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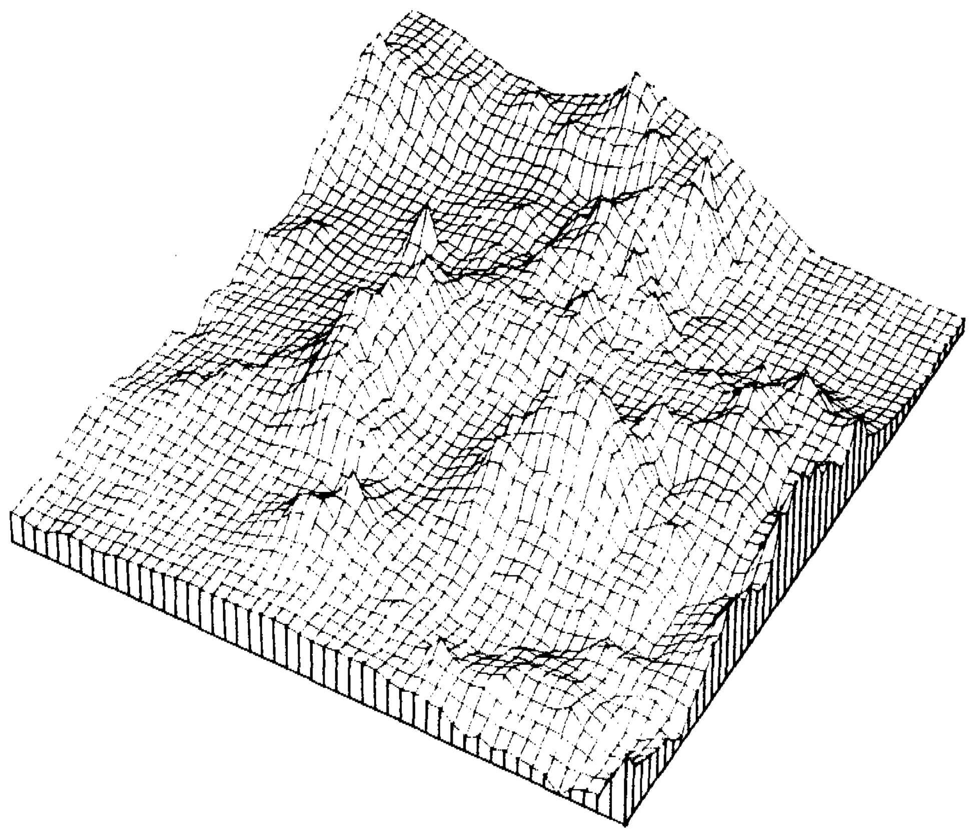
Mission report

Yemen Arab Republic/Kingdom of the Netherlands

Rada' Integrated Rural Development Project

Mission to the geohydrology section

April/May 1989



September 1989

Yemen Arab Republic
Ministry of Agriculture
and Fisheries

Kingdom of the Netherlands
Ministry of Foreign Affairs
Development Cooperation (Asia)
Department

RADA' INTEGRATED RURAL DEVELOPMENT PROJECT

Mission to the geohydrology section

W.K. Boehmer and L.A.M. Silvertant
25 April - 13 May 1989

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Ilaco
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1 INTRODUCTION

Dr W.K. Boehmer, senior consultant geohydrology, and L.A.M. Silvertant, computer programmer, visited RIRDP at Rada from 25 April to 13 May 1989. In accordance with the programme set up in RIRDP Internal Note No. 3 of 18-3-1989 and in Ilaco's letter No. 368/4.08.046 to DGIS, the mission covered the following subjects:

- installation of software on the HP Vectra and training of personnel of the geohydrological section in its use;
- initialization of the start of a new well inventory of the Rada basin 1990/1991;
- discussions at the TNO-WRAY project at Sana'a about cooperation in the use of computer equipment and software;
- replacement of the EM-34 electro-magnetometer;
- training in reporting;
- evaluation of the monitoring network and monitoring programme for rainfall and water levels;
- discussions about the tasks of the successor of Mr H. Nieuwenhuis;
- discussion of the tasks and the set-up of a programme for the geohydrological section after the departure of Mr H. Nieuwenhuis.

2 GEOHYDROLOGICAL SOFTWARE

2.1 General

Since March 1989, the geohydrological section of RIRDP possesses a HP Vectra desk-top computer of Hewlett Packard. The task of the mission was to install a number of geohydrological programs and train the geohydrologists and the computer programmer in the use of the computer and the software. During the mission the following computer programs have been installed:

- LOGPRO for reading eproms of electronic data loggers and processing of the data;
- GEOMAB and RESINT for the interpretation of geoelectrical resistivity soundings;
- FINELFLOW and FINELPLOT, the finite element groundwater model of the Rada basin (steady state conditions);
- SURFER and GRAPHER plot programs for graphical presentation of geohydrological data as contour maps vertical sections geophysical logs, and 3D-diagrams;
- the well inventory data of the 1983 well inventory under the LOTUS 1-2-3 spreadsheet format;

A more detailed description of the programs follows below.

2.2 Logpro

Since the use of the Siemens solid-state electronic recorders Preslogs and Rainlogs for measuring water levels, wadi flow and rainfall in the project area, the software package LOGPRO has been developed for the reading and processing of the pressure data registrated by the instruments on solid-state electronic memory blocks called Eproms. LOGPRO can be applied for the evaluation of Preslog data as well as of Rainlog data. The program has been installed on the HP Vectra at RIRDP and contains the following subroutines of importance for the project:

- reading and storage of Eprom data;
- making of administration files with particulars about the observation point, the start and end of the observation periods;
- adjusting of the data for the barometric pressure;
- plotting of data;
- determination of maximum and minimum water levels and the derivation of daily pumping hours and water abstraction from irrigation wells;
- calculation and statistical options;
- derivation of Rainfall;
- simulation options;

The program proved to be very suitable for the evaluation of Preslog data collected during the past three years. Recent improvements in the program make it necessary to reprocess the Preslogs in pumped wells on daily pumping hours. The results obtained by the old version of LOGPRO are not always accurate.

We trained Mr Eissa as well as Mr Teunissen in the use of LOGPRO. We also presented a demonstration to the management of the project to show the use of the collection of water levels and rainfall data and the possibilities of processing of the data. We developed demos to be used by Mr Eissa in order to show examples of the possible graphical and numerical processing of data collected with Preslogs and Rainlogs to the management and other interested parties.

Further developments of the instrumentation and extension of the application in the Project will require a continuous updating of the LOGPRO program package.

2.3 FINELFLOW and FINELPLOT

The computer programs FINELFLOW and FINELPLOT are, respectively, the calculation program and the plot program of the finite element model. Both programs have been installed on the HP Vectra together with the final calibrated data set of the steady-state groundwater model of the Rada Basin. The model has been installed in order to show the status of the model study and to demonstrate some of its possibilities to the management and other interested parties. The groundwater model becomes only fully operational after finalizing the unsteady state calibration phase planned at the end of this year. Then, the groundwater model can be used for simulation of the groundwater situation and quantification of the water problems so that measures against over-pumping can be proposed after proper determination of their effects. We have developed demo's for use by Mr Eissa to show the present status of the groundwater model to interested parties.

2.4 The Well Inventory

During 1982-1983 data have been collected from more than 3000 wells and boreholes in Al Bayda province. The results have been evaluated and described in the report "Study into water resources in Al Bayda Province" by Ilaco, 1984.

The original well inventory data base, containing the geohydrological data of all the wells, was implemented on a HP9845 computer at Arnhem, The Netherlands. The database programs to process the data of the well inventory and several plot routines have been written in HP-Basic.

In April 1989 this database and the original database processing and plotting programs have been converted to HP-ASCII for later implementation at RIRDP.

On 28 April we had a meeting in Sana'a at TNO-WRAY to inform us about the possibilities to enter the original database of this well inventory into the TNO database facilities and use their programmers for processing and plotting of maps. Soon it was clear that implementation of this option would be very expensive and time consuming. We propose therefore a conversion of the data base from HP-ASCII via MS-DOS ASCII into LOTUS files and processing these data by using LOTUS 1-2-3 and the plot program SURFER at the RIRDP office. Plotting of large A1-size maps can be carried out with the A1-plotter at the TNO-WRAY office for which a driver has to be obtained from Golden Software which is the supplier of SURFER.

2.4.1 Description of the well inventory geohydrological database

The data file of the well inventory contains:

- the well number
- altitude
- borehole number
- depth of the water table
- dynamic water level
- total depth of the well or borehole
- electric conductivity of the groundwater
- Cl-concentration
- annual water abstraction
- maximum water level
- minimum water level
- acidity of the water
- top of deeper aquifers
- pump discharge
- depth of alluvium
- power of the pump engine
- x- and y coordinates of the well
- water level elevation
- aerial photo number.

At the RIRDP office in Rada we started conversion of the complete database of the 1983 well inventory from HP-ASCII into MS-DOS ASCII. Since the editor installed on the HP Vectra did not work well we could not finish this job and convert the well inventory records into the LOTUS environment as needed for processing and plotting with the SURFER plot programs on the HP Vectra.

Therefore we have taken the complete database of the well inventory back to the head office at Arnhem for further conversion of the data files and development of LOTUS macros to extract and arrange the data for making tables and plotting of maps.

After this conversion we plan for the following mission:

- to implement the data of the well inventory at RIRDP;
- to make instructions for completion and extension of the data sets for processing with LOTUS 1-2-3 and the SURFER programs;
- to use this set-up in the future, for import and processing of data collected during well inventories made of the Rada catchment and new areas in the future.

2.5 GEOMAB and RESINT

In order to speed up the interpretation of geo-electrical soundings and the presentation of the results we installed programs GEOMAB and RESINT for the semi-automatic interpretation of geo-electrical soundings. GEOMAB runs under HP-Basic and RESINT is the MS-DOS version of the same program. RESINT has the advantage that it runs also on a portable computer like the Toshiba-1200.

