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THE ROLE OF WATER RESOURCE DEVELOPMENT IN INDUSTRIAL DEVELOPMENT: A PERSPECTIVE FOR AFRICA

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SYNOPSIS

The role of Water Resources in Industrial Development and the relationship of water to overall regional development is outlined, including the description of the direct and indirect benefits to Industrial Development of water use in other economic sectors. The concept of the River Basin as the basis for Integrated Regional Development is presented. The present and future role of Water Resources for Industrial Development in Africa is described. The international nature of Africa's Water Resources is illustrated and the potential of International River Basin Commissions or Authorities as a catalyst for Industrial Development through Integrated Regional Development for the efficient use and allocation of the regions water and other natural resources is proposed.

RESUMÉ

Le rôle de développement des ressources hydrauliques dans le développement industriel: Une perspective pour l'Afrique

L'article met en évidence le rôle des ressources hydrauliques dans le développement industriel et la rapport entre l'eau et le développement régional total. Il décrit les avantages directs et indirects que le développement industriel peut tirer de l'usage de l'eau dans d'autres secteurs industriels. Il presente le concept de Basin Fluvial comme base d'un développement régional intégré. Il decrit également le rôle présent et futur des ressources hydrauliques dans la développement industriel de l'Afrique. Il montre la nature internationale des ressources hydrauliques africaines et propose la possibilité de commissions ou autorites internationales des basins fluveaux comme point de départ du développement industriel à travers le développement regional intégré pour l'utilization et l'allocation efficace des eaux régionales et des autres ressources naturelles.

RESUMEN

El papel de desarrollo de recursos hidráulicos en el desarrollo industrial: Una perspectiva para Africa

El papel de recursos hidráulicos en el desarrollo industrial y la afinidad del agua con el desarrollo regional total se disticca. Se destaca el papel dé recursos hydráulicos en el desarrollo industrial y la relación del agua con respecto al desarrollo regional. Se describen los beneficios directos é indirectos para el desarrollo industrial con referencia al uso del agua en otros sectores económicos. Se presenta el concepto de Cuenca de Rio como basis para el Desarrollo Regional Integrado. El papel del presente y futuro del los aprovechamientos hidráulicos para el desarrollo industrial en Africa es descrito. La naturaleza internacional de los recursos hidráulicos del Africa son ilustrados y la potensial de los Comisión international de Cuenca de Rios o autrodades como catalises para desarrollo Industrial atravez de Desarrollo regional integrado para el uso eficiente y alocación de regiones de aguas y otros recursos naturales se propose.

INTRODUCTION

Water can become a constraint to industrial development when any of the following four conditions exist alone or in combination (Howe, 1978):

(1) water inputs into important production processes are fixed in relation to output;

(2) water supplies are fixed or only capable of slow and/or costly expansion;

(3) supplies are rigidly allocated among uses over time;

(4) water is a controlling factor in human health and productivity.

This paper will outline the relationship between water and industrial development. The Management of Water Resources to allow for the efficient allocation among all uses in balance with increased industrial development will be presented. The relationship and allocation of water from the perspective of African Industrial Development will be discussed. The role of Integrated International River Basin Development will be discussed and examples from Africa will be presented.

THE ROLE OF WATER IN INDUSTRIAL DEVELOPMENT

The need for water for industrial development is not limited to use of water in the production process. Water has a wide variety of activities in any economy and the interaction between the uses and industrial development occur directly and indirectly. Table 1 outlines these interactions. It is necessary, therefore, when planning water resource development for industrial development to look at an integrated development of all water resources activities. In the following sections the water use of each activity is described to give the reader a better understanding of the interaction outlined in Table 1.

Table 1. Interaction among Water Use Activities.

	Industrial	Waste Disposal	Hydropower	Agriculture	Navigation	Water Quality	Flood Control
Direct Benefit	x	x	x			x	x
Indirect Benefit		x	x	x	x	x	x

INDUSTRIAL WATER DEMAND

Water is but one factor input to industrial production. As such, there is no fixed water demand for each industry but rather a range of values due to the substitution effects of different technologies. Even with alternative technologies, some industries such as petro-chemical, pulp and paper, and steam electric power generator demand large quantities of water in their production processes.

