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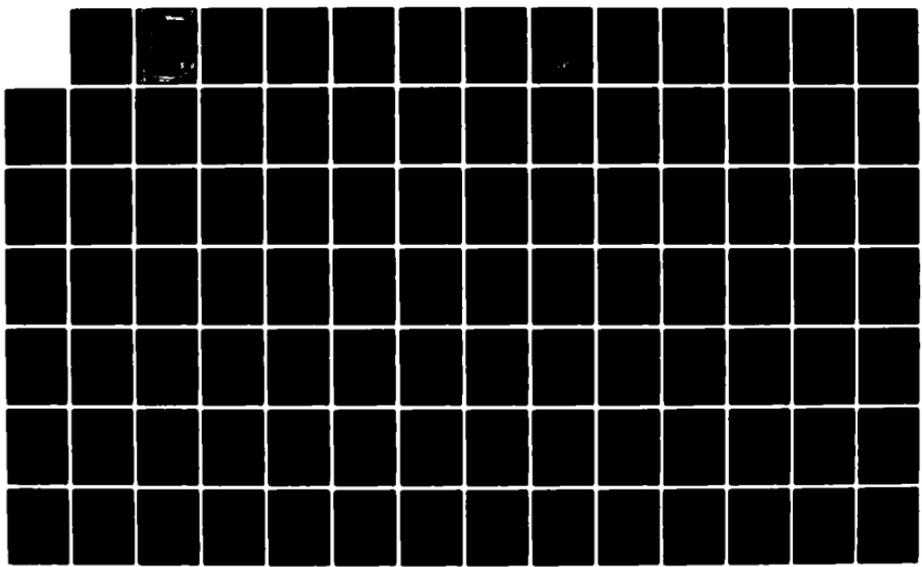
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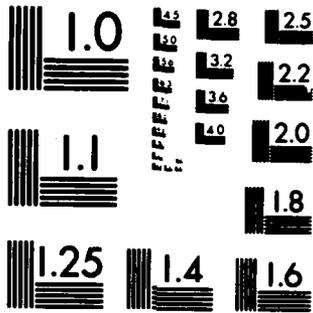
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designed to provide emergency or temporary mooring for commercial vessels and/or related barge,rafts.

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**FINAL REPORT
MARCH 1982**

**MISSISSIPPI RIVER NAVIGATION SYSTEM
ENVIRONMENTAL EVALUATIONS OF PROPOSED
MOORING FACILITIES**

BY

**PHILIP R. ABELL, CAREY W. BURCH, BRENDA L. DAWSON
CLARKE F. DILKS AND PATRICIA L. GILMORE**

**VERSAR, INC.
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**PROJECT OFFICERS:
OWEN D. DUTT AND KARON MARZEC
ENVIRONMENTAL STUDIES SECTION
CORPS OF ENGINEERS
ST. LOUIS DISTRICT**

**CONTRACTING OFFICER:
COLONEL ROBERT J. DACEY
DISTRICT ENGINEER
CORPS OF ENGINEERS
ST. LOUIS DISTRICT
ST. LOUIS, MO 63101**



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1.0 GENERAL INTRODUCTION

1.1 Background

As part of the Mississippi River Mooring Study, an investigation was undertaken under the direction of the St. Louis District, Corps of Engineers to evaluate the generic environmental implications of various alternative mooring devices and structures proposed in conjunction with the study. The area encompassed by the study is the Mississippi River Navigation System (MRNS). The MRNS consists of a number of individual rivers which have been improved by the Corps for commercial navigation. These rivers include:

- Mississippi River Mainstem
- Missouri River
- Ohio River
- Illinois River
- Kaskaskia River
- Tennessee River
- Cumberland River
- Arkansas River
- Kentucky River
- Red River
- Green River
- Ouchita River
- Monongahela River
- Allegheny River
- Kanawha River
- Yazoo River
- White River

The study area is depicted in Figure 1.

The investigation focused on the identification and evaluation of the types of effects and general environmental impacts that can result from the construction and operation of each of the types of mooring devices that are designed to provide emergency or temporary mooring for commercial vessels and/or related barge rafts. The types of mooring facilities evaluated include:

- Pilings
- Dolphins (pile clusters)
- Battered pilings
- Mooring cells
- Buoys
- Fleeting barges



LEGEND

- EXISTING PRINCIPAL WATERWAY
- WATERWAY UNDER CONSTRUCTION
- AUTHORIZED WATERWAY
- OTHER WATERWAY
- EXISTING LOCK OR LOCKS
- LOCK OR LOCKS UNDER CONSTRUCTION
- AUTHORIZED LOCK OR LOCKS
- LOCK NAMES
- NUMBER OF MULTIPLE LOCKS

SCHMATIC NOT TO SCALE

Figure 1

**MISSISSIPPI RIVER NAVIGATION SYSTEM
ADEQUATE MOORING FACILITIES
FOR WATER CRAFT**

U. S. ARMY ENGINEER DISTRICT, ST. LOUIS
LOWER MISSISSIPPI VALLEY DIVISION

- Anchor barges
- Shoreline deadmen and cables
- Unregulated moorings

The environmental implications inherent with the construction and utilization of each of these types of mooring facilities were examined in terms of physical, biological, and cultural resource parameters.

Section 2.0 of the report presents descriptions of navigable rivers comprising the MRNS that are being considered for the installation of emergency/temporary mooring structures. Descriptions of these mooring structures and their associated general environmental effects are provided in Section 3.0. Section 4.0 integrates the material developed in Sections 2.0 and 3.0 and identifies in matrix and narrative form areas of special consideration. The conclusions of the study are also presented in Section 4.0. Section 5.0 lists the references used and sources of additional information.

2.0 GENERAL ENVIRONMENTAL CONDITIONS

2.1 Introduction

The Mississippi River Navigation System is comprised of seventeen individual, interconnecting rivers. Portions of each of these rivers have been developed by the Corps of Engineers to accommodate commercial barge traffic transporting a diverse variety of cargoes. The rivers comprising the Mississippi River Navigation System are described below in terms of their physical (location, size, physiography), biological (flora, fauna and habitat) and cultural (recreation, landuse & development) resources. These descriptions will provide the basis for the identification of mooring facility impacts that are presented in subsequent sections.

2.2 Mississippi River Mainstem

2.2.1 Physical Characteristics

The Mississippi River Basin covers a drainage area of 1,245,000 square miles, and includes 41 percent of the land in the contiguous United States. The Mississippi River Basin covers parts of 31 states and two Canadian provinces (COE, 1979a). The alluvial valley of the Mississippi River extends over 35,000 square miles. The river's source is in Lake Itasca, in Minneapolis, Minnesota, and flows 1,578 miles to Fort Eads, Louisiana. It has been convenient to divide the river into the Lower (LMB) and Upper (UMB) Mississippi Basins, with the mouth of the Ohio River forming the division between them.

Changes in the Mississippi River for commercial navigation has altered the river's physical and biological characteristics substantially. The topography of the UMB is part of a glacial plain with highly erodible soils. The northern river valleys are steep and narrow, whereas in the middle portions of the UMB the uplands are flat with high bluffs bordering the floodplains which vary in width (UMRBC, 1980). The southern most portion is characterized by rolling narrow ridges with moderate to steep slopes. Here the major rivers have level, broad floodplains which have been altered by levee construction. The river has also been restricted by closing structures, dikes, and revetments in order to maintain a navigation channel.

The lower Mississippi River basin near the coast is composed of lowlands and natural marshes which begin at the Louisiana coast and continue 35 miles inland. North of the coastal region, the basin is composed of high ground (occupied by villages, cities and fertile farmland), and large areas of low lying lands bordering swamps. Elevation ranges from 300 feet above sea level at Cairo, Illinois, to sea level at the Gulf of Mexico.

The mean annual discharge of the Mississippi River below Tarbert Landing, Mississippi, (which is at river mile 306, approximately 8 river miles below the Outflow Channel) was approximately 451,000 cfs (cubic feet per second) over the 9 year period from 1964 to 1973, and represents 75 percent of the flow discharged. Another 150,000 cfs is diverted from the Mississippi River to the Atchafalaya River through the Old River Outflow Channel in the vicinity of Angola, Louisiana. The heaviest flows occur during the first half of the year with the heaviest rainfall occurring from late winter to early spring.

Water quality in the UMB has declined due to use of insecticides and herbicides, outflows of industrial and municipal wastewater, and increased erosion due to poor land use practices in both urban and rural areas. Water quality in the St. Louis metropolitan area is severely deteriorated due to increased sediment loads from the Missouri River, municipal and industrial discharges and navigational activities. Water in the Lower Mississippi mainstem comes from precipitation, runoff, inflows and groundwater. It is moderately hard water with maximum dissolved solids content of 344 milligrams per liter. Major pollutants for this region are chlorides and sediment (which cause major oxygen deficiencies in some parts). In the coastal zone, water quality is deteriorating and many areas are eutrophic. The major sources of this pollution are municipal wastes, industrial waste, runoff, and drainage from agricultural land. North of the coastal zone, pollutants come from urban storm water, construction site erosion, mining activities and wastewater disposal.

2.2.2 Biological Features

The Upper Mississippi River Basin (UMB) provides many types of aquatic habitats including channels, sloughs, wetlands, and lakes. There are two National Wildlife Refuges in the UMB: The Upper Mississippi River Wildlife and Fish Refuge, and the Mark Twain National Wildlife Refuge. Forests are of mixed hardwoods and fish species most common are trout, walleye, northern pike, bass, crappie, sunfish, bullheads, catfish, perch, carp and suckers.

Terrestrial vegetation on the flood plain on the UMB follows a general pattern of succession starting with alluvial deposition and ending with floodplain forest. Willows and cottonwoods pioneer the alluvium with the understory of cocklebur, wormwood and grasses. These trees are eventually replaced with silver maples, green ash, basswood, and American elm. In upland areas swamp white oaks and river birch dominate, with southern portions of the UMB supporting bald cypress and tupelo. In regions having moderate moisture conditions species present include sycamore, hackberry, hickory, black walnut, pin oak, and pecan.

In northern reaches of the UMB, north of Alton, Illinois, approximately 50 percent of the total area is aquatic habitat, and approximately 40 percent is designated as part of the national Refuge System (UMRBC, 1981). One-hundred species of fish have been recorded, 6 of which are abundant, 27 classified common, and 3 as rare. There are 300 species of birds in the UMB, 100 of which use it as a nesting area. Mammals that inhabit the area include beaver, river otter, mink muskrat, squirrel, racoon, white tailed deer, fox, coyote, and bobcat. Forty-one species of reptiles and 20 species of amphibians occur in this reach. Federally endangered or threatened species include the bald eagle, fat pocketbook pearly mussel, Higgin's eye pearly mussel, American peregrine falcon, arctic peregrine falcon, gray bat and Indiana bat.

In the region of UMB between Alton, Illinois and Cairo, Ohio there is a lower percentage of aquatic areas than in the upper portions, which comprise 30 percent of the area in this reach. No portions of this reach are included in the National Refuge System. Ninety-nine species of fish have been found of which 20 are common. Bird populations total 174, some of which nest, some of which are migratory. There are 50 mammal species, major upland animals being whitetailed deer, fox and coyote. Eighty-six species of amphibians and reptiles combined are expected to exist in this area.

The most common aquatic flora in the LMB are pondweed, southern wild rice, coontail, waterweed, and pond lillies. Other aquatic and wetland monocotyledons are water plantain, arrowhead, jack-in-the-pulpit, duckweed, and bur-reed. There are 200 species of freshwater fish among which the most abundant are red drum, carp, paddlefish, bass, walleye, and crappies.

Terrestrial habitats in the LMB consists of forests, prairie lands, crop lands, pasture lands, and swamps. The swamps support stands of bald cypress, tupelo, overcup oak, water locust, and other trees associated with the southern swamp. Marshes on the Mississippi also have cattails, bulrushes, sedges, and other aquatic plants. Invaders of sandbars and mudflats are the black willows and cottonwoods, with river birch and swamp white oak in open wetlands. Shorelines are dominated by silver maples and American elms.

Mammals, birds, amphibians, and reptiles are present in the marshy areas of the LMB. The marsh areas provide excellent habitat for furbearers and waterfowl. In the Mississippi flood plain, the larger swamps are ideal for nesting birds such as cormorants, anhingas, great blue herons, great egrets, green herons, black-crowned night herons, wood ducks, black vultures, red-shouldered hawks, and barred owls. In the marsh areas the following birds breed regularly: pied-billed grebe, American bittern, least bittern, king rail, Virginia rail, sora rail, common gallinule, and American coot. The Mississippi Valley is one of the chief migration routes for birds breeding in north-central America. Other riparian fauna that inhabit the bottomlands of the Mississippi River are racoons, muskrats, river otters, and minks.

Benthic organisms representative of the entire Mississippi Basin include mayflies, segmented worms, caddis flies, fingernail clams, and mussels. The most common phytoplankton are diatoms.

2.2.3 Cultural Features

The LMB supported a population of 3 million people in 1970 (COE, 1976). The area has become increasingly urbanized having 76 percent of the population being urban in 1970. The population of the UMB was approximately 4 million in 1975, 74 percent of which live in urban areas (UMRBC, 1980). St. Louis, Missouri, is the largest metropolitan region in the UMB having almost 60 percent of that regions total population.

Land use along the Mississippi includes transportation, agriculture, forests, mineral production, residential, commercial, industrial, and wildlife refuges. The natural land cover in the UMB consists primarily of forest in the north and south, prairies in the east and west, and a mixture of forests and prairies in the central portion. Much of the land has been converted to cropland which covers 58

percent of the land area. Forests constitute 18 percent of the land, pasture 10 percent, urban 7 percent, and other (including rural land, water and federal land) 7 percent.

In the reach from Alton, Illinois to Cairo, Illinois, lands adjacent to the river have been converted to agricultural use due to levee constructions. The floodplain is dominated by agricultural use. Traffic on the Upper Mississippi River amounted to 67,020,864 tons in 1977 (UMRBC, 1980). The major commodities transported were coal, petroleum, and grain.

Industries in the LMB are developing along the banks because of the increased need for a reliable water supply and an economical and dependable barge transportation system. Some industrial plants that can be found along the Mississippi include petroleum refineries, industrial and agricultural chemical plants, grain elevators and food processing plants. The Mississippi River Navigation System provides for efficient transportation of large volumes of bulk commodities, including grains, coal, petroleum, cement, stone, sand, gravel, chemicals and metal products.

The canalization of the river and development of head water reservoirs has increased recreational attractiveness because of more stable water levels and year round slack water pools for boating, fishing, swimming, camping and hunting.

A significant portion of the recreational activity in the UMB is large pleasure craft, fishing, and hunting. Much of the shoreland is inaccessible due to privately owned land between public roads and the river banks. Three-fourths of the public lands along the river are set aside for wildlife management, and only a small percentage of this is developed for recreation (UMRBC, 1980).

In the far northern portion of the UMB there were 27 million activity days of recreational use in 1975. Sports fishing being the most popular. There are approximately 14,000 archeological/historical sites, and there are portions of the basin that have been suggested as national wilderness areas, but have no official designation as yet. In the southern portion of UMB there are few access areas and recreational facilities and therefore less recreational use.

The 1917 and 1928 Flood Control Acts authorized several projects including levee construction floodways,

revetments, dikes, dredging, cutoffs, floodwalls, floodgates, and reservoirs (COE, 1979b). In 1927 a 9 foot channel from Cairo, Illinois to St. Louis, Missouri was authorized, and in 1930 congress authorized the 9 foot channel to be continued from St. Louis to Minneapolis, Minnesota. The lower Mississippi River has a 12 foot channel, and in addition, has a 40 foot deep-draft channel from Baton Rouge, La., to the Gulf of Mexico.

In the Upper Mississippi reaches, and in the Memphis COE District, there is concern about illegal mooring by barges that are tying to trees from deep water (COE, 1982e; COE, 1982f). Usually illegal mooring is in the form of barges waiting to pass through locks. In the Lower Mississippi most mooring is supplied by commercial concerns which utilize deadmen, docks, piles, anchors and buoys and mooring dolphins (COE, 1982g).

2.3 Ohio River

2.3.1 The Ohio River Basin

The Ohio River Basin is located in the North Central portion of the eastern United States. The Ohio River runs along the northeast-southwest axis of the basin and is fed by 18 major tributaries. The major rivers in the basin which flow into the Ohio River are the Tennessee, Allegheny, Monongahela, Kanawha, Kentucky, Green, and Cumberland Rivers. Of the six natural tributary basins to the Mississippi River, the Ohio River Basin contributes the largest flow (ORBC, 1979). The southern portion of the basin is dominated by the Tennessee River Basin. The eastern half of the Ohio Basin lies in the Appalachian mountains. The western half of the basin is in the midwestern farmlands.

Historically, the Ohio River Basin has been important to the economic development of the nation by providing for the transportation of people and goods throughout the mid-east United States. Total Ohio River tonnage has increased from 44 million tons in 1960 to approximately 151 million tons in 1977 (COE, 1980a). In 1976, the total freight transport in the basin was 178 million tons, which primarily included coal and coke, petroleum and petroleum products, aggregates, grains, chemicals, ores and minerals, and iron and steel (ORBSCC, 1969; ORBC, 1979). In 1975, the Ohio River Basin contained 21 million people; approximately 10 percent of the nation's population.

2.3.2 Physical Characteristics

The Ohio River drains 203,910 square miles of land in 11 states which include Illinois, Indiana, Ohio, Pennsylvania, New York, Maryland, West Virginia, Virginia, Tennessee, Kentucky and North Carolina. The Ohio River Basin is bounded on the north by the Great Lakes Basin, on the east by the divide of the Appalachian mountains, on the south by the Tennessee River Basin, and on the west by the drainage area of the Upper Mississippi River. The river itself is 981 miles long, is formed by the confluence of the Allegheny and Monongahela Rivers in Pittsburgh, Pennsylvania, and flows in a southwest direction to its mouth on the Mississippi River at Cairo, Illinois.

