

Water Resources Information in Yemen

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1. Introduction: water resources of Yemen: from scarcity to the crises

1.1-Renewable Water Resources:

The annual precipitation averages 500-800mm at western high lands, and less than 50mm at coasts of red sea and Gulf of Aden.

Surface water is considered to be an important source for irrigation in Yemen. Surface water consists of seasonal spate water and springs, with differing quantity & quality depending on the area. This source of water is less affected by drought and other natural and geographical factors. High runoff speed and heavy rainfall cause deep *Wadis* and form several water basins. Topographic patterns control the flow of rainwater and lead it in two directions, the outer water basins (draining to the west in the Red Sea and to the south in Gulf of Aden and Arabian Sea) and the internal water basins (draining east or west towards the Rub Al-Khali desert, the Ramlat al-Sabatain and Wadi Hadramout).

Surface water in Yemen is estimated to be about 1,500 Mm³/year. Around 50 diversion weirs and main distribution canals have been built by the government and dikes are built on many main *wadis* for the purpose of directing spate waters into branches of the *wadis* to earth canal spate irrigation systems, which irrigate around 120,000-150,000 hectares in the low lands of the country. There are also around of 800 medium & small dams for rainfall water harvesting in the highlands.

Groundwater resources are vital for Yemen's agriculture. For their recharge they depend mainly on spate running water and rainfall. Runoffs and springs in catchment's areas are the main sources of groundwater recharges. In Yemen, the estimated groundwater is around 1000MCM, which makes the total renewable water resource sum 2.5 MCM, while the total demand is estimated to be 3,400MCM with 900MCM deficit, which is covered from deep aquifers.

Ground water aquifers decline 1-7 meters annually with very rare recharge. This raises the cost of pumping and causes a deterioration of ground water quality including sea (salt) water intrusion in the coastal plain areas. Some basins have become very dry and some cultivation has been uprooted due to the depletion of the ground water which is highest, up to 6m per year, in the north side of the country (Sa'adh basin). The drillings then went deeper up to 800 m depth.

1.2- Non-conventional Water:

There is an undefined quantity of brackish water in some regions, which is being used for rock cutting industry mainly in high lands, as well as for irrigating some tolerant crops mainly in coastal plains. These cases are found in some ground water aquifers but it is not intensively investigated and exploited. And there is waste water can be described as follows:

Waste Water Quantity:

There are 12 treatment stations in Yemen that function and the total actual flow of the treated wastewater is around 125,000m³ per day, or 45.5MCM per year. The amount produced is considered approximately 55% of the total design capacity for these wastewater treatment stations. It is expected to reach the production at design capacity in the next ten years.

There are 3 treatment stations (stabilization Ponds) in Aden (new), Yarim, and Amran with design capacity of 60,000, 3,500, 6,000M³/day respectively. These stations started functioning in December year 2002. There are also, 6 stations under planning phase in Beit Al-faqih, Bagel, Zabid, Al-shaher, Zungbar, and Jiblah towns (districts).

Wastewater Quality:

The quality of the outflow varies from area to another, while it is very good quality in Hajah, it is very bad in Taiz, depending on the method of treatment as well as the capacity of the station and the operational circumstances. The quality is affecting the acceptance of farmers to use such water for their cultivations.

2. Water Resources Development and Uses

2.1- Water Resources Development:

Due to the water scarcity in Yemen, the state relies in its plans, policies, strategies, and actions to work in different directions to develop and conserve the water resources in the country.

- **Rainfall water harvesting**: through constructing the dams, and water constructions such as diversion weirs, water concrete tanks and canals, the purpose of these structures to provide surface water for multi-usages. The final aim is to reduce pumping the ground water from the deep aquifers, as well as to recharge the shallow aquifers from the reserved water in the dam reservoirs. There are around 1045 water-harvesting structures in the country.
- **Improving the Irrigation efficiency**: through introducing improved irrigation techniques either localized systems or improved surface irrigation systems. The irrigated area by improved systems (pipes, localized, sprinkler systems) is around 25,000Ha; this represents only 4% of the total area irrigated with ground water (344,691Ha) using traditional/surface irrigation practices, which their efficiency is ranged in 30-40% only.