The demand of use of water in industry is a complex process which requires clarification. There are four parameters: water intake, consumptive use, effluent quantity and effluent quality, and two processes: production process and waste treatment that characterize the technical aspects of industrial water demand. This is schematically illustrated in Figure 1.

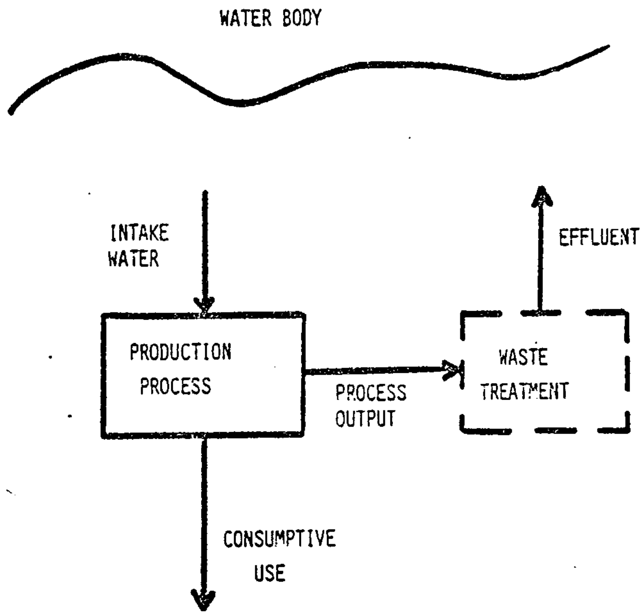

Figure 1. Schematic of Industrial Water Use.

The intake water is the amount of water that is withdrawn from the waterbody that is needed for the production process to operate. A list of intake water demand for various industries and technologies appropriate for development in Africa are found in Table 2. In certain industries, the quality of water intake is important.

Table 2. Industrial water demand (range of demand for appropriate African technologies)*.

Product	Unit of Production	Water Required per Unit (liters)
Food Products		
Canned Vegetables and Fruits	Ton	10 000 to 50 000
Meat Packing	Ton	8 000 to 30 000
Fish, Canning	Ton	16 000 to 20 000
Poultry	Ton	6 000 to 43 000
Milk	1 000 liters	2 000 to 5 000
Sugar	Ton of sugarbeets	2 000 to 20 000
Beer	1 000 liters	6 000 to 30 000
Pulp	Ton	50 000 to 150 000
Paper	Ton	200 000 to 1 000 000
Petroleum Refining	Ton of crude petroleum	10 000 to 30 000
Fertilizers	Ton (saltpetre)	270 000
Chemicals	Ton	10 000 to 500 000
Textiles		
Scouring, Wool	Ton	200 000 to 250 000
Dyeing and Finishing	Ton	60 000 to 200 000
Milling	Ton	50 000 to 350 000
Mining	Ton	1 000 to 12 000
Iron and Steel	Ton	10 000 to 50 000
Electric Power	Kilowatt-Hour	200
Automobiles	Ton	38 000

*Adapted from the Department of Economic and Social Affairs, United Nations, 1969.

A certain portion of intake water is consumed during the production process; this is called consumptive use. Consumptive use may be the direct use in the output of the industrial product (e.g., beverage industry) or evaporated in a cooling process (e.g., petro-chemical industry). Table 3 lists typical consumptive use percentage for various industries.

Table 3. Percentage of water intake consumed by selected industries in the United States.

Industry	% Consumption of Intake Water
Automobile	6.2
Beet Sugar	10.5
Chemicals	5.9
Coal Preparation	18.2
Corn & Wheat Milling	20.6
Distillery	10.4
Food Processing	33.6
Machinery	21.4
Meat	3.2
Petroleum	7.2
Poultry Processing	5.3
Pulp & Paper	4.3
Salt	27.6
Soap & Detergents	8.5
Steel	7.3
Sugar Cane	15.9
Textiles	6.7

Source: National Association of Manufacturers, 1959.

