- institute the environmental monitoring, evaluation and feedback systems on a long-term basis.

- To develop and implement appropriate land use and environmental programs in upper catchments to ensure the continued availability and suitability of water for downstreams use.
- To identify and implement the environmental protection measures across the entire watersheds.
- To expand, improve and coordinate the international assistance to improve the capabilities of Nigeria to assess, manage and protect the environment and natural resources.
- To provide necessary investments to ensure the control of water-borne human disease vectors in irrigated agriculture and polluted water as a source for water supply.

11.2 CURRENT PROBLEMS AND NEEDS

11.2.1 Environmental Problems in the Water Resources Sector

(1) General

The most complex and overriding cause of environmental degradation in Nigeria is poor management and the lack of information regarding quantity and quality of resources, resulting in poor decisions regarding use and renewal of resources (LCBC, 1992). Many water development activities exemplify the tenet that "one action causes many types of problems" in the environmental resources sector.

The overall scope of environmental concerns in Nigeria is significant (i.e., World Bank, 1990), and cannot be adequately addressed within the confines of the NWRMP. Discussion in this section will be limited to those areas of environmental concerns that most directly affect, and are affected by, water resources planning and development. While FGN (1989) listed a total of 14 major sectors and problem areas of the environment, two areas are directly involved in developing the NWRMP: (1) water resources management and (2) land use and soil conservation (JICA, 1992). Several other areas of concern (as expressed in FGN, 1989) indirectly influence the approach to water resources

planning, including: forestry, wildlife, and protected natural areas; marine and coastal area resources; and sanitation and waste management, including effects on human health. These areas of concern are addressed in the following sections.

Several other factors that exert pressure on environmental resources are difficult to address directly in the NWRMP. In general, these factors require long-term solutions at all levels of Nigerian society. The impacts of these factors on environmental resources are briefly discussed below:

- **Population growth.** Increased populations place increased demands on environmental resources to support the population. This growth is due both to birth rates and to immigration from economically-depressed areas outside Nigeria (World Bank, 1990). The increase results in persons, mostly the very poor, being forced to move into unused areas, or areas reserved for other uses, including forests, marginal lands, or slope lands. Use of these areas puts pressure on water resources, wildlife, and fisheries stocks.

  The "National Policy on the Environment" for Nigeria (FGN, 1989) makes reference to concern regarding population growth and concerns over environmental degradation, but does not directly address the problem of the country's burgeoning population, or ways to control it. While concern over environmental degradation is growing world-wide, much of the population growth in the next 60-years will be in developing countries where environmental degradation is already serious. In these countries, the poor often have no option but to consume all available local resources simply to survive (Baum and Tolbert, 1985; Mathews, 1991).

- **Land tenure.** Responsibility for land regulation and management has changed from the traditional local oversight to a "top-down" system of control and allocation. In general, these laws give individuals no stake in proper land management or environmental concerns, including maintaining sustainable harvest rates and practicing soil conservation. Open access has led to overuse of land and water resources. Avenues for landowning that do exist favor development as a condition of ownership, and frequently result in fragmentation of quality lands (Falloux and Rochegude, 1988).

- **Education.** An educated populace is essential for the concepts of sanitation, conservation, and land management to be understood and implemented. For farmers, a large amount of information regarding cropping practices, farming practices, fertilizer use, and

chemicals is necessary. However, education gets relatively low billing in determining sectorial priorities (FMPB, 1988).

- **Jurisdiction.** Effective environmental management requires coordinated effort and a reasonable system of incentives and penalties. Several Government agencies may have jurisdictional authority over the water resources sector. In addition, this authority may be dispersed through the national, state, and local levels. If jurisdiction is ambiguous, no effective monitoring or control of environmental resources is possible; therefore, there is no effective basis for enforcement (World Bank, 1990).
- **Poverty.** With regard to environmental management, poverty generally means that persons have no alternatives to harvesting available resources, even if that harvesting acts to degrade the environment. Use of marginal lands, cutting forests for fuelwood, and use of poisons for fishing are all evidence of the lack of alternate choices faced by the very poor. In addition, this group frequently crowds into the worst parts of large urban areas, where they are susceptible to health problems and diseases.

(2) Drought and Desertification

Desertification represents extreme degradation of soils as a result of many interacting factors. While a drought period can exacerbate the condition, it is not a necessary factor. Water management in arid areas can also be important. In semi-arid environments, a delicate seasonal balance exists between moisture and vegetation cover. A change in this balance can lead to a chain reaction of removal of cover, surface sealing, decreased infiltration, increased surface runoff, and less moisture available for plant growth and groundwater recharge (Alaku, 1991). Soil degradation resulting from vegetation removal, inappropriate agricultural or land use practices, lowered water tables, and depletion of soil moisture and nutrients will result in soil conditions that make normal uses impossible. Naturally-fragile systems are more susceptible to the various factors that promote desertification, and excessive use pressures on marginal lands due to population growth can also promote the condition.

The principal causes of desertification include:

- **Lowered water tables resulting from groundwater overdraft and poor surface water management.** Subsequent sections will

discuss the implications of vegetation removal on groundwater levels. Areas with vegetation removed are more subject to rainfall runoff and reduced infiltration, reducing the amount of recharge going to groundwater. In dry and drought-prone areas, groundwater may be used extensively for potable supplies and agriculture, further lowering the groundwater table (World Bank, 1990).

- Removal of vegetative cover. Removal of vegetation not only decreases groundwater infiltration, but also raises soil temperatures and decreases the ability of the soil to hold moisture. Removal of vegetation may result from overcutting of trees and foliage for firewood, or in putting previously unused land into agricultural production (lands unsuitable for use, or which have been degraded through overuse and deprived of needed fallow period) (World Bank, 1990).
- Overgrazing. Overgrazing can lead to the removal of selected fodder species by herds, which may decrease soil stability. Bushburning is frequently used to clear land for grazing; when young plant shoots begin to later emerge, herds are brought in. However, if grazing is permitted before seed production by the plants can take place, short-term productivity of the area will sacrifice the long-term utility of the land (NEST, 1991).
- Uncontrolled bushburning.

Once the trend of soil degradation and productivity loss begins, the combination of cause and effect results in a spread of the condition to adjacent areas. Groundwater tables continue to fall, infiltration decreases and runoff and erosion increases, and degradation of soils results in a change in mean grain size (toward larger sizes, as smaller grains are mobilized and removed). The soils lose the ability to support certain types of plants, resulting in reductions in numbers of species and plant density (NEST, 1991).

The ultimate results of desertification are a breakdown of the capacity of the soil to support plant growth. Changes in soil chemistry and grain size make the soils susceptible to mobilization by winds; the absence of trees or vegetation to slow wind speeds contributes further to soil movement and, eventually, to dune formation.

(3) Reduced Availability of Flow in Downstream Areas of Rivers

Demand for surface and groundwater that exceeds the available supply will rapidly result in environmental degradation. Common current demands for water include municipal and rural potable supplies, irrigation, livestock and sanitation uses. Additional requirements for industrial water can be significant in localized areas. The natural environment also needs a basic level of supply to maintain existing habitats and resources. Scarcity and misuse of water resources pose a serious and growing threat to sustainable development and protection of the environment (WCU, 1992).

Water resources planning seeks to match these different demands with adequate supplies, both to satisfy the existing situation, and to provide adequate supplies for projected future growth and other uses in all the different sectors requiring water, including the natural environment that people depend on for a variety of other needs. Failure to provide adequate supplies will result in supply shortages, leading in turn to deterioration of the local environment. This failure may be caused by poor or inadequate planning for provision of water resources, unexpected demands for water resulting from severe economic situations (increases in local population due to migration from drought, disease, famine, or war), local drought, or upstream diversion of water resources.

Environmental deterioration resulting from these situations includes:

- reduction in flow or storage volumes of rivers or reservoirs used for potable supplies, industrial processes, livestock watering, and irrigation.
- lowering of the groundwater table in the local area as a result of reduced recharge of groundwater from the rivers or lakes. In most of the coastal regions, local inhabitants depend heavily on groundwater for drinking, due to increased salinization of surface waters in lagoons, creeks, and estuaries as upstream development and flow reductions decrease freshwater influx (Ibe, 1990).
- overdraft of groundwater supplies as additional extractions are attempted to replace water no longer available in rivers and reservoirs. Nationwide, sustainable yields have yet to be determined for most groundwater basins. Available quantities over the basement complex particularly lack assessment. Aquifers

in sedimentary formations in the Sokoto and Chad Formation areas are likely currently overexploited. Along the coastal zone, seawater intrusion is degrading local groundwater supplies (FEPA, 1991).

- reductions in flows of natural springs and seeps as water tables are lowered.
- loss of water-dependent habitats such as wetlands, forests, etc., that depend primarily on natural water flows to maintain a healthy ecological balance.
- loss of hunting and fishing opportunities for local residents as habitat to support these stocks is reduced or eliminated.
- changes in cropping patterns as water availability (including volume, cost, and accessibility) is altered.
- changes in soil fertility, as increasing lack of water reduces the organic component and crop support ability of soils.
- changes in grazing accessibility for both local farmers that maintain livestock, and for nomadic pastoralists that must travel further to less certain water supplies; this situation may result in certain areas being overused by grazing animals, resulting in severe localized degradation of the land.

From a socioeconomic standpoint, this deterioration of the environment results in decreased food availability, makes increased demands on individual labor to acquire adequate supplies (whether for personal use or other economic use), and raises the costs of irrigation or industrial production or farming through the need to expend additional effort and/or funds to acquire adequate supplies. In extreme cases, farmers may be forced to leave the area, to find work on other farms, or to seek opportunity in urban areas (Dugan, 1990).

(4) Watershed Management

As with most problems involving environmental degradation, different manifestations of environmental deterioration are not distinct, but inter-related, resulting from common causes. Several categories of problems discussed under watershed management fall into this pattern; these include soil degradation, deforestation, soil erosion, coastal erosion, wildlife and fisheries losses, and flooding. The areas of concern, while discussed separately, have common causes, with a single action affecting a variety of environmental resources. However, these problems also have similar approaches to solutions

that must be planned and implemented on a watershed basis for the measures to be effective.

(a) Soil Degradation

Loss of productive soils, and reduced capacity of soils to support economically-important uses, is one of the most severe environmental problems facing Nigeria today. Degraded soils reduce fertility and agricultural productivity, render some areas unfit for agriculture, and decrease the quality and availability of water resources by reducing infiltration of runoff water, contributing to erosion, and failing to support vegetation cover.

The primary causes of soil degradation in Nigeria include:

- removal of vegetative cover, especially in forest areas, for agriculture or other uses. Population pressures in Nigeria have forced some persons or groups to move into previously secluded or unused areas for farming activities, grazing, or resource exploitation (Rochette, 1988). These areas are frequently of marginal productivity, having poor soils or being located on slopes or hillsides. The result is frequently overgrazing or overcropping of these areas, leading to further degradation of soils (World Bank, 1990; LCBC, 1992). Soils above the basement complex are generally not well-suited for agriculture (Barghouti and Lallement, 1988).
- removal of topsoil during land clearing, as a result of poor grading or land preparation practices (Baum and Tolbert, 1985). Mechanized soil preparation often compacts soil, decreases infiltration, and increases runoff.
- removal of natural nutrient sources in soils as a result of vegetation removal, cropping practices (i.e., monocropping), and stripping the land of wood (even removal of dead wood lying freely on the ground removes nutrient sources, promotes loss of moisture, and promotes soil degradation and erosion) (Floor and Gorse, 1988). Monocropping, frequently pursued throughout Nigeria, weakens soils. In the past, alternating periods of cropping and livestock allowed the cleanup of crop residues and replenishment of fertilizer by animals (Rochette, 1980; LCBC, 1992); now, artificial fertilizer are frequently used instead of fallow periods and animal uses. Due to lack of education, farmers have poor training in the application

of the products, and use fertilizer inefficiently, which results in excess nutrient runoff and water pollution.

- poor farming practices that fail to conserve the existing soils (cultivation down slopes promoting erosion, etc.).
- reduced availability of natural soil moisture due to restricted water availability and distribution (adverse meteorology), which results in drying out of soils and loss of organics (LCBC, 1992).
- mining and strip mining practices, with no land reclamation or revegetation after operations are completed (LCBC, 1992).
- bushburning.

(b) Deforestation

Tropical deforestation represents another serious threat to long-term environmental sustainability, as well as to much of the rest of the world (Mathews, 1991). Deforestation affects a wide range of other environmental situations, including water resources integrity, soil degradation and erosion, and desertification (Hashidu, 1992).

Historically, most of the southern zone was primary tropical rain forest; less than 10 percent of that area remains in its original forested condition (World Bank, 1990). Pressures of population growth and the need for basic commodities such as fuel and food are the driving forces behind the high rates of deforestation observed in Nigeria and throughout the world. As a result of these pressures, deforestation results from these principal causes:

- uncontrolled development of forest lands for agricultural and other uses. Construction of roads for access to forest areas for logging purposes, even under permit and at sustainable harvest rates, encourages other access (i.e., for cropping, hunting, etc.) (Cruz et al., 1992).
- lack of adequate controls and enforcement on timber harvesting practices. Only 10 percent of forest areas harvested annually for logging are replanted to provide future resources. The remainder is abandoned or left for local inhabitants to put to other uses. The increasing population will continue to apply pressure both to forestry supplies and to land availability for forestry practice (FEPA, 1991).
- continued reliance on fuelwood for cooking and heating. Nigeria's forests are currently exposed to non-sustainable uses such as

logging rates beyond sustainable harvest rates, unregulated fuelwood gathering, and conversion to other land uses such as agriculture. One of the major pressures on these forests is the ongoing need for fuelwood; 90 percent of the country's wood consumption goes for cooking and heating (World Bank, 1990).

- uncontrolled bushburning for clearing land for agriculture or grazing uses. After an area is burned, the next rainfall immediately mobilizes and erodes soils, resulting in sedimentation of rivers and lakes (Baum and Tolbert, 1985). NEST (1991) estimates of the relative susceptibility ratio of soils to erosion as: forest-1, grassland-10, agricultural areas-60, and exposed soil-100, indicating that soils recently exposed to bushburning are 100 times as susceptible to erosion as forested areas.
- mining. Open cast mining results in widespread tree-clearing and despoliation of the land (stripping) (Iwugo and Mahendra, 1992). These practices not only deforest large areas, but lead to erosion and water pollution.

(c) Soil Erosion

Soil erosion represents a widespread problem of localized sites of severe erosion and gully formation, reducing soil productivity and agricultural return, polluting watercourses, and threatening buildings, infrastructure, and lives. Gullies are immediate manifestations of drainage problems that annually consume a significant portion of local, state, and national budgets in stabilizing and reclaiming affected areas. Gully erosion results in dislocation of residents, frequent interruption of services and loss of infrastructure, and significant downstream sediment accumulation and siltation. The principal causes of soil erosion are:

- uncontrolled urban growth, including inadequate drainage infrastructure, removal of watershed vegetation, and increases in impervious surface areas.
- poor design, construction, and maintenance of roads.
- cultivation or other improper uses of unsuitable soil areas on slopes, etc.
- overgrazing of erosion-prone areas.
- mining or other land use practices that fail to emphasize land reclamation and conservation.