- **Extensive investigations for groundwater:** the purpose is to trace promising aquifers to cover the drinking water requirements for the increasing population.
- **Extensive studies for desalination:**
- Desalination is the moment discussion issue; this alternative is open for implementation in the coastal plain areas to provide the drinking water for the coastal cities, where it is hard to start the same in the high altitude areas which are located in areas of 2000-3000m above sea level. The main challenge is the cost recovery of the unit price of water which will be the main obstacle to start providing desalinated water for the publics especially in the mountainous areas.

2.2- Water Resources Use:

Agricultural sector is the dominant user for the water resources, while the domestic and industry sector are using 7-8% of the water resources, agriculture is using around 90% of the water resources (see **Table No 1**). The cultivated area of Yemen was estimated in 2003 to be about 1,199,104 hectares of which 45% is depending on rainfall (539,597 hectares), while 55% (659,507 hectares) is irrigated by: groundwater (67% =441,630 ha.) or surface water from seasonal water floods (Spate Irrigation, 23% = 153,892 ha.). Of the latter 63,985 hectares are irrigated by springs.

The main rainfall areas are mountainous, where terraces are built on and cultivated with cereals such as barley, sorghum, maize, millet, and some pulses. In some areas, particularly during dry seasons, supplementary irrigation is needed. Mostly surface and groundwater are used here for some other wheat and vegetable cultivations.

Many farmers are pumping groundwater from wells by using diesel pumps or electric pumps. Such wells can have different production volumes from one basin to another. Their production is between 5 liter/sec to 50 liter/sec. There are 52,000 to 55,000 active wells have been estimated in Yemen. These wells have a relatively low production. The volume of the water that is pumped every year from these wells is about 1.5 BCM. There are about 800 water well drilling rigs in use in Yemen that are owned by individuals or companies, who generally do not have any drilling permits, despite governmental legislation limiting the drilling of wells. Recently National Water Resources Authority started a program of registrations & licensing for the water wells drilling companies the records shows only 70 rigs only are licensed, and 1000 wells only are registered and licensed till May 2005.(NWRA activity report, May 2005).

There are also estimates that there will be an improvement for using the available water at a 35% to 60% higher efficiency rate in irrigated areas, which will result in a reduction of water consumption.

Table 1: Use of Water for a Period of 30 Years (1990-2010) in Different Water Use Sectors (Million cu. Meters/Year)

Water Use	1990	2000	2005*	2010*
Agriculture/Irrigaion	2,600	3145	3,235	3,328
Domestic/Urban/Rural	168	210	265	552
Industrial & Mining	31	45	65	90
Total	2,799	3,400	3,565	3,970

*Estimated.

Source: Adapted from: TNO Institute of Applied Geo-science Report, (1995).

It is clear that, there is big gap between the size of the use and the size of the renewable resources. The deficit is covered from the deep underground aquifers. The annual water share is not exceeding 125m³ per capita, which is below the water poverty line.

3. Institutional background of water resources management in Yemen: towards entity & integrity.

It worth to mention some facts:

- Two parts of Yemen (South & North) were unified in May 1990 there were two different data systems/regimes. There were scattered information resources in the unified country. In 1995 Dutch Government helped Yemen to establish collective water resources assessment studies. In 1996 a national water resources authority (NWRA) was established. Some of the water related departments in some agencies merged with NWRA. Although Water Law was ratified and issued in August 2002, Institutional de-fragmentation were still exists till May 2003, until New Ministry for Water & Environment was established in May 2003. Some water & environment related agencies merged within the new ministry, but Irrigation & Dams department still with Ministry of Agriculture & Irrigation and did not yet merged with the new established ministry.
- Water Law is under reformulation after establishing the new minister of water & environment.
- Most of the data collection and the information systems are still scattered among water resources/supply & sanitation/irrigation projects in autonomous agencies.
- National Water Resources Authority is the sole authority of water resources management & the law enforcement in the whole country.
- There is meteorological department in the Civil Aviation Authority under ministry of transportation establish and record meteorological data for civil aviation purposes.
- There is specialized over-all agency for statistics under the ministry of planning & international cooperation.
- There are several water resources & irrigation development projects underway.

Water Resources Institutions:

There are in Yemen different institutions dealing with water and wastewater. These institutions have by their mandate related responsibilities.