In the eastern half of the basin the stream gradients are steep; there are flash floods during the rainy season, and low flows during the dry seasons. Season high flows generally occur from January to March, having maximum flows in January. Low flows occur from July through October with lowest flows occurring in October (COE, 1980a). Average runoff is 17.3 inches per year (which is 30 percent of the rainfall), with higher values in the eastern half of the basin.

The Ohio River Basin lies in three major physiographic regions. The eastern portion, from central Ohio to Pittsburg, Pennsylvania lies in the Appalachian plateau, and is an area of rugged topography, steep stream gradients, narrow valleys, poor soils, and extensive forests. South of the Ohio River, from central Ohio to the mouth at the Mississippi River and including the unglaciated areas north of the Ohio River in Illinois and Indiana, is the Interior Lowland Plateau. North of the Ohio River is the drainage area called the Central Lowlands, which is characterized by deposits of glacial till and drift with alluvial deposits 20 to 200 feet deep.

Most of the water quality problems in the Ohio basin are due to runoff, municipal waste discharges, industrial pollution and coal mining. Organic wastes are the most significant cause of pollution, characterized by the high BOD from sewage treatment effluents. In 1979, the Ohio Basin Commission determined that 40 percent of municipal treatment facilities, and 26 percent of industrial treatment facilities needed improved wastewater treatment (ORBC, 1979).

There are four major sources of non-point pollution: agricultural and silvicultural runoff, mining runoff, urban runoff, and stream bed erosion. In the Ohio Basin, 10,070 miles of waterways are affected by acid mine drainage from coal mines (50 to 70 percent from abandoned mines, 25 percent from operational strip mines).

An interim method to decrease water pollution has been low flow augmentation by the construction of reservoirs which hold extra amounts that are released during low flows, diluting the effects of some of the pollutants.

2.3.3 Biological Features

A comprehensive description of the basins biota appears in Water Resources Development by the U.S. Army

Corps of Engineers in Kentucky (COE, 1980a). In the upper Ohio River mainstem, phytoplankton are predominately diatoms (129 species). In the upper industrialized reaches, benthic organisms are characterized by pollution-tolerant facultative anaerobes. In the middle and lower reaches numbers and diversity of benthic organisms increases. A total of 130 species of fish have been found in the Ohio River, and were found in decreasing order of numerical abundance to include, emerald shiner, gizzard shad, freshwater drum, channel catfish, carp and black bullheads.

The vegetation of the Ohio Basin includes three regions of the deciduous forest formation, characterized by mixed mesophytic forest in the upper reaches, western mesophytic forest in the lower mainstem, and the southeastern evergreen forests in the Mississippi alluvial valley. The mixed mesophytic forests are dominated by oaks, basswood buckeyes, and hickories.

The alluvial region has swamps consisting of bald cypress and tupelo; hardwood bottomland forests composed primarily of oaks, hickories, maples, and sweetgum.

The ranges of 72 mammals, 51 amphibians and 78 reptiles overlap the Ohio mainstem and include shrews, moles, bats, squirrels, mice, salamanders, toads, frogs, lizards, snakes. There are three major bird habitats: the flood plain forest; fields and croplands; and upland forests. Some of the impounded waters are periodically stocked with bass, catfish, bullhead, walleye, trout, northern pike and muskellunge. Commercial catches in the river were dominated by buffalo, carp catfish, drum, paddlefish, and mussels.

Waterfowl habitats comprise approximately 2000 square miles of the basin area and are utilized by duck, geese, and other migrating birds.

2.3.4 Cultural Features

In 1975 the population of the entire basin was 21 million. Sixty percent of the population was urban, 40 percent rural, with 10 percent of the rural on farms (ORBC, 1979). The population is concentrated in the northern portion with the highest density being in the Pittsburgh, Pennsylvania metropolitan area.

In 1975, 90 percent of the land in the basin was used for agricultural and silvicultural uses. Seven million acres were urban, 33 million acres cropland, 14 million acres pasture, 43 million acres forest, and 2 million acres water (ORBC, 1979).

Most of the Ohio River lies in the East Central General Farming and Forest Resource Region (ORBSCC, 1969). North of the river, in Ohio and Illinois, the basin lies in the Central Feed Grains and Livestock Region. The northeastern part of the river is urban-industrial and products include iron, steel and machinery. The south and southeast portions of the basin process coal, forest products and supports small farms. The northwest is farmland.

Uses of the river include hydroelectric power generation, commercial fishing, and transportation. In 1976, the Ohio River carried 148.4 million freight tons, with the major transport items being coal and coke (78.8 million tons), petroleum, (19.8 million tons), construction aggregates (17.4 million tons), grains (5.4 million tons), chemicals (9.1 million tons), ores and minerals (3.4 million tons) and iron and steel (4.3 million tons) (ORBSCC, 1969; ORBC, 1979).

There are 63,000 acres of National Park land contained in 10 sites in the basin. There are 620,000 acres of water in the basin used for outdoor recreation, with 372,000 acres of this being in navigation pools. Sports fishing and hunting are major recreational activities followed closely by recreational boating, swimming, picnicking, hiking and camping. The Appalachian plateau provides native trout fishing in its streams. Many of the dams and impoundments built along the river provide shoreline and river recreation.

The 9 foot slackwater navigation system on the Ohio River was authorized by the Rivers and Harbors Act of 1909. Through the years this was modified and by 1937 the number of locks and dams were reduced from 54 to 45. The Flood Control Acts of 1936-1938 developed the basis for a basinwide protection plan. By 1950 all but 6 of the original 54 locks and dams had been replaced with 14 higher dams, bringing the present total to 20.

By 1965 there were 75 reservoirs, 86 local flood protection projects, 56 small flood basin projects, and 74 upstream watershed projects. Today the entire 981 miles of the Ohio has a 9 foot deep and 500 foot wide channel (300 feet

wide at places of recurrent shoaling) and 440 structures maintained by the Corps of Engineers (ORBC, 1979). In addition, 777 miles of tributary rivers to the Ohio are maintained to a 9 feet depth. (ORBSCC, 1968). Mooring areas on the Ohio mainstem in the Louisville District (COE) are placed 10 miles apart, and were located for emergency and safety use (COE, 1982a). These mooring facilities consist of 2 floating buoys which are located 585 feet apart, and are anchored to concrete capped pile clusters by anchor chains. In the Huntington District (COE) mooring facilities are presently in the vicinities of the locks and dams, with plans to place mooring cells every 10 miles for emergency use when funds become available (COE, 1982b). This portion of the river is highly sloping, has fast currents, and fluctuations in river levels and therefore cannot use buoy type mooring structures.

2.4 Allegheny River

2.4.1 Physical Characteristics

The Allegheny River originates in northern Pennsylvania and flows northwest into New York State for 50 miles. From the New York stateline it then travels south for 250 miles and ends in Pittsburgh, Pennsylvania, where it joins the Monongahela River to form the Ohio River. The river has a total drainage area of 11,778 square miles.

The flow of the Allegheny River has wide seasonal variations, the heaviest being between December and April and the lightest being between August and October. The average flow for the entire drainage basin is 19,030 cfs (COE, 1975a).

The physiography of the basin in the northern section is a mature glaciated plateau, characterized by rolling plains, lakes and swamps. In the southern section there are unglaciated and maturely divided plateaus characterized by uplands, narrow valleys and steep inclines. Landslides are the major geologic hazard. The basin elevation ranges between 710 feet at the mouth to 2,500 feet in the eastern section.

Generally, the water quality of the river is good. However, brine from oil wells causes high concentrations of dissolved solids within the river (COE, 1975a). Other major sources of pollution include manufacturing, municipalities, runoff, and acid mine drainage. The Allegheny and Monongahela River together are responsible for the contribution of over half the acid mine drainage to the Ohio River Basin (ORBC, 1979; ORBSCC, 1969).

2.4.2 Biological Features

The majority of the phytoplankton population in the Allegheny River consists of diatoms and rotifers. There are 25 families of fish present including such pollution sensitive species as walleyes, muskellunge and largemouth bass. The abundance of fish is much lower in the navigable portions of the river than in the upper basins.

Acid mine drainage, municipal wastes and industrial effluents have severely reduced the benthic macroinvertebrate population in the Allegheny River. Characteristic organisms in the lower reaches of the river are pollution tolerant chironomids.

The land through which the mainstem of the river flows is a mixed mesophytic forest region which is characterized by broad leaved deciduous forests dominated by white oak, red oak, yellow birch, beech, sugar maple, hemlock, and yellow-poplar. Due to forest harvesting activities, transitional forests of spruce, pin oak, hemlock and hickory are increasing.

Shoreline wildlife is typical of the Carolina life zone. There are 250 species of birds, 47 species of mammals, 49 species of amphibians and reptiles. There is a diverse population of amphibians and reptiles ranging over 49 species, including rare and endangered species. Waterfowl are common along the river during migration seasons, and include the greater scaup, ring-necked duck, bufflehead, goldeneye, mallard, wood duck, and others.

2.4.3 Cultural Features

Land use adjacent to the river is largely related to forest resources which in 1967 comprised 40 percent of the basin acreage. Other uses consist of agricultural, industrial, and urban development. Agricultural uses have been declining due to decreasing soil quality, while resource development of coal, sand, gas and gravel have increased. Urban areas in the Allegheny basin include Pittsburgh, New Kensington and Lower Burrell.

Historically, the Allegheny River was used for transport of people and supplies, and for domestic and industrial water supplies. Today, river water is used for water supplies, cooling water for industry, transportation, and hydroelectric facilities. In 1964, the mainstem carried 4.87 million tons of cargo. By 1976 this increased to 5.4 million tons, the main materials of transport being coal, coke, sand, gravel, iron, steel and petroleum (COE, 1981a).

Recreational activities along the river include fishing, hunting, camping, boating, swimming, and sightseeing. Presently there are 10,515 acres of water suitable for recreational uses and approximately 18,491 acres of land developed for outdoor recreational pursuits. The primary recreation activity is boating.

Development of the river historically included purposes of navigation, flood control, power generation, water supply, low flow regulation, and recreation. In 1879 the federal government approved open channel improvements including 8 locks and dams, which were completed in 1938. The navigation channel extends 72 miles from the river mouth at Pittsburgh, Pennsylvania to East Brady, Pennsylvania, and has a minimum depth of 9 feet and a minimum width of 200 feet. There are 10 major reservoirs, of which 9 are operated by the Corps. One is operated by a power company.

2.5 Monongahela River

2.5.1 Physical Characteristics

The Monongahela River basin is located in the eastern portion of the Ohio River basin in the states of Maryland, Pennsylvania, and West Virginia. It is formed by the confluence of the West Fork River and Tygart River, located one mile south of Fairmont, West Virginia. It drains 7,384 square miles of land and is 128 miles long (Bissell, 1952; Morr, 1975). It flows north into Pennsylvania and joins the Allegheny River at Pittsburgh to form the Ohio River. It is bounded on the south and east by the divide of the Appalachian mountains, on the north by the Allegheny River basin, in the southwest by the Kanawha River basin, and on the west by the upper Ohio River basin.

The average stream flow of the Monongahela River at Morgantown, West Virginia is 4,340 cubic feet per second (cfs). As it joins with the Youghiogheny River its flow is increased to 12,140 cfs. Stream gradients are steep, stream valleys are deep, and flash flooding occurs during periods of high flow from January through March. Periods of low flow occur from July to early October.

The river basin ranges in elevation from 4,600 feet above msl at the head of the Cheat River to 700 feet at the mouth of the Monongahela River at Pittsburgh, Pennsylvania.

The Monongahela River suffers from several sources of water pollution including municipal sewage, industrial wastes, nonpoint sources, and acid mine drainage. Of all of these, acid mine drainage is the worst, with the entire basin suffering serious effects. When considering all 10,070 miles of the Ohio River basin that is affected by acid mine drainage, the Monongahela River basin is responsible for 22 percent of the stream miles affected by acid drainage (ORBSCC, 1969; Morr, 1975).

2.5.2 Biological Features

Flora and fauna of the Monongahela River are similar to that described in the Ohio River Basin and Allegheny River Basin. The predominate phytoplankton population consists of diatoms (that are more abundant in winter and spring), with smaller populations of green algae appearing in summer and

fall. Zooplankton are primarily rotifers, with Cladocerans being more abundant in the downstream polluted waters. Benthic organisms found in the cleaner water upstream from Pittsburgh, Pennsylvania, include midges, caddisflies, damselflies and stoneflies. In areas of pollution and low pH benthos consists of bloodworms, oligochetes, tubificids and 2 species of midges.

Some fish species commonly found in the upper Ohio basin in West Virginia are spotted bass, walleye, freshwater drum, carp, goldfish, shiners (several species) and gizzard shad. Federally endangered animals in West Virginia are southern bald eagle, peregrine falcon, Kirtland's warbler, Indiana bat, mountain lion, and pearly mussel. Shoreline wildlife is typical of the Carolina life zone and includes diverse populations of mammals, amphibians, reptiles and waterfowl.

The land through which the Monogahela flows is covered by a mixed mesophytic forest which is dominated by oaks, basswood, buckeyes, hickories, yellow birch, beech, sugar maple, hemlock, and yellow poplar.

2.5.3 Cultural Features

In 1979 the population of the Monongahela basin was 513,000, including the metropolitan area of Pittsburgh, Pennsylvania.

The river is used for transportation, recreation, power generation, and domestic and industrial water supply. Primary cargo carried on the Monongahela River is coal and coke, with the remainder being petroleum products, construction aggregates, and iron and steel. Coal is transported on the river from the mines in northern West Virginia, and southwestern Pennsylvania.

In the north end of the basin, at the mouth of the Monongahela River there is the urban area of Pittsburgh, Pennsylvania which is highly industrialized. Other metropolitan areas of Johnstown, Clarksburg, Morgantown and Fairmont, along with Pittsburgh held a total population of 3.2 million people in 1970. Industries in these metropolitan cities primarily manufacture machinery, make steel, purify minerals and produce chemicals. Along with mining and agriculture, these urban centers are a major part of the land use in the western half of the basin. The eastern half is primarily forest. The entire basin is underlain with coal bearing formations.

There are many natural, scenic, and historic places in the Monongahela basin, some of the most notable being the Sinks of Gandy, Canaan Valley natural area, the Cheat and Youghiogheny Rivers (designated as Wild and Scenic Rivers) and Indian Creek gorge (ORBC, 1975; Moor; 1975). From 1970 to 1975 the State Comprehensive Outdoor Recreation Plans (SCORP) of Maryland and West Virginia, and the Pennsylvania state water plan developed many recreational areas in the basin; recreational craft are allowed to use navigation channels, and most of the federal projects were enhanced by recreational benefits including boating, hiking, camping, fishing and hunting.

The existing navigation channel of the Monongahela River extends from Pittsburgh, Pennsylvania to one mile south of Fairmont, West Virginia, where the river forks at the Tygart and the South Fork Rivers. Navigation is made possible by a series of 9 locks and dams which maintain a channel depth of 9 feet for the 128.7 mile length. The channel is 300 feet wide to River Mile 115, and 250 feet wide above that point. The Corps finished these improvements by 1967. In 1965, there were 2 hydroelectric projects and by 1975 there were 10 hydroelectric projects on the Monongahela River. Port facilities are in Morgantown at the Hildebrand lock and dam, and at the Opekiska lock and dam in West Virginia (Morr, 1975).

2.6 Kanawha River

2.6.1 Physical Characteristics

The Kanawha River Basin drains 12,300 square miles of the States of North Carolina, Virginia and West Virginia. It is the largest northwardly flowing drainage system in the contiguous United States. It begins at the Blue Ridge Parkway at Blowing Rock, North Carolina, and ends at Point Pleasant, West Virginia at the Ohio River. It extends from the Monongahela Forest in the highlands of eastern West Virginia, to the coal fields of Logan County, in western West Virginia. The Kanawha River is formed by the junction of the New and Gauley Rivers, and flows northwesterly for 97 miles.

Average annual precipitation is approximately 43.5 inches, and average annual runoff is 18.5 inches at Charleston, West Virginia; which yields 10.4 million acre feet of runoff. Runoff is greatest from January to March and lowest from July to October (KRBCC, 1971).

A portion of the basin is in West Virginia and southwest Virginia where the topography is rugged with narrow floodplains in the east, and level bottomlands along the Kanawha. The Basin in eastern West Virginia and southwest Virginia, is characterized by a northeast-southwest oriented mountain range with resistant ridges of sandstone and conglomerates with valleys of erosive shales and limestones. The New River transversely crosses these ridges at right angles. In the southwest Virginia and North Carolina part of the basin there are rugged mountains, and narrow streams with steep slopes. Elevations range from 5,729 feet at Mt. Rogers in the Blue Ridge Province to 800 feet near the Ohio River.

Water quality problems result primarily from industrial and municipal wastes, with other significant sources including coal mine drainage, petroleum wastes, erosion and sedimentation and agricultural chemicals. The most serious water quality problem is in the lower Kanawha River, and is caused by discharge of organic chemical waste from the chemical industry complexes on a 55 mile reach of the river from Charleston, West Virginia to the mouth of the Kanawha River. Industrial waste loads contribute considerable taste and odor bearing substances which render the lower Kanawha River unsuitable as a domestic water supply without extraordinary treatment measures. It is also not recommended for water contact recreation in the area of Charleston, West Virginia (KRBCC, 1971).

2.6.2 Biological Features

The vegetative community of the Kanawha River Basin is primarily composed of the oak-hickory forest association. Shoreline species are dominated by sycamore, willow, river birch, and yellow poplar. Aquatic species are primarily phytoplankton, though some emergents do occur.

