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GROUNDWATER MANAGEMENT PERSPECTIVES FOR BORNO AND YOBE STATES, NIGERIA

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The Lake Chad Basin is one of the largest inland drainage basins in Africa. The Borno and Yobe States of Nigeria are located within the basin and cover an area of about 116,000 km^2. Groundwater is the predominant source of water supply and over 2,000 boreholes are found in the area. High rates of abstraction and a lack of adequate recharge have caused drastic declines in groundwater levels and operational difficulties. Proper management strategies are required. This paper examines the problems caused by over abstraction of groundwater and suggests management strategies aimed at improving the situation.

INTRODUCTION

The Lake Chad Basin extends over areas in the countries of Niger, Chad, Cameroun and Nigeria. Total areal extent within Nigeria is about 200,000 km^2, out of which Borno and Yobe States cover about 58 percent. Groundwater is the predominant source of water supply for domestic and other uses, while surface water is used mainly for irrigation purposes. Groundwater abstraction from boreholes for water supply has a long history. As many as 100 boreholes have been drilled and operated in Maiduguri town alone for water supply, and over 2,000 boreholes have been drilled and operated within the two States. Many more are still being drilled and operated by many agencies.

There is generally a high rate of abstraction without matching recharge. A general decline in rainfall for the area has led to the over exploitation of groundwater and the available groundwater resource is on the decline. Water levels in boreholes have fallen and borehole yields have drastically declined over the years. Groundwater resource management must be approached systematically.

HYDROLOGY/HYDROGEOLOGY

The area has many small rivers and streams and most of them are ephemeral, flowing for about three to four months a year. Some of them rise locally, while others have their tributaries outside the area. The climate is semiarid with a long dry season and a short rainy season lasting approximately between May and September. The temperature is generally high with a mean annual value of about 32^{o}C. Rainfall is generally low with a mean annual value of about 625 mm, while the mean annual evaporation rate is about 1600 mm (Marte, 1986).

The hydrogeology of the area is dominated by the Chad formation. Exploitable aquifers occur at depths of up to 650 m and comprise the upper, middle and lower zones which correspond to the phreatic, lower Pliocene and terminal continental aquifers described by the Lake Chad Basin Commission (LCBC) for the entire basin. Potential deep aquifers at depths greater than 700 m are unlikely ever to become economically feasible in the study area or elsewhere in the basin. For all practical purposes the development of groundwater resources is limited to the currently exploited aquifers to depths of about 650 m. The upper zone is termed the upper aquifer system because it is a heterogeneous body comprising more than one aquifer intercalated with less permeable beds. The middle and lower zones are termed separate aquifers since each is sufficiently isotropic as to be considered an individual hydrogeological unit. The geometry, lithology and hydrogeology of the aquifers are fairly well known due to the greater number of boreholes drilled in and around Maiduguri (Bumba et al., 1985).

GROUNDWATER RESOURCES OF THE AREA

The groundwater resources of the area come from the three aquifer system of the Chad formation and to a lesser extent are supplemented by the basement complex and the Fika shales.

The upper aquifer system

The upper aquifer system consists of at least three zones in and around Maiduguri. These zones, referred to as A, B, and C, are found at depths of 10-40 m, 40-70 m, and 78-99 m, respectively. They are usually screened under a multiple screening arrangement in the borehole where they are found to exist together. The yields from these boreholes range from 2 - 5 liters per second (l/sec). Recharge to this aquifer system occurs through vertical infiltration of rainfall as well as seepage along rivers and streams.

The middle aquifer system

This is the most widespread and best exploited confined aquifer in the Nigerian sector of the Chad Basin with a surface area in excess of 50,000 km^2. Its depth ranges from about 200 to 350 m. Lithologically it is the most varied aquifer, consisting mainly of sand and gravels with silt and clay intercalations. Recharge to this aquifer is reported to occur by horizontal inflow around the ridge of the rocky areas fringing the Chad basin and also by vertical percolation from a ridge popularly referred to as the Bama ridge. Yields of boreholes tapping this aquifer range between 5 and 10 l/sec.

The lower aquifer system

The lower aquifer system is found at depths of 420-650 m, with varying yields according to location ranging from about 15 l/sec to as high as 30 l/sec. Initially it was thought that the aquifer was mainly confined to the Maiduguri area but a recent geophysical survey indicates its presence beyond Maiduguri. Not much is known about the recharge to this aquifer but it is believed to be far from this area.

