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# Äspö Hard Rock Laboratory

## Backfill and Plug Test

## Sensor data report
## (Period: 990601-010101)
## Reprot No:2

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Clay Technology AB

January 2001

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# Abstract

This report presents data from the measurements in the Backfill and Plug Test during the period 99-06-01 to 01-01-01. Water pressure in the rock is measured in 73 points, pore water pressure in the backfill is measured in 33 points, total pressure is measured in 20 points and water pressure in the drainage layers of filter mats is measured in all 12 layers. The water saturation process in the backfill is checked in 57 measuring points.

The positions of the measuring points in the backfill are related to the backfill section, the number of the compacted layer, the tunnel axis, and the rock surface. The positions of the measuring points in the rock are related to the backfill section where the hole enters and the measuring section in the borehole.

Complete water saturation in the backfill sections with a mixture of 30% bentonite and 70% crushed rock, which are critical for the time until complete saturation, have reached 20 cm into the backfill and some wetting can be noted 40 cm from the permeable mats but no wetting is indicated in the centre of the sections (at 60 cm).

# Sammanfattning

I denna rapport presenteras data från mätningar i Backfill and Plug Test under period 99-06-01 till 01-01-01. Vattentryck i berget mäts i 73 punkter, porvattentryck i återfyllningen mäts i 33 punkter, totaltryck i 20 punkter och vattentryck i permeabla skikt av filtermattor mäts i alla 12 sektioner. Vattenmättnadsprocessen i återfyllningen mäts eller indikeras i 57 punkter.

Mätpunkternas positioner anges för återfyllningen i relation till återfyllningssektion, packningslager, tunnelcentrum och bergyta. För mätpunkterna i berget anges återfyllnings sektion som borrhållet mynnar i, var på bergytan hålet mynnar och mätsektion i borrhålet.

Full vattenmättnad har för de sektioner som innehåller återfyllning med en blandning av 30% bentonit och 70% krossat berg, vilka är kritiska för tiden till full vattenmättnad, nått 20 cm in i återfyllningen och en viss bevätning kan noteras 40 cm från de permeabla mattorna men ingen bevätning indikeras i mitten av sektionerna (60 cm in).

# Contents

# 1 Introduction

The installation of the Backfill and Plug Test was made during spring 1999. The different measurements started at different times as the transducers were connected to their data acquisition systems. In this report the data acquired until 2001-01-01 are presented. In general the data in this report are presented in diagrams covering the time period 1999-06-01 to 2001-01-01. The time axis in the diagrams represents days from 1999-06-01 except for readings from the flow meters.

A Test overview with the positions of the permeable sections, the positions of the measuring points and a brief description of the instruments is also included in this report. A quick guide to the positions of all instruments in the backfill that can be unfolded to A3 format is enclosed as the last page. Explanation of denominations is presented in Chapter 4.

General comments concerning the collection of the data are also given.

# 2 Comments

## 2.1 General

In this chapter short comments on general trends in the measurements are given. Sensors that are not delivering reliable data or no data at all are noted and comments on the data collection in general are given. A general observation is that the plug is still leaking water.

Since the backfill is not water saturated and the plug is not tight, very low water pressure is applied and measured in the backfill. On this reason most measurements of total and water pressure in the backfill yield values that are very low compared to the measuring range and the accuracy is thus not very high.

The first report covered the period up to 000601. This report is the second one and covers the results up to 001231. The following main activities, which may have affected the measurements, have been accomplished:

1. The pumping from the inner drained part behind the concrete wall was interrupted on October 16 and an arrangement that would yield a maximum water head of two meters above the roof was applied. After about 1 month the inner part of the drift was filled with water.

2. At the same time the water pressure in the mats in the 30/70 sections was temporarily reduced in order to reduce the leakage of salt water into the 0/100 section.

## 2.2 Total Pressure, Glötzl

Data are presented on pages 21-22.

The total pressure cells from Glötzl have not worked well and in late summer the regulation system broke down. It was sent for repair and was returned in December and the cells reinstalled. They seem to yield reliable results now except for P58 and P59, which are out of order.

The rather high pressure measured from most cells in section B (150-250 kPa) imply that there is a swelling pressure caused by the bentonite blocks installed at the roof in this section. The pressure measured in section A is lower and corresponds roughly to the hydrostatic pressure for most cells.

## 2.3 Total pressure, Roctest

Data are presented on page 23.

All cells seem to deliver reliable data. The same trend can be observed as for the Glötzl cells, that is hydrostatic pressure in section A and obvious swelling pressures in section B except for P61, which is placed in the roof close to the plug.

## 2.4 Suction, Wescore Psychrometers

Data are presented on pages 24-27.

The Psychrometers are mainly placed in the 30/70 backfill. The exceptions are W67 and W77 that are placed in the 0/100, and W83 and W84 that are placed among the bentonite blocks in B6. The psychrometers are not designed for measuring suction in these materials until they are very close to water saturation. Data from these sensors were not possible to evaluate and are therefore not presented.

These results are most interesting for evaluation of the wetting rate of 30/70, which is critical for when the flow testing can start.

The readings from the Psychrometers started earlier than 1999-06-01. Since the measurements earlier than that date did not differ from the measured results for days 0-100, that data have been excluded.

The suction of 30/70 is about 3000 kPa at the initial water content and decreases with increasing degree of saturation. At complete saturation the suction is about 1000 kPa or lower.

The measured values show that most sensors behave in a rational manner indicating that they function in a proper way. The following exceptions can be noted:

1. At some periods the scatter of measured values is rather high for a few transducers, especially at a period around 400 days. Some of this scatter is probably caused by outer disturbances. The problems have been overcome and good results are received during the last 5 months.

2. When the backfill is water saturated the transducers may give unreliable measurements, especially if free water has entered. This would explain the scatter in the late measurements of transducer W51.

The following transducers are judged to be water saturated and may give unreliable results now or in future: W3, W5, W7, W12, W16, W18, W21, and W51. All these transducers except W5 are located either with only one layer (20 cm) between the transducer and the permeable mat or close to the rock. It is thus logical to conclude that the saturation has reached at least 20 cm from the mats or the rock surface. The reason for the low suction read by transducer W5 is unclear. It could either be caused by malfunction or water leakage (e.g. along the tubes; see chapter 2.8).

The following transducers have started to yield decreased values but do not seem to be completely water saturated: W1, W6, W17, and W20. All these transducers except W1 are located with two layers (40 cm) between the transducers and the mats. It is thus logical to conclude that some water has reached 40 cm into the layer and no water has reached half way between the mats (60 cm).

## 2.5 Resistivity, resistivity probe

Data are presented on pages 28-29.

The purpose of the resistivity probes is to measure change in water content and to indicate when the bentonite free backfill (0/100) is saturated. Seven of the nine probes were installed in the 0/100 and the other two were installed in section A6. The probes were not originally designed for the 30/70 backfill. It has not been possible to evaluate the readings from the two probes placed in this material and the data from these are not presented.

The bentonite free backfill (0/100) has not been actively wetted through the mats but only through leakage in the floor and indirect via the mats from water entering the mats from the floor. The results indicate that most wetting (resistivity less than 30 Wm) has occurred in transducers W58, W73, and W79, which are located close to a mat or close to the floor.

## 2.6 Indication of saturation, CT tube

No water has come through the tubes placed in the backfill. W 63 and W66 were damaged during installation.

## 2.7 Pore water pressure in backfill, Glötzl

Data are presented on pages 30-33.

Glötzl pore pressure cells had the same problems as the total pressure cells and unreliable values were achieved between late summer and December. The water pressure is in general low but an average increase with about 20 kPa in comparison to the start values can be noted.

## 2.8 Pore water pressure in backfill, Druck

Data are presented on page 34.

The principle of this measurement is to lead water from the test volume to the measuring house in a tube, connect it to the Druck transducer and measure the pressure. So far water has only come through from one measuring point, U13, placed in section A2 layer three. The pressure in this point varies a lot between 0 and 80 kPa indicating that it has contact with the water pressure in one of the permeable mats. Since the rest of the Druck transducers have so far only been measuring atmospheric pressure the data from these are not presented, except for transducer U5, which thus represents atmospheric pressure. The pressure readings from the Druck transducers are related to the Z co-ordinate of the transducer in the measuring house. They are placed 0.5 – 1.5 m. below the centre point of the tunnel.

The observation that water has entered U13, which is located in the centre of section A2, confirms the suspicion that water leaks along the tubes in this section. This would explain why the psychrometer yields such low suction.

## 2.9 Water flow into permeable sections

Data are presented on pages 35-39.

The filling of the permeable mat sections was made in the following sequence: D3, D1, D5, D6, D2 and D4. The sequence for filling a mat was to let water flow into the bottom of the lower and the central mats till they were de-aired and water came from the top of the mats. The tube from the top of the mats was then closed. The filling was made carefully not to cause piping and to be able to follow the process. Different constellations between flow meters and permeable mats for different times were used to follow the process. The flow data is presented as flow to the different mats for the different constellations.

In general the pressure on the water to the mats have been 100 kPa except for during the last period, when a reduced pressure was applied after 470 days in all mats and when the pressure in the mat attached to the plug surface was increased just before the end of the year (580 days).

## 2.10 Water pressure in permeable mats, Druck

Data are presented on pages 40-41.

The pressures in the permeable layers are measured in the tubes leading to the centre positions of the centre mats. The pressure is related to the Z co-ordinate of the Druck pressure transducers in the measuring house. This corresponds well with the Z co-ordinate of the centre line of the tunnel. Since the tunnel is slightly inclined the centre point is about 3 dm above the level of the Druck sensors in D1 and about 1 dm below the sensors in D10.

The reduction in pressure after 470 days can be seen in some of the mats.

## 2.11 Water pressure in the rock, Druck

Data are presented on pages 42-56.

Only small changes of the water pressure in the rock have occurred during the last 6 months period. The pressure in the bore holes range from 0 to 3500 kPa. The highest pressures are found in the long boreholes. The pressure in the short bore holes in general range from 0 to 300 kPa. The exception is UR63 (left wall in section A1) that shows a pressure of 1500 kPa. The sensors connected to UR7 and UR30 also show higher pressures but the sudden changes indicate that the readings are not reliable. UR3, UR46 and UR164 were damaged during installation.

# 3 Geometry

The backfilled part is divided into backfill sections separated by drainage layers of permeable mats. The backfill sections are named 0, A1-A6 and B2-B6 and the mats are named D1-D12 according to Fig 3-1.

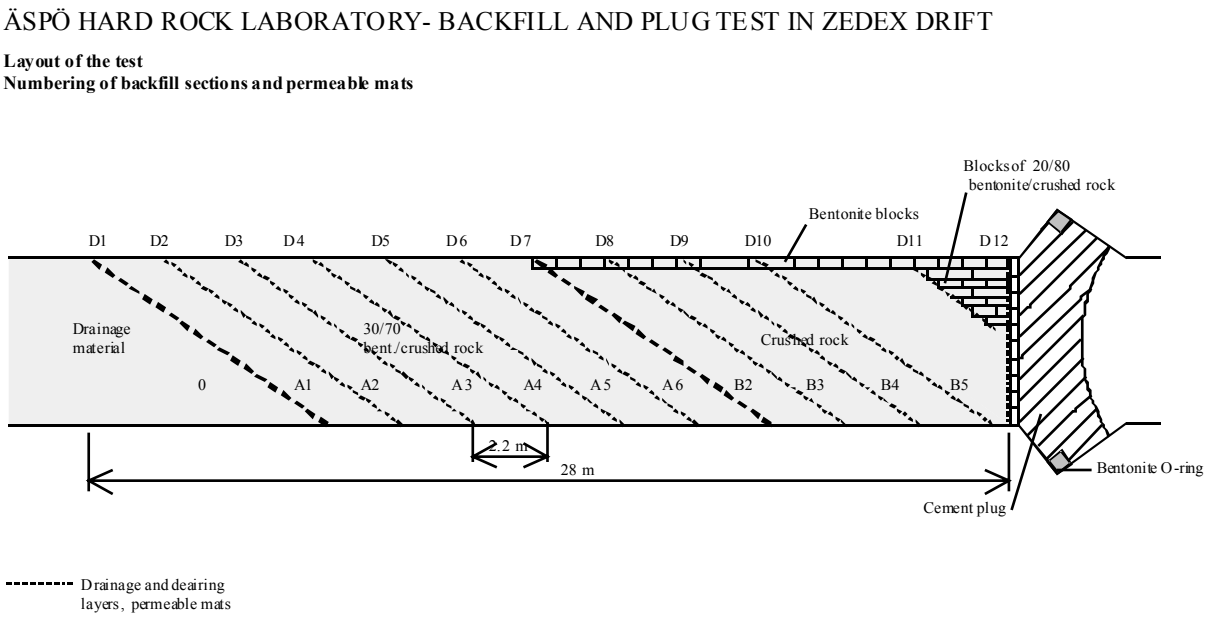


*Figure 3-1 Numbering of backfill sections and drainage layers (permeable mats).*

The permeable mats have been placed according to Fig 2-2. If the tunnel is supposed to be cylindrical the sections are elliptical with the large axis 8.7 m and the small axis 5.0 m. The tunnel axis is made the centre of a co-ordinate system with *x* and *y* co-ordinates. The drainage layer is divided into 3 parts with one upper, one central and one lower filter.

- The upper filter starts at $y$=3.3 m and fills the tunnel above that level. At the contact with the rock 0.2 m of filter mat is folded and attached to the rock surface in order to have a good hydraulic interaction with the rock.
- The central filter is placed at $-2.5<y<3.0$ and $-2.2<x<2.2$ as shown in Fig 3-2. The central filters have at least 0.3 m distance to the walls otherwise it has been cut to fulfil that demand.
- The lower filter has been placed between y=-2.8 and the floor with 0.2 m folded and attached to the floor. Since the floor is horizontal the ellipse is cut at about $y$ = -3.85.

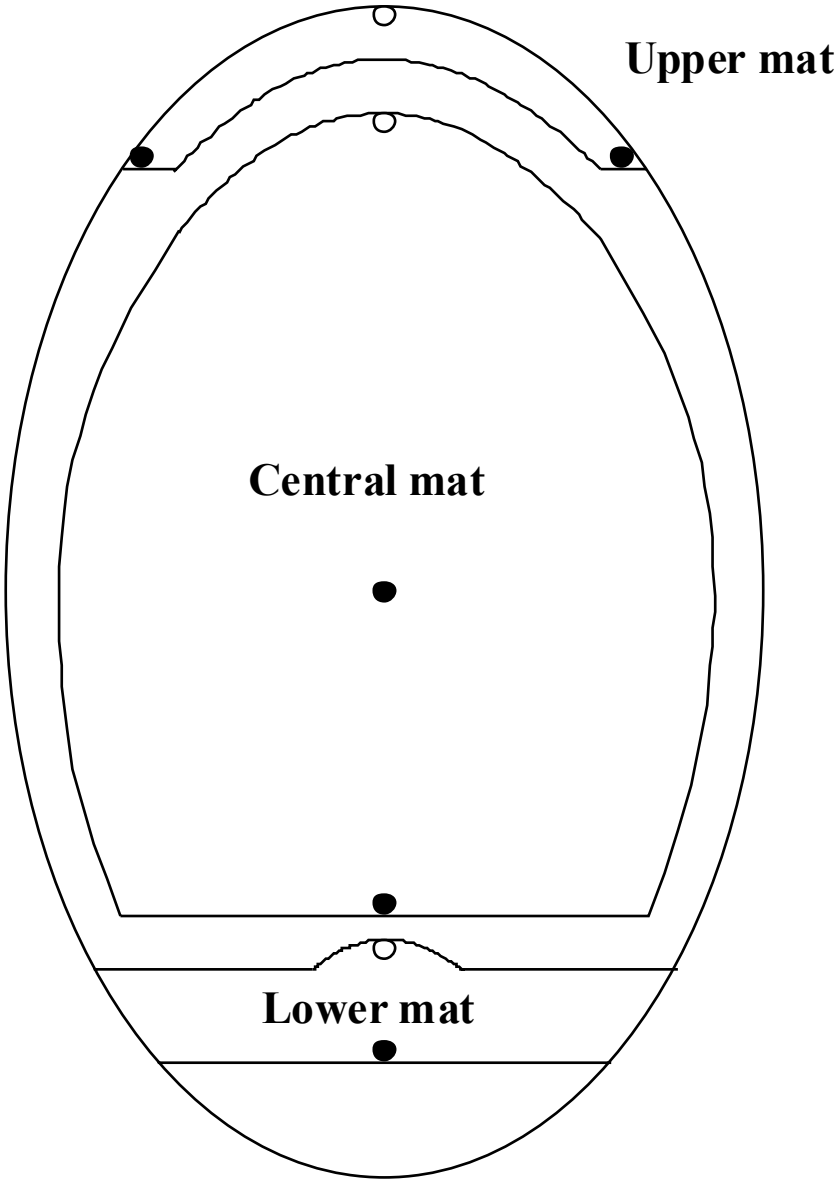


*Figure 3-2. Location of the filters in a drainage layer.*

Drainage layer D01 and D11 does not reach the floor. The central filter is cut 0.3 m from filter D12. Drainage layer D12 is made as the circular projection of the other drainage layers.

# 4 Location of instruments in the backfill

## 4.1 Brief description of the instruments

The different instruments that are used for measurements in the backfill are briefly described in this chapter.

### 4.1.1 Measurement of total pressure in the backfill

Total pressure is the sum of the swelling pressure (or effective stress) and the pore water pressure. It is measured with the following two instrument types:

- Glötzl total pressure cells of the hydraulic type. Two models have been used: E 10/20 KF 50 VA24 model A (Glötzl A) and model F (Glötzl B). The measuring range is 0-5 MPa. Type A is used for measurement in the soil while type B will be fixed to the rock surface with concrete.9 cells of type A and 4 cells of type B are installed.

- Roctest total pressure cell with vibrating wire transducer model TPC-0 (0-4 MPa). 8 cells of this type are installed in the backfill.

### 4.1.2 Measurement of pore water pressure in the backfill

The pore water pressure in the backfill is measured with the following two instrument types:

- Glötzl pore pressure cells of the hydraulic type. 18 pore pressure cells of model P4 S 50L VA with the measuring range 0-5 MPa are installed.

- Filter tips connected to Druck pore water pressure cells model PTX 1400 with tecalan tubes. The pore water pressure cells are located outside the test area. 16 devices with the measuring range 0-4 MPa are installed.

### 4.1.3 Measurement of the water saturation process in the backfill

The water saturation process is followed by the following three different techniques:

- Wescor psychrometers model PST-55. These devices measure the relative humidity in the pore system, which can be converted into water ratio or total suction (negative water pressure). The measuring range is 95.5-99.6 RH corresponding to the pore water pressure -0.5 to -6 MPa or the water ratio 11-25% of backfill with the composition 30/70 bentonite/ballast mixture. 27 psychrometers have been installed.

- Resistivity probes developed and built by Clay Technology and the University of Lund are used in the bentonite free backfill. The measuring principle is to apply an electrical current between two outer electrodes with the relative distance 30 cm and measure the drop in

potential between two inner electrodes with the relative distance 10 cm. The devices have been calibrated for different densities and water ratios of the backfill intended to be used. The measuring range is water ratios between 5 and 12%. 10 devices are installed.

- Filter tips connected to thin tecalan tubes. These filters, which mainly have been installed in the bentonite free backfill, are simple devices for indicating when water saturation has occurred in the measuring point.

### 4.1.4 Measurement of temperature

Since no heat is generated in the experiment, temperature can be measured in two points for the purpose of general information. Thermocouples of type K from Heraeus Electro-Nite AB have been used. Temperature can also measured by the psychrometers and by the devices for measuring hydraulic conductivity installed by ENRESA.

### 4.1.5 Other measurements

Local hydraulic conductivity will after water saturation be measured in section A4 with devices developed and installed by ENRESA in 13 points. These devices are not further dealt with in this report.

## 4.2 Strategy for describing the position of each device

Each instrument is named with a short unique name consisting of 1-2 letters describing the type of measurement and 1-3 figures numbering the device. In addition to the name a short description of the position is added.

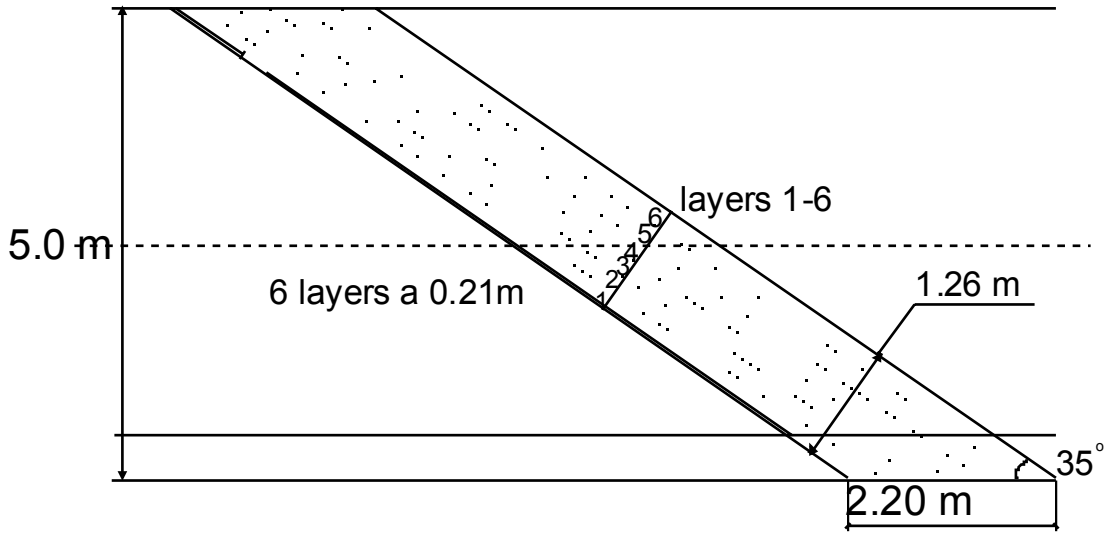


Figure 4-1. Subdivision of a backfill section into backfill layers.

The sections, separated by drainage layers, were shown in Fig 1-1. Sections A1-A6 and B2-B5 are divided into 6 layers with the thickness 0.21 m according to Fig 4-1. Each layer corresponds to one compaction sequence, which means that the backfill will be placed with a thickness before compaction that yields a thickness after compaction of 0.21 m. The layers are numbered 1-6.