Trout habitats make up 1,350 miles (37 percent) of the 3,660 miles of stream fishery habitat in the Kanawha Basin, with the remainder being habitat for warmwater species. 123 species of fish have been identified. There are two endangered species: the Kanawha minnow and the sharpnose darter. Fishable populations of trout are stocked by state and federal agencies. Some of the important fishing species found are smallmouth bass, walleye, rock bass, and flathead catfish.

Waterfowl habitat is sparse throughout the basin. Native wood ducks, woodcock, and snipe are found in small numbers, as are migrating ducks, especially along the New River. Mink, muskrat and beaver are important fur bearing animals, with opossum, raccoon and fox also being trapped in significant numbers.

2.6.3 Cultural Features

The population of the basin, is concentrated in the river valleys and upland plateau areas. The population is primarily rural. The population in 1967 was approximately 884,000. One-third of the people lived in urban areas and one-half lived in Kanawha County, West Virginia where Charleston is located. The population had declined 25 percent between 1950 and 1967.

Land use of the basin's 7,872,400 acres are by percent: 3 percent urban areas, 8 percent cropland, 20 percent pasture, and 71 percent woodlands. The primary economic activities are coal mining, chemicals, textiles, and light manufacturing. Because the topography is rugged, most development is in river valleys and upland plateaus. Few areas are suitable for agriculture or industrial sites. Coal is the principle mineral resource, with other significant resources including oil, gas, limestone, lead and zinc. In the pastureland, beef cattle predominate, followed by dairy cattle and sheep.

The navigation system handles 13 million tons of commercial traffic a year. Substances transported include chemicals, coal, coke, petroleum, and aggregates. Chemical industries depend heavily on water transportation. Coal

is transported throughout the valley to support the industrial production, as well as outside the valley. There are several hydroelectric power facilities.

Within the Kanawha River basin there are 3 federal multipurpose reservoirs providing recreation and fish and wildlife uses; 7 locally sponsored watershed projects which provide recreation; 2 national forests; 4 federal recreation facilities (the Blue Ridge Parkway, Mount Rogers National Recreation Area, Appalachian National Scenic Trail, and Highland Scenic Highway); 11 state parks and 5 state forests in West Virginia, 2 state parks in Virginia, and 1 state park in North Carolina. The navigation system supplies 62,000 recreation days of pleasure boating and related activities.

The Kanawha River has several tributaries that support native brook trout, particularly along the New River. The National Parks and forests provide boating, hiking, fishing, and scenic waterways. Reservoirs in the basin provide camping, picnicking, sightseeing, and boating. The state parks provide rustic and wilderness recreational experiences.

Many of the rivers in the Kanawha basin are very scenic, primarily due to the ruggedness of the topography. The Greenbriar River has been recommended as a "Wild and Scenic River" under the Wild and Scenic River Act.

Major water developments in the Kanawha River basin include: 3 federal multiple use reservoirs which provide 1,310,000 acre feet of storage for flood control and low flow regulation, 7 local upstream watershed projects which provide flood protection and water supply, 3 major local flood control projects, 3 snagging and clearing projects for flood control, and 4 upstream projects for flood control.

Three navigation structures completed in 1937 on the Kanawha River and one a dam on the Ohio River provide 91 miles of channel having a minimum width of 300 feet and a 9 foot depth.

The River and Harbor Act of 1930 authorized 2 high dams (to replace 4 upstream dams) to provide a 9 foot channel depth; these were completed in 1934. Finally, the remaining 6 downstream dams completed in 1898 on the Kanawha River were replaced by another dam on the Ohio. Navigation on the Kanawha is aided by mooring structures primarily found in the vicinity of locks and dams.

There are water supply facilities for 70 communities, and water treatment facilities for 90 communities in the Kanawha basin. Surface water is the major source of city and industrial water supply.

2.7 Kentucky River

2.7.1 Physical Features

The Kentucky River is formed by the confluence of three rivers, the North, Middle, and South Fork Rivers, near Beattyville, Kentucky. It flows 258 miles to its mouth at Carrolton, Kentucky; lies totally within the state of Kentucky; and has a drainage area of 6,966 square miles (COE, 1975c). The topography of the basin varies, being rugged and mountainous in the southeastern portion in the area known as the "coalfield area", level in the central portion, hilly in the northern areas. Upstream from Beattyville, the stream channels are characterized by steep slopes and are composed primarily of sandstone and silt. From Beattyville to Frankfort the river passes through a rich, fertile plateau known as the "Bluegrass". In the northern reaches of the river above Frankfort, Kentucky the river drains farmlands, and pastures characterized by gently rolling hills.

Streamflow on the Kentucky River behaves as a series of pools, due to the nature of the present navigation system. Mean discharges range from 3,515 cfs at Lock 14 to 8, 133 cfs at Lock 2. The chemical quality of the Kentucky River mainstem is within United States surface water standards, and within Public Health Standards for drinking water supplies (COE 1975c). Waters from the basins coalfields in the southeastern portion of the basin have high sulfate ion concentrations. In the Bluegrass area, calcium bicarbonate from the limestone formations causes hard water.

2.7.2 Biological Features

Aquatic flora common to the Kentucky River basin are common cattail, pondweed, water plantain, arrowhead, sedges, rushes, duckweed, and mud-plaintain. Diatoms dominate the phytoplankton community. The aquatic macroinvertebrate populations are comprised of pollution sensitive, facultative, and pollution tolerant species of midges, mayflies, caddisflies, and stoneflies. Other macroinvertebrates are beetles, crayfish, oligochetes, nematodes, snails, clams, mussels and tubifex worms.

Fish commonly found in the Kentucky River and tributaries are carp, drum, gizzard shad, gar, channel and flathead catfish, emerald and ghost shiner, largemouth bass, white crappie and silver chub.

The upper reaches of the Kentucky basin are forested with nearly one-third of the trees being white oak. Other trees present in order of abundance are chestnut oak, beech, black oak, yellow poplar, hickory, basswood, shortleaf pine, gum, hemlock, buckeye, and sycamore. Virgin stands of yellow poplar and black walnut still remain in parts of the basin. Bottomland trees that are common are maple, sycamore, elm, willow and birch. Laurel, rhododendron, and holly form the understory.

Fauna found in Kentucky that are expected to be found in the Kentucky River Basin are moles, shrews, bats, racoons, weasels, mink, otter, whitetail deer, turtles, snakes, salamanders and frogs. Migratory birds found include teal, mallard, black, and wood ducks, golden and southern bald eagles, peregrine falcon, and herons. Federally endangered species that inhabit the basin are the red-cockaded woodpecker, Indiana bat and the southern bald eagle.

2.7.3 Cultural Features

The Kentucky River basin supports a total population of 604,337. Land use in the basin changes with the changes in physiographic regions, and will be described for each region.

The "coalfield" region, is in the southeastern Kentucky River Basin, in those drainage areas upstream of Beattyville, Kentucky. This area has had limited development due to the rugged terrain, and so is confined to the narrow valleys. This region had a population of 106,700 in 1970, which was primarily rural and non-farm residential (COE, 1975c). Lumber and coal mining are the major industries in this area with gas and oil resources development.

The Kentucky "Bluegrass" region is in the central part of the basin between Frankfort and Beattyville, and had a population of 457,562 in 1970 (COE, 1975c). Agriculture is the main land use due to the regions rich soils, but urbanization and industrialization have also developed. Rural land uses such as pasture, cropland and forest use 94 percent of this regions 2.8 million acres of land. The horse industry utilizes alot of the 1 million acres of pastureland, forests occupy .6 million acres, and urban areas occupy .1 million acres of land in this region.

The Northern Kentucky Region lies in that portion of the basin downstream of Frankfort, Kentucky. It's population was 40,075 in 1970 (COE, 1975e). Land use in this region is 18 percent urban, 0.3 percent water, 24.2 percent cropland, 41.3 percent pasture, 30.2 percent forest, and 1.5 percent other.

Of all the major tributaries to the Ohio River, the Kentucky River had the lowest amount of river commerce (0.5 million tons in 1976). The primary freight transport consisted of construction aggregates (99 percent of these aggregates being sand, gravel and crushed rock).

The estimated annual visitation for recreational areas attributable to the Kentucky River Basin navigation system in 1979 was 210,700 people (COE, 1981b). One of the major recreational and fish and wildlife conservation areas is Carr Fork Lake, which was approved in 1962 and completed in 1979. Annual visitation at the lake was estimated at 436,000 in 1979 (COE, 1981b). The 3 multipurpose COE projects; Buckhorn Lake, Carr Fork Lake, and Booneville Lake; provide fishing, boating, swimming, camping, picnicking; hiking and playgrounds. Recreational areas in the Bluegrass region also provide horseback riding and golfing facilities.

The navigable portion of the system previously included the entire mainstem from Beattyville, Kentucky to Carrollton, Kentucky (ORBSCC, 1969). There were 14 locks and dams, 5 multipurpose reservoirs and 2 local protection projects. The first five locks and dams were constructed by the state of Kentucky and then ceded to the United States in 1880. In 1882 locks and dams 1 through 4 were rehabilitated by the Federal government, and from 1886-1917 locks and dams 5 through 14 were redone and a navigation depth of 6 feet established. There is hydroelectric power generation at lock and dam No. 7. At the present time, 10 of the upper 14 locks and dams have been closed due to reduced funding by Congress (COE, 1982a). Commercial carriers use three upper reaches in a very limited basis. The lower 4 locks and dams are currently being used by 2 companies. Coal is no longer moved on the river (COE, 1982a).

2.8 Green River

2.8.1 Physical Characteristics

The drainage area of the Green River basin covers the left bank tributaries of the Ohio River between Smithland Locks and Dam and Carrolton Locks and Dam. The Green River drains 9,230 square miles and flows from southcentral Kentucky for approximately 200 miles to its mouth on the Ohio just upstream of Evansville, Indiana. Average annual precipitation in the Green River basin is 50 inches, and annual average runoff is 15-20 inches.

The topography of the Green River basin is rugged and hilly in the eastern portions, having deep valleys and cavernous areas in the central parts, and with alluvial plains and gently rolling uplands in the western and northern portions of the basin (COE, 1977a). Elevations range from 1,800 feet above sea level near the source to 337 feet above sea level at the mouth.

Thirty two of the 33 municipal sewage treatment facilities that discharge into the Green River provide secondary treatment, however, many of these discharge into small streams which do not have sufficient capacity to assimilate these wastes (ORBC, 1979). Also, the Green River suffers from pollution caused by acid mine drainage, particularly in the western coal fields of Kentucky. Acid mine drainage has caused parameters such as pH, sulfate, dissolved solids to exceed federal recommended limits (COE, 1975d). Another source of water pollution is non-point runoff from farms and feedlots in the south-central portions of the basin (ORBC, 1979).

2.8.2 Biological Features

The aquatic vegetation in the Green River is more diverse above Lock and Dam No. 3 due to lower sediment loads. The phytoplankton community is diverse with green algae comprising over one-half of the total. Other phytoplankton include 10 major groups comprising 141 genera and 505 species. Zooplankton consist chiefly of cladocerans, copepods and rotifers. Macroinvertebrates include 9 taxonomic groups, and were predominated by mayflies, snails, caddisflies, and mussels.

Fish habitats are very diverse with smallmouth bass, walleye and whitesucker found in erosional habitats; and with largemouth bass, catfish, and shiners found in the slower and warmer depositional habitats.

Forests once covered the entire state of Kentucky, but large scale clearing has destroyed most of the original vegetation. There are a few scattered virgin forests that remain. The Green River Basin lies in the Western Mesophytic Forest, which includes 2 major plant communities. The north and western portion of the basin is forested with secondary oak and oak-hickory forests on the rolling plateaus; with ash, poplar, tulip tree, sugar maple, and pawpaw as associate species. The floodplain portions of the basin include southern "swamp" species like black willow, pecan, bald cypress, cottonwood, pin oak, etc. The southeastern portion of the basin is characterized by a variety of species ranging from swamp to prairie species. Wet areas have pin oak, swamp white oak and willow oaks. The plateau is inhabited by oaks, sugar maples and beech with understories of dogwood, redbud and wild cherry.

There is an abundant and diverse population of herptiles in Kentucky made up of 86 species due to the range of habitats from rocky karst topography to swamplands. These diverse habitats also support a wide variety of avifauna which include any inland species of waterbirds typically found in the eastern United States. The predominant game species are doves and quail. Other waterfowl include mallards, wood ducks, scaup and pintails. Three rare and endangered species from the Kentucky Fish and Resources List are the northern bald eagle, the golden eagle and the osprey. Federally endangered species are the southern bald eagle and peregrine falcon. Forty nine mammalian species have ranges in the Green River Basin including such species as cottontail, gray squirrel, whitetail deer, racoon, mink and beaver. The karst topography provides habitats for 10 species of bats, including the federally endangered Indiana bat.

2.8.3 Cultural Features

The population of the basin is predominately rural, and landuse is primarily agricultural. The total population of the basin was 163,731 in 1970. Three major urban areas; Bowling Green, Owensboro and Daviess had combined populations of 109,558 in 1970.

Land use in the Green River Basin is primarily agricultural and forested, and comprises 94 percent of the land area. The remaining 6 percent is urban. Surface mining is a significant land use, but it does not involve large portions of the land at any one time because the land is surface mined and then reclaimed. In 1972 surface mining occurred on 8,000 acres of the 6 million acres of land in the basin. Western Kentucky coal is an important economic resource to the local economy. Industrial development has remained adjacent to the river.

One of the dominant uses of the Green River is for the transport of goods, which in 1976 totaled 13.8 million freight tons of commodities. Coal and coke was the major freight, having 13.6 million tons transported, with 0.2 million tons of grain being transported, and less than .5 million tons each of chemicals, ores and minerals, and other. Currently only locks and dams 1 and 2 are used by two concerns: Peabody Coal Company and TVA, move coal into and out of the land that they own in the lower basin on this waterway.

There are 9,299 sq. mi. in the Green River Basin that provide for recreation. These provide recreation in the following areas: fishing, sightseeing, boating, swimming, camping, water skiing, picnicking and hunting (in descending order of user days) (ORBC, 1979). The largest recreational area near the Green River is Mammoth Cave National Park, which occupies 51,000 acres and supplies 79 percent of the available recreation. Most of this park is however undeveloped.

State parks comprise 7 percent of total recreational area. Direct recreational use of river from the municipal and private parks along the riverside is difficult due to steep banks, and strong currents; and undesirable due to turbid appearance. The navigation system provides passage of recreation vessels between navigation pools, but is discouraging to boating due to deterioration of aesthetic quality, absence of service facilities and limited development of riverside parks, trails and picnic areas.

The present navigation system has been in operation since 1956 and follows the Green River from its mouth at the Ohio to the mouth of the Barren River, where it turns and follows a channel 30 miles along the Barren River. There are 4 locks and dams on the mainstream of the Green River, and 1 on the tributary Barren River. These provide a 9 foot depth for 103 miles, and a 5.5 foot depth for the remaining 47 miles

to Bowling Green, Kentucky. Channel width varies from 200 feet in the lower portions to 100 feet in the upper portions. The navigation channel also extends 8 miles up Nolin River and Bear Creek, and 29 miles up the Rough River. Locks and dams 1 to 4 on the Green River, and lock and dam 1 on the Barren River were built by the Commonwealth of Kentucky prior to 1886, and purchased by the federal government in 1888. The Green River Basin has 4 multipurpose reservoirs and 5 local flood protection projects (COE, 1977a). Mooring facilities have been installed on the Green River at river miles 10.2 and 64.3, and consist of two floating mooring buoys anchored to concrete (COE, 1982a).

2.9 Cumberland River

2.9.1 Physical Characteristics

The Cumberland River originates at the junction of the Poor and Clover Forks Rivers, near Harlon, Kentucky. It flows 694 miles to the Ohio River near Smithland, Kentucky. It drains an area of 17,914 square miles in the states of Tennessee and Kentucky (COE, 1981b). The topography of the Cumberland River basin varies from being rugged and mountainous in the eastern portion, to a rolling low plateau in the west. The elevations range from 4,150 feet in the Cumberland mountains, to 302 feet at the mouth (COE, 1981b).

2.9.2 Biological Characteristics

Flora and fauna of the Cumberland River is similar to that described for the Ohio River Basin. Phytoplankton communities are composed primarily of diatoms and green algae. Benthic macroinvertebrates are predominated by mayflies, caddisflies and mussels. Fish species include smallmouth and largemouth bass, walleye, catfish and shiners.

Forests contain mixed mesophytic species such as oak, hickory, ash, poplar, tulip tree, sugar maple and associated species. Understories include rhododendron, laurel, dogwood and wild cherry. Animal species found in these forests include whitetail deer, gray squirrel, racoon, mink, beaver, reptiles and amphibians. These forests also support a large and diverse population of birds. Waterfowl include those inland species normally found in the eastern United States. Two federally endangered species that are found in this river basin are the southern bald eagle and peregrine falcon.

2.9.3 Cultural Features

The transport of goods on the Cumberland river was 11.3 million tons during 1976, and transport included 4.7 million tons of coal and coke, 1.3 million tons of petroleum, 2.4 million tons of aggregates, .2 million tons of chemicals and .3 million tons of iron and steel. The river is also used for hydroelectric power generation.

Most of the recreational facilities in the basin are those typical of multiple use water resource projects. There are 5 multipurpose lakes in the basin which afford recreational opportunities as well as fish and wildlife

conservation, forests, flood and water quality protection. At Lake Cumberland activities include boating, camping, picnicking and hiking. In addition, the area provides 2 State parks, 5 roadside parks, 1 county park, and 8 U.S. Forest Recreation Areas. The Big South Fork River provides white water canoeing opportunities, and runs through the Big South Lake Nation River and Recreational Area. This area offers unique cultural, historic, geologic, fish and wildlife, archeologic, scenic and recreational values (COE, 1981b). Hunting, fishing and trapping also contribute to recreational activities in the basin.

