SUSTAINABLE WATER RESOURCES MANAGEMENT IN SUDAN

Abdeen Mustafa Omer[1], University of Nottingham, UK

Abstract: For the 34 million people, who live in Sudan, environmental pollution is a major concern; therefore industry, communities, local authorities and central government, to deal with pollution issues, should adopt an integrated approach. Most polluters pay little or no attention to the control and proper management of polluting effluents. This may be due to a lack of enforceable legislation and/or the fear of spending money on the treatment of their effluent prior to discharge. Furthermore, the imposed fines are generally low and therefore do not deter potential offenders.

Keywords: *Sudan, water resources development, community water supply, effective water-supply management, environment*

INTRODUCTION

In Sudan, with more than 10 million people do not have adequate access to water supply, 20 million inhabitants are without access to sanitation and a very low proportion of domestic sewage being treated. The investment, which is needed to fund the extension and improvement of these services, is substantial (Omer, 2009). Most governments in developing countries are ready to admit that they lack the financial resources for proper water and sanitation schemes. Moreover, historically, bilateral and multilateral funding accounts for less than 10% of total investment needed. Thus, the need for private financing is imperative.

Many water utilities in developing countries need to work in earnest to improve the efficiency of operations. These improvements will not only lead to better services but also to enhanced net cash flows that can be re-invested to improve the quality of service. Staff productivity is another area where significant gains can be achieved. Investment and consumption subsidies have been predicated on the need to help the poor to have access to basic services and to improve the environment. Failure of subsidies to reach intended objectives is due, in part, to lack of transparency in their allocation.

A key element to successful private participation is the allocation of risks. How project risks are allocated and mitigated will determine the financial and operational performance and success of the project, under the basic principle that the risk should be allocated to the party, which is best able to bear it. Many developing countries (Sudan is not an exception) are encouraging the participation of the private-sector as a means to improve productivity in the provision of water and wastewaters services. Private-sector

[1] 17 Juniper Court, Forest Road, West Nottingham NG7 4EU, United Kingdom, email: abdeenomer2@yahoo.co.uk

Copyright © 2010 WASD

involvement is also needed to increase financial flows to expand the coverage and quality of services. Many successful private-sector interventions have been under taken. Private operators are not responsible for the financing of works, nonetheless they can bring significant productivity gains, which would allow the utility to allocate more resources to improve and extend services. Redressing productivity, subsidy and cross-subsidy issues before the private-sector is invited to participate, has proven to be less contentious. I have previously thought to encourage more private-sector involvement (Omer, 2008).

Sudan is geo-politically well located, bridging the Arab world to Africa. Its large size and extension from south to north provides for several agro-ecological zones with a variety of climatic conditions, rainfall, soils and vegetation. Water resources available to Sudan from the Nile system, together with groundwater resources, provide a potential for 30 years increase in the irrigated sub-sector. There are also opportunities for increased hydropower generation. The strategy of Sudan at the national level aims at the multipurpose use of water resources to ensure water security for attaining food security, drinking-water security, fibre-security, hydro-energy security, industrial security, navigation, waste disposal and the security at the regional levels within an environmentally sustainable development context and in harmony with the promotion of basin-wide integrated development of the shared water resources (Omer, 1995). At present, there are private-sector providers who do not have an enabling environment to offer the services adequately. There is a need for the government to have a mechanism to assist in the regulation and harmonisation of the private-sector providers. The government has continued to pay for the development and operation of water systems, but attempts are being sought to make the user communities pay water charges.

WATER RESOURCES

Sudan is rich in water (from the Nile system, rainfall and groundwater) and lands resources in Table 1. Surface water resources are estimated at 84 billion m3 and the annual rainfall varies from almost nil in the arid hot north to more than 1600 mm in the tropical zone of the south. The total quantity of groundwater is estimated to be 260 billion m3, but only 1% of this amount is being utilised. Water-resources assessment in Sudan is not an easy task because of uncertainty of parameters, numerous degrees of freedom of variables, lack of information and inaccurate measurements. However, according to seasonal water availability, Sudan could be globally divided into three zones: (a) areas with water availability throughout the year are the rainy regions (equatorial tropical zones); (b) areas with seasonal water availability; (c) areas with water deficit throughout the year, which occupy more than half the area of Sudan.