Ministry of Water & Environment (MWE):

The MWE, through the national water resources authority (NWRA) which is established under the presidential decree no 154/1996 is responsible for water resource planning and monitoring, legislation and public awareness. It should be mentioned that NWRA is under capacity building stage where it has only five branches in the Governorates, beside its headquarter in Sana'a.

Environment Protection Authority (EPA) is responsible to the issues related to applying the Environment Protection Law of 1995. This Law is stipulated an Environmental Impact Assessment (EIA) for projects which are by its nature a source of environmental pollution (Environment Protection Law, Article 36). EPA is responsible for observing and measuring the pollution of the natural resources in the country.

Also the MWE is responsible for water supply & sanitation services in the cities only. Within the ministry, Central Corporation for water supply and sanitation is responsible of water supply & sanitation. During the last years this corporation has been decentralized in some major cities. The ministry and its corporations are responsible for planning and developing water supply & sanitation services, which include implementing sewage systems, and constructing and operating the treatment plants.

Ministry of public works & urban Planning (MPWUP):

The ministry is responsible for observing and monitoring the drinking water purification stations.

Ministry of Local Administration (MLA):

The MLA is responsible for water supply & sanitation in the rural areas, (district, and village level). MLA is responsible in enforcing the Local Authorities Law (Decentralization Law) which issued at early 2000, aimed to establish local councils to work at the local level for more community participation and more decentralization of the administrative and financial processes. It is also mandated in this law for the local councils to manage and control the water resources in coordination and cooperation with the water resources authority.

Ministry of Agriculture & Irrigation (MAI):

Before establishing NWRA, the Ministry was responsible for the water resources planning & development, till 1996, when it was restructured to be responsible for irrigation activities, planning, development, and implementation and monitoring. MAI is functioning through its offices in the all Governorates. In addition to some specialized authorities in the fields of agricultural researches, agricultural and regional development authorities (RDA's), cooperatives, companies, and projects. The MAI is also responsible to provide the technical guidance and extension services for the farmers, as well as constructing the irrigation structures (small dams, canals, water tanks, diversion weirs ...).

4. Water resources strategies & policies and legislations: from theory to actions

All water related strategies, policies, and laws in Yemen are calling to consider the proper management of water resources, and should be utilized in proper rationalized manner.

The existing policies and the strategies have been developed after assessment of the water sector and irrigation sub-sector, these policies & strategies are as follow:

- Water Resources Policy and strategy.(2000-1999)
- Irrigation Water policy, (2001)
- Watershed Policy, (2000)
- Agricultural sector reform policy, (2000)
- Urban Water Supply and Sanitation Sector reform Policy, (1997)
- Wastewater reuse strategy, (under development)

All these policies and strategies are include clear statements to manage the water resources at basin level, and establish water basin committees to manage the water resources at the basin level, these committees could be established by cabinet (council of ministers) decree. It also includes statements related to information and data management and exchange among the sector's agencies.

The assessment of the mentioned policies & strategies describes the challenges of the water resources, which are as follows:

- Scarcity of water resources,
- Low water supplies and use efficiencies,
- Weak enforcement of water related laws/regulations,
- Lack of proper coordination among the water related agencies.
- Minor participation of the private sector,
- High population growth (3.01%)
- Minor public awareness.
- Lack of data/information

There are programs implementing projects to develop proper tools for water management at basin or Wadi level, such as:

- Irrigation Improvement project (IIP).
- Ground Water and Soil Conservation Project (GWSP).

There are also laws concerned water, environment that regulates the water resources and environment. Those laws are as follows:

- Environment protection Law.(1995)
- Water law (Ratified in August 2002), the new version is under new ratification at the parliament.

5. Existing Water Resources Information System:

Within the national water resources authority (NWRA) special unit/center is established to deal with water resources information in the country, this unit went into some stages of establishment with some difficulties to reach full functional objectives.

Due to non existence of data/information guidelines to design the water resources information system as required for the international organizations and some public authorities, this unit faced difficulties in adopting proper format for data system. Even though this unit reached to such Outputs during mid 1997 until mid 2005:

- Installation of computer hardware and software as well as a Local Area Network
- Consolidation of data sets available at NWRA
- Establishment of main database
- Establishment of branch databases
- Digitizing of maps: 1:250,000 hydrological maps for the whole of Yemen and 1:50,000 topographical maps for specific study areas.
- Extensive on the job training for database usage and development of database and GIS applications.
- Development of data entry modules for monitoring data, well inventory, etc.
- Storage of monitoring and well inventory data
- Development of automated import routines for data generated by data loggers
- Creation of output modules that can generate tabular and graphical output.
- Start of NWIS 1.0 containing a data retrieval interface and GIS application
- Interpretation to satellite image analysis.
- Continue entering reports & books to library database.