The instruments have been placed in the layers after compaction and are related to those layers. Each measuring point is also defined by the co-ordinates in the layer in a co-ordinate system equal to the one shown in Fig 4-2. The *x*-coordinate is the horizontal distance from the centre of the tunnel and the *y*-coordinate is the distance perpendicular to the *x*-axis. Some of the instruments are more important to place at a specified distance from the rock surface. For those cases the co-ordinate begins with the letter R and is given the co-ordinate with the intersection with the rock surface as centre. An instrument in the backfill will thus be named in the following way:

1. Type of measurement (1 letter)

2. Serial number (1-2 figures)

3. Section (1 letter, 1 figure)

4. Layer (1 figure)

5. *x*-coordinate

6. *y*-coordinate

Items 1 and 2 identifies the device and items 3-6 describes the location. A pore water pressure transducer (number 8) located in section A2, layer 3, 0.5 m left of the centre line and 0.3 m below the roof in the y-direction will be named:

W8 (A2/3/-0.5/R-0.3)

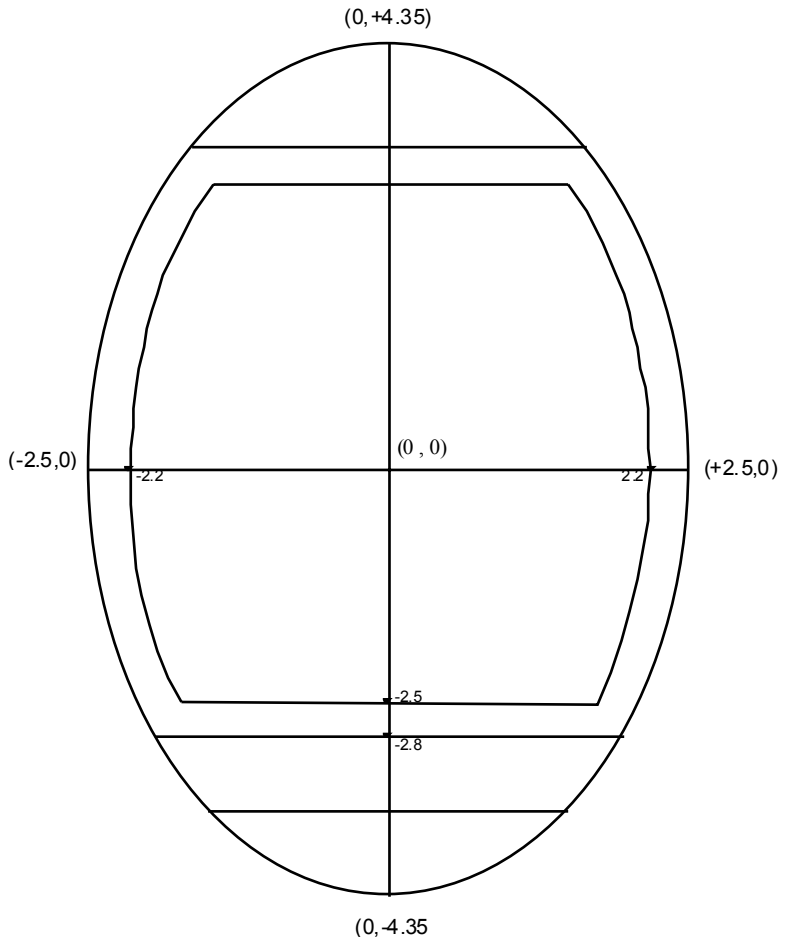


*Figure 4-2. Co-ordinate system for measuring point in each sections and layers*

## 4.3 Position of each instrument in the backfill

All instruments are placed in layers 1-4 in order to leave the two upper layers unaffected by transducers and cables. Another reason is that the entrance plate where the tubes are attached to the through connections are placed in layers 1-4, which means that the two final layers could be compacted without considering the problems of compacting around the through connections.

The positions of the instruments (except for ENRESA´s hydraulic conductivity devices) are described in Tables 4-1 to 4-4.

**Table 4-1 Numbering and position of instruments for measuring total pressure**

| Type and number | Section | Layer | X | Y | Fabricate | Remarks |
|---|---|---|---|---|---|---|
| P1 | A3 | 1 | 0 | R+0.2 | Glötzl A | Horisontal |
| P2 | A1 | 5 | 0 | R-1.1 | Glötzl A | Parallel |
| P3 | A2 | 3 | 0 | 0,6 | Rocktest | Parallel |
| P4 | A2 | 3 | 0 | R+0.65 | Rocktest | Parallel |
| P5 | A2 | 1 | 0 | R-0.2 | Rocktest | Parallel |
| P6 | A2 | 6 | 0 | -3,15 | Glötzl A | Horisontal |
| P7 | A4 | 3 | 0 | R-0 | Glötzl B | At rock |
| P8 | A4 | 3 | 0 | R+0 | Glötzl B | At rock |
| P9 | A5 | 3 | 0 | R-0.2 | GlötzlA | At rock |
| P51 | A6 | 3 | 0 | R-0.3 | Rocktest | Under blocks |
| P52 | B2 | 3 | 0 | R-0 | Glötzl A | Under blocks |
| P53 | B2 | 3 | 0 | 0,2 | Glötzl B | Horisontal |
| P54 | B2 | 6 | 0 | -2,78 | Rocktest | Horisontal |
| P55 | B3 | 3 | 0 | 0,3 | Glötzl A | Parallel |
| P56 | B3 | 3 | 0 | R+0.65 | Glötzl A | Parallel |
| P57 | B2 | 7 | 0 | R+1.1 | Rocktest | Parallel |
| P58 | B4 | 3 | 0 | R-0 | Glötzl A | Under blocks |
| P59 | B3 | 5 | 0 | R-1.1 | Glötzl A | Parallel |
| P60 | B4 | 1 | 0 | R-0.2 | Rocktest | Parallel |
| P61 | B6 | 10 | 0 | R-0 | Rocktest | Between blocks |
| P62 | B6 | 10 | 0 | P | Glötzl B | At wall |

**Table 4-2 Numbering and position of instruments for measuring pore water pressure (U)**

| Type and number | Section | Layer | X | Y | Fabricate | Remarks |
|---|---|---|---|---|---|---|
| U1 | A1 | 3 | 0 | 0,3 | Glötzl | |
| U2 | A1 | 3 | 0 | 3,1 | Glötzl | |
| U3 | A1 | 3 | 0 | -2,6 | Glötzl | |
| U4 | A1 | 3 | 2 | 0 | CT Tube + Druck | Twin tubes |
| U5 | A1 | 3 | -2 | 0 | CT Tube + Druck | Twin tubes |
| U6 | A2 | 1 | 0 | 0,3 | Glötzl | |
| U7 | A2 | 6 | 0,2 | 3,15 | Glötzl | |
| U8 | A3 | 1 | 0,25 | -2,8 | Glötzl | |
| U9 | A1 | 5 | -0,2 | R-1.1 | Glötzl | |
| U10 | A2 | 3 | 0 | 0,3 | Glötzl | |
| U11 | A2 | 3 | -0,2 | R+0.65 | Glötzl | |
| U12 | A2 | 3 | 1,3 | 0 | CT Tube + Druck | |
| U13 | A2 | 3 | -1,3 | 0 | CT Tube + Druck | |
| U14 | A2 | 6 | -0,15 | -0,1 | Glötzl | |
| U15 | A2 | 1 | -0,2 | R-0.2 | Glötzl | |
| U16 | A4 | 3 | 0 | 0,3 | Glötzl | |
| U17 | A4 | 3 | 0 | R-0 | Glötzl | |
| U18 | A4 | 3 | 0 | R+0 | Glötzl | |
| U19 | A4 | 3 | R-0 | 0 | Glötzl | |
| U20 | A4 | 3 | R+0 | 0 | Glötzl | |
| U21 | A5 | 3 | 0 | 0,3 | Glötzl | |
| U22 | A5 | 3 | 1,3 | 0 | CT Tube + Druck | Twin tubes |
| U23 | A5 | 3 | -1,3 | 0 | CT Tube + Druck | Twin Tubes |
| U24 | A5 | 3 | -0,2 | R-0.2 | Glötzl | |
| U51 | A6 | 3 | -0,2 | R-0.3 | CT Tube + Druck | Under the Blocks |
| U52 | A6 | 3 | -0,2 | -2 | CT Tube + Druck | Twin Tubes |
| U53 | B3 | 1-2 | 0 | R+0.05 | CT Tube + Druck | |
| U54 | B2 | 5 | -0,2 | R+0.2 | CT Tube + Druck | marked as w66 |
| U55 | B2 | 6 | -0,2 | R+0.65 | CT Tube + Druck | marked as w63 |
| U56 | B4 | 3 | 0 | R-0 | CT Tube + Druck | |
| U57 | B3 | 5 | -0,2 | R-1.1 | CT Tube + Druck | |
| U58 | B4 | 1 | -0,2 | R-0.2 | CT Tube + Druck | |
| U59 | B6 | 10 | 0 | R-0.05 | CT Tube + Druck | |
| U60 | B6 | 10 | 0 | R-C-C | CT Tube + Druck | Twin Tubes |

**Table 4-3 Numbering and position of instruments for measuring water content (W)**

| Type and number | Section | Layer | X (m) | Y (m) | Fabricate | Remarks |
|---|---|---|---|---|---|---|
| W1 | A1 | 1 | 0 | 0 | Wescor Psychrometer | |
| W2 | A1 | 3 | 0 | 0 | Wescor Psychrometer | |
| W3 | A1 | 5 | 0 | 0 | Wescor Psychrometer | |
| W4 | A2 | 1 | 0 | 0 | Wescor Psychrometer | |
| W5 | A2 | 3 | 0 | 0 | Wescor Psychrometer | |
| W6 | A2 | 4 | 0 | 0 | Wescor Psychrometer | |
| W7 | A3 | 1 | 0 | 0 | Wescor Psychrometer | |
| W8 | A3 | 3 | 0 | 0 | Wescor Psychrometer | |
| W9 | A3 | 3 | 0 | 2,5 | CT Tube | |
| W10 | A3 | 3 | 0 | R-0.5 | Wescor Psychrometer | |
| W11 | A3 | 3 | 0 | -2 | CT Tube | |
| W12 | A3 | 3 | 0 | R+0.5 | Wescor Psychrometer | |
| W13 | A3 | 3 | 1,2 | 0 | CT Tube | |
| W14 | A3 | 3 | R-0.3 | 0 | Wescor Psychrometer | |
| W15 | A3 | 3 | -1,2 | 0 | CT Tube | |
| W16 | A3 | 3 | R+0.3 | 0 | Wescor Psychrometer | |
| W17 | A3 | 4 | 0 | 0 | Wescor Psychrometer | |
| W18 | A4 | 1 | 0 | 0 | Wescor Psychrometer | |
| W19 | A4 | 3 | 0 | 0 | Wescor Psychrometer | |
| W20 | A4 | 4 | 0 | 0 | Wescor Psychrometer | |
| W21 | A5 | 1 | 0 | 0 | Wescor Psychrometer | |
| W22 | A5 | 3 | 0 | 0 | Wescor Psychrometer | |
| W23 | A5 | 3 | 0 | 2.5 | Wescor Psychrometer | |
| W24 | A5 | 3 | 0 | -2 | Wescor Psychrometer | |
| W25 | A5 | 4 | 0 | 0 | Wescor Psychrometer | |
| W51 | A6 | 1 | 0 | 0 | Wescor Psychrometer | |
| W52 | A6 | 3 | 0 | 0 | CT Res. Probe | |
| W53 | A6 | 3 | 0 | R-0.4 | Ct Tube | |
| W54 | A6 | 3 | 0 | -2 | Ct Tube | |
| W55 | A6 | 3 | -1,3 | 0 | Ct Tube | |
| W56 | A6 | 3 | 1,3 | 0 | Ct Tube | |
| W57 | A6 | 4 | 0 | 0 | CT Res. Probe | |
| W58 | B2 | 1 | 0 | 0 | CT Res. Probe | |
| W59 | B2 | 3 | 0 | 0 | CT Res. Probe | |
| W60 | B2 | 3 | 0 | 2,5 | Ct Tube | |
| W61 | B2 | 3 | 0 | R-0.3 | Ct Tube | Under the Blocks |
| W62 | B2 | 3 | 0 | -2 | Ct Tube | |
| W64 | B2 | 3 | -1,3 | 0 | Ct Tube | |
| W65 | B2 | 3 | 1,3 | 0 | Ct Tube | |
| W67 | B3 | 1 | 0 | 0 | Wescor Psychrometer | |
| W68 | B3 | 3 | 0 | 0 | CT Res. Probe | |
| W69 | B3 | 3 | 0 | R-0.3 | CT Tube | Under the Blocks |
| W70 | B3 | 3 | 1,3 | 0 | CT Tube | |
| W71 | B3 | 3 | -1,3 | 0 | CT Tube | |
| W72 | B3 | 4 | 0 | 0 | CT Res. Probe | |

| | | | | | | |
|---|---|---|---|---|---|---|
| W73 | B4 | 1 | 0 | 0 | CT Res. Probe | |
| W74 | B4 | 3 | 0 | 0 | CT Res. Probe | |
| W75 | B4 | 3 | 1,3 | 0 | CT Tube | |
| W76 | B4 | 3 | -1,3 | 0 | CT Tube | |
| W77 | B5 | 2 | 0 | 0 | Wescor Psychrometer | |
| W78 | B5 | 5 | 0 | 0 | CT Res. Probe | |
| W79 | B5 | 8 | 0 | 2 | CT Res. Probe | |
| W80 | B5 | 8 | 2 | 2 | Ct Tube | |
| W81 | B5 | 8 | -2 | 2 | Ct Tube | |
| W82 | B5 | 11 | 0 | 2 | Ct Tube | |
| W83 | B6 | 5 | 0 | R-C-C | Wescor Psychrometer | |
| W84 | B6 | 15 | 0 | R-C-C | Wescor Psychrometer | |

# 5 Location of instruments in the rock

## 5.1 Brief description of the instruments and the packers

Only water pressure is measured in the rock. The measurements are made in core drilled bore holes sealed with bentonite packers with the following measuring technique:

- Tecalan tubes from the packer are connected to Druck pore water pressure cells model PTX 1400. The pore water pressure cells are located in the measuring house. Measurements are made in 79 bore hole sections (measuring range 0-4 MPa).

Measurements are made in 1-3 sections in the bore holes. Most of the holes are only 1 m long with 1 packer installed in the outer 0.5 m. Two tubes are lead into each measuring section for deairing purpose. The measuring sections are sealed with packers with bentonite rings surrounded by rubber sealings.

## 5.1 Position of each measuring section

The measuring sections are identified with two letters and 2-3 figures. The letters are U (for pore water pressure) and R (for rock). The numbers are given in the following way:

Short holes in roof: 1-12

Long holes in the roof: 101-107

Short holes in the right wall (seen from the entrance of the drift): 21-32

Long holes in the right wall: 121-129

Short holes in floor: 41-52

Long holes in the floor: 141-147

Short holes in left wall: 61-72

Long holes in the roof: 161-167

Long hole in the end of the drift: 121

Table 5-1 shows the location of the measuring section for each instrument and the corresponding bore hole number. The backfill section in where the bore hole starts is also given

Figs 5-1 and 5-2 show the location of the measuring sections in vertical and horizontal cross

sections.

**Table 5-1 Numbering and positions of instruments for measuring pore water pressure in the rock**

| Type and number | Location | Measuring sect. (m) | Bore hole number | Section (TC) | Fabricate | Diameter (mm) | Remarks |
|---|---|---|---|---|---|---|---|
| UR1 | Roof | 0.5-1.0 | KZ0065I01 | A1 | Druck | 56 | |
| UR2 | Roof | 0.5-1.0 | KZ0063I01 | A2 | Druck | 56 | |
| UR3 | Roof | 0.5-1.0 | KZ0061I01 | A3 | Druck | 56 | Closed ? |
| UR4 | Floor | 0.5-1.0 | KZ0052G01 | A4 | Druck | 56 | |
| UR5 | Roof | 0.5-1.0 | KZ0057I01 | A5 | Druck | 56 | |
| UR6 | Roof | 0.5-1.0 | KZ0054I01 | B1 | Druck | 56 | |
| UR7 | Roof | 0.5-1.0 | KZ0052I01 | B2 | Druck | 56 | |
| UR8 | Roof | 0.5-1.0 | KZ0050I01 | B3 | Druck | 56 | |
| UR9 | Roof | 0.5-1.0 | KZ0048I01 | B4 | Druck | 56 | |
| UR10 | Roof | 0.5-1.0 | KZ0046I01 | B5 | Druck | 56 | |
| UR11 | Roof | 0.5-1.0 | KZ0043I01 | B5 | Druck | 56 | |
| UR12 | Roof | 0.5-1.0 | KZ0041I01 | B5 | Druck | 56 | |
| | | | | | | | |
| UR21 | Right wall | 0.5-1.0 | KZ0066B01 | O | Druck | 56 | |
| UR22 | Right wall | 0.5-1.0 | KZ0064B01 | O | Druck | 56 | |
| UR23 | Right wall | 0.5-1.0 | KZ0061B01 | A1 | Druck | 56 | |
| UR24 | Floor | 0.5-1.0 | KZ0057B01 | A2 | Druck | 56 | |
| UR25 | Right wall | 0.5-1.0 | KZ0057B01 | A3 | Druck | 56 | |
| UR26 | Right wall | 0.5-1.0 | KZ0055B01 | A4 | Druck | 56 | |
| UR27 | Right wall | 0.5-1.0 | KZ0053B01 | A5 | Druck | 56 | |
| UR28 | Right wall | 0.5-1.0 | KZ0050B01 | B1 | Druck | 56 | |
| UR29 | Right wall | 0.5-1.0 | KZ0048B01 | B2 | Druck | 56 | |
| UR30 | Right wall | 0.5-1.0 | KZ0046B01 | B3 | Druck | 56 | |
| UR31 | Right wall | 0.5-1.0 | KZ0044B01 | B4 | Druck | 56 | |
| UR32 | Right wall | 0.5-1.0 | KZ0042B01 | B5 | Druck | 56 | |
| | | | | | | | |
| UR41 | Floor | 0.5-1.0 | KZ0065G01 | O | Druck | 56 | |
| UR42 | Floor | 0.5-1.0 | KZ0063G01 | O | Druck | 56 | |
| UR43 | Floor | 0.5-1.0 | KZ0061G01 | O | Druck | 56 | |
| UR44 | Floor | 0.5-1.0 | KZ0059G01 | A1 | Druck | 56 | |
| UR45 | Right wall | 0.5-1.0 | KZ0059G01 | A2 | Druck | 56 | One tube |
| UR46 | Floor | 0.5-1.0 | KZ0054G01 | A3 | Druck | 56 | plugged |
| UR47 | Roof | 0.5-1.0 | KZ0059I01 | A4 | Druck | 56 | |
| UR48 | Floor | 0.5-1.0 | KZ0050G01 | A5 | Druck | 56 | |
| UR49 | Floor | 0.5-1.0 | KZ0048G01 | B1 | Druck | 56 | |
| UR50 | Floor | 0.5-1.0 | KZ0046G01 | B2 | Druck | 56 | |
| UR51 | Floor | 0.5-1.0 | KZ0043G01 | B3 | Druck | 56 | |
| UR52 | Floor | 0.5-1.0 | KZ0041G01 | B4 | Druck | 56 | |

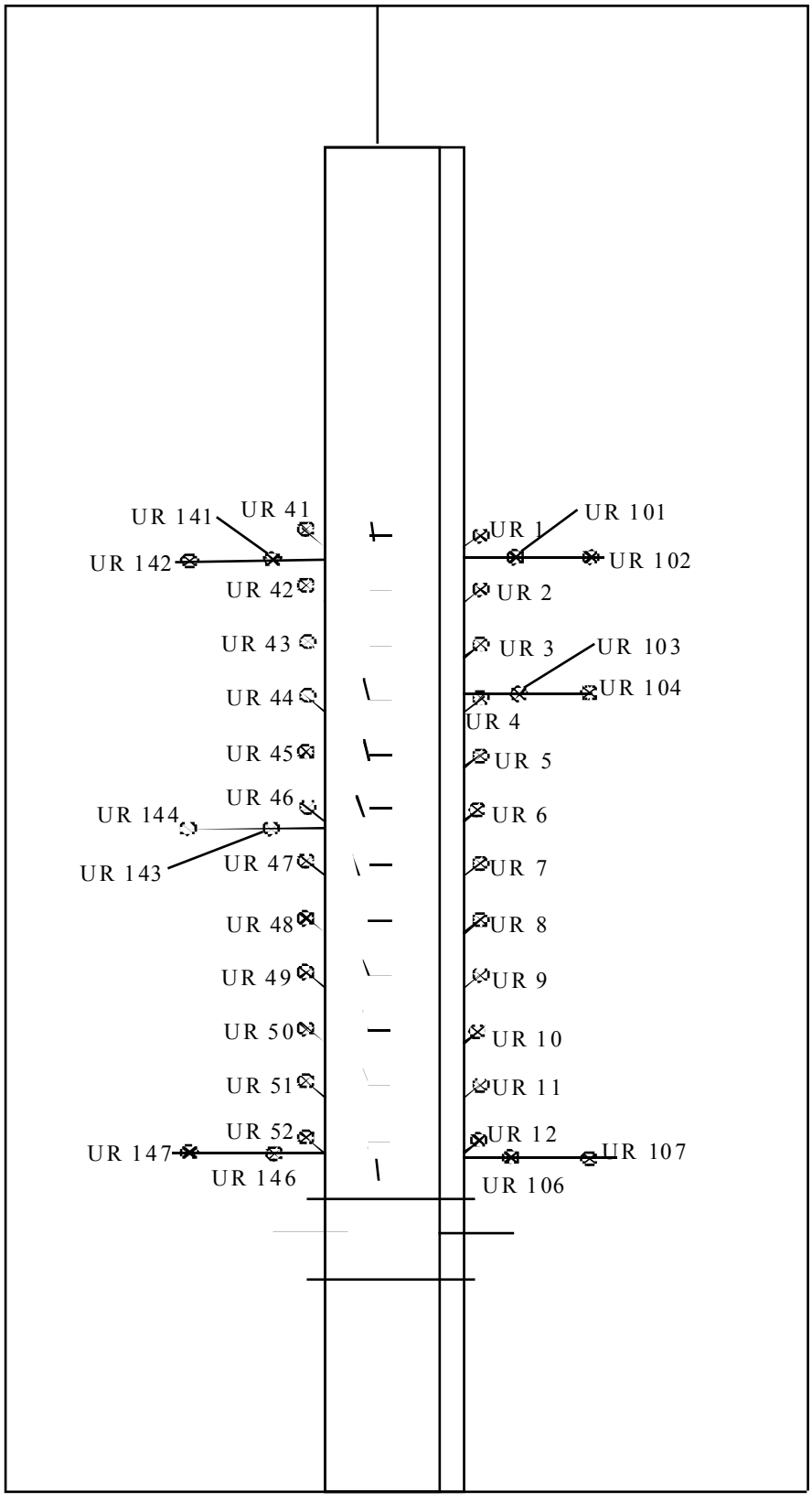


*Figure 5-1. Position of measuring points in the boreholes of the rock in the floor (left part) and the roof. Vertical section.*