In developed areas, especially those built on hillsides, increasing urbanization has resulted in densely-grouped buildings, removal of most vegetation, and increases in the amount of surface impervious to rainfall infiltration. Agricultural practices have emphasized short-term productivity over maintenance of the soil base and conservation, weakening the soils ability to withstand stress. As a result, rain that falls on these areas is rapidly mobilized in surface runoff. The combination of increased water volumes, steep gradients of flow, and the naturally-coarse sandy soils in many areas of Nigeria, has resulted in significant local erosion episodes. In many cases the listed factors are present in combination with inappropriate construction or land-clearing practices, further accelerating the process. This situation has been especially evident in many southern parts of Nigeria, where poor road design and drainage have resulted in some of the most severe erosion sites (World Bank, 1990). Such have been the contributors and causes of gully erosion in the South-East Region (Onwuemesi, 1990). The Ajali sandstone in southeastern region is "loose," with a low silt/clay content. Steep ridges and domes are associated with the adjacent Nsukka formation; both increase the susceptibility of soils to erosion.

Gully erosion in rural areas occurs naturally whenever rainfall runoff, lack of vegetative cover, and sandy soils combine, but these events are generally small, localized, and infrequent. More often, rural erosion events are the result of man's intervention, through inappropriate agricultural practices that expose soils to erosion, removal of vegetative cover, bushburning to clear land, or overgrazing, resulting in vegetation removal and soil degradation (NEST, 1991).

Mining activities have been linked to extensive erosion in the Jos area. In stripping the natural cover off the land, soils are exposed to rapid mobilization and erosion. In the Jos area, tin mining is commonly conducted in streambeds, placing the sites of erosion in areas where runoff water immediately concentrates. Lack of adequate soil conservation practices by mining concerns have led to soil degradation and erosion, resulting in land that is unsuitable for other activities, such as agriculture, after mining operations are concluded (NEST, 1991). In most of the areas, no attempt has been made to reclaim the land subjected to mining; the areas were abandoned in the disturbed state, rendering them unfit for most other uses (World Bank, 1990). Groundwater has been contaminated and water tables lowered in these areas.

Gully erosion was the prevailing problem reported in the NWRIS. Isu Associates (1993) reported on the numbers of erosion control sites in several States (Anambra-68; Cross River-102; Imo-158; Abia-247, including severe sedimentation in streams and interference with water supplies; Akwa Ibom-111). Gully erosion was reported as a problem in several States, but not quantified, in DeCrown (1993). Enplan (1993) reported that in the North-West Region gully erosion was not a significant problem, with only 9 projects reported (plus 15 proposed projects). In the North-East Region, only Adamawa State was listed as having gully erosion problems (WADSCO, 1993). TCI (1993) reported gully erosion problems in Benue and Bauchi States, the latter due primarily to mining activities.

(d) Coastal Erosion

Coastal areas of Nigeria are threatened by a variety of human activities that act to degrade the local environment and increase the frequency and magnitude of coastal erosion. These threats include industrialization, urbanization, intensive farming, land subsidence, and effluent discharges of sewage, industrial wastes, petroleum wastes, dredged materials, and solid wastes (FEPA, 1991). The primary causes of coastal erosion include:

- reduced freshwater influx into coastal and estuarine areas as a result of upstream diversions.
- overexploitation of resources and removal of vegetation in the watershed area.
- reduced sediment influx as a result of upstream modifications.
- poor conservation practices in the oil and minerals development sector, including land subsidence in the affected areas.

The coastal mangrove zone is one of the richest ecologically-productive zones in the world (World Bank, 1990), covering more than 9,000 sq. km (Ibe, 1990). Mangrove forest areas provide a wide variety of environmental benefits, including shoreline stabilization, erosion control, storm protection, and water transport for local trade (Dugan, 1990). These areas also provide sanctuary for birds and other wildlife, a nursery areas for fish and shellfish that are an important part of most Nigerian's diets (Ibe, 1990), and provide wood for fuel and construction for coastal inhabitants (Amadi, 1992).

Coastal areas represent the terminus of the many rivers that flow from the highlands to the sea. Any diversion of runoff flows in upstream portions of the watershed (for water supply, irrigation, etc.) results in reduced volumes of water reaching the coastal delta areas. This runoff flow brings with it a load of sediments that are deposited in coastal deltas, replenishing areas eroded by tidal and wave action.

Interruption of the natural cycle of accretion and erosion is exacerbated by local human activities. The fragile coastal ecosystem is increasingly subjected to human development uses, including urban expansion, waste disposal, minerals exploration, and exploitation of the resources of the area (World Bank, 1990). More than 25 percent of Nigerians now live around seven major coastal cities, and this increase in coastal population has been accompanied by increasing numbers of industries located in coastal areas for access to labor, materials, and water, in increases in volumes of waste generated, and in the need for land and infrastructure to accommodate this population (Amadi, 1992). Most of these industries discharge their waste effluents untreated into lagoons, rivers, and lakes in the coastal zone. The situation has led to overharvesting of local resources and degradation of the environment (Amadi, 1991).

The cover of vegetation that grows in the coastal zone is critical to the stability of the region. Environmental changes that damage or reduce this cover threaten that stability. Oil spills contribute to coastal erosion and degradation by killing vegetation that stabilizes soils in the area (NEST, 1991). Changes in salinity gradients in the coastal areas can also affect this vegetative cover. These gradients are governed by both tides and seasons; salinities are lower during the runoff period of the rainy season. Construction of access canals for oil exploration introduces higher-salinity water into lagoon and delta regions, changing the balance of flora (and fauna) and promoting erosion (Amadi, 1992). Saltwater intrusion in groundwater as a result of decreased infiltration also affects vegetation (Ibe, 1990).

Other factors contributing to coastal erosion include construction of dams on upstream rivers that traps sediments and starves coastal areas and beaches, and removal of vegetation or overgrazing on upstream grasslands that reduces infiltration and increases volume of surface runoff (Ibe, 1988). Reclamation of coastal wetlands through hydraulic sandfilling for urban

growth or highway construction is the primary cause of habitat loss in the coastal zone (Ibe, 1988; Amadi, 1991, 1992). Oil exploration and development activities also result in subsidence of coastal lands following withdrawal of these resources. This process of lowering of the effective land level further exposes these areas to erosion by tidal action (Ibe, 1988, 1990).

Salt water intrusion into local aquifers is a significant problem in coastal areas (Oteri, 1989). The uncontrolled development of the Coastal Plains sand aquifer in the Lagos area has resulted in saltwater intrusion. Overdevelopment is the major cause of salinization in most coastal areas; coupled with reduced river flows, the cumulative effect of overdevelopment and land reclamation has been a significant increase in instances of saltwater contamination of coastal aquifers.

(e) Wildlife and Fisheries Losses

Most of the residual wildlife faunal resources are to be found in the northeastern and southeastern border areas of the country. Wildlife is fast declining due to habitat loss and to unregulated hunting and poaching. In recent times, the cheetah, the pigmy hippopotamus, the giraffe, the black rhinoceros, and the giant eland have all virtually disappeared.

A variety of animal species are still prevalent in Nigeria. For instance, it is estimated that there are currently 20 or more species of highly-diverse primates, half of which are constantly under threat. Two primate species, the white-throated guenon and the sclaters guenon, are prevalent in Nigeria. Many species of mammals (about 274), birds (839), frogs (109) insects (20,000 species), and snakes (110 species) are still to be found in Nigeria.

Nigeria has about 40 game parks and wildlife reserves. These harbour several rare species of animals, which include gorilla, forest elephants, buffalo and leopards, which are currently being treated as endangered species of animals which should be protected from the threat of extinction caused by mass hunting and unrestricted forest devastation. In Nigeria, Decree No.85 of 1985 was promulgated to protect the most endangered animals.

While wildlife and fisheries concerns are not directly tied to degradation in the water resources area, policies that promote sustainable

development of water resources also act to promote benefits in wildlife and fisheries sectors (i.e., water quality and supply, watershed management, etc.). Degradation of water resources also affects the wildlife and fisheries sectors. Degradation in the wildlife and fisheries sectors is primarily due to:

- habitat loss.
- changes in water availability.
- unrestricted access to many natural areas by local inhabitants.
- urban encroachment/deforestation.

Habitat loss can be the result of many factors (World Bank, 1990). Direct habitat loss for wildlife results from deforestation (either through non-sustainable logging practices, or through clearing of forest for agricultural or grazing uses) and urban encroachment (as a result of lack of adequate planning or failure to enforce land use guidelines). Changes in water availability (lowering of the groundwater table, restriction of access, changes in surface flow patterns) can alter the carrying capacity of lands that remain accessible for wildlife, reducing the total numbers that can be supported. The need for protein in the diet of an increasing population drives an increasing incidence of hunting and poaching in areas designated for wildlife protection. The remaining concentrations of endangered wildlife occur mainly in undeveloped areas. These are also areas of significant water potential and available land; future development will put these areas, and as a result the wildlife associated with them, at risk (i.e., Ikom [Oban], Katsina-Ala, Mambilla, etc.).

For fisheries, habitat loss can result from a variety of upstream activities, including dam building (reducing flows and, as a result, inundated area), water diversions(reducing flows), upstream waste management practices (pollutants and trash affecting water quality), upstream development (erosion causing increases in turbidity; sedimentation burying habitat and reducing water depths), or urban encroachment (sandfill or land reclamation destroying lagoon areas) (NEST, 1991). Changes in water availability result in many of the same habitat changes, and also reduces the flushing and renewal actions of natural water systems. Increasing needs for fish protein also encourages overfishing of existing resources, without regard for sustainable yields.

Fisheries losses also result from water pollution (Akpan and Anadu, 1989) and mining (Iwugo and Mahendra, 1992). Runoff to rivers as a result of agricultural lands drainage, or discharge of domestic and industrial wastes is common. Occurrence of macroinvertebrates in streams has been observed to be lowest just below areas of significant drainage/runoff inflow (Akpan and Anadu, 1989), while being higher upstream and downstream of the point of contamination. Downstream, a greater number of habitat types, and therefore potential energy sources for other species available as food, was observed. Problems associated with the leaching of tailings piles, and from disposal areas, around mining activities result in the killing of fish and reduction of river populations (Iwugo and Mahendra, 1992).

A number of efforts are in place to promote increases in wildlife and fisheries habitats and populations (Hashidu, 1992), but it is uncertain whether these programs can reverse the recent decline in these areas. Where stock or habitat management plans are in place, they are frequently either inadequate or not enforced. Reforestation programs in the Federal Department of Forestry currently reclaim only 1 ha for every 10 ha that is logged each year, and stated targets for shelterbelt planting, plantation development, and afforestation are not being met. Management programs exist in only a few of the national parks and game reserves, and all of these areas are under pressure from development schemes, unrestricted encroachment, and diversion of resources to other national priorities. Integrated management of urban planning, water development, and habitat protection are needed to protect sensitive wetlands, lagoon, and coastal estuarine habitats.

While local fisheries supply only one-third of national demands, artisanal coastal fisheries supply the majority of local production. Estimates of the contribution of coastal artisans range from 60 percent (NEST, 1991) to more than 90 percent (FMAWRRD, 1988; Amadi, 1991). However, recent trends in catch per unit effort indicate that marine fisheries are overfished and overexploited (Amadi, 1991; FEPA, 1991).

DeCrown (1993), Enplan (1993), and TCI (1993) did not report information on fisheries for the Regional Technical Inventory Surveys. WADSCO (1993) indicated only that reduced water supplies were affecting fisheries. Isu Associates (1993) reported extensive problems with lack of adequate water for fish culture activities during the dry season in seven states.

Fish culture operations in Imo, Enugu, and Abia States reported problems with water pollution.

(f) Flooding

Flooding in general results from poor watershed management (Sangodoyin, 1989). In the city of Ibadan, flood damage has been observed as a result of the building of settlements too close to water courses. Upstream development and reduction in impervious area results in greater volumes of runoff. As a result, downstream areas receive greater runoff in stretches of the river that can no longer accommodate historic flows, and flooding occurs.

Several areas reported problems with flooding in the Regional Technical Inventory Surveys. The delta area of Rivers State floods during 4 to 5 months each year (Isu Associates, 1993). In the South-West Region, Oyo, Ogun, and Osun States reported short periods of flooding (a few days); some dredging projects are planned to control flooding (DeCrown, 1993). Enplan (1993) reported that 7 flood control and one river training projects were ongoing, but did not specify locations. TCI (1993) reported flooding along the Benue River. WADSCO (1993) reported most extensively on flood control and river training projects. The CBDA plans to channelize an 8.2 km length of the Yedseram/Ngadda River to augment flows to the Alau Dam for water supply for the city of Maiduguri (this project was listed under "Flood Control"). Proposals exist to widen and dike the Hadejia River in the Gashua area, and for diking and deepening of the Hadejia River (60 km) and Kefin Hausa River (40 km).

(5) Water Pollution, Water Hyacinth, and Eutrophication

Adequate water availability is obviated if the available supplies are not able to be used for the required purposes. The resulting lack of quality water can result in shortages in municipal or rural potable supplies, health problems for consumers, increased costs for treatment of supplies, increased costs for industrial users, loss of wildlife, and reduced crop yields (WCU, 1992).

Water Quality Standards and Monitoring. Nigeria currently has no national water quality standards, and none of the State Water Boards or Corporations is known to have established and developed its own water quality standards. The WHO International Guidelines have remained the only

reference for assessing water quality in Nigeria (FGN, 1991). There are indications that these international guidelines for drinking water are being routinely met in most of the large water-treatment plants in the urban areas. Operation and maintenance schedules of water treatment plants in rural areas are such that the international standards are unlikely to be met regularly.

There is no national water quality monitoring agency which currently initiates, plans, executes or coordinates water quality monitoring and data-gathering and related activities. Each State Water Board or Corporation has at least one laboratory for routine water analysis. Ad-hoc water analyses are also carried out as part of the wider research activities of some university departments and research institutes. Government parastatals, industrial organizations, and engineering consulting bodies also undertake occasional water analyses as part of their water resources projects. Under the River Basins Development Acts of 1976, the RBDAs are empowered to control pollution in rivers and lakes in their respective areas, but this function remains severely neglected.

The available water quality data of Nigeria are, therefore, a conglomeration of the uncoordinated activities of these various bodies and organizations. They show that most unpolluted groundwaters and surface waters are generally characterized by the following:

(a) low total dissolved solids concentrations(less than 200 mg/L);
(b) pH less than 7.0 for groundwaters and pH of about 7.0 for surface waters;
(c) low alkalinity (less than 40 mg/L as CaCO3);
(d) low total hardness (less than 60 mg/L as CaCO3);
(e) iron content (0.10 to 20.0 mg/L);
(f) high carbon dioxide content (for groundwater only);
(g) high turbidity (for surface waters only).

Available geological and hydrogeological information seems to support the observations of low concentration of total dissolved solids and the general "acidic" property of Nigerian waters. Bacteriological analyses of water sources and potable waters are not as widely and routinely carried out as are

physical-chemical analyses of water in most Government and non-governmental laboratories. However, total coliform and faecal coliform counts of up to 1,500 per 100 ml are not uncommon in poorly constructed hand-dug shallow wells and unprotected water supply streams located in the low-income and congested areas.