The most important research and development policies that have been adopted in different fields of water resources are as follows: (i) the water resource; (ii) irrigation development; (iii) the re-use of drainage water and groundwater; (iv) preventive and canal maintenance; (v) aquatic weed control and river channel development; (vi) protection plans. The physical and human resources base can provide for sustainable agriculture growth and food security for itself and for others in the region. Failure to do so in the past derives from several causes and constraints, which are manageable. These include misguided policies, poor infrastructure, low level of technology use, recurring droughts and

Table 1 Land use, land-resource zones and water resources (Omer, 2002)

(a) Land use (millions of ha)	
Geographical area (total Sudan area)	250.6
Land area	237.6
Cultivable area	8.4
Pastures	29.9
Forests and woodland	108.3
Uncultivable land	81.0
Area under crop (irrigated, rain-fed, mechanised and rain-fed traditional)	10.0

(b) Land-resource zones

Zone	*Area as % to total area of Sudan*	*Persons per km²*	*Mean average rainfall range (mm)*
Desert	44	2	0-200
QOS sands (sand dunes)	10	11	200-800
Central clay plains	14	19	200-800
Southern clay plains	12	8	800-900
Ironstone plateau	12	7	800-1400
Hill area and others	8	16	Variable

(c) Water resources

Water resource	*Available number*	*Static water level (m)*	*Number*
Haffirs	824	0-0	824
Slow sand filters	128	0-0	128
Open shallow wells	3000	0-10	3000
Boreholes deep wells	2259	0-25	1248
		26-50	478
		51-75	287
		76-100	246

(d) Geological formations

Basins	*Amount of water recharged (106 m³)*	*Water level below land (m)*	*Aquifer thickness (m)*	*Velocity (m/year)*	*Abstraction (106 m³/year)*
Sahara Nile	136	30-100	300-500	1-2.5	7.3
Sahara Nubian	20.6	10-50	300-500	0.8-1.5	1.5
Central Darfur	47.6	25-100	250-550	0.3-6.0	5.5
Nuhui	15.4	75-120	200-400	1.0-2.75	1.6
Sag El Na'am	13.5	50-1000	300-500	1.0-25.0	2.5
River Atbara	150	100-150	250-300	0.3-5.0	2.3
Sudd	341	10-25	200-400	0.1-1.8	1.8
Western Kordofan	15	50-70	300-500	0.1-0.3	1.7
Baggara	155	10-75	300-500	0.1-2.4	11.9
Blue Nile	70.9	10-50	250-500	0.1-2.5	10.2
The Alluvial	N.A	Shallow	N.A	N.A	N.A
Gedaref	41.7	50-75	200-500	0.1-2.0	1.2
Shagara	1.1	25-30	200-300	0.1-2.5	0.7

political instability. Perhaps the biggest challenge is that of finding resources for capital improvements in the light of changing water-quality regulations and ageing systems (James, 1994).

To ensure the sustainability of water supplies, an adequate institutional and legal framework is needed. Funds must be generated (a) for production, (b) for environmental protection to ensure water quality and (c) to ensure that water abstraction from groundwater remains below the annual groundwater recharge. Privatisation is part of a solution to improve services delivery in water and sanitation sector. At present, there is a transitional situation characterised by: (i) a resistance to water charge; (ii) insufficient suitable law/law enforcement; (iii) insufficient capacities; (iv) inadequate interaction between actors.

COMMUNITY WATER QUALITY AND SANITATION MANAGEMENT

Community water supply and sanitation management is a new form of cooperation between support agencies in the water and sanitation sector and communities. It involves a common search to identify problems with the local water supply and sanitation systems, to establish the possibilities for, and constraints on, management by communities, and to find possible solutions that may be tested. Some fundamental principles of community water and sanitation management are as follows: (i) increased management capacities are the basis for improved water and sanitation systems, and each community must develop its own specific management systems; and (ii) communities own the process of water charge; facilitators and local researchers participate in the community's projects, not the other way around.

Through this approach, the support agency is no longer the provider of technical goods or solutions, but the facilitator of process to enhance the capacity of the community to manage its own water and sanitation systems. Constraints include: (i) a lack of funds or substantial delays in allocating funds for essential requirements such as operation and maintenance of irrigation and drainage projects; (ii) deterioration in data-collection activities; (iii) a lack of appropriate and consistent policies for water development for both large- and small-scale projects; (iv) serious delays in completing water projects after major investments such as dams and other hydraulic structures, and main secondary canals not being completed; (v) an absence or inadequacy of monitoring, evaluation and feedback at both national and international levels; (vi) a lack of proper policies on cost recovery, and water pricing or, if policies exist, absence of their implementation; (vii) a shortage of professional and technical manpower, and training facilities; (viii) a lack of beneficiary participation in planning, implementation and operation of projects; (ix) inadequacy of knowledge, absence of appropriate research to develop new technologies and approaches and an absence of incentives to adopt them; (x) general institutional weaknesses and a lack of coordination between irrigation, agriculture, energy, healthy, environment and planning; (xi) inappropriate project development by donor agencies, for example irrigation development with drainage, supporting projects which should not have been supported; (xii) a lack of donor coordination resulting in differing approaches and methodologies, and thus conflicting advice.

As developing nations strive to provide a safe and reliable drinking-water supply to their growing and increasingly urbanised population is becoming more evident that

new approaches to this problem will be needed. To meet this challenge, new methods of reclaiming and re-using water have been developed in cost-effective and environmentally sound ways (Noureddine, 1997; Overseas Development Administration, 1987; Salih and Ali, 1992; Seckler, 1992).

