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Water Scarcity and Urban Africa: An Overview of Urban–Rural Water Linkages

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Summary. — A first review of urban Africa's dependence on larger landscapes for water is presented. Tables document: changing water sources between 1970s and 1990s; industrial and domestic wastewater treatment and disposal; electricity generation's dependence on water. Nearby groundwater and rivers were used in the 1970s; increasingly distant sources supplied the 1990s. Domestic and industrial wastes pollute groundwater and rivers. Africa's electricity depends upon large amounts of water, as dammed rivers or for power plant operation. Preserving urban Africa's scarce water supplies requires recognition of urban–rural water cycle linkages and holistic, coordinated, and equitable regional policies and practices that support ecosystem function. © 2002 Published by Elsevier Science Ltd.

Key words — Africa, urban, water, pollution, electricity, planning

1. INTRODUCTION

Much of urban Africa confronts—or will be confronted by—inadequate water supplies. In 1989 a continent-wide water crisis was predicted for the year 2025, when 22 countries with two-thirds of the continent's population would be water stressed (Falkenmark, 1989). A decade of literature with data aggregated at the global or national level has shown that water is less available on the African continent than in Europe, Asia, North America or Latin America; that population increases will reduce per capita water availability; and that conflict or cooperation could result as different water users—national and international—compete for a finite entity (e.g., Gleick, 1993, 2000; Johnson, Revenga, & Echeverria, 2001; Meigh, McKenzie, & Sene, 1999; Oudshoorn, 1997; Postel, 1992, 2000; Toset, Gleditsch, & Hegre, 2000; UN, 1997; World Bank, 1996).

Yet there is a paucity of literature about the implications of these conditions for African urban areas, which are experiencing the world's fastest rates of urbanization (UN, 1998). Much of the debate has centered on the theory and practices of water pricing, distribution and sanitation infrastructure (e.g., Baumann *et al.*, 1998; Boland *et al.*, 1997; Dinar, 2000; Mariño & Boland, 1999). Until very recently, outside of the environmental community little attention had been paid to where increased amounts of fresh water would come from, how and where it would be disposed of, or the implications of both for associated rural landscapes and for urban planning and policy. This neglected area of consideration is crucial, since fundamental ecosystem dynamics exist—whether acknowledged or not—that will ultimately determine the choices that can be made.

This paper seeks to shift the emphasis away from general discussions of water shortage, water pricing, and infrastructure. Instead, it will examine the ways in which African urban areas are linked by water to larger landscapes, and suggest some consequences of these

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linkages. As Baer and Pringle (2000) have noted, patterns of urban growth and their effects on aquatic systems vary from region to region and from city to city. Focused discussion, therefore, requires information about particular places. To this end three bioregional questions were posed for African urban areas: What is the source of municipal water supplies? How is domestically and industrially used water treated, and where is it disposed? To what extent does the electricity supply depend upon water?

Because so little information has been collected with which to answer these questions, tables presented in this paper will constitute a first overview of the direct and increasing water relations between African urban areas and ecosystems near and far. The term "urban area" is understood to describe a country's major population centers. Since African settlement patterns and populations vary greatly, an urban area can refer to anything from a "megacity" to a district capital or population center that has grown up around a mine. The author will argue that the dependence of urban water supply on the healthy function of local, and increasingly distant, water cycles is fundamental. If for no other reason than self-interest, urban water users have a responsibility to protect the ecosystems from which their water is extracted and to ensure that water returned to the environment does not become a source of contamination that will ultimately reduce water availability.

2. EVIDENCE OF AFRICAN URBAN WATER RELATIONSHIPS

(a) *Methodology*

The paucity of information about water before or after it enters urban infrastructure is reflected in the fact that no compilations of the data sought were found, and experts queried could think of none (UN Statistics Office, personal communication; Water and Environmental Health at London and Loughborough/WELL, personal communication). A survey questionnaire was sent to relevant government ministries in Anglophone and Francophone African countries, but replies were minimal. The last comprehensive continental survey of groundwater in Africa was carried out by the United Nations' Department of Economic and Social Affairs in 1973. Hydrological maps at scales from 1:1,000,000 to 1:1,500,000 were published for the Sahelian region by the Inter-African Committee on Water Studies (Comité interafricain d'études hydrauliques) between 1976 and 1982. The data for this article were gathered from an extensive literature review. Articles from journals of water science, public health, and urban studies contained useful information in the context of discussing other topics (e.g., Attalah, Ali Khan, & Malkawi, 1999; Gravelet-Blondin, Barclay, Carliell, & Buckley, 1997; Melloul & Hassani, 1999; Solo, 1999). Some descriptions of municipal sewage systems written by planners and plant managers were found in Loughborough University's Water and Waste Engineering for Developing Countries (WEDC) Conference publications (*Sanitation and Water for Development*, 1983; *Water and Sanitation for All: Partnerships and Innovations* 1997) and in *Proceedings of the Fifth African Water Technology Conference*, 1992. Histories and essays about particular countries or cities contained information on water and sanitation systems—more usually water supply than sewage disposal (e.g., Fyfe & Jones, 1968).

The Internet was a source of much of the information collected. Many institutions publish news articles, conference papers, chapters of books, doctoral dissertation abstracts, and data bases on their web sites (e.g., Water Supply and Sanitation Collaborative Council; International Institute for Applied Systems Analysis; United Nations University Press, International Development Research Center/IDRC, World Health Organization). Although the postings may not persist in time, searching by key words led to current and interesting work, often by African authors (e.g., Abiodun, 1997; Dubresson, 1997; Faruqui, 2000; Kgathi, 1998; Khroda, 1996; Matoussi, 1996; Myllylä, 1995; Tounkara, 1996). International construction companies maintain web sites with a range of detail (and accuracy) listing their contracts. Some countries and cities also maintain web sites which describe their water supply or sanitation systems. AQUASTAT, launched by the Food and Agriculture Organization and the Water Development Division of the United Nations, contains a world survey of freshwater quality and quantity and some country profiles http://www.fao.org/waicent/faoinfo/agricult/agl/aglw/aquastat/aquastat.htm, and the United Nations Environment Program/United Nations Centre for Human Settlements (Habitat)'s "Managing Water for African Cities" (MAWAC) program's web pages describe a few African cities http://www.un-urbanwater. net. Information also came from surprising web sites. The Gaborone, Botswana sewage treatment lagoons are described in detail—and located with precision—on a birdwatcher's site because their construction created a new location for viewing water birds on the edge of the Kalahari desert. But, the lagoons' function in sewage treatment was not discussed.

The lack of attention paid to the fundamental questions of water sources and disposal was demonstrated in the amount of information available. Although the World Gazetteer (2001) lists 3,102 "cities, towns and places" in Africa with populations greater than 10,000, water source data could only be found for 70 urban areas in 36 nations during the 1970s and for 67 urban areas in 29 nations during the 1990s. The treatment and disposal of water after domestic and industrial use has similarly not been well documented. Complete or partial information about domestic waste disposal was available for 43 urban areas in 24 countries, but for only 15 urban areas in 13 countries concerning industrial waste management. Water pollution problems were noted in 29 urban areas from 18 countries. No information was found about the other 3,035 municipalities' water supplies, 3,059 urban sanitation systems, or about water quality for the rest of the 3,077 African urban areas. Data may not have been collected. Salau (1990) cited "lack of adequate and accurate information on the quality and quantity of [Nigeria's] water resources" as a major limitation to planning.

Since most of the information about water sources and sanitation measures was found in relation to large, externally funded infrastructure development projects, countries without international contracts are underrepresented. Very little information was found for countries at war in the last decade, or for those without major oil, minerals or other exportable commodities. For this reason, the data presented in the following tables must be understood to be a survey based upon best available information. These data do not, therefore, constitute a statistical random sample. Rather, they simply represent all urban areas for which relevant information could be found. Their primary usefulness is in describing conditions of urban interactions with the water cycle throughout the continent. Filling the many existing gaps, and verifying the tabulated information, will require a systematic, coordinated data collection program.

Despite their limited number, these data provide important indications of trends—especially when self-comparisons are made over time. The water source information reflected two distinct periods of African urbanization—the early-mid-1970s and the mid-late 1990s. In 1975 a quarter of Africans lived in urban areas; by 1995, a little more than a third were urban residents (UN, 1998). A subset of 37 urban areas appearing in both data sets was used for comparison of changes in water sources between the early 1970s and the 1990s.

Certain conventions have been used in the data presentation. Because this article is concerned with organized municipal water supplies rather than "how an individual or industry can acquire water," private wells and boreholes have not been noted. Water supplies were identified as being "near" if they were within 25 kilometers of the urban areas, and "far" if at a greater distance. Rivers are conventionally classified as "national" if their drainage basin falls entirely within one country, or "international" when they drain more than one nation. When water is diverted from one drainage basin or watershed to another, it is referred to as an interbasin transfer (IBT).

