TENNESSEE VALLEY AUTHORITY

DRAFT

ENVIRONMENTAL STATEMENT

Browns Ferry Nuclear Plant Units 1, 2 and 3

1.0 SUMMARY: Browns Ferry Draft Environmental Statement
STATEMENT DATE: July 14, 1971
RESPONSIBLE FEDERAL AGENCY: Tennessee Valley Authority
TYPE OF PROPOSED ACTION: Administrative

<u>Description of Action</u> - This action is the construction and operation of a three-unit nuclear power generating station in Limestone County, Alabama.

<u>Environmental Impact</u> - The plant will interact with the environment in five principal ways: (1) It will require relatively minor adjustments in land use; (2) It may produce temporary stress on social infrastructure (schools, roads, housing, and similar services); (3) It will provide a stimulus to area economical development (jobs, attraction of visitors, etc.); (4) Small amounts and concentration of low-level gaseous and liquid radioactivity will be discharged; and (5) Possible minor influences from thermal discharges.

<u>Adverse Environmental Effects Which Cannot be Avoided</u> - The plant will release small quantities of radioactivity in low-level concentrations to the environment during normal operation. The best and highest degree of waste treatment available under existing technology within reasonable economic limits will be utilized in keeping radioactive wastes to the lowest practicable level. Heated water discharged into Wheeler Reservoir will produce a small temperature rise in a portion of the reservoir. Alternate cooling methods are being studied and will be implemented in the event Alabama Water Quality criteria are revised. In all cases, the systems chosen will be consistent with applicable Federal and state regulations. No significant environmental effects should result from these low-level radioactive releases and thermal discharges under these conditions. Certain short-term local environmental effects will result from construction activities of the Browns Ferry facility (reservoir turbidity, excavation, congestion). These will be minimized.

<u>Alternatives to the Proposed Action</u> - To meet the 1971-1972 winter peak load, TVA considered the following alternatives: (1) Base-loaded coal-fired units, and (2) Nuclear-fueled units. The second alternative provides the lowest cost of generating power and the least environmental impact. The purchase of power in the quantities needed is not a realistic alternative. TVA is considering alternative heat dissipation methods and will use the cooling method which keeps the thermal discharges well within applicable standards. TVA has also decided to provide extended treatment for liquid and gaseous radwaste.

<u>Federal and State Agencies to Review</u>

Atomic Energy Commission
Council on Environmental Quality
Environmental Protection Agency
Federal Power Commission
Department of Agriculture
Department of Commerce
Department of Defense
Department of Health, Education, and Welfare
Office of Economic Opportunity
Department of Housing and Urban Development
Department of the Interior
Department of Transportation
Appalachian Regional Commission
Alabama Development Office
Top of Alabama Council of Local Governments
North Central Regional Planning Development Commission

DETAILED TABLE OF CONTENTS

		Page
1.0	SUMMARY SHEET	frontispiece
	DETAILED TABLE OF CONTENTS	(i)
2.0	INTRODUCTION	2-1
3.0	GENERAL	3-1
3.1	Location of the Facility	3-1
3.2	Physical Characteristics of the Facility	3-1
3.3	Environment in the Area	3-3
	1. Topography	3-3
	2. History	3-3
	3. Geology	3-3
	4. Seismology	3-4
	5. Geography	3-5
	6. Climatology and Meteorology	3-5
	7. Hydrology	3-7
	(1) Ground Water	3-7
	(2) Surface Water	3-8
	(3) Water Use	3-8
	8. Land Use	3-9
	(1) Industrial Operations	3-9
	(2) Farming	3-10
	(3) Transportation	3-10
	(4) Forestry	3-10
	(5) Recreation	3-10
	(6) Wildlife Preserves	3-11

Page

(7) Population Distribution---------------------------- 3-11

(8) Waterways-- 3-12

(a) Navigation Use------------------------------- 3-12

(b) Growth--- 3-13

(9) Government Reservations and Installations-------- 3-13

9. Ecology-- 3-13

(1) Wildlife and Waterfowl---------------------------- 3-13

(2) Fish and Other Aquatic Life----------------------- 3-14

10. Chemical and Physical Characteristics of Air and Water- 3-16

(1) Air--- 3-16

(2) Water--- 3-16

(3) Streamflow-- 3-16

(4) Water Quality------------------------------------- 3-17

(5) Radiological Monitoring--------------------------- 3-18

(6) Temperature--------------------------------------- 3-18

11. Historical Significance of the Site------------------ 3-19

3.4 Electric Power Supply and Demand------------------------ 3-19

1. Power Needs--- 3-20

2. Consequence of Any Delays----------------------------- 3-21

4.0 ENVIRONMENTAL APPROVALS AND CONSULTATIONS---------------- 4-1

5.0 ENVIRONMENTAL IMPACT OF THE PROPOSED FACILITY------------ 5-1

5.1 Land Use Compatibility------------------------------------ 5-2

1. Industrial Operations--------------------------------- 5-3

2. Farming--- 5-3

3. Transportation-- 5-3

4. Forestry-- 5-3

Page

5. Recreation---------- 5-3
6. Wildlife Preserves---------- 5-4
7. Population Distribution---------- 5-4
8. Waterways---------- 5-5
9. Government Reservations---------- 5-5

5.2 Water Use Compatibility---------- 5-6
1. Industrial Water Uses---------- 5-6
2. Public Water Uses---------- 5-7
3. Impact on Water Resources---------- 5-7

5.3 Heat Dissipation---------- 5-8
1. Condenser Circulating Water---------- 5-8
2. Heat Removal Facilities---------- 5-9
3. Impact of Cooling Water Effluent on Temperatures in Wheeler Reservoir---------- 5-12
4. Applicable Thermal Standards---------- 5-14
5. Applicability of Section 21(b) Permit---------- 5-15

5.4 Chemical Discharges---------- 5-16

5.5 Sanitary Wastes---------- 5-18

5.6 Biological Impact---------- 5-19
1. Ecological Studies and Analyses Performed---------- 5-19
(1) Identification of Species Important to Sport and Commercial Use---------- 5-20
(2) Importance of Locale to Existence of Important Species, Considering States in Life History---- 5-21
(a) Spawning and Larval State---------- 5-21
(b) Fish Movements---------- 5-23

Page

(3) Time and Space Changes in Temperature Distribution---------------------------------- 5-24

(a) TVA Experiences on Effects of Heated Water-- 5-24

(4) Effect of Passage through Condenser on Planktonic Forms and Fish Larvae-------------- 5-27

(5) Implications of Withdrawal and Return of Cooling Water---------------------------------- 5-28

(a) Nutrient Circulation----------------------- 5-28

(b) Reduction of DO Concentrations in the Condensers------------------------------ 5-28

(c) Effects of Elevated Temperatures on Biochemical Oxygen Demand---------------- 5-30

(6) Measures Taken to Assure Adequate Ecological Studies---------------------------- 5-30

2. Studies to be Continued------------------------------- 5-30

3. Monitoring Programs----------------------------------- 5-31

(1) Environmental Monitoring Program---------------- 5-31

(a) General------------------------------------ 5-31

(b) Atmospheric Monitoring-------------------- 5-31

(c) Terrestrial Monitoring--------------------- 5-33

(d) Reservoir Monitoring---------------------- 5-34

(e) Quality Control---------------------------- 5-36

(2) Fish Monitoring---------------------------------- 5-36

(a) Adult Fish--------------------------------- 5-37

(b) Larval Fish-------------------------------- 5-38

Page

(3) Additional Monitoring for Investigation of Possible Thermal Effects---------------------- 5-41

(a) Frequency of Sampling---------------------- 5-41

(b) Water Quality Parameter-------------------- 5-41

(c) Plankton------------------------------------- 5-41

(d) Bottom Fauna--------------------------------- 5-42

(e) Analysis of Data----------------------------- 5-42

4. Potential Hazards to Fish of Cooling Water Intake and Discharge-- 5-43

5.7 Radioactive Discharges------------------------------------ 5-44

1. Waste Management-- 5-44

(1) Solid Radwaste System------------------------------ 5-45

(2) Gaseous Radwaste System--------------------------- 5-46

(a) Air Ejector Offgas Subsystem--------------- 5-48

(b) Gland Seal Offgas Subsystem---------------- 5-49

(3) Extended Treatment of Gaseous Radwaste----------- 5-49

(4) Liquid Radwaste System---------------------------- 5-51

(a) High Purity Wastes------------------------- 5-52

(b) Low Purity Wastes-------------------------- 5-52

(c) Chemical Wastes---------------------------- 5-53

(d) Detergent Wastes--------------------------- 5-53

(e) Fuel Cask Decontamination Waste------------ 5-54

(5) Additional Processing of Liquid Radwaste--------- 5-54

2. Important Pathways of Exposure to Man----------------- 5-54

(1) Pathways to Man------------------------------------ 5-54

Page

3. Estimated Increase in Annual Environmental Radioactivity Levels and Potential Annual Radiation Dose from Principal Radionuclides-------- 5-57

4. Conclusion-- 5-59

5.8 Construction Effects-- 5-60

5.9 Aesthetics--- 5-60

6.0 ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED------------ 6-1

6.1 Water Pollution-- 6-1

6.2 Air Pollution-- 6-1

6.3 Damage to Life Systems----------------------------------- 6-2

6.4 Threats to Health-- 6-2

6.5 Socioeconomic Effects------------------------------------ 6-3

6.6 Conclusions-- 6-3

7.0 ALTERNATIVES--- 7-1

7.1 Electric Power Purchases--------------------------------- 7-2

7.2 Alternative Generation----------------------------------- 7-2

7.3 Alternative Sites--- 7-3

7.4 Alternative Heat Dissipation Methods--------------------- 7-3

8.0 SHORT-TERM USES VERSUS LONG-TERM PRODUCTIVITY----------- 8-1

9.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES-- 9-1

APPENDICES

APPENDIX I	Construction Photographs
APPENDIX II	Preliminary Results of Monitoring
APPENDIX III	Studies by TVA and Others on the Effects of Heated Water at Paradise Steam Plant
APPENDIX IV	Proposed Research Project on the Effects of Heated Water on Aquatic Life

LIST OF TABLES

1. Major TVA System Capacity Additions Since 1949
2. Ambient Temperature Data Decatur, Alabama
3. Ambient Temperature Data Browns Ferry Nuclear Plant
4. Precipitation Data, Athens, Alabama
5. Precipitation Data - Browns Ferry Nuclear Plant
6. Snowfall Data, Decatur, Alabama
7. Water Supplies Within 20-mile Radius of Browns Ferry
8. Statistical Data for Nearby Counties
9. Common and Scientific Names of Fishes of Wheeler Reservoir
10. Water Quality - Tennessee River Mile 277.0
11. Observed Water Temperatures - Wheeler Reservoir Tennessee River Mile 300.3
12. Observed Maximum and Minimum Temperatures Wheeler Reservoir Tennessee River Mile 305.0
13. Selected Economic Data for Three Trade Areas in Northern Alabama and South Central Tennessee
14. Tagging and Recapture Data for Five Species of Fish - Wheeler Reservoir
15. Types and Locations of Samples Collected to Monitor Preoperational and Operational Conditions in Wheeler Reservoir in Relation to Browns Ferry Nuclear Plant
16. Larval Fish Sampling Stations in Wheeler Reservoir and Weekly Sampling Schedule
17. Sampling and Analysis Schedule - Environmental Radioactivity Monitoring
18. Principal Gaseous Radionuclides and Discharge Rates from Three-Unit Plant
19. Expected Annual Radioactive Releases in Liquid Effluents Excluding Tritium
20. TVA-Built Thermal-Electric Power Plants

LIST OF FIGURES

1. Tennessee Valley Region
2. Vicinity Map - 0 to 60 Mile Radius
3. Arrangement of the Plant Site
4. Artist Concept of Browns Ferry Plant
5. Browns Ferry Plant Simplified Steam Cycle
6. Wind Rose - Browns Ferry Site
7. Location of Water Supplies
8. Faults in Region
9. Aerial Photograph of Site
10. Population Distribution Within 10-mile Radius of Browns Ferry Site
11. Diffuser System and Channel Markings
12. Diffuser System Design
13. Surface Water Temperature Studies - Temperature Vs Distance Downstream
14. Surface Water Temperature Studies - Temperature Vs Distance Upstream
15. Temperature Survey in Vicinity of Jet Ports
16. Location of Wheeler Reservoir Temperature Monitoring Stations
17. Atmospheric and Terrestrial Monitoring Network
18. Reservoir Monitoring Network
19. Trap Net and Gill Net Stations

2.0 INTRODUCTION

TVA is a corporate agency of the United States created by the Tennessee Valley Authority Act of 1933 (48 Stat. 58, as amended, 16 U.S.C. §§ 831-831dd (1964; Supp. V, 1965-69)). In addition to its responsibilities for flood control, navigation, and regional development, TVA operates a power system supplying the power requirements for an area of approximately 80,000 square miles containing about 6 million people. Except for direct service by TVA to certain industrial customers and Federal installations with large or unusual power requirements, TVA power is supplied to the ultimate consumer by 160 municipalities and rural electric cooperatives which purchase their power requirements from TVA. TVA is interconnected at 26 points with neighboring utility systems.

The TVA generating system consists of 29 hydrogenerating plants and 11 fossil-fueled steam-generating plants now in operation. In addition, power from Corps of Engineers' dams on the Cumberland River and dams owned by the Aluminum Company of America on Tennessee River tributaries is made available to TVA under long-term contracts. Figure 1 shows the location of TVA's present generating facilities and those under construction, as well as the location of the above Corps and Alcoa dams. The approximate area served by municipal and cooperative distributors of TVA power is also shown.

Power loads on the TVA system have doubled in the past 10 years and are expected to continue to increase in the future. In order to keep pace with the growing demand it has been necessary to add substantial capacity to the generating and transmission system on a regular basis. The major system capacity additions since 1949 are shown in Table 1.

In 1966, as part of its construction program designed to meet increased requirements for generation, TVA decided to construct a nuclear plant on the Browns Ferry site in Limestone County, Alabama. An application to construct and operate Units 1 and 2 was filed with the Atomic Energy Commission (AEC) on July 7, 1966. After extensive review of the suitability of the site and the plant design by the AEC regulatory staff and the independent Advisory Committee on Reactor Safeguards, an Atomic Safety and Licensing Board granted a provisional construction permit on May 10, 1967. Construction was started on May 17, 1967. After a similar review, a permit was issued for Unit 3 on July 31, 1968. Construction for Unit 3 began on August 1, 1968. The Final Safety Analysis Report was submitted to AEC on September 10, 1970, along with a request for authorization to operate all three units of the plant at the designed power level. The AEC is continuing its review of the Browns Ferry Nuclear Plant. Under the current schedule, TVA expects to be permitted to load the nuclear fuel for Unit 1 in January 1972. Full operation of Unit 1 is expected to be authorized in May 1972, Unit 2 in April 1973, and Unit 3 in January 1974.

As a Federal agency, TVA is subject to the requirements of the National Environmental Policy Act of 1969 (NEPA) which became effective on January 1, 1970. In carrying out its responsibilities under the TVA Act, TVA follows a policy designed to develop a quality environment. As a result of this policy, TVA has long considered environmental matters in its decision making. Offices and divisions within TVA employ personnel with a wide diversity of experience and academic training which enables TVA to utilize a systematic, interdisciplinary approach to insure the integrated use of the natural and social sciences and the environmental design arts in planning and decision making as required by NEPA. This detailed statement on the environmental considerations relating to the Browns Ferry Nuclear Plant is being sent to state and Federal agencies for review and comment pursuant to that Act and Office of Management and Budget Circular A-95. It is also being submitted to AEC as the environmental report required of applicants by Appendix D to 10 CFR Part 50.

The Browns Ferry Nuclear Plant was initiated before NEPA became effective and the TVA Board of Directors has determined that it is not practicable to reassess the basic course of action in the design and construction of this plant. TVA has continued to study the plant design, however, so as to minimize adverse environmental consequences. For example, through a continuing study of the release of radioactivity to the environment, TVA has decided to provide extended radioactive waste treatment for gaseous radwaste and additional processing for the liquid radwaste. These systems will reduce the amount of radioactivity released to the environment substantially below the level which would have resulted from the plant design as approved by AEC for construction. In addition, although the plant as designed meets all present applicable water quality standards, studies of the use of cooling towers as an alternative heat dissipation method are underway, in order that the plant can fully meet any future temperature requirements on receiving water.

It should be noted that although the three units at Browns Ferry begin operation at different times, this environmental statement considers the plant as operating with all three units, in order to accurately assess the impact of the plant on the environment, and so that consideration of the cumulative effects of the plant can be assured.

The remainder of this statement is arranged in seven principal sections. The first section provides a baseline inventory of environmental information. The following six sections cover the environmental considerations set out in Section 102(2)(C) of NEPA, as implemented by the CEQ and AEC guidelines.

3.0 GENERAL

The purpose of this section is to provide a basic knowledge of the existing environment and the important characteristics and values of the Browns Ferry site as it presently exists in order to establish a basis for consideration of the environmental impact of the facility.

3.1 Location of the Facility - The Browns Ferry Nuclear Plant is located on an 840-acre tract on the north shore of Wheeler Reservoir in Limestone County, Alabama, at Tennessee River mile (TRM) 294. The site is approximately 10 miles northwest of Decatur, Alabama, and 10 miles southwest of Athens, Alabama. The proximity of the site to local towns, rivers, and state boundaries is indicated on the vicinity map. (Figure 2)

3.2 Physical Characteristics of the Facility - The plant will have the following principal physical structures on the site: reactor containment building, turbine building, radwaste building, service building, transformer yard, 161-kV and 500-kV switchyards, stack, and sewage treatment plant. Figure 3 shows the general arrangement of these facilities. Figure 4 is an artist's concept of how the plant will appear upon completion of construction.

The reactor containment building houses three General Electric boiling water reactors. The plant will have a total electrical generator nameplate rating of 3,456 megawatts. Nuclear fuel is contained inside each reactor pressure vessel. The fuel is in sealed zircaloy tubes and consists of slightly enriched uranium dioxide pellets. The fission process in the fuel produces heat. Water enters the pressure vessel below the fuel and moves through the assembly of fuel tubes called the reactor core. As the water passes through the core, the heat converts it to steam. The steam leaves the reactor through pipes near the top of the reactor, then passes through turbogenerators which generate electricity. The steam is then condensed to water and returned to the reactor, where the cycle is repeated. This closed-cycle process is depicted schematically in Figure 5. The electricity thus produced is distributed to meet the power needs of the TVA system.

The reactor power level will be regulated primarily by control rods. Boron, a chemical element which absorbs neutrons and thereby retards nuclear fission, is sealed within the control rods. The power of the reactor, therefore, can be controlled by positioning the control rods in the core. The power is increased by slowly withdrawing the control rods from the core. The power level may also be controlled, but to a lesser extent, by regulating the flow rate of the water which is circulated through the reactor core.

The principal ways in which the plant will interact with the environment, discussed later in detail, are:

(1) Release of minute quantities of radioactivity to the air and water;

(2) Release of large quantities of heat to Wheeler Reservoir; and

(3) Change in land use from farming to industrial.

3.3 Environment in the Area - In order to assess the impact of the facility on the environment, the following summary description is provided as a baseline inventory of the important characteristics of the region.

1. Topography - The general level of the ground in the area rises gradually from 558 feet above sea level at the north shore of Wheeler Lake to around 800 feet above sea level 10 miles north in the vicinity of Athens, Alabama. The average elevation of the plant site is 575 feet above sea level. The area around the site is generally flat.

2. History* - The Browns Ferry plant site is located in Limestone County, Alabama, which is bounded by Madison, Morgan, Lawrence, and Lauderdale Counties, and the Tennessee state line. Limestone County was first settled by white settlers about 1807, at a place called Simms' Settlement. Settlers were forbidden in sections belonging to the Indians claimed by both Cherokee and Chickasaws, who had, however, made no settlement of their own.

Areas around the site have been explored for Indian mounds, town sites, and artifacts. Nothing of archaeological value has been found on the site.

3. Geology - The regional geologic features in the Browns Ferry site area and the local geologic formations in the immediate plant area have been investigated. TVA studies made of

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* Information excerpted from Alabama Encyclopedia Vol. I, edited by Jesse M. Richardson

extensive drilling, excavation, and testing show that the underlying bedrock will provide more than adequate foundation for Browns Ferry plant structures.

The only formations involved directly in the site area are the unconsolidated materials overlying bedrock and the Tuscumbia and Fort Payne limestones. Only the lower 50 feet of the Tuscumbia formation was encountered at the Browns Ferry site. The Tuscumbia is characterized by medium-to-thick beds of light-gray, medium-to-coarse crystalline, fossiliferous limestone.

The maximum known thickness of the Fort Payne formation in northern Alabama is slightly over 200 feet. At the Browns Ferry site the total thickness, penetrated in one drill hole, is 145 feet. The formation consists of medium-bedded, silty dolomite and siliceous limestone with a few thin horizons of shale. It is predominantly medium to dark gray in color. Near the top, some of the beds are cherty and some of the cores showed zones which were slightly asphaltic. The most distinguishing lithologic feature is the presence of quartz- and calcite-filled vugs up to 1 inch in diameter.

4. Seismology - The Browns Ferry Nuclear Plant is located in an area far removed from any centers of significant seismic activity in historic time. No known earthquake has been centered nearer than 35 miles from the site. The maximum intensity to have been felt at the site in the recorded history of the area from a major earthquake, such as those which occurred in the Mississippi Valley in 1811-1812 (MM XII) or that which occurred in Charleston, South Carolina, in 1886 (MM X), might be felt in the Decatur area with a Modified Mercalli intensity of VII. Acceleration at the site from a recurrence

of any of these major shocks would be far less than the proposed desig. accelerations for ground motion (0.10g). The nearest faults which are known to exist in the region are shown in Figure 8. These inactive faults are approximately 60 miles away and the occasionally active faults in the New Madrid region of the Mississippi Valley are approximately 200 miles away.

5. Geography - The area surrounding the Browns Ferry site lies near the southern margin of the Highland Rim section of the Interior Low Plateaus. This physiographic subdivision is characterized by a young-to-mature plateau of moderate relief. The general level of the ground rises gradually from 558 feet above sea level at the north shore of Wheeler Reservoir to around 800 feet above sea level 10 miles north in the vicinity of the town of Athens, Alabama. This surface is modified by the drainage patterns of Poplar, Round Island, and Mud Creeks which flow across it from northeast to southwest.

The plant site is located on an old river terrace surface with an average elevation of 575 feet above sea level. The maximum probable flood at the site would reach elevation 561. This level would not create a threat to the plant.

6. Climatology and meteorology - The site is in a temperate latitude about 300 miles north of the Gulf of Mexico. The area is dominated in winter and spring by alternating cool dry continental air from the north and warm moist maritime air from the south.

During this period, migratory cyclonic disturbances with numerous thundershowers and thunderstorms pass through the area. Storms, including tornadoes, reach severest intensity in March and April when maximum air mass contrast generally occurs.

U.S. Weather Bureau statistics show four tornadoes reported in Limestone County in the 49-year period, 1916-1965. In the adjacent and more populated counties, Morgan and Madison, and within 20 to 25 miles of the site, 18 tornadoes were reported in the same 49-year period and 16 of them were within the last 16 years. About half of the tornadoes were classified as funnel sightings and include no documentation on destructive force. Tornadoes in the site area usually move from southwest to northeast and cover an average surface path 10 miles long and 200 yards wide. Winds of 200 mi/h are common in the whirl and occasionally may reach somewhat higher velocities. Months of reported maximum frequency of occurrence are March, April, and June. The probability of a tornado striking a point in Limestone County is about one chance in 5,880 years.

The climate at Browns Ferry site is interchangeably continental and maritime in winter and spring, predominantly maritime in summer, and generally continental in fall. Data collected over a 65-year period (1894-1959) at Decatur, Alabama, indicate the average annual temperature is 62.0° F., with monthly averages from 42.9° F. in January to 80.7° F. in July. The highest daily maximum temperature on record at Decatur is 108° F. and the lowest daily minimum is -12° F. Detailed temperature data are in Tables 2 and 3.

About 50 percent of the annual precipitation at the Browns Ferry site results from migratory storms in December through

April, with January, February, and March usually recording maximum amounts. Most of the remaining precipitation is in June, July, August, and early September when air mass thundershower activity is common. Months with least precipitation are September and October when regional anticyclonic systems often persist over the area. Detailed precipitation information is in Tables 4 and 5. Table 6 contains snowfall data.

Wind speed and direction data collected from February 11, 1967, to December 31, 1968, indicate that the prevailing wind at the site is from the southeast at speeds of 8-12 mi/h. Figure 6 shows the wind speed patterns in a wind rose plot for this time period. This data was collected from a 300-foot TVA meteorological tower at the Browns Ferry site.

There are no physiographical features in the area to cause local entrapment or accumulation of emissions during periods of anticyclonic circulation or atmospheric stagnation.

7. Hydrology -

(1) Ground water - Ground water at Browns Ferry is derived from precipitation. Studies of subsurface waterflow in the area indicate that ground water flows from the structural highs toward the structural lows in the area. Local alterations of rock strata by minor anticlines and synclines prevent long-distance ground water movement from the regional area into the Browns Ferry site area. The principal aquifer in the area is overlain by a thick mantle of residium that retards the movement of shallow ground water. Therefore, the ground water movement in the site is derived from local precipitation that has percolated into the residium. Ground water movement in the area is from the plant site to the Tennessee River.

(2) Surface water - Surface water is derived from precipitation remaining after losses due to evaporation and transpiration. It can be generally classified as local surface runoff or streamflow.

(3) Water use - From its head near Knoxville to Kentucky Dam near its mouth, the Tennessee River is a series of highly controlled multiple-use reservoirs. The primary uses for which this chain of reservoirs was built are flood control, navigation, and the generation of electric power. Secondary uses such as sport and commercial fishing, industrial and public water supply, waste disposal, and recreation have developed.

Water use in the area is not limited to reservoir water since several small public and private water supplies are taken from ground water sources. These withdrawals are small compared with surface uses.

The major industrial water users in the area are located upstream at Decatur, Alabama. These users withdraw a total of about 150 million gallons of process water from the reservoir each day. Most of this water is returned to the reservoir after use with varying degrees of contamination. One large water-using industry, the Champion Paper Division of U.S. Plywood, Inc., is located across the reservoir and some 12 miles downstream from Browns Ferry.

Five public water supplies are taken from Wheeler or Pickwick Reservoirs within the reach from Decatur, Alabama, 12 miles upstream from the site, to Colbert Steam Plant, 49 miles downstream from the site. The Decatur supply is the nearest one to the site. Water supplies for public users are listed in Table 7. The location of each of these water supplies is shown in Figure 7. The nearest downstream public water supply is located at Wheeler Dam.

Florence, Muscle Shoals, and a utility district in Lauderdale County are considering the construction of water supply intakes within the Tennessee River reach specified above. Also, the city of Athens is currently considering a surface water supply to supplement its ground supply, but this supply probably will be taken from the Elk River 23 miles above its confluence with the Tennessee River.

There are 32 public ground water supplies within a 20-mile radius of the site. The nearest supply is at Tennessee Valley High School, approximately 5 miles from the site, and serves approximately 400 people.

8. Land use - The dominant character of the land in the area of the site is small scattered villages and homes in an agricultural area. The statistical data on land use for the counties in the vicinity of the site are shown on Table 8.

(1) Industrial operations - Industrial areas are concentrated along the Tennessee River, primarily at the large population centers. The closest industrial area is adjacent to Decatur, Alabama. Minnesota Mining and Manufacturing Corporation, Monsanto Corporation, and Amoco Chemical Corporation are the three largest industries and are about 7 air miles from the site. The largest industrial complex near Browns Ferry is the Redstone Arsenal, which is located approximately 25 miles east of the site. This is the NASA center for research and development and is the principal single economic force in the area. The remaining industrial area is located in

the Muscle Shoals, Sheffield, Tuscumbia, and Florence area. It is anticipated that the gradual transfer of land from agricultural to industrial use will be continued.

(2) Farming - The dominant character of the land within a 60-mile radius is small, scattered villages and homes in an agricultural area. Between 60 percent and 80 percent of the land in counties nearest the site is used for agriculture. As indicated in Figure 9, the area immediately surrounding the site is still primarily a diversified agricultural region. However, increasingly greater amounts of land are being gradually transferred to industrial use.

(3) Transportation - There are no railroads or principal highways penetrating the site. The Louisville & Nashville Railroad is about 8 miles east of the site, running in a north-south direction, and the Southern Railroad is about 6 miles south of the site, with tracks running in an east-west direction. The nearest principal highways are U.S. 72, about 6 miles north of the site, and State Highway 20, about 4.5 miles south of the site.

(4) Forestry - There are no major commercial forestry operations in the vicinity of the site.

(5) Recreation - Land use for recreation development on Wheeler Reservoir includes Joe Wheeler State Park, Limestone County Park, Lawrence County Park, Mallard Creek public use area, Decatur Municipal Boat Harbor and Park, and Point Mallard Park. Also, there are four commercial boat docks within twelve miles of the site. A limited amount of shoreline has been developed for private residential use.

(6) Wildlife preserves - Approximately 1,240 acres or shoreline and backlands across the river are managed by the State of Alabama for wildlife use under a "use permit" arrangement with TVA which extends for an indefinite time period. Southeast of the site, between Rock Island Creek and the U.S. 31 causeway, the state is using an additional 1,360 acres for wildlife management, also under a "use permit" arrangement. Wheeler National Wildlife Refuge extends upstream from Decatur on both shores of the Tennessee River for approximately 15 miles.

(7) Population distribution - The area in which the Browns Ferry site is located has demonstrated moderate population growth during the last two decades. One of the fifteen counties within a 60-mile radius of the site has shown a decrease in population from 1960 to 1970; of the fourteen counties showing a population increase, seven counties have had significant growth. The general pattern has been a steady decrease in the farm population in all counties and an increase in the rural-nonfarm and urban populations. The counties with the greatest increase in population reflect the growth of the major urban areas - Huntsville, Decatur, and the quad-city area of Florence, Sheffield, Tuscumbia, and Muscle Shoals.

The 1960 population within a 4-mile and 10-mile radius of the site was 1,392 and 22,040, respectively. Figure 10 illustrates the 1960 population distribution within 10 miles of the site.

There are only three centers of population within 60 miles of the site with populations exceeding 25,000. These centers (Decatur, Huntsville, and quad-cities) are at 10, 30, and 30 miles, respectively, and at widely separated directions from the site. There are only three towns within a radius of 20 miles (Athens, Moulton, and Decatur) having a 1970 population greater than 1,800 persons. The population of Athens is expected to increase from 14,360 in 1970 to 22,000 in 1990. For Decatur, the population is expected to increase from 38,044 to 50,000 in the same time period. Within a 60-mile radius, the largest city is Huntsville, located approximately 30 miles due east from the site. The population of Huntsville is expected to increase from its 1970 level of 137,800 to 200,000 by 1990.

(8) Waterways - Figure 1 illustrates the Tennessee River.

(a) Navigation use - Tennessee River traffic, measured at Wheeler Lock 20 miles downstream from the Browns Ferry plant, amounted to 5.5 million tons in 1969, the latest year for which data are currently available. The principal tonnage was in grain and grain products, accounting for 2.5 million tons. Petroleum products, chemicals, and coal traffic each had over

0.5 million ton. The 1970 traffic at Wheeler Lock is estimated to be about 6 percent greater than 1969.

(b) Growth - It is estimated that the Tennessee River traffic will experience an average growth rate of about 4.8 percent annually to 1980, reaching a level of 40.5 million tons in that year.

(9) Government reservations and installations - There are no major government installations within 10 miles of the site. The Redstone Arsenal is located approximately 25 miles east of the site. TVA has the Wheeler Dam 19 miles downstream from the site; the Wilson Dam 35 miles downstream from the site; and the TVA National Fertilizer Development Center at Muscle Shoals, approximately 30 miles west of the site.

9. Ecology - The region around Browns Ferry supports wildlife, waterfowl, fish, and aquatic life. These important species are discussed in the paragraphs below.

(1) Wildlife and waterfowl - Wheeler Reservoir harbors the southernmost wintering population of substantial numbers of Canada geese in the United States. At its 35,000-acre Wheeler National Wildlife Refuge, 40,000 geese regularly spend the winter. Total waterfowl populations on Wheeler include up to 75,000 ducks, primarily mallards, blacks, green-winged teal, widgeon, pintail, gadwall, lesser scaup, and ringnecks. Over 14,000 man-days of waterfowl hunting take place each year on the Wheeler Reservoir. An additional 14,000 man-days are devoted to upland game hunting for rabbits, quail, squirrel, dove, snipe, raccoon, oppossum, and crows. Other public uses--fishing, artifact hunting, camping, picnicking, etc.,--account

for an additional 250,000 man-days of recreational activity on these wildlife management areas.

(2) Fish and other aquatic life - Wheeler Reservoir is classified as a normal, highly productive, warm-water aquatic environment. Benthic habitats in the reservoir range from deposits of finely divided silts to river channel cobble and bedrock. The most extensive benthic habitat is composed of fine-grained brown silt, which is deposited both in the old river channel and on the former overbank areas. The overbank areas are far more extensive than the old river channel and are the most productive.

The silt-laden overbank areas support communities of Asiatic clams, burrowing mayflies, aquatic worms, and midges. Cobble and bedrock areas, found primarily in the old channel, support Asiatic clams, bryozoa, sponges, caddisflies, snails, other clams, and some leeches. All these benthic forms are important sources of food for commercial fish and most are important to game fish.

In the very shallow overbank areas, the major algal species are the suspended diatoms and the green algae.

At times, zooplankton in the surface and deep waters is quite extensive. Common forms include rotifers, cladocerans, and copepods.

Investigations have shown the following fish to be important to sport use: largemouth bass, smallmouth bass, spotted bass, white bass, crappie, bluegill, and sauger. Important commercial fish are bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, blue catfish, carp, drum, and paddlefish. Table 9 lists the species encountered in various samples in Wheeler Reservoir.

A fish population survey for Wheeler Reservoir made in 1970 showed an average of 39,000 fish per acre with an average total weight of 738 pounds. Of the total number of fish counted in the survey, game and panfish accounted for approximately 47 percent; forage fish, 47 percent; and rough fish, 7 percent. The most numerous species were gizzard shad, bluegill, and the long-eared sunfish.

In a 1970 creel census (July through December), white crappie accounted for over 58 percent of the sport catch. Other percentages were: bluegill - 17 percent, smallmouth bass - 7 percent, largemouth bass - 5 percent, white bass - 5 percent, with black crappie, catfish, walleye, sauger, drum, yellow bass, and carp also appearing in the catch.

The 1967 commercial fish harvest for TVA reservoirs in north Alabama, which includes Guntersville, Wheeler, Wilson, and Pickwick Reservoirs, was 2.7 million pounds valued at $397,000. Buffalo dominated the catch, followed by catfish, carp, drum, and paddlefish. Based upon earlier surveys, Wheeler produced about 35 percent of the commercial catch in this area, Guntersville and Pickwick 30 percent each, and Wilson 5 percent.

The Browns Ferry plant is located directly downstream from an extensive area of shallow water, including the mouths of several creeks. Two additional extensive areas of shallow overbank habitat are located on the opposite side of the channel, directly across from the plant and about 2 miles downstream. Limited areas of shallow habitat occur directly downstream from the plant site. Areas of this type usually serve as spawning and nursery sites for most important fish species, as well as being areas of high production of food organisms.

10. Chemical and physical characteristics of air and water -

(1) Air - Other than the data described under Section 2.1.3, Climatology and Meteorology, no additional physical or chemical properties of air have been monitored.

(2) Water - The Browns Ferry site is located 19 miles upstream from the Wheeler Dam. The Tennessee River at Wheeler Dam has a drainage area of 29,590 square miles. The Wheeler Dam, located at river mile 275 in Lauderdale and Lawrence Counties, Alabama, was completed in 1936, forming TVA's third largest reservoir by area at the normal pool elevation of 558 feet. At this elevation the Wheeler Reservoir is 74.1 miles long and covers an area of 67,100 acres, with a volume of 1,131,000 acre-feet and a shoreline length of 1,063 miles. The reservoir has an average width of nearly 1.5 miles and is approximately 7,300 feet wide at the plant site.

(3) Streamflow - Since 1937, the U.S. Geological Survey has maintained a streamflow gaging station at Whitesburg, Alabama, 40 miles above the Browns Ferry site. The average daily streamflow at this station since 1937 has been 42,400 ft^3/s.

Flow duration data for the Whitesburg station have been prepared cooperatively by the U.S. Geological Survey and the Tennessee Valley Authority. For the 1940-1960 period, the following tabulation indicates the percent of time that various daily average streamflows were equaled or exceeded:

Average Daily Flow (ft^3/s)	Percent of Time Equaled or Exceeded
5,000	99.0
17,000	89.5
25,000	75.1
30,000	60.0
35,000	43.7

Considerable seasonal variation in streamflow occurs at the Whitesburg station. Data for the water years 1960 through 1964 indicates an average flow of about 32,000 ft^3/s during the summer months and about 76,000 ft^3/s during the winter months.

Channel velocities at the Whitesburg gage average more than 2 ft/s under normal winter conditions. Due to the lower summer flows, these velocities are reduced to a little more than 1 ft/s under normal summer conditions. These average winter and summer velocities drop to 0.7 ft/s and 0.3 ft/s, respectively, at the Browns Ferry site where the reservoir is wider and the slope of the water surface is less.

