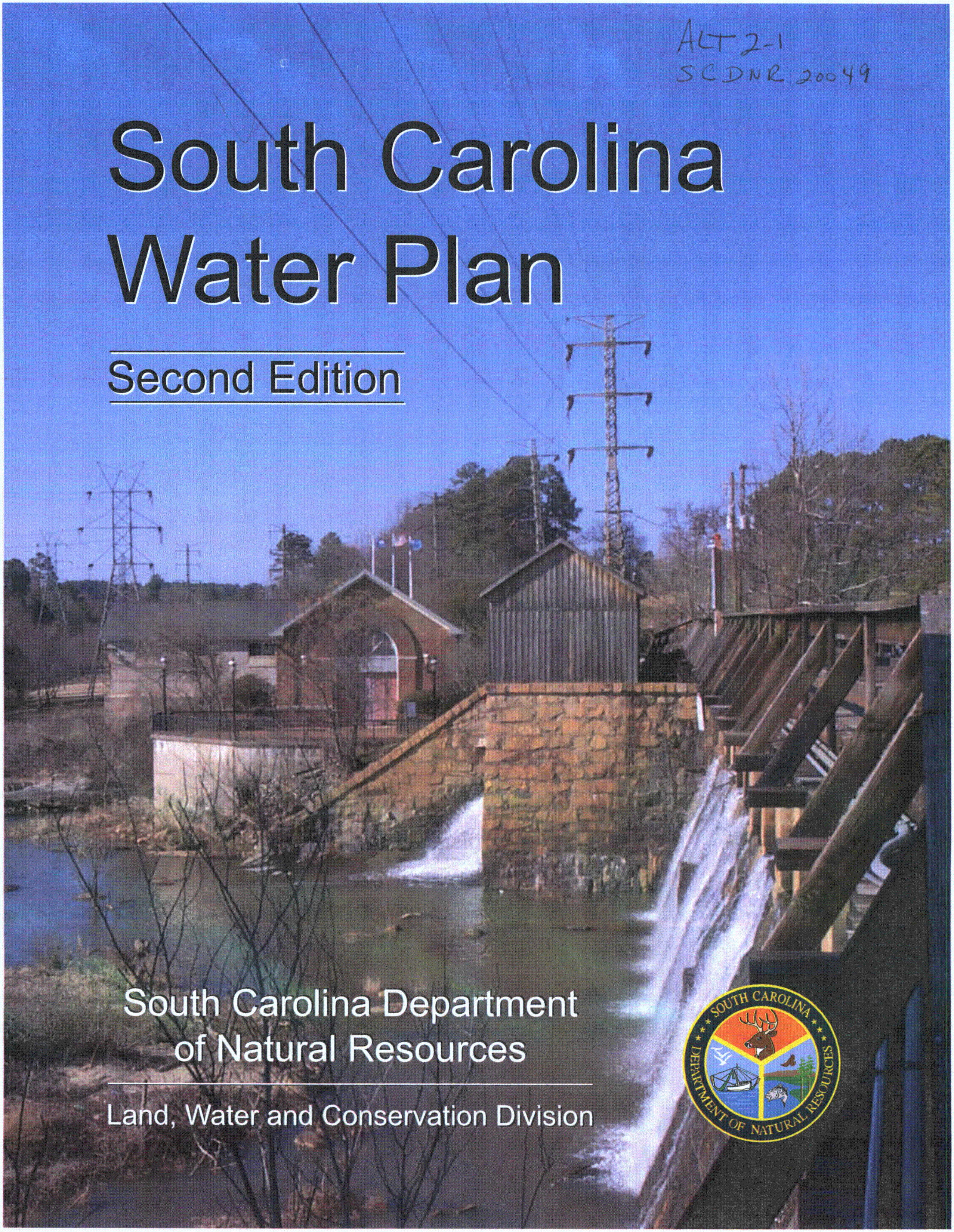
South Carolina Water Plan

Second Edition



South Carolina Department of Natural Resources

Land, Water and Conservation Division

On the cover: Water from the Columbia Canal falls over a spillway behind the old Columbia Water Works complex on the Congaree River in Columbia, South Carolina. The Columbia Canal, originally completed in 1824 to provide navigation past local rapids, was redesigned in 1891 to provide hydroelectric power to local industries. The red brick building in the center of the photograph was built in the 1890's and houses the pumps once used by the City of Columbia to supply water to its citizens. Although use of this pumping plant ended in the early 1970's, the canal still serves as a source of public-supply water and hydroelectric power for the City. Today, these buildings and the canal form part of Columbia's Riverfront Park. (Photograph by Andrew Wachob, S.C. Department of Natural Resources.)

SOUTH CAROLINA WATER PLAN

Second Edition

by

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STATE OF SOUTH CAROLINA
The Honorable Mark H. Sanford, Governor

South Carolina Department of Natural Resources

DNR

South Carolina Natural Resources Board

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The following letter transmitted the *South Carolina Water Plan–Second Edition* to:

Mark Sanford, Governor of South Carolina
David H. Wilkins, Speaker of the South Carolina House of Representatives
André Bauer, President of the South Carolina Senate and Lieutenant Governor

The *South Carolina Water Plan–Second Edition* is presented herewith in accordance with the provisions of the Water Resources Planning and Coordinating Act, §49-3-10, et. seq., Code of Laws of South Carolina, 1976, as amended. This act states that the Department of Natural Resources "shall advise and assist the Governor and General Assembly in: (1) Formulating and establishing a comprehensive water resources policy for the State, including coordination of policies and activities among the State department and agencies;..."

The Department of Natural Resources published the first State Water Plan in 1998. This second edition incorporates the experience and knowledge we gained from the severe drought of 1998-2002 and other timely water resources issues.

The plan contains the Department's conclusions and recommendations on the policies that it believes the State of South Carolina should adopt at this point in our history for the efficient, equitable, and environmentally responsible science-based management of its water resources. A principle concern has been sustainability.

The Department has examined virtually the entire range of water-resources issues facing the State, including the effects of neighboring states on our water availability. The problems of water shortage have been addressed, and guidelines and considerations for management of water in lakes, streams, and aquifers have been included. Each of the important purposes for which water is used has been studied, and appropriate guidelines have been drawn for insuring efficient, equitable use of these resources. While the solutions proposed may not be those that are finally adopted, they will certainly provoke further awareness and constructive thinking about the water-resource issues facing our State. Water resources planning is a continuous process.

The Department recognizes that the effective management of the State's water resources is beyond the scope of any one agency or organization and will require cooperation and shared responsibility among federal, State, and local agencies, public and private parties.

The Department submits this *South Carolina Water Plan–Second Edition* to you with the earnest hope that it will contribute importantly to the timely and wise use of South Carolina's most precious natural resource – our water.

The Department appreciates the valuable input and cooperation of the S.C. Department of Health and Environmental Control.

Respectfully submitted,

Michael McShane
Chairman

PREFACE

South Carolina experienced one of its worst multiyear droughts on record during the period from June 1998 to August 2002. Average precipitation was 10-30 percent below normal during the drought. Streamflows were at historic lows throughout the State, threatening water-supply intakes and causing saltwater intrusion in coastal areas. Lakes were being drained to perilously low levels in order to sustain water demands and downstream flows. Levels in Lake Thurmond, for example, dropped so low that the lake had only a few months of storage remaining for downstream flow requirements. Lakes in North Carolina, on the Yadkin-Pee Dee River, were being drained to meet water demands of North Carolina and of major industries in South Carolina, and to prevent saltwater intrusion from contaminating supply intakes in the Grand Strand area. Ground-water levels in shallow and deep aquifers dropped to record lows. Pumps in municipal and domestic wells had to be lowered, wells had to be deepened and, in some cases, new wells had to be drilled to keep pace with declines. Ground water levels in some areas of the State declined to the point that streams were losing water to the ground, the reverse of what normally occurs.

What if the drought had continued for another year? The thought of this had policy makers thinking about water. Suddenly, lawyers were reviewing State water laws and water-resource managers were thinking of more effective ways to manage water in the State. The drought, in fact, marked a turning point in how we viewed our water resources. The belief that only water-starved western states could run out of water was replaced by the stark realization that we could run out of water too. Water could no longer be taken for granted in South Carolina. This is the lesson that we learned from the drought.