While outlines of urban–landscape interactions may seem obvious for domestic and industrial water use and disposal, those associated with electricity are less apparent—but equally fundamental. Information about African electricity sources and interconnections are apparently more available in the literature because electricity has long been understood to be essential for economic development. Descriptions of national electricity infrastructure exist in Africa South of the Sahara 2000 (1999) and in the *Area Handbook* and *Country Studies* series of the Department of the Army and Library of Congress, USA. The United States Department of Energy provides country profiles with information about electricity supplies for some African nations at http://www.eia.doe.gov/emeu/cabs/cabsaf.html, as does the CIA World Factbook www.cia.gov/cia/publications/factbook. On the Internet some electricity boards maintain web pages, and information about hydroelectric projects can be found at environmental NGO websites containing reports about conditions of rivers, and in postings from business and general news agencies (e.g., Uganda Electricity Board, International Rivers Network, Swaziland National Trust Commission, African Energy, Pan African News Agency). Despite a variety of sources, specific details were scarce, information was often contradictory, and no compilations of regional or continental data were found. For instance, the vast majority of hydroelectric plant discussions did not mention the river involved. Tables were constructed to explore the implications of urban Africa's "hidden" dependence on water through electricity consumption. When information conflicted, most recent sources geographically closest to the location were chosen.

(b) *Where does African urban water come from?*

Table 1 supports the statement that many African urban areas in the early 1970s used ground water—springs, wells, boreholes—as their primary source of supply (UN, 1973).

Presenting data concerning 70 urban areas from 36 different countries, the table shows that whether dependent upon ground or surface water, most urban areas relied on sources that were nearby. Only North African and Saharan locations were reported to use groundwater from distant locations—all of which were interbasin water transfers (IBTs). Most extreme were the former Spanish military bases of El Aaiún and El Dakhla (former Villa Cisneros) in Western Sahara (former Spanish Sahara), which had groundwater delivered by tanker ships from the Canary Islands to augment local wells (UN, 1973).

Only one river was tapped by most locations, and almost two-thirds of river users relied upon a national river. Those depending upon more than one river used national rivers exclusively, as did IBTs supplying Addis Ababa, Kumasi, Nairobi, Johannesburg, Cape Town, Dar es Salaam, Bulawayo and Masvingo. Seven of the nine urban areas dependant upon international rivers—Brazzaville, Kinshasa, Maseru, Monrovia, Bamako, Niamy, Mbabane and Beitbridge—had grown up along their banks.

Less than one-third of the locations reported efforts to collect water for use. Of those that did, 85% had constructed dams, reservoirs or barrages; desalination was reported only at the Spanish military bases in Western Sahara (brackish water) and at Nouakchott (sea water) to supplement wells (UN, 1973).

The same categories of information for 67 urban areas in 29 countries during the mid-late 1990s are presented in Table 2. In addition, a column labeled "deficit" indicates the adequacy of an urban areas's water source—rather than the capability of municipal infrastructure—to meet current urban needs.

Most striking is the distance from which water was extracted. There were IBTs of both groundwater and surface water. Two urban areas drew groundwater from distant well fields, and 58% using rivers exploited those flowing further than 25 km away. Slightly more than half of the river users depended upon IBTs, 70% of which involved more than two rivers. Greater Johannesburg drew water from nine rivers, Durban and Cape Town from five, and Nairobi and Bulawayo from four. IBTs supplying Gaborone, Johannesburg and Port Elizabeth involved international, as well as national, rivers. Tripoli became dependent upon the Great Man-Made River Project, a 600 km IBT of fossil groundwater from under the southern Sahara Desert to the densely populated coast (American Society of Civil Engineers, 1998).

Forty-six percent of these 1990s urban areas made efforts to collect water. Most common was the construction of barrages, dams or reservoirs. Praia, Sao Vicente and Sal desalinated sea water. Windhoek, Bulawayo and Cairo reused treated wastewater to irrigate orchards, fodder, field crops or open space, and Addis Ababa had begun to use air dried solids from a sewage treatment plant in local reforestation efforts. Johannesburg returned treated wastewater to its Vaal Dam water supply. War-torn Monrovia, whose municipal water infrastructure was damaged in 1992, only began to have limited piped water from high-rise reservoirs in April 2001 (World Investment News, 2001). Despite these efforts, 52% of the water collecting and storing urban areas reported water deficits. Only 51% of the 1990s municipalities for which data existed reported adequate supplies. Eight of the 15 locations with insufficient data for inclusion in this calculation are in water-scarce Tunisia or in Libya, which relies upon fossil groundwater.

The preceding two tables suggest that as African urban areas grew, they extracted water from ever larger geographic areas. Table 3 documents this phenomenon.

Thirty-eight urban areas from 21 nations appearing in both Tables 1 and 2 were used for comparisons over time. The number of locations reliant upon groundwater decreased from 58% to 47% while the number using river water increased from 55% to 68%. Two cities reported the use of distant ground water sources—a pipeline from Thiès supplied Dakar, and the Akaki well fields contributed to Addis Ababa's needs. Dependence upon nearby rivers decreased from 62% to 42%, while the use of rivers flowing father than 25 km away increased from 39% to 58%. Interbasin water transfers increased from 43% to 54% of river users. The number of urban areas reliant upon only one river decreased from 76% of river users to 62%, while dependence on more than one river increased from 24% to 38%. In the 1990s more of the urban areas depended upon water from international rivers. Northern and southern African urban areas implemented wastewater recycling programs, and desalination plants were used in drought stressed Cape Verde.

The site-specific data in the preceding three tables are summarized quantitatively in Table 4.

From this it is clear that urban Africa depends upon both groundwater and surface water for its daily function, and that as they expand, urban areas drain ever larger landscapes. Rivers are increasingly significant water sources, and many locations have increased the number of rivers they tap. Some major urban and industrial areas rely upon rivers whose drainage basins are in foreign countries.

(c) *Where does urban water go?*

(i) *Domestic and industrial waste management systems*

The disposal of water after domestic or industrial use in urban Africa is not well documented. Table 5 provides information about the handling and disposal of domestic waste in 43 urban areas from 23 countries, and general urban information for seven countries.

Most people in most urban areas use some form of latrine for household sanitation. Liquids put in latrines are expected to infiltrate into—and be purified by—the surrounding soil. Solids are buried, dumped in rivers, or added to municipal water-borne waste streams. A small proportion of households have septic systems, and even fewer have access to water-borne sanitation. Sewage treatment plants are rare, and many of those that exist are in need of repair or are inadequate for the amounts and kinds of materials they receive. Most treatment plants were only constructed to handle water-borne domestic sewage. Ghana is one of the few countries in the world with treatment plants designed to treat septage and night soil as well as water-borne sewage (Heinss & Strauss, 1998). Treated or untreated, most sewage ends up in streams or oceans. A few urban areas in semi-arid or arid locations—such as Egypt, Morocco, Namibia, Botswana and Zimbabwe—use water from treatment plants for irrigation of crops or open space. Johannesburg returns treated wastewater to its Vaal Dam water supply.

Table 6 provides information about the types of industries and the fate of their used water in 15 urban areas from 13 countries, and general comments about a further three countries.

Large quantities of heavy metals, acids, solvents, oils and substances with complex chemistries are discharged daily from mines and industries across the continent. Only Namibia, South Africa and Zimbabwe reported having treatment programs for industrial wastes. Although countries such as Egypt and Nigeria have laws requiring treatment before disposal, equipment does not exist and there is no enforcement (DiLuciano, 1995; Egborge, 1998). Like domestic sewage, most treated and untreated industrial effluents are disposed of in streams or oceans.

(ii) *Aquatic consequences*

Table 7 notes some pollution problems experienced by 29 urban areas in 18 countries, and general comments about six countries.

Domestic and industrial wastes have polluted groundwater, streams and coastal regions all over the continent. Groundwater is being polluted by latrines in a wide range of soil types and climates. Gaborone, Lagos, Khartoum, Dar es Salaam, and Lusaka noted increased levels of nitrates and other contaminants (Abiodun, 1997; UNEP/UNCHS, undated, b). So great is the concern about groundwater contamination in the desert nation of Botswana that the "Low Cost Sanitation" and "Urban Squatter Upgrading" programs mandating pit latrines are considered to be policy failures (Kgathi, 1998). Sealed latrines are thought to be an interim solution, with central sewerage as the long-term solution. This is identical to the conclusion reached by officials in Bulawayo, when Zimbabwe was Rhodesia. According to Milne (1983), a 1956 policy mandated that all new houses in the "high-density" (low-income) areas have flush toilets; in 1959 a program was implemented to provide existing houses with flush toilets. Communal toilets and individual latrines had been found to have contaminated surrounding soil. When "eventually excavation for the installation of sewers was carried out, it was under the most unpleasant conditions" (Milne, 1983).

Groundwater is also contaminated by leachates from industrial and mining effluents disposed of in pits or constructed ponds.