Despite the constraints, over the last decade the rate of implementation of rural and peri-urban water supply and sanitation programmes has increased considerably, and many people are now being served more adequately. The following section describes the Sudan's experience in water supply and sanitation projects.

At Community Level

- Participatory approaches in planning, implementation and monitoring.
- Establishment and training of water tap committees.
- Clear ownership of improved water supply and sanitation systems.
- Technology and service level selection by consumers.
- Sensitive timing of hygiene and sanitation education.
- Establishment and training of reliable financial and maintenance management.

At District and National Level

- Integrated multi-sectoral approach development.
- Training approach and material development for district and extension staff.
- Continuing support from integrated multi-sectoral extension team.
- Establishment of technical support system.
- Multi-sectoral advisory group including training and research institutions.
- Development and dissemination of relevant information for district and extension staff.

WATER RESOURCE MANAGEMENT SYSTEMS

Water is a substance of paramount ecological, economical and social importance. Interrelationships inherent in water use should encourage integrated water management. Water resources are to be better managed to:

1. Ensure more reliable water availability and efficient water use in the agricultural sector.
2. Mitigate flood damage.
3. Control water pollution.
4. Prevent development of soil salinity and water logging.
5. Reduce the spread of water-borne diseases.

The emerging water crisis, in terms of both water quantity and quality, requires new approaches and actions. Priority areas needing concerted action in various sectors are as follows: (a) water use efficiency, (b) flood control, (c) management of scarce water resources, (d) water quality management and provision of safe drinking water and (e) coordination and integration of various aspects of water management, and water management with other related resources and societal concern. The following are recommended:

- Community must be the focus of benefits accruing from restructures, legislature to protect community interest on the basis

of equity and distribution, handover the assets to the community should be examined; and communities shall encourage the transfer the management of water schemes to a professional entity.

- The private-sector should be used to mobilise, and strengthen the technical and financial resources, from within and without the country to implement the services, with particular emphasis on utilisation of local resources.
- The government should provide the necessary financial resources to guide the process of community management of water supplies. The government to divert from provision of services and be a facilitator through setting up standards, specifications and rules to help harmonise the private-sector and establish a legal independent body by an act of parliament to monitor and control the providers. Governments to assist the poor communities who cannot afford service cost, and alleviate socialeconomic negative aspects of privatisation.
- The sector actors should create awareness to the community of the roles of the private sector and government in the provision of water and sanitation services.
- Support agencies assist with the financial and technical support, the training facilities, coordination, development and dissemination of water projects and then evaluation of projects.

The development of new, modern and complete water resources information systems is one of the basic needs for the implementation of the water resources management system. The decision process in drought or flood conditions, and also in over-exploitation cases, can only be correct if based on a reliable information system. A complete and comprehensive database on water availability, users, water quality monitoring, current technologies (like geographical information systems), is certainly the way to produce an efficient framework for decision-making. Lack of information is one of the most critical points regarding the development and implementation of the new management system (FAO, 1999). The types of data related to flood management include:

- Topographic data (elevations, land use, soils, vegetation, hydrography).
- Imagery (satellite images, aerial photographs).
- Administrative data (political boundaries, jurisdictional boundaries).
- Infrastructure data (roads, wells, utilities, bridges and culverts, hydraulic structure, properties, facilities).
- Environmental data (threatened and endangered species, critical aquatic and wildlife habitat, archaeological sites, water quality).
- Hydrometeorology data (stream flows, precipitation, temperature, wind, solar radiation, soil water, discharge rating curves, flood frequency, flood plain delineation).
- Economic data (stage-damage relationships, insured values, industries) and
- Emergency management data (emergency plans, census data, organisational charts).

GROUNDWATER

The desert environment is fragile and highly affected by human activities. Disturbances in the balanced ecosystems are apt to take place causing serious problems to the environment, and consequently, initiating geotechnical hazards. Urbanisation, climatic conditions and geomorphic and geologic

setting are usually the controlling factors influencing the types of these hazards.

One of the potential geotechnical hazards that may occur under desert conditions is sand drifting and dune movement. The problem of sand drifting and dune migration is of special interest in Sudan as moving sand covers approximately one-third of the country. Because sand poses natural erosionaldepositional hazards on the existing structures, such as roads and urbanised areas, it become necessary to study the behaviour of the sand forms in the different parts of the country.

Although deserts are known to be simply barren areas, they are scientifically defined in terms of water shortage or aridity, soil type, topography and vegetation. (Anon, 1979) presented a map showing the distribution of deserts in the world. According to this map, most of the Middle Eastern countries lie within the semi-arid, arid and hyper-arid desert zones, with an aridity index (ratio between annual precipitation and mean annual potential evapotranspiration) ranging between 0.03 and 0.02. Most of the geotechnical hazards are associated with desert environments. The desert environment, being a fragile ecosystem, needs to be treated with care. Intercommunications between different national and international agencies and education of the layman should help to keep the system balanced and reduce the resulting environmental hazards. In addition, any suggested remedial measures should be planned with nature and be engineered with natural materials.