The rate of abstraction of groundwater in the area has been analyzed by Ndubuisi (1990). Although many new boreholes have been drilled and added to the system, the total may not have changed greatly. This is mainly due to the implementation of a surface water supply scheme for Maiduguri in 1992, and the closing down of many of the operational boreholes.

The boreholes are designed with diameters of 150 mm or more with pump chambers up to 130 m deep in the case where a tapered design is used. The piezometric levels are below 50 m deep in some of the boreholes tapping the middle and lower aquifers for which the average setting depth of the pumps are between 80 and 90 m.

WATER ABSTRACTION RATE AND CONSEQUENCES

With more than 2,000 boreholes tapping the various aquifers in the area, further water level decline is expected. Groundwater resources have been and are still the main source of potable water supply for domestic, livestock and industrial use in this area. The largest demand is for domestic and livestock consumption which amount to over 80 percent of the groundwater use. There is general over exploitation of the aquifers as indicated by the falling water levels and the reduction in borehole yields.

Economic implications

Generally, the decline in groundwater level caused by over exploitation has produced high pumping heads necessary to abstract water from these aquifers. This has steadily and increasingly made pumping more expensive in the area.

Environmental implications

The environmental implications of over abstraction are many. Some shallow wells and boreholes have dried up and have been abandoned and put out of the system. There is a need to take precautions in order to safeguard the effects on the whole aquifer and Maiduguri has already been designated as one of the subsidence prone areas of the country.

CURRENT GROUNDWATER MANAGEMENT PRACTICE

Realizing the dangers posed by over exploitation and the imposed operational difficulties, some form of informal management practice has evolved. It consists of isolated uncoordinated efforts by individuals trying to understand the system through research on a personal level, mainly for academic purposes. No well documented policies on water resources management are in place. However, the efforts have somehow become a way of managing the groundwater resources of the area. Borehole siting criteria, pumping tests of completed boreholes, selection of appropriate pumping equipment for boreholes etc., though not properly documented, are being used systematically by the staff of the Borno and Yobe State Water Boards, the organizations responsible for the development, operation and maintenance of water supplies.

Due to the frequent loss of submersible pumps in boreholes, especially during the 1980s, and the associated difficulty of fishing the pumps due to the small size of the boreholes, the diameters of the boreholes have been standardized to 150 mm. With this design concept, it is easy to fish out pumps when they fall into the boreholes. Again on the advice of experts in the late 1970s, a surface water supply scheme for the town of Maiduguri has been implemented. Similarly, other surface water supply schemes have been recommended for some of the major towns in the area. Researchers in this part of the world and elsewhere have made valuable contributions. However, in spite of these many contributions, the majority of findings have not been implemented, and there do not seem to be concrete plans for implementing them in the future. Worst of all, even those involved in the actual exploitation of water resources of the area do not seem to be fully aware of the issues involved. In short, water resources management is neither scientific nor systematic.

FUTURE GROUNDWATER MANAGEMENT PERSPECTIVE

Groundwater resources have played and will continue to play an important role in meeting the water requirements, especially for domestic and livestock consumption in this area. The scientific management of groundwater resources of the area is absolutely essential for sustainable groundwater development and economic advancement. The following measures are suggested as a basis for a proper groundwater management strategy.

(a) Definition of a framework for water resources management

Water resources management involves a sequence of activities and decisions including needs assessment, problem analysis, resource allocation, planning and design, implementation, operation and maintenance, all of which are interrelated in a complex way. These activities are also based on other subactivities, which provide the basic information for decision making. Each decision is based on information on available alternatives, and their anticipated outcomes and effectiveness. For proper management, well coordinated water resources studies need to be undertaken. It is necessary to quantify all aspects of demand and relate it to available resources. Where the demand exceeds available resources, steps should be taken to either cut the demand to match the available resources or increase the supply. This will maintain a favorable balance between water demand and water supply while satisfying the various constraints of quality, technology, availability, sustainability and environmental and economic factors. Rigorous quantitative hydrogeological studies, geophysical investigations, assessment of aquifer parameters, evaluation of well and aquifer hydraulics to determine safe yields, optimum borehole spacings, water quality testing and economic analysis to determine optimum yields are important prerequisites for scientific management of groundwater resources. Extensive need exists for adequate and reliable data for water resources planning and management. In order to obtain such data, deliberate policies need to be put in place by the concerned authorities to provide the necessary financial backing and a conducive atmosphere to enable water experts and operators to become responsive and responsible to these tasks. The studies and activities that need to be carried out should consist of, but are not limited to the following.