Table 1. *African urban water sources in the early 1970s*[a]

Country (Total: 36)	Urban area (Total: 70)	Ground water		Surface collect	River			IBT
		Near	Far		Use	National	International	
Botswana	Gaborone	yes	no	dam	near	Ngotwane	no	no
	Serowe	yes	no	no	no	no	no	no
	Francistown	yes	no	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
	Lobatse	yes	no	barrage	near	Nnywane	no	no
Burkina Faso	Ouagadougou	w	no	no	no	no	no	no
	Bobo Dioulasso	dbh	no	no	no	no	no	no
Cape Verde	Praia	w	no	(n.d.)	no	no	no	no
	Sao Vicente	w	no	(n.d.)	no	no	no	no
	Sal	w	no	(n.d.)	no	no	no	no
Chad	N'Djamena	bh	no	no	no	no	no	no
Congo Republic	Brazzaville	no	no	no	near	no	Congo	no
Côte d'Ivoire	Abidjan	yes	no	no	no	no	no	no
Democratic Republic of	Kinshasa	no	no	no	near	no	Congo	no
Congo	Lubumbashi	w,sp	no	no	near	unspecified		no
	Katanga	w,sp	no	no	no	no	no	no
Djibouti	Djibouti	w	no	no	no	no	no	no
Egypt	Luxor	w	no	no	no	no	no	no
Equatorial Guinea	Rio Muni	w	no	no	no	no	no	no
Ethiopia	Addis Ababa	sp	no	dam	far	Legedadi	no	yes
Gabon	Libreville	w,sp	no	div.dam	yes	unspecified		no
	Port Gentil	w	no	no	no	no	no	no
Ghana	Accra	no	no	dam	near	Densu	no	yes
	Kumasi	no	no	dam	n+f	Owabi, Ofin	no	yes
	Bolgatanga	w	no	no	no	no	no	no
Guinea	Conakry	w	no	no	no	no	no	no
Kenya	Nairobi	sp	no	dam	n+f	Nairobi, Ruiru, Kiburu Chania	no	yes
Lesotho	Maseru	no	no	no	near	no	Caledon	no
	Butha Buthe	yes	no	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
	Teyateyaneng	yes	no	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
	Mohales Hoek	yes	no	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
	Quthing	yes	no	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
Liberia	Monrovia	yes	no	dam	near	no	St. Paul	no
Malawi	Lilongwe	w	no	no	(n.d)	(n.d.)	(n.d.)	(n.d.)
Mali	Bamako	no	no	(n.d.)	near	no	Niger	no
Mauritania	Nouakchott	no	w	desal.sea	no	no	no	gw
	Nouadhibou	w	no	no	no	no	no	no
	Akjoujt	w	no	no	no	no	no	no
	Atar	w	no	no	near	rb,unspecified	no	no

Morocco	Casablanca	w	no	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
Namibia	Windhoek	w	no	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
	Tsumeb	w	no	no	no	no	no	no
Niger	Niamey	no	no	(n.d.)	near	no	Niger	no
Nigeria	Lagos	no	no	(n.d.)	near	Ogun	no	no
	Maiduguri	w,bh	no	no	no	no	no	no
Rwanda	Kigali	w	no	no	no	no	no	no
	Gisenye	w	no	no	no	no	no	no
	Butare	w	no	no	no	no	no	no
Senegal	Dakar	bh	no	no	no	no	no	no
	Thiès	bh	no	no	no	no	no	no
Sierra Leone	Freetown	no	no	dam	near	Orugu, Guma	no	no
South Africa	Cape Town	no	no	reservoir	far	Erste, Berg, Steenbras	no	yes
	Johannesburg	no	no	dam	far	Vaal	no	yes
Sudan	Gedaref	w	no	no	far	no	Atbara	yes
Swaziland	Mbabane	no	no	(n.d.)	near	no	Mbuluzi	no
	Manzini	no	no	(n.d.)	near	Mzimnene	no	no
Tanzania	Dar es Salaam	no	no	reservoir	far	Ruvu	no	yes
	Tanga	w	no	no	no	no	no	no
	Dodoma	w	no	no	no	no	no	no
Togo	Lomé	w	no	no	no	no	no	no
Tunisia	Tunis	w	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
Western Sahara	El Aaiún	dw	ships	desal.brac	no	no	no	gw
	El Dakhla	(n.d.)	ships	deasl.brac	no	no	no	gw
Zambia	Lusaka	w	no	no	no	no	no	no
	Ndola	w	no	no	no	no	no	no
	Mazabuka	w	no	no	no	no	no	no
Zimbabwe	Harare	no	no	dam	near	Manyame	no	no
	Bulawayo	no	no	dam	far	Ncema, Umzingwane, Inyankuni	no	yes
	Mutare	no	no	dam	near	Odzani	no	no
	Beitbridge	no	no	dam	near	no	Limpopo	no
	Masvingo	no	no	dam	far	Mutirikwe	no	yes

[a] Totals: 70 urban and industrial areas in 36 nations; municipal, not private, systems. *Key*: Near: <25 km; Far: ⩾25 km; n + f: near & far; IBT: interbasin transfer; w: wells; dw: deep wells; bh: borehole; dbh: deep borehole; sp: springs; ships: brought by ship; no: do not use; div.dam: diversion dam; (rb): bore hole in dry river bed; desal.sea: desalinate sea water; desal.brac: desalinate brackish water; gw: ground water that is an IBT; (n.d.): no data.

Table 2. *African urban water sources in the 1990s*[a]

Country (Total: 29)	Urban area (Total: 67)	Ground water		Surface collect	River			IBT	Def.
		Near	Far		Use	National	International		
Algeria	Algiers	no	no	reservoir	no	no	no	no	yes
Botswana	Gaborone	no	no	dam	n + f	Ngotwane, Metsimotlhabe	Marico	yes	yes
	Serowe	yes	no	no	no	no	no	no	yes
	Selibe Phikwe	no	no	dam	far	Motloutse	Shashe	yes	no
	Mahalapye	(n.d.)	no	dam	far	Motloutse	no	yes	no
	Francistown	no	no	dam	far	no	Shashe	yes	no
	Lobatse	no	no	barrage, dam	n + f	Nnywane, Ngotwane	no	yes	yes
	Molepolole	wf	no	no	no	no	no	no	(n.d.)
	Kanye	wf	no	no	no	no	no	no	(n.d.)
Burkina Faso	Ouagadougou	no	no	dam	far	no	Nazinon	(n.d.)	yes
Cape	Praia	w	no	desal.sea	no	no	no	no	yes
Verde	Sao Vicente	w	no	desal.sea	no	no	no	no	yes
	Sal	w	no	desal.sea	no	no	no	no	yes
Côte d'Ivoire	Abidjan	yes	no	no	no	no	no	no	no
Democratic Republic of Congo	Kinshasa	(n.d)	no	no	near	Ndjili	no	no	no
Djibouti	Djibouti	w	no	no	no	no	no	no	no
	Tadjourah	w	no	no	no	no	no	no	no
Egypt	Cairo	w	no	reuse-s,l	near	no	Nile	no	no
	Alexandria	no	no	no	near	no	Nile	no	no
Ethiopia	Addis Ababa	yes	wf	dam, reuse-s	far	Legedadi, unspecified	no	gw, yes	yes
Ghana	Accra	no	no	dam	n + f	Densu	Volta	yes	yes
	Tema	no	no	dam	n + f	Densu	Volta	yes	yes
	Kumasi	no	no	dam	n + f	Owabi, Ofin	no	yes	no
	Winneba	no	no	(n.d)	near	Ayensu	no	no	(n.d.)
Kenya	Nairobi	sp	no	no	n + f	Nairobi, Ruiru, Chania, Kiburu	no	yes	yes
Lesotho	Maseru	no	no	no	near	no	Caledon	no	no
	Morija	yes	no	no	no	no	no	no	(n.d.)
	Mapoteng	yes	no	no	no	no	no	no	(n.d.)
Liberia	Monrovia*	w	no	dam	near	no	St. Paul	no	(n.d.)
Lybia	Tripoli	(n.d.)	fgw	(n.d)	no	no	no	fgw	(n.d.)
	Benghazi	(n.d.)	fgw	(n.d)	no	no	no	fgw	(n.d.)
Libya	Sirt	(n.d.)	fgw	(n.d)	no	no	no	fgw	(n.d.)
	Misratah	(n.d.)	fgw	(n.d)	no	no	no	fgw	(n.d.)
Malawi	Blantyre	no	no	(n.d.)	near	no	Shire	no	(n.d.)
Mali	Timbuctu	yes	no	(n.d)	no	no	no	no	no
	Gao	yes	no	(n.d)	no	no	no	no	no

