UNDP

Project RAB 89/003
Current technologies in water resources management in the Maghreb and the Mashrek

NEW TECHNOLOGIES FOR MONITORING, ASSESSMENT AND MANAGEMENT OF WATER RESOURCES

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Damas-Montpellier, December 1996

New technologies for monitoring, assessment and management of water resources

1. Introduction:

Water is rare and assessment of water resources for a sound management is one the major problems of the 21st century for a majority of countries in the world. The only exceptions are countries with low density of population in humid climates. That problem is particularly an acute one under arid, or semi-arid climates of middle East and North Africa.
For the last twenty years new technologies have been made available for water monitoring and water management: are they suitable for a reasonable expense?

2. Main new technologies:

The new technologies are mainly applied to sensors, data recording, data transmission, data processing and data bases. Hereafter we shall look at each of these categories.
Discharge measurement will not be considered here.

2.1. Sensors:

2.1.1. Water level measurements

For a long time, water level measurements were made by direct reading of the level on a staff gauge, recording being made by simply writing. The first records are very ancients (three thousand years on Nile river, probably more than one thousand years on Chiang Jiang river — blue river — in China). It is only during the present century that automatic recorders appeared with float devices and mechanical writing on a paper on a drum. During many years no sensible improvement was made.
Then, attempts were made to use the pressure of water height: the first real improvement was the bubbles' device that is still used with micro pump to deliver the back-pressure to the water height, the latest models being quite efficient although perhaps difficult to use depending of the place.
Then came the piezo-resistive sensors in which the distortion of a micro electronic device (Wheatstone's bridge) inside a thin slice of silicium gives the measure of the pressure and consequently of the water level. Such sensors became efficient when correction of drift induced by temperature and palliating of hysteresis effect on the metal were made.
The output of the sensor can be an analog signal proportional to the height, or better a digital signal giving directly the height of water. In the latter case there is less risk to lose information between the sensor and the recorder, even if the cable for transmission is very long; also the sensor can be replaced, if necessary, on site without removing the cable and with no new calibration except the easy fixation of level 0 on the recorder.

The last improvement of that sensor is to replace the piezo-resistive device by a piezo-capacitive device. For this one the distortion of the metallic membrane modifies the electric capacity; the advantage is a lesser hysteresis and a better behaviour with ice.
Those sensors are very easy to install and do not need an important structure, and much money can be spared.
We must mention also the ultrasonic systems; though they could deliver a quite accurate measurement they are more difficult to use on a natural river and need a more important structure for installation.

2.1.2. Rain measurement:

The most significant improvement is the use of electronic counting of the tipping of buckets of the raingauge, in place of the paper recording. Tipping bucket raingauge is the most used model and other systems are not really effective.

2.1.3. Water quality:

- **Suspended sediments in water and turbidity:** the concentration of suspended sediments is not the same thing than turbidity which correspond better to colloidal materials and to the colour of the water together with suspended sediments.
There are sensors for turbidity using absorption or dispersion of light through water; they are efficient for low concentrations (under two or three grams per litre). The main difficulty is the necessity to clean the sensor every two or three days, every week in the better case. And in natural rivers under dry climates the concentration of suspended sediments are completely over the range of measurement of the turbidimeters, until two hundred, five hundred g/l, even far more in some places (800 g/l in Yellow river in china, and 1700 g/l in some tributaries of Yellow river).
For concentrations over 3 g/l experimental devices exist which use a differential pressure sensor which give a precision of perhaps ten per cent, that can be consider as a good result. By using both a recording with this sensor and some samples during floods it is possible to get the turbidigram with enough precision to evaluate the discharge of suspended sediments during floods, which generally represent 90 to 95 % of the annual amount of suspended sediments. It could be interesting to develop the experimental device in a project where suspended sediments must be measured. That device was tested in Tunisia and in France (Alps).

- **Conductivity:** many types of sensors exist whose main inconvenient is the necessity to clean them often, at least every week. For saline waters with high conductivity it is possible to use induction sensors which are less sensible to deposits.