Undoubtedly, the recent drought was one of the worst on record, but its effects were also compounded by population increases that have taken place during the past 50 years. South Carolina's population has nearly doubled during this period, growing from 2.1 million in 1950 to 4.0 million in 2000. The population will continue to grow and the demand for water will correspondingly increase, but the amount of water that is available will remain essentially the same. What steps should the State take now to ensure that adequate amounts of water will be available in the future? This revision to the *South Carolina Water Plan* addresses this question. The *Water Plan* recognizes the economic importance of water and the multitude of uses that it has, from hydropower generation and water supply, to recreation and tourism. A fair and balanced approach to managing the resource must consider all users. The goal is to wisely use the water that is available to meet growing demands without jeopardizing the health, welfare, and quality of life of future generations. The *South Carolina Water Plan* provides guidelines for achieving such a goal.

EXECUTIVE SUMMARY

In 1998, the Department of Natural Resources published the first edition of the *South Carolina Water Plan*, a guide for managing the State's surface and ground water in order to maximize the use of this resource while protecting it for future use. In the middle of that same year, South Carolina entered into one of the worst droughts in its history, lasting until late in 2002. That drought reminded us that the State's water supply is not unlimited, and that careful management is needed to ensure water availability for future generations. This second edition of the *Water Plan* incorporates the experience of that drought and the lessons learned from it into the management strategies presented in the original *Water Plan*.

One of the more important recommendations in this *Water Plan* is the proposal to regulate surface and ground water withdrawals. Presently, there are no limitations on the amount of water that can be withdrawn from a river, and ground water withdrawals are regulated only in coastal counties. In order to sustain the resource and protect the environment and the rights of all water users, this edition recommends that the State be authorized to allocate and regulate surface and ground water withdrawals. The need for such authority was evident during the recent drought, when water levels in aquifers and flow rates in streams were at record lows, causing conflicts among competing uses. Regulating withdrawals would provide a mechanism to alleviate these conflicts and would ultimately benefit all users by encouraging conservation and efficiency.

This edition of the *Water Plan* also introduces a water-sharing strategy that relates lake inflows and lake levels to downstream releases and other lake withdrawals in an effort to balance and mitigate the negative impacts that water shortages have on all surface-water users. This strategy emphasizes the need for all users to share the burden of water shortage during prolonged droughts.

Because water availability is intrinsically tied to the quality of the water, this *Water Plan* provides an overview of existing water-quality regulations and programs. These programs have been successful in improving the quality of water in our streams, lakes, estuaries, and aquifers. The leading cause of water pollution in the State is polluted runoff. Sources of this pollution are diffuse and, therefore, difficult to control. Reducing polluted runoff must be the collective responsibility of government, agriculture, industry, and all citizens and can best be achieved by using an integrated watershed-management approach that addresses all water-related activities within an entire watershed.

Monitoring of the State's water resources is critical for evaluating the severity and duration of droughts and for predicting water shortages. One of the most important components of the hydrologic system is the shallow ground water that occurs in water-table aquifers and continually discharges to streams, sustaining flows during droughts. The *Water Plan* recommends the establishment of a Statewide water-table monitoring network to improve our capability of assessing hydrologic conditions and managing droughts.

Because three of the State's four major river basins—and thus much of its surface water—are shared with neighboring states, it is important that South Carolina establish formal mechanisms with Georgia and North Carolina for the equitable apportionment of all water shared with these states. Formal agreements, such as interstate compacts, will promote interstate coordination, reduce potential disputes between the states, enhance the flow regime of many of South Carolina's rivers, and extend the availability of water in during severe droughts.

South Carolina ordinarily receives ample water to meet its needs; however, because of the State's growing population and the uncertain and varying nature of water availability, consideration must be given to resource-management policies that can help maximize water availability. This edition discusses many practical practices and technologies geared toward maximizing availability, such as water conservation, construction of new reservoirs, and aquifer storage and recovery programs.

Water planning requires continual reassessment and updating to address changing social, economic, and environmental conditions and to reflect new data, knowledge, and technologies that become available. The effective management of the State's water resources is beyond the scope of any single agency or organization and will require cooperation and shared responsibility among Federal, State, and local entities, as well as public and private parties.

The *Water Plan* concludes with a summary set of recommendations that the Department believes will help protect the State's water resources for future generations and will help mitigate the effects of future droughts and water shortages. While the recommendations proposed in this plan may not be those that are finally adopted, they will certainly provide an awareness of the water resource issues facing our State and stimulate constructive thinking about how best to manage South Carolina's most precious natural resource.

ACKNOWLEDGMENTS

The authors would like to thank the following individuals who provided input with comments and/or reviews of this edition of the *Water Plan*. Their assistance is greatly appreciated.

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INTRODUCTION

The South Carolina Water Resources Planning and Coordination Act of 1967 assigned the overall responsibility for developing a comprehensive water resources policy for the State, including coordination of policies and activities among State departments and agencies, to the South Carolina Water Resources Commission. As part of government restructuring, this act was amended in 1993, and these responsibilities were placed with the South Carolina Department of Natural Resources (DNR).

The water resources policy plan consists of two parts. Phase I—an overall assessment of the water resources of the State—was published as Water Resources Commission Report No. 140, *South Carolina State Water Assessment*. The *Assessment* describes the State's stream, lake, and aquifer systems and provides information relating to the occurrence and availability of water in South Carolina. Phase II outlines guidelines and procedures for managing the State's water resources, and was first published in 1998 by the Department of Natural Resources as the *South Carolina Water Plan*.

Both the *Assessment* and the *Water Plan* must be updated periodically, on the basis of changes in water demand and availability, and the development of new technologies and management strategies. The updating of the *State Water Assessment* is underway. This second edition of the *South Carolina Water Plan* includes experience and knowledge gained from the severe drought of 1998-2002.

PURPOSE

The purpose of this *Water Plan* is to establish guidelines for the effective management of the State's water resources to sustain the availability of water for present and future use, to protect public health and natural systems, and to enhance the quality of life for all citizens.

The *South Carolina Water Plan* outlines procedures for assuring that future water requirements of the State can be met and acknowledges that (1) South Carolina usually possesses an abundance of water; (2) water is a limited natural resource and is a major factor for economic development; (3) there are regional and temporal variations in the amount of available water and in the demand for water; and (4) there are both intrastate and interstate competing demands for water. The *Water Plan* describes the source, availability, and quality of the State's water, as well as the demands for that water. It also outlines procedures by which (1) an accurate inventory of water withdrawn, stored, and discharged will be maintained; and (2) conflicting demands for water and damage to the natural resources will be minimized, especially during periods of water shortage.

LEGAL STATUS OF WATER IN SOUTH CAROLINA

The Supreme Court of South Carolina has established that water is subject to the Public Trust Doctrine and is, therefore, too important to be owned by one person.

> "The underlying premise of the Public Trust Doctrine is that some things are considered too important to society to be owned by one person. Traditionally, these things have included natural resources such as air, water ...and land.... Under this doctrine, everyone has the right to breathe clean air; to drink safe water; ... and to land on the seashores and riverbanks." [Sierra Club v. Kiawah Resort Assoc., 318 S.C. 119, 456 S.E. 2d 397 (1995)]

South Carolina abides by the Riparian Rights Doctrine and incorporates the concept of reasonable use of water in the Riparian Rights Doctrine. The Riparian Rights Doctrine holds that it is a fundamental right of any riparian landowner to the "reasonable use" of water [White v. Whitney Mfg. Co., 60 S.C. 254, 38 S.E. 456 (1901)]. The difficulty with water management is that any limitation the State might place on riparian rights could be challenged in court as a "taking." There is legal precedent, however, that the State has authority to manage water without compensating adversely affected riparians. In Rice Hope Plantation v. South Carolina Public Service Authority [216 S.C. 500, 59 S.E.2d 132 (1950)], the court said that the waters of the State are part of the public domain and the State may authorize the diversion of such waters for any purpose it deems advantageous to the public, without providing compensation to the riparian proprietors injuriously affected. Such a diversion is not a taking of private property by eminent domain, but a disposition by the public of the public property.