Mauritania	Nouakchott	bh	wf	(n.d.)	no	no	no	gw	yes
	Nouadhibou	w	w	reservoir	no	no	no	gw	no
	Akjoujt	w	no	(n.d)	no	no	no	no	no
Mozambique	Maputo	no	no	dam	near	no	Umbeluzi	no	(n.d.)
Namibia	Windhoek	bh	no	dam, reuse-l	far	Swacop	no	yes	no
	Tsumeb	w	no	no	no	no	no	no	yes
	Walvis Bay	no	no	dam	near	Kuiseb (rb)	no	no	yes
	Swakopmund	bh	no	(n.d.)	far	Kuiseb (rb)	no	no	yes
Niger	Niamey	no	no	(n.d.)	near	no	Niger	no	(n.d.)
Nigeria	Lagos	no	no	(n.d.)	near	Ogun	no	no	no
	Maiduguri	yes	no	dam	near	Ngadda	no	no	no
Senegal	Dakar	bh	wf	no	no	no	no	gw	yes
	Thiès	bh	no	no	no	no	no	no	no
Somalia	Mogadishu	yes	no	(n.d.)	no	no	no	no	(n.d.)
South Africa	Cape Town	no	no	reservoir	far	Erste, Palmiet, Steenbras, Berg, Riviersonderend	no	yes	yes
	Johannesburg	no	no	treated water to Vaal Dam	far	Vaal, Crocodile, Olifants, Tugela, Pongola	Limpopo, Komati, Usutu, Malibamats'o	yes	no
	Durban	no	no	no	n + f	Mzimkulu,Mooi, Mkomaas, Mgeni, Illovo	no	yes	yes
	Port Elizabeth	no	no	no	n + f	Great Fish, Sundays	Orange	yes	yes
Swaziland	Mbabane	no	no	dam	near	no	Mbuluzi	no	no
	Manzini	no	no	storage	near	Mzimnene	no	no	no
Tanzania	Dar es Salaam	no	no	storage reservoir	far	Ruvu	no	yes	yes
Tunisia	Jerid	dw	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
	Nefzaoua	dw	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
Tunisia	Gabès	dw	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
	Medenine	dw	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)	(n.d.)
Zambia	Lusaka	w	no	no	far	Kafue	no	yes	no

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Table 2—*continued*

Country (Total: 29)	Urban area (Total: 67)	Ground water		Surface collect	River			IBT	Def.
		Near	Far		Use	National	International		
Zimbabwe	Harare	no	no	dam	near	Manyame	no	no	yes
	Bulawayo	no	no	dam, reuse-l	far	Ncema, Insiza, Unzingwane, Inyankuni	no	yes	yes
	Mutare	no	no	dam	n + f	Odzani	Pungwe	yes	yes
	Beitbridge	no	no	off-river storage dam	near	no	Limpopo	no	no
	Masvingo	no	no	dam	far	Mutirikwe	no	yes	no

[a] Totals: 67 urban areas in 29 nations. Municipal, not private, systems. *Key*: Near: <25 km; Far: ≥25 km; n + f: near & far; IBT: interbasin transfer; Def.: Deficit, inadequate water supply (not infrastructure capability); *: war damaged infrastructure 1992; w: well; dw: deepwell; bh: borehole; dbh: deep borehole; sp: spring; fgw: fossil groundwater; wf: well field; no: do not use; desal-sea: desalinate seawater; reuse-l: treated liquid for irrigation; reuse-s: dried solids for fertilizer; (rb): borehole in dry riverbed; IBT: interbasin transfer; gw: ground water that is an IBT; (n.d.): no data.

Table 3. *Changes in urban water sources, 1970s–90s*[a]

Country (Total: 21)	Urban area (Total: 38)	Ground water		Surface collect		River early 1970s		River 1990s		1990 Def.
		1970	1990	1970	1990	Name	IBT	Name	IBT	
Botswana	Gaborone	near	no	dam	dam	Ngotwane	no	Ngotwane, Metsimothlabe, Motloutse, Marico	yes	yes
	Serowe	near	near	no	no	no	no	no	no	yes
	Francistown	near	no	(n.d.)	dam	(n.d.)	(n.d.)	Shashe	yes	no
	Lobatse	near	no	barr	barr dam	Nnywane	no	Nnywane, Ngotwane	yes	yes
Burkina Faso	Ouagadougou	near	no	no	dam	no	no	Nazinon	(n.d.)	no
Cape Verde	Praia	near	near	(n.d.)	des	no	no	no	no	yes
	Sao Vicente	near	near	(n.d.)	des	no	no	no	no	yes
	Sal	near	near	(n.d.)	des	no	no	no	no	yes
Côte d'Ivoire	Abidjan	near	near	no	no	no	no	no	no	no
Democratic Republic of Congo	Kinshasa	no	no	no	no	Congo	no	Ndjili	no	no
Djibouti	Djibouti	near	near	no	no	no	no	no	no	no
Ethiopia	Addis Ababa	near	n + f	dam	dam reuse-s	Legedadi	yes	Legedadi, unspecified	gw	yes
Ghana	Accra	no	no	dam	dam	Densu	yes	Densu, Volta	yes	yes
	Kumasi	no	no	dam	dam	Owabi, Ofin	yes	Owabi, Ofin	yes	no
Kenya	Nairobi	near	near	dam	dam	Nairobi, Ruiru, Kiburu, Chania	yes	Nairobi, Ruiru, Kiburu, Chania	yes	yes
Lesotho	Maseru	no	no	no	no	Caledon	no	Caledon	no	no
Liberia	Monrovia*	near	near	dam	dam	St. Paul	no	St. Paul	no	no
Mauritania	Nouakchott	far	n + f	des	(n.d.)	no	gw	no	gw	yes
	Nouadhibou	near	n + f	no	res	no	no	no	gw	no
	Akjoujt	near	near	(n.d.)	(n.d.)	no	no	no	no	no
Namibia	Windhoek	near	near	(n.d.)	dam reuse-l	(n.d.)	(n.d.)	Swacop	yes	no
	Tsumeb	near	near	no	no	no	no	no	no	yes
Niger	Niamey	no	no	(n.d.)	(n.d.)	Niger	no	Niger	no	(n.d.)
Nigeria	Lagos	no	no	no	no	Ogun	no	Ogun	no	(n.d.)
	Maiduguri	near	near	no	dam	no	no	Ngadda	no	no
Senegal	Dakar	near	n + f	no	no	no	no	no	gw	yes
	Thiès	near	near	no	no	no	no	no	no	no
South Africa	Cape Town	no	no	res	res	Erste, Berg, Steenbras	yes	Erste, Berg, Steenbras, Riviersonderend, Palmiet	yes	yes
	Johannesburg	no	no	dam	dam reuse-l	Vaal	yes	Vaal, Crocodile, Oliphants, Tugela, Pongola, Komati, Limpopo, Usutu, Malibamats'o	yes	no

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Table 3—*continued*

Country (Total: 21)	Urban area (Total: 38)	Ground water		Surface collect		River early 1970s		River 1990s		1990 Def.
		1970	1990	1970	1990	Name	IBT	Name	IBT	
Swaziland	Mbabane	no	no	(n.d.)	dam	Mbuluzi	no	Mbuluzi	no	no
	Manzini	no	no	(n.d)	storage	Mzimnene	no	Mzimnene	no	no
Tanzania	Dar es Salaam	no	no	res	storage	Ruvu	yes	Ruvu	yes	yes
Zambia	Lusaka	near	near	no	no	no	no	Kafue	yes	no
Zimbabwe	Harare	no	no	dam	dam	Manyame	no	Manyame	no	yes
	Bulawayo	no	no	dam	dam reuse-l	Ncema, Umzingwane, Inyankuni	yes	Ncema Umzing-wane, Inyankuni, Insiza	yes	yes
	Mutare	no	no	dam	dam	Odzani	no	Odzani, Pungwe	yes	yes
	Beitbridge	no	no	dam	dam	Limpopo	no	Limpopo	no	no
	Masvingo	no	no	dam	dam	Mutirikwe	yes	Mutirikwe	yes	no

[a] Totals: 38 urban areas in 21 nations. Municipal, not private, water supplies. *Key*: IBT: interbasin transfer; Def.: Deficit, inadequate water supply, not infrastructure capability; near: <25 km; far: ⩾25 km; n + f: near & far; no: do not use; *: war damaged infrastructure 1992; dam: one or more barrages, river dam, reservoir, storage dam or off-river dam; res: reservoir; reuse-l: treated liquid for irrigation; reuse-s: dried solids for fertilizer; gw: ground water import is IBT; fgw: fossil groundwater; (n.d.): no data.

Table 4. *Water sources for African urban areas*[a]

Water sources	Selected urban areas				Self-comparisons			
	Early 1970s (sample: 70)		1990s (sample: 67)		Early 1970s (sample: 38)		1990s (sample: 38)	
	#	(%)	#	(%)	#	(%)	#	(%)
Ground								
Total users	51	73	36	54	22	58	18	47
near only	48	94	28	78	21	95	14	78
far only	1	2	4	11	1	5	1	6
near & far	1	2	4	11	0	0	3	17
IBT	3	6	8	22	1	5	4	22
Incomplete data	2	3	10	15	0	0	0	0
Do not use	19	27	29	43	16	42	20	53
Rivers								
Total users	28	40	38	57	21	55	26	68
incomplete data	2	7	0	0	0	0	1	4
near	18	64	16	42	13	62	11	42
far	7	25	13	34	6	29	9	35
near & far	2	7	9	24	2	10	6	23
IBT	10	36	20	53	9	43	14	54
national	17	61	20	53	15	71	15	58
international	9	32	11	29	6	29	7	27
nat. & internat.	0	0	7	18	0	0	4	15
Depend on 1 river	23	82	24	63	16	76	16	62
national	12	52	13	54	10	63	9	56
international	9	39	11	46	6	38	7	44
Depend on >1 river	5	18	14	37	5	24	10	38
national only	5	100	7	50	5	100	6	60
nat. & internat.	0	0	7	50	0	0	4	40
Do not use	33	47	25	37	15	39	12	32
Unknown river use	9	13	4	6	2	5	0	0
Groundwater + river(s)	9	13	7	18	5	13	6	16
Collection								
Total users	20	29	31	46	16	42	25	66
no data	16	23	18	27	9	24	3	8
dam, reservoir	17	85	27	87	15	94	22	88
desalination	3	15	3	10	1	6	3	12
reuse, liquid	0	0	4	13	0	0	3	12
reuse, solids	0	0	2	6	0	0	1	4
Do not use	34	49	18	27	13	34	10	26
Deficit	no data		24	49	no data		17	47

[a] 1970s: Table 1, 70 urban areas in 36 nations; 1990s: Table 2, 67 urban areas in 29 nations; Self-comparisons: Table 3, 38 urban areas in 21 nations appearing in Tables 1 and 2. *Key*: Ground: ground water; Collection: collection, storage or processing of water; near = <25 km; far: ⩾25 km; dam,res: barrages and dams across rivers, storage dams, off-river dams; reuse-l: treated water for irrigation; reuse-s: dried solids for fertilizer; des: desalination sea or brackish water; IBT: interbasin water transfer; gw: ground water that is IBT; Deficit: inadequate water supply, not infrastructure capability.