- **pH:** many sensors exist but the difficulties are the same than for conductivity, with also the necessity to calibrate the sensor very often.

- **Dissolved matters:** specific electrodes exist for almost any matter (O_2, Ca, Mg, Na, K, heavy metals……). The problem is always the same: necessity to clean very often the sensors.

An attempt was made in Tunisia for a field automatic laboratory, self powered by solar cells, which eliminates the problem of cleaning. A prototype was realised, called **SATUNOR**, who seemed to be efficient.
- **Water temperature:** if piezoresistive or piezo capacitive sensors are user for water level, temperature of water, needed for the correction of the level measurement, is available with the same sensor; if not, a specific sensor must be used .

2.1.4. Meteorological measurements:

There are good sensors for this measurements.

2.2. Data recording:

Cmos technologies have made possible the designing of low energy, compact advanced data collection platforms. The main interesting characteristics are:

- possibility to have many inputs of different types (analog, digital, counting) suitable for any sensor.
- possibility to chose for each sensor the frequency of the measurement and the minimum threshold of variation for recording with a front keypad.
- possibility to make computation on the data before recording or sending a message (mean, total, extreme values,...).
- possibility of remote warning when thresholds are overcome for the variables.
- possible recording on removable flash-card EEPROM with high capacity (one year recording possible and even more). These flash-cards are very safe: completely water proof, with no connections at all, they operate by induction effect.
- possibility to read and remove data from the data collection platform (DCP) with a portable micro computer, on site.
- self-powered platforms by solar cells

2.3 Data transmission:

The DCP are able to formulate a message with a choice of raw or processed data; and to transmit that message to the user by any of the following systems:

- **phone** : needs a modem and use the normal phone network: it is efficient when the phone network is of good quality, though the system is sensible to electric perturbations due to thunder; the worknet can be interrupted by violent phenomena , floods for example or wind.
- **radio transmission** through UHF or VHF waves: efficient but needs an expensive structure.

- **satellite transmission** with:

METEOSAT: long message possible, very large area served, that is to say possibility of easy direct reception, possibly free of charge if data are hydrometeorological data within a **WMO** project..

After transmission by METEOSAT the data can be disseminated through the Global Transmission System (**GTS**) used by WMO in any country.

In America (North and Central) **GOES** is the equivalent of **METEOSAT**

ARGOS: low orbit satellites (NOOAH), little omnidirectionnal antenna on the DCP, low power consumption, but limited number of efficient passages each day, depending on the latitude (24 passages near the pole, and about 4 only near equator).

INMARSAT (**In**ternational **MAR**itime **SAT**ellite organisation)**:** system of 8 satellites for navigation that can be used for transmission of data by different ways (phone, fax, analog or digital transmission of data. Interesting by the possibility to transmit orders back to the DCP. The price depends on the number and length of the transmissions.

Meteor burst: similar to satellite transmission, the tracks of micro meteorites vaporised when entering into the atmosphere at about 100 km are used as a reflector for radio waves VHF. The system is still expensive and more or less efficient depending on the area where it is used and because of possible electrical perturbations in the atmosphere. The power necessary for transmission is high.

INTERNET: The WEB system can be used to make available processed hydrometeorological data for public at large, generally under graphical form; other general information can be disseminated through INTERNET. It is possible also to use through INTERNET a data base, with processing facilities, whose access can be restricted by a password.

2.4 Data processing

Several efficient softwares exist to process hydrometeorological data, as HYDATA from Wallingford institute, HYDROM, PLUVIOM and SAPHARY from ORSTOM and others. One of the main improvement is that data can be transferred from the DCP to the computer with no human intervention and less risk of error, the data being either directly recovered from the DCP to a portable micro computer, either from a removable memory to the computer in office. The softwares prepare the data to be entered in the data base and the data to be published, or to be use in projects (models, works for water resources management, ...)