The remaining intake water of the consumptive use plus any liquidified by-products from other inputs to the production process are combined into process waste. Of course, process waste is not treated so that it becomes directly industrial effluent and is discharged to a receiving waterbody. When process waste is very high in pollution, it is often passed through a waste treatment process before being discharged to the receiving waterbody. The effluent then is the output of the waste treatment process and can vary in quantity and quality (content of pollution) depending upon the technology of treatment. Table 4 is a list of the range of biological and chemical effluents from various industries to demonstrate their relative pollution potential.

Table 4. Bio-chemical pollution content of various industry effluents.

Source of Waste	5-Day, 20°C BOD Mg/liter
Beet Sugar Refining	450 - 2 000
Brewery	500 - 1 200
Cannery	300 - 4 000
Meat Packing	600 - 2 000
Milk Processing	300 - 2 000
Pulp and Paper	16 000 - 25 000
Tannery	500 - 5 000
Textiles	
Cotton Processing	50 - 1 750
Wool Scouring	200 - 10 000

Source: McGauhey, Engineering Management of Water Quality, McGraw-Hill, 1968.

As demonstrated above, when discussing industrial water use, one must look at the entire system and not focus on any one single parameter as a measure of industrial water demand. When locating more than one industry on a waterbody, it requires a careful planning of the effect of one industry effluent on the intake water of another industry. This requires in many cases the planning of industrial water use on a regional basis rather than on industry-by-industry basis, to allow for industry-environment and industry-interaction to be analyzed and their harmful effects minimized to make full utilization of the water resources of a region for industrial development.

An example of the need to view the entire industrial water system is the Steam Electric Industry (Fossil Fuel or Nuclear). For a 500 megawatt power station, the water intake requirement for once-through cooling is 227,000 liters per second, but the consumptive use is only 2770 liters per second, one percent of water intake. The effluent that is discharged has no biological or chemical pollution since it was used only for cooling but the effluent is approximately 10^{o}C hotter than the intake water passing through the cooling process. This large amount of heated water is discharged to a waterbody causing thermal pollution. Thermal pollution can have both negative and positive effects to a water ecology and likewise may enhance or decrease the possible use for other industries. If the thermal pollution was found to be detrimental or the large volume of intake water needed was not available, it is possible to install cooling towers or a cooling pond which recycles the water in the cooling process. This water intake is reduced to approximately 2% of once-through cooling and the effluent is reduced to about 1% of once-through cooling, but is at a higher temperature. This demonstrates the effect of alternative technologies; however, the addition of cooling towers or ponds add about 10% to the capital cost of the plant and require higher operating costs.

This example has shown that one needs to view the <u>entire</u> system of industrial water use as opposed to focusing on any one parameter of water use which would have given a distorted view, possibly leading to a situation constraining rather than enhancing further industrial development.

Water Disposal

Water bodies have a natural ability to assimilate waste material from industrial processes through a self-purification procedure. However, each waterbody has a limit to the amount of waste that it can accept before the self-purification mechanism becomes overloaded. In this event, the quality of the waterbody begins to degrade and loses the ability to perform other functions as listed in Table 1, thus limiting the amount of industrial development. In some cases, the amount of industrial use of the water for disposal can increase, if the industrial effluents are first treated by a waste treatment process thus reducing the quantity or concentration of pollutant in the effluent, and allowing for more effluents in total.

If the water quality due to waste disposal degrades and loses the ability to perform certain functions, it can have a direct effect upon industrial development as will be outlined below.

Hydropower

Water use for hydropower can be viewed as a direct industrial use as part of the electric power industry, or as an indirect use as part of an essential infrastructure necessary for industrial development. In either case, water for hydropower use has some special characteristics.

