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Review article

Sustainability criteria for water resource systems: sustainable development and management

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ABSTRACT

For the thirty-nine 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.

1. Introduction

In Sudan, with more than ten million people do not have adequate access to water supply, twenty 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, 1995). 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 reinvested 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. Subsidies are often indiscriminately assigned to support investment programmes that benefit more middle and high-income families, which are already receiving acceptable service. Consumption subsidies often benefit upper-income domestic consumers' substantially more than low-income ones.

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 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, 1995).

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 thirty 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 multi-purpose 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 (Noureddine, 1997).

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. In order 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. 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. 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; and (iv) Inadequate interaction between actors.

2. Water resources

Sudan is rich in water (from the Nile system, rainfall and groundwater) and lands resources (Table 1). Surface water resources are estimated at 84 billion m^3 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 m^3, 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; and (c) areas with water deficit throughout the year, which occupy more than half the area of Sudan.

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 km^2	Mean average rainfall range (mm)
Desert	44	2	0-200
QOS sands	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 (10^6 m^3)	Water level below land (m)	Aquifer thickness (m)	Velocity (m/year)	Abstraction (10^6 m^3/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

The most important research and development policies which have been adopted in different fields of water resources are: (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, and (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, and low level of technology use, recurring droughts and 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).

Environmentalists and regulators are already working on solving the next set of issues in their constant pursuit of better quality. Increasing watershed and source protection, combating microbial and organic contaminations that new detection techniques have enabled us to identify, controlling pesticide runoff, reducing chlorine by-products and upgrading ageing infrastructure are all receiving unprecedented attention. Surface-water systems are continuing to rely on conventional treatment (coagulation, flocculation, sedimentation, filtration and disinfections) for particulate removal, but other treatment processes such as ozone and granular activated carbon will see increased use, while new disinfections strategies will be needed to minimise both microbial risks and unwanted by-products from disinfections. Sudan is therefore moving into a new era in the protection of drinking-water supplies. It is now time for water utilities to combine creative management, dependable treatment methods and new technologies to ensure that drinking water is as safe as possible.

3. 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:

(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, and 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, e.g., irrigation development with drainage, supporting projects which should not have been supported; and (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 (ODA, 1987; Seckler, 1992; Salih et al., 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 are Sudan 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.

4. 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:

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

5. 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 erosional-depositional 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. Accordingly 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.

6. 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. Whereas 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, and 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 through 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 inter-agency 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. Generally, 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 (Appendix 1).
- Data specific to public health.
- Regulatory concerns, and
- 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 (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.

7. 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, 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. The following problems encountered so far need to be solved in the near future:

- The establishment of efficient operation, maintenance and repair procedures.
- Community participation in operation and maintenance.
- The extent to which initial costs can or should be recovered from water users.

In the past decades, 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; 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.

Table 2
Present water management of Sudan.

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

8. Goals and challenges

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.

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; and (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 litres per day per person; (xvi) Water should be available for ten livestock units at 450 l/d; (xvii) Potable water must be available within two kilometres of individual residences.

From a visual investigation of the River Nile (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 twenty-first 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.

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

9. The challenge of overcoming the country's diversity

Sudan is a federal republic of 2.5 million km^2 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.

Table 4
Main water resource issue in region.

South
- Abundant water resources
- Localised scarcity of water due to untapped water supplies
- High hydropower potential
- Water conflicts due to immigration of Bagara Arab (nomadic) from north to south
- Water-borne diseases
- International water conflicts

North
- Good water quality
- Scarcity of water resources
- Intensive erosion and sedimentation due to agriculture
- Frequent urban floods

Central
- Water quality problems due to untreated sewage
- Water-borne diseases
- Potential use for navigation and recreational purposes
- Intensive erosion and sedimentation due to agriculture
- High hydropower potential
- Intensive pollution of water supplies
- Localised scarcity of water supplies due to pollution and excessive use in large urban and industrialised areas
- Frequent urban floods

Northeast
- Scarcity of water resources
- Water quality problems due to untreated sewage
- In mining areas, water quality problems

West
- Scarcity of water resources
- Water conflicts
- Water-borne diseases
- Soil erosion and degradation caused by agriculture

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.
- Water 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 is 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. The water quality classification of water bodies by different classes of use is the basis for truly integrating the quality and quality of water management. 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 recognizes the economic value of water, as stated in 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.

Table 5

Capacity assessment for flood management: institutional factors.

High
• 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.
Medium
• Evidence of an updated national response plan. • Bilateral response agreements. • Evidence of regional preparedness and response training. • 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.
Low
• No existing flood response plan. • No evidence of mitigation-related activities. • 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.