2.5 Data bases:

Conservation of the precious hydrometeorological data is made in data bases in which raw data and processed validated data are recorded. Generally powerful mini computers are used like Sun station, with specialised SGBD softwares as ORACLE. But data of the base can be easily recorded also on CD ROMs, a very safe system of conservation. These CD ROMS can be duplicated easily and made available for users working with micro computers. It is a very efficient method of dissemination and preservation even if the data base on the CD Rom is fixed at a precise date and cannot be directly up-dated.

3. Value of the new technologies:

Do the new technologies worth the expense for them? In each specific case that question must be answered after a close evaluation of the real needs.

For example if you want to know the maximum height of water in a flood plain, and only that, it is surely not necessary to spend 18000 US $ for an advanced system with satellite transmission: a simple staff gauge covered with a wooden box is enough as when the water get back you can see the muddy mark of maximum level on the staff gauge.
So you must answer to such questions as: is it necessary to record precisely in time and height the variation of the water level? Do these variation must be known quickly at a long distance from the station? Is it easy and non expensive to get to the station at any time? etc...
Knowing which type of devices are built by manufacturers, it is possible to establish a list of technical specifications for each project. Some useful considerations: it is preferable not to have too many types of devices in a hydrometeorological service, for, in the contrary, the maintenance could be difficult. The lowest price is not always the best answer to a tender, technical quality must be closely considered. Existing stations with ancient systems as float recorders can be continued if they are well operating, it is always possible to adapt them with new recording and transmission system (for example with an electronic encoding device for float recorders).
In every case, rationalisation of the worknet must be considered previously any other decision.

2.5 Some examples of new technologies' applications:

2.5.1 A worknet in Amazon's catchment: about twelve years ago stations were installed on Amazon river and tributaries with a simple staff gauge, an observer who read the water level twice a day, a very simple transmitter (battery operated) with ARGOS system used at home by the observer, who manually enter the data in the transmitter through a front key pad. The transmitter also contains a clock . That was cheap and efficient for slow variation of the level and for the safety of the transmitter well protected in the house of the observer. Each observer can read one, two or more stations each days, and can read also rainfalls if there is a rain gauge.
Now more sophisticated stations have been installed.

2.5.2 A rain gauge on islet Sao Paul: fifteen years ago a tipping bucket recorder rain gauge was installed on islet Sao Paul amidst Atlantic ocean between Brazil and Africa. That very little island (150 meters long, 50 meters width and 15 meters high) is uninhabited and visited once a year by oceanologists who were interested by the rain in that place, for it is very close from the true value of rain on ocean. The transmission of the data was made by ARGOS. The data was at disposal in ARGOS centre in Toulouse and it was possible to get each day the last twenty four hours rainfall and the cumulated rainfall since the last visit. It was possible for example to get these data automatically through MINITEL system, very simply with a code number. The only technical problem was to prevent sea birds to let their dung inside the cone of the rain gauge: acute needles on the edge of the cone were efficient for dissuading them!

2.5.3 HYDRONIGER network: some 15 years ago a network with about 60 stations was installed in the Niger catchment. The stations used bubbles recorders and tipping buckets raingauges, the transmission being made through ARGOS system and it is still operating. The main difficulties came from bubble recorders, sometimes difficult to use in remote places, and from mercury switches of the rain gauges, too sensible to wind shaking. Now the mercury switches are replaced by electronic one who is safer.

2.5.4 Onchocercosis network: Some 12 years ago WHO (World Health Organisation) with ORSTOM has installed about eighty stations in 14 countries of west Africa to help the fight against the blind river disease (Onchocercosis). The vector of that disease is a little fly whose larva lives in the water of the rivers. The fight is made with insecticide discharged in the water in suitable places from helicopters. The quantity of insecticide depends on the discharge of the river to get an efficient concentration to kill larva but non dangerous for men. The stations installed use piezo resistive sensors with DCP transmitting data through ARGOS system. Each morning, before taking off, the pilots of the helicopters can read the discharges of the rivers on the receiving station and so they know exactly the good quantity of insecticide to use and the right time to do the work. The saving made with that system has paid the investment made for the hydrological stations in one year and a half.
We must point to a station installed in Fouta Djallon mountains in a remote place far from roads; the installation was made in 24 hours with an helicopter to carry the station and the people and after that it operated continuously during three years with no technical visits with its solar cells; at the end of the three years the drift of the measure was only of one centimetre for a total variation of 7 metres.

