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***Yemen Arab Republic***

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WATER SECTOR COOPERATION PROGRAMME  
YEMEN ARAB REPUBLIC - KINGDOM OF THE NETHERLANDS

Report 2

evaluation report  
WATER RESOURCES ASSESSMENT  
YEMEN ARAB REPUBLIC (WRAY)

5497

Centre for International Reference  
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The Hague, January 1985

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From September 8-25, 1984 a joint evaluation mission of the Governments of the Yemen Arab Republic and the Kingdom of the Netherlands evaluated the water sector activities of the Yemeni-Dutch development cooperation programme with the aim to advise on future water sector activities together with an assessment of priorities. To this end the following activities were evaluated:

Water Resources

- a. Water Resources Assessment Yemen Arab Republic
- b. Tihama Water Resources and Water Use Study
- c. Al Bayda Water Resources Study

Domestic Water Supply and Sanitation

- a. Support Rural Water Supply Department
- b. Water and Sewerage Dhamar/Ibb
- c. Water Supply and Sanitation Component "Rada Integrated Rural Development"

Irrigation

- a. Wadi Rima Supervision
- b. Irrigation component "Rada Integrated Rural Development"
- c. Irrigation component "Tihama Agricultural Extension"

The main findings, conclusions and recommendations of the mission are presented in a four-volume report:

Report 1: Main report water sector cooperation programme Yemen Arab Republic - Kingdom of the Netherlands

Report 2: Evaluation report Water Resources Assessment Yemen Arab Republic

Report 3: Evaluation report Support Rural Water Supply Department

Report 4: Review and recommendations Netherlands supported water sector activities in the Yemen Arab Republic

The rapporteurs have the pleasure to submit the draft reports for comments to the counterparts within the joint mission through the Central Planning Organization of the Yemen Arab Republic. After their reaction c.q. clearance these reports will officially be submitted to the Governments of the Yemen Arab Republic and the Kingdom of the Netherlands and through them to all projects concerned.

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## ABBREVIATIONS

DOH	Department of Hydrology
WRAY	Water Resources Assessment Yemen Arab Republic
YAR	Yemen Arab Republic
YOMINCO	Yemen Oil and Mineral Corporation

## SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The project "Water Resources Assessment Yemen Arab Republic" (WRAY) executed by the Department of Hydrology (DOH) of the Yemen Oil and Mineral Corporation (YOMINCO) and TNO-DGV, Institute of Applied aims at:

- nation wide collection, storage and evaluation of hydrological and hydrogeological data;
- providing technical information, advises and appraisals to the benefit of proper water resources management, development and conservation.

From September 8 to 25, 1984 a Dutch evaluation mission visited the Yemen Arab Republic (YAR). The main tasks of the evaluation mission were:

- evaluation water sector cooperation programme Yemen Arab Republic - Netherlands;
- project evaluation Water Resources Assessment YAR;
- project evaluation Support Rural Water Supply Department.

This report describes the project evaluation WRAY. The summarised conclusions and recommendations are presented below.

The provisional conclusions for phase I of the WRAY project are:

- The actual mining of groundwater resources in the YAR a country with limited water resources, makes a project like WRAY with its chosen set up very valuable;
- The project approach by which special attention is paid to training and institution building is strongly supported by the mission;
- Although the employees of DOH have a promising attitude towards the project still a lot of training and institution buiding is required before DOH is able for fullfill all its tasks;
- Within the framework of the project a lot of very valuable information has been obtained already. This information underlines that the groundwater resources situation in the YAR is very critical. The mission strongly advises that the available information is distributed to the Ministries and Authorities involved, as well as to the public.

Assuming that phase I of the WRAY project will be finalized according to plan, the mission likes to give the next recommendations for a Dutch supported follow-up of the WRAY project:

A general recommendation concerns the Supreme Water Council and its relation to DOH. The mission likes to stress that a strong Supreme Water Council is a first requirement for the YAR and that such a Council needs a well-functioning and well-equipped technical secretariat, which role can be played by DOH.

The mission recommends a phase II of the WRAY project for about three years focussing on the following goals:

- to further strengthen DOH through training and institution building;
- to supply information to Ministries, organizations and the public on proper use of water and protection of water resources;
- to establish sufficient technical background to make the Supreme Water Council able to fullfull its tasks.

Based on these goals the mission recommends for phase II the following activities:

- to continue monitoring in the Saadah and Wadi Surdud area and to process and publish the data. Also to keep the equipment in these areas in good condition and to do some additional fieldwork if required for a better understanding of the hydrological system;
- to improve the data bank and the library;
- to carry out a water resources study for the Sana'a basin which is the most critical basin in the YAR or a water resources study in an area in which a lot of new developments are expected in the near future (like the Marib area);
- to distribute information on the hydrological conditions of the country, new publications etc. among the Ministries, Authorities, organizations and the press;
- to execute specific studies, or to give advice on request of clients, both private and governmental. These services are (partly) to be paid for by the clients.

## 1. INTRODUCTION

Within the framework of the development cooperation between the Yemen Arab Republic (YAR) and the Kingdom of the Netherlands the "Water Resources Assessment Yemen Arab Republic" (WRAY) project is presently under execution. The Department of Hydrology (DOH) of the Yemen Oil and Mineral Corporation (YOMINCO) is the executing agency from Yemeni side. The Netherlands contribution to the project is carried out through TNO - DGV, Institute of Applied Geoscience.

The WRAY is a long-term cooperation programme with regard to water resources assessment taking into account the tasks and responsibilities of DOH. The programme aims at:

- nation wide collection, storage and evaluation of hydrological and hydrogeological data;
- providing technical information, advises and appraisals to the benefit of proper water resources management, development and conservation.

The plan of operations for phase I of the project was signed in December 1981. The programme started April 1, 1982.

