E/EIS-0121D

Draft
Environmental Impact Statement

Alternative Cooling Water Systems
Savannah River Plant
Aiken, South Carolina

March 1986
U.S. Department of Energy

DOE/EIS-0121D

Draft
Environmental Impact Statement

Alternative Cooling Water Systems
Savannah River Plant
Aiken, South Carolina

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

March 1986
U.S. Department of Energy

COVER SHEET

RESPONSIBLE AGENCY: U. S. Department of Energy

ACTIVITY: Draft Environmental Impact Statement, Alternative Cooling Water Systems at the Savannah River Plant, Aiken, South Carolina.

CONTACT: Additional information concerning this statement can be obtained from:

Mr. R. P. Whitfield, Director, Environmental Division,
U. S. Department of Energy
Savannah River Operations Office
P. O. Box A, Aiken, South Carolina 29802
(803) 725-3957

For general information on the Department of Energy's EIS process contact:

Office of the Assistant Secretary for Environment,
Safety, and Health, U.S. Department of Energy
ATTN: Dr. Robert J. Stern, Director
Office of Environmental Guidance (EH-23)
Room 3G-092 Forrestal Building
1000 Independence Avenue, SW
Washington, D. C. 20585
(202) 252-4600

ABSTRACT: The purpose of this Draft Environmental Impact Statement (DEIS) is to provide environmental input into the selection and implementation of cooling water systems for thermal discharges from the C- and K-Reactors and from a coal-fired powerhouse at the Savannah River Plant. The Savannah River Plant is a major U.S. Department of Energy (DOE) installation for the production of nuclear materials for national defense. The DEIS addresses the potential environmental consequences of constructing and operating once-through and recirculating cooling towers for the C- and K-Reactors; increased pumping to a raw water basin and direct discharge to the Savannah River for a coal-fired powerhouse; and no action. The potential environmental consequences assessed include effects on air and water quality, ecological systems, archaeological resources, endangered species, and wetlands.

COMMENT PERIOD: Written comments addressed to Mr. Whitfield and postmarked by May 19, 1986, will be considered in the preparation of the Final Environmental Impact Statement.

TABLE OF CONTENTS

Chapter		Page
	Cover Sheet	i
	Table of Contents	iii
	Preface	xii
	SUMMARY	S-1
1	NEED FOR COOLING WATER SYSTEMS AND PURPOSE OF THIS ENVIRONMENTAL IMPACT STATEMENT	1-1
	1.1 Need	1-1
	1.2 Purpose	1-3
	REFERENCES	1-4
2	COOLING WATER ALTERNATIVES AND PROPOSED ACTION	2-1
	2.1 Screening Process	2-1
	2.2 Proposed Action	2-4
	2.2.1 C-Reactor Cooling Water Alternatives	2-4
	2.2.1.1 Once-Through Cooling Tower (Preferred Alternative)	2-4
	2.2.1.2 Recirculating Cooling Towers	2-16
	2.2.1.3 No Action - Existing System	2-21
	2.2.2 K-Reactor Cooling Water Alternatives	2-22
	2.2.2.1 Once-Through Cooling Tower (Preferred Alternative)	2-23
	2.2.2.2 Recirculating Cooling Towers	2-28
	2.2.2.3 No Action - Existing Alternative	2-31
	2.2.3 D-Area Powerhouse Alternatives	2-33
	2.2.3.1 Increased Flow with Mixing (Preferred Alternative)	2-33
	2.2.3.2 Direct Discharge to Savannah River	2-36
	2.2.3.3 No Action - Existing System	2-40
	2.3 Comparison of Alternatives	2-41
	2.3.1 Alternatives for C-Reactor	2-42
	2.3.2 Alternatives for K-Reactor	2-49
	2.3.3 Alternatives for D-Area	2-49
	REFERENCES	2-60
3	AFFECTED ENVIRONMENT	3-1
	3.1 Savannah River Plant Site and Region	3-1
	3.1.1 Geography	3-1
	3.1.2 Socioeconomic and Community Characteristics	3-4
	3.1.2.1 Study Area	3-4
	3.1.2.2 Demography	3-4
	3.1.2.3 Land Use	3-8
	3.1.2.4 Public Services and Facilities	3-8

TABLE OF CONTENTS (continued)

Chapter Page

3 AFFECTED ENVIRONMENT (continued)

3.1.2.5 Housing 3-9
3.1.2.6 Economy 3-9
3.1.3 Historic and Archaeological Resources 3-9
3.1.4 Geology 3-11
3.1.4.1 Geologic Setting 3-11
3.1.4.2 Stratigraphy 3-11
3.1.4.3 Geologic Structures 3-13
3.1.4.4 Seismicity 3-13
3.1.4.5 Streambed Sediments 3-14
3.1.4.6 Geotechnical Properties of Sediments and Subsurface Materials 3-17
3.1.5 Hydrology 3-18
3.1.5.1 Surface-Water Hydrology 3-18
3.1.5.2 Subsurface Hydrology 3-23
3.1.6 Ecology 3-25
3.1.6.1 Terrestrial Ecology 3-25
3.1.6.2 Aquatic Ecology 3-28
3.1.7 Meteorology and Climatology 3-32
3.1.7.1 Regional Climatology 3-33
3.1.7.2 Local Meteorology 3-33
3.1.7.3 Severe Weather 3-38
3.1.7.4 Atmospheric Dispersion 3-41
3.1.8 Radiation and Radionuclides in the Environment . . 3-43
3.1.8.1 Sources of Environmental Radiation 3-43
3.1.8.2 Environmental Radiation Levels in the Southeastern United States 3-44
3.1.8.3 Environmental Radiation Levels in the Vicinity of the Savannah River Plant . . 3-45
3.2 Four Mile Creek (C-Reactor) 3-48
3.2.1 Geography 3-48
3.2.2 Historic and Archaeological Resources 3-49
3.2.3 Hydrology 3-49
3.2.4 Ecology 3-51
3.2.4.1 Terrestrial Ecology 3-51
3.2.4.2 Aquatic Ecology 3-52
3.2.5 Radioactivity Releases and Radionuclide Transport 3-53
3.3 Pen Branch and Indian Grave Branch (K-Reactor) 3-54
3.3.1 Geography 3-54
3.3.2 Historic and Archaeological Resources 3-54
3.3.3 Hydrology 3-56
3.3.4 Ecology 3-56
3.3.4.1 Terrestrial Ecology 3-56
3.3.4.2 Aquatic Ecology 3-57
3.3.5 Radioactivity Releases and Radiological Transport 3-58

TABLE OF CONTENTS (continued)

Chapter Page

3 AFFECTED ENVIRONMENT (continued)

3.4 Beaver Dam Creek (D-Area Coal-Fired Powerhouse) 3-60
3.4.1 Geography 3-60
3.4.2 Historic and Archaeological Resources 3-60
3.4.3 Hydrology 3-60
3.4.4 Ecology 3-61
3.4.4.1 Terrestrial Ecology 3-61
3.4.4.2 Aquatic Ecology 3-62
3.4.5 Radioactivity Releases and Radionuclide Transport 3-63
REFERENCES 3-64

4 ENVIRONMENTAL CONSEQUENCES 4-1

4.1 Alternatives for C-Reactor 4-1
4.1.1 Once-Through Cooling Tower 4-1
4.1.1.1 Construction Impacts 4-1
4.1.1.2 Operational Impacts 4-5
4.1.2 Recirculating Cooling Towers 4-18
4.1.2.1 Construction Impacts 4-18
4.1.2.2 Operational Impacts 4-20
4.1.3 No Action - Existing System 4-30
4.1.3.1 Water Quality and Hydrology 4-30
4.1.3.2 Ecology and Wetlands 4-31
4.1.3.3 Entrainment and Impingement 4-32
4.1.3.4 Endangered Species 4-33
4.2 Alternatives for K-Reactor 4-33
4.2.1 Once-Through Cooling Tower 4-33
4.2.1.1 Construction Impacts 4-33
4.2.1.2 Operational Impacts 4-35
4.2.2 Recirculating Cooling Towers 4-43
4.2.2.1 Construction Impacts 4-43
4.2.2.2 Operational Impacts 4-44
4.2.3 No Action - Existing System 4-52
4.2.3.1 Water Quality and Hydrology 4-53
4.2.3.2 Ecology and Wetlands 4-53
4.2.3.3 Entrainment and Impingement 4-54
4.2.3.4 Endangered Species 4-54
4.3 Alternatives for D-Area Coal-Fired Powerhouse 4-54
4.3.1 Increased Flow with Mixing 4-55
4.3.1.1 Construction Impacts 4-55
4.3.1.2 Operational Impacts 4-55
4.3.2 Direct Discharge to Savannah River 4-60
4.3.2.1 Construction Impacts 4-60
4.3.2.2 Operational Impacts 4-62
4.3.3 No Action - Existing System 4-65

TABLE OF CONTENTS (continued)

Chapter		Page
4	ENVIRONMENTAL CONSEQUENCES (continued)	
	4.3.3.1 Water Quality and Hydrology	4-65
	4.3.3.2 Ecology and Wetlands	4-66
	4.3.3.3 Entrainment and Impingement	4-66
	4.3.3.4 Endangered Species	4-66
	4.4 Cumulative Impacts of Alternative Cooling Water System Construction and Operation	4-67
	4.4.1 Surface-Water Usage	4-67
	4.4.2 Thermal Discharge Effects	4-68
	4.4.2.1 Onsite Streams and Savannah River Swamp	4-68
	4.4.2.2 Savannah River	4-68
	4.4.3 Ecology	4-69
	4.4.3.1 Terrestrial Areas	4-69
	4.4.3.2 Onsite Streams and Savannah River Swamp	4-70
	4.4.3.3 Savannah River	4-71
	4.4.3.4 Entrainment and Impingement	4-71
	4.4.3.5 Endangered Species	4-71
	4.4.4 Radiological Releases	4-72
	4.4.5 Air Quality	4-75
	4.5 Unavoidable/Irreversible Impacts of Alternatives	4-76
	4.5.1 Unavoidable Adverse Impacts	4-76
	4.5.2 Irreversible and Irretrievable Commitments of Resources	4-80
	4.5.3 Short-Term Uses and Long-Term Productivity	4-80
	4.6 Comparison of Alternatives for C- and K-Reactors and D-Area	4-80
	4.6.1 Alternatives for C-Reactor	4-80
	4.6.1.1 Once-Through Cooling Tower	4-80
	4.6.1.2 Recirculating Cooling Towers	4-81
	4.6.1.3 No Action	4-82
	4.6.2 Alternatives for K-Reactor	4-83
	4.6.2.1 Once-Through Cooling Tower	4-83
	4.6.2.2 Recirculating Cooling Towers	4-83
	4.6.2.3 No Action	4-84
	4.6.3 Comparisons for D-Area	4-84
	4.6.3.1 Increased Flow with Mixing	4-84
	4.6.3.2 Direct Discharge	4-85
	4.6.3.3 No Action	4-85
	REFERENCES	4-87
5	FEDERAL AND STATE ENVIRONMENTAL REQUIREMENTS	5-1
	5.1 Applicable Statutes and Regulations	5-1
	5.2 Historic Preservation	5-9
	5.3 Solid Waste Disposal	5-9
	5.4 Endangered Species	5-10

TABLE OF CONTENTS (continued)

Chapter		Page
5	FEDERAL AND STATE ENVIRONMENTAL REQUIREMENTS (continued)	
	5.5 Wildlife and Fisheries	5-10
	5.6 Water Quality	5-11
	5.7 Floodplains/Wetlands	5-13
	5.8 Air Quality	5-13
	5.9 Department of Energy Health and Safety Orders	5-14
	REFERENCES	5-15

LIST OF PREPARERS

DISTRIBUTION LIST FOR DRAFT ENVIRONMENTAL IMPACT STATEMENT

GLOSSARY

APPENDIX A. IDENTIFICATION OF COOLING WATER ALTERNATIVES FOR EVALUATION IN THE EIS

APPENDIX B. THERMAL MODELING

APPENDIX C. ECOLOGY

APPENDIX D. RADIOCESIUM INVENTORY AND TRANSPORT AND ATMOSPHERIC TRITIUM RELEASES

APPENDIX E. ARCHAEOLOGICAL AND HISTORIC RESOURCES

APPENDIX F. FLOODPLAIN/WETLANDS ASSESSMENT

APPENDIX G. RADIATION AND DOSE CALCULATION METHODS AND ASSUMPTIONS

APPENDIX H. SCOPING COMMENTS AND RESPONSES

LIST OF ILLUSTRATIONS

Figure		Page
2-1	C-Reactor Once-Through Cooling-Tower System (with Pumped Feed) Flow Diagram	2-6
2-2	C-Reactor Once-Through Cooling-Tower System with Pumped Feed	2-7
2-3	C-Reactor Once-Through Cooling-Tower System (with Gravity Feed) Flow Diagram	2-9
2-4	C-Reactor Once-Through Cooling-Tower System with Gravity Feed	2-10
2-5	C-Area Recirculating Cooling-Tower Flow Diagram	2-17
2-6	C-Reactor Recirculating Cooling-Tower System	2-18
2-7	K-Reactor Once-Through Cooling-Tower System with Pumped Feed	2-24
2-8	K-Reactor Once-Through Cooling-Tower System with Gravity Feed	2-26
2-9	K-Reactor Recirculating Cooling-Tower System	2-29
2-10	D-Area Existing System Flow Diagram	2-34
2-11	D-Area Discharge to Savannah River Alternative	2-37
2-12	D-Area Direct Discharge to Savannah River Flow Diagram	2-38
3-1	SRP Location in Relation to Surrounding Population Centers	3-2
3-2	Savannah River Plant Site Map	3-3
3-3	Counties in SRP Area	3-6
3-4	General Map of Archaeological Survey Area	3-10
3-5	Generalized NW to SE Geologic Profile Across the Savannah River Plant	3-12
3-6	Characteristics of Streambed Sediments, Four Mile Creek and Pen Branch	3-15
3-7	Savannah River Monthly Average Daily-Minimum Temperatures for 1971-1983	3-21
3-8	Hydrostatic Head of Groundwater Near H-Area and the Center of the SRP in Relationship to Principal Hydrostratigraphic Units	3-24
3-9	C-Area Tower, 1975-1979	3-35
3-10	K-Area Tower, 1975-1979	3-36
3-11	D-Area Tower, 1975-1979	3-37
4-1	K-Reactor Once-Through Tower, Total Solids Deposition	4-37
4-2	K-Reactor Recirculating Towers, Total Solids Deposition	4-46
4-3	C- and K-Reactor Once-Through Towers, Frequency of Occurrence of Elevated Visible Plumes	4-77
4-4	C- and K-Reactor Recirculating Towers, Total Solids Deposition	4-78

LIST OF TABLES

Table		Page
2-1	Temperatures Along Cooling Water Flow Path of C-Reactor Once-Through Mechanical-Draft Cooling Tower	2-14
2-2	Temperatures Along Cooling Water Flow Path--C-Reactor Recirculating Cooling Towers	2-21
2-3	Temperatures Along C-Reactor Cooling Water Flow Path: No Action (Existing System)	2-23
2-4	Temperatures Along Cooling Water Flow Path of K-Reactor Once-Through Mechanical-Draft Cooling Tower	2-27
2-5	Temperatures Along Cooling Water Flow Path--K-Reactor Recirculating Cooling Tower	2-30
2-6	Temperatures Along K-Reactor Cooling Water Flow Path: No Action (Existing System)	2-32
2-7	Temperatures Along Cooling Water Flow Path of D-Area Powerhouse for Increased Flow with Mixing Alternative	2-35
2-8	Temperatures and Passage Zone Sizes for D-Area Powerhouse Direct Discharge Into Savannah River	2-39
2-9	Temperatures Along Cooling Water Flow Path--D-Area Powerhouse--No Action (Existing System)	2-41
2-10	Comparison of Cooling Water Alternatives for C-Reactor	2-43
2-11	Comparison of Cooling Water Alternatives for K-Reactor	2-50
2-12	Comparison of Cooling Water Alternatives for D-Area	2-57
3-1	Distribution of June 1980 SRP Employees by Place of Residence	3-5
3-2	1980 Population for Counties and Places of 1000 Persons or Greater	3-7
3-3	Water Quality of the Savannah River, 1973 to 1982, Upriver of the SRP, at Pumphouse 3G and Downriver at the U.S. Highway 301 Bridge	3-20
3-4	Land Utilization, 1983	3-26
3-5	Average and Extreme Temperatures at Savannah River Plant, 1961-1981	3-34
3-6	Average Monthly Wind Speed for Bush Field, Augusta, Georgia, 1951-1981, and WJBF-TV Tower, 1976-1977	3-38
3-7	Precipitation at Savannah River Plant, 1952-1982	3-39
3-8	Extreme Wind Speeds for Area of Savannah River Plant	3-40
3-9	Tornado Occurrence by Month	3-41
3-10	Major Sources of Radiation Exposure in the Vicinity of the Savannah River Plant	3-46
3-11	Temperature and Dissolved Oxygen in Four Mile Creek	3-50
3-12	Four Mile Creek Water Quality	3-50
3-13	Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Four Mile Creek	3-55
3-14	Pen Branch and Indian Grave Branch Water Quality: November 1983 to May 1984	3-57
3-15	Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Pen Branch and Indian Grave Branch	3-59

LIST OF TABLES (continued)

Table		Page
3-16	Beaver Dam Creek Water Quality Downstream of All 400-D Area Effluents	3-61
4-1	Projected Total Construction Workforces at Savannah River Plant and Plant Vogtle	4-2
4-2	Increase in Annual Doses to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from C-Reactor Once-Through Cooling Tower (Pumped Feed)	4-14
4-3	Decrease in Annual Doses to Maximally Exposed Individual Resulting from a Decrease in Liquid Releases of Tritium from C-Reactor Once-Through Cooling Tower (Pumped Feed)	4-15
4-4	Decrease in Effective Whole-Body Collective Dose Resulting from Liquid Releases of Tritium from C-Reactor Once-Through Cooling Tower (Pumped Feed)	4-15
4-5	Effective Whole-Body Dose Increments Received by Maximally Exposed Individual Resulting from Operation of C-Reactor Once-Through Cooling Tower (Pumped Feed)	4-16
4-6	Effective Whole-Body Collective Dose Resulting from Operation of C-Reactor Once-Through Cooling Tower (Pumped Feed)	4-17
4-7	Changes in Annual Health Effects	4-18
4-8	Decrease in Doses to Maximally Exposed Individual Resulting from Cesium Redistribution Associated with C-Reactor Recirculating Cooling Towers	4-24
4-9	Decrease in Effective Whole-Body Collective Dose Resulting from Cesium Redistribution Associated with C-Reactor Recirculating Cooling Towers	4-25
4-10	Increase in Annual Dose to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from C-Reactor Recirculating Cooling Towers	4-26
4-11	Decrease in Annual Dose to Maximally Exposed Individual Resulting from a Decrease in Liquid Releases of Tritium from C-Reactor Recirculating Cooling Towers	4-27
4-12	Decrease in Effective Whole-Body Collective Dose Resulting from Liquid Releases of Tritium from C-Reactor Recirculating Cooling Towers	4-28
4-13	Changes in Effective-Whole-Body and Small and Lower Large Intestine Doses Received by Maximally Exposed Individual Resulting from Operation of C-Reactor Recirculating Cooling Towers	4-29
4-14	Changes in Effective Whole-Body Dose to Population Resulting from Operation of C-Reactor Recirculating Cooling Towers	4-30
4-15	Changes in Annual Health Effects	4-31
4-16	Increase in Annual Doses to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from K-Reactor Once-Through Cooling Tower (Pumped Feed)	4-42

LIST OF TABLES (continued)

Table		Page
4-17	Changes in Effective Whole-Body Dose Received by Maximally Exposed Individual Resulting from Operation of K-Reactor Once-Through Cooling Tower (Pumped Feed)	4-43
4-18	Decrease in Doses to Maximally Exposed Individual Resulting from Cesium-137 Redistribution Associated with K-Reactor Recirculating Cooling Towers	4-48
4-19	Decrease in Effective Whole-Body Collective Dose Resulting from Cesium-137 Redistribution Associated with K-Reactor Recirculating Towers	4-49
4-20	Increase in Annual Doses to Maximally Exposed Individual Resulting from Atmospheric Releases of Tritium from K-Reactor Recirculating Cooling Towers	4-50
4-21	Changes in Effective Whole-Body and Small and Lower Large Intestine Doses Received by Maximally Exposed Individual Resulting from Operation of K-Reactor Recirculating Cooling Towers	4-51
4-22	Changes in Effective Whole-Body Dose to Population Resulting from Operation of K-Reactor Recirculating Cooling Towers	4-52
4-23	Changes in Annual Health Effects	4-53
4-24	Cumulative Effective Whole-Body Doses with Present Cooling Water Systems (Existing Conditions) for C- and K-Reactors	4-74
4-25	Cumulative Effective Whole-Body Doses with a Once-Through Cooling Tower (Gravity Feed or Pumped Feed) for C- and K-Reactors	4-74
4-26	Cumulative Effective Whole-Body Doses with Recirculating Cooling Towers for C- and K-Reactors	4-75
4-27	Cumulative Health Effects	4-76
5-1	Required Regulatory Permits and Notifications	5-2

PREFACE

The purpose of this Environmental Impact Statement is to provide environmental input into the selection and implementation of cooling water systems for thermal discharges from C- and K-Reactors and from a coal-fired powerhouse in the D-Area at the Savannah River Plant (SRP); the Plant is a major U.S. Department of Energy (DOE) installation for the production of nuclear materials. Implementation of cooling water systems for these facilities is needed for compliance with the State of South Carolina Class B Water Classification Standards and Consent Order (84-4-W), dated January 3, 1984, and amended August 27, 1985, between DOE and the State of South Carolina Department of Health and Environmental Control (SCDHEC).

C- and K-Reactors, which are operating production reactors, discharge their cooling water directly to Four Mile Creek and Pen Branch, respectively. The onsite coal-fired powerhouse in D-Area discharges cooling water from cooling-system condensers into an excavated canal prior to discharge to Beaver Dam Creek. These facilities have been in operation since their construction in the 1950s.

On January 1, 1984, SCDHEC issued a National Pollutant Discharge Elimination System (NPDES) permit (Number SC0000175) for the Savannah River Plant. In this permit, the cooling water discharge limitations included a temperature limitation in onsite streams (i.e., cooling water discharges to onsite streams are not to exceed 32.2°C; in addition, the effluent must not raise the temperature of the stream more than 2.8°C above its ambient temperature) rather than in the Savannah River as previously permitted by EPA. To achieve compliance with these limitations, DOE and SCDHEC entered into a Consent Order (84-4-W) on January 3, 1984, that temporarily superseded the temperature requirements in the NPDES permit and identified a process for attaining compliance. Major elements of this process included a DOE agreement to complete a comprehensive study of the thermal effects of major SRP thermal discharges, the submittal of a thermal mitigation study, and the selection and implementation of cooling water systems.

On October 3, 1984, DOE submitted its Thermal Mitigation Study to SCDHEC describing the cooling water systems that could be implemented for C- and K-Reactors and the D-Area coal-fired powerhouse to achieve compliance with Federal and State water quality standards.

A Notice of Intent to prepare this EIS was published in the Federal Register on July 29, 1985 (50 FR 30728). That notice solicited comments and suggestions from interested agencies, organizations, and the general public for consideration in preparing the EIS. The preliminary scope was included in the Notice of Intent.

Comments were received by mail and at the scoping meeting held in Aiken, South Carolina on August 19, 1985. Written comments were received until August 31, 1985.

In response to the Notice of Intent, 12 individuals, organizations, and governmental representatives provided comments to assist in the preparation of this EIS. Appendix H provides the issues raised during the scoping process and cross-references to the appropriate Draft EIS chapter.

As part of the scoping process, DOE invited interested parties to comment on its preliminary determination of reasonable alternatives to be considered in the environmental impact statement (i.e., once-through and recirculating cooling towers for C- and K-Reactors, and increased pumping to the raw water basin for the D-Area powerhouse). Because DOE received no comments on this preliminary determination, it has identified these, in addition to direct discharge of D-Area cooling water to the Savannah River and "no-action" (required by the Council on Environmental Quality for implementing the National Environmental Policy Act), as the reasonable alternatives that it will consider in detail in this environmental impact statement.

This EIS was prepared in accordance with the Council on Environmental Quality NEPA regulations (40 CFR 1500-1508) and DOE's NEPA guidelines (45 FR 20694, March 28, 1980 as amended), by DOE and by DOE's contractors under the direction of DOE. Methodologies used and sources of information relied upon for analysis are identified in this EIS. In addition, available results of ongoing studies have been used.

Referenced material in the EIS is available for review in the U.S. Department of Energy's Public Reading Room, located at the University of South Carolina's Aiken Campus, Aiken, South Carolina, and the Freedom of Information Reading Room, Room 1E-190, Forrestal Building, 1000 Independence Avenue, S.W., Washington, D.C.

SUMMARY

PURPOSE

The U.S. Department of Energy (DOE) has prepared this draft environmental impact statement (EIS) to address the environmental consequences of the proposed construction and operation of cooling water systems for C- and K-Reactors and the D-Area coal-fired powerhouse at its Savannah River Plant (SRP) in accordance with Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969, as amended, and to provide input into the selection and implementation of such systems. In its preparation of this draft EIS, DOE has considered the comments that were submitted by government agencies, private organizations, and individuals during a public scoping period in August 1985.

NEED

The major sources of thermal effluents at the Savannah River Plant are the cooling water discharges from production reactors and the D-Area coal-fired powerhouse. Two of the operating production reactors, C- and K-Reactors, discharge their cooling water directly to Four Mile Creek and Pen Branch, respectively. The coal-fired powerhouse in D-Area normally discharges cooling water from cooling-system condensers into an excavated canal that flows into Beaver Dam Creek. At present, the discharges from these three facilities do not meet the temperature limits specified in the State of South Carolina's Class B water classification standards.

DOE must implement cooling water systems for the thermal discharges from C- and K-Reactors and the D-Area coal-fired powerhouse to comply with both the South Carolina Class B water classification standards [as contained in the renewed NPDES permit (Number SC0000175)] and a Consent Order (84-4-W), dated January 3, 1984, and amended August 27, 1985, between DOE and the State of South Carolina Department of Health and Environmental Control (SCDHEC). The Consent Order contains a compliance schedule for the completion of NEPA documentation and the construction and operation of cooling water systems to attain the Class B water classification standards, subject to the appropriation of funds by Congress. As stated in the NPDES permit, cooling water discharge temperature limits for C- and K-Reactors and the D-Area powerhouse are not to exceed an instream temperature of 32.2°C; in addition, the effluent must not raise the temperature of the stream more than 2.8°C above its ambient temperature unless a balanced biological community can be determined by a Section 316(a) demonstration study.

PROPOSED ACTION

The proposed action considered in this environmental impact statement is the construction and operation of cooling water systems for C- and K-Reactors and the D-Area powerhouse to attain compliance with the State of South Carolina's Class B water classification standards. DOE's preferred alternatives are to construct and operate once-through cooling towers for C- and K-Reactors, and to implement increased flow with mixing for the D-Area coal-fired powerhouse. Because the discharge temperatures of cooling water from these preferred alternatives will at times raise the ambient stream temperatures by more than 2.8°C, DOE will conduct Section 316(a) demonstration studies to determine whether a balanced biological community can be maintained.

ALTERNATIVES

DOE initially identified 22 possible alternative cooling water systems that could be implemented for C- and K-Reactors and 4 alternatives for the D-Area powerhouse. Using a structured screening process, DOE then identified those that would be reasonable to implement; the screening process and alternatives were documented in a Thermal Mitigation Study, which was submitted to SCDHEC on October 3, 1984. Based on the information contained in its Notice of Intent to prepare this EIS and the comments received during the public scoping period, DOE identified the cooling water alternatives that are considered in detail in this EIS.

Since the completion of the Thermal Mitigation Study, further design evaluations and studies of the alternatives to be considered in this EIS have been initiated to determine optimal performance parameters and to achieve lower costs. These evaluations and studies, which are still under way, have indicated that there are several areas in which optimization of performance and cost savings can be realized in the construction and operation of once-through towers without introducing major changes in the nature or magnitude of the environmental impacts. These areas include the consideration of gravity-feed versus pumped-feed towers, natural-draft versus mechanical-draft towers, and holding ponds (and their sizing) versus a chemical injection system for either dissipation or neutralization of chlorine biocide. Similarly, these evaluations and studies have also led to the development of thermal performance criteria that, when incorporated in the final design of a once-through cooling-tower system, would reduce the potential for cold shock (i.e., reduce the difference between ambient stream temperatures and stream temperatures when the cooling water is being discharged) to aquatic organisms.

The alternatives considered in this EIS for C- and K-Reactors are the construction and operation of once-through cooling towers (either mechanical or natural draft and either gravity or pump feed), the construction and operation of recirculating cooling towers, and the continuation of direct discharge - or no action [as required by the Council on Environmental Quality for implementing the procedural provision of the National Environmental Policy Act (40 CFR 1502.14)]. The alternatives considered for the D-Area coal-fired powerhouse are to increase the inlet water flow with mixing to the D-Area raw-water basin, and mix raw-water basin overflow with the cooling water discharge; to construct a new pipeline to enable a direct discharge to the Savannah River; and to continue the present operation - or no action.

AFFECTED ENVIRONMENT

The Savannah River Plant is a 780-square-kilometer (192,700-acre), controlled-access area near Aiken, South Carolina. This major DOE installation was established in the early 1950's for the production of nuclear materials for national defense. Six principal tributaries to the Savannah River are located on the Plant. Five of these streams have received thermal discharges from SRP cooling water operations. At present, Beaver Dam Creek, Four Mile Creek, and Pen Branch receive direct thermal discharges from the D-Area coal-fired powerhouse, C-Reactor, and K-Reactor, respectively.

The Plant is bordered on the southwest by the Savannah River, which it parallels for about 16 kilometers. About 9400 acres of the Savannah River swamp forest lie on the Plant from Upper Three Runs Creek to Steel Creek. Three breaches in a natural levee between the swamp system and the Savannah River allow water from Steel Creek, Four Mile Creek, and Beaver Dam Creek to flow to the river. The combined discharges of Steel Creek and Pen Branch enter the river near the southeastern corner of the Plant. During periods of flooding, the Savannah River overflows the levee and floods the entire swamp area, leaving only isolated islands.

The Savannah River downstream of Augusta, Georgia, is classified by the State of South Carolina as a Class B waterway, suitable for agricultural and industrial use, the propagation of fish, and, after treatment - domestic use.

The Savannah River Plant currently withdraws a maximum of 37 cubic meters per second, primarily for use as cooling water in production reactors and the D-Area coal-fired powerhouse. Almost all of this water returns to the river via SRP streams.

The thermal discharges from C- and K-Reactors have changed Four Mile Creek and Pen Branch from single-channel, meandering creeks to wide, multichannel, braided systems flowing within partially vegetated floodplains. Where the stream enters the swamp, eroded material has been deposited, and deltas have formed and continue to increase in size. An established 1817 acres of wetlands have been affected by the C- and K-Reactor thermal discharges. The estimated average annual loss of wetlands between 1975 and 1985 was about 54 acres.

Few aquatic organisms are found in the thermal areas of Four Mile Creek and Pen Branch. The thermal discharges prevent aquatic species from moving into the streams while the reactors are operating. Fish spawning in the streams and deltas is restricted. Fish are not present in the mouths of the streams except during the winter when they are attracted to the warm water plumes, making them vulnerable to cold shock when the reactors are shut down.

Water intake withdrawal from the Savannah River for C- and K-Reactors causes annual entrainment losses of about 43.1×10^6 fish eggs and larvae. These losses represent approximately 9 percent of the fish eggs and larvae passing the intake canals during the spawning season. In addition, impingement losses of about 8760 fish occur annually.

Portions of Four Mile Creek, Pen Branch, and the Savannah River swamp are too warm for the endangered American alligator. Low fish densities and high water levels also limit the forage value of these areas for the endangered wood stork.

The operation of the D-Area coal-fired powerhouse results in a withdrawal of about 2.6 cubic meters per second from the Savannah River and thermal discharges to Beaver Dam Creek. These discharges meet the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C except during periods from May through September, when water temperatures can reach as high as 36°C under extreme conditions. During extreme summer conditions and winter, the discharges from the D-Area powerhouse also result in not meeting the Class B water classification standard of a minimum ambient stream temperature rise of 2.8°C.

The thermal areas of Beaver Dam Creek and its delta support a large alligator population; the wood stork uses the area for foraging during the summer.

Water withdrawal from the river causes entrainment losses of about 3.0×10^6 fish eggs and larvae and impingement losses of about 4745 fish annually.

ENVIRONMENTAL CONSEQUENCES

No action - the once-through direct discharge of cooling water from C- and K-Reactors and the continuation of the thermal discharges from the D-Area powerhouse - would result in discharges that would not meet the State of South Carolina Class B water classification standard of a maximum instream temperature of 32.2°C. No action would also result in a continuation of the environmental conditions described above as the affected environment. The following sections summarize the environmental consequences of constructing and operating new cooling water systems for C- and K-Reactors and the D-Area coal-fired powerhouse.

C- AND K-REACTOR ONCE-THROUGH COOLING TOWERS (PREFERRED ALTERNATIVES)

The construction and operation of once-through cooling towers (either natural or mechanical draft and either pumped or gravity feed) are the preferred alternatives for C- and K-Reactors. Cooling water discharges from the once-through cooling towers would comply with the State of South Carolina Class B water classification standard of a maximum instream temperature of 32.2°C. Section 316(a) demonstration studies would be performed to determine whether a balanced biological community would be maintained when discharges raise ambient stream temperatures by more than 2.8°C. The reduction in the temperature of cooling water discharges as a result of once-through cooling tower operation and the continued discharge of approximately the same volume of cooling water would increase the available aquatic habitat for fishes and other organisms. Wetland losses estimated to be about 54 acres a year in the delta/swamp, would decrease as a result of reduced discharge temperatures and suspended solids, and some successional revegetation would occur.

For a natural or mechanical-draft, once-through, pump-feed tower, as much as 155 acres of uplands would be affected by construction. For a natural- or mechanical-draft, once-through, gravity-feed tower, approximately 80 acres of uplands would be affected by construction.

Annual entrainment (43.1×10^6 fish eggs and larvae) and impingement (8760 fish) losses would be about the same as those experienced with current operations. Final designs of the cooling towers would meet the EPA Maximum Weekly Average Discharge Temperature (MWAT) criteria to minimize the effects of cold shock on fish that could occur during a winter shutdown in Four Mile Creek and Pen Branch.

Air quality impacts, including fogging and icing, elevated visible plumes, and total-solids (drift) deposition would be negligible. The construction of the towers would disturb one known prehistoric archaeological site that has been determined to be not significant.

Current radiological releases, which would continue with the cooling water alternatives, are the remobilization of radionuclides in the Four Mile Creek and Pen Branch streambed systems, and radionuclides (principally tritium) from small process water leaks into the cooling water of the reactors' heat exchangers and releases into process sewers. The operation of once-through cooling towers for thermal discharges from C- and K-Reactors would not produce any significant changes in the remobilization of radionuclides in streambeds because the rate of cooling water discharges from the towers would remain essentially the same as current operations. The operation of a once-through cooling tower (at both C- and K-Reactors) would result in the annual release of about 100 additional curies of tritium to the atmosphere because of cooling tower evaporation and the discharge of about 100 curies less to the streams. Once-through cooling towers at both C- and K-Reactors would result in a total reduction in the maximum individual effective whole-body dose of about 2.3×10^{-4} millirem, and a decrease in the total collective dose to the 80-kilometer regional population and downstream water consumers by about 5.5×10^{-2} person-rem per year. These radiological dose changes are extremely small when compared with existing operations and natural background radiation, and doses remain within all applicable requirements and standards.

The estimated capital costs of constructing pumped- and gravity-feed, once-through, mechanical-draft cooling towers are about $109 million and $92 million, respectively. The estimated increases in annual operating costs for pumped- and gravity-feed towers above those for the existing systems are about $6.2 million and $3.8 million, respectively. In addition to those costs, the estimated costs to conduct Section 316(a) demonstration studies for C- and K-Reactors is $2.5 million. Construction would require about 22 months, after a 9-month lead design period. The use of a natural-draft cooling tower is expected to have similar capital cost and implementation schedule, and reduced operating costs.

C- AND K-REACTOR RECIRCULATING COOLING TOWERS

The construction and operation of recirculating cooling towers for C- and K-Reactors would enable DOE to comply with the State of South Carolina's Class B water classification standards, and would reduce thermal effects to Four Mile Creek and Pen Branch while reducing the current discharge (flow) rates by about 92 percent. The reduction in thermal effects would allow recolonization by fishes and other organisms, but the reduced flow would provide a smaller aquatic habitat area than the once-through cooling-tower alternative. Wetland losses estimated to be about 54 acres a year as a result of delta expansion, would essentially cease and the process of natural plant succession would occur in the area currently affected by thermal discharges, which is estimated to about 1,000 acres. An estimated 105 acres of uplands would be affected by construction of recirculating cooling towers for C- and K-Reactors.

Annual entrainment (eggs and larvae) losses would be reduced from 43.1×10^6 to 6.6×10^6, while annual impingement losses would be reduced from approximately 8760 to 1314 fish. Because the cooling water discharge from the recirculating cooling tower would comply with the State's Class B water classification standard of a maximum 2.8°C rise in ambient stream temperature, Section 316(a) demonstrations would not be required and no potential for cold shock to aquatic organisms would exist. Improvement of potential habitat for the American alligator, the wood stork, and fish over that resulting from existing conditions would occur due to the lower temperature in onsite streams.

Maximum annual total solids deposition from the recirculating towers could be higher than that for once-through cooling towers; however, deposition rates are far below levels that cause reduced vegetation productivity. The same prehistoric site - which has been determined to be not significant - that would be disturbed by the construction of the once-through towers would be affected by the construction of recirculating towers.

The operation of recirculating cooling towers, which would reduce flows in Four Mile Creek and Pen Branch, would result in a calculated decrease of about 1 curie of cesium released to the Savannah River. For both reactors, the operation of recirculating towers would also result in the annual release of about 850 additional curies of tritium to the atmosphere because of cooling-tower evaporation and the discharge of about 850 curies less to the streams. The reduction in radiocesium that would be remobilized, together with the changes in releases of tritium, would produce a total reduction (i.e., recircu-ating cooling towers at both C- and K-Reactors) in the maximum individual effective whole-body dose of about 0.75 millirem, and a decrease in the total collective dose to the 80-kilometer regional population and downstream water consumers of about 2.7 person-rem per year. These radiological dose changes are extremely small when compared with existing operations and natural background radiation, and doses remain within all applicable requirements and standards.

The estimated capital cost to construct recirculating cooling towers for C- and K-Reactors is about $153 million; this alternative would require about 28 months to construct after a 9-month design period. The estimated annual increase in operating costs is about $1.0 million.

D-AREA INCREASED FLOW WITH MIXING (PREFERRED ALTERNATIVE)

The implementation of increased flow with mixing for the D-Area powerhouse would reduce the thermal effects in Beaver Dam Creek during critical periods (May-September) by temporarily increasing the flow at these times. The lowering of water temperatures to comply with the State of South Carolina Class B water classification standard of a maximum instream temperature of 32.2°C would improve the aquatic habitat in the creek. A Section 316(a) demonstration would be performed to determine whether a balanced biological community is maintained when discharges result in raising ambient stream temperatures by more than 2.8°C.

Annual entrainment of fish eggs and larvae would increase by about 3 percent (3.0 to 3.1 x 10^6 fish eggs and larvae), while impingement losses would increase from 4745 to about 4887; about the same as those experienced with current operations. Temporary wetland disturbances are estimated to be about 4 acres during the periods when pumping would be necessary. Habitat of the endangered American alligator would not be affected, but some temporary alteration in wood stork foraging habitat could result from greater water depths during periods when extra pumping is required to meet temperature standards. There would be no impacts to air quality, noise, release of radionuclides, or archaeological resources due to the implementation of this alternative.

This alternative could be initiated without any capital costs. Annual operating costs would increase by about $30,000. In addition, the estimated cost to conduct a Section 316(a) demonstration study is $1.25 million.

D-AREA DIRECT DISCHARGE TO THE SAVANNAH RIVER

Discharging effluent directly to the Savannah River would lower water temperatures to ambient levels in Beaver Dam Creek. The removal of the discharge flow would lower water levels greatly in the creek, thereby reducing available spawning and foraging habitat for aquatic organisms. An estimated 1 acre of wetlands and 5 acres of uplands would be adversely affected by the construction of the direct-discharge pipeline. Small increases in water temperatures would occur within a mixing zone in the Savannah River and the discharge would meet State of South Carolina Class B water classification standards outside the mixing zone.

Entrainment and impingement effects would be the same as those experienced during present operations. The removal of the discharge from the D-Area powerhouse from the creek would greatly degrade the habitats of the endangered American alligator and wood stork. There would be no impacts on air quality, noise, radiological releases, or archaeological resources.

The construction of the discharge pipeline would require a capital cost of approximately $14 million and about 22 months to complete. Its operation would increase annual operating costs by about $50,000 per year.

CUMULATIVE ENVIRONMENTAL CONSEQUENCES

The major cumulative impacts associated with the construction and operation of the cooling water alternatives include surface-water usage, ecological impacts, radiological releases, and air quality impacts.

SURFACE-WATER USAGE

The Savannah River Plant currently withdraws approximately 37 cubic meters per second of water from the Savannah River. Approximately 2.4 cubic meters per second of this withdrawal is consumed, and the remainder is returned to the Savannah River via discharges to onsite streams. Total withdrawal from the Savannah River is currently about 24 percent of the 7-day, 10-year low flow, or about 13 percent of the average Savannah River flow.

Construction and operation of once-through cooling towers for C- and K-Reactor would not alter the amount of water currently withdrawn from the Savannah River; however, an additional 1 cubic meter of water would be consumed as a result of evaporative losses from the cooling-tower operation. Construction and operation of recirculating cooling towers would reduce the amount of water withdrawn from the Savannah River by about 19.2 cubic meters per second and would also result in an additional 1 cubic meter of water consumed as a result of cooling-tower evaporative losses.

Construction of the direct-discharge system for the D-Area powerhouse would not alter the existing amounts of water withdrawal or discharge. Implementation of the increased-flow-with-mixing alternative, which would require additional withdrawals to meet the 32.2° State Class B water classification standard, would also not result in any additional consumptive water losses because the increased withdrawals associated with this alternative would be returned to the Savannah River via Beaver Dam Creek.

ECOLOGY

The principal cumulative impact of the implementation of cooling water systems for C- and K-Reactors and the D-Area powerhouse would be a reduction in the temperatures of Four Mile Creek, Pen Branch, and Beaver Dam Creek. This temperature reduction would allow successional revegetation of thermally affected areas, improvement in wildlife habitats compared to existing conditions, and recolonization of thermally affected streams by fish and macroinvertebrates.

Construction and operation of once-through cooling towers for C- and K-Reactors would maintain approximately the same rates of flow and flow variability (i.e., when the reactors are operating as opposed to when they are not operating) in Four Mile Creek and Pen Branch. Construction and operation of recirculating cooling towers would significantly reduce the rates of flow in these streams, and also reduce the variations in flow. For the once-through cooling towers, the combined effect of reduced stream temperatures and maintenance of approximately the same flow rates would result in the establishment of a greater amount of aquatic habitat than for the recirculating towers; however, because of the larger flow rates and flow variability associated with the once-through cooling towers, operation of recirculating cooling towers would result in the successional recovery of a greater amount of wetlands.

Because of the difference in the rates of withdrawal of Savannah River water between the once-through and recirculating cooling towers, the cumulative Savannah River Plant annual entrainment and impingement losses resulting from cooling water withdrawal would remain about the same with operation of the once-through cooling towers, and would be reduced (36.5×10^6 fish eggs and larvae and 7446 fish annually) with the operation of recirculating cooling towers. Implementation of the increased-flow-with-mixing alternative for the D-Area powerhouse would result in a slightly greater annual cumulative rate of entrainment and impingement (0.1×10^6 fish eggs and larvae and 142 fish).

The implementation of any of the cooling water alternatives (i.e., once-through or recirculating cooling towers for C- and K-Reactors, and increased flow with mixing for the D-Area powerhouse) except the direct-discharge alternative for the D-Area powerhouse would not adversely affect any endangered species. Implementation of the direct-discharge alternative would result in a loss of foraging habitat for the wood stork and existing habitat for the American alligator due to the removal of the discharge flows from Beaver Dam Creek to the Savannah River.

RADIOLOGICAL RELEASES

Radiological doses associated with current SRP operations are within applicable limits and account for less than 0.1 percent of the total annual dose to an average individual within 80 kilometers of the Savannah River Plant. Construction and operation of either once-through or recirculating cooling towers would result in a very small decrease in the cumulative radiological doses associated with existing and planned SRP operations and other nuclear facilities within the vicinity of the plant. The reduction in cumulative radiological doses would be greater with the operation of recirculating cooling towers than with the operation of once-through cooling towers because of remobilization of cesium-134 and cesium-137.

AIR QUALITY

The operation of either once-through or recirculating cooling towers would increase cumulative solids deposition. Maximum annual total solids deposition would be greater for recirculating cooling towers than for once-through cooling towers, and would be far below levels that cause reduced vegetative productivity.

The operation of either once-through or recirculating cooling towers would also cause minor and temporary reductions in ground-level visibility and infrequent visible plumes and ice accumulations within 0.4 kilometer of the towers.