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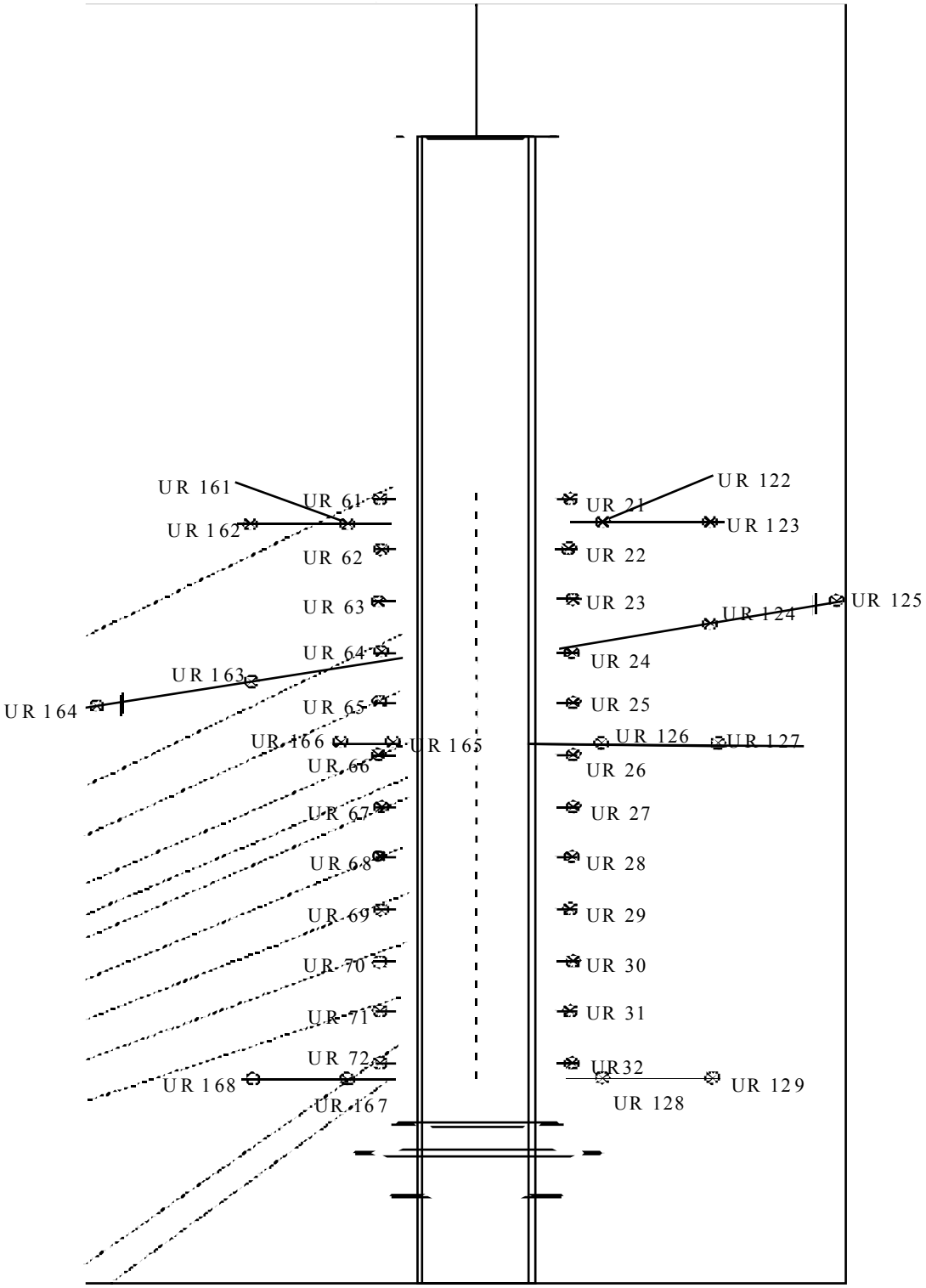
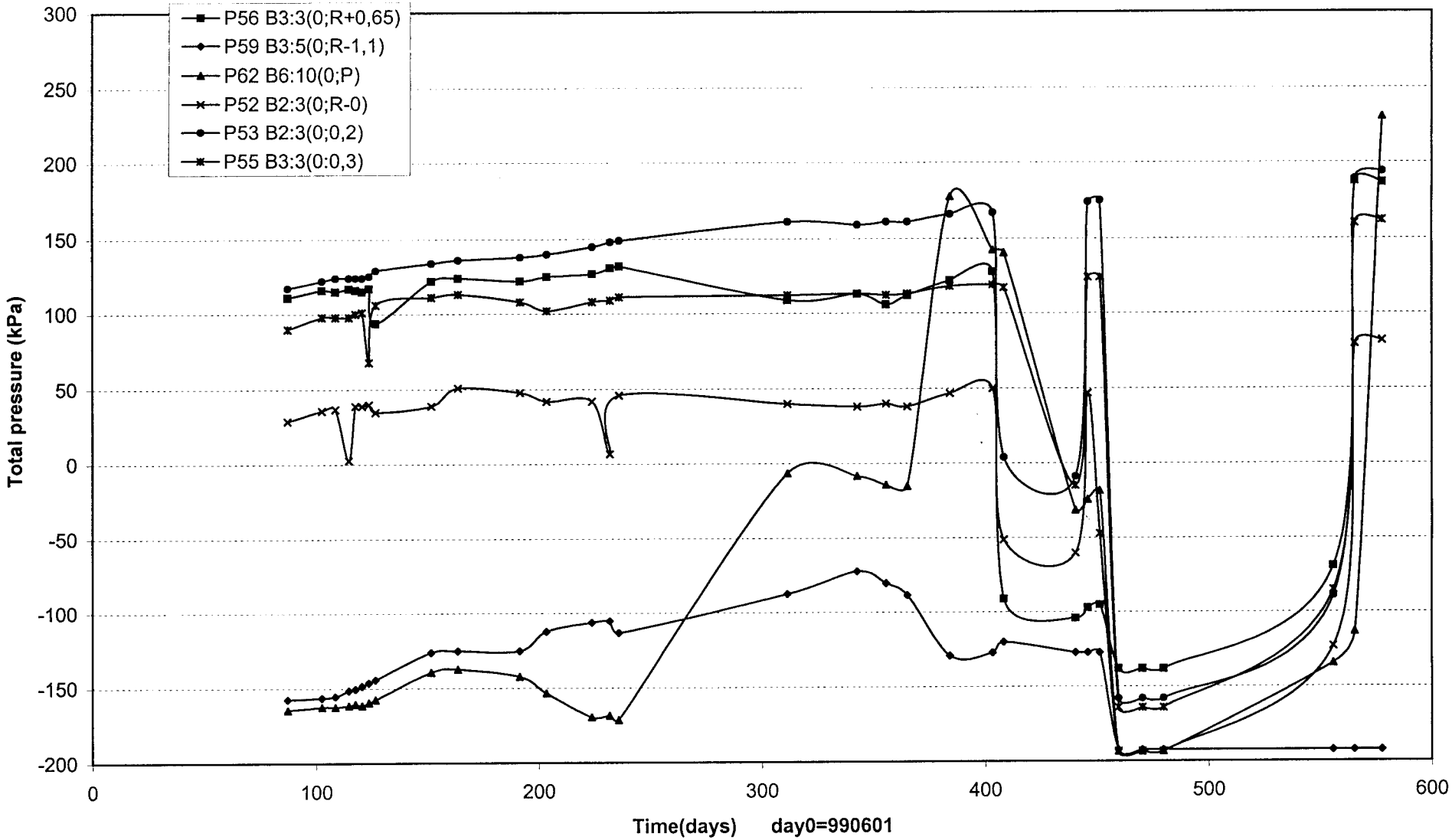
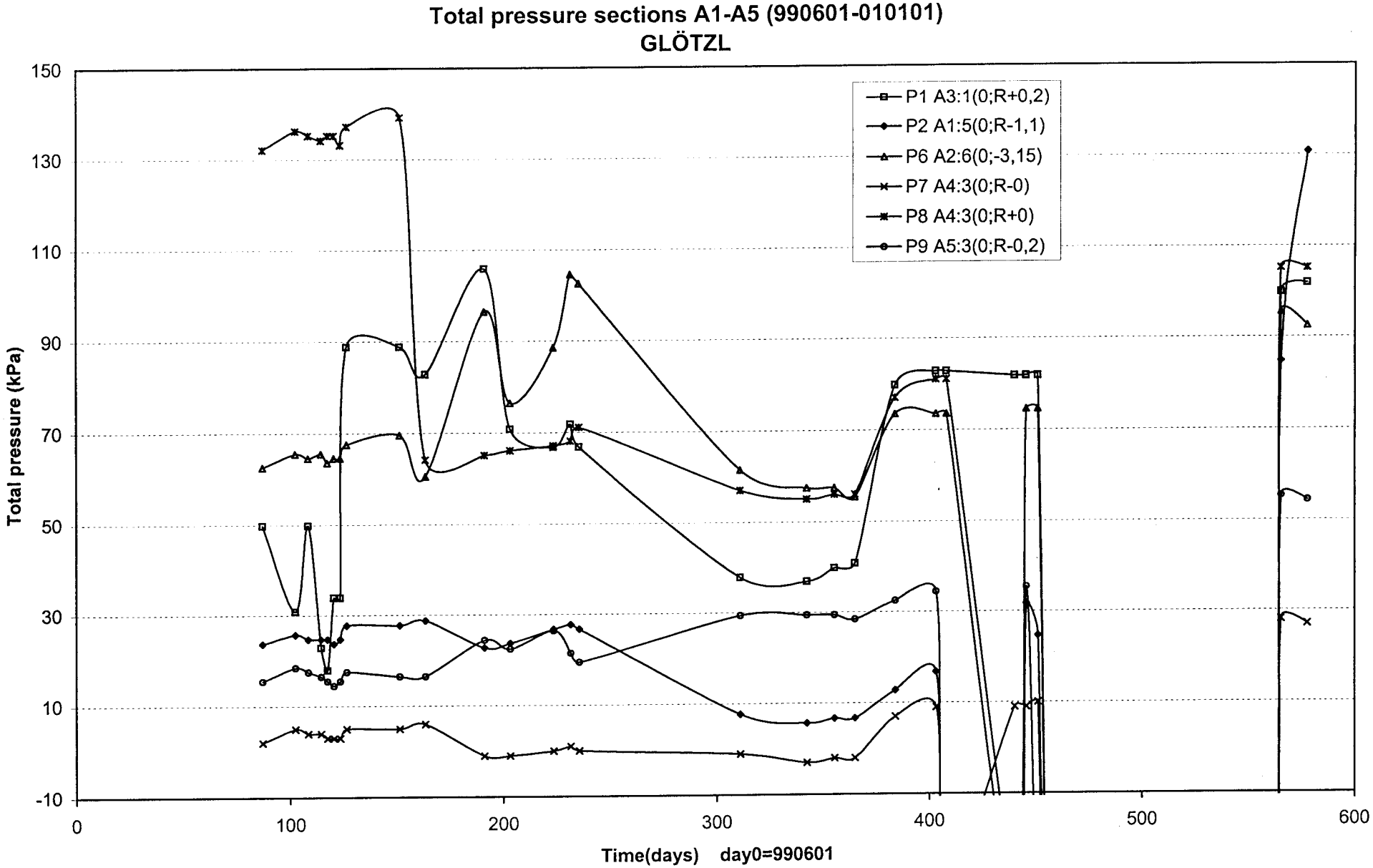
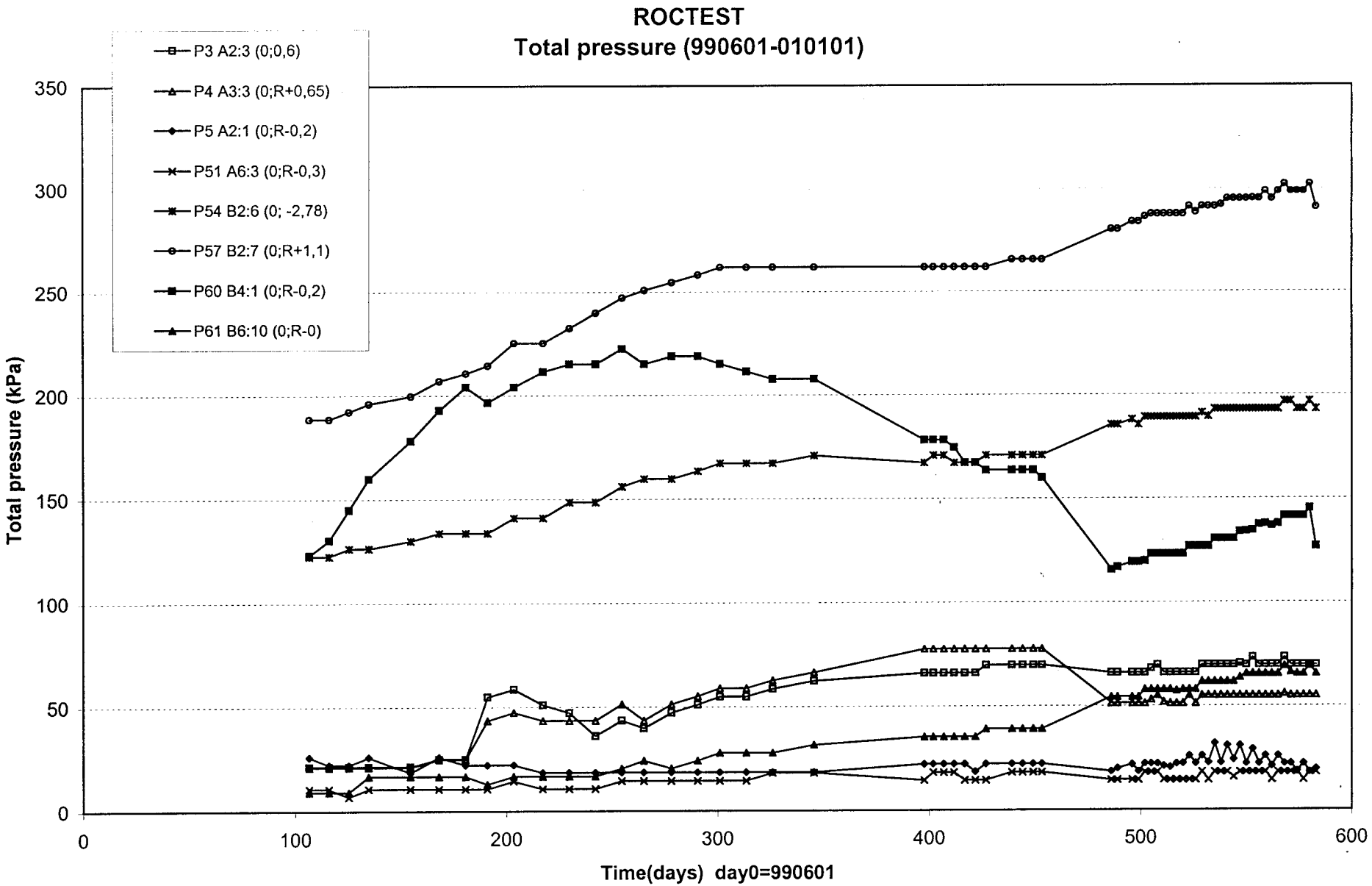


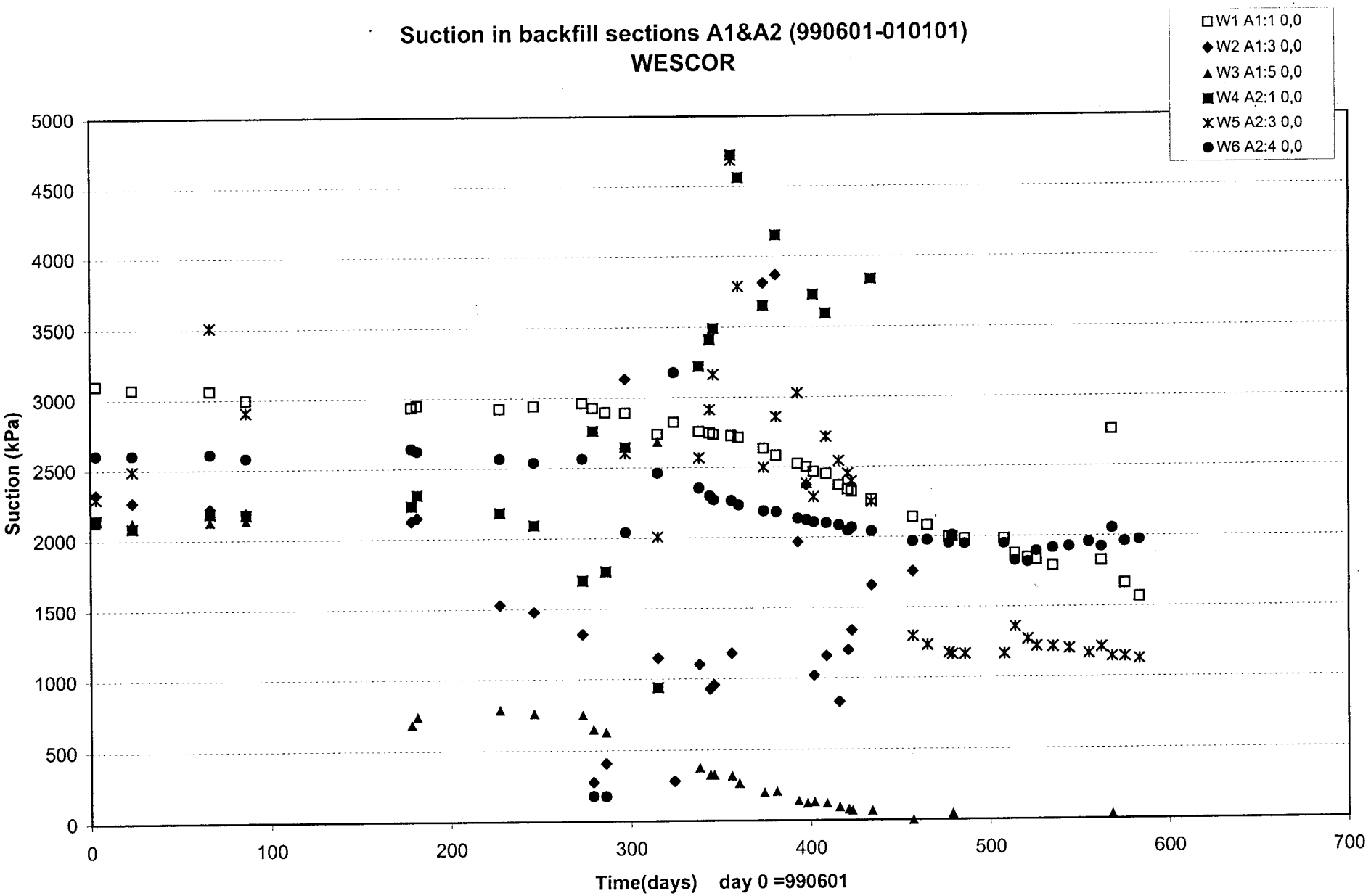

*Figure 5-2. Position of measuring points in the boreholes of the rock in the walls. Horizontal section*

## Total pressure sections B2-B4 (990601-010101)
## GLÖTZL

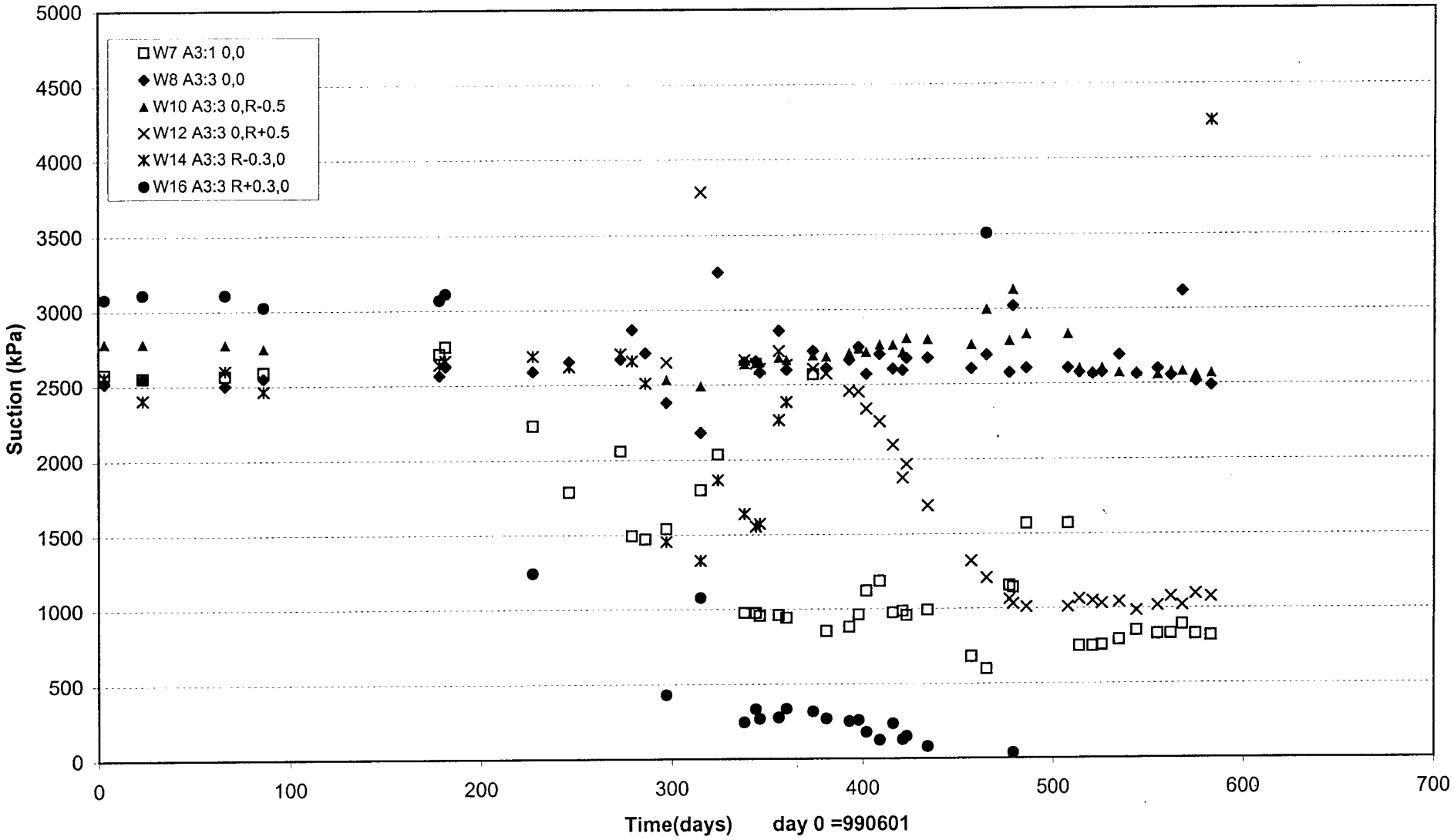



Total pressure sections A1-A5 (990601-010101)
GLÖTZL
P1 A3:1(0;R+0,2)
P2 A1:5(0;R-1,1)
P6 A2:6(0;-3,15)
P7 A4:3(0;R-0)
P8 A4:3(0;R+0)
P9 A5:3(0;R-0,2)
Total pressure (kPa)
150
130
110
90
70
50
30
10
-10
0
100
200
300
400
500
600
Time(days) day0=990601

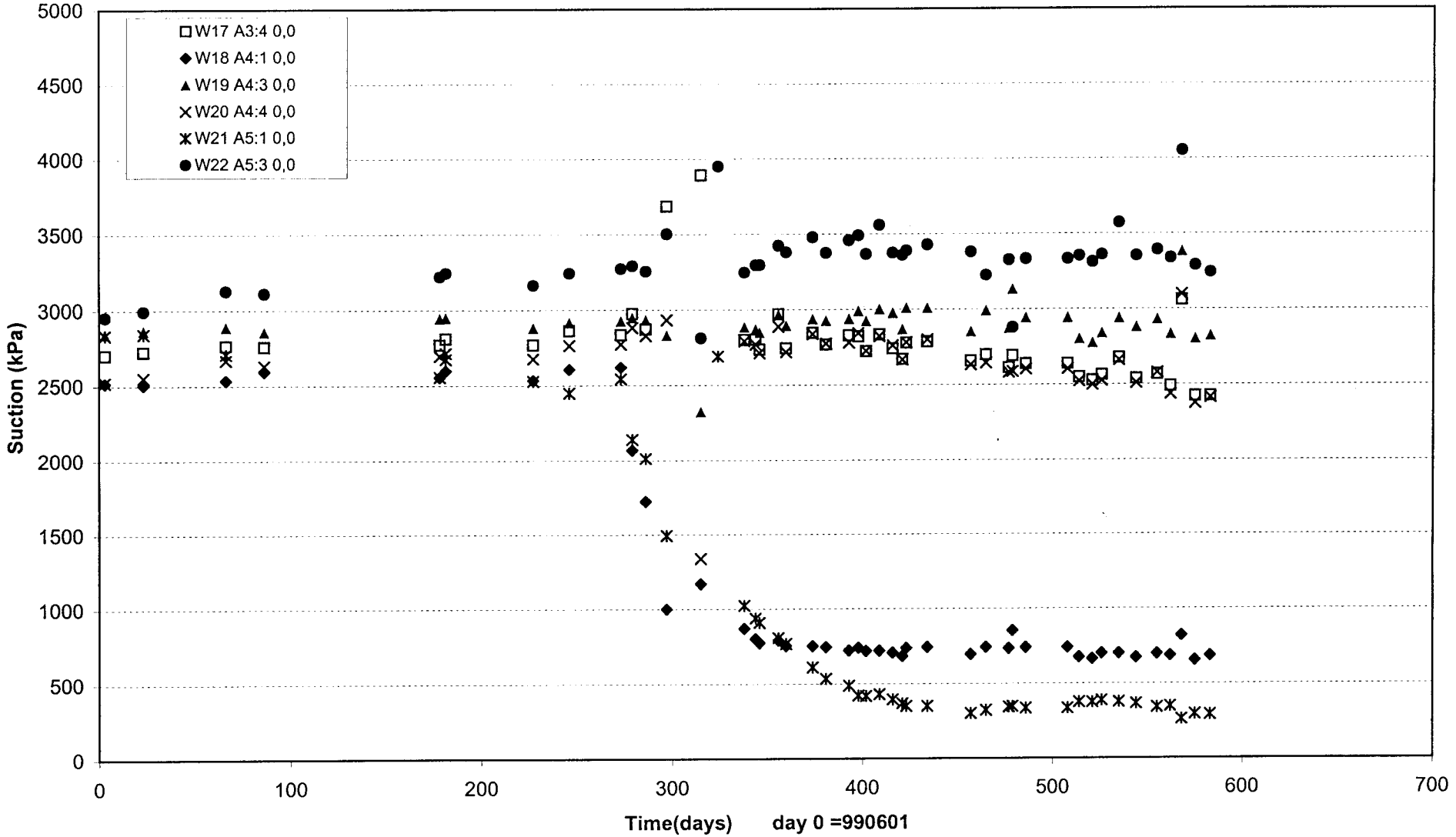

ROCTEST
Total pressure (990601-010101)
P3 A2:3 (0;0,6)
P4 A3:3 (0;R+0,65)
P5 A2:1 (0;R-0,2)
P51 A6:3 (0;R-0,3)
P54 B2:6 (0; -2,78)
P57 B2:7 (0;R+1,1)
P60 B4:1 (0;R-0,2)
P61 B6:10 (0;R-0)
Total pressure (kPa)
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
Time(days) day0=990601