Hydropower does not consume water directly in the generation of electricity. However, if an artificial reservoir is created to store water for power generation there can be an increase in evaporation due to the large surface area of the reservoir. This is particularly a problem in arid regions. For example in Egypt, 10% of the average yearly flow of the Nile River past Aswan evaporates from the Lake Nasser Reservoir behind the High Aswan Dam. Most hydropower is used as "peaking power" on a daily basis since fossil plants are expensive to start and stop, and cannot respond as efficiently as hydropower to changes in demand. However, on a seasonal or annual basis, it is beneficial to the electrical power system output when the releases of water are as uniform as possible over the year. This unified release will provide firm daily "peaking capacity power" to the electric power system. This firm peaking capacity will reduce the need for fossil plant capacity to make up the daily load when the reservoir releases are low. However, for multipurpose reservoirs, uniform releases are not consistent with other uses such as agriculture and flood control, and conflict results and release rules must be developed that weight the benefits of each purpose to the regional development. An example for the High Aswan Dam is given in ALARCON and MARKS, (1980).

Agricultural Water Use

Agricultural water use is an indirect benefit to industrial development. In many strategies for African Industrial Development, agro-industry is stressed for areas where irrigated agriculture is needed. Water is an important input then, to provide sufficient agricultural production as an input to industry. Secondly, if the output of irrigated agriculture is exported, the foreign exchange generated will be important to allow for the importation of capital goods necessary for industrial development. The increased income generated by increased agricultural production will also provide a greater market for industrial products.

Navigation

The use of water for navigation is an indirect benefit for industrial development. Navigation is part of the transportation infrastructure so important to development. It can be substituted by rail or truck but it allows for cheap transport of bulk commodities. This is important to keep costs down on industrial inputs.

Municipal Water Use

Municipal water supply is part of the infrastructure necessary to foster industrial development. The direct benefit of a good municipal supply system is that for small industries, the municipal supply system is the source of water intake for industrial production. As industries get larger, they tend to develop their own water supplies due to lower costs. Thus, a good municipal water system with low water rates can attract industrial development.

Secondly, industrial development requires a viable labor force. A good municipal supply which is related to better public health will attract good workers and increase their efficiency through better health leading to increased industrial production.

Water Quality

Water is sometimes used as a measure of increasing the self-purification potential of waterbodies. By increasing flow, it allows for the water quality to be improved. A high water quality level is important for uses such as municipal supply, fishery, and recreation, which are indirect benefits to industrial development.

Flood Control

The damage caused to life and property each year as a result of floods is enormous. With many of the best locations for industrial development in river valleys near to the source of water and main transport routes, it becomes important to protect these large investments from floods. At the same time, labor's reaction of living in a high risk flood zone may make it hard for industry to attract good and adequate labor.

How these activities relate to the industrial development of Africa will be presented in the next section.

The Link Between Industrial Development and Water in Africa

In a report on Long-Term Development Strategies for the Sahel-Sudan Area of West Africa (SEIFERT and KAMVANY, 1974), the following statements were made about the link between water and industrial development in West African nations:

CHAD - "The possibility of constructing a hydroelectric power plant...in southwest Chad...is listed in the development plan as essential to industrialization".

MALI - "There is also a plan to establish an iron and steel works, but depends on a firm agreement with neighboring countries and the building of the barrage (dam) at Gorena."

MAURITANIA - "Manufacturing industry is limited because of the small domestic market, lack of transport, scarcity of raw material, deficient supply of water and electric power..."
"Insufficient water is one of the serious problems facing the towns and villages in Mauritania."

NIGER - "Scarcity of water resources is the greatest impediment to economic development."

SENEGAL - "River traffic on the Senegal River into Mali [is limited] from July to September." [Due to low flows.]

UPPER VOLTA - "Industrial activity in Upper Volta has also been affected by the limitations of natural resources and skilled labor."

The above statements show how lack of adequate water resources can limit industrial development. Following, a few African examples of how water resources development directly contributes to industrial development will be given.

(1) Egypt: The completion of the High Aswan Dam and Hydropower station provided conditions for increased industrial development in Egypt. With a cheap source of electricity, Fertilizer and Aluminium Industries, both heavy electrical users, were established near Aswan; Irrigated Cotton production was able to continue (despite growing demand for foodstuffs) to supply raw materials for the textile industry; navigation was available year round from the Mediterranean to Aswan; and a fishery industry has developed in the Lake Nasser Reservoir.