COMPARISON OF ALTERNATIVES

For C- and K-Reactors, the principal environmental benefits of recirculating cooling towers compared to once-through cooling towers would be the reestablishment of a greater amount of wetlands and the reduction in entrainment and impingement losses. Recirculating towers for both reactors would cost about $5.2 million less to operate each year than the once-through towers with pumped feed, and $2.8 million less to operate than once-through towers with gravity feed. The principal environmental benefit of the once-through cooling towers compared to that for the recirculating cooling towers would be the maintenance of existing flow levels in the creeks and deltas, thus providing more potential aquatic habitat for fish and other aquatic organisms. The once-through cooling-tower system for both reactors would cost between $61 million (gravity feed) and $44 million (pumped feed) less to construct than recirculating cooling towers, and the construction would take about 6 months less than that for recirculating towers.

For the D-Area powerhouse, the principal environmental benefit of the increased-flow-with-mixing alternative over the direct-discharge alternative would be that it would maintain existing water levels in Beaver Dam Creek, thereby maintaining habitat for the endangered American alligator and wood stork and other aquatic organisms. It would also avoid adverse impacts to about 1 acre of wetlands and 5 acres of uplands that would result from the construction of the direct-discharge pipeline. There would also be a capital cost savings of about $14 million initially and about $20,000 per year thereafter.

Table S-1 summarizes and compares the environmental consequences of DOE's preferred cooling water alternative [i.e., once-through cooling towers (either mechanical or natural draft, and either pumped or gravity feed), recirculating cooling towers and the no-action alternative for C- and K-Reactors.

Table S-2 summarizes and compares the environmental consequences of DOE's preferred cooling water alternative (i.e., increased flow with mixing), direct discharge to the Savannah River, and the no-action alternative for the D-Area powerhouse.

FEDERAL AND STATE REQUIREMENTS

Table S-3 lists the permits and other environmental approvals required for the implementation of cooling water alternatives for C- and K-Reactors and the D-Area powerhouse and the current status of each requirement.

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for C- and K-Reactors.

Impacts	No Action[a]	Once-Through Cooling Tower (Preferred Alternative[b])	Recirculating Cooling Towers[c]
SCHEDULE FOR IMPLEMENTATION	Current	Construction of the system would require 22 months after a 9-month design period.	Construction of the system would require 28 months after a 9-month design period.
PRELIMINARY COST CAPITAL (MILLION $)	$0	$92-109	$153
ESTIMATED OPERATING COST INCREASE (MILLION $ PER YEAR)	$0	$3.8-6.2	$1.0
SOCIOECONOMICS	No additional workforce required.	Peak construction workforce of 400 persons and 8 persons for operation.	Peak construction workforce of 600 persons and 12 persons for operation.
WATER WITHDRAWAL AND DISCHARGE RATES	About 22.6 cubic meters per second withdrawn from the Savannah River and discharged to the creeks.	Withdrawal the same as for no action; discharge to the creeks would be about 92% of that for no action or 20.8 cubic meters per second.	Withdrawal of river water would be about 15% of that for no action or 3.4 cubic meters per second. Discharge to the creeks would be about 5% of that for no action or 1.2 cubic meters per second.
WATER QUALITY	Water temperature in the creeks would exceed State Class B water classification standards. Dissolved oxygen concentrations would continue to be below standards intermittently during the summer and suspended	State Class B water classification standards for temperature (32.2°C) and dissolved oxygen concentrations would be met; Section 316(a) demonstration studies will be performed for exceedances of 2.8°C rise in ambient stream temperatures. There would be some reduction in suspended	Same as for once-through towers except that Section 316(a) demostration studies would not be required. Dissolved solids concentrations in discharge would be higher than no action or once-through cooling towers because of

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for C- and K-Reactors (continued).

Impacts	No Action[a]	Once-Through Cooling Tower (Preferred Alternative[b])	Recirculating Cooling Towers[c]
	solids would continue to be slightly higher than ambient stream levels.	solids.	cycles of concentrations; however, total suspended solids discharged would be greatly reduced.
TEMPERATURE AND FLOW EFFECTS	There would continue to be few aquatic organisms in the thermal areas of the creeks and deltas. A thermal barrier will prevent aquatic movement in both creeks. Fish spawning in both creeks and deltas would remain reduced. There would continue to be a potential for cold shock during the winter.	Reestablishment of aquatic fauna, spawning, and foraging in present thermal areas. There would be no potential for cold shock as the MWAT (EPA, 1977) criteria for winter shutdowns would be met. Water levels would continue to fluctuate.	Similar mitigation of thermal effects that would occur with once-through towers except that habitat area for aquatic spawning and foraging would be smaller because of reduced flow and magnitude of water level fluctuations would be less.
ENTRAINMENT/ IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 43.1 x 10^6 fish eggs and larvae and the loss of about 8760 fish to impingement annually.	Effects would be about the same as for no action.	Annual entrainment and impingement losses would be reduced to about 6.6 x 10^6 and 1314, respectively.
HABITAT	Annual losses of about 54 acres of wetlands due to discharge temperatures and flows would continue.	Wetland losses would decrease; some revegetation of these areas would occur. Between 80 to 150 acres of uplands would be affected by construction.	Wetland losses would essentially cease and about 1500 acres of wetlands would successively revegetate; about 105 acres of

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for C- and K-Reactors (continued).

Impacts	No Action[a]	Once-Through Cooling Tower (Preferred Alternative[b])	Recirculating Cooling Towers[c]
			uplands would be affected by construction.
SALT DEPOSITION	None.	Maximum annual total solids deposition rates for each tower would be below levels that cause reduced vegetative productivity.	Maximum annual total solids deposition rates would be higher than for once-through towers but would still be far below levels that cause reduced vegetative productivity.
ENDANGERED SPECIES	Thermally affected areas of Four Mile Creek and Pen Branch would remain too hot for alligators and of limited forage value for wood stork; no impacts on other endangered species.	Alligator and wood stork foraging habitat would be improved by reduction in stream temperatures. No impacts on other endangered species.	Some alligator habitat would be available; however, lower flows would decrease potential habitat area resulting in less improvement than with once-through towers. Potential for enhancement of wood stork habitat would be increased due to lower water levels in the creeks and deltas. No impacts on other endangered species.
AIR QUALITY	No impacts.	Temporary small increases in air pollution and dust during construction.	Construction impacts would be similar to those for the once-through towers.
		Ice accumulation, visible plumes, and reduced ground-level visibility impacts from cooling tower operation would be small.	Total frequency of ice accumulation would be higher than once-through cooling tower. Visible plume

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for C- and K-Reactors (continued).

Impacts	No Action[a]	Once-Through Cooling Tower (Preferred Alternative[b])	Recirculating Cooling Towers[c]
			occurrence would be only slightly more frequent than that of once-through towers. Reduction in ground-level visibility would be less than for once-through towers and would occur over a somewhat wider area.
NOISE	No impacts.	Temporary increases in noise levels during construction. Noise from operation less than 70 decibels about 150 meters from towers.	Same as for once-through towers.
ARCHAEOLOGICAL AND HISTORIC SITES	No impacts.	One small nonsignificant prehistoric site near Four Mile Creek would be disturbed during construction.	Same site would be disturbed near Four Mile Creek as with the once-through towers.
RADIOLOGICAL	The cumulative maximum individual whole-body dose from SRP and planned facilities would continue at about 3.3 millirem per year. The total collective dose to the regional population would be about 81 person-rem per year; about 0.074 percent of natural background.	Annually, about 100 additional Ci of tritium would be released to the atmosphere and about 100 less Ci of tritium would be discharged to the streams. The maximum individual effective whole-body dose would decrease by 2.3×10^{-4} millrem per year. The total collective dose to the regional population would decrease by 0.055 person-rem per year. The	Annually, about 850 additional Ci of tritium would be released to the atmosphere and about 850 less Ci of tritium would be discharged to the streams. In addition, a calculated decrease of about 1 curie of cesium per year would result from reduced flows. The maximum

Table S-1. Comparison of the Impacts of the No-Action Alternative to the Combined Impacts of the Once-Through Cooling Towers (Preferred Alternative) and Recirculating Cooling Towers for C- and K-Reactors (continued).

Impacts	No Action[a]	Once-Through Cooling Tower (Preferred Alternative[b])	Recirculating Cooling Towers[c]
		dose changes are very small compared with existing operations and natural background radiation.	individual effective whole-body dose would decrease by 0.75 millirem per year. The total collective dose to the regional population would decrease by 2.7 person-rem per year. The dose changes are very small compared with existing operations and natural background radiation.

[a]No action is defined as the continuation of existing operations of C- and K-Reactors.
[b]The preferred alternative is to construct and operate once-through cooling towers (either pumped or gravity flow, and either mechanical or natural draft) for C- and K-Reactors. Characterization of environmental effects presented is based on a mechanical draft cooling tower. Construction and operation of a natural draft cooling tower would not substantially alter the characterization presented (i.e., the natural draft tower is expected to have similar capital cost and implementation schedule, reduced operating costs, and less drift deposition).
[c]The alternative is to construct and operate recirculating cooling towers for C- and K-Reactors.

Table S-2. Comparison of the No Impact Alternative to the Impacts of the Increased Flow with Mixing (Preferred Alternative) and Direct Discharge Alternative for the D-Area Coal-Fired Powerhouse.

Impacts	No action[a]	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
SCHEDULE FOR IMPLEMENTATION	Current	Current	Construction of this alternative would require about 22 months.
PRELIMINARY COST CAPITAL (MILLION $)	$0	$0	$14
ESTIMATED OPERATING COST INCREASE (MILLION $ PER YEAR)	$0	$0.03	$0.05
SOCIOECONOMICS	No additional work-force required.	No additional work-force required.	Peak construction work force of 40 persons.
WATER WITHDRAWAL AND DISCHARGE RATES	About 2.6 cubic meters per second would continue to be withdrawn from the Savannah River and discharged to Beaver Dam Creek.	Withdrawal and discharge rates would be the same as for no action except when withdrawal and discharge rates each could be as high as 4.5 cubic meters per second to meet the 32.2°C Class B water classification standard.	Withdrawal and discharge rates would be the same as for no action; however, thermal discharge would be directly to the Savannah River. All powerhouse thermal discharges would be removed from Beaver Dam Creek.
WATER QUALITY	Water temperatures in Beaver Dam Creek would continue to exceed the 32.2°C State Class B water classification standard during periods from May through	Water temperatures in the stream would meet the 32.2°C State Class B water classification standard; a Section 316(a) demonstration study will be performed for exceed-	In Beaver Dam Creek, water temperatures would be at ambient levels year-round. In the Savannah River, water temperatures beyond a mixing zone at the discharge point

Table S-2. Comparison of the No Impact Alternative to the Impacts of the Increased Flow with Mixing (Preferred Alternative) and Direct Discharge Alternative for the D-Area Coal-Fired Powerhouse. (continued)

Impacts	No action[a]	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
	September; water temperatures would also exceed the maximum ambient stream temperature rise standard of 2.8°C. Concentrations of suspended solids would remain slightly higher than in ambient streams.	ances of 2.8°C rise in ambient stream temperature. Slight increases in suspended solids concentrations would occur during periods of increased flow.	would meet the State Class B water classification standard of 32.2°C.
TEMPERATURE AND FLOW EFFECTS	There would continue to be reduced numbers of aquatic organisms and spawning in the thermally affected areas of Beaver Dam Creek during the warmer months. A thermal barrier would continue to restrict movement of fish in the creek.	Aquatic fauna would become established in present thermally affected areas of Beaver Dam Creek. Habitat area would increase during periods of increased flow. There would be no thermal barrier in the creek.	Low water levels in Beaver Dam Creek would greatly reduce existing aquatic habitat; however, the absence of thermal stress would allow full use of this habitat by aquatic organisms. There would be no thermal barrier in the creek. Fish spawning would be limited because of reduced habitat. An adequate zone of passage would be present in the river.
ENTRAINMENT/ IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 3.0 x 10^6 fish eggs and larvae and the loss of about 4745 fish due to impingement annually.	Increased water withdrawal over that for no action would increase entrainment losses by about 0.1 x 10^6 fish eggs and larvae and the loss of an additional 142 fish due to impingement annually.	Effects would be about the same as for no action.

Table S-2. Comparison of the No Impact Alternative to the Impacts of the Increased Flow with Mixing (Preferred Alternative) and Direct Discharge Alternative for the D-Area Coal-Fired Powerhouse. (continued)

Impacts	No action[a]	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
HABITAT	No impacts.	Operation would result in an estimated loss of about 4 acres of wetlands and about 4 acres of uplands.	Construction would result in an estimated loss of about 1 acre of wetlands and 5 acres of uplands.
AIR QUALITY	No impact.	No impact.	No impact.
ENDANGERED SPECIES	Existing thermal areas of Beaver Dam Creek would continue to support a large alligator population. The adjacent swamp area would continue to be used by wood storks for foraging. No impact on other endangered species.	No changes in existing alligator habitat. Some decrease in wood stork foraging habitat during increased flow periods. No impacts on other endangered species.	Loss of most of alligator habitat due to decreased temperatures and lowered water levels in Beaver Dam Creek. Loss of much of wood stork foraging habitat due to lowered water levels in Beaver Dam Creek. No impacts on other endangered species.
ARCHAEOLOGICAL AND HISTORICAL SITES	No impacts.	One site will be recommended for eligibility for nomination to the National Register of Historic Places. A request for "no effect" determination submitted to SHPO.	Survey of pipeline area revealed no historic sites.
RADIOLOGICAL RELEASES	No impacts.	No impacts.	No impacts.

[a]No action is defined as the continuation of existing operations of the D-Area coal-fired powerhouse.

Table S-3. Required Regulatory Permits and Notifications

Activity/facility	Requirement(s)	Agency	Status
Water			
Cooling water systems construction	Construction permits	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	To be submitted by March 31, 1987, subject to the appropriation of funds by Congress
	Section 404 permit[a]	U.S. Army Corps of Engineers (COE)	To be submitted prior to construction
	Section 401 certification[a]	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	Requested by COE as part of the dredge-and-fill permit process
	Section 10 permit for structures in navigable waters[a]	U.S. Army Corps of Engineers	To be submitted prior to construction
	Permit for structures in in navigable waters[a]	South Carolina Budget and Control Board	To be submitted prior to construction
Cooling water discharges	NPDES permit	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	Issued; modification to permit conditions to be made prior to operation of selected cooling water system

Table S-3. Required Regulatory Permits and Notifications (continued)

Activity/facility	Requirement(s)	Agency	Status
Compliance with delta 2.8°C temperature requirement[b]	Section 316(a) (thermal impact) demonstration	South Carolina Department of Health and Environmental Control, Industrial and Agricultural Wastewater Division	Plans for conducting studies to be submitted within 2 months of project completion
Water withdrawal/ water use	Quarterly reporting	South Carolina Water Resources Commission	Routine reports will continue to be submitted
Endangered species	Consultation/ biological assessment	U.S. Fish and Wildlife Service	Consultations with FWS in progress
Fish and Wildlife Coordination Act	Consultation/ consideration of fish and wildlife resources	U.S. Fish and Wildlife Service	Consultations with FWS in progress

Table S-3. Required Regulatory Permits and Notifications (continued)

Activity/Facility	Requirement(s)	Agency	Status
Migratory Bird Treaty Act	Consultation with FWS	U.S. Fish and Wildlife Service	Consultation with FWS in progress
Anadromous Fish Conservation Act	Consultation with FWS	U.S. Fish and Wildlife Service	Consultation with FWS in progress
Historic preservation	Archaeological survey and assessment	South Carolina Historic Preservation Officer	Surveys and assessments completed; consultation with SHPO in progress.
Floodplains/wetlands[c]	Assessment and determination	U.S. Department of Energy	Notice to be published in Federal Register concurrently with notice of availability of the draft EIS; determination published after completion of final EIS

[a]Applicable to the D-Area coal-fired powerhouse direct discharge alternative.
[b]Applicable to once-through cooling-tower alternatives for C- and K-Reactors and the increased pumping alternative for the D-Area coal-fired powerhouse.
[c]Refer to Appendix F.

CHAPTER 1

NEED FOR COOLING WATER SYSTEMS AND PURPOSE OF THIS ENVIRONMENTAL IMPACT STATEMENT

The implementation of cooling water systems for major sources of thermal effluents at the Savannah River Plant (SRP) is needed for compliance with the Clean Water Act and a Consent Order (84-4-W), dated January 3, 1984, and amended August 27, 1985, between the U.S. Department of Energy (DOE) and the South Carolina Department of Health and Environmental Control (SCDHEC). The purpose of this environmental impact statement is to address the potential environmental consequences of constructing and operating alternative cooling water systems for thermal discharges from C- and K-Reactors and from a coal-fired powerhouse in D-Area as input into the selection and implementation of such systems.

1.1 NEED

The Savannah River Plant is a controlled-access area of approximately 780 square kilometers (192,700 acres) near Aiken, South Carolina. It is a major DOE installation established in the early 1950s for the production of nuclear materials for national defense. Plant facilities, which can be characterized as heavy industry, consist of five production reactors (four operational and one in standby status), electrical and steam generating plants, two chemical separations facilities, fuel and target fabrication facilities, research laboratories, and support and administrative facilities.

The major sources of thermal effluents at the Savannah River Plant are the cooling water discharges from the production reactors and an onsite coal-fired powerhouse. Two of the currently operating production reactors, C- and K-Reactors, discharge their cooling water directly to Four Mile Creek and Pen Branch, respectively. The coal-fired powerhouse in D-Area normally discharges cooling water from cooling-system condensers into an excavated canal that flows into Beaver Dam Creek.

The thermal effluent from P-Reactor is cooled by an onsite 2700-acre cooling lake, Par Pond. Continued use of the recirculating cooling system for P-Reactor is anticipated, based on Section 316(a) and 316(b) studies that have been conducted by DOE, as required by the Federal Water Pollution Control Act, as amended (33 U.S.C. 1326). These studies, which have been submitted to SCDHEC, demonstrate the existence of a balanced indigenous biological community in Par Pond. L-Reactor discharges its cooling water to a 1000-acre cooling lake. Predictive Section 316(a) studies indicating the probable existence of balanced biological communities within and below the cooling lake have been submitted to, and approved by, SCDHEC. The restart of L-Reactor and the cooling lake are discussed extensively in the Environmental Impact Statement, L-Reactor Operation, Savannah River Plant (DOE, 1984a). Discussions of P- and L-Reactors are not in the scope of this EIS.

A renewed National Pollutant Discharge Elimination System (NPDES) permit (Number SC0000175) issued by SCDHEC became effective on January 1, 1984, for SRP operations. The purpose of this permit was to regulate the Plant's discharges of wastewater - including cooling water - to surface streams and other water bodies. As stated in the permit, cooling water discharge temperature limits for C- and K-Reactors and the D-Area powerhouse are not to exceed an instream temperature after mixing of 32.2°C; in addition, the effluent must not raise the temperature of the stream more than 2.8°C above its ambient temperature unless the maintenance of a balanced biological community can be determined by a Section 316(a) demonstration study.

To achieve compliance with these temperature limitations, DOE and SCDHEC entered into a mutually agreed-on Consent Order (84-4-W). This order temporarily superseded the temperature requirements in the NPDES permit and established a process for attaining compliance. Key elements of this process required DOE to:

- Complete a "Comprehensive Cooling-Water Study" of the thermal effects of operations at the Savannah River Plant
- Complete and submit a Thermal Mitigation Study to SCDHEC
- Submit and actively support funding requests to accomplish any actions resulting from the Thermal Mitigation Study
- Undertake work on the alternatives approved by SCDHEC, under a schedule to be established in an amendment to the Consent Order, subject to the appropriation of funds by Congress

In compliance with the Consent Order, DOE submitted a Thermal Mitigation Study (DOE, 1984b) to SCDHEC on October 3, 1984; the Comprehensive Cooling-Water Study, Annual Report (Du Pont, 1985) was submitted in July 1985.

On August 27, 1985, DOE and SCDHEC mutually agreed on an amendment to Consent Order 84-4-W of January 3, 1984, that established a compliance schedule for the completion of NEPA documentation by December 31, 1986. This amendment also established an implementation schedule for the start of construction of a selected cooling water system for C-Reactor on or before September 30, 1987, and completion of construction on or before March 31, 1989. The amendment established the date for the start of construction of a system for K-Reactor on or before September 30, 1987, and completion of construction on or before July 31, 1989. The Consent Order also established March 31, 1987, as the date by which DOE must submit a plan of study and an approvable schedule for the implementation of a cooling water system for the D-Area powerhouse.

Implementation of cooling water system alternatives at C- and K-Reactors and the D-Area coal-fired powerhouse is needed for compliance with South Carolina water classification standards [as contained in the NPDES permit (Number SC0000175)], and Consent Order 84-4-W between DOE and SCDHEC.

1.2 PURPOSE

The purpose of this environmental impact statement is to address the potential environmental consequences of constructing and operating cooling water systems for thermal discharges from C- and K-Reactors and from the coal-fired powerhouse in D-Area in compliance with Section 102(2)(C) of the National Environmental Policy Act of 1969, as amended, and to provide input into the selection and implementation of such systems.

The proposed action is to construct and operate cooling water systems for C- and K-Reactors and the D-Area powerhouse to attain compliance with the State of South Carolina's Class B water classification standards. The DOE's preferred alternatives are to construct and operate once-through cooling towers for the C- and K-Reactors, and to implement increased flow with mixing for the D-Area powerhouse.

This environmental impact statement considers three cooling water alternatives each for C- and K-Reactors and three alternatives for the D-Area powerhouse. The alternatives for C- and K-Reactors are the construction and operation of once-through cooling towers; the construction and operation of recirculating cooling towers; and the continuation of direct discharge - or no action [as required by the Council on Environmental Quality for Implementing the National Environmental Policy Act (40 CFR 1502.14)]. The three alternatives for the D-Area powerhouse are to increase the inlet water flow to the D-Area raw-water basin; to implement direct discharge to the Savannah River; and to continue the present operation - or no action.

This EIS describes the cooling water alternatives (Chapter 2) and the affected Savannah River Plant environment (Chapter 3), and assesses the potential environmental consequences of construction and operation of alternative cooling water systems, including cumulative and unavoidable and irreversible impacts (Chapter 4). Chapter 5 discusses Federal and State of South Carolina regulatory requirements/permits and studies and monitoring programs that are applicable to the construction and operation of the cooling water systems.

Three documents published in the last 2 years are relevant to an understanding of the potential environmental effects of the construction and operation of alternative cooling water systems. The Environmental Impact Statement, L-Reactor Operation, Savannah River Plant, Aiken, South Carolina (DOE, 1984a) describes alternative cooling water systems for L-Reactor and the potential environmental effects of these systems on the Savannah River and the onsite swamp system. The Thermal Mitigation Study - Compliance with the Federal and South Carolina Water Quality Standards, Savannah River Plant, Aiken, South Carolina (DOE, 1984b) discusses and evaluates 22 possible cooling water alternatives for C- and K-Reactors and the D-Area powerhouse. The Comprehensive Cooling-Water Study Annual Report, Savannah River Plant, Aiken, South Carolina (Du Pont, 1985) evaluates the environmental effects of the intake and release of cooling water on the structures and functions of aquatic ecosystems at the Savannah River Plant, including water quality, radionuclide and heavy metal transport, wetlands ecology, aquatic ecology, and endangered species.

REFERENCES

DOE (U.S. Department of Energy), 1984a. Final Environmental Impact Statement, L-Reactor Operation, Savannah River Plant, Aiken, South Carolina, DOE/EIS-0108, Savannah River Operations Office, Aiken, South Carolina.

DOE (U.S. Department of Energy), 1984b. Thermal Mitigation Study, Compliance with Federal and South Carolina Water Quality Standards, Savannah River Plant, Aiken, South Carolina, DOE/SR-5003, Savannah River Operations Office, Aiken, South Carolina.

Du Pont (E. I. du Pont de Nemours and Company, Inc.), 1985. Comprehensive Cooling-Water Study, Annual Report, DP-1697, Volumes 1-11, J. B. Gladden, M. W. Lower, H. E. Mackey, W. L. Specht, and E. W. Wilde (editors), Savannah River Laboratory, Aiken, South Carolina.

CHAPTER 2

COOLING WATER ALTERNATIVES AND PROPOSED ACTION

The U.S. Department of Energy (DOE) initially identified possible cooling water systems that it could implement for the C- and K-Reactors and the D-Area coal-fired powerhouse, and documented them in the Thermal Mitigation Study (DOE, 1984b). Based on a structured screening process and comments received on its Notice of Intent to prepare this environmental impact statement (EIS), DOE has identified reasonable cooling water alternatives that this EIS considers in detail.

Section 2.1 describes the screening process by which DOE determined the reasonable cooling water alternatives considered in this EIS; Section 2.2 describes these alternatives; Section 2.3 compares the environmental consequences of these alternatives.

2.1 SCREENING PROCESS

DOE used a structured screening process to identify, from among the many possible alternatives for cooling water systems for C- and K-Reactors and the D-Area coal-fired powerhouse, those that would be reasonable from environmental, engineering, scheduling, and cost perspectives. The Thermal Mitigation Study (DOE, 1984b) documents this screening process. DOE performed this screening in a three-step process that consisted of the following steps:

1. Identification oı possible alternatives

2. Selection of feasible compliance alternatives using "exclusionary" criteria

3. Selection of reasonable compliance alternatives using "discriminatory" criteria

The first step divided all alternative cooling water systems into two categories: those that could meet the State of South Carolina's Class B water classification standards and those that could not. For those alternatives that could not meet these water classification standards (such as rubble dams, small cooling lakes, and the current once-through systems), DOE did not consider any further assessment because both Federal and State regulations would prohibit the designation of streams to a classification other than Class B for the transport or assimilation of waste.

For those alternatives that could meet Class B water classification standards, DOE identified potential subcategories of generic cooling water systems for C- and K-Reactors and, separately, for the D-Area coal-fired powerhouse. These systems consisted of the following:

- Cooling towers
  - Once-through
  - Recirculating

- Cooling lakes and ponds
  - Offstream ponds
  - Cooling lakes
  - Multisource ponds/lakes

- Cooling lake/pond and cooling-tower combinations
  - Cooling lakes/ponds before cooling towers
  - Cooling lakes/ponds after cooling towers

For the D-Area coal-fired powerhouse, the identified alternatives included the following:

- Cooling towers
  - Once-through
  - Recirculating

- Direct discharge to the Savannah River

- Increased flow with mixing

DOE then developed minimum requirements for C- and K-Reactors for use in identifying possible alternatives for each of the generic categories. These requirements included sufficient surface area in cooling lakes or ponds for heat dissipation, and sufficient cooling capacity in once-through and recirculating cooling towers to attain a 32.2°C discharge during extreme meteorological conditions. Using these minimum requirements, DOE identified 22 possible cooling water alternatives for C- and K-Reactors and 4 alternatives for the D-Area powerhouse.

DOE applied "exclusionary criteria" to the possible cooling water alternatives to identify the feasible compliance alternatives. For C- and K-Reactors, the exclusionary criteria consisted of:

- The expected ability to perform successful Section 316(a) demonstrations if the Class B temperature limits were to be exceeded in the receiving stream after mixing

- A minimum of 400 acres of cooling-lake surface at or below 32.2°C to support a balanced biological community

- Sufficient cooling capacity to require, for screening purposes, no more than a 10-percent annual average production loss.

Application of these criteria led to the identification of 17 feasible compliance alternatives for C- and K-Reactors. DOE considered each of the four possible cooling water alternatives for the D-Area powerhouse to be feasible.

In the third step, DOE screened the 17 feasible compliance alternatives for C- and K-Reactors and the 4 alternatives for the D-Area powerhouse on the basis of "discriminatory" criteria to determine the reasonable compliance alternatives. These criteria included environmental impacts, implementation schedules, capital and operating costs, and relative operating complexity (i.e., multiple reactor cooling systems versus recirculation systems versus once-through systems). Based on these discriminatory criteria, DOE identified the following reasonable compliance alternatives:

C-Reactor

- 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek below the railroad track
- Recirculating cooling tower with a 20-acre offstream holding pond
- Once-through cooling tower with a 100-acre offstream holding pond
- Once-through cooling tower to a 500-acre once-through cooling lake on a tributary of Four Mile Creek with an embankment about 300 meters above the confluence with Four Mile Creek
- 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment on Four Mile Creek about 1280 meters above Road A

K-Reactor

- 1400-acre once-through cooling lake between Pen Branch and Four Mile Creek above the railroad track
- Recirculating cooling tower with a 20-acre offstream holding pond
- Once-through cooling tower with a 100-acre offstream holding pond
- Once-through cooling tower to a 600-acre once-through cooling lake on Indian Grave Branch with an embankment about 300 meters above the confluence with Pen Branch
- 800-acre cooling lake with a 400-acre hot arm to a once-through cooling tower with an embankment located about 610 meters above Road A on Pen Branch

D-Area Powerhouse

- Direct discharge to the Savannah River (bypassing Beaver Dam Creek)
- Increased flow with mixing

As part of the scoping process, DOE invited interested parties to comment on the alternatives it would consider in this environmental impact statement (Federal Register, 50 FR 30728). Based on the screening process documented in the Thermal Mitigation Study (DOE, 1984b) and its preliminary determination of alternatives to be considered in this environmental impact statement, DOE decided to consider the alternatives of once-through and recirculating cooling towers for C- and K-Reactors, and increased flow with mixing and direct discharge to the Savannah River for the D-Area coal-fired powerhouse. In addition, DOE is required to consider the alternative of "no action," in accordance with the Council on Environmental Quality's regulations for implementing the procedural provisions of the National Environmental Policy Act.

Appendix A provides a more detailed description of the screening process and criteria that DOE used to identify the reasonable alternatives for evaluation in this environmental impact statement.

2.2 PROPOSED ACTION

The proposed action is to construct and operate cooling water systems for the C- and K-Reactors and the D-Area powerhouse to attain compliance with the State of South Carolina's Class B water classification standards. Based on the screening process described in Section 2.1, the alternatives considered in this EIS are the construction and operation of once-through or recirculating cooling towers for C- and K-Reactors, increased flow with mixing or direct discharge to the Savannah River for the D-Area powerhouse, and no action. DOE's preferred alternatives are to construct and operate once-through cooling towers for C- and K-Reactors and to implement increased flow with mixing for the D-Area powerhouse.

The following sections describe these alternatives. The descriptions are based on preliminary and conceptual designs; specific engineering parameters and costs are subject to change during future design phases.

2.2.1 C-REACTOR COOLING WATER ALTERNATIVES

The cooling water alternatives for C-Reactor are the construction and operation of a once-through cooling tower, the construction and operation of recirculating cooling towers, and no action.

2.2.1.1 Once-Through Cooling Tower (Preferred Alternative)

The once-through cooling tower described in the *Thermal Mitigation Study* (DOE, 1984b) was a mechanical-draft tower that would receive the cooling water from C-Reactor from a new pump pit. Cooled water from the tower basin would then flow by gravity to a 100-acre offstream holding pond before discharging to Four Mile Creek.

Since the completion of the *Thermal Mitigation Study*, further design evaluations and studies have been initiated to determine optimal performance parameters and to achieve lower costs. These evaluations and studies, which are still under way, have indicated that there are several areas in which optimization of performance and cost savings can be realized in the construction and operation of once-through towers without introducing major changes in the nature or magnitude of the environmental impacts. These areas include the consideration of gravity-feed versus pumped-feed towers, natural-draft versus mechanical-draft towers, and holding ponds (and their sizing) versus a chemical injection system for either dissipation or neutralization of chlorine biocide. Similarly, these evaluations and studies have also led to the development of thermal performance criteria that, when incorporated in the final design of a once-through cooling-tower system, would reduce the potential for cold shock (i.e., reduce the difference between ambient stream temperatures and stream temperatures when the cooling water is being discharged) to fish.

The following sections describe the once-through cooling-tower for C-Reactor incorporating current design considerations. Each section discusses a once-through mechanical draft cooling tower with pumped feed and a holding pond, and then the major differences associated with a gravity-feed versus a pumped-feed tower, a natural-draft versus a mechanical-draft tower, and a holding pond versus a chemical injection system.

Description

For a once-through mechanical-draft system with pumped feed, the cooling water discharged from C-Reactor would be pumped to a mechanical-draft cooling tower. The cooled water from the tower would flow by gravity to an offstream 46-acre holding pond, from which discharges would enter Castor Creek, a small tributary of Four Mile Creek. Figures 2-1 and 2-2, which are based on preliminary design information, show a flow diagram and a site layout, respectively, of this once-through system.

To implement this once-through mechanical-draft system with pumped feed, the existing underground pipe carrying hot water from the reactor cooling water interceptor pit (Building 904-1C) to the existing cooling water effluent canal would be rerouted to a new pump pit. A similar pipe from this pump pit would carry cooling water overflows directly to the existing outfall canal (in case of a failure of all pumps or a failure of the header pipe from the pumps to the cooling tower). The new pump pit would be an underground reinforced-concrete structure. It would be located within the existing C-Reactor production area just southwest of Building 904-1C.

The pump pit would contain six 2.3-cubic-meter-per-second, 33.5-meter total-dynamic-head pumps with 932-kilowatt motors. Five pumps would normally operate, with the sixth available as a backup unit. The discharge piping from each pump would connect into a pipe header leading to the cooling tower. A control valve, check valve, and gate valve would be provided between each pump and the header pipe.

An Electrical Control Room would be located adjacent to the new pump pit; it would be founded on a concrete slab. This new control room would contain the necessary switchgear and instrumentation for the operation of all cooling-tower, chemical-treatment, and pump-pit equipment. The building would be dust tight, and would have interior lights and temperature and humidity controls, and would be insulated.

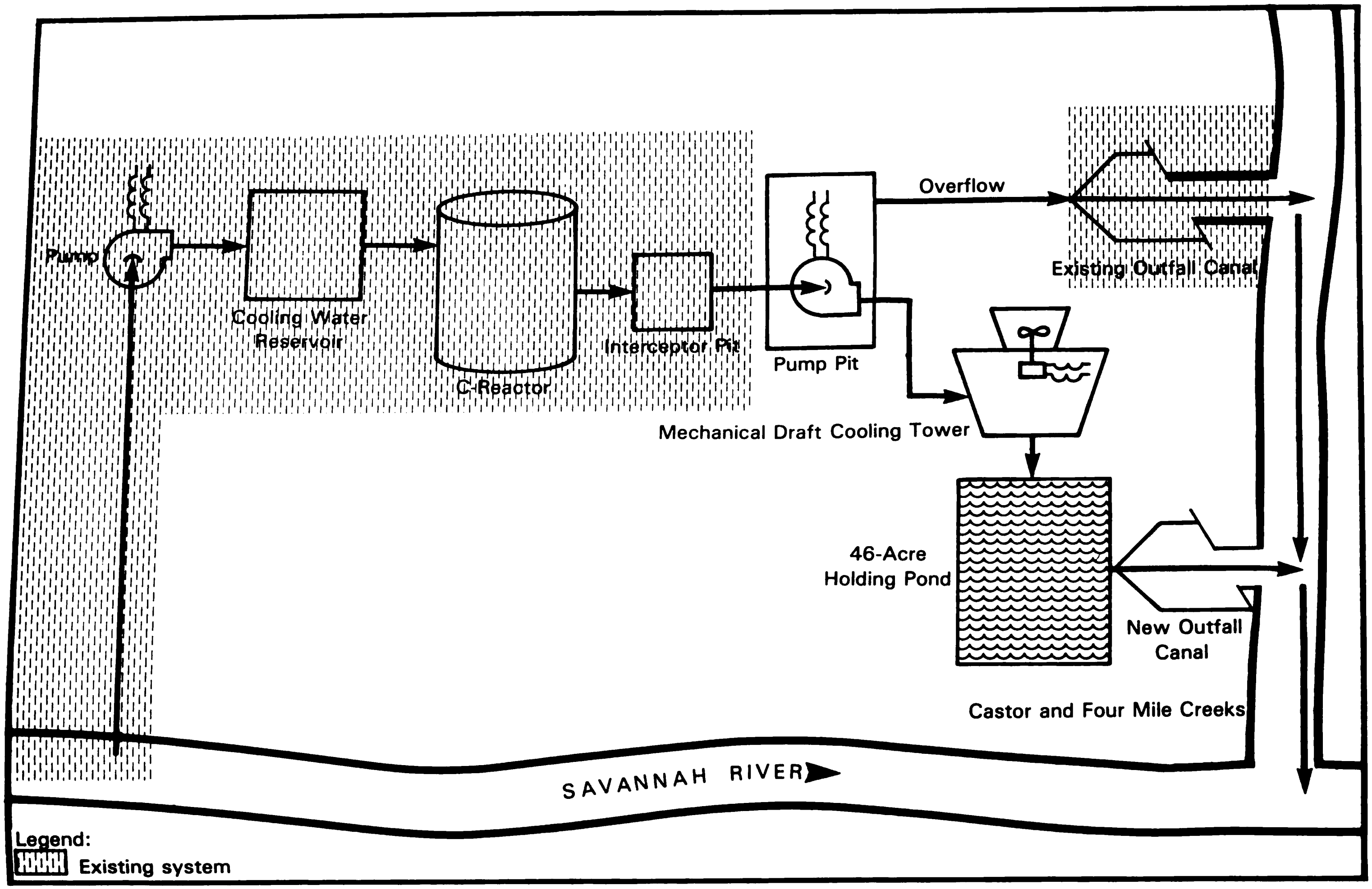


Figure 2-1. C-Reactor Once-Through Cooling Tower System (with Pumped Flow) Flow Diagram

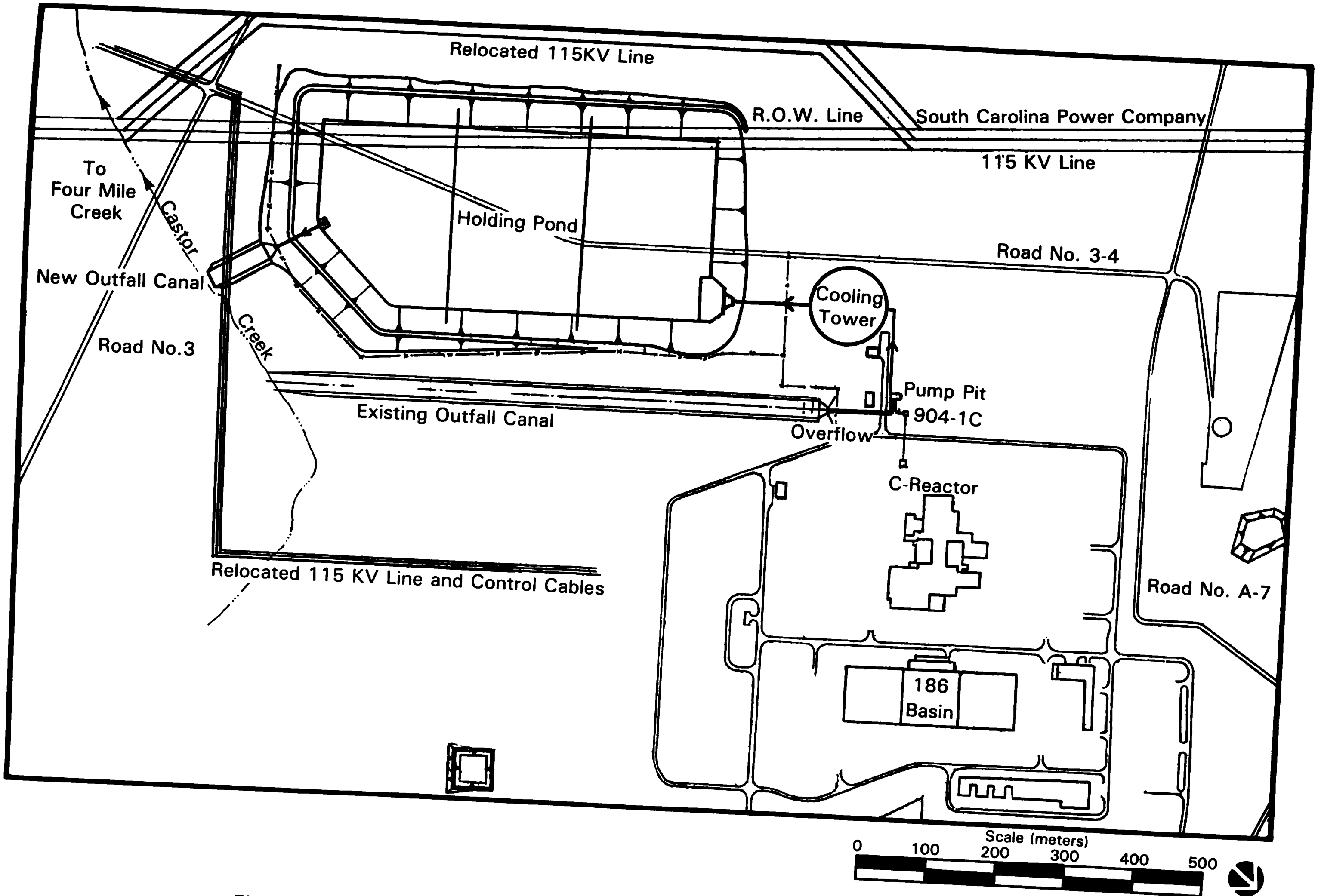


Figure 2-2. C-Reactor Once-Through Cooling Tower System with Pumped Flow

Based on preliminary design information, the mechanical-draft, once-through, reinforced-concrete, counterflow cooling tower would be approximately 100 meters in diameter and about 30 meters high, and would contain 24 fans, each driven by a 150-kilowatt motor. The tower would be situated over a reinforced-concrete basin, which would receive the cooled water flowing through the tower. An underground steel pipe would carry the flow by gravity to a holding pond.

The holding pond, which would be used to allow biocides to dissipate prior to discharge, would be constructed adjacent and parallel to the west side of the existing C-Reactor cooling water effluent canal. It would be formed by excavating an area that contains no natural waterway or wetlands, using excavated material to build compacted embankments to enclose a water-surface area of approximately 46 acres. The depth of water in the pond would be about 6 meters, which would provide approximately 790 acre-feet of volume, or 24 hours of cooling water retention. The maximum height of the embankment above the original ground elevation would be about 9 meters.

The outlet of the pipe from the cooling tower into the holding pond would be a reinforced-concrete headwall structure. Stone riprap would be provided at this outlet as well as above and below the normal water surface elevation around the perimeter of the pond for protection against erosion by wave action.

The outlet from the holding pond would consist of an overflow discharge weir; a vertical, rectangular, reinforced-concrete conduit and a curved transition section leading to reinforced concrete pipe; and a reinforced-concrete discharge headwall.

Downstream from the discharge headwall, a new riprap-paved canal 90 meters long and 25 meters wide would convey cooled effluent into Castor Creek (a tributary of Four Mile Creek) at a point 150 meters downstream from the present discharge point of the C-Reactor effluent canal.

A small water-treatment building would be located near the cooling tower. It would be used to store a chemical biocide, which would be injected into the cooling water stream to prevent biofouling in the tower system.

A once-through mechanical-draft cooling system with gravity feed, rather than pumped feed, to the cooling tower could also be constructed. For this type of once-through system, the cooling water discharged from C-Reactor would flow by gravity through a new effluent canal approximately 1160 meters long to a once-through mechanical-draft cooling tower located between SRP Road 3 and Castor Creek. Cooled water from the tower would be discharged through a new outfall canal directly to Castor Creek. Figures 2-3 and 2-4, which are based on preliminary design information, show a flow diagram and a site layout, respectively, of this once-through system.