Suction in backfill sections A1&A2 (990601-010101)
WESCOR
W1 A1:1 0,0
W2 A1:3 0,0
W3 A1:5 0,0
W4 A2:1 0,0
W5 A2:3 0,0
W6 A2:4 0,0
Suction (kPa)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
700
Time(days) day 0 =990601

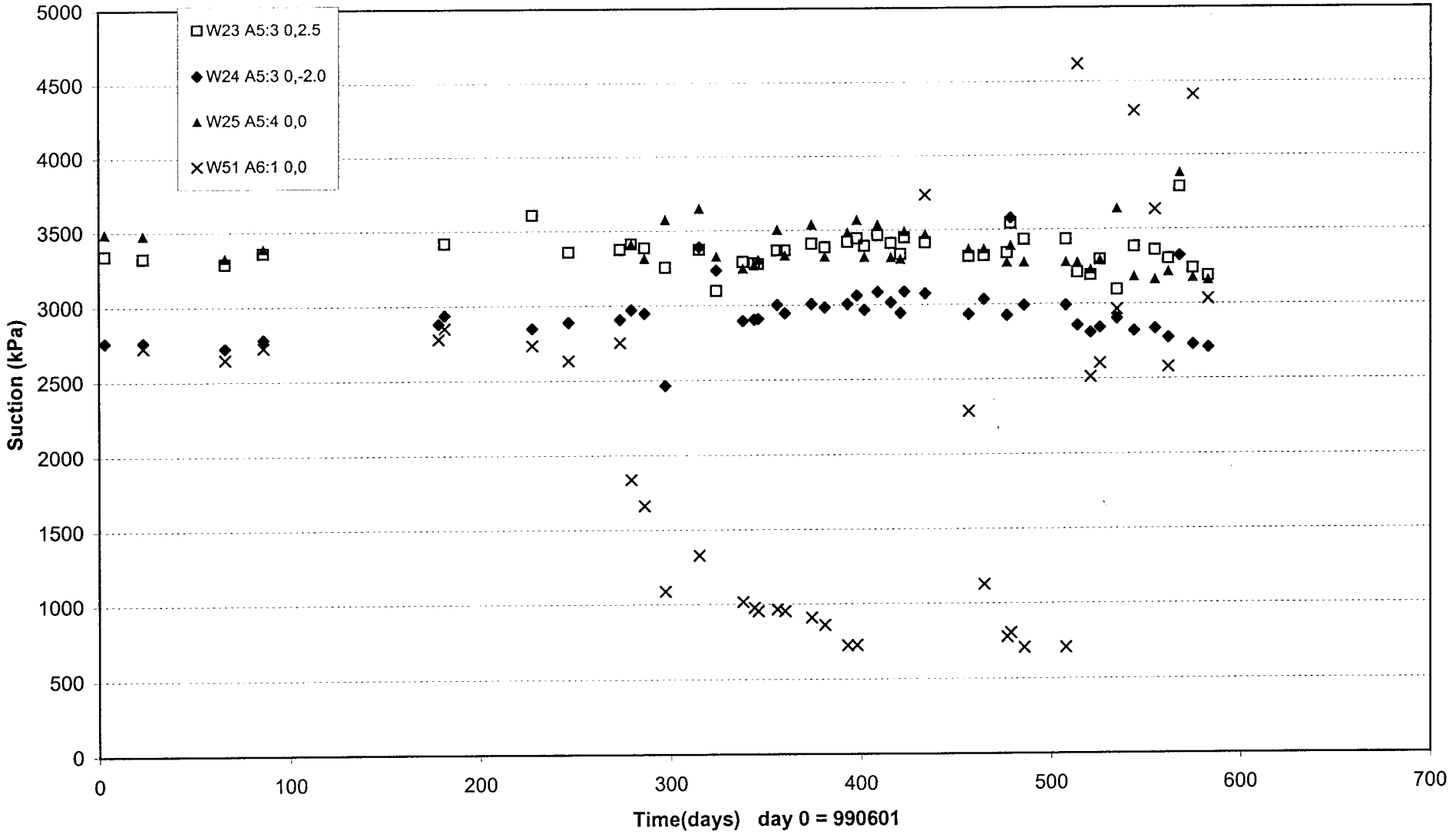
## Suction in backfill sections A3 (990601-010101)
## WESCOR



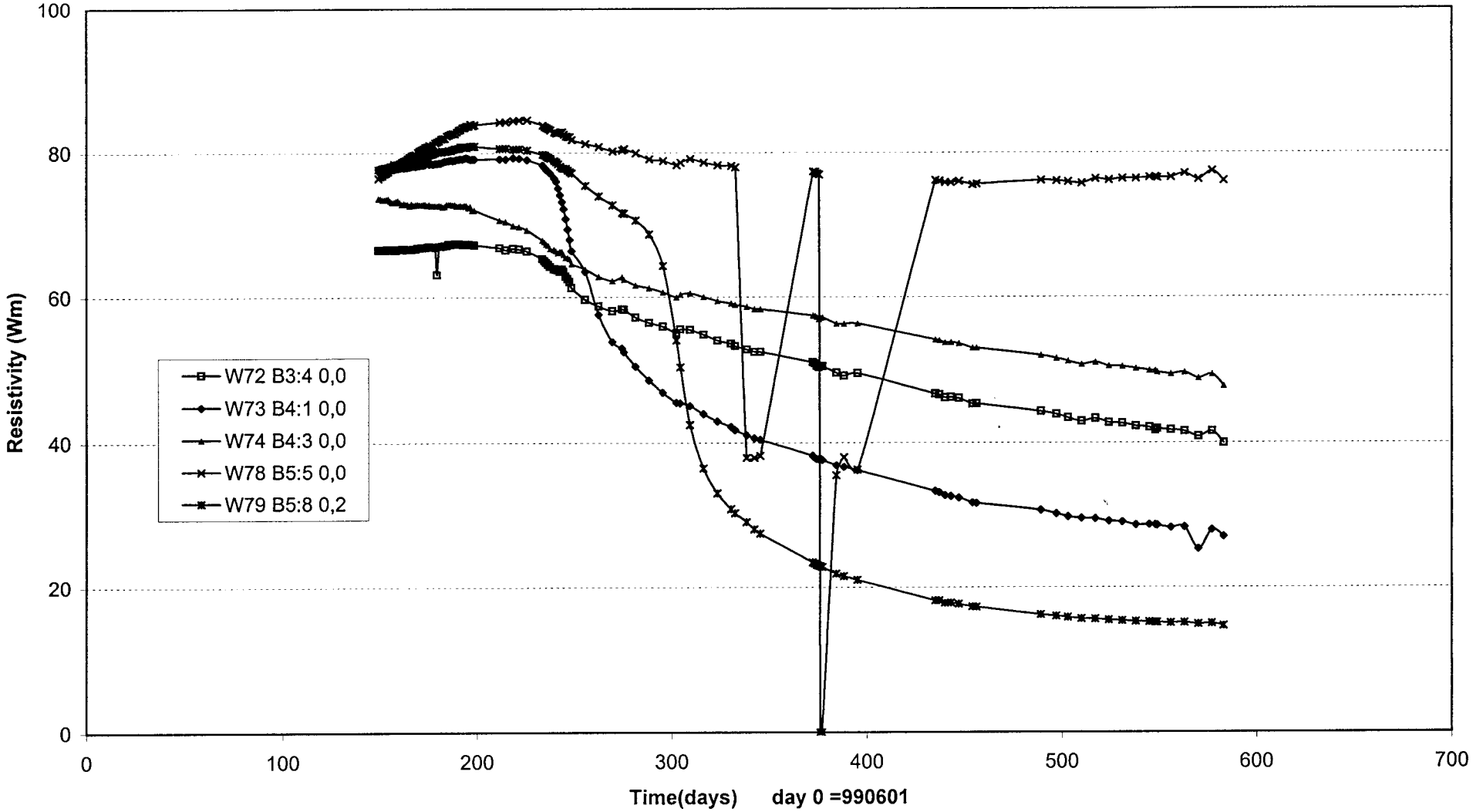
## Suction in backfill sections A4&A5 (990601-010101)
## WESCOR



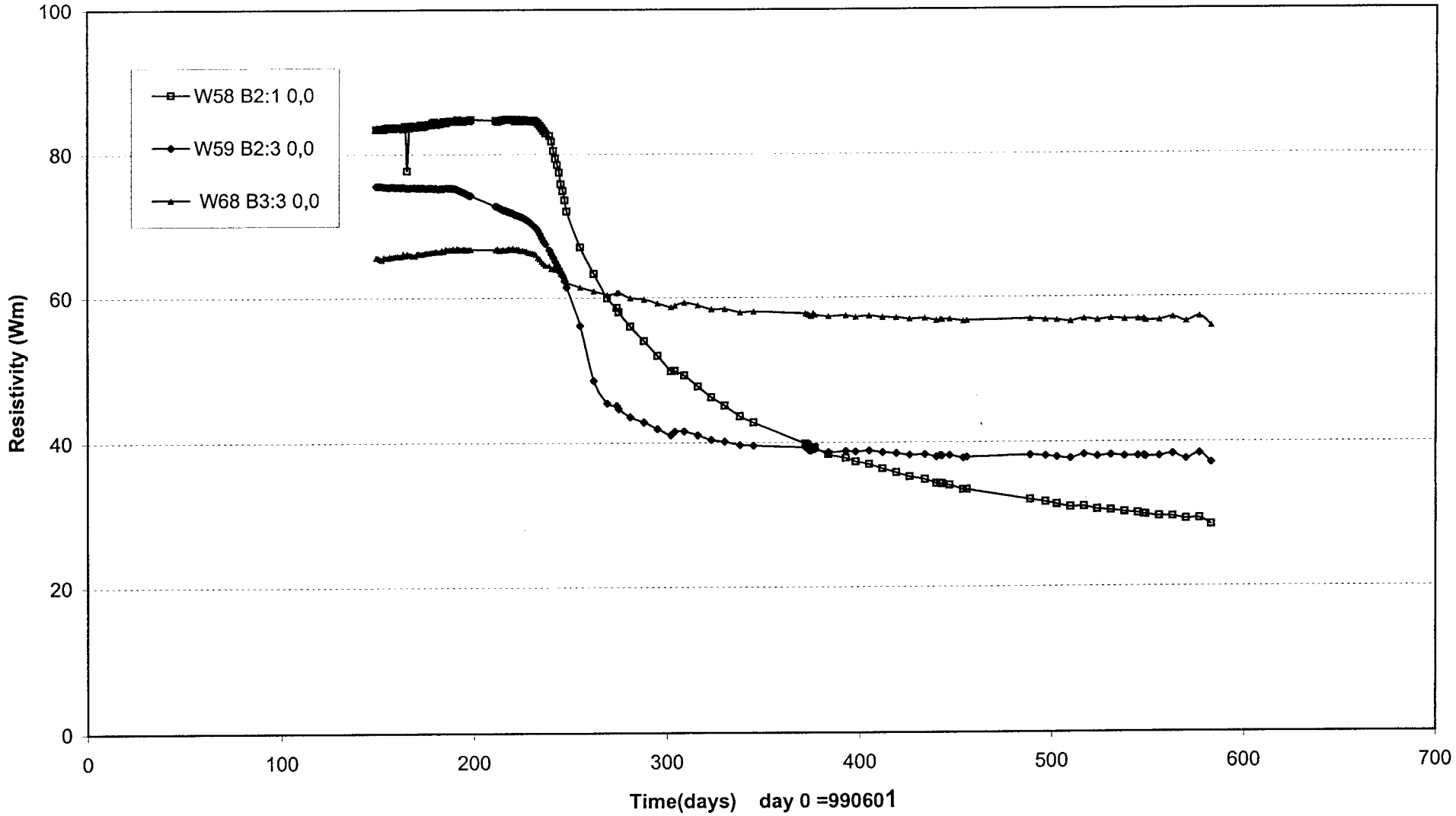
## Suction in backfill sections A5&A6 (990601-010101)
## WESCOR

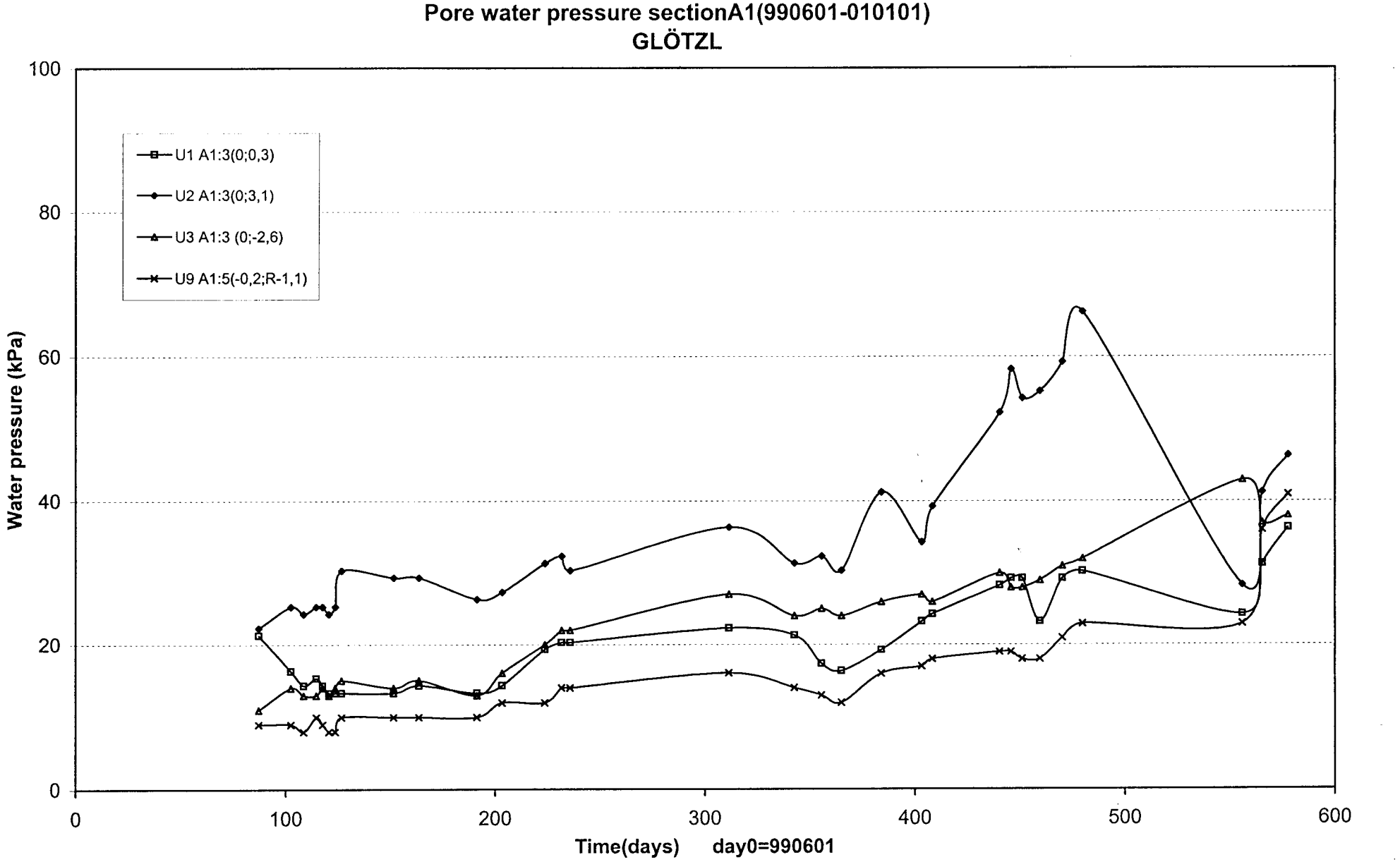


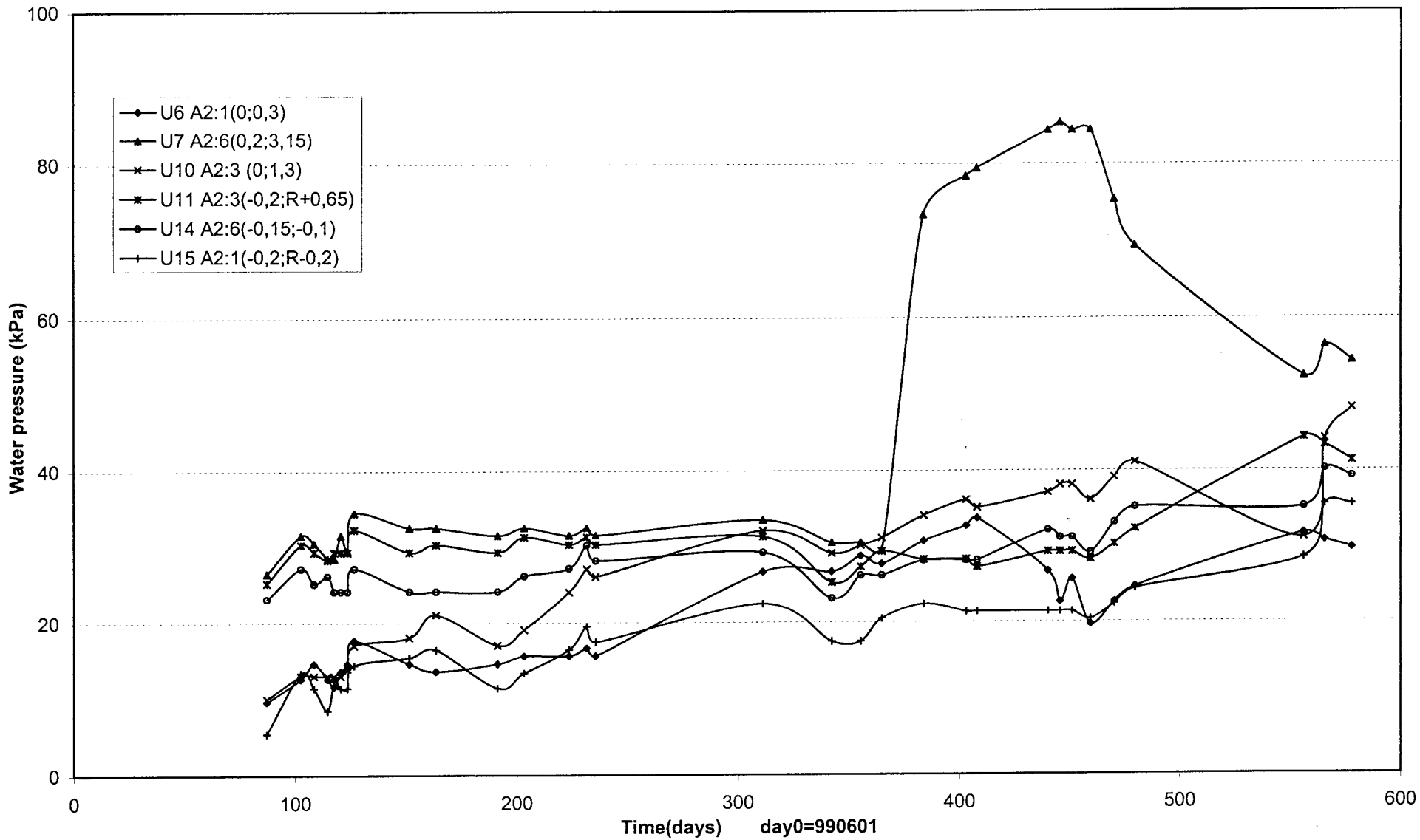
## Resistivity in backfill sections B3, B4&B5 (990601-010101)
## LTH-probe