From September 8 to 25, 1984 a Dutch evaluation mission visited the YAR for a joint evaluation of the Netherlands supported water sector activities in the YAR. The Dutch mission was composed as follows:

- W.A. Segeren, Land and Water Development Specialist, teamleader of the mission
  - J. Blom, Water Sector Specialist
  - M.T. Boot, Development Sociologist
  - A. Kuyvenhoven, Economist
  - E. Schultz, Civil Engineer/Hydrologist
  - G.J. Tempelman, Rural Sociologist
- J.L. IJzermans, desk officer YAR of the Netherlands Ministry of Foreign Affairs, accompanied the mission as resource person.

The main tasks of the joint evaluation mission were:

- evaluation water sector cooperation programme Yemen Arab Republic - Netherlands;
- project evaluation Water Resources Assessment YAR;
- project evaluation Support Rural Water Supply Department.

This report describes the project evaluation of the WRAY. The mission members A. Kuyvenhoven and E. Schultz paid special attention to this evaluation. The terms of reference for this project evaluation are attached as Annex 1. The itinerary is given in Annex 2.

For most of the time the mission members were accompanied by mr. Ahmed Wahib, YOMINCO, Department of Hydrology, and mr. J. van der GUN, TNO - DGV, Institute of Applied Geoscience, co-managers WRAY. Their helpful attitude and the extensive information supplied by them is very much appreciated by the members of the mission.

The active involvement of the Embassy of the Netherlands was of great importance to the work of the mission.



## 2. PROJECT DESCRIPTION

<u>Activity:</u>	Water Resources Assessment YAR (WRAY-I)
<u>Place:</u>	Entire Yemen Arab Republic with headquarters in Sana'a and field investigations in Saadah area and Wadi Surdud area.
<u>Executing authorities:</u>	a. YAR: Yemen Oil and Mineral Corporation (YOMINCO); executing agency: Department of Hydrology (DOH). b. Netherlands: Directorate General of International Cooperation (DGIS); executing agency: TNO - DGV, Institute of Applied Geoscience.
<u>Duration:</u>	40 months <u>Starting date:</u> April 1, 1982.
<u>Sector:</u>	022000 (water).
<u>YAR contribution:</u>	YR 4,783,000,- or Dfl. 3,500,000,-
<u>Neth. contribution:</u>	T.A. 5,000,000.- <u>F.A. 1,600,000.-</u> 6,600,000.-

### Summary of activities:

- Nation wide compilation of available data;
- The assessment of water resources in the Saadah basin and the Wadi Surdud area;
- To contribute to the establishment of a national data-bank;
- The training of manpower by means of continuous on-the-job training, short courses and fellowships.

### Justification:

The exploitation of the limited water resources in the YAR is increasing rapidly as a result of:

- increasing demands for agricultural, domestic and industrial uses;
  - availability of funds for water resources development programmes.
- To prevent over exploitation or water quality degradation, there is a need for water management and water control.

### Long-term objectives

- providing a significant contribution to the DOH's capability regarding water resources assessment;
- initiating a systematic regional water resources assessment programme in the YAR, which is considered to be a basic requirement for adequate water resources management.

### Immediate objectives:

- obtaining a nation wide compilation of relevant hydro(meteoro-) logical, hydrogeological and geophysical data, in order to facilitate the draft of a systematic regional water resources investigation programme for the YAR with its elements, ranked according to priority;

- obtaining a clear picture of the ground water and surface water resources of selected areas, by means of a detailed field study, preceded by an exhaustive inventory and recollection of already available data;
- establishing an experienced team of DOH hydrologists, hydrogeologists, geophysicists and technicians who are fully competent to deal with the demanding tasks of the DOH;
- contribution to the establishment of an adequate national data-bank for water resources data.

#### Plan of Activities:

- a. Mobilization:
  - Selection and preparation of teams; purchase of equipment and installation of office(s) and workshop.
- b. Training courses:
  - fellowships (in the Netherlands);
  - short courses in the YAR, as far as considered necessary;
- c. Technical activities in the selected areas:
  - data inventory and recollection;
  - data processing and preliminary evaluation of obtained field data;
  - processing, analysis and evaluation of data;
  - interpretation from the viewpoint of water resources use and management;
  - draft of report(s).
- d. Technical activities with respect to nation wide compilation of hydrological, hydrogeological and geophysical data:
  - inventory of available data;
  - inventory of available reports, publications and maps;
  - systematic review and analysis of all relevant data and reports.
- e. Technical activities databank:
  - assessment of amounts and types of data to be stored (now and in the future);
  - analysis of data reduction possibilities; estimation of expected frequencies and desired formats of retrieval;
  - selection (design) and introduction (if possible) of data bank system;
  - recommendation on data collection, storage and retrieval procedures.
- f. Organisation and other activities:
  - planning of activities Phase I;
  - monitoring of the projects progress;
  - organisation for technical reports and symposia;
  - maintenance of vehicles and equipment;
  - other activities.
- g. Planning of activities of Phase II.

#### Inputs

- a. Inputs YAR:
  - 26 team members;
  - office facilities; laboratory services; supplementary equipment; workshops and stores; office and rest houses at project area;
  - operational costs.

b. Inputs Netherlands:

- One co-project manager/hydrogeologist; one geophysicist; one technician; short mission experts;
- Office equipment; hydrological, geohydrological and geophysical equipment; means of transport;
- Technical assistance Saadah drilling programme.

### 3. PROGRESS OF THE PROJECT

In the next paragraphs the progress of the main project components will be discussed. This discussion is preceded by some general data with regard to personnel and financial aspects.