2.6 The computer room

The computer room at the RIRDP-office is too small for efficient working with two computers, two printers and one plotter. The dissipation of heat from a combined power consumption of 800 watt is too high for this small room. Dust and sunlight are handicaps for efficient working with the computers. We suggest to:

- enlarge the room by shifting of the wall with the door to the other side of the staircase and arrange a good ventilation of this room;
- install sun blinds before the window in order to facilitate working in the afternoon;
- arrange an efficient ventilation and to filter the air before entering the room;
- repair the lock of the door and the light in the room;
- make this room a quiet zone and keep dogs outside the office site in order to make the concentration possible necessary for this type of work.

2.7 Training of the computer staff

During our stay we instructed Mr Eissa, the project programmer, in the use of all the installed computer programs and the demonstration sets. We installed a program and supplied a parallel Centronics connection cable for ultra fast file transfer "UFO" between two computers. We instructed Mr Eissa in using this UFO utility.

However we expect that regular contact remains necessary for a proper backstopping in the working with our programs necessary for a proper working of the geohydrological section. This will be the case especially with:

- extension and installation of LOGPRO with new possibilities for processing of data from the newer types of Preslogs and Rainlogs with new options for water level observation;
- installation and training with LOGUTY, the program for operation of the newest type of Preslogs and Rainlogs with data transfer direct from the loggers into the computer, and conversion of these data into ASCII files readable by other program such as LOGPRO and LOTUS 1-2-3 for further processing;
- updating of program and Macros for LOTUS 1-2-3 necessary for a proper functioning and processing of data from the well inventories carried out in the province planned for 1990/1991;
- training of Mr Eissa in programming in HP-Basic and Quick-Basic for maintenance and extension of existing programs and making new programs as required by the project.

2.8 Cooperation with TNO-WRAY

Thursday 11 May we had a meeting with the staff of TNO-WRAY project in Sana'a.

We inspected computers, plotters and printers available at their office and discussed the use of their facilities and computer programs for set-up and evaluation of the old and future well inventories.

We found them not suitable for our purpose for the following reasons:

- the well data collected by RIRDP differ completely from those collected by the WRAY project;
- the type of output as generated by RIRDP programs cannot be made by WRAY.

In the future we plan to make use of the HP A1 plotter, installed at WRAY for plotting of our well inventory maps.
Therefore we agreed with WRAY to make input files, i.e. SURFER files at RIRDP, plot maps first on the A3/A4 plotter at RIRDP in order to eleminate errors and afterwards plot them on the A1 plotter in Sana'a.
We agreed in using our own plotting pens and paper.
TNO-WRAY agreed that we can use their facilities in the afternoons from 13:00 hours after telephonic appointment.
Ilaco will contact Golden Software to get a driver for the WRAY HP7570 A1 plotter.

TNO-WRAY proposed to input all the old and new well inventory data, collected by RIRDP in their own dBase III well inventory data base by their personnel.

2.9 Upgrading of instrumentation (computers, plotters, printers)

At the moment the RIRDP computer room is equipped with 2 computers: a HP Vectra and an IBM XT with 256 Kb internal memory, 2 printers, a data switch box, an A3/A4 plotter, which can only be connected to the IEEE bus on the HP Vectra, a stabilizer and an uninterruptable power supply.

We propose to upgrade the internal memory of the IBM computer up to 640 Kb and to replace the HP7475A plotter of the geohydrological section by the HP7550A A3/A4 plotter. The HP7550A plotter can be operated both under the MS-DOS operating system as under HP-Basic by the IBM computer and the HP Vectra. The plotter is approximately 3 times faster as the HP7475 and equipped with a 8 pens carrousel and an automatic paperfeeder, which is far more convenient to generate big amounts of plots as the operator does not need to watch the plotting process constantly. The price of a memory upgrade is Dfl 1700 and the price of the HP7550A plotter is Dfl 9500.

2.10 Programme of Mr. Eissa and software support and software extensions

Mr Eissa is willing to solve different problems by programming the solution in HP-Basic. We suggest another visit of Mr Silvertant to RIRDP for instruction and training of Mr Eissa in the use of HP-Basic and Quick-Basic. After this training session Mr Eissa can do the maintenance and programming of extensions of the installed basic programs himself.

We propose a more intensive support of Mr Eissa in information from Arnhem about new developments in useful software for RIRDP.

3 SITE SELECTION

3.1 Number of site selections and borehole logging

In 1987 11 sites, during 1988 15 sites, and from January to April 1989 8 sites have been selected for village water supply by the groundwater section of RIRDP in Al Bayda province.

The sites have been selected by using:

- aerial photo interpretation and hydrogeological fieldwork for mapping geology and tracing of faults and intrusive dikes;
- the electro-magnetic method (using an EM-34 of Geonics) for locating faults in the field;
- the geo-electrical method to locate aquifers and assess their thickness and depth.

The descriptions of the 26 site selections carried out during 1987 and 1988 have been published in Technical Note 3 "Groundwater investigations of the seventh phase" of May 1989.

All site selections carried out in 1989 have been described and will be published in a report on the site selections during 1989 in April 1990.

At the moment much attention is paid to training of the Yemini geohydrologists in the conduct of site selections and writing of site selection reports.

3.2 Instrumentation

Due to the frequent use of the EM-34 for site selection not only for RIRDP but also for the Rada water supply and sanitation project RWSSP, cables and coils of the instrument are badly damaged and have to be replaced. Testing of the instrument must reveal if both the sender and the receiver are still intact or have to be replaced also. Funds for a completely new instrument are required at least on the coming budget. Without an electro-magnetometer successful site selection which is a major service and task of the geohydrological section becomes impossible.

For proper site selection 3 to 10 soundings are required for each site. This number of soundings cannot be achieved with the geoelectrical method in one day at remote places in the province due to long travel times. Repeated visits are usually impossible due to the lack of time and other tasks. Therefore since the last six months the project investigated the possibilities of conducting electro-magnetic depth sounding with instrumentation developed by Geonics Canada, see also the visitor's report of January 1989, Chapter 1). This revealed the following:

- the electro-magnetometers TEM-37 and TEM-47 in combination with the interpretation program of GEONICS are suitable instruments for electro-magnetic depth sounding with a much higher productivity then geoelectrical sounding. This is of great importance for a better quality of the site selection study;

- calculations of theoretical resistivity profiles by Geonics revealed that useful information about water-bearing formations at depths greater than 150 m cannot be expected in the Tertiary volcanic formations. The same depth restriction is found with resistivity depth sounding in this formation;
- high surface resistivities of dry soil, sand and rock which are frequently found in the Al Bayda Province, do not hamper interpretation of the soundings made by the EM-method. This, in contrary to the difficult interpretation of geo-electrical soundings made under these circumstances;
- the presence of highly conductive clay layers at shallow depth hamper interpretation of EM-soundings. Here the geo-electrical method has the advantage over the EM-method and can thus not be completely missed;
- telephonic contact of Mr Teunissen with Geonics Canada revealed that the PROTEM III (or IIIc) is also a suitable instrument for making EM-profiles as required for tracing faults and intrusive dikes which is essential for site selection in the Al Bayda province. The combination of the two application methods, EM-profiling for tracing faults and more efficient depth sounding make it economically attractive to recommend the replacement of the EM-34 by a PROTEM-III or PROTEM-IIIc system with a TEM-57 receiver, (see for detailed information the quotation by Geonics, Canada available at the project). The price of such a system lies between US$ 50 000 and US$ 65 000.

The geoelectrical equipment available at the project remains important for site selection in case of low surface resistivity by clay and the resistivity logging of boreholes.

3.3 Interpretation programs GEOMAB and RESINT

The geo-electrical interpretation program GEOMAB has been installed on the HP Vectra. The largely automatic interpretation program will speed up and improve the interpretation of geo-electrical soundings. The program RESINT is the MS-DOS version of GEOMAB and can be used also on our portable Toshiba computers.

4 PUMPING TESTS

4.1 Problems with the implementation of pumping tests and test equipment

During 1989 no pumping tests have been carried out due to problems with the pump operator, as described in the visitors report of January 1989. The reasons are that the pump operator refused:
- to install a monitoring pipe together with the test pump in the borehole without which no water levels can be measured during pumping;
- to allow adjustment of the discharge rate by means of a valve necessary during the step-drawdown test as well as during the constant rate test.

After discussions with the head of the water section Mr Salah al Juffany and the pump operator Ali Quar about the problems, they agreed to be more cooperative and allow:
- the installation of an 18 or 25 mm (3/4-1 inch) diameter PVC monitoring pipe with the column pipes into the borehole;
- the hydrogeologist to use the valve for adjusting the discharge of the pump during the step-drawdown test and the constant discharge test.

During a visit to a site at As Suwraymih to observe the installation of the test pump we found that the present type of 3 inch diameter column pipes with flenses are unsuitable to be used as rising main for a test pump because:
- installation is too time-consuming;
- the presence of flenses hamper the installation of an observation pipe;
- the presence of flenses hamper any measuring of the water level by means of an electric probe.

Therefore we recommend strongly to replace the present column pipes with flenses by pipes with thread and sockets suitable for frequent use if possible with cardan connection. A search for such pipes and quotations have been asked for in the Netherlands. After arrival of these pipes at the project it must be investigated if a 25 mm steel pipe, to be used as monitoring-pipe for measuring water levels, should be welded permanently to the column pipe or that a monitoring pipe (PVC or galvanised steel tube) should be installed separately.

We expect that above measures make it possible to resume the necessary testing of newly drilled wells by RIRDP. This in order to obtain the hydraulic characteristics and pumping capacity of the well essential for a proper design of pump and engine to be installed in the borehole.

4.2 Interpretation and reporting

During our visit the mission paid special attention to interpretation and reporting of pumping tests. We paid several training sessions with Mr Teunissen, Mr Raweh and Mr Johaish in the interpretation of step-drawdown tests and constant discharge tests. An example of the pumping test report at Madhar is presented in Annex B of this report.
A report on pumping tests made by RIRDP is at present being prepared and will be published in due time.

5 MONITORING

5.1 Reports

In February 1989 RIRDP published the report "Monitoring of rainfall and groundwater levels in Al Bayda Province, 1976-1987". This report contains besides all the data collected during this period also an analysis of the rainfall.

In April 1989 the project published the report "Meteorological data taken at the RIRDP weather station in Al Khabar, 1978-1988", Technical Note 32.