Addis Ababa, Lagos and Lusaka all reported groundwater contaminated by industrial effluents (Abiodun, 1997; UNEP/UNCHS, undated, a, undated, b). Cadmium from mines has been found in Selebi Phikwe boreholes (Chenge & Johnson, 1996).

Streams of all types—perennial, intermittent, large, and small—have been so contaminated by untreated domestic and industrial waste that ecological function has been disrupted, and their ability to function as water supplies is compromised. Industrial effluents have caused fish kills in the Peleng River near Lobatse and contributed to the Nairobi River being described as an "open sewer." Small streams around Addis Ababa have become so polluted

Table 5. *Domestic waste management in some African urban areas*

Country	Urban area	Technology	Treatment	Disposal
Angola	Luanda	(n.d.)	none, industrial area	Baia do Cacuaco
Benin	Cotonou	Septic	Primary & secondary	Atlantic Ocean
Botswana	Gaborone	Water borne	Sewage lagoon	Liquids evaporate, solids (n.d.)
		Pit latrines	none or to sewage lagoon	Liquids into soil, solids buried in yard or removed
	Francistown	Water borne	(n.d.)	(n.d.)
		Pit latrines	none or municipal	Liquids into soil, solids buried in yard or removed
	Selebi Phikwe	Pit latrines	none or municipal	Liquids into soil, solids buried in yard or removed
Burkina Faso	Ouagadougou	Pit latrines	none	(n.d.)
		Soak pits	none	Seep into soil
		Septic tanks	none	"Dans la nature"
	Bobo Dioulasso	Pit latrines	(n.d.)	(n.d.)
Côte d'Ivoire	Abidjan	Water borne	none	Coastal lagoons
		Septic	none	Coastal lagoons
Democratic Republic of Congo	Kinshasa	Septic	none	Directly into river
Egypt	Alexandria	(n.d.)	Mostly untreated	Mediterranean Sea
	Greater Cairo	25% unsewered	15% fully treated	Mediterranean Sea or Nile River
		75% sewered	25% partially treated 60% untreated	Some treated liquid to desert irrigation
	Luxor	95% no service	none	Nile River
Ethiopia	Addis Ababa	Pit latrines	none or treatment plants	Untreated to stream channels
		Septic tanks	Treatment plants or none	Raw sewage air dried at Kotebe plant for use as afforestation fertilizer
		none	none	Untreated to stream channels
Ghana	Tema	Water borne	Treatment plant	(n.d.)
		Unsewered	none	(n.d.)
Kenya	Nairobi	Latrines	none	Nairobi River & small streams
		Water borne	Ineffective	Nairobi River
	Thika	Water borne	Anaerobic primary facultative, secondary facultative & maturation ponds	(n.d.)
	Kisumu	Water borne	Anaerobic primary facultative, secondary facultative & maturation ponds	(n.d.)
Lesotho	Maseru	Latrines	(n.d.)	(n.d.)
		Septic	(n.d.)	(n.d.)
		Water borne	(n.d.)	(n.d.)
Liberia	Monrovia	(n.d.)	Treatment plats obsolete; broken	Broken pipes release to city environment
Angola	Luanda	(n.d.)	none, industrial area	Baia do Cacuaco
Malawi	Blantyre	(n.d.)	Off-site treatment	Inadequate & untreated to open areas
		Latrines	Unimproved	(n.d.)

		Soakaway pits		Overflow
		Septic		(n.d.)
	Lilongwe	(n.d.)	Off-site treatment	Partially & untreated to open areas
		Latrines	Unimproved	(n.d.)
		Soakaway pits		Overflow
		Septic		(n.d.)
	Liwonde	(n.d.)	Off-site treatment	Inadequate & untreated to open areas
		Latrines	Unimproved	(n.d.)
		Soakaway pits		Overflow
		Septic	(n.d.)	
	Mzuzu	(n.d.)	Off-site treatment	Partially & untreated to open areas
		Latrines	Unimproved	(n.d.)
		Soakaway pits		Overflow
		Septic		(n.d.)
	Zomba	(n.d.)	Off-site treatment	Partially & untreated to open areas
		Latrines	Unimproved	(n.d.)
		Soakaway pits		Overflow
		Septic		(n.d.)
Morocco	Marrakesh	(n.d.)	(n.d.)	Wastewater spreading zone at El Azzouzia
	Ouled Teima	(n.d.)	Open cesspools	Raw sewage for irrigation
	Drarga	(n.d.)	Anaerobic digestion	Methane powers plant; treated wastewater for irrigation; denitirifcation reeds for structural use
Mozambique	Maputo	(n.d.)	none	Maputo Bay, or to one of 5 rivers flowing into bay
Namibia	Windhoek	Water borne	Activated sludge	83% reclaimed for potable water; 11% irrigation of parks & gardens; 6% to Aretaragus River
Nigeria	Lagos	Water borne	Ineffective plants	Coastal lagoon
Senegal	Dakar-center	Water borne	(n.d.)	(n.d.)
	periphery	none	none	(n.d.)
	Kaolack-center	Water borne	(n.d.)	(n.d.)
	periphery	none	none	(n.d.)
	St-Louis-center	Water borne	(n.d.)	(n.d.)
	periphery	none	none	(n.d.)
	Thiès-center	Water borne	(n.d.)	(n.d.)
Angola	Luanda	(n.d.)	none, industrial area	Baia do Cacuaco
	periphery	none	none	(n.d.)
	Louga-center	Water borne	(n.d.)	(n.d.)
	periphery	none	none	(n.d.)

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Table 5—*continued*

Country	Urban area	Technology	Treatment	Disposal
South Africa	Durban-center	Water borne	28 plants	Outfall to Indian Ocean
	townships	Latrines mostly,	(n.d.)	(n.d.)
		Water-borne few	(n.d.)	(n.d.)
	Johannesburg	Water borne	Nutrient activated sludge plant	Purified effluent to Vaal Barrage via Klip River
	townships	Latrines mostly,	(n.d.)	(n.d.)
		Water-borne few	(n.d.)	(n.d.)
Sudan	Khartoum	Septic	El Goz plant	White Nile
		Pit latrines	(n.d.)	(n.d.)
	Khartoum N.	Septic	El Haj Yousif plant	(n.d.)
		Pit latrines	(n.d.)	(n.d.)
Tanzania	Dar es Salaam	Water borne	Treatment plant	Outfall pipe to Indian Ocean
		Public septic	Treatment plant	Outfall pipe to Indian Ocean
		Pit latrines	Some untreated	Msimbazi Creek
	Univ. & airport	(n.d.)	Stabilization ponds	Rivers & streams
Tanzania	Mwanza	Septic tanks	Oxidation ponds	Mirongo River (treated or raw if plant failure)
		Pit latrines		
		Soakaway pits		
Zambia	Lusaka center	Water borne	(n.d.)	(n.d.)
		Pit latrines	(n.d.)	(n.d.)
Zimbabwe	Harare center	Water borne	Firle Disposal Works	(n.d.)
Algeria	Urban, general	(n.d.)	49 treatment plants: 11 being built 1999; 5 built 1996	(n.d.)
			Untreated	River beds & Mediterranean Sea
Botswana	Urban, general	Water borne		
		Septic	Sullage to water-borne system	(n.d.)
		Pit latrines	Sullage to water-borne system	(n.d.)
Egypt	Urban, general	(n.d.)	none	Nile River
Nigeria	Urban, general	Septic tanks	(n.d.)	(n.d.)
		Pit & bucket latrines	(n.d.)	(n.d.)
South Africa	Urban, general	Water borne	Treatment plants	46% sludge to landfills near cities & industry
Tanzania	Regional centers	Water borne	(n.d.)	(n.d.)
		Septic	Sullage to water-borne system	
Angola	Luanda	(n.d.)	none, industrial area	Baia do Cacuaco
		Latrines	(n.d.)	(n.d.)
Uganda	Urban, general	Pit latrines	(n.d.)	(n.d.)

