RBB

INSTITUTE of
HYDROLOGY

RBB.

DRAFT

Sinai Water Resources Study

Assessment of Phase 1 (Supplementary Action)
Second Addendum

Report on Mission to Egypt,
18 September to 10 October 1988

Institute of Hydrology
9 November 1988
5/27D1

EEC Project SEM/01/220/022

LIST OF CONTENTS

Summary

A three week mission to Cairo was undertaken by staff from NERC on behalf of EEC. The objectives were to review the first part of a groundwater management study of the Arish-Rafah area of north Sinai, review progress by RIWR in preparing for the second phase of SWRS, assist RIWR to prepare specifications for a shallow drilling programme to be funded by EEC, and to install data bases and provide training in their operation.

External consultants have now been appointed for Phase 2 and will present detailed planning programmes in their inception report. Some progress has been made in most aspects which required action, particularly in the past few months. With appropriate assistance from the external coordinator we remain reasonably confident that RIWR will shortly be in a suitable position to undertake Phase 2.

Our main concerns are the continued lack of hydrogeological staff and the shortage of staff numbers overall; limited attention to project resources and administration; and the lack of a monitoring network. Other projects are commencing in Sinai and it is important that this does not detract staff from SWRS priority activities. Additional efforts must be made to obtain data from other organisations and to ensure close collaboration with such organisations.

It was not possible to carry out a comprehensive assessment of Phase A of the Arish study as the delays in completing the well surveys had prevented the University team from completing their analysis.

Water levels are declining in the main irrigation area at Arish. It would appear that abstraction in this area is being supported by lateral inflow from adjacent areas, storage depletion and possibly upward leakage. Water levels have now declined below sea level over much of the area and saline intrusion is occuring, although the deterioration in water quality is probably due mainly to upward leakage. This situation suggests that abstraction is exceeding the available resources and must be carefully monitored. Phase B of the study should be started as a matter of some urgency and this should incorporate the work planned for Phase C.

Abstraction is also increasing rapidly in the Sheikh Zuwayid-Rafah area, mainly from the dune aquifer. However, the information for this area is more limited. There is some evidence to suggest that water levels are declining around Rafah and localised overabstraction may be occuring at the coast north of Seikh Zuwayid. A monitoring network is required in the area to obtain further information on the three aquifers. A numerical model would be appropriate.

Two data base systems (GRIPS and HYDATA) have been installed on two microcomputers at RIWR. The staff of the Computer Centre have been given training in the operation of these systems. An immediate priority is to transfer all existing data onto the data bases.

Sinai Water Resources Study, Egypt
Assessment of Phase 1 (Supplementary Action)

GENERAL

Background

Phase 1 of the Sinai Water Resources Study (SWRS) began in November 1980. The main objectives are to evaluate the water resources of the Sinai Peninsula, in particular the availability of groundwater, with special emphasis on areas of high priority development. The work is being funded under an EEC-Egypt Cooperation Agreement and is being undertaken by the Research Institute of Water Resources (RIWR) with assistance from external and local consultants.

The Natural Environment Research Council (NERC) were appointed by EEC in February 1987 to review and assess the activities and progress of Phase 1 and to assist RIWR in planning an extension of the project (Phase 2). In September 1987 a hydrogeophysical mission was undertaken by NERC as part of the First Addendum of the original contract. This included a review of the activities required in preparation for Phase 2. The development of a computerised data base was considered to be a particular priority. It was also recommended that a groundwater study of the El Arish area in northern Sinai should be implemented as a matter of some urgency.

Subsequently, a Second Addendum was signed between NERC and EEC on 29 July 1988 for a three week mission to Egypt to examine progress in preparation for Phase 2, set-up a data base and examine the results of the El Arish study.

Mission Activities

The activities to be covered during the mission were as follows:

- review the conclusions and recommendations of the first stage of the El Arish study
- assist RIWR to prepare technical specifications for the shallow drilling programme
- review progress made by RIWR in consolidating SWRS Phase 1 activities
- provide and install specified hydrological and hydrogeological database software, train RIWR staff in the use of the software and assist RIWR in the selection of data entry codes and appropriate well numbering systems.

The technical specifications of the mission are given in full in Annexe A. Following discussions with EEC Delegation Cairo at the start of the mission the emphasis placed on each of the hydrogeological activities was altered somewhat in order to take account of events that had taken place since the original terms of reference were prepared.

The mission team comprised a hydrogeologist (R.B.Bradford, who had been involved with the previous missions) and a data base specialist (D.S.Biggin). Both are from the Institute of Hydrology (IH), a component organisation of NERC. The data base software was GRIPS and HYDATA, which were developed by IH specifically for projects such as SWRS.

At the request of RIWR the start of the mission was postponed until 18 September 1988. This was due to delays in purchasing IBM compatible microcomputers and in completing the first stage of the Arish study. The mission team departed from Cairo on 10 October 1988.

This report is presented in two parts. The first covers the hydrogeological activities whilst the second part describes the data base training. A preliminary technical specification for the shallow drilling programme is included as an Appendix.

A.

Hydrogeological Mission

1. INTRODUCTION

Due to the delayed start to the mission discussions were held on arrival with the EEC Delegation to consider whether any modifications were required to the terms of reference of the mission. The following points were discussed, which led to a change of emphasis in some of the hydrogeological aspects:

(a) The Bureau de Recherches Geologiques et Minieres (BRGM) of Orleans, France have been appointed as external consultants for Phase 2. The external project coordinator arrived in Cairo on 6 August 1988. This date is taken as the start of Phase 2, which is to continue for three years.

The first progress report covering the period from 6 to 31 August was submitted on 5 September. The Inception Report was still under preparation at the time of the mission. As this will provide a detailed assessment of the project situation and a planning and cost survey, it was agreed with the Deputy Head of EEC Delegation in Cairo that the mission would only comment on the general progress made in preparing for Phase 2.

(b) The El Arish study is being undertaken in collaboration with Cairo University. An Interim Report, submitted in March 1988, was made available prior to the mission. However, as the borehole levelling survey had to be repeated no conclusions or recommendations had been prepared at the time of the mission. Consequently, it was agreed with the Cairo Delegation that the mission would attempt to provide independant conclusions which could then be compared in due course with those by RIWR/Cairo University. Their report is now due to be presented towards the end of October.

Several meetings were held with the University team during the mission. A visit was made by the hydrogeologist to the El Arish area with the senior members of the University team and staff from RIWR. The field visit had to be limited to two days towards the end of the mission due to other commitments of the University team.

Since the previous mission the Italian consultants Bonifica have undertaken a preliminary hydrogeological study of the area around Maghara in north central Sinai.

Discussions are still underway with the Japanese company JICA for a three year study of the hydrogeology of the northern part of Sinai. This project is still subject to approval by the Government of Japan but could begin in early 1989. A copy of an MSc thesis by Refai produced in 1984 describing the hydrogeology of the Sahel Qaa has been obtained. The same author is also due to finish a PhD in the near future covering the hydrogeology of South Sinai.

These various studies will provide important information for the SWRS. However, the activities to be undertaken during the second phase of SWRS should be reviewed in order to avoid any duplication of effort and to ensure that the various studies are coordinated.

The Italian and Japanese studies have been offered logistic support from RIWR. Staff from RIWR are likely to be involved in coordinating these activities but it is essential that this should not detract staff from undertaking the SWRS activities.

The continuing rapid development of the Sinai has resulted in RIWR becoming more involved in providing advice for local development schemes, moreso now that RIWR are now part of the Ministry for Public Supply and Water Resources. Other organisations in Sinai have groundwater staff, such as the Sinai Development Authority, Rafah Municipality and the General Authority for Rehabilitation and Development Projects (GARPAD).

Geophysical surveys have been undertaken by EGSMA on behalf of RIWR along areas of the Wadi Watir in southeast Sinai where serious flooding occurred earlier this year. The construction of five boreholes to provide local water supplies in this area is being supervised by RIWR. RIWR are also assisting Rafah Municipality to extend a wellfield east of Rafah.

Geophysical surveys are being carried out by EGSMA at the five provisional deep drilling sites selected by SWRS to be drilled with GoE funds. As yet RIWR have been unable to undertake their own geophysical surveys. The IP equipment is in Customs and the EM is being tested in Cairo. However, this equipment should be operational in the near future.

2. REVIEW OF PROGRESS

The Assessment Study Report of June 1987 identified various key operations that were required in preparation for Phase 2. A programme of work required during the first six months of 1988 was outlined in the mission report of December 1987. Three main tasks were identified:

- consolidate the operational aspects of SWRS in preparation for Phase 2.
- carry out an urgent study of the El Arish area where there were reports of a deterioration in water quality.
- continue and expand the collection of time-varying data, particularly in the high priority areas.

It was proposed that the funds remaining from Phase 1 could be reallocated to support the following activities:

(a) transfer of all existing data onto a data base system after purchase of suitable computers, training, and selection of an appropriate well numbering system

(b) completion of the pumping test programme and analysis of data

(c) establish raingauge sites in certain areas, such as Wadi Feran, to obtain information on rainfall variations with relief

(d) establish a new workshop in El Arish

(e) provide short training programmes for junior staff in data collection techniques.

The progress with the Arish study and the installation of a data base are discussed in other chapters of this report. Comments on the other activities are given below.

2.1 Assembly of existing data and literature

Some progress has been made in this respect, particularly in obtaining a copy of the SDS-1 water point inventory. Despite several attempts, there are still difficulties, for various reasons, in obtaining data from GMA, UNICEF and for irrigation wells in El Qaa. This needs to be resolved by the Steering Group. RIWR have proposed that they should act as a central source of information relating to the Sinai. The archiving of such data will require much better organisation than exists at present and advice was given as to how this could be arranged to easily access file data.