(4) Water quality - A comprehensive water quality survey of Wheeler Reservoir was made by TVA during the period May 1962 through April 1965. Results of analyses on samples collected at Tennessee River mile 277.0 are shown in Table 10. Surveys in the downstream reservoirs since 1965 confirm that these data are representative of (1) water quality in Wheeler Reservoir, (2) that there is little year-to-year change, and (3) that there has been no long-term degradation in water quality.

These results are representative of water quality conditions at the Browns Ferry site and indicate that the water quality is very good.

Biological conditions in Wheeler Reservoir were assessed from samples collected at five locations in the main river channel and in one backwater "slough" area. In general, biological populations in the reservoir represented conditions typical of main stream reservoirs. Wide distribution of mayfly larvae indicated good water quality. Plankton populations increased with distance downstream from Guntersville Dam, probably reflecting decreased water turbulence and reduced turbidity in the lower end of the reservoir.

(5) Radiological monitoring - Water samples collected monthly from Wheeler Reservoir (TRM 277.0) during the period from May 1964 through April 1965 showed that the gross beta activity ranged from 0.06×10^{-7} μCi/ml to 0.17×10^{-7} μCi/ml and averaged 0.10×10^{-7} μCi/ml. For the period July 1969 to June 1970 total gross beta activity in the water samples collected monthly from Wheeler Reservoir at the Browns Ferry site ranged from 0.035×10^{-7} μCi/ml to 0.093×10^{-7} μCi/ml and averaged 0.056×10^{-7} μCi/ml.

(6) Temperature - Water temperature observations at selected stations indicate Wheeler Reservoir is only weakly stratified during the summer months and unstratified at all other times. A summary of the observed surface and bottom temperatures is presented in Table 11. Temperature data at Tennessee River mile 305.0, collected by TVA's Hydraulic Data Branch during 1938 through 1943, indicate the temperature pattern observed one year is very similar to that observed in other years. The yearly maximum and minimum temperatures during this period are shown in Table 12.

11. Historical significance of the Browns Ferry site - The nearest historical place listed in the National Register of Historic Places is TVA's Wilson Dam which is 19 miles downstream from Browns Ferry. The possible impact on this historic place is discussed in Sections 5.7.2 and 5.7.3.

3.4 Electric Power Supply and Demand - TVA is the power supplier for an area of approximately 80,000 square miles containing about 6 million people. TVA generates, transmits, and sells power to 160 municipalities and rural electric cooperatives which in turn retail power to their own customers. The approximate areas served by these distributors are shown in Figure 1. These distribution systems, which purchase their power requirements from TVA, serve more than 2 million electric customers, including homes, farms, businesses, and most of the region's industries. TVA also supplies power directly to 46 industries which have large or unusual power requirements and to 11 Federal installations, including the Atomic Energy Commission plants at Oak Ridge, Tennessee, and Paducah, Kentucky.

The importance of an adequate supply of power on the TVA system is by no means limited to electric consumers in the area which TVA supplies directly. This system, which with 19.4 million kilowatts of presently installed generating capacity is the Nation's largest, is interconnected at 26 points with neighboring systems with which TVA exchanges power. The TVA system is, in effect, part of a huge power network. In a time of power emergency, operation of the TVA power system could have a definite impact on power supply conditions from the Great Lakes to the Gulf of Mexico, and from New England to Oklahoma and Texas.

During the past 20 years, loads on the TVA power system have increased approximately 7 percent per year. This rate of growth in power requirements has meant that the capacity of the generating and transmission system has been doubled every 10 years. Until the end of World War II, most of TVA's generating capacity was hydroelectric. By that time, however, most of the suitable hydroelectric sites had been developed, and beginning in 1949 substantially all of the capacity increases were met by the construction of fossil-fueled plants. In the middle 1960's, large-scale nuclear plants had become feasible, and TVA began to take steps to add nuclear capacity to its system. TVA has also begun providing pumped-storage and gas turbine capacity to meet system peak loads. Table 1 shows major TVA system capacity additions since 1949.

The amount of electricity generated in 1965 to meet customer requirements for power exceeded 70.0 billion kilowatt-hours. By 1970, annual electric generation for customer needs had totaled 92.7 billion kilowatt-hours. Generating needs are expected to reach 135 billion kilowatt-hours by 1975. TVA presently must add an average of 1500 megawatts or more of new generating capacity each year to keep up with the rapid increase in electrical power usage in this region.

1. Power needs - The demands on the TVA generating system result in peak demands occurring in winter and summer. The annual peak loads in the TVA service area usually occur between November and March because of electrical heating demands. However, due to seasonal exchange arrangements with other power systems, the expected loads which the TVA generating capacity must actually serve during the next several years will be greater in the summer than in

the preceeding winter. The following tabulation indicates expected loads to be served by TVA during the next several peak seasons:

Period	Estimated Peak Demand TVA System-MW	Net Interchange-MW		Load Served by TVA-MW
		Received	Delivered	
Winter 1971-72	18,300	2,917	--	15,383
Summer 1972	16,240	--	1,800	18,040
Winter 1972-73	20,200	2,060	--	18,140
Summer 1973	18,060	--	2,060	20,120
Winter 1973-74	22,400	2,060	--	20,340

To meet the load increases shown above, additional generating capacity totaling 360 megawatts will be added by TVA to meet the winter peak load to be served in 1971-72, 3,000 megawatts will be added to meet the winter peak load in 1972-73, and 3,405 megawatts will be added to meet the winter peak in 1973-74. Browns Ferry Units 1, 2, and 3 will contribute significantly to meeting these load demands by supplying 3,195 megawatts of the necessary generating capacity.

2. Consequences of any delays - To meet the 1971-72 winter load served by the TVA system (15,383 MW), the dependable capacity will be 18,630 megawatts. This capacity is expected to increase to 21,605 megawatts to meet the 1972-73 winter peak loads and to further increase to 25,005 megawatts to meet the 1973-74 winter peak load. The reserve margins on the TVA system during the winters of 1971-72, 1972-73, and 1973-74 are expected to be 3,247; 3,465; and 4,665 megawatts, respectively. Thus, if TVA is to adequately meet its obligations to its customers during the peak seasons of 1971-73, Browns Ferry Units 1, 2, and 3 are needed as planned.

4.0 ENVIRONMENTAL APPROVALS AND CONSULTATIONS

In addition to its own standards, TVA as a Federal agency is subject to comprehensive and broad-scale environmental procedures and Federal and state consultation and coordination requirements of the National Environmental Policy Act of 1969, 42 U.S.C. § 4321 (1970) (as implemented by Executive Order 11514 (35 Fed. Reg. 4247) and guidelines issued by the Council on Environmental Quality (36 Fed. Reg. 7724)). In addition, TVA is subject to Executive Order 11507 (35 Fed. Reg. 2573), and Office of Management and Budget Circulars A-78 and A-81, relating to the prevention, control, and abatement of air and water pollution in Federal facilities, as well as certain provisions of the Clean Air Act, as amended, 42 U.S.C.A. § 1857 (1970), and the Federal Water Pollution Control Act, as amended, 33 U.S.C.A. § 1151 (1970), which relate to the applicability of various Federal, state, interstate or local air and water quality standards. In addition, TVA is subject to the requirements of Office of Management and Budget Circular A-95 which insure that major generating and transmission projects are coordinated from the point of view of community impact and land use planning with state and local agencies.

TVA has consulted with several Federal, state, and local agencies and officials since 1966 in the planning and construction of the Browns Ferry plant. Federal agencies consulted include the U.S. Fish and Wildlife Service, U.S. Public Health Service, and the Federal Water Pollution Control Administration (now the Water Quality Office of the Environmental Protection Agency). State agencies consulted include the Alabama State Health Department, the Alabama Water Improvement Commission, and the Alabama Department of Conservation.

In addition, officials from Limestone and Morgan Counties and from Athens and Decatur, Alabama, have been consulted.

Regional agencies in the area include Top of Alabama Regional Council on Governments (Limestone, Madison, Marshall, Jackson, and DeKalb Counties), North Central Alabama Regional Planning and Development Commission (Morgan, Lawrence, and Cullman Counties), and Muscle Shoals Council of Local Governments (Lauderdale, Colbert, Franklin, Marion, and Winston Counties). These agencies are concerned with regional planning and development in their multicounty areas. TVA works closely with these agencies on a staff-to-staff basis.

Since a number of the regional concerns are broad in scope and apply to the entire north Alabama region, the regional agencies, the state, and TVA maintain an effective, continuing working relationship for considering these concerns. The resulting overall regional planning effort focuses attention on functional program requirements such as maintaining water quality, improving wildlife management, determining the future roles of agriculture and forestry, and promoting orderly industrialization and urbanization in the north Alabama region. The Browns Ferry project is consonant with positive steps for regional growth in the area.

5.0 ENVIRONMENTAL IMPACT OF THE PROPOSED FACILITY

The primary and secondary social and economic impact of the plant is discussed in this section. "Primary" is interpreted to mean those impacts directly attributable to the plant, while "secondary" is interpreted to be the long-range effects of the plant. Creation of additional employment in the area and purchase of construction materials from local businesses are identified as two primary impacts of the Browns Ferry plant. While the total magnitude of these impacts is large, the distribution of residences and local material supply sources occurs within forty miles of the plant site. A recent survey of the Browns Ferry construction employees showed that over 90 percent lived within a forty-mile radius of the plant site. More than 40 towns were supplying project workers, with nearly 25 percent coming from the Muscle Shoals area. The survey also revealed that, as of April 1971, at least 795 workers had moved into the forty-mile area, locating in at least nine different towns. Over one-half (436) went to Athens, Alabama; 130 located in Decatur; 45 went to Tanner; and the remainder to other nearby towns. Since the bulk of the project's employment needs have been satisfied by local residents, the project has had the secondary impact of tending to stabilize the local economy. At the present employment level (April 1971) of about 3,000 and an average annual wage of about $10,000, the annual income to the region from the project is about $30,000,000. However, Table 13 shows that the peak project employment income in 1970 is only a small percentage of total 1966 personal income for any of the indicated area units.

Purchases and contracts from the local economy over the total construction period will be around $5,000,000. As a primary impact, these purchases represent important contributions to some area businesses. As a secondary impact the additional revenues may offer the opportunity to slightly expand or upgrade facilities in individual instances, although it is unlikely that very many businesses depend on this construction activity as a basis for long-term revenue.

The 436 workers who moved into Athens from outside the area to work on the project represent the largest project-related concentration of population, but account for only 1.3 percent of the 1970 population of Athens and 0.6 percent of the school age population in the city.

Thus, no severe economic dislocation should occur as the project phases out. Employment will scale down gradually from its peak level of 3,000 to approximately 175 permanent operating personnel. These employees will become permanent citizens of the local area.

The following discussion assesses the probable impact of the construction and operation of the facility on the environment.

5.1 Land Use Compatibility - There are no anticipated routine operations of the plant which would prohibit attaining full use of the surrounding land or the Browns Ferry site. The following discussion should be related to the topics under Land use in the baseline inventory. Figure 9 shows the rural character of the area surrounding the site.

1. Industrial operations - The plant should not have an adverse impact on industrial operations in the area.

2. Farming - Except for the land required for the plant, no adverse impact on farming in the area is expected. Baseline hydrological information indicates that ground water movement would prohibit seepage of liquid wastes into surrounding land.

3. Transportation - There are no rearrangements of public roads. The plant should have no adverse impact on the use of land for transportation purposes.

4. Forestry - TVA, through its Division of Forestry, Fisheries, and Wildlife Development, has made investigations of superior hardwood specimens in the Tennessee Valley region. These investigations led to the location of and seed from a superior walnut specimen. Two large tracts of land on the Browns Ferry site will be planted to these superior walnut trees and used to supply seed for future stock.

5. Recreation - The plant should not have any adverse impact on the use of the land for recreation. In fact, the site will provide additional recreational facilities. Provisions are being made for recreation areas, and a visitors' information lobby and overlook will be constructed.

There is little likelihood that the warm water discharges would result in any adverse effect on water-contact recreation in Wheeler Reservoir. The discharged warmed water will mix rapidly in a relatively small zone near the plant and the limited increases in water temperature should not be objectionable to boaters or swimmers in adjacent areas of the reservoir.

Although during some months fish may avoid the immediate area of the plant discharges, in the winter the fish are likely to be attracted to the warm water. This has been the experience at other TVA steam plants.

6. Wildlife preserves - Although the construction of the plant will dislocate some wildlife from the immediate vicinity of the site, this is not expected to be significant. The plant should not have any adverse impact on the use of land for wildlife preserves.

7. Population distribution - The project will result in an approximate increase of 175 permanent jobs at the plant, therefore slightly increasing the pressures for residential development and on public and private facilities to provide the necessary services required. Since no significant social and economic problems have been caused by the large influx of personnel required for the construction of this plant, no adverse impact is expected on the population distribution of the area. The minimum exclusion distance for the site is 4,000 feet. There are no residences within 4,500 feet of the reactor building, and only 208 people within 2 miles. The area within a 10-mile radius is not expected to have significant resident population changes in the future.

[illegible] TVA Radiological Emergency Plan provides for orderly evacuation of people from the site and the surrounding area should the need arise.

TVA's Division of Navigational Development and Regional Studies maintains a continuous study of the population growth of the region. These studies will enable TVA to detect population increases in order to keep the emergency plan current and to ensure that operation of the facility can be properly maintained.

8. Waterways - The location of the diffuser pipes will require special precaution in use of the waterway for navigation purposes.

A barge traveling through water of any depth experiences an increase in draft as opposed to one sitting still. An increase in the speed or a decrease in the depth of water causes an increase in the draft, and the barge will assume a "bow-down" or "stern-down" attitude, depending upon several other factors. Since the water depth over the diffusers is about 10 feet less than in the approach channel, barges will experience some increase in draft as they cross the diffusers. Laboratory tests have shown that for barge speeds in the range of those encountered on Wheeler Reservoir, barges will usually assume a "bow-down" attitude. Navigation channel markers will indicate the location of safe water depths over the diffuser at extreme drawdown elevation. As shown in Figure 11, this section of marked navigation channel will be more than 1000 feet wide and is considerably wider than many sections of marked channel in Wheeler Reservoir and more than three times as wide as the minimum channel width on the Tennessee River waterway.

9. Government reservations - The construction and operation of the Browns Ferry Nuclear Plant should not significantly affect the other Government reservations identified in Section 3.3. Neither should it curtail the future development of Government reservations in the region.

5.2 Water Use Compatibility - Projection of the impact of the facility on the uses of surface and ground water resources of the region has been made in order to assure that adequate consideration is given to alternate and shared uses of the water and to overall plans for development of the area. TVA has discussed the construction and operation of the plant, with regard to the uses of the water, with the Alabama State Health Department, the Alabama Water Improvement Commission, and the Federal Water Pollution Control Administration (Water Quality Office of the Environmental Protection Agency).

Physical, chemical, and hydrologic characteristics of the water and details of water withdrawals were discussed previously in Section 3.3. This section considers the probable impact of the facility on present and projected uses of the water resources.

1. Industrial water uses - Capacity of the river to receive effluent from industrial waste treatment facilities without interfering with other water uses is an important consideration in the industrial use of the water. Potential effects of the facility on the water quality of the river as a result of elevating water temperatures include (1) theoretical lowering of dissolved oxygen concentrations in the water passing through the condenser, and (2) increased rate of biochemical oxygen demand and the increased magnitude of the ultimate biochemical oxygen demand of both municipal and industrial organic wastes in the water affected by elevated temperatures. The discussions of DO and BOD in Section 5.6 indicate that adverse effects on the waste assimilative capacity of the river will not be significant. DO and BOD monitoring will be conducted after the plant begins operation.

2. Public water uses - The major public water uses of the Wheeler Reservoir are for water supplies, recreation, and waste disposal. The closest downstream public surface water supply is Wheeler Dam, which is 19.1 miles downstream and which serves approximately 50 people. An analysis has been made to determine the minimum dilution to be expected between the condenser cooling water discharge and Wheeler Dam. The maximum concentration at Wheeler Dam water intake for a continuous release of r microcuries per second is estimated to be $2.9r \times 10^{-9}$ μCi/ml.

There are 32 ground water supplies within a 20-mile radius of the site. Because the ground water movements are away from these sources as indicated in Section 3.3, there should be no significant effects on ground water uses.

3. Impact on the water resources - The Browns Ferry Nuclear Plant is not expected to have significant impact on the water resources of the area. The plant should not affect the chemical or physical characteristics of Wheeler Reservoir, nor will it alter the present usage of this portion of the Tennessee River.

As will be noted in subsequent portions of this statement, the plant should not cause thermal nor radiological discharges that will adversely affect uses of the reservoir.

Other industrial and public uses, such as water transportation, boating, fishing, etc., should not be significantly affected by the presence of the plant in the area.

5.3 Heat Dissipation - The Browns Ferry plant will release heat to the environment as an inevitable consequence of producing useful electricity. Heat from the fission of nuclear fuel in the reactor is used to produce steam under high temperature and pressure to drive a turbine connected to a generator. After a significant portion of thermal energy in the steam has been converted to mechanical energy in the turbine, the low temperature, low pressure steam is converted to water in a condenser. Condensation is accomplished by passing large amounts of cooling water through the cooling coils in the condenser. This section discusses water quality as affected by thermal discharges.

1. Condenser circulating water - The primary purpose of the condenser circulating water system is to provide water to the condensers of the turbogenerator steam turbine to carry away heat rejected by steam condensation. A secondary purpose is to provide water for auxiliary cooling service and to disperse low-level radioactive wastes from the radwaste treatment building.

The system is designed to provide a flow of 1,890,000 gallons per minute (gal/min) to the condensers and a flow of 90,000 gal/min to auxiliaries for the three units. Three pumps are provided for each unit, each with a capacity of 220,000 gal/min at a design head of 32.5 feet. The pumping station is located at the land end of the intake channel, which has a bottom elevation of 523 feet above sea level. The nine circulating water pumps will carry the water through tunnels to the condensers.

No treatment is provided for the condenser circulating water. An Amertap cleansing system is provided for automatically cleaning condenser tubes when the system is in operation. This mechanical cleansing system uses small sponge rubber balls that are recirculated continuously through the condenser tubes. Therefore, it is not anticipated that the chemicals normally used for algal treatment will be required on this plant.

Operating the condensers requires that filling be accomplished by venting, evacuation by the vacuum system, and operation of at least two circulating water pumps. The three condensers may be operated fully flooded by only one pump by throttling the condenser discharge valves and venting only. The discharge from the condensers passes to the discharge tunnel and on to the diffuser system for mixing with the reservoir water. The diffuser system is described in the next section, Heat removal facilities.

Three pumps will normally operate in parallel for each unit. However, in an emergency if one pump is out of service, the two remaining pumps will deliver approximately 540,000 gal/min at a reduced head of about 20 feet. This is still sufficient flow for unit full load operation.

The cooling water will be drawn from and returned to Wheeler Reservoir. With the units operating fully loaded, the temperature of the cooling water will be raised 25° F. in passing through the condensers. The representative averages of seasonal temperatures of withdrawn and returned water are set forth below.

	Average Condenser Water Temperature	
	Inlet temperature	Outlet temperature Before Mixing
Fall	67° F.	92° F.
Winter	47° F.	72° F.
Spring	57° F.	82° F.
Summer	79° F.	104° F.

2. Heat removal facilities - It was recognized early in the plant design stages that the condenser water should not be discharged into the surface strata of Wheeler Reservoir. Instead, it was decided that, by means of a diffuser, the condenser water should be mixed as quickly as possible with as much unheated river water as

possible. By this procedure, no excessively warm surface strata will exist, the mixing zone will be restricted to a relatively small area, and the temperature rise after mixing will not exceed 10° F.

Based on extensive TVA studies (discussed in Section 5.6), available data, and the experience of others, at the time Browns Ferry was designed it was concluded that outside the mixing zone: (1) the average temperature over any cross-section should be limited to not more than 93° F. and should not exceed 95° F. at any point at any time, and (2) the rise in temperature of the mixed stream should be limited to not more than 10° F. above natural water temperature at any time. The mixing zone will not be permitted to exceed 75 percent of the total cross-section of the reservoir and will be limited to a reasonable distance from the outfall. These temperature limits have been used in design and are in line with those accepted by the Alabama Water Improvement Commission.

Figure 11 shows the physical relationship of the plant, cooling water conduits, and diffuser pipes, to the main channel and floodplain of Wheeler Reservoir at the plant site.

Thermal diffusion is accomplished by means of three perforated pipes, connected to the discharge conduits of the three units. These perforated, corrugated, galvanized steel pipes are laid side by side across the bottom of the 1,800-foot-wide channel. The channel is approximately 30 feet deep. The pipes are 17 feet, 19 feet, and 20 feet 6 inches in diameter and of different lengths. Each has the last 600 feet perforated on the downstream side with more than 7,000 two-inch diameter holes. Thus, approximately 22,000 holes spaced 6 inches on centers in both directions distribute the 4,400 cubic feet per second (approximate) of cooling water into the river for thermal mixing. The diffuser system design is shown on Figure 12.

The main channel where mixing takes place occupies about one-third of the width of the reservoir but carries about 65 percent of the flow. The reservoir outside the main channel at this location is approximately one mile wide and 3 to 10 feet deep at minimum pool level.

Predictions of surface temperatures upstream and downstream from the plant are shown on Figure 13 and 14 and have been made to illustrate thermal conditions that could exist when:

a. Total riverflow (17,000 ft^3/s) in mid-April would result in a maximum thermal rise of 10° F. above the normal water temperature of 65° F. in the main channel flow immediately below the plant;

b. Total riverflow (21,000 ft^3/s) in mid-August would result in a maximum thermal rise to 93° F. (8° F. above 85° F. normal water temperature) in the main channel flow immediately below the plant.

The dashed lines in Figure 13 and the shaded area in Figure 14 reflect the range of uncertainty in calculated results. Both of these examples illustrate extreme conditions that could occur infrequently when riverflows are relatively low.

To provide an estimate of the number of days in a year when one or both of the control temperatures, i.e., 10° F. rise and/or maximum of 93° F., might be reached, the streamflows and temperatures that actually existed at Wheeler Dam during 1966 and 1967 were analyzed. The mean flow in 1966 was 37,550 ft^3/s and 57,550 ft^3/s in 1967. The long-term mean flow is 49,000 ft^3/s.

It was assumed that all three units were in continuous operation and that all condenser flows were mixed with two-thirds of the streamflow. These calculations demonstrate that, even without allowance for unit outages which might coincide with periods of low flow and high temperature, special flow regulation will be required for only a small percentage of the time to keep water temperatures in the reservoir below the design control temperatures. During those periods when special controls might be applied, the thermal limits will be met by (1) regulating streamflows at the Browns Ferry site, or (2) decreasing power production, or (3) a combination of both.

The decision as to which approach will be used during these periods will be made only after careful consideration of the potential effects of the special operation on all other uses of the TVA reservoir system.

3. Impact of cooling water effluent on temperatures in Wheeler Reservoir - The objective of the diffuser system is to obtain complete mixing of the thermal effluent with that portion of the receiving water available for dilution within the minimum possible distance. Mixing is considered to be complete if the temperature at any point in the cross section is $R(\Delta T) + T$, where T is the temperature of the dilution water, ΔT is the increase in temperature of the condenser flow, and R is the ratio of the condenser flow to the dilution water flow.

As shown on Figure 11, the diffusers do not traverse the entire width of the reservoir. Hence, the entire reservoir flow will not be available for dilution. Field measurements showed that 65 percent of the flow would be available for mixing.

The diffuser design is such that the discharge is essentially constant for the entire length of the diffuser; therefore, the mixing characteristics of the diffuser could be determined from two-dimensional model tests. Such model tests were conducted at the Massachusetts Institute of Technology Hydrodynamics Laboratory for steady flow conditions.

It was found that for the range of flows from 10,000 to 40,000 ft^3/s the diffuser was essentially 100 percent efficient as a mixing device. Comparison of model temperatures with computed fully mixed temperatures showed that complete mixing always occurred in the prototype within 200 feet of the diffusers. These studies also show that completely mixed temperatures will often occur within 75 feet. Figure 15 shows the results (extrapolated from model studies) of a detailed temperature survey in the vicinity of the jet ports. For this case, a 15° F. drop in temperature would occur within 10 feet of the prototype diffuser and the entire flow would be within 1° F. of the fully mixed temperature within about 50 feet.

These tests also showed that an upstream wedge of warm water would develop at flows of less than 40,000 ft^3/s.

To learn more about the effect of unsteady and zero flow on the thermal regime of Wheeler Reservoir, construction of a three-dimensional model of a 5-mile-reach of the reservoir in the vicinity of the plant was begun. The model was designed to simulate all flow conditions including reverse reservoir flow.

This model will be used to obtain as much preoperational information as possible regarding the effects of many variables on the thermal regime of Wheeler Reservoir. Operation of the model will provide information to guide in the operation of Wheeler and Guntersville hydro projects and Browns Ferry so as to meet standards relative to thermal conditions in the Wheeler Reservoir.

A comprehensive picture of the thermal regime of the reservoir both before and after Browns Ferry goes into operation will be available from temperature monitoring stations at the Tennessee River mile indicated in the following table and shown in Figure 16.

Mile	Date Installed
275.0	Dec. 1968
285.2	Dec. 1970
293.6	Oct. 1968
297.6	Sept. 1969

Each station measures temperatures at ten elevations. The station at mile 293.6 also measures velocity and direction of flow and reservoir stage. Measurements from these stations are telemetered to a central data logger, punched or paper taped, and sent to the computer center for processing and storage. Selected points from the station at mile 293.6 are telemetered to the plant where they are available to the plant operating personnel. If it is found that additional stations are required after the plant goes into operation, they will be added. In addition, water surface temperatures will be monitored several times yearly by means of airborne infrared remote sensing equipment. Special studies consisting of around-the-clock measurements for controlled situations will be set up for the Browns Ferry plant. Essentially simultaneous instantaneous temperature measurements of a large surface area combined with selected vertical temperature measurements will provide additional information concerning the thermal regime of Wheeler Reservoir.

4. Applicable thermal standards - The Alabama proposed standards for water temperature state that "with respect to cooling water discharges only, the ambient temperature of receiving water shall not be increased by more than 10° F. by the discharge of such cooling water, after reasonable mixing; nor shall the discharge of such cooling waters after reasonable mixing cause the temperature of the receiving

waters to exceed 93° F." The Alabama temperature standards have been excepted from approval by the Water Quality Office, Environmental Protection Agency. However, TVA will meet any future applicable temperature standards.

Heat dissipation utilizing the diffuser system designed for Browns Ferry should control thermal discharges so that there is no significant adverse impact on the quality of the water in Wheeler Reservoir. (See Section 7.4, Alternative Heat Handling Methods, for further studies TVA has under way.)

Because of its location inside the state of Alabama, Browns Ferry discharges should not affect the quality of the waters of other states.

5. Applicability of Section 21(b) permit - TVA, as a Federal agency, is not required to obtain a certificate of compliance with applicable state water quality standards, in accordance with Section 21(b) of the Water Quality Improvement Act of 1970 (PL 91-224). TVA is, however, obligated by Section 21(a) of this Act and by Executive Order 11507, "Prevention, Control, and Abatement of Air and Water Pollution at Federal Facilities," to meet all state water quality standards in the operation of its facilities and TVA will meet this obligation. Estimated quantities and concentrations of liquid waste discharges expected from Browns Ferry Nuclear Plant have been reported to the Environmental Protection Agency, as required by Office of Management and Budget Circular A-81.

5.4 Chemical Discharges - Chemicals used at Browns Ferry Nuclear Plant include alum, chlorine, and a polymer used in the water filtration unit; sulfuric acid and sodium hydroxide used for makeup demineralizer regeneration, sodium chromate used as a corrosion inhibitor in closed-cooling water systems and suppression chambers; miscellaneous chemicals used for cleaning and decontamination of equipment; and sodium pentaborate used in the standby liquid control systems. Of these, only the filtration unit chemicals and the demineralizer regenerants are discharged to the river during normal operation. Safeguards against accidental release of other chemicals are provided.

Alum, chlorine, and a polymer are used in the water filtration unit. If the filtration unit were operated at rated capacity, annual consumptions of these chemicals would amount to 8,000 pounds of alum, 250 pounds of chlorine, and 150 pounds of polymer. The actual amounts, however, are expected to be less than 10 percent of these figures. Filtration units are backwashed into the water plant waste sump, and the liquid is pumped to the condenser water discharge conduits. During release, the concentration of alum is about 0.05 ppm, that of chlorine about 0.0003 ppm, and that of the polymer about 0.0002 ppm.

During regeneration of a makeup demineralizer, regenerant solutions containing sulfuric acid and sodium hydroxide are discharged into the water plant waste sump along with backwash and rinse water. The liquids are pumped into the condenser water discharge conduits where they are diluted by the condenser cooling water flow. The concentrations of sulfuric acid and sodium hydroxide in the diluted stream range from about 0.5 to 1.5 ppm each during release, depending upon whether one, two, or three reactor units are in operation. The concentrations are too low to have a measurable effect on the pH of the diluted stream. The U. S. Public Health Service Drinking Water Standards of 1962 specify a maximum sulfate concentration of 250 ppm. TVA's Instruction VIII, "Water Quality Management," specifies 150 ppm. If the makeup demineralizer were operated at its rated capacity, the annual discharge of sulfuric acid and sodium hydroxide would be approximately 66,000 and 36,000 pounds, respectively. The actual discharge is expected to be a fraction of this amount.

Chromate-containing water is drained from components of the closed-cooling water system only when necessary for maintenance purposes. Chromate-containing water from the suppression chamber will not be discharged to the river. In this connection, TVA is continuing to investigate ways to avoid the use of chromate in the suppression chamber and will make the necessary changes if these investigations show that other methods will meet the operation criteria. The water is drained from the closed cooling water system to the radwaste system where it is processed through a non-regenerable mixed bed demineralizer. The treated solution is expected to contain less than 10 ppm of chromate (as CrO_4^{--}), and the total annual release of chromate would rarely, if ever, be as much as 10 pounds. When released and diluted in the discharge conduits, the concentration of chromate is less than 0.013 ppm if one unit is operating and less than 0.0045 if three are operating. The U. S. Public Health Service Drinking Water Standards of 1962 specify a maximum concentration of 0.05 ppm for hexavalent chromium; this value corresponds to 0.11 ppm CrO_4^{--}.

Most equipment cleaning and decontamination operations will be performed with high-pressure water and with detergent solutions. These liquids will be treated in the radwaste system by filtration and will be released to the discharge conduits. Some decontamination operations will involve the use of chemicals such as sodium phosphate, sodium permanganate, ammonium citrate, nitric acid, and hydrofluoric acid. The amounts of such chemicals cannot be determined at this time. They will be drained to the chemical drain tank in the radwaste system where they will be neutralized. Further processing will depend upon the character of the solution. Processing will include filtration and may include demineralization prior to release to the discharge conduits.

Sodium pentaborate used in the standby liquid control system will not be released from the plant. Should it be necessary to drain solution from the system, it will be drained into drums. Storage tanks are designed to resist a design basis earthquake.

It is anticipated that releases of chemical wastes from the Browns Ferry Nuclear Plant will have no significant effect on the biota.

5.5 Sanitary Wastes - All the sewage from the plant will be collected in a yard sewage system which flows by gravity to a treatment plant. Sewage ejectors, which discharge into the yard system, are provided at the pumping station and gatehouse. The sewage treatment plant consists of two 15,000 gallons-per-day units arranged for parallel flow. Biological oxidation and reduction of solids by extended aeration and sedimentation are the methods of treatment. Effluent from the plant flows through a chlorine contact tank and then into the river. The sewage treatment plant is designed and will be operated in accordance with Federal and state standards.

5.6 Biological Impact - One of the most important considerations in carrying out the construction and operation of a nuclear power plant is the formulation of comprehensive ecological studies. This allows documentation of environmental characteristics prior to construction and operation of the plant in order that the effect of construction and operation on the environment can be estimated, and provides a basis for selecting measures to minimize any projected adverse effects. TVA has developed comprehensive ecological monitoring programs. Some of these are currently under way, while others are planned to commence prior to plant startup and continue after the plant is in operation. All of these programs are discussed at various points below.

1. Ecological studies and analyses performed - Subsection (1) lists some of the results of the fish monitoring investigations. Subsection (2) discusses the importance of the locale to the existence of important species, including the possible effects of heated water. While the extent to which all of these effects may be present at Browns Ferry is not yet fully known, it is important from an environmental standpoint to recognize all the possible effects of heated water in order to objectively judge the actual impact of the plant.

Subsection (3) discusses TVA's experience with heated water on aquatic life at its various steam plants. Subsection (4) discusses the passage of planktonic forms and fish larvae through the condensers. Subsection (5) discusses such cooling water phenomena as biochemical oxygen demand.

(1) Identification of species important to sport and commercial use - Fish monitoring investigations have been conducted quarterly since the winter of 1968. These investigations have shown the following fish to be important to sport use: largemouth bass, smallmouth bass, spotted bass, white bass, crappie, bluegill, and sauger. Important commercial fish are: bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, blue catfish, carp, drum, and paddlefish. Table 9 lists the species encountered in various samples in Wheeler Reservoir; as such, it represents neither a complete species list for the reservoir nor a list of the "important" species within each broad category. Important seasonal sport fisheries exist for all game fish noted with the exception of yellow bass, longear, and green sunfish. Important commercial species include the two species of buffalo and the three species of catfish; drum, carp, and paddlefish are of lesser commercial importance. Forage fish are poorly represented here; conventional sampling techniques employed in monitoring and population-inventory studies do not sample small forage fish efficiently. Smith-Vaniz (1968) reports more than 24 species of minnows including 16 species of Notropis in the Alabama sections of the Tennessee River system, as well as 18 species of darters. These totals do not include rare or endemic species reported from only one location.

It is difficult and in some cases perhaps invalid to assign given species to tropic levels, since many species will undergo ontogenetic changes in regard to trophic levels will assume a very broad trophic character as adults. Some generalizations are however possible. The basses and gars can be considered as true piscivores as adults; forage fish and some rough fish species can be considered planktivorous; the remainder are essentially omnivorous.

(2) Importance of locale to existence of important species, considering states in life history -

(a) Spawning and larval state -

Important areas - The Browns Ferry plant is located directly downstream from an extensive area of shallow water, including the mouths of several creeks. Two additional extensive areas of shallow overbank habitat are located on the opposite side of the channel, directly across from the plant and about 2 miles downstream. Limited areas of shallow habitat occur directly downstream from the plant site. Areas of this type usually serve as spawning and nursery sites for most important fish species, as well as being areas of high production of fish food organisms.

Possible impact of heated water - Appendix III outlines studies conducted by TVA and others on the effects of heated water on aquatic life. Appendix II describes some preliminary results of the type of monitoring being undertaken in order to fully assess the effects of heated water on aquatic life.

Based upon these studies, it is concluded that the heated water should have no significant adverse effects on aquatic life. The comprehensive monitoring programs which are described in Section 5.6.3 will be used to ascertain the extent to which these effects will apply at the Browns Ferry site after the plant begins operating.

Thermal characteristics of operation - At a riverflow of approximately 43,000 ft^3/s, the thermal discharge from the plant will result in a temperature rise of about 3° F. in the main river channel at a point 200 feet directly downstream from the diffuser pipes. The increase in temperature at the same point for a low flow of 20,000 ft^3/s will be about 8° F. Environmental considerations demand that the worst probable case coincident with plant operation be examined; this has been estimated to represent a flow of 17,000 ft^3/s in April and 21,000 ft^3/s in August. At this velocity, subject to the assumptions of steady flow in the channel, temperatures at a point 2 miles downstream would be elevated 6.5° F. in mid-August and 8.1° F. in mid-April. Similarly, surface temperature increases would be approximately 4.0° F. in mid-August and 6.1° F. in mid-April at a point 2 miles upstream.

Larval fish study - In order to judge the impact of heated water on spawning and larval states in the life history of various species, it is necessary to know to what extent the area to be affected by the plant's heated discharge is used as a spawning site by reservoir fishes. The specific objectives of this study are to:

1. Determine species composition and periodic abundances of larval fishes,

2. Acquire information on occurrence and abundance of young-of-the-year fishes, and

3. Ascertain aspects of the life history of larval, postlarval, and juvenile (young-of-the-year) fishes, such as growth rates, food habits, and movement.

Planned sample types, frequencies, locations, and analyses are discussed below.

Construction activity - Construction activities, notably those involving dredging and landfill, have altered about one-half mile of shoreline habitat. Landfill operations may have altered currents somewhat, contributed silt and excess turbidity, and temporarily affected the distribution of some species of fish directly below the plant. The extent to which these effects may be permanent has not been resolved.

(b) Fish movements - Returns of tagged fish in Wheeler Reservoir indicate that several species show extensive ranges of movement. Data for five species are presented in Table 14. The ranges of movement that are attributable to migratory and nonmigratory behavior are not known.

The heated water may have an effect on the migratory behavior of some fishes. Three-dimensional model studies are being conducted now to determine whether and under what conditions the heated water can extend the width of the reservoir. The linear dimensions, depth, and longevity of the heated area, together with its temperature, will be investigated with regard to its effect on migratory and nonmigratory movements of fishes.

Of the species present in Wheeler Reservoir which are known to make extensive spawning migrations, it appears that sauger are most likely to be affected. Sauger move upstream, usually to the tailwaters of Guntersville Dam, and spawn in late December and early January at temperatures of 41 to 43° F. The effects of a movement through elevated temperatures on reproduction of sauger are not now known. This is also true concerning the effect of the space distribution of the thermal plume on the migration of an important species.

Monitoring programs to consider fish movements are discussed below. One of the sampling stations established to monitor the effects of heated discharges is located directly opposite the plant site. It is anticipated that information gained from this station will include data on the reactions of fish to the thermal discharge and the spatial distribution of the thermal plume.