WATER RESOURCES MANAGEMENT GOALS

In recognition that the State's waters are part of the public domain, and are to be managed in the best interest of the public, the following are declared to be the water resources management goals of South Carolina:

1. To ensure that water of suitable quality and quantity is available for use when and where needed.
2. To manage the quantity and quality of both surface and ground water in an integrated manner to protect, maintain, and enhance the overall resource.
3. To use the *South Carolina Water Plan* to provide guidance for regional and local water planning efforts.
4. To develop interstate agreements with North Carolina and Georgia for the protection of water quality and quantity and for equitable allocation of surface and ground water.
5. To allocate surface and ground water to ensure the long-term availability of the resource.
6. To have a drought management and mitigation plan that establishes actions and procedures for different drought levels in order to minimize drought impacts.
7. To manage water shortages so that all users would share the burden.
8. To have a flood management and mitigation plan that establishes actions and procedures to minimize flood hazards and protect life and property.
9. To protect freshwater and estuarine ecological functions and habitats.
10. To regulate interbasin water transfers in a way that reflects the variability in water availability, respects the natural systems, and protects the source basin's present and future water demands.
11. To utilize advanced technologies, procedures, and practices to promote more efficient use of water and to maximize water availability.
12. To develop a water-conservation ethic by providing educational opportunities and information to the citizenry.

Some of these goals are already being addressed with existing programs; other goals have yet to be given appropriate attention. All of these goals, however, represent important steps toward the ultimate goal of protecting the State's waters so that this vital resource will be available for the use and benefit of all future generations.

SOUTH CAROLINA'S WATER RESOURCES

Although South Carolina has an abundance of clean, fresh water, it is unevenly distributed in both location and time. Almost all of the State's water is ground water, located beneath the land surface; only about 1 percent of the State's water is surface water. Most of the ground water is located in the Coastal Plain, and most of the surface water is located in large, manmade reservoirs on the major rivers. Water is most abundant during the spring months when streamflows and ground-water levels are at their highest; less water is available during the late summer and early fall, when streamflows and ground-water levels are typically at their lowest.

Although there is much more water under the ground, surface water is the source for most of the large water supplies in the State because of its convenience and availability. Seventy percent of the State's population rely on surface water, and 30 percent rely on ground water (Bristol and Boozer, 2003).

HYDROLOGIC SETTING

The State's physiographic and climatic settings are key factors that determine the availability and distribution of the State's water resources.

South Carolina contains all or part of four major river basins (Figure 1). These major basins, defined by the topography that controls surface water drainage, can be divided into subbasins on the basis of local drainage patterns. The two largest of these basins, the Yadkin-Pee Dee and the Catawba-Santee, encompass about 25 percent and 34 percent, respectively, of South Carolina's area and are shared with North Carolina. The headwaters of most of the major rivers in these two basins are located in North Carolina. The Savannah basin encompasses about 15 percent of the State and is evenly shared with Georgia, with a small area at its northern tip located in North Carolina. The ACE (Ashepoo-Combahee-Edisto) basin, which covers about 26 percent of the State, is the only major basin located entirely within South Carolina.

In South Carolina, the four major basins are divided into 15 subbasins, and these subbasins can be further divided into smaller local watersheds. In fact, the United States Geological Survey (USGS) has delineated more than 1,000 watersheds in South Carolina (Bower and others, 1999).

South Carolina contains parts of three major physiographic provinces that encompass the southeastern United States (Figure 2). These provinces—Blue Ridge, Piedmont, and Coastal Plain—are defined on the basis of physical geography and geology. The boundary between the Blue Ridge and Piedmont is defined by a sharp change in topographic slope at an elevation of about 1,000 feet, but from a hydrologic perspective, the Piedmont and Blue Ridge provinces are essentially the same. The boundary between the Piedmont and Coastal Plain, called the Fall Line, is defined as the surface contact between the metamorphic rocks of the Piedmont and the unconsolidated sediments of the Coastal Plain.

In the Coastal Plain, which encompasses about two-thirds of the State, sediments overlie basement rock (or "bedrock"), thickening from just a few feet near the Fall Line to about 3,800 feet at the southernmost corner of the State (Figures 3 and 4). These sediments form the aquifers that hold most of the State's water. Aquifers—extensive beds of sand or permeable limestone generally bounded above and below by

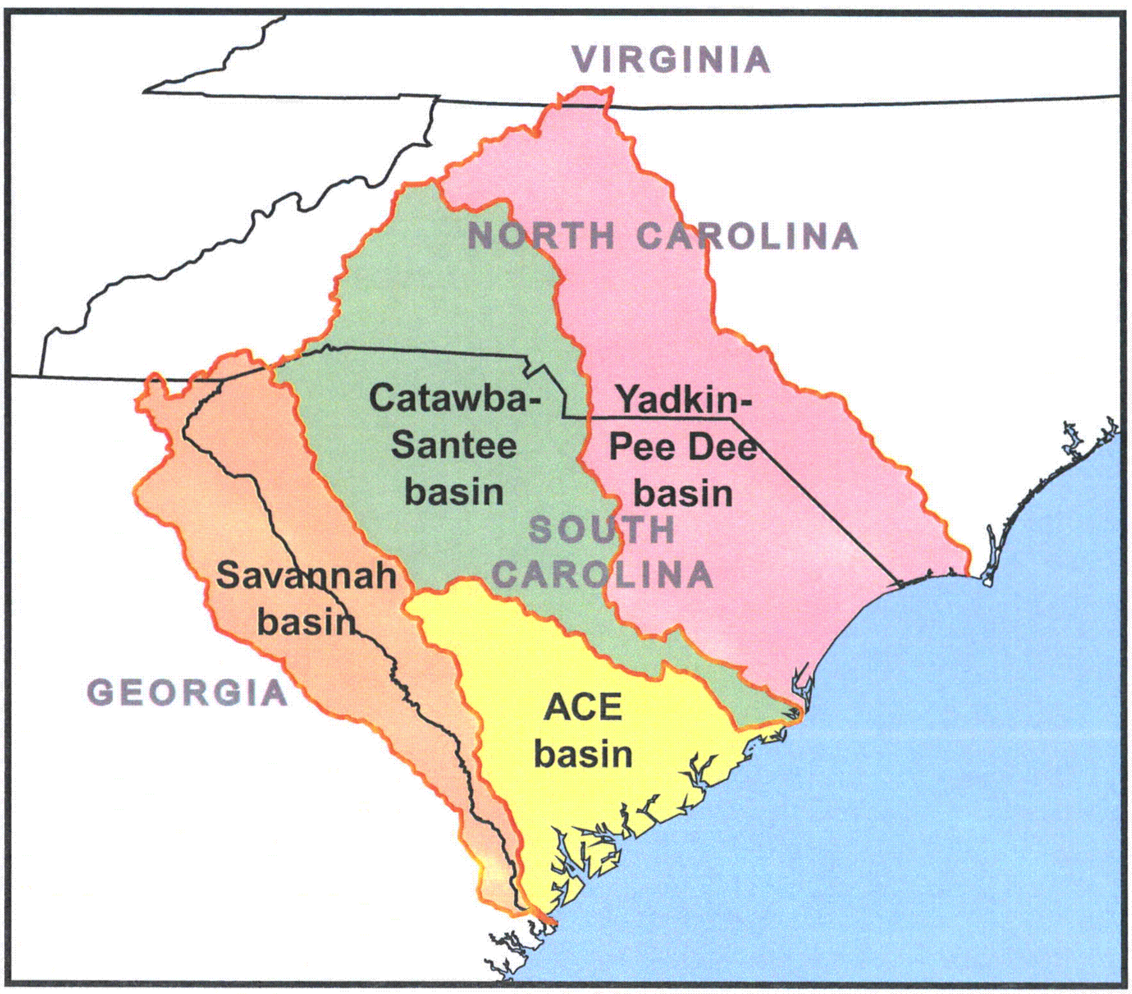


Figure 1. Major river basins in South Carolina. The ACE basin is the Ashepoo-Combahee-Edisto basin.

impermeable clay or rock—hold water in the pore spaces between sand grains or in voids within the limestone rock. Water enters an aquifer primarily in its outcrop area, where the sediments are at or very near to the surface. In this recharge area, precipitation and surface water slowly seep into the permeable sediments to replace water removed from the aquifer elsewhere. The storage capacity of these aquifers is great: probably 95 percent of the State's total volume of ground water is contained in the Coastal Plain aquifers.