#### 3.1 Personnel

The effective number of Yemeni personnel is around 25. Among them, there are eight professionals and six technicians. The Dutch staff is composed of a co-manager/hydrologist, a geophysicist and a technician. Temporal repatriation of the technician for medical treatment was compensated by a short mission of a geophysical engineer. From April 1984 onwards, a Dutch associate expert and a Yemeni technician contribute to the progress of the data base activities.

#### 3.2 Financial aspects

The global distribution of the allocated budget over the different components of Phase I of the project is presented in Table 1.

Up till 30-06-1984 the Yemeni expenditures amounted to YR 3,172,000.- whereas the Dutch expenditures amounted to Dfl. 3,836,000.-.

#### 3.3 Nation wide compilation of available data

In the YAR the available hydro(meteoro-)logical, hydrogeological and geophysical data can be divided in:

- basic field data, collected by different Ministries and Authorities;
- reports prepared by foreign consultants.

The first group of data proves to be difficult to obtain from the different Ministries and Authorities. This is why up till now data have been mainly compiled from reports prepared by foreign consultants.

The relevant data have been studied and interpreted by the project staff. This resulted in the publication "Hydrology and Hydrogeology of the Yemen Arab Republic" which was published in August 1984. The publication includes the following items:

- subdivision of the Yemen Arab Republic into geographical units;
- sources of hydrological and hydrogeological information;
- climate;
- surface water;
- groundwater.

The major part of the collected reports has now been transferred to the library of YOMINCO. The library is open to everyone. Publications can be found through a catalog system based on author and subject. The library does not dispose of an information channel to inform potential users about new obtained books, reports, journals etc.

Table 1. Global distribution of the allocated budget of the different components of the WRAY-I project

Subject	Final result	Cost Netherlands (x 1000 Dfl.)			Cost Yemen Arab Rep.
		technical	financial	ass. expert	(x 1000 YR)
Nation wide compilation	Report WRAY-1	220	-	-	50
Data base	Data base DOH systematic data collection and retrieval	40	-	150	100
Saadah study	Report WRAY-2/3 Training DOH network/borings hydro(geo)logical data	1750	700	-	1850
Surdud study	Report WRAY-4 Training DOH network/borings hydro(geo)logical data	2630	900	-	2650
Fellowships	2x 1 year Netherlands 1x 2 months Netherlands	60	-	-	150
TNO-Netherlands	Supervising backstopping and technical assistance equipment supply	300	-	-	-
		5000 "	1600	150	4800

" of which about 850 equipment and cars

### 3.4 Assessment of water resources in the Saadah area

The following activities have been carried out:

#### Field work:

- installation and operation of one simple stream flow station, five rainfall recorder stations, eight ordinary rain gauge stations and one meteorological station;
- an inventory of more than 1750 wells;
- geophysical well-logging in 62 wells;
- a geo-electrical survey including 241 vertical electrical soundings;
- sampling of groundwater at 15 wells for chemical analysis;
- 26 pump- and/or recovery tests of short duration;
- topographic levelling over a distance of approximately 35 km;
- operation of four groundwater level recorders and monthly monitoring of groundwater levels in approximately 70 wells.

#### Drilling programme:

Two deep borings (420 and 470 depth) have been made and geophysical well-loggings have been executed in these borings.

#### Monitoring:

- the stream flow station was abandoned after the execution of the field work as the discharge was very small compared to other components of the water balance;
- daily observations in the ordinary rain gauges by local observers;
- daily observations of rainfall, maximum- and minimum temperature, wind velocity, hours of sunshine and pan evaporation in the meteorological station at Dumeid;
- weekly collection of sheets from the rainfall recorder stations, the groundwater level recorders, and the temperature and relative humidity recorder by the observer assigned by DOH;
- monthly observations of groundwater levels by the observer of DOH.

#### Data processing and reporting:

The data and sheets collected during the fieldwork in the Saadah area are stored in the office of DOH. The data collected by the observer are controlled and stored by the hydrological networks section of DOH.

In October 1983 a summarizing interim report became available. Of the five annex reports three are completed (see list of references). The other two annex reports and the final report are presently under preparation.

### 3.5 Assessment of water resources in the Wadi Surdud area

Based on the selection criteria as formulated in the Plan of Operations, Wadi Surdud was selected as the second project area. Field work started in mid-December and has achieved the following:

- a hydrological network (meteorological station, streamflow station, 6 rainfall recorders and 6 rain gauges) has been installed and is operational;
- an inventory of approximately 750 wells has been made (during 4 2-week periods);

- data have been processed and preliminary maps (of groundwater level, electrical conductivity, abstraction, etc.) have been prepared;
- 136 geo-electrical soundings have been taken (during 4 2-weeks periods).

### 3.6 The establishment of a national data bank

All data that could be collected are now more or less stored in a data bank. Included are data on:

- existing ground water wells;
- groundwater levels;
- groundwater quality;
- well loggings and pumping tests;
- geo-electrical measurements;
- wadi discharges;
- rainfall

Still a lot of work has to be done in the field of controlling, ordening and mapping of the available data.

The intention is to put parts of the data bank on computer files suitable for processing with a mini computer. This process is in its preparatory phase. It has still to be decided which computer will be used.

The data are free accessible and can be copied at cost price. First clients have already obtained data from the data bank.

### 3.7 Training of manpower

The training mainly consists of continuous on-the-job training. In addition, four short courses were given at the DOH office in Sana'a:

- 5 - 10 February and 26 February - March, 1983: "Principles, field techniques and interpretation procedures of the electrical resistivity method";
- 7 - 9 May, 1983: "Introduction to geophysical logging in water wells";
- 21 - 26 May, 1983: "Introduction to hydraulics of groundwater and surface water";
- 6 - 10 November, 1983: "Introduction to aquifer tests".

The courses were attended by a part of the DOH team and some students of the University (3 to 8 people). For each course a syllabus has been made.