- groundwater monitoring and establishment of a groundwater data base

These activities mainly consist of collecting data on boreholes (an inventory), abstraction rates (quantity), water quality, water demand, water level monitoring, etc. One simple method of doing this is through the establishment of a groundwater monitoring network from which data on the occurrence, movement, quantity and quality of the groundwater could be obtained and analyzed (Olugboye, 1995). Efforts have already started and substantial data have been collected. However, the data collection efforts need to be appraised and improved in order to make it a formal process of collection and analysis. Regular and periodic reassessment of groundwater resources should be made.

- understanding the aquifer characteristics of the groundwater system

Another related issue is understanding the aquifer characteristics of the groundwater system. Although the aquifer characteristics have been fairly well known, their practical application to estimate recharge has not been defined. It is necessary to understand the aquifer behavior and interactions with infiltrating and deeply percolating water. There is also a need to investigate further and establish areas of possible recharge to the aquifers and recharge capacity.

- creation of a forum for dissemination of research findings on groundwater

The history of water resources planning and development in this area in general has been characterized by ad hoc solutions. It is unfortunate that since the first free flowing (artesian) boreholes were sunk during the colonial era in the late 1950s, no concrete plans for the management of the Chad Basin aquifers has emerged. Many have failed to understand the importance of proper groundwater resources management. It is the responsibility of water resources professionals to emphasize to public policy makers the importance of groundwater resources management. As a first step, the water industry operators themselves need to be properly educated on these issues . The improved management of the State water agencies should be precisely targeted so that staff can appreciate their position in relation to the need for the combined development and conservation of water resources.

(b) Water conservation measures

Groundwater conservation is of paramount importance. Non structural measures of water resources conservation are a real alternative in water resources management and should be considered and evaluated along side the structural measures. The following water wastage reduction measures can be considered.

- leakage detection and repairs

The repairs of visible leakages on water mains, at well heads, consumer connections, taps, etc. and detection and repair of invisible leaks will greatly enhance the water availability. Water, which would otherwise get wasted, is now conserved. Water loss through leakages of the distribution network can reach as much as 50 percent of the water produced. Therefore an adequate leak detection program should be established by state water agencies while prompt attention should be given to the repairs of any reported or discovered leakages. Already, under the National Water Rehabilitation Project (NWRP), being financed under a World Bank loan covering the entire country, such a system is being put in place. This should therefore be adopted and strengthened over the years.

- rationing of water supplies

Water rationing is another way of augmenting the water supply for a given area. Water rationing involves the imposition of water cut off to some selected areas on a rotational basis (the process is referred to as shifting). This practice is aimed at forcing consumers to collect and conserve water until their next turn to get the supply. The success of water rationing depends on how much publicity is given to the program and how effectively the shifting operation is carried out. It is also very important to carefully select the areas to be affected in order to avoid irreparable losses (damages) in sensitive areas such as hospitals and prisons.

- creation of water scarcity awareness

A campaign strategy needs to be initiated to create awareness among consumers regarding the scarce nature of water resources and the need for its quality protection and quantity conservation. When consumers understand and realize the value of water and become sensitive to wastage of water, they will be willing to support programs that promise to eliminate water shortages. They should also realize the necessity of the long and smooth running of equipment such as pumps, pipes, and taps, and also learn to care for them properly.

Adequate public enlightenment programs are vital for water conservation measures to be effective. These should include radio and television announcements and bumper stickers that portray the need for water conservation and the benefits of effective water usage. Water user associations can also be established.

- control of freeflow (artesian) boreholes in the area

There are many artesian boreholes in the area, which waste water continuously. This is a serious situation, which has been realized long ago. Initiatives in the 1980s were met with strong opposition mainly from villagers who rear herds of animals. The inhabitants could not be convinced of the purpose of control measures and the government had to abandon the idea. The problem is further compounded by the high temperatures of the water that come from the boreholes, in which case the water has to be allowed to cool before use. Another aspect of water quality is high iron and manganese contents, which make the water corrosive, thereby requiring corrosion resistant pipe. With the present level of awareness of the need for water conservation and the level of determination to solve the problem, the issue needs to be reconsidered.