The water treatment implication of the currently available water quality data of the various water sources is that, apart from the removal of such obvious impurities as turbidity, iron, and micro-organisms (coliforms), it may also be necessary to stabilize the water by increasing its pH and alkalinity so that it does not corrode potable water distribution pipes, which are predominantly asbestos cement, cast iron and steel pipes. Water treatment technology options must take notice of this additional water treatment objective.

The causes of water quality degradation include:

- uncontrolled or untreated discharges from industrial processes or waste handling, containing toxic materials entering water supplies or areas important for fisheries. These discharges include sewage, industrial effluents, and solid waste.

  In many urban areas, values for many water quality parameters considered as standards exceed recommended levels, including solids, pH, ammonia, oxygen demand (BOD), and iron (FEPA, 1991; FGN, 1991). High levels of nutrients in these discharges lead to eutrophication and proliferation of aquatic weeds, including water hyacinth. Industrial discharges include metals, organics, chemicals, and agents with high oxygen demand from such locations as canneries, pulp mills, and waste facilities. These agents can also be mobilized by rainfall and washed into adjacent water bodies. Immediately evident effects can include strong odors and fish kills (NEST, 1991).

  Recent surveys indicate that more than 80 percent of Nigerian industries discharge solid, liquid, or gaseous effluents untreated to the environment (World Bank, 1991a). Industries are currently implementing waste handling and wastewater treatment measures primarily on a voluntary basis; specific discharge information provided by those industries indicates that compliance with standards is unsatisfactory (Aina and Adepipe, 1992).

  Contaminated water is frequently associated with urban areas, where industry is concentrated, and handling of human and solid

waste, especially in poor areas (World Bank, 1990). But water pollution in urban areas can be significant far downstream from cities. Wastes are transported to rivers and lakes, infiltrate into groundwater, and enter the coastal zone's lagoons and estuaries.

- unwise land use practices (farming, land clearing, road building, overgrazing, etc.) that result in increased rates of soil erosion, which enters water supplies.
- improper or unsafe practices in applying fertilizers, herbicides, or pesticides related to agriculture (FEPA, 1991). The "Feed the Nation" campaign of 1976 began the extensive unregulated use of inorganic fertilizers in Nigeria (NEST, 1991). Commonly used nitrogen/phosphorus/potassium (NPK) fertilizers are ill-suited to the sandy and acidic soils common in Nigeria, resulting in poor uptake by crops. Applied fertilizers eventually are mobilized by rainfall runoff and wash into water bodies. The situation is worsened when local farmers, unfamiliar with safe handling practices and unaware of the low uptake rates, overapply the fertilizers, resulting in increased pollutant runoff (NEST, 1991). Pesticides and herbicides are more recent, but no less dangerous, threats to water quality. Unregulated and improper use of crops and plants can lead to mobilization and transport to water bodies. In the current poor economic climate, some individuals have gone so far as to use these chemicals in hunting and fishing (NEST, 1991).
- proliferation of aquatic weeds that reduce water circulation and the dissolved oxygen required to maintain a healthy aquatic environment.

In recent years, studies of water pollution have become more common, pointing to the need for continued focused studies on the problem. Concentrations of nitrate in groundwater in boreholes near villages in Upper Benue River area exceeded 100 ppm; these levels were blamed on poor sanitation practices, poor waste disposal practices, and lack of education (Mbuno and Ibrahim-Yusef, 1993). In the South-East Region, very high nitrate and nitrite values in both surface and groundwater, as well as in food, were attributed to large-scale uncontrolled applications of fertilizers for agriculture (Egboka and Ezeonu, 1990). The observed levels exceeded recognized standards, and were at levels historically correlated to increased incidences of diseases and cancers. Such occurrences are common in developing countries trying to increase food supplies to feed their populations; these cases are generally attributed primarily to lack of knowledge by farmers, and inadequate

contact by local extension agents to disperse information regarding proper application and use of fertilizers.

Similar problems were noted by (Ojiegbe, 1990). In Imo State, in the Cross River basin, fertilizer runoff was contaminating both surface and groundwater. Sampling of river water before, during, and after fertilizer application (during the farming season) indicated that wells and streams displayed steadily-increasing concentrations of nitrates, due mainly to poor application techniques and improper fertilizer loading ratios. High nutrient levels in water, whether as a result of fertilizer runoff or disposal of untreated waste, promote algal growth and lead to eutrophication, fish kills, and proliferation of aquatic weeds.

Similar problems surround the use of pesticides as well as fertilizers (Atu, 1989). Pesticides are used for pest control in rice fields, but are often used directly for fish kills and harvesting. Fertilizers that are improperly applied wash into water sources. Handling of these materials is also a problem, resulting in frequent spills, fires, and improper disposal.

Contamination of water supplies due to improper waste management practices is a continuing problem. At Ahmadu Bello University in Zaria, faecal coliforms and faecal streptococci in well water exceeded WHO standards (Okuofu, et al., 1990). High levels of ammonia-nitrogen and iron were also observed. These pollutants were from both human and livestock sources. Poor well construction and maintenance practices were blamed; wells were uncovered, with unlimited access.

Many Nigerians use hand-dug wells near watercourses as a water supply; however, streams are also used for waste disposal. Sampling in Ibadan in seven areas along streams indicated that the farther downstream the sample was collected, pollution levels increased; lack of sanitary waste disposal was a major contributor to the problem (Sangodoyin, 1989).

Pollutants in shallow aquifer wells in Onitsha were traced to leachates from solid waste/refuse dumps (Ojiako, 1989), resulting from uncontrolled land disposal of solid wastes. Major pollutant problems are associated with leaching of tailings piles and disposal areas in mining areas (Iwugo and Mahendra, 1992). Open cast mining results in deforestation and despollation of the land

(stripping); large-scale excavations cause local subsidence, lower the groundwater table, and result in leaching from tailings that kill fish and reduce river populations. Slurry pumped from mines also silts and contaminates rivers.

Very few sewage treatment plants exist in Nigeria. None were discussed in the Regional Survey reports. Sewage treatment helps to reduce the local nutrient loading in watercourses.

(6) Oil Pollution in the Niger Delta Region

In the last 30 years, Nigeria has experienced increased activities in the areas of oil exploration and exploitation, refining and products marketing operations. While these activities have generated immense financial benefits for the country, the oil industry operations have also created serious health and environmental problems in general and introduced the pollutants as liquid discharges and oil spills into the water environment in particular. The environmental impact of these activities has been of concern to both the Government regulatory agencies and oil company operators; therefore, various monitoring and control programs have been formulated and implemented to ameliorate environmental problems associated with the oil industry.

Crude oil exploration and marketing activities are mainly concentrated in the Niger Delta region. Oil exploration and production activities are carried out in the designated oil concession areas duly leased out to various oil companies operating under joint venture agreement with the Nigerian National Petroleum Corporation (NNPC). Currently, Nigeria is producing the crude oil at an average of 2 million barrels per day within the constraints of the production quota imposed by the OPEC, and there are three refineries located at Port Harcourt, Warri and Kaduna.

Various materials are released into the environment in the the course of oil production operations. These include:

- drill cuttings, drilling mud, and fluids used for stimulating production;
- produced fluids: oil and water, and chemicals injected into them to control corrosion or assist the separation of oil from water; and
- general industrial waste.

Despite careful precautions, accidents do occur periodically in the drilling for and exploitation of oil. These accidents have been shown to result from the equipment failure and human error. It is known that majority of the oil spills occurred through accidental discharges attributed to equipment failure such as malfunctioning, over-loading, corrosion or abrasion of parts. "Nigeria's Threatened Environment" (NEST, 1991) indicates that:

- Oil spills are common wherever petroleum is exploited,
- In 1970, there was one oil spill of 150 barrels; a year later there were 14 involving 15,110 barrels.
- In 1974 there were 105 oil spills; another 154 in 1978; 241 in 1980; 216 in 1982.
- In the 13-year period from 1970 to 1982, a total of 1,581 oil spills involving nearly 2 million barrels of oil were reported in Nigeria.

Although there is no data available on the environmental impacts of oil spills, they may include:

- loss of aquatic fauna and flora;
- loss of drinking, industrial and irrigation water;
- destruction of farmlands;
- health hazards; and
- loss of property of human population in affected areas.

It has been generally reported that a great percentage of these oil spills occurred in sensitive environments in onshore and offshore areas of Nigeria, and the effects of these spills have been catastrophic in many respects depending upon the oil dosage, the oil type, meteorological conditions, physical geography of the area and the biota; in particular, majority of the oil spill incidents occurred in the purely mangrove swamp zones and the offshore areas of the Niger Delta which constitute the most productive biological areas.

The oil industry has undoubtedly brought the economic benefits to many of the Nigerian people, but it has left in its trail a complicated mix of the environmental pollution problems, the most notable of which being oil pollution. Public policy relating to the socio-economic and environmental considerations should be the most important factors in the continued

exploitation and utilization of the petroleum industries. Environmental quality considerations should constitute the essential criteria in any policy formulation for the oil industry. To date, the environmental policy objectives for this sector have been incorporated in various recommendations on oil pollution prevention and control which emanated from several international and domestic seminars on the petroleum. These policy issues and objectives included (1) the enactment of legislation, (2) the environment impact statement (EIS) and environment impact assessment (EIA), (3) the national contingency plan, (4) the long-term monitoring and surveillance, (5) socio-economic and health aspects of environmental impacts, (6) the funding for damages resulting from oil pollution, and (7) environmental awareness and education.

The Government policies for amelioration of the environmental problems associated with the oil industry have been embedded in the various sections of the Petroleum Decrees and Regulations, and recent efforts have been directed towards the enforcement of the provisions of these legislations through effective monitoring programs which include the oil-spill control and effluent discharge monitoring programs. As a matter of fact, the FEPA is putting together the comprehensive guidelines capable of ensuring the standards of treatment, storage and disposal of waste generated in the course of oil production, in conjunction with the Petroleum Ministry. Already the Petroleum Decrees have been enacted to deal with erring companies, under which where any offense is committed by a body corporate, or by a member of a partnership of other persons concerned with the management of such firm or business, shall on conviction be liable to fine not exceeding ₦ 500×10^3. It is of many public opinions that there would be difficulties in the implementation of these provision for some political reasons, and these would hardly be adequate for the preservation of the environment from oil spillage.

(7) Water-Related Diseases

Tropical climates have historically been subjected to a wide variety of disease organisms and vectors. The exposure cycle for many of these diseases revolves around water, generally found in abundance in tropical areas. The occurrence of this wide variety of diseases is not unexpected; however, recent evidence indicates that an unwanted side effect of some types of water projects is an increase in some disease rates.

- **Water-borne diseases.** Formation of large stationary water bodies, such as reservoirs for irrigation projects, and distribution systems that promote slow-moving water with fringe aquatic vegetation (irrigation canals, etc.) are habitat favored by vectors, producing microclimates which enhance parasite transmission (Abdulmumin, 1992), primarily schistosomiasis and malaria. Field studies near irrigation projects have found evidence of higher incidence of vectors near reservoir areas (compared to areas farther away), poorer overall health of children, and higher incidence of diseases (Abdulmumin, 1992). Populations displaced by reservoir projects also run increased risks of exposure to communicable diseases in the relocation area.

  Disease transmission through water is also common in crowded urban areas with poor or inadequate infrastructure supporting too many inhabitants. This situation is exacerbated by improper waste disposal, unsanitary conditions, and concurrent use of local water bodies for both consumer use and waste management. Human health can also be affected by toxic materials in the water they use, resulting from agricultural chemicals in water supplies, discharges of untreated industrial effluents, or improper disposal of toxic wastes.

Limited studies have demonstrated evidence of increased water-related disease rates following implementation of water projects (Iwugo, 1992). In studies in the area of the SCIP, schistosomiasis was observed in 31 percent of the irrigation workers surveyed, a rate significantly higher than was observed in previous surveys for Borno Nigerians in general (Betterton and Fryer, 1987).

Water related diseases are generally classified into four main types:

- Water-borne diseases which are spread through water supplies by ingestion (faecal-oral route); examples are typhoid, cholera, diarrhoea and dysentery which are all now endemic in all the 30 States of Nigeria.
- Water-based diseases which are spread through an aquatic invertebrate animal (e.g., worms, including flukes and trematodes). Most depend on aquatic crustacean hosts (called intermediate or secondary hosts) for their transmission. Faeces or excreta from infected humans contain worm eggs, which enter the secondary crustacean hosts through the contaminated water. Parasite larvae emerging from the intermediate host are able to bore through human skin, and thus are transmitted to humans by direct skin contact with water. One important water-based disease, schistosomiasis (bilharzia), is dependent on Bulinid snails as the main secondary host, and it has been widely observed in some

water resources development projects (e.g., the Kainji Dam Hydropower project, the Bakolori Dam project) in Nigeria. Another water-based disease, drancunculiasis (guinea worm) infection, is transmitted by ingestion of water containing the microscopic crustacean secondary host of the disease (Cyclops species). Guinea worm is still very prevalent in all the 30 States of Nigeria, where over 600,000 persons were estimated to be infected in 1989, with the highest reported incidence being in Kwara (including Kogi) State, Anambra (including Enugu) State, Borno State, Sokoto State and Ondo State. The disease organism leaves the secondary host once it is inside the primary host, the human body.

- Water-related insect-vector diseases are transmitted by insect vectors which breed around or in water. Mosquitoes, tsetse flies (Glossina species) and Simulum species are the most important vectors of water-related diseases; they carry a wide range of infections including malaria, sleeping sickness, onchocerciasis (river blindness) and viral diseases. The diseases are transmitted when the insect bites an uninfected human. Several of these diseases are prevalent in areas where water resources development projects have been implemented. Malaria is endemic as a result of poor drainage systems.
- Water-washed diseases result from inadequate provision and use of water for personal hygiene. The most important water-washed diseases are diarrhoeas transmitted by a faecal-oral route; others include skin ulcers, scabies, skin fungus infections, and trachoma. Ironically, scabies or a skin fungus infection has been reported among the farmers resettled as a result of the construction of the Bakolori Dam in the Sokoto-Rima Basin.

Table 11-1 summarizes the major types of water-related diseases and their preventive strategies.

In addition to the water-related diseases, which are essentially communicable or infective diseases, water resources development projects can also have other environmental health impacts:

- surface water may be contaminated by chemical substances such as fertilizers and pesticides, which are intentionally used in the project to boost production, but the unregulated use of which may result in toxic effects in humans using the water for drinking, cooking, fishing, etc., and also in water pollution (e.g., eutrophication and excessive weed growth);
- increase in salinity in surface or groundwater; and
- a rise in the water table (resulting in water logging) and alkalinity.