Through extensive on the job training in database design, data processing, application development and GIS applications the capacity of the Information System has been improved. A first version of the National Water Information System (NWIS 1.0) was developed in house. Hence this Information System can be operated and maintained by staff of the Information Department without external assistance. Not only is the staff of the Information System capable of designing and programming such a system, also much attention was given to writing technical documentation for the system developed.

The branch databases have been established and staff of the branches has been trained in using the database. Several annual monitoring reports have been generated from the database by staff of the Monitoring Department of NWRA-HQ, and branches.

National Water Information System (NWIS) at NWRA needs to be consolidated and further enhancements are required. Additional functionality is required in order to make NWIS a full fledge decision support system. The current system is only intended for internal usage. A distributable version needs to be developed as well as an Internet version of the system. Staff should be further trained in Database, GIS, Satellite image analysis and their applications for future Water Management Plans. The library database

needs to be consolidated and inventory of other libraries is required. Regular data collection should continue and many maps like geological, land use, detailed topographical, etc. remain to be digitized.

Therefore a national planning has been made; an overview for this plan is given below in brief explanation of each main activity to be provided:

Monitoring Data

Monitoring is one of the most essential activities of NWRA. At this moment regular monitoring takes place in the areas of Sadah, Surdud, Taiz, Abyan, Lahej, Hadramawt and Sana'a. Staff of the Monitoring Department is doing manual data entry and automatic importing. The role of the Information System is to follow-up closely this activity and to ensure data quality. With the establishment of the Huddaidah Branch and start of the first phase of the National Monitoring Project, the amount of data to be processed is expected to increase.

Digitizing

The National Water Information System consists of two core components: The database and a digitized map repository. Digitizing of maps is an essential and time-consuming activity that is expected to continue until the end of the 2008. Maps that still (partly) have to be digitized include:

- Hydro-geological maps (RUSS Map)
- Geological maps
- Boundaries of study areas
- Topographic maps of study areas

Well Inventory

Well inventory data often functions as the basis for water management studies. Data entry and processed of well inventory data currently is in progress for the regions Amran, Rada'a and Tihama. The well inventory for the regions Abyan, Lahej, Sana'a, Sa'dah basin and wadi Hadramawt have been completed. Well inventories that were carried out by other organizations in the past have been transformed to the unified database structure of NWIS. The staff of the Information System should ensure proper processing of the data involved for new study areas.

Processing of Socio-Economic Data

A suitable database structure for storing socio-economic evolving from water management studies data has to be developed. This exercise already started for the data of the Taiz Water Management Plan. As the survey methodologies differ per Water Management Region, the collected data has to be unified in order to make interregional comparisons possible. An important role of the Information System is to standardize the data structures and to put boundary conditions on data surveys carried out by NWRA staff and external contractors.

Satellite Image Analysis

Already for the Sana'a, Sa'dah Basin, Abyan, Hadramawt and Taiz Water Management Plan remote sensing techniques were used to observe the change of for example vegetation over time. These techniques will also prove very useful for future Water Management Plans like Rada' and Hudaidah. Specialized training is required. Specific applications need to be outlined in cooperation with the Planning Departments.

Application Development

Until now application development is done in-house to ensure a sustainable system. The first version of NWIS offers limited functionality. Main objective was to obtain feedback from NWRA staff. This should result in a specification document for a second version of NWIS that fully integrates all requirements NWRA has.

An Environmental Information Management System (EIMS) that was developed for Yemen by a specialized software company contracted by FAO can cover a part of these requirements. EIMS offers document indexing, mapping tools and database management tools based on MS Access. The main aim of the information system department is to develop the same software tools.

NWIS version 2.0 will integrate EIMS and additional tools like:

- Library database application
- Data entry modules
- Tabular and Graphical output of data
- Additional mapping functionality

Different levels of access will be defined in order to ensure data security. To complete NWIS Version 1.0 and development NWIS Version 2.0 Database expert is required.