(c) Demand management

One way of augmenting water supplies is to reduce the pressure on water demand through restriction of water use. There are a variety of ways through which this can be achieved.

- metering of consumers

Water metering of consumers can reduce water usage greatly. A metered system can save water more than an unmetered one. As much as a 50 percent reduction in water demand can be achieved by metering consumers in large cities. Only major consumers are being metered now while the metering of small consumers is not cost effective. However, with increasing awareness of the water scarcity situation and increased cost of water, the economic viability of metering small consumers can also be considered.

- improvement of water use effectiveness

Improvement of water use effectiveness can be achieved through the imposition of high prices for water for domestic use as well as other purposes. Water rates should be such as to convey the scarcity value of the resource to the users and to foster the motivation for economic use of water. Regular leak detection and repairs of faulty pipe and plumbing facilities in pipe distribution systems and at houses could become routine conservation practices if consumers are made to pay for water equitably.

(d) Source enhancement

Source enhancement comprises structural measures aimed at improving the source of water. These may consist of rehabilitation of existing facilities or the provision of entirely new facilities, or their combination.

- rain water harvesting

Rainwater harvesting comprises not only the collection and storage of rainwater in surface and subsurface reservoirs for future use but also prevention of water so stored from evaporation and seepage losses. The in situ storage includes roof water collection, collection in ponds and collection in other artificial storage structures. Rainwater is generally of good quality and has been helpful in augmenting other sources. This is usually practiced on an individual or family basis. Its practice on a large scale is yet to be found in this area mainly due to the nature of the roofs as well as the difficulty of providing an efficient collection and storage system. However, with the present situation of water scarcity and renewed efforts to look for ways of augmenting sources, the method is worth trying. Detailed studies and their application on large scale should therefore be the first step towards achieving success.

- artificial recharge

Artificial recharge of groundwater through surplus surface water resources is achieved by induced recharge, spreading, and injection methods. The suitability of a particular method depends upon the hydrogeological characteristics of the aquifer to be recharged, quality of the source water, and the level of available technology in the area.

Induced recharge is achieved by increasing the withdrawal from the aquifer. Spreading methods comprise an increase in the surface area of infiltrating water. In the injection method, water is fed directly to the depleted aquifers by a tube well or shaft or connector well. Each has its advantages, disadvantages and limitations. Great care must be taken in their application so that the issue of pollution and possible irreparable damage to the aquifer is avoided. Aquifer recharge has been practiced in many parts of the world to enhance groundwater sources. These methods can be applied in this area. A thorough understanding of the aquifer characteristics is however necessary. Earlier studies (Odigie et al., 1991) have recommended its application but no practical steps have been taken to implement it as yet.

- internal inter basin water transfer

These refer to the inter basin water transfer schemes where the source and the receiving basins are within the same country, in this case Nigeria. They are relatively of lesser scope and hence cost. Likewise political and environmental considerations are less complex and their related problems are easier to solve than the external ones. Two such transfer schemes have so far been identified which are the Hawal-Ngadda and the Dindima transfer schemes. Government reports on these are available and need to be pursued to their logical conclusions.

- external inter basin transfer

These refer to the inter basin water transfer schemes for which the source of water to be transferred does not originate or lie within the country to which the water will be transferred. Such transfer schemes are usually of higher dimensions involving long distances and possibly requiring various large structures to facilitate transfer, and they have higher costs. Furthermore, such schemes involving international boundaries have greater political dimensions and hence are more complex to deal with than the internal ones. Three external inter basin water transfer schemes have been proposed for the Lake Chad Basin area based on the following concepts: the Serbeouel-El Obeid, Italian Bonifica's Trans-Aqua concept, and the Zaire-Chad-Niger (ZCN) concept. These have been extensively treated elsewhere (Umolu, 1990).

GOOD MANAGEMENT PRACTICE

All the above issues cannot be accomplished unless good management practices evolve within the State Water Agencies. With the application of good management practices, most of these problems can be tackled effectively.

(a) Improved management of the State Water Agencies' operations

The availability of a sizeable number of qualified manpower to deal with hydrogeological, engineering and managerial aspects of water resources management is of paramount importance. The present efforts by the Borno State Water Corporation and the Yobe State Water Board are very encouraging and should be expanded and intensified. These should include attainment of higher qualifications in the various fields, short courses within and outside the State Water Agencies, seminars, and conferences and general in-house training of subordinates by their superiors. Such forums like management committee meetings, departmental and sectional meetings should also be used to broaden the staff's ideas on the various aspects of water resources management. Emerging problems such as over exploitation, land subsidence and deteriorating water quality and their implications to society should be discussed and the need for careful management of water resources be emphasized to them.