In the Piedmont region, which lacks the porous sediments that form aquifers in the Coastal Plain, ground water is stored in fractures in the bedrock and in a soil-like layer of weathered rock called saprolite that rests upon the bedrock. The continuity and permeability of bedrock fractures and the thickness of saprolite control the occurrence of ground water, which is replenished primarily by precipitation seeping into the saprolite and bedrock fractures. The storage capacity of fractures and saprolite is very small compared to that of the Coastal Plain aquifers.

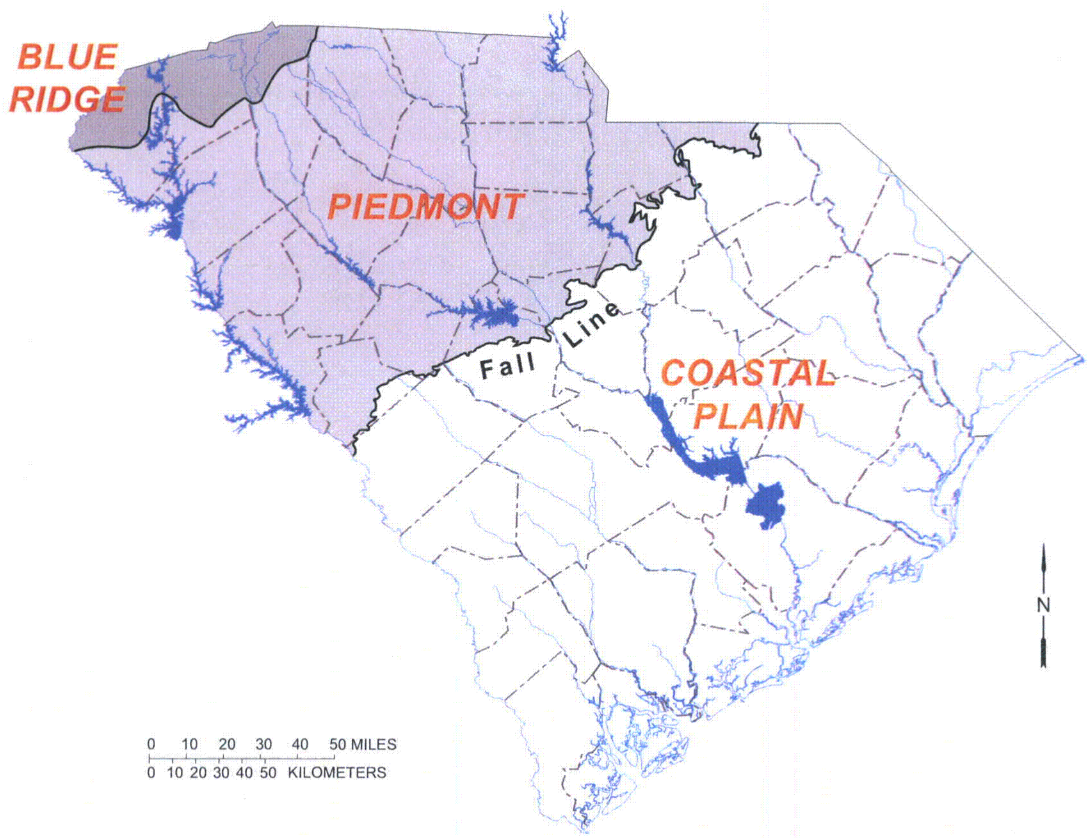


Figure 2. Location of physiographic provinces and the Fall Line in South Carolina.

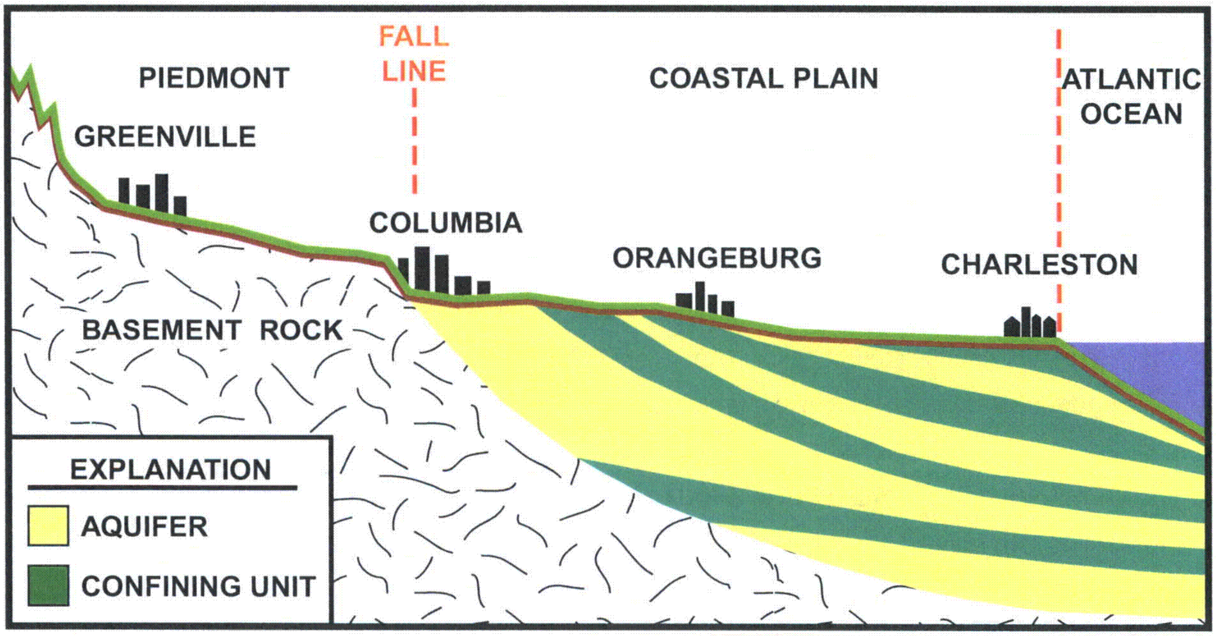


Figure 3. Simplified hydrogeologic cross section through South Carolina.

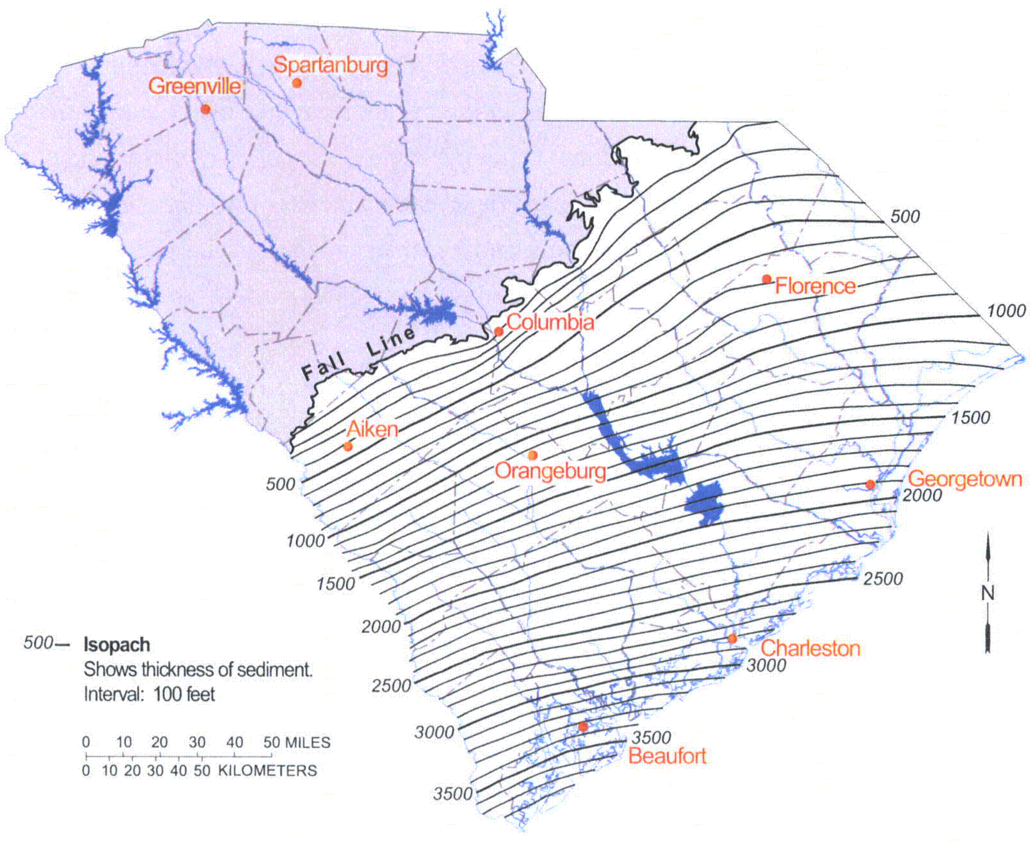


Figure 4. Thickness of Coastal Plain sediments in South Carolina, in feet.