(2) Ghana: The Volta Dam Project in 1969 provided enough hydroelectric power to allow the construction of a huge aluminium factory and aluminium smelter in Ghana as well as export power to Togo and Begin to aid in their infrastructure development (KAMARCK, 1971).

(3) Zambia/Zimbabwe: The Kariba Dam and power plant on the Zambezi River (first stage 1960) allowed expansion of copper mining and refining in Zambia; growth of manufacturing in Zimbabwe and the construction of an electrolyte ferrochrome plant, possible only with cheap power from Kariba (KAMARCK, 1971). Cheap hydropower alone is not sufficient for industrial development. The Owen Falls Hydroelectric Project is an example.

(4) Uganda: When the Owen Falls Project was completed in 1954, it was not until 1957 that a copper smelter was established. The small industries which com-

prised most of Uganda's growth were not power-oriented and widely dispersed. Thus, it was necessary to make a 50 year agreement with Kenya to export electricity to make the project financially stable (HOWE, 1978).

As these last examples have shown, energy is an important input to industrial growth. With the current high cost of oil and the lack of coal in Africa, the full utilization of African Hydroelectric Potential is necessary. The greatest hydroelectric potential in Africa is in Zaire (500 billion Kilowatt hours annually - KwhA); Angola (200 billion KwhA); Malagasy Republic (100 billion KwhA); and Cameroon (100 billion KwhA). Congo, Central African Republic, Gabon, and Liberia also have significant potential (KAMARCK, 1972). Figure 2 shows the location of major hydropower sites in Africa.

Large scale irrigation schemes can prove quite successful in arid and semi-arid regions in Africa. Egyptian agriculture and the Gezira scheme in Sudan have proven successful. Other schemes successful to varying degrees are the Office du Niger scheme in Mali; the Richard Todd scheme in Senegal (KAMARCK, 1975); the Accra Plans Project in Ghana; the Kafue Flats in Zambia; and the Cunene River scheme in Namibia (BALEK, 1977; KAMARCK, 1979).

Village Water Supply (SAUNDERS and WARFORD, 1976) and Drawers of Water (White et al, 1977) are both good references for the role of municipal water supply to public health and productivity in Africa.

The important aspect about water quality management in Africa is the false notion that environmental protection is only a luxury affordable by the Developed Nations. The costs of environmental degradation are enormous and may not reveal themselves till many years later, when it is too late to address the problem. This is quite true of groundwater contamination, and groundwater is the main source of water in many parts of Africa.

An important feature of maintaining environmental quality at the initial stage of industrial development is that it is vastly cheaper to provide environmental protection in the construction stage than to retrofit waste treatment after production is underway. Africa is in a unique position to be able to learn from the mistakes of the developed nations and benefit from the new environmental protection technologies that have been recently developed. The question is not whether Africans can afford to protect the environment, but whether they can afford not to.

The water resources uses that have been outlined above do not exist independent of each other, but are rather linked in complex physical, economic, and political networks. Thus, when analyzing industrial water use, one must analyze all the links in an integrated fashion. The next section will provide a mechanism for that type of analysis.

THE ROLE OF INTERNATIONAL BASIN PLANNING IN AFRICAN INDUSTRIAL DEVELOPMENT

The demand for industrial water use cannot be analyzed separately from the other activities of water use due to the interaction that takes place within the waterbody, economy, and across political borders. Therefore, industrial water demand must be analyzed systematically within a regional framework. Since water is the key to the analysis, the most appropriate regional framework is the River Basin of Lake Basin. (The River Basin will be discussed in detail, but the discussion is equally applicable to lake systems.) The River basin includes the area into which water falls and through which water drains generally flowing to a common terminal point. Thus, the implications of development can be traced throughout the basin, indicating sources of conflict and collective opportunity (STONE, 1977). Many political institutions share jurisdiction over river basins, na-

