07:20
SGAB
INJECTION TEST
1.30
1.20
1.0
0.5
0.0
10⁺⁰
10
10⁺²
10⁺³
dt (s)
dte (s)


P ×10^+3 kPa
DIAGRAM C7
FI10
1986-02-06
170- 190
13:07:20
SGAB
INJECTION TEST
1.30
1.20
10^+2
10^+3
dt (s)
0.20
0.15
0.10
√1/dt-√1/(tpp+dt)
(√s)

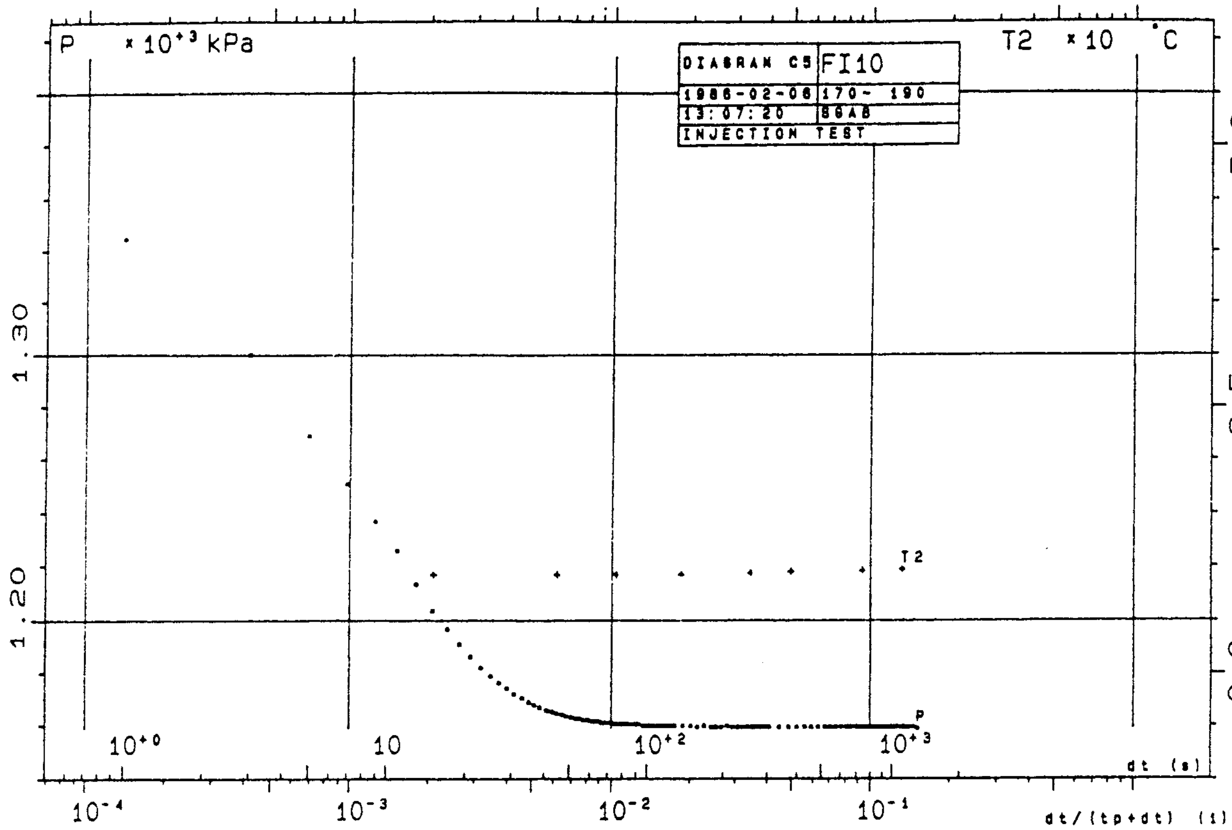
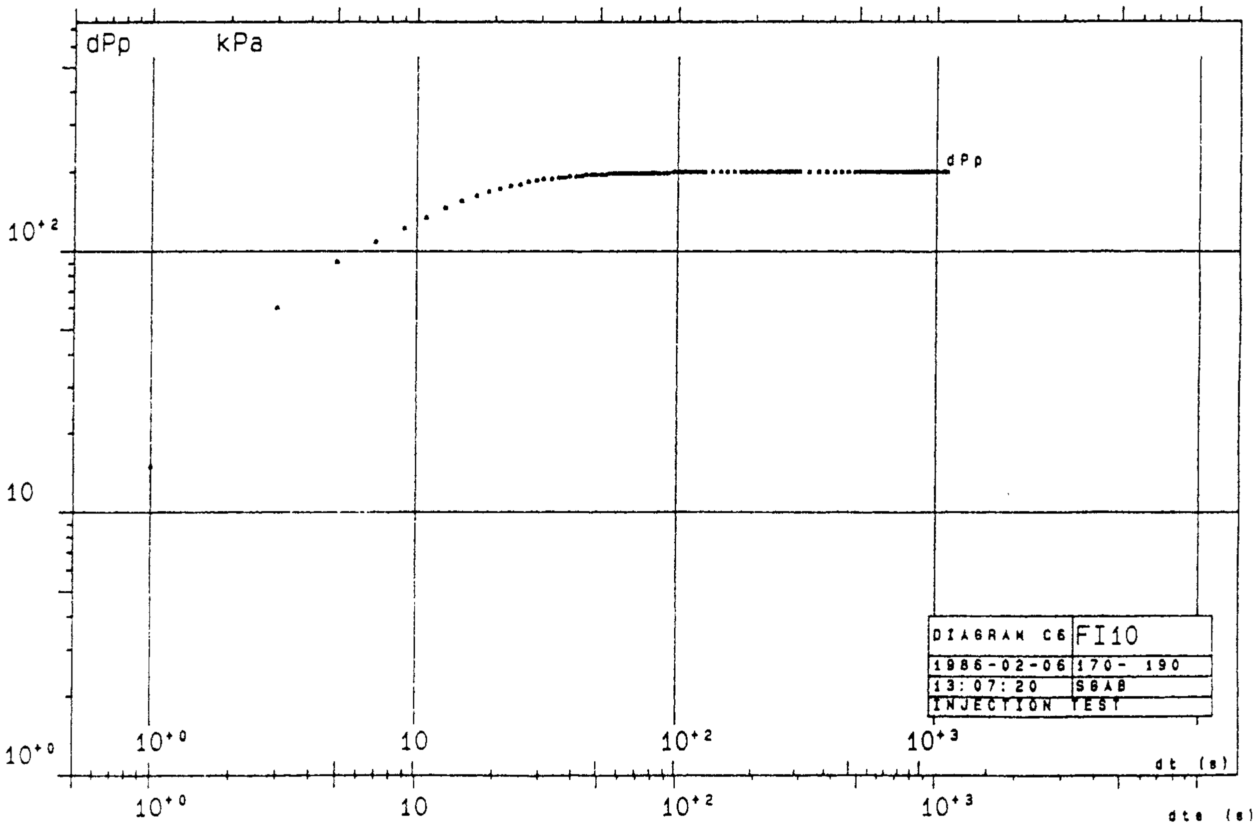