Table 6. *Industrial waste management in some African urban areas*

Country	Urban area	Industry	Treatment	Disposal
Angola	Luanda	Cement; battery; oils & soap; petroleum refineries	none	Baia do Cacuaco
	Benguela	Textile mills	none	Cavaco River
	Lobito	Textile mills	none	Cavaco River
Botswana	Selebi Phikwe	Copper & nickel mines	(n.d.)	(n.d.)
Burkina Faso	Ouagadougou	Unspecified	none	"Dans la nature"
Côte d'Ivoire	Abidjan	Unspecified	none	Coastal lagoons
Ethiopia	Addis Ababa	Unspecified	none	Stream beds
Kenya	Nairobi	Heavy metals; machine oils; brewery; tannery; manufacturing	none	Nairobi River, other small streams
Malawi	Lilongwe	Toxic & clinical	none	"Careless"
		Industrial	none	Solid: on premises or open sites elsewhere; Effluent: septic tanks
Mozambique	Maputo	126 unidentified	none	Delagoa Bay & rivers into bay
Namibia	Windhoek	Unspecified	Oxidation ponds	Irrigation of fodder
South Africa	Pinetown	Textile mills	Color removal on site, municipal treatment plant	Umbilo River
Tanzania	Dar es Salaam	Unspecified, Pugu Road textile mills; Vingunguti abattoir	none	Msimbazi River
Zambia	Lusaka	(n.d.)	(n.d.)	Pits & old quarries
Zimbabwe	Harare	Soap; tanning; mineral oil; fat; metal plating; refinery, etc.	Backfill	Campbell's quarry, off Hatfield Rd.
		other wastes, Unspecified	Separation & treatment ponds	Workington, Austin Road
Algeria	General	Petroleum	none	Mediterranean Sea
		Unspecified	none	Stream beds & Mediterranean Sea
Egypt	General	Chemicals; steel; iron; cement; oil & soap; tannery; pulp & paper; sugar; tiles & marble; textiles	80% untreated	Nile River
Tunisia	General	Industrial effluent	Untreated	Mediterranean Sea

by domestic and industrial waste that they cannot be used downstream as sources of drinking water, and contamination of the lower Nile has resulted in a decline of freshwater available to Cairo and Alexandria (Aquatsat, 1997; Myllylä, 1995; UNEP/UNCHS, undated, a). The Ogorode thermal power plant at Sapele damages the Benin River with discharges of boiling water (Egborge, 1998).

Coastal waters near major urban and industrial centers are polluted by untreated industrial waste from Dar es Salaam on the Indian Ocean to Cape Town, and along the Atlantic coast as far as Baia do Cauaco, 15 km north of Luanda (Chenge & Johnson, 1996). Petroleum spills degrade the Niger Delta's coastline (Egborge, 1998). The Mediterranean coast of North Africa is similarly polluted. Untreated industrial effluents have almost extinguished artisanal fishing in Luanda's Baia do Cauaco, and Maputo's coast is not safe for swimming. Treatment plants can make a difference. After a new plant was installed in Cotonou to handle sullage from septic systems, the coastal environment improved (Solo, 1999).

These reports indicate that the capacities of soil and aquatic systems to purify and dilute have been—and continue to be—overwhelmed

Table 7. *Water pollution concerns in some African urban areas*

Country	Urban area	Type	Place and problem
Angola	Luanda	Industrial	Baia do Cacuaco's artisanal fishing almost extinct
	Benguela	Industrial	Cavacao River: untreated textile effluent
	Lobito	Industrial	Cavacao River: untreated textile effluent
Botswana	Gaborone	Domestic	Ground water: nitrates from pit latrines
	Selebi Phikwe	Mining	Groundwater: traces cadmium near BLC mines
	Lobatse	Industrial	Peleng River: fish kill; Peleng village: boreholes closed
Côte d'Ivoire	Abidjan	Industrial & domestic	Lagoons: excessive pollution in & around city by untreated effluents
Democratic Republic of Congo	Kinshasa	Industrial & domestic	Groundwater: untreated effluents
Egypt	Alexandria	Industrial & domestic	Montaza water supply canal: sewage enters; Rosetta & Damietta, Nile, Mediterranean Sea: untreated effluents
	Greater Cairo	Industrial & domestic	Nile River: increased water treatment costs; Mediterranean Sea: untreated effluents contributing to fisheries decline
Ethiopia	Addis Ababa	Industrial & domestic	Surface & groundwater: domestic waste, heavy metals & other industrial toxins
Ghana	Accra	Domestic	Densu River: solid & liquid waste; Weija Dam: sewage
Kenya	Nairobi	Industrial & domestic	Nairobi River: untreated effluent; Groundwater: latrines & septic tank leaks
Malawi	Lilongwe	Domestic	Lilongwe River polluted when treatment plant breaks down
	Blantyre	Industrial & domestic	Mudi & Chitawira Rivers: untreated discharge
Morocco	Marrakesh	Domestic	Children: Salmonella in those residing near water spreading area
Mozambique	Maputo	Industrial & domestic	Maputo Bay: unsafe for swimming; groundwater: high nitrate levels
Niger	Niamey	(n.d.)	Contaminated groundwater
Nigeria	Lagos	Industrial & domestic	Coastal Lagoons & Groundwater: untreated effluents
	Onne	Industrial	Rivers & creeks: fertilizer plant
	Sapele	Industrial	Benin River: boiling water discharges from Ogorude thermal plant
	Niger Delta	Industrial	Warri River: refinery, steel & other industrial effluents; Coastal area: petroleum spills
Sudan	Khartoum	Domestic	Groundwater: septic systems
	Khartoum North	Domestic	Groundwater: septic systems
Swaziland	Manzini	Solid waste	Landfill leaches chemicals into groundwater & Mzimnene River
Tanzania	Dar es Salaam	Industrial & domestic	Groundwater: latrines; Msimbazi Creek: textile effluents
	Mwanza	Domestic	Groundwater and surface water pollution
Zambia	Lusaka	Industrial & domestic	Groundwater: latrines, city dumps, informal sewage & waste disposal, industrial effluents
Zimbabwe	Harare	Industrial & domestic	Mukuvusi River by Campbell's Quarry disposal site; Manyame River & Lake Chivero by industry & sewage
Algeria	Urban, general	Industrial	Rivers & coasts by raw sewage, petroleum refineries & industrial wastes
Egypt	Urban, general	Industrial & domestic	Decline of fresh water due to continuous discharge untreated wastes (mostly Greater Cairo & Alexandria)

Table 7—*continued*

Country	Urban area	Type	Place and problem
Malawi	Urban, general	Industrial & domestic	Rivers threatened by untreated effluents, chemical spills & agrochemicals; decline fish species, deteriorate river systems
Angola	Luanda	Industrial	Baia do Cacuaco's artisanal fishing almost extinct
South Africa	Urban, general	Industrial	Surface & Groundwater: runoff from landfills contains heavy metals (lead, nickel,molybdi-num; coastal pollution)
Tunesia	Urban, general	Industrial	Coastal pollution
Uganda	Urban, general	Domestic	Groundwater: threatened by nitrates from latrines

by both the content and volume of daily domestic and industrial waste additions. The resulting degradation of water stored in the ground or flowing on its surface reduces the amount of water available for urban and ecosystem function.

(d) *Does urban electricity depend upon water?*

The water dependence of Africa's electricity grids is detailed in Table 8.

Most striking is the ubiquity of hydroelectric power. It is a major source of electricity for 26 countries from the Sahel to southern Africa, and a secondary source for a further 13. Many hydroelectric power dams were built after the rapid oil price increase of the early 1970s. Hydroelectric dams are, however, vulnerable to drought when river flows are reduced. Cities and towns in countries from a wide range of climates were affected by drought induced power shortages in the 1980s and 1990s. These included Egypt, Cameroon, Côte d'Ivoire, Ghana, pre-war Liberia, Malawi, Morocco, Namibia, Nigeria, Sao Tomé and Príncipe, Sudan, Swaziland, Zambia and Zimbabwe. Côte d'Ivoire shifted from a 1970s policy that had resulted in 90% hydroelectric capacity to one of gas-fired thermal plants after the 1980s droughts (Hodgkinson, 2000).

Yet, a shift to fossil fuel or nuclear power plants does not provide an escape from water dependence. Water is required for processing and cooling all fossil fuel and nuclear power plants; lack of water can, thus, constrain electricity production (see Gleick, 1993, pp. 70–76 for detailed discussion). Seventeen countries rely primarily on electricity generation from plants fueled by a petroleum product, while the semi-arid to arid countries of Zimbabwe, Botswana and South Africa burn coal. One reason that Apartheid South Africa proposed a pan-African power grid based on the hydropotential of the Congo River in the 1970s was the hope of eliminating dependence upon its water-intensive, coal-fired electricity generating plants. It was estimated that importation of 40,000 MW of hydropower could save South Africa 500,000 megaliters of water per year, the equivalent of an entire river (Olivier, 1976).

Electrical generating technologies with minimal water requirements—photovoltaic cells, wind turbines and geothermal units—are not in widespread use on the African continent. Solar-powered photovoltaic cells which require little, if any, water are only used to supply independent institutions, such as schools and hospitals. Wind generators, which use no water, operate in the Cape Verde Islands, and four 50 kW wind turbines were embedded in the Mogadishu grid in the late 1980s (Grepne, 2000; Laitin, 1993). Kenya began to exploit geothermal resources at Olkaria in the 1980s (Whitaker, 1984).