10. 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 increasing demands of the population for water. The imbalance in the population- water resources equation strains society and 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 urbanization 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.

The expanded region of the Middle East and North Africa (MENA) has the most desert and arid areas per capita. There is a serious water challenge in the MENA region (Sudan is not an exception) that grows more serous with time. It is the challenge of resolving international water issues peacefully and concluding all-inclusive and comprehensive riparian agreements on international water basins. The issues of international water management in the region, surface and groundwaters, are not all resolved, and conflicts over sharing their waters exist. It is feared that such conflicts, added to already explosive disputes, may trigger clashes that threaten stability in region.

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 above 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 civilization to continue at its natural pace, new forms of affordable and clean energy will have to come on line. Failure of human civilization to introduce new forms of energy will render that civilization 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.

11. 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.

Table 6
Summary of the situation relating to data and information exchange in Nile basin.

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 6 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

12. 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 (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 since 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 for there 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.

13. 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 than countries with similarly structured economies, the overall level of economic development is still significant. A weathier 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.

Table 7
Diverse water challenge**.**

Country	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

Source: World Resources Institute 1998 and 2000. World Resources 1998-1999. World Resources 2000-2001.

14. Increasing water resources stress

As per capita water resources availability decreases (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 (Appendixes 2-5). 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.

(i) The community must be the focus of benefits accruing from restructuring; (ii) Legislation should be introduced to protect community interest on the basis of equity and distribution; (iii) Handing over the assets to the community should be examined; (iv) Communities should encourage the transfer the management of water schemes to a professional entity; (v) The government should provide the necessary financial resources to guide the process of community management of water supplies; (vi) The government should divest 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; (vii) The private sector should 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; (viii) The government should assist the poor communities who cannot afford service cost; and (ix) Social-economic negative aspects of privatisation should be alleviated.

15. Conclusion

1. 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 which are most influential to the total water scene in Sudan.
2. 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.
3. The communities should be fully utilised in any attempts to promote the local management of water supply and sanitation systems.
4. There is little notion of 'service, invoice and move on.' As a result, there are major problems looming with sustainability of completed projects.

5. 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.
6. 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.

Appendix 1
The descriptive formulaes.

Main criteria	Sub-criteria	Formulae
Food	Grain security	$\sum_{It=1}^{N} \frac{Grain\ production\ (t/year)}{Required\ grain\ consumption\ (t/year)}$
Economic	Value added	$\sum_{i=1}^{N}$ {Return (SD) – Cost (SD)} Where N = number of sectors (agriculture, industrial, domestic water supply, navigation, power generation)
Water	Water security	Water security = [total available water resources – Total water requirements] (10^6 m^3 / year) $\sum_{i=}^{K} \frac{Volume\ of\ water\ used\ from\ resource}{Potential\ of\ resource}$
	Water sustainability	Where K = number of water resources (surface water, shallow groundwater, deep groundwater, desalination, etc.)

Appendix 1
(Continued).

Main criteria	Sub-criteria	Formulae
Socio-economic	National employment	$\sum_{i=1}^{K}$ Total employment of sector $_i$ Where K = number of sectors (agriculture, industrial, domestic water supply, power generation and navigation)
	New settlers	Total homes tender of agriculture sector
	Land *per capita*	$\frac{Total\ cultivated\ land}{Total\ population}$ $(hectare / capita)$
	Water *per capita*	$\frac{Available\ water\ resources}{Total\ population}$ (m^3/capita/year)
	Shisto paracites	Shisto paracites prevalence = number of shisto patients over the country

	prevalence Typhoid paracites prevalence	Number of typhoid patients over the country
Environmental	Agro-chemical *per capita*	$\sum_{i=1}^{N} \frac{Pesticide\ used\ in\ (kg/year)}{Population}$ Where N = number of pesticides used all over the country
	Industrial effluent integrated water quality index	Integrated water quality index for sewage or industrial wastewater PTi = $\frac{APLPi}{SP/Pi}$ IWQI = $\frac{1}{K}\sqrt{\sum_{i=1}^{i=K} PI_i^{\ 2}}$ Where: PTi = population index for parameter K APLPi = actual population loads of parameter K SPLPi = standard pollution load of parameter K $IWQI_{S/I}$ = Integrated water quality index (S= Sewage wastewater, I= industrial wastewater) K = number of proposed water quality parameters
	Domestic effluent integrated quality index	Same as above

Appendix 2. The Relationship between Influence Factors and Managerial Practices for Performance Evaluation (Sheu et al., 2008).