Most of the more important reports on the region have been obtained. A library of reference books and technical papers is an important part of the general training but has not yet been properly established.

Some software has been provided by BRGM. A number of different word processing, spreadsheets and other software packages are now available on the new microcomputers, although not much use has yet been made of these programs. Some training would be appropriate in this respect to make greater use of the software available.

2.2 Microcomputers

Three Commodores were purchased in early August 1988. A further Commodore has also been purchased by BRGM. It was intended that two would be used in the regional offices but at present these are still in the Cairo office. An A3/A4 plotter was purchased during the mission but at least one further plotter is needed.

The data base aspects are discussed in Section B. There is now the major task of entering existing data onto the data base.

2.3 Recruitment of hydrogeologists

There are still no permanent hydrogeological staff. Whilst it is accepted that suitably qualified staff are difficult to recruit, the lack of hydrogeological staff is a serious constraint which needs to be resolved. We understand that a local hydrogeological consultant with considerable experience has recently accepted an appointment, but this will be only part-time. The external Project Coordinator will require hydrogeological assistance.

Staff numbers are still inadequate in general, particularly in the regional offices. Activities of the El Arish office are only supervised on a part-time basis by senior staff. One of the senior geological staff is about to move to the El Tor office to supervise activities in the southern Sinai. We understand that a further six junior staff, all engineers, have been recruited and will take up their positions in the near future.

The loss of staff, once trained, is appearing as a potential problem. The duties of individual staff still need to be more clearly defined and adhered to as staff apparently tend to be given varying duties according to short term priorities. This is due in part to the lack of staff. BRGM are preparing a detailed assessment of staffing and organisational arrangements.

2.4 Base maps

Suitable base maps with a UTM grid at a scale of 1:25000 have been prepared for the El Arish-Rafah study area. A base map at 1:50000 of the El Qaa area is under preparation.

2.5 Drilling specifications

Most drilling for RIWR is now being undertaken by REGWA, who have a permanent camp at El Arish. Relationships between RIWR and REGWA are very good. A standard contract is available in Arabic. An outline specification for the shallow drilling has been prepared as part of this mission.

2.6 Pumping test programme

Although pumping test equipment was provided for the project, this has not been utilised and pumping tests are still being undertaken under contract. Pumping tests were made on several wells in the El Arish area in January 1988 in cooperation with the Cairo University team. The quality of data has been improved but, for example, discharge rates are measured by containers which is far from satisfactory. Some of the data being collected is unnecessary, for example recovery data from step tests. There are at least 10 existing RIWR wells that were drilled for pumping tests which have not yet been tested and this still remains a priority task.

Some training on the analysis of pumping tests has been given recently by the Project Coordinator.

2.7 Job descriptions

These are still required (see 2.3. above).

2.8 Rationalisation of climate network

It was intended that the climate network would be selected in cooperation with the GMA. Attempts to achieve this have so far been unsuccessful and the reasons for this need to be considered by the Steering Group.

The three duplicated GMA/RIWR stations have now been removed. Some plans have been prepared by RIWR to rationalise the climate network and these will be discussed with an external hydrological consultant from BRGM during his visit planned for mid-October.

2.9 Raingauge network

Plans to install raingauges in Southern Sinai have not, by and large, been implemented. Data is still being received and collated from the existing network. A full listing of the raingauge and climate sites will be presented by BRGM.

2.10 Arish workshop

Designs have been prepared for the new workshop to be built in El Arish and a local contractor is likely to be appointed for the work in the near future.

A detailed report has not been prepared on the state of the transport. Whilst qualified mechanics are difficult to recruit, no repair work on the vehicles purchased during Phase 1 appears to have been undertaken. This aspect requires further action to ensure that the transport remains available for the duration of the project.

An inventory of equipment had not been prepared. Action on this aspect was requested by the mission.

2.11 Arish study

This is discussed in section 3. The study results have been delayed by need to repeat the levelling survey.

2.12 Monitoring network

The selection of a monitoring network was considered a high priority since, despite the duration of Phase 1, little time-varying information on water levels or water quality has been collected. Some limited monitoring has been made in Arish but the RIWR have made little progress in selecting a network for the routine collection of groundwater data. This situation needs to be remedied as a matter of priority.

It would appear that most (if not all) of the water level dippers are no longer working. Chart recorders are to be supplied from US funds.

2.13 Equipment

Tenders for the supply of further equipment were being examined at the time of the mission. The bids were considerably higher than expected and this was discussed with RIWR at the request of the EEC delegation.

About 50% of the cost of the bids was due to the hydrological equipment whereas only about 30% of the allocation was intended for such equipment. A budget cost was originally allocated for further hydrological equipment as it was considered that rationalisation of the climate network would provide most of the requirements and that the need was mainly for some more low-cost raingauges and for replacement parts. However, RIWR had included a large number of additional raingauges and transducer systems in the specification. The transducer systems are intended only for an assessment of their application under the conditions found in the Sinai. It was subsequently decided that the number of such items would be reduced to a cost approaching the budget. The total cost was thereby reduced to a figure reasonably close to the allocation for further equipment.

We note, however, that the tender did not include spares and replacement parts for existing equipment which were included in the funds allocated. These need to be ordered once RIWR have completed their inventory.

2.14 Local consultants

The local consultant requirements for Phase 2 have not yet been established. We understand that a hydrogeological consultant and a hydrological consultant are soon to join the SWRS on a part time basis. A local geophysical consultant is assisting with the geophysical surveys in W. Watir and the selection of the initial sites for deep drilling.

2.15 Project administration

This aspect is to be examined by BRGM. It would appear that little action has been taken to review and improve administrative procedures. Better copying facilities, particularly for maps, are needed.

2.16 Training programmes

Only limited training has been given over the past year. Some experience has been gained in pumping test operations and analysis and in preparing well inventories during the El Arish study. BRGM will prepare a detailed training programme.

2.17 Shallow drilling programme

RIWR have identified the Wadi Gerafi in east Sinai as a possible additional target for the high priority shallow drilling programme. The SDS-1 considered this area to have a potential for irrigation from groundwater if a source could be identified.

3. ARISH-RAFAH GROUNDWATER MANAGEMENT STUDY

Groundwater abstraction in the coastal area of northeast Sinai between Arish and Rafah has increased particularly in recent years. This development has been largely uncontrolled and, despite several previous studies of the area, the availability of groundwater is still rather uncertain. A monitoring network has not yet been established.

The groundwater quality in the main abstraction area at Arish is reported to be deteriorating and there is growing concern as to whether the aquifer can continue to support further abstraction. Nile water has recently begun to be imported by pipeline to Arish. A groundwater management strategy is required as a matter of some priority to control future abstraction in the area and safeguard supplies.

In view of the concern regarding abstraction in the Arish area in particular, it was proposed that a study of the area should be undertaken as a matter of priority.

The consulting services of the Faculty of Engineering of Cairo University were appointed by RIWR in November 1987 to undertake a groundwater management study of the Arish-Rafah area, with particular emphasis on the Quaternary aquifer at El Arish.

The study is planned in three phases as follows:

- **Phase A.** The assembly, review and analysis of existing information and preparation of a new inventory of water points. The information would be used to describe the present situation and make recommendations for further data collection.

used to describe the present situation and make recommendations for further data collection.

- Phase B. Collection of new data.

- Phase C. Evaluation of the availability of groundwater and the development of a numerical model to examine alternative abstraction strategies.

An Interim Report was submitted in March 1988 presenting existing information from previous studies. Four pumping tests were also undertaken in January 1988, together with several infiltration tests in the dune areas.

RIWR were responsible for the survey of water points. Unfortunately, the levelling had to be repeated and some difficulty was encountered with obtaining data on the private wells.

Due to delays in the surveying, the University team had not completed their evaluation of the information nor been able to draw any conclusions at the time of the mission. However, we had been informed that their report would be available.

This was discussed with the EEC Delegation who proposed that if possible the mission should attempt to draw independant conclusions which could then be compared to those made by the University team.

Several meetings were held with the University team and staff from RIWR to discuss the work undertaken so far and a short visit was made to the study area with the team. However, the well inventories and well location maps were not made available until the last day of the mission.

Since we are not yet in possesion of all of the data available, we are not in a position to make a proper assessment of the results and conclusions of the study. This will be undertaken when the report becomes available. Nonetheless, we have attempted to draw some tentative conclusions at this stage, based mainly on discussions with the team and from the results of the earlier studies.

Various suggestions were made to the University team to assist them in the evaluation and presentation of the information and thereby help in formulating a programme of further work. These included the following:

- a map to show the general availability of groundwater data, using conventional well symbols where possible, so as to highlight areas lacking data and to show where interpretation was based on only limited data.

- more detailed estimates of the variation in domestic and agricultural use throughout the year to estimate annual abstraction.

- an analysis of the likely future demands for the various requirements and their ditribution.

- estimates of consumptive groundwater use.

- more detailed graphical plots of the history of abstraction and alternative estimates of abstraction based on agricultural area and crop type/water source duty demand.

* a map to show the distribution of abstraction, perhaps using a subdivision of the grid, for each of the previous studies to show how the pattern of abstraction has varied.

* attempt preliminary estimates of inflow using the Darcy ap proach.

* using well logs define the distribution of specific yield and areas where clay layers occur.

* more detailed analysis of the chemistry data to (a) show where and to what extent the water quality has become unacceptable for

* irrigation and (b) provide hydrochemical evidence to distinguish the possible alternative sources of poor quality water.

* examine the importance of well parameters on water quality using statistical techniques.