To construct this cooling system, a diversion box would be installed around the existing underground pipe carrying hot water from the C-Reactor cooling water interceptor pit (Building 904-1C) to the existing outfall canal. The

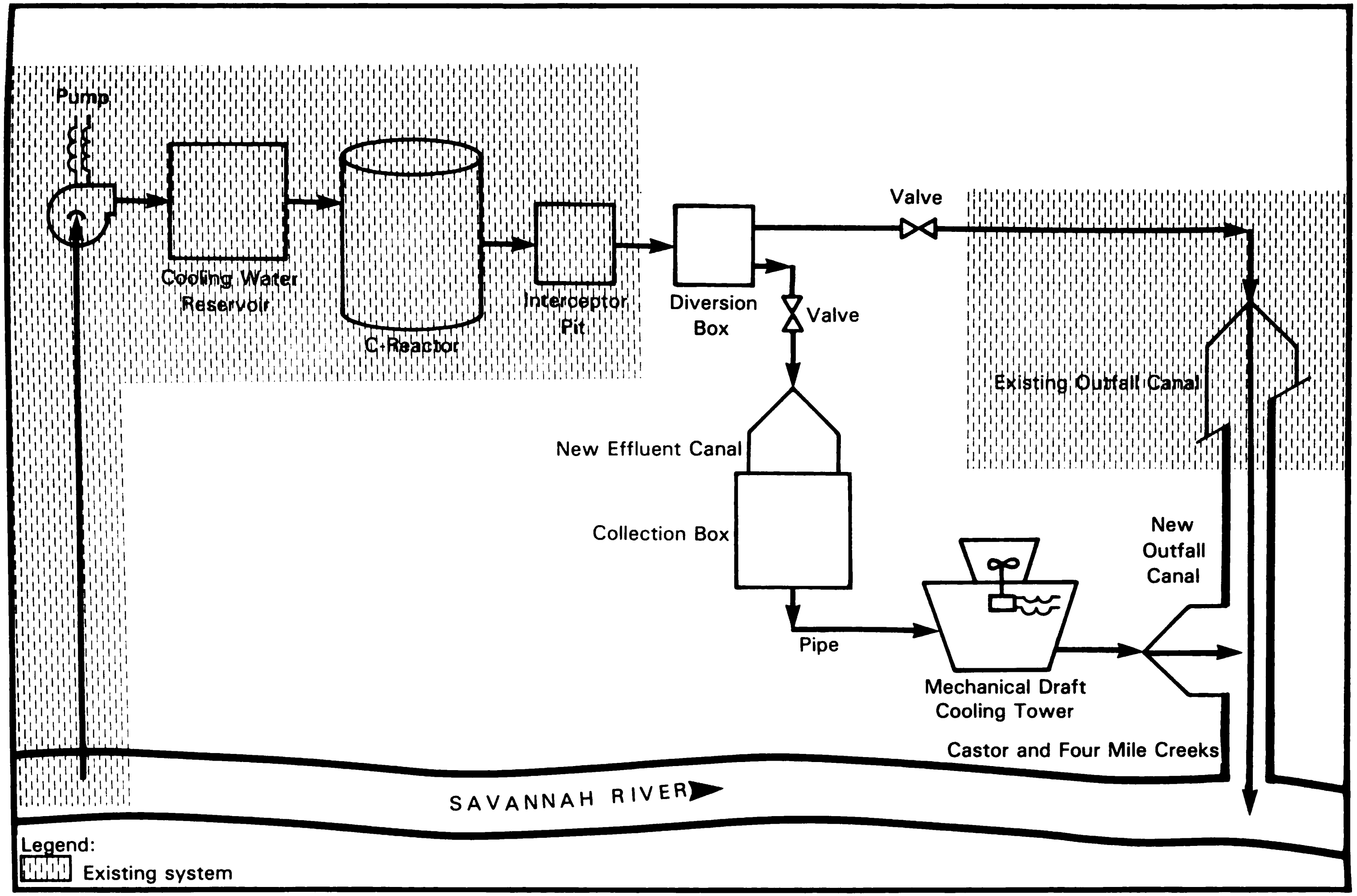


Figure 2-3. C-Reactor Once-Through Cooling Tower System (with Gravity Flow) Flow Diagram

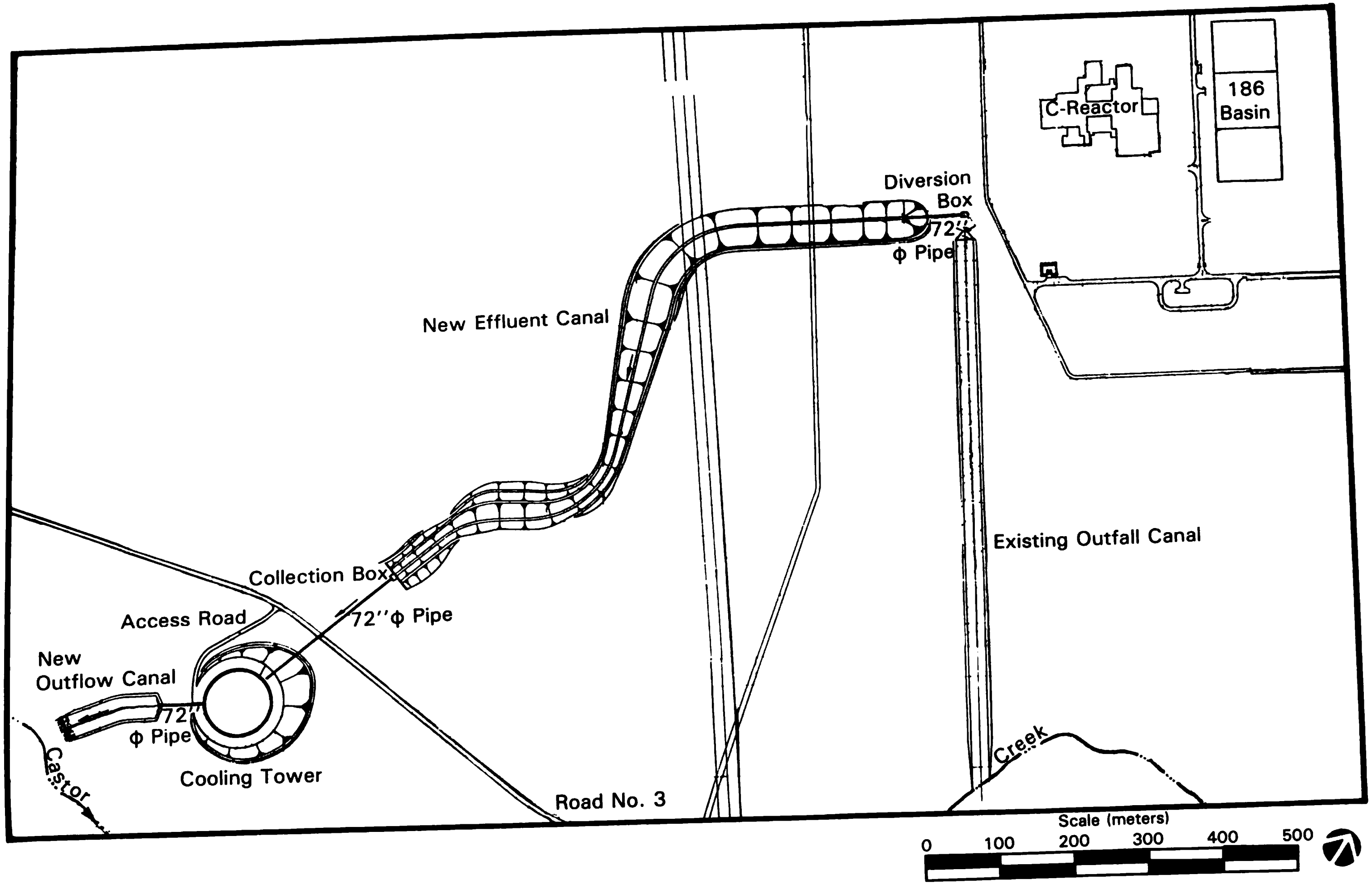


Figure 2-4. C-Reactor Once-Through Cooling Tower System with Gravity Flow

diversion box would have two outlets, each containing an isolation system. During reactor operation, cooling water effluent would be routed through a new effluent canal, collection box, and underground piping to the cooling tower. The new diversion and collection boxes would be underground reinforced-concrete structures located west and southwest of the existing C-Reactor production area.

A new underground steel pipe would run about 100 meters from the diversion box to a new riprap-lined effluent canal. This canal would be about 1160 meters long, and would cross under the existing South Carolina Electric and Gas Company transmission line. It would lead to a new collection box approximately 120 meters northeast of Road 3. A new underground steel pipe would carry the cooling water flow under Road 3 from this box to the new cooling tower.

A new control room located near the cooling tower would contain the necessary switchgear and instrumentation for the operation of all cooling-tower and chemical-treatment equipment.

A mechanical-draft, once-through, reinforced-concrete, counterflow cooling tower, as described above for the pumped-feed tower, would be situated over a reinforced-concrete basin, which would receive the cooled water flowing through the tower. An underground pipe and outfall canal would carry the flow by gravity to Castor Creek, approximately 1.5 kilometers above Four Mile Creek.

The outlet of the pipe from the cooling tower into the outfall canal would be a reinforced-concrete headwall structure. Stone riprap would be provided at this outlet for protection against erosion.

Downstream from the discharge headwall, a new riprap-paved outfall canal about 150 meters long and 30 meters wide would convey cooled effluent into Castor Creek (a tributary of Four Mile Creek) at a point about 1.5 kilometers downstream from the discharge point of the existing C-Reactor outfall canal.

A small water-treatment building would be located near the cooling tower. It would be used to store a chemical biocide, which would be injected into the cooling water stream to prevent biofouling in the tower system.

In the absence of a suitable area for a holding pond, as described for the pumped-feed system, a system for injecting a chemical dechlorination agent, such as sodium sulfite, would be installed. The dechlorinating agent would be injected in sufficient quantities to meet established chlorine effluent limits. Chemical storage tanks and distribution piping would be provided, as would metering pumps and controls, which would be located in the small water-treatment building near the cooling tower.

For the pumped-feed and the gravity-feed towers, the cooling-tower, and - for the pumped-feed tower - the holding-pond area would be enclosed by a patrol road and fence with personnel and vehicular gates. Access roads would be provided, and parking, loading, and equipment storage areas would be paved at the cooling tower and accessory buildings. Areas around the cooling tower - and, for the pumped-feed tower, the holding pond - would be regraded and seeded, or, if necessary, covered with stone or paving as appropriate to restore natural surface drainage. An adequate stormwater-drainage system would be constructed inside the fenced area; it would include erosion protection and would discharge into natural drainage ways.

Cooling-system electrical loads would be supported by increasing the electrical capacity of existing substations in C-Area. These substations would be enlarged by adding new control buildings, transformers, and galvanized-steel towers with concrete foundations, and by extending fencing and site improvements. New substations, oil circuit breakers, switchgear, and feeder breakers would be incorporated into the plant supervisory-control system.

Sections of a 115-kilovolt transmission line would be upgraded in capacity or replaced, and about one-fourth of the wood-pole structures would be replaced.

For the pumped-feed tower, approximately 1200 meters of SRP 115-kilovolt transmission line and parallel supervisory-control and relay cable would have to be relocated around the holding-pond area and Road 3-4. Another 1200 meters of South Carolina Electric and Gas Company 115-kilovolt transmission line that runs through the pond area would be rerouted around the pond. For the gravity-flow tower, two 13.8-kilovolt feeder lines, each about 2 kilometers long (approximately half of each line underground), would provide electric power to the cooling-tower fan motors.

Outside lighting and power distribution to the new cooling-tower facilities would be provided. Communications facilities would be extended from the existing C-Area system. Monitoring instrumentation for this cooling system would be installed in the C-Reactor Central Control Room. It would contain monitoring and control instruments that would be connected to instrumentation at the cooling-tower facilities. These instruments would measure such conditions as water temperature at the tower discharge and water flow to the stream. New alarms in the Central Control Room would indicate fan drive system vibration at the cooling tower or a high cooling-tower discharge temperature.

Most of the cooling water system construction would be completed with minimal impact on reactor operation. Careful scheduling would ensure that the work necessary to connect the system with the existing facilities is accomplished during scheduled reactor shutdowns.

Safety practices during construction would be in accordance with applicable safety standards. Occupational exposure to low-level radiation and to chemical contact or inhalation will be minimized by monitoring procedures and by protective equipment and clothing.

Preliminary design evaluations and studies, which are in progress, indicate that optimization of performance and cost savings might be realized by the construction and operation of a natural-draft, once-through cooling tower rather than a mechanical-draft tower. If such an optimization of performance and cost savings could be realized, the description of a natural-draft tower (pumped or gravity feed) would not differ appreciably from that presented above for the mechanical-draft tower. The major differences would be the size of the tower (e.g., approximately 150 meters high for the natural-draft tower versus 20 meters for the mechanical-draft tower) and the extent of the electrical system upgrade (e.g., the natural-draft tower could require less system upgrade due to the elimination of the fans and motors associated with the mechanical-draft tower).

Thermal Performance

The ability of a once-through mechanical-draft cooling tower to cool the C-Reactor secondary cooling water to a specified temperature depends on the influent hot water and the air (wet-bulb) temperatures. The former is a function of river (reactor-intake) temperature and reactor power. Both the river and the wet-bulb temperatures vary throughout the year, with diurnal fluctuations superimposed on seasonal cycles. At full reactor power, the cooling-tower discharge water temperature would show a weak correlation with the river temperature and a significant correlation with the wet-bulb temperature. Preliminary design information has suggested the following once-through mechanical-draft, cooling-tower system parameters: duty equal to 7.4×10^9 Btu per hour, range of 48°C, influent water temperature of 80°C, effluent water temperature of 32°C, wet-bulb temperature of 27°C, and an approach of 5°C. The cooling system parameters for a natural-draft cooling tower would approximate those of the mechanical-draft tower. At lower wet-bulb temperatures, natural-draft discharge temperatures would be somewhat less than those from a mechanical-draft tower (Kennedy, 1972).

The once-through cooling tower would be designed to enable the discharge to meet the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C). For the preliminary design of the mechanical-draft tower, the temperature standard would be exceeded, on average, only 8 hours per year (based on Bush Field meteorological data for the period 1953 through 1982), with the maximum hourly discharge temperature equal to 33°C (based on a maximum recorded hourly wet-bulb temperature of 28°C). Final tower design and operation would ensure that the 32.2°C requirement is always met.

The C-Reactor effluent discharge to Four Mile Creek includes the 11.3 cubic meters per second of secondary cooling water flow plus approximately 0.5 cubic meter per second of auxiliary flow (with insignificant heat load), less approximately 0.9 cubic meter per second of evaporation in the tower (assuming the dissipation of all heat by evaporation, at preliminary design conditions). The Four Mile Creek flow, other than the C-Reactor effluent, is approximately 0.6 cubic meter per second. Table 2-1 lists seasonal average water temperatures along the cooling water flow path (based on an average of Bush Field meteorological data for the period 1953 through 1982) with the corresponding ambient stream temperature for the preliminary design of the once-through mechanical-draft cooling tower. Table 2-1 also lists downstream temperatures under extreme summer conditions; the discharge temperature is based on wet-bulb temperatures for July 17-21, 1958, and the ambient meteorology for July 12-16, 1980.

Table 2-1. Temperatures (°C) Along Cooling Water Flow Path of C-Reactor Once-Through Mechanical-Draft Cooling Tower

Location	Winter average	Spring average	Summer average	Summer extreme[a]
Hot water to tower	68	72	74	76
Discharge to creek	24[b]	28	30	32
Four Mile Creek at				
Road A	23	27	30	32
Road A-13	21	26	30	32
Swamp delta	20	26	30	32
Ambient creek[c]	9	23	29	33

[a]Values are a 5-day average.
[b]Values based on preliminary computer model; final tower design will meet the criteria stipulated for maximum weekly average temperature (MWAT) for fish survival during a winter shutdown (EPA, 1977).
[c]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

During average winter and spring conditions, the discharge from the once-through cooling tower would raise the ambient stream temperature in Four Mile Creek above the 2.8°C maximum temperature rise specified in the State of South Carolina's Class B water classification standards. Accordingly, a Section 316(a) study would be performed to demonstrate whether a balanced biological community is maintained.

The thermal performance of the once-through mechanical-draft tower with gravity feed would be similar to that of a pumped-feed tower. The tower discharge water temperature is a function of plant outflow and ambient wet bulb temperatures. The former is the same for each; the latter is practically the same because of the locations of the gravity- and pumped-feed towers.

Effluent flow rates and temperatures in Four Mile Creek would also be similar for gravity- and pumped-feed towers. Flows and evaporation from the tower for each would be equal. Tower discharge temperatures would be equivalent, and the temperature decrease along Four Mile Creek would be small. The slightly smaller flowpath of the gravity-feed system would result in negligible differences in creek temperatures from those of the pumped-flow system.

Resource Utilization

The existing withdrawal of about 11.3 cubic meters per second of water from the Savannah River to C-Reactor would be unchanged for the once-through cooling-tower alternative. Discharges from C-Reactor to the river would be reduced by about 0.9 cubic meter per second, and the total suspended solids would be reduced either by settlement in a holding pond (pumped feed) or a cooling-tower basin (gravity feed). Chemical biocide added to the cooling water to protect the tower would either be dissipated by the use of a holding pond (pumped feed) or would be neutralized (gravity feed). All discharges would meet State of South Carolina Class B water classification standards.

Construction of a once-through mechanical-draft cooling tower system (gravity or pumped feed) would be completed in approximately 18 months after a 9-month lead design period. The estimated peak contractor manpower requirement, based on preliminary design information, is about 200 persons for C-Reactor, assuming a combined workforce with K-Reactor. The maintenance and operating workforce would be increased by approximately four mechanics. For the pumped-feed tower, approximately 90 acres of uplands would be disturbed by construction, including about 14 acres for the relocation of utility lines. For the gravity-feed tower, approximately 40 acres of uplands would be disturbed by construction.

The present peak electrical load in C-Area is about 30.3 megawatts. An estimated additional 3.5 megawatts (gravity feed) or 7.5 megawatts (pumped feed) would be required for the system pumps, fans, lighting, and other electrical equipment. The total energy required per year would be equivalent to that produced by the combustion of crude oil at the rate of approximately 7,000 barrels (gravity feed) or 15,000 barrels (pumped feed) for the entire project period.

The estimated capital cost for the once-through mechanical-draft cooling tower with pumped feed is approximately $55 million, including about $8.3 million for contingencies; estimated annual operating costs are $3.1 million. The estimated capital cost for the once-through mechanical-draft cooling tower with gravity flow is approximately $47 million, including about $7 million for contingencies; estimated annual operating costs are $1.9 million. In addition to these costs, the cost to conduct a Section 316(a) demonstration study is estimated at $1.25 million. Preliminary design criteria also suggest a 3-percent annual loss of reactor power attributable to the operation of a once-through cooling-tower system.

If current design evaluations and studies result in the selection of a natural-draft rather than a mechanical-draft cooling tower, the major differences would be lower energy requirements and operating costs.

2.2.1.2 Recirculating Cooling Towers

For recirculating cooling towers, the cooling water discharges from C-Reactor would be pumped to two mechanical-draft towers in series (preliminary design). Water from the first tower would be discharged to the inlet of the second tower. Cooled water from the second tower would be returned to the existing C-Reactor cooling water reservoir (186-C basin). Blowdown flow from the second tower would be discharged to a 20-acre holding pond prior to discharge. Figures 2-5 and 2-6, which are based on preliminary design information, show a flow diagram and a site layout, respectively, of this recirculating system.

To implement a recirculating mechanical-draft cooling-tower system for C-Reactor, the existing underground pipe carrying hot water to the reactor cooling water interceptor pit (Building 904-1C) from the existing C-Area heat exchangers would be rerouted to a new underground reinforced concrete pump pit, as discussed in Section 2.2.1.1 for the once-through mechanical-draft tower with pumped feed. An overflow pipe would connect to the existing pipe leading to the Building 904-1C pit.

The new pump pit for this alternative would contain six 2.3-cubic-meter-per-second, 40-meter, total-dynamic-head pumps, each with 1300-kilowatt motors. Five of the pumps would normally operate, with the sixth available as a backup unit. The discharge piping from each pump would connect into a common pipe header. This pipe would run underground from the new pump pit around the west, north, and east sides of C-Area to the inlet of the first cooling tower. A control valve, check valve, and gate valve would be provided between each pump and the header pipe.

Reinforced-concrete counterflow cooling towers would be constructed near the Building 186-C basin. The preliminary design for this alternative is based on two towers in series. The number and size of the towers would be determined during the course of detailed design. Each would be approximately 70 meters in diameter and extend about 20 meters above the ground. Water discharged from the first tower would be pumped to the inlet of the second tower, located nearby, by four pumps, each with 750-kilowatt motors. The second tower would be constructed on top of about 5 meters of earth fill, so most of its discharge could flow by gravity back to the Building 186-C basin for reuse.

The first tower would utilize stainless-steel or ceramic fill to withstand the high cooling water temperatures. The second tower could use the more standard polyvinylchloride fill, because the water reaching this tower would have been partially cooled at the first tower. Each tower would be equipped with 12 fans, each with a 190-kilowatt motor.

A small water-treatment building would be located near the cooling towers. It would be used to store a chemical biocide that would be injected into the cooling water stream to prevent biofouling in the tower system.

Approximately 0.6 cubic meter per second of the second tower discharge would be drained by gravity through an adjustable valve to the existing overflow

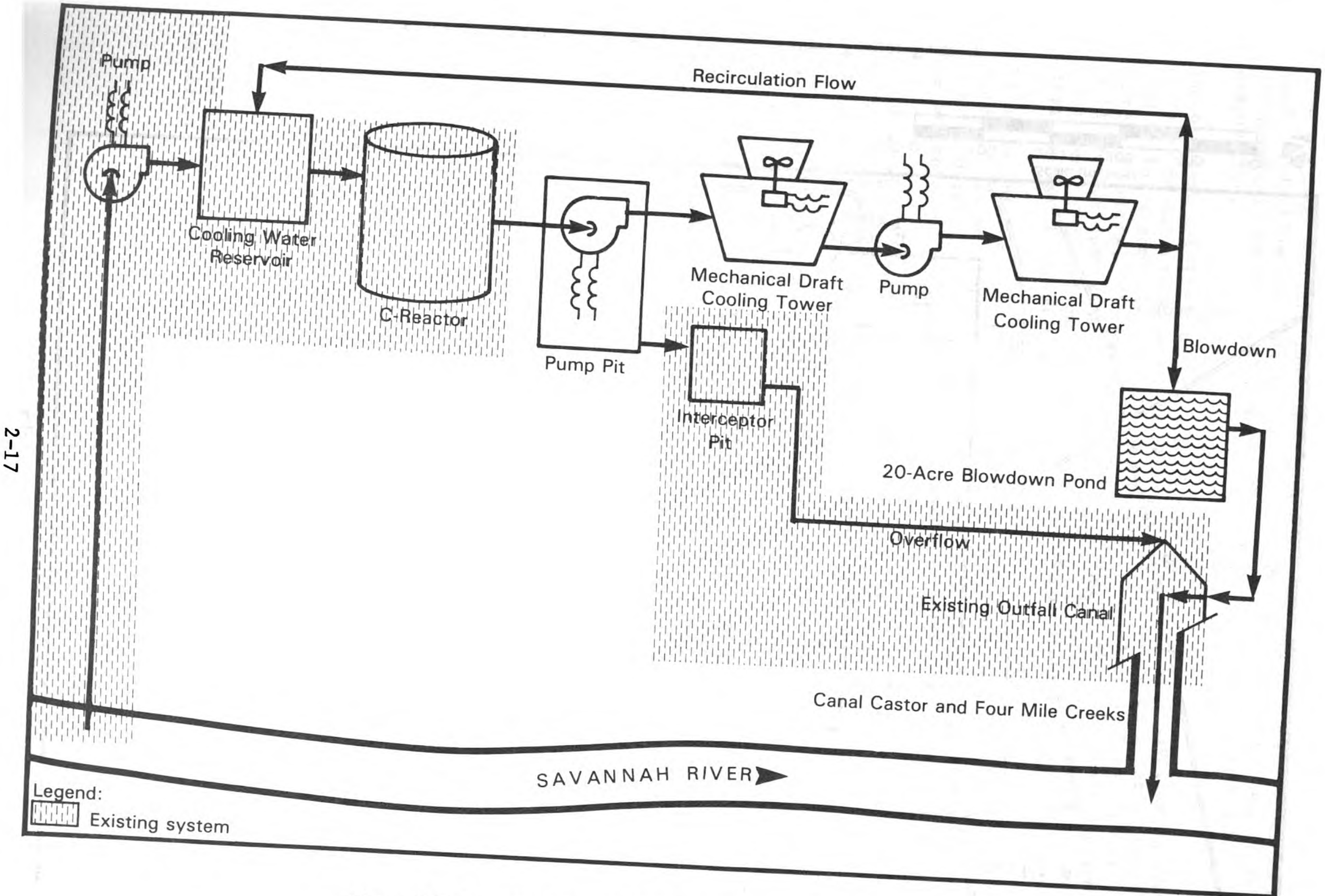


Figure 2-5. C-Area Recirculating Cooling Tower Flow Diagram

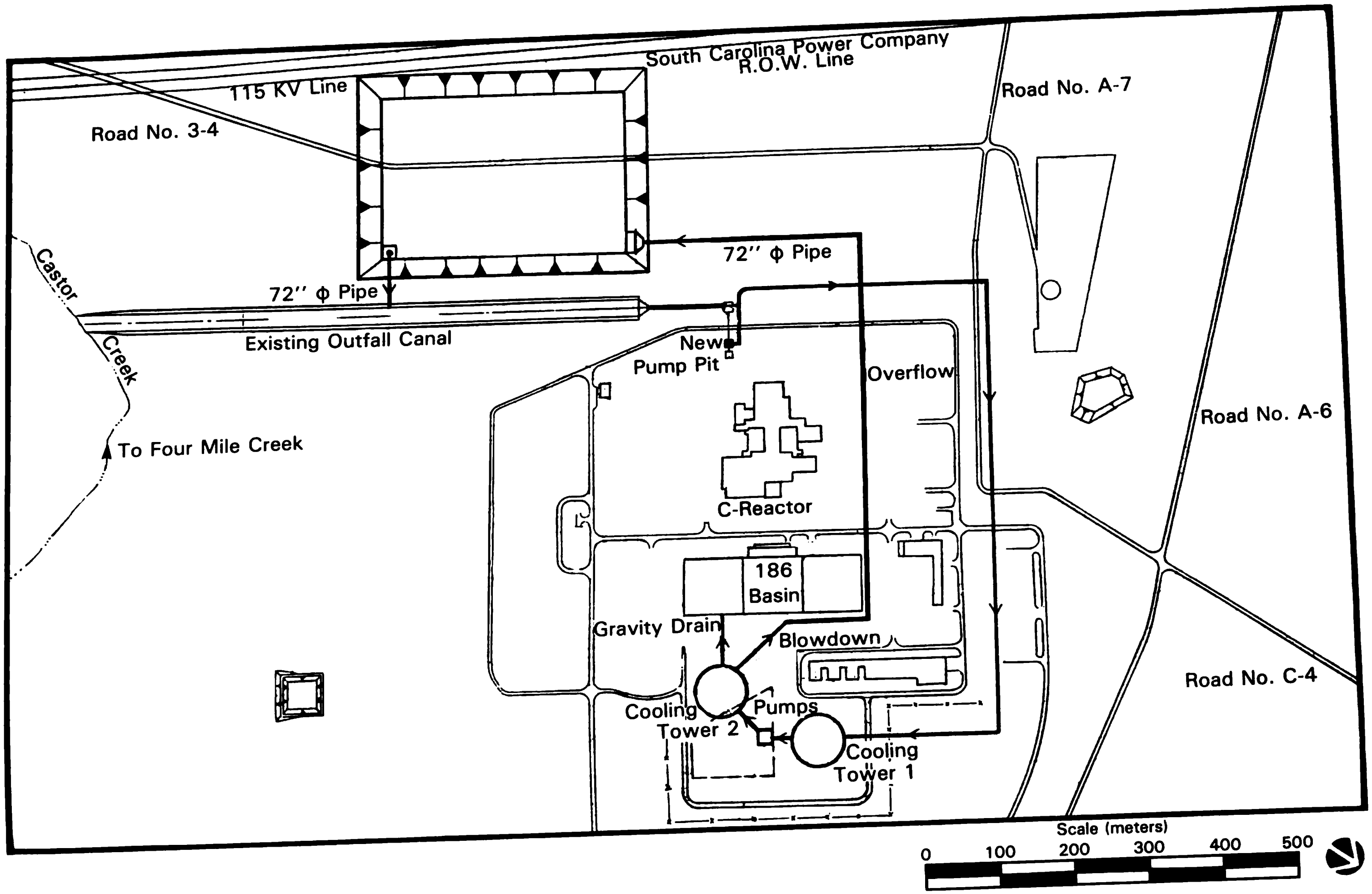


Figure 2-6. C-Reactor Recirculating Cooling Tower System

pipeline from Building 186-C and to a new line leading to the blowdown holding pond. This blowdown flow is necessary to keep the concentrations of solids and chemicals in the cooling water from constantly increasing due to evaporation.

The blowdown holding pond would be formed partially by excavating an area that contains no natural waterway or wetlands. This excavated material would be used to build compacted embankments to enclose a water-surface area of approximately 20 acres. The water in the pond would be about 3 meters deep, which would provide approximately 200 acre-feet of volume, or 5 days' blowdown retention. The maximum height of the embankment above the original ground elevation would be about 3 meters.

The outlet of the pipe into the blowdown pond would be a reinforced-concrete headwall. Stone riprap would provide protection from erosion by wave action at this outlet, as well as above and below the water surface elevation around the perimeter of the pond.

The blowdown holding pond would allow biocide chemicals to dissipate before the blowdown water was discharged and would also allow suspended solids to settle out.

The outlet from the blowdown holding pond would be a reinforced-concrete overflow weir designed to discharge at a low velocity to promote even settling over the full pond area. A reinforced-concrete pipe would convey the discharge by gravity back into the existing outfall canal. The flow would then follow the present path of cooling water to Four Mile Creek and the Savannah River.

The cooling-tower area would be inside a patrol road and fence with gates for personnel and vehicles. Access to this area would be from existing roads in the C-Reactor production area.

A new electrical control room would be centrally located within the C-Reactor production area between the pump pit and the cooling towers. This room would be larger than that for the once-through cooling tower and would contain the necessary switchgear and instrumentation for the operation of both cooling towers and of chemical-treatment and pump-pit equipment.

As described above for the once-through cooling tower, new substations, transmission lines, power distribution systems, and instrumentation and alarms in the C-Reactor Central Control Room would be required. Construction, safety, and fire prevention practices would be the same as those discussed for the once-through tower.

Thermal Performance

The thermal performance of the recirculating cooling-towers alternatives (i.e, its ability to cool the C-Reactor secondary cooling water) would vary with the wet-bulb temperature of the ambient air. This variation consists of diurnal fluctuations superimposed on seasonal cycles.

The recirculating cooling-tower system is designed for low tower discharge temperatures leading to compliance with the State of South Carolina's Class B water classification standards (i.e., a maximum instream temperature of 32.2°C). Bush Field meteorological data for 1953 through 1982 indicate a maximum hourly wet-bulb temperature of 28°C.

Preliminary design information has suggested the following recirculating cooling-tower system parameters: duty equal to 8.9×10^9 Btu per hour, range of 51°C, influent water temperature of 70°C, effluent water temperature of 13°C, wet-bulb temperature of 10°C, and an approach of 2.8°C. Based on these preliminary parameters, the discharge from the recirculating-tower system would approach (i.e., within a degree or so) the maximum hourly wet-bulb temperature.

For the preliminary design parameters cited above, the blowdown flow to Four Mile Creek is about 0.6 cubic meter per second at three cycles of concentration; the corresponding withdrawal from the Savannah River is about 1.7 cubic meters per second, which replaces both the blowdown and evaporation of about 1.1 cubic meters per second from the tower. Table 2-2 lists seasonal average water temperatures for the discharge along the cooling water flow path (based on the preliminary design parameters and meteorological data at Bush Field from 1953 through 1982), along with the corresponding ambient stream temperature. The discharge temperature is less than the ambient stream temperature, except in winter; the stream temperature increases downstream because of solar insolation and mixing with warmer ambient flow.

Table 2-2 also lists downstream temperatures under extreme summer conditions - discharge based on wet-bulb temperature for July 17-21, 1958, and ambient meteorology for July 12-16, 1980. Cooling water discharges resulting from the implementation of the recirculating cooling-tower system would comply with the State of South Carolina's Class B water classification standard of not raising the ambient stream temperature by more than 2.8°C.

Resource Utilization

C-Reactor presently receives approximately 11.3 cubic meters of cooling water per second from the Savannah River. This continuous flow passes through the reactor heat exchangers and discharges down Castor Creek and Four Mile Creek back to the river. If the recirculating cooling-towers alternative were implemented, the discharge would be reduced to about 0.6 cubic meter per second. The amount of water removed from the river would also be reduced, to about 1.7 cubic meters per second to make up for losses from blowdown and evaporation.

This alternative would be constructed in approximately 24 months after a 9-month design period. The estimated peak manpower requirement for C-Reactor is 300 persons, assuming a combined workforce with K-Reactor. The maintenance

Table 2-2. Temperatures (^{o}C) Along Cooling Water Flow Path--C-Reactor Recirculating Cooling Towers

Location	Winter average	Spring average	Summer average	Summer extreme[a]
Hot water to tower	69	72	74	74
Discharge to creek	10	17	23	25
Four Mile Creek at				
Road A	9	20	26	29
Road A-13	9	20	27	32
Swamp delta	9	21	27	32
Ambient creek[b]	9	23	29	33

[a]Values are a 5-day average.
[b]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

and operating workforce would be increased by approximately six mechanics. Approximately 50 acres of uplands would be disturbed by construction.

The present peak electrical load for C-Area is about 30.3 megawatts. The electrical load would be decreased 2.6 megawatts because of the 85-percent reduction in electrical load to pump water from the Savannah River to the 186-C basin. The total yearly energy reduction caused by this project would be the equivalent of the electricity produced by the combustion of approximately 5200 barrels of crude oil.

The capital cost of this alternative would be approximately $80 million. Estimated annual operating costs are $500,000. Previous studies of a recirculating cooling tower with a 2.8°C approach (DOE, 1984a) suggest an annual loss of reactor power attributable to operation of the recirculating cooling-tower system that would be as low as 6 percent.

2.2.1.3 No Action - Existing System

The existing once-through cooling water system for C-Reactor withdraws approximately 11.3 cubic meters of water per second from the Savannah River at the 1G and 3G pumphouses. From these pumphouses the water passes through an interconnected network of underground pipe to the Building 186-C basin, which has a capacity of approximately 95,000 cubic meters.

The cooling water and the overflow from the 186-C basin are drawn by gravity through the reactor building to an interceptor pit and then through an underground steel pipe. The water flows to a reinforced-concrete headwall at the existing C-Reactor cooling water outfall canal. This canal, lined with concrete and stone riprap, dissipates the energy of the discharge as it flows to Castor Creek, a tributary of Four Mile Creek. The discharge flows along Castor Creek and Four Mile Creek to the Savannah River, about 8 kilometers downstream from the D-Area powerhouse and the river-water pumping stations.

C-Reactor discharges approximately 11.3 cubic meters of reactor cooling water per second at an average temperature of 70° to 77°C. This flow includes 10.5 to 10.9 cubic meters per second from the reactor heat exchangers and 0.3 to 0.6 cubic meter per second of service water and other flows. It does not include any overflow from the 186-C basin, which is normally 0.2 cubic meter per second but can be as high as 0.95 cubic meter per second. This overflow is always at ambient water temperature and, therefore, adds no heat load.

Thermal Performance

The temperature increase of the secondary cooling-system water at C-Reactor normally ranges between 51°C (average summer) and 61°C (average winter). Virtually the entire flow withdrawn from the Savannah River is discharged to Four Mile Creek, with the auxiliary systems water mixing with the heated secondary cooling water.

The temperature of the effluent water varies with the temperature of the river water, although the seasonal fluctuations of the latter are damped by an inverse relationship between intake water temperature and temperature increase. Table 2-3 indicates seasonal average and summer extreme temperatures along the cooling water flow path. The downstream heat-loss characteristics are based on meteorological data from Bush Field between 1953 and 1982; the extreme summer conditions are for the 5-day period July 12-16, 1980. Table 2-3 also lists ambient creek temperatures corresponding to the indicated meteorological conditions.

Table 2-3 illustrates that the State of South Carolina's Class B water classification standard that specifies a maximum instream temperature of 32.2°C is exceeded at all times along points in the creek during C-Reactor operation. The heat loss along the creek implies an evaporation rate of approximately 0.5 cubic meter per second between the discharge and the delta - less than 5 percent of the discharge flow.

2.2.2 K-REACTOR COOLING WATER ALTERNATIVES

The cooling water alternatives for K-Reactor are the same as those for C-Reactor; that is, the construction and operation of a once-through cooling tower, the construction and operation of recirculating cooling towers, and no action.

Table 2-3. Temperatures (°C) Along C-Reactor Cooling Water Flow Path: No Action (Existing System)

Location	Winter average	Spring average	Summer average	Summer extreme[a]
Withdrawal from river	8	17	23	28
Discharge from heat exchanger	68	72	74	76
Discharge to creek	66	69	71	73
Four Mile Creek				
Road A	53	56	59	61
Road A-13	46	50	53	55
Swamp delta	39	43	47	48
Ambient creek[b]	9	23	29	33

[a]Values are a five-day average.
[b]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

2.2.2.1 Once-Through Cooling Tower (Preferred Alternative)

The once-through, mechanical-draft cooling tower with pumped feed for K-Reactor would be the same as that described for C-Reactor (Section 2.2.1.1), except the holding pond would be constructed adjacent and parallel to the north side of the existing cooling water effluent canal (Figure 2-7). The pond would be formed by excavating an area that contains no natural waterway or wetlands and by using the excavated material to build compacted embankments that would enclose a water-surface area of approximately 35 acres. The depth of the water in the pond would be about 9 meters, which would provide approximately 975,000 cubic meters (790 acre-feet) of volume, or 24 hours of cooling water retention. The maximum height of the embankment above the original ground elevation would be about 20 meters.

Downstream from the discharge headwall of the holding pond, a new riprap-paved, 24-meter-wide, 30-meter-long outfall canal would convey cooled effluent to the existing effluent discharge canal, 120 meters above its intersection with Indian Grave Branch.

A small water-treatment building would be required near the cooling tower. This building would be used to store a chemical biocide that would be injected into the cooling water stream to prevent biofouling in the tower system.

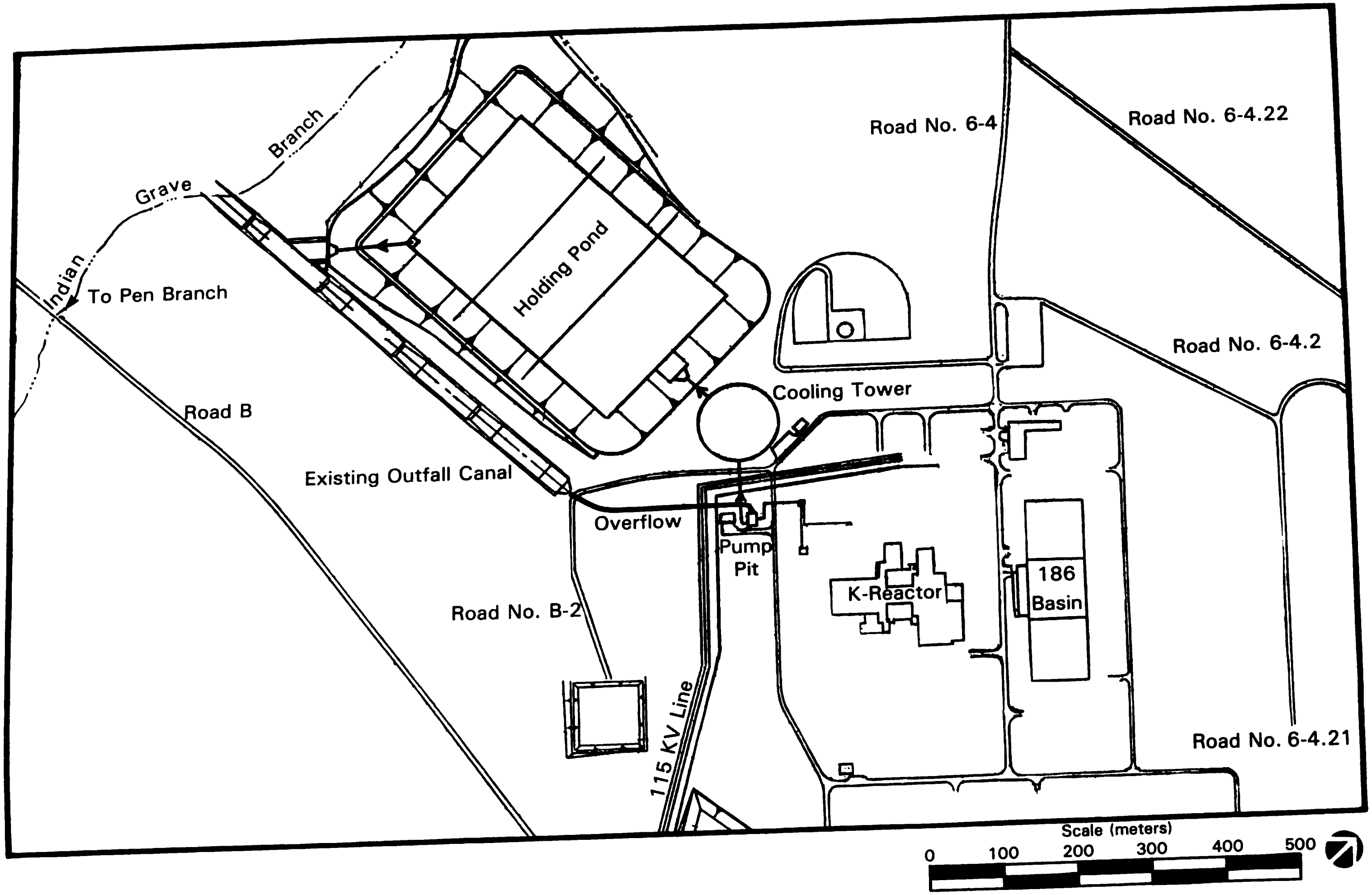
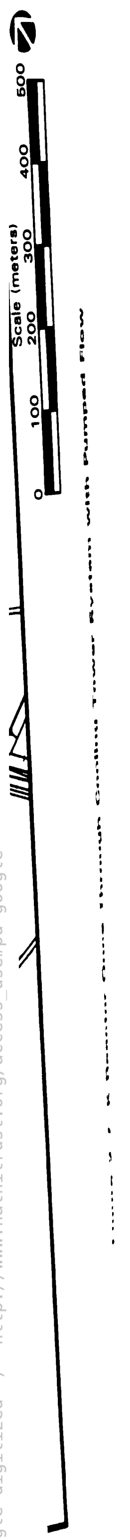


Figure 2-7. K-Reactor Once-Through Cooling Tower System with Pumped Flow



The once-through, mechanical-draft cooling tower with gravity feed for K-Reactor would be similar to that described for C-Reactor (Section 2.2.1.1), with the exception of the new effluent and outfall canals. The new K-Area effluent canal would be about 730 meters long and would require a multiple-pipe culvert crossing under Road B (Figure 2-8). The outfall canal from the cooling tower would be about 50 meters long and would enter Indian Grave Branch approximately 800 meters below the existing outfall canal discharge point.

K-Area receives power from the 115-kilovolt transmission grid; power distribution, loads, and required facilities would be the same as those described for C-Reactor in Section 2.2.1.1, except approximately 500 meters of 115-kilovolt transmission line and parallel supervisory-control and relay cable would have to be relocated around the pump pit and electrical-control room area for the once-through tower with pumped feed; two 13.8-kilovolt feeder lines, each about 1.2 kilometers long, would provide electric power to the fan motors for the once-through tower with gravity feed.

If optimization of performance and cost savings could be realized through the implementation of a natural-draft rather than a mechanical-draft tower, the major differences in the descriptions of these systems would be the same as those presented for C-Reactor in Section 2.2.1.1.

Thermal Performance

The thermal performance of a once-through mechanical-draft cooling tower with pumped feed for K-Reactor would be similar to that for C-Reactor, as described in Section 2.2.1.1.

Because of the slightly lower stream flow in Pen Branch (0.3 cubic meter per second) compared to that in Four Mile Creek (0.6 cubic meter per second), average winter stream temperatures would be slightly higher in Pen Branch than in Four Mile Creek.

Table 2-4 lists seasonal average water temperatures along the cooling water flow path (based on Bush Field meteorology data from 1953 through 1982), along with the corresponding ambient stream temperatures.

Table 2-4 also lists downstream temperatures under extreme summer conditions; the discharge temperature is based on wet-bulb temperatures for July 17-21, 1958, and the ambient meteorology for July 12-16, 1980.

During average winter and spring conditions, the discharge from the once-through cooling tower would raise the ambient stream temperature in Pen Branch above the 2.8°C maximum temperature rise specified in the State of South Carolina's Class B water classification standards. Accordingly, a Section 316(a) study would be performed to demonstrate whether a balanced biological community is maintained.