No candidates have been proposed for fellowship training in the Netherlands, partly because of a lack of suitable candidates, partly because potential candidates are indispensable in the project.

#### 4. SIGNIFICANCE, EFFECTIVENESS AND EFFICIENCY OF THE PROJECT

##### 4.1 Significance

The water situation in the YAR is very critical mainly because of a tremendous increase in groundwater irrigation during the last twenty years. At present in most of the aquifer systems mining of groundwater occurs; mining being a situation in which the abstraction of groundwater from an aquifer exceeds the recharge. An overview of the changing water situation and an indication of its implications for irrigated agriculture is presented in Annex 3.

By Degree no. 5 of 1978 the Department of Hydrology has been created within the Geological Survey Board of YOMINCO with the following main responsibilities:

- to collect and to organize water-related studies, and to carry out studies throughout the country;
- to collect data in the hydrological field, both surface and groundwater, and to receive any data in this field from all other sources.

Given the limited water resources in the YAR a competent national institution such as DOH can be regarded as essential for future water resources management. Expected benefits can be summarized as follows:

- a governmental organization, able to execute (geo)hydrological studies and to give advice to solve regional or practical hydrological problems;
- clear information to Ministries, organizations and the public on possibilities for proper water use and the damage that can be expected from wrong or over exploitation of water;
- sufficient technical background to establish legislative rules with regard to proper use of water and protection of the water resources.

Within this context the significance of the project will be clear as the project contributes to:

- institution building and training to strengthen the DOH to fulfill its tasks;
- the provision of information on water resources for present and future drinking and irrigation purposes. Such information may reduce the number of unsuccessful drillings (and save costs) and minimize the risk of poorly prepared irrigation projects, or wrongly located well sites;
- signaling unacceptable reductions in ground water resources and future water shortages;
- avoidance of potential capital losses caused by an unjustified development of agricultural land. Once such a capital loss materialises as a result of water shortage, employment will suddenly and severely be reduced;
- avoidance of intrusion of salt water in the aquifers of the Tihama region;
- provision of information required for the development of a water right and user code.



#### 4.2 Effectiveness

As phase I has still about one year to go only general comments can be made concerning the effectiveness of the project. The mission likes to make the next comments:

- the report "Hydrology and Hydrogeology of the Yemen Arab Republic" provides a very good insight in the water resources of the YAR, as well as in the critical situation caused by mining of groundwater resources. To get the maximum effect of the obtained information, great attention should be paid to the distribution of this information both to the Ministries and Authorities and to the public;
- the fieldwork executed in the Saadah area and the fieldwork under execution in the Surdud is valuable in two respects. On the one hand a large amount of valuable data was obtained from which a comprehensive picture of the water resources situation in the areas could be abstracted. On the other hand the fieldwork provides good possibilities for the employees of DOH to get acquainted with the collection and processing of different types of data and to get a good insight in the different groundwater resources systems;
- the data base that is presently under preparation gives DOH good possibilities to distribute relevant information to clients;
- the mission has the impression that, although there is a promising attitude within DOH, still a lot of training and institution building is required before DOH is able to perform all its tasks.

More generally, present achievements can be summarized as follows:

- institution building to improve DOH's capabilities to execute its tasks is making good progress;
- an overall picture has been obtained of the water situation in the YAR;
- solutions can now be formulated and measures taken to prevent unacceptable use of water.

#### 4.3 Efficiency

All project activities suffer more or less from delays varying from a few months to more than one year. The main reasons for delays are:

- very tight schedule of activities and underestimation of the amount of work;
- difficulties in obtaining data from the various Yemeni ministries and institutes;
- lack of adequate financial and administrative support from YOMINCO, especially delayed provision of funds to cover operation and drilling costs;
- manpower constraints.

Although these delays cause problems, it is the missions impression that they do not influence the quality of the work and that the project is being executed in an efficient way. The mission is of the opinion that the utmost is being done to make the project a success. The approach followed by the project to pay special attention to training and institution building is strongly supported by the mission.

To carry out its functions properly, a Department of Hydrology may well have to employ approximately 100 staff members, of which a considerable proportion needs to be highly qualified. This figure is in accordance with internationally accepted standards and tasks, and certainly relevant in the circumstances of the YAR.

The present staff of DOH (including expatriate personnel) consists of about 30 persons. Compared to the estimated need DOH is seriously understaffed. In many respects, the present size of DOH can be considered critical, both in terms of personnel and tasks to perform, and any reduction in its present staff would undoubtedly jeopardize essential functions.

At present the annual costs of DOH amounts to YR 5 million. At full strength recurrent costs can therefore be estimated to be YR 15 million.

#### 4.4 Conclusions

The mission likes to draw the next provisional conclusions regarding phase I of the WRAY project:

- The actual mining of groundwater resources in the YAR, a country with limited water resources, makes a project like WRAY with its chosen set up very valuable;
- The project approach by which special attention is paid to training and institution building is strongly supported by the mission;
- Although the employees of DOH have a promising attitude towards the project, still a lot of training and institution building is required before DOH is able to fullfull all its tasks;
- Within the framework of the project a lot of very valuable information has been obtained already. This information underlines that the groundwater resources situation in the YAR is very critical. The mission strongly advises that the available information is distributed in a more active way both to the Ministries and Authorities involved, and to the public;
- The collected data allows for a formulation of solutions and measures to be taken in order to prevent unacceptable use of water. However, on this subject the project has not yet given any recommendation.

## 5. FOLLOW UP OF THE WRAY PROJECT

Assuming that phase I of the WRAY project will be finalized according to plan, the mission recommends further Netherlands support to a follow up of the WRAY project. Considerations and recommendations for such a follow up are presented below.