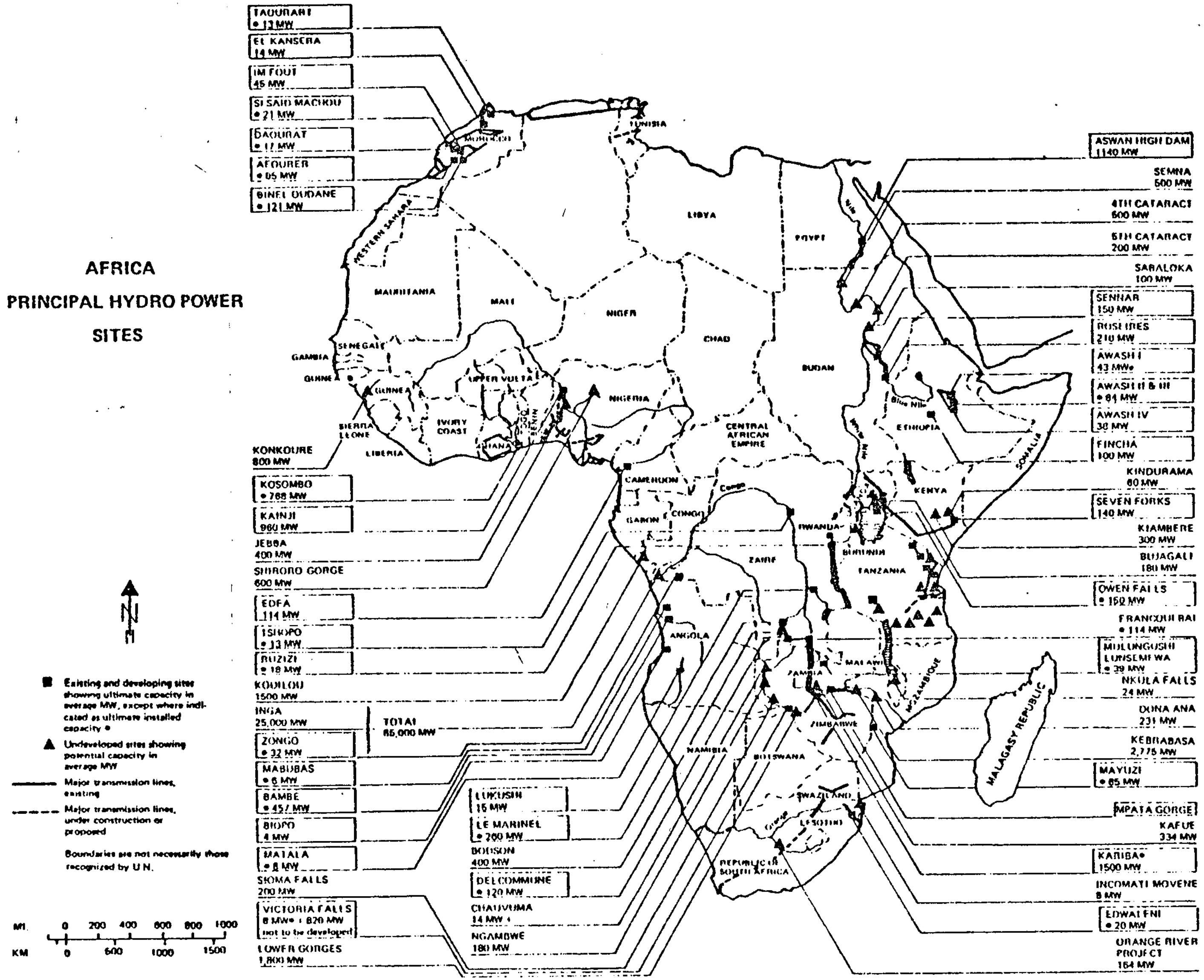

Figure 2. Hydropower Potential in Africa. (From KAMARCK, 1971).

tions, provinces, municipalities.

A river basin that lies within the territories of two or more nations is called an international river basin. Although each country has control over the resources flowing within its territory, (subject to general rules of international law), a nation cannot exercise such control until the water reaches its territory; and control is relinquished once these waters leave its territory (STONE, 1977).

Conflict over the control of international water is a major issue in international affairs. "Few issues between nations and people generate greater controversy and, on occasion, even hostility, than those involving competing interests in the use of water of international rivers." (Garretson et al, 1967).