The modern 9 foot depth navigation project was completed in 1965, and extends 308 river miles to Carthage, Tennessee. Its width varies from 300 feet in the lower river to 100 feet in the upper section (ORBSCC, 1969).

Originally, there were 14 locks and dams built between 1888 and 1924. The modern project was authorized in 1946 in the Rivers and Harbors Act, and was modified in the 1954 Rivers and Harbors Act (COE, 1981b). The Barkley Canal connecting the Tennessee River to the Cumberland River, which began construction in 1965 affords a 17 mile shorter route from the Cumberland River to downstream Ohio points. Mooring structures used are found upstream and downstream of all locks and dams and include such structures as floats, and wood pile dolphins.

2.10 Tennessee River

2.10.1 Physical Characteristics

The headwaters of the Tennessee River are in the mountains of western Virginia and North Carolina, eastern Tennessee, and northern Georgia. The Holston and French River join at Knoxville, Tennessee to form the Tennessee River, which flows 652 miles to the Ohio River near Paducah, Kentucky (COE, 1981b). The drainage area is 40,910 square miles and lies mostly in Tennessee, and includes parts of Kentucky, Virginia, North Carolina, Georgia, Alabama and Mississippi (ORBSCC, 1969).

Mean annual precipitation is 52 inches, and mean annual runoff is 22 inches. Deep soils and dense groundcover slow the runoff. However, heavy storms between December and April are potential causes of floods. At Kentucky Dam, 22 miles from the river mouth, flow has averaged 64,180 cubic feet per second (cfs). At Fort Loudoun Dam, farthest upstream on the Tennessee, the average flow is 13,500 cfs.

The western half of the Tennessee basin is less rugged than the eastern portion. The elevations range from 6000 feet in the rugged mountainous regions of the Great Smokey Mountains, to 302 feet in the flat rolling lands near the mouth (COE, 1981b). The total river fall from the highest elevation at Thorpe dam to the lowest at Kentucky dam tailwaters is 3192 feet over 714.2 river miles.

2.10.2 Biological Features

Flora and fauna of the Tennessee River are similar to those described for the Ohio River Basin. Phytoplankton communities are composed primarily of diatoms and green algae. Benthic macroinvertebrates are predominated by mayflies, caddisflies and mussels. Fish species include smallmouth and largemouth bass, walleye, catfish and shiners.

Forests contain mixed mesophytic species such as oak, hickory, ash, poplar, tulip-tree, sugar maple and associated species. Understories include rhododendron, laurel, dogwood and wild cherry. Animal species found in these forests include whitetailed deer, gray squirrel, racoon, mink, beaver, reptiles and amphibians. These forests also support a large and diverse population of birds. Waterfowl include those inland species normally found in the eastern United States.

Two federally endangered species that are found in this basin are the southern bald eagle and peregrine falcon.

2.10.3 Cultural Features

The topography of the basin has provided sites for development for navigation, flood control, and hydroelectric power generation. Land usage on the river banks varies between urban, industrial, recreational and residential. Primary industries operating on the riverbank include coal fired and hydroelectric power facilities, grain storage facilities, coal transfer facilities, aluminum processing facilities, and a chemical processing facility near Paducah (TVA, 1982). In 1978, there was an annual traffic volume of 31,634,500 tons of cargo consisting primarily of grains, coal, stone, sand, gravel, and petroleum.

The Tennessee Valley Authority (TVA) is a corporate agency of the federal government, which was created by an act of Congress in 1933. Its purposes are flood control, navigation, electric power, and development of regional resources. By 1963 the TVA system was comprised of 32 major dams (9 main river, 23 tributary).

One of the responsibilities of TVA was developing the recreation potential of the region. When TVA began there were no more than 500 recreational boats in the basin. By 1963 there were 52,000 on the reservoirs, with an estimated equal number off shore within short-haul distances. Five demonstration lakefronts were developed for parks and recreation, as well as numerous other harbors and parks, in order to show how an undeveloped reservoir riverfront could be planned to provide recreation. This was done to help stimulate state and local governments, as well as private concerns to further develop the full recreational benefits of the TVA projects. Borrow areas were sometimes used to create boat harbors. Construction camps and villages built by TVA are now privately owned resorts and state parks.

A canal around Muscle Shoals, an area of rapids in Alabama, was completed in 1836 by the federal government. Until 1933, navigation improvements consisted of four separate canals with locks, one navigation dam, one federally owned power-navigation dam and numerous dikes and dredged cuts.

The Tennessee River navigation system provides a channel the entire length, 650 river miles, from Knoxville, Tennessee to Paducah, Kentucky. The minimum channel depth is 11 feet, and the minimum channel width is 300 feet. Commercial navigation channels over this length were attained by 1945, but full navigation depth was not achieved until November 1952. The first navigation lock in a tributary stream was the Melton Hill Dam lock on the Clinch River in 1963. Presently, the waterway is comprised of 9 main-river reservoirs, the Melton Hill dam on the Clinch River which provides 61 miles of upstream navigation, navigation feeder channels in 10 reservoirs, and numerous tributary reservoirs. Mooring facilities are found above and below each lock and dam (COE, 1982d).

2.11 Kaskaskia River

2.11.1 Physical Characteristics

The Kaskaskia River lies entirely within the State of Illinois. It begins in Champaign County Illinois, 5 miles northeast of Urbana, and flows 325 miles southwesterly entering the Mississippi River 8 miles above Chester, Illinois (COE, undated). It drains 5,840 square miles of southwest Illinois. A flat plain composed of glacial drift lies to the east of the river, and the land west of the river is mostly morainic and eroded to various degrees (COE, 1975b).

Most of the communities along the Kaskaskia River provide both primary and secondary sewage treatment and there is relatively little industrial pollution. The principal pollutants of the Kaskaskia River come from agricultural activities and from coal mining. The upper basin area has extensive grain farming which relies on inorganic chemical fertilizers. Many instances of nitrogen or phosphorous spills have occurred along the Kaskaskia River and caused extensive damage to the aquatic populations (Larimore, 1978).

Other sources of agricultural pollution include drainage from dairy farms, especially in that portion of the basin near the St. Louis metropolitan area, and runoff from numerous cattle and hog feed lots in the upper basin. Sudden flushing of animal wastes from these operations by storm events can cause fish kills and damage other segments of the aquatic community. Throughout most of the year the Kaskaskia River carries a heavy silt load which is considered the most important form of pollution in the lower river. This source of pollution is directly influenced by agricultural cultivation activities.

Historically, pollution from mine wastes has been considered a problem in the area. Although coal mining has increased in the lower basin in recent years, modern pollution control strategies such as stabilization of spoil deposits, deep-well and landfill disposal of wastes, and waste treatment have reduced the acid drainage problem.

2.11.2 Biological Features

Submerged aquatic vegetation in the Kaskaskia system is limited to smaller headwater streams, backwaters, and floodplain pools. Development of submerged vegetation in the

main river is restricted by high turbidity, that limits light penetration, and by drastically fluctuating water levels that either drown the plants or leave them stranded on drying mudflats. Emergent plants and those that inhabit gravel bars, mud flats, and moist shorelines form the most diverse communities of aquatic plants. The dominant emergent plants along the main stem are hibiscus, arrowroot, and cattails. In the flood plain pools and backwaters, submerged vegetation includes coontail, water milfoil, and pondweed. These pools and backwaters often support surface mats of algae. Riverbank vegetation is dominated by willows, sycamores, maples, and tupelos.

Along the lower Kaskaskia River, the shifting sand and soft silt bottom materials prevent the establishment of a permanent benthic community. Special habitats such as stable mud banks, backwater areas, submerged logs, and occasional areas of gravel or small rubble do support an abundance of benthic organisms. These benthic organisms include midge larvae, mayfly nymphs, worms, and an occasional freshwater mussel.

Largemouth bass, white crappie, black crappie, carp, and channel catfish are the most important sport fish in the Kaskaskia River. Other important sport fish include yellow and black bullheads, flathead catfish, several species of sunfish and the freshwater drum.

Ducks, coots, and rails moving through the Kaskaskia Valley in their migrations use the water areas for different lengths of time in different seasons of the year. Large concentrations of ducks stop on the backwater areas and floodplain pools of the lower Kaskaskia River during their fall migrations.

Shore birds such as the spotted sandpiper, greater yellowlegs, and waterthrush, wade and feed along the shoreline. The great blue, green, and night herons nest next to or over the waters of the Kaskaskia and feed directly on aquatic organisms.

2.11.3 Cultural Features

Most of the land surrounding the Kaskaskia navigation system is agricultural and is primarily used as general farms which raise a variety of crops and livestock. The predominant nonfarm land use is coal mining.

The primary use of the Kaskaskia since canalization has been for recreation. Oxbow areas provide sport fishing and canoeing. Public access to the river is limited due to lack of roads. Other water related activities are pleasure boating, skiing, and hunting. There are a number of archeological and historic sites in the basin. There are no known areas with wilderness characteristics, but one region has nine identified natural areas, one of which has been formally designated.

The Illinois Farm Drainage Act of 1879 produced improvements rapidly in the drainage of the upper reaches of the Kaskaskia River and along several of the major tributaries, notably Shoal Creek, Silver Creek, and the West Okaw. Channel clearing and straightening, and ditching of poorly drained areas lowered the water table and hastened the runoff of water so that the flood peaks became higher and low flows became lower. Many aquatic habitats, marsh areas, and floodplain pools that were important breeding and feeding grounds for fish and waterfowl were eliminated.

In 1962 the Rivers and Harbors Act authorized channelization and canalization of the lower 50 miles of the Kaskaskia River in order to provide a navigation channel 9 feet deep by 225 feet wide. By 1965 a dam at Carlyle was nearly complete which impounded 26,000 acres of water. By 1971, the dam at Shelbyville was impounding 11,000 acres. Navigation improvements in the lower Kaskaskia River below Fayetteville were started in June 1966. This project was designed to shorten the Kaskaskia between its mouth and Fayetteville from 52 miles to 36 miles. This was accomplished by eliminating meanders, excavating much of the channel, placing dredge material inside confinement levees along the banks of the navigation channel, and installing a lock and dam near the river mouth to control water depth to establish navigation on the lower 36 miles. This project was virtually complete by 1973 (Larimore, 1978).

2.12 Illinois Waterway

2.12.1 Physical Characteristics

The Illinois Waterway flows 326 miles from Lake Michigan at Chicago, Illinois, to its mouth at the Mississippi River at Grafton, Illinois, approximately 38 miles above St. Louis, Missouri. The Illinois Waterway drains approximately 29,010 square miles of land in Indiana, Wisconsin, and Illinois.

The Illinois Waterway obtains its waters from five major sources: diversion from Lake Michigan, the Des Plaines River, the Kankakee River, the Sangamon River and other smaller tributaries. At the present time, the Des Plaines River, via the Chicago Sanitary and Ship Canal (CS&SC) and the Cal-Sag Channel, receives 3200 cubic feet per second of water from Lake Michigan. A portion of this flow is intended for navigational purposes while the remainder is used for municipal and industrial water supply in the Chicago region and then returned to the waterway as treated wastewater. The second source is water of the Des Plaines River that comes from its basin which drains that part of Illinois north of Chicago and Joliet and part of the state of Wisconsin. The third contributor to the Illinois waterway is the Kankakee River that drains east central Illinois and parts of western Indiana. The fourth major source is the Sangamon River whose confluence contributes to the flow just above Beardstown at River mile 98. Other smaller tributaries contributing to the discharge at Grafton include the Fox, Vermillion, Mackinaw and Spoon Rivers. The average discharge at Grafton is approximately 24,000 cubic feet per second (Emge et al., 1974).

The Illinois Waterway can be considered polluted immediately below Chicago because certain water quality parameters (e.g., DO, BOD, fecal coliform and others) exceed the standards set by the state of Illinois. In general, effluents from municipal treatment plants and industrial activities account for the poor quality of the water. From Chicago, the waterway goes through a recovery zone until reaching the Peoria-Pekin area where it is again subjected to similar types of effluents. Then, it undergoes another period of recovery until its confluence with the Mississippi River. The river is also subject to considerable thermal pollution as a result of over 18 power plants that use the waters of the waterway for cooling purposes and then return the artificially heated water to the waterway (COE, 1980b).

2.12.2 Biological Features

Aquatic plants in the upper section of the waterway are characterized by attached filamentous algae and free floating phytoplankton. Green algae and diatoms are the most abundant planktonic forms in this section of the Waterway. The aquatic biological communities, both floral and faunal, become more abundant and diverse in downstream areas.

The fish and wildlife populations in the upper portion of the Waterway are under severe stress from industrial complexes, dolomite quarries, flood control structures, navigation and barging facilities and expanding urbanization. The decreased velocity caused by dam construction has caused siltation problems to such a degree that darters and other species that require moderate to fast currents have been eliminated and replaced by pollution tolerant species such as carp, and other roughfish. The benthic fauna of the upper sections of the waterway consist primarily of sludgeworms.

The zooplankton population is generally low throughout the lower portions of the Illinois River. Populations consist mostly of rotifers and, to a lesser extent, crustaceans. The percentage of crustaceans is generally larger in the lower reaches of the waterway. The greatest abundance and diversity of benthic organisms in this part of the waterway are found near Beardstown, Illinois, where the large and relatively unpolluted Sangamon River dilutes the more polluted Illinois Waterway. Below Beardstown, mussels, fingernail clams, insect larvae and snails are found with some degree of regularity.

Presently, there are only two species of fish that occur regularly throughout this section of the waterway: the carp and the emerald shiner. A number of other species can be considered common below Beardstown. The shad, bluntnose minnow, and the black bullhead are a few that seem to be tolerant of some pollution. The carp and black bullhead are generally the only fish abundant enough above Beardstown to produce a sizeable catch for the recreational fisherman. Most of the better food and game fish are found in the backwater areas and floodplain lakes. Two of the major factors limiting the occurrence and abundance of sportfish above Beardstown are the scarcity of food and the stress of man induced pollutants (COE, 1980b).

2.12.3 Cultural Features

The major portion of the drainage basin is being used for farming or pasturage except in highly urbanized sections and adjacent to the City of Chicago. Industrial usage of the Illinois Waterway is concentrated in the Peoria and Chicago areas.

The Waterway provides various recreational opportunities such as boating, skiing, fishing, hunting, and scenic enjoyment at various locations.

Public use of nearly 95 percent of Illinois streams is prohibited due to existing riparian laws. Illinois has traditionally been ranked as 46th in the nation in terms of providing recreation but is ranked 4th in terms of population. To this end, local and state organizations have and are continuing to acquire land for public use along the Waterway for recreational and cultural activities.

There is little fishing opportunity in the northern reaches of the Waterway above Dresden Island Lock and Dam because of poor water quality. Fishing that is done in the upper reaches is confined primarily to the Des Plaines River (parallels the CS&SC) in the Cook County Forest Preserve District and the catch consists of rough fish such as carp, bullheads, and suckers.

Sport fishing in the Illinois Waterway is done primarily in the backwater lakes, although there is some fishing on the Illinois River, itself. The shallow, fertile lakes, primarily in the Lower Illinois Waterway, provide spawning ground, food, and habitat for populations of largemouth bass, crappies, bluegills, yellow perch, and other sport fish.

Recreational boating is an increasing demand on water resources. There are several public and private boat marinas and launching facilities on the Waterway but not enough for future demands. Boating participation for the 19-county area bordering the Illinois Waterway was 18,861 in 1966 (Emge, 1974).

By the 1930's construction of locks, dams and levees were accomplished. At the present time the Illinois Waterway provides a 9 foot depth minimum channel by means of seven dams and locks and intermittent dredging. Five of the

dams maintain nearly continuous pools in the 95 miles from Lake Michigan to Starved Rock, Illinois. In this segment, the waterlevel drops about 135 feet. However, it drops only 25 feet in the remaining 230 miles to the Mississippi River. This segment has only two dams. The lower 80 miles of the Waterway are in the pool formed by the Lock and Dam 26 on the Mississippi River at Alton, Illinois. Although the river has a low gradient, it does not meander and provides a direct transportation route from the Great Lakes to the Mississippi River Valley.

2.13 Missouri River

2.13.1 Physical Characteristics

The Missouri River Basin encompasses one sixth of the area of the contiguous United States. It is bounded on the west by the continental divide of the Rocky Mountains, in the north by the Hudson Bay drainage basin in Canada, by the Souris-Red River basins on the northeast, by the upper Mississippi River basin on the east, and by the Arkansas-White-Red River basins on the south (COE, 1979c). It includes all or part of the states of Nebraska, Montana, South Dakota, Wyoming, Kansas, Missouri, North Dakota, Colorado, Iowa, Minnesota, and parts of Canada (MRBC, 1980). The Missouri River is formed by the junction of the Jefferson, Gallatin and Madison Rivers at Three Forks, Montana and flows southeast for 2,315 miles to its junction with the Mississippi River, 15 miles above St. Louis, Missouri. The U.S. portion of the basin drains 513,300 square miles, and the Canadian basin area covers 90,700 square miles (MBIAC, 1971).

Annual precipitation varies from an average of 35 inches in the Rockies, 14 inches in the Plains, 26 inches in the Central Lowlands and 36 inches in the Highlands. Runoff varies from more than 12 inches annually in the mountains and southeast, to less than 1 inch in parts of the plains. At the mouth of the Missouri average annual flow is 89,000 cfs. Abnormally high and low flows are not uncommon. Drought potential is high with runoff being half of the mean during 10 percent of the years of record. Flooding is common in some drainage areas and is typically due to snowmelt, spring rains and thunderstorms. The Missouri River is fed by the following major tributaries: Yellowstone, Little Missouri, Cheyenne, Niobrara, Platte, Kansas, Osage, Gasconde, Milk, James, Big Sioux, Little Sioux, Grand and Chariton.