5.2 Rainfall

The present operational monitoring network in Al Bayda Province consists of:

- 1 meteorological station at Al Khabar;
- 1 meteorological station at Al Bayda (operated for US-Aid);
- 2 hand operated rain gauges;
- 10 mechanical rainfall recorders;
- 8 electronic Siemens rainfall recorders.

The project plans to complete the rainfall network with three more rainfall stations equipped with electronic recorders at Al Bayda, Markhah, and two in Mahajabah. In order to compare the effect of the height of installation of the raingauge above ground surface on the recorded rainfall, one of the recorders will be installed in the field and the other will be installed on the roof of a nearby house at Mahajabah.

Automatic electronic weather station at Al Khabar or another place of the province for a continuous record of reliable data. Present hand measurements are unreliable.

5.3 Water-levels

In the Rada catchment groundwater levels are measured by hand in 15 open wells and boreholes, 5 Preslogs and 1 mechanical recorder installed in open wells and boreholes.

Monitoring of water levels in the rest of the Al Bayda Province occurs by means of 8 Preslogs. 6 Preslogs have been installed in the vicinity of Rainlogs in order to compare the water level fluctuations with rainfall. RIRDP plans to install another Preslog near Juban in order to follow the water level in this area. No Preslog is foreseen for Jubairy. Reporting on the groundwater levels occurs annually. The next report is foreseen in March 1990.

All the observation wells monitored by RIRDP are abandoned boreholes or open wells with or without irrigation pumps. Monitoring occurs with approval of the owners of these wells. The position of these monitoring points is not always at the most suitable site to follow the water level behaviour in the area. until this moment no monitoring borehole could be realized in the groundwater inflow area of the Rada Basin NW of wadi Tha near Nodes 14 or 16 of the Rada groundwater model. This area is of great importance for determining and safe-guarding of the recharge of groundwater into the Rada Basin. We propose therefore the drilling of one observation borehole of 150 m deep NW of el Hamaydha wadi Tha. In case an abandoned borehole can be found in this area only the installation of a casing with a slotted section will be sufficient. Borehole of 80 m deep in the Rada plain in the centre of an important irrigation area with heavy pumping between Rada and Al Qadri 1 km north of the Rada - Al Bayda road.

5.4 Temperature

Monitoring of temperature is of great importance for agricultural activities such the determination of average, minimum and maximum daily temperature. The occurrence of days with temperatures below zero, and in calculations on evapotranspiration and crop water requirements.

At the moment monitoring of temperature occurs at the weather station of Al Khabar and at the electronic weather station near Al Bayda. RIRDP wishes to increase the points for recording temperature on an hourly basis at 5 more locations in order to obtain a better insight in the temperature fluctuations in the province. The following 5 stations are proposed near agricultural extension centres:

- Wadi Tha
- Sabah
- Rahba
- Juban
- As Sawmah

We propose the use of the Siemens solid state electronic temperature loggers of the same type like the Preslogs and Rainlogs for the following reasons:

- to obtain more reliable and more frequent temperature readings than collected in the past by daily readings of minimum and maximum temperature at the extension centres. This resulted many times in unreliable data and frequent periods of no data;
- to reduce the number of time-consuming visits to the remote stations to 1 to 4 times per year;
- the project has experience with these instruments and is fully equipped for reading and processing of the data. The use of any other type of recorder will cost extra time and money in gathering experience and software development;
- extension of LOGPRO with a temperature processing module will be a relatively small operation.

Installations of these recorders should be in proper weather huts and carried out by the project geohydrologist.

5.5 Wadi-flow

Since 1988 recording of flood flow in wadi beds with Preslogs buried in the wadi-beds proved to be successful. At the moment 6 Preslogs have been installed in 5 different wadis in the province.

At the moment the method is most reliable in the registration of the time and duration of the floods. However, the correct registration of the water level during the flood is still questionable due to the position of the sensor of the Preslog at least 30 cm below the wadi-bed. The hydrologist of the project investigates the possibility of an improved installation of Preslogs with the Preslog sensor at or very close to the surface of the wadi-bed in order to ensure that the recorded pressures correspond with the water level in the wadi during the floods.

5.6 Monitoring equipment

At the moment the following monitoring equipment is in use and planned in the Al Bayda province.

Meteorological equipment

- 1 meteorological station at Al Khabar;
- 1 electronic meteorological station in Al Bayda;
- 2 hand-operated rain gauges;
- 10 mechanical rainfall recorders to be visited monthly;
- 8 Siemens electronic recorders or Rainlogs to be visited once or twice per year;
- 3 extra Rainlogs for extra rainfall stations are planned for the period 1990/1991.

Water level equipment

- 13 Siemens electronic water level recorders
- 1 mechanical recorder
- 4 water level measuring tapes
- 1 extra Preslog for an extra observation point is planned for the period 1990/1991.

Wadis

- 6 Siemens electronic recorders are at the moment in use for registration of wadi flow with the hydrological section of RIRDP
- unknown number of extra Preslogs estimated at 6 more stations for measuring wadi flow and water levels in surface reservoirs (at present this monitoring task is carried out by the engineering section).

6 GROUNDWATER MODEL OF THE RADA BASIN

6.1 Present status of the study

During 1987 the project started with a groundwater model study of the Rada Basin. The study is carried out with a low budget and the study is therefore as much as possible done in cooperation with the University of Wageningen. The model study is carried out in two phases:

- a fist phase of data collection, set-up of the model and steady state calibration;
- a second phase of unsteady state calibration and running of some planning runs and reporting.

The first phase has been finalized in June 1989 by the report "Groundwater model of the Rada Basin, Volume I - Model design and steady state calibration".

This first phase comprised:

- data collection and set-up of the model by L.J. Dijkhuis;
- development of the finite element model including a proper water balance and an extensive plot program for output and start of calibration by B. Minnema;
- finalization of the steady state calibration and reporting by W.K. Boehmer;
- installation of the programs FINELFLOW and FINELPLOT on the HP Vectra of RIRDP by L.A.M. Silvertant.

6.2 Planned finalization and introduction of the groundwater model at RIRDP

At the moment the second phase is being carried out by H. Nieuwenhuis in Arnhem as subject of his three-month study phase after termination of his DGIS-contract at RIRDP. We hope to complete the study for the end of this year and to install the program during our mission early next year. After installation the use of the model as one of the tools for water management will be demonstrated to the management of RIRDP, the Ministry of Agriculture and other interested parties.

7 BUDGET

7.1 Maintenance and replacement of monitoring and geophysical equipment

All monitoring equipment is subject to aging and wear and have a practical and economic life-time.

Of all equipment the mechanical recorders have the longest life time and require monthly visits and change of paper and pens. Paper and pens should be always available in sufficient supply to keep them in working order. Replacement of 5 recorders may be sufficient to replace damaged or old instruments.

They have the highest costs in installation and maintenance because they require the best protection and monthly visits plus manual processing of the data in the office.

Water level measurement equipment is subject most to wear or damage especially when used for pumping tests. We estimate that they must be replaced annually by new instruments.

Electronic recorders are subject to aging and have to be replaced in approximately 3 years by new instruments because they stop working, become unreliable or old-fashioned and have to be replaced by newer types with more possibilities and better software support. Batteries have to be replaced every one or two measuring periods (once every 6 months to 2 years depending on the interval time of 15 minutes to 1 hour). Recalibration of Preslogs by the manufacturer is estimated at 30 Preslogs and Rainlogs during the coming three year budget period. 90 sets of Eproms and batteries are required for operation of the Preslogs and Rainlogs.

5 electronic temperature recorders are required for monitoring temperature in the province.

The requirements for maintenance of the weather station are:

- paper for recorders;
- replacements of the thermometers which are subject to damage;
- replacement of weather huts which are subject to aging.

At this moment two Thommen precision altimeters are in use for measuring elevations for geohydrological and engineering purposes in the project. For the well inventory foreseen in the coming budget period both instruments must be used. Replacement of one altimeter due to damage or loss is expected during the coming budget period.

The purchase of a Protem IIIC electro-magnetometer of Geonics is proposed to replace the EM-34 and increase geophysical depth-sounding for site selection as described in Chapter 3 Section 2.

7.2 Budget 1990/1992

The following instrumentation budget is foreseen for the years 1990/1991. All costs are inclusive handlings costs in Arnhem but exclusive transport costs andimport costs in the YAR).

For the monitoring network:

- 10 Preslogs en 4 Rainlogs for extension of the network and replacement of instruments in 1990	Dfl	72 000
- replacement of 8 Preslogs and 3 Rainlogs in 1991	Dfl	56 520
- replacement of 7 Preslogs and 4 Rainlogs in 1992	Dfl	56 880
- 5 Preslogs as temperature loggers and weather huts	Dfl	39 000
- 90 sets of Eproms and batteries for 1990 to 1992	Dfl	18 000
- Recalibration of 20 Preslogs in 1990 and 1992	Dfl	12 240
- 1 electronic automatic weather station	Dfl	25 000
- replacement of 5 mechanical rainfall recorders	Dfl	10 000
For site selection and borehole logging:		
Geohydrological and geophysical software	Dfl	15 000
Protem IIIc with accessories and computer program	Dfl	130 000
2nd resistivity probe for geophysical borehole logger	Dfl	3 000
For monitoring, pump testing and well inventory:		
Test pump with 300 m rising main (ID = 75 mm) NTP thread	Dfl	25 000
15 water level metres		
7 x 100 meter	Dfl	7 000
5 x 200 meter	Dfl	8 000
3 x 300 meter	Dfl	7 500
Replacement of 1 Thommen precision altimeter	Dfl	6 000
Miscellaneous:		
Such as cables geol. instrument, Ec-meters, maintenance of mechanical recorders, theft, repair equipment, and unforeseen extra equipment	Dfl	65 000
Total	Dfl	556 140
Drilling of one monitoring borehole and installation of casing	Dfl	50 000
Installation of 150 m casing in abandoned borehole to construct a permanent monitoring well	Dfl	15 000

8 PROGRAMME MR TEUNISSEN UNTIL DECEMBER 1989

The following work programme is proposed for Mr Teunissen for the period until the arrival of the successor of Mr H. Nieuwenhuis in December 1989.