THE POLICY REGIME IN WATER QUALITY MANAGEMENT

Apart from effluent regulations, and sometimes, national water quality guidelines, a common observation is that few developing countries (Sudan is not an exception) include a water-quality-policy context. Although water supply is seen as a national issue, pollution is mainly felt at, and dealt with at, the local level. With few exceptions, national governments have little information on the relative importance of various types of pollution (agriculture, municipal, industrial, animal husbandry, aquaculture), and therefore, have no notion of which is of greatest economic or public health significance. Usually freshwater quality management is completely divorced from coastal management even though these are intimately linked. Consequently, it is difficult to develop a strategic water quality management plan or to efficiently focus domestic and donor funds on priority issues. A national water quality policy should include the following water quality components:

- A policy framework that provides broad strategic and political directions for future water quality management.
- A strategic action plan for water quality management based on priorities that reflect an understanding of economic and social costs of impaired water.

This plan should include the following components:

- A mechanism for identifying national priorities for water quality management that will guide domestic and donor investment.
- A plan for developing a focused and cost-effective data programme for water quality and related uses, as a basis for economic and social planning.
- A consideration of options for financial sustainability including donor support, public-private sector partnerships, regional self-support initiatives.

- A regulatory framework that includes a combination of appropriate water quality objectives (appropriate to that country and not necessarily based on Western standards) and effluent controls.

  This includes both surface and groundwater.

- A methodology for public input into goals and priorities.
- A process for tasking specific agencies with implementation so that accountability is firmly established and interagency competition is eliminated.
- Specific mechanisms for providing drinking water monitoring capabilities, at the community level if necessary.
- National data standards that must realistically reflect national needs and capabilities. Nevertheless, the objective is to ensure reliable data from those organisations that provide information for national water management purposes and at the community level for drinking water monitoring.

The design criteria in any water-quality programme are to determine the management issues which water quality data are required. In general, there are four categories of data objectives:

- Descriptive data that are typically used for government policy and planning, meeting international obligations and for public information.
- Data specific to public health.
- Regulatory concerns.
- Aquatic ecosystem health.

The last category is not normally included in many developing countries for reasons of cost and complexity. In most developing countries, countries with transitional economies, and some developed countries, the technology of monitoring has changed little since 1970s, yet some of the largest advances in monitoring in recent years involve technical innovation that serve to reduce costs and increase efficiency. Admittedly, not all of these are inexpensive; however when deployed appropriately, they may eliminate traditional monitoring, or reduce costs by increasing the efficiency of more traditional approaches to chemical monitoring. Types of innovation include: biological assessment, use of surrogates, use of enzymatic indicators, miniaturisation, automation and simplification of laboratory analytical methods.

The water quantity situation is highly variable in Sudan reflecting different levels of development and different needs for water quality programmes in Table 2. The conventional paradigm of water quality monitoring is not suitable for the Sudan being too expensive, inefficient and ineffective. Financial and sustainability issues include cost avoidance and cost reduction, local and accountability frameworks that encourage good business practices by senior programme managers, the use of new cost-effective technologies for monitoring and a variety of donor/public/private sector linkages that focus on commercial benefits that permit the transfer of certain parts of water quality programmes to the private-sector.

SUSTAINABLE DEVELOPMENT

In Sudan, with limited water resources and increased demands to cope with the rapid development, it is paramount to inaugurate strategies that control this valuable resource through augmentation and conservation measures. Such measures essentially include rationalisation of water use, minimising losses, quality protection, exploration,

Table 2 Present water management of Sudan (Omer, 2007)

Using of resources	*Sources*	*Institutions*	*Pricing principle*	*Price details*
Urban	Surface and groundwater	National Water Corporation (NWC)	Full cost recovery	Progressive rate with increasing uses. Rates lower in the north
Major rural villages	Mostly groundwater	Rural Water Corporation (RWC)	Stand pipe free, recovery of recurrent costs, charges for yard and house connections	Progressive rates but less comparative to urban cities
Rural villages	Groundwater	District Councils	As above	Not available
Livestock	Surface and groundwater	Rural Water Corporation (RWC)	All investments and recurrent costs	Regressive, no charges on relatively small use
Mines	Surface and groundwater	National Water Corporation (NWC)	Full cost recovery	Progressive rates
Wildlife	Mostly surface	Rural Water Corporation (RWC)	Full cost of boreholes	Regressive

artificial recharge and water harvesting techniques. A schematic technological advancement of low cost water supply systems such as dug wells, roof top catchments, haffirs and small dams combined with development of guidelines for settlement policy will hopefully lead to an improvement of water supply systems, water quality and reduction of the distance to the supply points (World Resources Institute, 2002).