There are three major physiographic divisions within the basin. The Rocky Mountains make up 55,000 square miles of the western portion of the Missouri River basin. It is a mountainous area with high peaks (many surpassing 14,000 feet), rugged topography and high valleys. East of the Rocky Mountain system are the Great Plains (covering 360,000 square miles) The west central area of the plains is characterized by flat gently rolling topography, having a slope of 10 feet per mile, and elevations ranging from 5,500 feet in the west to 1,500 feet at the east boundary of the plain. South and west of the river, the surface topography

has been shaped by erosion of the fluvial plains with isolated mountains appearing where erosion surrounded uplifts. The north and east portion of the plain was influenced by glaciers and the topography is shaped by the erosion of glacial drift. The Central Lowlands to the east of the plains are level except where stream development has created a hilly topography. The 7 million acre hilly and mountainous Ozark Plateau lies in the southeast portion (MBIAC, 1971).

The Environmental Protection Agency's "National Water Quality Inventory" report of 1974 rated the basin's water quality as poor (COE, 1978b). High sediment transport was the basis for this poor rating. The headwaters in the mountains are clean and free of pollution. Major problems in the plains area are high sediment and dissolved solids concentrations.

The flow of the Missouri River at Sioux City, Iowa is essentially controlled by the six mainstem lake projects. During the non-navigation winter season 15,000 to 20,000 cfs of water is released. During the eight-month navigation season the discharge ranges from 30,000 to 35,000 cfs. Between Sioux City and the mouth an average of 15,000 to 20,000 cfs is added from tributaries.

Runoff from agricultural crop lands are polluted with fertilizers, pesticides and herbicides. Livestock areas contribute high concentrations of organic wastes and microbic populations. Municipal and industrial wastes also contribute pollutants. Electric power generation facilities withdraw water, and discharge, on the average, water 18°F warmer.

Ground water is the principal municipal and industrial water supply, and has a variable quality. Some alluvial sources have high chloride, sulphate and sodium concentrations. In eastern Montana, central South Dakota, western Iowa and northwestern Missouri, total dissolved solids often exceed 2,000 mg/l.

2.13.2 Biological Features

Riverine and riparian habitats are being adversely impacted along most of the subbasins of the Missouri River, primarily due to encroachment of agricultural lands on the river. This is causing loss of vegetation along the river's edge as well as in the river which is removing

necessary habitats for aquatic and terrestrial animals. Common tree species along the Missouri river banks are cottonwood, willows, and sycamore. Emergent wetland species include Cattails, Bulrushes, and southern wild rice.

Many native fish can still be found in the Missouri River, but some such as the sturgeon and paddlefish are threatened. Colder tributaries support trout, and the reservoirs support trout, bass, northern pike, and walleye. Extensive areas of wetlands are still present in the Dakotas, Montana, and Nebraska, and duck, geese, and other waterfowl populations utilize this resource. The basin has approximately 2,518,000 acres of wetland. Mink and raccoons are also found in these wetlands, marshes and streams.

The Missouri basin has been dominated by grasslands and prairies in the plains; and forests, shrublands, mountain grasslands, and alpine tundra in the mountains. In recent years, significant acreage of the plains grasslands have been converted to agricultural (cropland) use.

Small game are abundant including wild turkeys, fox, squirrels, and cottontail rabbit. Some species that are declining due to diminishing habitats include prairie chicken, quail, ring-necked pheasant and upland game birds. A lot of aquatic dependent wetland species such as the otter (nearly extinct), whooping crane, northern bald eagle, white pelican, trumpeter swan, and osprey are declining.

2.13.3 Cultural Features

Half of the basin's population resides in metropolitan areas. In 1975 the population was estimated at 9 million, and although there has been a slow increase since 1940, it has declined in proportion to the U.S. population due to declines in small farm and agricultural employment. An important ethnic group is the native American Indian. There are 23 reservations which in 1975 had an estimated population of 654,000.

In 1975, 92 percent of all land in the Missouri basin was used for agricultural purposes. Of this, more than half was for pasture and rangeland. Forest and woodlands comprise about 7 percent of the land. In 1970 the basins produced 33 percent of the nation's wheat crop, 25 percent of sorghum, 25 percent of hay and 22 percent of grain corn. They also produced 20 percent of the nation's livestock.

Other important uses of the land are forest and forest products (timber, lumber, furniture, textiles), and metallic and non-metallic minerals including fossil fuels.

In 1803 the federal government received title to all of the basin land as a part of the Louisiana Purchase. Now more than 86 percent of this land is private, state, and county owned (MBIAC, 1971). The remaining federal land is managed by the U.S. Forest Service 19.4 million acres, the Bureau of Land Management 18.5 million acres; the National Park Service 2.3 million acres and the Corps of Engineers 2.2 million acres.

Water from both ground and surface sources is used for irrigation and cooling water. Water consumed does not equal stream flow depletions since water is also taken from ground water sources. The river is also used for transport of goods, primarily farm products with chemicals, food, petroleum, metal, stone, clay, paper and textiles also being transported.

In the past 40 years many major reservoirs have been built for multiple purpose uses, including irrigation, flood control, hydroelectric power, navigation, recreation, and fish and wildlife.

There are three major types of recreation in the basin: scenic, historical and natural; land oriented; and water oriented. There are 5,200 public recreation areas in the basin. Activities offered, in order of decreasing participation are sightseeing, swimming, picnicking, nature walks, fishing, boating, hunting, camping, hiking, and water skiing (MBIAC, 1971).

Many unique natural and cultural areas have been preserved by the Federal Government including: scenic badlands, mountain ranges and canyons, coniferous forests, wetlands, landmarks and geologic formations. Several National Parks preserve these areas and provide outdoor recreation, and include Glacier, Yellowstone and Rocky Mountain Parks. Several rivers are being considered for designation as wild and scenic rivers.

Navigation on the main stem from Sioux City, Iowa to the mouth near St. Louis was eased by the construction of a 9 feet deep and 300 feet wide channel. At present there are no mooring structures, primarily due to the fact that it is

an open navigation channel without locks and dams. There are no emergency mooring facilities on the Missouri at this time. There are several swing bridges which present a 30 minute wait, and barges nose into the shore to wait. In the case of emergencies, barges will tie off to trees with cables, some of the trees having wood collars for protection (COE, 1982h).

There are 6 major reservoirs in the Missouri mainstem. They were authorized in 1944 under the Pick-Sloan Act creating the Missouri Basin Commission program and were constructed by the Army Corps of Engineers. Other projects for multipurpose use are being built by the Corps and the Bureau of Land Management in every subbasin in the Missouri basin. Thousands of small reservoirs and farm ponds have been built by the Soil Conservation Service, states, local governments, and private individuals.

In total there are 107 major reservoirs, 1,387 minor reservoirs, 112 million acre feet of storage with 99 percent of project areas being used for the multiple purposes of flood control, water supply, hydroelectric generation, navigation, fish and wildlife, recreation, and irrigation.

2.14 Arkansas River

2.14.1 Physical Characteristics

The Arkansas River originates in the Rocky Mountains in central Colorado and flows 1,450 miles southeasterly through Colorado, Kansas, Oklahoma, and Arkansas (via the navigation system), and empties into the Mississippi River 599 miles above the Head of Passes, Louisiana (COE, 1979d). The Arkansas watershed covers approximately 160,650 square miles, is about 870 miles long, and averages 185 miles wide. The river has a total fall of about 11,400 feet from its headwaters to the Mississippi River (COE, 1977d).

From its origin in the Rockies to Pueblo, Colorado, the Arkansas River travels through rugged mountains and mountain foothills. At Pueblo it enters the Great Plains Section and travels through rolling prairies in eastern Oklahoma and Arkansas above Little Rock (COE, 1979d). Between Fort Smith and Little Rock, the river once again flows through a mountainous area. The alluvial flood plain in this area varies from one half mile to 6 miles in width and is bounded by sandstone hills and mountains. Below Little Rock it enters the Mississippi River Valley. The entire fall of the river is 11,400 feet, and its slopes vary from 110 feet per mile in the mountains to 0.4 feet per mile at the mouth.

Mainstem flows of the Arkansas River below Great Bend, Kansas cannot be used for most water supply purposes due to chloride contamination from natural and manmade sources.

2.14.2 Biological Features

Game fish species include largemouth bass, spotted bass, crappie, striped bass, walleye, white bass, channel catfish, blue catfish, flathead catfish, and various sunfishes. The more notable nongame fish species include buffalo, carpsucker, carp, freshwater drum, paddlefish, bowfin, and gar (COE, 1977c).

Riverbank and aquatic vegetation are typical of the Mississippi river area. Terrestrial flora is dominated by trees, such as tupelo, bald cypress, willows, and cottonwoods. Phytoplankton are the most abundant aquatic species, although wetlands and backwater areas with emergents such as bulrushes, cattails, and southern wild rice are important habitat areas.

2.14.3 Cultural Features

Agriculture is the main industry in the Arkansas portion of the basin. Cotton, soybeans, and rice predominate, with peaches, grapes, cattle, pasture and poultry as major farm products above Little Rock.

The navigable portion of the river is used for transport of goods. During the period from 1966 to 1977, the average annual tonnage transported was 3,370,000 tons. Tonnage transported in 1974 was 7,078,184 (COE, 1977b), and in 1978 10.2 million tons (COE, 1979a). Commodities transported were primarily petroleum, coal, bauxite, iron and steel, grain and chemicals.

Recreational activities afforded by the Arkansas River system are fishing, camping, picnicking and boating. Major projects include Blue Mountain Lake, which is surrounded by 5 parks; Nimrod Lake, which has 7 parks, and 2 wildlife areas providing 2,400 acres of public duck hunting and 1,200 acres of goose hunting; and Bayou Meto basin, which provides the finest wintering grounds for waterfowl (COE, 1979a). There are 57 parks presently in the Arkansas portion of the basin (with 10 more planned for the future), and 40 parks in Oklahoma. In 1978, 14 million people visited the basin.

In the northwestern sections of the basin multiple purpose projects provide access to many scenic areas equipped with overlooks and observation platforms. Fisheries resources are an important recreational activity with game fish including catfish, white bass, sauger, largemouth bass, crappie and striped bass. Hunting is also a major recreational activity in areas such as the Pine Bluffs at the Tustin Halder Wildlife Management Area, the White River National Wildlife Refuge, Lake Dardanelle, Ozark Lake, Nimrod Lake, and Blue Mountain Lake. Small game includes quail, rabbit, dove, turkey, squirrel, and waterfowl.

Arkansas became a territory in 1819 and the first steamboat started traversing lower parts of the river in 1820. In 1824 Congress authorized the removal of snags in the lower Mississippi River System and work began on the Arkansas River in 1832. The McClellan-Kerr Arkansas River Navigation System was authorized by the Rivers and Harbors Act of 1946. Work began in 1950, and navigation was opened in 1969 (COE, 1979a).

The McClellan-Kerr Navigation System provides for a channel 9 feet deep and 448 miles long, beginning in the Mississippi River at the mouth of the White River, then 10 miles upstream in the White River to the mouth of Wild Goose Bayou. The system then connects by a 9 mile canal to Arkansas Post on the Arkansas River where it follows the channel of the Arkansas River for 378 miles to the mouth of the Verdigris River. From that point, the channel follows the Verdigris River 50.3 miles to the head of navigation at Catoosa, Oklahoma. A minimum channel width of 250 feet is provided for the Arkansas River, 300 feet for the White River and the Arkansas Post Canal, and 150 feet for the Verdigris River. The waterway has been canalized throughout its length by construction of 17 locks and dams (COE, 1979a). All lock chambers are 110 feet by 600 feet. Power generation is included in the Dardanelle, Eufaula, Keystone, Robert S. Kerr, Ozark, and Webbers Falls dams. In the upper navigation channel mooring cells are provided at Lock and Dam 14 and 18, with plans for one at Lock and Dam 15. Emergency mooring facilities are provided on the Kerr and Webbers Falls pools due to long wind fetches which can produce 7 and 8 foot waves. In the lower portions of the channel, temporary mooring cells are located above and below each dam. Holding areas have fleeting barges typically attached to shoreline deadmen, with some attached by anchor (COE, 1982i).

2.15 White River

2.15.1 Physical Characteristics

The White River is 720 miles long, originating in the Boston Mountains of northwest Arkansas and flowing downstream to join the Mississippi River above Head of Passes, Louisiana. The White River Basin contains 27,765 square miles, 10,622 in southern Missouri and 17,143 in northern and eastern Arkansas. The basin is fan-shaped, about 250 miles long in a north-south direction, and varies in width from about 210 miles near the Missouri-Arkansas State line to about 50 miles in the southern part near the mouth of the river.

Stream flow varies widely throughout the basin; having larger amounts of precipitation and more impervious terrain in high streamflow areas (Ozark Plateau), and having caverns and sinkholes causing lower streamflows in the areas of the Coastal Plain.

The runoff of the basin varies during the year, being highest during the months of March, April and May and lowest during the summer and fall. The average annual runoff ranges from 12 to 24 inches. The average annual volume of flow increases from 16,400 cfs at Beaver, Arkansas to 30,700 cfs at Clarendon, Arkansas.

In the northern and western portions of the basin the terrain is flat to rolling and dissected by deep, narrow, meandering stream valleys. The Boston Mountains in the southern part of the basin provides the highest and most rugged terrain. The eastern part of the basin is in the Coastal Plain where the terrain is flat to gently rolling.

The elevation of the White River at its source is about 2,050 feet above MSL and the low water elevation at the mouth is about 107 feet above MSL. The streambed through the Ozark Mountains is composed mostly of rocks, boulders, and gravel. Downstream the banks and streambed are composed of fine sand, silt, and clay.

The chemical quality of the surface waters of the basin is good to excellent for most uses. Waters of the basin, in general, are somewhat hard due to calcium bicarbonate. However, in most areas of the basin, the surface waters are virtually free from other chemical and organic pollutants. There are no natural salts, no oilfield brines,

and few sediment problems. Pollution of streams in the basin is not extensive or widespread. However, there are some problems caused by municipal waste treatment facilities, industrial operations, dairy feedlot operations, and agricultural operations. Pollution has caused fish kills by depleting oxygen, rapidly changing temperatures, and introducing toxic materials. Increased turbidity and concentrations of nitrates and other plant nutrients have resulted from pollution.

2.15.2 Biological Features

The basin is famous for its fish resources. The Ozark Mountain streams provide high quality habitat for smallmouth bass. Trout are available in several cold-water streams. Warm-water fish abound in large impoundments, natural lakes, and alluvial streams of the lower part of the basin. Species such as bowfin, buffalo, bullheads, carp, catfish, garfish, paddlefish, quillback, sturgeon, suckers, and turtles are found here. The lower basin also supports large waterfowl populations on flooded ricefields, natural overflow bottom lands, and permanent waters.

Forests cover 60 percent of the basin. About 90 percent of the trees are hardwoods with the remainder being pine and cedar. In the alluvial bottomlands, deciduous broadleaf vegetation is characteristic. Common species are red oaks, white oaks, elms, hackberry, and hickories. River swamps support baldcypress, tupelo, oaks, and willows.

The basin contains about 21,000,000 acres of wildlife habitat, including 12,400,000 acres of forest land supporting populations of big game such as deer and turkey, and small game such as squirrel, rabbit, opossum, raccoon, quail, and dove.

Waterfowl found in the area during the fall and winter include blue-winged teal, canada geese, mallards, pintails, and green-winged teal. Other birds found in the bottomlands include anhingas, wood ducks, black-crowned night herons, American egrets, and great blue Herons (Pettingill, 1953).

In the larger swamps, conditions are ideal for nesting of such birds as the double-crested cormorant, anhinga, great blue heron, American egret, green heron, black-crowned night heron, wood duck, black vulture, red-shouldered hawk, barred owl, and pileated woodpecker.

2.15.3 Cultural Features

The basin is predominantly agricultural with a population of 1,188,000 in 1960 and projected to increase to 2,400,000 by 2020. The urban population is expected to rise from its present 42 percent of the total to 82 percent.

Land use in the basin is approximately 60 percent forest; 13 percent cropland; 16 percent pastureland; 1 percent lakes and streams; 1 percent urban; and the remaining 7 percent highway, railway, transmission lines and mining area.

The major economic activities in the basin are agriculture, producing soybeans, cotton, rice, and hay; and manufacturing industries mainly involved with processing agricultural, forestry, and mineral products.

The river is used extensively for float-fishing and other recreational purposes, fisheries for trout and other game fish, irrigation, fish farming, generation of hydroelectric power, and municipal and industrial water supply purposes. The average annual movement of commerce is about 500,000 tons, consisting of grain, sand and gravel, and logs. Normally commercial traffic consists of one and two barge tows, powered by 600 to 700 horsepower towboats.

The White River Basin is nationally known for the scenic quality of its natural and man-made resource and for the recreational opportunities they offer. Basin resources provide opportunities for sightseeing, picnicking, camping, swimming, boating, water skiing, and hiking. Also available are big and small game and waterfowl hunting and both lake and stream fishing.

There are three national forests in the basin with many recreation sites, trails, and scenic drives; a national wildlife refuge; game management and hunting areas; fishing lakes and stream segments (especially for trout fishing); and numerous parks, lakes and ponds.

White River improvements began in 1870 with snagging operations. In 1969 the channel was increased to a depth of 5 feet and a 125 foot width below Augusta, Arkansas to the mouth. Corps improvements have included 6 dam and reservoir projects for flood control, hydroelectric power, water supply, and recreation and fish and wildlife uses; 1 local protection levee to protect alluvial valley land; 9

watershed protection and flood prevention programs including agricultural water management channels; and numerous drainage facilities. The private sector has also constructed many levees and hydroelectric power plants. At present the navigation channel is open with no locks and dams, with 75 percent of the channel being complete with a 9 foot channel depth. There are no mooring facilities in the lower portion and barges rely on natural, unregulated structures (COE, 1982c).