- Monitoring and filing of:
  - . groundwater levels
  - . rainfall
- Operation of the weather stations Al Khabar and Al Bayda (or make if possible arrangements about the temporary operation with other sections e.g. agricultural extension);
- Operation and maintenance of Preslogs and Rainlogs;
- Operation and maintenance of mechanical raingauges;
- Collect data for the groundwater model as far as required by the groundwater modelling study carried out in Arnhem;
- Conduct of a limited number of site selections, (see list of LCCD's);
- Conduct and interpretation of pumping tests on village water supply wells equipped by the project;
- Compilation and interpretation of pumping tests to be published in a special pumping test report.

The following tasks have to wait until the arrival of Mr Timmermans, the successor of Mr Nieuwenhuis:

- expansion of the monitoring network into the Al Bayda province;
- interpretation of meteorological data and water level data;
- the initiation and conduct of well inventory studies of the Rada Basin and areas near Juban;
- the operation of the groundwater model of the Rada Basin and a study of water management planning.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The HP Vectra desktop computer is of great significance for the geohydrological section of RIRDP. The computer is in use for the following tasks of the section:

- reading and processing of data collected and stored by the electronic recorders Preslog and Rainlog by LOGPRO;
- running the groundwater model FINELFLOW and FINELPLOT;
- interpretation and presentation of geoelectrical soundings by GEOMAB and RESINT;
- presentation of electro-magnetic profiles with LOTUS 1-2-3;
- the storage of well inventory data in LOTUS 1-2-3;
- the storage and presentation of monitoring data.

The present computer room is too small for proper working of computers and people due to extreme heat production, dust and stagnant air circulation.

The conduct of pumping tests requires improvement of the test pump of higher capacity and with easier pipe connections, the installation of a monitoring pipe with the rising main of the pump in the borehole and the use of a valve to adjust the discharge rate during the tests.

The program of Mr Teunissen during the coming six months should be limited to site selection, continuation of the monitoring programme, writing of the pumping test report. The introduction of the groundwater model and the well inventory programme should be held up until the arrival of a successor of Mr Nieuwenhuis.

9.2 Recommendations

We recommend:

- to reprocess all data files from Preslogs collected from pumped wells with the newest version of LOGPRO in order to obtain more accurate results;
- storage of all the data collected from the monitoring network; in LOTUS 1-2-3;
- to expand the monitoring network with
  . 2 new rainfall stations with Rainlogs at Markhah and Mahajabah,
  . 1 automatic weather station to replace the meteo station at Al Khabar in order to reduce the discontuous collection of climatological data,
  . one extra water level monitoring point with Preslog at Juban;
  . with two monitoring boreholes, one in the Rada plain 2 kilometer North of Rada town and one 2 km Nort of wadi Tha at the positions of Node 14 or 16 of the groundwater model of the Rada Basin;
- to replace the present HP7554 A3/A4 plotter by the HP7550A plotter for a higher production and its compatibility with both the MS-DOS as well as the HP operating systems as required by the project;
- to use the Al-plotter of the TNO/WRAY project for plotting of well inventory maps;

- to start a new well inventory of the Rada Basin in 1990 using the recent aerial photographs in order to update the well inventory of 1983;
- to use LOTUS 1-2-3 for storage and processing of well inventory data and to apply SURFER and GRAPHER for plotting maps and sections of the well inventory;
- to process the well inventories of wadi Hubaba and Shuba'a for which well data have been collected in June 1988;
- to enlarge the computer room considerably and improve air-conditioning;
- to purchase a new test pump of larger capacity and with easier pipe connections and a to install a monitoring pipe for water levels during the pumping tests of drinking water supply wells. A proper crane should be installed on the lorry for installation of the test pump. The maximum discharge rate of the test pump should be 7 l/s from a depth of 180 m below surface in order to be more compatible with the water requirements of a village of 2000 inhabitants. The present test pump, connected also to the new set of pipes, should be maintained for smaller capacity boreholes;
- to install a suitable program for the processing, interpretation and presentation of pumping tests;
- more training of the dutch and yemini staff of the hydrogeological section in different hydrogeological subjects such as:

  . pumping test analysis and safe yield determination for drinking water supply wells;
  . proper site selection including not only geological and geophysical aspects but also hydrological aspects like water use and groundwater potential of the proposed site and the writing of a proper site selection report;
  . the significance of monitoring, and the interpretation and presentation of their results;
  . the installation of Preslogs, reading of the results and maintenance of the instruments;
  . writing of monitor reports;
  . well inventory, collection of well data, making of computer data files, drawing of hydrogeological maps and reporting;

- More training of Mr Eissa, the computer programmer of RIRDP, by Mr Silvertant in:

  . programming in HP-Basic and Quick-Basic;
  . installation and use of new programs;
  . installation and use of the well inventory data bank in LOTUS 1-2-3 and processing of the data with SURFER;

- the development of a computer data base system for storage of the hydrological data in LOTUS 1-2-3;
- to start in cooperation with the agricultural section of RIRDP to work out a plan for water conservation for the Rada basin taking into account the groundwater potential as determined by the groundwater model study;
- to present and discuss the thus formed water conservation plan with the management of RIRDP. After proper discussion this plan should be presented to the ministry of agriculture and regional and local representatives for further discussion and measures against over-pumping and the proper management of the water resources;
- to work out a proper information campaign for the promotion of awarenwess about water scarcity and discuss the necessity of water management measures.

ANNEX A
WORK PROGRAMME
OF THE MISSION

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WORK PROGRAMME OF THE MISSION

25 April: Departure Arnhem and arrival Sana'a

26 April: Meeting at T.N.O. Sana'a with Mr W. Luxembourg about planning of a visit during our stay in Yemen for discussion about cooperation in the use of software and hardware.
Departure to and arrival at Rada.

27 April: General meeting with project management and the members of the project team.
Introduction to the General manager and discussion about the programme for the period of our mission.
Inspection of computer configuration of the Geohydrological section.
Installation of the LOGPRO software package for the evaluation of eprom data from electronic recorders.
Discussion with Mr Eissa about computer programs to be applied in the geohydrological section and training aspects.
Instruction of Mr S. Joheish about determining the relationship between rainfall and groundwater-levels.

28 April Day off (Friday)

29 April Extension and testing of the plot program of LOGPRO with a new module. Instruction of Mr Eissa, the Yemini project programmer in the use of LOGPRO.
Meeting with the team members of the geohydrological section about the programme of the next two weeks.
Discussion about:

. problems with the conduct of pumping tests;
. the interpretation of pumping tests;
. the lay-out of a pumping test report.

Field trip to the lava plateau of Jabl Isbil which is the main recharge area of the Rada ground water basin in the light of the groundwater model study.

30 April Discussion with Mr Teunissen about the LOGPRO package extension of the graphical program of LOGPRO with 5 build-in tests and development of demo routines for demonstration purposes.
Discussion with Mr S. Joheish and Mr J. Raweh and instruction about the use and interpretation of water-level data.
Instruction to Mr Teunissen about the set-up of a site selection report.
Discussion about EM-equipment.
Field trip to the northern Rada plains with Mr H. Nieuwenhuis in order to verify some findings of the groundwater model study.

1 May	Implementation of the LOGPRO package on the HP Vectra.
Instruction of Mr Teunissen in the set-up of a site selection report and a pumping test report.
Field trip to Agabah Riyashiah

2 May	Implementation and extension of the groundwater model programs FINELFLOW and FINELPLOT of the Rada basin.
Conversion of output data of the groundwater model to DOS ASCII files for use as input for the SURFER program to plot contour maps and 3D-images.
Instruction of Mrs Teunissen, Joheish and Raweh about the interpretation and reporting on pumping tests.
Field trip to As Suwraymih for inspection of the installation of a monitor pipe for a pumping test in a water supply well.
Inspection of the sites for water supply wells selected by the geohydrological section of RIRDP at Qarab and Dar Khalaban.

3 May	Instruction of Mr Eissa in the use of the LOGPRO package regarding calculations and graphic presentation of Eprom data.
Conversion and implementation of the 1983 Well inventory data base of the Al Bayda Province into LOTUS data files.
Instruction in the determination of the a safe abstraction rate, and the proper installation depth of the pump in a tested borehole using the pumping test data of Madhar.
Field trip along the western border of the Bani Siad plain in order to model the eastern border of the Rada groundwater model.

4 May	Meetings with the project team members, the members of the water and sanitation section and the hydrologists about test pumps, monitoring equipment and geophysical instrumentation, the tasks and work programme of the project geohydrologists and the budget for 1990 and 1991. Training in reporting.
Set-up of a demonstration set for the program CALCLOG of the LOGPRO package. Instruction of Mr Eissa with all the possibilities of the LOGPRO-package and the groundwater model program FINELPLOT; Demonstration of the possibilities and explanation of LOGPRO and the groundwater model to the team members.

5 May	Installation and testing of the groundwater model package FINELFLOW and running of the steady-state groundwater model of the Rada basin.
Finalizing the instructions on writing a pumping test report.
Discussions of the shopping list.

6 May	Day off (Friday)

7 May	Day off (public holiday)

8 May	Conversion of the data of the 1983 well inventory from HP-ASCII to MS-DOS ASCII for processing with LOTUS and SURFER.
Discussions about the tasks to be carried out during the next 6 months by the geohydrological section, and setting up of a programme for fieldwork and reporting.

Need and replacement of equipment and software for the next 2 year budget and making up of purchase orders for immediate requirements.

9 May — Servicing and testing of Preslogs and Rainlogs, writing of a mission report. Fieldtrip to the north eastern part of the Rada Basin for checking water levels and elevations used and calculated by the groundwater model.
Explanation to Mr Eissa of the set-up of the database of the well inventory.

10 May — Meeting with the general manager, the Yemini staff and Dutch team leader and team members for discussion about the findings of the mission followed by a successful demonstration of LOGPRO to the general manager by Mr Eissa, the programmer of RIRDP.
Departure to Sana'a.

11 May — Visit TNO/WRAY project at YEMINCO office in Sana'a.
Investigations of programs, computers and plot equipment and its availability for RIRDP for plotting maps of the next well inventory.