In the past decade, sustainability has increasingly become a key concept and ultimate global for socio-economic development in the modern world. Without a doubt, the sustainable development and management of natural resources fundamentally control the survival and welfare of human society. Water is an indispensable component and resource for life and essentially all human activities rely on water in a direct or in direct way. Yet supplying water of sufficient quantity and safe quality has seldom been an easy task. Although sustainability is still a loosely defined and evolving concept, researchers and policy-makers have made tremendous efforts to develop a working paradigm and measurement system for applying this concept in the exploitation, utilisation and management of various natural resources. In water resources arena, recent development has been synthesised and presented in two important documents published by ASCE (1998) and UNESCO (1999), which attempt to give a specific definition and a set of criteria for sustainable water resource systems. When considering the long-term future as well as the present, sustainability is concept and goal that can only be specified and implemented over a range of spatial scales, of which urban water supply is a local problem with great reliance on the characteristics and availability of regional water resources. Sudan needs assistance in developing and implementing (a) river-basin management, (b) diffuse source pollution, (c) environmental restoration and (d) urban storm drainage. At present the international, bilateral donor agencies and relevant United Nations bodies provide

such assistance. The international associations constitute an additional, but as yet untapped, source of assistance. The solution, which should be seriously explored, is the forging of partnerships with bodies such as the World Bank and the appropriate United Nations agencies.

GOALS AND CHALLENGES

Advanced research and technology contribute to resolving water shortage and sanitation problems, and non-conventional reliable water supplies cannot be provided unless the environmental impacts are taken into consideration. Looking to the future, Sudan has a set the following priorities for water resource research and development until the year 2020: (i) increase overall water-use efficiency to the maximum limit. This could be achieved by (a) improving the irrigation system and assure its flexibility to cope with modern farm irrigation system, (b) developing the farm system, (c) drawing up a proper mechanism for water charges; (ii) Modify the cropping pattern; for example (a) planning the different cropping pattern according to water quality, (b) gradually replacing sugar cane by sugar beet, (c) introducing genetic engineering and tissue culture to develop salt tolerance crops, and (d) reducing the area of clover (Berseem); (iii) Re-use all the possible agricultural drainage water using proper technological means to deal with its quality, especially after implementing the irrigation development programme; (iv) Plan properly the re-use of sewage effluent after drawing up guidelines for its use; (v) Research agreements of losses and suggest conservation projects; (vi) The conjunctive use and management of reservoirs and groundwater sources in the Nile valley, giving special consideration to drought conditions; (vii) Develop non-renewable groundwater resources in the deserts on a sustainable basis; (viii) Water harvest rainfall in desert areas and make full use of torrential streams and flash floods; (ix) Use new economical technology of seawater desalination; (x) Raise public awareness about water resource scarcity and government management plans; (xi) Consider laws to match with the required development and existing scarcity; (xii) Establishment of efficient operation, maintenance and repair procedures; (xiii) Community participation in operation and maintenance; (xiv) The extent to which initial government investment can or should be recovered from water uses; (xv) Domestic potable water supply should reach at least 25 l/day per person; (xvi) Water should be available for 10 livestock units at 450 l/day; (xvii) Potable water must be available within 2 km of individual residences.

From a visual investigation of the River Nile in Table 3, the major sources are industrial effluents, crude sewage from blocked, broken or overloaded sewers, sewage effluents, surface runoff and solid wastes which have been dumped into the river. Therefore, remedial and improvement measures must be taken before the environment becomes further polluted and the natural resources are completely over-exploited (Omer, 2000). The challenges facing and enhancing the ecology in the 21st century are as follows: (a) drinking-water sources should be treated with chemicals; (b) suitable toilet facilities should be provided along the main roads to minimise pollution; (c) proper arrangements should be made for litter dumping and waste disposal; (d) local people should be fully educated about environment matters and hygiene; (e) previous damage should not be allowed to continue while planning for a balanced development in the future; (f) the concept of the ecosystem (involving education and interpretation of the natural environment) must be promoted.

Table 3 Wastes in River Nile water (Omer, 2008)

Materials	*(%)*
Paper, wood	50.0
Ferrous residues	12.5
Glasses	11.0
Organic wastes	10.0
Plastics	5.0
Non-ferrous residues	1.5
Other	10.0

THE CHALLENGE OF OVERCOMING THE COUNTRY'S DIVERSITY

Sudan is a federal republic of 2.5 million km2 located in the eastern Africa. The country is divided into 26 states and a federal district, in which the capital, Khartoum is located. Sudan is known as a country of plentiful water, with highest total renewable fresh water supply in the region. Table 4 shows some of the most significant regional diversities concerning water issues.

Adequate water management is essential to sustain development. Competing needs for this beneficial resource include municipal supply, industry and agriculture, among others. The National Water Act of 1994 (Law No. 1155) defines the objectives, principles and instruments of the National Water Resources Policy and the National Water Resources Management system. The law establishes the institutional arrangement under which the country's water policies are to be implemented. The National Water Resources Policy was proposed to achieve:

- *Sustainability*: to ensure that the present and future generations have an adequate availability of water with suitable quality.
- *Integrated management*: to ensure the integration among uses in order to guarantee continuing development.
- *Security*: to prevent and protect against critical events, due either to natural causes or inappropriate uses.