2.5.5 Worknet in Tunisia: About fifty DCP are used in Tunisia for different projects (little dams, national network ...);. Some of the stations have transmitters working through ARGOS system; in general the functioning seems to be very efficient, with very few defaults. One of the DCP (with no transmission) is operating on Mejerdah river since five years, in a difficult place with much sediments, with no deficiency at all.

2.5.6 MED-HYCOS: MEDiterranean **HY**drometeorological **C**ycle **O**bserving System is a programme concerning 28 countries around Mediterranean Sea and Black Sea.

2.5.6.1: Présentation:

MED-HYCOS PROGRAMME

Mediterranean Hydrological Cycle Observing System
Description of priority research actions

2.5.6.1.1. Definition of the problem area and its relevance to the European Union:

Conference in Barcelona (November, 1995) identified water management as a vital issue, which deserves special attention in the European MEDA action plan. In the spirit of this pronouncement the countries of the Mediterranean rim have taken the initiative to begin a collaborative program of regional assessment and management of water resources, both quantity and quality. They have been joined by countries of the Black Sea basin, which plays a major role in terms of water exchange with and pollution fluxes to the Mediterranean Sea.

In the Mediterranean basin, scarcity of freshwater, increasing incidents of floods, and deterioration of quality of water are problems which require regionally agreed solutions. In this context, the development objective of MED-HYCOS is to better integrate water resources management decision making into Mediterranean socio-economic development and environment protection activities, including MEDA, through a multi-sectoral and multi-country approach.

2.5.6.1.2. Current solutions and limitations:

Each countries of the considered area has developped more or less actions for a better assessment of water resources both in quantitative and qualitative terms, but collaborations between the countries are very few, the level of the technologies used for that are very different, specially between countries on the north side of the Mediterranean Sea and countries on the south side, or countries round the black sea.

2.5.6.1.3. Proposed priority research actions in relation with the problem area:

Representatives of twenty eight countries of the Mediterranean and Black seas expressed the view that to reach this objective there was a need to, *inter alia*: (i) **modernise hydrometeorological monitoring region-wide and promote exchanges and technology transfer between the agencies responsible for water resources; (ii) achieve a better understanding of regional hydrometeorological phenomena and environmental trends; and (iii) encourage free circulation of quantitative and qualitative standardized and consistent data on water resources as well as environment. This information flow and knowledge transfer initiative will allow the optimal use at country level of the most recent advancement in regional hydrology and is expected to create a development partnership culture between the countries and between all communities within those same countries, and to increase the efficiency and economy of the use of water.**

2.5.6.1.4. Current state of art:

Water being since a long time an acute problem in the considered region (Mediterranean Sea and Black Sea countries), there are many scientists involved in studies relevant of the problem considered and some institutions have a particularly good expertise(Italian and Spanish Hydrographic services, ORSTOM in France, Bulgarian and Romanian Hydrometeorological Institutes among other for example). Advanced technologies are avalaible from some european manufacturers (in France ,Germany, Italy, Great Britain for example).