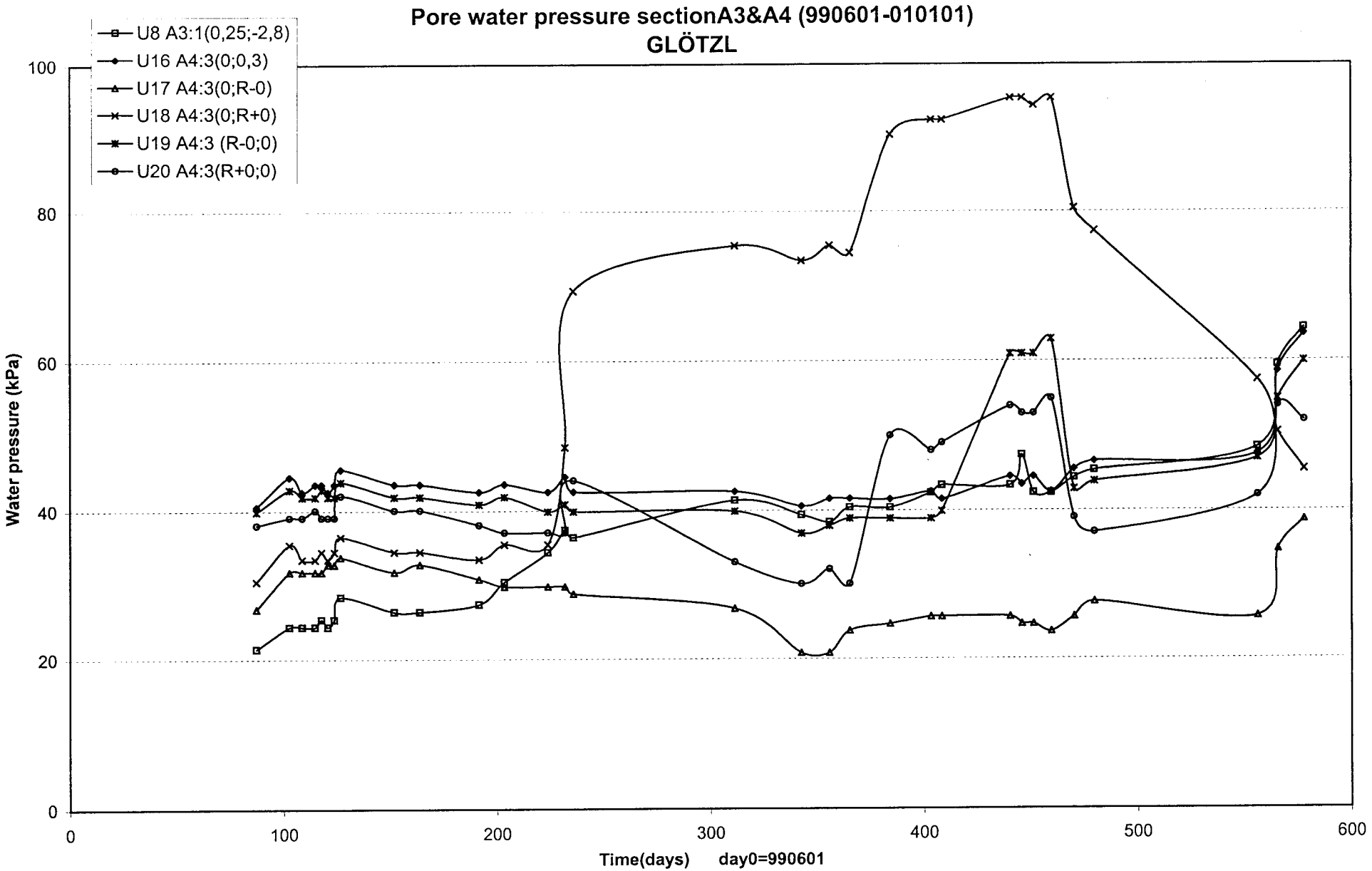


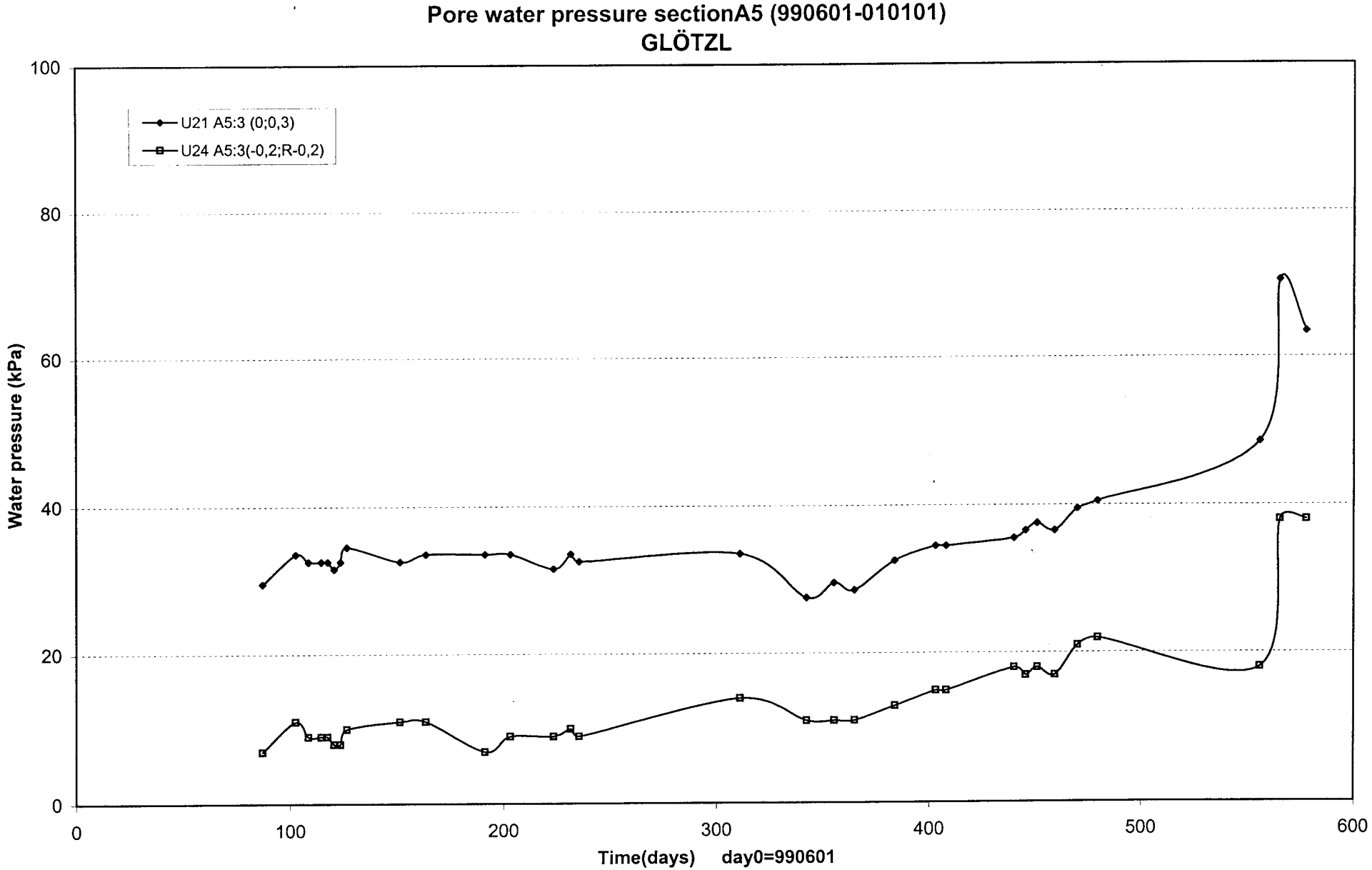
**Resistivity in backfill sections B2 (990601-010101)**
**LTH-probe**



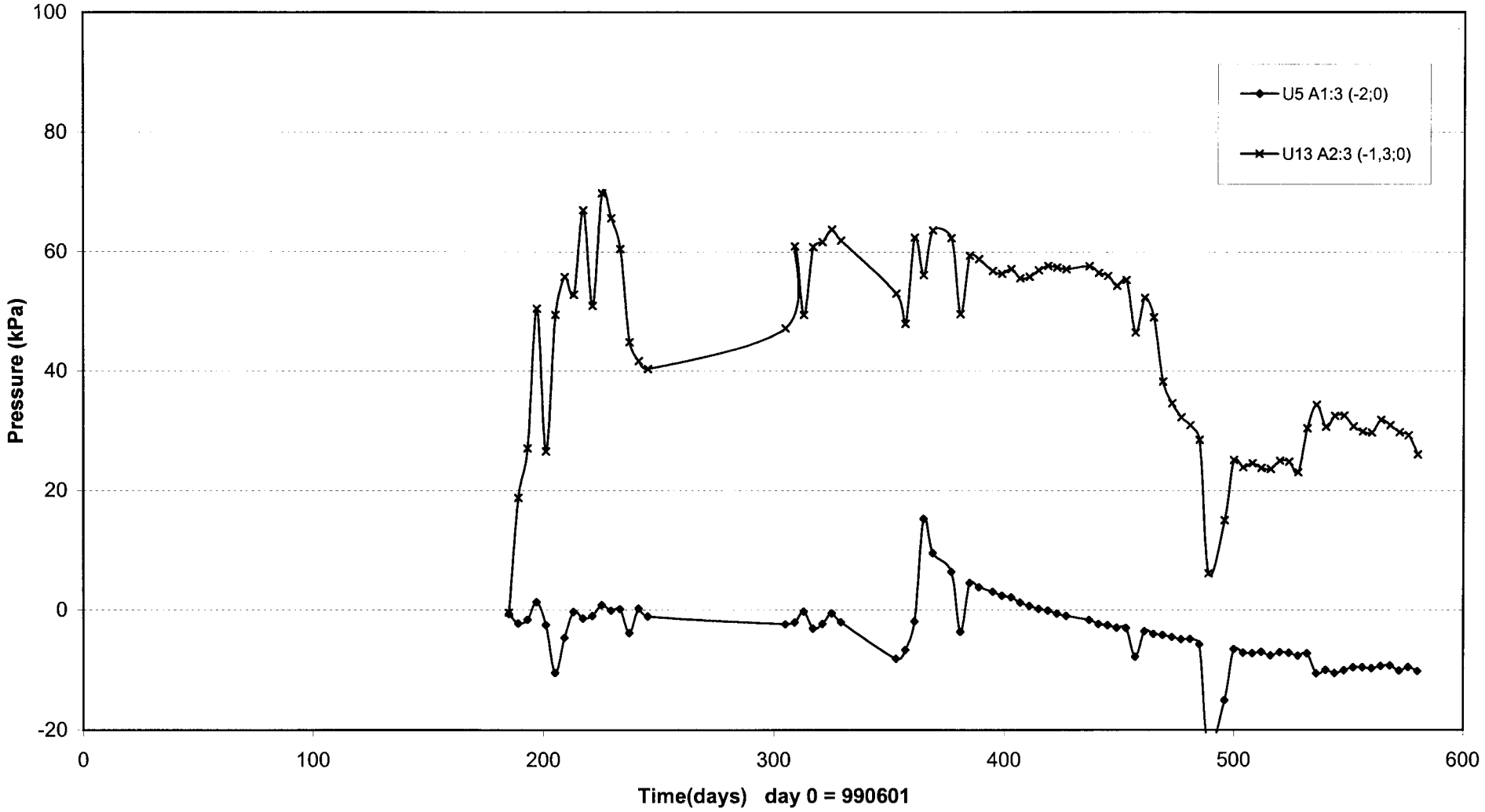

Pore water pressure sectionA1(990601-010101)
GLÖTZL
U1 A1:3(0;0,3)
U2 A1:3(0;3,1)
U3 A1:3 (0;-2,6)
U9 A1:5(-0,2;R-1,1)
Water pressure (kPa)
0
20
40
60
80
100
0
100
200
300
400
500
600
Time(days) day0=990601


Pore water pressure sectionA2 (990601-010101)
GLÖTZL
U6 A2:1(0;0,3)
U7 A2:6(0,2;3,15)
U10 A2:3 (0;1,3)
U11 A2:3(-0,2;R+0,65)
U14 A2:6(-0,15;-0,1)
U15 A2:1(-0,2;R-0,2)
Water pressure (kPa)
0
20
40
60
80
100
0
100
200
300
400
500
600
Time(days) day0=990601

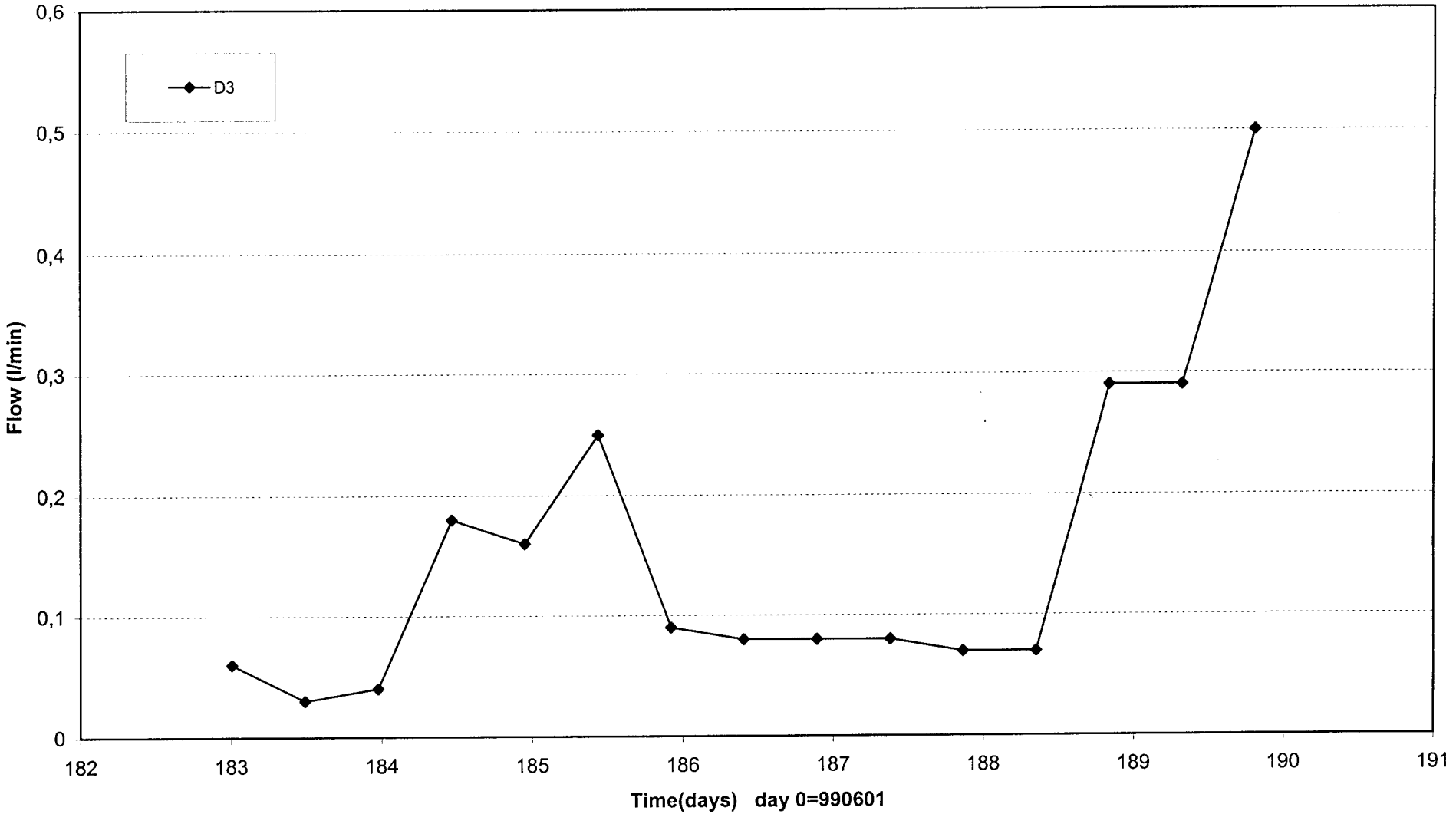

Pore water pressure sectionA3&A4 (990601-010101)
GLÖTZL
U8 A3:1(0,25;-2,8)
U16 A4:3(0;0,3)
U17 A4:3(0;R-0)
U18 A4:3(0;R+0)
U19 A4:3 (R-0;0)
U20 A4:3(R+0;0)
Water pressure (kPa)
0
20
40
60
80
100
0
100
200
300
400
500
600
Time(days) day0=990601


Pore water pressure sectionA5 (990601-010101)
GLÖTZL
U21 A5:3 (0;0,3)
U24 A5:3(-0,2;R-0,2)
Water pressure (kPa)
100
80
60
40
20
0
0
100
200
300
400
500
600
Time(days) day0=990601

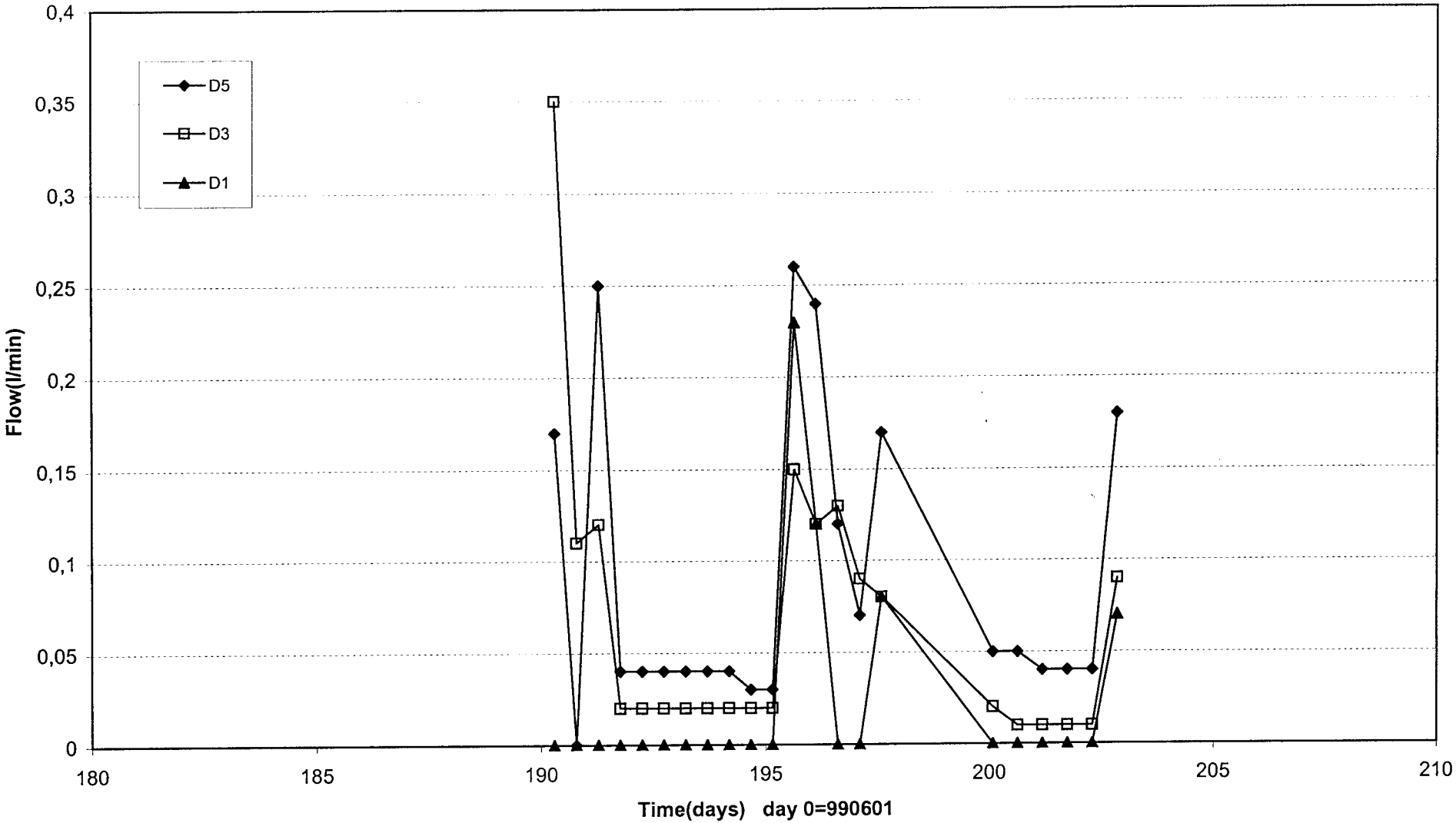
## Water pressure in backfill sections A1&A2 (990601-010101)
## DRUCK

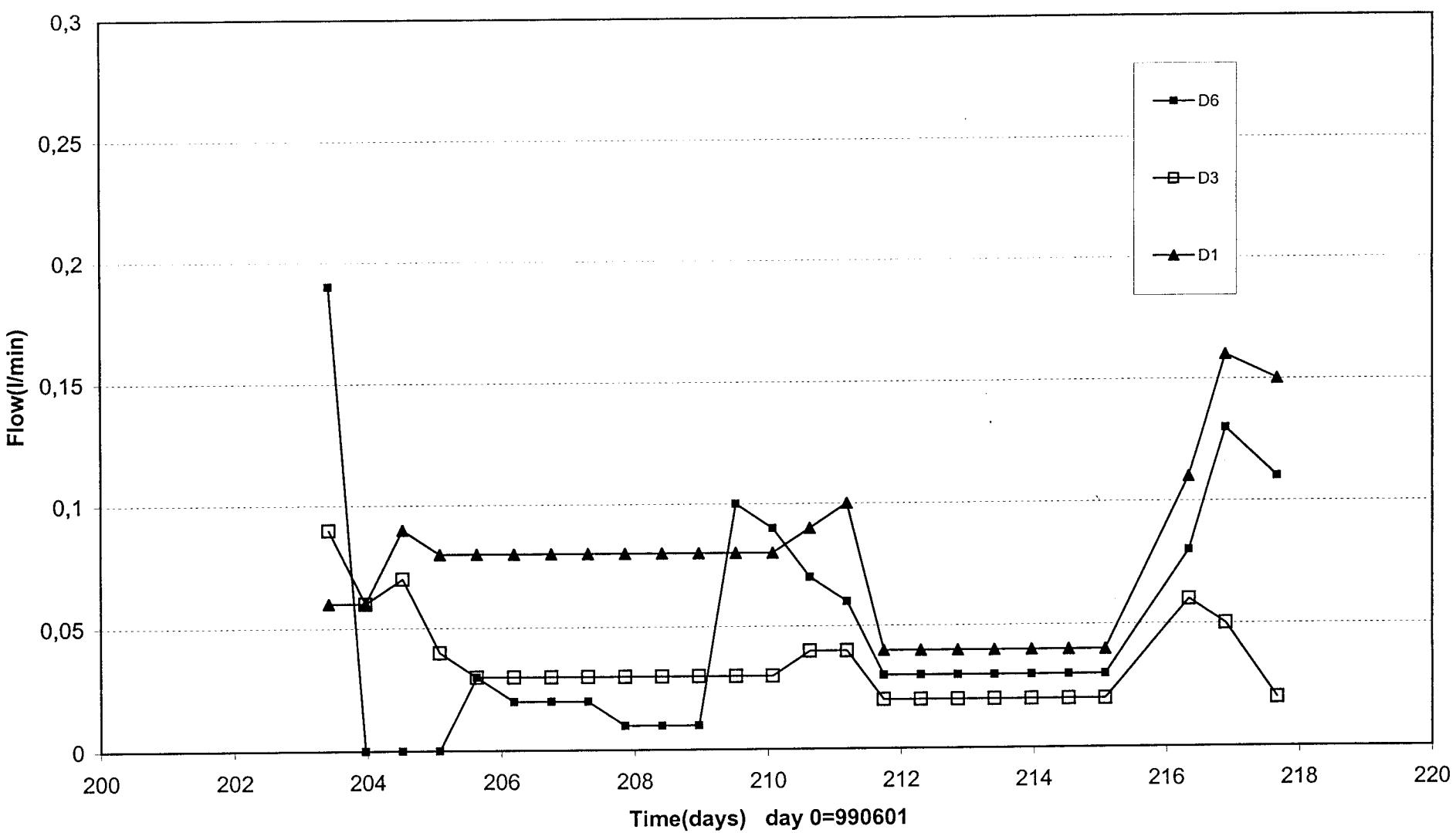


## Flowmeter

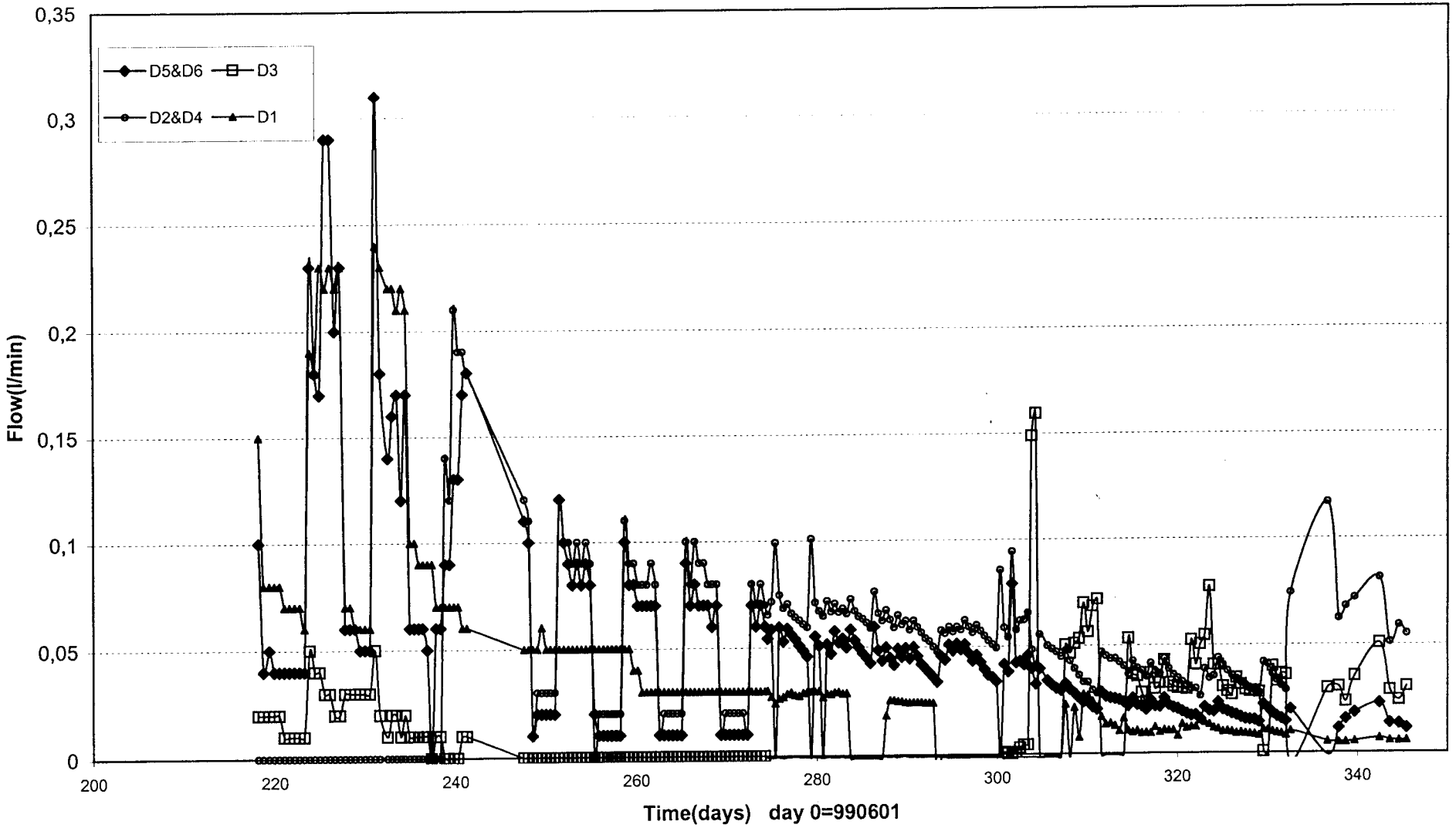

D3
0,6
0,5
0,4
0,3
0,2
0,1
0
Flow (l/min)
182
183
184
185
186
187
188
189
190
191
Time(days) day 0=990601