Africa contains 64 first-order (linked directly to the sea or to inland lakes) international drainage basins (SAND, 1973). With this in mind, water for African Industrial development is an international river basin planning problem.

The need exists for an international agency such as the UN or its branch agencies, to aid in the efficient utilization of international water resources. A few examples of UN participation in this area are found in STRZEPEK and LENTON, (1978), and STONE, (1977), who discuss a UNDP project for the allocation of the waters of the Vardar/Axios rivers between Yugoslavia and Greece, and BALEK, (1977), who presents the WMO study of the hydrometeorology of the ten-nation Nile basin. The question arises as to how to analyze the water reservoirs in this complex setting.

Analysis of International River Basins

The International River Basin is such a complex physical, economical, and political system, that many times, standard engineering analysis is not sufficient to analyze the system interactions. This problem requires a modern system analysis approach that can address the interactions between economic, political, and hydrologic systems (MISER, 1980).

STRZEPEK and LENTON (1978), and STONE (1977), present state-of-the-art water resource system analysis techniques for the analysis of an international river basin. These methods address the problems of variation in streamflow, economic costs and benefits and constraints imposed by international agreements. Not all techniques are directly transferable from one basin to another and thus methods must be chosen or developed that are appropriate for the major problems confronting a river basin.

Need for International Cooperation

In the development of Water Resources for African Industrial Development, an agency such as UNIDO, or the Economic Community for Africa (ECA), should play a major role in developing and cataloging a method for the planning of International Multipurpose River Basin Systems. It is also essential that an agency coordinating African Industrial Development cooperate with the UN agencies that deal with the other water resource activities, such as the FAO, the UNEP, the UNDP, the WMO, and the WHO, to develop the proper institutional framework in which to perform effective river basin planning. There exists a great need to develop international commissions for the planning of international rivers, such as the Permanent Joint Technical Committee for the Nile (Sudan-Egypt); the four-nation Inter-State Committee for the Senegal River; the Niger River Basin Development Committee; and the Lake Chad Basin Commission, for example. Each river basin has specific hydrologic, economic, and political problems which are best addressed by the nations involved, using their expertise on local hydrology, institutions, and economics. It is important to develop extensive cooperation and information transfer among member nations. This communication will help legitimize any recommendations that result from such a commission as truly the best for the development of the basin as a whole. In this way, all nations will benefit from the optimal utilization of a natural resource, such as water.

The planning of any river basin is a major undertaking requiring a large well-trained inter-disciplinary team. The efforts required in collecting data, developing methods of analysis and formulating development scenarios to be analyzed are great. With such a task, it is important that as much as possible be done to foster the transfer of information and technologies about river basin planning between the various river basin commissions. This exchange of information will allow planners to learn from successes and failures, and to avoid the unnecessary duplication by other commissions of existing tools, especially when the size of the task is great and there are very few skilled personnel. It is also advisable to use international experts whenever needed, to help train and advise river basin commissions on the new and powerful tool for river basin planning. These international experts can also play an important role as an impartial observer to avoid any single national domination in the planning process.

Albert LEPAWSKY (1963) stresses the need of international experts in international river basin planning: "What cannot be accomplished solely by national statesmen in the realm of (international) river basin development may yet be wrought by international administrators..., and by a new breed of professional and technical experts concerned with the planning and development of international river resources."

CONCLUSION

This paper has attempted to show the important link between Industrial Development and Water Resources Development. It is not meant to imply that water alone is responsible for development, but rather that together with the proper economic, political, and social conditions, it is an essential ingredient to the process. It has shown the importance of water in African Industrial Development and the need to analyze water resources development for industrial use in a systematic regional framework.

It was illustrated that for Africa, the International River Basin was the most important regional framework for which water resources planning should take place. The need to develop international commissions for systematic river basin planning was stressed.

The role of water resources in the economic development of Africa has a multi-objective, multi-purpose character. The interaction between the various activities of water resources can best be analyzed at the river basin level. It is at this level that the best opportunity exists for the efficient allocation of water resources between the different sections of the economy to foster balance of economic growth.

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