Because watersheds are defined by surface drainage patterns, the movement of surface water and, to a large extent, ground water in shallow water-table aquifers is restricted to the individual basin. The movement of ground water in deeper aquifers, however, is not restricted to local drainage basins.

Surface water and ground water are connected hydraulically, but their interaction is often overlooked in water-resource management considerations. During dry periods, streamflows and lake levels are maintained by discharged ground water (base flow); at other times, aquifers are recharged when water seeps from lakes and streams into the ground. Because many natural processes and human actions affect this interaction, it is important for water managers to consider ground water and surface water as a single resource.

SOUTH CAROLINA'S WATER BUDGET

When water enters a watershed, it becomes part of the total water budget for that watershed, whether it flows on the surface or below it. The water budget equation

Inflow – Outflow = Change in Storage

includes all the water in the watershed.

In a typical year, about 56 inches of water (averaged over the State) comes into South Carolina from all sources. Precipitation is the source of about 48 inches, or 85 percent of the total, and streamflow from North Carolina accounts for the remaining 8 inches. Loss of water from the State occurs primarily through evapotranspiration (the conversion of liquid into vapor by the processes of evaporation and transpiration) and discharge from streams into the ocean. In an average year, 34 inches of water are evapotranspired, 21 inches are discharged into the ocean from streams, and less than 1 inch is discharged into the ocean from aquifers (Figure 5).

Precipitation is distributed unevenly over the State. The mountainous northwestern part of the State receives the most precipitation, the central part receives the least, and coastal areas tend to receive slightly more than inland areas (Figure 6).

Average annual evapotranspiration is also distributed unevenly over the State, being greatest along the coast and in the warmer southern part of the State, and lowest in the cooler Piedmont region (Figure 7).

The annual difference between precipitation and evapotranspiration is greatest in the northwestern part of the State and least in the southern part (Figure 8). When precipitation exceeds evapotranspiration, water is added to the surface- and ground-water systems, increasing streamflow and aquifer storage.

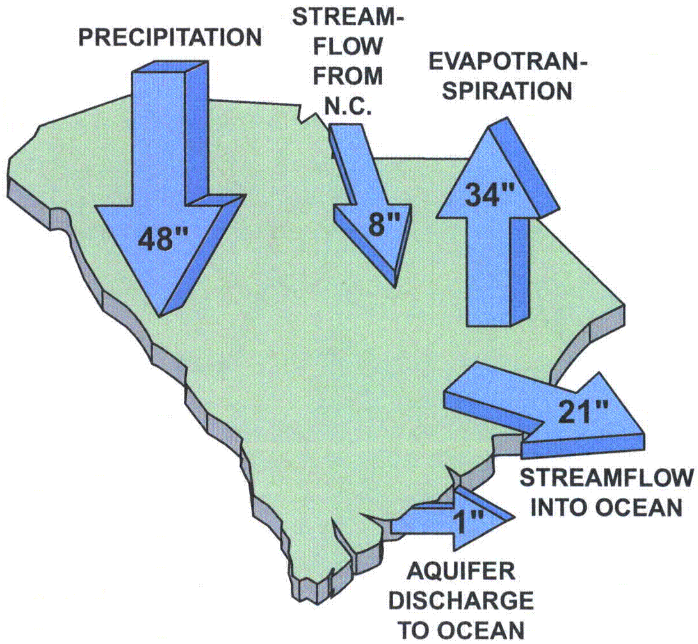


Figure 5. South Carolina's water budget.

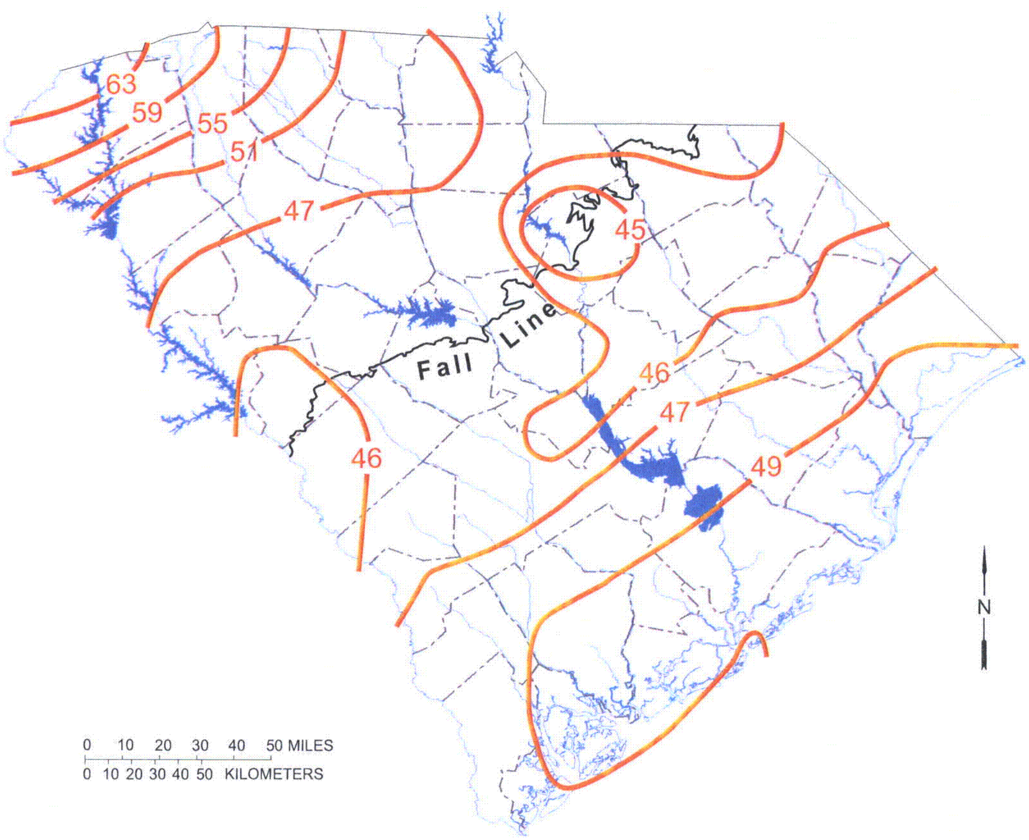


Figure 6. Average annual precipitation, in inches, for the period 1948-1990.