2.16 Red River

2.16.1 Physical Characteristics

The Red River is located in southeastern Oklahoma, northeastern Texas, southwestern Arkansas, and northwestern Louisiana. It is bounded by the basins of the Canadian River on the north; the Ouachita-Black Rivers on the east; the Upper Red, Trinity, and Sabine Rivers on the west and south; and the Mississippi-Atchafalaya system on the southeast. The 400 mile long Red River Basin encompasses an area of approximately 29,500 square miles having a width of 130 miles at its upper end which tapers to 20 miles near the mouth.

The runoff of the Red River varies greatly during the year, being high during winter and spring and low in summer and fall. Above-average runoff takes place predominantly in the 5 month period of January through May with the greatest runoff normally occurring in May. Approximately 76 percent of the annual runoff occurs during this period. Below-normal flow is associated with the 4-month period of July through October with the lowest runoff usually occurring in August. Flow during this period accounts for about 12 percent of the annual runoff. The average annual volume of flow increases from 5,230 cfs at Colbert, Oklahoma, to about 30,700 cfs at Alexandria, Louisiana.

The Red River Basin area consists of a large alluvial valley flanked by gently rolling terrain. The elevation is generally below 400 feet (MSL). The lower Red River Basin is characterized by high ridges of chert and sandstone and intervening wide, flat valleys trending in a general east-west direction. The basin area consists of a large alluvial valley flanked by gently rolling terrain. Sinuous stream courses, natural levees, oxbow lakes, and abandoned stream channels are the predominant physiographic features.

Red River water is high in chlorides, sulfates, and dissolved solids content, and is moderately hard to hard. Mainstem flows cannot be used for many purposes due to the chloride contamination from natural and manmade sources (COE, 1977c). Water in the tributary streams generally is of good chemical quality, even during periods of low streamflow, and is suitable for municipal and industrial uses with little treatment. In many streams where poor quality occurs during low flows, the most frequent causes are oilfield or industrial discharges.

2.16.2 Biological Features

Fish habitat is widely variable. Natural lakes are numerous along the mainstem of the Red River, and in general are very productive. Species such as bass, crappie and catfish are found in these lakes. Mountainous tributaries support good populations of smallmouth bass. Channel catfish are found in mainstem river waters.

Extensive Red River bottomland forests of major importance to woodland wildlife remain in the basin area, primarily in the complex backwater area below Alexandria, Louisiana. Major hardwood species common to these bottomlands include pecan, hackberry, ash, elm, sweetgum, various red oaks, river birch, tupelo and water oak.

Forested tributary bottoms make up the most valuable wildlife habitat in the basin area, generally sustaining good populations of whitetail deer, squirrels, rabbit, bobwhite quail, raccoons, armadillo, opossum, fox, beaver and mink, and in certain areas, turkeys (COE, 1979a). Waterfowl use of the mainstem is generally poor to moderate.

2.16.3 Cultural Features

Land use in the Red River Basin is roughly 18 percent cropland, 58 percent forest-woodland, 17 percent pastureland, and 7 percent urban, farmsteads, roads, etc. Agriculture and lumbering are the main industries in the Arkansas portion of the basin (COE, 1977b).

Red River water is used by the mineral industry in the extraction and processing of raw mineral materials, as part of the mining process, or to wash the product in preparation for further use or treatment. River water is also used for irrigation of croplands.

Two relatively distinct recreation resource areas are recognized in the basin: the upper mountainous and low rolling hills, and the lower coastal plain area. The upper portion has approximately 25 percent of the basin's developed recreation facilities. Ideal reservoir locations, free-flowing streams, the broken topography, and the abundance of vegetation, wildlife, and open space, give the upper or northern portion of the basin outstanding outdoor recreational potential.

The lower coastal plain has low rolling hills in the north and alluvial plain in the south. The river is slow and meandering which creates wide valleys, oxbow lakes and swamps which provide sources of recreation.

Boating, swimming, camping and picnicking are the primary recreation demand activities. Existing recreation facilities in the basin can accommodate 1.7 million of these activity occasions combined. In 1965 the demand for these 4 activities was 18 million, leaving a shortage of 16 million activity occasions. There is presently a surplus of boating water but shortage of facilities. Access to riverfronts is another main problem.

In 1829 the River and Harbor Act authorized improvements from Fulton, Arkansas to the mouth of the river near Simmesport, Louisiana (COE, 1979a.) At present, navigation to Fulton can only be achieved at high river stages. Navigation waterways are under construction from the mouth to Shreveport, Louisiana. In addition to the levees and bank protection works along the mainstem of the Red River, local interests have constructed numerous improvement works throughout the basin for flood control, water supply, recreation, and other purposes. Most of these works are of minor scope and their benefits affect areas of rather limited extent.

2.17 Ouachita

2.17.1 Physical Characteristics

The Ouachita River Basin is located in south central Arkansas and north central Louisiana. It extends generally in a southwesterly and westerly direction towards Arkansas River drainage basin, (COE, 1979b). The Ouachita River originates in the Ouachita Mountains near Mena, Arkansas, and is bounded in the east by the Texas River Basin, on the west and southwest by the Red River Basin. The basin drains 20,000 square miles. The major tributaries of the Ouachita River are the Little Missouri, Caddo, Saline Rivers and the Bayou Bartholomew. The mean annual flow at the river mouth is 27,000 cfs. Throughout the hilly uplands, the Ouachita River flows through rugged terrain. It then passes through the alluvial valley of the Mississippi to enter the Red River, (COE, 1978a). Stream gradients range from 12 feet per mile in the upper reaches to 0.9 to 0.2 feet per mile near the mouth.

The quality of surface water is influenced by agricultural and industrial utilization (petroleum, metal and paper). The quality of water has been reduced by the influx of fertilizers, pesticides, herbicides, and sediment loads. There are also large amounts of dissolved solids from ground water effluents.

2.17.2 Biological Features

Fish species that occur can be found in COE, 1974; and include; white bass, yellow bass, walleye, crappie, channel catfish and drum. Game species in the basin include deer, squirrel, turkey and waterfowl; nongame species found are water birds, hawks, owls and songbirds. The American alligator, southern bald eagle, and the red wolf are federally endangered species found in the Ouachita and Black River Basins. Waterfowl use of the basin is dependent upon whether or not bottomland hardwood areas are flooded during migration flights.

Upland portions of the basin support a pine-hardwood forest type which includes associated hardwoods like oaks, persimmon and tupelo. Northern uplands support primarily hardwoods, including oak, hickories, black cherry, maples, elms, and beech. Alluvial areas support hardwood forests with lower sites having overcup oak, water hickory, baldcypress, and swamp tupelo.

2.17.3 Cultural Features

The population of the Louisiana portion of the basin was 209,998 in 1970; 58 percent of which were urban residents. The population in the Arkansas portion of the basin was 151,210 in 1970, and 40 percent of these were urban residents (COE, 1974).

Land use in the Louisiana portion of the basin was 69 percent cropland, 6 percent pasture, 4 percent urban, 1 percent small water area, and 1 percent other. Land use in the Arkansas portion of the basin in 1967 was 82 percent pasture, 3 percent urban, 1 percent small water area, and 1 percent other. Higher lands in the floodplain are well suited for agricultural purposes. Remaining flood plain lands are forested with hardwoods.

Principal river commerce consists of moving petroleum, chemicals, logs, sand and gravel and agricultural products. Farming and livestock is an important economic activity in the basin. The principal industries include petroleum and petroleum products, paper and paper products, lumbering, chemicals, and barite mining.

Recreational benefits were included in the design of new locks and dams scheduled to open in 1982. There are also 65,000 acres of a National Wildlife Refuge in the basin. The river mainstream is used primarily for boating, skiing, swimming and fishing. Access to the river is limited, and sites are not fully developed.

River improvements were authorized in 1871 and completed in 1926, and provided a 6-1/2 foot channel from the mouth of the Black River at Louisiana to Camden, Arkansas. Total navigable miles were 351 miles. The 1950 and 1960 Rivers and Harbors Act authorized an increased channel depth to 9 feet and extended the channel from the mouth of the Red River to Camden (COE, 1977d). The Felsenthal and Calion Locks and Dams are scheduled to open in 1982.

2.18 Yazoo River

2.18.1 Physical Characteristics

The Yazoo Basin is situated in the northwest quarter of Mississippi and encompasses approximately 13,355 square miles. It is about 200 miles long and has a maximum width of approximately 110 miles. About 268 square miles of the basin are covered with water. It is bordered on the north by the drainage divides of the Wolf and Hatchie River basins, on the east and south by the divides of the Tombigbee and Big Black River basins, and on the west by the Mississippi River, (COE, 1979b). The Yazoo River is formed near Greenwood, Mississippi, at the confluence of the Tallahatchie and Yalobusha Rivers. The basin waters discharge into the Mississippi River via the Yazoo Canal at Vicksburg, Mississippi.

The runoff in the basin varies seasonally and flooding is a recurrent problem in much of the basin. The highest amount occurs during February, March, and April (33 percent of the annual total) with peak flows in March. Minimal runoff takes place in August, September, and October with October being the driest for the basin.

The terrain of the basin can be divided into the Alluvial Plain and the Uplands. The Alluvial Plain, which is approximately 50 miles wide at the maximum, extends approximately 200 miles on a north south direction from Memphis, Tennessee to Vicksburg, Mississippi and covers an area of 6,600 square miles. The topography of the Plain ranges from flat to gently sloping with successive ridges and swells that once were stream borders.

The basin uplands exhibit a varied topography. The terrain is characterized by rugged to rolling hills with valleys ranging from one-half to two miles wide. The Pontotoc Ridge is a densely wooded area with pronounced relief. This province has the highest elevations in the basin, around 700 feet, and is composed of erosion resistant soils, (COE, 1977e).

Water quality in the Yazoo Basin is generally poor due to heavy silt, (COE, 1977e), surface water is affected by agricultural non-point pollution in the form of runoff containing pesticides and herbicides. All water bodies surveyed in the Yazoo Delta have these chemicals. Lakes have generally low levels of these chemicals, but 4 lakes have been

closed to commercial fishing due to excessive pesticide levels in fish (COE, 1977). Pollution in the basin is not a major problem. The greatest volume of point source pollution originates from municipal and industrial waste. Basin industries are all classified as producing biodegradable waste. The largest centers of organic waste production are Vicksburg, Yazoo City, and Greenville.

2.18.2 Biological Features

The streams, rivers, and lakes on the basin have low biological productivity, especially in the primary elements of the aquatic food chain (phytoplankton, periphyton, and macrophytes). Increasing levels of turbidity, sedimentation, and pesticides have caused the decline of sport and commercial fisheries in the basin.

The principal tributaries and the upper Yazoo River are dominated by gizzard shad, emerald shinner, and smallmouth buffalo, while the middle reach of the Yazoo is dominated by carp and green sunfish. Other species found in the Yazoo include longnose gar, skipjack herring, shortnose gar, and longear sunfish.

Aquatic macrophytes and the trunks and adventitious roots of partially submerged trees, especially bald cypress and willow, provide habitat for macroinvertebrates, which in turn provide a food source for forage and game fish. Alligator weed is a problem macrophyte in some portions of the Yazoo.

The Yazoo Alluvial Plain contains the oak-gum-cypress forest type, with overcup oak, Nuttall oak, sweetgum, tupelo, and bald cypress. However, bottomland forests are suffering a decline due to a conversion to agricultural land. Federally endangered wildlife in the Yazoo River Basin include the southern bald eagle and the American alligator.

The Central Alluvial Plain has suffered a severe lack of wildlife habitat due to extensive clearing for agriculture which has left the area bare of woodlands and thickets. Populations of the Alluvial Valley are determined by duration of standing waters. However, the Yazoo Backwater habitat is the most productive in the basin, supporting a large number of wildlife species, including green heron, American woodcock, pileated woodpecker, deer, squirrel, turkey, raccoon, mink, bobcat, wood duck, and migrant waterfowl.

2.18.3 Cultural Features

The Yazoo basin was primarily agrarian until the late 1930's. World War II changed the basin from an agrarian society to an industrial and commercial economy based on agricultural diversification and mechanization. The basin has declined in population since 1940 due to the migration of displaced farm labor to other areas of employment.

Since fertile agricultural land is one of the most valuable resources of the basin, agriculture is understandably the most important use of land, accounting for 55 percent of the basin area. Soybeans and cotton are the principle crops harvested. Forested land has been significantly reduced. In the alluvial plain, bottomland forests have been cleared and converted to soybeans and cotton; in the uplands barren areas are being converted to loblolly pine plantations and forage crops. Forests comprise 35 percent of the land area. There is a low concentration of industry producing textile mill products, food and industries products, chemical and allied products, and lumber and furniture. Industry occupies 0.1 percent of land area. Despite the highly productive farmlands, the basin is one of the most economically depressed regions in the nation, (COE, 1976).

Recreational activities in the basin include hunting, fishing, water sports and visiting archeological, historical, and environmental sites. Major recreational areas include 4 Corps reservoirs in the uplands, 2 national forests, national and state parks, a national wildlife refuge, and state wildlife and waterfowl management areas. There are two renowned features which add to wildlife attributes of the basin and these are the bottomland forests and the wetlands. Notable areas are Delta National Forest (59,000 acres), Delta Hills Bluffs (upland hardwood-pine forest), Chestnut Oak Disjunct (landmark in National Registry of Natural Landmarks), Sunflower Wildlife Management Area, Yazoo National Wildlife Refuge and Hillside National Wildlife Refuge.

The only recreational facilities adequate for water sports, and hunting and fishing are found in the upland areas. Oxbow lakes and other delta areas are not developed primarily due to inadequate access.

There are 730 archeological sites on record in the basin, most of which are the late prehistoric occupation of the area, exemplified by large prominent mounds. There are

included in this 156 Indian sites and 28 Civil War sites, (COE, 1977e).

Flooding is a recurrent problem in much of the basin, in spite of large expenditures for flood control and drainage improvements. The Corps has completed many flood control structures, including levees, reservoirs, and drainage ditches. In 1875 the River and Harbors Act authorized removal of snags, wrecks, etc., work was completed in 1888. The Rivers and Harbors Act of 1968 authorized channel improvements from the river's mouth to Greenwood, Mississippi to a depth of 9 feet over the 164.9 miles. This would include a lock and dam at Vicksburg, Mississippi. This navigation project is scheduled for completion in 1985. Presently river vessels can reach Greenwood 45 percent of the time. Other river improvement projects are the Yazoo Backwater Project, authorized in 1941 to provide protection from backwater flooding by the Mississippi River, and the Yazoo Headwater Project, which was authorized in 1928 and consisted of 4 dams with channel improvements, levees and fish and wildlife preservation.

3.0 DESCRIPTIONS AND ENVIRONMENTAL IMPACTS OF MOORING FACILITY ALTERNATIVES FOR THE MISSISSIPPI RIVER

Mooring facilities in the Mississippi River Navigation System are used for emergency or temporary mooring of vessels. Economic activity such as loading or unloading of cargo does not characteristically occur at a mooring facility. Rather, these facilities serve for such purposes as emergency repairs, rest locations for tow boat operators, and staging areas for vessels waiting for other tows to pass through locks or use fleeting facilities.

All mooring facilities, regardless of type, have certain common usage features. They provide an area outside of the main navigation channel where the tow boat and/or barges can be secured and remain immobile for a period of time. The tow boat usually remains with the barges while moored. These similarities in usage result in certain environmental impacts which are common to all mooring facilities. These generic impacts will be addressed in the following section before discussing specific impacts related to particular types of emergency/temporary mooring facilities addressed in this study.

3.1 General Impacts Common to All Mooring Facilities

3.1.1 Physical Impacts

The physical impacts, and generally all impacts resulting from mooring facilities, can be separated into those impacts attributable to constructing the facility, the physical presence of the facility and those impacts resulting from use of the facility. One negative impact which can conceivably be produced by all types of mooring facilities is a change in water quality in the immediate vicinity of the structure due to the leaching of various chemical substances from the structures itself.

The wooden pilings used to construct dolphins and battered pilings are usually treated with a preservative, commonly creosote. This substance can leach into the water in sufficient quantity from a "new" piling to create a small oil slick in the immediate vicinity. As the piling ages and the majority of the preservative has leached out, the concentration will decrease. Mooring structures using steel, either in the form of steel piles, steel sheet piling (mooring cells), steel hull barges (fleeting barges and anchor barges), or steel cables (buoys and shoreline deadmen) can also introduce various metal ions into the water. This activity may increase with age

of the structure as the protective finish deteriorates and the metal progressively oxidizes. These substances (creosote and metal ions) would not be introduced in quantities sufficient to cause any significant problems. Any impacts will be extremely localized and occur in the microhabitat immediately adjacent to the structure itself.

A second physical impact common to most mooring facilities is the possibility of floating debris collecting on the upstream side of the structure. This impact would most likely occur following heavy precipitation events when runoff is increased and debris, in the form of lumber, logs, limbs, etc., is swept downstream. In extreme cases this could result in large unsightly buildups of debris collecting on the upstream side of the mooring facility. In addition to the negative aesthetic impacts of this occurrence, it can constitute a navigation hazard should the material break free and float downstream as single mass. This debris in some cases, could lodge against the banks, possibly causing gouging and subsequent erosion problems.

During the construction phase of many types of mooring facilities, some minor air quality impacts could occur in the immediate area. These air quality impacts result from exhaust emissions of workboats, cranes, pile drivers and other heavy machinery used to construct mooring facilities. Carstea et al. (1975) compared the largest predicted carbon monoxide emissions resulting from construction of small structures with the yearly carbon monoxide emissions from different counties in New York. The study concluded that contribution to air quality degradation was negligible.

Another related physical impact occurring during construction activity is an increase in noise levels from internal combustion engines in workboats and related equipment. Heavy equipment rarely produces noise levels above 80 dB(A) beyond 200 feet from the source (Carstea et al. 1975). These authors stated these noise levels are generally considered acceptable for the short time periods such as those required to install mooring structures.