12 May — Day off and departure to Amsterdam

13 May — Arrival at Amsterdam

ANNEX B
PUMPING TEST
AT MADHAR

ANNEX B
PUMPING TEST AT MADHAR

Subsection Geohydrology

CONTENTS

LIST OF FIGURES

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ANNEX B
PUMPING TEST AT MADHAR

B.1 Introduction

The village of Madhar is situated 19 kilometers SSW of Rada, in the mountainous area of Ar Ryashia. The borehole is situated 750 m west of the village in the valley. The borehole was drilled after a site selection by the project carried out in February 1987 described in the 4th site selection report of 1987. The borehole has been drilled by rotary hammer drilling in July 1987.

Particulars about the location of the borehole are as follows:
Site Region: Ar Riashhiyah village: Madhar
Well no: 1357
Coordinates: X: 475 km Y: 1575 km; Elevation: 2608 m above M.S.L.
Top. map No.: 1444 D2 Aerial Photograph: YE 8/14

The pumping test described below has been carried out from 2 December to 5 December 1987. The tests comprised a step-drawdown test, a constant rate test and a recovery test. The results and the evaluation of the tests are described below.

The purpose of this borehole is to supply drinking water to the village with a population of 800. The need for water is estimated at 100 l/d/person including drinking water for cattle. This means a total daily demand of 800 x 0.1 = 80 m^3/day.

B.2 Hydrogeology of the site

B.2.1 Geology

The geology of the site has been investigated during the site selection and is described in the site selection report.

Figure B.1 shows the geology of the environment of the borehole. The whole area is underlain by Tertiary Yemen volcanics composed of a succession of alternating basalt lavas and volcanic tuff layers. South-west of the village we find a large area of volcanic centres. Some major SW-Ne striking step-faults cut the area. The valley is filled with up to 10 m of alluvium tapped by a number of shallow wells.

B.2.2 Groundwater potential

The borehole is situated in a valley 3 km NE of the main water shed of the area. The catchment area of this borehole is approximately 10 km^2. The average rainfall in the area is estimated at 270 mm/year. The annual rainfall varies between 215 mm and 330 m/y for a return period of 5 years. Previous groundwater studies by Ilaco, 1984 revealed that the infiltration rate to the groundwater may be estimated at 3-5 % of the annual rainfall. This means that the recharge of the groundwater of the

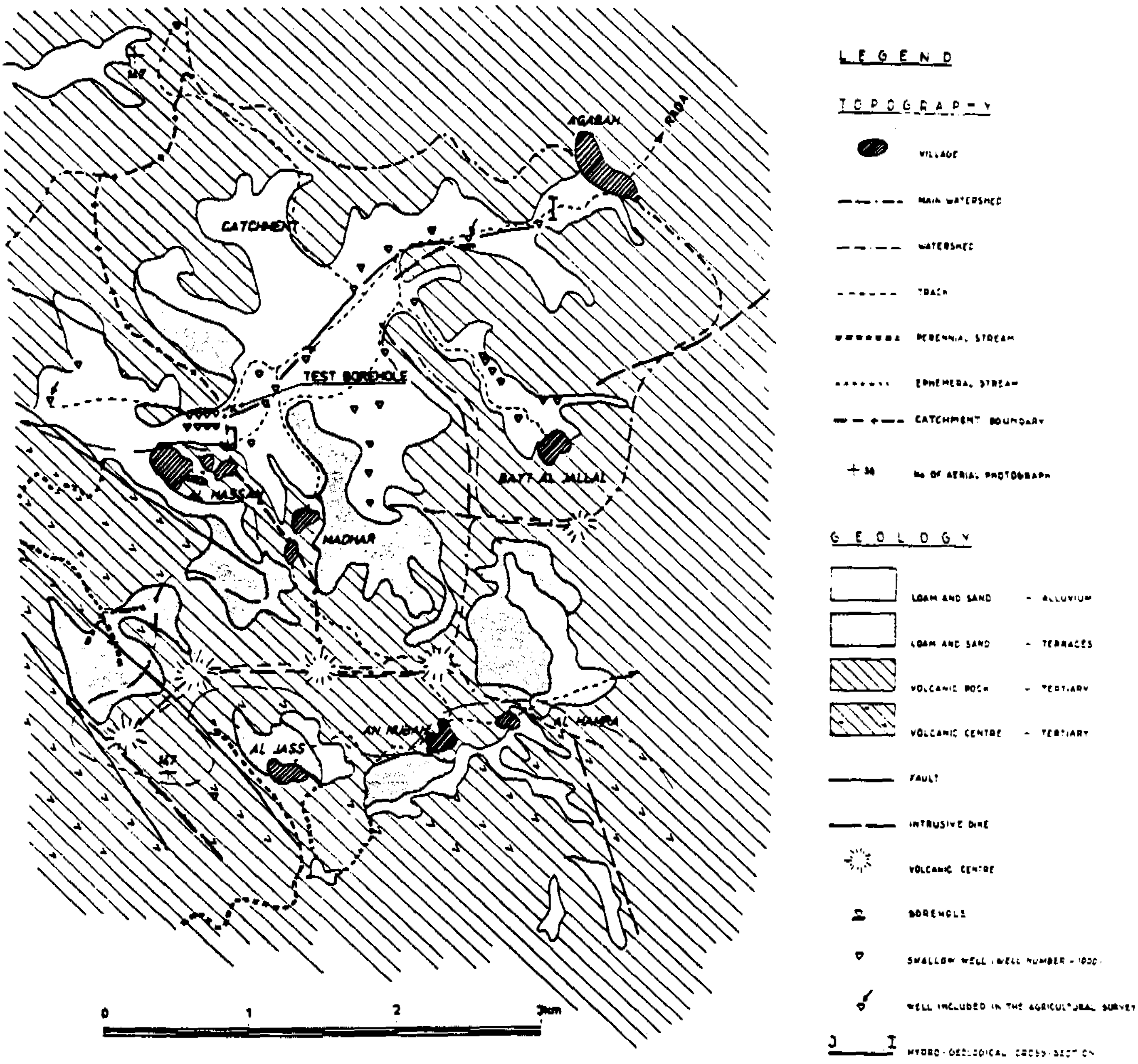

Figure B.1 - Borehole location and catchment of the drinking water supply well at Madhar catchment upstream of this borehole is in the order of 100 000 m^3/year which is several times the quantity of 30 000 mm^3/year required by the village.

B.3 Borehole description

B.3.1 Lithology

Table B.1: Lithological description of the borehole

0-3 m	soil (loam and highly weathered basalt)
3-14 m	weathered black and grey basalt
14-16 m	reddish brown clay
16-38 m	grey - black basalt
38-40 m	weathered black basalt
40-42 m	fine grained black alluvium
42-48 m	various colored tuff layers
48-56 m	clay and finegrained alluvium
56-58 m	weathered black basalt
58-82 m	black to grey basalt
82-86 m	highly weathered black basalt
86-98 m	varicolored weathered to highly weathered basalt and tuff layers
98-102 m	hard greenish basalt
102-114 m	greenish weathered tuff

B.3.2 Electrical resistivity and spontaneous potential log

Figure B.2 shows the electrical resistivity log (SN) and spontaneous potential log (SP) of the borehole. The electrical resistivity log starts at the depth of the water level at 40 m which is more than 25 m below the perched water table in the alluvial aquifer tapped by the shallow wells. The log clearly shows the alluvial aquifer from 42-44 m interbedded in the volcanic rock. Higher resistivities between 25 and 80 ohm.m related to basalt layers are encountered between 60 and 85 m. Deeper than 85 m the resistivity of the weathered varicolored basalt is approximately 20-35 ohm.m.

The spontaneous potential log shows:

- low potentials of 700 mV between 35 and 48 m corresponding to alluvium and weathered basalt;
- higher potentials of 900 mV are found from 48-54 m corresponding with clay and alluvium;
- lower potentials of 850 mV with some higher peaks are encountered from 54-85 m, corresponding with basalt layers;
- a markedly higher potential of 1025 mV is found from 85-96 m corresponding with weathered basalt layers;
- the greenish weathered tuff layers from 102 m to 114 m give a potential of 825 mV.