* differentiate seasonal from longer term changes in water quality.

* identify the relative contribution from alternative sources of recharge.

* attempt estimates of the depletion in storage.

3.1 Conclusions and recommendations for Arish area

The following conclusions are based on discussions with the team during the mission.

1. Abstraction appears to have doubled during the 1980's and extended into new areas. The increase in abstraction has occured when recharge from rainfall or floods has been limited, although data are insufficient to quantify recharge from these sources. A water balance approach to estimate resources may be inappropriate given the uncertainty of the available data.

2. Recharge of deep groundwater along faultlines is not considered to be a significant source of recharge. Similarly we have reservations as to whether potential recharge in the El Hassana - El Hama catchment, as suggested by the University team, makes a significant contribution to abstraction at Arish.

3. Groundwater abstraction in the area between Arish and the airport is exceeding recharge. Water levels in this area have declined by an average of about 1.5m since 1981 and are now below sea level over a wide area. This decline in water levels indicates that storage is being depleted. Normally where there is a risk of saline intrusion water levels should not be allowed to decline below sea level. Upconing often precedes the inland movement of the saline interface.

4. Abstraction appears to be supported by lateral recharge from adjacent

4. Abstraction appears to be supported by lateral recharge from adjacent areas, from storage in the alluvial aquifer and by upward leakage from the underlying kurkar aquifer. Additional information is required on the aquifer extent, hydraulic characteristics (particularly specific yield) and the thickness of freshwater (say, <2500mg/l). The abstraction may be drawing upon groundwater accumulated over a prolonged period. It would seem that a steady state situation has not yet developed.

5. Saline intrusion is now occuring but appears to be limited to the wadi channel on the eastern edge of Arish where the salinity now exceeds 6000mg/l. The situation in this area needs to be monitored. Wastewater return beneath Arish may have formed a recharge barrier to saline intrusion but water level data are required to confirm this.

6. Upward leakage is considered to be the main cause of the present deterioration in water quality. More detailed analysis of the chemistry data may indicate the proportion of recharge from this source. An isotope survey may also indicate whether abstraction is depending on groundwater accumulated over a prolonged period.

7. The situation now requires careful monitoring and a monitoring network should be established without delay. Given the uncertainty in estimating the quantity and frequency of recharge from rainfall and run-off, particularly since historical data are limited and rather unreliable, an appropriate monitoring network may prove to be the only effective way of managing the system.

8. Any significant additional abstraction in the dune areas or along the wadi upstream of the airport is likely to accelerate the decline in water levels and the deterioration in water quality in the main irrigated area by intercepting inflow. This area also includes important sources of supply for Arish which must be safeguarded.

9. Future supply options could consider a redistribution of abstraction involving the dune areas in order to spread abstraction for the different needs over a wider area. It is suspected that the aquifer extends over a greater area than has previously been believed but the aquifer extent and the thickness of freshwater have not been adequately defined despite several geophysical surveys. The available data is generally biased towards the agricultural area and relatively limited information is available outside this area, mainly because of difficult access.

10. We would recommend that a groundwater model is developed to examine recharge concepts and alternative strategies and that the design of this model should be undertaken as soon as possible. Further work during the second phase of the study should be geared towards the development and calibration of such a model.

During Phase B of the study, which should be implemented without delay, routine monitoring will be implemented and additional data obtained from a programme of drilling and testing.

[Incomplete - A detailed review of the Arish and Ratah area will be included when the University team report is received]

B.

Data Base Software and Training

1. INTRODUCTION

The original terms of reference called for the data bases to be set up at Cairo, El Arish and El Tor with training at each site. However the RIWR decided to purchase only one set of software which would be installed in their Cairo office and that the Computer Centre staff should be trained in the operation of the systems. Once the software has been appraised and if found suitable then the situation can be reviewed.

2. INSTALLATION

2.1 Hardware

RIWR purchased three Commodore 40-40 microcomputers in August 1988. These are IBM compatible. The computers have Technology Inc. EGA Wonder boards installed simulating the enhanced graphics adapter (EGA) used by IBM which is the standard method of producing quality graphics on an IBM microcomputer. The computers have NEC colour monitors. Two Star LC-10 dot matrix printers are available.

Plotting facilities were not provided until the last two days of the mission. The RIWR Computer Centre has two plotters for use with their Texas minicomputer but they are incompatible with the microcomputers.

Two microcomputers had uninterruptable power supplies (UPS) which provide a smoothed power supply for the microcomputer and contain internal batteries capable of providing about thirty minutes of emergency power.

The two Commodore microcomputers having printers and uninterruptable power supplies are located in the Computer Centre office while the third Commodore is located in the senior staff office. At present most of the work undertaken by the Computer Centre is on Mackintosh microcomputers but these microcomputers are not compatible with the Commodore microcomputer.

Initially there were problems with the power supply. For approximately half of each working day the supply was such that the batteries were being used. This meant either work had to stop or the microcomputers had to be used with a non-stabilised power supply. These problems were resolved after the first week of the mission when a new power cable was installed.

2.2 Software

The software packages provided are two dedicated database systems developed by the Institute of Hydrology for use on IBM and IBM compatible microcomputers. HYDATA is a database whose main features are the ability to store, edit, print and plot hydrological data for a maximum of 1000 stations. GRIPS is a database with the ability to store, edit, print and plot hydrogeological data from a maximum of 100000 stations. A series of user defined codes enables the stations on GRIPS to be sorted and selected data from subsets to be analysed. Both software packages have the ability to read in and produce ASCII computer files. Each software package included a comprehensive manual.

The main differences between hydrological and hydrogeological data bases are the number of stations and type of data. Often hydrological data are available for only a limited number of stations but the quantity of data for each station may be large, particularly where at least daily stage and daily meteorological readings are collected over a long time period. Conversely hydrogeological data may be available for a large number of stations but with each station perhaps having a limited amount of data.

One copy of GRIPS and one copy of HYDATA were installed on separate Computer Centre microcomputers. However it is not possible to reproduce the EGA quality colour graphics normally displayed because of slight variations in the control codes used by the previously installed non-IBM EGA board. Monochrome graphics of EGA standard can be produced but with bad screen flicker. This slight incompatibility only applies to the screen displays but could be overcome by installing a different enhanced colour graphics board. If the screen flicker still persisted then a different colour monitor would need to be purchased.

3. TRAINING

During initial discussions with RIWR the Project Manager intended that the Computer Centre staff would be responsible for the operation of the software packages. Therefore training in operating the systems was provided for the three technical members of the Computer Centre:

Miss Gihan Ibrahim Ali (systems analyst)
Mr Mostafa Mahmoud (programmer)
Miss Sahar Kamal El Din (programmer)

Mr Gamal Allam, administrative head of the Computer Centre, also attended when his other duties permitted.

These staff were instructed in the installation of the packages onto the microcomputer and in the initialisation programs which have to be run prior to any data being added.

Demonstrations were given to senior members of the RIWR staff to demonstrate the capabilities of the two software packages. Greater emphasis was placed on the GRIPS package given the importance of groundwater in the Sinai.

The main part of the training was concentrated on the input of data via the keyboard and computer file, the editing or correction of data and the output of data in printed, computer file and graphical forms. Special emphasis was placed on the use of the comprehensive manual in order that RIWR staff would be able to cope with aspects not perhaps covered during the mission.

During the training a test was set which involved use of both a training data set and the manual. The staff satisfactorily demonstrated their knowledge of the software.

However part of the HYDATA package involves the fitting of rating curves to gauging data and, although the computer staff were shown how to do this, it would be preferable for this to be carried out by a hydrologist rather than the non-specialist computer staff. The Senior Hydrologist and a local hydrological consultant were given demonstrations of HYDATA accordingly.

Each package has a certain amount of technical vocabulary with which the non-specialist may not be familiar. During the training some of the terms used were explained to the computer staff.

The senior staff must be closely involved in running both GRIPS and HYDATA to achieve the maximum benefit. This would serve the dual purpose of making them more aware of the capabilities of the packages and in instructing them in the operations of the software which at present is confined to the three members of the computer staff.

HYDATA handles the data as blocks of one year. The use of codes for the selection of data subsets, a sophisticated numbering system and the co-ordinate system used are therefore not as important as in GRIPS. The discussions below dealing with code, numbering and co-ordinate systems only apply to the GRIPS software package.

4. CODES

In GRIPS it is possible to assign to each station a number of codes which can be used to select subsets of data for further analysis. Each station can be assigned a maximum of:

1 physiographic area
4 geological formation
4 aquifer
1 data source

Extensive discussions were held with the senior staff to explain the use and the advantages of using the codes. The list of codes selected was prepared in co-operation with the senior staff and is shown in Table B.1.

Table B1   GRIPS Codes

	Physiographic Areas		Geological Formations
1	Northwest Coast	1	Quaternary
2	Hegayib/El Hasana	2	Pleistocene
3	Northeast Coast	3	Pliocene
4	Lower Wadi Arish	4	Miocene
5	Upper Wadi Arish	5	Oligocene
6	El Qaa/Abu Durba	6	Upper Eocene
7	El Gerafi	7	Lower Eocene
8	Wasit	8	Palaeocene
9	Dahab	9	Maestricht
10	Kid	10	Campanian
11	Umm Adawi	11	Turonian
12	Feiran	12	Cenomanian
13	Sidr	13	Lower Cretaceous
14	Baba	14	Upper Jurassic
15	Tayiba	15	Lower Jurassic
16	Gharandal	16	Triassic
17	Wardan	17	Upper Palaeozoic
18	Sudr	18	Lower Palaeozoic
19	Lahata	19	Pre.Cambrian
20	El Raha	20	

	Aquifer		Data Source
1	Stabilised dunes/beach deposits	1	RIWR boreholes
2	Alluvium	2	Other boreholes
3	Kurkur	3	Dug wells
4	Upper clastic aquifer	4	Springs
5	Middle calcareous aquifer	5	Trenches
6	Lower clastic aquifer	6	
7	Weathered basement complex	7	
8	Fractured basement complex	8	
9	Basalts	9	
10		10	
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

It is possible to alter the names of the codes in effect deleting them or reassigning them. This should not be carried out without a great deal of thought as all codes already assigned to GRIPS will also be altered.