To achieve such objectives, water management must be implemented according to the following principles:

- Water is a public good, and it is a finite resource that has economic value.
- The use of water required to meet people's basic needs shall have priority, especially in critical periods.
- Water management shall comprise and induce multiple uses.
- The river basins are the appropriate unit for water management, and water management shall decentralise, with the participation of government, stakeholders and society.

Water resources plans are developed to guide future decisions and are to be developed for each river basin and state, as well as the country. The objective is to coordinate efforts and establish guidelines and priorities for water allocation and water pricing. The priorities established for water allocation will be used in critical drought conditions. Water pricing is the single most controversial instrument of the law. The pricing system is also the most difficult step to implement. The pricing system recognises the economic value of water, as stated in

Table 4 Main water resource issue in region (Omer, 2000)

Region	*Water resource issues*
South	1. Abundant water resources 2. Localised scarcity of water and untapped water supplies 3. High hydropower potential 4. Water conflicts arising from immigration of Bagara Arabs (nomadic) from north to south 5. Water-borne diseases 6. International water conflicts (upstream and downstream countries)
Central	1. Water quality problems from untreated sewage and other pollution 2. Water-borne diseases 3. Potential use of rivers for navigation and recreational purposes 4. Intensive erosion and sedimentation from agriculture 5. High hydropower potential 6. Excessive use in large urban and industrialised areas 7. Frequent urban floods
North	1. Good water quality 2. Scarcity of water resources 3. Intensive erosion and sedimentation from agriculture 4. Frequent urban floods
Northeast	1. Scarcity of water resources 2. Water quality problems from untreated sewage 3. In mining areas, water quality problems from effluent
West	1. Scarcity of water resources 2. Water conflicts between nomadic and non-nomadic tribes 3. Water-borne diseases 4. Soil erosion and degradation caused by agriculture

the principles of the policy. The development of a new, modern and complete water resources information system is one of the basic needs for the implementation of the water resources management system. The decision process in drought or flood conditions, and also in overexploitation cases, can only be correct if based on a reliable information system. A complete and comprehensive database on water availability, users, water quality monitoring, current technologies (like geographical information systems), is certainly the way to produce an efficient framework for decision-making. Lack of information is one of the most critical points regarding the development and implementation of the new management system. The institutional framework provides the basis by which all actions are taken, and an assessment of its functional character helps determine the collaborative potential. The resulting criteria for measuring a given community's institutional capacity can be found in Table 5.

WATER SCARCITY IMPACTS AND POTENTIAL CONFLICTS

The failure of water resources to meet the basic requirements of society has a host of social, economic, environmental and political impacts. Water scarcity is man-made phenomenon brought about by the

Table 5 Capacity assessment for flood management: institutional factors (Omer, 2008)

High capacity (plans, etc., in places)	• Basin-wide management plan has been drafted. • Natural mitigation strategy in place. • Basin-wide coordination and communications strategy instituted. • Trained emergency management staff coordinating at the regional level. • Effective regulatory policies that address floodplain occupancy. • Decentralised decision-making with a high degree of local autonomy. • Evidence of an updated national response plan. • Bilateral response agreements. • Evidence of regional preparedness and response training.
Medium capacity (evidence of activity on-going)	• Some trained emergency management staff at the local and/or national level. • Evidence of some regulatory policies designed to address floodplain occupancy. • Attempts to decentralise decision-making, moderate local discretion. • No existing flood response plan. • No evidence of mitigation-related activities.
Low capacity (no formalisation in place nor apparently evolving)	• Poor local-and national-level coordination and communications. • Little or no evidence of flood preparedness and response training. • No regulatory policies addressing floodplain occupancy. • Centralised decision-making, no evidence of local autonomy.

increasing demands of the population for water. The imbalance in the population water resources equation strains society has an adverse impact on domestic hygiene, public health and cost of domestic water and could impart political problems as a serious as bringing down government. On the social side, water scarcity adversely impacts job opportunities, farm incomes, credibility and reliability of agricultural exports and ability of the vulnerable to meet the cost of domestic water. Economically, the adverse impact is displayed in the loss of production of goods, especially agricultural goods, the loss of working hours because of the hardships society faces as a result of water scarcity. The impacts of water scarcity on regional stability are addressed with reference to water in the Middle East Peace Process, taking into account the serious impacts of conflicts and potential water war.