TABLE 11 - 1 CLASSIFICATION OF WATER-RELATED INFECTIONS AND PREVENTIVE STRATEGIES APPROPRIATE FOR EACH TRANSMISSION

Category	Examples	Preventive Strategy[1]
Water-borne infections		
(a) Classical	Typhoid, cholera	• Improve quality of drinking water.
(b) Non-classical	Infective hepatitis	• Prevent casual use of other unimproved sources
Water-washed infections		
(a) Skin and eyes	Scabies, trachoma	• Increase water quantity used
(b) Diarrhoeal diseases	Bacillary dysentery	• Improve accessibility and reliability of domestic water supply • Improve hygiene
Water-based infections		
(a) Penetrating skin	Schistosomiasis	• Decrease need for contact with infected water[2]
(b) Ingested	Guinea worm	• Control snail populations[2] • Reduce contamination of surface water by excreta[3]
Infections with water-related insect vectors		
(a) Biting near water	Sleeping sickness	• Improve surface water management
(b) Breeding in water	Yellow fever	• Destroy breeding sites of insects • Decrease need to visit breeding sites • Use mosquito netting
Infections primarily resulting from defective sanitation		
	Hookworm	• Improve excreta disposal practices

1 Strategies apply to all examples in that category.
2 Applies to schistosomiasis only.
3 The preventive strategies appropriate to the water-based worms depend upon the precise life cycle of each, and this is the only general restriction that can be given.

(8) Socio-Economic Impacts

The most important economic issues dealing with water resources development are resettlement problems. Resettlement of local inhabitants is necessary to accommodate large water-related projects such as reservoirs and irrigation systems. This resettlement is a common source of significant financial drain on these projects.

For construction of the Kainji Reservoir, more than 44,000 people were displaced; approximately 6,100 persons were displaced for construction of the Jebba Reservoir. In both cases, NEPA constructed new houses for the displaced residents, who were primarily farmers. However, the locations of the lands to which the Kainji area farmers were relocated were not a good substitute for the fadama lands flooded by the reservoir, having infertile soils, poor access, and no

infrastructure to support irrigated farming. The same was true in the Jebba relocation area; in addition, the Jebba Reservoir inundated a region of clay-rich soil that local villagers had used to make pottery.

Studies in areas downstream of these projects have indicated reduced water availability, restriction of viable agriculture areas (a shrinking of the fadama), and lowered fishery yields. The rate of farmers abandoning their land is high, as evidenced by the trend over time toward larger plot sizes in the KRIP area, as farmers take over abandoned adjacent plots. During project construction, access to fields may be lost for up to several years, requiring compensation not only for land lost, but also for crops that could not be grown (Thompson, 1992).

Other environmental concerns dealing with construction of large water projects and resettlement of inhabitants include creation of slum areas used by workers, merchants, and others, having no sanitation or other facilities. In general, sites used for construction materials in these areas are not reclaimed after use, leading to land degradation and erosion.

(9) Lack of Environmental Impact Assessment for Water-Related Projects

Water resources projects may initiate or exacerbate environmental degradation and loss of environmental resources. A lack of historic emphasis on environmental needs has allowed the natural environment to degrade. Historically, little coordinated statutory or enforcement structure has existed to safeguard the environment. Projects have historically been implemented with no focus on environmental problems. There has been a lack of coordination between responsible Ministries for projects that affect wide sectors of the economy and populace.

Table 11-2 shows the comparative severity of environmental problems in each of the six regions addressed in the NWRMP. The table focuses on the environmental problems identified in this section of the NWRMP report, and deals with the problems in terms of river basin management. The level of environmental problems indicated in the table points to the need for coordinated management of environmental resources, including careful determination of the potential effects of water-related projects in areas already suffering environmental degradation.

TABLE 11-2 COMPARATIVE SEVERITY OF EXISTING ENVIRONMENTAL PROBLEMS ASSOCIATED WITH RIVER BASIN MANAGEMENT FOR THE NWRMP

Environmental Problem	NW	NE	CW	CE	SW	SE
Drought/Desertification	3	3	2	1	1	1
Watershed Management						
Soil degradation	3	3	2	1	1	2
Deforestation	3	3	3	1	3	3
Soil erosion	1	1	1	1	2	3
Coastal erosion	1	1	1	1	3	3
Wildlife/Fisher losses	2	2	2	1	3	3
Flooding	2	2	2	2	3	3
Reduced Water Availability Downstream	3	3	2	1	1	1
Water Pollution	1	2	2	1	3	3
Water Hyacinth/Eutrophication	1	2	2	1	3	2
Water-related Disease	2	3	3	2	3	3
Socio-Economic Impact	3	3	3	1	1	1

Key: 3 = severe; 2 = moderate; 1 = minor

11.2.2 Environmental Problems Associated with Water Resources Projects

There have been a number of notable cases of adverse environmental impacts, particularly water-related diseases, resulting from water resources development projects. In recognition of these problems, the JICA Team recognized that due emphasis need be given to the major water resources-related environmental problems, and the need to combine environmentally-sound management approaches with sustainable development (LCBC, 1992). Environmental problems and impacts associated with drinking water supply, river basin development, reservoir development and dam construction are indicated as the major areas of concern, and are displayed in Table 11-3 and discussed in detail below.

The NWRIS summarized the general environmental situations and problems related to the water resources sector. The scope of the surveys (JICA, 1992b) was limited to existing or proposed water resources projects. Based on the general requirements of the Terms of Reference under which the surveys were conducted, little specific information is available to evaluate environmental conditions at and around water projects in Nigeria. The primary reasons for this include:

- this type of information has historically not been a priority for monitoring and collection.
- few, if any, coordinated data collection programs exist in the several ministries dealing with water-related problems.
- unreliable recording and record-keeping prevents widespread use of existing information.

TABLE 11-3 MAJOR IMPACTS OF WATER RESOURCES DEVELOPMENT ON THE ENVIRONMENT

Environmental Parameter	Development Projects				
	Dams and Reservoirs	Irrigation	Inland Waters/ Coastal Zone	Water Supply	Drainage/ Sewerage
Surface water hydrology	3	1	2	3	3
Surface water quality	2	3	3	2	2
Groundwater hydrology	2	2	2	1	1
Air quality	1	1	2	2	2
Erosion/sedimentation	3	2	2	2	2
Thermal stratification	3	1	1	1	1
Geology/seismicity	3	1	1	1	1
Drainage and salinity	3	3	1	1	1
Soil fertility	2	2	1	1	1
Fisheries	3	3	3	3	2
Terrestrial wildlife	2	1	2	2	1
Forests	2	1	3	2	1
Navigation	2	1	2	1	1
Land use	3	3	1	1	1
Nutrition	3	3	1	1	1
Flood control	2	1	1	3	3
Highways/railways	2	1	1	1	1
Archaeological significance	2	1	1	1	1
Resettlement	3	1	1	1	1
Aesthetics	2	1	1	1	1
Public health	3	3	2	1	1
Socio-economic Impact	3	3	3	2	2

Key: 3 = severe; 2 = moderate; 1 = minor or negligible

Several programs are proposed or underway to improve the collection, recording, handling, and evaluation of environmental information. Most of these programs are funded by international agencies (World Bank, AfDB, EEC, and others), and are designed to strengthen the capabilities of Nigeria's water-related Ministries to gather, handle, store, and assess environmental information. This type of information is essential to future planning and implementation of decisions regarding the development of water resources.

(1) Multipurpose Dam Projects

(a) General Environmental Problems and Impacts

Dams are built and reservoirs are created for:

(i) electricity power generation;
(ii) water supply for irrigation, domestic, and industrial uses; and
(iii) flood control.

The environmental problems and impacts of dams constructed for any of or a combination of these purposes are similar, and are shown on Table 11-4.

Dam projects are highly complex and are all likely to have significant environmental impacts and require extensive environmental documentation. The nature of the adverse impacts is mainly determined by project siting. The magnitude of the environmental impacts usually depends on the size of the reservoir. Small dams or "mini-hydro" schemes have considerably less impact on the environment than projects involving large dams. However, the cumulative impact of a large number of small dam projects on the same river should not be underestimated.

Some of the major environmental impacts associated with dam and reservoir projects are briefly discussed below, while a detailed list is provided as Appendix-6.

(i) **Changes in hydrology:** Dam operation activities have an important impact on the downstream river flow. In coastal areas, a considerable decrease in river flow may cause saline waters to penetrate further upstream, and therefore may affect the flora and fauna of the lower river and the river banks. Changes in flow rates and volumes in streams cause stream channel erosion, contributing to downstream siltation and sedimentation.

(ii) **Resettlement:** The magnitude of the resettlement impact depends on the number of people living in the future reservoir area who must be relocated. Both tangible and intangible types of impacts must be considered.

(iii) **Loss of agricultural land:** If agriculture exists in the future reservoir area, land will be lost as a result of inundation. The magnitude of the impact depends on the area of the land lost and the value of the crops under production.

(iv) **Loss of infrastructure and housing:** The magnitude of this impact depends on the number and value of human settlements lost when the reservoir area is flooded. Infrastructure, such as electrical transmission lines and roads, may be interrupted by flooding of the area.

TABLE 11 - 4 POTENTIAL ENVIRONMENTAL AREAS OF CONCERN IN WATER RESOURCES DEVELOPMENT MULTIPURPOSE DAM PROJECTS[a]

Environmental Area Concern	NW	NE	CW	CE	SW	SE
Drought/Desertification	×	×	×			
Watershed Management						
Soil degradation	×	×	×	×	×	×
Deforestation				×	×	×
Soil erosion					×	×
Coastal erosion					×	×
Wildlife/Fishery losses	×	×	×	×	×	×
Flooding						
Reduced Water Availability Downstream	×	×	×	×	×	×
Water Pollution	×	×	×	×	×	×
Water Hyacinth/Eutrophication	×	×	×	×	×	×
Water-related Disease	×	×	×	×	×	×
Socio-economic Impact	×	×	×	×	×	×

[a] Includes reservoir dams, irrigation/drainage projects, and hydropower projects

(v) **Loss of natural vegetation and wildlife habitat:** The magnitude of this impact is determined by the area of natural vegetation that will be lost due to inundation and also by the vegetation type. A number of wild animals living in the reservoir area will disappear as a result of habitat destruction.

As a stretch of river is transformed into a lake, species characteristic of running waters will disappear as a result of loss of riverine habitat. Furthermore, the roads built for the dam project will provide increased access to the region where the project is implemented. Natural vegetation and wildlife will be affected by wood cutting and other secondary activities.

(vi) **Fisheries:** Riverine fisheries usually decline due to changes in river flow, deterioration of water quality, loss of spawning grounds and barriers to fish migration. A reservoir fishery, which may be more productive than the previous riverine fishery, is created.

(vii) **Aquatic weed growth:** Criteria to consider for prediction of possible aquatic weed growth are: (1) the occurrence of pest plant species in the region; (2) the trophic status of the future lake area; and (3) fertilizer input from upstream activities. If vegetation is cleared prior to flooding of the reservoir area, nutrient input from

decomposing vegetation will be less. Nutrients could help support reservoir fisheries.

(viii) **Water-related diseases:** During the construction phase, diseases may be introduced in the project area by workers hired from other areas. After flooding of the reservoir, new vegetation may develop in the lake area, which may provide a habitat for vectors of diseases such as schistosomiasis and malaria.

(ix) **Loss of scenery and pollution:** Mining and quarrying of construction material can locally disfigure the landscape and cause land and water pollution.

(x) **Soil erosion:** Removal of vegetation cover at the site of borrow pits exposes the soil to erosion processes.

(xi) **Reservoir siltation:** Suspended solids carried by the river settle in the reservoir, limiting its storage capacity and lifetime and depriving downstream waters of sediments and the downstream population of water. Many agricultural areas on floodplains have always depended on infusions of nutrient-rich silt to sustain productivity. While the loss of nutrients could be compensated by fertilizer inputs to maintain agricultural productivity, the loss of water in the floodplains results in complete loss of agricultural productivity.

(b) Examples of Environmental Problems and Impacts of Dam and Reservoir Projects in Nigeria.

There are well over 300 dams/reservoirs/lakes, and these are classified by surface and state below in Table 11-5. Apart from the dams built for water supply purposes in the 1950s and early 1960s in the south part, subsequent dams, particularly in the 1970s and thereafter, have been designed to satisfy the combined needs of community water supply, irrigation, flood control and, in some cases, hydropower generation.

The environmental problems and negative environmental impacts of dams and irrigation on the environment and the people in Nigeria have been summarized in NEST (1991) as follows:

(i) reservoir flooding of large areas;

(ii) population displacement;

(iii) creation of aquatic environments favorable for the multiplication of harmful organisms;

(iv) elimination of silt supply to floodplains;

(v) decreased fishing in downstream areas;

(vi) salinity and water logging problems;

TABLE 11 - 5 SURFACE AREA OF LAKES AND RIVERS BY STATE

State	Surface Area (ha)							Total
	0 - 5	5 - 10	10 - 50	50 - 100	100 - 1,000	1,000 - 10,000	> 10,000	
Anambra	13	-	1	-	-	-	-	14
Bauchi	5	-	4	1	2	-	2	14
Bendel	-	11	-	1	2	-	-	14
Benue	2	-	1	1	-	1	-	5
Borno	3	-	1	-	-	-	-	4
Cross River	2	1	4	4	3	-	1	15
Gongola	5	2	26	5	12	-	1	51
Imo	11	5	-	-	1	1	-	18
Kaduna	4	3	6	9	9	2	-	33
Kano	4	6	1	3	11	6	2	33
Kwara	7	6	3	-	4	-	-	20
Niger	-	-	-	-	4	-	1	5
Ogun	-	-	1	-	-	1	-	2
Ondo	-	1	-	-	2	1	-	4
Oyo	2	-	3	2	3	1	-	11
Plateau	8	1	10	3	5	-	-	27
Rivers	-	16	-	-	-	-	-	16
Sokoto	2	-	1	-	11	2	1	17
Total	68	52	62	29	69	15	8	303

Source: Ita, et al. (1985) - : none

(vii) weed problems;

(viii) dam failure, with loss, with loss of lives and property;

(ix) loss of fadama land due to lack of water flow and fall or groundwater table downstream of dam; and

(x) drying up of wetlands and associated impacts on bird migration in the Hadejia-Nguru wetlands.

Some of these environmental problems and impacts are elaborated in NEST (1991). Fred Pearce in his article titled Death of an Oasis, in the May-June 1992 issue of AUDUBON, has highlighted the negative impacts of large dam projects for irrigation in the northern parts of Nigeria, particularly the environmental problems associated with the Tiga Dam, Challawa George Dam, and the Bakolori Dam as they affect pastoral agriculture.

There are very few systematic EIA studies on dams and reservoir projects for the reasons which have been indicated earlier. The few EHIA studies on dams and irrigation projects which have been documented are summarized in Appendices 11-3, 11-4 and 11-5.

At the LWIP (Iwugo, 1992), samples were collected for water quality, soil productivity, and ecological studies in the existing scheme and in the area of proposed expansion. The focus of the study was environmental health - evidence of increased disease rates (especially water-related diseases) following implementation of the project. This approach is used where projects already exist or where data not available. The study reviewed at compliance with WHO standards for water significance criteria, and looked at fertilizer use, training of project personnel, sanitation, and waste disposal.

Multipurpose dam projects include reservoir dams, irrigation/drainage projects, and hydropower projects. For four categories of hydropower dams (existing, proposed, existing mini-, proposed mini-), information on significant environmental problem areas, as developed by the World Bank Working Paper on the Nigerian environment (World Bank, 1990), was compiled by the National Socioeconomic Inventory Survey. A total of 24 projects were evaluated in the seven major environmental categories. This information was tabularized in a supplement to the National Socioeconomic Inventory Survey in Tables N-6.1A through N-6.1D (Skoup & Co., 1993b).