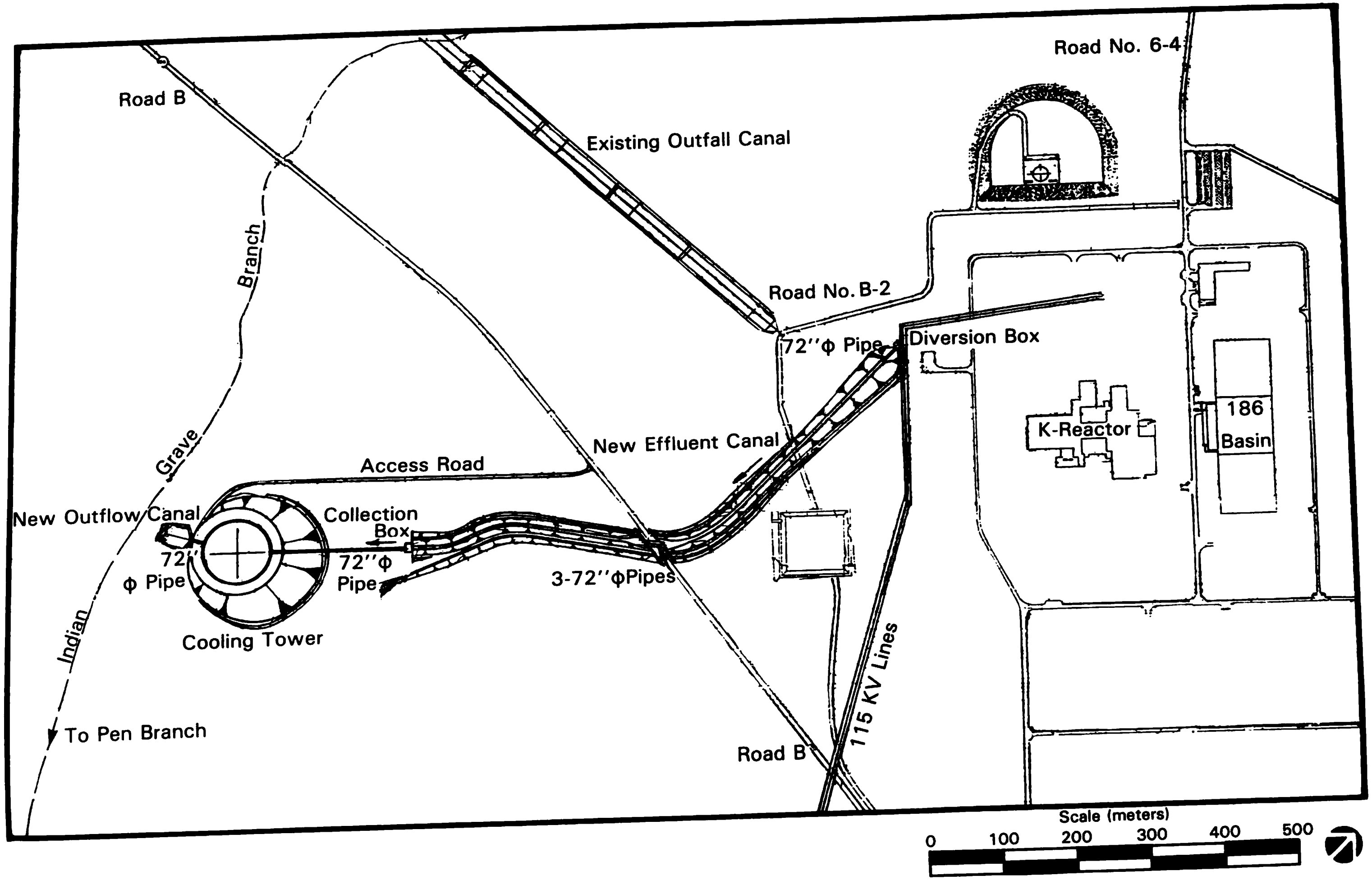


Figure 2-8. K-Reactor Once-Through Cooling Tower System with Gravity Flow

Table 2-4. Temperatures (°C) Along Cooling Water Flow Path of K-Reactor Once-Through Mechanical-Draft Cooling Tower

Location	Winter average	Spring average	Summer average	Summer extreme[a]
Hot water to tower	68	72	74	76
Discharge to creek	24[b]	28	30	32
Pen Branch at				
Road A	24	27	30	32
Railroad bridge	22	27	30	32
Swamp delta	21	26	30	32
Ambient stream[c]	9	23	29	33

[a]Values are a five-day average.
[b]Values based on preliminary computer model; final tower design will meet the requirements stipulated for maximum weekly average temperature (MWAT) for fish survival during a winter shutdown (EPA, 1977).
[c]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

The thermal performance of a once-through mechanical-draft cooling tower with gravity feed of heated water would be similar to that of the pumped-feed tower. The tower discharge water temperature is a function of plant outflow and ambient wet-bulb temperatures. The former is the same for each alternative; the latter is practically the same because of the proximity of the proposed locations of the gravity- and pump-feed towers.

Effluent flow rates and temperatures in Pen Branch would also be essentially the same for the gravity- and pumped-feed systems. The slightly shorter flowpath of the gravity-feed system would result in a negligible change in creek temperatures from those of the pumped-feed system (listed in Table 2-4).

The thermal performance characteristics of a natural-draft cooling tower would approximate that of the mechanical-draft tower. At lower wet-bulb temperatures, natural-draft discharge temperatures would be somewhat less than those from a mechanical-draft tower (Kennedy, 1972).

Resource Utilization

The existing withdrawal of about 11.3 cubic meters of water per second from the Savannah River to K-Reactor for the once-through cooling-tower alternative would be unchanged. Discharges from K-Reactor to the river would be reduced by the amount of evaporation from the cooling tower, and the total suspended solids would be reduced by settlement in either a holding pond (pumped feed) or a cooling-tower basin (gravity feed). Chemical biocide added to the cooling water to protect the tower either would dissipate through the use of a holding pond (pumped feed) or would be chemically dechlorinated (gravity feed). The State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C would be met.

Construction of a once-through, mechanical-draft, cooling-tower system (gravity- or pumped-feed) could be completed in approximately 22 months, after a 9-month lead design period, assuming procurement is completed after that for C-Reactor. The estimated peak contractor manpower requirement, based on preliminary design information, is about 200 persons for K-Reactor, assuming a combined workforce with C-Reactor. The maintenance and operating workforce would be increased by approximately four mechanics. For the pumped-feed tower, approximately 65 acres of uplands would be disturbed by construction, including about 5 acres for relocating utility lines; for the gravity-feed tower, approximately 35 acres of uplands would be disturbed by construction.

The estimated total energy requirements for either the pumped- or gravity-feed system would be the same as those identified for C-Reactor (Section 2.2.1.1).

The estimated capital cost for the once-through mechanical-draft cooling tower with pumped feed is approximately $54 million, including about $8.3 million for contingencies; estimated annual operating costs are $3.1 million. The estimated capital cost for the once-through mechanical-draft tower with gravity flow is approximately $45 million, including about $7 million for contingencies; estimated annual operating costs are $1.9 million. In addition to these costs, the estimated cost to conduct a section 316(a) demonstration study is $1.25 million. Preliminary design criteria also suggest a 3-percent annual loss of reactor power attributable to the operation of a once-through cooling-tower system.

If current design evaluations and studies result in the selection of a natural-draft rather than a mechanical-draft cooling tower, the major differences in expected resource utilization from those described above for the mechanical-draft tower would be lower energy requirements and operating costs.

2.2.2.2 Recirculating Cooling Towers

The description of the recirculating mechanical-draft cooling towers and their associated facilities, power distribution, and construction safety is essentially the same as that contained in Section 2.2.1.2 for C-Reactor, except that the discharge would be to Indian Grave Branch, a tributary of Pen Branch. Figure 2-9 shows the K-Reactor recirculating cooling-tower system.

Major differences between the C-Reactor description and that for K-Reactor are as follows: (1) the blowdown retention pond would be excavated from a hillside just north of the K-Area effluent canal; and (2) the maximum height of the embankment above the original ground elevation for the blowdown

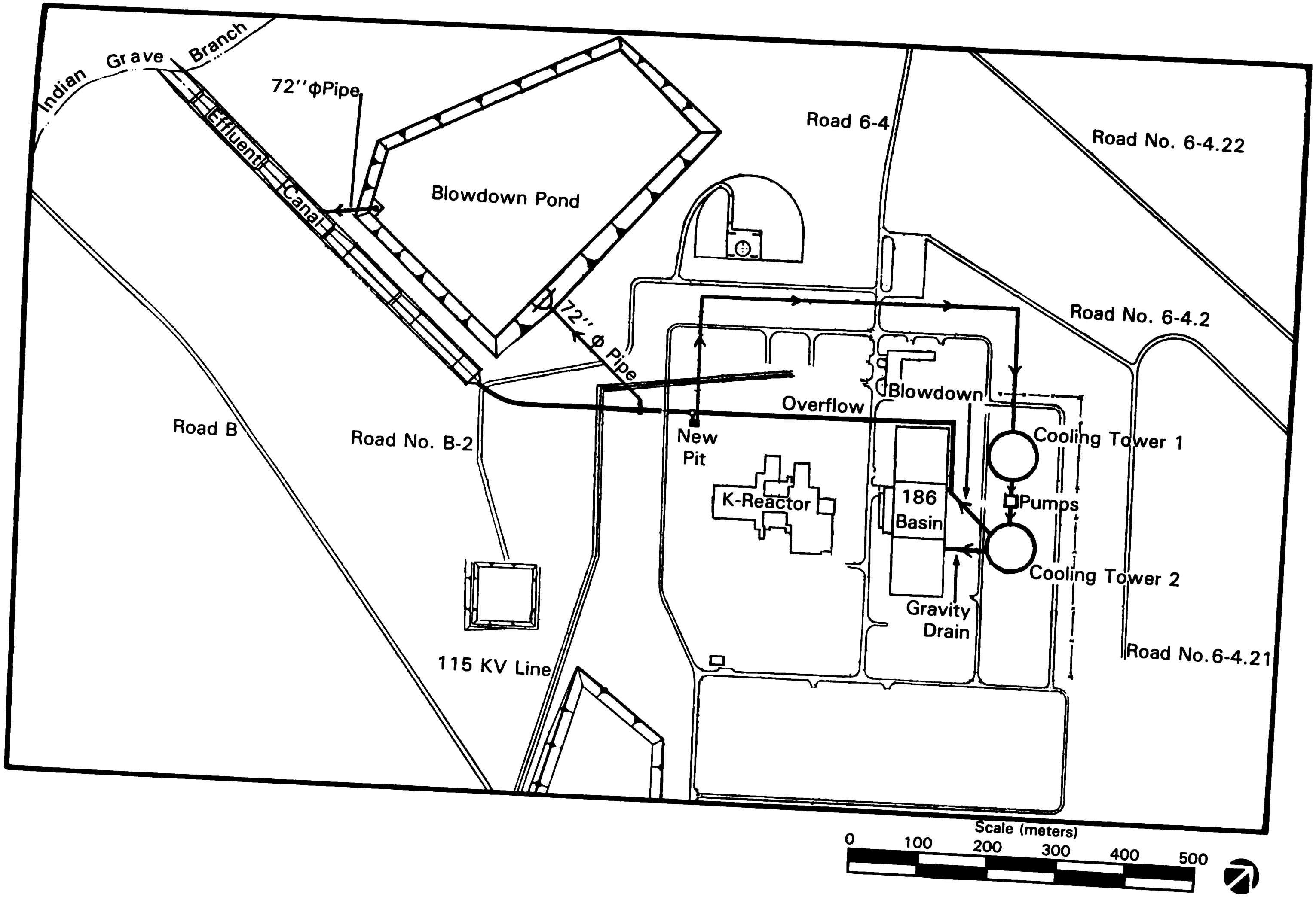


Figure 2-9. K-Reactor Recirculating Cooling Tower System

retention pond would be about 10 meters. The blowdown retention pond would provide the same retention capability as that for C-Reactor (i.e., approximately 200 acre-feet of volume, or 5 days blowdown retention).

Thermal Performance

The thermal performance of the recirculating cooling towers for K-Reactor would be similar to that of the recirculating cooling-tower for C-Reactor, as described in Section 2.2.1.2.

Because of the slightly lower stream flow in Pen Branch compared to Four Mile Creek and discharges from the recirculating cooling water system that are below calculated ambient stream temperatures during spring and summer, the average spring and summer stream temperatures would be slightly lower in Pen Branch than in Four Mile Creek.

Table 2-5 lists seasonal average water temperatures for the discharge along the cooling water flow path (based on meteorological data at Bush Field from 1953 through 1982), along with the corresponding ambient stream temperatures.

Table 2-5. Temperatures (°C) Along Cooling Water Flow Path--K-Reactor Recirculating Cooling Tower

Location	Winter average	Spring average	Summer average	Summer extreme[a]
Hot water to tower	69	72	74	74
Discharge to creek	10	17	23	25
Pen Branch at				
Road A	9	19	26	29
Railroad bridge	9	20	26	29
Swamp delta	9	20	26	32
Ambient creek[b]	9	23	29	33

[a]Values are a 5-day average.
[b]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

Table 2-5 also lists downstream temperatures under extreme summer conditions - discharge based on wet-bulb temperature for July 17-21, 1958, and ambient meteorology for July 12-16, 1980.

Resource Utilization

K-Reactor presently receives approximately 11.3 cubic meters of cooling water per second from the Savannah River. This continuous flow is passed through the reactor heat exchangers and discharged down Indian Grave Branch and Pen Branch back to the Savannah River. With this alternative, the discharge would be reduced to the quantity of blowdown flow, or about 0.6 cubic meter per second. The amount of cooling water removed from the river would also be reduced to approximately 1.7 cubic meters per second to allow for makeup of losses due to both blowdown and evaporation.

This alternative could be constructed in approximately 28 months after a 9-month design period, assuming procurement for C-Reactor is completed prior to that for K-Reactor. The peak contractor manpower requirement is estimated to be 300 persons for K-Reactor, assuming a combined workforce with C-Reactor. The maintenance and operating workforce would be increased by approximately six mechanics. Approximately 55 acres of uplands would be disturbed by construction of this system.

The present peak electrical load for K-Area is about 28.7 megawatts. The electrical load will be reduced by 2.6 megawatts because the 85-percent reduction in the requirement for pumping water from the river to the 186-K basin more than offsets electrical requirements for pumps, fans, lighting, and other recirculating-tower equipment. The total yearly energy reduction by this project would be equivalent to the electricity produced by the combustion of approximately 5,200 barrels of crude oil.

The estimated capital cost of this alternative is $73 million. Annual operating costs are estimated to be $500,000. Previous studies of a recirculating cooling tower with a 2.8°C approach (DOE, 1984a) suggest an annual loss of reactor power attributable to operation of the recirculating cooling-tower system that would be as low as 6 percent.

2.2.2.3 No Action - Existing Alternative

2.2.2.3.1 Description

The Pen Branch/Indian Grave Branch system is the receptor for cooling water discharges from K-Reactor. Pen Branch carried only low, natural flows before SRP construction in the early 1950s. It now accommodates the much higher flow (11.3 cubic meters per second) resulting from K-Reactor cooling water discharge.

The cooling water supply to K-Reactor is similar to that for C-Reactor, described in Section 2.2.1.3.

2.2.2.3.2 Thermal Performance

Approximately 96 percent of the 11.3 cubic meters (10.5 to 10.9 cubic meters per second) pumped from the Savannah River to K-Area is used as secondary cooling water, with the remainder (0.3 to 0.6 cubic meter) used for auxiliary systems. The temperature increase of the secondary cooling-system water normally ranges between 51°C (average summer) and 61°C (average winter). Virtually the entire flow withdrawn from the Savannah River is discharged to Pen Branch, with the auxiliary systems water mixing with the heated secondary cooling water.

The temperature of the effluent water varies with the temperature of the river water, although the seasonal fluctuations of the latter are damped by an inverse relationship between intake water temperature and temperature increase. Table 2-6 indicates seasonal average and summer extreme temperatures along the cooling water flow path. The downstream heat-loss characteristics are based on meteorological data from Bush Field between 1953 and 1982; the extreme summer conditions are for the 5-day period July 12-16, 1980. Table 2-6 also lists ambient stream temperatures corresponding to the indicated meteorological conditions.

Table 2-6 illustrates that the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C is exceeded at all times along points in the stream during the operation of K-Reactor. The heat loss along the stream implies an evaporation rate of approximately 0.5 cubic meter per second between the discharge and the delta - less than 5 percent of the discharge flow.

Table 2-6. Temperatures (°C) Along K-Reactor Cooling Water Flow Path: No Action (Existing System)

Location	Winter average	Spring average	Summer average	Summer extreme[a]
Withdrawal from river	8	17	23	28
Discharge from heat exchanger	68	72	74	76
Discharge to outfall	66	69	71	73
Pen Branch at				
Road A	60	64	67	68
Railroad bridge	53	56	59	61
Swamp delta	43	47	50	52
Ambient stream[b]	9	23	29	33

[a]Values are a 5-day average.
[b]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

2.2.3 D-AREA POWERHOUSE ALTERNATIVES

The alternatives for the D-Area coal-fired powerhouse are increased flow with mixing (DOE's preferred alternative), direct discharge to the Savannah River, and no action. The following sections describe these alternatives.

2.2.3.1 Increased Flow with Mixing (Preferred Alternative)

The D-Area powerhouse uses water pumped from the Savannah River for cooling. Most of this water is discharged from the condensers into an excavated canal that flows into Beaver Dam Creek about 1700 meters upstream from the Savannah River swamp. A closed-loop recirculation system utilizing an existing cooling tower can provide an alternative cooled water supply for one of the four units.

During current normal operations, water is pumped by three of six pumps located in the Building 681-5G pumphouse, situated on a small inlet cove about 1.6 kilometers upstream from the mouth of Beaver Dam Creek. The rated capacity of each pump is about 0.8 cubic meter per second, with a maximum sustained flow for all six pumps of about 4.5 cubic meters per second. The water flows through an underground pipeline to a raw-water receiving basin in Building 483-1D. Excess water not utilized in the powerhouse and 400-Area water-treatment plant overflows a weir to mix with the powerhouse effluent stream before discharging into the D-Area outfall canal (Figure 2-10). The corresponding flow rate in Beaver Dam Creek at the SRP Health Protection Department monitoring station using various numbers of pumps is as follows: three pumps, 2.6 cubic meters per second; four pumps, 3.5 cubic meters per second; five pumps, 4.1 cubic meters per second; and 6 pumps, 4.5 cubic meters per second.

The increased-flow-with-mixing cooling water alternative would require the intermittent use of four to six pumps to provide a total flow (as much as 4.5 cubic meters per second at the HP monitoring station) of Savannah River water to the raw-water receiving basin. The overflow rate would be adjusted to maintain a maximum instream temperature of 32.2°C. The temperature would be monitored by an automatic monitoring station, maintained at the compliance point, and displayed in the powerhouse control room. The existing one-unit recirculation system with a cooling tower would continue to operate as at present.

Because sufficient pumping capacity is already available in the Building 681-5G pumphouse, no major new construction would be necessary to implement increased flow with mixing, and the plan could be implemented immediately. However, increased operation of the existing pumps would require circulation of more water from the Savannah River, consumption of more electricity, and a slight increase in maintenance cost.

Thermal Performance

The temperature of the D-Area cooling water withdrawn from the Savannah River rises as it passes through the powerhouse condensers. The flow from one of the four powerhouse condensers normally is directed to a cooling tower (design

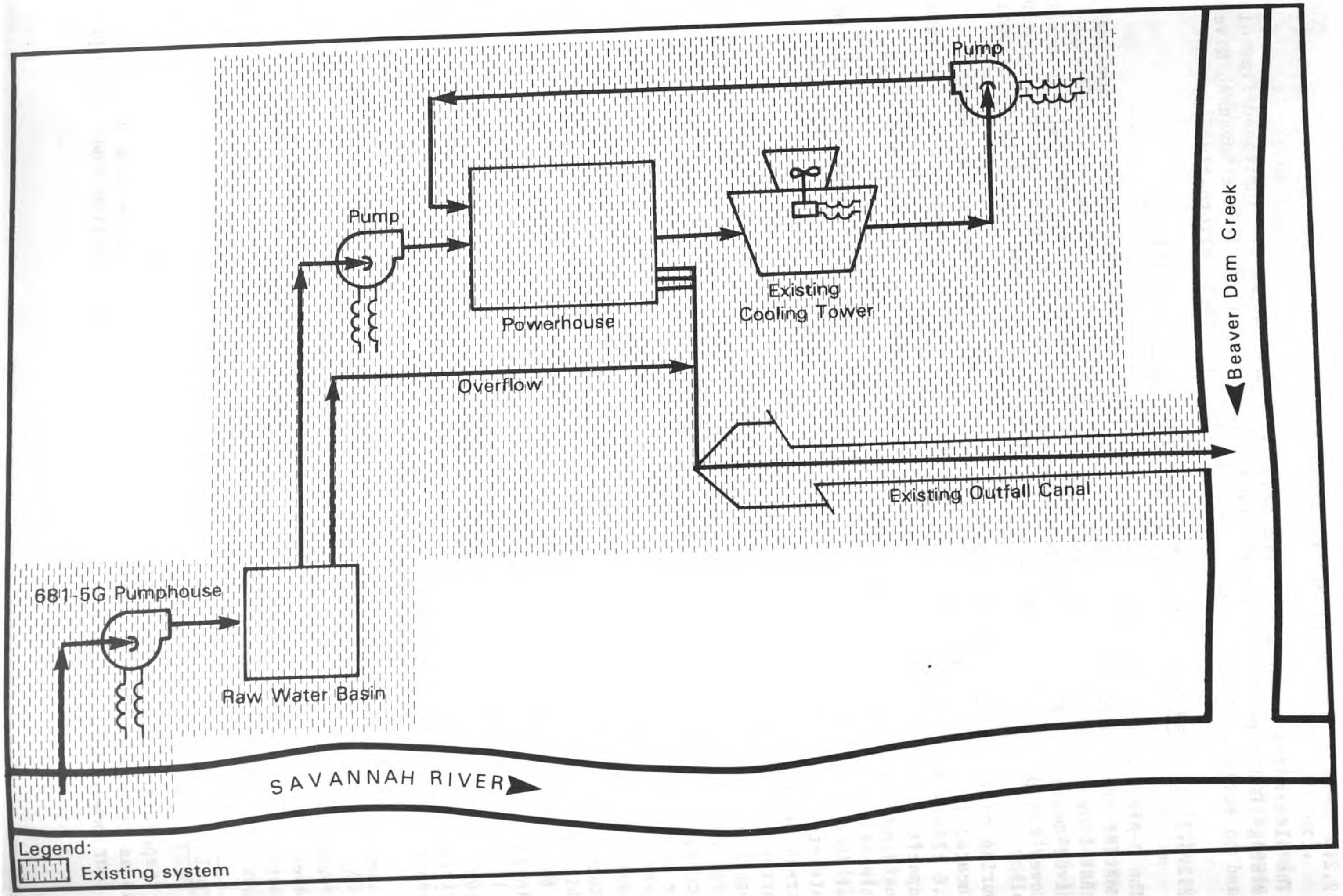


Figure 2-10. D-Area Existing System Flow Diagram

conditions for the cooling tower are: hot-water temperature, 40°C; wet-bulb temperature, 24°C; discharge temperature, 32°C). The blowdown flow from the cooling tower is negligible compared to the flow through the once-through system. The rate of evaporation from the cooling tower at design conditions is approximately 0.01 cubic meter per second; thus, essentially all of the water (99.5 percent at normal flow) withdrawn from the Savannah River for D-Area cooling is discharged to Beaver Dam Creek.

The temperature of the D-Area powerhouse cooling water discharge will vary due to variations in the temperature of the water withdrawn from the Savannah River and powerhouse loadings. Table 2-7 shows seasonal average water temperatures along the cooling water flow path (based on meteorological data for Bush Field from 1953 through 1982) along with the corresponding ambient stream temperature assuming an 8°C rise in the temperature of cooling water withdrawn from the Savannah River as it passes through the powerhouse condensers and operation of as many as 6 pumps (4.5 cubic meters per second) during extreme summer conditions.

Table 2-7. Temperatures (°C) Along Cooling Water Flow Path of D-Area Powerhouse for Increased Flow With Mixing Alternative

Location	Current operation			Increased flow with mixing during summer extreme[a]
	Winter average	Spring average	Summer average	
Withdrawal from river	8	17	23	28
Discharge to creek	16	25	31	32
Swamp delta	15	24	31	32
Ambient creek[b]	9	23	29	33

[a]Values are a 5-day average.
[b]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

Table 2-7 indicates that under average seasonal meteorological conditions the discharge to the creek from the operation of the D-Area powerhouse will meet the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C, provided that, under extreme summer conditions, the flow to the raw-water basin will be increased from 2.6 to as high as 4.5 cubic meters per second to decrease the discharge temperature. During winter conditions, the current discharge from the D-Area powerhouse would continue to exceed the Class B water classification standard of a maximum 2.8°C ambient rise in stream temperature. A Section 316(a) demonstration study would be performed to show whether a balanced biological community would be maintained.

Resource Utilization

The current flows in Beaver Dam Creek downstream from the D-Area discharge canal average approximately 2.6 cubic meters per second. During extreme summer conditions, the implementation of this alternative would increase that flow to a maximum of 4.5 cubic meters per second, and would temporarily affect an estimated 4 acres each of uplands and wetlands.

No appreciable change in the chemical characteristics of the effluent is expected because no chemicals would be used in implementing this alternative.

Each operating pump at the Building 681-5G pumphouse consumes approximately 8700 kilowatt-hours of electricity per day. When all four D-Area units are operating, three pumps are required to supply cooling water. Assuming that additional pumping is continued all day whenever the discharge water temperature exceeds 31°C, the estimated increase in electric-power consumption is approximately 6 percent. The amount of electricity used at this pumphouse is a small portion of the overall SRP use. Therefore, the incremental increase in the use of electricity for D-Area would be extremely small.

The estimated increase in annual operating cost for incremental electric consumption is $30,000. In addition, the cost to conduct a Section 316(a) demonstration study is estimated at $1.25 million.

2.2.3.2 Direct Discharge to Savannah River

Another alternative for the cooling water discharge from the D-Area powerhouse is the extension of the existing discharge piping to the Savannah River (Figures 2-11 and 2-12). The existing cooling water system would continue to pump the present flow from the Building 681-5G pumphouse to the Building 483-1D raw-water receiving basin and through the condensers. The existing cooling tower would continue to operate as a recirculating system for one condenser. However, the existing discharge headers from the condensers would be intercepted by a new interceptor sump. From this point a new underground pipe about 1.5 kilometers long would enable the water to flow by gravity to the Savannah River, about 91 to 152 meters downstream from the Building 681-5G pumphouse. The existing effluent discharge canal would no longer receive cooling water, but would continue to receive overflows from the raw-water basin.

The new pipeline would be located between the existing supply pipeline from the pumphouse and the existing power lines running to the pumphouse. It would cross under an unnamed stream and extend through approximately 400 meters of swamp before reaching the river.

The discharge structure at the river would be a sparging type extending into the river about 90 to 150 meters downstream of the 5G intake structure to avoid any recirculation. The system would promote mixing of the cooling water effluent with the river water flow.

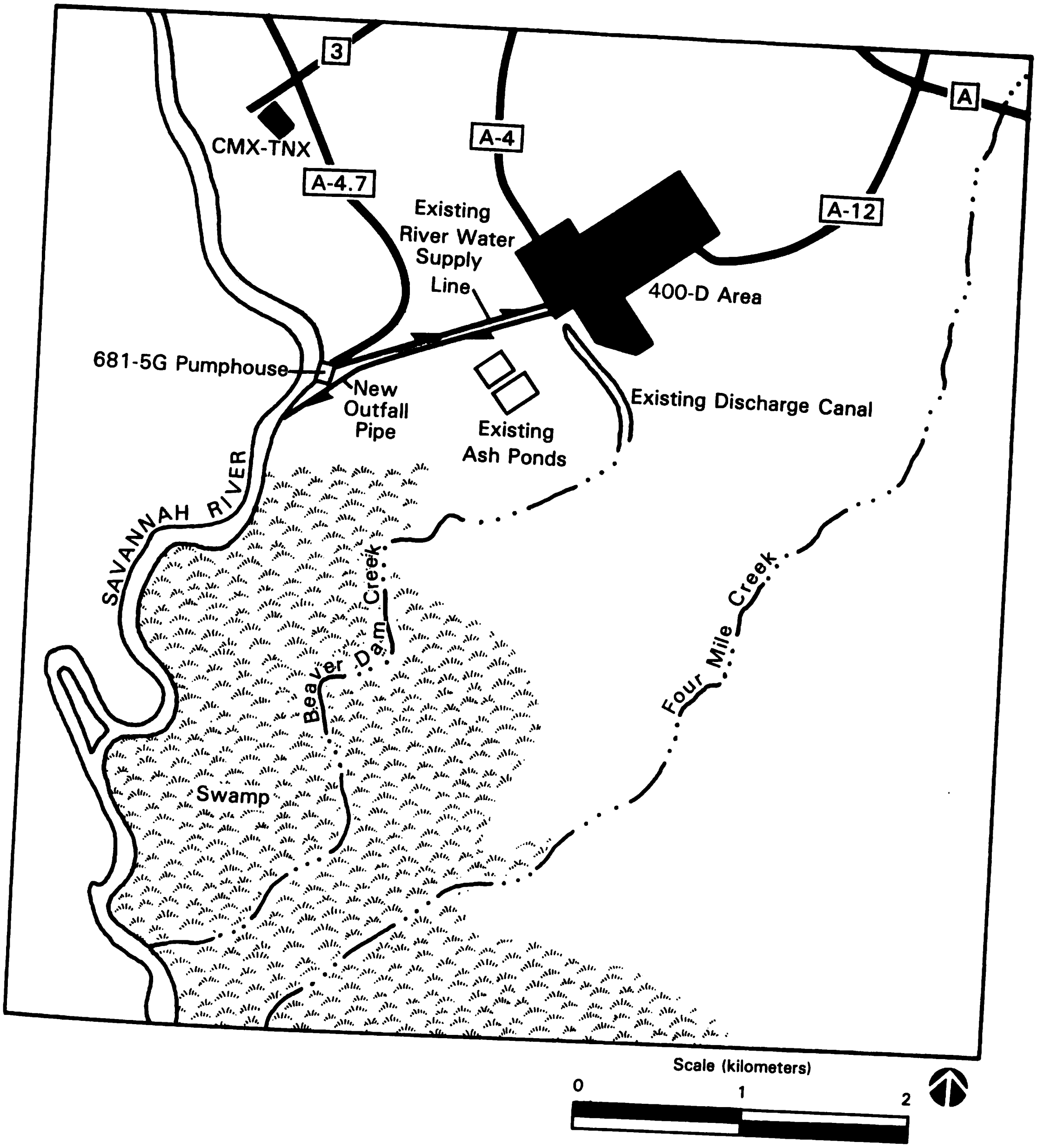


Figure 2-11. D-Area Discharge to Savannah River Alternative

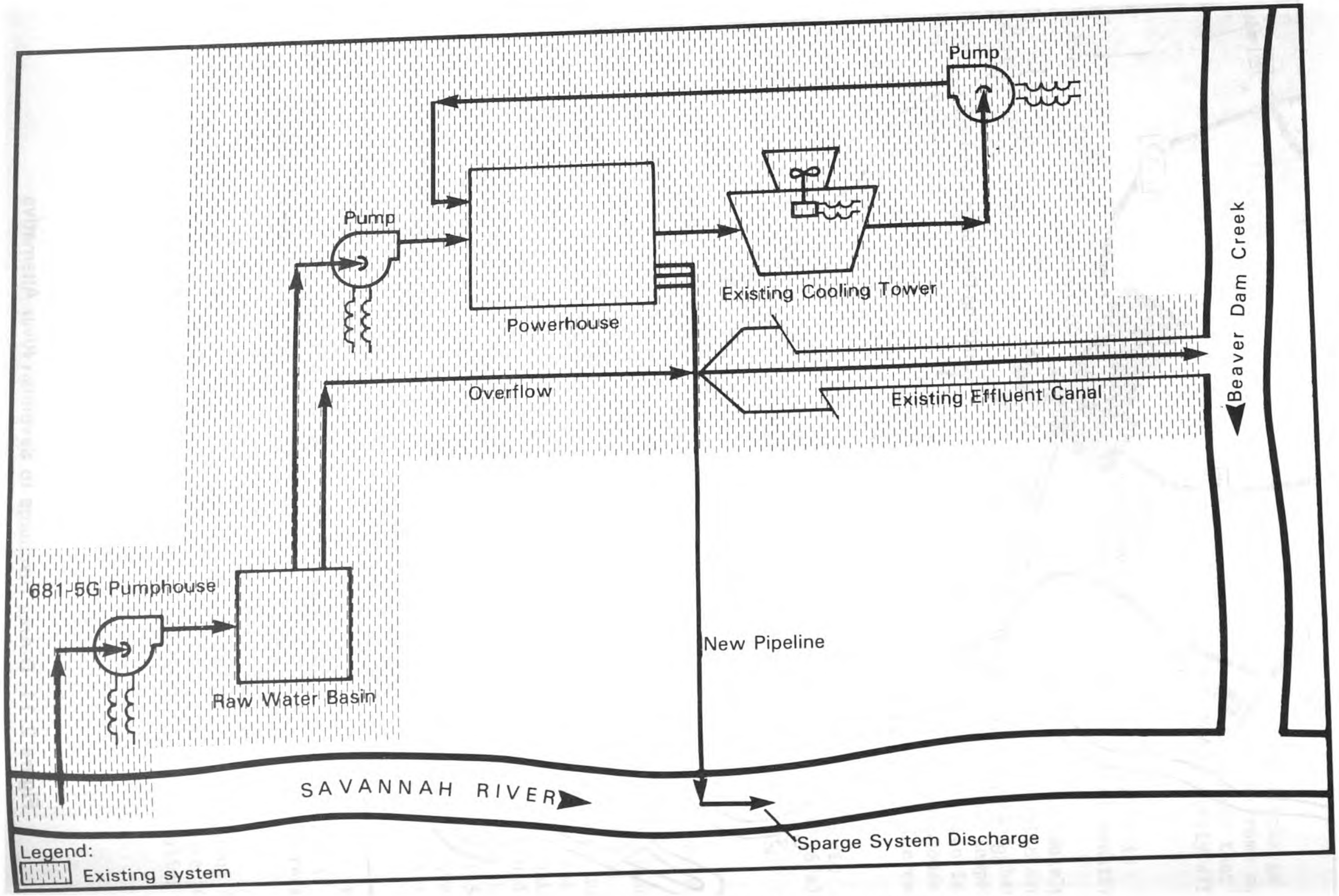


Figure 2-12. D-Area Direct Discharge to Savannah River Flow Diagram

Thermal Performance

With the direct-discharge alternative, the temperature of the D-Area powerhouse cooling water discharge would vary due to variations in the temperature of water withdrawn from the Savannah River and powerhouse loadings. Table 2-8 shows the seasonal variation in river and discharge temperatures and indicates that these temperatures for all average seasonal conditions are less than 32.2°C, assuming an 8°C rise in the temperature of cooling water withdrawn from the Savannah River as it passes through the powerhouse condensers. During extreme summer conditions the discharge temperature is 36°C.

Table 2-8. Temperatures and Passage Zone Sizes for D-Area Powerhouse Direct Discharge Into Savannah River[a]

Location or area	Winter average	Spring average	Summer average	Summer extreme[b]
Temperature (°C)				
Withdrawal from river	8	17	23	28
Discharge to river	16	25	31	36
Maximum river cross-sectional area (percent of total) having temperature (°C) less than				
2.8 (excess)	99.7	99.7	99.5	99.3
32.2 (absolute)	100	100	100	99.7
Maximum river width (percent of total) having temperature excess (°C) less than				
2.8 (excess)	95	95	94	93
32.2 (absolute)	100	100	100	96

[a]Based on results of thermal modeling as described in Appendix B.
[b]Modeling parameters for summer extreme use minimum 7-day average flow with an average frequency of once in 10 years (7Q10) for the Savannah River.

In accordance with the State of South Carolina's regulations for water classifications and standards, the ambient water temperatures of Class B waters may not be increased by more than 2.8°C or exceed a maximum of 32.2°C as a result of thermal discharges, unless a mixing zone has been established. The purposes of the mixing zone are to allow the safe passage of aquatic organisms and to allow for the protection and propagation of a balanced indigenous population of aquatic organisms; this zone is to be based on critical flow conditions.

Table 2-8 lists the (percentages of total cross-sectional areas and widths) corresponding to temperatures of less than 2.8°C and temperatures of less than 32.2°C. Even under summer extreme conditions, the zone of passage would encompass 93 percent (width) and 99 percent (cross-sectional area) of the Savannah River.

Resource Utilization

The existing flow of water from the Savannah River to the D-Area powerhouse would be unchanged. Flow in the existing effluent canal, however, would be reduced from the current average of about 2.6 cubic meters per second to about 0.5 cubic meter per second during normal powerhouse operations; at maximum powerhouse operations, the flow in the canal would be about 0.3 cubic meter per second. This flow would increase to about 0.9 cubic meter per second when the powerhouse is shut down. Beaver Dam Creek would receive intermittent rainfall runoff and groundwater seepage in addition to this reduced flow. Chemical and suspended-solids characteristics of the cooling water effluent would be unchanged.

Connection of the new outfall pipe to the existing condenser outlet piping would require temporary shutdown or units operating in a once-through mode at the time of connection.

Construction of the pipeline to the river could be accomplished in approximately 22 months with a peak contractor manpower requirement of 40 persons. No increase in the maintenance or operation workforce would be necessary. The 22-month construction schedule includes the building of a new temporary road, a support structure for the pipeline through low-lying areas, and the submittal and approval of necessary permits. An estimated 5 acres of uplands and 1 acre of wetlands would be disturbed by construction. Any excess excavated material would be removed from the construction area and deposited at an approved spoil site so that natural drainage would not be disturbed.

Construction of the sparge system would disturb the river bank, and would be restored to protect the floodplain system downstream.

The capital cost of this alternative would be approximately $14 million. There would be $50,000 additional operating costs associated with this alternative.

2.2.3.3 No Action - Existing System

Under the no-action alternative, the existing withdrawal of Savannah River water and discharge to Beaver Dam Creek would continue. An average of about 2.6 cubic meters per second of water would be pumped from the Savannah River to the D-Area powerhouse for cooling and then discharged from the cooling system to Beaver Dam Creek.

Thermal Performance

Table 2-9 shows seasonal average water temperatures along the cooling water flow path (based on meteorological data at Bush Field from 1953 through 1982), along with the corresponding ambient stream temperature, assuming an 8°C rise in the temperature of cooling water withdrawn from the Savannah River as it passes through the D-Area powerhouse condensers.

Table 2-9 indicates that during average conditions, the discharge to the creek will meet the maximum instream temperature standard of 32.2°C. However, under extreme meteorological conditions, the discharge temperature could be as high as 4°C greater than that allowed by the State of South Carolina's Class B water classification standard. During winter conditions, the discharge from the D-Area powerhouse would also exceed the Class B water classification standard of a maximum 2.8°C ambient rise in stream temperature.

Table 2-9. Temperatures (C°) Along Cooling Water Flow Path--D-Area Powerhouse--No Action (Existing System)

Location	Winter average	Spring average	Summer average	Summer extreme[a]
Withdrawal from river	8	17	23	28
Discharge to creek	16	25	31	36
Swamp delta	15	24	31	36
Ambient creek[b]	9	23	29	33

[a]Values are a 5-day average.
[b]Values assumed equal to equilibrium temperatures calculated from Bush Field meteorological data.

2.3 COMPARISON OF ALTERNATIVES

For each of the three facilities, selection of the no-action alternative would result in a continuation of present cooling water discharges that would not comply with the State of South Carolina's Class B water classification standard of a maximum instream temperature of 32.2°C. The construction and operation of either once-through or recirculating towers for C- and K-Reactors and implementation of either increased flow with mixing or construction and operation of direct discharge to the Savannah River for the D-Area powerhouse would result in discharges that would comply with this standard. Construction and operation of once-through cooling towers for C- and K-Reactors and implementation of increased flow with mixing for the D-Area powerhouse would also require the conduct of Section 316(a) studies to determine whether a balanced biological community is maintained, because discharges from these alternatives would exceed the Class B water classification standard of a maximum instream ambient temperature rise of 2.8°C. The following comparison discusses the major differences that would occur from the implementation of each of the alternatives.

2.3.1 ALTERNATIVES FOR C-REACTOR

Either of the two cooling-tower alternatives would significantly reduce the thermal impacts in Four Mile Creek and the Savannah River swamp. The major environmental difference between these alternatives is that the recirculating cooling towers would withdraw less water from the river (about 1.7 cubic meters per second) and release less to the creek (about 0.6 cubic meter per second) than the once-through tower (about 11.3 and 10.4 cubic meters per second, respectively). This would result in reduced entrainment losses of fish eggs and larvae and reduced impingement losses of adults and juveniles with the recirculating towers. The reduced flow in Four Mile Creek and its delta would also result in successional reestablishment of a greater amount of wetlands than would occur with the once-through cooling-tower alternative; on the other hand, the reduced flow would also provide less aquatic habitat in the creek and parts of the swamp than would occur with the once-through tower. Both alternatives would improve habitat over existing conditions for the endangered wood stork and American alligator.

The impacts of both systems on air quality would be similar; however, because the recirculating cooling-tower system includes two towers operated in series with three cycles of concentration the total frequency of ice buildup near the towers would be greater for the recirculating system (510 hours versus 208 hours), as would the maximum annual deposition of total solids (6 kilograms per acre per year within 2.0 kilometers of the tower versus 1 kilogram per acre per year]. Because these deposition rates are far below the levels that can cause reduced vegetation productivity (83 kilograms per acre per year), no impacts on vegetation or wildlife are expected.

The operation of the once-through cooling tower would not cause any significant changes in the remobilization of radionuclides contained in the Four Mile Creek bed, because the flow in the creek would remain essentially unchanged. The operation of recirculating towers would result in a calculated decrease of about 0.4 curie of cesium released to the Savannah River over a year due to the reduced flow. The implementation of either the once-through cooling tower or recirculating cooling towers would slightly reduce the radiological doses to the maximum individual and the regional population that are associated with the existing direct-discharge system, which are well within standards. The decrease in maximum individual and collective (population) doses, however, would be greater for recirculating cooling towers than for once-through towers.

Table 2-10 provides a summary comparison of the alternatives for C-Reactor.

Table 2-10. Comparison of Cooling Water Alternatives for C-Reactor

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
SCHEDULE FOR IMPLEMENTATION	Current	Construction of the system would require about 18 months after a 9-month design period.	Construction of the system would require about 24 months after a 9-month design period.
PRELIMINARY COST CAPITAL (MILLION $)	$0	$47-55	$80
ESTIMATED OPERATING COST INCREASE (MILLION $ PER YEAR	$0	$1.9-3.1	$0.5
SOCIOECONOMICS	No additional work force required.	Peak construction workforce of 200 persons; four additional mechanics required for operation.	Peak construction workforce of 300 persons; six additional mechanics required for operation.
WATER WITHDRAWAL AND DISCHARGE RATES	About 11.3 cubic meters per second is withdrawn from the Savannah River and discharged into Four Mile Creek.	Withdrawal the same as for no action; discharge to Four Mile Creek would be about 92% of that for no action or 10.4 cubic meters per second.	Withdrawal of river water would be about 15% of that for no action or 1.7 cubic meters per second. Discharge to Four Mile Creek would be about 5% of that for no action or 0.6 cubic meters per second.
WATER QUALITY	Water temperature in Four Mile Creek would exceed State Class B water classification standards. Dissolved oxygen concentrations in Four Mile Creek	State Class B water classification standards for temperature (32.2°C) and dissolved oxygen concentrations would be met; a Section 316(a) demonstration study	Same as for once-through tower except that a Section 316(a) demonstration study would not be required. Dissolved solids concentrations in discharge would be higher than no

Table 2-10. Comparison of Cooling Water Alternatives for C-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
	are below standards intermittently during the summer and total suspended solids are slightly higher than ambient stream levels.	will be performed for exceedances of 2.8°C rise in ambient stream temperatures. There would be some reduction in the total suspended solids.	action or once-through cooling tower because of cycles of concentration; however, total suspended solids discharged would be greatly reduced.
TEMPERATURE AND FLOW EFFECTS	There would continue to be few aquatic organisms in the thermal areas of Four Mile Creek and its delta. A thermal barrier will prevent aquatic movement in Four Mile Creek and Castor Creek. Fish spawning in the creek and delta would remain reduced. There would continue to be a potential for cold shock during the winter.	Aquatic organisms would become established in present thermal areas. Thermal barrier would be removed. The creek and delta would be opened to fish spawning and foraging. There would be no potential for cold shock as the MWAT (EPA, 1977) criteria would be met. Water levels would continue to fluctuate.	Similar mitigation of thermal effects that would occur with once-through tower except that habitat area for aquatic spawning and foraging would be smaller because of reduced flow, and magnitude of water level fluctuations would be less.
ENTRAINMENT/ IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 21.6 x 10^6 fish eggs and larvae and the loss of about 4380 fish to impingement annually.	Effects would be about the same as for no action.	Annual entrainment and impingement losses would be reduced to about 3.3 x 10^6 and 657, respectively.

Table 2-10. Comparison of Cooling Water Alternatives for C-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
HABITAT	Flow and temperature impacts would continue to result in the loss of about 28 acres of wetlands each year.	Wetland losses would decrease; some successional revegetation would occur. Between 45 to 90 acres of uplands would be affected by construction.	Wetland losses would essentially cease and about 1000 acres of wetlands would successively revegetate; about 50 acres of uplands would be affected by construction.
SALT DEPOSITION	None.	Maximum annual total-solids deposition within about 2 km of the tower would be about 1 kilogram per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.	Maximum annual total-solids deposition within about 2 km of the tower would be about 6 kilograms per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.
ENDANGERED SPECIES	Thermally affected areas of Four Mile Creek and swamp would continue to be too hot for alligators. Low fish densities and high water levels limit forage value for wood stork. No impacts on shortnose sturgeon and red-cockaded woodpecker.	Alligator habitat would be improved by lower water temperatures. Some improvement of wood stork foraging habitat would result from increased fish concentrations although continued high flows would maintain deep water conditions. No impacts on shortnose sturgeon and red-cockaded woodpecker.	Some alligator habitat would be available; however, lower flows would decrease potential habitat area resulting in less improvement than with once-through tower. Potential for improvement of wood stork habitat would be increased due to lower water levels in the creek and delta. No impacts on shortnose sturgeon and red-cockaded woodpecker.