Integrated water resources planning and management are considered very complex issues. These issues are usually addressed through the multi-sectoral, interdisciplinary and hierarchal decomposition approaches. In general, integrated resource management indicates the consideration of water, social, socio-economic, economic and environment issues. Fresh water is considered an important issue nowadays due to its scarcity, especially in Sudan. Water authorities usually control water discharge along rivers, canals and drains. The water service industry has aggressively pursued contracts for the management or ownership of urban water utilities around the world.

Appendix 3. Access to improved drinking water sources in rural Sudan.

Appendix 4. Access to improved drinking water sources urban Sudan.

Appendix 5. Costs, and environment.

Water supply factor (WSF) = (Actual water supply/Planned water supply) (1)

Diurnal stability factor (DSF) = (Standard deviation of diurnal flow rates from an average daily flow rate/Average daily flow rate) (2)

Water supply uniformity factor (WSUF) = (An absolute value of the difference between WSF of individual off-take and WSF of whole canal/WSF of whole canal (3)

Technical efficiency factor (TEF) = (Water supply + transit flow + out flow)/(Head water diversion + side inflow) (4)

Appendix 5.1
Alternative and complementary measures.

Information based instruments	Targeted information provision Naming, shaping and faming Registration, labelling and certification
Private and voluntary regulation	Self-regulation Voluntary regulations Governments and negotiated agreements Private regulations Professional regulations Civic regulations
Support mechanisms and capacity	Research and knowledge generation Demonstration projects and knowledge diffusion Network building and joint problem solving

Planning methodologies/processes for sustainable river basin management must include, support or promote:

- Integration of knowledge from all relevant disciplines.
- Handling of different kinds of uncertainty.
- Identification of most relevant value.
- Rational argumentation based on the identified values, relating them to alternative choices in the planning process.
- Inclusion of knowledge owned by relevant actors.
- Inclusion of the ideological orientations represented by relevant actors.
- Participation in the most critical phases of the process.
- A procedure for defining the actors that should be involved.
- Handling of power asymmetries.
- Learning.
- Procedures that ensure that ideological orientations are not suppressed (for consensus-based processes).

Appendix 5.2
Growth in annual GHG emissions amount (10^6 Mt of CO_2) by which have increased since 2007 (EPA, 2008).

Item	**10^6 Mt of CO_2**
Electrical generation (coal)	436.5
Electrical generation (natural gas)	197.3
Transportation (petroleum)	403.7
Substitution of ozone depleting substances	108.0
All others	-94.1

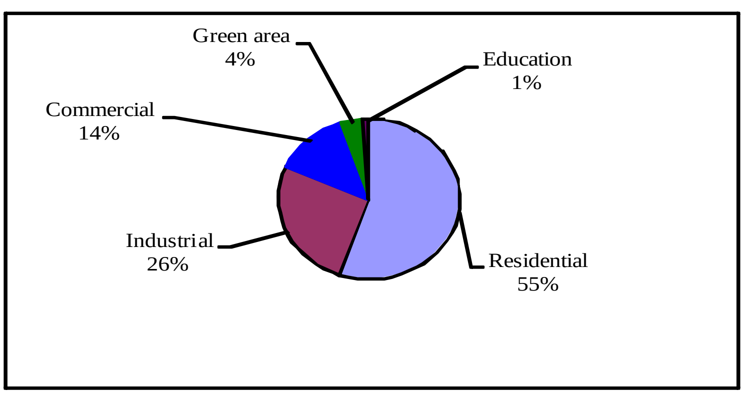
The indicator of naturally available water resources per capita has become the standard index for measuring the degree to which a country is facing water scarcity and is often used to show a growing global water crisis. An indicator of water scarcity is specific sustainability indicator useful for directing policy formation and resource allocation in the water sector within the overall context of sustainable development. In the Food and Agriculture Organisation's (FAO) report review of world water resources by country, the water resources per capita being used as the point at which a country is defined as water scare (FAO, 2003).

Appendix 5.3
Monitoring techniques for stream restoration projects (Skinner et al., 2005).

Category	Sub category	Parameters
Physical	Geomorphology	River reconnaissance Platform descriptors Instream descriptors Bed load Flow width and depth Suspended sediment concentrations Repeat cross-sections Repeat ground or aerial photography Bed material sampling Bank conditions
	Hydrology	Precipitation Stream stage or flow Velocity patterns

Appendix 5.3
(Continued).

Category	Sub category	Parameters
Ecological	Physical habitat	Large woody debris Meso-habitat composition River habitat surveys River corridor surveys
	Biological	Marginal vegetation surveys Instream vegetation surveys Macro-invertebrate surveys Fish surveys
Chemical	Water quality	Numerous compounds



Appendix 5.4. Land use division for future development plan.

Appendix 5.5. Bulk Burden Western Sudan**.**

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