(3) Time and space changes in temperature distributions - Fish will probably not remain in the area immediately downstream of the diffuser pipes for a distance of 100 feet, due to the thermal gradients and temperatures. The warmer stretches below this area are likely to be more attractive and less detrimental to younger fish. In general, preferred temperature within a species decreases with increasing age. Adult predators may frequent this area during feeding periods. Increased water temperatures in late autumn, winter, and early spring may serve to concentrate fish in the vicinity of the diffuser tubes. Production of food organisms in this area beyond the usual "productive season" may serve as an attractant to young fish; concomitantly, predators will be attracted by the increase in their food resources. This may increase sport and commercial fishing in the vicinity.

(a) TVA experience on effects of heated water - Since 1955, TVA has been observing the distribution in streams and in reservoirs of heated waters discharged from TVA's thermal-electric power plants. The first plants were relatively small compared to the sizes of receiving streams. Over the years the sizes of individual units, power plants, and thermal rises in the condenser cooling water have gradually increased. To ensure that aquatic life in receiving streams is not being adversely affected by thermal discharges, biological surveys have been made at all of TVA's plants. Table 20 illustrates characteristics of these plants.

Typical of these surveys are the detailed temperature and biological studies made in August and September of 1967 at the Widows Creek power plant on Guntersville Reservoir. Heated water there is discharged into the edge of the reservoir, where it "floats" into the main channel and rapidly mixes with streamflow. Temperature and biological data were collected along cross sections of the reservoir above and below the plant. Temperature of the discharge water was between 84° F. and 86° F., about 10° F. higher than temperature in the river above the plant. The warm water plume spread diagonally across the river in less than the upper 10 feet of water, or less than half the river depth. Bottom fauna and periphyton growth were sampled and analyzed.

Results of these studies showed that: (1) the horizontal area of the reservoir covered by the zone of elevated temperatures is small; (2) the maximum temperatures observed in the mixing zone were in the top two feet of water; (3) the maximum increase in temperature in the mixing zone was 10.3° F. on August 30, and 6.1° F. on August 31; (4) the temperature increase in the Tennessee River water after complete mixing was less than 1° F.; (5) the diversity and abundance of bottom fauna above and below the steam plant discharge were similar, and slight differences are attributed to variability of substrate rather than to temperature effects;

(6) the observed periphyton growth was not consistent with the proximity of the observation stations to the discharge; consequently, the differences in growth are not considered to be due to the steam plant discharges; and (7) the discharge from the Widows Creek Steam Plant does not produce significant effects on aquatic life in the Tennessee River.

Although temperature rise in condensers of TVA's fossil-fueled plants typically varies from 10° F. to 18° F., results of similar temperature and biological surveys show that the thermal discharges from the various plants produce no significant adverse effects on aquatic life in the receiving waters. It is interesting to note that fishing in the warm water during the winter months is very popular at most TVA steam plants.

Initial operation of the Paradise Steam Plant on the Green River in Kentucky did produce significant adverse effects on aquatic life. However, these effects were detected by environmental monitoring conducted by TVA and outside consultants. As a result of the findings of the biological studies, lower thermal criteria were established by TVA and cooling towers were installed. Continuing studies are assessing the effectiveness of these measures to correct the effects of initial operation of the plant. Preliminary results indicate that the adverse effects experienced are not permanent. Appendix III provides a detailed analysis of the Green River studies.

TVA's experience demonstrates that warm condenser water can be discharged into surface streams without significant adverse effects on aquatic life. The Paradise experience, although somewhat atypical due to the nature and small size of the Green River, demonstrates the value of comprehensive monitoring programs in detecting adverse effects of thermal discharges at an early stage in plant operation, and indicates that such effects are not permanent.

(4) Effect of passage through condenser on planktonic forms and fish larvae - The volume of water used for condenser cooling raises the possibility that newly-hatched fish and food organisms will pass through the condensers. The temperature rise of approximately 25° F. and pressure changes involved in pumping may kill many of these organisms in the condenser cooling water. However, since only ten percent of the water passing the site at mean annual flow passes through the condensers, any adverse effects are not expected to be significant.

Newly-hatched fish (larval fish) are essentially planktonic, as are many food organisms and the eggs of some species of fish. These may be unable to avoid or withstand the currents in the intake area. The extent to which entrainment of larval fish will be significant is unknown; however, investigations are to be initiated in 1971 to ascertain the distribution and abundance of larval and young fish in several areas of the reservoir, including areas directly above and below the plant site. Further details on this program are contained below.

(5) Implications of withdrawal and return of cooling water - The three units and auxiliaries at Browns Ferry require the withdrawal and return of approximately 1,980,000 gallons of water per minute. The water is withdrawn from and returned to approximately the same level. This constitutes about ten percent of the water passing the site at mean annual flow.

(a) Nutrient circulation - Plankton may be destroyed by passage through the condensers. Destruction of plankton in the condensers will release nutrients that could result in the growth of heterotrophic slimes. This possible effect will be detected by monitoring programs, but no significant adverse effects on important species populations are anticipated.

(b) Reduction of DO concentrations in the condensers - Since warm water can hold less oxygen in solution than can cooler water, the theoretical effects of elevation of water temperatures some 25° F. in passing through the condensers has been considered. For example, the oxygen saturation concentration in water at 85° F. is 7.7 milligrams per liter, whereas at 110° F. the saturation concentration is 6.3 milligrams per liter.

Observations of DO concentrations in Wheeler Reservoir above and below the Browns Ferry site indicate that in the summer months DO concentrations are not at saturation but in the range of 75-80 percent of saturation. Thus, instead of 7.7 mg/l of DO in water at 85° F. the actual concentration is observed to be approximately 6 mg/l. Thus, during the warmer months of the year, even after the temperature is elevated 25° F. in passing through the condenser, saturation concentrations are not apt to be exceeded. Consequently, as regards elevation of water temperatures, no significant reduction in oxygen concentrations should occur.

Another factor tending to lower DO concentrations in water passing through a condenser is the partial vacuum existing at the discharge end of the condenser. This partial vacuum results from the fact that the discharge end of the condenser lies above the hydraulic gradient. This situation is common to all TVA steam plants. While vacuum pumps are installed to remove any accumulated air, experience has shown that very little air accumulates and needs to be removed from the system. Consequently, no significant quantity of oxygen should be lost at Browns Ferry due to this hydraulic situation.

These conclusions are consistent with findings above and below TVA's Paradise power plant where the temperature elevation in water passing through the condensers is approximately the same as at Browns Ferry, and a significant negative pressure exists at the downstream ends of the condenser.

No significant adverse effects on important species populations are anticipated due to the reduction of DO concentrations in the condensers, since no significant quantity of oxygen will be driven off.

(c) Effect of elevated temperatures on biochemical oxygen demand - To provide an estimate of the quantitative effect on oxygen consumption of organic wastes in the waters of Wheeler Reservoir, an organic load of 25,000 pounds per day of 5-day BOD was assumed to be discharged into the reservoir immediately downstream from the plant.

Based on a low total streamflow of 21,000 ft^3/s, an increase in temperature from 85° F. to 93° F., and applicable Streeter-Phelp equations, calculations show that the increase in temperature would result in an increased DO depression of less than 0.1 mg/l.

It is not anticipated that this would have any adverse implications on important species populations.

(6) Measures taken to assure adequate ecological studies - TVA has consulted with the Fish and Wildlife Service, U.S. Department of the Interior, and the Alabama Department of Conservation in developing plans for environmental monitoring for the Browns Ferry plant. A quality control program for radioactive monitoring has been established with the Alabama Department of Public Health Radiological Laboratory and the Eastern Environmental Laboratory - EPA, in Montgomery, Alabama. In addition, TVA has discussed environmental monitoring plans with the Alabama State Health Department, the Alabama Water Improvement Commission, the Bureau of Sport Fisheries and Wildlife, and the Bureau of Commercial Fisheries of the U.S. Fish and Wildlife Service.

2. Studies to be continued - There are no ecological studies to be completed prior to operation of the plant which will affect plant design. The three-dimensional model studies on the diffuser systems will be continued after the plant begins operation.

3. Monitoring programs - The following monitoring programs will be used to determine present and continuing ecological relationships.

(1) Environmental Monitoring Program

(a) General - The preoperational environmental radioactivity monitoring program has the objective of establishing a baseline of data on the distribution of natural and man-made radioactivity in the environment near the plant site. With this background information, it will then be possible to determine, when the plant becomes operational, what contribution, if any, the power plant is making to environmental radioactivity.

Field staffs in TVA's Division of Environmental Research and Development and the Division of Forestry, Fisheries, and Wildlife Development carry out the sampling program outlined in Table 15. Sampling locations are shown in Figures 17 and 18. All the radiochemical and instrumental analyses are conducted in a central laboratory at Muscle Shoals, Alabama. Alpha and beta analyses are performed on a Beckman Low Beta II low background proportional counter. A Nuclear Data Model 2200 multichannel system with 512 channels is used to analyze the samples for specific gamma-emitting isotopes. Data are coded and punched on IBM cards or automatically printed on paper tape for computer processing specific to the analysis conducted. An IBM 360 Model 50 computer is used to solve multimatrix problems associated with identification of gamma-emitting isotopes.

(b) Atomospheric monitoring - Remote air monitoring stations are located at distances out to 35 miles from the plant and the perimeter monitors out to 10 miles; the local stations are inside the plant boundaries. All the monitors are capable of sampling air at a regulated flow of 3 ft^3/min through a Hollingsworth and Voss HV-70 particulate filter; in series with, but downstream of, the particulate filter is a charcoal filter used to collect iodine. Each monitor has a collection tray and storage container to collect rainwater and a horizontal platform that is covered with gummed acetate to catch and hold heavy particle fallout. Thermoluminescent dosimeters are used to record gamma radiation levels at each remote and perimeter station.

Local and perimeter monitors transmit data on airborne beta-gamma levels into the plant by radiotelemetry. These stations will be used to detect any significant airborne release, while the remote monitors will monitor outlying populated areas.

Air filters are collected weekly and analyzed for gross beta activity and specific gamma-emitting isotopes. No analyses are performed until 3 days after sample collection. For the specific radionuclide analysis, the filters for each station for a month are composited and analyzed. The monthly results are combined for each station to obtain a semiannual average. The averages for each station are combined to yield an average for each group of monitors.

Rainwater is composited monthly and analyzed for gross beta activity, specific gamma-emitting isotopes, and radiostrontium. For the gross analysis, a maximum of 500 ml of the sample is boiled to dryness and counted. A gamma scan is performed on a 3.5-liter monthly sample and the results averaged the same as air filters. The strontium isotopes are separated chemically and counted in a low background system.

The gummed acetate that is used to collect heavy particle fallout is changed monthly. The sample is ashed and counted for gross beta activity.

Charcoal filters are collected biweekly and analyzed for radioiodine. The filter is counted in a multichannel system.

(c) Terrestrial monitoring -

Milk - Milk is collected monthly from four farms within a 10-mile radius of the plant and from nearby retail distributors and analyzed for gamma-emitting isotopes and for radiostrontium. So that any relationship between fallout on pastureland and the presence of radionuclides in milk might be seen, pasturage is also sampled at the four farms.

Vegetation - In addition to the pasturage samples mentioned previously, vegetation samples are collected near each monitoring station in the network to determine possible plant uptake of radioactive materials from the soil or from foliar deposition. The data for the specific radionuclide analysis of vegetation are averaged for the four principal locations--local, perimeter, remote, and farm.

Soil - Soil samples are collected near each monitoring station in order that any relationship between the amount of radioactive material found in vegetation and that in soil might be established. The averages for specific analyses are obtained in the same fashion as those for vegetation.

Water - Domestic water supplies, such as surface streams and wells, are sampled and analyzed. Well water is obtained from four private farms within a 10-mile radius of the plant. Public water supplies obtained from the Tennessee River at Decatur, Wheeler Dam, and Sheffield are also analyzed.

Environmental gamma radiation levels - Thermoluminescent dosimeters are placed on a 500-foot grid within the plant boundaries and on the perimeter and remote air monitors to determine the gamma exposure rates at these locations.

Poultry and food crops - Poultry and food crops were collected for the first time during the summer of 1970 and will be obtained again in the summer of 1971. Corn, oats, peaches, tomatoes, potatoes, and chickens were analyzed.

(d) Reservoir monitoring - Samples are collected quarterly along nine cross sections in Wheeler Reservoir--at Tennessee River miles 277.98, 283.94, 288.78, 291.76, 293.70, 295.87, 299.00, 301.06, and 307.52. Samples collected for radiological analysis include water from eight of these cross sections, fish and plankton from three cross sections, and bottom fauna and sediment from four cross sections, as shown in Table 15. In addition, water, plankton, bottom fauna, and sediment are collected at a station located within 500 feet of the diffusers (TRM 29[illegible]). The locations of these cross sections are shown on the accompanying map (Figure 18) and conform to sediment ranges established and surveyed by the Hydraulic Data Branch, TVA. Station 307.52 is located 13.5 miles upstream from the plant diffuser outfall and was selected as a control station.

Samples of water, net plankton, sediment, Asiatic clams, and two species of fish collected quarterly (plankton in only two quarters) are analyzed for radioactivity. Gamma and gross beta activity are determined in water (dissolved and total activity), net plankton, sediment, shells and flesh of clams, flesh of a commercial and a game fish species, and also in the whole body of the commercial species. Tritium is determined in river water and certain public water supplies. The ^{89}Sr and ^{90}Sr contents are determined by appropriate radiochemical techniques for all samples except flesh of clams and white crappie.

Water - From all of the nine cross sections a total of 24 water samples is collected quarterly for determination of suspended and dissolved radioactivity. The locations and depths for sampling are shown in Table 15. Water samples are also collected monthly at the point of plant discharge to the Tennessee River (within 500 feet of the diffuser) and at a point on the Elk River. These samples are a part of the quality control program.

Fish - Radiological monitoring of fish is accomplished by analyzing three composite samples from collections at each of three sampling stations--miles 283.94, 293.70, and 299.00. One sample is composited from the flesh of at least six white crappie, 8 inches or longer; one from the flesh of at least six smallmouth buffalo, 14 inches or longer; and one from at least six whole smallmouth buffalo, 14 inches or longer. These are collected quarterly and analyzed for gamma and gross beta activity. The ^{89}Sr and ^{90}Sr concentrations are determined on the whole fish and flesh of buffalo only, which are as nearly equal in size as possible. The composite samples contain approximately the same quantity of flesh from each of the fish. For each composite, a subsample of at least 50 to 100 grams (wet weight) of material is drawn for counting. After the plant goes into operation, fish will also be sampled at the station located within 500 feet of the diffuser.

Plankton - As indicated in Table 15, net plankton (all phytoplankton and zooplankton caught with a 100 μ mesh net) is collected for radiological analyses at two depths at each of four stations by horizontal tows with a 1/2-meter net. At least

50 grams (wet weight) of material is necessary for analytical accuracy. Collection of this amount will probably be practical only during the period April to September (spring and summer quarters) because of seasonal variability in plankton abundance. Samples are analyzed for gamma and gross beta activity and ^{89}Sr and ^{90}Sr content.

<u>Sediment</u> - Sediment samples are collected from Ekman dredge hauls made for bottom fauna. Gamma and gross beta radioactivity and ^{89}Sr and ^{90}Sr content are determined quarterly in a composite sample collected from each of two points in the cross section at five stations. Locations of these points at each station are shown in Table 15.

<u>Bottom fauna</u> - The flesh of Asiatic clams collected from two points in the cross section at five stations (Figure 18) is analyzed for gamma and gross beta activity at quarterly intervals. The ^{89}Sr and ^{90}Sr contents are determined on the shells only. A 50-gram (wet weight) sample provides sufficient activity for counting.

(e) <u>Quality control</u> - A quality control program has been established with the Alabama Department of Public Health Radiological Laboratory and the Eastern Environmental Laboratory - EPA, Montgomery, Alabama. Samples of air, water, milk, vegetation, and soil collected around the plant are forwarded to these laboratories for analysis. Results are exchanged for comparison.

(2) <u>Fish monitoring</u> - Monitoring areas and stations and sampling locations for fish monitoring are shown in Figure 19. Trap nets (two each in areas A, B, and C) are utilized to provide fish for: (a) radiological analyses, (b) tagging for

investigations of fish movements, and (c) studies on age structure and growth rates of fishes. Gill nets (10 each at stations 1, 2, and 3) provide data used for analyses of: (a) species presence, (b) species abundance, and (c) species diversity. The combination of these three aspects of fish distribution will form the basis for assessment of thermal effects. Information on age structure of species' populations, growth rates, movements of selected species, studies on larval and young fish, results of population inventories and creel censuses will be added in an attempt to provide as complete a picture as possible of thermal effects on fish populations.

It is anticipated that three full years (12 quarters of sampling) of preoperational data will be available; postoperational sampling will be conducted for at least two full years (8 quarters of sampling) and preferably three full years. Assessment of effects will be of a "before-after" nature, utilizing within-station comparisons of characteristics of catch and supportive data. Preliminary results of fish monitoring are given in Appendix II.

(a) Adult fish - The objective of this program is to determine species composition, relative abundance, and movement of fish in Wheeler Reservoir. To judge the effects, both adverse and beneficial, of heated water on fish and their habitat, baseline measurements will be made below, within, and above the proposed heated water discharges.

Fish will be collected quarterly with gill and trap nets set in overbank and channel areas indicated on Figure 19. Data collected from trap nets will be used to determine species composition, movement, and numbers and weights of game and commercial fish per lift at each station before and after plant operation. To determine movement, selected species will be tagged. Fish tagged before the plant operates will serve as the basis for determining normal movement within the reservoir.

Gill nets will be fished one week when trap nets are not in the water. Catches from these nets will supply information on species composition, relative abundance, and fish distribution and movement.

Rotenone samples will be taken below the plant during the summer quarter of each year before and after operation. These samples will serve as a basis for determining standing crop, species composition, and reproductive success.

Quarterly and annual progress reports will be prepared and distributed.

(b) Larval fish - In conjunction with present monitoring of adult fish populations in the vicinity of Browns Ferry Nuclear Plant, there is a need to investigate larval fishes during and after the spawning season and throughout the succeeding summer. It would be of significance to know to what extent the area to be affected by the plant's heated discharge is used as a spawning site by reservoir fishes. The objectives of this phase are:

1. To determine the species composition and periodic abundance of larval fishes.
2. To acquire information on occurrence and abundance of young-of-the-year fishes.
3. To ascertain aspects of the life history of larval, postlarval and juvenile (young-of-the-year) fishes. Such aspects as growth rates, food habits, and movement will be studied as time and facilities permit.

In addition, this study will enable an assessment to be made of the effects of passage through the condensers of fish larvae.

Indirect effects on fish populations will also be investigated. For example, growth rates will be studied. Young fish (this term includes all stages from newly-hatched individuals to and including young-of-the-year fish) provide possibly the best test animals for studies on growth rates because of their rapid absolute and relative rates of growth, their abundance, and because it is relatively easy to process large numbers in a short time.

Sampling will begin just prior to the earliest suspected spawning of species concerned. Larval and postlarval fishes will be collected by towing a net of one-meter diameter constructed of 1/32-inch nylon mesh. Sampling stations and a weekly sampling schedule are described in Table 16.

Stationary nets may be utilized for sampling in the intake basin, depending on accessibility to the basin and on water currents in the basin.

Sampling will be continued until young of all species concerned are large enough to enable them to avoid the meter net. Sampling for young fish will be continued, following the meter-netting phase, by beach seining, electrofishing, and perhaps by surface and midwater trawling. Beach seining will commence before the meter-netting phase ends, in order to maintain continuous sampling throughout the early summer. If conditions of fish concentration and water transparency permit, cast-netting may also be employed.

Sampling will begin in late March or April, pending completion of gear development. Two days sampling per week should be sufficient with two stations being sampled per day. The same schedule will be used for later phases--beach seining, electrofishing, trawling--and will continue into late September.

In terms of analysis of samples, primary importance will be attached during the first season to identification of species and the acquisition of a reference collection.

(3) <u>Additional monitoring for investigation of possible thermal effects</u> - The objective of this monitoring program is to determine if detectable changes occur in selected water

quality and biological parameters in affected areas of Wheeler Reservoir after the Browns Ferry Nuclear Plant begins operation. Appendix IV discusses proposed research.

(a) Frequency of sampling - Surveys were started in January 1969, and are now being made quarterly (Table 17). They will be continued through the first year after all three units are in operation. The frequency and extent of sampling during the second year of full plant operation will depend on results obtained during the first period of study.

(b) Water quality parameters - From eight cross sections (Figure 18) temperature and DO concentrations will be determined at the depths shown in Table 15. Water samples will also be collected in the main channel at each station from a depth of 1 meter for determination of stable trace elements of chromium, copper, iron, zinc, nickel, manganese, iodine, and potassium. At TRM 277.0 the water samples are also being periodically analyzed for coliforms, BOD, color, turbidity, odor, nitrogens, phosphates, pH, alkalinity, total hardness, SO_4, SiO_2, conductance, suspended solids, and total solids (Table 10).

(c) Plankton - For quantitative population estimates, zooplankton are sampled by filtering four or more liters of water, collected with a Van Dorn bottle, through a No. 20 (150 μ) mesh Wisconsin net or bucket. If organisms are too scarce to obtain reliable results by this method, a Clarke-Bumpus net is utilized so that more water can be filtered. Samples are collected from depths and locations in the cross section as shown in Table 15 and Figure 18. Total dry weight, number, and species composition are determined for all samples.

The quantity and photosynthetic activity of phytoplankton present in water samples are estimated by determinations of chlorophyll content, species composition, total number, and primary production rate. Samples of plankton are collected at three points in the cross section at each station (Table 15).

(d) Bottom fauna - Three dredge hauls are made with a Petersen or Ekman dredge at each of three points in six of the eight cross sections of the reservoir. Only two points are being sampled at TRM 307.5 since water is confined mostly to the original channel at minimum pool elevation. Four points are being sampled at TRM 291.8 because of the dissected nature of the channel. Sampling points at the eight stations are located at various distances from the left bank of Wheeler Reservoir in accordance with bottom morphology shown by sediment range profiles. Markers are located on shore and buoys are located in the river to identify sampling stations. The number of samples may be altered depending on the variability observed. Locations are listed in Table 15. Samples are being analyzed for total number and species composition.

(e) Analysis of data - Data collected at three key sampling stations have been selected for routine analysis--TRM 288.8, TRM 293.7, and TRM 307.5. The warm water diffuser is located at approximately TRM 294. A modified control charting procedure will be employed in this study.

Because of possible seasonal trends, means and variances will be calculated for each quarter. The variances will be used to construct a band of values from which the variables would differ only rarely by chance alone.

For unreplicated data, where an estimate of the variance is not available from other sources, trend charts will be used to detect changes in the overall mean. The interpretation of these charts will necessarily be subjective, but where variability is low, the trend charts should be adequate to detect significant changes. Trend charts and modified control charts will be made after the last preoperational survey has been completed.

4. Potential hazards to fish of cooling water intake and discharge - Small meshed traveling screens are provided on the circulating water pump intakes so that larger fish forms will not be entrapped or pass through the condensers. The traveling screen consists of a number of screen sections, fastened top to bottom, to form an endless belt of screens. The screens move continually through the cooling water intake to remove trash and other debris. This debris, along with any entrained fish, is washed off the screen in their upward pass and returned to the reservoir.

TVA has not encountered problems with fish entrapment at any of its large coal-fired steam plants, all of which are equipped with similar screens.

5.7 Radioactive Discharges - In the operation of any nuclear plant, radioactive materials are produced by fission and activation of materials in the reactor. Most of this radioactive material is retained in the fuel elements and removed with the spent fuel, and small amounts are retained in the reactor vessel and associated piping. Normally, small amounts of fission products from inside the fuel rods leak into the coolant. The necessity to continually renew a portion of the primary coolant results in the accumulation of both liquid and gaseous wastes during normal reactor operation. Demineralization and filtration remove all but a small fraction of the dissolved and suspended radioactive matter (but none of the tritium) from the liquid wastes. Liquid wastes containing low concentrations of radioactive impurities are filtered, sampled, analyzed, and diluted as discharged.

1. Waste management - TVA's policy is to keep the discharge of all wastes from its facilities, including nuclear plants, at the lowest practicable level by using the best and highest degree of waste treatment available under existing technology, within reasonable economic limits.

This policy has been implemented at Browns Ferry by improving plant design to include extended treatment for gaseous radwaste and by changing the processing for liquid radwaste. Hydrogen recombiners and 6 charcoal beds will be added to each unit to reduce radioactive gaseous wastes to very low levels. By processing floor drain wastes through a demineralizer, radioactivity in liquid effluents will also be reduced to very low levels. Population doses due to these very low level discharges are considered to be unmeasurable with existing measurement techniques. Calculated doses to the population are given in Section 5.7.2.

The radioactive waste systems are designed to dispose of the radioactive process wastes generated during plant operation. These wastes can be solid, liquid, or gaseous. The liquid and gaseous radioactive wastes are discharged to local water and to the atmosphere, respectively, at concentrations which at a maximum are well below established regulatory limits. Liquid wastes which cannot be reused, discharged to the environs within the regulatory limits, or reprocessed effectively, are packaged for offsite disposal, as are solid wastes.

All gases and liquids are carefully monitored before being released, and complete records are maintained to ensure that concentrations and quantities released are well within applicable limits. Discharge and shipment of solid, gaseous, and liquid radioactive wastes are in accordance with AEC Regulations 10 CFR Parts 20 and 71.

A detailed discussion of the waste processing equipment itself is not undertaken here since it will be evaluted in the context of the 10 CFR Part 50 licensing procedure. Sections (1), (2), and (4) below describe the solid, gaseous, and liquid radwaste systems as originally designed. Sections (3) and (5) describe the extended treatment of gaseous radwaste and additional processing of liquid radwaste respectively.

(1) Solid radwaste system - The solid radwaste system collects, processes, stores, packages, and prepares

for shipment solid radioactive waste materials produced through operation of the three reactor units.

Wet solid wastes are stored in phase separator tanks or the spent resin tank. After appropriate storage periods, the wet solid wastes are packaged in 55-gallon drums, disposable tanks in reu able shields, or disposable tanks with integral shields.

Dry solid wastes, such as contaminated rags, paper, clothing, spent filter elements, laboratory apparatus, small parts and equipment, and tools, are collected in suitable containers placed throughout the plant. Compressible wastes are packed into 55-gallon drums with a baling machine. Large-sized noncompressible items are packed in 55-gallon drums or are mixed with compressible materials and put through the baling machine. Large-sized contaminated items are encapsulated in steel containers or encased in concrete.

Solid radwastes are packaged and shipped from the plant in accordance with the requirements of the AEC, the U.S. Department of Transportation, and the states through which the wastes pass en route to the disposal area.

(2) Gaseous radwaste system - One gaseous radwaste system is provided for each unit. Each system, as originally designed, collects and processes gaseous radioactive wastes from the main condenser air ejectors, the startup vacuum pumps, and the gland seal condensers. The processed gases from each unit are routed to the plant stack for dilution and elevated release to the

atmosphere. Each air ejector offgas line at the stack is continuously monitored by radiation monitors.

Gaseous radwaste consists mostly of the many isotopes of the inert gases krypton and xenon which result only from leaky fuel. In addition, a small amount of volatile iodine may be present, as well as radioactive gaseous products resulting from nuclear reactions with the reactor water and with air dissolved in the water.

The activity leaving the stack is substantially below that leaving the reactor because of decay in transit and the fact that part of the N-13 and N-16 and most of the O-19 remain with the condensate and do not follow the noncondensibles. Other radioactive gases which may also be present are H-3, N-17, Ar-37, and Ar-41. These will be present in amounts so low that they are insignificant when compared with the N-13. About one percent of the activity arriving in the primary steam at the turbine will go to the gland seal condensate.

Gases routed to the plant stack include air ejector and gland seal offgases and gases from the standby gas treatment system. Dilution air is provided by fans within the plant stack. Dilution air input to the stack is required to dilute the hydrogen concentration in the stack gas to less than 4 percent by volume.

The stack is designed to enable prompt mixing of all gas inlet streams in the base and to allow location of sample points as near the base as possible. Stack drainage is routed to the liquid radwaste collection system via a submerged inlet sump. Design values for volume releases from a single unit are given below:

Hydrogen (from Reactor Water Decomposition)	154 ft^3/min
Oxygen (from Reactor Water Decomposition)	77 ft^3/min
Air (Inleakage to Turbine Condenser)	12 - 28 ft^3/min
Water Vapor (to Saturate)	43 - 46 ft^3/min
Activated and Noble Gases	Negligible
Total Gases	286 - 305 ft^3/min

In the absence of fuel rod leaks, N-13 from the air ejector offgases and the N-16 and O-19 from the gland seal system are the principal contributors to environs radiation dose. If fuel rod leaks do occur, the noble radioactive gases, Xe and Kr, become the principal contributors.

(a) Air ejector offgas subsystem - As originally designed, the air ejector subsystem collects gases from the condensers and passes them through holdup piping and filters prior to release to the stack. The 30-minute holdup is provided by means of a long, large-diameter pipe. The pipe is buried underground to provide shielding.

The air ejector offgases are processed through either one of the two particulate filter trains at a time. The other filter train that is not being used provides redundancy to ensure the availability of filters at all times. These filters have a design efficiency of 99.95 percent for particles 0.3 micron and larger.

When the maximum permissible radioactivity concentration in the offgas line is exceeded at the monitoring point, a valve in the line near the stack closes automatically after 15 minutes unless the operator acts to reduce the concentration. This prevents release of excessive radioactivity to the atmosphere.

(b) <u>Gland seal offgas subsystem</u> - The gland seal offgas subsystem collects gases from the gland seal condenser and the mechanical vacuum pumps and passes them through holdup piping prior to release to the stack. This subsystem provides a 1.75-minute holdup time to allow decay of N-16 and O-19. The holdup time if provided by a long, large-diameter pipe between the gland seal exhauster and the stack. Operating and design pressure is atmospheric; no explosive mixture is present during normal operation. No filters or radiation monitors are required.

(3) <u>Extended treatment of gaseous radwaste</u> - The gaseous radwaste system will be changed to further reduce radioactive gaseous wastes to very low levels. Hydrogen recombiners and charcoal beds will be installed in the air ejector offgas system for each unit. The offgases from each unit's air ejector will be passed through hydrogen recombiners. These react radiolytic hydrogen and oxygen to produce water, which can then be condensed and removed. Recombiners reduce the volume of the offgases by about 90 percent and thereby permit greater decay time in the holdup piping downstream of the recombiners. The principal gaseous isotopes and estimated quantities of each are shown in Table 18.

Addition of this equipment substantially increases the holdup time for radioactive noble gases, thus reducing the expected dose at the site boundary to a small fraction of that expected with the 30-minute holdup alone. The following table shows the doses calculated for the 3-unit plant with hydrogen recombiners and 6 charcoal beds installed on each unit.

As Originally Designed With 30-Minute Holdup	Stack Limit 1/	Extrapolated BWR Operating Experience 2/
Fuel Defects %/Unit	0.8	0.5
Offgas Release, Ci/sec	1.11	0.65
Site Boundary Dose, mrem/yr	500	290

Recombiners and Charcoal Beds Installed 3/		Extrapolated BWR Operating Experience 2/
Site Boundary Dose (fence post) mrem/yr	4.6	2.7
Percent 10 CFR Part 20 Limits	0.93	0.54

Releases based on a condenser air inleakage of 18.5 ft^3/min.

1/ For 30-minute holdup.

2/ Based on semiannual operating reports to AEC on BWR's.

3/ For 7.7 day holdup of Xe and 16.5 hour holdup for Kr.

This table is based on actual releases from an operating reactor of similar design to the Browns Ferry plant; it assumes three-unit operation for 365 days per year. The calculations do not take credit for the fact that units are out of service for some periods during the year.

The timing of the completion of the recombiner charcoal bed installation in the air ejector offgas subsystem is not firm, but the work cannot be completed in time to be ready for startup of the first unit. The tentative schedule is for the equipment to be installed and operational before startup at the beginning of the second fuel cycle on Unit 1. Based on BWR operating experience, it is expected that the plant can begin operation while the design and installation of the extended gas treatment system is being completed.

(4) Liquid radwaste system - The liquid radwaste system as originally designed collects, treats, and returns processed radioactive liquid wastes to the plant for reuse. Treated radioactive wastes not suitable for reuse are discharged from the plant or packaged for offsite disposal.

A single system, located in the radwaste building, is designed to handle the radioactive liquid wastes from all three units of the plant. The following are included in the liquid radwaste system:

1. Piping and equipment drains carrying potentially radioactive wastes;
2. Floor drain collector systems in controlled access areas and those areas which may contain potentially radioactive wastes; and
3. Tanks, piping, process equipment, instrumentation, and auxiliaries necessary to collect, process, store, and dispose of potentially radioactive wastes.

The system is divided into several subsystems so that the liquid wastes from various sources can be kept segregated and processed separately. Cross connections between the subsystems provide additional flexibility for processing of the wastes by alternate methods. The liquid radwastes are classified, collected, and treated as either high purity, low purity, chemical, or detergent wastes.

(a) High purity wastes - High purity (low conductivity) liquid wastes are collected in the waste collector tank, and then processed by filtration and ion exchange through the waste filter and waste demineralizer. After processing, the waste is pumped to a waste sample tank where it is sampled and then, if satisfactory for reuse, transferred to the condensate storage tank to be recycled as makeup water. If the analysis of the sample reveals water of high conductivity (>1 μmho/cm) or high radioactivity concentration ($>10^{-3}$ μCi/ml), it is returned to the system for additional processing.

(b) Low purity wastes - Low purity (high conductivity) liquid wastes are collected in the floor drain collector tank. These wastes generally have low concentrations of radioactive impurities. Processing consists of filtration and subsequent transfer to the floor drain sample tank for sampling and analysis. If the analysis indicates that the concentration of radioactive contaminants is sufficiently low, the sample tank batch is released to the condenser circulating water as necessary to meet plant effluent requirements. Because no radium-226 or radium-228 of plant origin will be present, and because the potential concentration of iodine-129 is very low, a value of $10^{-7} \mu Ci/ml$ above the background is taken as discharge conduit concentration limit for an unidentified mixture of radioisotopes. It is expected that a substantial fraction of the liquid entering the floor drain system will be of low conductivity. This liquid will be transferred to the high purity system for processing by demineralization.

(c) <u>Chemical wastes</u> - Chemical wastes are collected in the chemical waste tank and are of such high conductivity as to preclude treatment by ion exchange. The radioactivity concentrations are variable and substantially affected by the use of decontamination solutions and by the amount of fission product radioactivity present. Normally, the radioactivity concentrations are low enough to meet discharge conduit concentrations limits (after dilution), and these wastes are processed by filtration and dilution in the same manner and with the same equipment as the low purity wastes.

(d) <u>Detergent wastes</u> - Detergent wastes are collected in the laundry drain tanks. These wastes are primarily from radioactive laundry operations and decontamination solutions which contain detergents. Detergent wastes are of low radioactivity concentration ($\leq 10^{-5} \mu Ci/ml$). Because these wastes will foul ion exchange resins and filter media, they are kept separate from the high and low purity wastes. They are sampled, filtered through the laundry drain filter, and discharged into the circulating water discharge conduits.

These liquid wastes are released at a rate to give an unidentified isotope concentration of not more than $10^{-7} \mu Ci/ml$ in the discharge conduits during the period of the discharge. Since the discharge occurs only part of the time, the daily average concentration in the conduits is correspondingly less. The discharge from the conduits to the environs, therefore, is less than MPC for a mixture with unidentified radioisotopes, that is, 10^{-7} μCi/ml. Mixing in Wheeler Reservoir provides additional dilution.

(e) <u>Fuel cask decontamination waste</u> - Water used in decontaminating the spent fuel shipping cask is collected in a tank in the radwaste building. The radioactivity concentration of this water should be less than 10^{-6} μCi/ml. This low activity water is filtered with the laundry drain filter and discharged.

Tritium is present in the plant effluent. However, the concentration expected in the diluted effluent is about 10^{-8} μCi/ml. The MPC for tritium in drinking water is 3×10^{-3} μCi/ml. The proposed Appendix I to 10 CFR Part 50 would require that the estimated annual average concentration of tritium prior to dilution in a natural body of water should not exceed 5×10^{-6} μCi/ml. Thus, it is evident that the tritium in the effluent from the Browns Ferry Nuclear Plant is negligible.

(5) <u>Additional processing of liquid radwaste</u> - The operation of the liquid radwaste treatment system will be modified to further reduce radioactive liquid wastes to very low levels. Because a substantial fraction of the liquids entering the floor drains is expected to be of low conductivity, it will be possible to process than by demineralization. The demineralized effluent will have a lower radioactivity content and will be recycled or discharged.

This modification of liquid radwaste treatment for Browns Ferry will result in a substantial reduction of radioactivity released in liquid effluents. Excluding the minimal quantities of tritium previously mentioned, only about 5 Ci/yr of radioactive material is expected to be released in liquid effluents from all three units. Table 19 shows the reduction in quantities of principal isotopes resulting from this modification.

2. Important pathways of exposure to man - This section covers the important pathways of exposure to man, estimated increase in environmental radioactivity levels, and potential annual doses to individuals and population groups from principal radionuclides discharged.