## Flowmeter

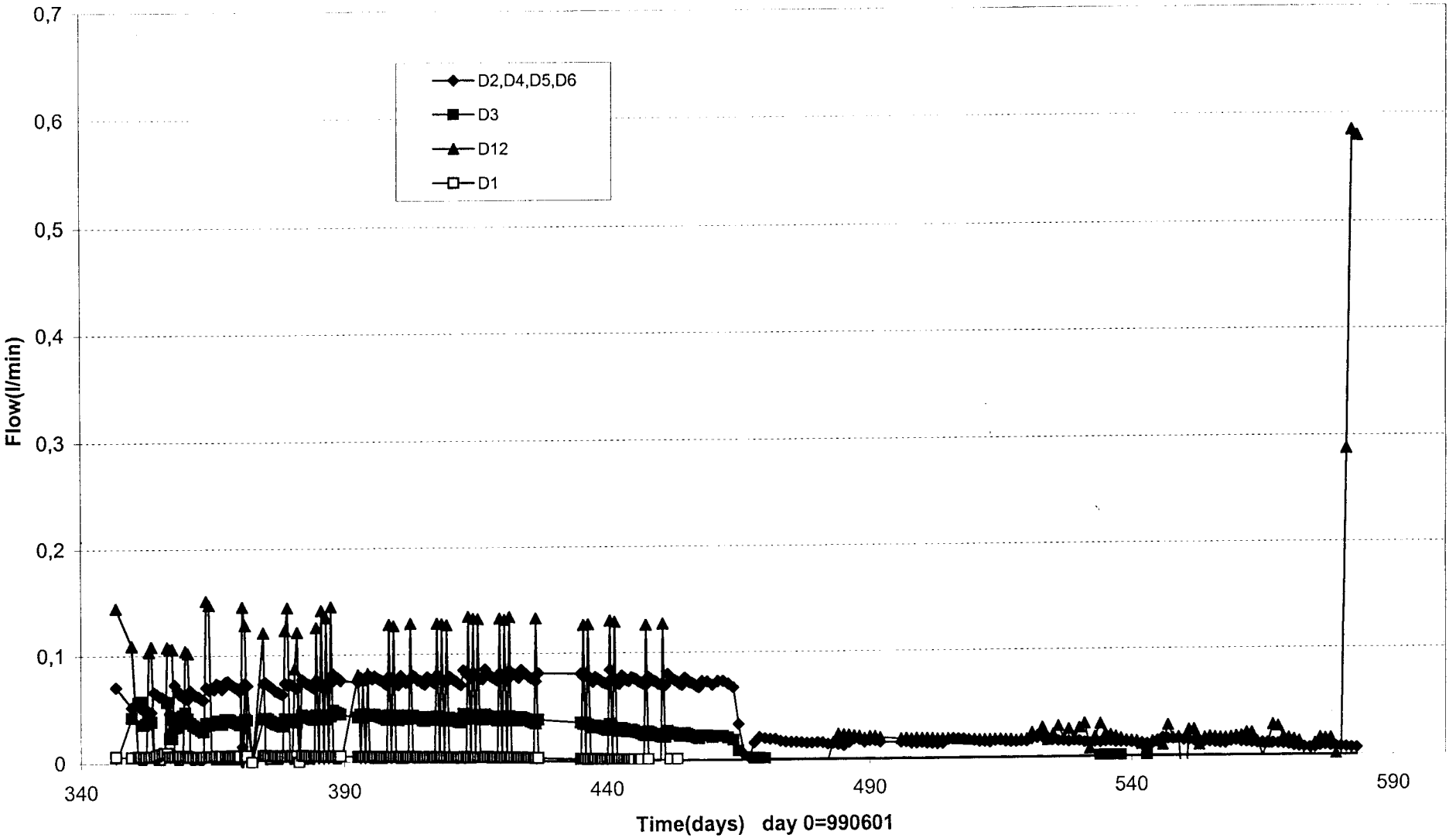

0,4
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
D5
D3
D1
Flow(l/min)
180
185
190
195
200
205
210
Time(days) day 0=990601


Flowmeter
0,3
0,25
0,2
0,15
0,1
0,05
0
Flow(l/min)
200
202
204
206
208
210
212
214
216
218
220
Time(days) day 0=990601
D6
D3
D1

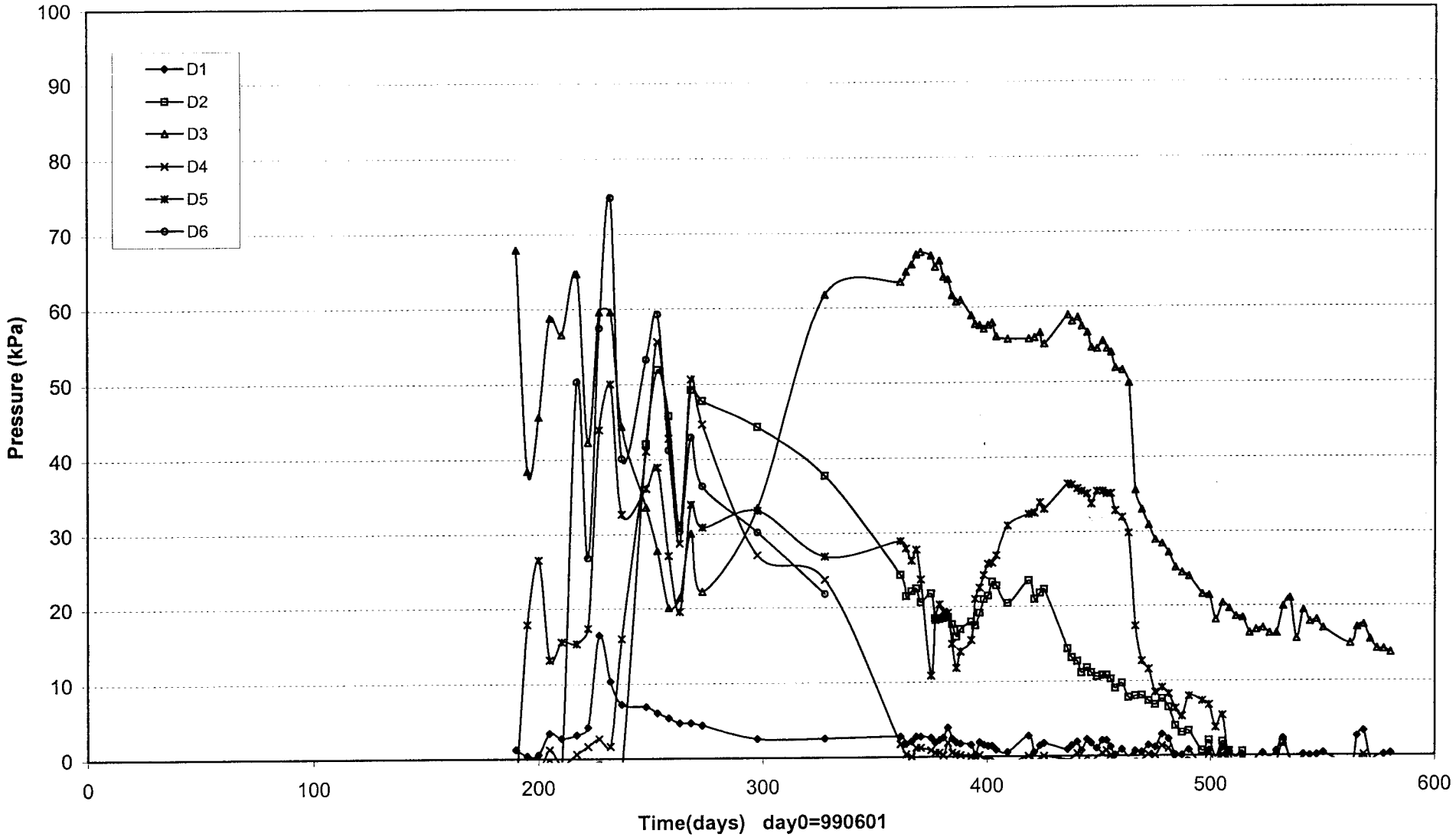
## Flowmeter


D5&D6
D3
D2&D4
D1
0,35
0,3
0,25
0,2
0,15
0,1
0,05
0
Flow(l/min)
200
220
240
260
280
300
320
340
Time(days) day 0=990601

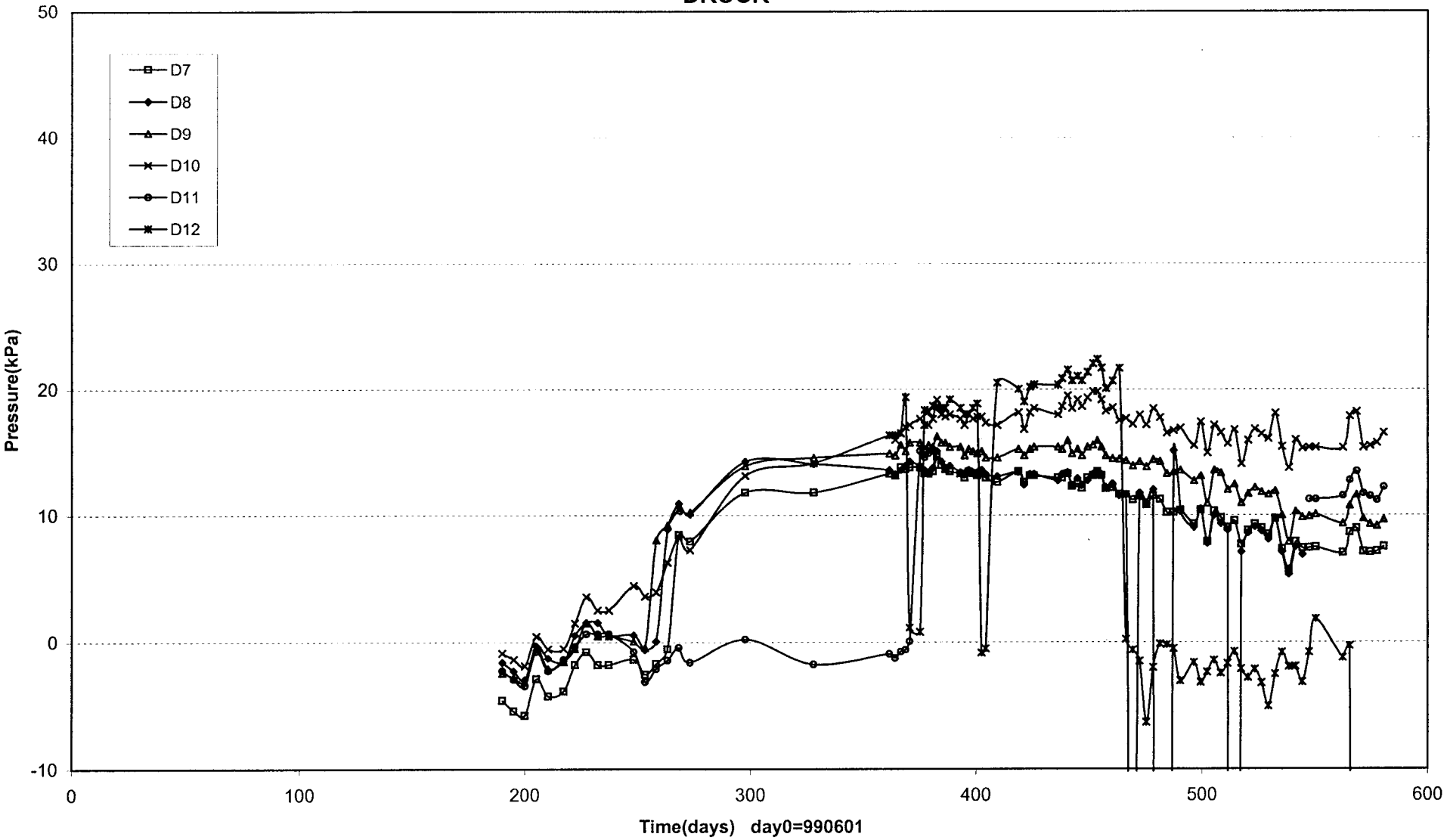
## Flowmeter(000601-010101)



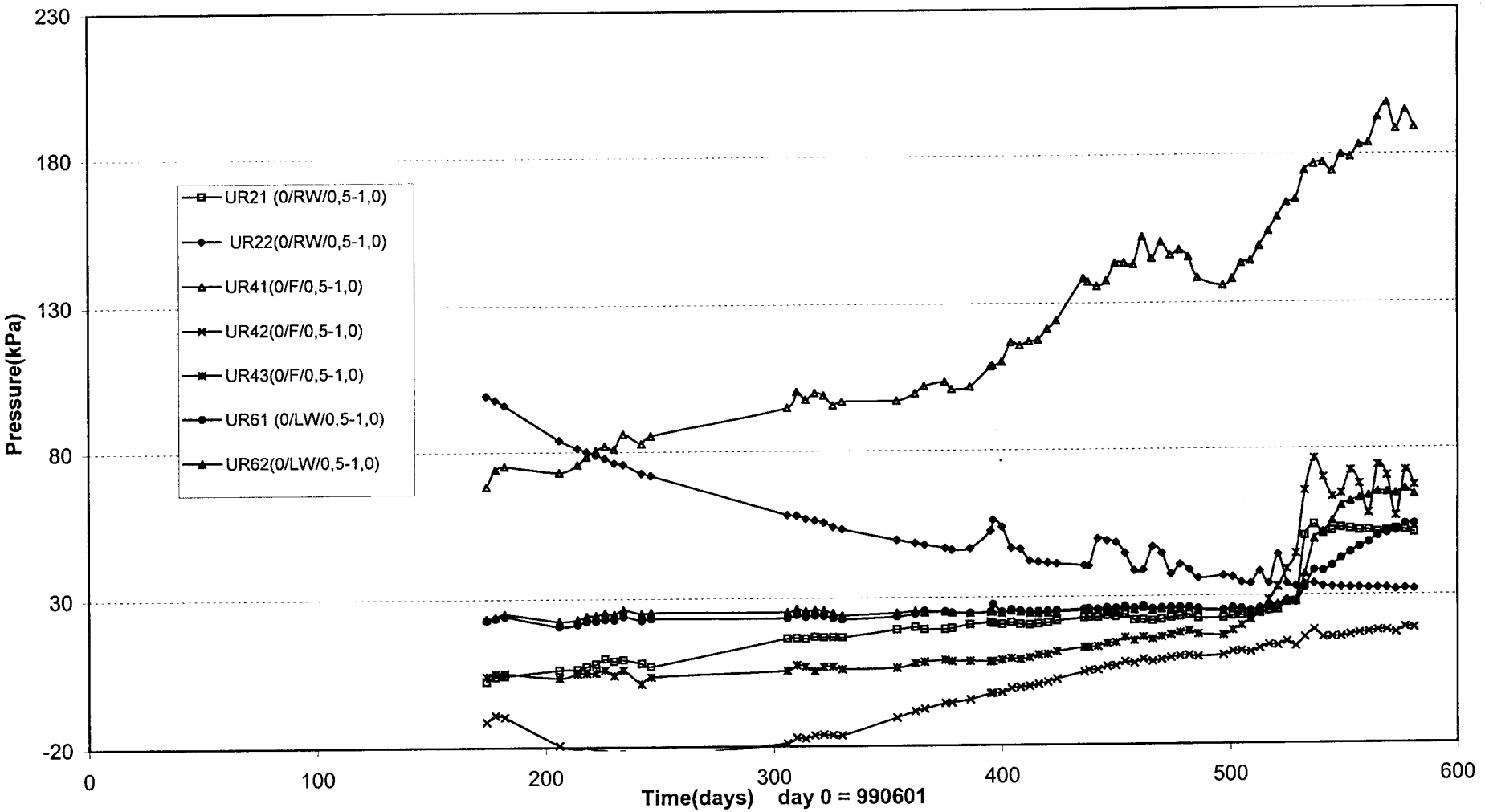
## Water pressure in permeable mats D1-D6 (990601-010101)
## Druck



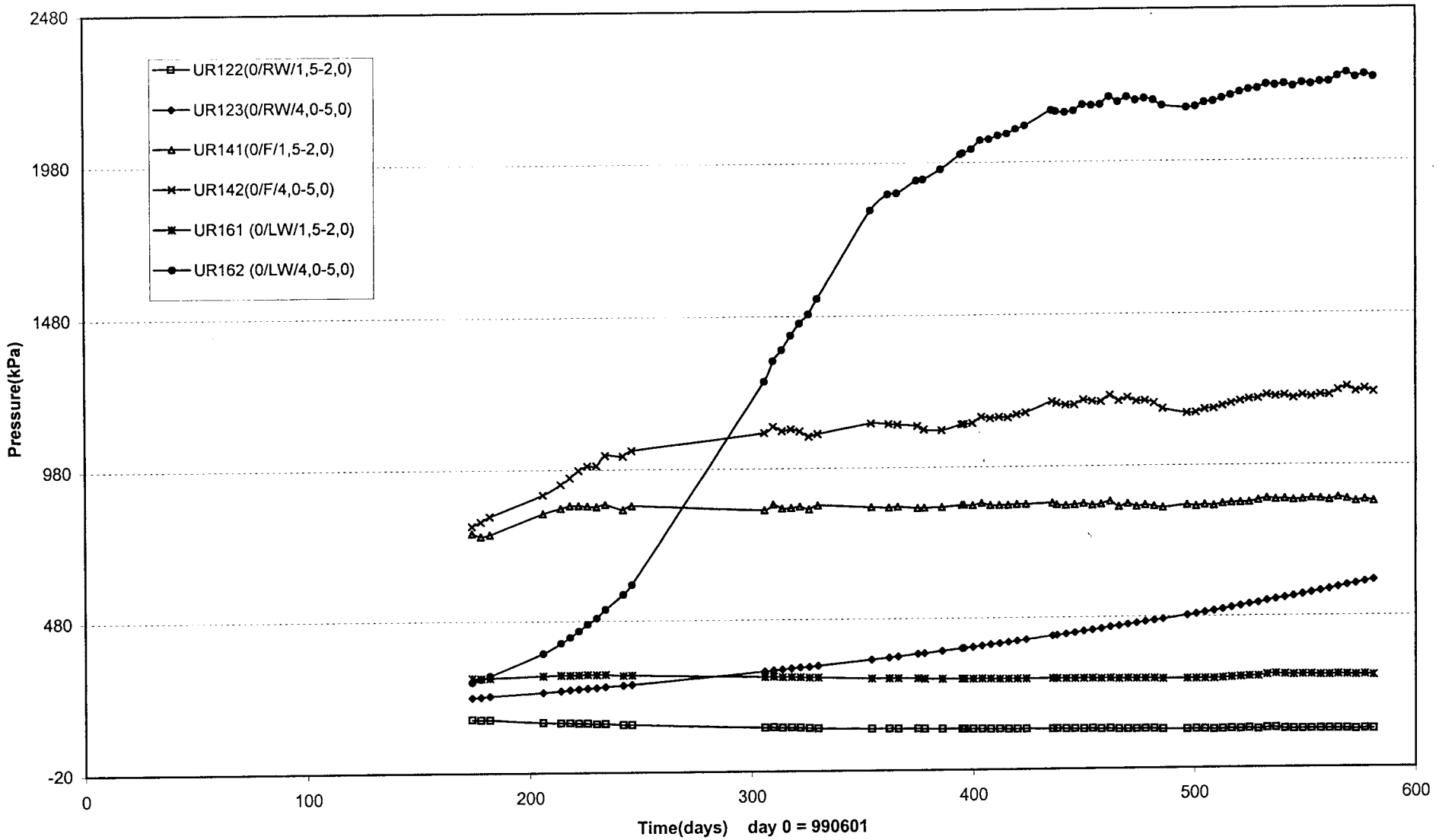
## Water pressure in permeable mats D7-D12 (990601-010101)
## DRUCK



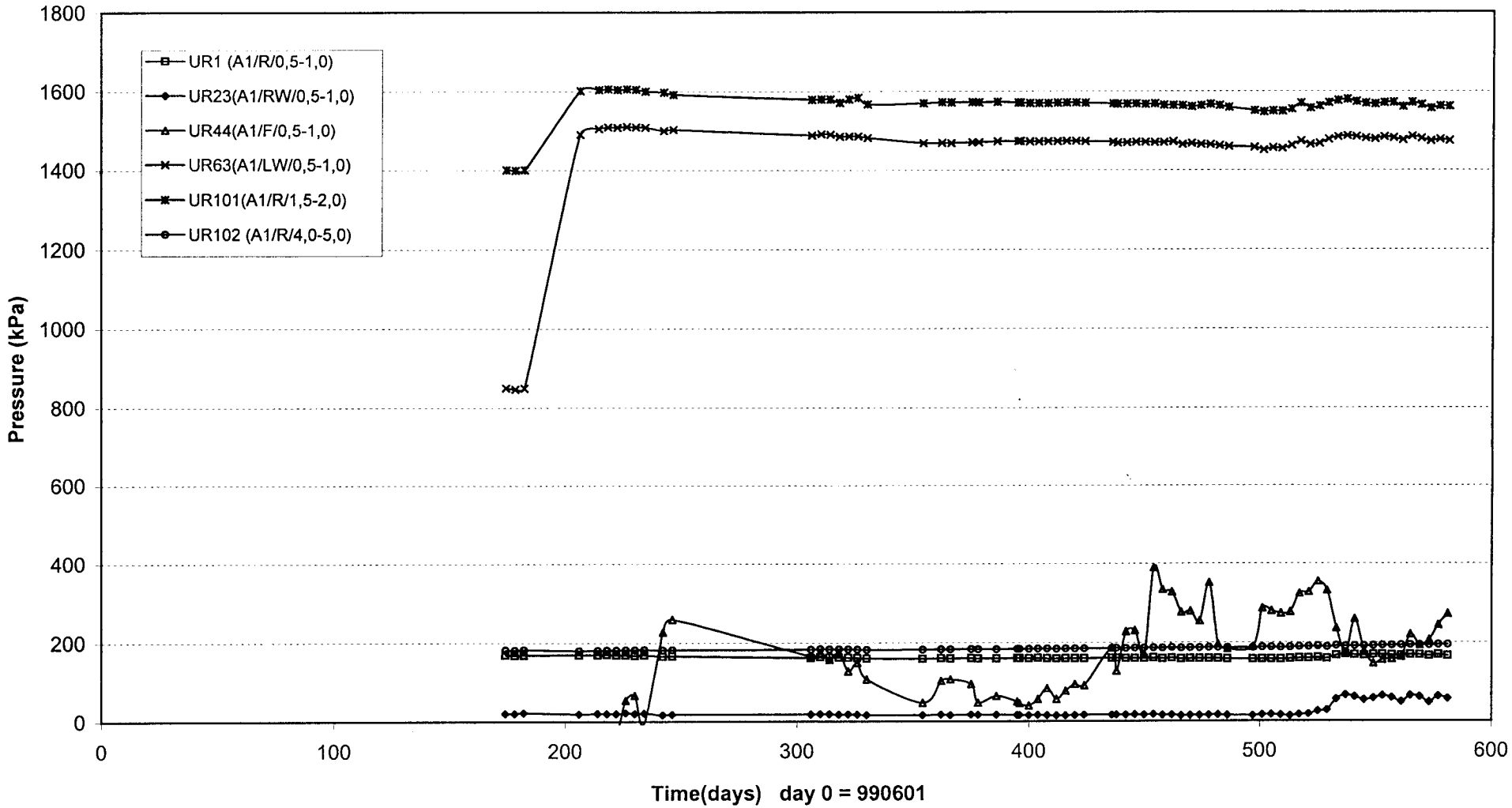
## Water pressure in bore holes section 0(990601-010101)
## DRUCK