Africa's electricity grid is fragmented. Very few countries have comprehensive electrification. National agencies provide electricity primarily to capital cities, major district towns and mining or industrial centers. Exceptions include Egypt, which had linked practically all villages to the national grid by 1984, Libya, where most houses were reported to have had electricity by 1977, and Mauritius, where 80% of the population reportedly had access to electricity in 1995 (El Musa, 1991; Lenaghan, 1989; Office of Foreign Disaster Assistance, 1980). Several countries have separate grids for different regions of the country (e.g., Angola, Cameroon, Central African Republic, Democratic Republic of Congo, Ghana, Kenya, Madagascar,

Table 8. *Water dependence of African national electric grids*[a]

Country	Major sources	Other sources	Hydroelectric dam names	River name	Exports to	Imports from
Algeria	therm-gas	hydro, coal	(n.d.)	(n.d.)	Morocco	none
Angola[b]	hydro	petrol, therm-gas	Cambambe, Biópo, Matala Catumbela,	Cuanza, Cunene	none	Namibia
Benin	hydro	petrol	none	N/A	none	Ghana
Botswana	coal	petrol	none	N/A	none	Namibia, South Africa
Burkina Faso	therm	hydro	Bagré, Kompienga	Nakambé, Kompienga	none	none
Burundi	Hydro	therm	Rwegura, Mugere, Mugomba	(n.d.)	none	DRC
Cameroon	hydro	therm-diesel	Edéa; Lagdo, Song-Loulou	Sananga, Kebbi	none	none
Cape Verde	diesel	wind	none	N/A	none	none
Central African Republic (CAR)	hydro	therm	Boali	M'Bali	DRC	DRC
Chad	oil	none	none	N/A	none	none
Congo Republic	hydro	therm	Moukoukoulou, Djoué,	Niari (n.d)	none	DRC
Côte d'Ivoire	therm-gas, steam	hydro	Ayamé I amber II, Buyo,Soubré, Kossou,Taabo	Bia; Bandama, Sassandra	none	Ghana, in drought
Democratic Republic of Congo (DRC)	hydro	therm	Inga I amber II, Katende, Lubilanji II, Mobayi-Mbongo	Congo, Lulua, unspecified	CAR,Burundi, Congo Rep, Zambia, Zimba-bwe, South Africa	CAR, Rwanda
Djibouti	therm-oil	none	none	N/A	none	none
Egypt	petrol	hydro	Aswan high dam	Nile	none	none
Equatorial Guinea	diesel	hydro	Bikomo	Riaba	none	none
Eritrea	therm-diesel	none	none	N/A	none	none
Ethiopia	hydro	therm-diesel, geotherm	Awash I,II, Koka, Fincha, Tis Abay, Melka-Wakena	Awash, Fincha, Abay	none	none
Gabon	hydro	therm-gas	Tchimbele, Kinguele, Poubara	M'Bei, Ogooué	none	none
Gambia	therm	none	none	none	none	none
Ghana	hydro	therm-gas,diesel	Akosombo, Kpong	Volta	Togo, Benin	Côte d'Ivoire in drought
Guinea	hydro	(n.d.)	Garafiri	Konkouré	none	none
Guinea Bissau	therm	none	none	none	none	none
Kenya	hydro	therm-oil, geotherm, gas, diesel	Masinga,Gitaru, Kamburu, Kindaruma	Tana	none	Uganda

Algeria	therm-gas	hydro, coal	(n.d.)	(n.d.)	Morocco	none
Lesotho	hydro	none	Muela plant[c]	none	none	none
Liberia[d]	diesel; gas	hydro	Mt. Coffee	St. Paul	none	none
Libya	therm	gas/petrol	none	none	none	none
Madagascar	hydro	therm	Andekaliha	(n.d.)	none	none
Malawi	hydro	therm	Nkula, Kapichira, 3 unspecified	Shire	none	Mozambique
Mali	hydro	therm	Sélinguay, Félou, Sotuba, Markala, Manantali[e]	Sankarani, Bafing	none	none
Mauritania	diesel	none	none	none	none	none
Mauritius	diesel	hydro bagasse/coal	Grand River SE, Grand River NW, Champagne, Ferney, Le Val, Tamarind Falls, Reduit, Magenta, Cascade Cecile, La Ferme	Grand River (n.d.)	none	none
Morocco	coal, therm	hydro, oil	Alwahda, 23 unspecified	Ouergha, (n.d.)	none	Spain, Algeria
Mozambique	hydro	coal, petrol	Cahora Bassa, Chicamba, Mavuzi, Corumana	Zambezi; Revue, Sabie	South Africa, Zimbabwe, Malawi, Swaziland	South Africa
Namibia	hydro, coal	diesel	Ruacana	Cunene	Angola Botswana	South Africa, Zambia
Niger	thermal	none	none	none	none	Nigeria
Nigeria	therm-gas/oil, hydro	therm-coal	Kainji, Jebba, Shiroro	Niger, unspecified	Niger	none
Rwanda	hydro	therm-diesel	Gisenyi, Ntaruka, Mururu.	Mukungwa, Ruzizi	Burundi, DRC	Uganda
Sao Tomé amber & Príncipe	therm	hydro	Guêguê	(n.d.)	none	none
Senegal	therm	none	none	none	none	none
Seychelles	diesel	none	none	none	none	none
Sierra Leone	petrol	hydro	Bumbuna?	Rokel	none	none
Somalia	oil, diesel	wind?	none	none	none	none
South Africa	coal	hydro, nuclear?	Gariep	Orange	Mozambique, Zambia, Swaziland, Namibia, Botswana, Lesotho	Mozambique, DRC, Zambia (via Zimbabwe)
Algeria	therm-gas	hydro, coal	(n.d.)	(n.d.)	Morocco	none
Sudan	therm hydro		Roseires, Sennar, Khashm al Qirbah	Blue Nile, Atbarah	none	none
Swaziland	hydro	diesel	Ezulwini, Edwaleni, Magaduza, Mbabane	Little Usuthu (Lusushwana)	none	South Africa, Mozambique

Continued next page

Table 8—*continued*

Country	Major sources	Other sources	Hydroelectric dam names	River name	Exports to	Imports from
Tanzania	hydro	therm-gas, diesel	Kidatu complex, Pangani Falls	Great Ruaha Pangani	none	Uganda
Togo	therm	hydro	Kpalimé	(n.d.)	none	Ghana
Tunisia	therm	hydro	(n.d.)	(n.d.)	none	none
Uganda	hydro	therm-diesel	Nalubaale, Maziba	Nile (n.d.)	Kenya, Rwanda, Tanzania	Rwanda
Zambia	hydro	(n.d.)	Kafue, Kariba North	Kafue, Zambezi	Namibia, South Africa, Zimbabwe	DRC in drought, South Africa
Zimbabwe	coal, hydro	therm	Kariba South	Zambezi	none	DRC, Zambia, Mozambique

[a] *Key*: hydro: hydroelectric; therm.: thermal (unspecified fuel); therm-coal: coal-fired thermal; therm-diesel: diesel-fired thermal; therm-gas: gas-fired thermal; geotherm.: geothermal; therm-oil: oil-fired thermal; petrol: petroleum (general); (n.d.): no data; ?: current function uncertain.

[b] Kapunda Dam (Cuanza River), Lomaum Dam (Catumbela River) and Gove (Cunene River) war damaged; do not function.

[c] Muela hydroelectric plant built on tunnels from Katse Dam on the Malimabatšo River.

[d] Reflects 1985 pre-war infrastructure.

[e] Despite Feb. 2001 agreements, no generation as of Oct. 31, 2001.

Namibia, Nigeria, Rwanda, Sudan, Tanzania). As Table 8 indicates, however, there are international connections between national power grids. Although two regional power pools have been constructed through the interconnection of national grids (Mediterranean Power Pool and Southern African Power Pool), most of the participating countries do not provide rural electrification.

In several nations urban areas receive electricity from hydropower dams beyond their national boundaries (e.g., Angola, Benin, Central African Republic, Kenya, Niger, South Africa, Togo, Zimbabwe). National drought emergencies, therefore, can have regional urban repercussions. Lomé and Cotonou suffered when interior Ghana's drought reduced power generation at the Akosombo Dam. Drought increased Nairobi's dependence upon electricity from the Nalubaale (formerly Owns Falls) dam in Uganda, and Zimbabwe's towns on the Cahora Bassa Dam in Mozambique. A national problem is internationalized when drought affects interconnected electricity grids.

3. REPERCUSSIONS

Distant ecosystems are weakened by urban water withdrawals. Consequent lowering of water tables results in reduction or cessation of springs and increasingly dry root zones in soils. Both indigenous vegetation and agricultural crops are more vulnerable to drought stress, and wells have to be dug deeper. As these landscapes are less able to sustain vegetation and rural lives, people migrate periodically or permanently to urban areas as environmental refugees, increasing demands on urban infrastructure and services (Myers, 1994). Degraded landscapes are also less able to function as water sources—disturbed vegetation results in decreased abilities to absorb and retain precipitation essential for stream flow.