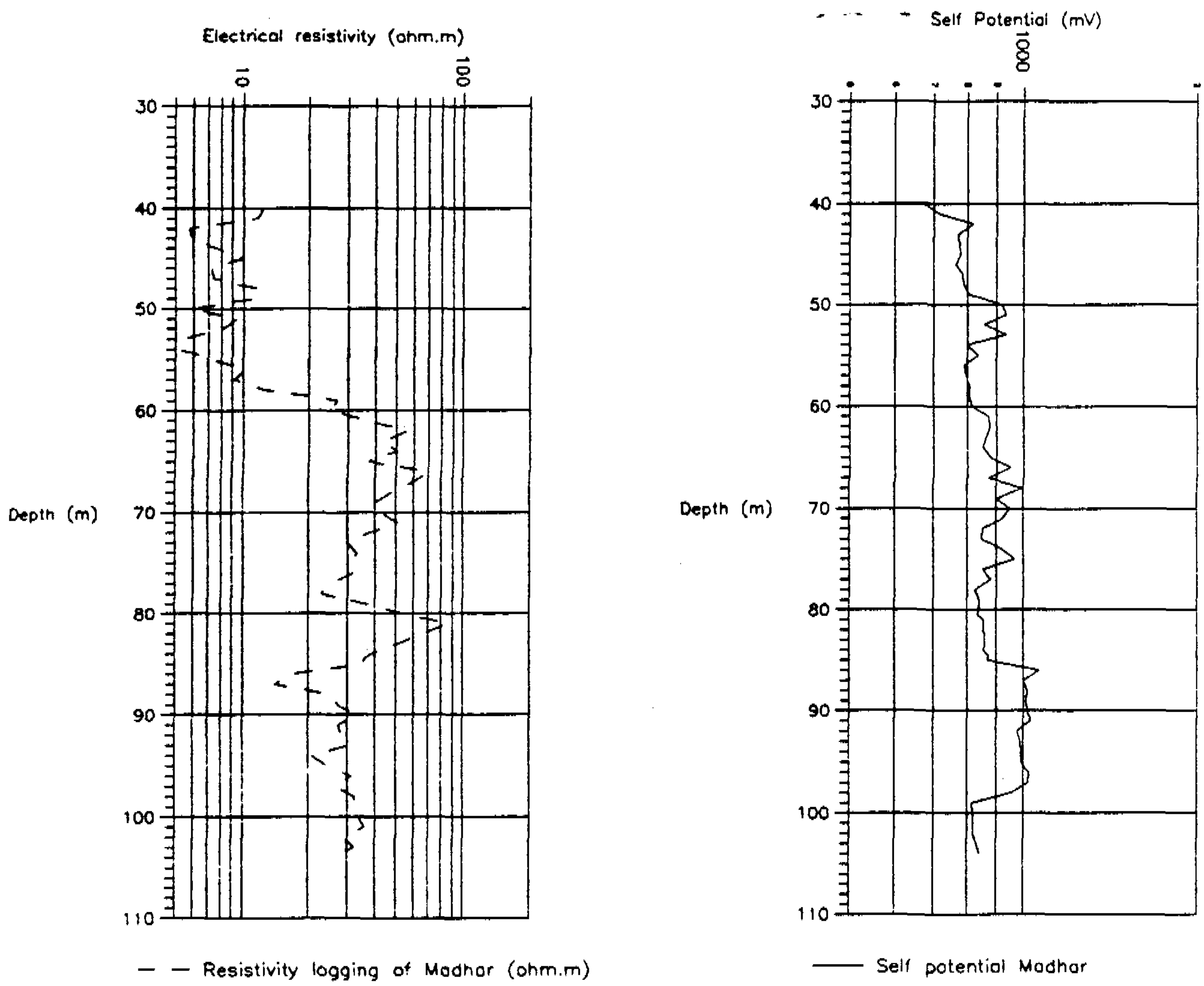

Figure B.2 - Electric resistivity log (SN) and spontaneous potential log (SP) of the water supply well at Madhar

B.3.3 Aquifers

During the drilling operations water was struck at the following depths:

- little water at a depth of 42-45 m in alluvium in between the volcanic rock;
- more water at the bottom of a weathered basalt layer at 83 m;
- a major aquifer at 88 m in weathered basalt;
- at 102 m more water in weathered tuff.

The electrical conductivity (Ec) of water samples is between 0.411 and 0.437 mS/cm, indicating fresh groundwater.

B.3.4 Screens and casing

The drilling diameters of the borehole are:

from 0 - 15 m 15 inch
from 15 -114 m 12 inch

Following the depths of the aquifers and the different logs of the borehole we decided to the following screen and casing depths and diameters.

From:

0 - 15 m :	12 3/4"	surface casing with cement grout
0 - 40 m :	8 7/8"	mild steel blind casing (angular space cement grouted)
40 - 45 m :	8 7/8"	mild steel slotted screens ??
45 - 83 m :	8 7/8"	mild steel blind casing (angular space cement grouted)
83 -112 m	8 7/8"	mild steel slotted screens
112 -114 m	8 7/8"	blind casing with bottom plug

B.4 Pumping tests

B.4.1 Set-up

From 2-4 December 1987 a step-drawdown test followed by a constant rate and recovery test was carried on the borehole.
Test pumping occurred with the pumptest unit of RIRDP comprising:

- a submersible electric turbine pump installed at a depth of 90 m equipped with a 3 inch valve to adjust the discharge rate;
- an electric generator set;
- a test drum of 70 l;
- an electrical water level meter.

B.4.2 Step-drawdown test

The step-drawdown test composed of 3 steps of one hour each was carried out at 1-12-1987.

The following discharge rates have been applied during the three steps of the test:

Step 1: Q= 5.5 l/s
Step 2: Q= 7.1 l/s
Step 3: Q= 9.1 l/s

Figure B.3 shows the time - drawdown and time-yield graphs of the step-drawdown test. The three incremental drawdowns at 60 minutes of each step deduced from the graph are as follows:

Figure B.4 shows the 60 minutes incremental drawdown versus the discharge for the three steps of the step-drawdown test.

Figure B.5 shows the ratio of the incremental drawdown versus the discharge rates of the pump.

Interpretation yields: B = 500 s/m^2
C = 14225 s^2/m^5
yielding $BQ + CQ^2 = 500xQ + 14225xQ^2$ for the one-hour drawdown for Q<=7.1 l/s. Figure B.5 shows that above equation yields the one-hour drawdowns for yields upto 7.1 l/s. The drawdown at higher pumping rates increases rapidly and is not described by the equation.

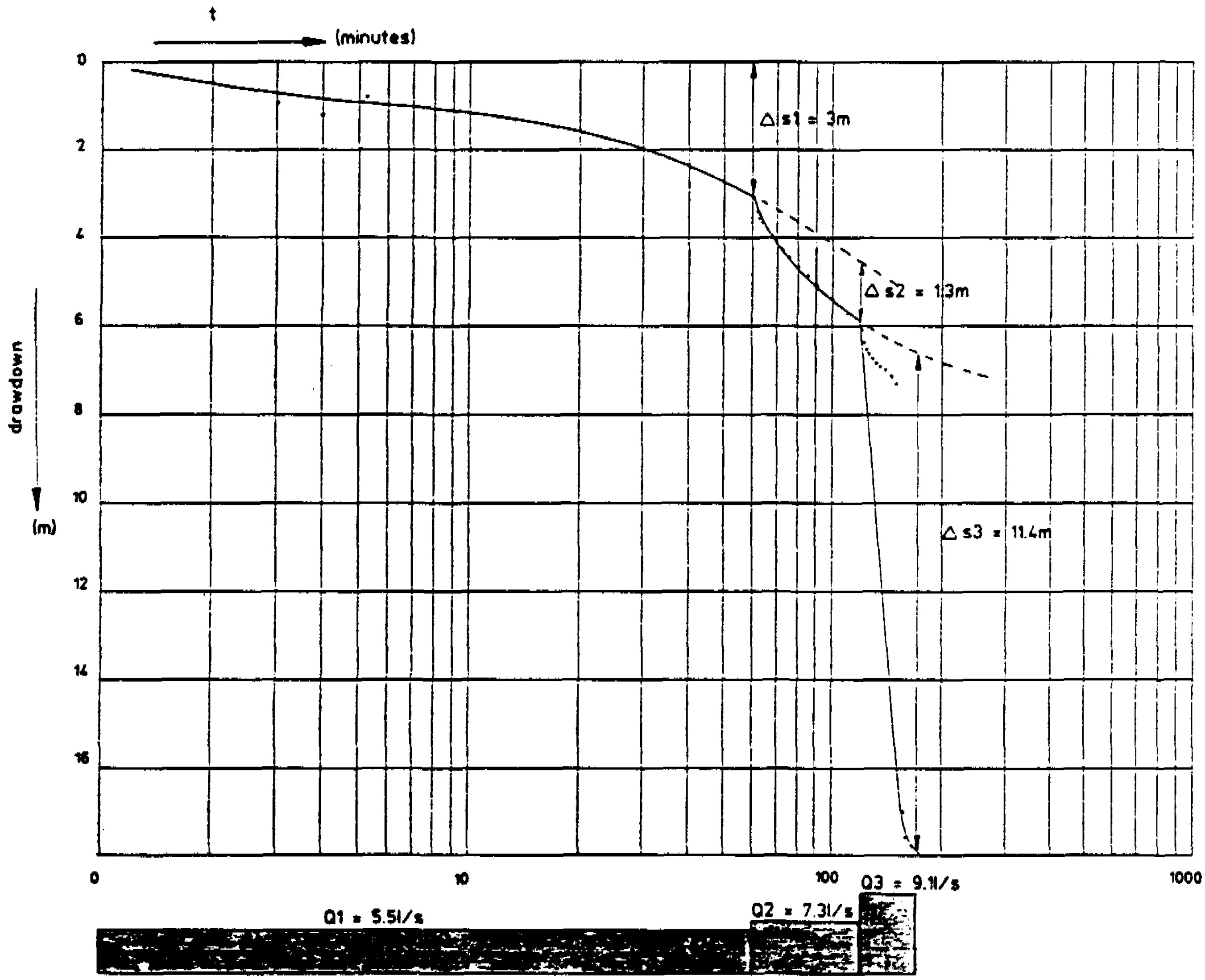

Figure B.3 - Time-drawdown and time-discharge of the step-drawdown test on the water supply borehole at Madhar

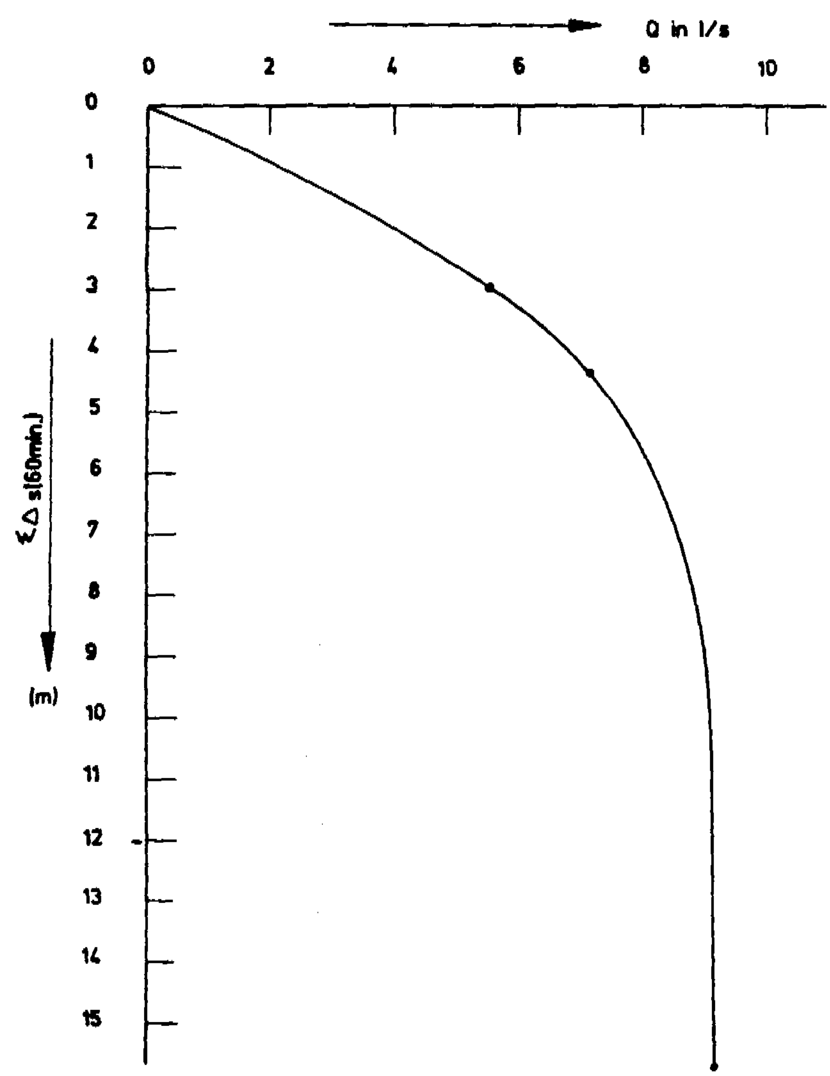

Figure B.4 - Discharge versus 60 minutes incremental drawdown of the step drawdown test on the water supply well at Madhar