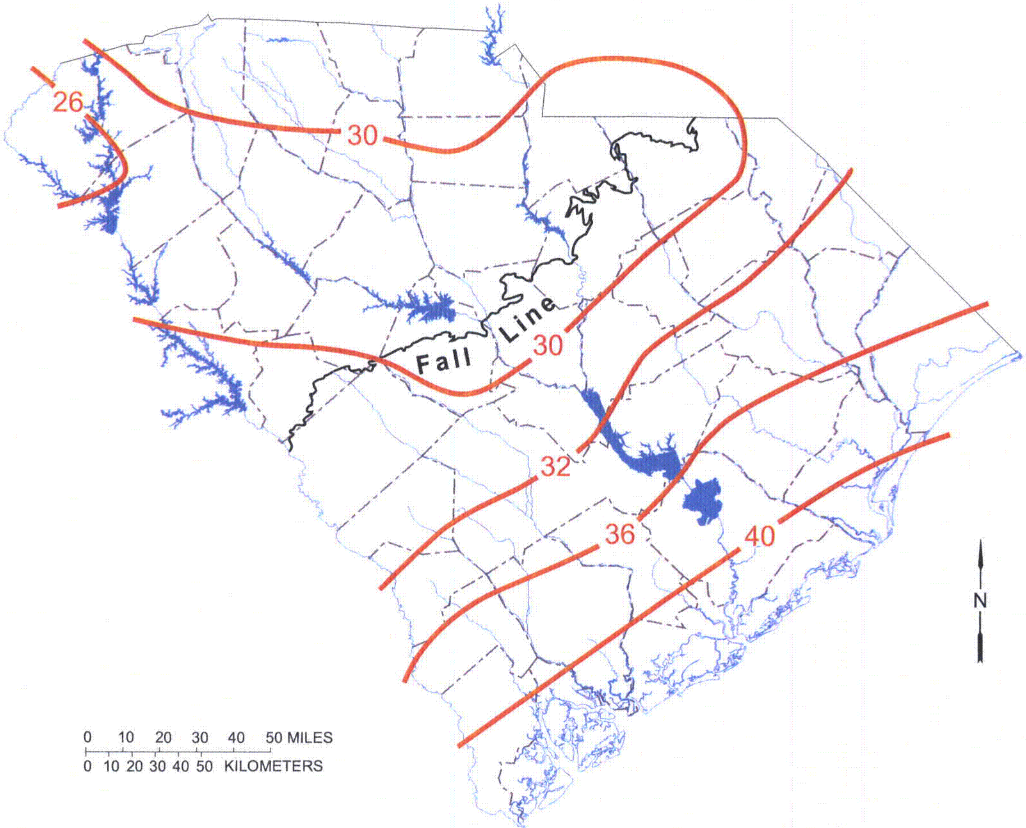


Figure 7. Average annual evapotranspiration, in inches, for the period 1948-1990.

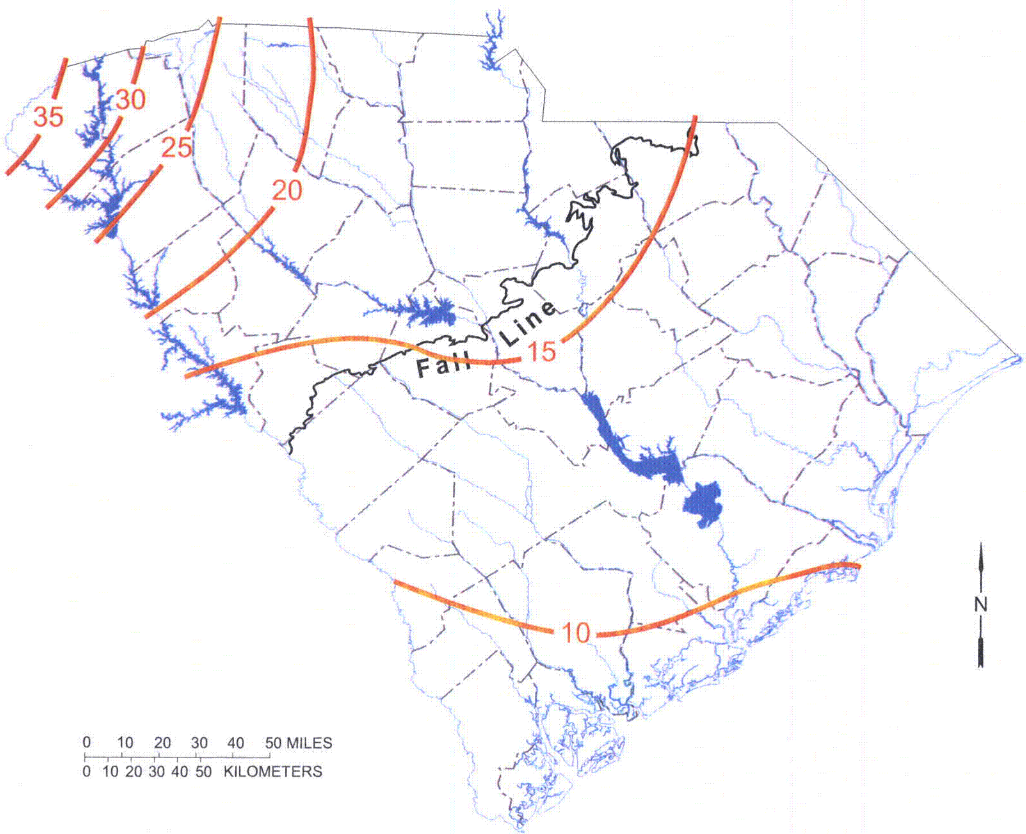


Figure 8. Average annual precipitation less evapotranspiration, in inches, for the period 1948-1990.

VARIATIONS IN WATER AVAILABILITY

The availability of water—especially surface water—is strongly influenced by seasonal variations in precipitation and evapotranspiration. Precipitation is generally high during the summer months and low during the fall months, whereas evapotranspiration is generally high during the warm summer and fall months and low during the cool winter months (Figure 9). As a result, streamflows and lake levels tend to be highest in the winter and lowest in the summer and fall (Figure 10).

Ground-water supplies are also subject to seasonal variation and decline due to prolonged drought, but usually to a lesser degree than surface-water supplies. Ground-water levels lowered during the summer and fall, the result of both increased pumping and reduced recharge, usually recover during the winter and spring, owing to increased aquifer recharge and reduced pumping (Figure 11). Multiyear droughts lower aquifer water levels by limiting the recharge that normally occurs during the wet winter and spring months (Figure 12).

In addition to seasonal variations in the water supply, long-term variations in the climate can, over time, affect the water supply. Climate changes affect precipitation, temperature, and evapotranspiration, gradually changing the "normal" values. Because the normal amount of precipitation is essentially the average annual precipitation for the last 30 years, this value will change as the climate changes. Figure 13 illustrates how the normal rainfall amounts in South Carolina have changed during the 20^{th} century. Over the past 50 years, there has been a trend toward increasing precipitation; a normal amount of rain in the 1990's, for example, would have been a greater-than-normal amount in the 1950's.

One of the biggest challenges in water resources management is satisfying the demands of all users at all times by getting the water where it is needed when it is needed. On average, there is more than enough water in South Carolina to meet the needs of all users, but water shortages can occur because of the variable nature of the surface water supply. Seasonal variations in precipitation can produce extreme variations in streamflow rates; tropical storms or long, steady rainfall events can flood rivers that, during drier months, are reduced to much lower than normal flows (see Table 1). This wide range of surface water availability is a major problem for resource managers trying to allocate and sustain surface water for all users. Compounding this problem is the fact that demand for water is usually greatest during times when the supply is lowest.

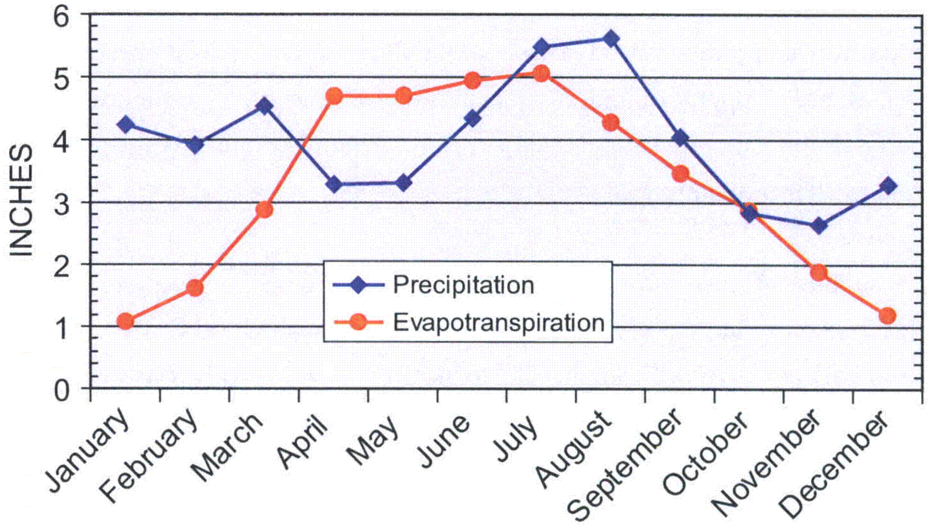


Figure 9. Average annual statewide precipitation and evapotranspiration for South Carolina, by month.