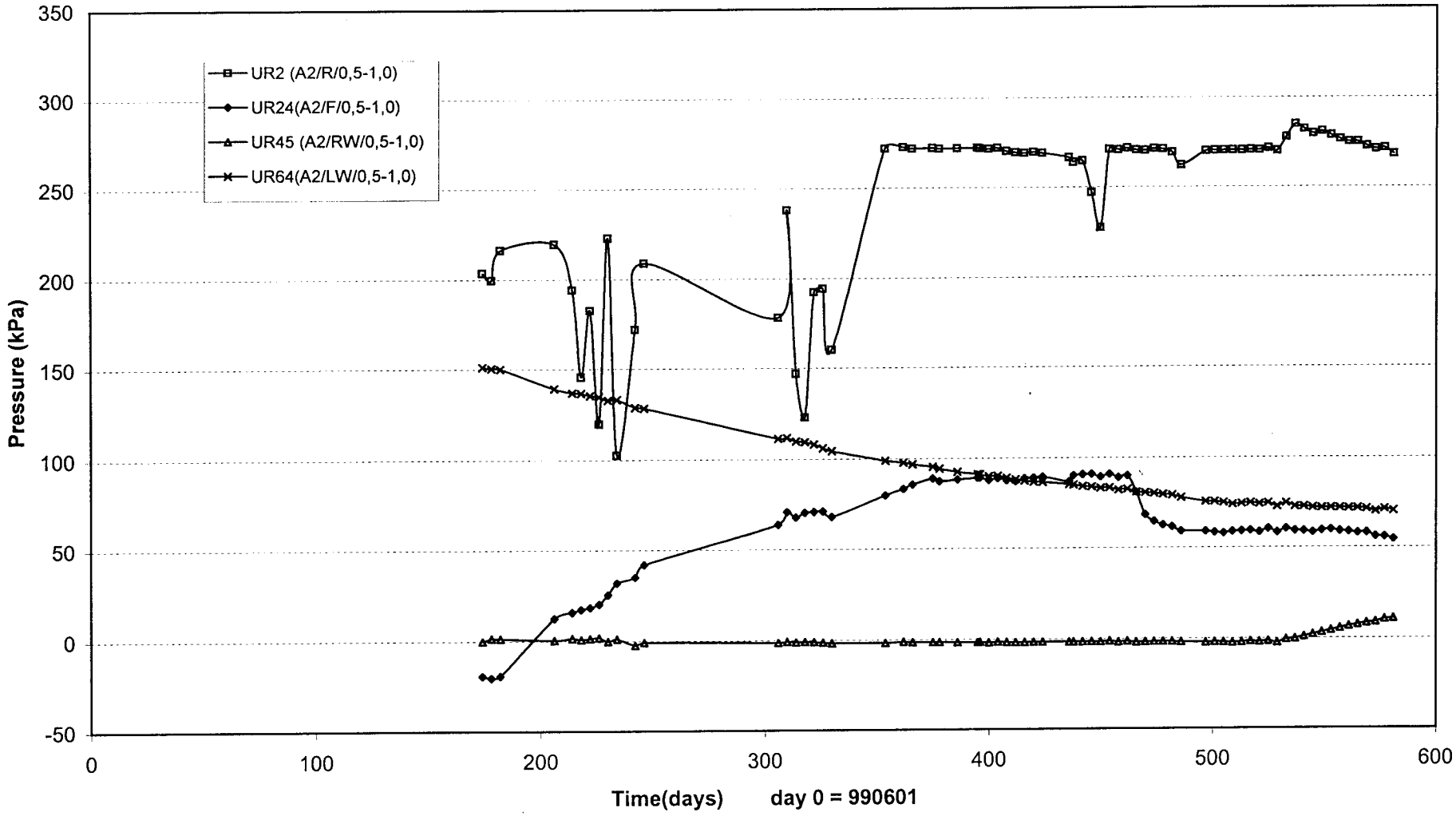
## Water pressure in bore holes section 0(990601-010101)
## DRUCK



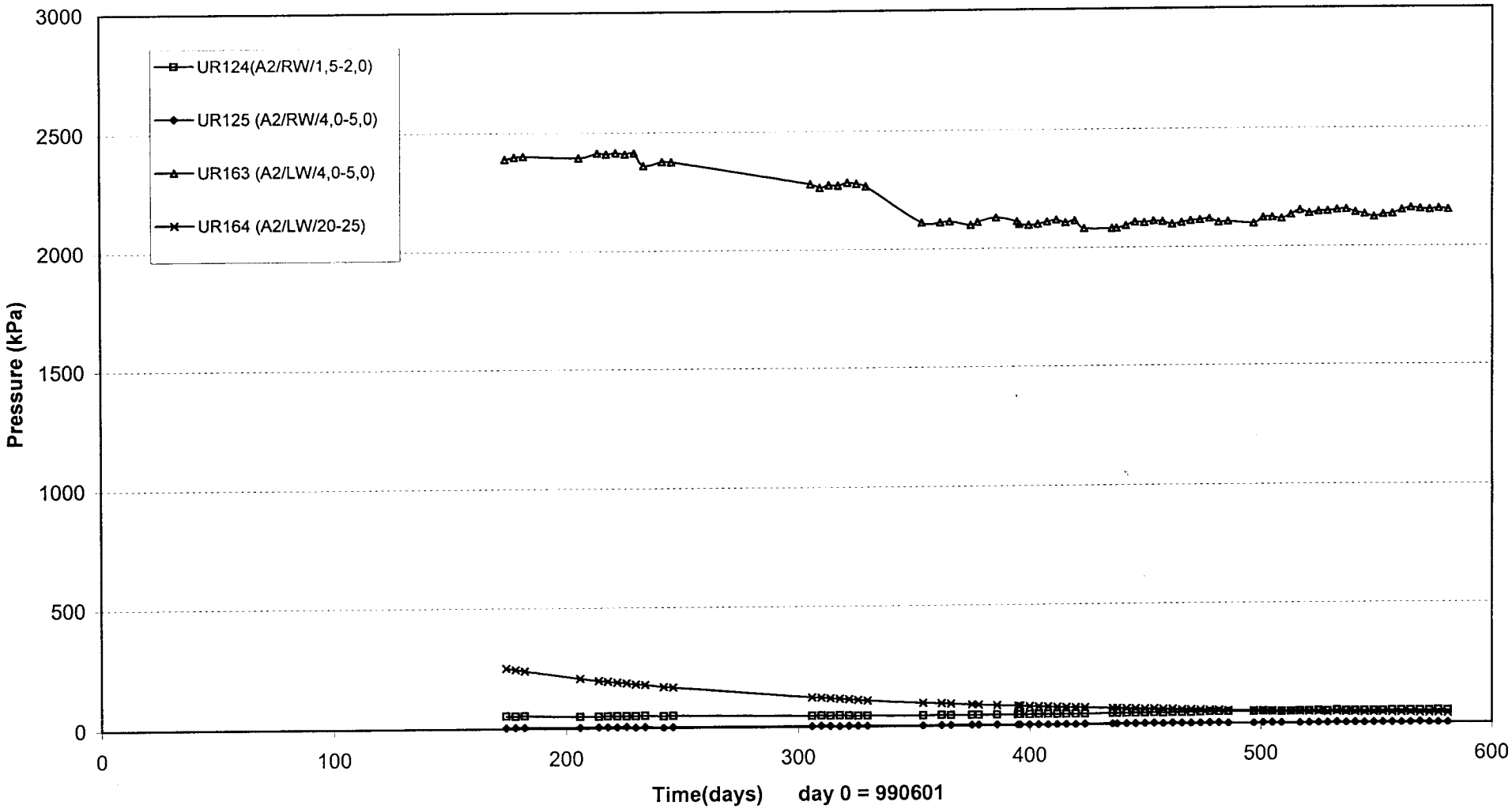
## Water pressure in bore holes sectionA1 (990601-010101)
## DRUCK



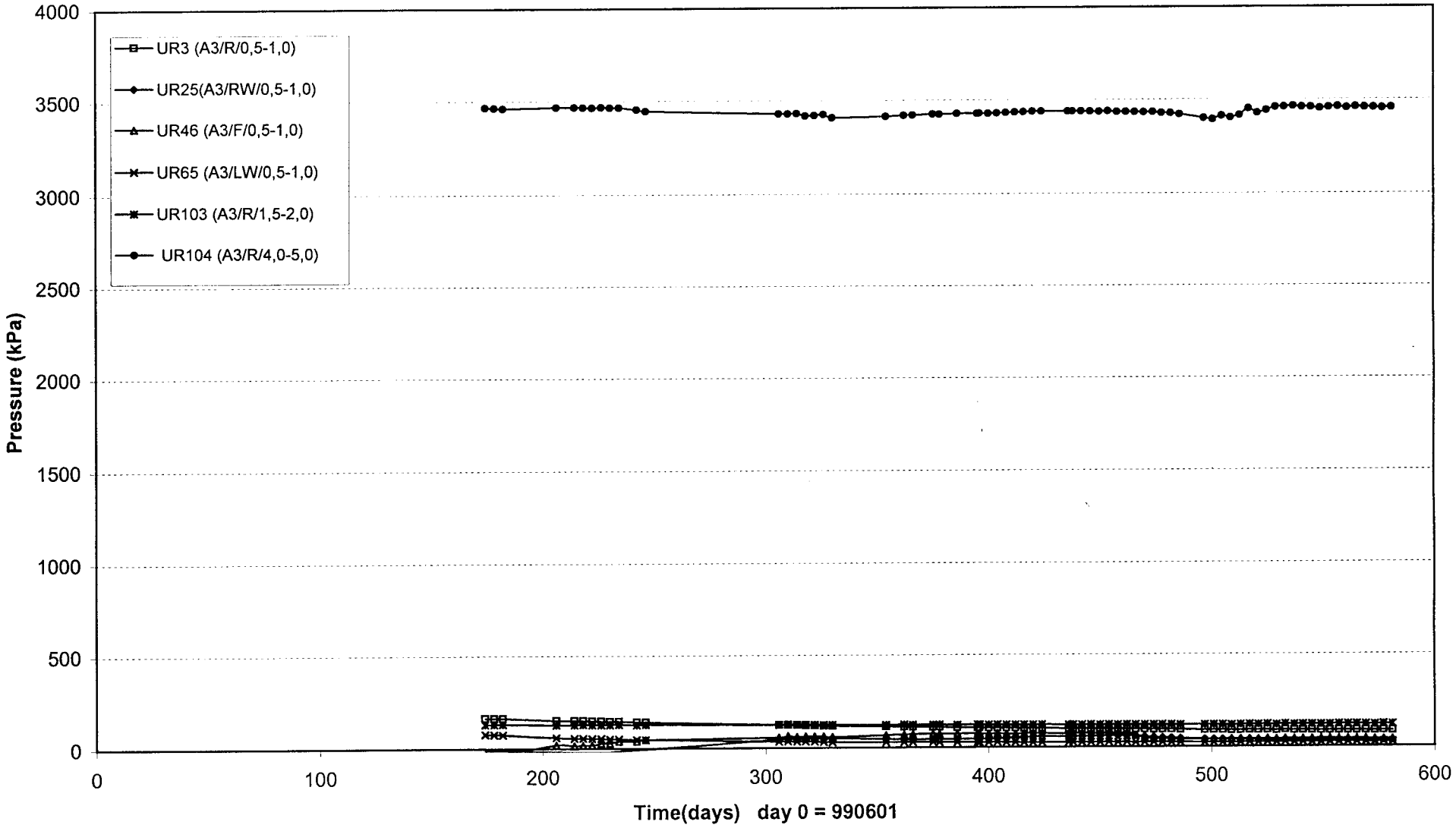
## Water pressure in bore holes sectionA2 (990601-010101)
## DRUCK



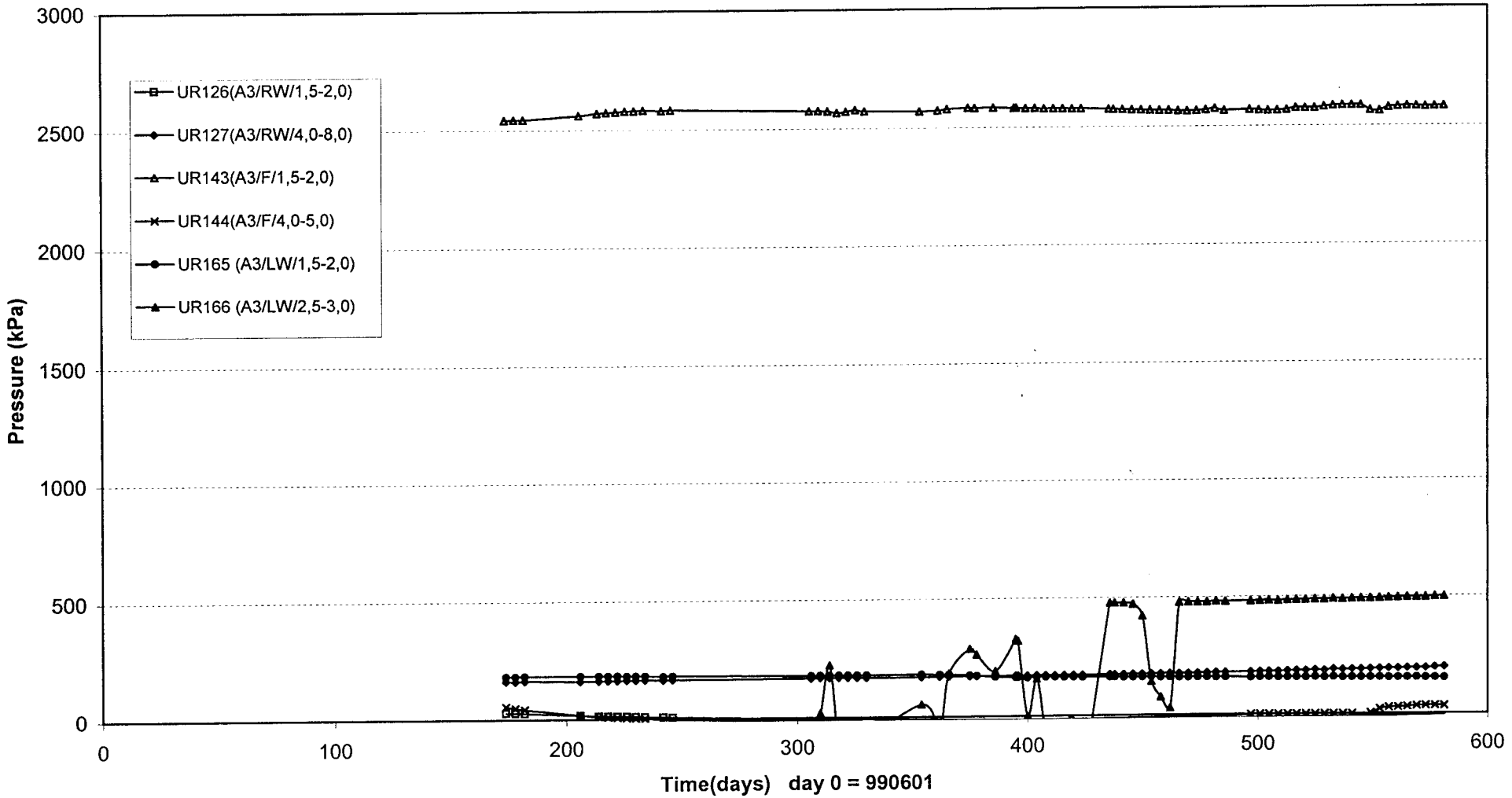
## Water pressure in bore holes sectionA2 (990601-010101)
## DRUCK



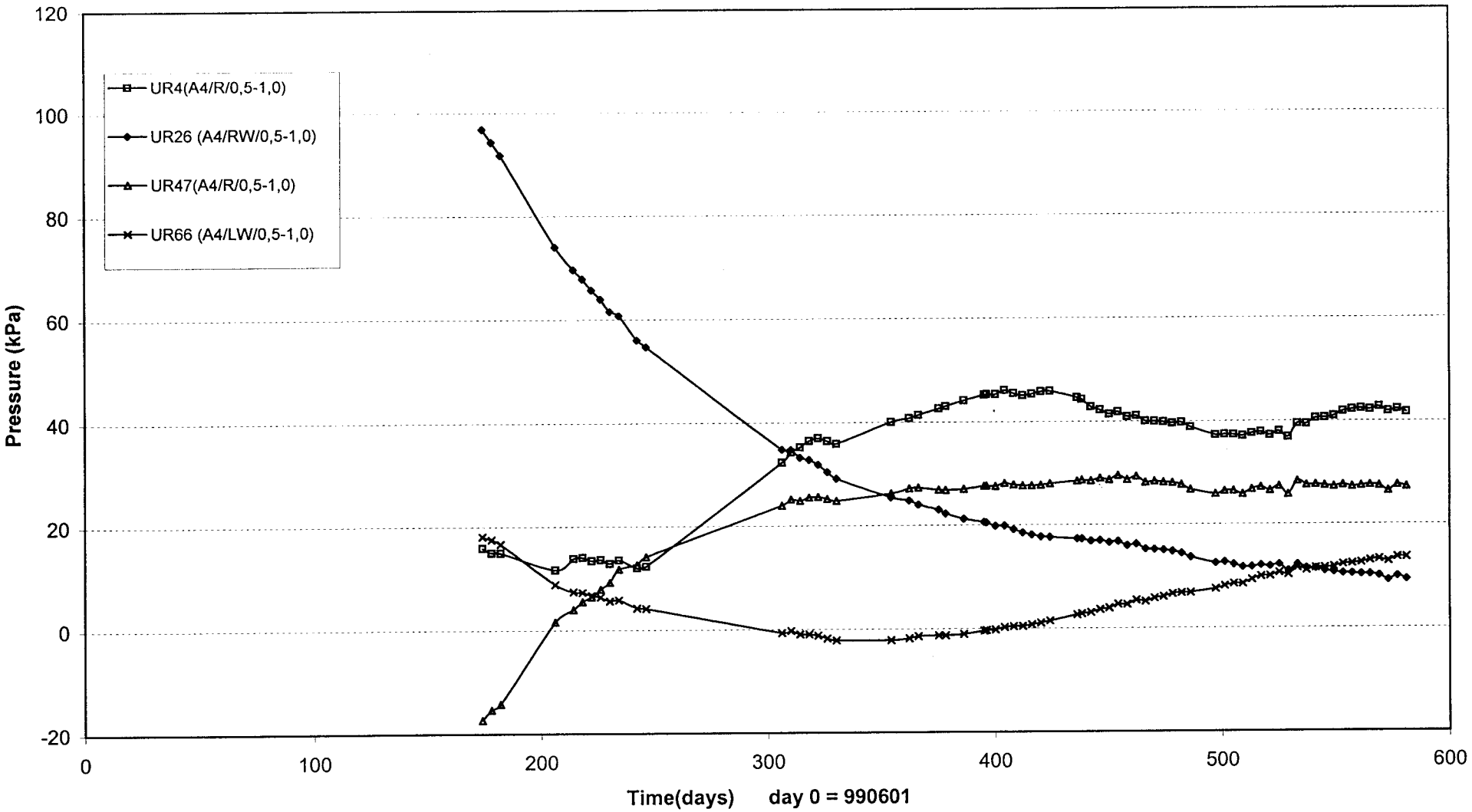
## Water pressure in bore holes sectionA3 (990601-010101)
## DRUCK



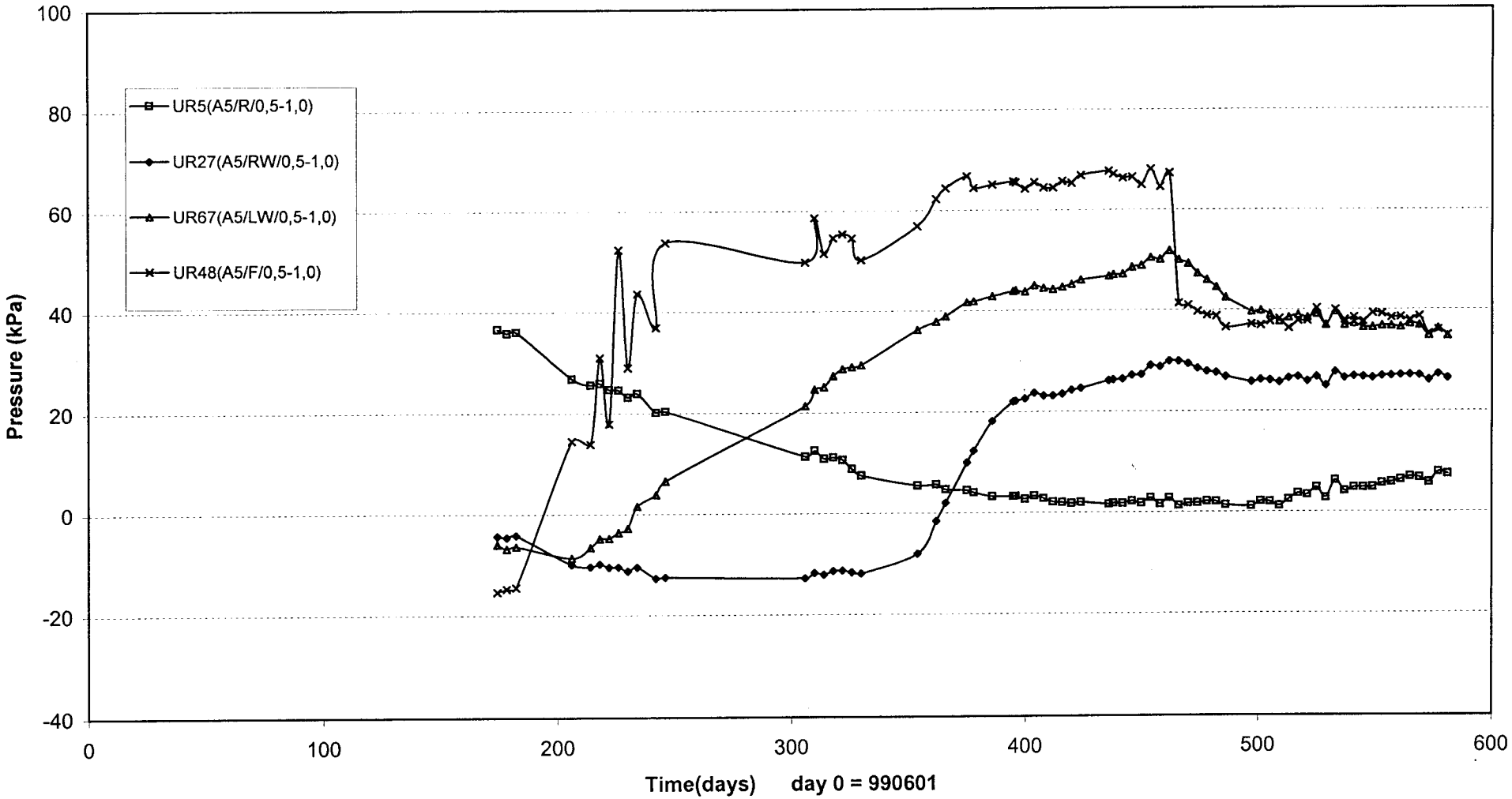
## Water pressure in bore holes sectionA3(990601-010101)
## DRUCK