Larger hydropower projects, where significant areas were flooded during reservoir filling, were assumed to have displaced wildlife and rendered forest areas unusable. In most categories, no information exists for the stated concerns. Some studies regarding effects on downstream fishery losses have been conducted. Hydropower generation capability at Kainji Dam is used for peaking purposes only; this uneven discharge regime results in erosion and flooding downstream. This lack of constant flow maintenance makes downstream productivity tenuous and unpredictable.

For proposed large hydropower projects, significant forest areas would be inundated for three of the five listed projects (based only on reservoir surface area projections). Wildlife and fishery losses due to habitat loss and modification are expected. The larger reservoirs (Zunguru, Makurdi, Lokoja)

are expected to have significant evaporation and sedimentation problems, based on design information and existing feasibility studies.

Environmental information for existing and proposed mini-hydropower projects is almost non-existent. In many cases the reservoirs have been built and filled, but the hydropower component has not been implemented. Reservoir waters may currently be used for irrigation or drinking water, varying with location of the project. For inland navigation projects, information was collected only on sedimentation problems and dredging projects to improve river navigability. A total of 22 projects were listed by Skoup & Co. (1993b):

- Reservoir dams. DeCrown (1993) reported a number of water supply dams in Oyo and Osun States as having problems with adequate supplies of water and growth of aquatic weeds. Isu Associates (1993) and TCI (1993) did not report reservoir information. Enplan (1993) did not record any problems. Only WADSCO (1993) indicated problems with water quality; dams in Jigawa and Borno States reported problems with sedimentation from upstream, and the introduction of noxious materials into reservoir waters.
- Irrigation. All five regional surveys reported that the major problems listed by irrigation projects dealt with the condition of facilities and quality of support from local extension officials.

(2) Flood Control, River Management, and Land Reclamation Projects

(a) Environmental Aspects of River Basin Development

River basin development on an integrated basis is a new concept which started gaining momentum less than 30 years ago. Integrated river basin development involves the appropriate and economically- and environmentally-sustainable use of a watershed, with due attention to use/preservation of natural resources. The emphasis in watershed development has generally been on agriculture, including fishery and forestry projects, but should extend to any intervention involving land use which affects the hydrological cycle. In Nigeria, river basin development responsibilities are vested primarily on the various Departments of the FMWRRD, and also on the RBDAs, which were established under the River Basins Development Authorities Decree, No. 25 of

1976. The very wide-ranging functions of these RBDAs are fully outlined in that Decree.

The potential environmental areas of concern associated with Flood Control, River Management, and Land Reclamation Projects for the six regions of the NWRMP are shown in Table 11-6. Within the limitations of the Terms of Reference for the Regional Technical Information Surveys, no information on environmental conditions along the listed river reaches was available. In general, modification of river basins for navigation increases flow speeds, increases erosion and sediment transport, eliminates fish habitat, and decreases stock size (see Section 11. 2. 3).

TABLE 11 - 6 POTENTIAL ENVIRONMENTAL AREAS OF CONCERN IN WATER RESOURCES DEVELOPMENT - FLOOD CONTROL, RIVER MANAGEMENT, AND LAND RECLAMATION PROJECTS

Environmental Area of Concern	NW	NE	CW	CE	SW	SE
Drought/Desertification						
Watershed Management						
Soil degradation						
Deforestation						
Soil erosion						
Coastal erosion					×	×
Wildlife/Fishery losses	×	×	×	×	×	×
Flooding						
Reduced Water Availability Downstream						
Water Pollution					×	
Water Hyacinth/Eutrophication						
Water-related Disease						
Socio-economic Impact						

The remaining sections of the report on River Basin Development will confine itself to: (i) fish species in rivers and lakes; (ii) mining areas.

(b) Fisheries Aspects

Nigeria has numerous water bodies, which include the Rivers Niger and Benue and their very numerous tributaries, and also many natural lakes (e.g., the Chad) and man-made lakes (e.g., the Kainji, Tiga, Bakalori, Chalawa George), and reservoirs and flood plains. The estimated total area of the inland bodies of water in Nigeria is 125,470.82 km^2 as distributed on Table 11-7. The vast inland, brackish, and marine bodies of water contain enormous finfish and shellfish resources, with an estimated total yield potential of 517,360 tonnes, which are distributed as shown in Table 11-8.

TABLE 11 - 7 SUMMARY OF WATER SURFACE AREAS

Water Body	Area (ha)
Lake Chad (Nigerian sector)	550,000
Kainji Lake	127,000
Major Rivers (Anambra, Benue, Cross, Imo, Kwa Ibo, Ogun, Osun, Niger (exclusive of the Kainji and Jebba reservoirs))	10,812,000
Cattle, Fish and Flood Ponds	8,000
Reservoirs	275,000
Flood Plains	575,000
Miscellaneous stagnant pools of seasonal rivers	200,000
Burrow pits and mining paddocks	100
Total	12,547,100

Source: Ita, et al. (1985)

TABLE 11 - 8 ANNUAL FISH YIELD POTENTIAL IN THE INLAND AND MARINE WATERS

Source	Annual Yield Potential (tonnes)
Rivers and floodplains	226,550
Lake Chad	24,500
Kainji Lake	8,500
Other natural lakes and reservoirs	35,000
Coastal and brackish waters	190,000
Inshore waters	16,620
Offshore waters:	
(a) demersal resources (50 - 200 m)	6,730
(b) pelagic resources	9,460
Total	517,360

Source: NIOMR Technical Paper No.79 (1992)

(c) Extent of Exploitation of Fishery Resources in Nigeria

Nigeria has a diversity of finfish and shellfish fauna, consisting of over 250 species in inland waters, with about 86 species in Lake Chad alone, and 199 species from 78 families in brackish and marine waters. Fishery resources in Nigerian inland and marine waters are exploited at different levels; some are over-exploited, while others are under-exploited or unexploited. Five levels of exploitation have been recognized, as indicated in Table 11-9. These are unexploited, under-exploited, moderately-exploited, intensively-exploited, and over-exploited.

TABLE 11 - 9 EXTENT OF EXPLOITATION OF FINFISH AND SHELLFISH RESOURCES IN VARIOUS WATER BODIES

Water Body	Level of Resources Exploitation	Remarks
Lake Chad	Intensively exploited	Regulations on mesh sizes and their strict enforcement needed.
Kainji Lake	Intensively exploited	Strictly enforced management measures required to prevent over exploitation.
Other natural lakes and reservoirs	Unknown, moderately and intensively exploited	Often subjected to obnoxious methods of fishing; extensive resource evaluation in these bodies of water is urgently required.
Rivers and floodplains	Moderately to intensively exploited	Most rivers and flood plains are subjected by fishermen to obnoxious methods of fishing; strict conservation measures required.
Coastal and brackish waters	Intensively exploited	Conservation measures required to protect commercially-important resources (e.g. the bonga, sardinella, juvenile shrimps, and the young of high-value fish in nursery grounds.
Inshore waters (0 to 50 m)	Intensively exploited to over-exploited	Shrimps are intensively exploited, while finfish are over-exploited; management measures for resource conservation are inadequate and in some aspects defective.
Demersal resources (50 to 200 m)	Under-exploited	Parapenseus longirostris is presently the target resource.
Demersal resources (200 to 600 m)	Unexploited	There are unexploited high-value resources, including Ariomma spp., Denrex spp., and Red Sea crabs in this depth zone.
Offshore pelagic resources (e.g., tunas and tuna-like fishes)	Unexploited to moderately exploited	There is one Nigerian-based tuna fishery; resources are poached by foreign vessels.

Source: NIOMR Technical Paper No.79 (Tobor, 1992)

(d) Major Mining Operations

Mineral resources are abundant in Nigeria, and their exploitation on a large-scale in the country probably started earlyin this century with tin mining in Jos. The abundant mineral resources of Nigeria may be classified into the following three broad categories:

(i) **Fuel minerals:** coal, lignite, petroleum, natural gas, and uranium;

(ii) **Metallic minerals:** cassiterite, columbite, tantalite, gold, and iron; and

(iii) **Industrial minerals:** limestone, marble, gypsum, gravel, feldspar, and sand.

Apart from petroleum and natural gas, which should be treated as special mineral resources, the mining of coal, tin, and iron ore, and the quarrying of limestone and constructional materials (i.e. gravel and sand), are extensive in Nigeria and pose considerable environmental impacts.

Nigeria's major coal mines are located in Enugu State. Most of the tin mined is in Jos (Plateau State), while the most of the country's iron ore is embedded in Kwara, Benue, Kaduna, and Enugu States, but most mining operations are on the deposits in Kwara State. Limestone and marble occurs in almost every state of Nigeria, and they are the major raw materials for cement production.

(e) Environmental Problems of Mining

The environmental problems associated with mining operations are largely undocumented, but are very visible. For instance, in the coal mining areas of Enugu State, the tin mining areas of Jos in Plateau State, and in those areas where limestone and gravel and sand are quarried, the stream and river beds in these areas are easily silted. In Jos, open-cast mining of cassiterite and columbite has resulted in a landscape of steep-sided mounds and multicolored rivers and ponds or lakes which number over 600. The abandoned pits resulting from open-cast mining in the Jos Plateau are usually more than 10 meters deep and are over 50 meters wide. Many of them contain permanent water bodies which are suitable habitats and breeding places for mosquitoes which cause malaria and yellow fever. All these ponds constitute permanent physical danger for both human beings and animals.

Open-cast tin mining generate heaps of excavated materials which could greatly disturb the movement of people and livestock, and more importantly make the mining areas unsuitable for agriculture, settlement, industrial development, and other uses.

Quarrying of building materials is becoming rampant and largely uncontrolled in several towns and cities. This type of activity accelerates soil erosion, river bed siltation, gully erosion, and land subsidence, and also the general degradation of the overall landscape and land uses in the areas concerned. The opening of quarries for building materials needs to be carefully regulated in all States. There is also an urgent need to initiate appropriate

machinery (institutional and technical) to plan and execute the reclamation and restoration of already-mined and quarried lands in various parts of the country.

The provisions made for mining in the EIA Decree should be strictly enforced.

(3) Water Supply and Sanitation Projects

The discussion of water supply and sanitation projects excludes multipurpose dam projects (see 11. 2. 2 (1) above).

(a) Environmental Problems Associated with Community Water Supply Projects

The components of a typical community water supply (CWS) system are comprised of: (i) the source and intake; (ii) the transmission mains; (iii) the treatment plant; and (iv) the distribution system. Each component of the system may present environmental problems, but the major environmental problems are usually associated with the source and intake component, particularly if these are large dams or impounded reservoirs with a surface area of 2,000 ha or more, or groundwater sources being abstracted at rates greater than about 10,000 m^3/day. Environmental problems may also be related to: (i) project siting; (ii) design criteria; (iii) constructional practice and method; (iv) operation end maintenance; and (v) other engineering design factors. The major environmental problems which are generally associated with community water supply systems are summarized as follows:

- Pollution of the water supply source by upstream waste inflows from communities, industries, agricultural runoffs, and soil erosion runoff.
- Abstraction of raw water for the CWS, conflicting with other beneficial water uses for both surface and groundwaters.
- For dams and reservoirs, creation of habitats and breeding grounds for water-related diseases.
- For groundwaters, hazards of land subsidence caused by excessive groundwater pumping; this may lead to saline intrusion of the aquifer.
- Resettlement of population and food insecurity accentuated by loss of land by flooding and erosion.

- Impairment of historical/cultural monuments and areas.
- Pollution of the soil by sludges and treatment chemicals and atmospheric pollution by chlorine, and also endangering of operators' health.
- Creation of stagnant water bodies in borrow pits and quarries which may act as habitat for disease vectors.
- Introduction of new diseases (e.g. sexually-transmitted diseases and tuberculosis) and prostitution, gambling, and drug abuse to the local population.

A more exhaustive list of environmental problems is provided in Appendix-3. The potential environmental areas of concern associated with Water Supply and Sanitation Projects for the six regions are shown in Table11-10.

TABLE 11 - 10 POTENTIAL ENVIRONMENTAL AREAS OF CONCERN IN WATER RESOURCES DEVELOPMENT

Water Supply and Sanitation Projects*

Environmental Area of Concern	NW	NE	CW	CE	SW	SE
Drought/Desertification	×	×	×			
Watershed Management						
Soil degradation	×	×	×			
Deforestation						
Soil erosion						
Coastal erosion					×	×
Wildlife/Fishery losses						
Flooding						
Reduced Water Availability Downstream	×	×	×	×	×	×
Water Pollution	×	×	×	×	×	×
Water Hyacinth/Eutrophication						
Water-related Disease						
Socio-economic Impact						

(b) Examples of Environmental Problems Caused by Water Supply Projects

There are no documented scientific and quantitative information and data on the environmental problems caused by water supply projects per se in Nigeria. There have been descriptive newspaper reports on the outbreaks of some water-related diseases (e.g. cholera, typhoid fever, hepatitis, guinea worm, etc.) resulting from either the lack, non-availability, or inadequacy of water supply schemes. Most of the reported outbreaks usually relate to the

water source/intake or project site. Some of the known environmental (health) problems which relate to water supply projects are briefly reviewed below on the basis of the types of raw water source.

(c) Groundwater

A major objective of several of the projects was to provide the water supply-starved communities with water, and as a result reduce the high incidence of water-related diseases resulting from the use of easily-contaminated supplies. The execution of borehole projects by the various organizations were largely uncoordinated, and individual installations were casual and unplanned. Nigeria, as a country, has no effective water rights and use legislation. A combination of the aforementioned situations has exacerbated the following quantitatively undocumented and largely ignored environmental problems:

(i) Excessive groundwater pumping and the accompanying lowering of the groundwater table and saline water intrusion from the sea in the heavily-populated, industrially-developed coastal cities of Lagos State, Rivers State, and perhaps Bendel and Cross River States, located atop sedimentary rock geology. Sea water intrusion in Lagos water supplies has been a recurring problem since the late 1970s, and available evidence suggests the lowered water table favours the seepage of saline coastal/sea water to the bed of the Ogun river, which is the major water supply source for the Iju Water works. During the periods when the Lagos water supply source was subject to saline water intrusion, the chloride concentrations in the public water supplies could be over 300 mg/L, giving rise to salty taste or temporary bouts of running stomach (diarrhoea) among consumers. There are no widely-reported cases of saline intrusion in Rivers State, Bendel State or Cross Rivers State, but isolated cases of borehole water with high chloride content (greater than 300 mg/L) have been observed in these States by the State Water Boards and/or DFRRI monitoring teams.

(ii) There are reported cases of groundwater (from boreholes) which have been polluted by petroleum products in some areas of Lagos State. This oil pollution of groundwater was attributed to corroded underground oil storage tanks. Incidents of this nature are likely to be quite prevalent in various cities and towns. Most water supply wells in the oil producing areas of Rivers State, Bendel State, Akwa Ibom, Imo, and Anambra are reported to be either already polluted with oil or are seriously threatened by oil

pollution. Large parts of Ondo and Bendel States are underlain by tar sands, and groundwater from these formations are subject to pollution from aromatic phenolic compounds.