The basis of the physiographic code selection were the catchments given in the Sinai Development Study Phase I (SDS-1) report. A total of twenty eight areas cover the whole of Sinai. By combining some of these areas the total was reduced to twenty suitable for entry onto GRIPS. The twenty geological codes were based on the main stratigraphical divisions found in Sinai. Some of these units were broken down into smaller units where it is considered important to do so.

At first the RIWR staff wanted to repeat the stratigraphic terms used for the geological codes as the aquifer codes. Following further discussions with both the staff and the consultant hydrogeologist a list was produced of much broader classes based on hydrogeological parameters, such as permeability. This should give greater versatility in manipulating the GRIPS data. As a consequence only nine of the possible twenty codes were assigned. The data source codes were selected on the most common sources of the data and only five of the possible ten codes were used. The unused codes can be assigned at a later date if required.

5. WATER POINT NUMBERING SYSTEM

In order to enter data onto GRIPS it is necessary to define a single numbering system. GRIPS identifies each data type as belonging to a station whose name is an alphanumeric string of a maximum of eight characters.

There are four main water point numbering systems at present being used in Sinai:

(i) Sinai Development Study Phase 1 (SDS-1) system in which the whole of Sinai was divided up into half degree rectangles. These were then numbered according to a row and column system and the water points numbered consecutively within each rectangle; for example water point 42 in rectangle 12 would be 12-42.

(ii) RIWR system where each RIWR borehole is given a consecutive number. This system covers the whole of Sinai.

(iii) A system used by Cairo University for the El Arish- Rafah local study in which a metric grid has been produced for the area. The grid has been divided into five by five kilometre rectangles which are numbered sequentially. The water points are also numbered sequentially in each rectangle.

(iv) Other local systems where the water points have been numbered consecutively with the area name as a prefix; for example El Qaa 14

A series of discussions were held with the senior staff to produce a unified numbering system which gives a unique identification using no more than eight characters.

Several alternative systems were considered:

(a) The national system used by the RIGW. This system is based on quadrangles of four degrees of latitude by six degrees of longitude which are subdivided into ninety six rectangles each of thirty minutes. Each quadrangle is assigned a different indentifier with the same identifiers occurring in each major quadrangle. However, use of this system meant that the full identifier followed by a water point number would exceed the eight characters accepted by GRIPS.

(b) A grid pattern composed of quarter degree rectangles. This has the advantage that the standard 1:50000 topographical maps used by the RIWR would cover the same area. However to cover all Sinai would result in a water point number with too many characters.

(c) The simplest approach for the RIWR would be to continue the SDS-1 numbering system. The 1:50000 topographic maps would then make a quarter of one of the SDS-1 rectangles. The new water points would be added consecutively. The main advantage of this system is that water points in the SDS-1 inventory do not have to be renumbered.

The relatively small number of rectangles would be suitable for GRIPS. This numbering system was adopted by RIWR.

There are several implications in selecting the new numbering system.

- If the data are to be transferred to a national archive at the completion of the study the numbering system will have to be altered. As the data will be held on computer file a simple reformatting computer program will need to be written.
- All existing and new water points not included in the SDS-1 inventory will have to be plotted on suitable maps in order to determine the co-ordinates and to assign a SDS-1 style number. The staff were shown a simple way of plotting a water point and determining the co-ordinates of this point as a UTM reference and as latitude and longitude.

6. CO-ORDINATES

There are two types of co-ordinate system that can be used. The location is defined by latitude and longitude or by reference to a metric grid. (The metric grid is a rectangular representation of the Earth's curved surface which is divided into narrow strips called Universal Transverse Mercator (UTM) zones and for a relatively small area such as Sinai give a good approximation.)

GRIPS was originally designed to be project orientated and as such would be dealing with relatively small areas. This means that GRIPS only uses a metric co-ordinate system. However the original co-ordinates entered can be either metric or latitude and longitude which GRIPS would convert.

The choice of using a metric grid rather than latitude and longitude was taken after discussions with both the RIWR and the Survey Department. The water points in the El Arish-Rafah local study have been surveyed by the Survey Department and the locations given as eastings and northings on a UTM grid. The co- ordinates of all other water points in Sinai will have to be either determined or redetermined as the co-ordinates given in the SDS-1 inventory are quoted to the nearest degree or minute of latitude/longitude (one minute is approximately 1800m). The use of the UTM grid will enable the point co-ordinates to be quoted to within one hundred metres.

7. DATA ENTRY

The RIWR data is not yet in a readily usable form as the data tend to be filed by type rather than by station.

A master list of all water points should be drawn up. This should use the following headings.

GRIPS/HYDATA number	Previous number	UTM metric co-ord.	Latitude DDMMSS	Longitude DDMMSS	Topo. sheet

Once this list is compiled then it should be updated at least once a month.

The initialisation program for GRIPS was run. The maximum number of stations for the study was set at ten thousand (this figure, once set, cannot be altered) and the codes shown in Table 2.1 were entered.

Data for the El Tor area were assembled so that a start could be made on data entry onto GRIPS. The codes for some twenty five water points, which included both SDS-1 and RIWR stations, were assigned and the metric co-ordinates determined. These station details entered together with chemistry data for some of the water points. In addition data from pumping tests for one site at El Arish were added and a start was made on entering lithological logs.

GRIPS can handle some types of data not collected routinely by RIWR. These include isotropic values, grain size (sieve analysis) data, and laboratory rock properties. Perhaps one additional data type that could be collected by RIWR is field chemistry data on temperature, pH and conductivity as well as a brief sample description. The information card used in the El Arish-Rafah study contains information that GRIPS cannot handle. These details are mainly concerned with the water use and some of the pump details.

CONCLUSIONS AND RECOMMENDATIONS

A. Hydrogeological Mission

1. Preparation for Phase 2 SWRS

The external consultants have been appointed for Phase 2, which is deemed to have started on 7 August 1988. As their Inception Report will include a detailed review of the situation, only a general assessment was made of progress since the consultants visit in October 1987.

Some progress has been made in most of the activities requiring action, although significant progress with certain aspects did not take place until recently. We are still particularly concerned over the lack of progress in the following areas:

- there are no experienced hydrogeologists attached to the team
- a monitoring network has not been established nor has the pumping test programme been completed
- administrative procedures need to be improved, particularly in relation to expenditure on field allowances and inventories of project equipment and facilities

Other groundwater projects have been undertaken or are planned for Sinai. These need to be coordinated with the SWRS programme. It is important, given the limited staff numbers available, that staff are not diverted from high priority SWRS activities. Cooperation with other organisations working in Sinai is essential.

Renewed attempts should be made to gather all existing information relevant to the SWRS study, particularly data from GMA, for the deep boreholes drilled by UNICEF and borehole data from Sahel Qaa. A particular priority is to enter all existing data onto the data base systems.

2. Arish-Rafah Study

The University team undertaking the first phase of the groundwater management study of the Arish-Rafah area had not completed their report at the time of the mission due mainly to delays in completing the well survey. Consequently, we have been unable to carry out a detailed review of their conclusions and recommendations at this time. This will be made when their report is received.

Nonetheless, following several meetings with the University team a number of recommendations were made to enhance their analysis and data presentation, particularly to improve estimates of consumptive use and the chemistry data.

3. Well Specifications

An outline technical specification has been prepared with assistance from RIWR for the shallow drilling programme in high priority areas. As far as possible we have attempted to take local materials, drilling methods and technical skills available into account. We would not for example normally suggest the use of bentonite and the cable percussion drilling method would be more appropriate to some of the holes to be drilled. The specification will require further detail and perhaps some modification by RIWR. Accent has been given to the development and testing.

B. Data Base Installation and Training

The hydrological data base, HYDATA, and the hydrogeological data base, GRIPS, were installed on two microcomputers of the RIWR Computer Centre. Apart from a minor hardware fault both packages performed satisfactorily.

The three technical members of the Computer Centre were trained in the operation of both HYDATA and GRIPS. Their enthusiasm was encouraging and they appear to have a good understanding of both packages.

The mission provided advice to the senior staff who:

* devised a suitable set of codes for GRIPS
* accepted the metric co-ordinate system
* adopted the SDS-1 water point numbering system

Although only a limited amount of data was added to GRIPS, this included the major data types. The existing data needs to be assembled in a form which will allow the speediest entry onto GRIPS and HYDATA. During the mission it was repeatedly stressed that with any computer data base there is the task of entering existing data. Once the backlog of data have been entered then it is an easy task to enter data as it is collected but there is no easy way to avoid the initial data entry.

The entry of the backlog of data should be given a high priority. The SDS-1 inventory has now been obtained by RIWR and contains details of some seven hundred and fifty water points. The details of about one hundred and fifty RIWR boreholes are available and there are a further several hundred water points in the El Arish- Rafah area.

Now that the Phase 2 SWRS programme has begun, it is unlikely that there will be sufficient staff available to prepare and enter the existing data. We recommend that at least two staff should be assigned full-time to this activity. It would be preferable to complete this by January 1989. We understand that six engineers are being recruited and that two of these will be responsible for data entry. If this is not possible then two staff should be recruited on contract for a period of 3 months to enter existing data.