Table 2-10. Comparison of Cooling Water Alternatives for C-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
AIR QUALITY	No impacts.	Construction would result in temporary small increases in carbon monoxide and hydrocarbons from engine exhaust. Also some transient increases in airborne dust.	Construction impacts would be similar to those for once-through tower.
		Maximum annual-mean frequency of reduced ground-level visibility to less than 1000 m would be about 5 hours per year occurring at 8.5 km to WNW-NNW of tower.	Reduction in ground-level visibility would be about 1 hr per year occurring about 4 km SW of the towers.
		Maximum ice accumulation on horizontal surfaces would be no more than 1 mm beyond 0.8 km of the tower. Maximum predicted thickness would be 7 mm, occurring within 0.4 km of the tower with a total frequency of about 208 hours per winter season.	Ice accumulation would be similar to that for once-through tower, except that total frequency would be 510 hours per winter season.
		Maximum occurrence of visible plumes would be about 50 hrs per year within 0.4 km of the tower.	Visible plume occurrence would be similar to that of once-through tower but within a wider area (2 km of the tower).
NOISE	No impacts.	Construction would cause some temporary increases in noise in the project area.	Same as for once-through tower.

Table 2-10. Comparison of Cooling Water Alternatives for C-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
		Operation noise beyond about 152 m from the tower would average less than 70 decibels. Sound would consist of fan noise and falling water.	About the same as for once-through tower.
ARCHAEOLOGICAL AND HISTORIC SITES	No impacts.	One small nonsignificant prehistoric lithic and ceramic scatter near Four Mile Creek would be disturbed.	Same site would be disturbed as with once-through tower.
RADIOCESIUM TRANSPORT	About 21.9 Ci of radiocesium were released from the C-Reactor area through 1980. Creek sediments at SRP Road A-7 exhibit average cesium-137 concentrations of 37.5 picocuries per gram.	The operation of this alternative would not result in any significant changes in remobilization of radionuclides since flow in Four Mile Creek would remain essentially unchanged.	The operation of this alternative would reduce flows in Four Mile Creek resulting in a calculated decrease in cesium released to the Savannah River by about 0.4 Ci per year.
RADIOLOGICAL RELEASES AND DOSES	The cumulative maximum individual dose would continue at about 3.3 millirem per year. The dose to the population would be about 81 person-rem per year. Population doses are about 0.074 percent of natural background.	The amount of radioactivity released would not change, however, the pathway would be affected. Annually, about 50 additional Ci of tritium would be released to the atmospheric pathway and about 50 Ci less of tritium would be	Annually, about 425 additional Ci of tritium would be released to the atmospheric pathway and 425 less Ci of tritium would be released to the liquid pathway. The change in cesium-134, cesium-137, and tritium releases would reduce the maximum

Table 2-10. Comparison of Cooling Water Alternatives for C-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
		released to the liquid pathway. This would reduce the maximum individual dose by 1.1×10^{-4} millirem per year and the collective dose to the regional population and downstream water consumers would decrease by 0.028 person-rem per year.	individual effective whole-body dose by about 0.3 millirem per year, and the collective dose to the regional population and downstream water consumers would decrease by about 1.1 person-rem per year.

[a]No action is defined as the continuation of existing operations of C-Reactor.

[b]The preferred alternative is to construct and operate once-through cooling towers (either pumped or gravity flow, and either mechanical or natural draft). Characterization of environmental effects presented is based on a mechanical draft cooling tower. Construction and operation of a natural draft cooling tower would not substantially alter the characterization presented (i.e., the natural draft tower is expected to have similar capital cost and implementation schedule, reduced operating costs, and less drift deposition).

2.3.2 ALTERNATIVES FOR K-REACTOR

The comparisons of impacts of the two cooling-tower alternatives are similar to those associated with C-Reactor. The recirculating cooling towers would allow the reestablishment of approximately 500 acres of wetlands, compared to more limited revegetation with the once-through cooling-tower alternative; however, there would be less aquatic habitat in the creek and swamp due to the lower flow associated with the recirculating system.

The implementation of either system would result in cooling water discharges that are in compliance with the 32.2°C Class B water classification standard for temperature and dissolved oxygen standard. Also, both systems would improve habitat over existing conditions for the alligator and wood stork.

Similar impacts to air quality and noise would be expected from both systems; however, because the recirculating cooling-tower system includes two towers in series with three cycles of concentration, the recirculating towers would cause more frequent ice buildup (500 hours versus 138 hours) and visible plumes (100 hours versus 75 hours). Salt deposition would also be greater with the recirculating towers (6 kilograms per acre per year at 2 kilometers versus 1 kilogram per acre per year) than with a once-through system. Because these deposition rates are far below the levels that can cause reduced vegetation productivity (83 kilograms per acre per year), no impacts on vegetation are expected.

The remobilization of radionuclides and dose effects would be similar to those described for C-Reactor. The recirculating cooling towers would result in a calculated decrease in the amount of cesium released to the Savannah River by about 0.6 curie per year. Both the maximum individual and the regional collective doses would decrease through the implementation of either the once-through cooling-tower or the recirculating-cooling-towers alternative.

Table 2-11 provides a summary comparison of the alternatives for K-Reactor.

2.3.3 ALTERNATIVES FOR D-AREA

The implementation of the increased-flow alternative would not alter the flow or temperature of Beaver Dam Creek except during those periods (May through September) when the system could be activated to maintain water temperatures below 32.2°C. Therefore, the existing aquatic habitat would be maintained, and its value to alligators, fish, and other aquatic organisms would be improved because of lower water temperatures and intermittent higher flows. The direct-discharge alternative would remove the D-Area powerhouse thermal discharge from Beaver Dam Creek and would reduce the creek flow to near-ambient levels. This alternative would result in a significant reduction in the available aquatic habitat in the creek, and would adversely affect alligators that now use these areas. Heated effluent discharged directly into the Savannah River would not adversely affect the River's aquatic habitat because a zone of passage would be maintained.

Table 2-11. Comparison of Cooling Water Alternatives for K-Reactor

Impacts	No action[a]	Once-through cooling tower (preferred alternatives[b])	Recirculating towers
SCHEDULE FOR IMPLEMENTATION	Current	Construction of this system would require about 22 months after a 9-month design period.	Construction of this system would require about 28 months after a 9-month design period.
PRELIMINARY COST CAPITAL (MILLION $)	$0	$45-54	$73
ESTIMATED OPERATING COST INCREASE (MILLION $ PER YEAR)	$0	$1.9-3.1	$0.5
SOCIOECONOMICS	No additional work force required.	Peak construction workforce of 200 persons; four additional mechanics required for operation.	Peak construction workforce of 300 persons; six additional mechanics required for operation.
WATER WITHDRAWAL AND DISCHARGE RATES	About 11.3 cubic meters per second would continue to be withdrawn from the Savannah River and discharged into Pen Branch.	Withdrawal the same as for no action; discharge to Indian Grave/Pen Branch would be about 92% of that for no action or 10.4 cubic meters per second.	Withdrawal of river water would be about 15% of that for no action or 1.7 cubic meters per second. Discharge to Indian Grave/Pen Branch would be about 5% of that for no action or 0.6 cubic meters per second.
WATER QUALITY	Water temperature in Pen Branch would exceed State Class B water classification standards. Dissolved oxygen concentrations in Pen Branch are below standards	State Class B water classification standards for temperature (32.2°C) and dissolved oxygen concentrations would be met; a Section 316(a) demonstration study will be	Same as for once-through tower except that a Section 316(a) demonstration study would not be required. Dissolved solids concentrations would be higher than no action

Table 2-11. Comparison of Cooling Water Alternatives for K-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
	intermittently during the summer and total suspended solids are slightly higher than ambient stream levels.	performed for exceedances of 2.8°C rise in ambient stream temperatures. There would be some reduction in the total suspended solids.	or once-through cooling tower because of cycles of concentration; however, total suspended solids discharged would be greatly reduced.
TEMPERATURE AND FLOW EFFECTS	There would continue to be few aquatic organisms in the thermal areas of Pen Branch and its delta. A thermal barrier will prevent aquatic movement in Pen Branch and Indian Grave. Branch. Fish spawning in the creek and delta would remain reduced. There would continue to be a potential for cold shock during the winter.	Aquatic organisms would become established in present thermal areas. Thermal barrier would be removed. The creek and delta would be opened to fish spawning and foraging. There would be no potential for cold shock as the MWAT (EPA, 1977) criteria would be met. Water levels would continue to fluctuate.	Similar mitigation of thermal effects that would occur with once-through towers except that habitat area for spawning and foraging would be smaller because of reduced flow, and magnitude of water level fluctuations would be less.
ENTRAINMENT/ IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 21.6 x 10^6 fish eggs and larvae and the loss of about 4380 fish to impingement annually.	Effects would be about the same as for no action.	Annual entrainment and impingement losses would be reduced to about 3.3 x 10^6 and 657, respectively.

Table 2-11. Comparison of Cooling Water Alternatives for K-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
HABITAT	Flow and temperature impacts would continue to result in the loss of about 26 acres of wetlands each year.	Wetland losses would decrease; some successional revegetation would occur. Between 35 to 60 acres of uplands would be affected by construction.	Wetland losses would essentially cease and about 500 acres of wetlands would successively revegetate; about 55 acres of uplands would be affected by construction.
SALT DEPOSITION	None.	Maximum annual total-solids deposition within about 2 km of the tower would be about 1 kilogram per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.	Maximum annual total-solids deposition within about 2 km of the tower would be about 6 kilograms per acre per year. Deposition rates are far below levels that cause reduced vegetation productivity.
ENDANGERED SPECIES	Thermally affected areas of Pen Branch and swamp would continue to be too hot for alligators. Low fish densities and high water levels limit forage value for wood stork. No impacts on shortnose sturgeon and red-cockaded woodpecker.	Alligator habitat would be improved by lower water temperatures. Some improvement of wood stork foraging habitat would result from increased fish concentrations although continued high flows would maintain deep water conditions. No impacts on shortnose sturgeon and red-cockaded woodpecker.	Some alligator habitat would be available; however, lower flows would decrease potential habitat area resulting in less improvement than with once-through towers. Potential for improvement of wood stork habitat would be increased due to lower water levels in the creek and delta. No impacts on shortnose sturgeon and red-cockaded woodpecker.

Table 2-11. Comparison of Cooling Water Alternatives for K-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
AIR QUALITY	No impacts.	Construction would result in temporary small increases in carbon monoxide and hydrocarbons from engine exhaust. Also some transient increases in airborne dust.	Construction impacts would be similar to those for once-through tower.
		Maximum annual-mean frequency of reduced ground-level visibility to less than 1000 m would be about 5 hours per year occurring at 15 km to NW of tower.	Reduction in ground-level visibility would be less than that for once-through tower (1 hr vs. 5 hrs) occurring over a somewhat wider area.
		Maximum ice accumulation on horizontal surfaces would be no more than 1 mm beyond 0.8 km of the tower. Maximum predicted thickness would be 7 mm, occurring within 0.4 km of the tower with a total frequency of about 138 hours per winter season.	Ice accumulation would be similar to that for once-through tower, except that total frequency would be 500 hours per winter season.
		Maximum occurrence of visible plumes would be about 75 hrs per year within 0.4 km of the tower.	Visible plume occurrence would be only slightly more frequent than that of once-through towers.
NOISE	No impacts.	Construction would cause some temporary increases in noise in the project area.	Same as for once-through tower.

Table 2-11. Comparison of Cooling Water Alternatives for K-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
	.	Operation noise beyond about 152 m from the tower would average less than 70 decibels. Sound would consist of fan noise and falling water.	About the same as for once-through tower.
ARCHAEOLOGICAL AND HISTORIC SITES	No impacts.	No impacts.	No impacts.
RADIOCESIUM TRANSPORT	About 16.2 Ci of radiocesium were released from the K-Reactor area through 1980. Creek sediments at the Pen Branch delta exhibit average cesium-137 concentrations of 4.7 picocuries per gram.	The operation of this alternative would not result in any significant changes in remobilization of radionuclides since flow in Pen Branch would remain essentially unchanged.	The operation of this alternative would reduce flows in Pen Branch resulting in a calculated decrease in the cesium released to the Savannah River by about 0.6 Ci per year.
RADIOLOGICAL RELEASES AND DOSES	The cumulative maximum individual dose would continue at about 3.3 millirem per year. The dose to the population would be about 81 person-rem per year. Population doses are about 0.074 percent of natural background.	The amount of radioactivity released would not change; however, the pathway would be affected. Annually, about 50 additional Ci of tritium would be released to the atmospheric pathway and about 50 Ci less of tritium would be released	Annually, about 425 additional Ci of tritium would be released to the atmospheric pathway and 425 less Ci of tritium would be released to the liquid pathway. The change in the cesium-134, cesium-137, and tritium release would reduce the

Table 2-11. Comparison of Cooling Water Alternatives for K-Reactor (continued)

Impacts	No action[a]	Once-through cooling tower (Preferred alternative[b])	Recirculating towers
		to the liquid pathway. This would reduce the maximum individual dose by 1.1 x 10^{-4} millirem and the collective dose to the regional population and downstream water consumers would decrease by 0.028 person-rem per year.	maximum individual dose by about 0.45 millirem, and the collective dose to the regional population and downstream water consumers would decrease by about 1.6 person-rem per year.

[a]No action is defined as the continuation of existing operations of K-Reactor.
[b]The preferred alternative is to construct and operate once-through cooling towers (either pumped or gravity flow, and either mechanical or natural draft). Characterization of environmental effects presented is based on a mechanical-draft cooling tower. Construction and operation of a natural-draft cooling tower would not substantially alter the characterization presented (i.e., the natural-draft tower is expected to have similar capital cost and implementation schedule, reduced operating costs, and less drift deposition).

The increased-flow alternative would affect an estimated 4 acres of wetlands and 4 acres of uplands due to intermittent flooding when the system is operating. Construction of the pipeline for the direct-discharge alternative would adversely affect about 1 acre of wetlands and 5 acres of uplands.

Entrainment and impingement impacts would remain at present levels for the direct-discharge alternative. However, increased flow with mixing would result in increased annual entrainment losses of about 0.1×10^6 fish eggs and larval and impingement losses of about 142 fish.

Habitat for the American alligator and the wood stork would not be affected appreciably by the increased-flow alternative; however, during its operation, the intermittent increases in water level could decrease the area of foraging habitat for the wood stork. Implementation of the direct-discharge system would degrade much of the existing alligator and wood stork habitat in Beaver Dam Creek due to the significant decrease in flow and elimination of slightly warmer winter temperatures.

No radiological impacts will occur from the implementation of either alternative for the D-Area powerhouse.

Table 2-12 provides a summary comparison of the alternatives for D-Area.

Table 2-12. Comparison of Cooling Water Alternatives for D-Area

Impacts	No action[a]	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
SCHEDULE FOR IMPLEMENTATION	Current	Current	Construction of this alternative would require about 22 months.
PRELIMINARY COST CAPITAL (MILLION $)	$0	$0	$14
ESTIMATED OPERATING COST INCREASE (MILLION $ PER YEAR)	$0	$0.03	$0.05
SOCIOECONOMICS	No additional work-force required.	No additional work-force required.	Peak construction work force of 40 persons.
WATER WITHDRAWAL AND DISCHARGE RATES	About 2.6 cubic meters per second would continue to be withdrawn from the Savannah River and discharged to Beaver Dam Creek.	Withdrawal and discharge rates would be the same as for no action except when withdrawal and discharge rates each could be as high as 4.5 cubic meters per second to meet the 32.2°C State Class B water classification standard.	Withdrawal and discharge rates would be the same as for no action; however, thermal discharge would be directly to the Savannah River. All powerhouse thermal discharges would be removed from Beaver Dam Creek.
WATER QUALITY	Water temperatures in Beaver Dam Creek would continue to exceed the 32.2°C State Class B water classification standard during periods from May through	Water temperatures in the stream would meet the 32.2°C State Class B water classification standard; a Section 316(a) demonstration study will be performed for exceed-	In Beaver Dam Creek, water temperatures would be at ambient levels year-round. In the Savannah River, water temperatures beyond a mixing zone at the discharge point

Table 2-12. Comparison of Cooling Water Alternatives for D-Area (continued)

Impacts	No action[a]	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
	September; water temperatures would also exceed the maximum ambient stream temperature rise standard of 2.8°C. Concentrations of suspended solids would remain slightly higher than in ambient streams.	ances of 2.8°C rise in ambient stream temperature. Slight increases in suspended solids concentrations would occur during periods of increased flow.	would meet the State Class B water quality classification standard of 32.2°C.
TEMPERATURE AND FLOW EFFECTS	There would continue to be reduced numbers of aquatic organisms and spawning in the thermally affected areas of Beaver Dam Creek during the warmer months. A thermal barrier would continue to restrict movement of fish in the creek.	Aquatic fauna would become established in present thermally affected areas of Beaver Dam Creek. Habitat area would increase during periods of increased flow. There would be no thermal barrier in the creek.	Low water levels in Beaver Dam Creek would greatly reduce existing aquatic habitat; however, the absence of thermal stress would allow full use of this habitat by aquatic organisms. There would be no thermal barrier in the creek. Fish spawning would be limited because of reduced habitat. An adequate zone of passage would be present in the river
ENTRAINMENT/ IMPINGEMENT	Water withdrawal would continue to cause entrainment losses of about 3.0×10^6 fish eggs and larvae and the loss of about 4745 fish due to impingement annually.	Increased water withdrawal over that for no action would increase entrainment losses by about 0.1×10^6 fish eggs and larvae and the loss of an additional 142 fish due to impingement annually.	Effects would be about the same as for no action.

Table 2-12. Comparison of Cooling Water Alternatives for D-Area (continued)

Impacts	No action[a]	Increased flow with mixing (Preferred Alternative)	Direct discharge to Savannah River
HABITAT	No impacts.	Operation would result in an estimated loss of about 4 acres of wetlands and about 4 acres of uplands.	Construction would result in an estimated loss of about 1 acre of wetlands and 5 acres of uplands.
AIR QUALITY	No impact.	No impact.	No impact.
ENDANGERED SPECIES	Existing thermal areas of Beaver Dam Creek would continue to support a large alligator population. The adjacent swamp area would continue to be used by wood storks for foraging. No impacts on other endangered species.	No changes in existing alligator habitat. Some decrease in wood stork foraging habitat during increased flow periods. No impacts on other endangered species.	Loss of most of alligator habitat due to decreased temperatures and lowered water levels in Beaver Dam Creek. Loss of much of wood stork foraging habitat due to lowered water levels in Beaver Dam Creek. No impacts on other endangered species.
ARCHAEOLOGICAL AND HISTORICAL SITES	No impacts.	One site will be recommended for eligibility for nomination to the National Register of Historic Places. A request for "no effect" determination submitted to SHPO.	Survey of pipeline area revealed no historic sites.
RADIOLOGICAL RELEASES	No impacts.	No impacts.	No impacts.

[a]No action is defined as the continuation of existing operations of the D-Area coal-fired powerhouse.

REFERENCES

DOE (U.S. Department of Energy), 1984a. Final Environmental Impact Statement, L-Reactor Operation, Savannah River Plant, Aiken, South Carolina, DOE/EIS-0108, Savannah River Operations Office, Aiken, South Carolina.

DOE (U.S. Department of Energy), 1984b. Thermal Mitigation Study, Compliance to Federal and State Water Quality Standards, Savannah River Plant, Aiken, South Carolina, DOE/SR-5003, Savannah River Operations Office, Aiken, South Carolina.

EPA (U.S. Environmental Protection Agency), 1977. Temperature Criteria for Freshwater Fish: Protocol and Procedures, EPA-600/3-77-061, Duluth, Minnesota.

Kennedy, John F., 1972. "Wet Cooling Towers," in Engineering Aspects of Heat Disposal from Power Generation, R. M. Parsons Laboratory for Water Resources and Hydrodynamics, Massachusetts Institute of Technology, Cambridge, Massachusetts.

CHAPTER 3

AFFECTED ENVIRONMENT

This chapter describes the environment of the Savannah River Plant (SRP) and the nearby region that would be affected by the cooling water alternatives associated with C- and K-Reactors and the D-Area powerhouse; it also describes the three affected onsite streams.

3.1 SAVANNAH RIVER PLANT SITE AND REGION

3.1.1 GEOGRAPHY

The Savannah River Plant is located in southwestern South Carolina. The Plant occupies an almost circular area of about 780 square kilometers (192,700 acres), bounded on its southwestern side by the Savannah River, which is also the border between the States of South Carolina and Georgia. Portions of Barnwell, Aiken, and Allendale Counties, South Carolina, lie inside the SRP boundary. The major population centers closest to the SRP site are Augusta in Georgia, and Aiken, North Augusta, and Barnwell in South Carolina. Figure 3-1 shows the location of the SRP site in relation to surrounding population centers within a 240-kilometer radius.

The SRP facilities include five nuclear production reactors (four currently operating and one in standby condition), two chemical separations areas, a fuel and target fabrication facility, and various supporting facilities (Figure 3-2).

The locations of the various Plant areas with reference to the five major stream systems that drain the site are shown in Figure 3-2. Most of the Plant areas drain toward the Savannah River, which ranges from 27 to 104 meters above sea level. C-Reactor is located near the middle of the SRP site. K-Reactor is about 5 kilometers southeast of C-Reactor. L- and P-Reactors are about 5 and 10 kilometers east of K-Reactor, respectively. R-Reactor is about 12 kilometers northeast of K-Reactor. The D-Area powerhouse is about 10 kilometers southwest of C-Reactor.

Almost all the SRP site is drained by tributaries of the Savannah River. Each tributary is fed by several small streams. One small stream in the northeastern sector of the site drains to the Salkehatchie River rather than the Savannah River.

The southwestern border of the Plant is the Savannah River Swamp System (SRSS). About 9400 acres (8 percent) of the Savannah River swamp forest lie on the Plant from Upper Three Runs Creek to Steel Creek. The SRP swamp area borders the Savannah River for approximately 16 kilometers and averages about 2.4 kilometers in width (Figure 3-2).

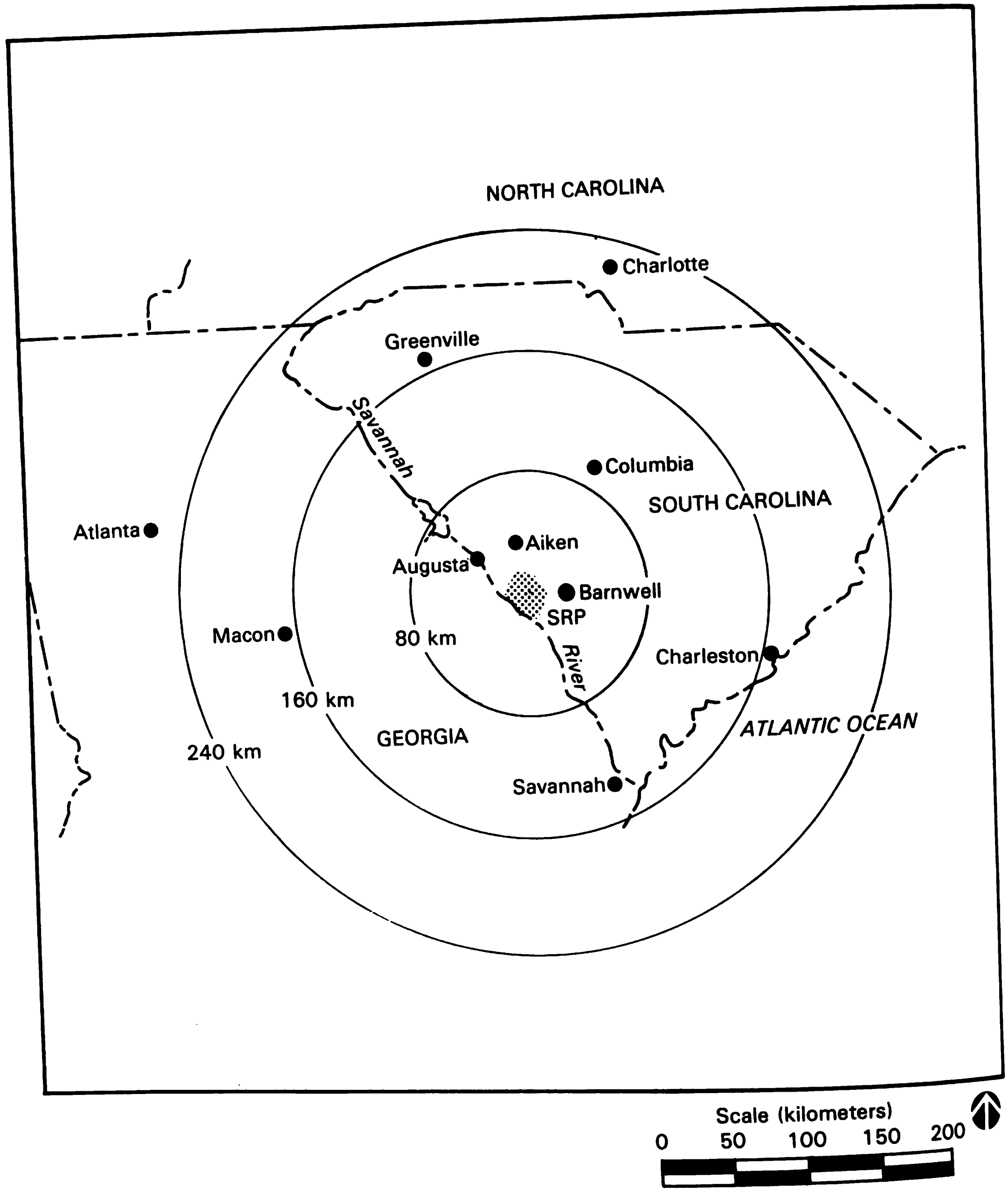


Figure 3-1. SRP Location in Relation to Surrounding Population Centers

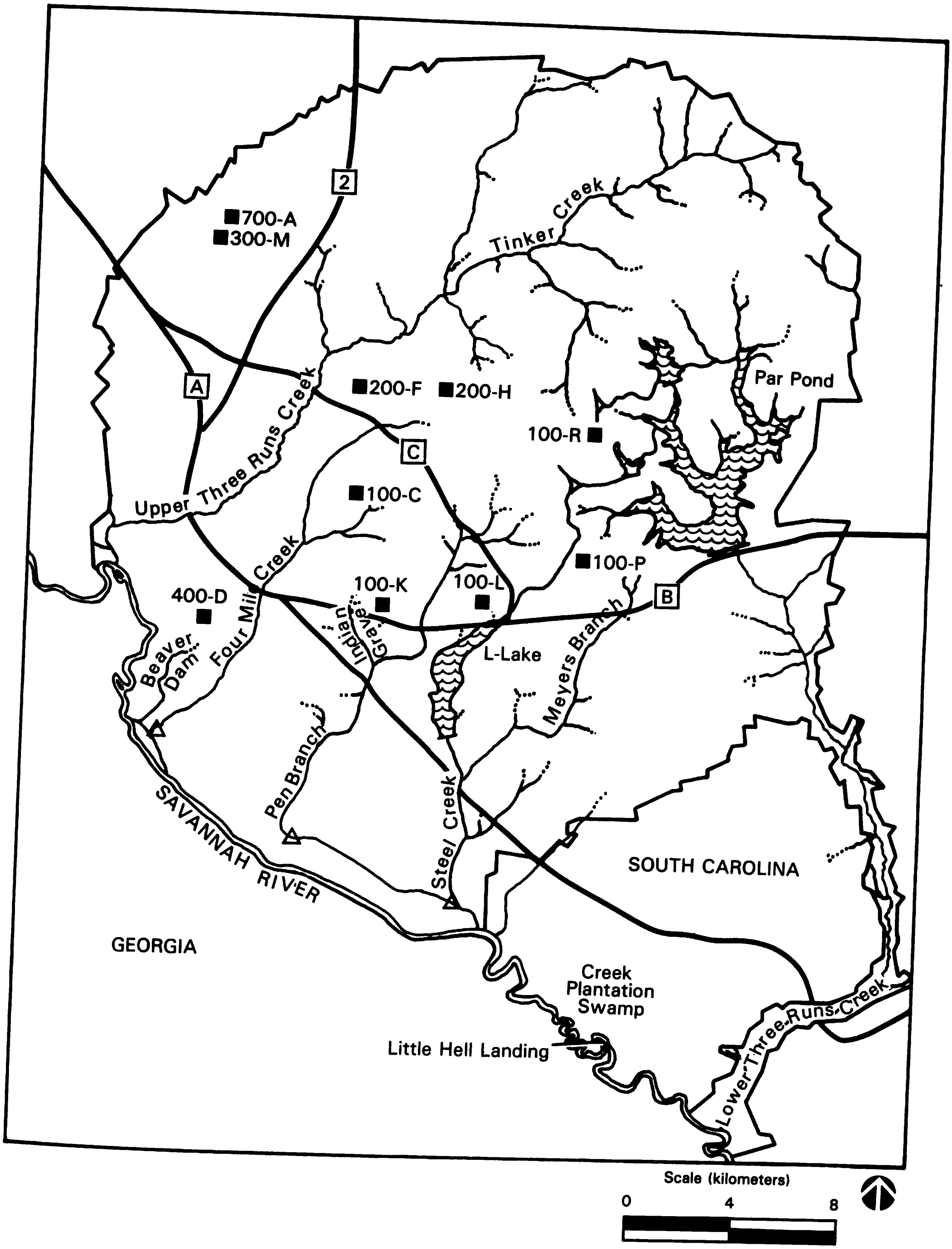


Figure 3-2. Savannah River Plant Site Map

A small embankment or natural levee has been built up along the north side of the river by sediments deposited during periods of flooding. Three breaches in the levee allow water from Steel Creek, Four Mile Creek, and Beaver Dam Creek to flow to the river. The combined discharges of Steel Creek and Pen Branch enter the river near the southeastern corner of the Plant. On the landward side of the levee, the ground elevation decreases to form the swamp system, which contains stands of cypress-tupelo forest, bottomland hardwoods, and some open marsh areas.

During periods of high river level, river water overflows the levee and stream mouths and floods the entire swamp area, leaving only isolated islands. The overflows occur when river elevations exceed 27 meters above mean sea level (MSL) as measured at the SRP boat dock. During flooding, the water from these streams flows through the swamp parallel to the river and enters the river southeast of the mouth of Steel Creek at Little Hell Landing after crossing an offsite swamp.

3.1.2 SOCIOECONOMIC AND COMMUNITY CHARACTERISTICS

A comprehensive description of socioeconomic and community characteristics for the area around the Savannah River Plant was presented in the report Socioeconomic Baseline Characterization for the Savannah River Plant Area, 1981 (ORNL, 1981). Information contained in the 1981 report was subsequently updated in the report Socioeconomic Data Base Report for Savannah River Plant (DOE, 1984a); additional information on the topics presented in this section can be found in the updated report.

3.1.2.1 Study Area

The permanent operating and construction force at the Savannah River Plant has averaged 7500, ranging from a low of 6000 in the 1960s to the current 15,500 (August 1985). In 1980, approximately 97 percent of SRP employees resided in a 13-county area surrounding the Savannah River Plant (Table 3-1). Of these 13 counties, 9 are in South Carolina and 4 are in Georgia. The greatest percentage of employees now reside in the six-county area of Aiken, Allendale, Bamberg, and Barnwell Counties in South Carolina, and Columbia and Richmond Counties in Georgia (Figure 3-3). Together, these six counties house approximately 89 percent of the total SRP workforce. These six counties were chosen as the study area for the assessment of potential socioeconomic and community effects of the proposed cooling water alternatives because the percentage of employees residing in these counties has remained essentially the same since the early 1960s.

3.1.2.2 Demography

Table 3-2 lists the 1980 populations in the study area for counties and places of more than 1000 persons. The largest cities in the study area are Augusta in Georgia, and Aiken, North Augusta, and Barnwell in South Carolina. Of the 31 incorporated communities in the study area, 16 have populations under 1000 persons, and 11 have populations between 1000 and 5000 persons. Aiken,

Table 3-1. Distribution of June 1980 SRP Employees by Place of Residence

Location of residence	Percent of SRP labor force
South Carolina	80.0
Aiken County	58.8
Allendale County	1.8
Bamberg County	2.0
Barnwell County	8.8
Edgefield County	1.1
Hampton County	1.2
Lexington County	1.6
Orangeburg County	1.7
Saluda County	1.0
Other counties	2.0
Georgia	19.9
Columbia County	3.1
Richmond County	14.8
Burke County	0.3
Screven County	0.8
Other counties	0.9
Other states	0.1
Total	100.0

Source: DOE, 1984b.

Columbia, and Richmond Counties, which comprise the Augusta Standard Metropolitan Statistical Area (SMSA), had a total population of about 327,400 in 1980; however, most of this population resides outside cities or towns. About two-thirds of the total six-county population resides in rural or unincorporated areas.

Over the last three decades, the rate of population growth has varied from county to county. From 1950 to 1980, the counties comprising the Augusta SMSA experienced a positive growth rate; the combined average annual rate was about 3 percent. The most significant population increases occurred in Columbia County, which experienced an average growth rate between 1960 and 1980 of about 10 percent per year. The rural counties - Allendale, Bamberg, and Barnwell - experienced population declines between 1950 and 1970; reversals of this decline occurred between 1970 and 1980 when population increases for these counties ranged from 9 to 16 percent. The population growth rate

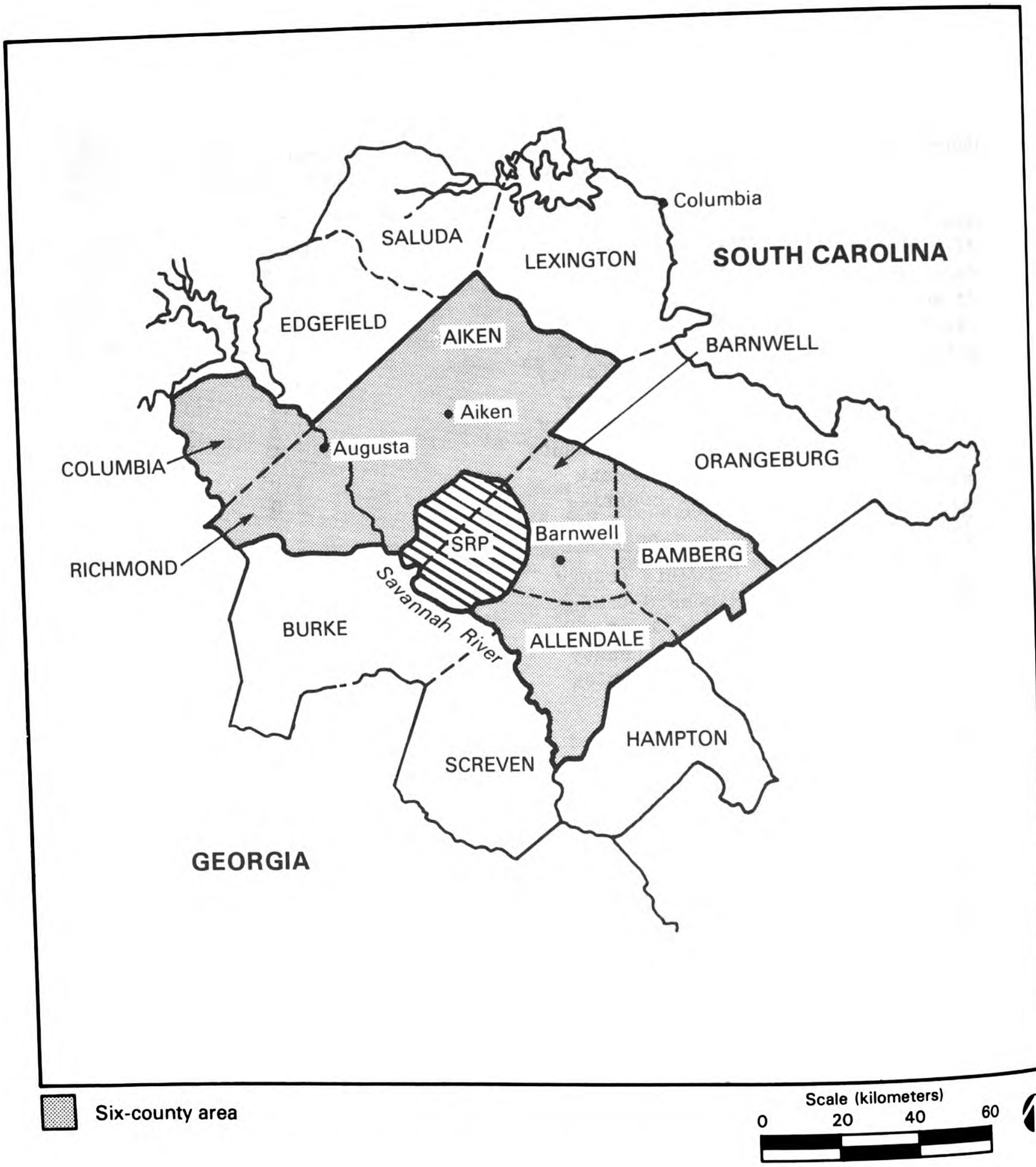


Figure 3-3. Counties in SRP Area

Table 3-2. 1980 Population for Counties and Places of 1000 Persons or Greater[a]

Location	1980 population
Aiken County, South Carolina	105,625
City of Aiken	14,978
Town of Jackson	1,771
City of North Augusta	13,593
City of New Ellenton	2,628
Allendale County, South Carolina	10,700
Town of Allendale	4,400
Town of Fairfax	2,154
Bamberg County, South Carolina	18,118
Town of Bamberg	3,672
City of Denmark	4,434
Barnwell County, South Carolina	19,868
City of Barnwell	5,572
Town of Blackville	2,840
Town of Williston	3,173
Columbia County, Georgia	40,118
City of Grovetown	3,384
City of Harlem	1,485
Richmond County, Georgia	181,629
City of Augusta	47,532
Town of Hephzibah	1,452
Study area total	376,058

[a]Adapted from the Bureau of the Census (1982a,b).

experienced in the study area during the last two decades was about equal to that experienced in the southern United States and slightly less than the growth rate experienced in the South Atlantic Region (Bureau of the Census, 1983).

In 1980 the estimated population in the 80-kilometer area around the Savannah River Plant was approximately 563,300 persons. The year 2000 population in this area is estimated at 852,000 persons. This estimate was calculated using the 1970-to-1980 growth rate of each county in the 80-kilometer area, assuming these growth rates would continue in the future. For counties that experienced a negative population growth rate between 1970 and 1980, the calculation assumed that no continued population decline would occur.

3.1.2.3 Land Use

In the six-county study area, less than 8 percent of the existing land use is devoted to urban and developed uses. Most land uses of these types are in and around the Cities of Augusta and Aiken. Agriculture accounts for about 21 percent of total land use; forests, wetlands, water bodies, and unclassified lands that are predominantly rural account for about 70 percent of total land use.

All the counties in the study area have a land-use plan, and Columbia and Richmond Counties have zoning ordinances. The projected future land uses of the study area are very similar to the existing land-use patterns. Developed urban land is projected to increase by 2 percent in the next 20 years. The largest percentage of this growth is expected to occur in Aiken and Columbia Counties, as a result of the expansion of the Augusta metropolitan area.

Agricultural land throughout the study area is undergoing a transition from smaller operations to larger consolidated farms. This is especially true in the rural areas of Allendale, Bamberg, and Barnwell Counties.

3.1.2.4 Public Services and Facilities

There are nine public school systems in the study area. County-wide school districts are located in each county except Bamberg, which has two districts, and Barnwell, which has three. An estimated total of 3642 new students could have been accommodated in the study area school districts in 1982.

Of the 120 public water systems in the study area, 30 county and municipal systems serve about 75 percent of the population. All but four of the municipal and county water systems - the Cities of Aiken, Augusta, and North Augusta, and Columbia County - obtain their water from deep wells. Aiken obtains some of its water from Shaws Creek and Shiloh Springs, while Columbia County and the Cities of Augusta and North Augusta obtain water from the Savannah River. For those municipal and county water systems that use groundwater as their supply, restrictions in system capabilities are due primarily to storage and treatment capacity rather than availability of groundwater.

Most municipal and county wastewater-treatment systems have the capacity to treat additional sewage. Selected rural municipalities in Allendale, Bamberg, and Columbia Counties and the City of Augusta in Richmond County have experienced problems in treatment-plant capacities. Programs to upgrade facilities are under way or planned in most of these areas.

3.1.2.5 Housing

Since 1970, the largest increases in the number of housing units have occurred in Columbia, Richmond, and Aiken Counties. Columbia County has grown the fastest, more than doubling its number of housing units. Between 1970 and 1980, Aiken and Richmond Counties each experienced about a 36-percent increase in the number of housing units. In Aiken County, one-fourth of this increase resulted from the high growth rate in the number of mobile homes.

The vacancy rate for owner-occupied housing units for the six-county area in 1980 was 2.3 percent. Individual county rates ranged from 3.6 percent in Columbia County to 0.8 percent in Barnwell County. Vacancy rates for rental units in 1980 ranged from 14.8 percent in Columbia County to 7.1 percent in Bamberg County; the average for the study area was 10.5 percent.

3.1.2.6 Economy

The results of the 1980 Census of Population indicate that between 1970 and 1980 there was a 35-percent increase in total employment, from 75,732 to 102,326 employees, in establishments with payrolls in the six-county area. Service sector employment increased at these establishments by 65 percent, mirroring a national trend toward a service-based economy. Employment in manufacturing increased by 27 percent, adding more than 9000 employees. Most of the overall expansion in the number of employment positions occurred in Richmond and Aiken Counties.

About 31 percent of the workforce in the six-county area in 1980 was employed in the service sector, and 27 percent in the manufacturing sector. Retail trade was the third largest category, accounting for 15 percent of the workforce. The remaining 27 percent of the workforce was dispersed among the seven additional categories of employment reported by the Census. In 1980, fewer than 2 percent of workers in the study area were employed in the category of agriculture, forestry, and fishing, while nearly 4 percent were employed in that category in 1970.

3.1.3 HISTORIC AND ARCHAEOLOGICAL RESOURCES

In 1985, 66 sites in the study area were listed in the National Register of Historic Places (see Appendix E). Richmond County had the largest number of sites (26), most of which are in the City of Augusta. Approximately 25 more National Register sites are in Aiken and Allendale Counties.

Various archaeological surveys have been conducted at the Savannah River Plant in past years through the Savannah River Plant Archaeological Resource Program, by the South Carolina Institute of Archaeology and Anthropology. An intensive archaeological and historic survey was conducted in 1984 in the Pen Branch and Four Mile Creek watersheds (Figure 3-4). As discussed in Appendix E, a total of 65 sites were located, and about two-thirds of these sites were not considered significant due to the lack of site integrity and limited research potential. Consultations with the State Historic Preservation

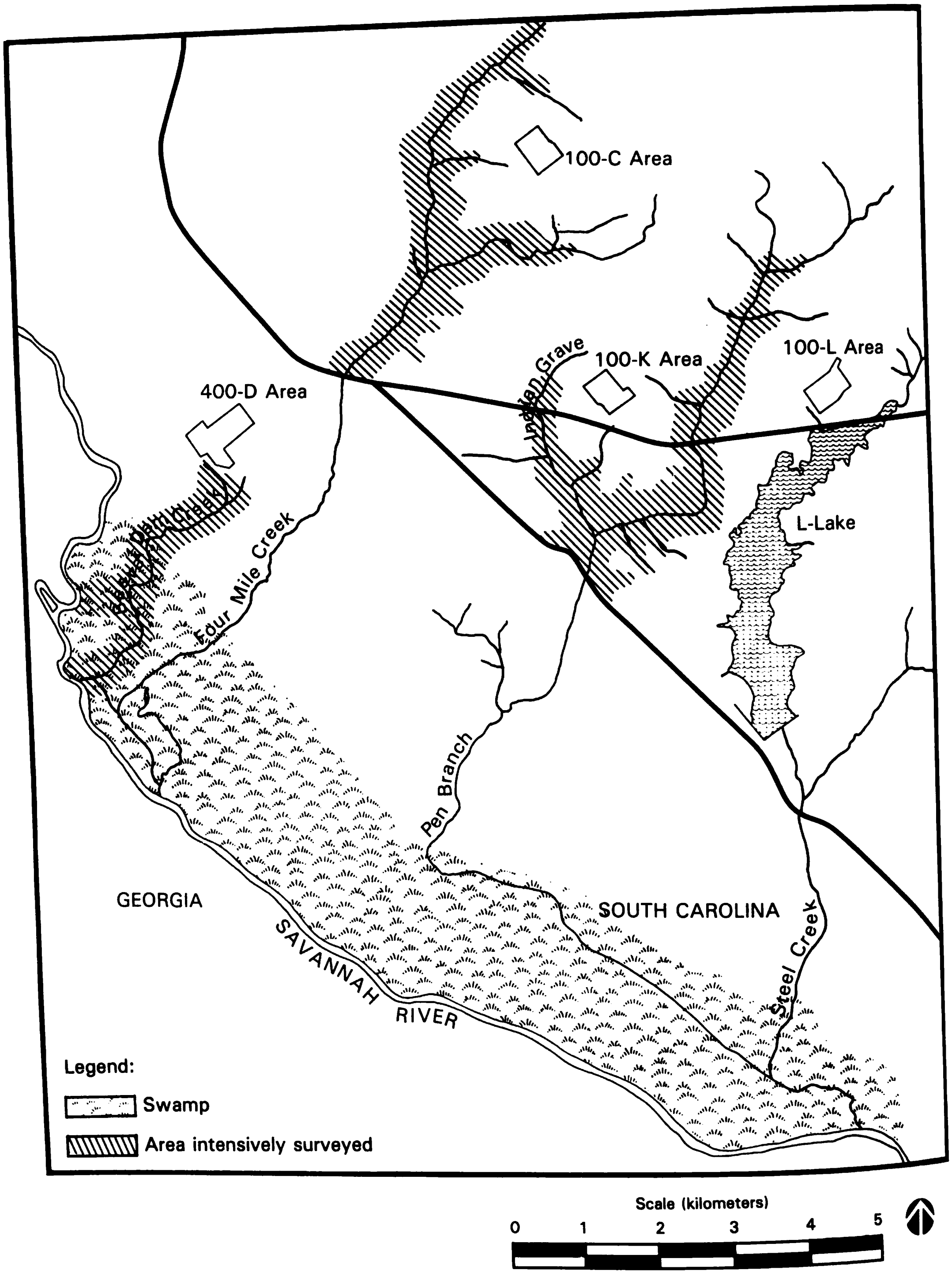


Figure 3-4. General Map of Archaeological Survey Area

Officer have determined that none of the potentially significant sites possess the necessary characteristics for nomination for inclusion in the National Register of Historic Places (see Appendix E). Intensive archaeological and historic resources surveys of the Beaver Dam Creek floodplain area and the area west of the creek in D-Area were conducted during October and November of 1985. Only one site, 38BR450, was located in the survey areas. As discussed in Appendix E, site 38BR450 is considered a significant archaeological resource and will be recommended for eligibility for nomination to the National Register of Historic Places.