(iii) The DFRRI water and sanitation program aims at the simultaneous provision of low-cost, easily maintained and operated and socially-acceptable water supply system (usually a borehole, hand-dug well, or protected spring) and a basic sanitation system (usually a ventilated improved pit [VIP] latrine). If the VIP latrine is located upstream of the water supply system, it would eventually result in the pollution of the supplied water. No supporting data are yet available in Nigeria, but experiences of such programs in Botswana and other Southern and East African countries have shown that VIP latrines lead to the bacteriological contamination of groundwater supplies and also an increase in the nitrate concentrations of the groundwater.

(iv) Most groundwater supply systems are poorly planned, constructed and operated, and an evident consequence of this is the deterioration of the product water quality. Total coliform and faecal coliforms of up to 1,500-per 100-ml and 50-per 100-ml, respectively, are not uncommon in several hand-dug shallow wells and unprotected water supply streams which were surveyed over the past fifteen years in several low-income and congested urban and rural settlements.

(v) Domestic and industrial solid wastes disposal practices are unplanned, virtually unregulated and very undeveloped in most areas. Careful surveys and groundwater quality monitoring are likely to reveal the presence of some persistent and non-biodegradable organic chemicals, and perhaps heavy metals like lead, zinc and cadmium in high concentrations in borehole waters located near solid waste dumping fields (usually referred to as sanitary landfills) which are prevalent in several cities of Nigeria.

(vi) Water quality data from boreholes is scarce. DeCrown (1993) reported incidences of saltwater intrusion in wells in coastal areas of Warri and rural Delta State. Enplan (1993) listed a number of boreholes in Kaduna State (depth zero to 100m) that showed significant drawdown in water levels (ranging from 20 to 100m). Those wells were listed as having high yields (>100 lps); no indication of decreases in yield were noted. WADSCO (1993) listed more than 7,000 wells in the Northeast region, but none were indicated as having problems. TCI (1993) reports indicated water level drawdown and yield decreases in some wells, but these reports were not quantified. Isu Associates (1993) did not report borehole information.

(d) Surface Water

Most of the environmental problems associated with surface water supply schemes are related to the source/intake component or the project siting stage, and these may be summarized as follows:

(i) **River pollution:** indiscriminate disposal of domestic sewage, industrial wastewaters, solid wastes, accidental spillage of chemicals during transportation, and domestic uses such as clothes washing (laundry) and bathing have all led to several water supply rivers and streams in parts of Nigeria being grossly polluted with organic matter. Public water supply river sources which are visibly polluted are the River Kaduna, River Escravos, River Forcados, the Samaru Stream in Zaria, River Ogunpa in Ibadan, River Siasa and Ologe Lagoon in Lagos, as well as several others. In 1978/1979, the Samaru Stream was found to have an annual average dissolved oxygen concentration of about 1.7 mg/L just before flowing into the Kubani reservoir, which is the water supply source for Ahmadu Bello University, which then had a resident population of about 7,000 persons.

In the Regional Technical Inventory Surveys, only one surface water supply project reported problems. The Enugu Urban Water Scheme indicated problems with upstream pollution and erosion into the water source. The erosion problem also affects the scheme's facilities (Isu Associates, 1993).

(ii) **Water-related diseases:** the various water-related diseases which have been discussed above are prevalent in several surface water supply schemes, particularly in cases of impounded reservoirs and dams. Cholera outbreaks are now "endemic" in many towns and villages; so also are other water borne diseases such as dysentery, typhoid, diarrhoea, infective hepatitis, etc. Water-based diseases such as schistosomiasis and guinea worm (dracunculiasis) are also prevalent.

(iii) **Eutrophication:** this is the enrichment of a water body by such nutrients as phosphates and nitrates, which in the presence of an adequate carbon source and sunlight leads to the prolific growth of algae and other water weeds. The seemingly intractable problem of water hyacinth in the lagoon waters of Lagos, Ogun, Ondo, and Bendel States is essentially a eutrophication process which might have been precipitated by indiscriminate disposal of untreated domestic sewage and solid wastes, and also by widespread and

liberal use of fertilizers over the past ten years in the OFN program.

(iv) **Siltation of river beds:** many areas are experiencing accelerated soil erosion, which has an impact on the surface water bodies. Tropical river waters are normally characterized by high turbidity, but there is evidence of the increasing turbidities of several water supply rivers and reservoirs in Nigeria. Increased turbidity due to river bed siltation results in increased water treatment costs, lower fish populations, decreased waterways navigability, and loss of reservoir capacity.

11.2.3 Environmental Needs in the Water Resources Sector

(1) General

The primary focus of the Nigerian "National Policy on the Environment" is to " ... restore, maintain, and enhance ecosystems and ecological processes for the functioning of the biosphere" (FGN, 1989). The policy stresses the concept of promoting optimum sustainable yield in such sectors as forestry, fisheries, and wildlife. Just as Section 11.2.1 addressed the concept that "one action causes many types of problems" in the environmental resources sector, one remedial action can improve many types of environmental problems. This section will highlight the need for an integrated environmental protection program implemented by several Departments and Ministries; the Water Resources Decree of 1992 gives FMWRRD significant powers to protect watersheds and water resources, but cooperation and coordination with other agencies will be needed to make this effort a success. The recommendations will focus on education at all levels of government and society; effectively, the FGN must develop an environmental curriculum to promote knowledge and sensitivity toward the needs and relationships of the Nigerian people with the natural environment (LCBC, 1992).

In this section, some of the primary environmental needs facing Nigeria today are discussed. Section 11.2.1 identified several areas of significant environmental degradation in Nigeria, and discussed the causes and results of those problems. Section 11.2.2 presented specific information on environmental problems related to water resources projects. This section

addresses approaches to solutions to environmental problems as they relate to water resources development.

(2) Drought and Desertification

Desertification is the result of unfavorable natural processes occurring over years (drought) with mismanagement of natural resources in an area, resulting in environmental degradation and potentially significant long-term devastation of large areas. Setting aside the causes of drought, which occurs on a scale more vast than any one country and is difficult to address in terms of approaches to end its effects, this section concentrates on approaches to combatting desertification in local areas, and in making those areas less susceptible to drought when it does occur.

Table 11-11 summarizes the primary causes and results of desertification, and also approaches to solutions to the problem. Primary causes and results of desertification were discussed in Section 11.2.1, and are listed in Table 11-11 to allow comparisons with proposed solutions. Those solutions are discussed in more detail below.

TABLE 11-11 APPROACHES TO SOLUTIONS - DESERTIFICATION AND DROUGHT

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
Desertification and drought	CAUSES Lowered water tables Reduced surface water availability Removal of vegetation cover Overgrazing Bushburning RESULTS Reduced capacity for infiltration Increased evapotranspiration rates Soil degradation and erosion	Maintain sustainable groundwater yield on a sub-basin basis Microclimate modification, including increased implementation of windbreaks, improved cropping practices, and programs and structures emphasizing soil stabilization Revegetation / afforestation programs to promote rainfall infiltration and stabilize large areas Controls on grazing rotation and intensity to reduce soil degradation

Desertification is the manifestation of several types of land degradation, combined with adverse climate conditions, that were previously

discussed in Section 11.2.1. As such, control of desertification will involve integrated approaches on several areas.

Drought relief programs frequently discuss drilling of additional boreholes to provide additional water supplies. However, based on the lack of historic data on groundwater level changes and borehole yields in Nigeria, these programs are going forward without adequate knowledge of the sustainable yield of the basin. The likely result will be the eventual exceedence of that yield, and further environmental degradation as a result of reduced water availability.

Two approaches are commonly used to promote increases in soil moisture, to stabilize soils and prevent erosion, and to reduce temperatures and resultant evapotranspiration. In arid areas where little water is readily available, shelterbelts are valuable in modifying the local microclimate to increase soil moisture and humidity (World Bank, 1990). Soil stabilization is important for maintenance of soil quality and integrity; shelterbelts reduce wind velocities that can mobilize soil particles (NEST, 1991), physical barriers (vegetated hedges and strips, sand fences, etc.) prevent large-scale movement of soils; and appropriate cropping practices can minimize soil exposure and maintain moisture (NRCC, 1992b). Crop harvesting practices needed to maintain soil organics are frequently ignored; residues are removed for other uses (fuel, animal feed, building materials, etc.). Farmers need to be educated to leave these residues in place as much as possible. Afforestation practices can help prevent soil erosion and act as animal food (agro-forestry).

In drought-prone areas, a constant posture in terms of planning must be emphasized (Alaku, 1991). Planners (and extension officials) should assume drought is coming when planning for agriculture, farming, and ranching activities. Strategies such as water harvesting during rain events should be encouraged (NEST, 1991; NRCC, 1992b). Appropriate range management and protection of vegetation, soil, and water resources in areas with fragile ecologies are the most important aspects of arresting or preventing desertification (NRCC, 1992b).

In areas that receive more rainfall, and in existing forest reserves in arid areas, maintenance and enhancement of vegetative cover (either trees or grasses) promotes infiltration and reduces runoff and evaporation (FEPA, 1991;

NEST, 1991; NRCC, 1992b). Water resources management practices emphasize the need for increased levels of "artificial" groundwater recharge, especially in arid northern areas. Ezeigbo (1990) recommends surface spreading and infiltration of water using low dams placed across ephemeral streams (in areas of suitable geology and soil characteristics).

Measures to provide adequate land, water, and forage for pastoralists have been underway since the 1950s. A program to identify, acquire, and develop grazing reserves is currently being assisted by funds from the World Bank (Hashidu, 1992). Development of the reserves includes infrastructure, small dams to provide watering areas, and other support services. Currently, approximately 2.5 million ha have been set aside as grazing reserves, with an overall target of 10 percent of lands (approximately 9 million ha) (Aina and Adepipe, 1991; NRCC, 1992b).

(3) Reduced Availability of Flow in Downstream Areas of Rivers

The history of water resources and irrigation development in Nigeria is highlighted by the construction of numerous dams to provide consistent water supplies to irrigated areas, and to reduce flooding of agricultural lands.

The long-term effects of these dams have been significant ecological changes in downstream agricultural areas adjacent to rivers, and in the morphology of the river beds themselves. The primary ecological changes in downstream areas are related to the decrease in water availability resulting from flow regulation and diversion to other uses. Changes are also related to soil degradation, agricultural practices, and socio-economic factors affecting human health. These indicators of environmental degradation were discussed in several subsections of Section 11.2.1, and are reviewed below. The causes and consequences of these problems are summarized in Table 11-12; approaches to solutions are listed in the table and discussed in detail below.

TABLE 11-12 APPROACHES TO SOLUTIONS - REDUCED AVAILABILITY OF FLOWS ON DOWNSTREAM AREAS

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
Ecological changes in fadamas	**CAUSES** Reduced water availability Altered type of water body vegetation	Re-examine/modify operation of large irrigation dams to better approximate historic natural flows
	RESULTS Loss of habitat for wildlife, fisheries Loss of fishing opportunities Loss of grazing opportunities and access Loss of soil fertility Change from flood agriculture to rainfed agriculture in floodplain areas Overdraft of groundwater supplies Human health changes	Reduce scale of planned irrigation schemes; emphasize small-scale schemes Land use restrictions in fadama areas; maintain some planned level of flooding; maximize water releases Control groundwater extractions based on sub-basin safe-yield limits Promote local groundwater recharge during the rainy season through appropriate agricultural practices (contouring, cropping, fallow, etc.)
Lowering of river basin channel	**CAUSES** Reduced water availability Elimination of flood cycle	Mediate agricultural/grazing schedules to assure access; promote fallow and land regeneration
	RESULTS Lower river basin level Lowered groundwater table Reduced recharge of groundwater	Maintain/expand protected habitats and designated areas and reserves

The focus of this section is directed toward the effects of reduced water availability on lands bordering the rivers, which have historically been subject to innundation during wet season runoff, and where residual soil moisture farming anddry season grazing were commonplace. This is the classical description of fadama land, and the discussion in the remainder of this section will address those specific areas, as they represent a vital part of Nigeria's agricultural sector.

The hydrologic cycle of fadama lands (innundation, residual moisture) makes them highly productive, and is conducive to the formation of long-term features such as permanent wetlands. This cycle promotes groundwater recharge, acts as a water quality filter, and participates in flood control by absorbing runoff flows and releasing them over extended periods. These areas are important sources of nutrient storage, and provide nutrients and biomass to both local users and downstream areas. The ability of perennial wetlands to stabilize microclimates means that these areas can be used as a base on which to build anti-desertification programs (Dugan, 1990). Sustainable resources

available from these areas include forest reserves, wildlife, fisheries, forage, agriculture, and water supply.

The effect of dams and irrigation projects on these downstream areas has been to reduce the area of innundation, often keeping the flow completely within the permanent channel (Thompson, 1992). This chokes off the historic supply of silt tothe floodplains, results in loss of soil fertility, and forces a change in cropping patterns from flood and residual moisture agriculture to (less-productive) rain-fed agriculture in upland areas away from the water resource (NEST, 1991). This restriction of water availability reduces the size of wetlands habitat, resulting in loss of fishing opportunities, changes in fishing strategy, and reduced fish catches (Dugan, 1990; Ali, 1990). The innundation period is frequently a period of migration to feeding and breeding grounds for fish; this capability is lost or reduced. The long-term effects are reduced populations of fish and lower sustainable harvests (Ali, 1990).

The NWRMP will direct significant attention at ways to improve the productivity of wetlands, irrigation technologies, and existing facilities to provide for the growing population of the country. One potential measure that will be evaluated is described as "emergency relief" through modification of the release schedule from existing dams, combined with wet season releases to simulate (on a low level) historic flooding patterns.

The operational rules for existing large dams and irrigation projects must be re-evaluated and modified to restore historical flow levels in critical rivers. In addition, the NWRMP should re-evaluate existing and partially-completed water projects for maintenance or modification with regard to economic benefits and ecological impact (LCBC, 1992). From an ecological standpoint, this proposed modification of release schedules should better approximate the historic natural cycle of innundation, and should be encouraged and implemented to the maximum extent possible (Hollis, 1992). Water releases should be maximized to some planned level of flooding, with excess capacity of upstream reservoirs used to avoid catastrophic flooding only. In order to minimize conflicts, land use planning in fadama areas that are innundated should emphasize agricultural, artisanal, and pastoral uses compatible with the flooding and recession of river water, while restricting or eliminating unnecessary infrastructure (buildings, roads, etc.).

The history of irrigation success has been that small-scale and decentralized schemes have been more successful (from a cost-benefit standpoint) than large schemes (NEST, 1991). From an environmental standpoint, small schemes are less stressful on the environment, able to respond more quickly to changes and needs of the local environment, and are cheaper to initiate and maintain. Promotion of smaller-scale irrigation should also improve water use efficiency and promote conservation, which will benefit downstream users and habitats (Barghouti and Lallement, 1988; FEPA, 1991).

Flooding of fadama land has historically been the major source of groundwater recharge in areas adjacent to the rivers (Adams and Hollis, 1988). While a modified innundation cycle will improve groundwater recharge downstream of many major dams, shallow groundwater will continue to be an important source for irrigation during residual moisture and dry season farming periods. Recent trends in water policy are toward drilling of large numbers of boreholes for water supply and irrigation (through various foreign-assisted programs); in fadama areas where groundwater reservoirs are relatively shallow and localized, the need for additional studies on groundwater yield and sustainability is critical (FMAWRRD, 1988; Adams and Hollis, 1988).