DIAGRAM C5 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
P ×10^+3 kPa
T2 ×10 °C
1.30
1.20
5.0
2.5
0.0
T2
P
10^+0
10
10^+2
10^+3
dt (s)
10^-4
10^-3
10^-2
10^-1
dt/(tp+dt) (1)



dPp kPa
dPp
10^+2
10
10^+0
DIAGRAM C6 FI10
1986-02-06 170- 190
13:07:20 SGAB
INJECTION TEST
10^+0
10
10^+2
10^+3
dt (s)
dte (s)

List of SKB reports

Annual Reports

1977-78
TR 121
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Summaries
Stockholm, May 1979

1979
TR 79-28
The KBS Annual Report 1979
KBS Technical Reports 79-01 – 79-27
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Stockholm, March 1980

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The KBS Annual Report 1980
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1984
TR 85-01
Annual Research and Development Report 1984
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Stockholm, June 1985

1985
TR 85-20
Annual Research and Development Report 1985
Including Summaries of Technical Reports Issued during 1985. (Technical Reports 85-01 – 85-19)
Stockholm, May 1986

1986
TR 86-31
SKB Annual Report 1986
Including Summaries of Technical Reports Issued during 1986
Stockholm, May 1987

1987
TR 87-33
SKB Annual Report 1987
Including Summaries of Technical Reports Issued during 1987
Stockholm, May 1988

1988
TR 88-32
SKB Annual Report 1988
Including Summaries of Technical Reports Issued during 1988
Stockholm, May 1989

1989
TR 89-40
SKB Annual Report 1989
Including Summaries of Technical Reports Issued during 1989
Stockholm, May 1990

1990
TR 90-46
SKB Annual Report 1990
Including Summaries of Technical Reports Issued during 1990
Stockholm, May 1991

Technical Reports

List of SKB Technical Reports 1991

TR 91-01
Description of geological data in SKB's database GEOTAB
Version 2
Stefan Sehlstedt, Tomas Stark
SGAB, Luleå
January 1991

TR 91-02
Description of geophysical data in SKB database GEOTAB
Version 2
Stefan Sehlstedt
SGAB, Luleå
January 1991

TR 91-03
1. The application of PIE techniques to the study of the corrosion of spent oxide fuel in deep-rock ground waters
2. Spent fuel degradation
R S Forsyth
Studsvik Nuclear
January 1991

TR 91-04
Plutonium solubilities
I Puigdomènech[1], J Bruno[2]
[1]Enviromental Services, Studsvik Nuclear, Nyköping, Sweden
[2]MBT Tecnologia Ambiental, CENT, Cerdanyola, Spain
February 1991

TR 91-05
Description of tracer data in the SKB database GEOTAB
SGAB, Luleå
April, 1991

TR 91-06
Description of background data in the SKB database GEOTAB
Version 2
Ebbe Eriksson, Stefan Sehlstedt
SGAB, Luleå
March 1991