Annexe

TERMS OF REFERENCE

The Consultant will undertake a mission to Egypt in order to assist the Research Institute for Water Resources (RIWR) in the consolidation of phase I operations of the Sinai Water Resources Study (SWRS) prior to commencement in July 1988 of the phase II programme.

The mission will cover:

a) Review of conclusions of El Arish aquifer study

The RIWR is now undertaking with the assistance of Cairo University staff a study to establish the present situation in El Arish in regard to the deterioration of groundwater quality resulting from the rapidly increasing demand for water supplies in the area.

Interim report No.1 of the study dated March 1988 is enclosed for information.

On completion of this study, which will be mainly based on existing data being collated under the study, the RIWR/Cairo University will make recommendations for subsequent drilling/testing and monitoring programmes required to allow formulation and implementation of an appropriate groundwater management strategy for the El Arish area.

The Consultant will provide one hydrogeologist (Mr R Bradford) for a 3-week mission to Egypt in order to review the conclusions and recommendations of the El Arish study and assist the RIWR in the preparation, by the end of the mission, of specifications for the shallow drilling programme to be launched in late 1988.

In addition, the Consultant will review progress since his last visit on the other activities to be undertaken by the RIWR in order to consolidate SWRS phase 1 operations, details of which are given in appendix 2 of the Consultant's report dated December 1987.

b) Provision of data-base software

The Consultant will provide appropriate software requirements to allow the establishment of a hydrological/hydrogeological data-base system utilising the IBM-compatible microcomputers now installed in the RIWR headquarters in Cairo, El Arish and El Tor.

The software to be provided shall be one (1) GRIPS and one (1) HYDATA system and must include the following general specifications:-

(i) Hydrological - store, edit, print and plot basic hydrological data, storage and presentation of data being in calendar or hydrological years

- produce summaries of daily data for publication and monthly data for graphical output and in ASC II text form for transfer by floppy disc to other machines.

(ii) Hydrogeological:
- Stores hydrogeological data for up to 1000 stations
- Up to 13 types of data for each station
- Extensive use of menus and screen addressing for ease of use
- User-defined station names used to reference sites
- Geographic locations given by UTM grid co-ordinates
- Data input from keyboard or computer files to allow conversion from existing computer storage systems or solid state memory instruments
- Fully inter-active editing facilities
- Optional automatic update of water level records if station datum changed
- Tabular printer output for all data types
- Project title included in all output
- Simple company logo included on all graphic output
- Map output for specified data types showing parameter values at stations
- Standard graphs for most data types
- Time series graphs for water levels, electrical conductivity, temperature and barometric pressure data
- Output to computer file for further analysis
- Password protection to limit system access and three levels of operator permission to reştruct use to:

output only
output and input
or output, input and editing

Specific details of the software proposed by the Consultant will be forwarded by telex to the RIWR prior to commencement of the mission.

c) Provision of training in data-base operations

The Consultant will provide one specialist in computer operations on hydrological/hydrogeological activities to undertake a 3-week mission to Egypt in order to:

- install the aforementioned data base system on the one micro-computer.
- train the RIWR computer staff in the use of the software programme components
- confirm that the RIWR data collection and well numbering systems are appropriate for the data base
- assist the RIWR in the selection of suitable data base codes
- to assist the RIWR to enter some existing data onto the system

Appendix

SINAI WATER RESOURCES STUDY (SWRS)
PRELIMINARY TECHNICAL SPECIFICATION FOR
SHALLOW DRILLING
AND CONSTRUCTION FOR
PHASE 2 HIGH PRIORITY AREAS OF INVESTIGATION

Technical Specification - Format

100 GENERAL

200 DRILLING

300 CONSTRUCTION

400 MATERIALS

500 DEVELOPMENT

600 TESTS

700 SAMPLING AND REPORTING

1. General

100. DESCRIPTION AND PURPOSE OF WORKS

The works to be undertaken under contract consist of the drilling and construction of about --- boreholes, each not more than --- m in depth.

The boreholes to be drilled will be of two types:

(a) Piezometers, approximately--- no.
(b) Test boreholes approximately--- no.

The purpose of the works is to obtain hydrogeological information to assist an assesssment of the occurrence and availability of groundwater resources in certain areas of the Sinai which are described below.

Whilst the test wells constructed under this contract may in due course be used for water supply purposes, the main objective of the works is to obtain scientific information on the aquifer conditions in each area. The contract therefore includes significant sampling and testing components.

101. LOCATION OF WORKS

The works are to be carried out in the following areas of the Sinai region of Egypt:

- El Arish to Rafah area of North Sinai
- Sahel el Qaa and El Tor in southwest Sinai
- Wadi Gerafi in east Sinai

The general location of these areas is shown in Figure . The approximate areas of each proposed drill site is shown in Figure . These sites may be altered by the Engineer following detailed geological and geophysical investigations and are indicative only.

The exact position of each borehole to be constructed will be determined and marked on the ground only by the Engineer during the course of the contract. It shall be the Contractors responsibility to give adequate notice to the Engineer so that the position of each borehole can be marked sufficiently far in advance to avoid delay in the work.

It shall be the Engineers responsibility to show the Contractor or his agent the position of each site to be drilled. No payment shall be made for any drilling at a site not selected and approved by the Engineer.

The Contractor shall make his own arrangements for access to the site and to each of the boreholes to be constructed.

(a) Arish and Sheikh Zuwayid-Rafah areas

The northeastern coastal area of Sinai between Arish and Rafah has been designated a high priority area of study by SWRS.

In recent years the area under cultivation and the demand for potable water supplies has increased in these areas. Available evidence suggests that this has caused a deterioration in water quality. Recently, part of the urban water demand has been met from imported Nile water but there is an urgent need to quantify the groundwater availability to provide an appropriate strategy for managing the water resources.

The first phase of a ground water management sturdy of this area has recently been completed. This has assembled hydrogeological and other information on the area, which will be made available to the Contractor on request. The second phase of this study will include detailed monitoring of the area for subsequent analysis and model studies. The works to be undertaken in this Contract will provide additional information on the aquifers in this area to assist this second phase of the management study and provide additional sites for a monitoring network.

The area of general study covers the area of from El Arish to Rafah. Dune sands, cover much of the area. Average annual rainfall is about 100 mm increasing eastwards to about 300 mm at Rafah. Rain occurs on average on about 15 days/year, mainly between November and March. Large floods can occur along the Wadi El Arish during this period.

The coastal area is generally accessible by paved roads but access away from these roads is by unpaved roads. Access for heavy vehicles is particularly difficult in the sand dune areas.

A generalised geological sequence is given in Table ---. The Contractor should familiarise himself with the geological conditions in the study area.

The main aquifers are as follows:

- dune and beach sands. These occur mainly along the coastal belt and provide local water supplies in the area east of Sheikh el Zuwayid. The dune sands are being developed for potable water supplies.

- alluvial deposits of the Wadi El Arish. These form the main aquifer in the area, having a total thickness of 40 to 60 m and a saturated thickness of 10 to 30m.

- kurkar (calcareous sandstone). This formation occurs throughout the area and forms the main aquifer at Rafah where they are at least 60m thick. Poor quality water may occur in this formation.

(b) Sahel El Qaa-El Tor

Sahel el Qaa is an extensive valley bordering the Red Sea in southwest Sinai.

This area has a high agricultural potential and in recent years pilot farm development has begun in the northern part of the valley. However, the groundwater resources of the area need to be studied in order to provide an appropriate strategy for the development of the area.

El Tor is a regional centre situated on the coast about midway along the valley. Groundwater is abstracted at El Tor for urban supplies and also to supply Sharm el Sheikh. The area is undergoing rapid development and there is an increased risk of saline intrusion occurring at El Tor. Rainfall in the valley is generally less than 20 mm/year. Access is generally good over most of the valley.

The valley has a thick sequence of unconsolidated Quaternary deposits. These deposits form the main aquifer but brakish water occurs at depths of about 150 to 200m. SWRS have undertaken some drilling in this area but the main source of information is an MSc thesis by Refai submitted in 1983. SWRS are currently undertaking the assembly of hydrogeological data for the area which will be made available to the Contractor. It is the responsibility of the Contractor to familiarise himself with the geological conditions in the area.

The work to be undertaken as part of this contract will provide additional information on the groundwater conditions in the area and provide a network of monitoring sites.

102. ASSISTANCE FOR ENGINEERS INSPECTIONS

The Contractor shall give all necessary assistance to the Engineer during the contract to enable him to carry out such examinations of the works as are required from time to time.

103. CLEANING UP OF SITES

The Contractor shall keep the sites of the wells and any temporary works clear from obstructions and debris as far as possible during the contract. As soon as possible after completing each site the Contractor shall remove all plant, debris, equipment and accommodation from the site so as to restore the site as far as possible to the satisfaction of the owners, tenants and occupiers and the Engineer.

104. LANGUAGE

All communications from the Contractor to the Engineer shall be in Arabic. All time sheets, drilling and testing records, notes, documents etc shall be in Arabic.

105. DATUM FOR MEASUREMENTS

All measurements of borehole depths, geological formations, water levels shall be taken from a fixed point at ground level at each wellhead. All units shall be in metric except where otherwise provided.

106. CONTRACTORS PERSONNEL

The Contractors attention is drawn to the necessity for an effective organisational structure comprising adequate numbers of personnel qualified and experienced in the specialist fields necessary to ensure compliance with the contract requirements and adherence to the construction programme. Each drilling rig shall for the whole of each shift be in the direct charge of an experienced well driller who shall be competent to take all measurements and samples and to record and report all information required by the Engineer. A technically experienced superintendent shall also be employed to supervise the work.