As was noted above, fadama and wetlands areas are extremely productive, and sustain a wide variety of resources. These valuable areas should be protected through area management plans; additions to the protected areas should be made wherever possible. On a watershed basis, local efforts at promoting groundwater infiltration through contour farming, cropping rotation, and use of fallow periods will also benefit aquatic habitats within those watersheds, as groundwater extractions and evaporation will be reduced, eliminating two significant areas that divert water from these productive habitats (Barghouti and Lallement, 1988).

Fadama areas have historically been areas used by pastoralists for grazing cattle during the dry season, after innundation and flood recession farming was completed. This land use was beneficial to both groups, as the manure from the herds provided an important source of soil organics and nutrients. Reduction in flows downstream of dams has reduced agricultural productivity in fadama areas, precipitated a move toward crop watering using groundwater throughout much of the year in these areas, and reduced or eliminated periods and areas where pastoralists have access to water and

forage. The government is moving to expand areas of grazing reserves to accommodate the majority of pastoralists (discussed earlier), but some of these needs will remain, and local farmers who maintain livestock will also want access for their herds. Management programs for fadama lands should include these uses, and should work with local leaders to assure that all needs are addressed.

(a) Reduction in Low Flow Volume in the Lower Niger

This section addresses the environmental aspects of lowered flow volumes in the Lower Niger and estuary, in relation to proposals for upstream development and use of the Niger River as a primary waterway for commerce. Table 11-13 lists the causes and results of this lowered flow volume, and also lists approaches to resolving the conflicts associated with maintaining water flow volumes in the Lower Niger. Previous sections of the NWRMP have discussed the hydrology of the Niger River, and noted the ongoing trend of reductions in flow volume from 1970 to the present. These reductions are due in part to the continuing drought condition that affects much of the upper drainage basin of the Niger and its major tributaries; however, some portion of the flow reduction is also due to upstream development that diverts flow from the river itself, including dams, irrigation projects, water supply, and evaporation.

The environmental consequences of reduced surface water availability in fadama areas was discussed in Section 11.2.1. In the Lower Niger, many of the same effects will be felt, including increases in the salinity of coastal rivers, saltwater intrusion in groundwater supplies, and lowering of the groundwater table. Rates of sediment accretion in the Niger Delta will decrease, resulting in increased erosion and land loss in that area as a result of ongoing tidal action. Reduced water availability and increased erosion will also result in changes to flora, especially in sensitive mangrove areas, and have widespread implications for wildlife stocks, coastal fisheries, and local inhabitants.

From the standpoint of maintaining sustainable development of resources in the Lower Niger and Delta, it is suggested to, if possible, maintain a flow level equal to or greater than the historic average flow since 1970. Using this date as a starting point places the upper extreme of flow volume measurements in a period of higher-than-average rainfall, with annual

TABLE 11-13 APPROACHES TO SOLUTIONS - MINIMUM MAINTENANCE FLOWS IN THE LOWER NIGER RIVER

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
Reduction in Lower Niger River flows	**CAUSES** Upstream development Building of upstream dams Water diversions	Maintain historic average flows in the Lower Niger River (since 1970) Promote upstream watershed management plans and practices to maintain historic levels of sediment transport
	RESULTS Increase in salinity in coastal rivers; salt water intrusion Lowered of groundwater table, affecting local water supplies Reduced accretion/sediment deposition in coastal areas Increased erosion and land loss in coastal areas Changes in flora and fauna in coastal areas, losses of habitat and nursery areas for coastal fisheries due to salinity changes, erosion	Minimize upstream dams and diversion structures
Reduction in ability and duration for river navigation	**CAUSES** Reduced flows in major rivers; causes as discussed above	De-emphasize large commercial navigation schemes; given flow patterns and conditions in major rivers, construction and maintenance costs of navigation system would be very high; major population centers are not located on major rivers, and can be served effectively by rail and truck from existing ports at Lagos, Port Harcourt, and Calabar
	RESULTS Results in proposals to build estuary barrages (effectively dams on the lower river) to maintain water levels; other proposals include extensive dredging and channelization to maintain water level; system would be extremely expensive Estuary barrage would result in downstream erosion, increased salinity, lowered groundwater tables, changes in flora and fauna and loss of fishery nursery areas; above the dam, sedimentation problems are likely, and logistics of handling flooding must be addressed	

averages falling almost continuously since that time. The resulting average target will be higher than the current flow average, but not as high as averages from the early 1970s, and thus represents a good middle ground as a basis for future water policy. Future years will see both higher and lower flow volumes, but the long-term average will approximate the historic average, with concomitant implications for support of ongoing physical and biological processes in the Delta area.

Watershed management programs, to be discussed in subsequent subsections of Section 11.2.3, must be expanded from focussing primarily on a small scale (local improvement and oversight) and extended to a vast area to cover the watershed of the Niger and its tributaries. Flow modeling based on historic gauging data must be instituted, both to assist in water management and to determine the potential impacts of upstream development in diverting water from the river system. Upstream diversions should be minimized, and water efficiency should be stressed to reduce diversions and maintain target flow levels.

(b) Reduced Ability and Duration for River Navigation

Plans have for many years been advanced to institute an extensive system of commercial inland navigation on Nigeria's rivers, especially on the Niger and Benue Rivers (FMAWRRD, 1988). Reduced flow volumes in the Lower Niger (as a result of lower flow volumes in the Upper Niger and Benue) will restrict the potential for commercial navigation on the river, and curtail the time periods during which navigation is possible. The causes of this reduced flow are the same as those discussed in Section 11.2.1 above.

The conflict of lowered river flows and plans to expand river commerce has resulted in proposals to build an estuary barrage in the Lower Niger Delta, to maintain water levels at a depth that allows navigation year-round. Other aspects of the navigation proposal include extensive dredging to deepen river reaches, and channelization to maintain water depths. This river navigation system would be extremely expensive to build and maintain. Works would have to be designed to withstand the seasonal changes in flows in these major rivers, a change in volume of 30:1 between wet and dry seasons. Specific to the proposal for a barrage, environmental effects would include downstream erosion, lowering of the groundwater table, changes in flora and fauna

assemblages, and loss of critical fishery nursery areas. Above the dam, sedimentation problems are likely, and the logistics of handling large water volumes during seasonal flooding periods must be addressed.

From an environmental standpoint, the logical solution to the lack of existing suitable conditions indicates that large commercial inland navigation schemes should be de-emphasized. Existing flow patterns and conditions on major rivers would require significant modification, and construction costs and annual maintenance requirements would be very high. In Nigeria, most major population centers are not located on the Niger or Benue Rivers. The country can be served more cost-effectively by rail and truck from existing port facilities at Lagos, Port Harcourt, and Calabar. Existing flow conditions are adequate to support local coastal passenger and commerce traffic.

(4) Watershed Management

The integrity of any watershed is tied up in a number of factors; the degradation of any of these factors reduces watershed integrity and threatens all of the elements of the watershed. Degradation can include a variety of problems, each with its own needs; these problems include soil degradation, deforestation, soil erosion, coastal erosion, wildlife and fisheries losses, and flooding.

(a) Soil Degradation

From an economic standpoint, soil degradation is probably the most serious environmental problem facing Nigeria, as it is the precursor for several other problems, including loss of soil productivity, erosion, and, ultimately, desertification (World Bank, 1990). Table 11-14 summarizes the primary causes and results of soil degradation; these were previously discussed in Section 11.2.1. Approaches to solutions to the problem of soil degradation are also summarized in Table 11-14, and discussed below.

TABLE 11-14 APPROACHES TO SOLUTIONS - SOIL DEGRADATION

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
	CAUSES	
Soil degradation	Removal of vegetation cover	Active watershed management
	Removal of topsoils	Policies and practices
	Development of poor or marginal soils	Revised agricultural practices (education of farmers, etc.)
	Poor farming practices	
	Lack of fallow period	Standards for use suitability for all lands in Nigeria
	Overgrazing	
		Restrictions on land clearing approvals and practices
	RESULTS	
	Removal of natural nutrient sources	Promotion of land fallow practices in agricultural cycle (education)
	Reduced infiltration	
	Reduced ability to support beneficial uses	

Planning and management of all activities affecting soils is the most positive and effective method of preventing or reversing degradation of soils. The Nigerian "National Policy on the Environment" emphasizes the need for integrated land use and soil management planning. Important elements of this approach are the needs for a database on soil types and suitabilities throughout Nigeria, and evaluation of the use potentials and constraints of those soils for incorporation into appropriate planning processes (Baum and Tolbert, 1985; FGN, 1989; LCBC, 1992).

More than one-half of Nigeria's soils are considered to be of low productivity. This problem is frequently exacerbated by intensive cultivation and inappropriate farming practices (FEPA, 1991). Sustainable use of soil resources in Nigeria will require investigation and mapping of soil capacities, as well as problem areas where uses should be restricted (NRCC, 1992b). Appropriate agricultural practices will also be an important factor in preventing and reversing soil degradation, including emphasis on contour planting (rather than downslope cultivation) and use of vegetation barriers to stabilize soils and prevent erosion (FEPA, 1991). Demonstrated benefits have been seen by combining afforestation and water management to reduce land degradation and water pollution in mining areas. The reclaimed land is planted with grass, bushes, and even producing crops (fruit trees); in some cases, abandoned pits have been used for fish farming (Iwugo and Mahendra, 1992).

Agricultural methods that maintain and enhance soil condition and productivity must be communicated to farmers through extension services or local cooperatives; the farmers must agree that revised practices will be beneficial before they are convinced to change their traditional farming methods. Such approaches as alley cropping and polycropping help to continuously build soil nutrients, reduce erosion, promote infiltration, and reduce usage of chemicals (NEST, 1991).

The traditional practice of fallowing land should be emphasized as much as possible. When combined with non-agricultural vegetation, cropping that returns nutrients to the soils, or rotational cropping practices, long-term soil productivity can be maintained, and degradation and erosion prevented or reversed.

Irrigated agriculture is an area targeted for increased emphasis by policymakers, who are hoping to increase the intensity of agricultural production to feed a growing population. The effect of soil degradation in this area is potentially more devastating for its impact on this policy. Care must be taken to develop an economic policy that does not encourage inappropriate cropping leading to soil degradation; through extension services, farmers must also be familiarized with methods to avoid waterlogging, salinization, and alkalization of soils, problems that have affected other large-scale irrigation projects (Barghouti and Lallement, 1988; Dugan, 1990).

Inappropriate land preparation practices are a serious source of degradation and loss of soils in Nigeria. Strict adherence to land use and land clearing guidelines and suitability are promulgated by the National Agricultural Land Development Authority (NALDA), and should be incorporated into all local land use planning activities (Aina and Adepipe, 1991; NRCC, 1992b).

(b) Deforestation

Increases in population have resulted in increased pressures on all types of land use activities in the country, and expansion of these uses into previously unused or restricted areas. Increased pressure on resources in inhabited areas has resulted in consumption of forest resources in those areas beyond the capacity for replenishment. In some previously unused or restricted

areas, use that exceeds management plan guidelines has outstripped replenishment rates. The causes and consequences of deforestation were discussed in Section 11.2.1. Halting the trend of deforestation, and eventual expansion of forested areas and forest reserves, is a primary objective of the "National Policy on the Environment" (FGN, 1989). Table 11-15 summarizes the primary causes and results of deforestation, and lists approaches to addressing this problem. These approaches are discussed in detail below.

Deforestation represents one of the gravest direct challenges to water resources development, resulting in loss of watershed integrity, erosion, soil degradation, and reduced water quality (Mathews, 1991; Verinumbe, 1991). Similar to the concept of sustainable yield discussed for groundwater supplies, long-term successful development of forestry products depends on adoption and enforcement of sustainable harvesting policies (FGN, 1989; World Bank, 1990). Forest reserves currently comprise approximately 10 percent of Nigeria's total land area. Within the individual states, forest reserves vary from a high of 26 percent of land area in Cross River State, to less than 1 percent in Rivers State. Other States with a high percentage of their land area in forest reserves include Sokoto, Kaduna, Kano, Bauchi, Oyo, Ondo, and Ogun.

TABLE 11-15 APPROACHES TO SOLUTIONS - DEFORESTATION

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
Deforestation	**CAUSES** Uncontrolled development of lands for agriculture or other uses Lack of adequate controls and enforcement on timber harvesting practices Continued reliance on fuelwood for cooking and heating Uncontrolled bushburing for land clearing **RESETS** Loss of wildlife habitat Reduction in integrity of water resources; reduced infiltration rates and reduced water quality	Intensify reforestation, afforestation programs Adopt and enforce sustainable harvesting practices in forest areas Promote alternatives to fuelwood, especially in urban areas Adjust fuelwood and forest products prices to reflect real costs Enforce ban on bushburing Expand the areas included in existing forest reserves, and restrict access to these areas as much as possible

Adoption of sustainable harvesting policies in both protected and unprotected areas will require cooperation and involvement on national, state, and local levels; at the latter level is where mismanagement occurs first. Sustainable management can successfully be based on local decisions and traditional practices only if local decision makers are aware of the stake they have in its success (Floor and Gorse, 1988). At the national level, consistent guidelines and guidance for conservation, land use planning, property rights, sustainable forestry practices, afforestation, and land rehabilitation (especially in arid areas) must be provided to the State and local levels (Mathews, 1991). The FMANR is currently moving to put in place management plans for all forest reserves, based on sustainable yield practices (Hashidu, 1992).

Efforts to increase the production of the forest section include afforestation and seedling planting programs with annual targets of 60,000-ha, adding additional plantation forest areas, increasing shelterbelt development in the arid north, and developing conservation and proliferation programs for endangered fruit trees. Vegetation is a commonly-used tool for rural water management; recommendations are to select those plant types with deep roots and large crowns. Appropriate vegetation can utilize deeper soil water and conserve soil, moderate climate, and yield wood. The vegetation also acts to prevent the direct physical impact of raindrops on tropical soil, which destroys soil structure and seals fine soil pores, reducing infiltration and accelerating erosion. Forests help to increase humidity, decrease temperature, and reduce soil water evaporation (Verinumbe, 1991).

On the large scale, additional areas should be identified, set aside, and gazetted as forest reserves, including multi-purpose reserves (agro-forest or silvo-pastoral areas) (FMAWRRD, 1988), industrial reserves, and environmental reserves. Management plans for existing and expanded forest reserves must limit access to these areas, and the sustainable harvest approach must be applied to both macro-scale logging and incidental wood removal. Enforcement of this access limitation is the only approach to maintaining sustainable yields (FEPA, 1991).

Land for industrial forest plantations (providing wood products for use by various industries [Federal Department of Forestry, 1991]), should be restricted to productive zones with adequate soils and rainfall (Floor and Gorse, 1988). Environmental forest plantations (planted to protect ecosystems in the

arid north or curb erosion in the south) should be instituted as needed to meet local needs, recognizing that additional benefits beyond the immediate need are gained (increased rainfall infiltration, provision of wildlife habitat, soil conservation, etc.).