2.5.6.1.5. Justification to undertake the proposed research to the European level:

The partners of that project include European Union member countries: France, Greece, Italy, Spain, Portugal and non-member countries having close relations with European Union: Albania, Algeria, Cyprus, Croatia, Egypt, Israel, Jordan, Macedonia, Malta, Morocco, Slovenia, Tunisia, Turkey, Palestinian Authorities, Syria, Lebanon, Bulgaria, Romania, Ukraine , Moldavia, Russia and Georgia.
The countries of the Mediterranean region and the region as a whole are facing a number of problems such as: fresh water scarcity, drought, desertification, flash floods, pollution, water

sharing, etc. The countries, through their representatives have expressed the opinion, in the May 1995 meeting, in Montpellier, that struggling at the national level only might not be enough to attain the socio-economic objectives and that there is a need to put the national problems in the regional perspective and therefore benefit from the added value provided by a collaborative approach, as proposed by MED-HYCOS. The project will therefore provide the countries and the region with tools to:

I. rationalize the use of water resources in the region. A key factor in development and prevention of water usage conflicts.

II. create a regional partnership for the monitoring of water resources in quantity and quality for the benefit of regional development and improved management of the Mediterranean Sea and the Black Sea, and in particular for pollution control.

III. better understand the regional hydrological phenomena and trends which require larger scale observation networks.

IV. modernize regions water resources agencies.

V. improve cooperation among the regions national water agencies.

VI. sustain research programs which are demand-driven by regional development issues.

VII. integrate water resources agencies into the regions development decision making, thereby providing the opportunity for integrated water resource development and management.

VIII. promote and facilitate the standardization of hydrological measurements and regional compatibility among national hydrological systems.

IX. promote and facilitate the real time circulation of water and environment data throughout the region.

If we recalled that in the Barcelona conference in 1995 it was pointed to the fact that « water management is a vital issue, which deserves special attention in the **European MEDA action plan**. » all these considerations place the project to the level of the European Union

2.5.6.1.6. Level of support:

The project is supported by a first funding of the world bank which considers water as a main problem in the region. This important support cannot be more than 11% of the total budget. So if it was possible to initiate the project in rather good conditions, now it is necessary to get new funding for development of the programme, specially for the maesurement of the water quality and for the development of a regional data base. Governments themselves, having agreed with the Project Document, provide about a half of the necessary funding, but is not sufficient. WMO provides services for several actions among which the providing of free transmission of the data through the METEOSAT system and their dissemination through GTS system.

2.5.6.1.7: IMMEDIATE OBJECTIVES, OUTPUTS AND ACTIVITIES

62. IMMEDIATE OBJECTIVE 1: Installation of a network of key stations of multisensor-equipped Data Collection Platforms (DCPs) for the collection and transmission of several variables related to water resources monitoring.

DCPs will transmit data to the METEOSAT Data Receiving Stations (MDRS), that will be installed at the Regional Centre and at national and sub-regional centres, as necessary.

OUTPUT	ACTIVITIES
□ 1.1 DCPs in participating countries,one METEOSATData Receiving Station (MDRS) at PRC and, as needed and possible, in participating countries and sub-regional centres.	1.1.1 Finalize the list of stations according to the criteria agreed upon by the relevant national agencies and obtain agreement on procedural arrangements needed to rehabilitate or upgrade the stations according to MED - HYCOS standard. The objective is to install at least 150 DCPs. 1.1.2 Prepare national and regional agreements for the implementation of MED - HYCOS, including the operation and maintenance protocols for the selected stations. 1.1.3 Prepare specifications for the supply, installation and commissioning of telemetry system, including necessary training activities to be undertaken at the national and regional levels for counterpart staff. 1.1.4 Procure and install equipment. 1.1.5 Organize and implement the day-to-day activities for the operation and maintenance of the telemetry system.
1.2 Trained personnel	1.2.1 Implement a training programme for the operation and the maintenance of the different elements of the data acquisition and telemetry system both at the national and regional levels.

63. IMMEDIATE OBJECTIVE 2: Development and implementation of the regional data base for water resources at PRC.

The data base will be fed in two ways:

(a) In real-time, by the network of key hydrological stations installed by this project;

(b) At regular intervals, by national agencies operating their normal networks.

The data base will serve such objectives as monitoring the operation and the management of the regional network of key stations, the dissemination of the data to different primary and secondary users at the national, regional and global levels and the preparation of products for the regional monitoring of the water resources.