Table. Simplified Stratigraphy: El Arish - Rafah area.

Dune sands			Holocene
Raised beach deposits			
Recent wadi deposits		5 - 25 m	
Upper sands [with thin silts and clay lenses (4-20m)]		5 - 30 m	Pleistocene
Lower sands/gravels (with clay lenses)		5 - 30 m	
Calcareous sandstone (kurkar)	Upper (continental facies)	20 m	
	Lower (marine facies)	40 m	
Upper conglomerate			Pliocene
Lower marl			
Clay			Miocene
Limestones, clays and shales			Cretaceous

2. Drilling

200. METHOD OF DRILLING

The boreholes shall be drilled by the direct-circulation, rotary mud-flush method using bentonite mud. The Contractor shall put forward the type(s) of drilling rig, plant, and type of bentonite he intends to use. Imported bentonite shall be preferred. The Contractor shall ensure that the rig(s) can:

- drill the holes at the specified diameters and depths with reasonable speed and ease

- has sufficient capacity to install the string of casing and screen of the weights and dimensions required

- has sufficient capacity to free stuck pipe or casing

- can handle a drilling string (including drill pipe and collars, stabilizers etc) of such weight and dimensions to ensure reasonable penetration with the minimum of misalignment

- the mud pumps are of sufficient capacity to ensure the annular velocities will provide proper and efficient cleaning of the hole during drilling

The bottom hole drilling assembly shall be stabilised by incorporating drill collars of suitable diameter and weights and appropriate stabilizers/reamers placed at strategic locations above the bit in order to minimise hole deviation and misalignment.

Surface storage for circulating drilling fluids may be ground pits or tanks of adequate size for the hole to be drilled. The storage shall be effectively divided into two or three sections and designed so that adequate settling of cuttings can occur. The settled cuttings shall be cleared from the storage from time to time to minimise the recirculation of cuttings. The sand content shall not exceed 2% by gross value of the drilling fluid entering the hole.

The Contractor shall be responsible for the provision of water for drilling purposes and for an adequate reserve supply on site to ensure continuity of operations.

The properties of the drilling fluid (mud-weight, viscosity, filter loss, sand content, EC and pH) shall be monitored during drilling operations at intervals of not more than 6 hours or at the Engineers request in order that these properties remain consistent with good drilling practice and cause least damage to the aquifer. At all times the Contractor shall have the necessary equipment of standard manufacture in good working order to measure these properties.

The Contractor shall be entirely responsible for any fishing operations and all costs related to such operations resulting from any cause whatsoever.

It shall be the Contractors responsibility at his own cost to prevent the collapse of unstable strata by installing conductor pipes, temporary or permanent casing. The cost of removing temporary casing or reaming to install such casing shall be borne by the Contractor.

201 TYPES OF BOREHOLES

Typical designs of the boreholes to be drilled under this contract are shown in Figures A and B. The Contractor is required to satisfy himself as to the sufficiency of the designs.

Three types of boreholes are to be constructed:

(a) Piezometers for geophysical logging and monitoring of water levels

(b) Piezometers for geophysical logging and for monitoring of saline intrusion and water levels

(c) Test wells for pumping tests.

General information is given in Table 1.

202 ABANDONMENT OF BOREHOLES

The Contractor shall be entirely responsible for completing each borehole true to alignment, verticality and to the depth determined by the Engineer. No excuse for his failure to do so will be accepted.

Should the Contractor fail to complete any borehole or if at any stage completion is prevented by collapse or other cause or by faulty workmanship or negligence on the part of the Contractor the the Engineer will order the work to be discontinued and/or the hole to be abandoned. The Contractor shall then refill and plug the hole all at his own cost using materials approved by and to the satisfaction of the Engineer.

A replacement hole shall then be drilled at a location designated by the Engineer and at no additional cost to the Employer.

The Contractor may where possible recover or salvage materials from a hole so abandoned but such materials shall only be used elsewhere on the contract if permission to do so is given by the Engineer.

203. SEQUENCE OF OPERATIONS - PIEZOMETERS

The sequence of operations for the deep piezometers at paired sites and single piezometer sites shall be as follows:

(a) Drill and install surface conductor casing

(b) Drill at 8 1/2 inch diameter to required depth
(c) Run geophysical logs as specified in clause 701
(d) Place backfill to depth selected for completion if required
(e) Run casing and screen to depth selected for completion as specified in clause 300
(f) Place gravel pack as specified in clause 301
(g) Develop well as specified in clause 501
(h) Top-up gravel pack (if required) and place grout
(i) Construct concrete plinth, fix well cap and clear site

The sequence of operations at the shallow piezometers at the paired sites shall be as above except that item (c) will not be required. The deep piezometer shall be constructed first where paired piezometers are to be constructed.

204. SEQUENCE OF OPERATIONS - TEST WELLS

The sequence of operations for the test wells shall be as follows:

(a) Drill and install surface conductor casing
(b) Drill at 17 1/2 inch diameter to depth selected from logs of adjacent deep piezometer
(c) Place casing-screen assembly to the depth selected for completion according to clause 300
(d) Place gravel pack according to clause 301
(e) Carry out initial development by air lift as specified in clause 501
(f) Carry out final development with pump as specified in clause 502
(g) Perform step test according to clause 601
(h) Perform constant rate and recovery test as given in clause 602
(i) Top-up gravel pack (if required) and place grout
(j) Construct plinth, fix wellcap and clear site

205. CESSATION OF WORK

The Engineer reserves the right to stop drilling operations in the event of the following:

- the work is not carried out in a satisfactory manner
- further drilling is unlikely to be advantageous
- any other relevant cause

In this event payment shall only be made for the amount of work done up to the time of stoppage.

206. WAITING TIME

Waiting time shall be such time as the whole of the drilling equipment and staff are on site and is available for use, and all operations connected with the contract are at a standstill due to absence of instructions from the Engineer where required and/or lack of materials to be supplied by the Engineer provided that a request for necessary instructions and/or materials has been given with reasonable warning, which in the case of instructions shall be 48 hours and for materials 14 days.

3. Borehole Construction

300. INSTALLATION OF CASING AND SCREEN

After receiving the geophysical, drilling and lithological logs from the Contractor for each piezometer the Engineer shall select the following:

- the depth of completion
- the number, length and position of screens
- the test well design where appropriate
- the depth of the adjacent shallow piezometer where appropriate

These will be installed by the Contractor accordingly. The hole shall be cleaned by circulating drilling fluid before installing the screen(s) and casing.

The well string shall be set truly central in the borehole by means of centralisers made from the same material as the casing and screen and spaced at vertical intervals of not more than 15 metres. The bottom of the well string shall be closed by a conical end cap.

Prior to placing the gravel pack the well string shall be suspended from the surface and shall not be allowed to bear on the bottom of the hole until placing of the gravel pack is complete.

301 PLACING OF GRAVEL PACK

After the casing and screen has been run clean fresh water shall be circulated at very low pump rates from the surface through the casing with a non-return foot valve. Light mud will be displaced from the screen and casing and annular space. The drill pipe will be connected to the foot valve during circulation of the annular space.

As soon as the drilling mud starts to thin, gravel will be poured through funnels simultaneously from two opposite sides into the annular space between the well string and the borehole wall. Placement shall continue until the level of the gravel pack reaches 2.5 metres below ground level.

Slow circulation shall be carried out continuously during the placement of the gravel pack. The level of the gravel pack shall be measured frequently during and at completion of the operation.

302 PLINTH AND CAPPING

Following development of the piezometer and testing of the test well the depth of the gravel pack shall be measured and further pack added if required to bring the level of the pack up to the required depth.

Fine sand shall then be placed on top of the gravel pack to a depth of 2 metres. Cement grout shall then be placed in the annulus from the top of the sand up to ground level. A concrete plinth of the dimensions specified shall then be constructed.

Each borehole shall be capped with a tamper proof cap securely fixed to the top of the casing and of a type approved by the Engineer.

4. Materials

400 GENERAL

All casing and screen shall be new and of the type, material and standard specified below and shall be approved by the Engineer.

The Contractor should satisfy himself as to the suitability of the specified materials in regard to strength and other properties for installation to the depths required by the specification.

401. CASING

The casing shall meet the following specifications:

	Piezometer	Test Well
Material	Galvanised. mild steel	Mild steel (Spiral weld)
Diameter (mm)-nominal	100	250
Wall thickness (mm)- "	6.35	. 6
Joints	Screwed	Butt-welded
Weight/metre (kg)	*	*
Grade	*	*

* Information to be supplied by RIWR

402 SCREEN

The screen shall meet the following specifications:

Material, diameter,wall thickness and weight/metre as for casing.
Longitudinal welded.
Nominal open area not less than 10%.
Slot type- Piezometer: vertical slots, offset circumferentially
1.5 mm width
Test Well: bridge slots
1.5 mm width

Slots shall be machine made and free of burrs or irregularities. The screen shall be fitted with a sump of 2.5m in length of the same material as the screen and casing and ending in a conical shape for the test well. A suitable screw cap may be used to close the bottom of the sand trap on each piezometer.

403. PACK

The gravel pack (filter) shall consist of washed material with the following characteristics:

- natural sand and gravel (coarse sand to fine gravel) having not more than 10% of less than 1.5 mm grain size; not more than 10% of more than 6mm grain size; and a d50 of 3mm.

- siliceous, with no chalky or limestone material

- hard, rounded grains

404. CEMENT GROUT

The cement grout shall be a mixture of Portland cement and water at a ratio of 19 to 23 litres of water per 43 kg of cement with a slurry density of not less than 1.6 g/cc.