### 5.1 General recommendation on the relation between the Department of Hydrology and the Supreme Water Council

In January 1982 a Supreme Water Council has been established aiming at a coordinated effort of Ministries and Authorities for adequate water resources management. (More details can be found in Annex 4). However, since its start, the Supreme Water Council does not function according to expectation. Given the critical water situation in the YAR the mission is convinced that every effort should be made for an effective functioning of the Supreme Water Council.

An important contribution to the functioning of the Supreme Water Council will be a strong and well equipped technical secretariat. DOH may be the most suitable organization to play this role. On the one hand the main responsibilities of DOH are such that it will be increasingly in the position of assisting in an effective functioning of the Supreme Water Council. On the other hand, an important part of the tasks of DOH will have much more impact when the results are utilized by the Supreme Water Council. This is why the mission likes to stress that the relation between the Supreme Water Council and the Department of Hydrology will have to be clarified and strengthened.

Realizing that there are many problems to solve before the Supreme Water Council and the technical secretariat will function according to expectation, perhaps an intermediate solution can be found in establishing a technical secretariat with representatives from the technical departments within the different Ministries that are represented in the Supreme Water Council. This intermediate technical secretariat may have the next tasks:

- to present and discuss reports prepared by the different members;
- to propose and discuss technical and legal measures to obtain an optimal water management;
- to coordinate different projects with common interests;
- to coordinate fieldwork like drilling of wells, monitoring of networks etc.;
- to exchange relevant data;
- to standardize instruments, codifications etc.

It may be suggested that DOH will be the coordinator of such an intermediate technical secretariat. After several years of experience a decision can be made concerning a more permanent structure.

Summarising, the mission likes to stress that a strong Supreme Water Council is a first requirement for the YAR and that such a Council needs a well functioning and well equipped technical secretariat. It is suggested this task to be given to DOH that is equipped to carry out this function. In an intermediate phase a temporary technical secretariat could be created with representatives from the technical departments of the different Ministries that are represented in the Supreme Water Council. DOH could be coordinator of this temporary technical secretariat.

## 5.2 Proposed activities for phase II of the WRAY project

The mission recommends a phase II of the WRAY project for about three years and focusing on the following goals:

- to strengthen DOH through training and institution building;
- to improve the hydrological data bank and assure that all relevant data will be stored in the bank and data retrieval will be an easy and accessible process;
- to supply information to Ministries, organizations and the public on proper use of water and protection of water resources;
- to establish sufficient technical background to make the Supreme Water Council able to fulfill its tasks.

Based on these goals the mission recommends the following activities:

- to continue monitoring in the Saadah and Wadi Surdud areas and to process and publish the data. Also to keep the equipment in these areas in good condition and do some additional field work if required for a better understanding of the hydrological system;
- to improve the data bank;
- to improve the library;
- to execute a water resources study in the Sana'a basin which is the most critical basin in the YAR or in an area in which a lot of new developments are being expected in the near future (like the Marib area);
- to distribute information (e.g. by means of a monthly information sheet) on the hydrological conditions of the country, new publications, etc. among the Ministries, Authorities, organizations and the press;
- to execute specific studies or to give advice on request of clients, both private and governmental. These services are (partly) to be paid for by the clients. Within the project a budget should be fixed for this purpose to subsidise for example 50% of the costs.

For a proper functioning of DOH after termination of phase II, it is proposed that DOH's staff will grow during phase II from 25 to about 50 employees with annual costs of about YR 10 million.

The mission suggest that the Netherlands Government continues to support DOH for a next three year term with more or less the same involvement as in phase 1. Inputs from the Netherlands can be:

- One co-project manager; one hydrogeologist; one geophysicist; one technician; short mission experts.
- Office equipment; hydrological, geohydrological and geophysical equipment; means of transport.
- Technical assistance; hydrological advising.

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TNO - DGV, Institute of Applied Geoscience  
Hydrology and Hydrogeology of the Yemen Arab Republic  
A summary of available information  
Report WRAY-1  
Sana'a, Delft, August 1984

Annex 1: Terms of reference evaluation Water Resources Assessment Yemen Arab Republic (WRAY)

Those parts of the Terms of Reference directly related to the project evaluation WRAY are presented below. The complete Terms of reference are attached as Annex 1 of the Main Report.

Objectives of the evaluation

The objectives of this joint evaluation are:  
to study objectives and progress of the "Water Resources Assessment" project and comment on its effectiveness and efficiency in order to submit recommendations on possible follow up activities after termination of the present project period.

Evaluation points

General points to be examined are:

- Policy aspects:
  - . Role and functioning of the Supreme Water Council and action taken to a more rational exploitation of water resources;
  - . The contribution of the central hydrological department to improvement of water resources management; information transmission to "users"; relation to Supreme Water Council.
- Organizational aspects:
  - . Co-ordination of different water resources projects, expertise and data both within Yemen-Netherlands co-operation programme (WRAY, Tihama Water Resources Study, Al Bayda Water Resources Study) as well as between water projects in general;
  - . The need to integrate water resources studies with water development projects (e.g. RIRDP).
- Technical aspects:
  - . Reliability and usefulness of the collected data;
  - . Appropriate technology for data bank development (use of models, automation);
  - . Institution building versus technical studies.
- Economic aspects:
  - . Assessment of costs involved with the start and functioning of a hydrological department in relation to expected benefits, comparison to international standards.
  - . Feasibility of an economic cost-benefit analysis of the DOH activities and/or water resources studies in general.
  - . Possibilities to charge for supply of hydro(geo)logical information.

In addition the following specific points should be examined:

- Policy aspects
  - . Were the original objectives in the framework of existing conditions realistic?