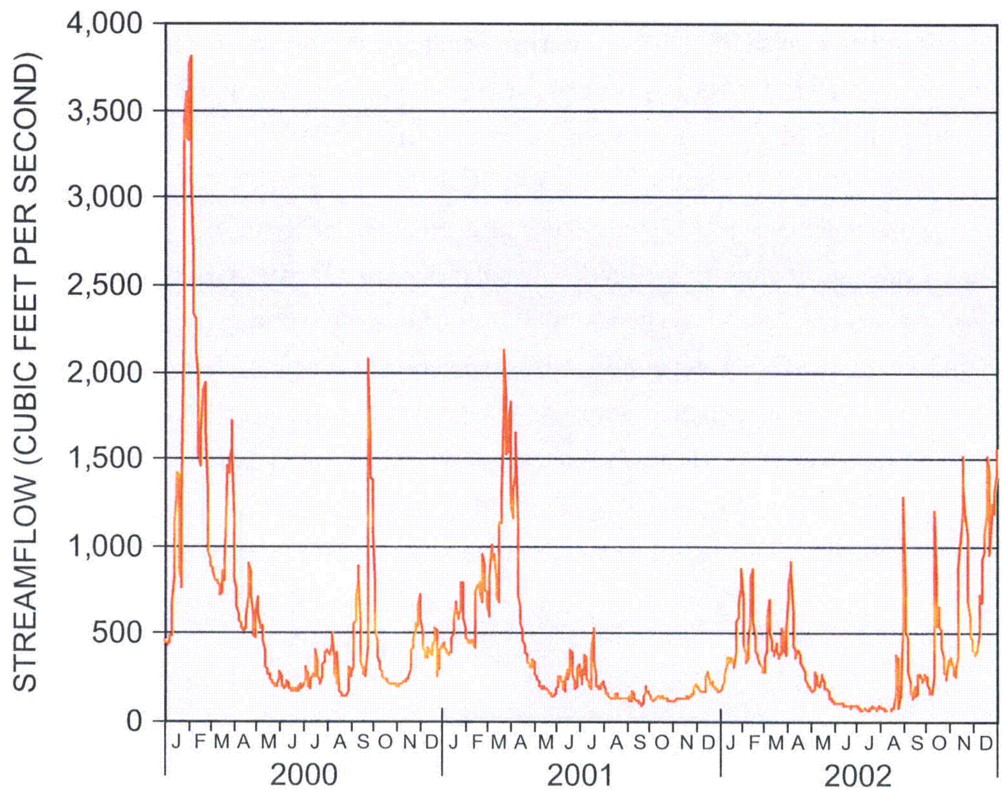


Figure 10. Streamflow in the Lynches River, showing seasonal variation in flow.

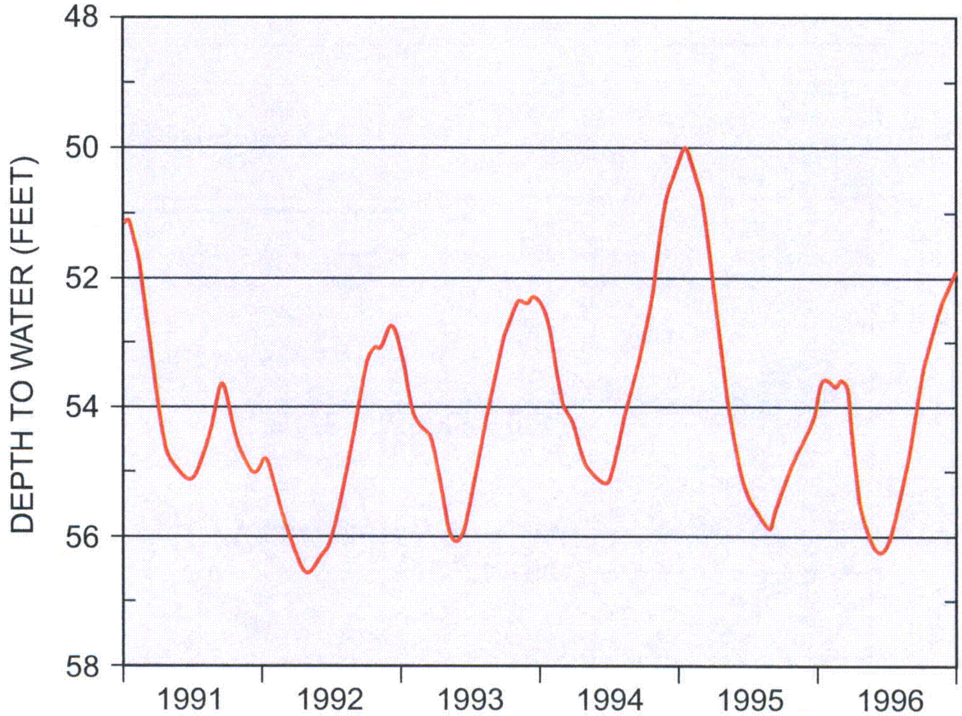


Figure 11. Hydrograph showing typical seasonal variation in ground-water level.

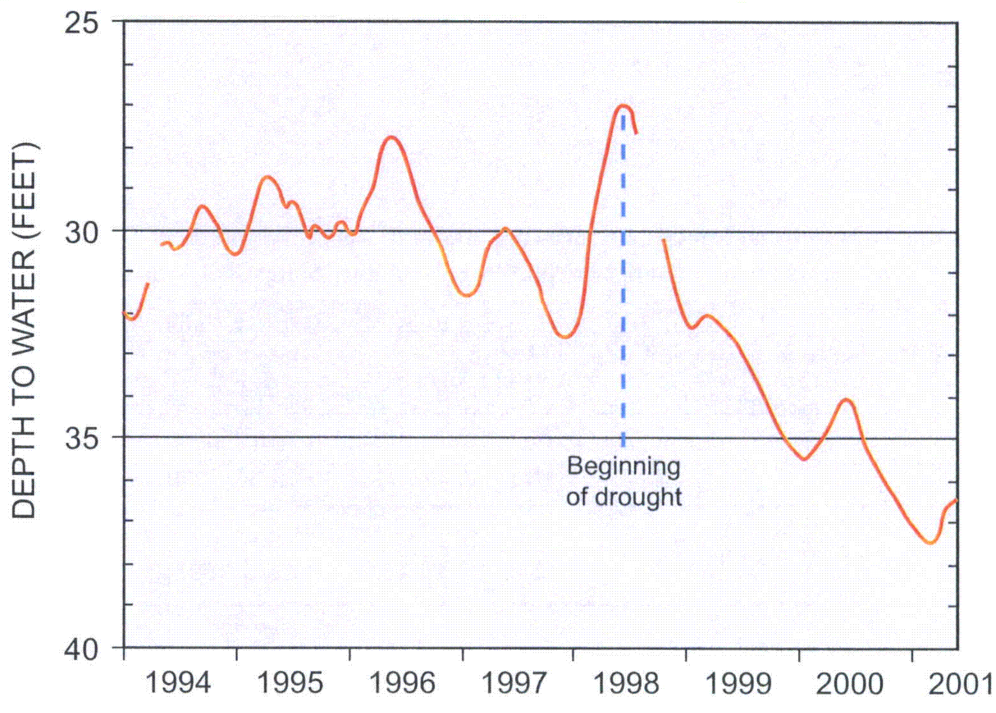


Figure 12. Hydrograph showing effect of prolonged drought on ground-water level in a Greenville County well.