A third type of adverse physical impact occurring during construction is the inevitable spillage of oils, grease, fuels, and refuse by the construction crew. While Federal law prohibits discharges of this nature to the waters of the U.S., it is common for accidents of this nature to occur. This activity results in temporary, localized pollution which is diluted as it is carried downstream. It should be recognized that while dilution does not mitigate this effect, it does significantly reduce the potential impacts.

The three impacts from construction activities discussed above (air emissions, noise, and spills) could also occur during the life of the project. When tows have moored for overnight or longer, the engines will require a warm-up period before departing the mooring facility. This can result in emissions from the exhaust gases and attendant noise. During the period while the tow is moored, minor spills of petroleum products can also occur that can contribute to localized water quality degradation. Bilge pumping activities frequently aggravate this condition. None of these impacts is likely to have significant consequences unless the mooring facility is located in biologically sensitive area or an area that includes sensitive audio receptors.

General impacts to water quality resulting from mooring activities can be caused by propwash from vessels at the facility. This effect can scour and resuspend bottom sediments. The slight increases in turbidity produced by propwash are generally insignificant. A more serious problem can occur if significant quantities of toxic materials are present in the sediments which is common in urbanized river reaches. This is possible also if a large spill occurred in the vicinity in the past or if the facility is located adjacent to an active or inactive industrial discharge. Larger structures such as mooring cells can also cause localized change in flow patterns. This could result in bottom scour in areas with toxic pollutants.

An additional general impact of mooring structures occurs in those areas subject to ice covers during the winter season. Ice can accumulate on piles and structures (buoys, cables, etc.) eventually submerging the buoys or weakening the other structures to the point where they break free and are carried downstream, becoming hazards to navigation.

Most of the mooring structures will result in loss of a very minor amount of water surface area and a small loss of river benthic area. Some rough estimates of this surface area were made by U.S. Army Corps of Engineers (undated) for buoys and mooring cells. According to their estimate, each buoy will occupy about 80 square feet of water surface area, but an insignificant amount of river bottom. Each mooring cell will occupy approximately 470 square feet of river surface and an equal amount of river benthic area.

3.1.2 Biological Impacts

Adverse biological impacts can occur during the construction of any type of mooring facility. The noise of

construction activities can disturb sensitive receptor biological populations. Sensitive populations would include heron rookeries and spawning populations of fish. This can be an important consideration in that disturbance during critical stages of nesting or spawning can significantly reduce the reproduction capabilities and result in lower populations in the succeeding year classes. Noise and related disturbance caused by the use of a mooring structure adjacent to one of these biologically sensitive areas can, over a period of several years, result in the abandonment of the nesting or spawning site by the species. This phenomenon is particularly true of avian species.

The use of artificial lighting on vessels moored overnight can also cause behavioral modifications in populations of aquatic and terrestrial fauna. This form of disturbance would only be significant in sensitive areas such as those described above for noise disturbance.

Propwash from vessels using the mooring facilities can adversely affect rooted aquatic vegetation, benthic macroinvertebrates, and spawning or juvenile fish in nursery areas. Rooted aquatic vegetation can be torn loose from the substrate by bottom scour resulting from propwash. This, in turn, can have adverse consequences for juvenile fish which use the vegetation for cover and lurking areas. Serious scour can also displace benthic invertebrates such as mussels which normally inhabit surface sediment layers. Should significant amounts of benthic material be resuspended, adverse impacts caused by smothering of adjacent mussel and shellfish beds could be experienced.

All of the mooring devices provide some habitat for sessile organisms and many of the larger piling structures and barges provide cover and lurking areas for fish and other crevice dwelling organisms. Pelagic game fish are reportedly (Mulvihill et al, 1980) attracted to buoys. Another beneficial impact in this respect is the use of pilings and other mooring structures as resting areas by birds. In some cases these structures may be used for nesting purposes. In particular, ospreys, a raptor species have been observed to use piling structures for nesting locations, although this would be unlikely in mooring areas that would be used frequently.

3.1.3 Cultural Impacts

A number of cultural or socioeconomic impacts have been identified in relation to the construction and use of

mooring facilities. One area of potential impact is increased congestion of the waterway. This effect may be caused by workboats being used at the project site during the construction phase and by the presence of large tows moored at the structure during the life of the project. Congestion caused by the presence of workboats will be minimal and of a temporary nature. The duration of construction activities depends on the type structure to be installed and can range from several days to a week. The use of the mooring facility by large tows has a greater potential to create a congestion problem. In most cases the mooring facilities are located adjacent to the main navigation channel. An important factor to be considered in the design of mooring facilities is the typical size of tow (and the maximum size) used on the waterway where the site is located. There should be adequate clearance in the main navigation channel for another tow of the same size to safely pass. Consideration should be given to developing criteria to govern the size of tows permitted to moor at specific facilities.

Congestion can also be experienced by recreational craft using the waterway. This is particularly true if waterskiing is a popular sport in the area of concern. The area required for a skier to maneuver safely is considerably greater than the space requirement for small craft used for fishing or pleasure cruising. The presence of buoy anchors or cables in the water also constitutes a particular hazard for water skiers. If cables are an integral part of the structure, clear warning should be posted on the structures to notify skiers to avoid this hazardous area.

Another area of potential cultural impact is the aesthetics of a mooring site. The determination of the aesthetic impact will be largely subjective for the different types of mooring structures. However, certain criteria can be used to determine the likely impacts on the aesthetics of an area. The first criterion is the uniqueness of the structure. Even if many of the potential impacts of a structure will be unique and observable, but it is only another addition to what already exists, it could have a relatively small cumulative aesthetic impact. One more mooring structure will go unnoticed, whereas the first in an area or a radically different type will be more perceptible.

The second criterion affecting aesthetics is the magnitude of the structure. The greater the change, the more pronounced the aesthetic effect. For example, anchor or fleeting barges will probably be more aesthetically undesirable to most individuals than buoys or dolphins, mainly due to the magnitude and mass of the structure.

The third aesthetic consideration is the sensitivity of the area affected. Different areas will be affected to different degrees according to the existing or perceived usage of the area. The addition of new mooring facilities will have little impact in an industrial or commercial area while the same mooring facility located in a natural area or adjacent to a recreational park or residential shoreline area will result in considerable change in the area's aesthetic character.

Carstea, et al. (1975) ranked areas in ascending order of aesthetic sensitivity to environmental change. An adaptation of their ranking is as follows:

- waste land or any area of land or water specifically authorized for the disposition of waste products, including their processing through sewage plants, incineration, etc.
- industrial areas
- commercial areas
- undeveloped open land, public or private (e.g., farmland, stretches along highways, unimproved urban or suburban lots of sufficient size to be considered distinct from the zoned area of which they must be a part, etc.)
- recreational areas, including parkland, undisturbed woodland and other wilderness areas, beaches, and shoreline areas not used commercially or industrially
- residential, which can be further subgraded on an ascending scale from multiple apartment houses to detached single-family dwellings

The sensitivity of these areas to environmental change forms the basis for an additional criterion when evaluating aesthetic impact. This criterion can be considered when evaluating the aesthetic impact of a given mooring structure with the surrounding environment. In other words, how well the structure's appearance blends or harmonizes with its

surroundings. When addressing this criterion, there is no substitute for sound, professional judgement based on experience.

A secondary impact related to aesthetic change is a potential decrease in property value due to a decrease in aesthetic appeal. This impact is probably most observable and sensitive in residential areas. In such a case, it is not solely the negative aesthetic value of the mooring structure itself that is important but also other aesthetic changes associated with its use. These changes include the presence of tows at the structure, the noise of towboats, diesel exhaust emissions and the presence of trash, accidental spillage of petroleum products and litter. Other locations where this consideration can be important is adjacent to parks and shoreline recreation areas. Adverse impacts to water quality can have negative implications should these areas support body contact (swimming, etc.) recreational pursuits.

Another location where property values can be changed is small craft marinas. These facilities could experience decreased business revenues in extreme cases. The increased congestion, presence of litter, and safety considerations caused by a nearby mooring area can result in a reluctance on the part of prospective customers to use such facilities. This is more likely to be a problem for larger marinas catering to sailing craft and large pleasure cruisers.

The physical act of placing pilings or other anchoring materials into the river bottom or shoreline could damage or destroy archaeological remains. Although this can be considered unlikely, during the planning phase of any structure the National Register of Historic Places should be consulted.

The preceding sections have discussed the general types of impacts which are common to many of the mooring structures. In the following sections, only individual impacts which are related to a specific structure will be discussed. It should be recognized that any or all of the preceding general impacts can occur in addition to the specific impacts presented below.

3.2 Pilings, Dolphins and Battered Pilings

3.2.1 Structural Description

Piling structures vary widely according to the construction materials used and the design of the facility.

A piling can consist of a single wooden pole driven into the river bed. This type of structure would, however, be suitable only for mooring of small recreational craft. In order to provide the structural integrity needed to secure larger commercial craft, a large number of wooden poles, steel H-piles, or steel pipes are driven into the river bed in clusters. These structures are known as pile clusters or dolphins. Some of the possible variations of their design are described below.

- Steel H-Pile Dolphins

Steel piles having an H-shaped cross-section are driven into the river bed at an angle with several piles downstream and several upstream. The piles converge at the top in a triangular configuration and are joined by steel crossmembers. Mooring cleats or rings are subsequently attached.

- Timber Dolphins

These typically consist of a cluster of treated wooden poles averaging 12 inches in diameter which are driven into the river bottom and bound with steel cable and bolted together near the top. Usually, the outer piles are battered (driven at an angle) for stability. The inner cluster of poles are driven vertically into the river bed. Mooring rings or pegs are attached.

- Steel Pipe Dolphin

Typically, four hollow steel pipe piles (approximately 8 inches in diameter) are driven vertically into the river bed in a square configuration. Several diagonal braces connect the pipes and provide additional structural integrity. The vertical pipe piles may also be filled with sand or other grout material. Mooring rings or pegs are then fastened.

- Battered Pilings

Battered pilings and structures to which angled supports or braces are added on the side opposite the tie-off location (usually landward) to increase their structural stability.

3.2.2 Impacts of Pilings, Dolphins and Battered Pilings

The typical impacts of mooring piles are initial construction turbidity which has physical and biological significance, noise associated with driving the pilings, and their impact on aesthetics.

- Physical Impacts

The process of driving piles into the river bed causes increased turbidity which is generally very slight and may not even be noticeable unless the substrate is composed of loose, extremely fine-grained sediments. This turbidity is generally minimal and of short duration.

- Biological Impacts

One type of biological impact which could potentially occur from mooring piles relates to the physical impact discussed above - namely turbidity effects. Increased turbidity, depending on severity, may reduce primary productivity, interfere with respiration of fish, alter the suitability of spawning areas, reduce bottom habitat diversity, and smother benthic organisms (Carstea, et al., 1975). None of these possible turbidity induced impacts are likely to be of any significance for pile driving operations due to the small amounts of suspended material generated. It should be pointed out that, in some instances, fish have been attracted to construction sites due to the suspension of sediments and related organic matter. These resuspended organics may provide a desirable food source which proves attractive enough to outweigh the turbidity and noise disturbances produced. It should be recognized that this effect is temporary and extremely localized.

The other likely biological impacts resulting from pile driving operations are the effects of noise and vibrations on aquatic and terrestrial fauna. These disruptions may temporarily force fish or avian species from the area or cause behavioral modifications. This could interrupt spawning activities, by which significant impacts could result. The most successful mitigation technique would be to avoid known spawning areas since propwash, noise and disruptive effects of mooring operations could negatively affect these resources throughout the life of the project. Similarly, wildlife refuges or bird nesting areas adjacent to the project site may be adversely impacted by the noise of pile driving. This effect would be most pronounced during the breeding season.

● Cultural Impacts

The general aesthetic impacts common to all mooring structures have been discussed in Section 3.1.3. In some specific cases, piling structures could conceivably produce a positive aesthetic impact. Piling are often used by gulls and other birds as resting places. In heavily industrialized or commercial areas, the presence of birds attracted to pilings can provide a welcome relief to urban or industrial surroundings. It should also be recognized that pilings are perhaps, with the exception of buoys, the least aesthetically displeasing than other mooring structures. Plans for removing the piling and other support structures after their effective life span should be reviewed when the structure is proposed for construction. There are severe navigational problems in many areas of the United States due to the chronic decay and drifting away of pieces of old pilings. Piles or portions of piles remaining just below the water level also present navigational hazards (Mulvihill, et al., 1980).

3.3 Mooring Cells

3.3.1 Description

The typical mooring cell is constructed of steel sheet piling driven into the river bottom to form a circular cell 25 to 50 feet in diameter. These cells are then generally filled with sand, gravel, concrete or other inert fill material. If granular material (gravel) is used, it normally varies in size from peagravel to cobblestones (U.S. Army Corps of Engineers, undated). Cells filled with granular material are typically capped with concrete. Pegs or mooring rings are added to the side of the cell to facilitate the attachment of mooring lines. Navigational aids are frequently constructed on the concrete cap.

3.3.2 Impacts

Most of the impacts discussed for piling type mooring structures also apply to mooring cells. The principle differences are the possibility of the oxidation of the steel piles and the subsequent release of ferric ions. Other impacts include a slightly greater increase in noise levels and duration during the pile driving operation, a slight increase in the negative aesthetic impact of the structure, and loss of greater amounts of benthic area.

- Physical Impacts

The process of driving steel piling for mooring cells will generally produce levels of turbidity similar to that of driving wooden piles. This impact has been previously discussed in Section 3.2.2.

The sheet steel piling used to construct mooring cells will gradually oxidize over time. As this rusting takes place, other metal impurities in the steel, in addition to the iron, will be introduced into the water columns. This process is so slow that no appreciable impact on water quality is anticipated. If the exposed metal surface above the water is painted periodically, the possibility of paint spilling into the water can also result in localized and minor changes in water quality. Again, this impact will be very minor, localized, and of short duration.

In locating the mooring sites, the geology of the area should be considered to ensure that the sheet piles are driven into the most suitable river bed substrate. This precaution will lessen the chance of premature structural failure due to piling refusal if rock is encountered at shallow depths.

One impact uniquely associated with steel pile mooring cells is the greater difficulty in removing the structure from the waterway after its useful life. As mentioned in the previous section on piling structures, the planning process for any mooring structure should consider the useful life of the structure and make provisions for its maintenance and eventual removal. Interlocking steel sheet piles are somewhat more difficult to remove than simple wooden pilings and may require the use of heavier equipment.

- Biological Impacts

The most notable difference between open piling structures and piling in relation to biological impacts are concerned are the increased noise levels associated with driving the steel pile sections. The impact of the pile driving weight on a steel piling produces a greater noise level than that of driving wooden piles. This increase in noise could adversely affect adjacent sensitive biota to a greater extent than driving wooden piles.

- Cultural Impacts

The aesthetic impact of a mooring cell is likely to be greater than wooden pile structures.

Individuals tend to perceive the wooden structures as more "natural". This consideration would only be significant in areas where aesthetic impact is important, such as scenic reaches of river or reaches adjacent to parks and wildlife refuges. Historically, moorings cells have received greater application in urbanized/industrialized reaches of waterways and pilings in less developed areas.

3.4 Buoys

3.4.1 Description

Buoys are floating structures, usually a hollow structure filled with expanded polystyrene or foamed urethane to provide buoyancy. A metal tower superstructure is embedded into the flotation frame and rises above the flotation portion. Mooring rings or chain links are attached to this metal superstructure by shackles to facilitate the attachment of mooring lines.

Three types of anchoring devices are commonly used to hold buoys in place. The first involves boring to bedrock and filling the hole with concrete or grout to hold the anchor chain or cable. A second type of anchoring device is an exploding type developed and utilized exclusively by the Navy. The device is dropped so that it penetrates the soft river bottom and then explodes, spreading a set of leg-like devices which provide stability. The third means of anchoring buoys involves the use of a shoreline deadman device. In all cases a heavy steel cable or chain attaches the buoy to the anchoring device.

3.4.2 Impacts

Most of the impacts associated with buoys result from the methods used to install them. As mentioned above, the most frequently used methods of anchoring buoys are borings into the bedrock or the use of deadmen and cables. Either of these methods can potentially produce localized turbidity.

- Physical Impacts

If the buoy anchoring device is installed by boring into the river bed, localized turbidity will result. This turbidity is not likely to be of greater magnitude than that associated with the driving of piles, but may be dispersed further due to the continuous nature of the boring process and the deposition of boring tailings on the immediately adjacent benthic area.

@anchor would probably not be feasible from an engineering/design aspect for these types of sediments.

- Biological Impacts

The previously mentioned adverse impacts of turbidity on the biota can occur with either type of anchoring device used. The major mitigative measure for these alternatives is to avoid biologically sensitive areas.

The construction of deadmen and associated cable devices cause temporary and minimal impacts to the biological environment. During installation of this type of device, a small amount of terrestrial area may be disrupted with resultant adverse effects to vegetation. Revegetation of ground cover, e.g. grasses and forbes, will occur quickly through invasion of adjacent unaffected species. In regard to benthic considerations, periodic movement or dragging of mooring cables along the river bed may disrupt rooted aquatic vegetation or benthic organisms in the affected area. No significant adverse impacts to terrestrial wildlife or pelagic species have been identified in relation to this alternative.

Although buoys are among the smallest structural devices used for mooring purposes, they still have the potential of attracting fish to the area. Mulvihill, et al (1980) mention that pelagic game fish have been observed to be attracted to buoys.

- Cultural Impacts

Other than aesthetic influences and increased congestion in the area due to moored tows, there are no notable cultural impacts resulting from the installation and use of mooring buoys.