The Engineer may instruct the Contractor to add between 1.5 and 2.5 kg of bentonite per sack of cement to reduce shrinkage during setting. In such a case 25 litres of water may be used.

5. Cleaning and development

500 CLEANING AND DEVELOPMENT

After each borehole has been constructed but prior to development any drilling fluid and debris shall be cleaned out by circulating clean, fresh water at a low pump rate.

501 DEVELOPMENT BY AIR-LIFT (Piezometers and test wells)

Following the initial cleaning operations the Contractor shall install an air-lift arrangement for further cleaning and initial development. The equipment will consist of an air compressor, air and pumping (or drop) pipes, flexible high pressure hose, discharge pipe, weir tank and the necessary fittings for the proper operation of the air-lift assembly. Excessive spraying of the working area during the air-lift operations shall be avoided. The Contractor shall also include any other items not mentioned above which in his experience are also required for proper operation of the air-lift.

For the development of the test wells, the size of the compressor shall be such as to be capable of lifting water from a depth of 150 m bgl at a rate of 5 to 10 litres per second. The pumping pipe shall be of 75 mm diameter. Both the pumping pipe and the air-line pipe shall be capable of being placed to a depth of 150 m.

For the development of the piezometers, the compressor should be capable of lifting water from 150 m bgl at a rate of 2.5 l/s. the 4 inch casing can be used as the pumping pipe.

The air-lift development procedure shall be as follows:

(i) The air-lift assembly shall be lowered initially to 10 m above the top of the screen (except for the piezometers required to monitor saline intrusion, where the assembly shall be lowered to 1/3 submergence) and operated at a low rate of pumping for such a period as directed by the Engineer's Representative. This shall be repeated at such depth intervals as directed by the Engineer's Representative to a depth of 1 m above the base of the screen. The well depth shall then be checked and any material in the sump will be removed by pumping.

(ii) The air-lift assembly will then be lifted and operated in cyclic stop-start mode of pumping and backwashing at depth intervals and for such a period as selected by the Engineer's Representative of the length of screen to 3 m above the screen. The well depth shall then be checked.

(iii) The air-lift assembly will then be operated in surge-pumping cycles down the length of the screen to 1 m above the base of the screen at depth intervals and for periods directed by the Engineer. The air-pipe shall be maintained within the drop pipe so that surging occurs only from the falling column of water within the drop pipe after ceasing the pumping cycle. The release of air for air-surging using the air-line protruding below the drop pipe shall not be allowed. The depth of the well shall then be measured and any material in the sump which has accumulated to a thickness of more than 0.5 to 0.75 of the sump shall be removed by pumping.

Operations (i) to (ii) above may be repeated individually or in combination if so required by the Engineer until the discharge water is clear and free of sand.

502. DEVELOPMENT BY PUMPING (Test wells)

After initial development of the test well with the air-lift arrangement and to the approval of the Engineer a pump capable of delivering between 5 and 25 l/s from a depth of 100 m shall be installed immediately after withdrawing the air-lift assembly.

There shall be sufficient clearance between the rising main and the casing to allow a 25 mm diameter water-level dipping pipe to be temporarily attached to the side of the rising main to a depth of 1 m above the top of the pump. The pump intake shall be set 1.5 m above the top of the screen. The Engineer may require the pump to be placed within any cased portion of the borehole where such casing has been placed to separate lengths of screen.

A suitable valve shall be provided in the discharge pipework to permit control of the discharge together with an orifice plate arrangement to measure discharge (ref. Clause 603).
The Contractor shall then develop the borehole by initially pumping at the minimum rate of the pump for a period directed by the Engineer. The rate will then be increased progressively in stages up to a maximum of 25 l/s and durations selected by the Engineer. During each stage the pump shall be operated in stop-start cycles at such time intervals as directed by the Engineer.

503. MEASUREMENTS DURING DEVELOPMENT

During development by compressed air and the pump the following measurements shall be undertaken:

a) Rest water level before and after cleaning of the borehole

b) Water levels and discharge rates during airlift pumping at time intervals as directed by the Engineer.

c) Water levels and discharge rates during pump surging and overpumping at such time intervals as directed by the Engineer's Representative.

d) Sand content at time intervals selected by the Engineer during development with the pump.

6. Pump testing

600. DESCRIPTION

Two types of test are to be undertaken on each test well. The first shall be a step (production) test consisting of four steps without intervening recovery. The second test shall be a constant rate (aquifer) test followed by a recovery test.

601. STEP-TEST

The water level in the test well shall be allowed to recover for 24 hours following the satisfactory completion of the pumping development operations. The pumping test equipment installed will then be used by the Contractor to carry out a four stage step test. This test can be started before 24 hours have elapsed after pumping development if the Engineer decides that the water level has recovered sufficiently for the step test.

Each step will be of two hours duration without recovery between each step. The pumping rate will be held constant during each step. The approximate rates of pumping will be as follows:

Step	Pumping Rate (litres/second)
1	5
2	10
3	15
4	20

unless the Engineer decides that other rates will be more appropriate from the yield drawdown information obtained from the development operations.

The rest water level in the test well and in each adjacent piezometer shall be measured immediately prior to the test. Throughout each step the water levels shall be measured and recorded at the following times:

Time since pumping commenced or increased (minutes)	Time interval (minutes)
0-5	1/2
5-10	1
10-30	2
30-60	5
60-240	10

Discharge rates shall be measured at the following times:

Time since pumping commenced or increased (minutes)

1
5
10
at 10 minute intervals thereafter

Recovery levels are not required at the end of the step test.

602. CONSTANT RATE TEST

Water levels in the test well and piezometers shall be allowed to recover for 24 hours following the step test unless the Engineer decides that water levels have recovered sufficiently for the constant rate test to begin.

The constant rate test shall be of three days duration. The discharge shall remain constant for the entire period of the test. The exact discharge of the test shall be decided by the Engineer using information from the step test.

The rest water level in the test well and in each adjacent piezometer shall be measured immediately prior to the test. Throughout the test the water levels shall be measured and recorded in the test well and each piezometer at the following times:

Time since pumping commenced or increased (minutes)	Time interval (minutes)
0-5	1/2
5-10	1
10-30	2
30-60	5
60-240	10
240-600	15
600 and subsequently	30

Discharge rates shall be measured at the following times:

Time since pumping commenced (minutes)
1
5
10
15
20-60 at 10 minute intervals
60 to end of test at 20 minute intervals

At the end of the test a recovery test will be carried out for a period of 24 hours. Water levels shall be measured and recorded in the test well and each piezometer at the same frequency and times following shutdown as for the constant rate test. The test pump shall not be removed until the recovery test is complete.

603. MEASURING EQUIPMENT

Water levels shall be measured by an approved electrical contact gauge of standard manufacture and of at least 100 metres length with centimetre and metre graduations. At least four such gauges in working order shall be kept on site. At least four stopwatches, each in working order, shall also be kept on site.

Discharge rates shall be measured during development and each test by means of an orifice plate and manometer arrangement capable of measuring rates between 5 and 30 l/s. The Contractor may put forward other methods to measure discharge for approval by the Engineer or combinations of measurement methods. The measurement method shall be set up and calibrated in an approved manner in accordance with standard practice and to the satisfaction of the Engineer.

604. DISPOSAL OF WATER

The Contractor shall negotiate, arrange and be responsible for all temporary works required to carry the discharge a minimum of 50 metres from the site in an impermeable channel or pipe. Thereafter the water shall be channelled so that the disposal does not damage property or cause nuisance.

605. INTERRUPTIONS DURING TEST PUMPING

In the event of interruption of any stage or step during pump testing operations the Contractor shall repeat the test at a time to be decided by the Engineer. The Contractor shall bear the cost of any test that is interrupted where, in the opinion of the Engineer, this is due to negligence on the part of the Contractor.

7. Sampling and Reporting

700. FORMATION SAMPLING

Routine samples are required at 2.0 metre intervals and at significant changes in strata. Samples shall be collected from the return of circulating fluid at the well head by a suitable method that will ensure that the samples are representative of the strata penetrated.

Duplicate samples each of about 0.5 kg shall be taken. One set shall be partially washed and placed in strong approved plastic bags. Each shall be clearly marked with waterproof labels to indicate the well number and the depth at which the sample was taken. The second set shall be left unwashed and shall also be placed in approved strong plastic bags and clearly marked. Both sets of samples shall be made available to the Engineer during construction.

701. GEOPHYSICAL LOGGING

Geophysical logs shall be made by the Contractor on the deep piezometers at paired sites and each single piezometer site to the full depth of the drilled hole immediately on completion. The geophysical logs will include self-potential, long and short normal resistivity and gamma. Each log shall be of standard acceptable to the Engineer.

A copy of each log shall be supplied to the Engineer without delay so as to determine, in conjunction with the lithological samples, the depth of completion and final design.

702. WATER SAMPLES

Representative water samples of not less than 1 litre shall be taken after 1 hour, 8 hours and then at intervals of 12 hours during the constant rate test. Each sample shall be stored in an airtight, plastic bottle and clearly labelled with the well number, date and time of sampling. These samples shall be handed to the Engineer without delay.

703. RECORDS

Detailed daily records shall be kept of all operations and tests during the construction of all boreholes. The Engineer shall have full access to all data and information as well as the right to witness all operations at any time.

704. REPORTING REQUIREMENTS

The Contractor shall prepare a daily drilling report containing the following information: depth drilled, strata penetrated, any loss of circulation, drill time, mud properties, bit records, operations carried out, full tally of tools, collars and drill pipes, materials installed, standing time and any other relevant information.