(1) Pathways to man - Although the amounts of radioactivity added to the environment from plant operation are small, critical exposure pathways to man have been identified in order to estimate the maximum dose to the individual and to establish the sampling requirements for the environmental radiological monitoring program. These pathways include:

1. Whole body dose from gaseous releases.
2. Drinking water from Wheeler Reservoir and from wells in the immediate vicinity of the plant.
3. Swimming, boating, fishing, or walking along the shore of the lake in the vicinity of the plant.
4. Eating fish from the lake.
5. Consuming milk and other dairy products from locations affected by the gaseous releases.
6. Eating foods grown in areas adjacent to the plant site affected by the gaseous releases.

The environmental monitoring program provides sampling necessary to determine the dose received through these critical pathways. The following items indicate the measurement made and samples collected in order to make the critical pathway-dose correlation.

1. Thermoluminescent dosimeters will be utilized to measure the whole body dose received from the gaseous emissions from the plant. The results from these dosimeters can be compared with the calculations presented in Appendix E, Browns Ferry Nuclear Plant Final Safety Analysis Report, and other doses can be calculated in any sector at any given distance using meteorological data collected at the site. The dosimeters are located on a 500-foot grid onsite, which extends out to a distance of one mile, and at each air monitoring station offsite.

2. River water samples are collected at the point of discharge of the diffuser pipes to the river, 500 feet below this point, and at four other river cross sections, 3 miles to approximately 15 miles downstream of the site. All public water intakes receiving water from the Tennessee River within 50 miles downstream and 15 miles upstream of the plant are also collected. Private well water samples are collected from 10 locations within 4 miles, and 9 public well water supplies are sampled within a 20-mile radius of the plant. The results obtained from the analysis of these samples can be used to calculate the dose received from drinking water from Wheeler Reservoir or wells in the vicinity of the plant.

3. Results obtained from the samples referenced in Item 2 can be used to calculate the dose an individual might receive while swimming, boating, fishing, or walking along the shore of the lake in the vicinity of the plant.

4. Samples of river water, bottom sediment, plankton, and three species of fish are taken from 9 cross sections of Wheeler Reservoir. These samples will be correlated to determine the dose received by an individual eating fish obtained from Wheeler Reservoir.

5. &6. Samples of air particulate matter are collected continuously on fiber glass filters and gum paper trays at 12 locations out to a distance of 35 miles from the plant. In addition, charcoal filters are utilized at each monitor station to sample for iodine. Samples of soil, vegetation, food crops, and milk are also collected to determine dose to the surrounding population through the consumption of food or dairy products.

All samples referenced will be analyzed for the 10 most biologically significant gamma-emitting radioisotopes found in the liquid waste stream of the plant. In addition, an analysis for $^{89,90}Sr$ and ^{3}H will also be performed.

3. Estimated increase in annual environmental radioactivity levels and potential annual radiation dose from principal radionuclides - As previously noted, the releases of radioactivity to unrestricted areas from the Browns Ferry Nuclear Plant will be so low as to be unmeasurable with present measurement techniques. However, TVA has calculated the expected increase in radioactivity levels and potential radiation doses to the population as a result of these low-level releases. These calculations, by necessity, were based on the following very conservative assumptions.

(a) All three reactors operate at full power, 365 days per year, with 0.8 percent failed fuel.

(b) All persons within a four-mile radius of the plant drink water having the same radioactivity concentrations as that in the plant effluent, before dilution (no public water supplies are actually located within this four-mile zone).

(c) For estimation of individual doses, the hypothetical individual is assumed to be located at the highest dose point on the site boundary, 24 hours a day, 365 days per year.

Based on these conservative assumptions, estimated quantities and concentrations of radioactivity released to the environment and calculated radiation doses to the population are summarized as follows:

ESTIMATED QUANTITIES AND CONCENTRATIONS OF RADIOACTIVITY RELEASES AND CALCULATED RADIATION DOSES BROWNS FERRY NUCLEAR PLANT

	Browns Ferry	Proposed 10 CFR Part 50 Appendix I Limit
A. Liquid Effluents		
1. Annual total quantity (except tritium)	5 Ci	15 Ci
2. Annual average concentration (before dilution in Wheeler Reservoir)	1.3×10^{-9} μCi/ml	2×10^{-8} μCi/ml
3. Annual average concentration of tritium (before dilution in Wheeler Reservoir)	1×10^{-8} μCi/ml	5×10^{-6} μCi/ml
4. Annual whole-body dose to any individual (based on specific isotope identification)	1 mrem	5 mrem
B. Gaseous Effluents		
1. Annual whole-body dose to any individual	4.6 mrem	10 mrem
C. Total Annual Whole-Body Dose to any Individual	5.6 mrem	-----
D. Total Estimated Population Dose (Based on 1,360 people within the 4-mile radius)	3.0* man-rems	-----

*Annual Population doses from naturally occurring background radiation to persons within four miles of the plant is estimated to be 156 man-rems. The Browns Ferry Nuclear Plant will contribute only about 2 percent of this naturally occurring population dose.

4. Conclusion - TVA intends to use data from plant operating records, experience from other operating boiling water reactors of similar design to Browns Ferry and the results of its extensive environmental monitoring program to assure that the plant is operated in accordance with TVA's environmental protection objectives. Based on the very low releases of radioactivity expected from from the Browns Ferry plant, and the calculated low doses to individuals and the general population in the vicinity of the plant, it is concluded that the Browns Ferry Nuclear Plant will operate within all applicable regulations and with a minimum risk to the health and safety of the public.

5.8 Construction Effects - The Browns Ferry plant has been under construction since September 1966, when site preparation began. Construction of units 1 and 2 began in May of 1967, and of unit 3 in August of 1968. All excavation work for structures has been completed, and 53% of the facility has been constructed. All access facilities have been constructed. The roads are still to rough grade. Asphalt surfacing will be completed in 1973.

The condenser water diffuser pipes are currently being placed in the river. The remains of the dike across the intake channel, which was used during the construction of the intake structure, is being dredged. These activities will cause some increased turbidity in the water, but it will be of short duration. Plans call for the riverside to be riprapped. Some of this work has been completed.

The remaining construction activities should not have an adverse impact on the area. Remaining chemical cleaning operations that may be required will be conducted to ensure that any liquids released have been effectively neutralized and diluted to acceptable concentrations prior to release.

A small marina has been constructed to accommodate several boats which will be used in ecological studies.

In addition, a fill has been made for the facilities to be used in the research project on the effects of heated water on aquatic life.

5.9 Aesthetics - The aesthetic design of the Browns Ferry Nuclear Plant is based on the broad principle of total environmental planning, having for its objective the creation of harmony between plant and environment.

The site is a virtually level tract along the shore of Wheeler Lake. The plant structures are grouped in a diminishing progression of scale from the reactor and turbine buildings, with their reinforced concrete bases and high, ribbed metal-sided superstructures, to the lesser service and office buildings. A berm around the base of the reactor building forms a transition between the lake shore and the concrete walls. Earth mounds provide a shield around the area used for removal of radioactive wastes. The concrete service building is a transition between the reactor and turbine building masses and the smaller steel-framed office building. A 600-foot-high hyperbolic curved concrete stack for **offgas emissions** is designed and positioned as a focal point.

Particular attention is given to site development and landscaping. Natural features of the terrain are preserved as much as possible and utilized to reduce the impact of the installation on man and environment. The plant approach and entry area is fenced to contain and channel circulation through the control points. A specially designed steel fence, of the vertical picket type, departs from the customary industrial fence of mesh and barbed wire. Roads, walks, and planting are planned to create a human scale as a pleasant and inviting setting for both employees and visitors. A visitor overlook makes use of a natural rise in the terrain for a comprehensive view of the project and the lake. The principal access highway closely follows the alignment and grade of an existing county road.

6.0 ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED

The CEQ Guidelines require a discussion of any probable adverse environmental effects which cannot be avoided, such as water or air pollution, damage to life systems, urban congestion, threats to health or other consequences adverse to the environmental goals set out in Section 101(b) of NEPA.

6.1 Water Pollution - Chemical, sanitary, and radioactive wastes will of necessity be discharged into Wheeler Reservoir. Prior to being discharged, however, various treatment is provided to ensure that all applicable standards are met and the quantities and concentrations released will be small enough to ensure that any probable adverse environmental effects are insignificant or undetectable. Additional processing of liquid radwaste will be instituted to keep releases as low as practicable. Water, aquatic life, and life systems will be monitored. Extensive studies on the effects of heated water on aquatic life will be conducted in order to detect any adverse effects.

6.2 Air Pollution - Radioactive releases in the form of gaseous wastes will be discharged into the air. Installation of hydrogen recombiners and charcoal beds will assist in holding these releases to the lowest practicable levels, consistent with current technology and feasibility of available systems. This should hold these releases to levels that will avoid significant adverse environmental effects. Careful monitoring will be conducted to ensure this result.

6.3 Damage to Life Systems - When cooling water passes through the traveling screens enroute to the condensers, fish larvae may be drawn into the intake water. At this time, it is not known the extent, if any, to which fish larvae are present near the condenser cooling water intake. Studies are under way to determine this, and, as operating experience is gained, to develop steps which could prevent or reduce the intake of fish larvae. Plankton present in the condenser cooling water will also be destroyed, in the sense that it is changed as a source of food when seasonally subjected to temperatures in excess of 96.8° F. in passing through the condensers. However, at the time when the most adverse conditions exist for plankton damage, only about 25 percent of the total riverflow passes through the condensers. Based on TVA's experience with other large thermal plants, rapid reseeding of plankton populations downstream of the condenser outfall would be expected. To the extent that this plankton serves as a food source to aquatic life, its destruction is an adverse effect which cannot be avoided.

There may be some loss of existing river bottom fauna and habitat in the immediate vicinity of the diffuser pipes, which is an adverse effect which cannot be avoided.

While these effects cannot be avoided, they are not expected to damage significantly any life system. Extensive studies to be conducted will forewarn possible adverse effects.

6.4 Threats to Health - The facility is being designed and constructed and will be operated in accordance with all applicable Federal and state regulations in order to assure that the health and safety of the public will be safeguarded.

6.5 Socioeconomic Effects - The "primary" and "secondary" social and economic impacts were covered in Section 5.0. As indicated, the total magnitude of these impacts is large; however, the distribution of residences and local material supply sources occurs over a forty-mile radius of the plant site. While this may produce temporary stress on the social infrastructure (schools, roads, housing, and similar services), it will also provide a stimulus to area economical development (jobs, attraction of visitors, etc.). There should be no severe social or economic dislocation as the project construction phases out.

6.6 Conclusion - The operation of Browns Ferry will result in some probable adverse environmental effects which cannot be avoided. However, these effects are not expected to conflict with the environmental goals set out in Section 101(b) of NEPA. If any adverse effects attributable to operation of the plant become evident through the various environmental monitoring programs, then appropriate steps will be taken to correct the situation.

7.0 ALTERNATIVES

Section 102(2)(C) of NEPA requires a discussion of alternatives to the proposed action, and Section 102(2)(D) requires an agency to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources."

Decisions leading to plans to construct the Browns Ferry facility were made in 1965-1966, four to five years prior to passage of the National Environmental Policy Act. At that time TVA made economic studies comparing nuclear with conventional fossil-fired units. These studies indicated that nuclear units offered significant economic advantages. The facility is now over 53 percent constructed, with over 90 percent of the design completed. The amount of money expended on the project through May 1971 is $354,740,000. Photographs of various parts of the construction, taken in March and April 1971, are shown in Appendix I. There are no feasible alternatives available at this time to the continued construction and operation of the Browns Ferry facility.

Even though construction on Browns Ferry began prior to passage of NEPA, TVA will, of course, comply with NEPA to the fullest extent possible at Browns Ferry.

7.1 Electric Power Purchases - To supply equivalent amounts of power and energy on a year-round basis to TVA, another large electric utility with extensive transmission interconnections would have to install generating capacity in amounts slightly greater than that of Browns Ferry, build several high capacity transmission lines to the TVA area, and transmit the power to TVA. To construct such facilities on another power system would not avoid an impact on the environmentment, but would only transfer such impact from one area to another. Even if the assumption is made that the plant locational factors and costs would be equal, the cost of transmission lines, the transmission line losses, the use of land for transmission line rights of way, and the exposure to transmission line outages would result in waste of natural resources, materials, and funds, and would provide a more costly and less reliable source of power for the TVA region than will Browns Ferry.

7.2 Alternative Generation - Planning for this capacity required that considerations be given to maintaining a practical mix of hydro, pumped-storage hydro, gas turbine, coal-fired, and nuclear generating units. The system needs, as suggested by TVA planning studies, required that the generating capacity represented by Browns Ferry be either base-loaded coal-fired units or nuclear-fueled units, and detailed consideration was given to these alternatives. Estimates of the total installed cost, assessment of the technical aspects of the offerings, and an economic evaluation were made in comparison with an alternative coal-fired unit similar to our Cumberland Steam Plant.

Because of the unavailability of natural gas and low sulfur residual fuel oil for base-load generating capacity of the magnitude of Browns Ferry, they offer no feasible alternative to the nuclear facility.

There are no sites available in the TVA service area for hydroelectric generation of this capacity.

Thus, there is no feasible alternative to the proposed construction and operation of Browns Ferry for base-load generating capacity of the size required.

7.3 Alternative Sites - The Browns Ferry site was chosen because of the proximity to large load centers and existing transmission lines, the need for added capacity in the area, and the favorable physical characteristics, including hydrology, geology, meteorology, and seismology. It is not practicable to reassess and choose an alternative site at this state in the development and construction of the Browns Ferry plant.

7.4 Alternative Heat Dissipation Methods - TVA's experience with steam plants on the Tennessee River demonstrates that dissipation of heat into the river from existing power plants has not resulted in significant adverse effects on aquatic life. The Paradise studies show the effectiveness of monitoring programs in detecting adverse effects which may develop. TVA's experience at all of its steam plants, and particularly at Paradise, indicates that a maximum temperature of 93° F., and a 10° F. rise, should adequately protect aquatic life in the Tennessee River. Comprehensive monitoring programs already started at Browns Ferry and TVA's extensive knowledge of aquatic life in

Wheeler Reservoir will enable TVA to assess any effects the cooling water discharges may have on aquatic life in Wheeler Reservoir.

Regardless of what temperature standards may finally be adopted by Alabama and approved by the Environmental Protection Agency, TVA will take such steps as are necessary to prevent the development of any significant adverse effects of the Browns Ferry plant on aquatic life.

Results of the comprehensive monitoring programs, in conjunction with the research to be conducted in cooperation with the Environmental Protection Agency outlined in Appendix IV, should provide the data necessary to fully evaluate the current thermal standards and any effects which they may have on aquatic life.

TVA is aware that Alabama may in the future, with EPA approval, tighten present standards for thermal releases. TVA will, of course, take appropriate action on a timely basis to meet any future applicable standard and to protect the aquatic environment.

Among the alternatives being studied to meet possible lower temperature standards are cooling towers for one or more of the Browns Ferry units in various combinations with the utilization of various amounts of cooling water from Wheeler Reservoir. Cooling lakes are not being considered at this time, since the geography of the area is not well suited to development of a large lake. In addition, the physical arrangement of the plant facilities is essentially complete and does not lend itself to the use of such cooling facilities.

Current studies of alternatives will permit the decision on any type of needed auxiliary cooling system to be made on a timely basis. TVA studies indicate that the maximum rise in river temperature will not exceed 5° F. with only the first power unit in service--utilizing the diffuser system with supplementary flow in Wheeler Reservoir and/or by adjustments to the power load carried by the unit. Supplementary flows and load adjustments would only be needed a very small percentage of the time.

8.0 SHORT-TERM USES VERSUS LONG-TERM PRODUCTIVITY

CEQ Guidelines call for a discussion of the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. This requires an assessment of the construction and operation of the plant for cumulative and long-term effects from the perspective that each generation is trustee of the environment for succeeding generations.

The local short-term uses of the environment are those required to construct and operate the facility. Radioactive effluents will be discharged to the environment, but will be small fractions of the 10 CFR Part 20 limits. A variety of environmental monitoring methods will be utilized to detect and evaluate any radiological impact which might lead to long-term effects in order that timely corrective action can be taken, if required. The effects of chemical and thermal discharges are expected to be negligible.

During the 35-year lifetime of the plant, the site will be used for several environmentally related activities, including recreation, forestry development, and research.

Comprehensive monitoring and studies are scheduled or under way to determine possible effects from plant operation. TVA has a wide variety of experienced personnel in many disciplines to ensure that studies are properly conducted. Experienced consultants will be engaged from time to time to examine TVA findings and to work in areas of special expertise.

These considerations ensure that the local short-term uses of the environment involved in the construction and operation of the plant will not jeopardize the long-term productivity of the environment.

9.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The CEQ Guidelines call for a discussion of any irreversible and irretrievable commitments of resources which would be involved in the construction and operation of Browns Ferry. This requires identifying the extent to which operation of the facility curtails the range of beneficial uses of the environment.

The Browns Ferry plant is located in a rural, relatively isolated and sparsely populated area. The plant will not curtail the beneficial use of land and water resources in the area.

The annual requirement for natural uranium for each reactor is approximately 200 tons of U_3O_8. Some of this uranium can ultimately be recycled for other uses. About 2,000,000 gallons of fuel oil is required for the auxiliary boilers and generators. To the extent that this fuel is consumed and not subject to being recycled to other uses, it is an irreversible and irretrievable commitment of resources. This commitment of resources will be relatively small, however, compared to the benefits obtained from the electricity which will be generated. Moreover, the dependable production of electricity is essential to the health, safety, and welfare of the people.

Since the ultimate disposition of the plant buildings and equipment has not been determined, it must be assumed that both land and construction materials are irreversibly committed. It is unlikely, however, that more than the equipment and land directly in and beneath the reactor building will be ultimately irreversibly and irretrievably committed.

LIST OF TABLES

1. Major TVA System Capacity Additions Since 1949
2. Ambient Temperature Data Decatur, Alabama
3. Ambient Temperature Data Browns Ferry Nuclear Plant
4. Precipitation Data, Athens, Alabama
5. Precipitation Data - Browns Ferry Nuclear Plant
6. Snowfall Data, Decatur, Alabama
7. Water Supplies Within 20-mile Radius of Browns Ferry
8. Statistical Data for Nearby Counties
9. Common and Scientific Names of Fishes of Wheeler Reservoir
10. Water Quality - Tennessee River Mile 277.0
11. Observed Water Temperatures - Wheeler Reservoir Tennessee River Mile 300.3
12. Observed Maximum and Minimum Temperatures Wheeler Reservoir Tennessee River Mile 305.0
13. Selected Economic Data for Three Trade Areas in Northern Alabama and South Central Tennessee
14. Tagging and Recapture Data for Five Species of Fish - Wheeler Reservoir
15. Types and Locations of Samples Collected to Monitor Preoperational and Operational Conditions in Wheeler Reservoir in Relation to Browns Ferry Nuclear Plant
16. Larval Fish Sampling Stations in Wheeler Reservoir and Weekly Sampling Schedule
17. Sampling and Analysis Schedule - Environmental Radioactivity Monitoring
18. Principal Gaseous Radionuclides and Discharge Rates from Three-Unit Plant
19. Expected Annual Radioactive Releases in Liquid Effluents Excluding Tritium
20. TVA-Built Thermal-Electric Power Plants

Table 1

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
Thomas H. Allen 1/	3	330,000	990,000	5-22-59	10-25-59
Bull Run	1	950,000	950,000	6-12-67	6-12-67
Colbert	5	2 @ 200,000	1,396,500	1-18-55	11- 7-65
		2 @ 223,250			
		1 @ 550,000			
Gallatin	4	2 @ 300,000	1,255,200	11- 8-56	8- 9-59
		2 @ 327,600			
John Sevier	4	1 @ 223,250	823,250	7-12-55	10-31-57
		3 @ 200,000			
Johnsonville	10	4 @ 125,000	1,485,200	10-27-51	8-20-59
		2 @ 147,000			
		4 @ 172,800			
Kingston	9	4 @ 175,000	1,700,000	2- 8-54	12- 2-55
		5 @ 200,000			
Paradise	3	2 @ 704,000	2,558,200	5-19-63	2-27-70
		1 @ 1,150,200			
Shawnee	10	175,000	1,750,000	4- 9-53	6-17-57
Widows Creek	8	5 @ 140,625	1,977,985	7- 1-52	2- 7-65
		1 @ 149,850			
		1 @ 575,010			
		1 @ 550,000			

1/ Leased January 1, 1965, from Memphis, Tennessee, Light, Gas, and Water Division

Table 1
(Continued)

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
TVA Hydro					
Boone	3	25,000	75,000	3-16-53	9- 3-53
Chatuge	1	10,000	10,000	12- 9-54	12- 9-54
Cherokee *	2	30,000	60,000	1-29-53	10- 7-53
Chickamauga *	1	27,000	27,000	3- 7-52	3- 7-52
Douglas *	1	26,000	26,000	8- 3-54	8- 3-54
Fontana *	1	67,500	67,500	2- 4-54	2- 4-54
Ft. Patrick Henry	2	18,000	36,000	12- 5-53	2-22-54
Guntersville *	1	24,300	24,300	3-24-52	3-24-52
Hiwassee *	1	59,500	59,500	5-24-56	5-24-56
Melton Hill	2	36,000	72,000	7- 3-64	11-11-64
Nickajack	4	24,300	97,200	2-20-68	4-30-68
Nottely	1	15,000	15,000	1-10-56	1-10-56
Pickwick *	2	36,000	72,000	10-31-52	12-31-52
South Holston	1	35,000	35,000	2-13-51	2-13-51
Wheeler *	5	32,400	162,000	3- 4-50	12-18-63
Wilbur *	1	7,000	7,000	7-19-50	7-19-50
Wilson *	6	3 @ 25,200 3 @ 54,000	237,600	1- 6-50	4-12-62

* Other units in this plant installed in period prior to 1950.

Table 1
(Continued)

MAJOR TVA SYSTEM CAPACITY ADDITIONS
SINCE CALENDAR YEAR 1949

Plant	Number of Units	Nameplate Capacity-kW Unit	Nameplate Capacity-kW Total	Commercial Operating Date First Unit	Commercial Operating Date Last Unit
Alcoa Hydro					
Bear Creek	1	9,000	9,000	4-14-54	4-14-54
Cedar Cliff	1	6,375	6,375	8-22-52	8-22-52
Chilhowee	3	16,667	50,000	8-28-57	10-18-57
Tennessee Creek	1	10,800	10,800	5-19-55	5-19-55
Corps of Engineers Hydro					
Barkley	4	32,500	130,000	1-20-66	3-30-66
Center Hill	3	45,000	135,000	12-11-50	4-11-51
Cheatham	3	12,000	36,000	11-21-59	11- 9-60
Dale Hollow *	1	18,000	18,000	11-17-53	11-17-53
Old Hickory	4	25,000	100,000	4- 9-57	12-23-57
J. Percy Priest	1	28,000	28,000	2- 3-70	2- 3-70
Wolf Creek	6	45,000	270,000	10- 6-51	8-22-52

* Other units in this plant installed in period prior to 1950.

Table 2

AMBIENT AIR

TEMPERATURE DATA
DECATUR, ALABAMA

1879-1958

Month	Avg Temp °F	Avg Max Temp °F	Avg Min Temp °F	Extreme Max Temp, °F	Extreme Min Temp, °F
December	43.7	53.0	34.3	78	- 1
January	42.9	52.3	33.4	79	- 3
February	44.6	54.9	34.4	84	-12
Winter	43.7	53.4	---	---	---
March	53.1	64.1	42.0	93	12
April	61.8	73.2	50.3	92	26
May	70.4	81.8	59.0	100	34
Spring	61.9	73.0	---	---	---
June	78.2	89.3	67.1	108	44
July	80.7	91.2	70.1	107	54
August	79.9	90.6	69.1	107	52
Summer	79.6	90.4	---	---	---
September	74.6	85.9	63.3	104	37
October	63.0	75.2	50.9	100	26
November	51.2	62.3	40.1	86	3
Fall	62.9	74.5	---	---	---
Annual	62.0	72.8	51.2	---	---

Table ?

AMBIENT AIR

TEMPERATURE DATA-BROWNS FERRY NUCLEAR PLANT

March 1967-October 1969

Month	Average Temp °F	Average Max Temp °F	Average Min Temp °F	Extreme Max Temp °F	Extreme Min Temp °F
December	44.4	58.6	25.3	71.0	16.0
January	38.7	57.0	19.5	67.0	10.0
February	38.7	58.3	26.9	67.0	13.0
Winter	40.6	57.9	---	---	---
March	50.7	66.2	31.6	84.0	21.0
April	62.8	74.4	49.6	86.0	33.0
May	67.9	77.9	56.7	89.0	40.0
Spring	60.5	72.8	---	---	---
June	76.5	83.4	62.9	97.0	54.0
July	77.4	82.6	70.2	98.0	55.0
August	75.8	82.8	67.9	99.0	48.0
Summer	76.6	82.9	---	---	---
September	68.5	75.0	57.9	89.0	37.0
October	60.3	72.8	46.6	87.0	30.0
November	48.2	60.5	31.8	78.0	24.0
Fall	59.0	69.4	---	---	---
Annual	59.2	70.7	45.6	---	---

Table 4
PRECIPITATION DATA
Athens, Alabama

1935-1969

Month	Average Number of days with 0-01 inch or more	Monthly Average (inches)	Extreme Monthly Max. (inches)	Extreme Monthly Min. (inches)	Max. in 24 hours (inches)
December	9	5.45	13.70	0.91	4.80
January	11	5.97	14.59	1.53	3.97
February	9	5.62	10.54	1.31	4.85
Winter	29	17.04	---	---	---
March	10	6.17	13.68	1.80	7.35
April	9	4.70	9.34	1.44	2.90
May	8	3.94	9.10	0.33	3.04
Spring	27	14.81	---	---	---
June	7	3.61	9.12	0.50	3.12
July	9	4.47	10.97	0.79	3.27
August	7	3.67	9.36	0.36	3.84
Summer	23	11.75	---	---	---
September	6	3.10	7.45	0.47	3.91
October	5	2.62	6.62	0.15	2.16
November	8	4.17	11.79	1.01	3.02
Fall	19	9.89	---	---	---
Annual	98	53.49	---	---	---

Table 5

PRECIPITATION DATA - BROWNS FERRY NUCLEAR PLANT

March 1967-October 1969

Month	Days with 0.01 inch or more	Monthly Average (inches)	Extreme Monthly Maximum (inches)	Extreme Monthly Minimum (inches)	Maximum in 24 hours (inches)	% of Obs with Precipitation
December	14.5	6.20	8.26	4.14	2.10	11.3
January	12.0	4.99	5.49	4.50	1.63	11.5
February	8.0	2.69	4.11	1.28	1.78	6.4
Winter	34.5	13.88	---	---	---	---
March	6.3	3.13	5.73	1.64	1.56	4.6
April	8.0	3.62	4.75	2.36	4.75	6.2
May	8.0	4.45	6.10	3.03	2.01	6.5
Spring	22.3	11.20	---	---	---	---
June	5.3	1.25	2.14	0.70	1.27	2.0
July	10.0	4.82	7.27	3.23	1.70	4.9
August	11.0	4.96	9.16	1.83	2.76	5.9
Summer	26.3	11.03	---	---	---	---
September	7.0	1.99	2.99	0.70	0.93	5.0
October	6.0	2.38	2.59	2.06	1.23	3.2
November	13.0	4.11	5.34	2.88	1.55	9.1
Fall	26.0	8.48	---	---	---	---

Table 6

SNOWFALL DATA
DECATUR, ALABAMA

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Average Snowfall (inches)	0.9	0.8	0.2	T	0	0	0	0	0	T	0.2	0.6	2.7
Average No. Days (trace or more)	1	1	1	*	0	0	0	0	0	*	*	1	6
Average No. Days (0.1 inch or more)	*	*	*	0	0	0	0	0	0	0	*	*	1

T - trace (not measurable)

* - less than one day

Table 7

WATER SUPPLIES WITHIN 20-MILE RADIUS OF BROWNS FERRY AND SUPPLIES TAKEN FROM TENNESSEE RIVER BETWEEN DECATUR AND COLBERT STEAM PLANT

Ref. No.	Public Water Supply	Distance From Site (Miles)[1]	Estimated Population Served[2]	Maximum Demand	Source
1.	Andrell Girl Scout Camp	10.2	220	5,500	Ground
2.	Athens[3]	10.5	16,300	1,900,000	Ground
3.	Chalybeate Jr. High School	13.3	300	7,500	Ground
4.	Clements High School	8.0	650	16,000	Ground
5.	Colbert Steam Plant[3]	49.0	350	65,000	Surface (TRM 245.0)
6.	Courtland[3]	11.6	1,780	40,000	Ground
7.	Decatur[3]	12.0	42,600	17,000,000	Surface (TRM 306.0)
8.	E. Limestone High School	17.2	800	20,000	Ground
9.	Elkmont[3]	17.2	390	15,000	Ground
10.	Fisherman's Resort	17.0	100	2,200	Ground
11.	Hartselle[3]	16.5	11,400	833,000	Surface (Flint Creek Mile 12.3)
12.	Hatton Elementary School	19.6	160	3,100	Ground
13.	Lawson's Trailer Court	9.4	160	10,000	Ground
14.	Lucy Branch Park	8.0	170	700	Ground
15.	Midway Elementary School	13.0	150	3,800	Ground

1. Radial distance to ground supplies (and Flint Creek intake for Hartselle) and river mile distance (from mile 294.0) to surface supplies.

2. For municipal water supplies the population served was estimated by multiplying the number of meters by 3.75.

3. Municipal supply or TVA supply.

Table 7
(Continued)

WATER SUPPLIES WITHIN 20-MILE RADIUS OF BROWNS FERRY AND SUPPLIES TAKEN FROM TENNESSEE RIVER BETWEEN DECATUR AND COLBERT STEAM PLANT

Ref. No.	Public Water Supply	Distance From Site (Miles)[1]	Estimated Population Served[2]	Maximum Demand	Source
16.	Moulton[3]	18.7	2,775	400,000	Ground
17.	Moulton Heights Jr. High School	8.7	200	5,100	Ground
18.	Neel Elementary School	15.8	120	3,100	Ground
19.	New Hope Jr. High School	18.0	260	6,400	Ground
20.	Owens Jr. High School	12.0	450	11,000	Ground
21.	Piney Chapel Jr. High School	15.2	440	11,000	Ground
22.	Pleasant Grove Elementary School	9.7	100	2,600	Ground
23.	Priceville High School	17.7	900	22,000	Ground
24.	Pryor Branch Rest Area	9.5	270	800	Ground
25.	Rogersville[3]	13.0	1,433	150,000	Ground
26.	Sheffield[3]	39.7	16,300	2,407,000	Surface (TRM 254.3)
27.	South Limestone Water and Fire Protection Authority[3]	16.7	610	40,000	Ground
28.	S.W. Center Elementary School	8.5	190	4,700	Ground

1. Radial distance to ground supplies (and Flint Creek intake for Hartselle) and river mile distance (from mile 294.0) to surface supplies.

2. For municipal water supplies the population served was estimated by multiplying the number of meters by 3.75.

3. Municipal supply or TVA supply.

Table 7
(Continued)

WATER SUPPLIES WITHIN 20-MILE RADIUS OF BROWNS FERRY AND SUPPLIES
TAKEN FROM TENNESSEE RIVER BETWEEN DECATUR AND COLBERT STEAM PLANT

Ref. No.	Public Water Supply	Distance From Site (Miles)[1]	Estimated Population Served[2]	Maximum Demand	Source
29.	Speake High School	19.5	500	13,000	Ground
30.	Spring Creek Dock	9.8	120	4,400	Ground
31.	Tanner High School	9.8	780	20,000	Ground
32.	Tennessee Valley High School	5.0	400	10,000	Ground
33.	Town and Country Motel	10.0	200	3,100	Ground
34.	Town Creek[3]	17.0	1,594	50,000	Ground
35.	Trinity[3]	7.0	780	80,000	Ground
36.	West Limestone High School	15.5	550	14,000	Ground
37.	Wheeler Dam[3]	19.1	50	72,000	Surface (TRM 274.9)
38.	Wilson Dam (National Fertilizer Development Center[3])	34.6	2,500	4,000,000	Surface (TRM 259.4)

1. Radial distance to ground supplies (and Flint Creek intake for Hartselle) and river mile distance (from mile 294.0) to surface supplies.

2. For municipal water supplies the population served was estimated by multiplying the number of meters by 3.75.

3. Municipal supply or TVA supply.

Table 8

STATISTICAL DATA FOR NEARBY COUNTIES

Employment - 1960	MORGAN	MADISON	LIMESTONE	LAWRENCE
Agriculture	1,852	3,305	2,765	2,099
Forestry and Fisheries	183	23	44	11
Mining	39	33	8	14
Construction	1,888	2,789	1,116	677
Manufacturing	6,161	13,637	2,304	1,315
Transportation	527	636	264	121
Communication	332	382	118	16
Utilities	163	303	79	156
Wholesale and retail trade	3,219	6,220	1,784	760
Finance, insurance, and real estate	594	859	151	59
Business and personal services	1,893	3,853	1,094	478
Entertainment and recreation services	92	186	35	24
Hospitals	426	390	135	33
Education services	838	1,807	566	282
Welfare and nonprofit organizations	212	335	75	6
Professional and related services	345	866	122	49
Public administration	726	2,117	494	224
Industry not reported	477	741	127	123
Total Employment	19,961	38,482	11,281	6,437

Table 8
(Continued)

STATISTICAL DATA FOR NEARBY COUNTIES

	COUNTIES			
Agricultural Use - 1964	MORGAN	MADISON	LIMESTONE	LAWRENCE
Total farmland (acres)	212,124	335,534	277,443	250,804
Number of farms	2,156	1,949	2,025	1,951
Percent of total land	57.7	65.3	79.5	57.1
Cropland harvested	1,738	1,695	1,741	1,623
Value of Products Sold - 1964 (Dollars)				
(Commercial farms only)				
Crops	4,534,577	13,841,386	10,344,299	8,214,073
Poultry & poultry products	4,411,756	653,119	1,737,650	2,751,190
Dairy products	761,844	954,294	885,537	593,183
Other livestock	3,354,374	1,701,699	1,267,874	1,063,890
Total	13,063,734	17,159,501	14,239,710	12,624,637
Livestock & Poultry on Farms - 1964 (Number)				
Cattle and calves	34,568	43,869	32,512	30,959
(milk cows)	(3,366)	(3,627)	(3,940)	(3,221)
Sheep and lambs	430	211	178	17
Hogs and pigs	13,888	14,599	9,264	11,467
Chickens (4 months old and older)	344,899	121,344	258,883	280,806
Manufacturing Employment - 1966 (by place of work)	9,239	12,421	1,022	1,049

Table 9 Common and scientific names* of fishes of Wheeler Reservoir

Game

Largemouth bass - Micropterus salmoides
Smallmouth bass - Micropterus dolomieui
Spotted bass - Micropterus punctulatus
White bass - Morone chrysops
Yellow bass - Morone mississippiensis
White crappie - Pomoxis annularis
Black crappie - Pomoxis nigromaculatus
Bluegill - Lepomis macrochirus
Warmouth - Lepomis gulosus
Longear sunfish - Lepomis megalotis
Green sunfish - Lepomis cyanellus
Redear sunfish - Lepomis microlophus
Rock bass - Ambloplites rupestris
Sauger - Stizostedion canadense

Rough

Longnose gar - Lepisosteus osseus
Shortnose gar - Lepisosteus platostomus
Spotted gar - Lepisosteus oculatus
Skipjack herring - Alosa chrysochloris
Mooneye - Hiodon tergisus
Bigmouth buffalo - Ictiobus cyprinellus
Smallmouth buffalo - Ictiobus bubalus
Channel catfish - Ictalurus punctatus
Flathead catfish - Pylodictis olivaris
Carp - Cyprinus carpio
Drum - Aplodinotus grunniens
Spotted sucker - Minytrema melanops
Hog sucker - Hypentelium nigricans
Golden redhorse - Moxostoma erythrurum
Black redhorse - Moxostoma duquesnei
River redhorse - Moxostoma carinatum
Blue catfish - Ictalurus furcatus
Paddlefish - Polyodon spathula

Forage

Threadfin shad - Dorosoma petenense
Gizzard shad - Dorosoma cepedianum
Orange spotted sunfish - Lepomis humilis
Logperch - Percina caprodes
Brook silversides - Labidesthes sicculus
Golden shiner - Notemigonus crysoleucas
Emerald shiner - Notropis atherinoides
Bluntnose minnow - Pimephales notatus
Fantail darter - Etheostoma flabellare
Blackstripe topminnow - Fundulus notatus

*According to American Fisheries Society Special Publication No. 6, 1970.