An increase in forest reserves to 20 percent of Nigeria's total land area is targeted (FMAWRRD, 1988; Hashidu, 1992), which would result in a total of approximately 19 million ha under reserve. This level of effort will be necessary to meet the projected wood needs for Nigeria through the year 2020 (FMAWRRD, 1988). Major deficits in supply are currently forecast for fuelwood, which represents 97 percent of the overall projected wood and wood products shortfall.

Outside of designated reserves, local programs can also contribute to increases in forest cover and wood supplies. A program of "interstitial" forestry, targeted at planting trees in a decentralized, accessible manner, would promote tree planting around villages, along travel paths to fields and water supplies, and in other areas where an ongoing local presence will act to monitor success and appropriate use (Floor and Gorse, 1988). Trees planted as windbreaks also act as fuel sources for local inhabitants. Afforestation's benefits include reducing land degradation and water pollution (Iwugo and Mahendra, 1992).

The interaction of conflicting statutes on land clearing, land tenure, and traditional attitudes regarding wood as a "free" good have acted to distort the price of fuelwood. Clarification of government policies, enforcement of yields at sustainable levels, and adherence to management plans for reserves should result in more realistic prices for fuelwood (Floor and Gorse, 1988; World Bank, 1990; FEPA, 1991). Realistic pricing will also spur the switch to improved efficiency in fuelwood use (improved stoves) and to alternatives to fuelwood (including liquid petroleum gas or kerosene), especially in urban areas, where per capita use is disproportionately higher than in rural areas (Floor and Gorse, 1988). Nigeria has vast reserves of natural gas that are virtually untapped. As a by-product of oil production, 18-billion cubic metres of gas are flared annually as constituting a menace (NEST, 1991). At current production levels, Nigeria's natural gas reserves will last more that 130-years, and are a resource that deserves consideration to alleviate both the fuelgas demand and as an energy source for electricity production (using gas turbines, combined steam-gas cycle, etc.).

(c) Soil Erosion

Soil erosion is the very visible culmination of several areas of environmental degradation, including deforestation and soil degradation. In the southern part of Nigeria, the composition of the soil also contributes significantly to the erosion process, but soil erosion is only the end product of ongoing environmental problems. The primary causes and consequences of soil erosion were discussed in Sectio11.2.1. Table 11-16 summarizes those causes and consequences, and lists approaches to addressing the problem; these approaches are discussed in detail below.

Government reports and publications generally discuss completed erosion control projects, and announce the need for additional projects (both at very high costs), but give little mention to methods of prevention, or what types of management practices or planning approaches are necessary in the upstream watershed to reduce or prevent erosion problems. Many of the primary causes of erosion are directly related to the absence of adequate urban planning and enforcement, or to inadequate engineering practices related to infrastructure construction. In Anambra State, significant erosion has frequently been the result of inattention to the drainage parameter in rural road construction (World Bank, 1990). Inadequate drainage at the point of erosion points to the need for upstream watershed vegetation and drainage planning to reduce surface runoff, a strategy made difficult by the increasing density of buildings and structures in urban areas, traditional placement of towns (now grown to cities) on hilltops and hillsides, and pressure to convert vegetated areas to other uses. All of the same pressures and practices that result in desertification, soil degradation, and deforestation, discussed above, contribute to eventual soil erosion and gully formation. All of the control measures discussed previously will contribute to prevention of soil erosion.

In rural areas, soil erosion may take longer to emerge as a problem, but a wide variety of causes contribute. Land use planning and controls are the first step in controlling how land is used at the local level, and a combination of control measures that complement measures to relieve other environmental problems are effective, including revegetation and afforestation of watershed areas, drainage modifications (small check dams, etc.) to slow runoff and promote infiltration, and agriculture practices (crop rotation, contour farming) that prevent soil degradation (NEST, 1991).

The need for local involvement in planning and enforcement of land use controls is most evident in the need to stop environmentally-destructive practices such as bushburning to clear land, and mining the soil along river banks and drainage courses for building materials. Those practices, while traditionally accepted, greatly accelerate the erosion process. Extension services must work with local planners to demonstrate the need for, and long-term benefit of, environmentally-friendly land use practices. Erosion control recommendations require the integrated use ofagronomic and engineering practices to: 1) protect soil and 2) reduce runoff. Increased plant cover, especially in the wet season, modified tilling practices to fit the local rainfall patterns, promotion of increased absorption of rainfall and decrease in runoff volume, and reduction of runoff velocities are key approaches (Onwuemesi, 1990).

TABLE 11-16 APPROACHES TO SOLUTIONS - SOIL EROSION

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
Soil erosion	CAUSES Uncontrolled urban growth Removal of vegetation and increase in impervious surface area in upstream areas Inadequate urban drainage infrastructure Poor construction and design practices and lack of maintenance in roadbuilding Cultivation of unsuitable soil areas (on slopes, etc.) Overgrazing of erosion-pone areas Mining practices that fail to emphasize land reclamation and conservation	Active watershed management policies and practices, including upstream drainage control and reforestation/afforestation programs Improved urban and rural land use planning at all levels of government, with increased emphasis on responsibility and enforcement of plans at the local level to prevent land clearing and construction practices that promote erosion Improvements and additional requirements in construction practices, especially for roads and large infrastructure projects Curb environmentally-destructive practices such as bushburning, soil mining (for building materials, etc.), and unwise agricultural methods that promote erosion Controls on grazing rotation and intensity that decrease infiltration and promote runoff erosion Strengthen and enforce requirements on land tenants (i.e., mining companies, large land users) to adopt land use practices that control or prevent erosion

Measures to provide adequate land, water, and forage for pastoralists have been underway since the 1950s. A program to identify, acquire, and develop grazing reserves is currently being assisted by funds from the World Bank (Hashidu, 1992). Development of the reserves includes infrastructure, small dams to provide watering areas, and other support services. Currently, approximately 2.5 million ha have been set aside as grazing reserves, with an overall target of 10 percent of lands in Nigeria (approximately 9-million ha) (Aina and Adepipe, 1991; NRCC, 1992b).

In the Jos area, mining activities have altered the landscape and contributed to significant soil erosion. Little or no attempt at land reclamation was made, and the minerals areas were abandoned in their disturbed condition. Permits for these types of minerals extraction (tin, coal, oil, etc) must be accompanied by the requirement to return the land to its original condition, to maintain drainage patterns, and to mitigate soil degradation through revegetation and restoration of watershed integrity (FEPA, 1991; NEST, 1991).

(d) Coastal Erosion

Erosion in the coastal zone of Nigeria results from both natural processes of tidal and sea level changes (Ibe, 1988), and from the results of human influences in the coastal and upstream areas (World Bank, 1990). The primary causes and results of coastal erosion were detailed in Section 11.2.1. Table 11-17 summarizes approaches to addressing the problem; these approaches are discussed below.

TABLE 11 - 17 APPROACHES TO SOLUTIONS - COASTAL EROSION

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
Coastal erosion	**CAUSES** Reduced freshwater influx into estuarine areas Vegetation removal in watershed area; urbanization Lack of accretion (replenishment of sediments) Overexploitation of local resources Poor conservation practices in the oil and minerals exploration and development sector, including land subsidence in these areas **RESULTS** Loss of groundwater resources in the coastal zone due to lowered water levels or contamination by saltwater intrusion Reduced quality and availability of groundwater Loss of mangrove and lagoon habitat Shoreline erosion	Maintain historic levels of freshwater inflow into lagoon and estuarine areas Restrict access to sensitive areas through appropriate land use planning, especially near urban areas Strengthen and enforce environmental controls and requirements for all minerals exploration in the coastal zone Revegetation and protection of damaged areas Improved watershed management policies and practices, focussing on water quality, upstream development, and appropriate uses

In an area constantly exposed to natural erosion processes, activities in the watershed that reduce freshwater inflow to coastal areas can remove the counterbalancing influx of sediments that maintain the delicate equilibrium that exists there. Riverine and runoff sediment inputs replenish materials washed away by natural coastal processes. This freshwater inflow also maintains the delicate salinity balance in coastal areas (see also discussion above on Maintenance of Flow in the Lower Niger River and Estuary), a balance that affects plant and animal communities and groundwater supplies.

The coastal zone is a naturally-fragile ecosystem to which access must be carefully controlled. The rapid growth of urban areas in the coastal zone, partially in response to immigrants fleeing rural economic conditions, has severely stressed adjacent natural ecosystems. The growth has outstripped whatever land use planning and regulations exist in those areas. The

development of comprehensive and effective land use plans, and enforcement of those requirements, is essential if the valuable resources of the coastal area are to remain available for sustainable uses (World Bank, 1990). Sustainable development of the coastal zone depends on halting urbanization of shorelines, adopting regionally-sound erosion control measures, and implementing land use controls to preserve important ecological areas (FEPA, 1991). Mangrove areas need particular attention because of their multiple roles of providing resources (fuelwood, food), checking erosion through sediment stabilization, and providing critical habitat for fisheries and birds (Amadi, 1991). Mangrove forests need to be as carefully managed as other forest reserves; however, although mangrove forest comprises approximately one percent of the total Nigerian land area, only 3 percent of mangrove areas are in forest reserves. Management plans for these areas should designate additional areas for reserves, and develop criteria for their sustainable development (Ibe, 1988).

Damage to natural communities in the coastal zone as a result of minerals exploration and development (primarily oil) has been extensively documented (NEST, 1991; Amadi, 1992). While requirements for environmental protection inoil exploration and development have existed for many years, compliance and enforcement have not always been a priority. Sustainable development in the coastal zone requires that these regulations be enforced, and that past environmental damage be mitigated to the extent possible (FEPA, 1991), including controlling subsidence, spill cleanup, and revegetation of damaged areas (Ibe, 1990).

Structural measures for combatting coastal erosion are extremely expensive to construct and maintain, frequently increase local erosion, and may decrease productivity downstream. Natural processes are generally more cost-effective when combined with appropriate land use planning and management. These measures include controls on rates and location of urbanization, setbacks from coastal areas, restoration and reforestation of damaged areas, and enforcement of these requirements (Ibe, 1990).

(e) Wildlife and Fisheries Losses

A significant goal of the NWRMP should be to maintain and improve biological diversity, and protect unique habitats, ecosystems, and species

(LCBC, 1992). The benefits of special habitats are myriad. Certain isolated or protected forest reserves, and especially rain forest areas, are significant areas of biodiversity reserve, in some cases the last refuge for many types of wildlife and birds remaining. Only 22,264 km^2 have been set aside as national parks, with another 9,750 km^2 proposed (NPB, 1993). This combined area represents only 3 percent of Nigeria's land area.

Mangrove forest areas stabilize the coastal environment, preventing saltwater intrusion into coastal aquifers and protecting water quality in coastal areas. Other benefits of mangrove forest areas include provision of economic returns from plants (fruit, firewood, building materials), habitat for endangered wildlife and birds, and a unique breeding ground for most of the commercially-important species taken in coastal fisheries (Amadi, 1991, 1992; NRCC 1992).

Wetlands areas in northern Nigeria provide valuable sources of dry season water, groundwater recharge, and vegetation and fodder for grazing. During the wet season, these areas provide flood storage and slow release of floodwaters, protecting downstream users. Wetlands trap sediments and retain nutrients, and also release these nutrients to downstream users as plant and animal matter. Many fisheries depend on innundation of these wetland areas as nurseries for fish spawning during the wet season, and yields are generally tied to the extent and volume of annual flooding. They are a valuable year-round source of protein from fisheries and wildlife, and often an important sanctuary for migrating wildlife (NRCC, 1992).

Areas designated for groundwater recharge should be set aside as forest reserves, as afforestation/reforestation promotes groundwater recharge and protects water quality in underground aquifers (NRCC, 1992).

(f) Flooding

Flooding is a very visible manifestation of the incompatibility of human development in defiance of natural processes. Flooding is a natural seasonal phenomenon that has widespread implications for natural ecological systems. Flood waters recharge groundwater supplies, replenish soils through accretion, flush accumulated sediments and toxins from river basins, and maintain the salinity mix in coastal areas.

Flooding impacts on human development when man attempts to circumvent, control, or ignore this natural process. Table 11-18 lists the primary causes and results of flooding as it impacts human activities. Approaches to solutions to these problems are listed in the table and detailed below.

TABLE 11 - 18 APPROACHES TO SOLUTIONS - FLOODING

Problem	Primary Causes and Results	Needs (Approaches to Solutions)
Flooding	**CAUSES** Upstream vegetation removal Deforestation Inappropriate land use practices Inadequate drainage controls Increases in percent impervious area **RESULTS** Increased runoff and erosion Increased sedimentation in receiving water Flood control works and structures frequently only transfer the problem further downstream Expensive to engineer remedies (capital and O&M)	Restricted land use and improved controls around rivers to prevent high occupancy, land clearing, and increases in impervious surface Watershed management to tie land use to long-term land suitability Upstream revegetation/afforestation to increase groundwater recharge and reduce surface runoff Construction in or across floodplains carefully designed and managed to minimize restrictions of flow Off-line storage/release based on hydrologic cycle (above some historic average maximum) to prevent catastrophes; small decentralized facilities located in rural areas

Seasonal flooding is a critical aspect of natural ecological systems. Rivers, bays, and adjacent natural communities have developed over time in response to such a condition. These communities rely on the influx of water and sediment accretion; the life cycle of many of Nigeria's most important fisheries species depends on this natural cycle. Control of flooding generally entails a reduction in the amount of water in drainage courses. The implications of long-term reductions in water flows were discussed earlier.

In urban areas, flooding is generally caused by rapid urbanization without adequate regard for drainage controls. The increased ratio of impervious area in urbanized regions prevents infiltration of rainfall, which is rapidly mobilized in runoff flows. Rapid urbanization is frequently accompanied by lack of planning or inattention to requirements, resulting in

construction of facilities (even dwellings) in drainage courses and on floodplains. Since the amount of upstream runoff grows with urban expansion, these facilities become increasing susceptible to innundation, even in minor rainfall events (NEST, 1991).

In rural areas, unexpected flooding is generally attributable to poor management or use practices in the watershed, including upstream vegetation removal and deforestation that reduce infiltration and increase surface runoff. Flooding in river flood plains is considered expected flooding; land use management guidelines in fadama areas should reflect the seasonal cycle, and activities and construction of infrastructure should be planned and restricted accordingly.

The result of these inappropriate land use activities is increased runoff and erosion and increased sedimentation in receiving waters (see also discussions on Soil Erosion and Water Pollution). Flood control works, designed to channel the increased water volume and prevent it from reaching areas that would normally be innundated, frequently only transfer the problem further downstream (the volume of water generated has been increased, not reduced). Structural control measures are also very expensive to construct and maintain.

Control and enforcement of inappropriate land uses adjacent to drainage courses and river basins is the most obvious method of minimizing damage to human activities due to flooding. These controls should prevent land clearing, construction of buildings for occupancy, and any increases in impervious surface in the designated floodplain or drainage course (NEST, 1991). These measures will help to limit the volumes of water generated adjacent to the drainage areas. However, long-term control on flooding intensity and effects can only be achieved through integrated watershed management that ties land suitability, land use, and downstream development together. Runoff volumes from a given area vary based on soil type, slope, degree of development, and rainfall intensity. For any watershed in Nigeria, the amount of runoff generated by a given amount of rainfall can be estimated fairly well; these watershed models must be used to determine appropriate land uses and development strategies in the long-term.