During the course of the works at each borehole and not later than 30 days after the completion of work at each borehole the Contractor shall submit the following reports in bound form:

(a) Daily drilling report
(b) Well development reports
(c) Pumping test reports
(d) Geophysical logs
(e) Well completion details report

These must be submitted to the Engineer before the invoice is submitted for each completed borehole.

705. WELL SURVEY

A well shall not be deemed complete until it has been surveyed under the Engineer's supervision and accepted by the Engineer. The survey shall consist of the following measurements:

- total depth drilled
- total depth after placing casing and screens
- depth to standing water level after development
- compliance with clause 706

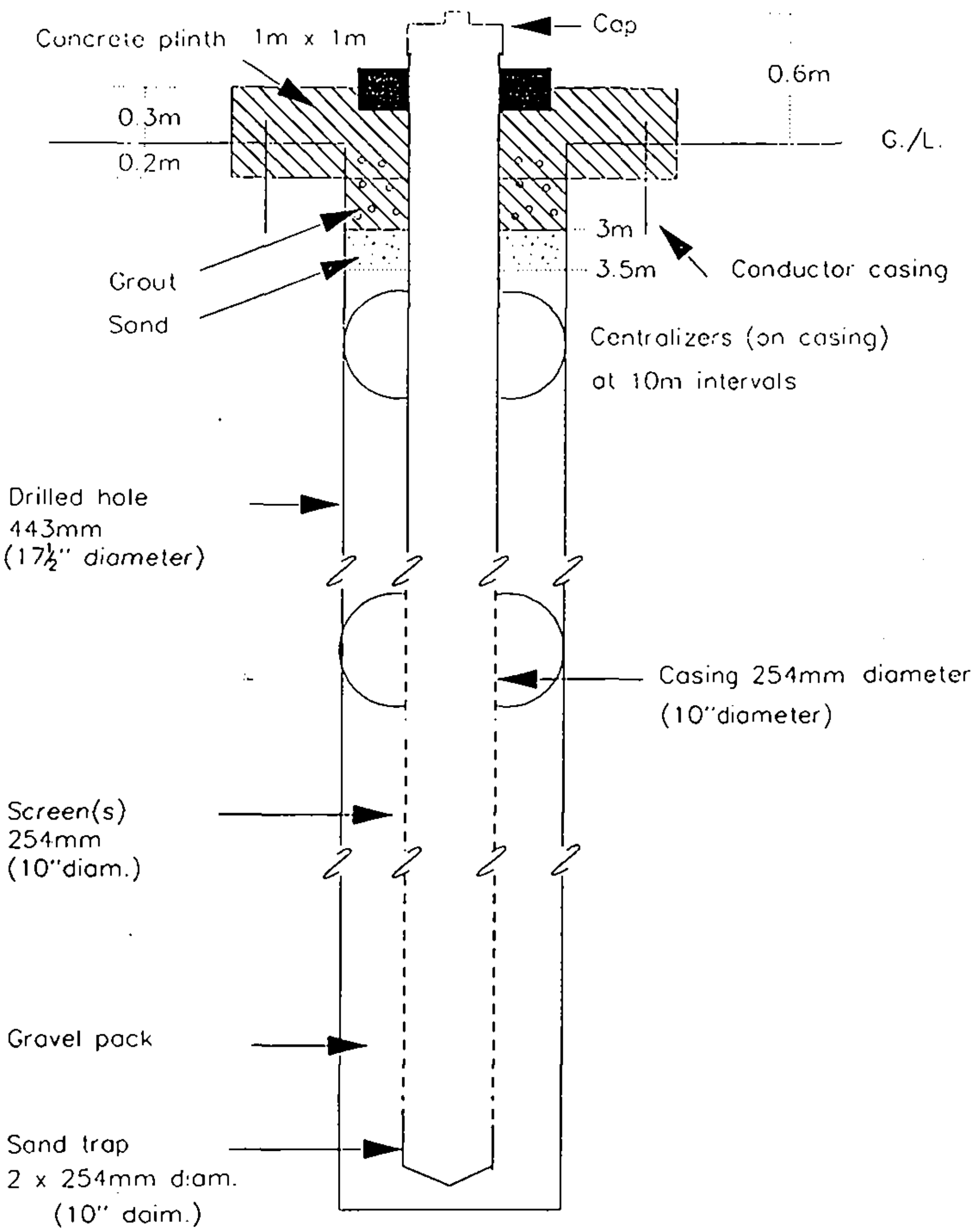
The survey shall be carried out by the Contractor in the presence of the Engineer, who shall be notified when individual parts of the survey are to be performed.

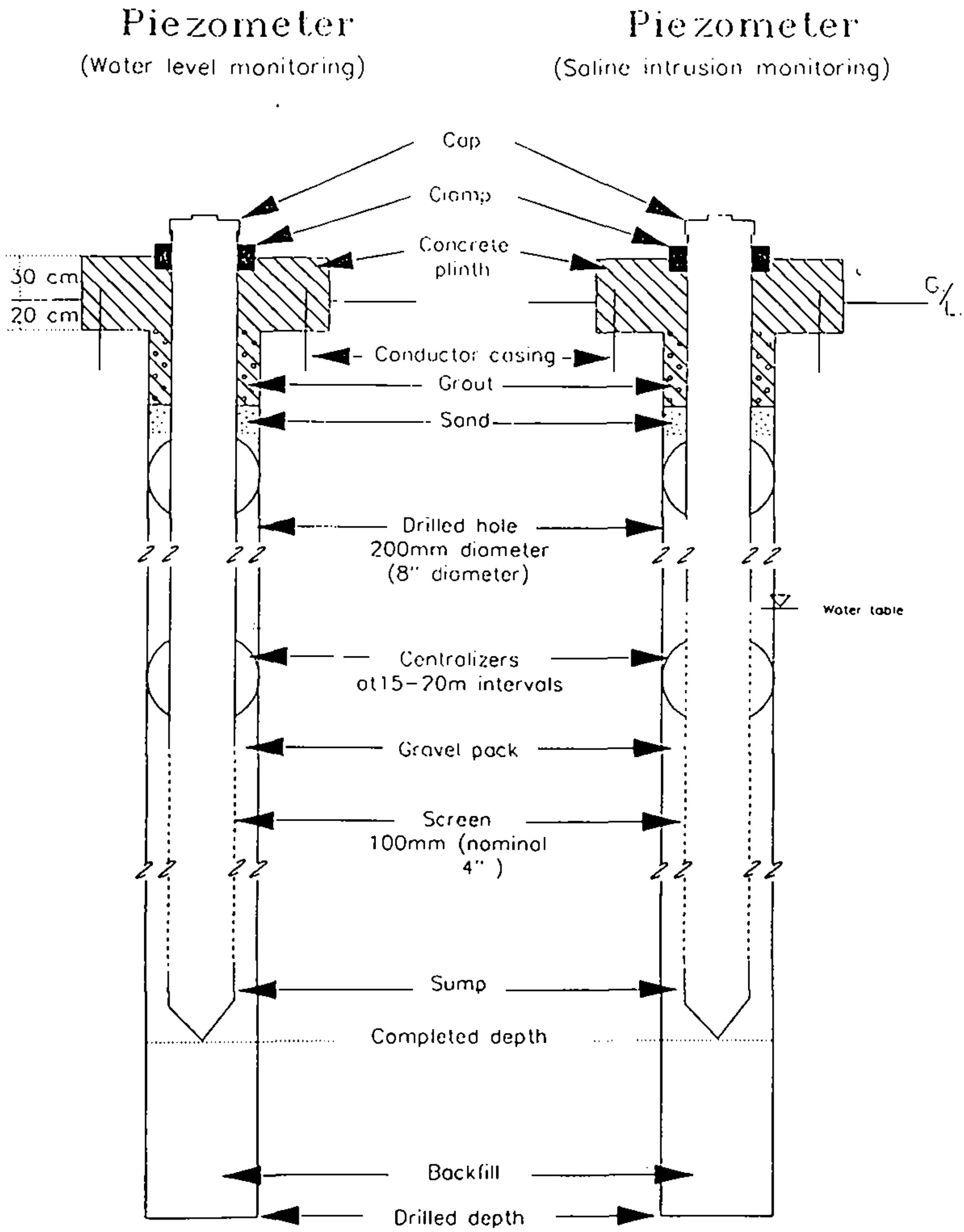
706. VERTICALITY AND ALIGNMENT

The borehole shall be sufficiently vertical and straight to allow insertion of the casing and screen and, in the case of the test wells, allow the satisfactory installation and operation of the test pump.

Should these conditions not be met the Engineer may not accept the borehole in which case no payment shall be made in respect of the borehole and the Contractor shall make the necessary corrections at his own expense.

Test well


Cap
Concrete plinth 1m x 1m
0.6m
0.3m
0.2m
G./L.
3m
3.5m
Conductor casing
Grout
Sand
Centralizers (on casing)
at 10m intervals
Drilled hole
443mm
(17½" diameter)
Casing 254mm diameter
(10"diameter)
Screen(s)
254mm
(10"diam.)
Gravel pack
Sand trap
2 x 254mm diam.
(10" daim.)


Piezometer
(Water level monitoring)
Piezometer
(Saline intrusion monitoring)
Cap
Clamp
Concrete
plinth
30 cm
20 cm
C/L
Conductor casing
Grout
Sand
Drilled hole
200mm diameter
(8" diameter)
Water table
Centralizers
at15-20m intervals
Gravel pack
Screen
100mm (nominal
4")
Sump
Completed depth
Backfill
Drilled depth