OUTPUT	ACTIVITIES
2.1 Regional database installation, implementation and operation	2.1.1 Analyze the existing regional data bases, such as in the BLUE PLAN and in the FRIEND-AMHY Project. 2.1.2 Define the content and structure of the data base. 2.1.3 Prepare specifications of the additional hardware and software taking into account the existing systems in the region. 2.1.4 Procure and install equipment. 2.1.5 Prepare procedures for day-to-day operation and maintenance of the regional data base.
2.2 Arrangements for the exchange of data and information	2.2.1 Analyze existing systems in the region for information exchange and prepare protocols for data exchange and dissemination.
2.3 Trained personnel	2.3.1 Organize training activities for the regional, national and, as necessary, sub-regional data bases administrators.

64. IMMEDIATE OBJECTIVE 3: Implementation of a regional computer network for the monitoring of the regional water resources.

The networking of the MED-HYCOS PRC with the national hydrological and meteorological services. and other existing information networks and data bases at the national, regional and global levels will provide the region with a medium for easy and fast dissemination and exchange of data and information in the field of water resources, a prerequisite for any efficient and cost-effective operational regional monitoring system. A site will be opened on

World Wide Web system of Internet to allow a free access for the public at large to selected data and information.

OUTPUT	ACTIVITIES
3.1 A regional computer network system	3.1.1 Survey of national and regional databases to be connected to the regional database, including their actual status, the available equipment and the local telecommunication facilities. 3.1.2 Devise the structure and the basic functions of the system and prepare specifications of equipment to be installed at the national and regional levels. 3.1.3 Open a site on INTERNET 3.1.4 Procure and install equipment. 3.1.5 Negotiate information exchange arrangements. 3.1.6 Operate the system.
3.2 Trained staff at the regional and national level	3.2.1 Implement training programmes for the operation and maintenance of the system.

65. IMMEDIATE OBJECTIVE 4: Improvement of national hydrological services and networks notably through provision of new equipment and development of related training programmes.

OUTPUT	ACTIVITIES
4.1 Rehabilitated or upgraded selected hydrological stations	**NOTE:** Activities pertaining to the installation of DCPs are covered under Immediate Objective 1. 4.1.1 Procure additional equipment in consultation with the national agencies required for the rehabilitation or upgrading of the selected stations (including water quality measurements). 4.1.2 Ensure installation of equipment and their correct operation and maintenance by the national agencies.
4.2 New or improved national database networking	4.2.1 Procure additional hardware and software for improving national databases and their networking with other databases in allied fields.
4.3 Sub-regional centres	4.3.1 Procure additional hardware and software to improve or create subregional centers for special purposes as hydrological modeling or use of arial data (remote sensing) together with DCPs point data.
4.4 Trained personnel	4.4.1 Organize relevant training activities for the personnel in charge of the operation and the maintenance of the MED - HYCOS network and of the national database and computer networking.

Many others worknet s can be mentioned: for example in South Africa and on Nile river, Meteor Burst is used, ARGOS in Cameroon, etc...:

*les réseaux de surveillance sismologique des Pyrénées,
* la surveillance hydro-pluviométrique du bassin de la Loire,
* la surveillance hydro-pluviométrique du bassin de la Seine,
* la surveillance hydro-pluviométrique du Cameroun pour la Société Nationale de l'Electricité,
* la surveillance hydro-pluviométrique de rivières telles que le Tarn, la Garonne pour le compte d'Electricit* De France,
* le réseau mobile de stations de mesures météorologiques de M*t*o France,
* le réseau de surveillance météorologique du territoire algérien.

In annexes joined there are: List of technical specifications for the Data collecting platforms (DCP) of MED-HYCOS programme and technical caracteristics of the choosen DCPs. The specifications were established according to the purpose of the project and to the environmental conditions.

A tender was issued by WMO and five bids were received, among which one was choosen as meeting the best whith the specifications required for the lower price; **it must be pointed on the fact that price was a secondary criterion, technical specifications being the main criterion.**