3.1.4 GEOLOGY

3.1.4.1 Geologic Setting

The Savannah River Plant is located in the Aiken Plateau physiographic division of the Upper Atlantic Coastal Plain of South Carolina (Cooke, 1936). Figure 3-5 shows a generalized northwest-to-southeast geologic profile across the Savannah River Plant. The Aiken Plateau at the Plant is characterized by interfluvial areas with narrow, steep-sided valleys. Because of the Plant's proximity to the Piedmont region, it has somewhat more relief than the near coastal areas; onsite elevations range from 27 to 104 meters above mean sea level.

The center of the Plant is about 40 kilometers southeast of the Fall Line (Davis, 1902) that separates the Atlantic Coastal Plain physiographic province from the Piedmont physiographic province (Figure 3-5). Crystalline rocks of Precambrian and Paleozoic age underlie a major portion of the gently seaward-dipping coastal plain sediments of Cretaceous and younger age. Sediment-filled basins of Triassic and Jurassic age occur within the crystalline basement throughout the coastal plain of Georgia and the Carolinas (DOE, 1984b). One of these, the Dunbarton Triassic Basin, underlies parts of the Plant (Marine and Siple, 1974).

3.1.4.2 Stratigraphy

Coastal Plain sediments in South Carolina range in age from Cretaceous to Quaternary; they form a seaward-dipping and thickening wedge of mostly unconsolidated sediments. Near the center of the Plant at H-Area, these sediments are approximately 280 meters thick (Siple, 1967). The base of the sedimentary wedge rests on a Precambrian and Paleozoic crystalline basement, which is similar to the metamorphic and igneous rocks of the Piedmont, and on the siltstone and claystone conglomerates of the down-faulted Dunbarton Triassic Basin (Figure 3-5). Based on the stratigraphy developed by Siple (1967), immediately overlying the basement is the Tuscaloosa Formation (175 meters thick), which is of Upper Cretaceous age and is composed of waterbearing sands and gravels separated by prominent clay units. Overlying the Tuscaloosa is the Ellenton Formation (Paleocene Age), which is about 18 meters thick and consists of sands and clays interbedded with coarse sands and gravel. Four of the formations shown in Figure 3-5 - the Congaree, McBean, Barnwell, and Hawthorn - comprise the Tertiary (Eocene and Miocene) sedimentary section,

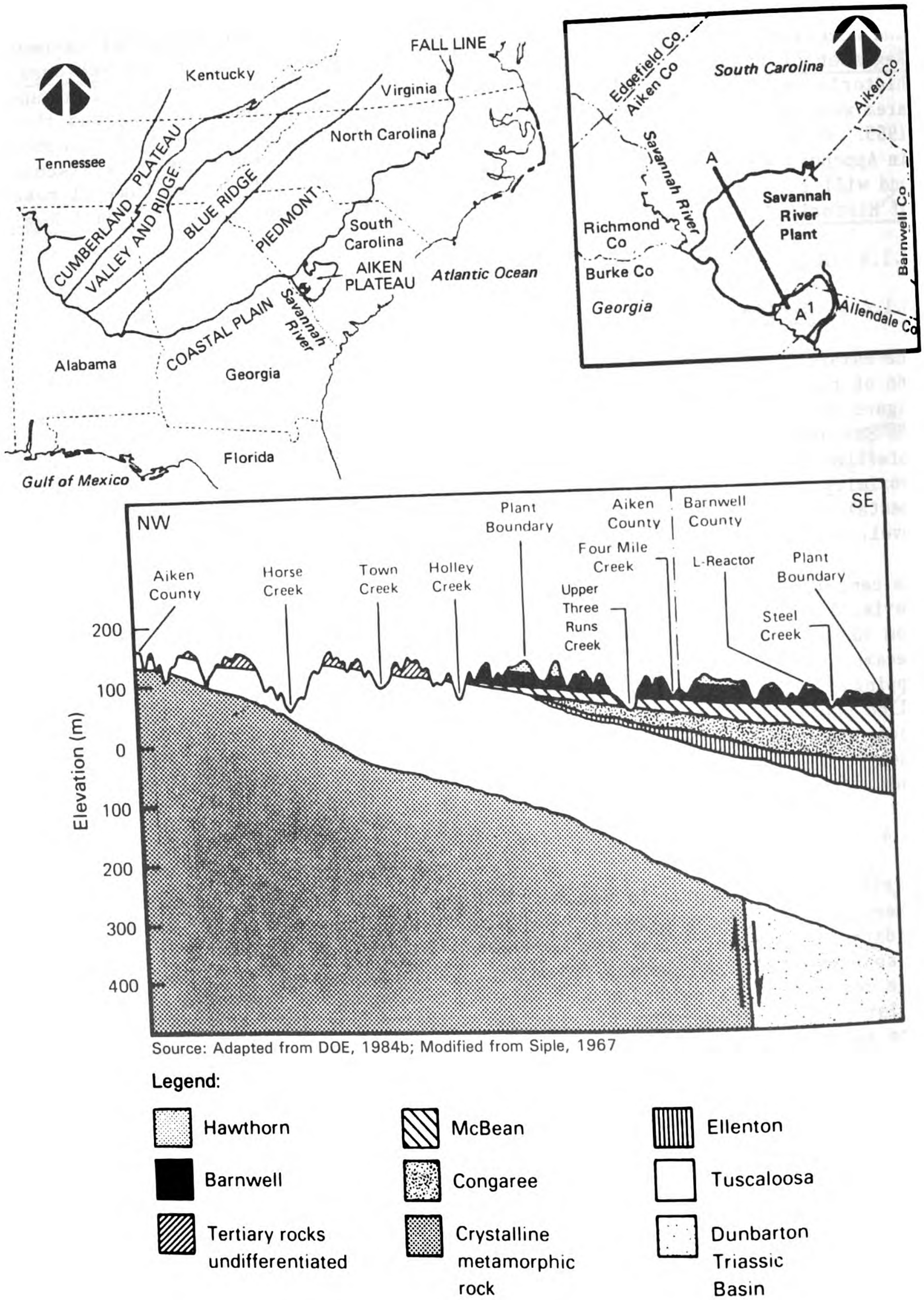


Figure 3-5. Generalized NW to SE Geologic Profile Across the Savannah River Plant

which is about 85 meters thick and consists predominantly of clays, sands, clayey sands, and sandy marls. The near-surface sands of the Barnwell and Hawthorn Formations are generally loosely consolidated; they often contain thin, sediment-filled fissures (clastic dikes) (DOE, 1984b).

Quaternary alluvium is found at the surface in floodplain areas and as terrace deposits. Soils at the Plant are generally uniform and rather shallow, about 1 meter deep. They are characterized by bleached Barnwell-Hawthorn sediments, which result in a light-tan sandy loam.

3.1.4.3 Geologic Structures

The down-faulted Dunbarton Triassic Basin underlies the southeastern portion of the Savannah River Plant and contains several interbasinal faults. However, the sediments overlying these faults show no evidence of basin-induced movement since their deposition during the Cretaceous Period (Siple, 1967; Marine and Siple, 1974). Other Triassic-Jurassic basins have been identified in the Coastal Plain tectonic province of South Carolina and Georgia; these features can be associated with the South Georgia Rift (Marine and Siple, 1974; Popenoe and Zietz, 1977; Daniels, Zietz, and Popenoe, 1983). The Piedmont, Blue Ridge, and Valley and Ridge tectonic provinces, which are associated with Appalachian Mountain building, are northwest of the Fall Line (Figure 3-5). Several fault systems occur in and adjacent to the Piedmont and the Valley and Ridge tectonic provinces of the Appalachian system; the closest of these is the Belair Fault Zone, about 40 kilometers from the Plant, which is not capable of generating major earthquakes (Case, 1977).

Surface mapping, subsurface boring, and geophysical investigations at the Plant have not detected any faulting of the sedimentary strata or any other geologic hazards that would affect SRP facilities (DOE, 1984b).

3.1.4.4 Seismicity

Two major earthquakes have occurred within 300 kilometers of the Savannah River Plant: the Charleston earthquake of 1886, which had an epicentral modified Mercalli intensity (MMI) of X, and was located about 145 kilometers away; and the Union County, South Carolina, earthquake of 1913, which had an epicentral shaking of MMI VII to VIII, and was located approximately 160 kilometers away (Langley and Marter, 1973). An estimated peak horizontal shaking of 8 percent of gravity (0.08g) was calculated for the site during the 1886 earthquake (Du Pont, 1982a). Site intensities and accelerations for other significant earthquakes have been published by DOE (1982, p. G-7). No reservoir induced seismicity is associated with Par Pond (see Figure 3-2).

On June 8, 1985, a minor earthquake of local magnitude 2.6 (maximum intensity: MM III), and focal depth of 0.96 kilometer occurred at the Plant near Aiken, South Carolina. The epicenter was just to the west of C- and K-Areas. The acceleration produced by the earthquake was estimated to be less than 0.002g (Stephenson, Talwani, and Rawlins, 1985).

3.1.4.5 Streambed Sediments

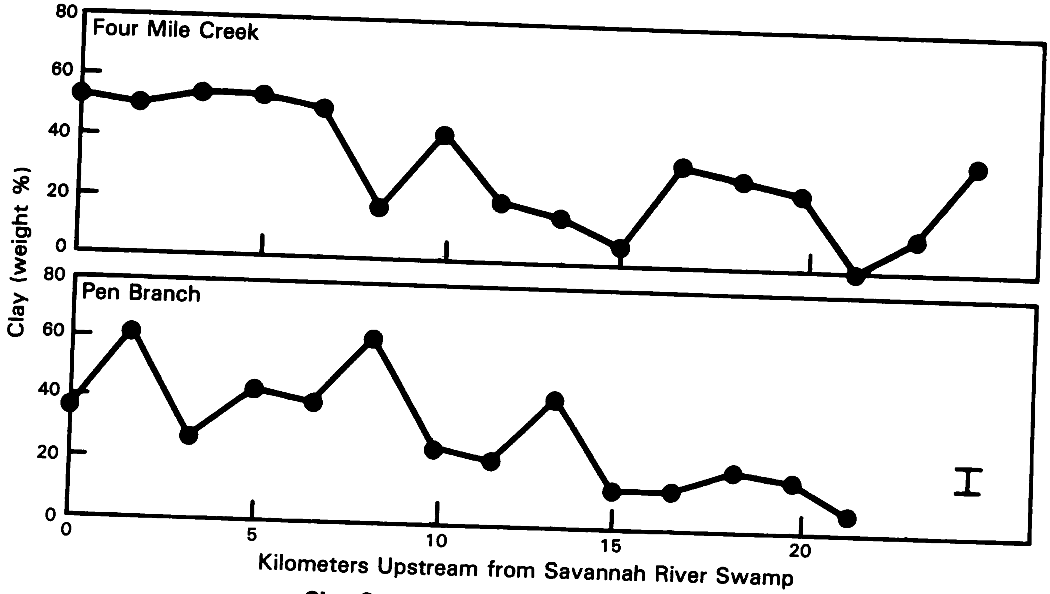
Most of the cesium-137 that has been discharged to SRP creeks by Plant operations and by fallout from offsite weapons testing is associated with the silts and clays found in the streambed and with suspended solids. The principal mechanisms for this association are (1) cation exchange with kaolinite and gibbsite clay minerals; (2) sorption on minerals; and (3) chelation with naturally occurring organic material. Figure 3-6 shows the variation in ion-exchange capacity, clay content, and content of organic materials along the course of Four Mile Creek and Pen Branch. A distribution coefficient of K_d = 3960, measured for sediments from Four Mile Creek (Kiser, 1979), and the work by Prout (1958) demonstrate the affinity of cesium-137 for the sediments and suspended solids in the system.

The mineral composition of each particle-size fraction of the stream sediment was observed to be quite uniform. Quartz was found to account for 80 percent of the sand and 90 percent of the silt-size fraction; kaolinite dominated the clay-size fraction (Hawkins, 1971). Minor gibbsite was found in approximately half of the sediment and soil samples, regardless of location.

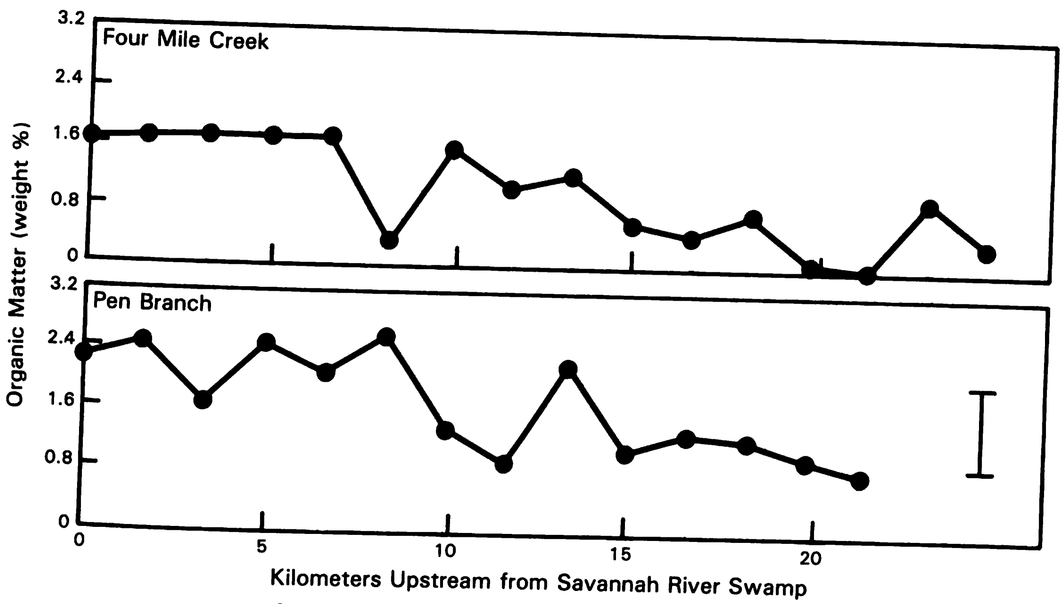
The cation-exchange capacity (CEC) of sediment generally increases as particle size decreases, because of an increase in organic matter, clay-mineral content, and surface area in the finer fractions. Upstream samples contain less clay and organic matter and have lower CEC values than those from near the Savannah River swamp. Overall, the CEC of all samples was very low because of the paucity of organic matter (1.26 percent sediments, 1.52 percent soils) and the predominance of kaolinite. Kaolinite has the lowest CEC of the common clay minerals; the CEC for SRP soils and sediment typically ranges from about 1.5 to 15.2 milliequivalents per 100 grams (Siple, 1967).

As a result of these affinities, sedimentation and sorption processes control the distribution of cesium-137. The resuspension, transport, and deposition of sediment are governed by the hydraulic properties of the sediment and streambed and by the creeks varied flow regime as a consequence of reactor operations. In addition, the finegrained creekbed and floodplain sediments (clay and silt) are usually associated with higher cesium-137 concentrations than are the coarser grained sediments.

Since the early 1950s, the flow regimes of Four Mile Creek and Pen Branch, including Indian Grave Branch, have been increased by the discharge of cooling water and process effluent directly into the creeks. The drainage patterns of the two creeks changed with erosion in the stream channels and deposition near the point of discharge to the swamp. Deltas developed in the swamp. Depositional environments in both creeks presently extend from their deltas to about 2.4 kilometers below SRP Road A, where near-neutral (neither erosion nor deposition) conditions exist (Ruby, Rinehart, and Reel, 1981).



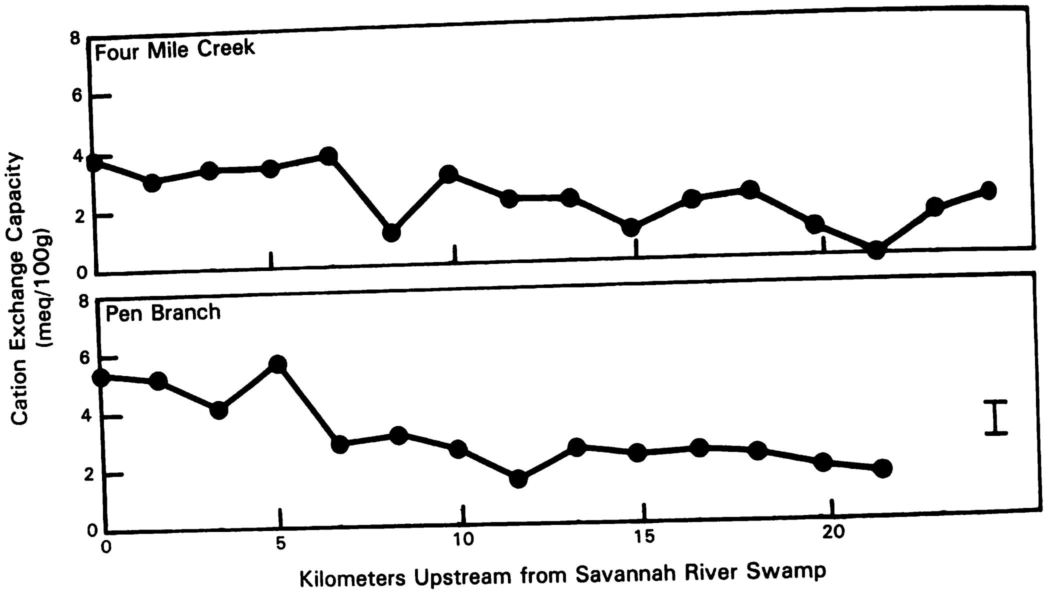
Clay Content of Streambed Sediments



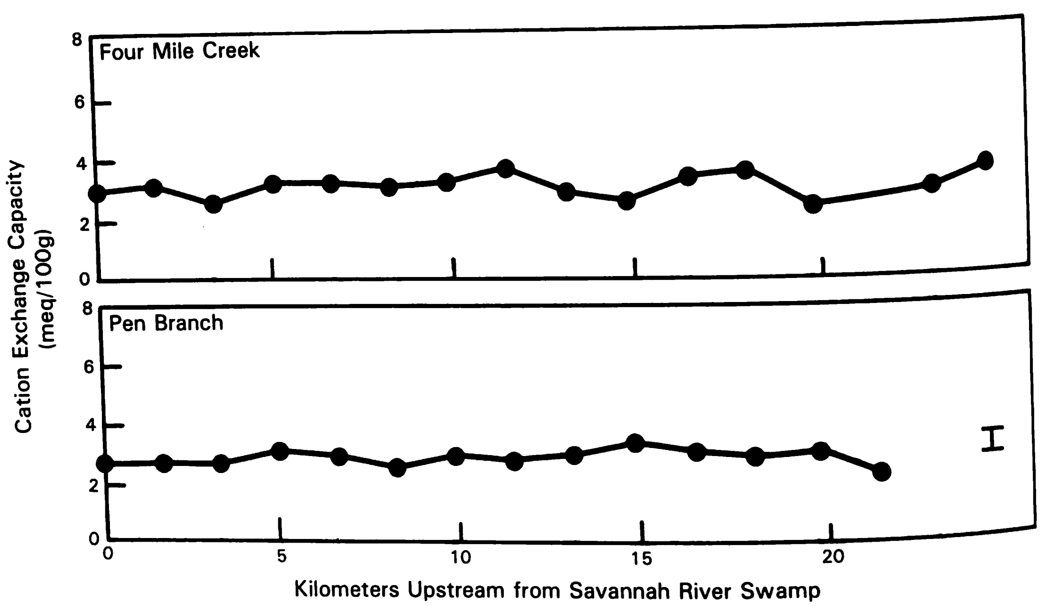
Organic Matter Contents of Streambed Sediments

Note: Range in 9 soils from source area of sediments
Source: Hawkins (1971)

Figure 3-6. Characteristics of Streambed Sediments, Four Mile Creek and Pen Branch



Cation Exchange Capacity of Streambed Sediments



Cation Exchange Capacity of the Clay Fractions of Streambed Sediments, Organic Matter Removed

Note: Range in 9 soils from source area of sediments

Source: Hawkins (1971)

Figure 3-6. Characteristics of Streambed Sediments, Four Mile Creek and Pen Branch (continued)

3.1.4.6 Geotechnical Properties of Sediments and Subsurface Materials

Near the center of the Savannah River Plant, the Congaree Formation (25 to 30 meters thick) consists of interfingered beds of very dense sands [SC and SM, according to the Unified Soil Classification System (Lambe and Whitman, 1969)] with stiff silts. Near its contact with the overlying McBean Formation, the Congaree is characterized by a silty to sandy marl. Exploratory drilling showed that penetration resistance [as measured by the standard penetration test (SPT) (Lambe and Whitman, 1969)] of the Congaree Formation is consistently very high, frequently greater than 50 blows per 30 centimeters of penetration. Geophysical surveys indicate a shear-wave velocity of about 470 meters per second over the entire thickness of the Congaree Formation.

A stiff to hard, glauconitic-clay to marl unit, which thickens from about 2 meters in the central portion of the Plant to about 18 meters in the south-southeast portion, separates the Congaree and McBean Formations. This clay is known locally as the "green clay."

The McBean Formation, about 18 to 21 meters thick in the central region of the Plant, is composed of sands (SM, SP), clay sands (SC), silts (ML, MH), and clays (CL, CH) in the upper section, and of impure calcareous sands (SM, SC) and silts (ML); indurated broken to slightly broken marl and fossiliferous limestone might be present in the lower section. Exploratory borings have encountered very soft plastic-clay lenses within and immediately overlying the calcareous sediments. Portions of the calcareous zone, where present, have been subjected to the subsurface leaching of appreciable amounts of calcareous material. Thus, this zone is characterized by high penetration resistance where the material is competent, and very low penetration resistance, with drops of drilling rods of 2 to 3 meters and loss of drilling fluids, where dissolution and removal of material have occurred. The U.S. Army Corps of Engineers grouted the calcareous zone beneath major structures when the facilities on the Plant were constructed in the early 1950s (COE, 1952). The zone with dissolution characteristics immediately overlies an impure limestone that is characterized by high blow counts. The limestone units are discontinuous; where they are present, the upper surface of the limestone is generally irregular and undulatory. Above the basal calcareous zone, the sands of the McBean are medium-dense with penetration resistance typically in the range of 10 to 30 blows per centimeters. In some areas, such as stream valleys, the upper McBean sands can be in a very loose to loose state. Except in stream valleys, shear-wave velocities are expected to range from about 300 meters per second in the upper portion of the formation to 440 to 470 meters per second in the lower portion.

A 3.5-meter-thick clay unit known locally as the "tan clay" separates the McBean Formation from the overlying Barnwell Formation. The total thickness of the Barnwell in the central portion of the Plant is about 25 meters, but it varies depending on the amount of erosion that has occurred. The sands of the Barnwell Formation are typically classified as SC and SM with some SP material, whereas the clayey material is usually classified as CL, ML, and MH. Penetration resistance in the Barnwell is frequently low, with the sandy material exhibiting loose to very loose densities and the clays soft to very soft consistencies. Two zones of loosely compacted material have been identified, one near the top of the formation and the other near its base. In these zones, the penetration resistance is usually less than 4 blows per 30 centimeters.

Undifferentiated floodplain alluvial sediments consist of interfingering lenses of inorganic, very loose to loose and medium-dense sands (SP), gravels (GM-GP), and clay-sand mixtures (SM and SC). The very soft and soft inorganic and organic silts (ML, MH, and OH) and clays (GC) of this zone have also been encountered in floodplain sediments. Typical deposits are about 5 meters thick in the center of the valley and pinch out toward the valley walls. Colluvial deposits are located on the flanks of the stream valleys and are partially mixed with the floodplain sediments. They are composed of reworked sediments of the McBean and Barnwell Formations and form a drape 3 or more meters thick over the valley slopes.

The potential for settlement and liquefaction exists beneath structures founded above areas with low penetration resistance.

3.1.5 HYDROLOGY

3.1.5.1 Surface-Water Hydrology

The principal surface-water body associated with the Plant is the Savannah River, which adjoins the site along its southwestern border. The total drainage area of the river, 27,388 square kilometers, encompasses all or parts of 41 counties in Georgia, South Carolina, and North Carolina. More than 77 percent of this drainage area lies upriver of the Plant (Lower, 1985). On the Plant, a swamp lies in the floodplain along the Savannah River for a distance of about 16 kilometers; the swamp is about 2.4 kilometers wide.

Six principal tributaries to the Savannah River are located on the SRP site: Upper Three Runs Creek, Beaver Dam Creek, Four Mile Creek, Pen Branch, Steel Creek, and Lower Three Runs Creek (Figure 3-2). Five of these onsite streams have historically received thermal discharges from SRP cooling water operations. Currently, only Beaver Dam Creek, Four Mile Creek, and Pen Branch are receiving direct thermal discharges from the D-Area coal-fired powerhouse, C-Reactor, and K-Reactor, respectively. Both L-Reactor and P-Reactor discharge to cooling impoundments before the effluent is released to Steel Creek and Lower Three Runs Creek, respectively. The P-Reactor effluent is recirculated in Par Pond prior to discharge, whereas L-Reactor discharges its cooling effluent to a "once-through" cooling impoundment. No direct discharge of SRP cooling water is made to the Savannah River.

Streamflow Characteristics

Natural discharge patterns on the Savannah River are cyclic: the highest river levels are recorded in the winter and spring, and lowest levels are recorded in the summer and fall. Stream flow on the Savannah River near the

Plant is regulated by a series of three upstream reservoirs: Clarks Hill, Russell, and Hartwell (DOE, 1984b). These reservoirs have stabilized average annual stream flow to 288.8 cubic meters per second near Augusta (Bloxham, 1979) and 295 cubic meters per second at the Savannah River Plant (DOE, 1984b).

The river overflows its channel and floods the swamps bordering the Plant when its elevation rises higher than 27 meters above mean sea level (which corresponds to flows equal to or greater than 438 cubic meters per second) (Marter, 1974). River-elevation measurements made at the SRP Boat Dock indicate that the swamp was flooded approximately 20 percent of the time (74 days per year on the average) during the period from 1958 through 1967.

The peak historic flood between the years 1796 and 1981 was estimated to be 10,190 cubic meters per second (DOE, 1984b). Since the construction of the upstream reservoirs, the maximum average monthly flow has been 1242 cubic meters per second for the month of April (1964-1981).

There are three significant breaches in the natural river levee at the SRP site; they are opposite the mouths of Beaver Dam Creek, Four Mile Creek, and Steel Creek. During periods of high river level (above 27 meters), river water overflows the levee and stream mouths and floods the entire swamp area. The water from these streams then flows through the swamp parallel to the river and combines with the Pen Branch flow. The flows of Steel Creek and Pen Branch converge 0.8 kilometer above the Steel Creek mouth. However, when the river level is high, the flows are diverted parallel to the river, across the offsite Creek Plantation Swamp; ultimately they join the Savannah River flow near Little Hell Landing (DOE, 1984b).

Water Quality

Historically, the Savannah River has been subjected to many factors that affect the water quality. Completion of the Clarks Hill Dam, located upstream from the Plant at River Mile 237.7, resulted in decreased silt loading and turbidity downstream. Because of the depth of withdrawal, the temperature of the water decreased by about 5°C (Neill and Babcock, 1971). From 1951 until 1956, downstream reaches of the Savannah River were dredged to improve channel alignment and navigability. This dredging temporarily increased suspended solids, turbidity, and dissolved nutrients.

Improved wastewater treatment by municipalities since the mid-1960s has reduced the nutrient loading and biochemical oxygen demand; however, industrialization of the river basin in the metropolitan Augusta, Georgia, area has increased total waste loading (DOE, 1982).

Variability of all water-quality parameters has diminished over the last 20 years, primarily because of flow stabilization by upstream dams. The pH of the river is generally slightly acid. The river water is relatively soft, well oxygenated, and low in chemical and biological oxygen demand (Lower, 1984). Table 3-3 compares the 10-year mean Savannah River water quality measurements upriver, at, and downriver of the Plant.

Table 3-3. Water Quality of the Savannah River, 1973 to 1982 Upriver of the SRP, at Pumphouse 3G and Downriver at the U.S. Highway 301 Bridge[a]

Parameter	Upstream of SRP mean concentration, 1973-1982 (mg/l[b]) RM 158.5	Pumphouse 3G mean concentration, 1973-1982 (mg/l[b]) RM 155.5	Hwy. 301 Bridge mean concentration, 1973-1982 (mg/l[b]) RM 118.7
Temperature (°C)	17.7	19.0	18.1
pH (units) (range)	5.3-7.6	5.3-8.0	5.5-7.3
Dissolved oxygen	9.6	9.7	9.5
Alkalinity	13.8	17.7	13.9
Conductivity (μm hos/cm)	66.8	NA	67.9
Suspended solids	17.1	24.1	16.2
Volatile solids	23.4	22.1	23.3
Total dissolved solids	47.9	58.6	48.2
Total solids	65.2	83.0	65.7
Biochemical oxygen demand	1.6	0.73	1.5
Chemical oxygen demand	NA[c]	10.7	NA
Chlorides	5.3	6.2	5.1
Kjeldahl nitrogen (N)	NA	1.0	NA
Nitrates + nitrites (N)	0.693	0.294	0.637
Sulfates (SO_4)	5.17	4.34	5.14
Total phosphates (PO_4)	0.464	0.098	0.421
Aluminum (Al)	0.382	0.97	0.443
Ammonia (N)	0.108	0.147	0.090
Calcium (Ca)	2.24	3.66	2.23
Sodium (Na)	7.66	9.33	7.24
Iron, total (Fe)	0.34	0.90	0.32
Lead (Pb)	NA	0.42	NA
Manganese (Mn)	NA	0.01	NA
Mercury (Hg)	0.002	0.001	0.002

[a]Source: Du Pont, 1985b.
[b]Except as noted.
[c]NA - No analysis.

The annual average temperature of the Savannah River 3 kilometers upriver of the Plant, from 1979 to 1982, was 17.8°C with a range of individual sample analyses of 1.5 to 26.0°C. Similarly, below the Plant the average annual temperature was 18.4°C and the range was 6.5 to 26.0°C. Monthly average daily-maximum temperatures above and below the Plant for the period from 1971 to 1983 are presented in Figure 3-7. The river temperature increased by about 1.0°C on the average over the 18 river miles between Ellenton Landing and Milletville, South Carolina, below Steel Creek. This increase was due, in part, to the natural warming as the water tended toward its equilibrium temperature as the result of impoundments upstream.

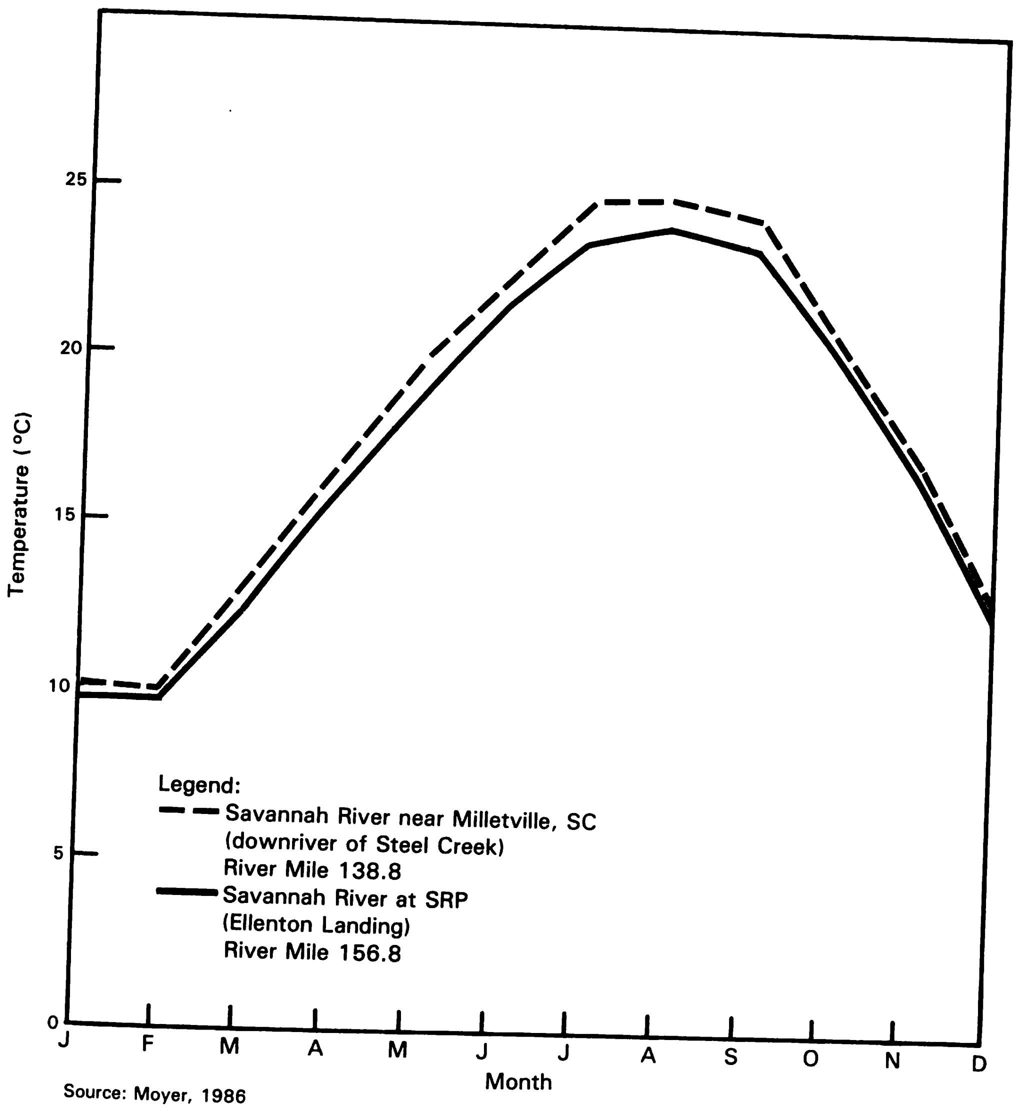


Figure 3-7. Savannah River Monthly Average Daily-Maximum Temperatures for 1971-1983

As shown in Figure 3-7, June, July, August, and September are the warmest river-temperature months. The average river temperature during these months was about 25 percent higher than the annual average river temperature. From June 1955 through September 1982, the river temperature at Ellenton Landing equaled or exceeded 28°C three times and equaled or exceeded 28.3°C once (DOE, 1984b).

Water Usage

The Savannah River downstream from Augusta, Georgia, is classified by the State of South Carolina as a Class B waterway, suitable for agricultural and industrial use, the propagation of fish, and - after treatment - domestic use. The river upstream from the Plant supplies municipal water for Augusta, Georgia (River Mile 187), and North Augusta, South Carolina (River Mile 201). Downstream, the Beaufort-Jasper Water Authority in South Carolina (River Mile 39.2) withdraws water to supply a population of about 51,000. The Cherokee Hill Water Treatment Plant at Port Wentworth, Georgia (River Mile 29.0), withdraws water to supply a business-industrial complex near Savannah, Georgia, that has an estimated consumer population of about 20,000 (Du Pont, 1982b). Plant expansions for both systems are planned for the future.

The Savannah River Plant currently withdraws a maximum of 37 cubic meters per second (about 90 percent of the maximum pumping rate of 41 cubic meters per second) from the river, primarily for use as cooling water in production reactors and coal-fired powerhouses (DOE, 1984b). Almost all this water returns to the river via SRP streams; consumptive water use is about 0.9 cubic meter per second at C- and K-Reactors, 1.3 cubic meters per second at L- and P-Reactors, and about 0.3 cubic meter per second at the D-Area coal-fired powerhouse (DOE, 1984b).

The river also receives sewage treatment plant effluents from Augusta, Georgia; North Augusta, Aiken, and Horse Creek Valley, South Carolina; and other waste discharges along with the heated SRP cooling water via its tributaries. Withdrawal of an average of 2.6 cubic meters per second from the river for cooling and the return of an average of 0.7 cubic meter per second from both units of the Vogtle Electric Generating Plant is expected later in the 1980s (NRC, 1985). The Urquhart Steam Generating Station at Beech Island withdraws approximately 7.4 cubic meters per second of once-through cooling water. Upstream, recreational use of impoundments on the Savannah River, including water contact recreation, is more extensive than it is near the Plant and downstream. No uses of the Savannah River for irrigation have been identified in either South Carolina or Georgia (Du Pont, 1982b).

3.1.5.2 Subsurface Hydrology

The aquifers and aquitards (or confining beds) that underlie the Savannah River Plant comprise the hydrogeological system of the area. Here the Coastal Plain sedimentary aquifers consist of the Barnwell (combined with the overlying Hawthorn as one mapping unit), McBean, Congaree, Ellenton, and Tuscaloosa Formations (Figure 3-5). The principal aquitards include the "tan clay," which separates the Barnwell and McBean Formations, the "green clay," which separates the McBean and Congaree Formations, the basal Congaree Ellenton clay, and the clay units in the Tuscaloosa Formation (Figure 3-8). South and east of Upper Three Runs Creek, the water table (or unconfined groundwater) generally occurs in the Barnwell Formation. Groundwater in the underlying units occurs under semiconfined and confined conditions.

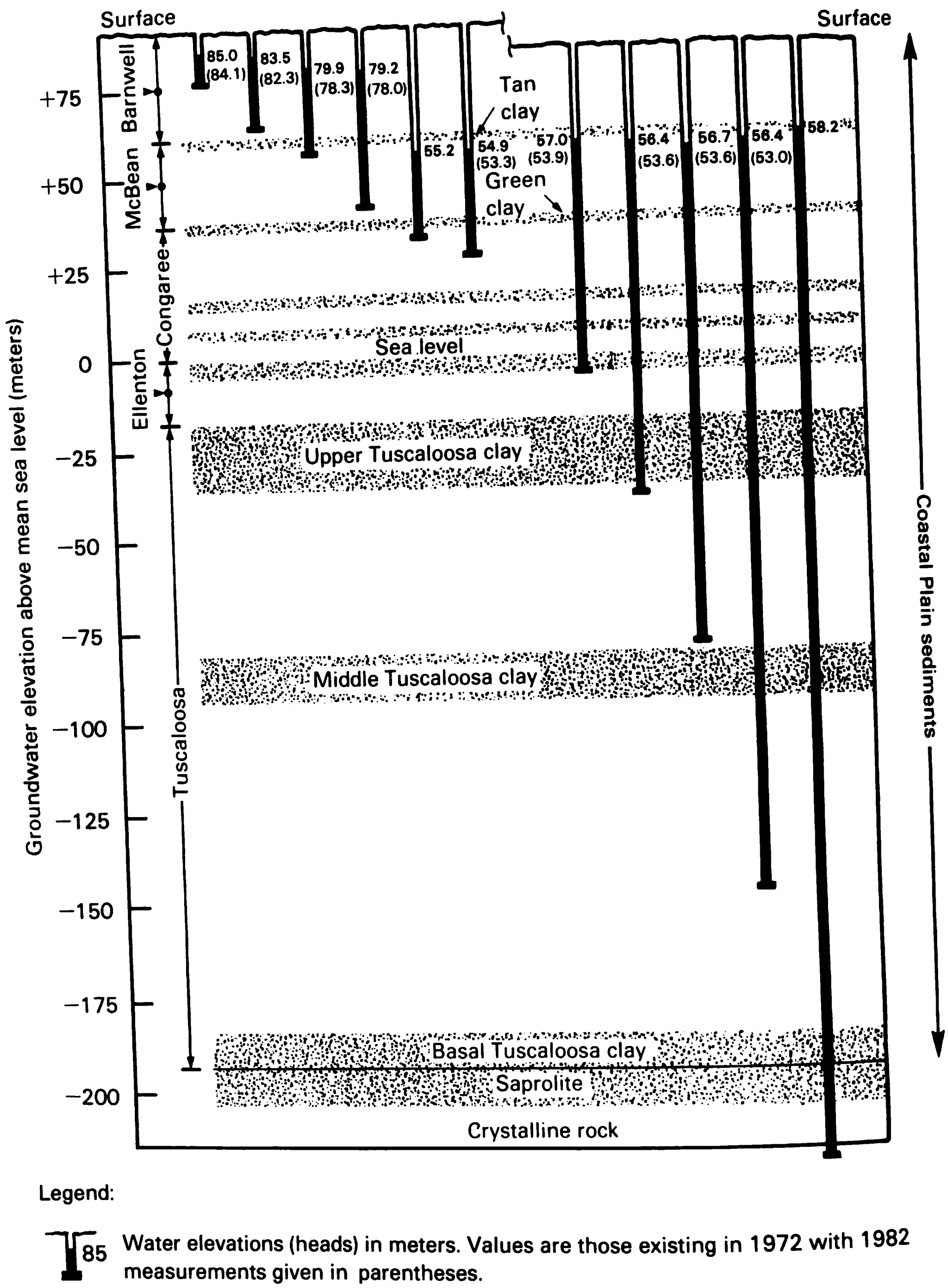
The Barnwell Formation at the Plant is recharged by precipitation, which moves in a predominantly vertical direction to the water table at a rate of about 0.9 to 2.1 meters per year (Haskell and Hawkins, 1964). Natural discharge from the Barnwell Formation is to the perennial creeks and to the McBean Formation. From a water budget analysis for the central part of the Plant, Hubbard and Emslie (1984) estimated that the annual recharge to the Barnwell Formation is about 38 centimeters with about 13 centimeters of groundwater discharging to the creeks and 25 centimeters seeping through the "tan clay" to the McBean Formation.

The McBean Formation is recharged in offsite areas and by seepage from the Barnwell Formation. Natural discharge is toward Upper Three Runs Creek, Four Mile Creek, Pen Branch, and Indian Grave Branch, which is a tributary of Pen Branch. There is no appreciable seepage through the "green clay" aquitard to the Congaree Formation in the central part of the Plant.

The Congaree Formation is recharged in offsite areas and by seepage from the McBean Formation. Natural discharge is toward the wetlands along Upper Three Runs Creek and the Savannah River. There is no appreciable seepage downward through the basal Congaree-Ellenton clay or upward through the "green clay." As a result of the natural discharge, the potentiometric head in the Congaree is lower than that in the Tuscaloosa Formation in a broad area within about 10 kilometers of Upper Three Runs Creek and the Savannah River.

The Tuscaloosa Formation is recharged in offsite outcrop areas near the Fall Line in Aiken County, and through the overlaying sediments north and west of Upper Three Runs Creek. Natural discharge is toward the wetlands along the Savannah River. The Ellenton Formation is apparently hydraulically connected to the Tuscaloosa, and its direction of groundwater flow is probably similar to that of the Tuscaloosa.

The water in the Coastal Plain sediments tends to be of good quality, suitable for municipal and industrial use with minimal treatment. It is generally soft, slightly acid, and low in dissolved and suspended solids.



Sources: ERDA, 1977; Du Pont, 1984b

Figure 3-8. Hydrostatic Head of Groundwater Near H-Area and the Center of the SRP in Relationship to Principal Hydrostratigraphic Units

Most municipal and industrial water supplies in Aiken County are developed from the Tuscaloosa Formation, which occurs at shallower depths as the Fall Line is approached. Domestic water supplies in Aiken County are primarily developed from the Barnwell, McBean, and Congaree Formations. In Barnwell and Allendale Counties, the Tuscaloosa Formation occurs at increasingly greater depths; some municipal users are therefore supplied from the shallower Congaree and McBean Formations or from their limestone equivalent. In these counties, domestic supplies are developed from the Barnwell and McBean Formations.

3.1.6 ECOLOGY

The United States Government acquired the 780-square-kilometer (192,700 acres) Savannah River Plant in 1951 (Du Pont, 1985b). At that time the land was approximately two-thirds forested and one-third cropland and pasture (Dukes, 1984). With the exception of the production and support areas, many previously disturbed areas and open fields have been reclaimed by natural succession or have been planted with trees; these areas are managed by the U.S. Forest Service. Today more than 90 percent of the Plant is forested. Table 3-4 lists recent SRP land utilization, other than the land used for chemical or nuclear processes and support facilities. The Plant, which was designated as a National Environmental Research Park in 1972, is one of the most extensively studied environments in this country (DOE, 1984b).

This section describes the ecology of the Savannah River Plant and the surrounding region. Appendix C presents results of many studies conducted in the Savannah River, the Savannah River swamp, and the onsite streams.