- . If the project encounters problems with improving office skill and work, how could improvements be reached?
- . Has a division of responsibilities taken place among the several governmental institutions involved in water study and development. What consequences does this have on the work of DOH?
- . What is the policy with regard to DOH's position now and in the future; e.g. in relation to the Supreme Water Council?
- . Who are the actual users of information provided by DOH? What is their opinion on DOH up till now? What is their opinion concerning DOH's future?
- . Should DOH itself execute regional studies or should DOH's task be limited to:
  - a. co-ordination (water resources studies to be executed by others)
  - b. centralized data processing (computerized data bank) and maintainance of a national hydro(geo)logical network
  - c. provision of hydro(geo)logical data to users (NWSA, TDA, CAMA, RWSD, Sana'a University, Supreme Water Council, Regional Development Projects etc.)
- Organizational aspects
  - . Relation Between DOH and the project "United Geological and Water Resources Mapping of the Two Yemens" and the "Yemen Project for Joint Natural Resources"?
  - . Co-ordination between the several water resources studies executed recently (a.o. those supported by Netherlands: Tihama, Al Bayda and Sadah and Wadi Surdud) in terms of well numbering, accuracy, techniques (questionnaires, equipment), approach to data processing etc.
- Technical aspects
  - . Standardisation of computer equipment within the several institutions (DOH, TDA, CAMA, etc.)
  - . How much of the existing data (hydro(geo)logical, meteorological) have been collected so far? What were the bottlenechks? What is their quality?
  - . Results of the fieldwork, (quantative and qualitative) in Sada and Wadi Surdud
  - . What insight has been obtained in the water resources of YAR as a whole?
  - . How are the collected data processed and stored?
  - . How is the accessability of the data for futher use?
- Economic aspects
  - . Cost comparison with similar studies executed in YAR.

Annex 2: Itinerary evaluation Water Resources Assessment  
Yemen Arab Republic (WRAY)

Monday September 10

09.30 a.m. Discussion between Kuyvenhoven (team), Schultz (team) and Van der Gun (TNO) concerning the detailed programme for the evaluation of the Water Resources Assessment YAR (WRAY).

Tuesday September 11

08.30 a.m. Visit of Kuyvenhoven and Schultz to Yemen Oil and Mineral Corporation (YOMINCO).

Discussions with:

- J. van der Gun  
General aspects and progress WRAY project
- Ahmed Wahib, Director Department of Hydrology (DOH)  
General aspects WRAY project
- F. Nota (Directorate General International Cooperation, DGIS)  
Progress national hydrological data base
- Abdullah Salam Nagi, Deputy Director YOMINCO  
Introductory visit
- Library YOMINCO

Wednesday September 12

08.00 a.m. Departure for Saadah with:

- J. van der Gun
- Ahmed Wahib
- Saad Saleh, observer Saadah area
- Tahir Mosle, technician
- A. Kuyvenhoven
- E. Schultz

01.00 p.m. Visit to Saadah basin

- Dumeid (meteorological station)
- well recorder at Saadah
- rain gauge at Al Higjrah
- sandstone area in the North of Saadah basin
- private well under construction

Thursday September 13

08.00 a.m. Visit to Saadah basin

- abandoned discharge measurement structure at Al Gudami
- rainfall recorder at Al Gudami
- deep well (470 m) with recorder at Damaj
- fruit area

01.00 p.m. Departure for Sana'a

Friday September 14

10.00 a.m. Preparing first draft chapters of the evaluation report Water Resources Assessment YAR.



Saturday September 15

- 08.30 a.m. Technical presentation WRAY project at the office of DOH
1. Welcome/introduction Ahmed Wahib
  2. Surface water and groundwater in the YAR Jac van der Gun
  3. WRAY's data base activities Philip Nota
  4. General aspects WRAY's water resources assessment studies Jac van der Gun
  5. Selected aspects of the Saadah study
    - a. Geo-electrical survey Abdel-Latif
    - b. Drilling Ahmed Wahib
    - c. Geophysical well-logging Mohamed Abdul Hamid
    - d. "Natural" recharge sandstone aquifer Jac van der Gun
  6. Selected aspects of the Wadi Surdud study
    - a. Well inventory Noory Gamal
    - b. Hydrological network Mohammed Danikh
  7. Final discussion

Sunday-September 16

10.30 a.m. Departure for Hodeidah with:

- J. van der Gun
- M.A. Poolman (Netherlands Embassy)
- A. Kuyvenhoven
- G.J. Tempelman (team)
- E. Schultz

visits to:

rainfall recorders at Sug As Self, Mafhag and Khanis Bani Saad discharge measurement structure in Wadi Surdud at Faj Al Hussein.

Monday September 17

07.00 a.m. Visit to the fieldwork in Wadi Surdud area

- geo-electrical measurement
- lecture concerning geohydrological research methods by R. van Overmeeren (DGV-TNO)
- salt dome
- seepage area along the coast
- meteorological station at Ad Dahi
- 1,000 ha state farm

Annex 3: Changing water situation in the Yemen Arab Republic

1. Groundwater recharge and abstraction

The only primary source of water in the YAR is rainfall. No rivers are entering the country nor does groundwater flow into the country. The average annual rainfall in the YAR varies from less than 100 mm along the Red Sea and the eastern part of the country to a maximum of 1800 mm in the Ibb region. About 90% of the country receives less than 600 mm of rainfall annually.

Regarding to topography three zones can be distinguished: the Highlands, the Midlands and the Lowlands (see figure 1). In the Highlands and the Midlands the rain falls mainly on the mountain slopes, causing surface runoff. In the Lowlands where the terrain is more or less flat, surface runoff from rainfall is less important and more local.

Rain that falls on the mountain slopes is for the major part stored in local depressions, or artificially collected by farmers to grow crops on terraces. This part of the rainwater will finally evapo(transpi)rate. A minor part of the rainwater - 5 to 10% - is transported through the different wadis to the Lowlands or local plains in the Highlands and Midlands. Where the wadis enter the Lowlands or the plains the farmers use the water as much as possible for spate irrigation.