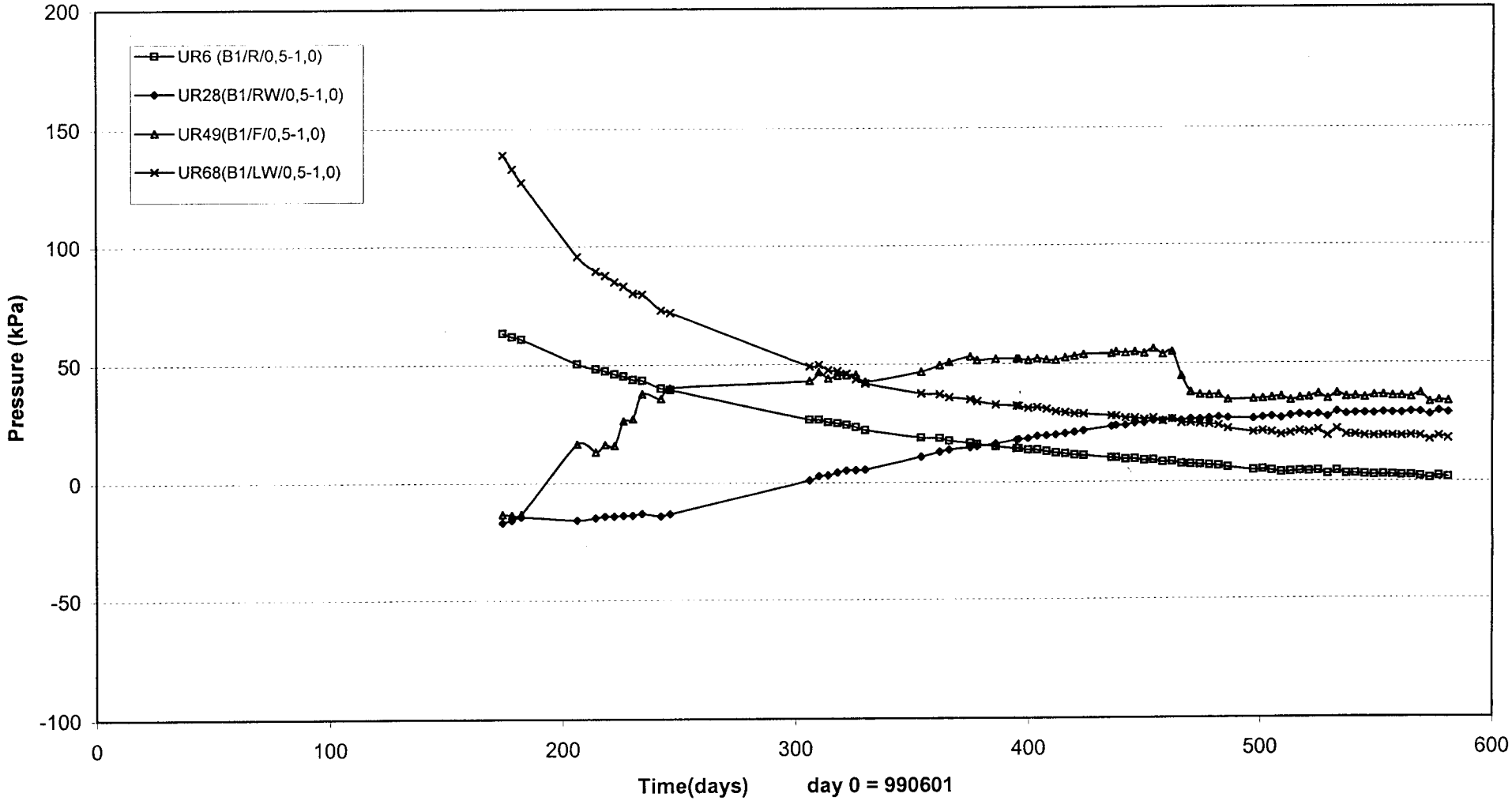
## Water pressure in bore holes sectionA4 (990601-010101)
## DRUCK



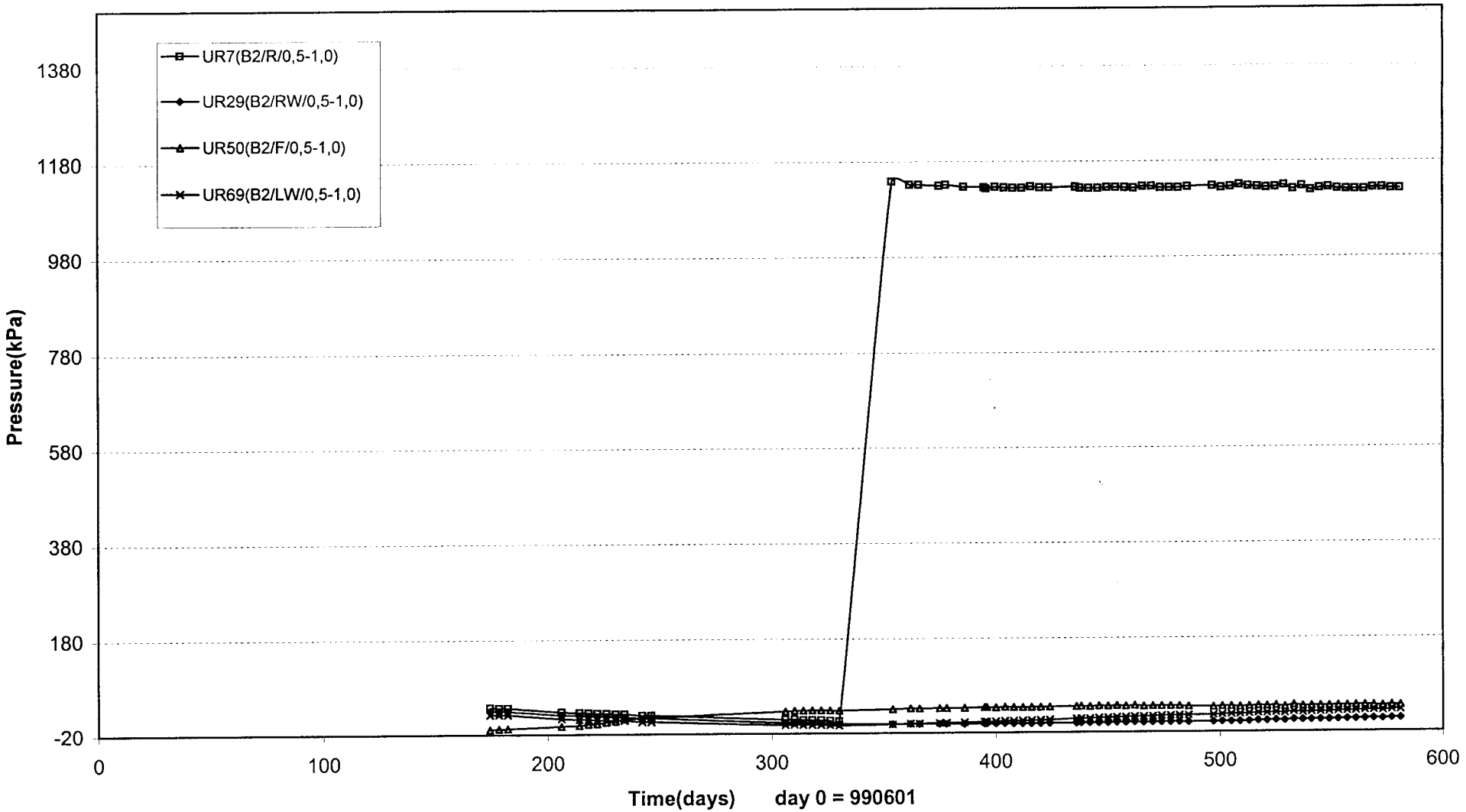
## Water pressure in bore holes sectionA5 (990601-010101)
## DRUCK



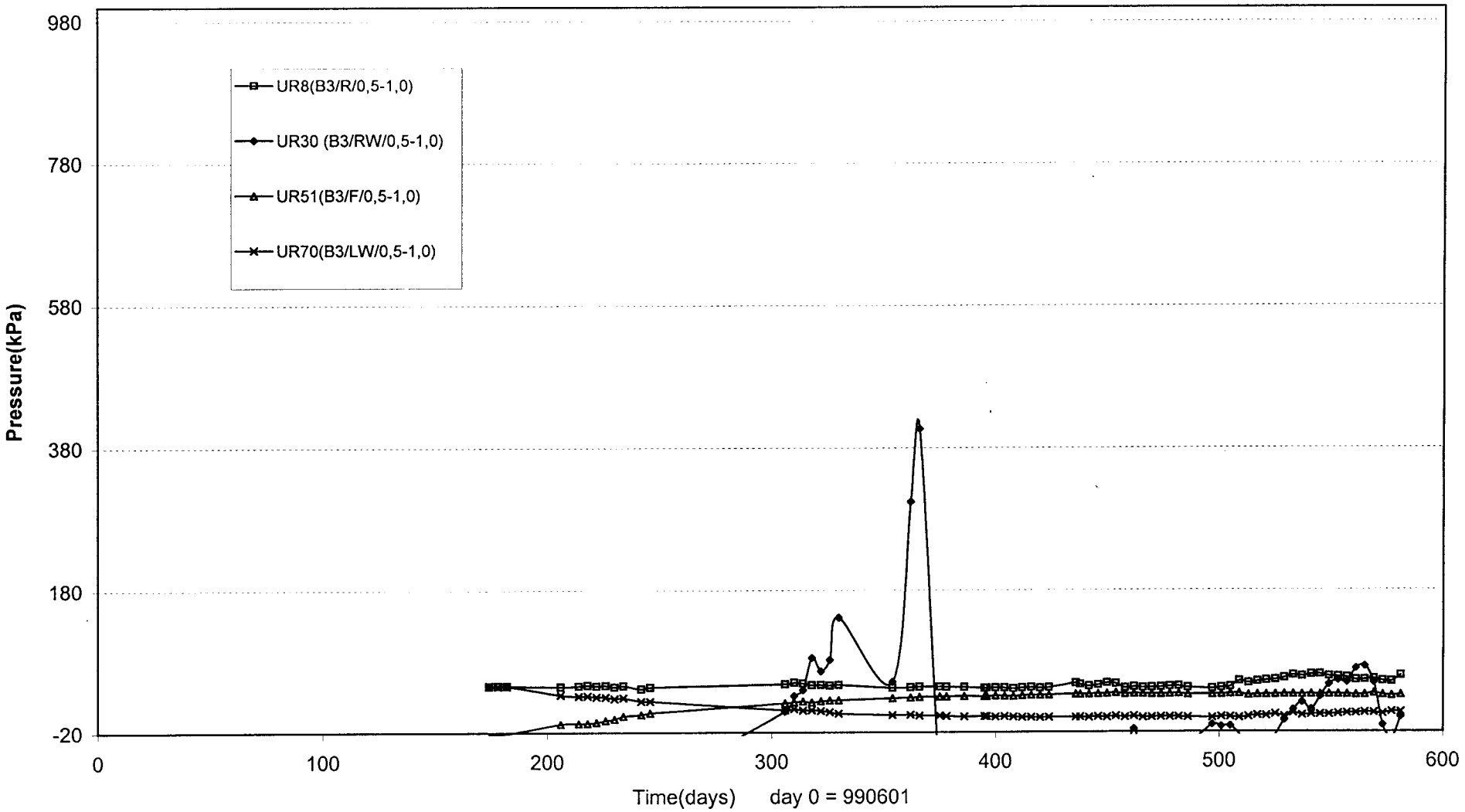
## Water pressure in bore holes sectionB1 (990601-010101)
## DRUCK



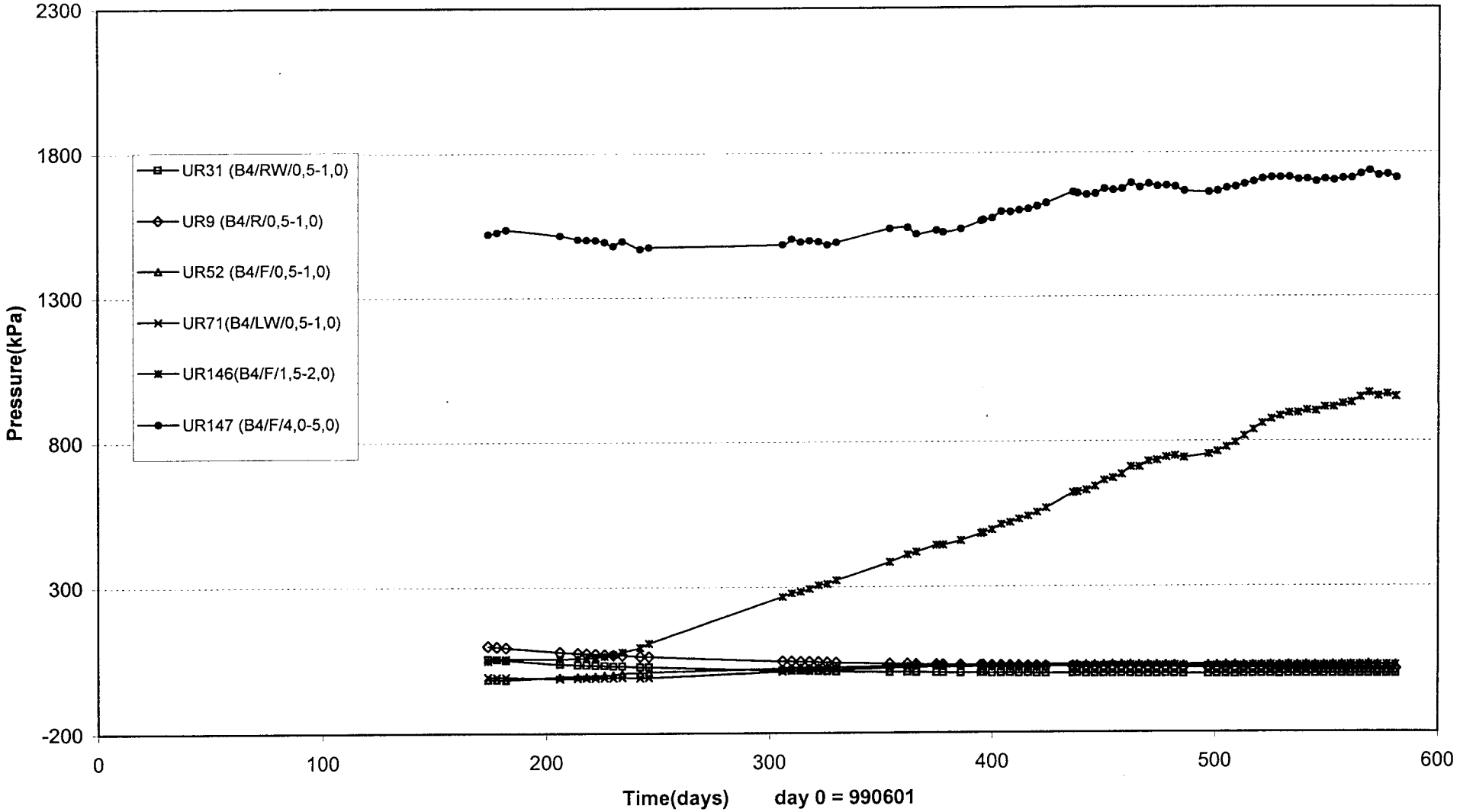
## Water pressure in bore holes sectionB2(990601-010101)
## DRUCK



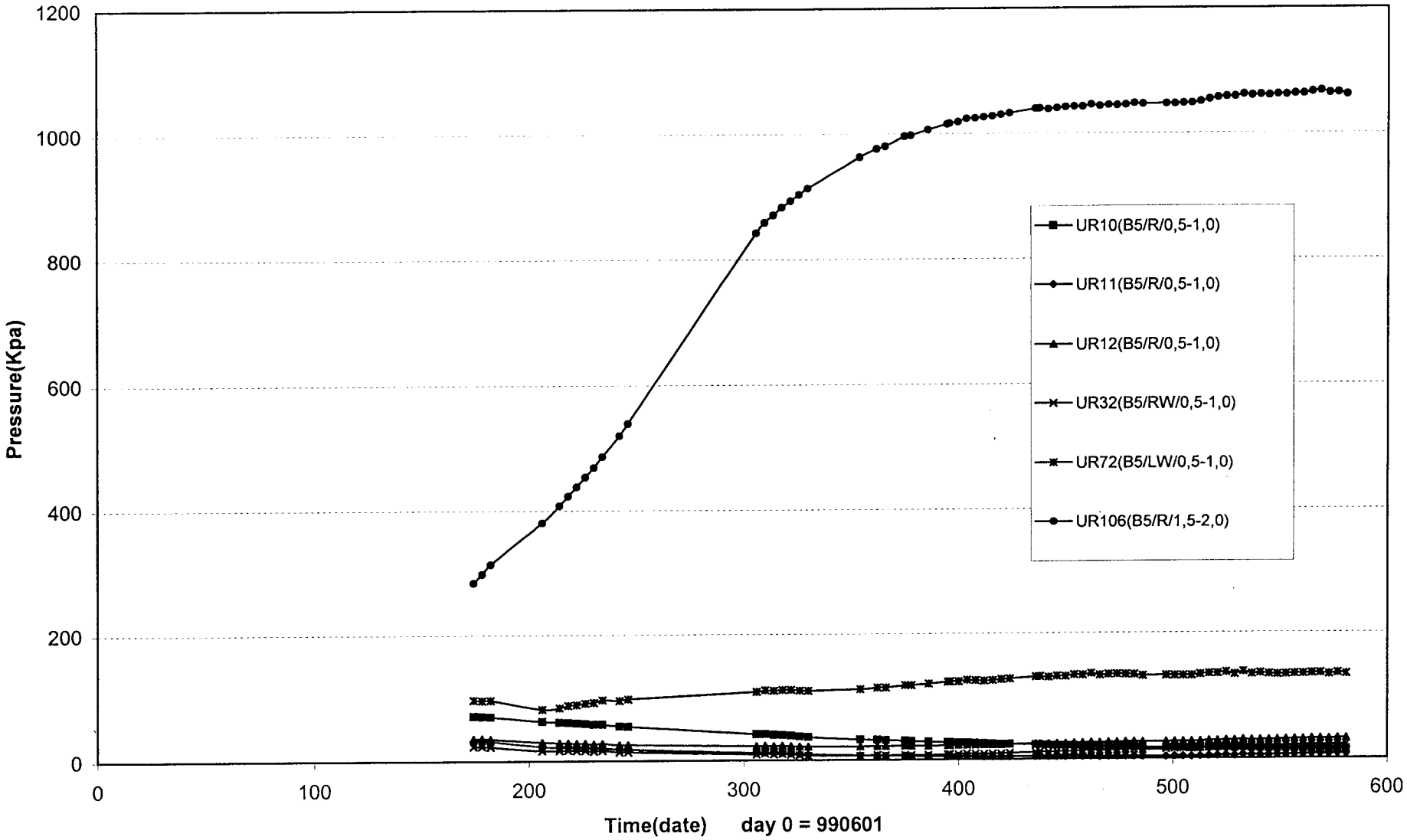
## Water pressure in bore holes sectionB3 (990601-010101)
## DRUCK



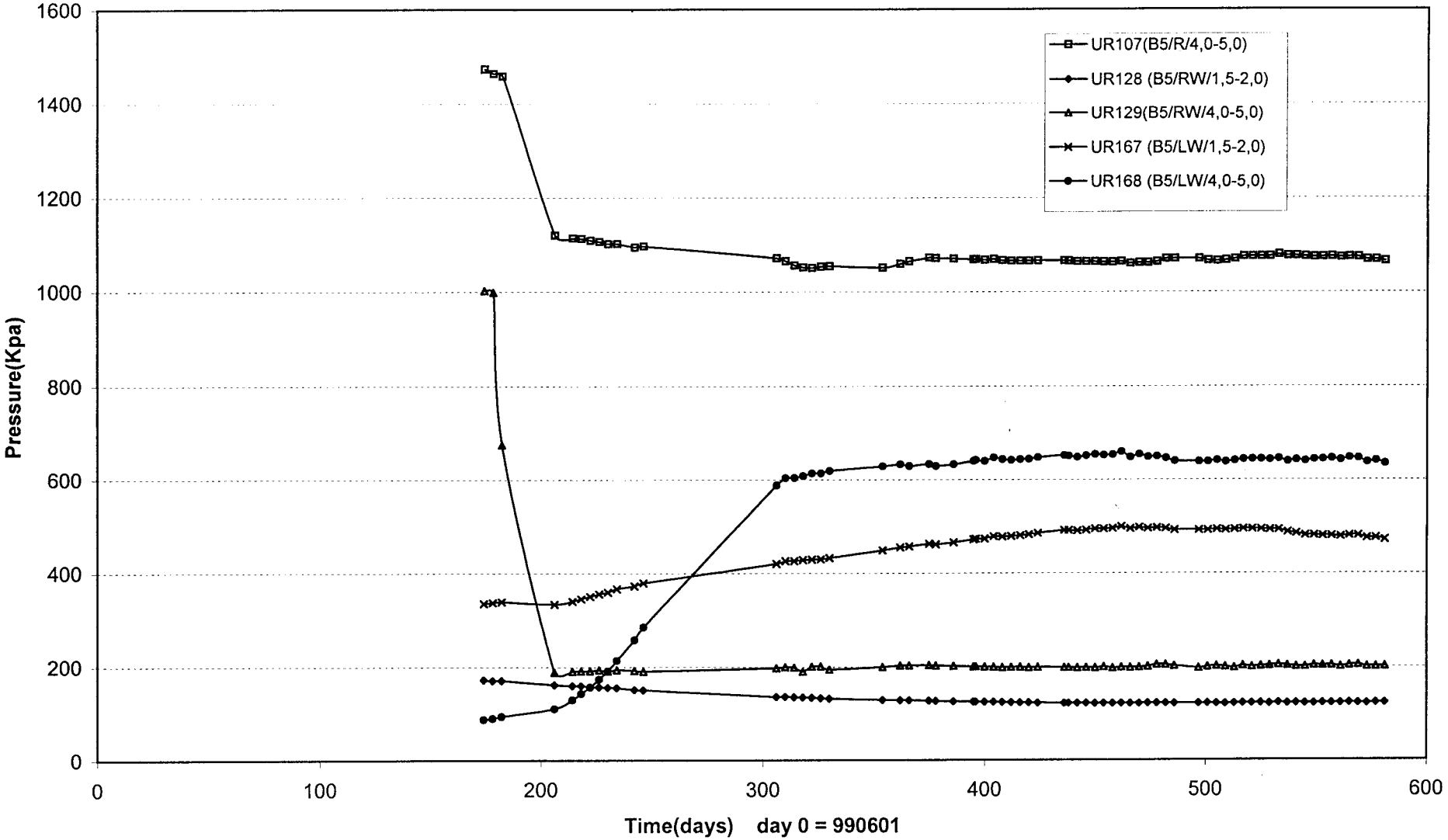
## Water pressure in bore holes sectionB4 (990601-010101)
## DRUCK



## Water pressure in bore holes section B5(990601-010101)
## DRUCK

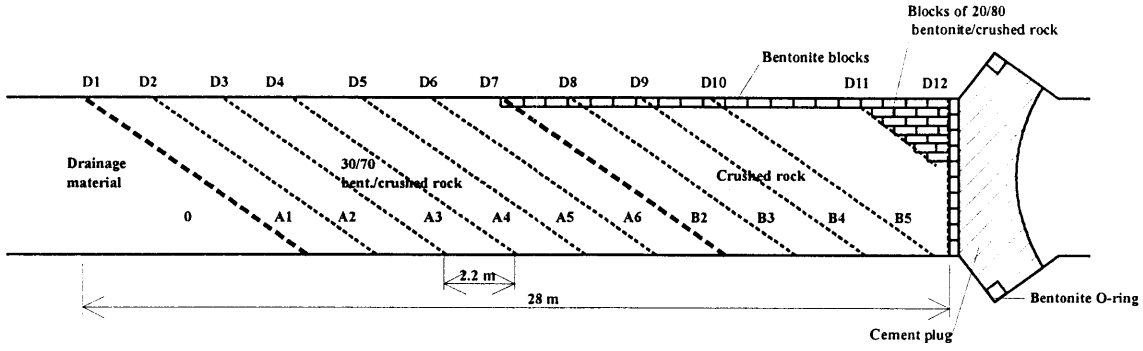


## Water pressure in bore holes section B5(990601-010101)
## Druck



# Quick guide

**Layout of the test**
**Numbering of backfill sections and permeable mats**




--------- Drainage and deairing layers, permeable mats

## Backfill transducer

W 8 (A2 / 3 /-0,5 /R - 0,3)

Gauge type
Gauge number
Section
Layer
X Coordinate(m)

Y coordinate(m)
Or distance from rock surface:
R+ signifies distance from floor
R- signifies distance from roof

## Rock transducer

UR 124 ( A2/ RW/ 1,5 – 2,0)

Water pressure in rock
Gauge number
Corresponding backfill section

Location (e.g. RW=right wall)

Depth in borehole(m)

**Gauge types:**
**W=Water ratio**
**U=Water pressure**
**P=Total pressure**

## Co-ordinate system