3.1.6.1 Terrestrial Ecology

Soils

A general soils map of the Savannah River Plant (Adelott, 1977) grouped the soil types into 23 mapping units. The dominant types are Fuguay/Wagram Soils (27.3 percent), Dothan/Norfolk soils (9.6 percent), Savannah River Swamp and Lower Three Runs Corridor (9.4 percent), Troop Loamy Sand, Terrace phase (8.4 percent), Gunter Sand (7.5 percent), and Vaucluse/Blaney Soils (6.5 percent). Together these units account for approximately 70 percent of the soil types that occur on the Savannah River Plant.

Vegetation

The Savannah River Plant is near the line that divides the oak-hickory-pine forest and the southern mixed forest. Consequently, it has species representative of each forest association (DOE, 1984b). In addition, SRP vegetation has been influenced strongly by farming, fire, soil features, and topography.

Table 3-4. Land Utilization, 1983[a]

Land	Area (acres)
Open fields	650
Slash pine	35,000
Longleaf pine	37,500
Loblolly pine	48,000
Pine-hardwood (60% pine)	4,000
Hardwood-pine (60% hardwood)	6,300
Scrub oak	2,000
Upland hardwoods	4,500
Bottomland hardwoods	29,000
Other pine	100
Subtotal	167,050
Wetlands	
Creeks/floodplains	24,500
Savannah River Swamp	10,000
Par Pond	2,500
Carolina bays	1,000
Other	1,000
Subtotal	39,000
Total	206,050[b]

[a]Adapted from Dukes, 1984.
[b]Exceeds total acreage of the Savannah River Plant because of overlap in wetlands and bottomland hardwood acres.

No virgin forest remains in the region. Except for the production areas and their support facilities, the U.S. Forest Service has reclaimed many previously disturbed areas through natural plant succession or by planting with pine (Du Pont, 1985b).

A variety of vascular plants (150 families, 1097 species) occur on the Savannah River Plant (Dukes, 1984). (See Appendix C for greater detail and Appendix F for a discussion of wetlands and floodplains.) Typically, scrub oak communities cover the drier sandy areas; longleaf pine, turkey oak, bluejack oak, blackjack oak, and dwarf post oak with ground cover of three awn grass and huckleberry dominate such communities. Oak-hickory hardwoods are prevalent on more fertile, dry uplands. The characteristic species are white oak, post oak, southern red oak, mockernut hickory, pignut hickory, and loblolly pine with an understory of sparkleberry, holly, greenbrier, and poison ivy.

The composition is more variable on moist soils found along small streams or on old floodplains. Characteristic species include tulip poplar, birch, sweet gum, willow oak, water oak, and loblolly pine. The understory can include dogwood, members of the honeysuckle family, holly, and red buckeye.

Bottomland hardwood forest borders the Savannah River swamp where it is subject to occasional flooding. Some common trees are sweet gum, swamp chestnut, red maple, hackberry, laurel, blue birch, river birch, water oak, willow, sycamore, winged elm, and loblolly pine. Palmetto, switch cane, greenbrier, grape, crossvine, and trumpet creeper are also common.

The swamp bordering the Savannah River is subjected to seasonal flooding with winter and early spring water levels 3 to 4.5 meters higher than those of summer and fall. Bald cypress and tupelo gum are the dominant trees in the Savannah River swamp, where standing water is present almost year-round. Black gum and water oak are also present.

The status of the smooth coneflower (Echinacea laevigata), which is found on the Savannah River Plant along the Burma Road, as a threatened and endangered species is currently under status review by the U.S. Fish and Wildlife Service (Currie, 1985). To date, the U.S. Fish and Wildlife Service has not identified any "critical habitat" on the Savannah River Plant. Commercially valuable plant biota on the Savannah River Plant include approximately 175,000 acres of timber managed by the U.S. Forest Service.

Wildlife

The diversity and abundance of wildlife that inhabit the Savannah River Plant reflect the interspersion and heterogeneity of the habitats occurring at the site. Because of its mild climate and the variety of aquatic and terrestrial habitats, the Savannah River Plant contains a varied and abundant herpetofauna (DOE, 1984b). Gibbons and Patterson (1978) provide a comprehensive description of the herpetofauna of the site, including taxonomy, distribution, and ecological information. The species on the Plant include 31 snakes, 26 frogs and toads, 17 salamanders, 10 turtles, 9 lizards, and 1 alligator (Dukes, 1984).

Species collected during intensive field studies on Steel Creek, particularly during 1981 and 1982, are considered to be representative of species occurring on similar creeks and wetland areas. Frogs and toads, turtles, and salamanders (in order of decreasing relative abundance) constituted more than 85 percent of the 65 species (69 percent of those on the Plant) found (DOE, 1984b).

Biologists have identified more than 213 species of resident and migrant birds on the Plant. Gamebirds such as quail and dove were initially abundant on the Plant but have declined since the 1960s because the conversion of agricultural fields to forests has reduced the carrying capacity for these species. The South Carolina Wildlife and Marine Resource Department initiated a turkey-breeding program on the Plant in 1972. As of 1984, about 135 turkeys had been captured and used to restock other areas of the State (Dukes, 1984).

Waterfowl on the Plant are mainly winter migrants. Wood ducks are the only waterfowl species to breed consistently in the SRP region, although hooded mergansers might sometimes breed. An estimated 10,000 to 15,000 ducks and coots spend the winter on the site; most congregate on Par Pond and on other large ponds and Carolina bays. Another 1000 to 2000 ducks spend the winter in the lower swamps and on the Savannah River (Dukes, 1984).

Commercially and Recreationally Valuable Biota

The ecosystems on the Savannah River Plant support many commercially and recreationally valuable game populations; however, DOE restricts recreational use to controlled hunts for white-tailed deer and feral hogs. Many species are highly mobile and travel offsite where activities such as hunting are allowed. Other resident species that are edible and that travel offsite include the ring-neck duck, wood duck, bullfrog, and various species of turtles. The slider turtle is the most abundant turtle known to migrate offsite; other common species that move offsite include the Florida cooter and the snapping turtle (DOE, 1984b).

Endangered and Threatened Species

Three species listed as endangered by the U.S. Fish and Wildlife Service - the American alligator, the wood stork, and the red-cockaded woodpecker - have been identified on the Plant. As stated above for plant species, the U.S. Fish and Wildlife Service has not identified any "critical habitat" for animal species on the Savannah River Plant. (See Appendix C for more detail.)

Listed Federally as endangered, the alligator is common locally and breeds in Par Pond, near D-Area, in the Savannah River Swamp, along Steel Creek, in Pond B, and in Lower Three Runs Creek. The ecology of this species on the Savannah River Plant has been examined intensively (Du Pont, 1985b).

According to recent studies, wood storks observed on the Savannah River Plant are from the Birdsville rookery near Millen, Georgia. The Steel Creek delta, Beaver Dam Creek area, and other sites in the Savannah River swamp provide important feeding habitat for storks from this rookery (Du Pont, 1985b).

The red-cockaded woodpecker has a very restrictive requirement for nesting habitat; it nests only in old (more than 50 years) stands of pines. In 1986, the Plant had one active (breeding) colony located near the northern Plant border and two lone males located near the southeastern Plant border (F. Brooks, U.S. Forest Service, personal communication with J. L. Oliver, NUS Corporation, February 20, 1986).

3.1.6.2 Aquatic Ecology

Aquatic Flora

The Savannah River is the dominant water body associated with the Savannah River Plant. The river has experienced two significant alterations since the early 1950s: (1) dredging in the main channel as far as Augusta, Georgia, and

(2) completion of upstream reservoirs (Clarks Hill in 1952; Hartwell in 1961; Russell in 1984). These changes have affected the aquatic community by reducing shallow habitat and reducing transport of sediment and allochthonous particulate organic material (Patrick et al., 1967). The microflora of the Savannah River is dominated by diatoms, although blue-green algae are sometimes common upstream from the Plant; their abundance is caused by organic loading from municipal sources. The abundance and species distribution of phytoplankton result, to some extent, from upstream reservoir overflow. Macrophytes, most of which are rooted, are limited to shallow areas of reduced current, such as oxbows, behind sandbars, in swamp areas, and along the shallow margins of tributaries. Eight species of vascular plants have been identified from the Savannah River adjacent to the Plant; the most common are water milfoil, hornwort, alligatorweed, waterweed, and duck potato (DOE, 1984b).

Aquatic Fauna

Shallow areas and quiet backwaters and marshes of the Savannah River near the Plant support a diverse aquatic invertebrate fauna. However, the bottom substrate of most open portions of the river consists of shifting sand that does not provide the best habitat for bottom-dwelling organisms. During the 1950s, the river experienced a decrease in the total number of invertebrate species; this decrease has been attributed primarily to the effects of dredging (Patrick et al., 1967). The stabilization of the river discharge and the elimination of habitat caused by the reduction in the flooding of backwater areas might have contributed to the decline. Some recovery occurred during the 1960s and 1970s, but complete recovery has not taken place. The groups most affected are those sensitive to the effects of siltation and substrate instability. Mayflies and dragonflies predominated among insect fauna in earlier surveys. In more recent surveys, dipterans (true-flies) have been dominant (DOE, 1984b; ECS, 1985).

Results of insect faunal studies conducted have indicated substantial organic loading to the river upstream from the Savannah River Plant. True-flies (particularly chironomids) dominated the drift communities, which is typical of a riverine system. Mollusks, such as snails and clams, are also an important component of the Savannah River invertebrate community. The Asiatic clam, Corbicula fluminea, is found in the river and larger tributary streams in the vicinity of the Plant (DOE, 1984b).

The Savannah River drainage is typical of southeastern coastal plain systems, exhibiting a diverse fish fauna represented by 102 species (Dahlberg and Scott, 1971). Eighty species have been found in the streams, swamp, and river near the SRP site (Paller and Osteen, 1985).

A study of certain biota in the Savannah River was initiated in July 1982 (Du Pont, 1985b). The focus of this study was to examine the occurrence, relative abundance, and distribution of adult and larval fishes in the river, the SRP intake canals, and lower reaches of tributary creeks. (See Appendix C for additional discussion.) Previous data and studies were reviewed, incorporated, or extended in this study.

Researchers collected 80 fish species as part of this study. The dominant small fishes (excluding minnows) were sunfishes (especially redbreast) and flat bullheads. The dominant large fishes were bowfin, spotted suckers, and channel catfish. Other important species were largemouth bass, American eel, white catfish, longnose gar, striped mullet, silver redhorse, chain pickerel, and quillback carpsucker. The most abundant small forage species were shiners and brook silverside (Du Pont, 1986b; Paller and Osteen, 1985).

Species composition varied due to seasonal changes in fish movement and activity (e.g., spawning). The most conspicuous change was a decrease in the relative abundance of sunfish during January. Bowfin, spotted sucker, flat bullhead, and channel catfish were more abundant during January. The greatest number of species (37) was captured during May, possibly because of migratory movements or seasonal changes in activity related to spawning. Recruitment of young of the year might have increased the relative abundance of some species during August (Du Pont, 1985b).

Thermal effluents affect the structure of fish communities in the streams and swamp on the Savannah River Plant. Studies of nonthermal, thermal, and post-thermal areas in SRP stream and swamp systems indicate that the thermal streams have markedly reduced species richness and abundance in relation to ambient-temperature areas. In these ambient-temperature areas, habitat factors (cover type, water depth, water velocity) can strongly influence species composition. The greatest differences in fish community structure occurred between the swamp sites and areas sampled along the lower reaches of the Four Mile Creek corridor. Species richness declined substantially and mosquitofish clearly dominated collections. Mosquitofish were either absent or minor components of the community at ambient-temperature sites (Du Pont, 1985b).

The 1983 ichthyoplankton sampling program extended from February through July; it included 26 river transects, 2 intake canals, and 33 tributary creeks of the Savannah River between River Mile (RM) 29.6 and 187.1. During 1983, researchers collected and identified 43,294 fish larvae and 7138 fish eggs (Du Pont, 1985b).

Ichthyoplankton densities were highest downstream of the Plant during February, March, and April, highest near the Plant during May, and highest upstream of the Plant during June and July. These trends correlated with temperature and probably occurred because the lower river warmed to suitable spawning temperatures before the upper river (Du Pont, 1985b).

During March and April 1983, ichthyoplankton density decreased nearly five-fold near the Plant between RM 141.7 and RM 150.4. This phenomenon did not result from the destruction of larvae by thermal plumes from the Plant because river temperatures were not abnormally elevated in the region; nor was it due to entrainment, because only 6.6 percent of the river discharge was entrained during March and 4.2 percent in April. The marked increase in ichthyoplankton abundance below RM 150.4 probably resulted from an influx of larvae from spawning areas in the swamps bordering the Plant. When river levels are unusually high, as they were during the 1983 spawning season, SRP thermal effluents discharge into the swamp rather than directly into the main channels of the receiving streams. The resulting temperature increases in the swamp might have stimulated spawning.

Patterns in stream-swamp ichthyoplankton abundance on the Savannah River Plant were comparable with those of adult fish. Generally, ichthyoplankton densities at swamp and creek mouth stations were substantially higher than those at creek stations upstream from the swamp. Results from sampling throughout the Steel Creek delta revealed that spawning activity differs substantially in the different microhabitats available in the delta area. The deepwater, open-canopy areas were the most productive for ichthyoplankton; centrarchids (sunfish and bass), cyprinids (minnows), and percids (darters) dominated collections. Although clupeids (herring and shad) were collected in the delta/swamp areas, the numbers were much lower than those observed at creek mouth stations. Generally, anadromous species appear to make minimal use of swamp areas for spawning and restrict these activities to the creek mouths. No striped bass ichthyoplankton have been collected in swamp or creek mouth locations.

During 1984, 1938 fish were collected from impingement samples on 107 sampling dates. The number of fish impinged daily ranged from 0 to 190, with an average of 18 fish per day (Paller and Osteen, 1985). The average number of fish impinged during 1984 was approximately half of the 37 fish impinged daily during 1983 (Paller et al., 1984), but was similar to the average of 19 fish impinged during 1982 (ECS, 1983). These three years of data (1982 to 1984) indicate that more than twice as many fish are impinged as the 7 per day reported during 1977 (McFarlane, Frietsche and Miracle (1978). Generally, all researchers found that sunfishes were the most dominant fish impinged, followed by shad and herring. Highest rates of impingement generally occurred in the spring, associated with flood conditions (Du Pont, 1985b; Paller and Osteen, 1985).

Entrainment of larval fish and eggs at the SRP pumphouses during the 1984 spawning season totaled 23.4×10^6 ichthyoplankters (17.6×10^6 larvae and 5.8×10^6 eggs (Paller, O'Hara, and Osteen, 1985)), which was 37.0 percent less than the 37.2×10^6 larval and eggs entrained in 1983 (Paller et al., 1984). The 1983 and 1984 entrainment values represent 8.3 and 9.3 percent, respectively, of the total ichthyoplankton that passed by the intake canals and structures (Paller, O'Hara, and Osteen, 1985). (See Appendix C for more details concerning entrainment and impingement studies).

Endangered and Threatened Species

Recent fisheries surveys on the Savannah River revealed that the endangered shortnose sturgeon spawn in the vicinity of the Savannah River Plant (Du Pont, 1985b). Shortnose sturgeon larvae were collected in river water upstream, downstream, and adjacent to the Plant during 1982 (two larvae collected), 1983 (six collected), and 1984 (two collected). All of the sturgeon larvae collected during 1982 were taken from the section of river between RM 150.8 and

RM 157.3, with none collected from the intake canals. One of the seven shortnose sturgeon larvae collected in 1983 was found in the 1G intake canal, one was found in the 3G intake canal, and the remaining five were found adjacent to or downstream of the Plant. During 1984, both shortnose sturgeon larvae were collected below the Plant. No larvae or juveniles were collected from any SRP tributary stream during 1982, 1983 (Du Pont, 1985b), or 1984 (Paller, O'Hara, and Osteen, 1985).

A biological assessment of the potential effects of SRP operations on the shortnose sturgeon in the Savannah River (Muska and Matthews, 1983) was submitted to the National Marine Fisheries Service (NMFS). The NMFS and DOE-SR have concurred that the population of the shortnose sturgeon in the Savannah River would not be jeopardized by SRP operations (Oravetz, 1983).

Commercially and Recreationally Valuable Biota

All thermal streams on the Savannah River Plant support depauperate fish populations, especially during periods of reactor operations. However, the Savannah River supports both commercial and sport fisheries (Appendix C). Most fishing is confined to the marine and brackish waters of the coastal regions of South Carolina and Georgia. The only commercial fish of significance near the Plant are the American shad, the channel catfish, and the Atlantic sturgeon. (The commercial catch of American shad from the Savannah River during 1979 was 57,600 kilograms.) These species are exploited to a limited degree by local fishermen.

Sport fishermen are the principal consumers of river fishes, primarily sunfish and crappie. Striped bass are classified as game fish in South Carolina and Georgia (Ulrich et al., 1978).

The Fisheries Section of the Georgia Department of Natural Resources (GDNR) published the results of a fisheries study conducted on the Savannah River from July 1, 1981, to June 30, 1982 (Georgia Game and Fish Division, 1982). GDNR researchers collected data from sports fishermen on fishing effort, harvest, species sought, habitat or location fished, and angler origin. Approximately 4600 anglers fish in the freshwater section of the Savannah River. Georgia residents constitute 68.2 percent of these anglers. The anglers fish in both the mainstream (58.2 percent) and oxbows, creeks, and lakes (41.8 percent) of the river. Freshwater anglers fish (43.8 percent of their time) for bream (i.e., bluegill, redbreast sunfish, warmouth, redear sunfish, and spotted sunfish); bream account for 73 percent of the fish caught. Largemouth bass is the next most popular species (38 percent of the time); however, success is low (2.5 percent of the fish caught). About 90,000 kilograms of freshwater fish are harvested from the lower Savannah River annually.

3.1.7 METEOROLOGY AND CLIMATOLOGY

The description of the meteorology of the Savannah River Plant is based on data collected at the Plant and at Bush Field in Augusta, Georgia (Du Pont, 1980a, 1982b; NOAA, 1985). Additional information in the following sections was obtained from magnetic tapes containing data from the onsite meteorological program for the period 1975 through 1979.

3.1.7.1 Regional Climatology

The SRP area has a temperate climate, with mild winters and long summers. The region is subject to continental influences, but it is protected from the more severe winters in the Tennessee Valley by the Blue Ridge Mountains to the north and northwest. The SRP site and the surrounding area are characterized by gently rolling hills with no unusual topographical features that would have a significant influence on the general climate.

Winters are mild and, although cold weather usually lasts from late November to late March, less than one-third of the days have a minimum temperature below freezing.

3.1.7.2 Local Meteorology

SRP Meteorology Data System

Meteorological data are collected from a system of seven towers located adjacent to each production area on the Plant and from the WJBF-TV tower about 15 kilometers northwest of the SRP boundary. The seven towers are instrumented at the stack height of 61 meters with vector vanes designed for turbulence measurements (Kern and Mueller, 1979). The TV tower is instrumented at seven levels (Hoel, 1983) with bivanes and fast-response cup anemometers to provide the same type of information as that received from the SRP towers (Kern and Mueller, 1979). Platinum resistance thermometers at each of eight levels on the TV tower provide temperature information on the lowest 300 meters of the atmosphere.

The data measured by this tower system are received in the Weather Center Analysis Laboratory (WCAL) on the Plant. The data collected from the SRP tower system and the WJBF-TV tower are used for real-time emergency-response situations.

In addition to the tower data, extremes in daily temperature and rainfall are recorded, and continuous measurements of temperature, relative humidity, and pressure are kept. Rain gauges are located at various locations on the SRP site.

Temperature and Humidity

Table 3-5 lists the average and extreme temperatures recorded for the Plant. The annual average temperature at the Plant is 18°C. The monthly average ranges from 7°C in January to 27°C in July (see Table 3-5). The extreme temperatures observed are -16°C and 41°C. The Augusta, Georgia, long-term temperature data are in agreement with those for the Savannah River Plant.

Table 3-5. Average and Extreme Temperatures (°C) at Savannah River Plant, 1961-1981

Month	Average temperature			Extreme temperature	
	Daily maximum	Daily minimum	Monthly	Record maximum	Record minimum
Jan.	13	2	7	30	-16
Feb.	16	3	9	27	-16
Mar.	20	7	13	32	-12
Apr.	25	12	18	35	0
May	28	16	22	37	5
June	32	19	26	41	9
July	33	21	27	41	14
Aug.	32	21	27	40	13
Sept.	29	18	24	38	5
Oct.	24	12	18	33	-2
Nov.	19	7	13	32	-8
Dec.	15	3	9	28	-11
Year	24	12	18	41	-16

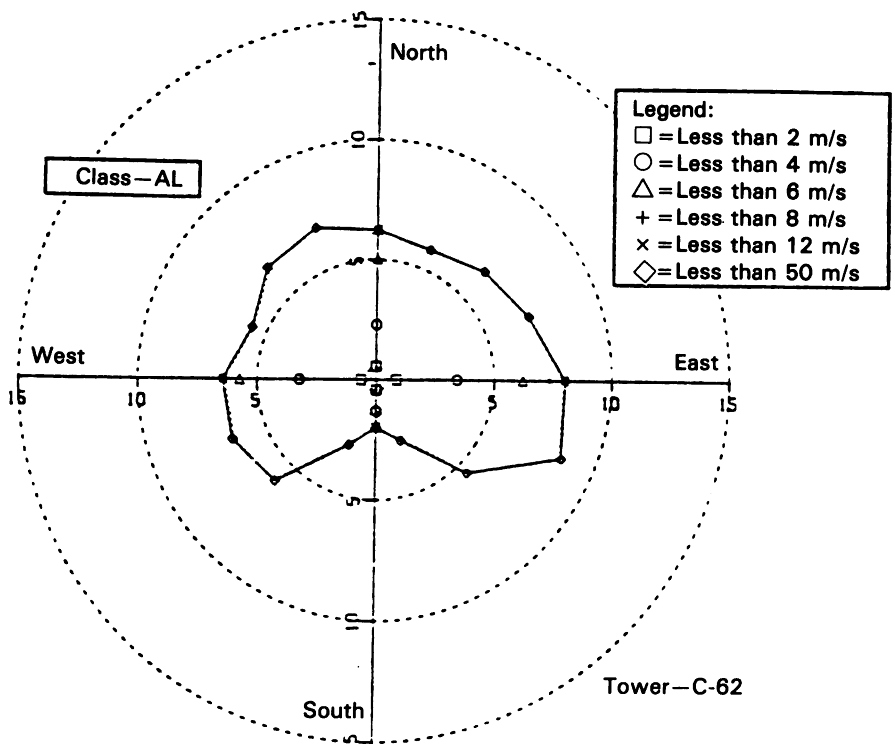
The length of the growing season for the Augusta area is normally 241 days, with the first freeze on November 12, and the last on March 16. Freezing temperatures have been observed, however, as early as October 17, and as late as April 21.

The annual average daily relative humidity for the Plant ranges from 43 to 90 percent.

Average Wind Speed and Direction

The average wind speed measured in Augusta from 1951 to 1981 was 3.0 meters per second. The average recorded at a height of 10 meters on the WJBF-TV tower near Beech Island, about 15 kilometers northwest of the Plant, was 2.5 meters per second from 1976 to 1977. The average monthly wind speed for Augusta, Georgia, is listed in Table 3-6 along with the prevailing wind direction for each month. This table also lists the monthly and annual average wind speeds for three levels of the television tower.

Annual wind-direction frequencies for the C-, K-, and D-Areas are shown in the transport plots (Figures 3-9 through 3-11). These figures show the percentage of time that the wind blows from each of 16 directions (22.5° sectors). The information presented in these figures was produced from data taken at the 61-meter level (the stack height in most SRP production areas). Seasonal



Windrose Data

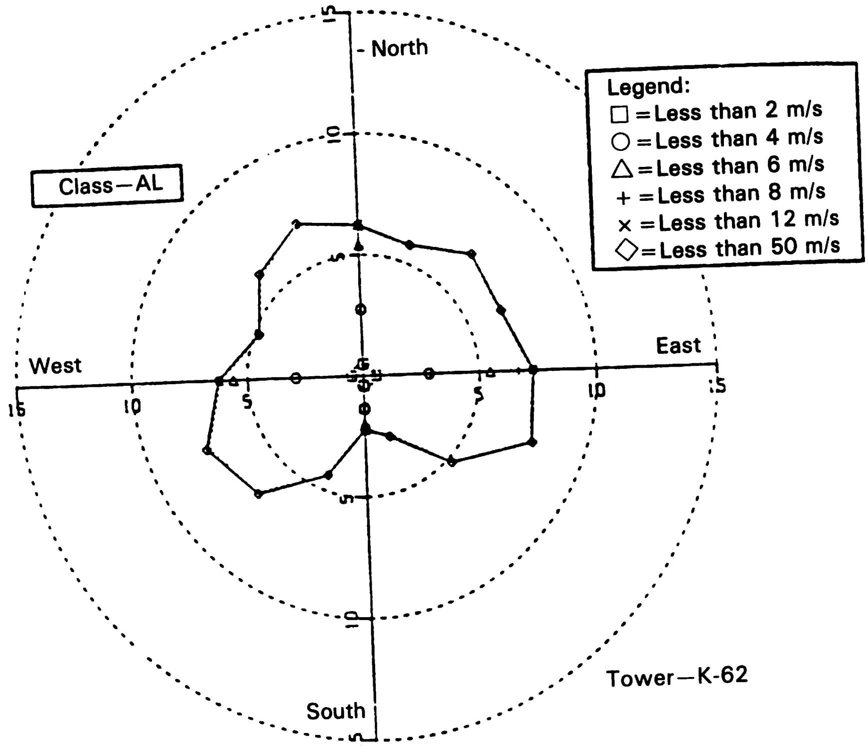
Minimum Date MMDDYY 10175
Minimum Time ZULU 0000
Entries All Classes 114938

Maximum Date MMDDYY 123179
Maximum Time ZULU 2400
Entries This Class 114938

0 0 0 0 0 0 0 0 0 0 0

	■■■■■Speed in Meters/Sec.■■■■■								■■■■■ Percent Time Wind & Speed ■■■■■						
Direction	0-2	2-4	4-6	6-8	8-12	>12	Average Speed	Total Tot	0-2	2-4	4-6	6-8	8-12	>12	Total
N	497	1016	665	115	2	0	2.42	2295	.43	.88	.58	.10	.00	.00	2.00
NNE	563	1457	971	330	53	0	2.77	3374	.49	1.27	.84	.29	.04	.00	2.94
NE	562	2257	2483	1288	245	10	3.55	6845	.49	1.96	2.16	1.12	.21	.00	5.96
ENE	713	2482	2934	1216	98	31	3.39	7474	.62	2.16	2.55	1.06	.08	.02	6.50
E	733	2980	2899	759	49	0	3.21	7420	.64	2.59	2.52	.66	.04	.00	6.46
ESE	641	2754	2425	636	43	0	3.21	6499	.56	2.40	2.11	.55	.03	.00	5.65
SE	681	2492	2831	1350	159	0	3.47	7513	.59	2.17	2.46	1.17	.14	.00	6.54
SSE	604	2070	3418	1576	159	5	3.71	7832	.53	1.80	2.97	1.37	.14	.00	6.81
S	636	2000	3162	1189	188	4	3.59	7179	.55	1.74	2.75	1.03	.16	.00	6.25
SSW	543	2290	2739	957	191	4	3.45	6724	.47	1.99	2.38	.83	.17	.00	5.85
SW	622	2563	2740	1190	231	12	3.54	7358	.54	2.23	2.38	1.04	.20	.01	6.40
WSW	666	2600	2827	1377	487	26	3.68	7983	.58	2.26	2.46	1.20	.42	.02	6.95
W	979	2940	3196	1310	733	59	3.36	9217	.85	2.56	2.78	1.14	.64	.05	8.02
WNW	1152	2846	3119	1834	928	91	3.30	9770	1.00	2.48	2.71	1.42	.81	.07	8.50
NW	877	2026	2102	880	382	19	3.03	6286	.76	1.76	1.83	.77	.33	.01	5.47
NNW	655	1268	972	216	41	0	2.57	3152	.57	1.10	.85	.19	.03	.00	2.74
No Direction	2800	3046	1413	580	141	37	2.06	8017	2.44	2.65	1.23	.50	.12	.03	2.00
Avg. Speed	1.21	2.96	4.87	6.70	9.09	14.11	3.19								
Tot. Entry	13924	39087	40896	16603	4130	298		114938							

Figure 3-9. C-Area Tower 1975-1979



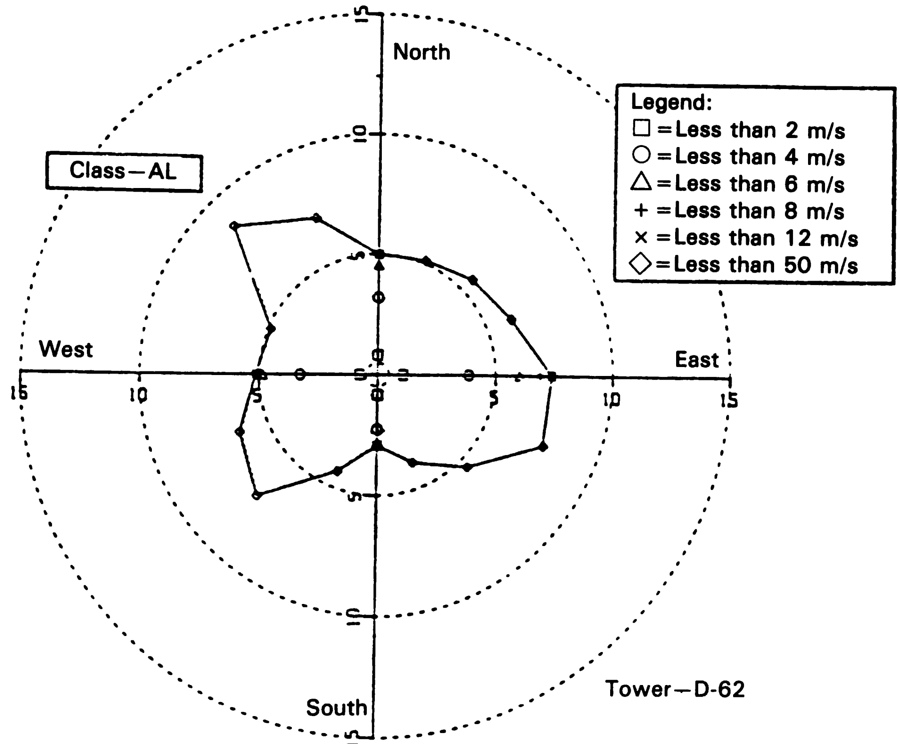
Windrose Data

Minimum Date MMDDYY 10175
Minimum Time ZULU 0000
Entries All Classes 113511

Maximum Date MMDDYY 123179
Maximum Time ZULU 2400
Entries This Class 113511

	Speed in Meters/Sec.								Percent Time Wind & Speed						
	0	0	0	0	0	0	0		0	0	0	0	0	0	
Direction	0-2	2-4	4-6	6-8	8-12	>12	Average Speed	Total Tot	0-2	2-4	4-6	6-8	8-12	>12	Total
N	469	1076	747	195	48	0	2.66	2535	.41	.95	.66	.17	.04	.00	2.23
NNE	634	1774	1696	691	168	12	3.11	4975	.56	1.56	1.49	.61	.15	.01	4.38
NE	563	2807	2922	1145	114	38	3.52	7589	.50	2.47	2.57	1.01	.10	.03	6.69
ENE	710	3336	3446	848	107	9	3.38	8156	.63	2.94	3.04	.75	.09	.00	7.45
E	569	2744	3069	613	83	26	3.42	7104	.50	2.42	2.70	.54	.07	.02	6.26
ESE	542	2173	2212	469	48	2	3.22	5446	.48	1.91	1.95	.41	.04	.00	4.80
SE	644	2368	3013	815	97	4	3.41	6941	.57	2.09	2.65	.72	.08	.00	6.11
SSE	496	2336	3755	1043	177	18	3.73	7825	.44	2.06	3.31	.92	.16	.01	6.89
S	536	2569	3037	752	185	12	3.35	7091	.47	2.26	2.68	.66	.16	.01	6.25
SSW	559	2600	2532	700	131	13	3.55	6535	.49	2.29	2.23	.62	.12	.01	5.76
SW	688	2828	3018	1072	167	18	3.42	7791	.61	2.49	2.66	.94	.15	.01	6.86
WSW	608	2789	2606	1034	330	38	3.48	7405	.54	2.46	2.30	.91	.29	.03	6.52
W	631	2588	2982	1391	675	56	3.71	8323	.56	2.28	2.63	1.23	.59	.04	7.33
WNW	614	2339	3011	1725	995	84	3.87	8768	.54	2..06	2.65	1.52	.88	.07	7.72
NW	614	2090	1881	944	343	37	3.37	5909	.54	1.84	1.66	.83	.30	.03	5.21
NNW	444	1315	951	324	74	1	2.89	3109	.39	1.16	.84	.29	.06	.00	2.74
No Direction	2247	2071	1623	555	132	81	2.23	7709	1.98	2.71	1.43	.49	.12	.07	2.23
Avg. Speed	1.25	2.99	4.86	6.69	9.16	14.85	3.31								
Tot. Entry	11568	40803	42501	14316	3874	449		113511							

Figure 3-10. K-Area Tower 1975-1979



Windrose Data

Minimum Date MMDDYY 10175
Minimum Time ZULU 0000
Entries All Classes 105815

Maximum Date MMDDYY 123179
Maximum Time ZULU 2400
Entries This Class 105815

0 0 0 0 0 0 0 0 0 0 0

Direction	Speed in Meters/Sec. 0-2	2-4	4-6	6-8	8-12	>12	Average Speed	Total Tot	Percent Time Wind & Speed 0-2	2-4	4-6	6-8	8-12	>12	Total
N	886	1522	600	77	30	0	2.22	3115	.84	1.44	.57	.07	.02	.00	2.94
NNE	973	2269	1100	179	28	33	2.52	4582	.92	2.14	1.04	.17	.02	.03	4.33
NE	927	3253	2630	627	71	0	3.03	7508	.88	3.07	2.49	.59	,06	.00	7.10
ENE	825	2961	2332	422	71	0	2.99	6611	.78	2.80	2.20	.40	.06	.00	6.25
E	796	2672	1669	265	39	0	2.81	5441	.75	2.53	1.58	.25	.03	.00	5.14
ESE	905	2490	1414	334	38	3	2.68	5184	.86	2.35	1.34	.32	.03	.00	4.90
SE	1389	3733	2741	842	401	24	2.91	9130	1.31	3.53	2.59	.80	.38	.02	8.63
SSE	1039	2933	2639	596	191	14	2.98	7412	.98	2.77	2.49	.56	.18	.01	7.00
S	858	2531	1457	305	132	14	2.74	5297	.81	2.39	1.38	.29	.12	.01	5.01
SSW	902	2542	1460	410	120	4	2.73	5438	.85	2.40	1.38	.39	.11	.00	5.14
SW	1072	2620	1609	452	170	13	2.69	5936	1.01	2.48	1.52	.43	.16	.01	5.61
WSW	1149	2907	1696	466	229	21	2.71	6468	1.09	2.75	1.60	.44	.22	.02	6.11
W	1124	2960	2292	941	513	16	3.03	7846	1.08	2.80	2.17	.89	.48	.01	7.41
WNW	1015	2757	2552	1037	659	48	3.19	8068	.96	2.61	2.41	.98	.62	.04	7.62
NW	868	2127	1747	674	281	6	2.93	5703	.82	2.01	1.65	.64	.27	.00	5.39
NNW	842	1896	1119	250	54	0	2.54	4161	.80	1.79	1.06	.24	.05	.00	3.93
No Direction	3047	2791	1408	497	163	9	1.89	7915	2.88	2.64	1.33	.47	.15	.00	2.94
Avg. Speed	1.21	2.91	4.78	6.73	9.18	13.12	2.73								
Tot. Entry	18617	44964	30465	8374	3190	205		105815							

Figure 3-11. D-Area Tower 1975-1979

transport is generally as follows: winter, northwest to southeast; spring, west to east; summer, toward the southeast through north to northeast; and autumn, toward the southwest and southeast. Because the pollutant dispersion depends on atmospheric stability, annual wind roses are available for each of the seven SRP towers for each of seven Pasquill-type stability classes; seasonal wind roses are also available (Hoel, 1983).

Table 3-6. Average Monthly Wind Speed for Bush Field, Augusta, Georgia, 1951-1981 and WJBF-TV Tower, 1976-1977

Month	Bush Field: Mean speed (m/sec)	Bush Field: Prevailing direction	WJBF-TV tower elevation (m): 10	36	91
Jan.	3.2	W	3.0	4.5	6.1
Feb.	3.4	WNW	2.9	4.6	5.8
Mar.	3.6	WNW	3.3	4.5	5.9
Apr.	3.4	SE	2.8	4.2	5.4
May	2.9	SE	2.5	3.7	5.0
June	2.8	SE	2.4	4.0	4.8
July	2.6	SE	2.0	3.1	4.4
Aug.	2.5	SE	2.1	3.2	4.3
Sept.	2.5	NE	2.1	3.3	4.7
Oct.	2.6	NW	2.4	4.1	5.6
Nov.	2.8	NW	2.4	4.1	5.6
Dec.	3.0	NW	2.7	4.4	6.3
Annual	3.0	SE	2.5	3.9	5.3

Precipitation

The average annual rainfall at the Savannah River Plant from 1952 through 1978, was about 120 centimeters (Du Pont, 1982b). The average at Augusta from 1951 to 1980 was about 113 centimeters (NOAA, 1985). Table 3-7 lists the means and extremes of precipitation for the Plant from 1952 to 1982. The maximum monthly precipitation was about 31.6 centimeters, recorded in August 1964. Hourly observations in Augusta show that the intensity of the rainfall is normally less than 1.3 centimeters per hour.

3.1.7.3 Severe Weather

Extreme Winds

The strongest winds in the SRP area occur in tornadoes, which can have wind speeds as high as 116 meters per second. The next strongest surface winds

Table 3-7. Precipitation at Savannah River Plant, 1952-1982[a]

Month	Monthly precipitation (cm)		
	Maximum	Minimum	Average
Jan.	25.6	2.3	10.7
Feb.	20.3	2.4	10.9
Mar.	28.0	3.8	12.9
Apr.	21.0	1.5	8.9
May	27.9	3.4	10.8
June	27.9	3.9	11.1
July	29.4	2.3	12.5
Aug.	31.6	2.6	11.7
Sept.	22.3	1.4	10.2
Oct.	27.8	0.0	6.2
Nov.	16.5	0.5	5.9
Dec.	24.4	1.2	9.5
Annual			121.3

[a]Adapted from Du Pont, 1983c.

occur during hurricanes. During the history of the SRP, only Hurricane Gracie, in September 1959, had winds in excess of 34 meters per second. Winter storms with winds as high as 32 meters per second have been recorded occasionally (Du Pont, 1982b). Thunderstorms can generate winds as high as 18 meters per second and even stronger gusts. The highest 1-minute wind speed recorded at Augusta between 1951 and 1984 was 28 meters per second. Table 3-8 lists the extreme wind speeds for 50- and 100-year return periods for three locations about equally distant from the Plant (Simiu, Changery, and Filliben, 1979).

Thunderstorms

There is an average of 54 thunderstorm days per year at the Plant. The summer thunderstorms occur primarily during the late afternoon and evening; they can be accompanied by strong winds, heavy precipitation, or, less frequently, hail (NOAA, 1985). Summer thunderstorms are attributable primarily to convective activity resulting from solar heating of the ground and the presence of a moist unstable maritime tropical air mass. Thunderstorm activity in the winter months is attributable mainly to frontal activity.

Tornadoes

In the Southeastern United States, most tornadoes occur in early spring and late summer, with more than 50 percent occurring from March through June. In South Carolina, the greatest percentage of tornadoes occur in April and May,

Table 3-8. Extreme Wind Speeds for Area of Savannah River Plant[a] (meters per second)

Station	Return period	
	50-year	100-year
Greenville, S.C.	35	38
Macon, Ga.	30	31
Savannah, Ga.	35	39

[a]Adapted from Simiu, Changery, and Filliben, 1979.

about 20 percent (Pepper and Schubert, 1978) in August and September. The latter are spawned mainly by hurricanes and waterspouts. One or two tornadoes can be expected in South Carolina, during April and May, and one can be expected each in March, June, July, August, and September (Purvis, 1977).

Weather Bureau records show 278 tornadoes in Georgia over the period from 1916 to 1958, and 258 in South Carolina for the period from 1950 to 1980 (Table 3-9) (Hoel, 1983). The general direction of travel of confirmed tornado tracks in Georgia and South Carolina is southwest to northeast.

Occasional tornadoes are to be expected in the SRP area. Investigations of tornado damage near the Plant in 1975 and 1976 indicated wind speeds varying from 45 to 78 meters per second (Du Pont, 1980a).

Hurricanes and High Winds

Thirty-eight damaging hurricanes occurred in South Carolina during the 272 years of record (1700 to 1972); the average frequency was one storm every 7 years. These storms occurred predominantly during August and September. At the SRP site, 160 kilometers inland, hurricane wind speeds are significantly lower than those observed along the coast. Winds of 34 meters per second were measured on the 61-meter towers only once during the history of the Plant, when Hurricane Gracie passed to the north on September 29, 1959 (Du Pont, 1982b).

Precipitation Extremes

Heavy precipitation can occur in the SRP area in association with either localized thunderstorms or hurricanes. The maximum 24-hour total was about 15.2 centimeters, which occurred during August 1964 in association with Hurricane Cleo.

Table 3-9. Tornado Occurrence by Month

Month	Georgia (1916-1958) Number	Georgia (1916-1958) Percent	South Carolina (1950-1980) Number	South Carolina (1950-1980) Percent
Jan.	24	8.6	6	2.3
Feb.	23	8.3	14	5.4
Mar.	49	17.6	26	10.1
Apr.	93	33.5	40	15.5
May	20	7.2	53	20.5
June	14	5.0	20	7.8
July	5	1.8	17	6.6
Aug.	10	3.6	25	9.7
Sept.	8	2.9	23	8.9
Oct.	2	0.7	8	3.1
Nov.	15	5.4	11	4.3
Dec.	15	5.4	15	5.8
Total	278		258	

Hail and Ice Storms

Hail in association with a severe thunderstorm can be expected to occur in the area about once every 2 years. Damage from such hail is rare. Ice storms caused by freezing rain can be expected about once every 4 years and are usually of short duration (Du Pont, 1982b).

3.1.7.4 Atmospheric Dispersion

Atmospheric Stability

The transport and dispersion of airborne material are direct functions of air movement. Transport direction and speed are governed by the general patterns of airflow (and by the nature of the terrain), whereas the diffusion of airborne material is governed by small-scale, random eddying of the atmosphere (i.e., turbulence). Turbulence is indicated by atmospheric stability classification. About 25 percent of the time, the atmosphere is unstable in the SRP regions; about 25 percent of the time it is neutral; and about 50 percent of the time it is stable.

Mixing Heights and Low-Level Inversions

The mixing height is the level of the atmosphere below which pollutants are easily mixed; it is often equal to the base of an elevated inversion. The depth of the mixed layer at the Plant has been measured by an acoustic sounder (Schubert, 1975). The acoustic data indicate that, as the day progresses, the mixing height rises beyond the 1000-meter range of the sounder.

An analysis of 5 years of upper-air meteorological data recorded at several stations in the SRP area (Holzworth, 1972) provides further mixing-height information. The average afternoon mixing height is about 1005 meters in the winter, 1700 meters in the spring, 1890 meters in the summer, and 1400 meters in the autumn. Mixing heights over the SRP site could be expected to be slightly lower.

Temperature inversions (air temperature increases with the height above the ground) inhibit atmospheric turbulence; hence, they are associated with small rates of atmospheric diffusion. Detailed temperature-inversion data are available from instruments on the WJBF-TV tower. The 1974 temperature measurements between 3 and 335 meters were analyzed to determine the frequency of occurrence of several categories of temperature structure (Pendergast, 1976). About 30 percent of the time, a temperature inversion extended to or beyond the 3-to-335-meter layer. About 12 percent of the time, there was an elevated inversion with an unstable layer below; this represents the early-morning breakup of a nighttime inversion. About 9 percent of the data showed an inversion at the lower levels with an unstable layer above; this represents the transition period between an unstable daytime regime and the onset of a nighttime inversion.

Restrictive-Dilution Conditions

The dilution capacity of the atmosphere depends on local wind speed, wind-direction variability, mixing depth, and the vertical temperature profile. From 1960 to 1970, the SRP area had about 50 forecast-days of high air-pollution potential, or an average of about 5 days per year (Holzworth, 1972). Air pollution episodes are most frequent in autumn, when large anti-cyclones, which are characterized by low wind speeds, clear weather, and large-scale temperature inversions, become nearly stationary off the Atlantic coast, affecting much of the Eastern United States.

Air Quality

The States of South Carolina and Georgia have established air-quality-sampling networks. The Savannah River Plant operates an onsite sampling network. These networks monitor suspended particulates, sulfur dioxide, and nitrogen dioxide. Ambient concentrations of these pollutants near the Plant in 1984, were below local air-quality standards (Du Pont, 1985a).

Correlation of Predicted to Measured Offsite Airborne Radionuclide Concentrations

A statistical air-pollution model, XOQDOQ, uses joint-frequency data on wind speed, wind direction, and atmospheric-stability class to estimate average relative effluent concentrations, X/Qs, and average relative deposition values, D/Qs, at specified locations and at standard radial distances downwind. It is based on a modified Gaussian-plume equation that assumes uniform horizontal dispersion over each of 16 sectors and calculates vertical dispersion using curves fitted with polynomials (Sagendorf and Goll, 1977). The mixing height is set to 1000 meters.