The major part of the rain that directly falls on the Lowlands or the local plains in the Highlands or Midlands will only reach the upper 2 to 3 meters of the soil. This part of the rainwater will evaporate from the bare soil or evapotranspire through crops and trees. Less than 10% of the rainfall contributes to the groundwater reservoirs.

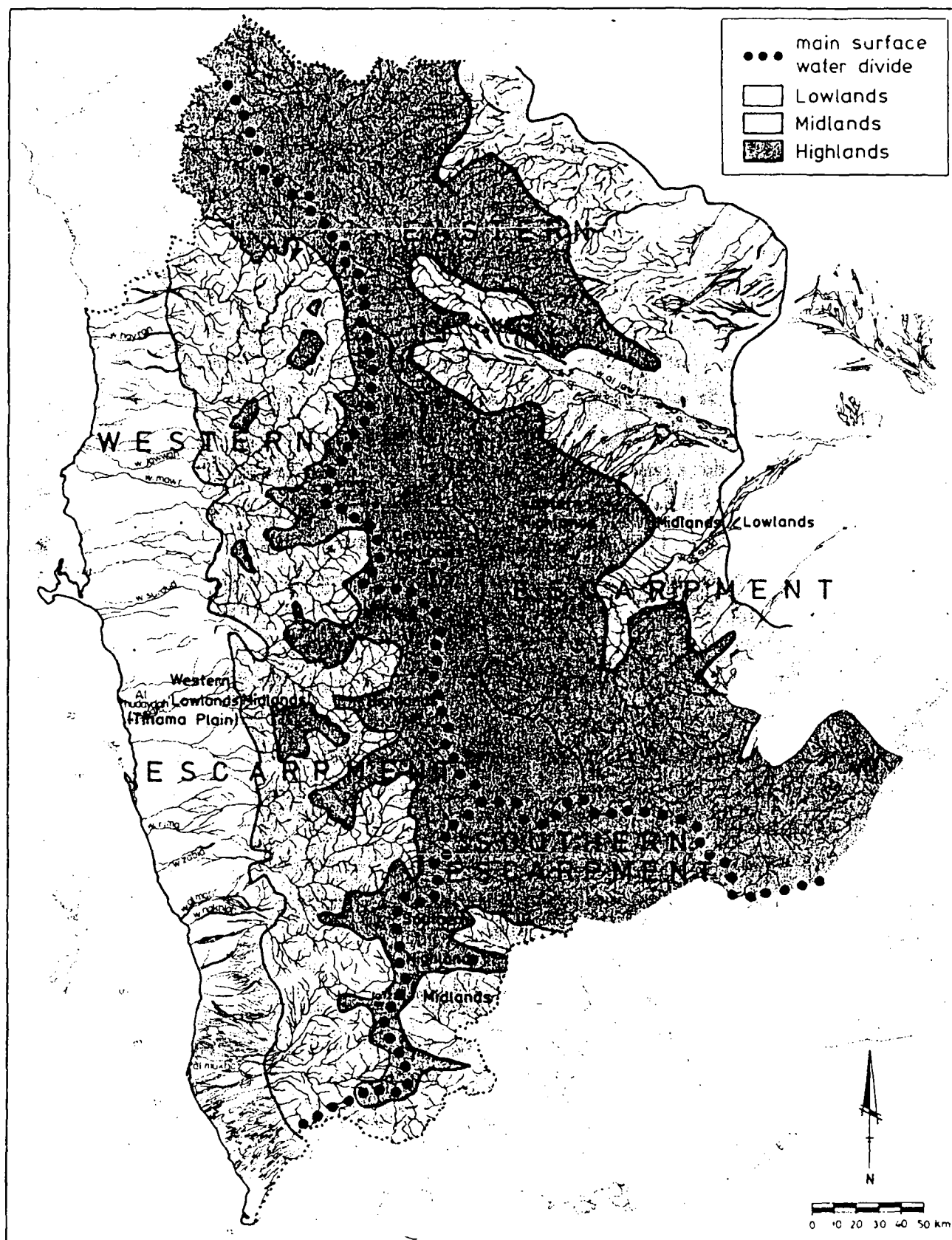
The above mentioned surplus rainwater and a part of the wadi discharges contribute to the recharge of the groundwater reservoirs. In principle two types of groundwater reservoirs can be distinguished, namely the Lowlands and the local basins in the Midlands and Highlands.

From this groundwater reservoirs there is a more or less small natural discharge. In the Tihama plain this discharge is towards the Red Sea and in the eastern Lowlands towards Saudi Arabia. In the local basins in the Midlands and Highlands there could be some superficial outflow. From old, where the groundwater level is not too deep ( 20 m), drinking water and/or irrigation water is taken from dug wells.

During centuries this system of recharge, storage in the groundwater reservoirs and discharge had been more or less in equilibrium.

From about 1960 in the Tihama plain and from an even later date in the other areas a tremendous change took place in the use of water resources due to the introduction of pumps and the drilling of deep wells, mainly for irrigation with groundwater. Recent data obtained through the WRAY project show that in the major part of the basins mining of groundwater occurs (see table 2).

Figure 1: Geographical units  
(WRAY-I, 1984)



The magnitude of the mining in relation to the available storage in the different reservoirs is such that in some of the reservoirs a significant reduction of the abstraction is already required to prevent their exhaustion within some decades. Especially the central wadis in the Tihama plain, the Saadah basin and the Sana'a basin are critical areas.