Staff should be trained to cope with their duties, while improved direction and supervision of operations/field staff and office (personnel) staff should be sought so as to increase productivity. Record keeping should be improved so that past problems and their solutions can provide valuable records of experience for dealing with current operating or managerial difficulties. The staff should be very much involved in all aspects of the responsibilities of their organization, from planning, development, implementation to operation and maintenance. There are various reports and findings on the water resources of this area which are scattered in files and books which need to be collated together and sieved to define useful and implementable recommendations. New techniques of water resources management should be acquired and adopted at all levels.

The design and operation of groundwater exploitation structures should be such that they assure sustainability. The necessity to drill boreholes using standardized procedures should not be over looked. Detailed geophysical investigations and hydrogeological studies have to be carried out before locating and drilling boreholes. The drilling activities of the area should be closely monitored. Individuals, drilling contractors as well as Governmental and non-governmental organizations should strictly adhere to guidelines on borehole siting and withdrawal permits imposed.

Routine (electrical and mechanical) maintenance, service to clean up clogged screens of boreholes to remove accumulated silt and fine sand in good time and other general preventive maintenance should be designed and followed strictly. Long-term water supply planning to meet the normal level of projected demands should be kept in view always. Cost effective and multi-disciplinary approaches for sustained water supply also need to be developed, while the performance of existing and future water supply schemes should be enhanced.

(b) Conjunctive surface/groundwater use and management

Using groundwater in conjunction with surface water is a very important aspect of water resources management. Such conjunctive use is especially important in arid and semiarid regions. When water resources are a limiting factor in the development of a region, then their optimum utilization is a main concern to society. The aim of the groundwater-surface water conjunctive use scheme is to use water from both surface and ground sources in a combined (conjunctive) manner, i.e. taking advantage of the complementarities in hydrologic, hydrogeologic, environmental and socioeconomic features of utilizing from each source to achieve the given objective. In general, where surface water and groundwater are managed as part of a conjunctive scheme, a decrease in the rate of draft in the groundwater is possible. Furthermore, a lower overall cost of supplies can be obtained through a conjunctive use scheme. Greater flexibility and better control in supply and use of water to meet demands, and a more meticulous and assured way of providing water will be achieved, which will greatly help the management of the State water agencies concerned. Planned groundwater utilization will also improve hydrogeological conditions of the aquifer systems. Thus, conjunctive use of the two sources for water supply is not only highly imperative and prospective, but also eminently suitable in scheduling usage.

At present, a conjunctive groundwater-surface water scheme has only been envisaged for Maiduguri, the Borno State capital, and Damaturu, the Yobe State capital. Although no studies have been carried out to obtain an optimum water usage from the two sources, Maiduguri is presently being served by both surface water from the reservoir of the Alau Dam and groundwater. In order to have a proper basis for management of the conjunctive use scheme, there is the need to develop a management (water allocation) model which can be used as a tool in determining the optimal schedule of abstraction from the two sources to meet demand at all times. Due to the fact that water demand can change on a frequent basis, while the rainfall pattern is also erratic, such a model must be simple and be capable of being easily updated. In the case of Damaturu, the Yobe state capital, only the groundwater resource has been developed to some extent, and a surface water supply is only being anticipated and is at its preliminary planning stage.

(c) Formation of water resources development coordination committee

A water resources development coordination committee needs to be established. It will harmonize the various water activities of the numerous agencies involved in water resources development and utilization in the two States. The committee should consist of professionals within the state water agencies, the polytechnics, universities and representatives of the government office responsible for the state water agencies. The committee can be charged with the responsibility for planning, monitoring and coordinating the activities of all agencies involved in the development andutilization of water resources. Periodic reports on the activities of the group are also to be submitted to the government on a regular basis under such an arrangement.

CONCLUSION

Groundwater development and utilization have reached alarming rates in Borno and Yobe States. Over exploitation and the economic, social and environmental consequences have been discussed. Methods of water resources management have been suggested for future scientific and technical management of this scarce resource. Recommendations for taking practical steps to implement these suggestions have been put forward.

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