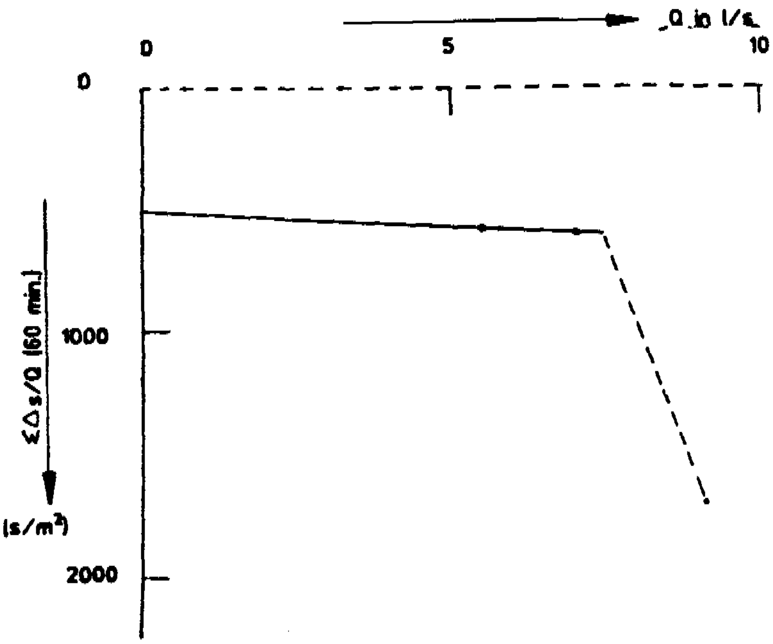

Figure B.5 - Discharge versus the ratio of the 60 minutes incremental drawdown and the discharge for the three steps of the step drawdown test on the water supply well of Madhar

B.4.3 Constant rate test

The maximum possible discharge rate for a constant rate test deduced from the step-drawdown test is approximately 7 l/s. Higher pumping rates yield too high drawdowns due to much higher well loss. During the constant rate test we pumped at 6.5 l/s. The duration of the test is from 2-3 December 1988, and comprises 24 hours pumping followed by 24 hours of recovery. Appendix I shows the water level readings during both periods (not given in this visitors report).

Figure B.6 shows the water level behaviour throughout the test period. Figure B.7 shows the time-drawdown graph and Figure B.8 the time-recovery graph plotted on semi-logarithmic paper with time on the logarithmic scale. Figure B.9 shows the residual drawdown plotted versus log t/t'.

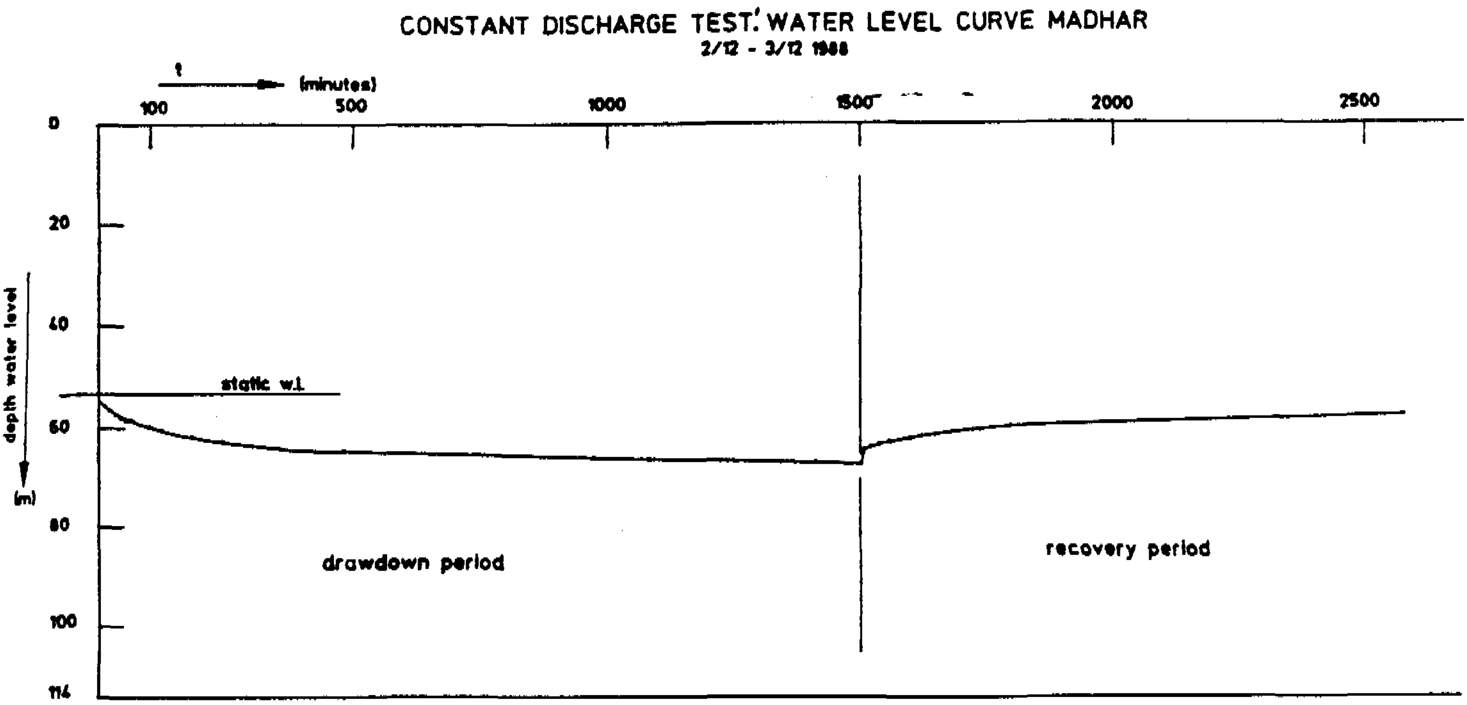

Figure B.6 - Water level behaviour during the constant discharge test on the water supply well of Madhar

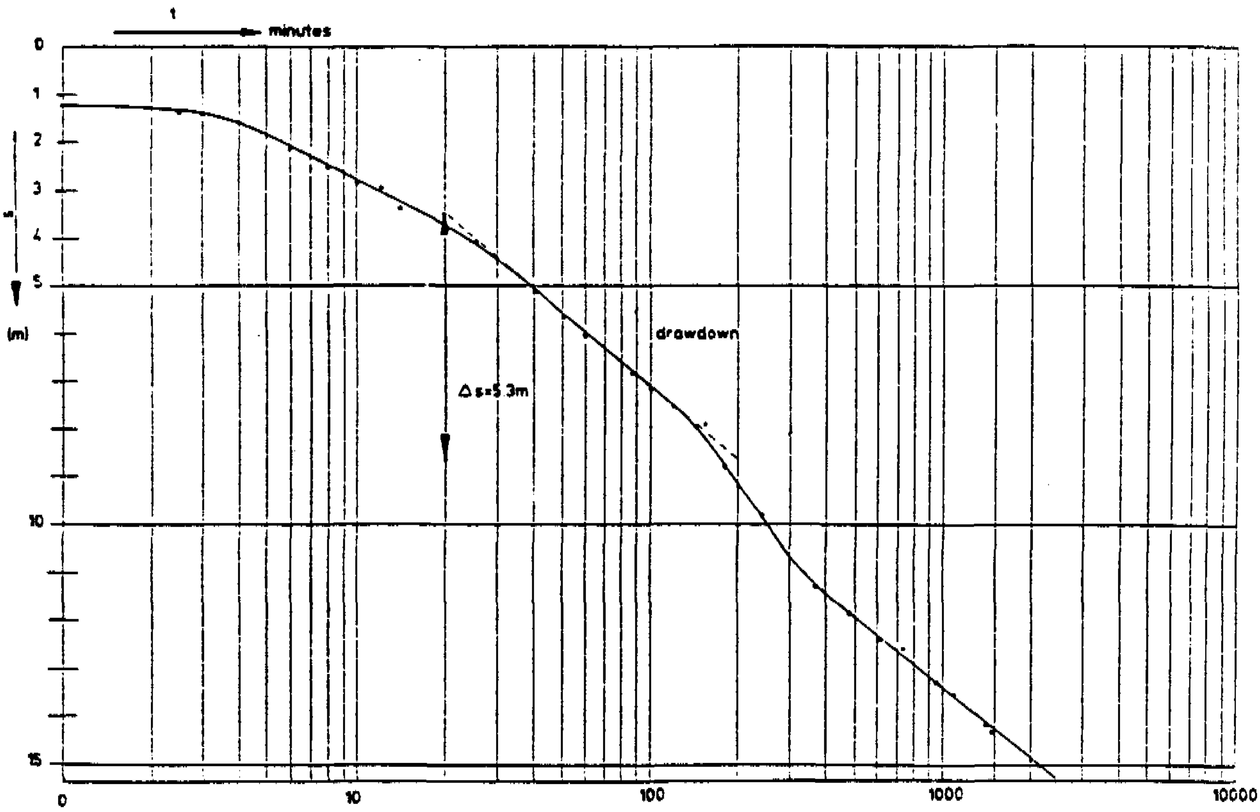

Figure B.7 - Time-drawdown in the pumped well during the pumping period of a constant rate test on the water supply well of Madhar analysed using the Jacob method