Table 10
WATER QUALITY - TENNESSEE RIVER MILE 277.0

Date	Time CS 24-hr. Clock	Location in Stream	Depth	Coliforms Total	Coliforms Fecal	Water Temp.	DO	5-day 20°C BOD	Color	Turb.	Threshold Odor	Org.N	Nitrogen NH_3-N	Nitrogen NO_2-N	Nitrogen NO_3-N	Phosphates Sol.	Phosphates Tot.
1965			ft.	MPN/100 ml		°C.	mg/l	mg/l	PCU	JCU	No.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1-19	1410	Middle	1	2,300	130	5.7	-										
	1412		10			5.5	11.2										
	1416		20			5.4	11.2										
	1418		30			5.4	11.3										
	1421		40			5.4	11.3										
	1425		45			5.4	11.2										
	1426		Comp.*			-	-	2.3	5	43	0.0	0.09	0.05	0.00	0.03	0.06	0.20
2-11	0644	Middle	1**	360	160	-	-										
	0645		1			7.6	11.2										
	0647		10			7.6	11.1										
	0649		20			7.5	11.0										
	0651		30			7.3	11.2										
	0653		40			7.1	11.2										
	0654		Comp.*			-	-	1.5	5	25	0.0	0.10	0.02	0.00	0.20	0.10	0.12
3-19	0927	Middle	1			9.3	10.8										
	0929		10			9.3	10.9										
	0933		20			9.3	10.9										
	0938		25			9.3	10.9										
	0943		30			9.3	10.6										
	0946		40			9.3	11.0										
	0950		50			9.3	10.7										
	0951		Comp.*			-	-	1.6	5	26	0.0	0.00	0.18	0.01	0.02	0.14	0.17
	0952		1**	110	6	-	-										
4-22	0640	Middle	1			19.6	10.4										
	0642		10			19.5	10.3										
	0643		20			19.4	10.3										
	0644		30			18.6	9.6										
	0646		40			18.1	8.6										
	0649		46			17.7	-										
	0651		Comp.*			-	-	3.7	15	25	0.0	0.10	0.08	0.00	0.08	0.10	0.22
	0710		1**	110	<2.3	-	-										
Maximum				3,600	940	20.2	11.3	4.6	15	91	2.0	0.58	0.18	0.01	0.24	0.51	0.95
Minimum				<2.3	<2.3	5.4	4.9	0.9	0	7	0.0	0.00	0.00	0.00	0.00	0.09	0.06

Date	Time CS 24-hr. Clock	pH	Alkalinity $CaCO_3$ Phen.	Alkalinity $CaCO_3$ Tot.	Total Hardness $CaCO_3$	Ca	Mg	Cl	Na	K	Fe, Total	Mn, Total	SO_4	SiO_2	Specific Conductance at 25°C.	Solids Sus.	Solids Dis.	Solids Tot.
1965			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	mg/l	mg/l	Micromho/cm	mg/l	mg/l	mg/l
1-19	1426	7.6	0	48	71	22.4	3.8	19	7.00	0.83	720	60	23	5.3	196	16	127	143
2-11	0654	7.8	0	49	70	20.6	4.6	13	5.40	0.70	480	0	13	5.4	145	15	109	124
3-19	0951	7.7	0	52	74	21.3	5.1	13	5.05	0.40	280	0	12	5.9	167	22	105	127
4-22	0640	8.1	0	46														
	0643	8.0	0	57														
	0646	7.7	0	54														
	0651	-	-	-	[illegible]	[illegible]	2.9	6	2.21	0.76	790	0	10	4.8	152	3	88	91
Maximum		8.1	0	54	[illegible]	[illegible]	5.1	23	[illegible]	1.33	3,680	600	[illegible]	6.5	[illegible]	116	137	236
Minimum		6.9	0	28	48		1.9	4	1.88	0.40	70	0	9	1.2	114	2	67	75

*Surface, mid-depth, bottom composite.
**Surface bacteriological only.

Table 10 (Continued)

WATER QUALITY - TENNESSEE RIVER MILE 277.0

BFNP

Date	Time CS 24-hr. Clock	Location in Stream	Depth	Coliforms Total	Coliforms Fecal	Water Temp.	DO	5-day 20°C. BOD	Color	Turb.	Threshold Odor	Org.N	Nitrogen NH_3-N	Nitrogen NO_2-N	Nitrogen NO_3-N	Phosphates Sol.	Phosphates Tot.	pH	Alkalinity $CaCO_3$ Phen.	Alkalinity $CaCO_3$ Tot.	Total Hardness $CaCO_3$	Ca	Mg	Cl	Na	K	Fe, Total	Mn, Total	SO_4	SiO_2	Specific Conductance at 25°C.	Solids Sus.	Solids Dis.	Solids Tot.
1964			ft.	MPN/100 ml		°C.	mg/l	mg/l	PCU	JCU	No.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	mg/l	mg/l	Micromho/cm	mg/l	mg/l	mg/l
5-5	0750	Middle	1	3,600	620	18.5	8.1	1.9	0	29	0.0	0.03	0.00	0.00	0.00	0.25	0.51	7.6	-	40	48	15.9	1.9	5	2.05	1.03	1,020	60	11	5.7	114	24	75	99
	0800		10			18.5	8.0																											
	0805		20			18.4	7.9																											
	0810		25			18.3	8.0	1.2	0	32	0.0	0.58	0.01	0.01	0.11	0.51	0.95	7.5	0	40	48	15.8	2.0	5	1.88	0.99	960	30	11	4.6	116	31	69	100
	0820		30			18.3	7.9																											
	0825		40			18.2	7.8																											
	0835		50			18.1	7.7	1.3	0	91	0.0	0.14	0.00	0.01	0.05	0.18	0.45	7.4	0	44	52	17.6	1.9	4	2.16	0.95	690	50	9	5.6	123	72	76	148
6-2	1520	Middle	1	<2.3	<2.3	25.0	8.0	3.8	10	14	0.0	0.01	0.00	0.00	0.00	0.02	0.06	8.0	0	38	54	14.7	4.1	7	2.48	1.33	230	30	16	3.8	118	17	67	84
	1524		10			24.8	7.9																											
	1528		20			23.9	7.6	2.3	10	13	0.0	0.00	0.00	0.00	0.02	0.00	0.06	7.9	0	37	49	14.4	3.2	7	2.16	0.88	300	0	16	4.3	115	6	69	75
	1536		30			23.7	6.9																											
	1540		40			23.6	6.9																											
	1545		45			23.6	6.8	2.2	10	14	0.0	0.00	0.00	0.00	0.00	0.06	0.08	7.5	0	37	54	14.1	4.6	6	2.16	0.99	460	220	14	4.3	120	48	72	120
7-8	1445	Middle	1	<2.3	<2.3	28.3	7.4	4.6	10	7	0.0	0.56	0.00	0.00	0.01	0.06	0.07	7.7	0	44	53	18.1	3.1	12	4.89	0.70	70	0	17	5.7	164	5	98	103
	1455		10			28.2	7.3																											
	1505		20			28.1	7.1	3.3	5	64	1.0	0.33	0.00	0.00	0.24	0.03	0.08	6.9	0	28	60	18.0	3.6	23	4.89	0.70	80	0	17	5.6	169	116	120	236
	1515		30			27.6	7.1																											
	1525		40			27.2	6.9	3.7	10	9	2.0	0.40	0.03	0.00	0.00	0.08	0.14	7.8	0	44	59	18.5	3.2	12	5.05	0.70	70	0	16	5.4	159	7	96	103
8-13	1300	Middle	1	5	<2.3	29.2	6.5	2.3	5	7	0.0	0.25	0.00	0.00	0.00	0.03	0.08	7.4	0	49	70	22.3	3.5	18	6.62	0.70	240	140	22	1.2	132	10	116	126
	1305		10			29.0	6.2																											
	1310		20			28.9	5.7																											
	1315		30			28.8	5.9	3.2	5	14	0.0	0.12	0.00	0.00	0.01	0.04	0.09	7.4	0	48	70	22.3	3.5	18	6.62	0.83	330	140	22	4.8	192	18	112	130
	1320		40			28.8	6.0																											
	1330		47			28.7	4.9	2.2	5	64	0.0	0.32	0.06	0.00	0.00	0.03	0.13	7.4	0	50	70	22.2	3.7	19	6.62	0.83	3,680	600	16	4.8	189	53	110	163
9-18	1011	Middle	1	110	3	24.4	6.8	1.1	5	13	0.0	0.07	0.00	0.00	0.00	-	0.15	7.4	0	44	68	21.1	3.6	19	8.27	0.70	600	30	22	5.0	189	33	118	151
	1015		10			24.4	6.8																											
	1020		20			24.4	6.8	0.9	5	14	0.0	0.15	0.00	0.00	0.04	-	0.10	7.4	0	45	69	21.5	3.6	19	6.62	0.70	1,060	60	16	4.9	183	19	118	137
	1030		30			24.4	6.9																											
	1045		40			24.4	6.7	1.2	5	19	0.0	0.20	0.01	0.00	0.00	-	0.18	7.3	0	44	68	21.0	3.8	19	6.47	0.70	400	90	20	4.9	185	73	115	138
10-6	0610	Middle	1	81	36	21.4	-	1.9	5	14	0.0	0.01	0.05	0.00	0.00	0.06	0.09	7.6	0	36	71	22.5	3.6	20	8.80	0.70	440	0	13	4.6	208	6	137	143
	0615		10			21.4	7.3																											
	0619		20			21.4	7.3																											
	0624		25			21.5	7.4	1.7	5	14	0.0	0.02	0.00	0.01	0.01	0.05	0.11	7.6	0	44	72	22.3	3.9	20	8.80	0.70	460	0	13	4.0	204	19	128	147
	0627		30			21.5	7.4																											
	0630		40			21.5	7.3																											
	0635		48			21.5	7.2	1.6	5	14	0.0	0.04	0.02	0.01	0.01	0.05	0.10	7.7	0	46	71	22.7	3.5	20	8.80	0.70	580	0	13	4.6	264	9	134	143
11-23	1504	Middle	1	940	940	14.0	8.9																											
	1509		10			14.0	8.9																											
	1514		20			14.0	8.8																											
	1518		30			14.0	8.7																											
	1521		40			14.0	8.9																											
	1525		45			14.0	8.8																											
	1526		Comp.*			-	-	2.0	5	20	0.0	0.17	0.02	0.00	0.00	0.10	0.37	7.3	0	40	57	17.5	3.2	13	8.44	0.83	880	140	16	6.5	161	28	112	140
12-15	0625	Middle	1	1,100	230	9.7	9.9																											
	0630		10			9.7	10.0																											
	0633		20			9.7	10.1																											
	0637		30			9.7	10.1																											
	0640		40			9.7	10.0																											
	0641		Comp.*			-	-	1.7	5	14	0.0	0.12	0.00	0.00	0.00	0.10	0.15	7.4	0	43	64	20.0	3.5	16	7.00	0.83	780	30	12	6.2	172	2	129	131

*Surface, mid-depth, bottom composite.

Table 11

OBSERVED WATER TEMPERATURES - WHEELER RESERVOIR TENNESSEE RIVER MILE 300.3

May 1964 to May 1965

Date	Distance From Right Bank % of Width	Surface--1 ft Depth Temperature ° F	Bottom Temperature ° F	Bottom Depth, ft
May 6, 1964	33.3	66.0	65.7	(30)
	66.6	65.8	65.7	(30)
June 2, 1964	33.3	74.5	73.9	(25)
	66.6	74.5	73.9	(30)
July 8, 1964	33.3	83.1	81.9	(25)
	66.6	82.8	81.5	(30)
August 13, 1964	33.3	82.6	80.6	(27)
	66.6	82.6	80.6	(30)
September 18, 1964	33.3	75.6	75.4	(27)
	66.6	75.7	75.7	(28)
October 6, 1964	33.3	69.3	69.1	(24)
	66.6	69.4	69.1	(35)
November 23, 1964	33.3	56.8	56.8	(25)
	66.6	57.2	57.2	(30)
December 15, 1964	33.3	49.5	49.5	(25)
	66.6	49.5	49.5	(25)

Table 11
(Continued)

OBSERVED WATER TEMPERATURES - WHEELER RESERVOIR TENNESSEE RIVER MILE 300.3

May 1964 to May 1965

Date	Distance From Right Bank % of Width	Surface--1 ft Depth Temperature ° F	Bottom Temperature ° F	Bottom Depth, ft
January 19, 1965	33.3	43.5	43.5	(22)
	66.6	43.9	43.9	(27)
February 11, 1965	33.3	46.8	46.8	(20)
	66.6	46.9	46.9	(30)
March 18, 1965	33.3	49.6	49.6	(20)
	66.6	49.6	49.6	(30)
April 22, 1965	33.3	64.7	64.8	(25)
	66.6	65.7	64.8	(34)

Table 12

OBSERVED MAXIMUM AND MINIMUM
TEMPERATURES-WHEELER RESERVOIR
TENNESSEE RIVER MILE 305.0

1938 - 1943

Calendar Year	Surface Temperature °F. * Maximum	Minimum
1938	82.9	37.2
1939	87.4	43.5
1940	83.1	34.9 **
1941	83.7	44.1
1942	82.9	42.1
1943	86.0	42.1

* Data from records, Hydraulic Data Branch, TVA.

** Temperature recorded as ice was clearing

Table 13

SELECTED ECONOMIC DATA FOR THREE TRADE AREAS IN NORTHERN ALABAMA AND SOUTH CENTRAL TENNESSEE

Trade Area	Number of Counties	1970 Population			1966 Personal Income		1967 Retail Sales		
		Trade Area	Largest County	Largest City	Trade Area	Principal County	Trade Area	Principal County	Principal City
Huntsville, Ala-Tn	6	341,141	186,540	137,802	$770,253	$595,983*	$418,374	$299,526*	$245,922
Quad-Cities, Ala-Tn	6	201,350	117,743#	47,146#	388,080	255,582#	230,704	143,016#	103,135#
Decatur, Ala	3	157,032	77,306	38,044	296,825	193,340	179,467	102,572	77,873
Totals	15	699,523	381,589	222,992	1,455,158	1,044,905	828,545	545,114	426,930

All dollar amounts are in thousands of dollars ($000's).

* Disclosure regulations of the Office of Business Economics require that income data for SMSA's be reported as a single unit. Hence, Madison and Limestone Counties are reported as the Huntsville SMSA. For the sake of comparability of data, retail sales are shown above on the same basis.

\# Due to commuting patterns between Colbert and Lauderdale Counties, principal county data include both counties while city data are for Florence and Sheffield combined.

Table 14

TAGGING AND RECAPTURE DATA FOR FIVE SPECIES OF FISH
WHEELER RESERVOIR

February 1969-January 1971

Species	Total Tagged	Returns	Percent Returns	Net Movement Returns (km)	Range (km) +	Range (km) -
Channel catfish	1,776	32	1.8	-1.3	23.3	29.0
Blue catfish	395	14	3.5	-0.9	19.3	15.3
Flathead catfish	460	46	10.0	-0.5	27.4	13.7
White crappie	823	37	4.5	+6.2	128.7	24.1
White bass	230	9	3.9	-15.5	37.0	33.8

\+ Upstream from point of release.

\- Downstream from point of release.

Table 15

TYPES AND LOCATIONS OF SAMPLES COLLECTED
TO MONITOR PREOPERATIONAL AND OPERATIONAL CONDITIONS IN WHEELER RESERVOIR
IN RELATION TO THE BROWNS FERRY NUCLEAR PLANT

TRM Station	Distance From Left Bank		Depths for Water	Depths for Zooplankton, Chlorophyll, and Phytoplankton Cell Counts	Depths for Productivity[1]	Benthic Fauna	Sediment	Fish[2]
	feet	percent	meters	meters	meters	n[3]	n	
274.90								R
	1,000	13	1,5	1,5		3		
277.98	4,000	51	(1),5	1,5		(3)	(3)	
	6,500	83	(1),3,5,(10),15	(1),3,5,(10),15	0,1,3,5	(3)	(3)	
	1,500	16	1,5	1,5		3		(T)
283.94	3,600	40	(1),5	1,5		3		
	7,100	78	(1),3,5,(10)	1,3,5,10	0,1,3,5	3		
	2,000	20	1,5	1,5		3		
288.78	4,000	41	(1),3,(5)	1,3,5	0,1,3,5	(3)	(3)	
	8,000	82	(1)	1		(3)	(3)	
	1,000	12	1	1		3		
	3,000	36	1,5	1,5		3		
291.76	5,000	60	(1)	1		3		
	7,000	84	(1),(5)	(1),3,(5)	0,1,3,5	3		
	4,450	43	1	1		3		
293.70	6,800	65	(1)	1	0,1,3,5	(3)	(3)	(T),G,R
	9,200	88	(1),3,(5),7	1,3,5,7		(3)	(3)	
293.88	6,300	80	(1),(5)	(1),(5)		(3)	(3)	

Table 15 (contd.)

TYPES AND LOCATIONS OF SAMPLES COLLECTED
TO MONITOR PREOPERATIONAL AND OPERATIONAL CONDITIONS IN WHEELER RESERVOIR
IN RELATION TO THE BROWNS FERRY NUCLEAR PLAN

TRM Station	Distance From Left Bank feet	Distance From Left Bank percent	Depths for Water meters	Depths for Zooplankton, Chlorophyll, and Phytoplankton Cell Counts meters	Depths for Productivity[1] meters	Benthic Fauna n[3]	Sediment n	Fish[2]
	2,000	22	1	1		3		
295.87	4,000	44	(1),3,(5)	1,3,5	0,1,3,5	3		
	7,500	82	(1)	1		3		
299.00								(T),G
	700	6	1	1		3		
301.06	3,200	26	(1),3,(5)	1,3,5	0,1,3,5	3		
	7,200	58	(1)	1		3		
307.52	1,800	24	(1),3,(5)	(1),3,(5)	0,1,3,5	(3)	(3)	R
	2,8C0	37	(1),5	1,5		(3)	(3)	

1. Location of lower depths depends on depth of photic zone.
2. G = gill net; T = trap net; R = rotenone.
3. Number of dredge hauls.
( ) Indicates samples for radiological analyses. Water, sediment, plankton, and benthic fauna will also be collected within 500 feet below the diffuser (TRM 293.88) and analyzed for gamma activity. Fish will be sampled at this station after the plant goes into operation.

Table 16

LARVAL FISH SAMPLING STATIONS IN WHEELER RESERVOIR AND WEEKLY SAMPLING SCHEDULE

Station		Number of Hauls Day	Number of Hauls Night
First Day's Sample			
Upstream - TRM 297-299			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6
Plant Site - TRM 294			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6
C. Intake basin (stationary net)*			
Second Day's Sample			
Downstream - TRM 284-285			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6
Elk River - ERM 4			
A. Mid-channel			
1. Surface		2	2
2. 5-meter		2	2
B. Shoreline - surface		2	2
	Total	6	6

* Sampling with stationary net in intake basin will be scheduled according to construction progress.

Table 17

SAMPLING AND ANALYSIS SCHEDULE
ENVIRONMENTAL RADIOACTIVITY MONITORING

Station Location	Air Filter	Charcoal Filter	Rain-water	Heavy Particle Fallout	Soil	Vegetation	Milk	River Water	Well Water	Public Water	Aquatic Life and Sediment
Muscle Shoals	W	BW	M	M	SA	SA	M			M	
Lawrenceburg	W	BW	M	M	SA	SA					
Fayetteville	W	BW	M	M	SA	SA					
Huntsville	W	BW	M	M	SA	SA					
Cullman	W	BW	M	M	SA	SA					
Rogersville	W	BW	M	M	SA	SA					
Athens	W	BW	M	M	SA	SA	M				
Decatur	W	BW	M	M	SA	SA	M			M	
Courtland	W	BW	M	M	SA	SA					
Site NW	W	BW	M	M	SA	SA					
Site N	W	BW	M	M	SA	SA					
Site NE	W	BW	M	M	SA	SA					

W - Weekly BW - Biweekly M - Monthly Q - Quarterly SA - Semiannually

Table 17

(Continued)

SAMPLING AND ANALYSIS SCHEDULE
ENVIRONMENTAL RADIOACTIVITY MONITORING

Station Location	Air Filter	Charcoal Filter	Rain-water	Heavy Particle Fallout	Soil	Vegetation	Milk	River Water	Well Water	Public Water	Aquatic Life and Sediment
Farm B						M	M		M		
Farm H						M	M		M		
Farm T						M	M		M		
Farm D						M	M		M		
Wheeler Dam										M	
Elk River								M			
Wheeler Reservoir								M-Q			Q

W - Weekly BW - Biweekly M - Monthly Q - Quarterly SA - Semiannually

Table 18

PRINCIPAL GASEOUS RADIONUCLIDES
AND EXPECTED DISCHARGE RATES FROM THREE-UNIT PLANT[1]

Isotope	Half Life	Probable Maximum Discharge Rate, Ci/s 6 Bed
^{83m}Kr	1.86 hr	7.1×10^{-5}
^{85m}Kr	4.4 hr	5.1×10^{-3}
^{85}Kr	10.4 yr	8.0×10^{-5}
^{87}Kr	1.3 hr	2.7×10^{-5}
^{88}Kr	2.8 hr	3.6×10^{-3}
^{89}Kr	3.2 min	---
^{131m}Xe	12.0 day	1.0×10^{-4}
^{133m}Xe	2.3 day	1.9×10^{-4}
^{133}Xe	5.27 day	2.1×10^{-2}
^{135m}Xe	15.6 min	---
^{135}Xe	9.2 hr	1.9×10^{-7}
^{137}Xe	3.8 min	---
^{138}Xe	17.0 min	---
Total		3.0×10^{-2}

[1] Extended system with hydrogen recombiners, holdup piping, and six charcoal beds and with 0.8 percent fuel defects.

Table 19

EXPECTED ANNUAL RADIOACTIVITY RELEASE IN LIQUID EFFLUENTS EXCLUDING TRITIUM[1]

Discharge Rates for Three-Unit Plant

Isotope[2]	Half-Life	Release Rate (Ci/yr)[4] System as Designed	With Add'l Processing
Sr-89[3]	50.6d	2.9×10^{-1}	3.6×10^{-2}
Sr-90[3]	28y	7.8×10^{-2}	9.8×10^{-3}
Sr-91[3]	9.7h	3.6	4.5×10^{-1}
Mo-99[3]	66h	7.7	9.6×10^{-1}
I-131	8.05d	3.6	4.5×10^{-1}
I-133	20.8h	6.0	7.5×10^{-1}
I-135	6.7h	2.7	3.4×10^{-1}
Cs-134	2.1y	3.9×10^{-2}	4.9×10^{-3}
Cs-137	30y	7.8×10^{-2}	9.8×10^{-3}
Ba-140[3]	12.8d	7.7	9.6×10^{-1}
Ce-144[3]	284d	1.0×10^{-2}	1.2×10^{-3}
Np-239	2.35d	7.8	9.8×10^{-1}
Co-58	70d	4.2×10^{-1}	5.2×10^{-2}
Co-60	5y	4.2×10^{-2}	5.2×10^{-3}
	TOTAL	40 Ci/yr	5 Ci/yr

1. Tritium releases are expected to approach about 20 Ci/yr from the plant. The distribution between gaseous and liquid wastes will depend upon the actual amount of water leaving by each route.

2. Isotopes having a half-life less than 2.3 hours were excluded because the holdup in the plant would generally be sufficient to result in negligible concentrations in released wastes. Other isotopes of the elements listed were considered. The radionuclides Zr-95, Nb-95, Ru-103, Ru-100, Te-129m, Te-132, Nd-147, Na-24, S-35, P-32, Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Cu-64, Ni-65, Zn-65, Zn-69m, Ag-110m, Ta-182, and W-187 were also considered. These radionuclides may be present, but if present will be negligible or in trace concentrations relative to those isotopes listed and were omitted from the table.

3. Daughter isotopes of Yttrium, Technetium, Lanthanum, and Praseodynium may be observed in waste samples in equilibrium with or approaching equilibrium with their parent depending upon sample and analysis timing and procedure.

4. Although two significant numbers are used in expressing the release rates as a convenience for making further calculations, only one significant figure is warranted by the source data.

TABLE 20

TVA-BUILT THERMAL-ELECTRIC POWER PLANTS

Plant	Unit Number	Normal Full Load, per Unit (megawatts)	First Year of Commercial Operation: First Unit	First Year of Commercial Operation: Last Unit	Total Plant: Thermal Rise in Condensers (°F)	Total Plant: Condenser Flow (gal/min)	Total Plant: Heat to Stream (Btu) (billions per hr)	Mean Flow of Receiving Stream (ft^3/s)
Browns Ferry	1-3	1,150	'72	'74	25	1,800,000	22.2	49,000
Bull Run	1	900	'67		18	397,900	3.6	4,310
Colbert	1-4	200	'55	'55	13	865,500	5.8	50,500
	5	500	'65					
Cumberland	1,2	1,300	'72	'73	12	1,616,000	9.3	24,000
Gallatin	1,2	250	'56	'57	16	592,400	4.7	18,000
	3,4	275	'59	'59				
John Sevier	1-4	200	'55	'57	15	454,000	3.5	3,540
Johnsonville	1-6	125	'51	'53	13	1,029,000	6.5	61,000
	7-10	150	'58	'59				
Kingston	1-4	150	'54		14	967,000	6.9	6,300
	5-9	200		'55				
Paradise	1,2	690	'63	'63	26	452,400	5.8	8,370
Shawnee	1-10	150	'53	'56	12	1,076,000	6.5	255,400
Watts Bar	1-4	60	'42	'45	10	280,800	1.5	26,400
Widows Creek	1-4	135	'52		15	1,092,400	8.2	35,200
	5,6	130		'54				
	7	525	'61					
	8	525	'65					

LIST OF FIGURES

1. Tennessee Valley Region
2. Vicinity Map - 0 to 60 Mile Radius
3. Arrangement of the Plant Site
4. Artist Concept of Browns Ferry Plant
5. Browns Ferry Plant Simplified Steam Cycle
6. Wind Rose - Browns Ferry Site
7. Location of Water Supplies
8. Faults in Region
9. Aerial Photograph of Site
10. Population Distribution Within 10-mile Radius of Browns Ferry Site
11. Diffuser System and Channel Markings
12. Diffuser System Design
13. Surface Water Temperature Studies - Temperature Vs Distance Downstream
14. Surface Water Temperature Studies - Temperature Vs Distance Upstream
15. Temperature Survey in Vicinity of Jet Ports
16. Location of Wheeler Reservoir Temperature Monitoring Stations
17. Atmospheric and Terrestrial Monitoring Network
18. Reservoir Monitoring Network
19. Trap Net and Gill Net Stations