Predictions of the model were compared with measurements in air of the inert radioactive gas, krypton-85, which is routinely emitted in small quantities from the SRP chemical-separations facilities. The model predictions were slightly higher than the measured values (Telegadas et al., 1980).

3.1.8 RADIATION AND RADIONUCLIDES IN THE ENVIRONMENT

3.1.8.1 Sources of Environmental Radiation

Environmental radiation consists of natural background radiation from cosmic, terrestrial, and internal body sources; medical radiation; radiation from weapons test fallout; radiation from consumer and industrial products and air travel; and radiation from nuclear facilities.

Natural radiation contributes about 48 percent of the annual dose of 195 millirem received by an average member of the population within 80 kilometers of the Savannah River Plant. Medical exposure accounts for 47 percent of the annual dose, and the combined doses from offsite weapons test fallout, consumer and industrial products, and air travel account for about 5 percent of the dose. Releases of radioactivity to the environment from the Plant account for less than 0.1 percent of the total annual dose (DOE, 1984b).

External natural radiation comes from cosmic rays and the emissions from natural radioactive ores. It is highly variable with location and altitude. Internal natural radiation arises primarily from potassium-40, carbon-14, rubidium-87, and daughters of radium-226. The widespread distribution of fertilizers and food, as well as population mobility, has an averaging effect for these long-lived radionuclides that produce the internal dose. The estimated average internal radiation exposure in the United States from natural radioactivity is 28 millirem per year (BEIR III, 1980).

Medical radiation is the largest source of exposure to manmade radiation in the United States. The average dose to an individual from medical and dental X-rays, prorated over the total population, was 78.4 millirem per year (BEIR III, 1980). (Prorating the dose over the population, as used here and in following parts of this section, is a means of arriving at an average dose that, when multiplied by the population size, produces an estimate of population exposure. It does not mean that every member of the population receives radiation exposure from these sources.) In addition, radiopharmaceuticals administered to patients for diagnostic and therapeutic purposes account for an average annual dose of 13.6 millirem when prorated over the population. The occupational exposure of 0.45 millirem per year to medical and dental personnel must be added to these patient doses. Thus, the average medical radiation dose in the U.S. population is about 92.5 millirem per year.

Fallout from nuclear weapons tests is a small source of radioactivity in the environment. The large-scale atmospheric tests conducted by the United States and the Soviet Union in 1961 and 1962 introduced radioactive materials into the stratosphere that were later distributed worldwide. A small amount of radioactivity from these tests continues to be deposited. The more recent

Chinese and French tests have maintained a relatively constant rate of fallout deposition. The past and present fallout contributes to human exposure through (1) external radiation from radioactive material on the earth's surface; (2) internal radiation from inhalation of airborne fallout; and (3) internal radiation from ingestion of food and water contaminated by fallout.

Cesium-137 deposited from past nuclear weapons tests is the major source of long-lived external gamma radiation from fallout. Short-lived radionuclides also contributed significantly to external radiation for a few years after major tests but now contribute little to the dose. The current dose rate from external gamma radiation is estimated at 0.9 millirem per year (EPA, 1972).

Most doses from inhalation of fallout are received in the years immediately after exposure. However, doses from strontium-90 and plutonium-239 will be received over a lifetime because of the long residence time of these radionuclides in the body. The annual dose from inhaled fallout radioactivity was estimated at only 0.04 millirem in 1969 (EPA, 1972) and is now even lower.

Ingestion of radioactivity in food and water is the largest source of radiation exposure from fallout. The estimated dose from this source of exposure in 1980 was 3.7 millirem per year: 0.6 millirem from carbon-14, 0.4 millirem from cesium-137, and 2.7 millirem from strontium-90.

The average annual total-body dose in 1980 from fallout from nuclear weapons tests was estimated at 4.6 millirem: 0.9 from external gamma and 3.7 from ingested radioactivity.

A variety of consumer and industrial products yield ionizing radiation or radioactive materials causing radiation exposure to the general population. Some of these sources are television sets, luminous-dial watches, airport X-ray inspection systems, smoke detectors, tobacco products, fossil fuels, and building materials. The estimated total-body dose for the U.S. population from these sources is 4 to 5 millirem per year (BEIR III, 1980). About three-fourths of this dose is from external exposure to naturally occurring radionuclides in building materials.

Persons who travel by aircraft receive additional exposure from cosmic radiation; at high altitudes the atmosphere provides less shielding from this source. The average annual dose to an airline passenger is 2.8 millirem, which when prorated over the entire U.S. population amounts to an average dose of 0.5 millirem per year (BEIR III, 1980).

3.1.8.2 Environmental Radiation Levels in the Southeastern United States

The contribution of cosmic radiation to natural background dose varies with both latitude and altitude and thus will be unique to a particular location. Sea-level doses range from 30 millirem per year in Florida to 45 millirem per year in Alaska; the exposure rate increases to 200 millirem per year at an altitude of about 2400 meters (EPA, 1977). The average unshielded cosmic radiation dose in Georgia and South Carolina is 40 millirem per year (EPA, 1972).

Terrestrial gamma radiation (external to the human body) is attributed primarily to gamma-emitting radionuclides in the natural radioactive series derived from uranium and thorium, with some additional contribution from potassium-40. Variation in the distribution of these natural radioactive materials with geologic formations and their inclusion in construction materials commonly used in urban areas lead to a wide variation with location. The average unshielded external dose from this source is 60 millirem per year in Georgia and 70 millirem in South Carolina. However, the variation in these states, including the SRP area, ranges from 6 to more than 350 millirem.

Nuclear facilities in an area will also contribute to the environmental radiation level. The growth of the nuclear industry and nuclear facilities in the southeastern United States - from West Virginia to Florida and from Arkansas to South Carolina - has been rapid, most of it occurring in the 1970s. In this region, 24 power reactors were either operating or licensed to operate in 1981. Another 34 power reactors were under construction and 4 reactors were being planned. When all of these are operating, there will be 62 power reactors in the southeastern United States. Typically, the average radiation dose to individuals within 80 kilometers of a nuclear facility is quite low. Data on releases from 46 nuclear powerplants operating in 1979 indicate that the average radiation dose within 80 kilometers of a plant was 0.025 millirem (NRC, 1982).

An airborne radiological survey of the Savannah River marine region was performed in 1975 to establish terrestrial dose equivalent rates (Hayes, 1977). These rates varied from about 0.001 millirem per hour over water to 0.009 millirem per hour at one location on Wassaw Island. In general, the higher rates occurred over beaches, where heavy minerals containing natural thorium and uranium occur. Excluding the water areas, the terrestrial rate averages about 0.003 millirem per hour in this area, which is comparable to other Coastal Plain rates of 0.002 to 0.003 millirem per hour and is about one-half that measured for the Plant. The average dose equivalent rate for the Savannah River marine area is about the same as that measured in Galveston, Texas, and Cape Canaveral, Florida, and somewhat less than that in the Los Angeles, California, area. One radiation anomaly defined in this survey was noted on Hutchinson Island, Florida, where dredge spoils have been deposited. The cesium-137 concentration of the post-1957 dredge soil sediment ranges from about 0.3 to 2.7 picocuries per gram. About half the cesium-137 in the post-1957 sediment can be attributed to fallout from weapons testing (Marter, 1974).

3.1.8.3 Environmental Radiation Levels in the Vicinity of the Savannah River Plant

A summary of the major sources of exposure for the population within 80 kilometers of the Plant and for the river-water-consuming population in Beaufort and Jasper Counties, South Carolina, and in Port Wentworth, Georgia, is presented in Table 3-10. Many of the factors such as the internal radionuclide dose and the medical dose are independent of the site. The factors that are site-dependent are discussed below.

Table 3-10. Major Sources of Radiation Exposure in the Vicinity of the Savannah River Plant

Source of exposure	Dose to average individual (mrem/yr)	Percent of exposure
Natural background radiation		
Cosmic radiation	32.0	
External terrestrial gamma	33.0	
Internal	28.0	
Total	93.0	47.6
Medical radiation		
Diagnostic X-rays	78.4	
Radiopharmaceuticals	13.6	
Medical and dental personnel	0.5	
Total	92.5	47.3
Weapons test fallout	4.6	2.4
Consumer and industrial products	4.5	2.3
Air travel	0.5	0.3
Nuclear facilities (other than SRP)	0.1	0.1
Savannah River Plant environmental radioactivity (1980)	0.2	0.1
Grand total	195.3	

The Savannah River Plant and the surrounding area lie between latitudes 33°N and 34°N, with an altitude variation between sea level and roughly 300 meters. The estimated total unshielded dose equivalent from cosmic radiation in the vicinity of the Plant within an 80-kilometer radius is 35 millirem per year, of which 29 millirem per year are from the ionizing component and 6 millirem per year are from neutrons (Langley and Marter, 1973). Shielding by buildings and the body reduces the cosmic radiation dose to about 32 millirem per year - a 10-percent reduction.

Within 80 kilometers of the Plant, measured external gamma dose rates range from 6 millirem to 385 millirem per year (Dukes, 1984). A value of 55 millirem per year represents the average unshielded external terrestrial background in the vicinity of the Plant. Shielding by buildings and the body reduces this terrestrial radiation dose to about 33 millirem per year - a 40-percent reduction.

Atmospheric testing caused 25,600,000 curies of cesium-137 to be deposited on the earth's surface (United Nations, 1977). About 104 millicuries of cesium-137 per square kilometer were deposited in the latitude band 30°N to 40°N, where South Carolina is located. The total deposition was 2850 curies in the 27,400 square kilometers of the Savannah River watershed and 80 curies of cesium-137 in the 780 square kilometers of the Plant. The deposited cesium-137 became attached to soil particles and has undergone only slow transport from the watershed. Results from routine SRP Health Protection Department monitoring programs indicate that since 1963 about 1 percent of the 2850 curies of cesium-137 deposited on the total Savannah River watershed has been transported down the river (Hayes, 1983).

Onsite monitoring conducted by the SRP Health Protection Department from 1976 to 1982 shows that an average of 50 millicuries per square kilometer of cesium-137 were in the upper 5 centimeters of the soil column within an 80-kilometer radius (Du Pont, 1983a). This value is one-half the amount originally deposited from worldwide fallout and implies that some of the radiocesium has undergone hydrologic transport to the Savannah River.

SRP monitoring in the Savannah River shows that the concentration of radiocesium in river water has been very low in the past several years. From 1979 through 1982, the mean concentration of cesium-137 at the U.S. Highway 301 bridge was 0.08 picocurie per liter and was near the limit of detection at the control station upriver of the Plant (Du Pont, 1980b, 1981, 1982c, 1983a). For the second quarter of 1983, measurements of the radiocesium in the potable water at the North Augusta, Beaufort-Jasper, and Cherokee Hill water-treatment plants averaged 0.006, 0.028, and 0.033 picocurie per liter, respectively, or less than 0.017 percent of the EPA drinking water standard of 200 picocuries per liter (Kantelo and Milhom, 1983).

Turbulence in the Savannah River generally keeps fine soil particles in suspension. These particles are deposited where the river velocity and turbulence are low, such as inside river bends, downstream from obstructions, in oxbow lakes, and on the floodplain, and where flocculation occurs in the estuary below River Mile 40. Riverbed sediments upstream from the Plant normally have about 1 picocurie per gram or less of radiocesium (Du Pont, 1982b).

In 1974, riverbed sediments downstream of the Plant had concentrations of radiocesium of about 2 picocuries per gram near the U.S. Highway 301 bridge and 6.5 picocuries per gram at the South Carolina Highway 119 bridge near Clyo, Georgia (Du Pont, 1982b). Studies performed in 1978 showed that the radiocesium concentrations were about 0.6 picocurie per gram at the control station above the Plant and less than 0.8 picocurie per gram at sampling stations between Little Hell Landing and the Highway 301 bridge (Du Pont, 1982b).

In 1983 the tritium concentrations in the potable water produced by the Beaufort-Jasper and Cherokee Hill water-treatment plants averaged 2100 and 2800 picocuries per liter, respectively, or less than 14 percent of the EPA drinking water standard of 20 picocuries per milliliter; very low concentrations of cobalt-60, strontium-89 and -90, iodine-129, uranium, and plutonium-239 were also measured in the water produced by these plants (Du Pont, 1984).

Whole-body bioaccumulation factors - the ratio of cesium-137 concentrations in fish and cesium-137 concentrations in water - for fish taken from the Savannah River at the U.S. Highway 301 bridge from 1965 to 1970 average about 2300. The mean bioaccumulation factor for 20 species of fish (527 specimens) from Steel Creek was found to be 2019 whole-body and 3029 flesh (Smith et al., 1982; Ribble and Smith, 1983).

The radiation dose to a hypothetical individual on the Plant boundary from 1984 SRP atmospheric releases of radioactive materials was 2.4 millirem maximum and 0.87 millirem average. The average dose from SRP atmospheric releases to persons living within 80 kilometers of the Plant was 0.2 millirem per year. The maximum radiation doses to an individual downriver of the Plant who consumed Savannah River water were 0.2 millirem (adult) at the Cherokee Hill water treatment plant at Port Wentworth, Georgia, (near Savannah) and 0.18 millirem (child) at the Beaufort-Jasper County water treatment plant near Beaufort, South Carolina (Du Pont, 1985a).

The only other nuclear facility within 80 kilometers that has been operational during the operating history of the Savannah River Plant is a low-level-waste burial site operated by Chem-Nuclear Systems, Inc., near the eastern boundary of the Plant. This facility, which started operation in 1971, releases essentially no radioactivity to the environment (Chem-Nuclear Systems, Inc., 1980), and the population dose from normal operations is negligible.

The Plant has monitored onsite streams since the early 1950s. Water quality monitoring in onsite streams shows that radioactive releases prior to entry into the Savannah River are well within DOE concentration guidelines established for releases to uncontrolled areas (Ashley and Zeigler, 1981; Ashley, Zeigler, and Culp, 1982; Ashley et al., 1982; Du Pont, 1985b).

Appendix D contains additional information on radiocesium and tritium in the SRP environment.

3.2 FOUR MILE CREEK (C-REACTOR)

3.2.1 GEOGRAPHY

Four Mile Creek follows a generally southwesterly path to the Savannah River for a distance of about 24 kilometers (Figure 3-2). In the Savannah River swamp along the river, part of the creek flow empties into Beaver Dam Creek.

The remainder discharges through an opening in the levee between the swamp and the river, seeps through the levee into the river, or moves through the swamp and mixes with the flows from Steel Creek and Pen Branch (Du Pont, 1985b).

Four Mile Creek and Beaver Dam Creek together drain about 90 square kilometers. Reactor cooling water from C-Area is discharged to Four Mile Creek. After the junction with the C-Reactor cooling water, the creek flows about 11 kilometers before entering the Savannah River swamp (Du Pont, 1985b).

3.2.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

The most recent archaeological and historic resources survey of the Four Mile Creek watershed area was conducted from May through August 1984. A total of 25 sites were located in the watershed during this survey (see Figure E-1 in Appendix E). Only one site (38BR548) in the Four Mile Creek survey area could be affected by the proposed cooling-tower alternatives for C-Reactor. Site 38BR548 is a small prehistoric lithic and ceramic scatter located on a terrace edge adjacent to the bank of the northern branch of Four Mile Creek. No further work has been recommended for this site, because the potential yield of additional research information is negligible.

3.2.3 HYDROLOGY

The average flow upstream of any SRP discharge to Four Mile Creek is about 0.015 cubic meter per second, which is increased by SRP discharges and drainage to about 0.6 cubic meter per second just upstream from the confluence with the C-Reactor discharges. After the junction with the C-Reactor cooling water discharge, the creek flows about 11 kilometers before entering the river swamp at flow rates exceeding 11 cubic meters per second during periods of C-Reactor operation (Lower, 1985).

Prior to 1951, Four Mile Creek was a small, single-channel, meandering creek flowing through broad, heavily vegetated floodplains. C-Reactor discharges changed the creek to a wide, multichannel, braided stream system flowing within denuded floodplains (Ruby, Rinehart, and Reel, 1981). Severe erosion straightened, widened, and deepened sections of the stream channel immediately below the reactor discharge point. Further downstream, multiple channels formed across the floodplain to accommodate the increased flow and sediment load. A combination of thermal stress, flooding, and root disturbance caused extensive vegetative loss in a zone around the creek. Deltas accreted at the stream mouth, where much of the substantial volume of eroded material was deposited. The initial rapid progression of deposition gradually tapered off as the drainage system increased in size. Present deposition rates are slow, and minor recolonization of thermally resistant vegetation has begun (Ruby, Rinehart, and Reel, 1981).

Table 3-11 provides a comparison of temperature and dissolved oxygen data from sampling stations above and below C-Reactor discharges (Du Pont, 1985b).

Table 3-11. Temperature and Dissolved Oxygen in Four Mile Creek[a]

Location	Mean temperature (°C)	Mean dissolved oxygen (mg/l)
Four Mile Creek upstream of C-Reactor	16.0	7.6
Four Mile Creek downstream of C-Reactor at Road A	38.5	6.6

[a]Source: Adapted from Jacobsen et al., 1972; Du Pont, 1985b.

Relative to upstream concentrations from the Four Mile Creek Road A-7 site, concentrations of sulfates, aluminum, calcium, and sodium were slightly to significantly reduced at the mouth of Four Mile Creek (Table 3-12). Some buffering might thus have occurred in the onsite swamp for the Four Mile Creek flow prior to the river confluence; however, concentrations of chlorides and total iron were unchanged or were increased (Du Pont, 1985b).

Table 3-12. Four Mile Creek Water Quality

Parameter, mean concentration (mg/l)[b]	Four Mile Creek upstream of C-Reactor at Road A-7	Four Mile Creek downstream of C-Reactor at the mouth
pH (units) (range)	5.0-7.6	5.7-7.9
Chlorides	3.3	4.84
Sulfates	5.94	5.45
Aluminum	0.53	0.43
Calcium	3.40	2.00
Sodium	10.8	6.32
Iron, total	0.29	0.33
Mercury, total	0.001	<0.002

[a]Source: Adapted from Du Pont, 1985b.
[b]Except as noted.

3.2.4 ECOLOGY

3.2.4.1 Terrestrial Ecology

The Four Mile Creek floodplain has approximately 1900 acres of wetlands, which is principally (72 percent) bottomland hardwoods. Downstream of the C-Reactor outfall, open water and emergent marsh near the stream have replaced the original hardwood community. Away from the thermally affected areas in the floodplain, hardwoods occupy 445 acres. Overall, approximately 60 percent (1147 acres) of the Four Mile Creek wetlands have been impacted by C-Reactor discharges (Du Pont, 1985b).

The star-nosed mole, marsh rabbit, beaver, muskrat, rice rat, river otter, and mink are mammals commonly associated with wetland/floodplain habitats. Studies indicate that none of these mammals inhabit reactor effluent streams on the Savannah River Plant during periods of elevated water temperatures. Beaver and otter, however, have been found to reoccupy these streams within 24 hours of reactor shutdown (Du Pont, 1985b).

Waterfowl use of Four Mile Creek is associated primarily with the delta area where Four Mile Creek empties into the Savannah River swamp. A census of this system and the stream deltas was taken by aerial surveys weekly from November 1 to April 1, from 1981 to 1983. In addition, ground counts were conducted between October and March, 1981 to 1984 (Du Pont, 1985b).

The Savannah River Swamp System is used extensively by waterfowl, particularly during the fall and winter months when these areas provide foraging habitat for migratory species. Based on roost counts, 1200 wood ducks and mallards wintered (1983-1984) in the Steel Creek delta and associated areas. Waterfowl use of the swamp normally is associated with open areas with sparse vegetation caused by increased flows and heated effluent. Of the 12 waterfowl species, researchers have performed the most thorough studies of the foraging ecology of the wood duck, followed by that of the mallard. Most of the swamp (thermal, post-thermal, and nonthermal) was used by migrating wood ducks from October through March. Wood duck use of thermal areas of Four Mile Creek began to decline in late February and shift to other areas of the swamp. Mallard ducks use the Four Mile Creek delta area during the winter if water levels are low (Du Pont, 1985b).

Approximately 22 species of amphibians and reptiles reside in the natural (i.e., nonthermal) streams and swamps of the Savannah River Plant. All of these species have also been reported in the post-thermal areas of Steel Creek (Du Pont, 1985b).

No amphibians or reptiles are known to persist on a routine basis in areas of severe thermal alteration, although some species of frogs live in aquatic habitats that experience elevated temperatures, and some have deposited eggs in aquatic sites where extreme temperatures occurred. Frogs and toads exhibit life history changes under elevated thermal conditions, particularly as tadpoles, by developing and metamorphosing more rapidly and at smaller sizes than larvae developing under normal temperature conditions (Du Pont, 1985b).

The slider is the most prevalent turtle on the Plant. This species apparently thrives in areas of moderately elevated water temperatures; here they have faster growth rates and attain larger body sizes than turtles from local natural habitats. These changes can be attributed to improved diet quality, a longer growing season, and more rapid ingestion rates (Du Pont, 1985b).

A few other reptile species, primarily water snakes and turtles, might also occur in thermally affected areas, but not in numbers characteristic of ambient-temperature streams in the region (Du Pont, 1985b).

No self-sustaining reproducing populations of the American alligator have been observed in Four Mile Creek or its delta (Du Pont, 1985b). Wood storks were observed feeding in the Four Mile Creek swamp area in 1984 but not in 1983 (Coulter, 1986).

3.2.4.2 Aquatic Ecology

Aquatic Flora

Four Mile Creek is a relatively deep (0.3- to 1.5-meter), fast-flowing (about 140 centimeters per second) stream above its confluence with the Savannah River swamp. In this area the flora is sparse, reflecting the influence of high flow and elevated (greater than 40°C) water temperatures. The substrate is primarily sand, organic matter, silt, and clay. In backwaters and shallow areas, particularly on clay outcrops, thick mats of bluegreen algae cover the bottom. Tag alder and wax myrtle dominate the riparian vegetation. Further downstream toward the swamp, the stream is braided over a marsh-like area where a few standing dead bald cypress remain. In this area, defined and deeper channels are relatively free of vegetation, but there are thick growths of sedges on the banks. Thick mats of blue-green algae cover the shallower areas. Deeper substrates (mainly sand) are void of vegetation (Du Pont, 1985b).

Aquatic Fauna

Studies conducted for the Comprehensive Cooling-Water Study sampled macroinvertebrates from the lower and middle reaches of Four Mile Creek between November 1983 and May 1984. In addition, samples were collected from the mouth of Four Mile Creek from September 1982 through August 1983 (Du Pont, 1985b; Appendix C).

Four Mile Creek had the fewest taxa (16 to 29) and nearly the lowest density considering all sampling methods (natural and artificial substrates) of all SRP streams sampled, including the thermally disturbed sites (Du Pont, 1985b; Appendix C). The macroinvertebrates were dominated by nematode roundworms (Nematoda), segmented worms (Oligochaeta), and midges (Diptera). Also collected - in decreasing order of abundance - were caddisflies (Trichoptera), mayflies (Ephemeroptera), snails (Gastropoda), springtails (Collembola), and scuds (Amphipoda).

Many aquatic studies have been conducted during the past 34 years on the Savannah River Plant; however, the most intensive study (the Comprehensive Cooling-Water Study) of the fish community of the SRP streams and the Savannah River began in 1983 (Du Pont, 1985b). Appendix C summarizes the results of this investigation and presents additional pertinent data.

Creek flows and reactor effluent discharge temperatures influence the relative abundance, species composition, and seasonal occurrence of adult fish in Four Mile Creek. Adult fish are most abundant in the mouth of the creek during the winter (December through February), when C-Reactor is operating. Fish avoid this region during periods of excessively high water temperatures (greater than 40°C), which usually occur from May to October.

Upper Four Mile Creek was sampled between Road A and the swamp during a 50-day reactor shutdown in early 1984. Mosquitofish accounted for more than 97 percent of the fish collected at the three sites; other species collected included bowfin, sunfish, mudminnows, shiner, and pickerel. A more diverse assemblage of fish was collected from the lower Four Mile Creek station between the delta and the Savannah River. Gizzard shad (42 percent) and largemouth bass (14 percent) dominated the catch; mosquitofish comprised only 2 percent. The low abundance and low species diversity at both stations is related to the extremely low habitat diversity in Four Mile Creek.

The Comprehensive Cooling Water Study (Du Pont, 1985b) included a sampling program to characterize the adult fish community of SRP streams for fish spawning. Researchers collected ichthyoplankton samples weekly at six locations in Four Mile Creek; they collected 203 ichthyoplankters between March 14 and June 3, 1984. The dominant taxa were sunfish or bass (32 percent) and the brook silverside (14 percent). Other taxa present were shad, crappie, yellow perch, darters, minnows, and carp (Appendix C). Because C-Reactor was not operating during most of March 1984, mean temperatures were only 5° to 10°C above Savannah River temperatures. During this time, ichthyoplankton were absent from the middle and upper reaches of the creek, but were found in low densities in the creek mouth and swamp. During C-Reactor operation, creek temperatures ranged from 30° to 50°C; as expected, few ichthyoplankters were present. Brook silversides and other unidentifiable eggs and larvae collected during C-Reactor operations from the middle and upper reaches might have drifted into the channel from adjacent refuge areas (Appendix C).

Ichthyoplankton abundance in Four Mile Creek and the associated swamp appear to be strongly influenced by water levels in the Savannah River (Du Pont, 1985b; Appendix C). High river flows probably transport ichthyoplankton into thermally impacted portions of the swamp from adjacent unimpacted areas. In addition, some fish might use thermally impacted areas for spawning during high river flows because flow patterns for the heated water are altered dramatically during such periods.

3.2.5 RADIOACTIVITY RELEASES AND RADIONUCLIDE TRANSPORT

Approximately 53.4 curies of cesium-137 (decay corrected to 1980) have been released to Four Mile Creek. Of this total, about 31.5 curies were released to the creek from the F- and H-Areas, where the stream flow averages less than 0.5 cubic meter per second (Lower, 1984; Lower and Hayes, 1984). The remainder (21.9 curies) was released from the C-Reactor area, where the cooling water discharge to the creek is about 11 cubic meters per second. Creek sediments at SRP Road A-7 (above the confluence of Four Mile Creek and the C-Reactor cooling water discharge) exhibit average cesium-137 concentrations of 37.5 picocuries per gram, some four times the average concentration in the delta area. Table 3-13 lists radionuclide concentrations in water, sediments, and aerial survey results for Four Mile Creek.

Released tritium remains soluble in Four Mile Creek. Tritium concentrations and river flow are measured routinely at U.S. Highway 301. Comparisons of the amount of tritium released from SRP facilities with the amount of tritium measured in transport in the Savannah River have continued to show excellent agreement (about 97 percent in 1983) (Lower and Hayes, 1984).

Approximately 388,600 curies of tritium were released to Four Mile Creek through 1980. Of this total, about 139,200 curies were released to the creek from the F- and H-Areas. The remainder (249,400 curies) were released from the C-Reactor area (Du Pont, 1985b). Approximately 99 percent of the F- and H-Area tritium was from seepage-basin migration.

3.3 PEN BRANCH AND INDIAN GRAVE BRANCH (K-REACTOR)

3.3.1 GEOGRAPHY

Pen Branch follows a path roughly parallel to Four Mile Creek until it enters the Savannah River swamp (Figure 3-2). The only significant tributary to Pen Branch is Indian Grave Branch, which flows into Pen Branch about 8 kilometers upstream from the swamp. Pen Branch enters the swamp about 5 kilometers from the river, flows directly toward the river for about 2.4 kilometers, and then turns and runs parallel to the river for about 8 kilometers before joining with Steel Creek about 0.8 kilometer from its mouth at the river.

Pen Branch and Indian Grave Branch drain about 56 square kilometers of watershed upstream from the swamp. Indian Grave Branch receives the cooling water from K-Reactor. Upstream from K-Area discharges, the flow of Indian Grave Branch averages about 0.03 cubic meter per second and that of Pen Branch 0.1 to 0.3 cubic meter per second.

3.3.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

The most recent archaeological and historic resources survey of the Pen Branch watershed area, which includes Indian Grave Branch, was conducted from May through August 1984. Forty sites were located in the watershed during this survey (see Figure E-1 in Appendix E). Of the sites found in the Pen Branch area, none is in an area that could be affected by the proposed cooling-tower alternatives for K-Reactor.

Table 3-13. Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Four Mile Creek (C-Reactor)

Location	Water (pCi/l)[a]		Sediment (pCi/gm)[b]	Aerial Survey (μR/hr)[c]	
	Cs-134, Cs-137	H-3	Cs-137	Cs-137 (min)	Cs-137 (max)
Opposite F- and H-Areas	e	e	e	1.2	38.1
Road A-7[f]	e	800,000	18.0	NA	NA
Below F-Area to Road 3	e	e	e	1.2	19.0
Road A	2.08	70,500[d]	37.5	-	1.2
Road A[f]	2.05	61,000	e	NA[g]	NA
Delta	e	e	8.6	1.2	4.8

[a]Three-year-mean concentration unless otherwise noted. Sources: Ashley and Zeigler, 1981; Ashley et al., 1982; Ashley, Zeigler, and Culp, 1982.
[b]Five-year-mean concentration (1977-1981). Source: Lower, 1984.
[c]1979 Survey. Source: Boyns and Smith, 1982.
[d]1980 and 1981 data only.
[e]No data available.
[f]1984 data only. Source: Du Pont, 1985b.
[g]NA = Not available.

3.3.3 HYDROLOGY

Since November 1976, a USGS flow recorder has been maintained at SRP Road A-13.2 on Pen Branch. From 1976 to 1982, the flow at this station ranged from a minimum of 0.6 cubic meter per second when K-Reactor was not operating to a maximum of 26.9 cubic meters per second during simultaneous K-Reactor operation and heavy precipitation. During water year 1982, the mean flow rate at this station was 10.8 cubic meters per second.

Before 1951, Pen Branch was a small, single-channel meandering creek flowing through a broad, heavily vegetated floodplain. K-Reactor effluent changed the creek to a wide, multichannel, braided stream system flowing within denuded floodplains (Ruby, Rinehart, and Reel, 1981). Severe erosion straightened, widened, and deepened sections of the stream channel immediately below the reactor discharge point. Further downstream, multiple channels formed across the floodplain to accommodate the increased flow and sediment load. A combination of thermal stress, flooding, and root disturbance caused extensive vegetative loss around the creek. Deltas accreted at the stream mouth where a substantial volume of the eroded material was deposited. Deposition was initially rapid, and then gradually tapered off as the drainage system increased in size. Present deposition rates are slow, and minor recolonization of thermally resistant vegetation has begun (Ruby, Rinehart, and Reel, 1981).

Data collected under the recent intensive water quality study initiated in July 1983 suggest that input of large flows (11 cubic meters per second) of Savannah River water at high temperatures (40°-70°C) has the most pronounced effect on the water quality of Pen Branch. Concentrations of nutrients, cations, and metals in the thermal portion of Pen Branch reflect those of its source water, the Savannah River (Du Pont, 1985b). Table 3-14 provides a comparison of selected water-quality parameters from sampling points upstream and downstream of K-Reactor discharges.

3.3.4 ECOLOGY

3.3.4.1 Terrestrial Ecology

Indian Grave Branch/Pen Branch have about 1730 acres of wetlands upstream of the swamp. Emergent marsh (115 acres) and open water (145 acres) are common below the K-Reactor discharge point. Some hardwoods exist on the outer perimeter of the thermally affected areas (326 acres), but most occur in nonthermal tributaries (338 acres) or upstream of the K-Reactor discharge (724 acres). K-Reactor cooling water releases have altered more than 38 percent (670 acres) of the Indian Grave Branch/Pen Branch forested wetlands (Du Pont, 1985b). Wildlife and the habitat for wildlife in the Pen Branch system are similar to those found in the Four Mile Creek area (Section 3.2.4.1).

Table 3-14. Pen Branch and Indian Grave Branch Water Quality: November 1983 to May 1984[a]

Parameter, mean concentration (mg/l[b])	Pen Branch upstream of K-Reactor at Road B	Indian Grave Branch downstream of K-Reactor	Pen Branch downstream of K-Reactor at Road A-13
Temperature (°C)	12.4	57.6[c]	49.8[c]
Dissolved oxygen	8.4	5.7	5.9
pH (units) (range)	5.3-8.5	5.9-6.7	5.6-8.1
Total suspended solids	10.5	11.7	25.1
Chloride	2.3	5.2	5.1
Phosphorus, total	0.029	0.078	0.083
Nitrate-nitrogen	0.035	0.289	0.266
Calcium, total	3.7	3.0	2.8
Aluminum, total	0.57	1.35	1.58
Sodium, total	1.7	5.3	5.5
Iron, total	0.54	1.06	1.22

[a]Adapted from Du Pont, 1985b.
[b]Except as noted.
[c]During reactor operations; other tabulated values represent measurements made during reactor operations and during periods of reactor shutdown.

3.3.4.2 Aquatic Ecology

Aquatic Flora

The substrate from the upper reaches of Pen Branch is primarily sand and silt, with interspersions of leaf packs, woody debris, macrophytes and algae, and isolated gravel beds (Du Pont, 1985b). Blue-green algal mats similar to those in Four Mile Creek cover the substrate. Riparian vegetation includes sedges, grasses, wax myrtle, and buttonbush, while duckweed is abundant in the many side pools and channels.

The delta region of Pen Branch is characterized by an open and closed canopy of living and dead bald cypress and tupelo. Many channels braid through the area in a shallow sheet flow. Dominant vegetation consists of smartweed, arrowhead, creeping burhead, water primrose, sedges, and duckweed. Fewer emergent plants are located at the delta closed canopy areas.

Aquatic Fauna

Between November 1983 and May 1984, studies for the Comprehensive Cooling-Water Study sampled macroinvertebrates from one station in the main Pen Branch channel and two stations in the Pen Branch delta (Du Pont, 1985b; Appendix C). The main channel of Pen Branch is dominated by (in decreasing abundance) segmented worms (Oligochaeta), midges (Diptera), roundworms (Nematoda), and snails (Gastropoda). Also present were mayflies (Ephemeroptera), caddisflies (Tricoptera), beetles (Coleoptera), scuds (Amphipoda), and mites (Hydracarina).

Nearly twice as many taxa occurred in the delta area than in the main channel. In the delta, sites with a closed canopy exhibited a higher average density (Du Pont, 1985b; Appendix C). Species composition was very similar to that of the main Pen Branch channel (i.e., midges, segmented worms, roundworms, and mayflies dominate).

The dominant adult fish in the nonthermal upper reaches of Pen Branch are sunfish, bullheads, and chubsuckers. Most of these species are benthic in habitat or are found near instream woody structures. Fish species generally associated with fast-flowing waters (i.e., darters) are absent. The thermal reaches of Pen Branch are dominated by shiners, sunfish, madtoms, and darters.

Ichthyoplankton abundance in Pen Branch is very low, ranging from zero to greater than 50 per 1000 cubic meters (Du Pont, 1985b; Appendix C). Among the ichthyoplankton, the dominant species was the mosquitofish, which is more tolerant of high temperatures. The few ichthyoplankters present probably drifted into the main channel from adjacent cooler refuge areas. The area above the reactor discharge is populated by minnows and darters in very low abundance.

3.3.5 RADIOACTIVITY RELEASES AND RADIOLOGICAL TRANSPORT

Approximately 16.2 curies of cesium-137 (decay corrected to 1980) have been released to Pen Branch from the K-Reactor area (Lower and Hayes, 1984), where the creek (Indian Grave Branch) receives a cooling water discharge of about 11.3 cubic meters per second. Sediment samples 8 centimeters in depth obtained from the Pen Branch delta-swamp system below Road A-13.2 typically exhibit cesium-137 concentration less than 1.5 picocuries per gram (Du Pont, 1985b). Table 3-15 lists radionuclide concentrations in water and aerial radiological survey results for Pen Branch and Indian Grave Branch. After receipt of cesium-137 from both Pen Branch and Steel Creek (DOE, 1984b), the sediments at the mouth of Steel Creek exhibit average concentrations of 16.7 picocuries per gram.

Approximately 357,600 curies of tritium were released to Pen Branch from the K-Reactor area through 1980. Approximately 41 percent of this tritium was from the K-Area containment basin migration (Du Pont, 1985b). Released tritium, which remains soluble in Pen Branch and Indian Grave Branch, is released to the Savannah River via Steel Creek. Tritium concentrations and river flow are measured routinely at U.S. Highway 301.

Table 3-15. Radionuclide Concentrations in Water and Sediment and Aerial Radiological Survey Results for Pen Branch and Indian Grave Branch (K-Reactor)

Location	Water (pCi/l)[a]		Sediment (pCi/gm)[b]	Aerial Survey (μR/hr)[c]	
	Cs-134, Cs-137	H-3	Cs-137	Cs-137 (min)	Cs-137 (max)
Road A	1.63	34,700	(d)	-	1.2
Road A[e]	1.52	32,000	(d)	NA[f]	NA
Delta	(d)	(d)	4.7	-	1.2
Steel Creek-Pen Branch Mouth	(d)	(d)	16.7	(d)	(d)

[a] Three-year-mean concentration unless otherwise noted. Sources: Ashley and Zeigler, 1981; Ashley et al., 1982; Ashley, Zeigler, and Culp, 1982.
[b] Five-year-mean concentration (1977-1981). Source: Lower, 1984.
[c] 1979 survey. Source: Boyns and Smith, 1982.
[d] No data available.
[e] 1984 data only. Source: Du Pont, 1985b.
[f] NA = Not available.

3.4 BEAVER DAM CREEK (D-AREA COAL-FIRED POWERHOUSE)

3.4.1 GEOGRAPHY

Beaver Dam Creek is located 1.6 to 3.2 kilometers west of Four Mile Creek; it flows in a southwesterly direction from the 400-D Area through the Savannah River swamp to the Savannah River (Figure 3-2). Beaver Dam Creek is the receiving-water body for the cooling water effluent from the coal-fired powerhouse in the D-Area.

Since June 1974, a flow recorder located 1.6 kilometers downstream from D-Area in Beaver Dam Creek has recorded an average discharge of about 2.4 cubic meters per second during D-Area operation.

3.4.2 HISTORIC AND ARCHAEOLOGICAL RESOURCES

Intensive archaeological and historic resources surveys of the Beaver Dam Creek floodplain area and the area west of the creek in D-Area were conducted during October and November of 1985. Only one site, 38BR450, was located in the watershed during these surveys (see Figure E-1 in Appendix E). Site 38BR450 is considered a significant archaeological resource and will be recommended for eligibility for nomination to the National Register of Historic Places.

3.4.3 HYDROLOGY

Since placement of the heavy-water plant on standby status in 1982, the only direct thermal input to Beaver Dam Creek has been that resulting from the powerhouse operations. Thermal effluent also enters the lower portion of Beaver Dam Creek via Four Mile Creek, which receives C-Reactor discharges. The water from Beaver Dam Creek mixes with part of the flow from Four Mile Creek in the onsite swamp before it is discharged to the Savannah River through the mouth of Beaver Dam Creek (Jacobsen et al., 1972). Data from the water quality station at the mouth of Beaver Dam Creek thus reflects inputs from both streams (Du Pont, 1985b). At this station, the flow inputs from Beaver Dam Creek and Four Mile Creek are approximately equal (Du Pont, 1982b).

The water quality station located in Beaver Dam Creek upstream from the onsite swamp is the only station monitored routinely in a thermally impacted zone. From 1973 to 1982, Beaver Dam Creek received heated effluents from both the powerhouse and the heavy-water production facilities. Since June 1974, flows in the creek have ranged from about 1.2 to 5.6 cubic meters per second (Du Pont, 1985b). With the exception of temperature criteria, all other water classification requirements for Class B streams (see Section 3.1.5.1.2) were met at this station. Water quality data for selected parameters are provided in Table 3-16.

Table 3-16. Beaver Dam Creek Water Quality Downstream of All 400-D Area Effluents (November 1983-May 1984)[a]

Parameters	Mean concentration (mg/l[b])
Temperature (°C)	21.9
Dissolved oxygen	7.5
pH (units) (range)	6.4-7.6
Chlorides	5.8
Nitrate + nitrite (as N)	0.24
Iron, total	1.16
Total alkalinity (as $CaCO_3$)	13.2
Phosphorus, total	0.078
Calcium, total	3.0
Aluminum, total	1.51
Sodium, total	5.6
Suspended solids	46.4

[a]Adapted from Du Pont, 1985b.
[b]Except as noted.

3.4.4 ECOLOGY

3.4.4.1 Terrestrial Ecology

Before the Savannah River Plant began operations, Beaver Dam Creek was probably an intermittent stream. During the construction of facilities in D-Area, a canal was built to carry cooling water to the creek, which discharges after 1700 meters to the Savannah River swamp. A narrow band of bottomland hardwood and scrub-shrub forest borders the stream from the D-Area process-water outfall to the swamp (Du Pont, 1985b).

Current D-Area powerhouse thermal discharges, combined with the slow-flowing backwaters along the creek, have provided habitat for a dense population of alligators. A minimum of 28 alligators representing multiple size classes (equivalent to age classes) longer than 1 meter inhabit this stream (based on aerial surveys from December 1983 to March 1984). Subsequent ground surveys in April and May 1984 resulted in the capture of 11 alligators representing age classes of 1-, 2-, and 3-year-olds. With the exception of one 3-year-old, the other 10 alligators were probably not large enough to have been observed during the aerial surveys. The backwater areas along the creek provide excellent breeding and nesting habitat; they probably support a self-sustaining alligator population, because both adult and juvenile sizes have been observed (Du Pont, 1985b).

In 1983 between 306 and 363 wood storks were observed onsite from June 21 to September 29 (Smith et al., 1983; Coulter, 1986). There were a total of 15 group sightings during 35 observation days, with 80 percent of the sightings occurring on Beaver Dam Creek (7 sitings) and Steel Creek (5 sitings) (Coulter, 1986). The 12 sightings that were made on the two creeks accounted for more than 90 percent of the total members of wood storks observed on the site (Coulter, 1986).

In 1984, more than 370 wood storks were observed on the Plant from May 20 to November 16. There were a total of 59 group sightings during 89 observation days, with more than 54 percent of the sightings occurring on Beaver Dam Creek and Steel Creek (Coulter, 1986). Use of Four Mile Creek was documented in 1984 for the first time and accounted for 22 percent of the group sightings (Coulter, 1986). The 32 sightings that were made on Beaver Dam Creek (19 sitings) and Steel Creek (13 sitings) accounted for 54 percent of the total number of wood storks observed on the Plant (Coulter, 1986).

Apparently wood storks were more widely dispersed over the site in 1984 than 1983. However, some of the variability may be explained by an increased effectiveness of observers in locating birds, a more intensive survey, and a survey of longer duration.

Estimates of prey density and biomass from the 1984 and 1983 Steel Creek sites were highly variable. Generally, however, there was a higher density and biomass of prey in 1984. No prey density or biomass data were collected on Beaver Dam Creek (Coulter, 1986).

3.4.4.2 Aquatic Ecology

Aquatic Flora

Immediately below the discharge structure, Beaver Dam Creek is characterized by a deep channel (1 to 2.5 meters) and a substrate of shifting sand, fly ash, organic deposits, and occasional clay outcrops (Du Pont, 1985b). Riparian vegetation is dominated by wax myrtle and tag alder. The aquatic flora are sparse, reflecting the influence of high flow and elevated water temperatures.

Aquatic Fauna

Studies conducted for the Comprehensive Cooling Water Study sampled macroinvertebrates from the middle reaches of Beaver Dam Creek between November 1983 and May 1984. In addition, samples were collected from the mouth of Beaver Dam Creek from September 1982 through August 1983 (Du Pont, 1985b; Appendix C).

More species were collected in Beaver Dam Creek than in the other thermally influenced streams (i.e., Four Mile Creek and Pen Branch). Dominant macroinvertebrate species were segmented worms (Oligochaeta), roundworms (Nematoda), midges (Diptera), stoneflies (Plecoptera), and snails (Gastropoda). Also found in lesser abundance were mites (Hydracarina), scuds (Amphipoda), dragonflies (Odonata), and caddisflies (Tricoptera).

The dominant species of adult fish in Beaver Dam Creek are mosquitofish, sunfish, and gizzard shad (Bennett and McFarlane, 1983; Du Pont, 1985b). Relative abundance and species composition increase toward the creek mouth and swamp where greater habitat diversity occurs and temperatures are somewhat moderated (Du Pont, 1985b).

Ichthyoplankton in Beaver Dam Creek reflected the adult composition, with sunfish or bass being dominant. Although thermally influenced, Beaver Dam Creek exhibited greater density and species diversity than the other thermal streams (i.e., Four Mile Creek and Pen Branch), but it did not produce the density expected considering the lower level of thermal loading (Du Pont, 1985b; Appendix C).

3.4.5 RADIOACTIVITY RELEASES AND RADIONUCLIDE TRANSPORT

Approximately 0.004 curie of cesium-137 (decay corrected to 1980) has been released to Beaver Dam Creek from D-Area (Lower and Hayes, 1984). Data on cesium-137 concentrations are not available for Beaver Dam Creek. However, based on the release data, such concentrations are considered to be negligible.

Released tritium remains soluble in Beaver Dam Creek. Approximately 124,100 curies of tritium were released to Beaver Dam Creek from D-Area through 1980 (Du Pont, 1985b).