Conditions of scarcity propel an increase in competition among the different sectors of water use with results, invariably, at the expense of irrigated agriculture. Pure market forces create a gradient under which water flows from the poor to the rich. Tough decisions await politicians, and the consequences are expected to displease one or more parties, and please others. The scene of domestic politics becomes as fluid as water itself, with politicians shifting positions continuously in response to domestic pressures. The political fallout from water resources scarcity on the domestic scene is parallel to the impact the scarcity has on domestic households in terms of basic needs for drinking and food preparation, on domestic hygiene and on public health. Other important factors have a delayed response to water scarcity, and these pertain to the integrity of the environment,

and deterrence it imparts on development investment and economic credibility of the country. The cost of mitigating these problems and of the provision of services to the increased urbanisation could very well be beyond the ability of government to bear. The political consequences resulting from this will not be in favour of domestic stability, and social explosions can be anticipated.

A bilateral agreement was reached between Egypt and the Sudan in 1959 by which the two countries share the Nile flow: 55.5 billion cubic meters to Egypt, 18.5 billion to Sudan and 10 billion were allocated to evaporation. Hopes are high for achieving a more extensive participation by the other riparian parties in what could be a multilateral treaty on the Nile encompassing the other riparian states in addition to Egypt and Sudan. The aforementioned agreement is not complete; it lacks the entry of other legitimate riparian states, lacks water quality components and tends to focus on quantity measures and miss important management issues. It is to be noted that regional relations, including those among the riparian parties, are connected to the political, economic and trade network of international relations. Water is not the only determinant factor in shaping the nature of bilateral, regional or international relations.

Water relations can be transformed into a positive sum game by which all parties can be made to win. One common gain to all is the environmental protection of the common watercourse or water body. Lack of cooperation and agreement will most likely lead to environmental neglect and water quality degradation, which is loss to all. International encouragement to attain cooperation can, therefore, be brought to bear on the regional parties, and efforts of international lending agencies can be called upon to pool with the regional and international efforts to achieve this objective. It has been stipulated by many that under conditions of scarcity, water conflicts can lead to hostile actions between riparian parties. Experience in the region indicates that water, in its own right, has not been the cause of any of the wars that have broken out in the region.

Today's advanced societies heavily depend on energy. The principal sources of energy and electricity generation today are solar, wind, biomass, hydropower and fossil fuel. Energy from hydropower is short of meeting the current or future energy requirements, and the fossil fuel resources, being depleted with time, will eventually run out. For human civilisation to continue at its natural pace, new forms of affordable and clean energy will have to come on line. Failure of human civilisation to introduce new forms of energy will render that civilisation doomed, and the quality of life will deteriorate. If this unlikely scenario actually takes place, the requirements will decrease because the mechanism of making it available for use (pumping) diminishes. The more likely scenario is more optimistic one, and it is that a new form of energy generation will be introduced in which case water desalination becomes affordable and its pumping from the coastal desalination plants become possible at reasonable cost. The way out of the looming water crisis rests, therefore, in the invention of new forms of energy generation that will make possible the reliance on desalination and in the recycling of wastewater for reuse in agricultural production and for environmental reasons. Integrated management of the three resources of water, energy and the environment will result in better results with a positive sum for society.

COMMON LANGUAGE AND CULTURE

A common language and similar culture simplify communication and reduce the potential for misunderstandings. In Nile basin where several languages are spoken, an international language, English, is used with some success by multi-jurisdictional basin management authorities.

PRIMARY FACTORS PROMOTING DATA AND INFORMATION EXCHANGE

Data and information exchange is more probable when needs are compatible and when there is potential for mutual benefit from cooperation in Table 6. Where countries are working on developments that are beneficial to both countries as well as other riparians, there is little incentive to hide project impacts. This means that because data and information exchange is unlikely to lead to pressure from surrounding countries that might restrict developments, countries have less reason to restrict access to their data and information resources. It is important, therefore to be no perceived clash of interests in development plans and needs. An example of this might be in developing their part of the basin primarily for hydroelectric development, while the lower riparians are more interested in developing the irrigation potential of their portion of the basin. By constructing large storage dams in the upper part of the basin, the river Nile seasonal flow might be evened out, reducing flooding downstream while increasing irrigation water supplies and even making downstream run-of-the-river hydroelectric projects more profitable. Ecosystem effects would have to be considered.

SUFFICIENT LEVELS OF ECONOMIC DEVELOPMENT

Sufficient levels of economic development across a basin are needed to permit joint funding of cooperative processes, particularly data collection and dissemination. Although countries with differing levels and forms of economic development may, at times, have more complementary needs

Table 6 Summary of the situation relating to data and information exchange in Nile basin (Omer, 2007)

River basin	*Nile basin*
Basin states or territories	Burundi, Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda
Cooperative frameworks in place	Nine of the countries of basin are pursuing the development of a cooperative framework
Major languages spoken	More than six official languages and numerous unofficial languages
Major water issue facing the basin	Rapid population growth, environmental degradation, under development
External funding of cooperative basin initiatives	Extensive external funding of cooperative initiative
Range of GDP *per capita* of the basin	$550-$3000
Extent of data/ information exchange	Information exchange through the cooperative framework being developed is beginning to occur

Table 7 Diverse water challenge (WRI, 2002)

	Egypt	*Sudan*
Per capita annual water resources 2000 (m^3)	34	1187
Per capita annual withdrawal (m^3)	921	666
Per capita annual withdrawal for agriculture (m^3)	86	94

than countries with similarly structured economies, the overall level of economic development is still significant. A wealthier country in a river basin may be able to assist with the funding of data collection activities in the neighbouring country with much needed data and helping to build confidence between the two countries.