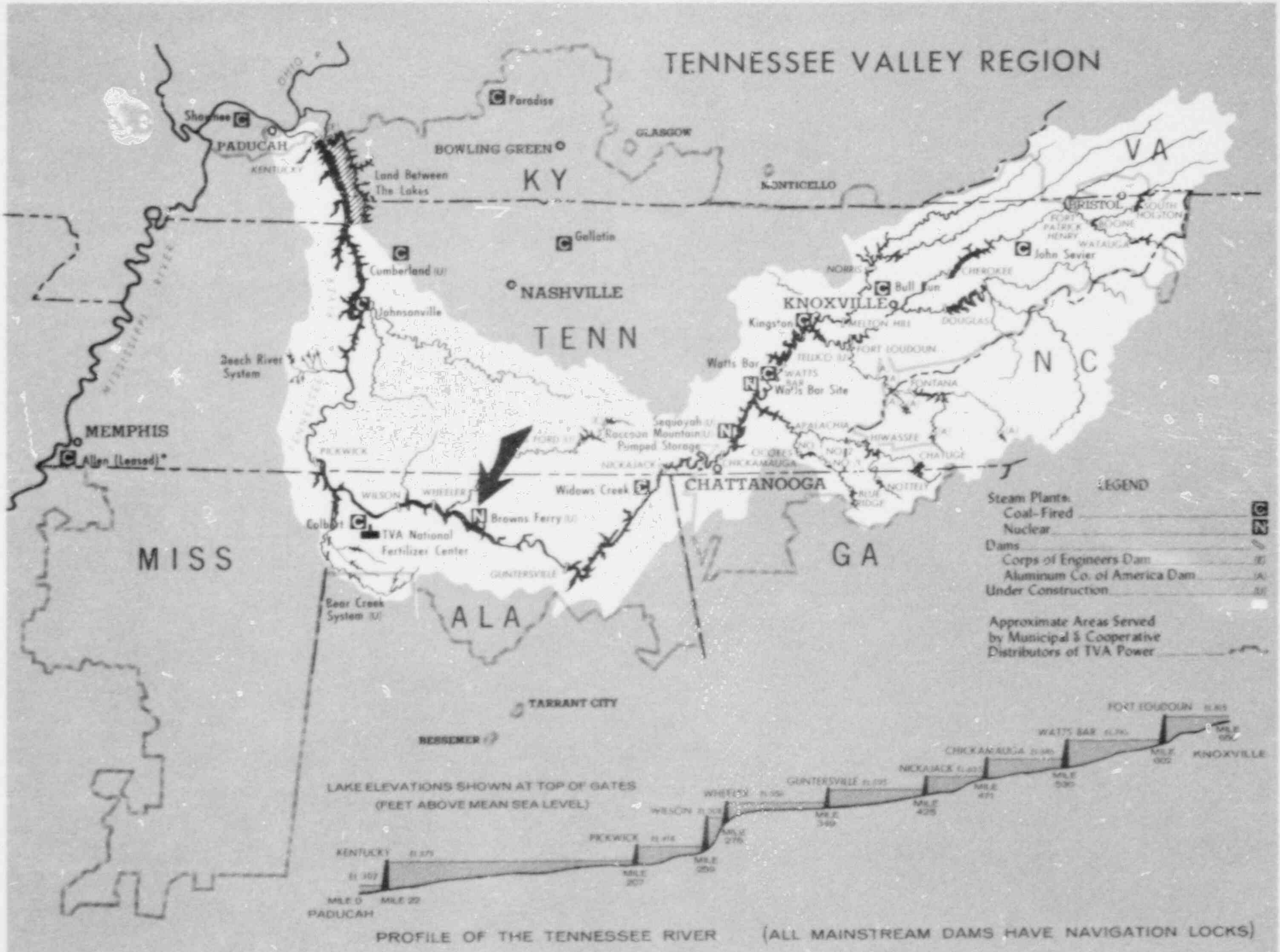


Figure 1

*Includes gas turbine installation under construction

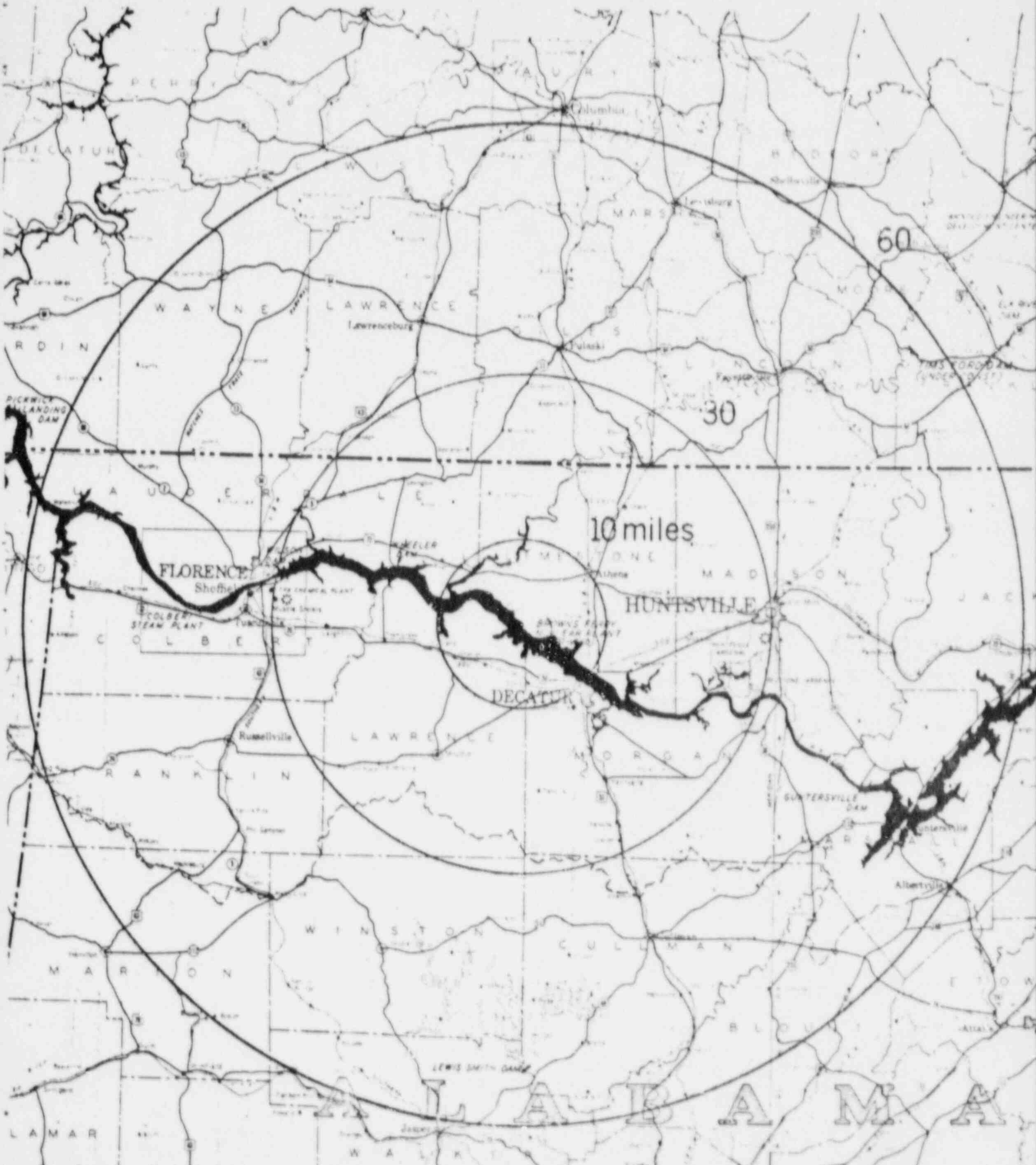


Figure 2

VICINITY MAP -- 0 TO 60 MILE RADIUS

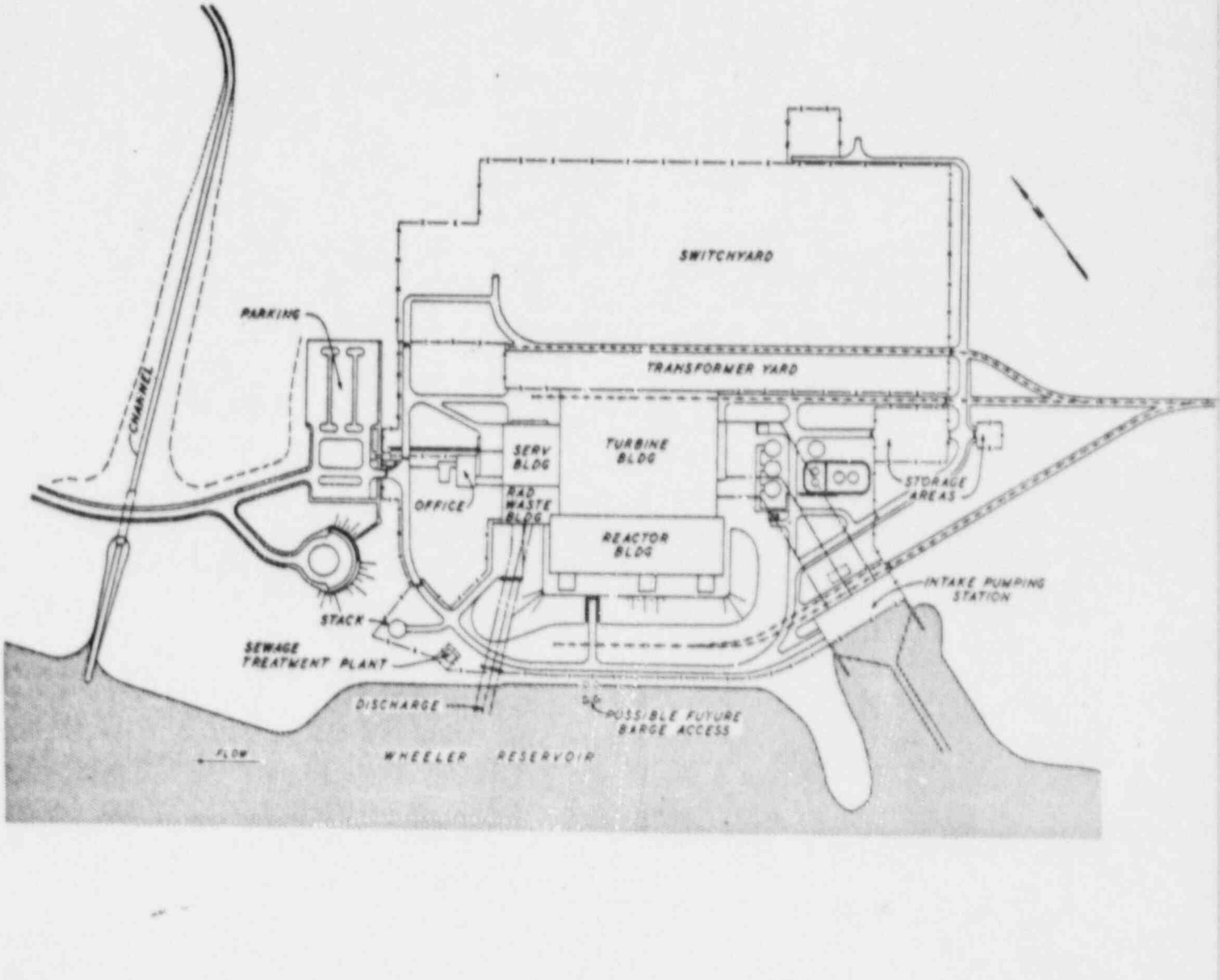


Figure 3

Arrangement of the Plant Site

Figure 4

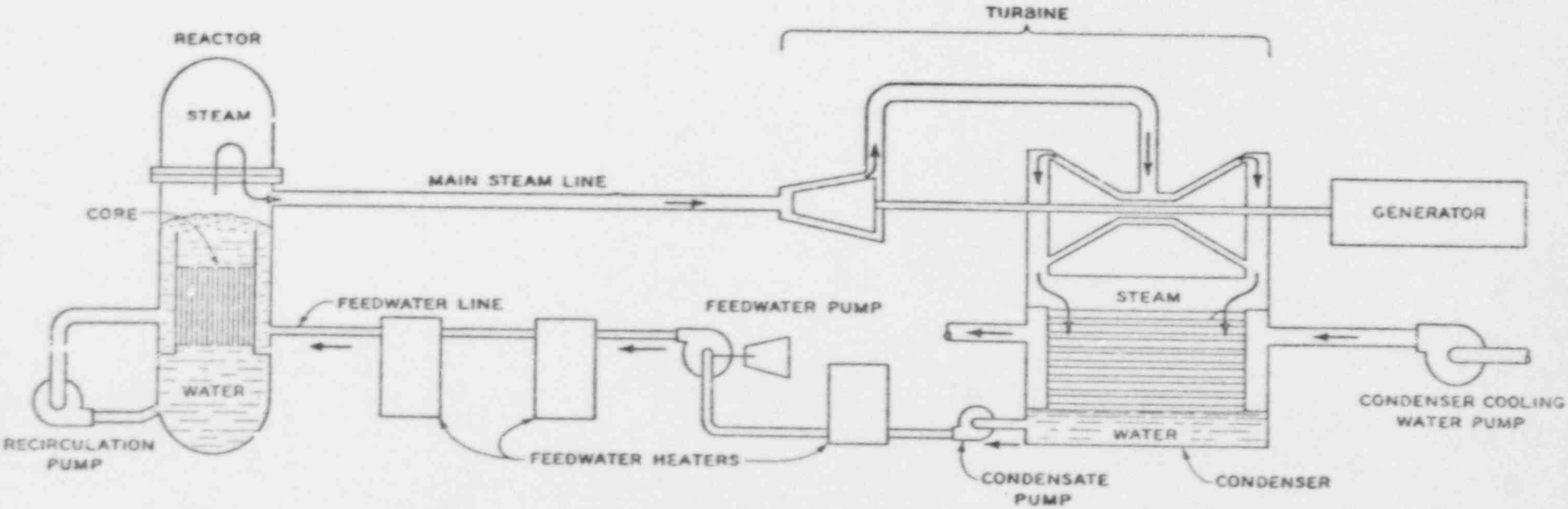


Figure 5

Browns Ferry Plant Simplified Steam Cycle

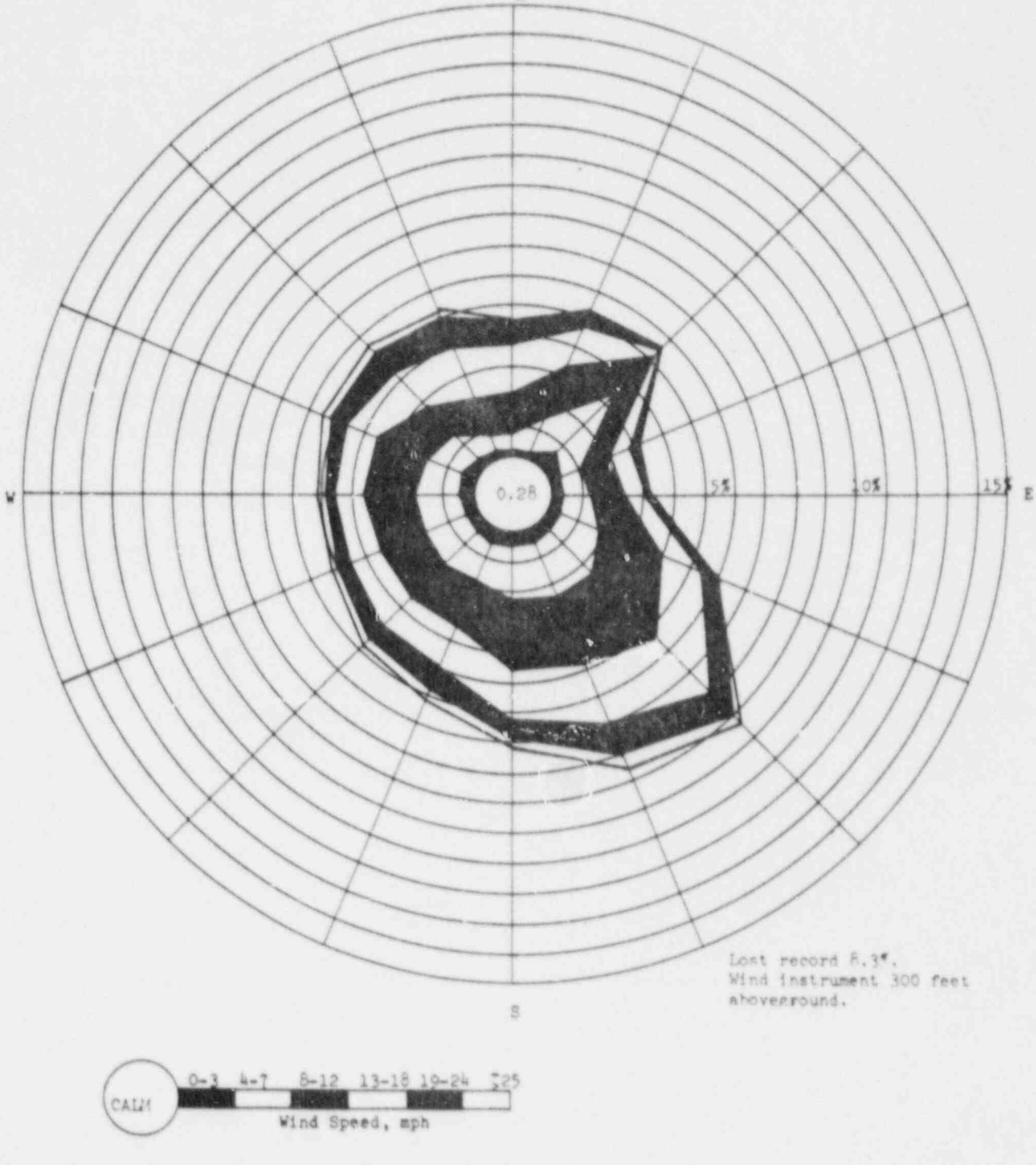


Figure 6

WIND ROSE - BROWNS FERRY SITE

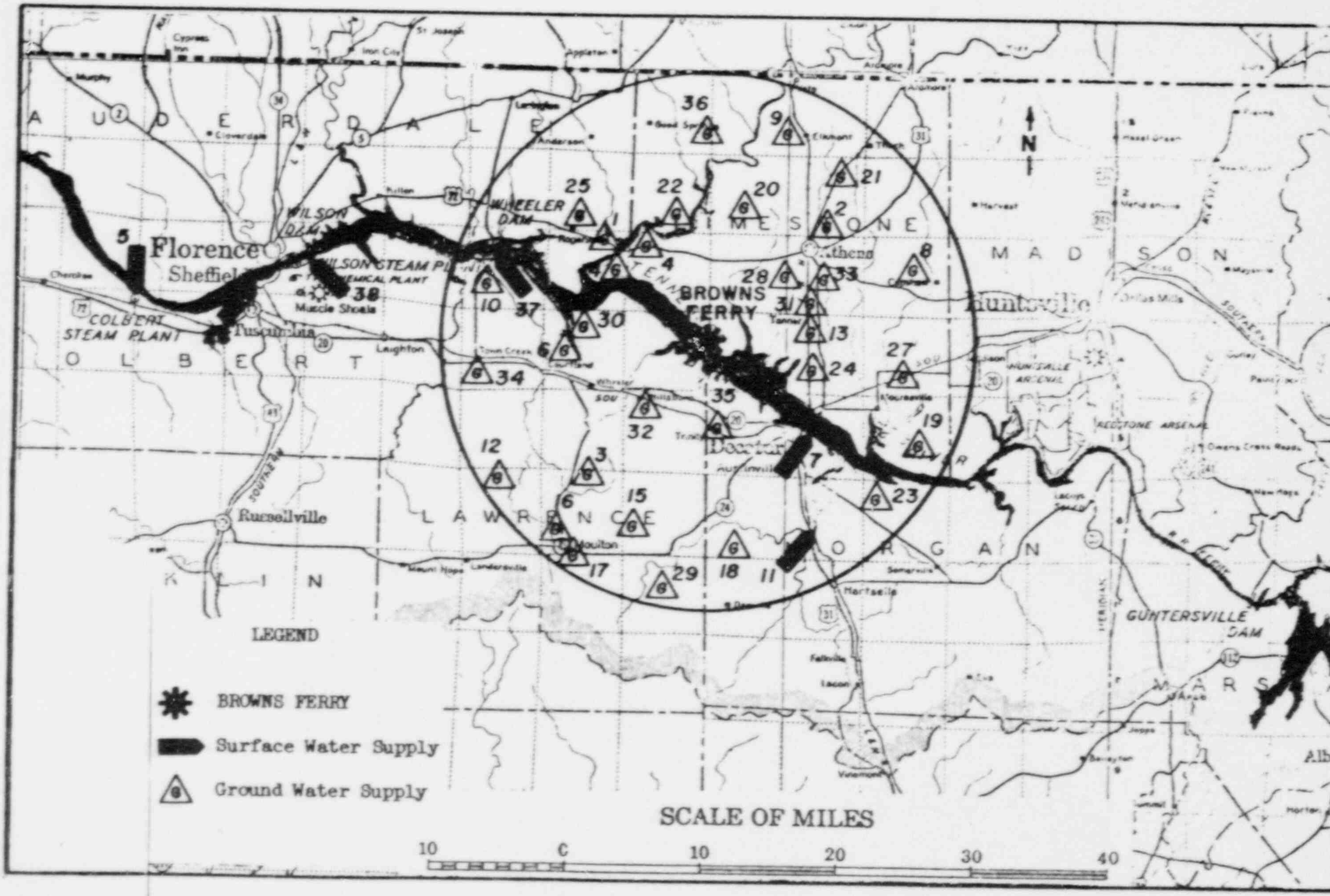


Figure 7

LOCATION OF WATER SUPPLIES

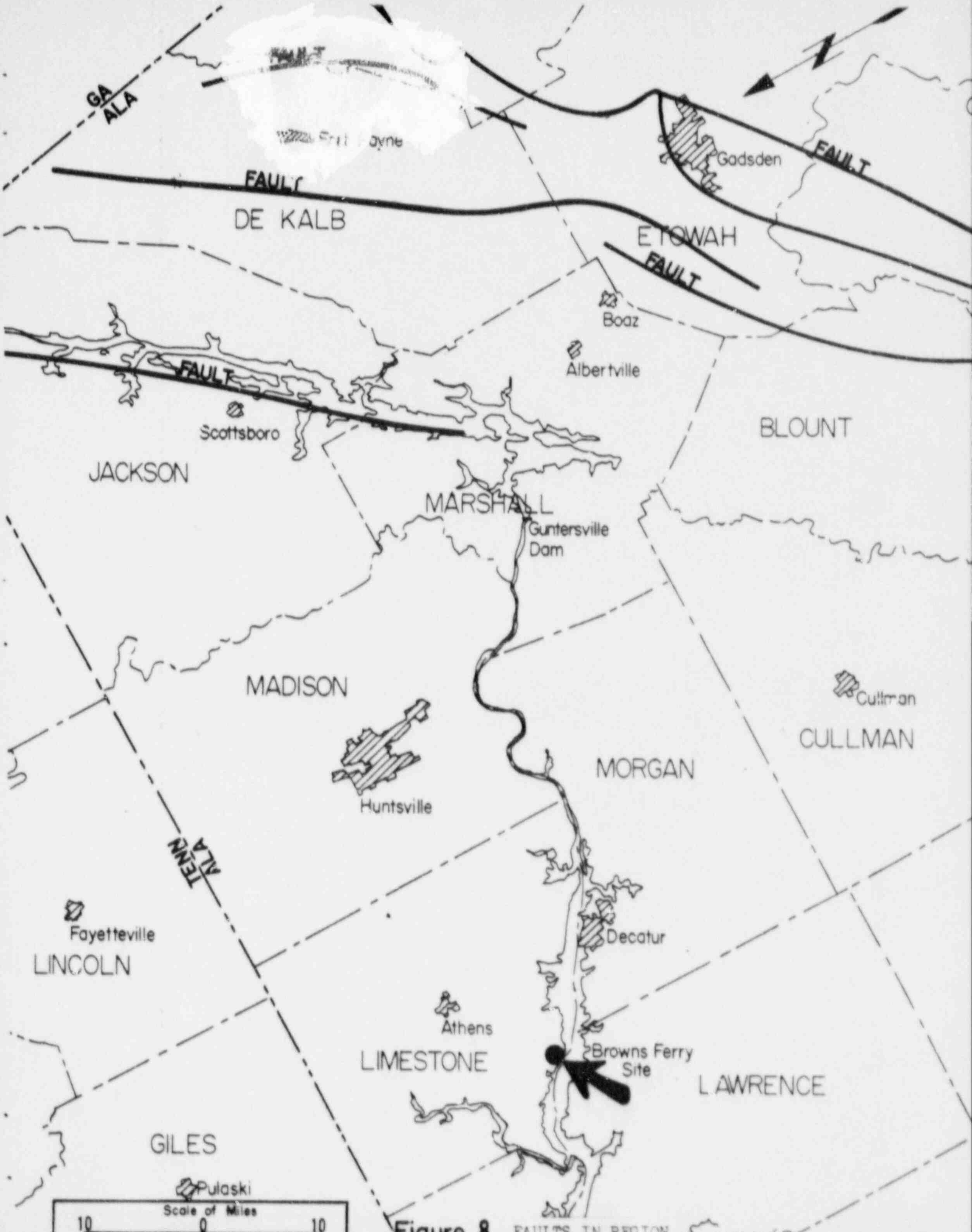


Figure 8 FAULTS IN REGION

Figure 9

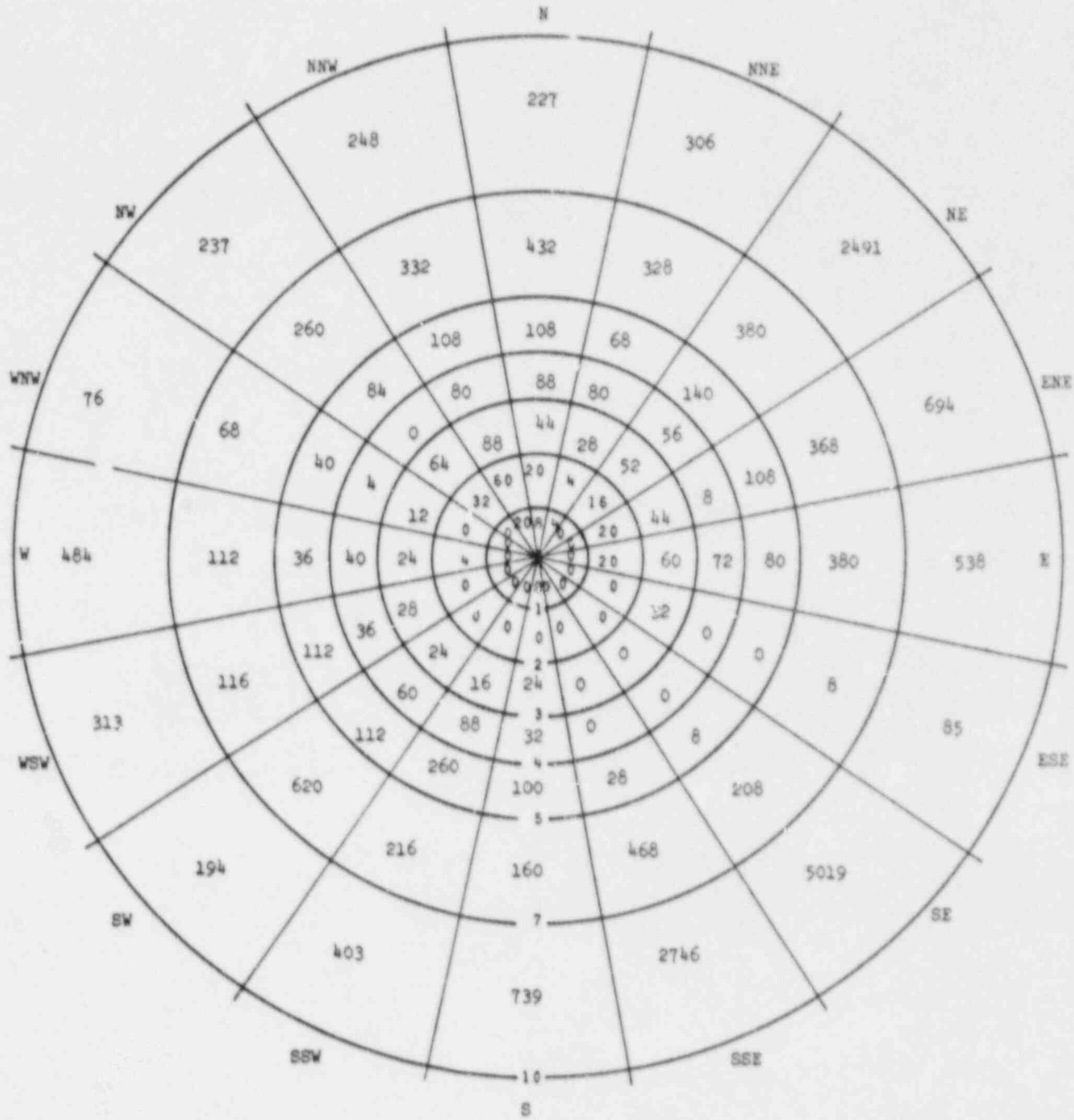


Figure 10

POPULATION DISTRIBUTION WITHIN
10-MILE RADIUS OF BROWNS FERRY SITE

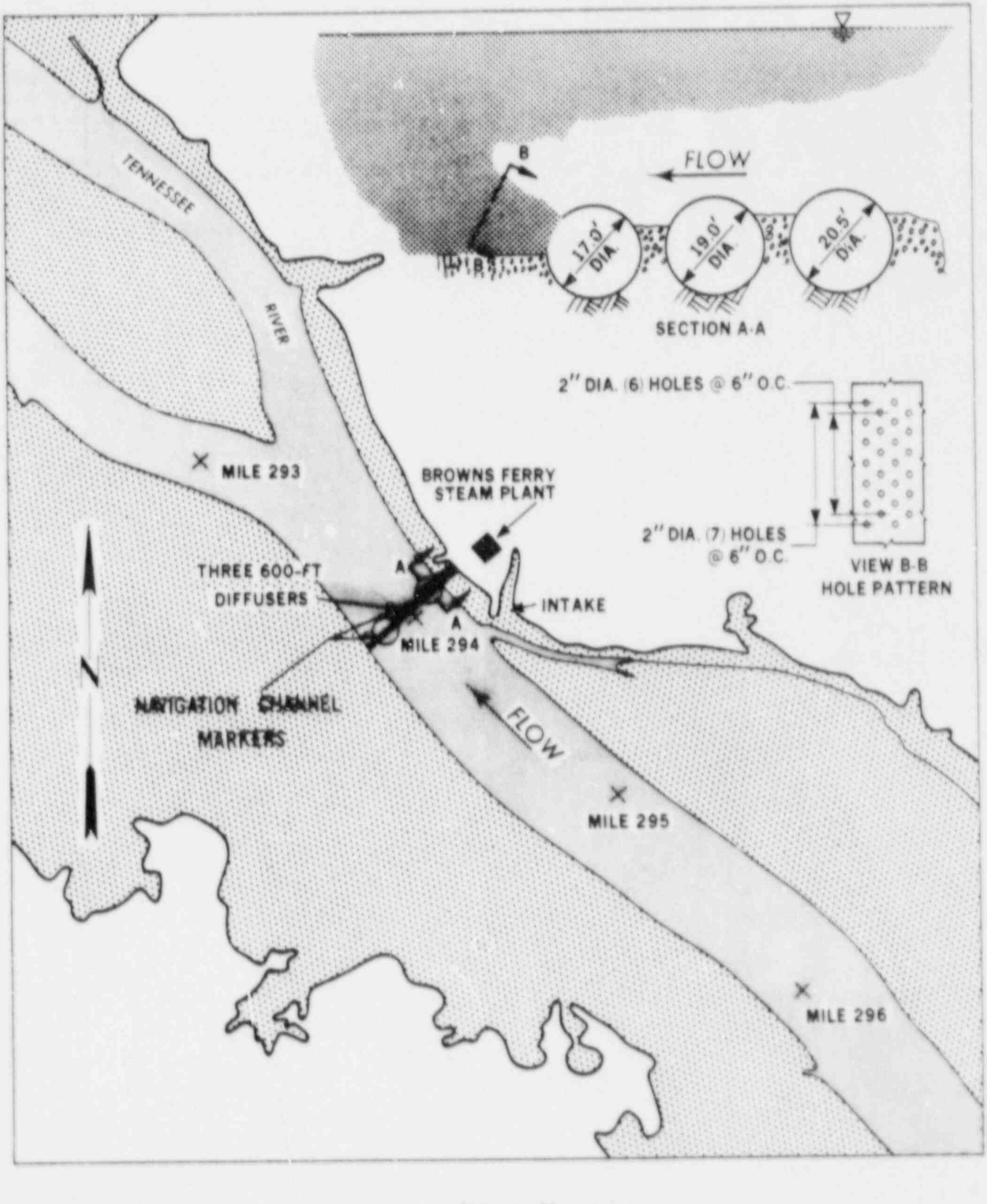
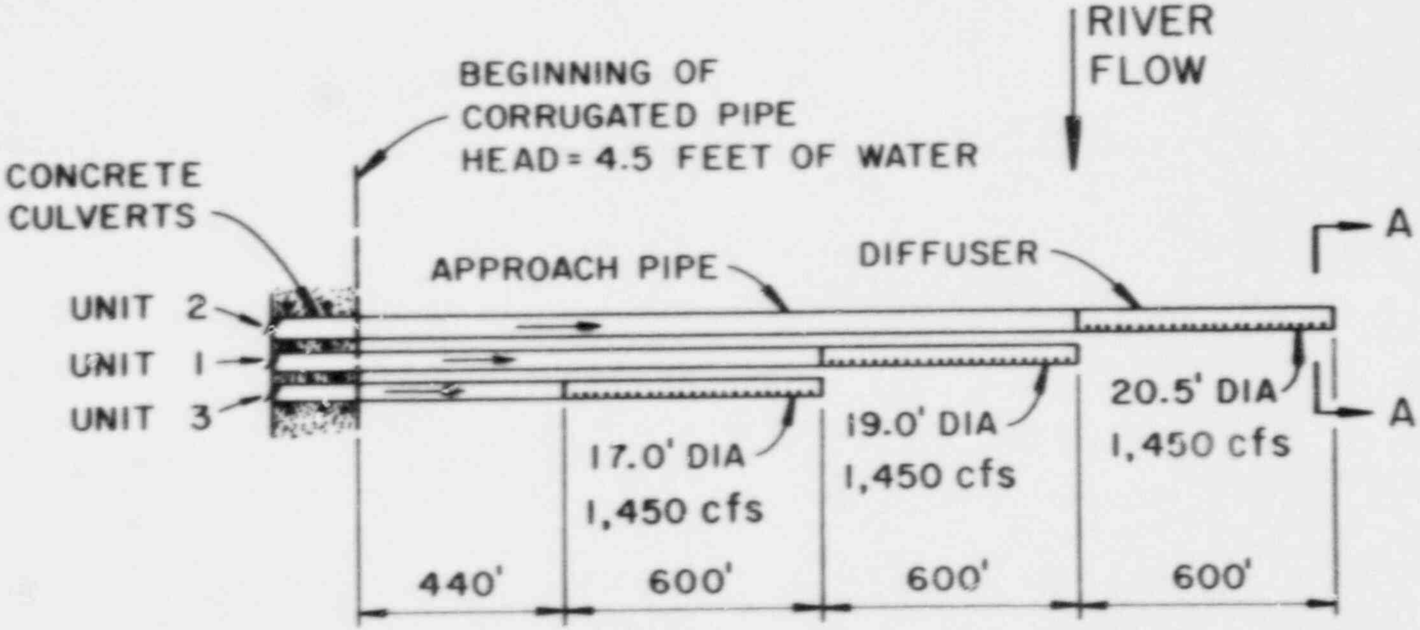
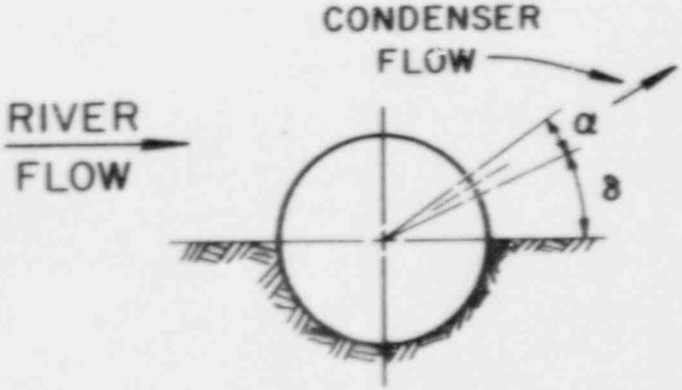


Figure 11
Diffuser System and Channel Markings



PLAN



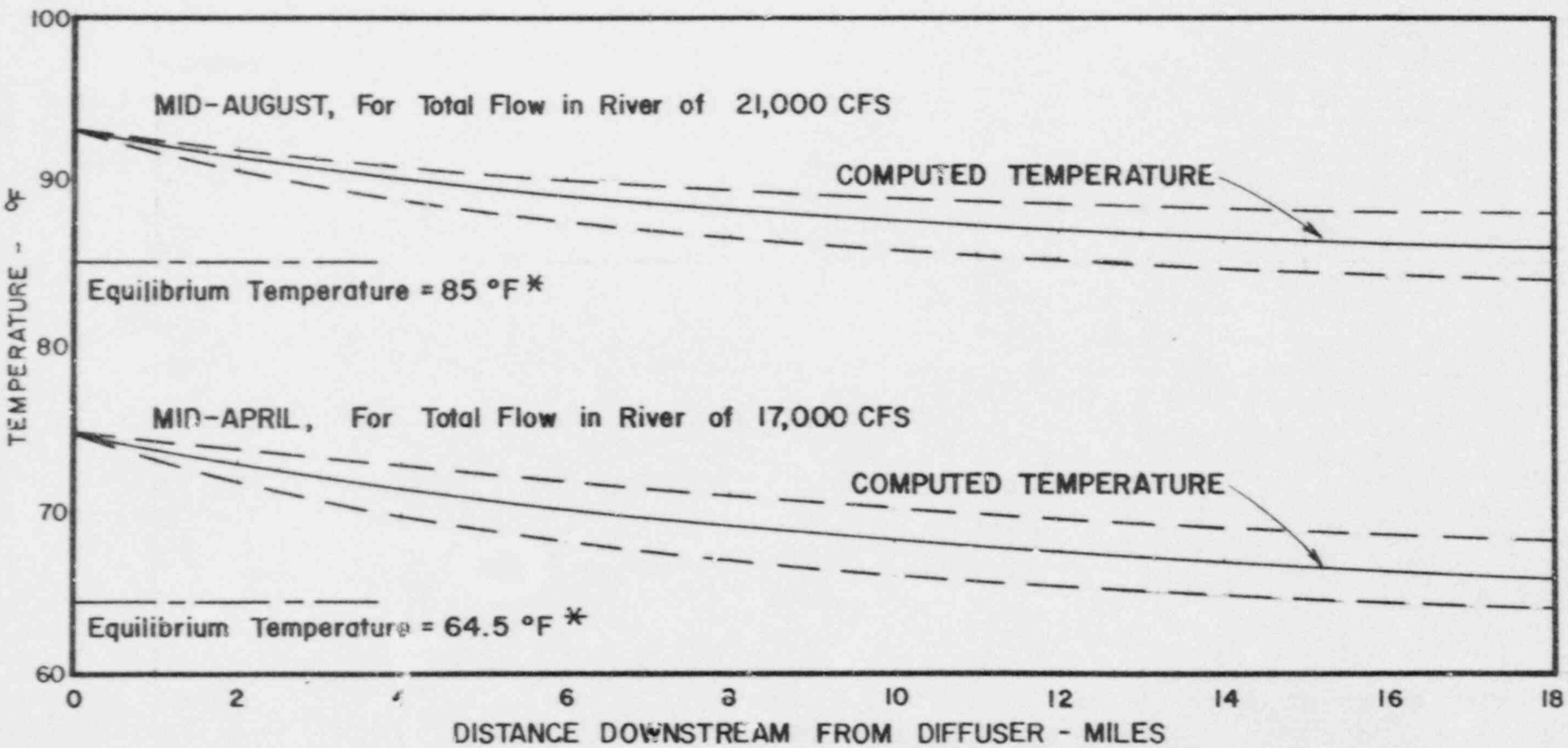
SECTION A-A

GALVANIZED STEEL PIPE
STRUCTURAL PLATE
#3 GAGE, 2"x6" CORRUGATION

ALTERNATIVE HOLE PATTERNS	
1" HOLES	2" HOLES
ALTERNATELY 25 AND 26 HOLES PER CORRUGATION	ALTERNATELY 6 AND 7 HOLES PER CORRUGATION

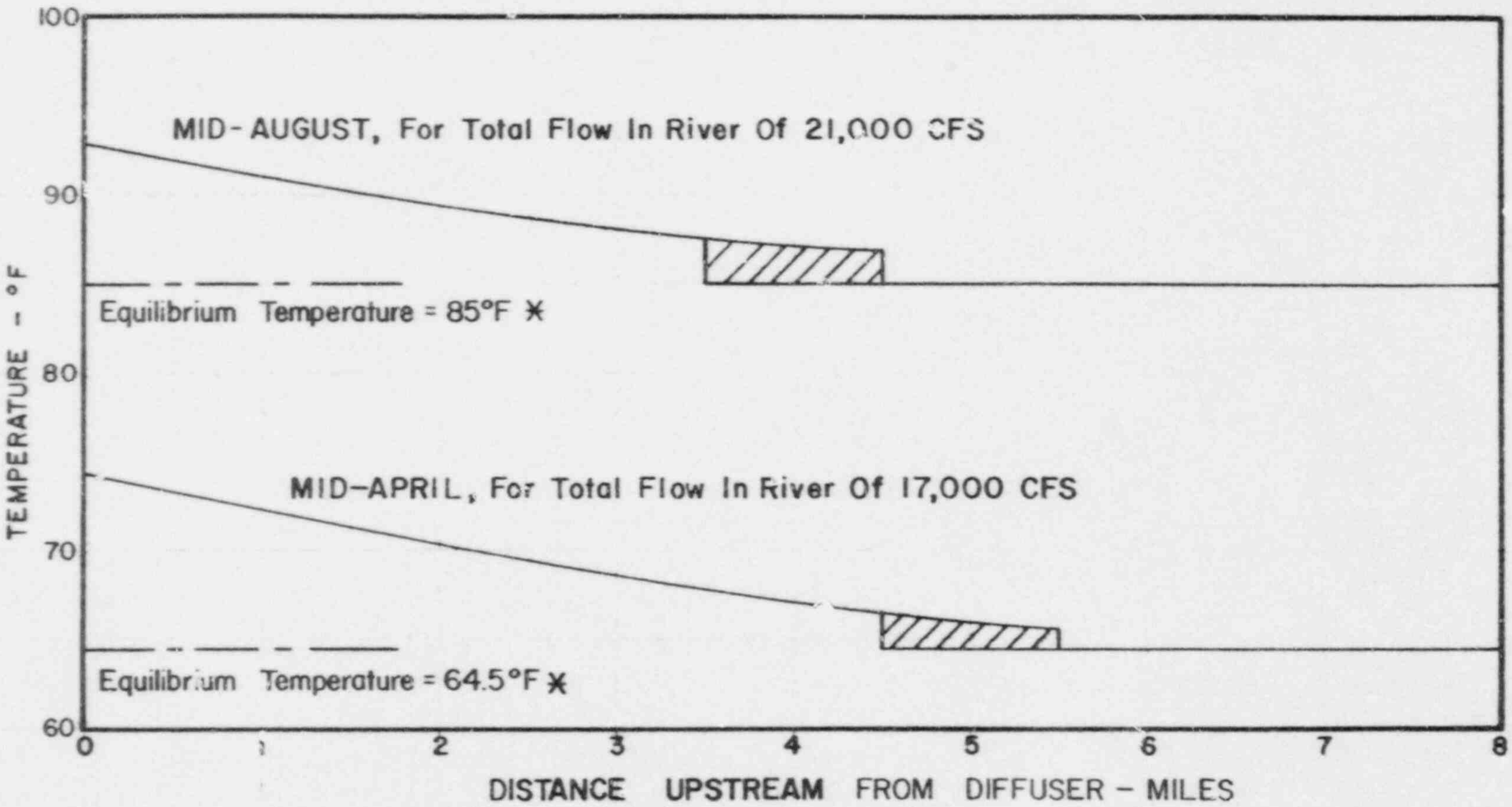
2" HOLE SCHEME
ACCEPTED FOR CONSTRUCTION
$\alpha \approx 21^\circ$ AND $\delta \approx 24^\circ$