3.5 Fleeting Barges and Anchor Barges

3.5.1 Description

Both of these alternatives involve using an old barge which is anchored in place. The only essential difference between the two types is the means by which the barge is anchored. In the case of a fleeting barge, the barge is held in place by cables attached to deadmen along the shoreline. An anchor barge is usually held in place with one large anchor on the bow and two anchors on the stern.

3.5.2 Impacts

Barges, either fleeting or anchor, are perhaps the largest and most conspicuous type of mooring alternatives. Most of the unique impacts associated with these mooring devices are related to their size.

- Physical Impacts

The physical impacts associated with the use of aging barges as mooring structures are mainly related to the light inhibiting effect created by them. There will be a decrease in light penetration in the area beneath the barge. The only notable physical effect of this reduction in light penetration will be a small localized decrease in water temperature. Unless the barge is located in a slackwater area with very poor circulation, this temperature change will be very slight and does not represent a significant impact.

- Biological Impacts

The reduction of light penetration into the water column beneath a barge will reduce photosynthesis and primary productivity. This effect will be negligible for phytoplankton since the shaded area represents a very small percentage of the total water surface area. Should the barge be located over an area of rooted aquatic vegetation, the impact may be more observable. Such rooted plants are sessile and in the prolonged absence of sunlight may experience stunted growth or die off entirely. This effect will be magnified during mooring activities when more extensive areas of the water surface are covered by the barge traffic and attendant tows. For these reasons, beds of rooted aquatic vegetation should be avoided when selecting a site to install mooring barges.

The positive benefit of mooring barge is their ability to provide cover for fish. Fish using such cover will be inaccessible to avian predators and many species may find this an attractive feature. In this way, such structures provide a man-made alternative to deadfalls and overhangs.

- Cultural Impacts

There are a number of unique cultural impacts associated with the use of barges as mooring alternatives. The first of these is the potential for a negative public perception of the aesthetics. Since older, less serviceable barges are generally battered, many people may

perceive the structure as "junk" rather than having a design purpose. This impact can be mitigated in two ways. The first way is to avoid areas which are likely to generate conflicting aesthetic perceptions. Section 3.1.2 provides some considerations which address this aspect. A second means of mitigating the negative aesthetic impacts is to upgrade the appearance of the barge. This can be accomplished by the application of a fresh coat of paint which can also provide greater safety if it increases the visibility of the structure. There is a tradeoff involved in that greater visibility means greater conspicuousness in the eyes of the observer and can aggravate aesthetic impacts.

An additional cultural impact of mooring barges is their potential interference with other waterway uses, particularly recreation. A barge structure will require more space than any other type of mooring structure. Cables used to attach the barge to anchors or shoreline deadmen also pose a hazard, particularly to water skiers. Hazardous areas around the barge should be clearly marked to avoid accidents. These concerns have been discussed previously.

On the positive side, sport fishing activities in the area of mooring barges will probably benefit from the structure. This is a direct result of the attraction these barges have for fish which may utilize the cover provided. Public access to the barge has cultural implications. Should gamefish species be attracted to the vicinity of the barge, this effect could provide the public initiative to trespass on the structure. Should any injuries to individuals be sustained while on the structure, it is likely that the government could be legally liable. If the public is to be allowed access to the structure, signs disclaiming the government's (Corps') liability should be prominently displayed. A more realistic approach would be to post "No Trespassing" signs and make public access to the structure difficult if not impossible.

3.6 Shoreline Deadmen and Cables

3.6.1 Description

Shoreline deadmen consist of a solid anchoring device placed along the shoreline. This could exist in the form of a large concrete block which is constructed by pouring concrete into an excavation or it could consist of pilings driven into the banks. A ring or chain is attached to this immobile device and a cable extends out into the water to which the tow can be attached.

3.6.2 Impacts

- Physical Impacts

There may be some leaching of metals into the water from the cables used to attach tows to the deadmen, but this impact will be sufficiently minor as to warrant no further consideration. If barge tows have to nose into the shoreline in order to attach the cable, turbidity can be generated by the barges disturbing bottom sediments. If the tows actually touch the shoreline, localized increase in erosion could also result. The placing of deadmen along the shoreline will also result in local disturbance of vegetation and soil cover. If suitable measures such as riprap or other erosion control devices are not installed, shoreline erosion conditions could develop. This erosion can be aggravated by propwash from the tow boats.

- Biological Impacts

The installation of shoreline deadmen may result in some destruction of vegetation along the shoreline. This will be a relatively minor impact. If a heron rookery is located at the site, the disturbance could have a severe impact on behavior with a possible decrease in nesting success. This impact on nesting would also occur during the life of the project as a result of tow usage of the mooring site. The best mitigative measure, as in all such cases, is to avoid these sensitive areas.

If rooted aquatic vegetation is present along the shallow areas adjacent to the shore, this vegetation could be impacted by use of the mooring site. The hulls of vessels nosing into shore could disturb aquatic and shoreline vegetation. The presence of the tow immediately above the vegetation would result in a reduction of photosynthesis due to reduced penetration of sunlight.

- Cultural Impacts

The only likely cultural impact of shoreline deadmen would be aesthetic if the mooring site is located in a scenic area. This impact would only be readily perceived during use of the site for mooring operations, since the deadmen structures will be relatively inconspicuous.

Another impact in this area is the possibility of these structures representing an unnecessary economic expenditure. According to U.S. Army Corps of

Engineers (undated), such facilities have been placed at many locations in the past, but few river craft used them.

3.7 Unregulated Mooring Use

3.7.1 Description

Unregulated mooring is defined as any mooring activity that occurs without the use of a mooring structure. An example of such use is when a tow noses into shore and ties up to trees or other physical objects on the river bank. Other stabilization devices may also be employed at this time. This activity would usually occur during an emergency situation only and could occur at any accessible point along the river shoreline.

3.7.2 Impacts

Impacts resulting from unregulated mooring are usually one-time events in that the site is chosen randomly and is usually the nearest accessible area the tow operator can reach. However, it should be recognized that the potential exists for readily accessible areas to be used more than once.

- Physical Impacts

A certain amount of bank disturbance is likely to occur if the barges come in contact with the shoreline. Small sections of the bank can be dislodged into the water, resulting in a localized increase in turbidity. The benthic substrate immediately adjacent to the shoreline is likely to be disturbed also. Both types of disturbance may produce localized turbidity. The disturbance of the bank and possible removal of protective vegetation may result in increased erosion in the immediate area. This erosion could contribute increased suspended solids to the river for an extended period of time after the actual mooring period.

- Biological Impacts

The bank disturbance, discussed in the preceding section, could include some destruction of forbes and shrubs growing on the edge of the bank shoreline. Likewise, the contact of barge hulls against the benthic substrate can uproot aquatic vegetation in the shallow area immediately adjacent to the bank.

The use of trees to moor a tow will probably result in damage to those trees to which mooring lines

have been attached. The action of the mooring line rubbing against or cutting into the tree can partially girdle the tree. The area below the girdle may show the effects of starvation as a result of the interruption of nutrient flow from the leaves. Since a mooring line may only partially girdle the tree, it is unlikely that the tree will be killed as a direct result of this activity. However, the wound in the bark may provide access to fungi, plant pathogens, and insects. These effects generally serve to shorten the life of the tree by making it more susceptible to disease. In a worst case situation, the mooring cable could either cut through the tree or pull the tree into the river.

If fish spawning areas or avian rookeries are located at the site, the disturbance produced by the mooring activity can result in adverse behavioral changes. Turbidity produced by the tow scraping the benthic substrate or shoreline can also produce localized, minor adverse effects due to the resuspension of benthic material.

- Cultural Impacts

The principal cultural impact of unregulated mooring is the potential destruction of private property. As previously mentioned, the bank in the immediate area may be damaged and some damage can occur to riverbank vegetation and trees at the mooring location.

4.0 AREAS OF SPECIAL CONSIDERATION FOR MISSISSIPPI RIVER NAVIGATION SYSTEM MOORING ALTERNATIVES

This section identifies and ranks those parameters and impacts which may require special consideration during site specific planning for mooring facilities located in the Mississippi River Navigation System. Due to the high degree of variability between river systems within the study area, it is not possible to develop a ranking scheme which would be accurate, applicable, or specific to, in each individual river. The following matrix compares riverine parameters with mooring alternatives, ranking the environmental impacts in terms of duration and magnitude. While the matrix does not rank one mooring alternative as inherently better than another, given site specific concerns it can provide a ranking of alternative structures on the basis of their environmental impacts.

4.1 Matrix-Mooring Alternatives vs. Environmental Parameters

The matrix is designed to show the relative impacts of the mooring alternatives upon various physical, biological, and cultural parameters associated with the river systems in the study area. Thus, the matrix is best used as a planning tool. Once a site or sites are selected, the matrix can serve to identify site specific environmental parameters of concern in relation to each mooring alternative. Site specific comparisons between alternatives can then be made. It should be noted that the actual selection of a mooring alternative for a site must also consider costs, engineering, design, and other factors.

The matrix assesses the environmental impacts of the installation and the physical presence of the mooring structures. All impacts were considered either temporary or permanent. A temporary impact (indicated in the matrix by a "T") occurs only during the installation of the structure, and abates when the construction is completed. An example is the impact to water quality of increased turbidity during the driving of wooden pilings. Permanent impacts are those which continue for the life of the structure or which have the potential to occur for the life of the structure. Examples are impacts to water quality from metal ions leaching from steel piling and impacts on floods from all structures in the waterway respectively. Permanent impacts are indicated on the matrix by the letter "P". Permanent impacts take precedence over temporary impacts, whether beneficial or adverse.

The magnitude of the impacts was determined from the information presented in Section 3. These determinations

		PILINGS (WOOD)	PILINGS (STEEL)	DOLPHINS (WOOD)	DOLPHINS (STEEL)	BATTED PILINGS	MOORING CELLS	BUOYS WITH BORED ANCHORS	BUOYS WITH EXPLODING ANCHORS	BUOYS WITH DEADMEN	FLEETING BARGES	ANCHOR BARGES	SHORELINE DEADMEN	UNREGULATED MOORING USE
WATER	WATER QUALITY	T, M	P, N	T, M	P, N	T, M	P, N	T, M	T, S		P, M	P, M		
	WATER TEMPERATURE										P, N	P, N		
	ICE COVER	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, N		
	LIGHT PENETRATION										P, M	P, M		
AIR	AIR QUALITY	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N
	FLOODS	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, M	P, M	P, M		
PHYSICAL PROCESSES	SHORE EROSION						P, N				P, M	P, M		P, M P, S
	SEDIMENTATION						P, N							
	BOTTOM SCOUR						P, N							P, N
	TREES													
FLORA	GROUND COVER										P, M	P, N		P, M P, S
	PHYTOPLANKTON										P, M	P, N		P, M P, N
	ROOTED AQUATIC PLANTS											P, N	P, N	
	ENDANGERED SPECIES											P, S	P, S	
									T, N					P, M
									T, N					P, M P, S

KEY TO SYMBOLS: B - BENEFICIAL IMPACT, N - NEGLIGIBLE IMPACT, M - MODERATELY ADVERSE IMPACT, S - SIGNIFICANTLY ADVERSE IMPACT, T - TEMPORARY IMPACT, P - PERMANENT IMPACT, □ - NO IMPACT.

MISSISSIPPI RIVER NAVIGATION SYSTEM
MATRIX OF RANKED ENVIRONMENTAL IMPACTS

	UNREGULATED MOORING USE	SHORELINE DEADMEN	ANCHOR BARGES	FLEETING BARGES	BUOYS WITH DEADMEN	BUOYS WITH EXPLODING ANCHORS	BUOYS WITH BORED ANCHORS	MOORING CELLS	BATTED PILING	DOLPHINS (STEEL)	DOLPHINS (WOOD)	PILINGS (STEEL)	PILINGS (WOOD)
BIRDS	P, M	T, M	T, N	T, N	T, N	T, N	T, N	P, B	P, B	P, B	P, B	P, B	P, B
LAND ANIMALS	P, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N
FISH	P, N		P, B	P, B	P, B	P, B	P, B	P, B	P, B	P, B	P, B	P, B	P, B
SHELLFISH						T, N							
BENTHIC ORGANISMS	P, M					T, N	P, B	P, B	P, B	P, B	P, B	P, B	P, B
ENDANGERED SPECIES	P, M	T, N	T, M	T, M	T, M	T, N	P, B	P, B	P, B	P, B	P, B	P, B	P, B
SPAWNING & NURSERY AREAS	P, S		P, B	P, B	P, N	T, S	P, N	P, N	P, N	P, N	P, N	P, N	P, N
AVIAN NESTING AREAS	P, S	T, S	T, M	T, S	T, S	T, S	T, M	T, S	T, S	T, S	T, S	T, S	T, S
WILDERNESS	P, M	P, S	P, S	P, S	P, S	P, S	P, S	P, S	P, S	P, S	P, S	P, S	P, S
PARKS	P, N		P, N										
WETLANDS	P, S	P, N	P, M	P, M	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, N	P, N
FORESTRY	P, N												
AGRICULTURE													
RESIDENTIAL	P, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N	T, N
COMMERCIAL	P, N												
INDUSTRIAL													
MINING & QUARRYING													
FAUNA													
LAND USE													

KEY TO SYMBOLS: B - BENEFICIAL IMPACT, N - NEGLIGIBLE IMPACT, M - MODERATELY ADVERSE IMPACT, S - SIGNIFICANTLY ADVERSE IMPACT, T - TEMPORARY IMPACT, P - PERMANENT IMPACT, □ - NO IMPACT.

FOOTNOTES

- 1 Any proposed mooring structure should be compatible with riverfront planning designs and is dependent on site specific planning information.
- 2 The rating shown on the matrix represents a "worst case" evaluation. Impacts could range from significantly adverse if the resource is destroyed to beneficial if access is improved.

considered both the actual impacts and their significance relative to the other impacts. Impacts are thus prioritized as being beneficial (B) adverse but negligible (N), moderately adverse (M), and significantly adverse (S). Areas with no impacts are left blank.

Impact parameter areas consist of water, air, physical processes, flora, fauna, land use, recreation, aesthetics, and man-made facilities. Each parameter consists of several subparameters, further refining the impact areas. While most of the parameters and subparameters are self-explanatory, some require further explanation. The water parameter consists of water quality, water temperature, ice cover, and light penetration. The ice cover subparameter refers to the effect of ice on the mooring structure (with resultant environmental impacts) while the other subparameters are assessed according to the effect of the mooring structure on them.

Other subparameters requiring explanation are floods (physical processes), boating (recreation) landscape design and historical/archaeological sites (aesthetics). The flood sub-parameter is assessed according to the impacts of floods on the structures with resultant environmental effects as well as the impacts of the structures on flooding. The boating subparameter was considered to benefit from all regulated mooring structures due to increased recreation opportunity (fishing) and increased safety aspects (emergency mooring); however there also exists a potential for increased risk to boaters as the mooring structures also become an additional obstacle to avoid. Thus this subparameter should be carefully reevaluated during the site specific planning. Landscape design refers to local or regional riverfront plans or community building and design restrictions directed toward controlling the appearance of an area. The impact of mooring structures upon such plans or restrictions must be determined on a site or community specific basis (except for unregulated mooring). Historical and archaeological sites should also be treated on a site specific basis. Although given a worst case assessment in the matrix, the actual impacts may range from the worst case to beneficial (improved access).

4.2 Conclusions

While no formal ranking of mooring alternatives can be made which is applicable to all of the highly variable environmental settings of the rivers investigated, some general conclusions regarding mooring alternatives can be made. In most cases, any form of regulated mooring structure is

preferable over unregulated mooring. The use of pilings, mooring cells, and buoys is generally more environmentally compatible than deadmen, fleeting barges, and anchor barges. General conclusions on specific alternatives are discussed below.

Wooden pilings have few significant impacts except during installation, when pile driving noise may have adverse effects on sensitive receptors such as residential areas, spawning grounds, and avian nesting areas. Steel pilings, wooden dolphins, and steel dolphins are similar to wooden pilings in environmental impacts.

Mooring cells have similar impacts, though they also can affect erosion, sedimentation, bottom scour, and aesthetics to a greater degree than wooden pilings.

The impacts associated with buoys are variable, being primary dependant upon how the buoy is anchored. The use of buoys with exploding anchors or deadmen anchors can have moderate to significant adverse impacts upon several sub-parameters particularly those relating to fauna.

Fleeting barges and anchor barges are similar in impacts, and have the potential to adversely affect water quality, rooted aquatic plants, avian nesting areas, and aesthetics with some degree of significance.

Shoreline deadmen (also used to anchor some buoys and fleeting barges) have the potential to impact primarily terrestrial subparameters such as shore erosion, trees, groundcover, and avian nesting areas. They could also be considered to be a hazard to waterskiing and boating if the anchor cables/chains are not marked.

Unregulated moorings are the most likely to have an adverse impact upon most of the parameters considered, with many of their impacts being significant. Unregulated moorings can be considered to provide no beneficial impacts other than safety during emergency situations.

As previously stated, each of the rivers are variable from mile to mile, and general recommendations as to what type of mooring structures are best to use in each river cannot be made. It has been found that the placement of mooring structures is, however, dependent on whether the river has open navigation or navigation through locks and dams systems. River sections with open navigation generally depend on natural, unregulated mooring (i.e., tying to trees, nosing into shore, etc.). Those sections of rivers where navigation

is regulated by locks and dams, generally have mooring facilities above and below the dams. River reaches with moveable bridges (e.g. drawbridges, swing bridges) also have mooring facilities for waiting tows. Other general placements of mooring structures are in those places where there is a need for emergency mooring, and are typically found where changes in weather and changes in flow or water levels can affect the safety of the barges.

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5.2 Corps Offices Contacted

Divisions: Cincinnati
Vicksburg
Districts: Fort Worth
Huntington
Kansas City
Little Rock
Louisville
Memphis
Nashville
New Orleans
Omaha
Pittsburgh
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