WEB Page Development

One of the most effective ways of promoting the NWRA-HQ with Branches is by completing designing and implementing a web page on the Internet (WWW.NWRA-YEMEN.ORG). NWRA needs to come up with a clear policy what kind of information will be made available to the public. For development a two-phase approach is recommended:

- Intranet: an intranet web page behaves exactly as an Internet page. The only difference is that only staff of NWRA that is connected to the computer network can access the page. Therefore an Intranet is intended for internal usage only. However it provides an excellent way of designing and testing a web page before exposing it to the outside world.
- Internet: Once the Intranet web page has been created and tested and approved by NWRA, it can be published on the Internet. Notice that the Internet web page can also be a subset of the Intranet web page. The activity will be mainly aimed at enhancement of the web page. One staff member of the Information System needs to be assigned as web master, handling all requests coming from outside. The web master is also responsible for the technical operation of the site and therefore preferably should be included in the development phase. Proposed

is to include this in the tasks of the database support staff to be recruited. As this activity is continuous, training of a second staff member is recommended. This staff member will function as a backup.

Library

The NWRA library contains more than 1,000 documents related to water. A library database storing information about these documents it will be integrated in web and NWIS 2.0. In parallel abstracts of all the documents need to be made, followed by an evaluation of external studies available. To this extent an inventory form was created. Finally an inventory of available libraries in Sana'a is requested.

Database support

One support is required for Information System Department and Branches of NWRA. This support will upgrade the NWRIS Version 1.0 and solving all problems in database for branches by adding new processing items for new stations.

Internal Training

Besides extensive on the job training, 6 major training courses (Database, GIS, RS, Digitizing, Library, Maintenance) are proposed for the next three and a half year.

User training NWIS: Both NWIS 1.0 and NWIS 2.0 require user training. For NWIS 1.0 the user training is relatively short and proposed is to add general introduction training to MS Access. The user training for NWIS 2.0 is scheduled after the application development has been completed.

Internet web page design: A number of staff in and Branches the Information System should be trained in Web Page Development using MS FrontPage. Reason for including staff from Branches to obtain a multidisciplinary input for designing the Web Page and updated with last data information.

NWIS system administration: It is recommended to train at least two system administrators for NWIS. Preferably this should be the same staff as involved in the application development.

NT Network management: Until now training in management of the computer network of NWRA was done on the job. This is most effective as practical problems are encountered constantly. However to ensure that the operating staff has sufficient knowledge with new Network equipments in NWRA-HQ and Branches, a refreshment course treating all aspects of LAN management is recommend. These courses should be done by the company, which will install the servers, network and email system.

Human Resources

The Information System unit currently has current staffing of the Information System of 5 members.

For next input from the information system is in particular required for the following activities:

- Building Network in Branches
- Well inventory processing for new study areas
- Processing for new network stations
- Satellite image analysis for new study areas
- Application Development
- Update NWRA Web Page
- Internal computer training courses
- Using DSL for connecting NWRA-HQ with branches
- Continuo digitizing maps.

6. Water resources statistics problems:

- The data still exist among several agencies in variable formats.
- The data incomplete & with time-cut series and with low quality.
- Most of the information are estimated and predicted for each agency purposes.
- Low public investment in the water resources management.
- Lack of sufficient and efficient human resources.
- Poor coordination among external donors....

7. Recent actions to correct the situation:

- Establishing National Water Resources Information Unit (NWIS).
- Rehabilitation the existing water resources monitoring network.
- Expansion of the existing monitoring network.
- Strengthening the coordination links with water using agencies (water supply, irrigation private sector), Statistics Agency, the Meteorological agency and the environment authority, as well as with the donors.

7. Recommendations:

- Support is still needed to steer the attempts of the National Water Resources Authority to have country wide organized information system.
- Need to develop water resources information guidelines.
- Need to develop guidelines for predictions, estimations and indicators in Yemen water resources information.
- Need to develop and improve data base information system.
- Need to specific and targeted training programs.
- Need for donors coordination to support water resources management programs.
- Need for proper capacity building.

References:

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- *Agricultural Statistics Department, agricultural statistics books, 2003.*
- *National Water Supply Corporation, Annual reports of 2002, 2003.*
- *National Water Resources Authority, progress report, May 2005.*