Figure 12
Diffuser System Design



* Assumed upstream water temperature

Figure 13
SURFACE WATER TEMPERATURE STUDIES
TEMPERATURE VS DISTANCE DOWNSTREAM



✳ Assumed upstream water temperature

Figure 14

SURFACE WATER TEMPERATURE STUDIES

TEMPERATURE VS DISTANCE UPSTREAM

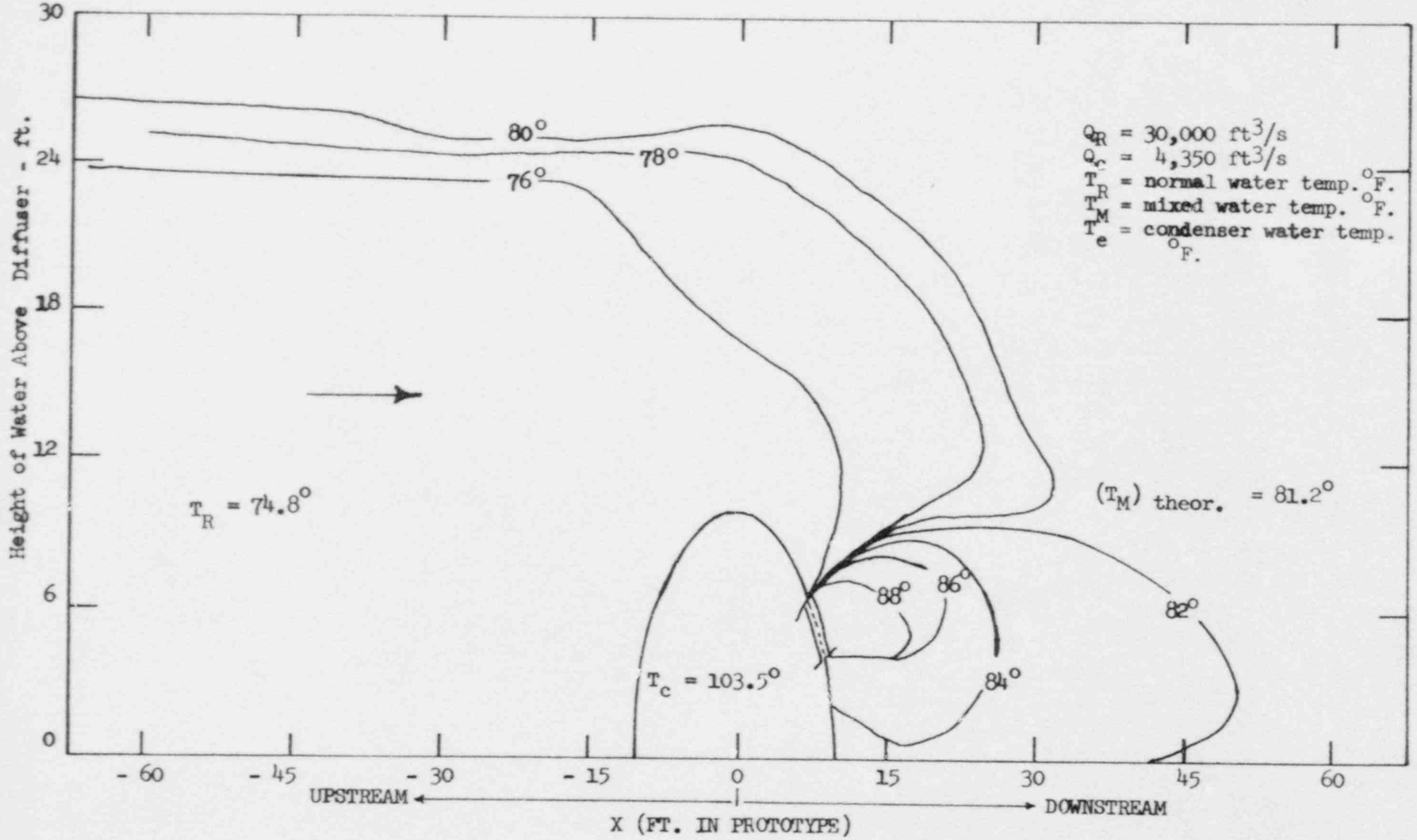


Figure 15 Temperature Survey in Vicinity of Jet Ports

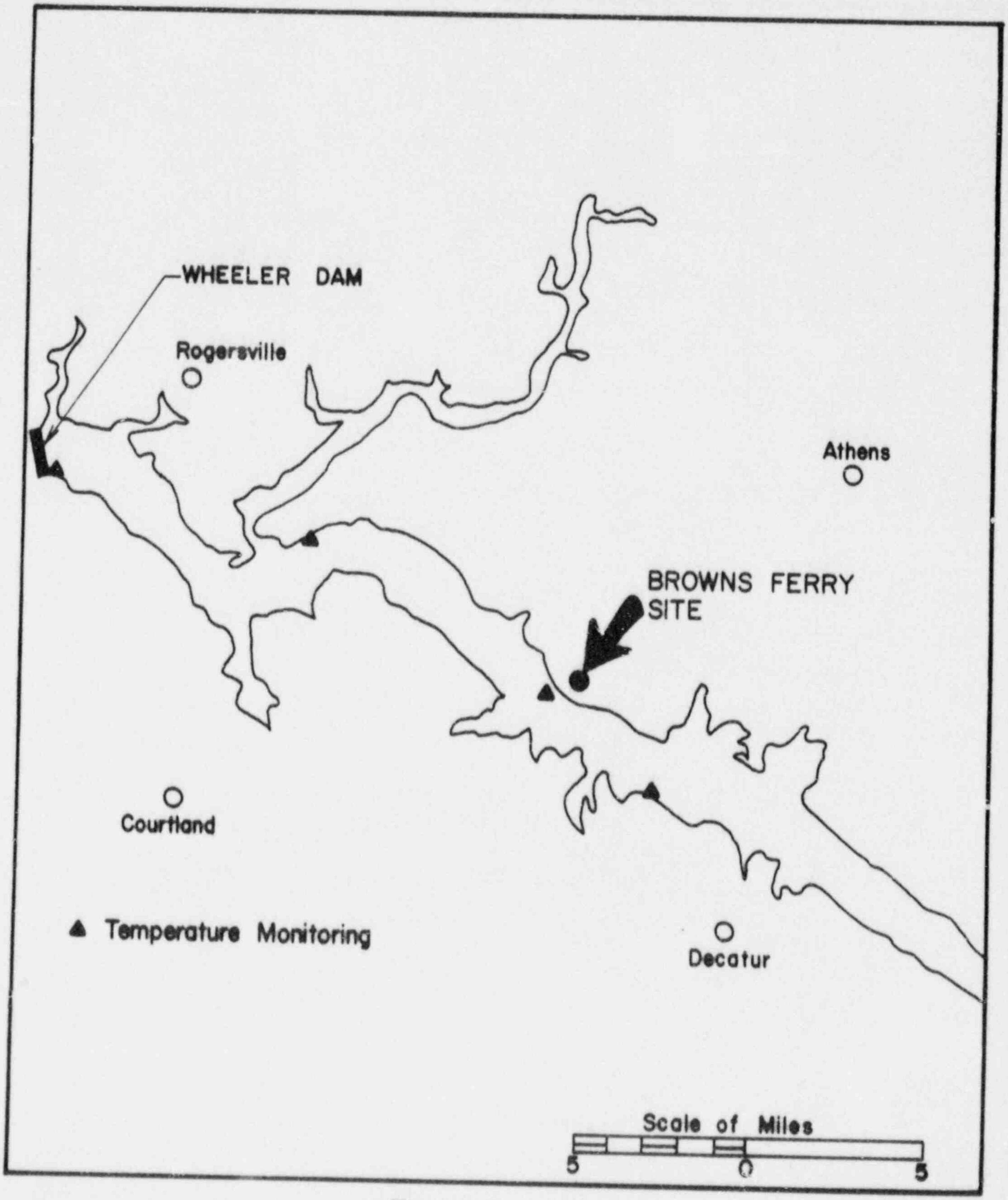


Figure 16

LOCATION OF WHEELER RESERVOIR TEMPERATURE MONITORING STATIONS

ATMOSPHERIC AND TERRESTRIAL MONITORING NETWORK

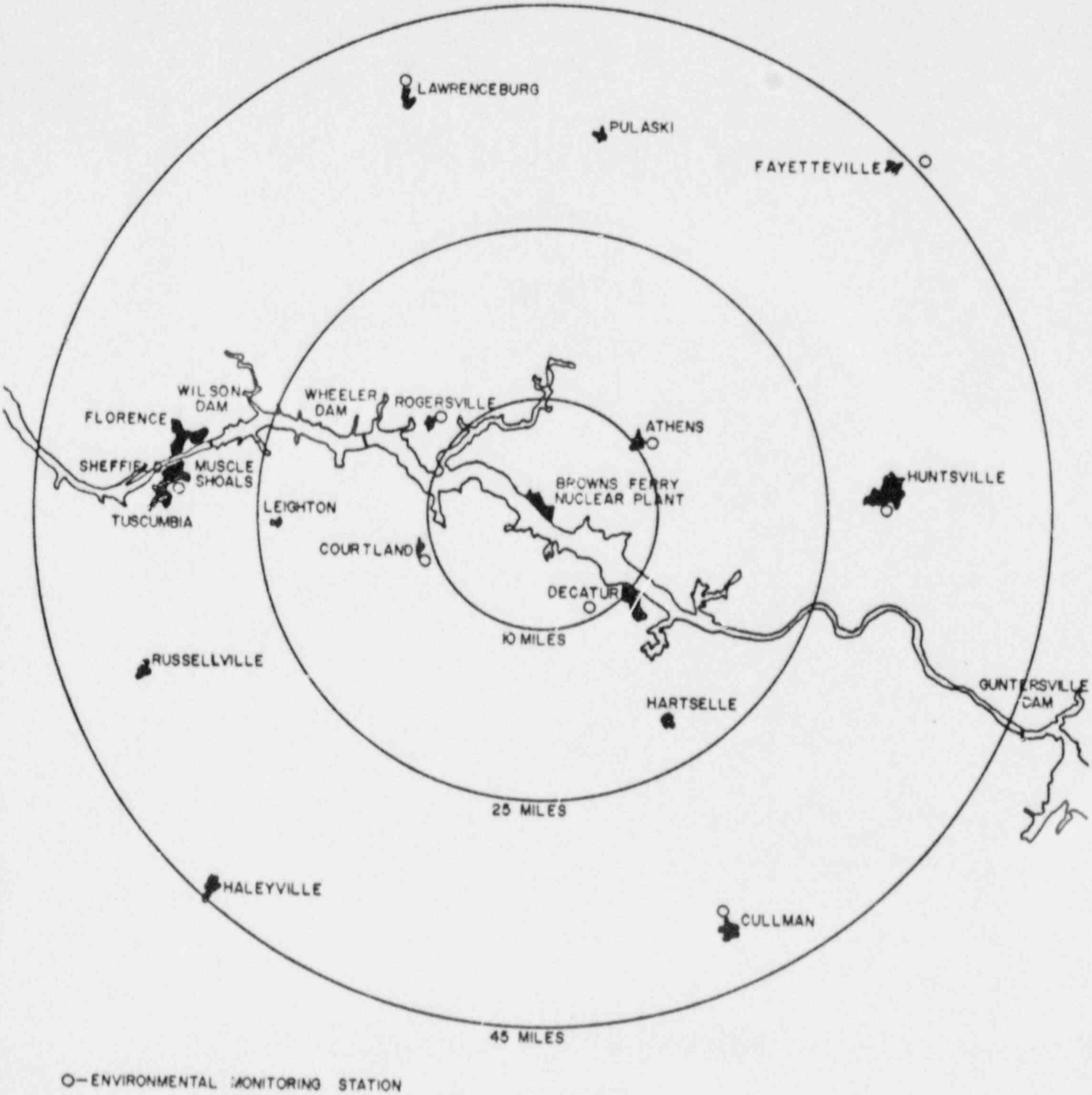
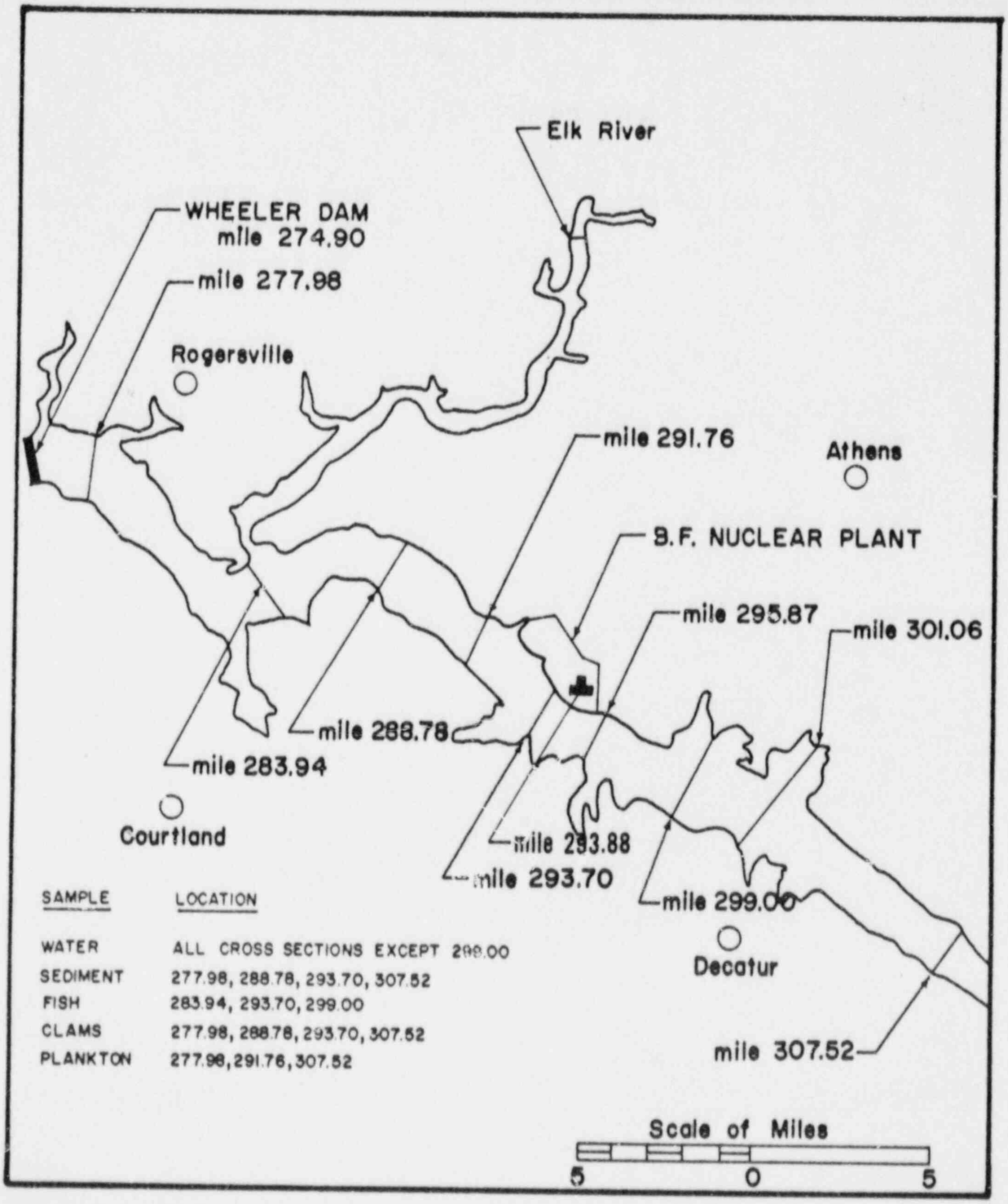


Figure 17

RESERVOIR MONITORING NETWORK



SAMPLE	LOCATION
WATER	ALL CROSS SECTIONS EXCEPT 299.00
SEDIMENT	277.98, 288.78, 293.70, 307.52
FISH	283.94, 293.70, 299.00
CLAMS	277.98, 288.78, 293.70, 307.52
PLANKTON	277.98, 291.76, 307.52

Figure 18

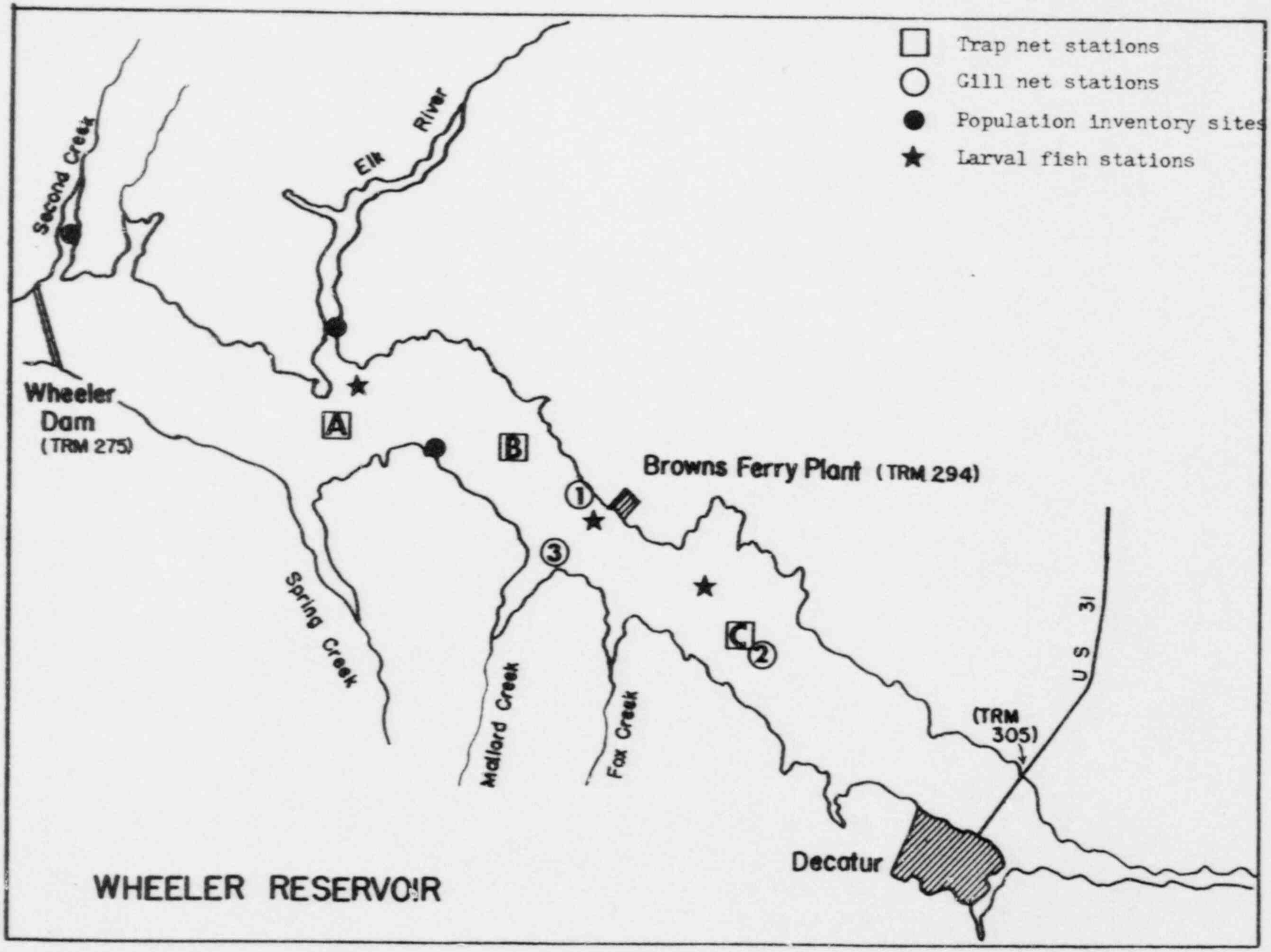


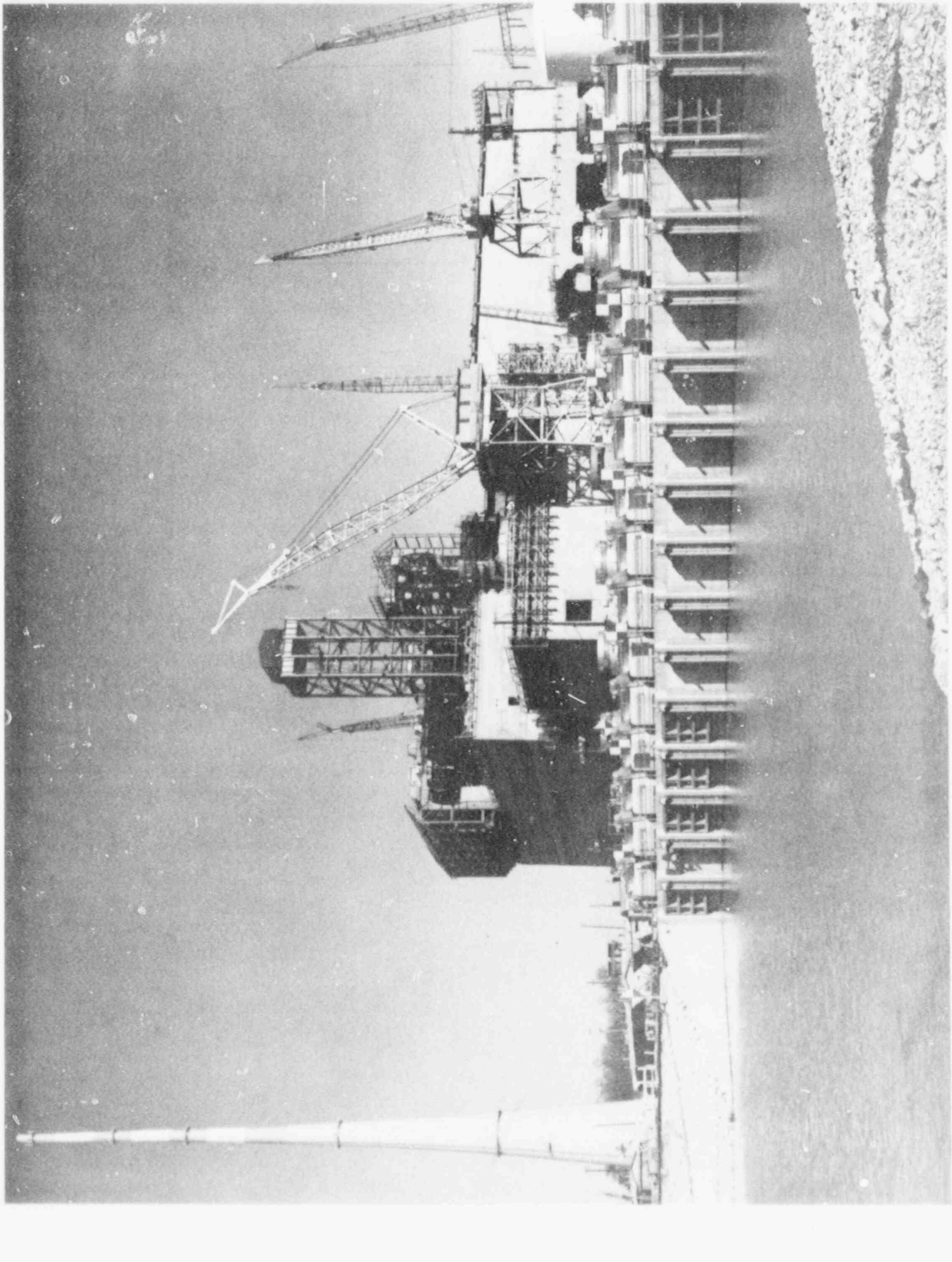
FIGURE 19

TRAP NET AND GILL NET STATIONS

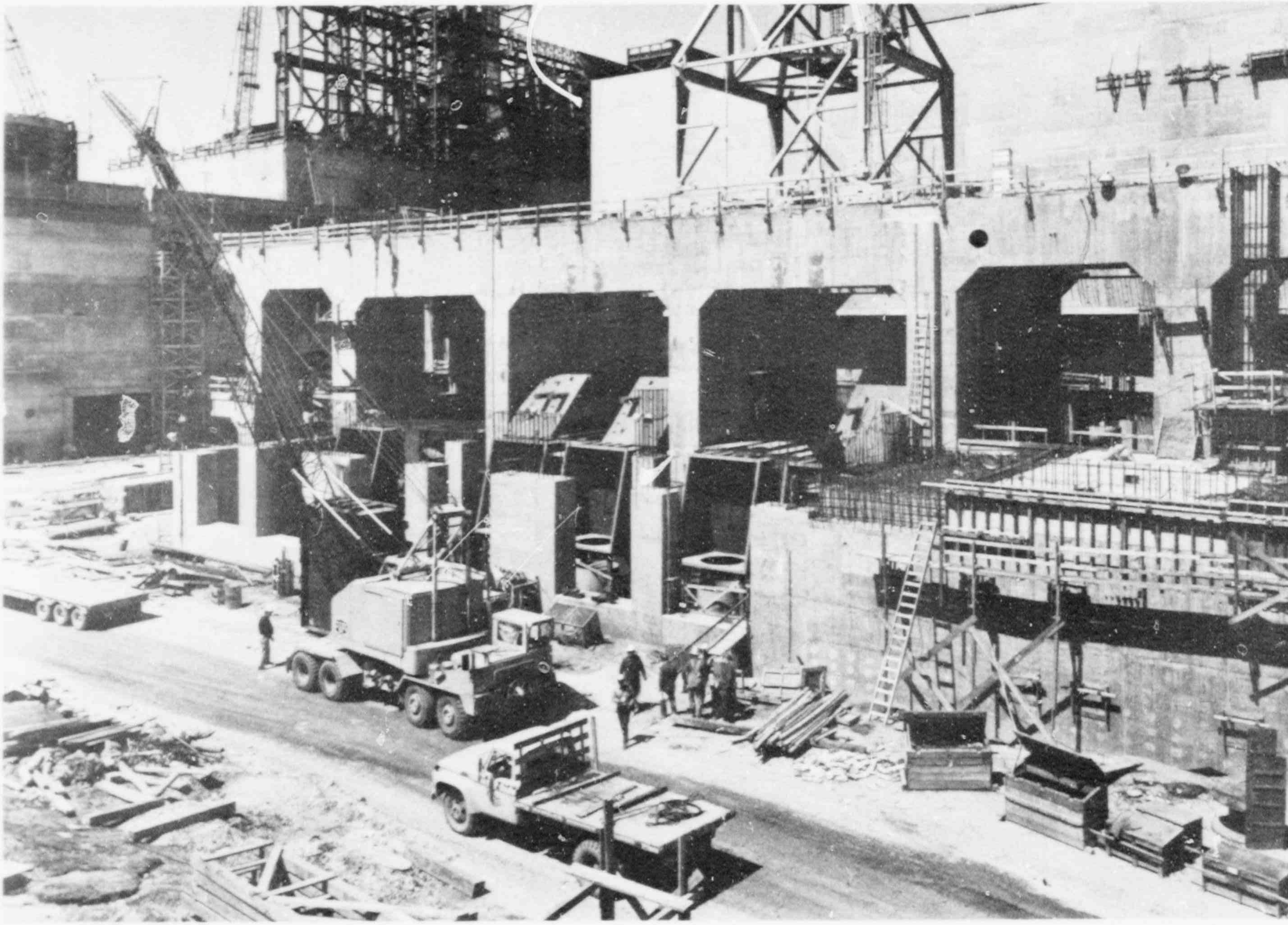
APPENDIX I

CONSTRUCTION PHOTOGRAPHS

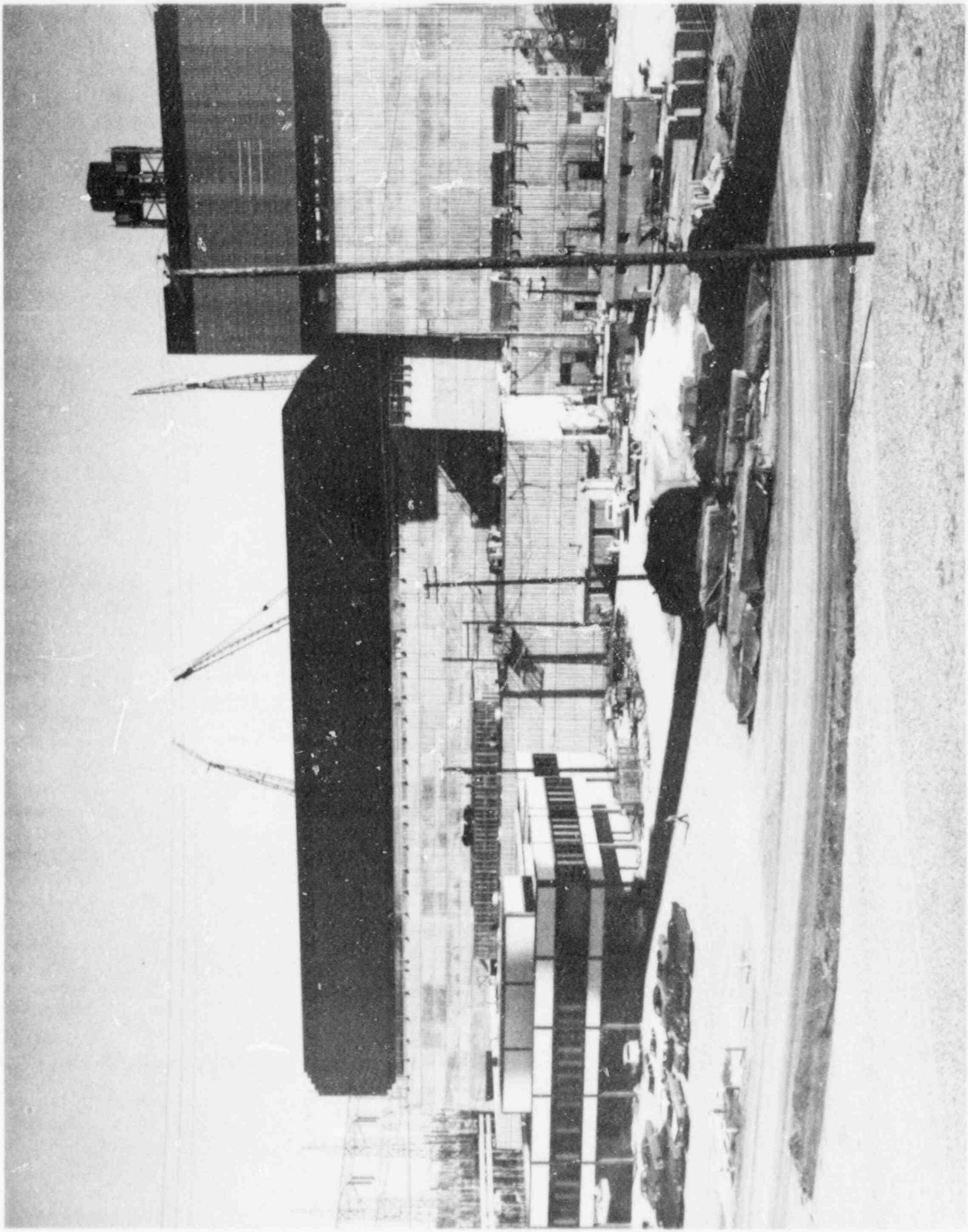
Attached are photographs of the construction site at Browns Ferry Nuclear Plant. These photographs were taken in March and April of 1971.

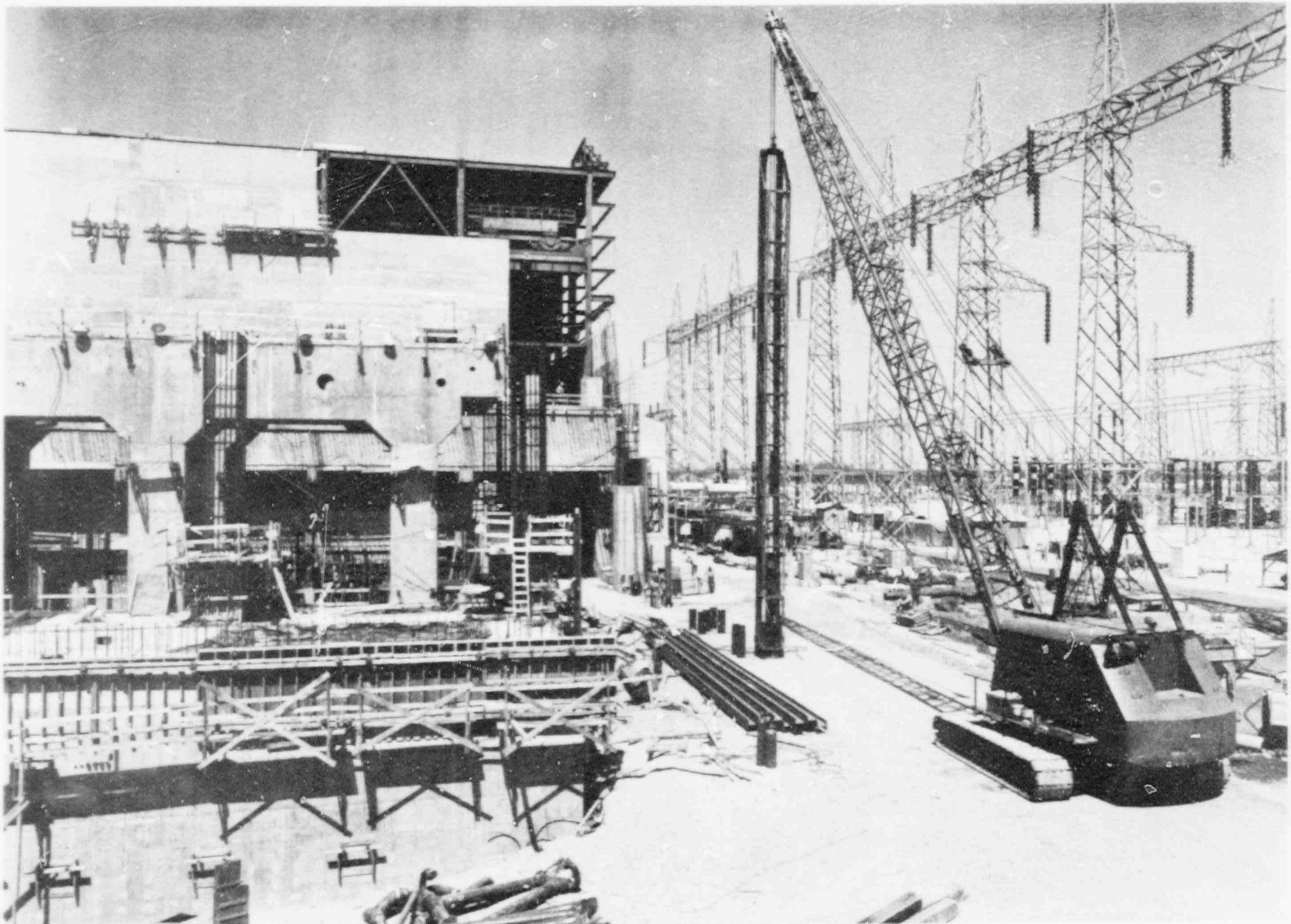


General yard grading along river bank south of the reactor building in the area of the 36-inch water line from the biothermal pumping station to the biothermal area - view west

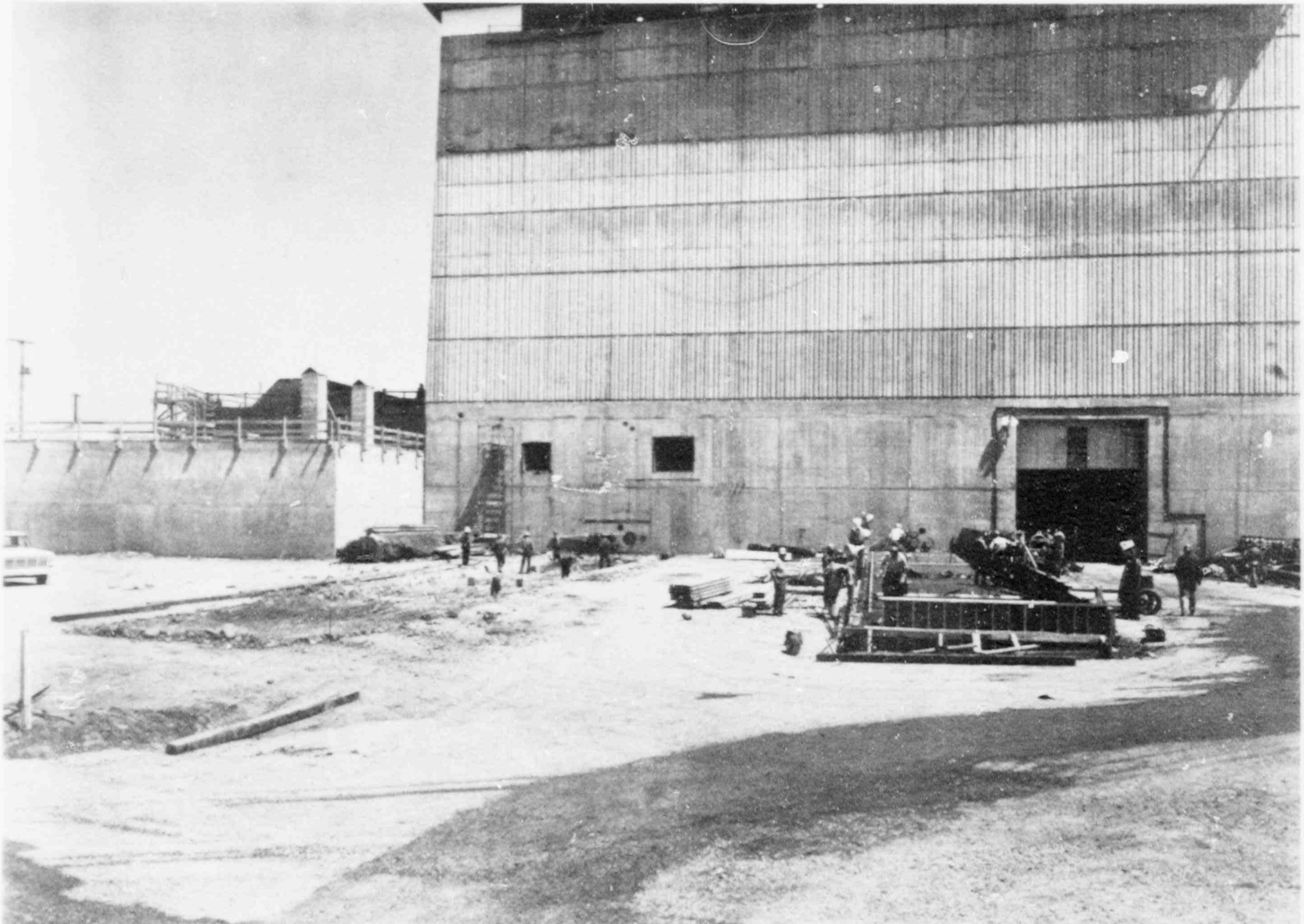


Unit 3 condenser erection - view looking west

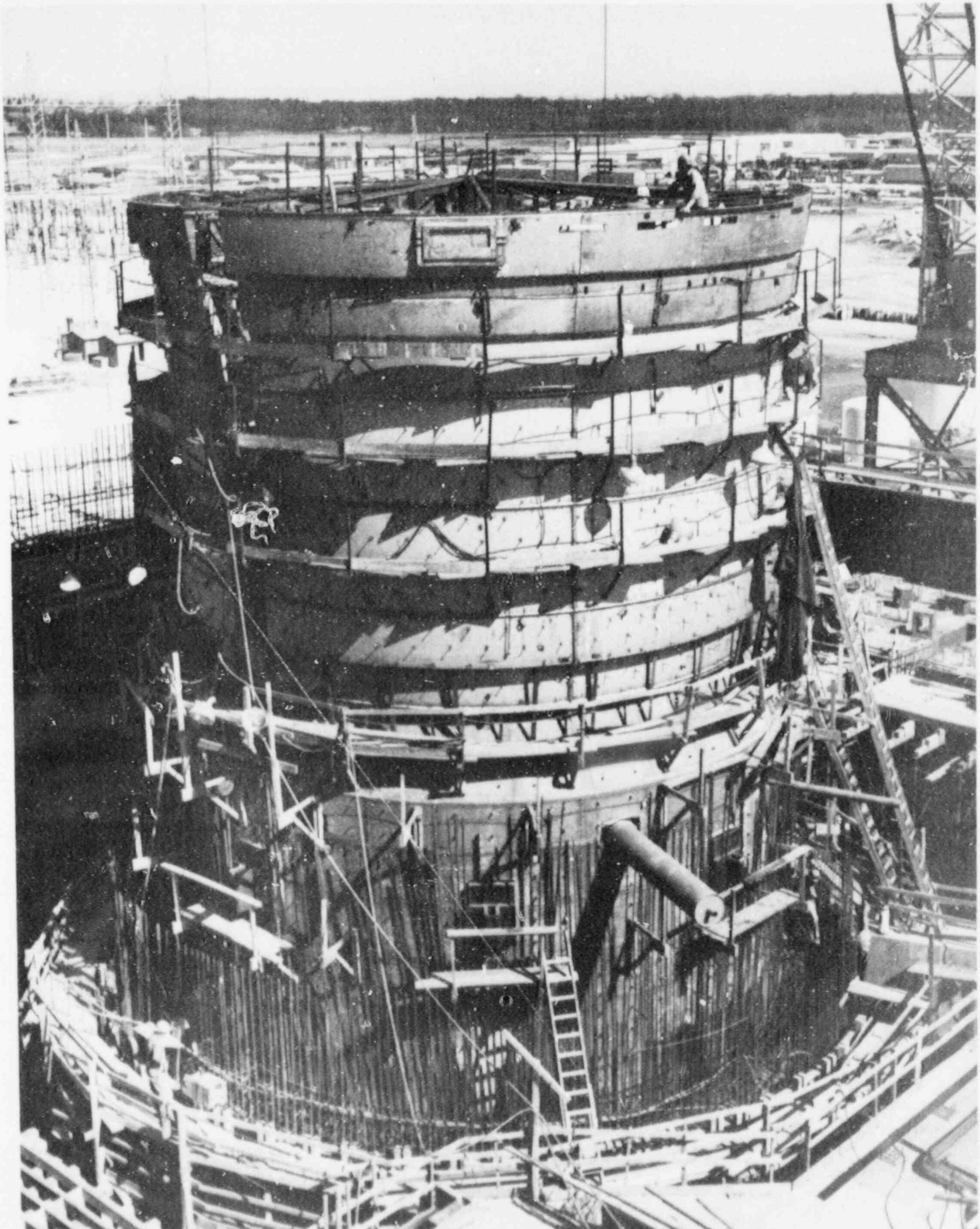


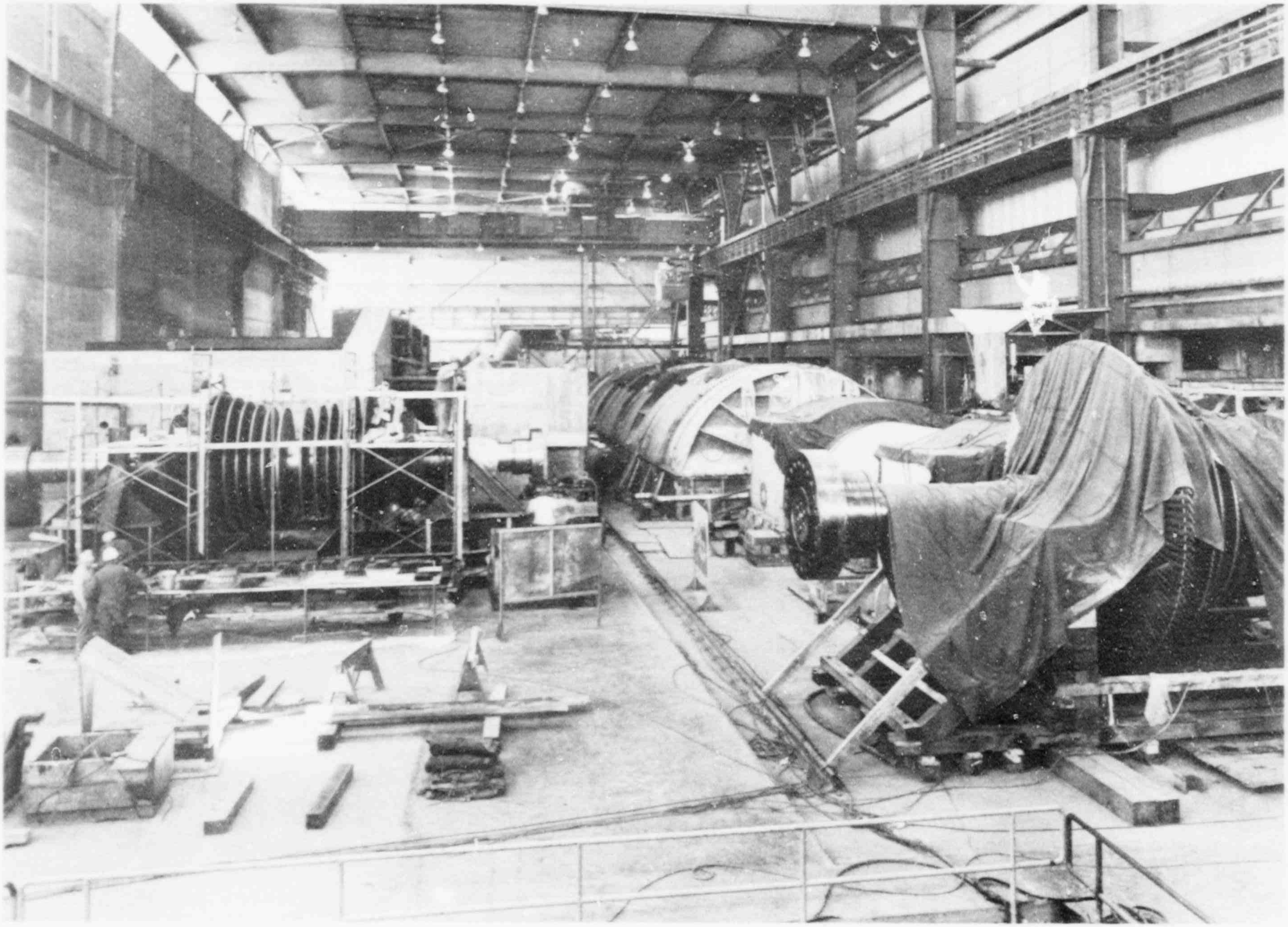


Driving H-beam piling along the unit 3 turbine a-line wall - view looking northwest