Removal of both near and distant groundwater at rates greater than annual recharge can cause degradation through seawater intrusion along coasts, as has happened (or threatened) at locations as distant as Casablanca and Lomé, or collapse of the aquifer which reduces future water storage capabilities. (UN, 1973). Dams profoundly disrupt river function, inundate some ecosystems, and impair others (Adams, 1992; McCully, 1996). Dams and river diversion projects have been a major creator of environmental refugees by displacing people and their ways of life.

Untreated wastewater released into African landscapes has lasting—and cumulative—consequences. Since 53% of the surface of the African continent has no discharge to the sea, many contaminants added to soil and water will persist and become concentrated, rather than being diluted and "flushed out" over time (UN, 1973). The consequent decline in water quality has serious implications for water quantity, as is already being experienced in Cairo and Alexandria, and is a source of concern in Gaborone and Lusaka (Aquatsat, 1997; Kgathi, 1998; UNEP/UNCHS, undated, a). Fresh water polluted by natural or man-made substances is unusable for most environmental and human function. Contaminated aquifers are very difficult and expensive to purify—if possible at all.

Most African countries do not have comprehensive urban or rural electrification. Extension of electricity will require new approaches. The World Commission on Dams' final report makes clear that hydroelectric power dams are not as beneficial as once thought, and the environmental destruction they create is not reversible (World Commission on Dams, 2000). Africa's endemic water shortage suggests that conventional fossil fuel and nuclear plants are also problematic. The only known technologies with which to generate electricity without water consumption are photovoltaic cells (solar), which require very little water, or wind, which requires none at all.

In the early 1970s most African capital and industrial cities were wholly or partly dependent upon local groundwater sources (UN, 1973). Today many African cities depend on distant landscapes for their water supplies. Rivers once used to define political boundaries may now be shared water sources. Land use or political decisions affecting these distant watersheds have a direct bearing on basic urban function. Deforestation, overgrazing and intensive rowcropping—as well as treaty obligations with neighboring states—could be reflected in urban water taps. Conversely, urban water consumption and disposal can alter near and distant ecosystems and profoundly affect rural societies. Simple questions about urban water uses and disposal, therefore, lead to complex environmental, social, political and economic interactions that should be considered in urban, regional, national and international planning and policy.

4. VALUING WATER

As the finiteness of water became evident in the industrialized world, the need to assign value to water was recognized. Two distinct perspectives have emerged: water as a scarce natural resource and water as a common global good. In the first instance, water is a commodity subject to the rules of the market place, and in the second, water belongs to the earth and all species and must be used by humans with restraint and respect. A brief overview of the structure and implications of each value system follows; detailed discussion is beyond the scope of this paper.

The scarce resource approach centers upon assigning economic value to human needs and uses of water, and asserting that water can be owned and commodified. Accordingly, water shortage or scarcity could—and should—be managed by market forces (Mohamed & Savenije, 2000). Pricing is the "economic tool" for controlling water demand, and resource economics provides the necessary "tools" for valuing ecosystems by determining individual's and societies' "willingness to pay" (American Society of Civil Engineers, 1998; Dinar, 2000; Farber & Bradley, 1999). Proponents state that if it is true that water is a necessity, then pricing would be an ineffective management tool, since users would pay any price to obtain water. But, the argument continues, urban water supply is not a necessity, since people can dig wells or collect water from a river. This means that urban water supply is simply important for quality of life, so use can be controlled by price (Baumann & Boland, 1998). Within this logic system the cost of providing water and sanitation is born by the users through "user fees" rather than by taxes, and service provision can be privatized (Fritsch & Prud'homme, 1997). Some propose that price concessions should be made for the poor (Komives, Whittington, & Wu, 2001). Implementation of a scarce natural resources/ commodity-based value system for water involves restructuring service provision and implementing new systems of use measurement and accounting. Since the 1980s, some locations have used "least-cost planning" to provide water at "minimum" costs by "balancing reliability, profitability and affordability" (Baumann & Boland, 1998). In most pricing systems, industry and households are charged at different rates, since water is an "input to production" for industry but a "final good" consumed by households (Hanemann, 1998). In this system pollution can also be commodified and priced—and "rights" to pollute can be traded (Kumar, 1997).

When valued as a global common good, water is understood to be a fundamental component of ecosystem function and essential for all life (Barlow, 1999; Barlow & Söderbaum, 2001). Access to essential amounts of water is considered to be a human right, and international law ensures that human rights cannot be bought or sold (Barlow, 1999, 2001; Gleick, 2000). No person or institution has a right to unlimited water, and neither could anyone be denied access to it (Gleick, 2000). Under a global common good value system, notions of sustainability inform decisions about amounts of water abstraction, and of equity guide distribution (Gleick, 1998). Water use is kept below levels that disrupt water cycles and ecosystems, and water use is also modified by consideration for the water needs of diverse cultures and human groups in the present and the future (Barlow, 2001; Gleick, 1998; Petrella, 2001). The provision of water and sanitation is a public service (Barlow, 2001). Private sector participation is not excluded, but control of water supplies and sanitation systems remains with the public (Barlow, 2001). Water users are responsible for the quality of used water returned to the environment; "polluter pays" rules are enforced, and commitments are made to reclaim contaminated water (Barlow, 1999). The common good approach to water use is consistent with the way most people in the world currently value and use water. But, for many members of industrialized societies, this value system and approach challenge basic perceptions and would require a "revolution" in thought and behavior (Petrella, 2001).

Throughout the 20th century water was considered to be infinite and provision of urban water and sanitation was understood to be a series of "big pipes" engineering problems (Newman, 2001). "Excessive" water was moved from rivers to needy urbanizing and industrializing areas. Waste management was handled by low-cost removal and untreated discharge into the environment (usually rivers, lakes or oceans). The data presented in this paper show the consequences of this approach to water in the African environment. Distant rivers were dammed and landscapes drained for urban function, and near and distant waters have been polluted—some irreversibly. This has resulted in the disruption of ecosystems as well as the destruction of rural livelihoods.

5. CONCLUSIONS AND POLICY ISSUES

That urban areas are intimately connected to larger landscapes is not a new idea (Mumford, 1956; UNESCO, 1985; Davies & Day, 1998). What is new is the recognition by multilateral institutions that these linkages are essential to existence. The UNDP/UNEP/World Bank/ World Resources Institute *World Resources 2000–2001* uses the language of environmental economics to argue that the effects of ecosystem decline are being experienced in every nation and that "we must recognize that the well-being of people and ecosystems is interwoven and that the fabric is fraying" (UNDP/UNEP/World Bank/ World Resources Institute, 2000, pp. viii, ix).

As Barlow (2001, p. 79) stated, there is agreement that "the human race has taken for granted and massively misjudged the capacity of the earth's water systems to sustain our demands upon it," that water is finite, that 31 countries face water stress and scarcity, and that rates of diversion, pollution and depletion have been "astonishing." Disagreement is about the nature of the threat and the solution to it.

This paper has shown some of the ways in which African urban areas intervene in local and regional water cycles through acquiring and disposing of water and using electricity. Further research would detail the effects of this intervention on the affected nonurban societies and ecosystems. Clearly, urban areas are consuming disproportionate amounts of water and contaminating groundwater, rivers and coasts. The costs of this behavior—in both monetary and ecological terms—is high and growing higher. The situation is not sustainable. Dr. Quett Masire, then President of Botswana and Chairman of SADC, stated that

> Our ideals of sustainable development do not seek to curtail development. Experience elsewhere has demonstrated that the path to development may simply mean doing more with less. As our population grows, we will certainly have less and less of the resources we have today. To manage this situation, we will need a new ethic, one that emphasizes the need to protect our natural resources in all we do (Chenge & Johnson, 1994, p. xi).

This "new ethic" is embodied in the "ecosystem approach" called for in the aforementioned UNDP/UNEP/World Bank/World Resources report. Adopting an ecosystem approach means

> we evaluate our decisions on land and resource use in terms of how they affect the capacity of ecosystems to sustain life, not only human well-being but also the health and productive potential of plants, animals, and natural systems. (UNDP/UNEP/World Bank/ World Resources Institute, 2000, p. viii).

To initiate a new water ethic, a call has gone out for a "World Water Contract," in which water will be redefined and revalued in the contexts of scarcity and equitable access for all lives and ecosystems (Petrella, 2001).

There are no apparent methodologies for the complex and interdisciplinary work that is needed to support these new approaches, and the paucity of data limits modeling efforts. A beginning might be made by identifying such fundamentals as urban interventions in the water and nutrient cycles for particular places. Historical Environmental Impact Assessment (Showers, 1996) could facilitate scientists and social scientists working together to establish trends and baseline information that might clarify interactions and, perhaps, shed light on causalities.

No longer is a single-factor analysis sufficient. Integrated, holistic thought is required to plan and implement truly ecologically sustainable, equitable and integrated policies and projects. Urban planners and government officials must appreciate that the boundaries drawn on a map have little relationship to an urban areas's true boundaries, which are defined more correctly by water extraction and disposal. Decisions made about urban water and sanitation must encompass their bioregional consequences, with analysis extended in space and time to include urban–landscape interactions. Most fundamentally, researchers and planners must always ask: "Does it work ecologically?"

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