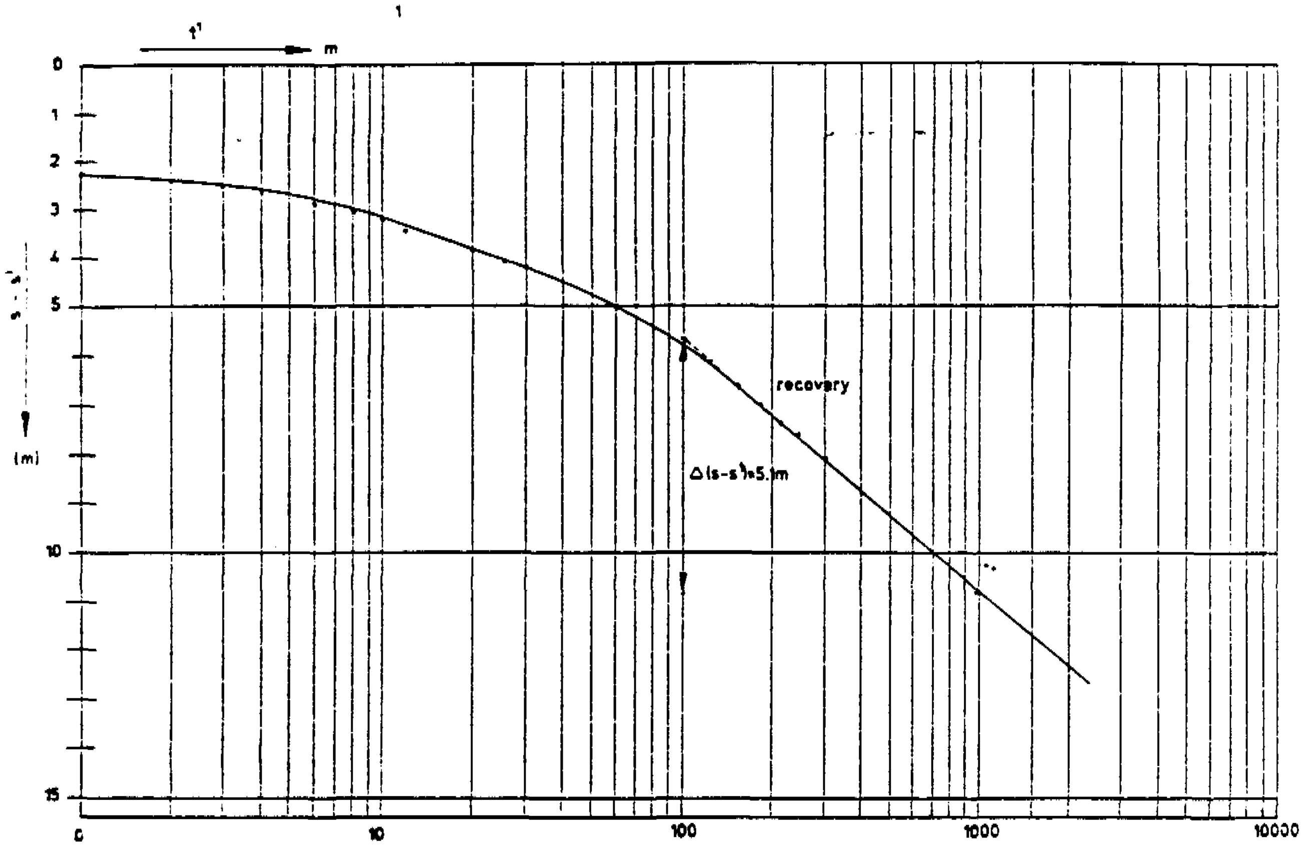

Figure B.8 - Time-recovery in the pumped well during the recovery period of a constant rate test on the water supply well of Madhar analysed using the Jacob method

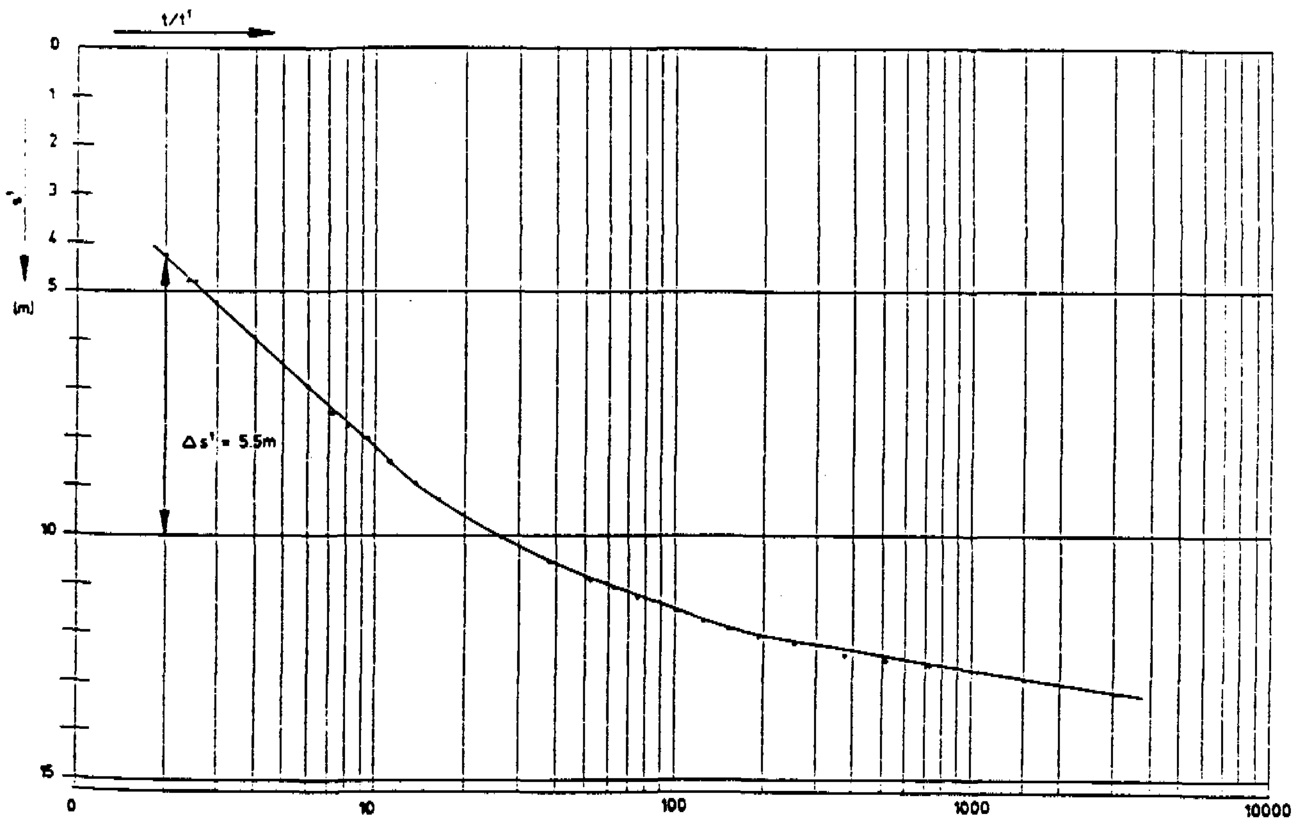

Figure B.9 - Residual drawdown graph of the pumped well from the recovery period of a constant rate test on the water supply well of Madhar analysed using the Jacob method

Both the time-drawdown and time-recovery graphs show straight lines after a brief curved line plot during the first 10 minutes. The drawdown graph shows a steeper graph between 150 and 300 minutes of pumping. Apart from this anomaly both the graphs are characteristic plots for an infinite confined aquifer and can be analyzed by the Jacob method. The transmissivity calculated by this method is as follows:

$$kD = 2.3\ Q/(12.6 \times ds)$$

where,

- Q = the discharge rate m^3/d = 537.7 m^3/d for this test
- kD = the transmissivity of the aquifer in m/d
- ds = The drawdown per log cycle in m.

Using the

Drawdown graph:	ds = 5.3 m and kD = 18.5 m^2/d,
Recovery graph:	ds = 5.1 m and kD = 19.2 m^2/d
Residual drawdown graph	ds = 5.5 m and kD = 17.8 m^2/d
Average	ds = 5.3 m and kD = 18.5 m^2/d

The residual drawdown graph of Fig. B.9 shows no complete recovery of the water level at the end of the recovery period nor after backward extension of the straight line plot. This probably due to the extra jump in drawdown seen on the time drawdown plot between 150 and 300 minutes of pumping and probably not because of an aquifer of limited dimensions. The reason of this extra jump in drawdown of 3 m may be caused by a fall of the water level below a minor inflow point of water into the borehole.

B.5 Determination of the save abstraction rate of the borehole

The following data are of importance for the determination of a safe abstraction rate the depth of the water level and the installation depth of the pump in the borehole.

The water requirements of the village are 80 m^3/d or 30 000 m^3/year .

The estimated recharge of the groundwater on the catchment amounts 100 000 m^3/year and is thus several times the water requirements, even after subtraction of estimated water abstractions by other wells.

The water required by the village can be satisfied by pumping at a rate of 5.5 l/s during 7 hours per day.

For this pumping regime we find the following water level behaviour:

- a daily drawdown of 3.98 + a well loss of 3.18 m = 7.16 m after 7 hours of pumping followed by a recovery of the water level during the rest period;
- an extra long term drawdown of 1.40 m for 10 days, 2.80 m for 100 days and 4.20 m for 1000 days without recharge of the groundwater;
- a seasonal fluctuation of the water level estimated at 5 m;

- this brings the total depth of the water level after 1000 days of pumping without recharge at 11.40 m + 68 m + 5 m = 84.40 m.

The installation depth of the pump should be at a depth of 88 m at the main inflow point of water into the well. At greater depths the borehole is improductive making deeper installation of the pump useless.

B.6 Conclusions and recommendations

The safe yield of the borehole: Q = 5.5 l/s during 7 hours per day.
The daily drawdown = 7.16 m
Total dynamic depth of the water level = 79.40 m +/- 5 m
The recommended installation depth of the pump = 88 m which is the main depth of inflow of water into the borehole.

Appendix B.I

List of drawdown and recovery data

(to be included in later pumping test reports).