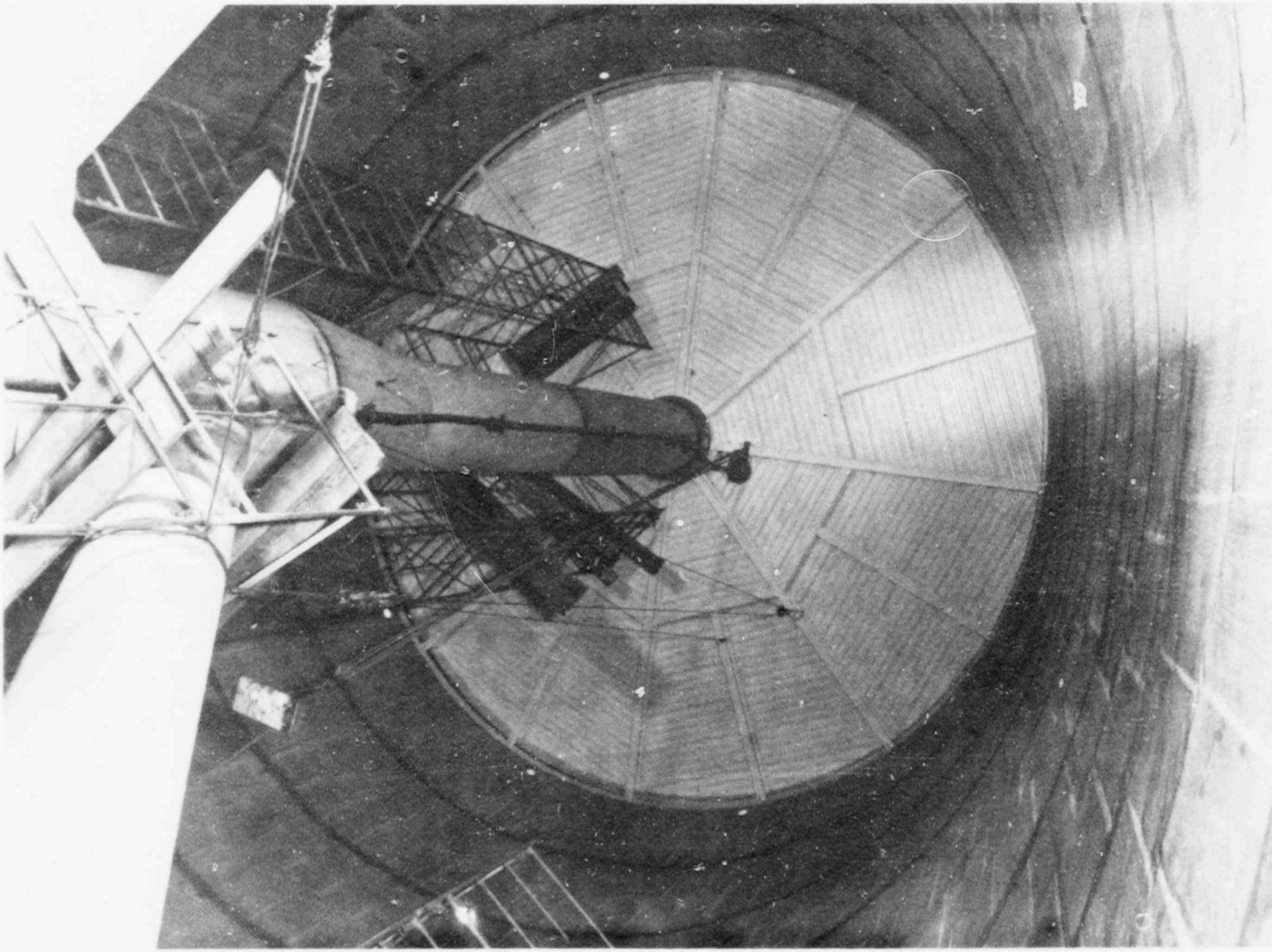


kHR & EECW pipe tunnel south of unit 1 reactor building - view looking north

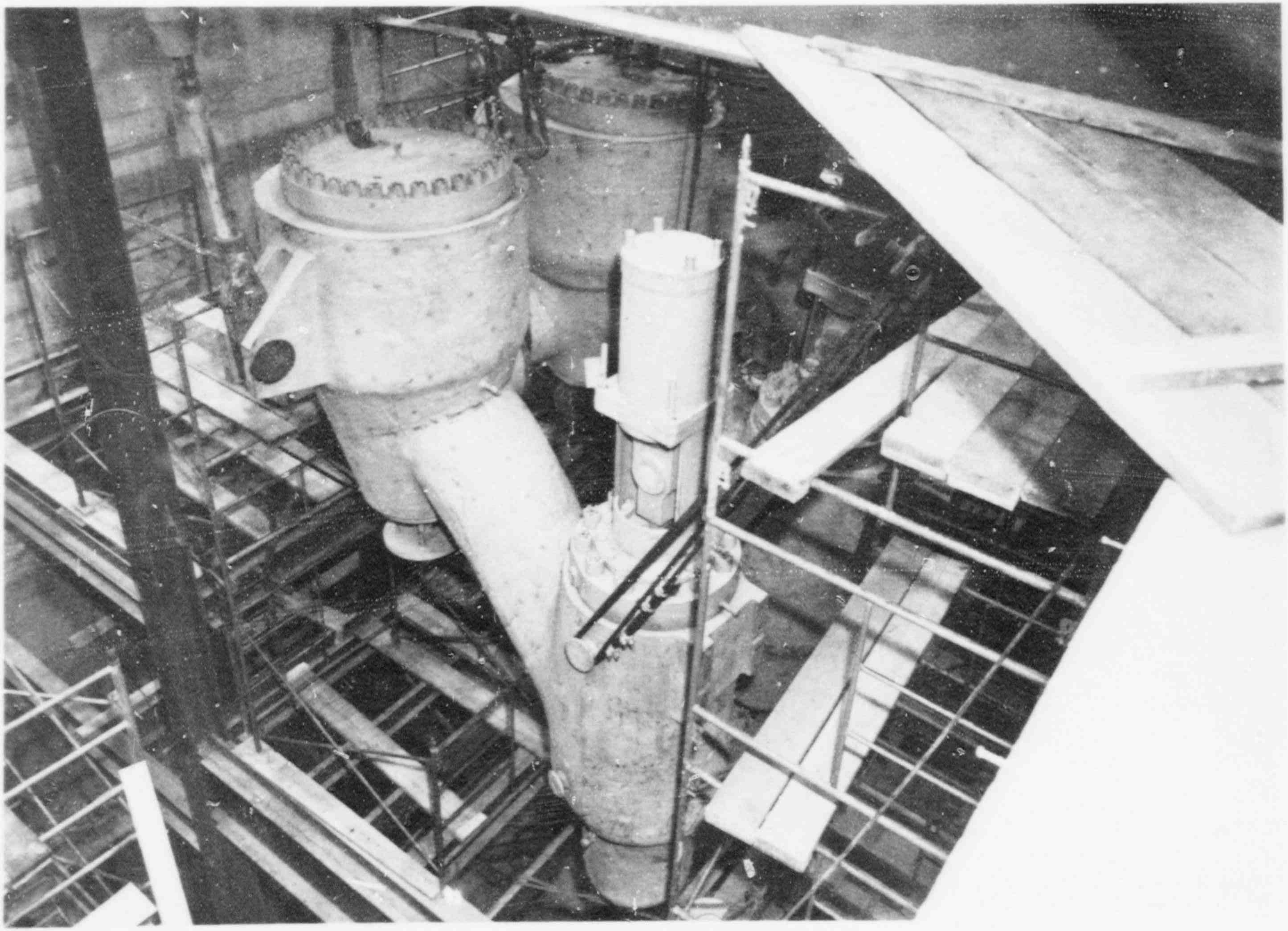




Unit 1 turbine bay - view looking south on the elevation 617.0 floor



Off-gas exhaust stack and roof deck at elevation 667.0



Installing unit 1 turbine stop valves and control valves

CRD housing clean room and handling device for moving housings into the drywell for installation

APPENDIX II

PRELIMINARY RESULTS OF MONITORING

Analyses of characteristics of gill-net catches have been made on the basis of two full years (8 quarters) of sampling.

Diversity and Abundance--Species diversity* appears to follow a characteristic repetitive pattern at Stations 1 and 2 (Figure 1). Importance values** of channel catfish and white bass also follow characteristic repetitive patterns (Figure 2 and 3); these species may be useful as indicator species. Additional species will be considered as indicators if characteristic patterns of abundance emerge at the termination of the preoperational phase of monitoring.

Tagging--As of the winter quarter (January) 1971, a total of 4,480 fish representing 16 species has been tagged and released. Of these, 158, or approximately 3.5 percent, have been recaptured.

Future efforts in this aspect of the monitoring program may include intensive tagging and displacement of selected species in order to more clearly elucidate patterns of movement of important species. In addition, we are considering the possibility of using sonic fish tags to track individual fish in order to investigate avoidance reactions to thermal discharges.

Population Inventories--Sampling of selected coves with rotenone provides data on reproductive success and early growth of

---

* Diversity = (no. species - 1) / $\log_e$ total catch.

**Importance value (I.V.) = (catch/trap night) x 100 (frequency of occurrence).

Figure 1. Diversity of gill-net catch, Wheeler Reservoir.

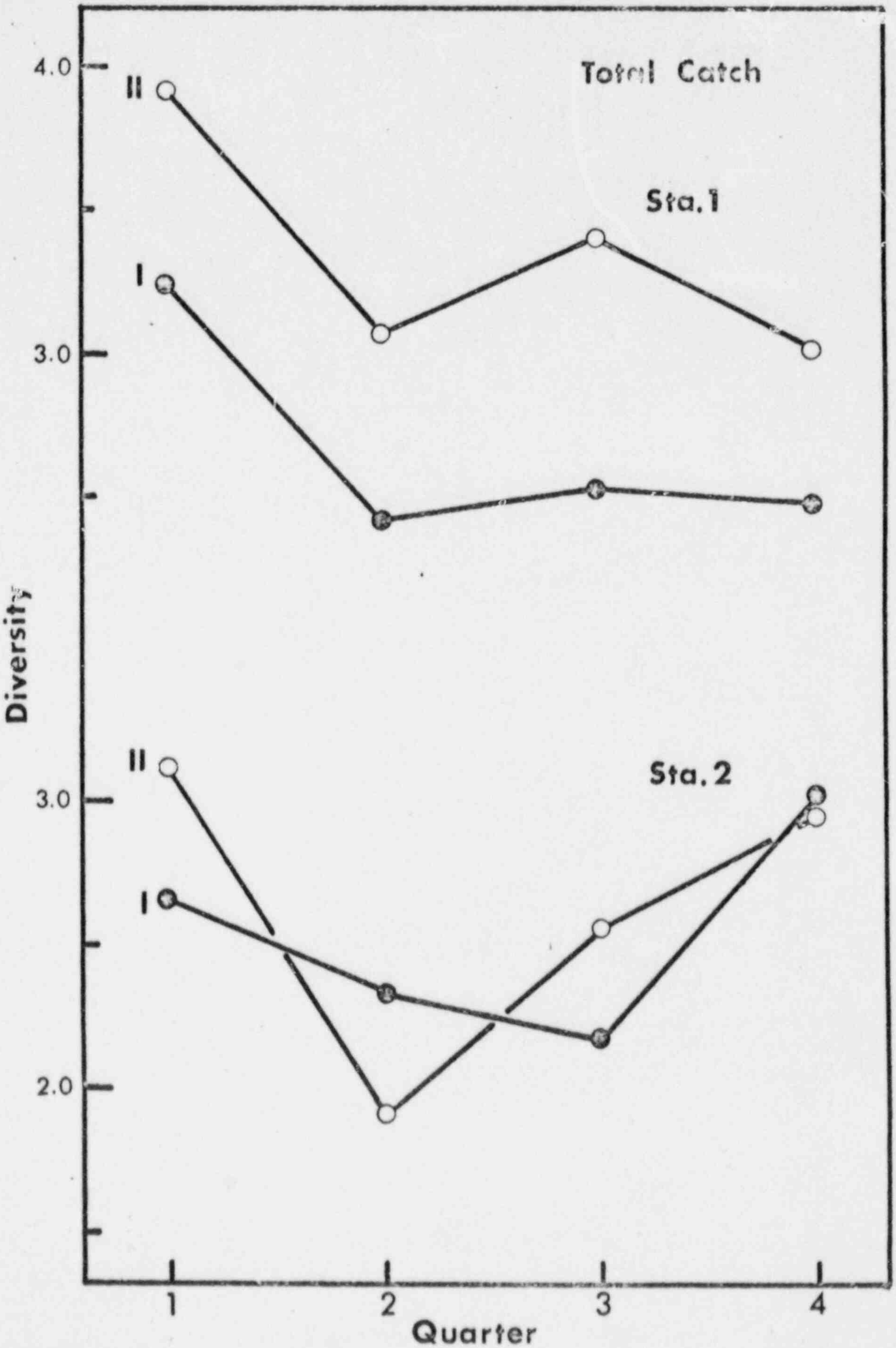


Figure 2. Log importance values, Channel catfish, Wheeler Reservoir

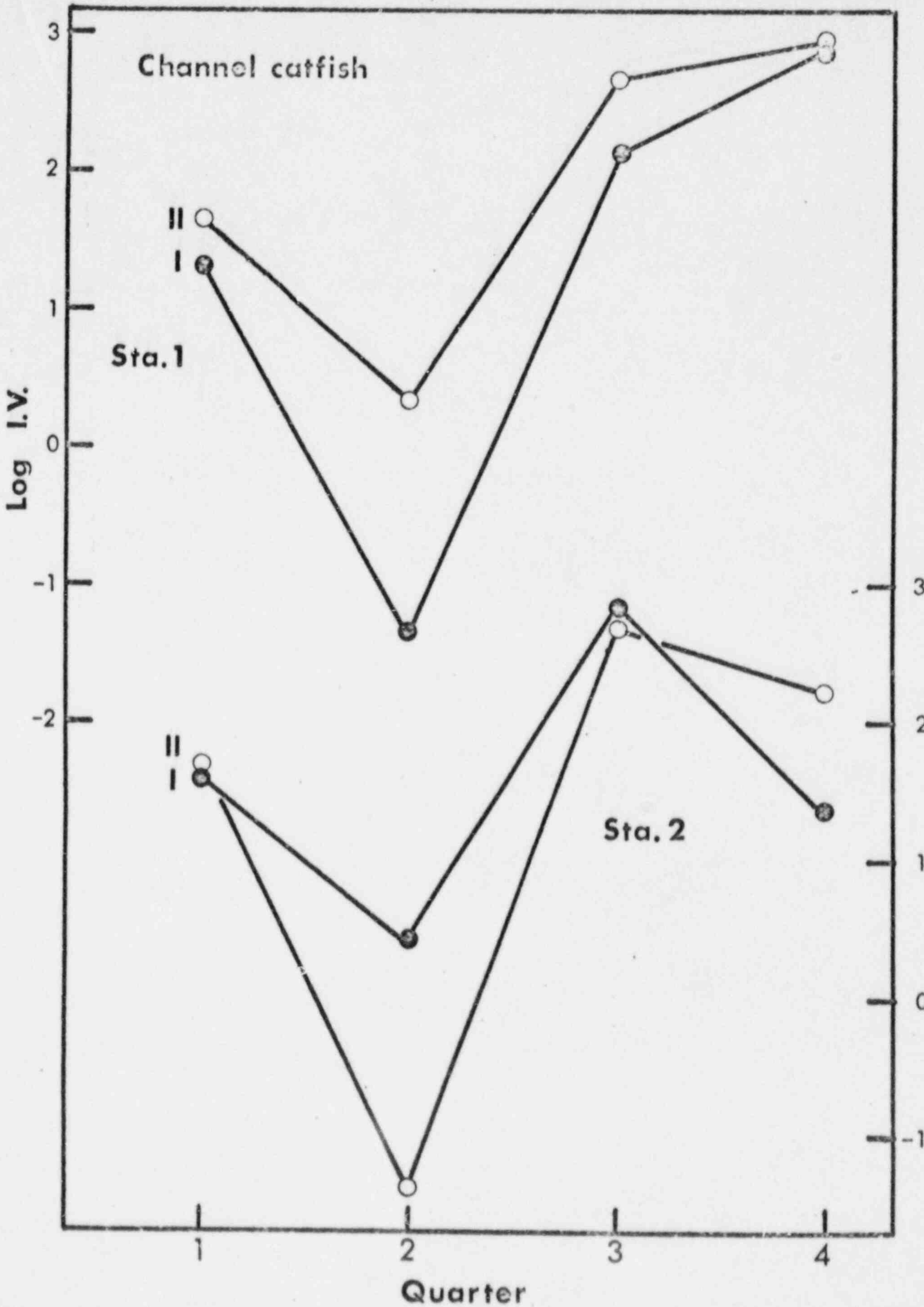
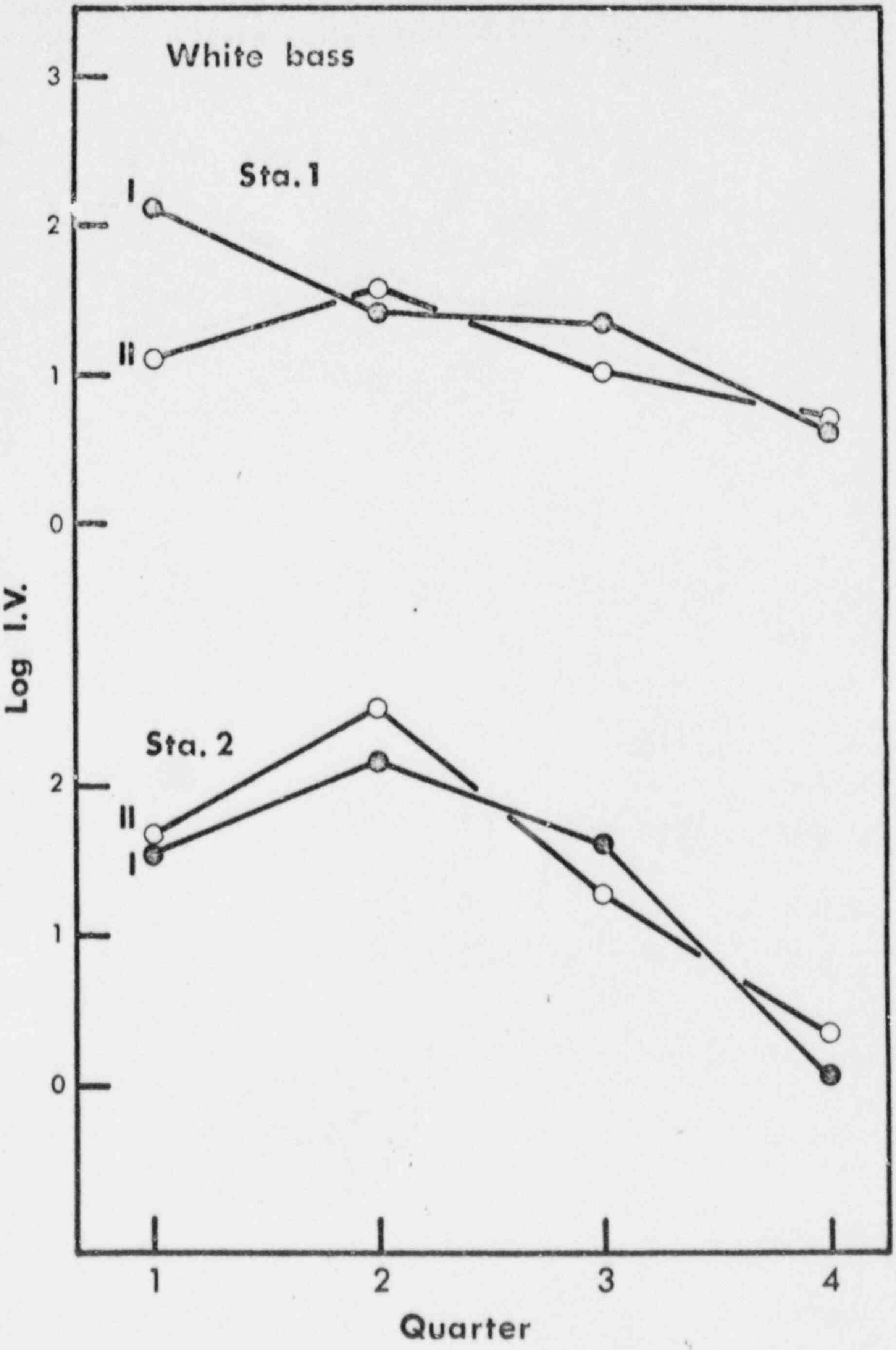


Figure 3. Log importance values, White bass, Wheeler Reservoir.



certain species, provided such samples are repeated for several years for the same coves at the same time of year. Estimates of production, based on three coves sampled in both 1969 and 1970 range from 414 to 1,157 kg/ha (370 to 1,033 pounds per acre). Inspection of the data indicates that gizzard shad may be subject to large fluctuations in year-class strength. The same may be true for other species (bluegill, spotted sucker), while some species (largemouth and smallmouth bass, freshwater drum) appear to have only minor fluctuations in reproductive success. These data will serve as baseline data with which to compare results in the postoperational phase of sampling.

APPENDIX III

STUDIES BY TVA AND OTHERS ON THE EFFECTS OF HEATED WATER AT PARADISE STEAM PLANT

Introduction

The Paradise Steam Plant consists of three units--two of 650 megawatts each, and one of 1,150 megawatts. Prior to operation, baseline monitoring of fish and fish-food organisms were made. The maximum river temperature (average over any cross section) permitted by TVA was 95° F. Two years after operation of units one and two commenced, studies made of aquatic life in the Green River below the plant noted reductions in levels of aquatic life below those indicated in the baseline studies. As a result of these studies, units one and two operate on cooling towers when high water temperatures exist. Unit three operates on cooling towers at all times. Temperature criteria of 90° F. for the maximum river temperature averaged over any cross section and limiting surface temperature to 93° F. were put into effect in 1968. Further monitoring is being conducted to assess effects of the tighter thermal controls.

The following discussion provides a synopsis of the effects of heated water on aquatic life at Paradise Steam Plant.

1. Studies by the Academy of Natural Sciences of Philadelphia

The Green River does not possess the normal complement of biotic characteristics of flowing streams. The departure toward a stillwater situation is largely attributable to long-existing alterations of the stream for navigation. The pool on which the Paradise plant is located is maintained by navigation locks, thus creating a "canal-type" situation. Summer stream velocities are low because of the deep channel and low flows. Benthic insect fauna are scarce in this pool situation because channel margins are steep and the overbank area development of a littoral fauna is sharply limited. In addition, heavy barge traffic within the pool churns bottom sediments thus creating unstable substrate conditions.

Stream invertebrates are largely restricted to zooplankton, predominantly species typical of lakes. Since benthic insects are scarce, the transitory zooplankton community assumes the major role in converting plant material to animal protein and thus constitutes a major energy channel connecting the fish population to the detrital-algal base in the food chain.

The staff of the Philadelphia Academy of Sciences directed by Dr. Ruth Patrick investigated the attached and planktonic flora, protozoa, invertebrate fauna, and insect fauna. Samples were collected over a 20-mile stretch of river extending downstream from a station 1 mile above the plant. The preoperational study was conducted in 1961--about two years prior to plant startup. A second study was conducted in 1965--two years after startup of the plant.

The 1965 study showed a reduction in species diversity and abundance, compared to that established in the 1961 study. The invertebrates showed the greatest decline over the four-year interval. The major changes were nearest the plant and were less severe at greater distances. The presence of coal dust and heavy barge traffic apparently contributed to the degeneration in quality.

2. Fish Population Studies

Dr. Hunter Hancock of Murray State University, Kentucky, made an extensive survey of the effects of heated water on fish population. With fish as with the food chain organisms, diversity of species and abundance are taken as a general indication of quality. Dr. Hancock made fish counts in the summers of 1961, 1963 (after startup), 1964, 1965, 1966, and 1967. Catches were poor in 1961 and became poorer afterwards. Catches were on the order of one fish per net day of effort. A general decline in catch was experienced at all stations after startup. The catch improved in 1965 and 1966, but was low again in 1967. Thus, the relative abundance of fish in all operational years up to the use of cooling towers in 1968 was lower than the 1961 preoperation level. The composition of the catch showed a smaller fraction of game fish and a larger fraction of edible rough fish. However, some game species (white bass and spotted bass) were more numerous in 1966 than in 1961 collections. The forage, nonedible rough, and pan fish were not present in great enough numbers to show a trend. Since the trend in catch was the same at stations above and well below the plant, as in the immediate vicinity of the plant, it is difficult to conclude how much of the effect was due to the addition of waste heat. A more recent study was made in 1970; preliminary results of this study are similar to those found in 1965-66.

3. Studies of Zooplankton by TVA Biologists

TVA biologists made a special study of the effects of temperature on zooplankton. Laboratory studies indicated a lethal threshold of about 97° F. for the dominant species of the Green River. Laboratory results were substantiated by a series of field studies in May of 1964. Field studies revealed a large mixed plankton population isolated in the floating pool of warm water which develops upstream of the plant. Zooplankton were extremely abundant here at temperatures up to, but not exceeding 96.8° F. The organisms were being seeded in this area by the approaching colder water and were flourishing at temperatures below the lethal limit. Sampling in the discharge canal where temperatures exceeded 101° F. indicated the organisms were not surviving passage through the condensers. To prevent plankton depletion of downstream reaches over extended periods or distances, either the temperatures within the condensers must be reduced below the thermal threshold for zooplankton or a portion of the streamflow permitted to bypass the plant and seed that flow diverted through the plant.

During the period May 15 to May 27, 1964, sufficient zooplankton bypassed the steam plant to reseed effluent water. Approximately 3 miles below the plant the zooplankton population equalled or exceeded population levels measured in unmodified upstream reaches. Rapid recovery was attributed to an accelerated reproductive rate in the thermally favorable downstream areas.

4. Periphyton Studies

Periphyton is an association of aquatic plants, both pigmented and nonpigmented, growing attached or clinging to the various types of substrate surfaces (river bottom, logs, stems, and leaves, etc.) in a river or lake. Periphyton in rivers is the principal food source for many benthic, herbivorous organisms and grazing fish, provides shelter, contributes oxygen to water, and constitutes a major source of river phytoplankton. Studies were undertaken to characterize the rate of periphyton production in the Green River.

General methods employed in the surveys included the collection of temperature data throughout cross sections of the receiving waters both above and below the discharge point, collection of bottom fauna with a Petersen dredge above and below the discharge point, and the use of racks of artificial substrates (plexiglass slides) for collection of periphyton growth below the surface. The slides were analyzed for total organic matter, phytopigment absorbency, and autotrophic index.

The periphyton data provide a good indication of the effects of cooling water passing through the condensers. If water passing through the condensers is heated too much, aquatic organisms (such as phytoplankton and zooplankton) suspended in it are killed. After being killed, these organisms can form a "luxury level" of food for heterotrophic or "slime" organisms downstream. These heterotrophic organisms are dependent upon organic matter for food. In contrast to this, autotrophic organisms (e.g., phytoplankton) rely on inorganic carbon and other minerals in the water for their food supply. Consequently, any marked reduction in the ratio of autotrophic to heterotrophic organisms in the total mass of periphyton could indicate that elevated temperature is killing at least some of the plankton passing through the condensers and increasing "slime" growth.

The following conclusions were drawn: (1) During the summer months periphyton growth rates in the Green River are substantially reduced in the vicinity of the steam plant. In the late fall and early winter, downstream growth rates may be moderately enhanced. (2) Recovery generally occurred about 15 miles downstream. (3) The station in the immediate vicinity of the Paradise Steam Plant showed the largest proportion of heterotrophic slimes. Below the plant the proportion of algae in the periphyton increased progressively with distance and was greater at the downstream recovery stations than at the upstream control stations. (4) Downstream from the plant, the relative periphyton production rates progressively increased. The warm water discharges clearly favored the production of the heterotrophic slimes during the warm summer months. (5) As regards the total supply of fish food in the periphyton, little net change due to the plant was observed. However, the findings indicate that the potential for problems due to slime growth would be increased in any industrial water-using operations located close downstream from the power plant.

The first unit at Paradise went into commercial operation in May 1963. While the second unit did not go into commercial operation until November 1963, it was initially fired up on August 21, 1963. During the initial firing, flow in the Green River was less than condenser flow. During two periods in the fall of 1963 (September 12 to September 13, and September 23 to October 1), the maximum mean temperature determined at Green River mile 99.5 exceeded 95° F.

Five winter fish inventories were made by TVA and Kentucky biologists in the years 1962-1966. A much larger winter fish population is consistently found in the vicinity of the discharge canal than in the river above and below the plant. Distribution of fish by type paralleled summer findings, except game fish were much more numerous than in preoperational samples. Fishermen know that steam plant discharge canals are excellent spots for fishing in winter months.

The 95° F. temperature maximum recommended in 1962 remained in effect during 1963, 1964, and 1965. Because of the reduction in species diversity and abundance indicated by Dr. Pr[illegible]'s 1965 study, it was concluded that the temperature criteria should be changed. About this time the construction of a third unit at Paradise was planned. Cooling towers were to be provided for the new unit. Since the existing two units were required to operate under reduced load for a long period each year to meet the 95° F. criterion, and since operation would be further curtailed by new temperature limits, it appeared desirable to provide cooling towers for all three units. A maximum mean river temperature of 93° F. was allowed until the first cooling tower was put into operation during the summer of 1968. The new criteria established by TVA limit maximum mean river temperature to 90° F. and surface temperature to 93° F.

APPENDIX IV

PROPOSED RESEARCH PROJECT ON EFFECTS OF HEATED WATER ON AQUATIC LIFE

Proposed Research Project on Effects of Heated Water on Aquatic Life

TVA is planning a large-scale biological research project to explore the effects of heated water on aquatic life. This is a long-term project to be conducted in cooperation with the Environmental Protection Agency.

The objectives of the proposed experiments are:

1. To determine the relationship between annual temperature regime and growth, reproduction, mortality, and yield of warmwater commercial and sport fish populations living under nearly natural conditions. Each of the above processes will be modeled mathematically using methods similar to those described by Ricker (1958) and Beverton and Holt (1957). Parameters in these models will be related to the annual temperature regime using several equations reviewed by Andrewartha and Birch (1954) and Watt (1968). These results will be used to predict the effect of different annual temperature regimes on growth, mortality, reproduction, production, and yield from a fishery.

   Measures of condition and size distribution will also be made on the fish. Emphasis in these studies will be placed on sport and commercially valuable fish populations because these populations are of immediate and measurable importance. The significance of changes in fish populations is more easily evaluated, from the viewpoint of human economics, than is the significance of changes in other aquatic populations, and increased water temperature will probably have a greater effect on fish than on other aquatic life.

2. The accuracy of "safe" water temperature regimes estimated using laboratory experiments will be evaluated by comparing results from the channel studies with "safe" levels determined by using both LD_{50} values and experiments similar to those done by Mount and Stephan (1967).

3. The relationship between annual temperature regime and the production of warmwater, commercially valuable mussel populations living under nearly natural conditions will be determined using the same methods as will be used for fish.

4. The relationship between annual temperature regime and the production of warmwater bottom fauna and other fish food organisms will be modeled using methods similar to those to be used for the fish studies.

5. The effect of different annual temperature regimes on the ecological relationships between fishes and their food organisms will be studied using conceptual models similar to those developed by Beverton and Holt (1957). The models will be fitted to the data by the method of

least squares, and then the effect of temperature on the parameters in the model will be studied.

6. The effect of different annual temperature regimes on algal community composition will be determined by estimating the relative frequencies of occurrence of different groups. Mathematical models for algal productivity will be constructed.

7. The effect of temperature on the relationships among streambottom microbial populations will be studied.

8. The effect of different annual temperature regimes on the competitive interaction between two species of fish will be investigated.

9. The effect of annual temperature regime on the predation of one species of fish on another fish species may be investigated.

10. The feasibility of using systems models for determining the effect of different annual temperature regimes on the structural and functional relationships of stream communities will be investigated.

In completing the above objectives, the Browns Ferry project will provide data for establishing temperature criteria for warmwater streams, data for determining the accuracy of laboratory estimates of safe water quality criteria, and data for investigating the potential of applying systems analysis in ecology.

A total of eight naturalistic stream channels will be used. Two of these channels will serve as biological controls water of natural temperature. The other six channels will contain water with temperatures elevated to some degree above that in the control channels.

Water will be supplied to the channels from Wheeler Reservoir. Water of natural temperature will come through a special intake located near the upstream end of the intake canal for the power plant. Warm water for the three pairs of experimental channels will be heated in heat exchangers. The source of heat for the heat exchangers will be warm water discharged through a manifold from the power plant condensers.

The captive fish and associated biota will be exposed to the experimental conditions 100 percent of the time. In streams or reservoirs receiving heated discharges, effects of heat would be less since upper limit temperatures in the heat-receiving stream or reservoir will occur only intermittently due to variables such as variations in streamflows, powerloads, etc. Consequently, the controlled experiments should yield the most detrimental (or beneficial) effects possible of the particular heat regimes.

The findings from the research should have wide application. Given proper interpretation, they should be of great value in setting or adjusting water quality standards for temperature. The data obtained should help define the degree of protection needed for aquatic life, together with the degree to which warmwater streams can be used, in the public interest, to absorb heated discharges from industry.

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