INCREASING WATER RESOURCES STRESS

As per capita water resources availability decreases as shown in Table 7, tensions between riparian nations may rise and make cooperation difficult. Stress may, therefore, reduce cooperation and data sharing rather than strife.

The historical background of the basin may have a lasting effect on current negotiations. Past conflicts can have a deleterious effect on the prospects for establishing cooperative practices, such as data sharing. Where there is a history of conflict between two nations, both nations may view the present situation primarily as competitive and focus on conflicting rather than common interests. Democracies may find it easier to negotiate cooperative arrangements with other democracies. Political differences can lead to legacies of mistrust developing between countries.

CONCLUSIONS

A booming economy, high population, land-locked location, vast area, remote separated and poorly accessible rural areas, large reserves of oil, excellent sunshine, large mining sector and cattle farming on a large scale, are factors that are most influential to the total water scene in Sudan. It is expected that the pace of implementation of water infrastructure will increase and the quality of work will improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is also easier and more transparent. The communities should be fully utilised in any attempts to promote the local management of water supply and sanitation systems. There is little notion of 'service, invoice and move on'. As a result, there are major problems looming with sustainability of completed projects. A charge in water and sanitation sector approach from supply-driven approach to demand-responsive approach call for full community participation. The community should be defined in terms of their primary role as user/clients. Private-sector services are necessary because there are gaps, which exist as a result of the government not being able to provide water services due to limited financial resources and increase in population. The factors affecting the eco-environmental changes are complex, interrelated and interactive. The deterioration problems of water and sanitation have attracted some attention in recent years. There is an urgent need to study possible rehabilitation measures to ensure a sustainable and excellent water quality and improved sanitation.

BIOGRAPHY

Abdeen Omer is a qualified Mechanical Engineer with a proven track record within the water industry and renewable energy technology. He has graduated from University of El Menoufia, Egypt, BSc in Mechanical Engineering in 1982. Working as Chief Mechanical Engineer for National Water Equipment Manufacturing Co. Ltd. and as Assistant Researcher for National Council for Research/Energy Research Institute, Sudan.

REFERENCES

Anon. (1979). 'Map of the world distribution regions', *MAB Tech Note* Vol. 7, pp. 7-15.

ASCE. (1998). 'Task Committee On Sustainability Criteria, Sustainability Criteria for Water Resource Systems', ASCE, Reston, Virginia, USA.

FAO. (1999). 'The State of Food in Security in the World', United Nations Food and Agriculture Organisation, Rome, Italy.

James, W. (1994). 'Managing Water as Economic Resources', Overseas Development Institute (ODI), UK.

Noureddine, R.M. (1997). 'Conservation planning and management of limited water resources in arid and semi-arid areas', In Proceedings of the 9th Session of the Regional Commission on Land and Water Use in the Near East, Rabat, Morocco, pp. 15-21.

Omer, A.M. (1995). 'Water resources in Sudan', *NETWAS* Vol. 2, pp. 7-8.

Omer, A.M. (2000). 'Water and environment in Sudan: the challenges of the new millennium', *NETWAS* Vol. 7, No. 2, pp. 1-3.

Omer, A.M. (2002). 'Focus on groundwater in Sudan', *International Journal of Geosciences Environmental Geology* Vol. 41, No. 8, pp. 972-976.

Omer, A.M. (2007). 'Water in the Sudan', *Water International* Vol. 32, No. 5, pp. 894-903.

Omer, A.M. (2008). 'Water resources and freshwater ecosystems in Sudan', *Renewable and Sustainable Energy Reviews* Vol. 12, pp. 2066-2091.

Omer, A.M. (2009). 'The dilemma of plenty and scarcity of water resources in Sudan', *Natural Resources: Economics, Management and Policy* Vol. 1, pp. 1-49.

Overseas Development Administration (ODA). (1987). 'Sudan Profile of Agricultural Potential', Overseas Development Administration, Survey, UK.

Salih, A.M.A., & Ali, A.A.G. (1992). 'Water scarcity and sustainable development', *Nature and Resources* Vol. 28, p. 1.

Seckler, D. (1992). 'Private Sector Irrigation in Africa-Water Resources and Irrigation Policy Studies', Winrock International Institute for Agricultural Development, UK.

UNESCO. (1999). 'Sustainability Criteria for Water Resource Systems', Cambridge University Press, Cambridge, United Kingdom.

World Resources Institute (WRI). (2002). 'World Resources 2000-2001', New York, USA.