Table 2. Indication of groundwater recharge and abstraction in million m<sup>3</sup>/year in different basins. ( WRAY-I, 1984)

basin	Recharge	Abstraction	Indication over exploitation*
<u>Tihama plain</u>			
Wadi Mawr	80	50	
Wadi Surdud	60	25	
Wadi Siham	18	70	50
Wadi Rima	30	100	70
Wadi Zabid	82	120	40
Wadi Rusyan	25	5	
<u>Central Highlands**</u>			
Sana'a	25 - 50	30 - 38	0 - 15
Dhamar	11	11	
Amran	18	18	
Rada	30	20	
<u>Eastern Highlands, Midlands and Lowlands</u>			
Saadah	20 - 60	76	15 - 50
Al Jawf		30	
Marib	83	29	

\* This is a very rough figure indicating that mining occurs. A study is required to draw detailed conclusions.

\*\* Although the figures for the Central Highlands give the impression that the recharge is greater than the abstraction it is known that locally within these basins already serious problems occur resulting in wells falling dry.

2. Analysis of the economics of groundwater use for irrigated crop production

Faced with the problem of potential mining of groundwater, and analysis of the economics of groundwater use for irrigated crop production may shed some light on the question of how to prevent groundwater exhaustion in the next decades. A first attempt to analyse cost and returns of pump irrigation was carried out for Al Bayda province and has been discussed in chapter 5 of the Main Report (RIRD, 1984).

In the Al Bayda study, the annual costs of providing irrigation water to the farmer are estimated as the annual annuity of the investment costs in well construction, pump house, engine and ancillary equipment plus the recurrent costs of fuel and maintenance. The possible depletion costs of mining groundwater are not taken into account. Details of the calculations are given in the Al Bayda study, Vol. II; the overall costs of providing one m<sup>3</sup> water by borehole and by shallow well are shown in Tables 3 and 4 for various well depths and water table depths (heads). On the whole, shallow wells turn out to be more costly per m<sup>3</sup> than boreholes, especially at low annual discharges, and are therefore more suitable for remunerative cash crops than for the production of food crops.

In chapter 5 of the Main Report, the cost figures per m<sup>3</sup> water are compared with the net returns of irrigation per m<sup>3</sup> for eight different crops (commercial as well as food crops), and the effect of the relative difference between net returns and costs, the effect of using efficiency prices reflecting true scarcities instead of actual market prices, and the effect of water savings through higher efficiency on the demand for water is indicated. Considering the favourable domestic prices for most crops, the underpricing of water and the present inefficiencies in water distribution, it is concluded that the success of long-term conservation of water depends on:

- improved efficiency in water use;
- increases in the price of water in combination with rationing;
- reducing incentives to grow water-intensive crops.

Table 3. Costs of irrigation water pumped from boreholes (YR/m<sup>3</sup>)<sup>a</sup>

Well depth (m)	Head (m)						
	10	15	20	30	40	50	60
50	0.25	0.31	0.36	0.45	-	-	-
75	0.28	0.34	0.39	0.48	0.57	0.66	-
100	0.31	0.36	0.42	0.51	0.59	0.68	0.79
150	0.36	0.42	0.47	0.56	0.65	0.73	0.84
200	0.44	0.49	0.55	0.63	0.72	0.81	0.91
250	0.51	0.57	0.62	0.71	0.80	0.89	0.99

a) At an annual discharge of 60,294 m<sup>3</sup>.

Table 4. Costs of irrigation water pumped from shallow wells (YR/m<sup>3</sup>)

Well depth (m)	Head (m)	Annual abstraction (m <sup>3</sup> ) <sup>a)</sup>			
		10,000	15,000	22,240	30,000 <sup>b)</sup>
10	5	1.02	0.69	0.48	0.36
20	5	1.62	1.09	0.75	0.56
20	10	1.66	1.13	0.79	0.59
20	15	1.77	1.21	0.85	0.64
30	20	2.45	1.67	1.17	0.88
40	30	3.18	2.18	1.53	1.17

a) At a pump discharge of 5 l/s and .. pumping hours per day

b) Average annual discharge for the selected areas

Annex 4: Aims and membership of the Supreme Water Council

The Supreme Water Council aims at coordinating the efforts of the Ministries and other relevant organizations concerned with drinking water supply, irrigation and power stations; making plans and policies to develop the water resources and advocating proper use which guarantees and seeks the general consent of the public as follows:

1. developing plans and policies and coordinating the necessary scientific research in the field of water;
2. establishing laws and regulations to coordinate efforts and programme planning for water use within the framework of the adopted plans and policies and in accordance with the public interest;
3. study and evaluation of reports, statistics and maps about water;
4. following the implementation of policies, plans and programmes concerning research in the field of water and the means of developing water resources and organizing water use;
5. study the reports prepared by the parties concerned and taking the correct decisions;
6. organizing participations in conferences about water inside and outside the country.

The Supreme Water Council should consist of the following representatives:

1. Minister of Electricity, Water and Sewerage, Chairman
2. Vice Minister of Electricity, Water and Sewerage, Vice Chairman and Member
3. Deputy Minister of Agriculture and Fisheries, Member
4. Deputy Minister of Public Works, Member
5. Deputy Minister of Municipalities and Housing, Member
6. Deputy Minister of Religious Affairs, Member
7. Deputy Chairman of the Central Planning Organization, Member
8. Undersecretary of the Development Cooperation Union, Member
9. Director General of National Water and Sewerage Authority, Member
10. Director General of Yemen Oil and Mineral Corporation, Member
11. Director General of the Rural Water Supply Department, Member
12. Director General of Civil Aviation and Meteorology, Member
13. Qualified and experienced members from each of the technical and financial departments appointed by the Minister for a five years renewable term (the Council chooses the Undersecretary out of its members).

The Council must meet once every two months and the meeting is considered official only if more than half of its members is present. Decisions can be taken by the majority of the members present. In case of a tie, the Minister can break up this deadlock.