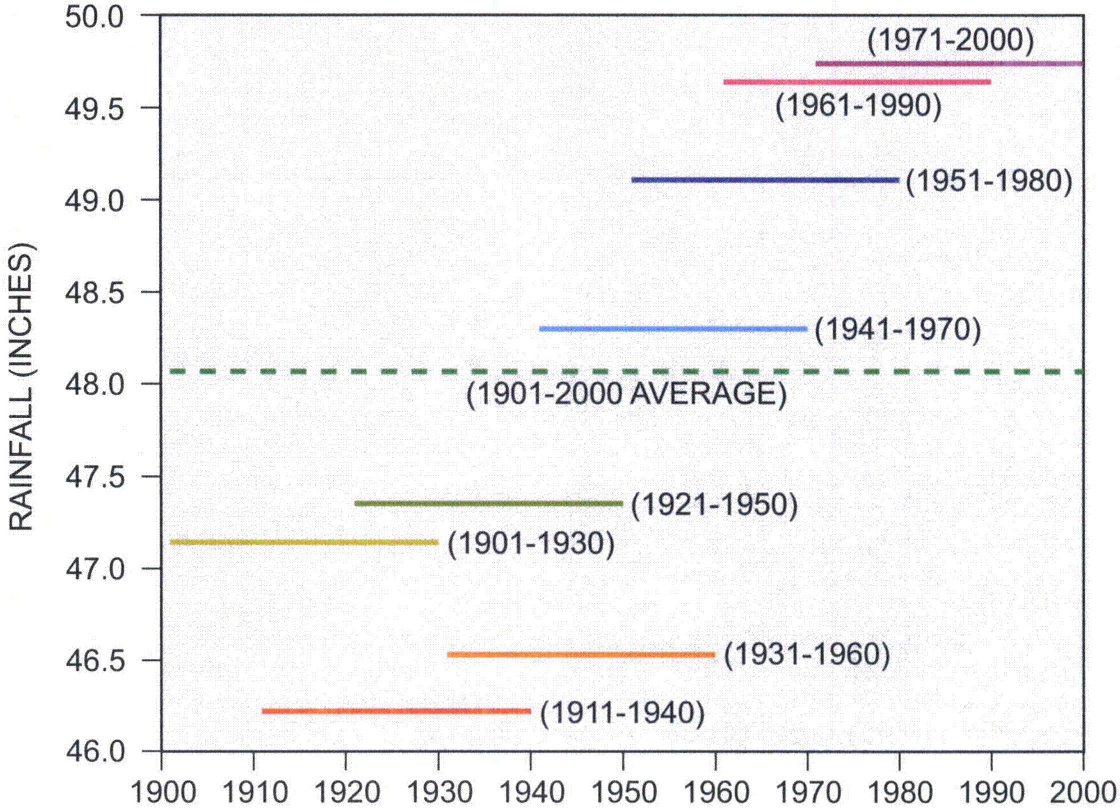


Figure 13. "Normal" precipitation values for South Carolina during the 20th century.

Table 1. Lowest and highest daily mean flows, in cubic feet per second, during a given year for several streams in South Carolina (data from United States Geological Survey)

Station name and location	Lowest daily mean flow (date)	Highest daily mean flow (date)	Annual mean flow (year)
Waccamaw River near Longs	58 (Nov. 18, 1999)	28,100 (Sep. 23, 1999)	3,556 (1999)
Congaree River at Columbia	1,360 (Sep. 16, 1998)	90,600 (Feb. 5, 1998)	11,680 (1998)
Stevens Creek near Modoc	7.1 (Sep. 1, 1998)	16,300 (Mar. 9, 1998)	544 (1998)
Coosawhatchie River near Grays	0.06 (Jul. 10, 1998)	7,030 (Feb. 6, 1998)	718 (1998)

WATER USE

Two of the most important elements in water resources management are knowing how much water is available and knowing how much water is being used. Knowing how much water is being used requires accurate and comprehensive water use reporting.

In order to effectively manage the State's water resources, and in particular to minimize the impact of droughts, comprehensive and accurate monitoring of water use is needed. Prior to the early 1980's, water use reporting in South Carolina was not required; reports were supplied voluntarily to State and Federal agencies. Water use reporting became more regular as a result of the South Carolina Water Use Reporting Act of 1982, which required reporting to the State any withdrawal of 100,000 gallons or more per day. Present regulations call for anyone withdrawing in excess of 3 million gallons in any month to register and report that use annually to the South Carolina Department of Health and Environmental Control (DHEC). Water-use reporting is now enforceable and penalties can be issued to those who fail to report. Accurate estimates of ground and surface water use are still difficult to obtain. Irrigation-use estimates are particularly poor because of inadequate reporting procedures.

INSTREAM USE

All of the uses for surface water and ground water in South Carolina can be classified as either instream use or offstream use. Instream uses are those that take place without diverting or withdrawing water from a stream. Instream uses are nonconsumptive, in that no water is lost from the stream as a result of that use. Instream water uses include maintenance of fish and wildlife habitat, recreation, navigation, wastewater assimilation, and hydroelectric power generation. Hydroelectric power generation has, by far, the greatest demand for water of all uses.

OFFSTREAM USE

Offstream uses are those that involve withdrawing or diverting the water from a stream, lake, or aquifer. The offstream-use categories presented here—including thermoelectric power generation, industrial, public supply, crop irrigation, golf course irrigation, and self-supplied domestic—are those used by DHEC in its water use reporting programs. Because offstream uses involve removing water from its source (stream, lake, or aquifer), these uses are usually consumptive, meaning that some of the water withdrawn is not returned to its source.

Thermoelectric power generating facilities—both nuclear and fossil fueled—use large quantities of water for cooling purposes. At these facilities, tens of millions of gallons per day are lost to evaporation and become unavailable to downstream users. These losses, although seemingly large, represent only 1 to 2 percent of the total volume of water withdrawn for thermoelectric use.

Industrial water use includes water used for washing, cooling, manufacturing, and processing materials, primarily chemicals and allied products. This use category represents self-supplied industries, and does not include water used for industrial purposes that was purchased from a public supply system.

Public supply includes any public or private utility that distributes water for sale to the public primarily for domestic, commercial, or industrial use. The majority of the State's large public supply systems depend on surface water, but there are some systems in the Coastal Plain—the city of Sumter being the largest—that rely entirely on ground water.

Crop irrigation represents self-supplied water used for agricultural and horticultural irrigation, except for golf course irrigation. Irrigation generally occurs during a 150-day period from late March through August. During this growing season, irrigation use can have a significant impact on the overall water supply. Crop irrigation is highly consumptive; much of the water withdrawn is lost to evapotranspiration.

Golf course irrigation represents all self-supplied water applied to golf courses. This water use is greatest in the coastal counties, which have the majority of the golf courses. Like crop irrigation, golf course irrigation is highly consumptive.

Self-supplied domestic use represents the water used by the population not served by public supply systems. Practically all of these withdrawals are from ground-water sources. This use was calculated by applying a water use rate of 75 gallons per day per person not served by a public supply system.

Other offstream use categories include **mining** (water used for the extraction, dewatering, milling, and other preparations that are part of mining activities), **aquaculture** (water used for the production of aquatic organisms in captivity), **commercial** (water used for hotels, restaurants, office buildings, and other commercial facilities), and **livestock** (water used for animals, feed lots, dairies, poultry, and animal specialties). These uses make up a very small percentage of the total offstream water use, and are therefore not included in the water use data presented in the following section.

The **interbasin transfer** of water is an offstream use not included in DHEC's water use categories. Regardless of the eventual use for the water at its destination, interbasin transfer is a 100-percent consumptive use for the source basin.

WATER USE IN THE YEAR 2000

Water use data for the year 2000 is presented to illustrate the relative magnitudes of the water uses in South Carolina. These numbers come from the forthcoming revised *South Carolina State Water Assessment*, which contains a detailed description of how these estimates were made.

Hydroelectric-power water use (instream) was estimated at 36,175 MGD (million gallons per day) for the year 2000, which is less than 75 percent of the 50-year average for this use. This very low total—the third smallest annual total since 1950—is the result of the drought that began in 1998. Reduced streamflows and lake levels limited the amount of water available to generate electricity.

Offstream water withdrawals in South Carolina during the year 2000 totaled 7,362 MGD, of which 5,840 MGD was used for thermoelectric power generation. The combined total of all other offstream uses for the year 2000 was 1,522 MGD, of which industry used 37 percent, public supply 36 percent, crop irrigation 17 percent, golf course irrigation 6 percent, and self-supplied domestic 4 percent. Streams and lakes provided nearly all of the supply for hydroelectric and thermoelectric power generation and 71 percent of the supply for all other uses. Wells and springs provided the remaining 29 percent. Table 2 lists the water use data by county in South Carolina for the year 2000, and Table 3 presents a summary of water use for each basin during that same year.

TRENDS

Water use in South Carolina is linked to many social, economic, technological, and regulatory factors. The demand for water is closely tied to the State's population; as the population grows, so too will the demand for water. Further industrial development and the ever-increasing demand for electricity will also increase the need for available water. The combined water demand for industry, public supply, crop and golf course irrigation, and domestic use is expected to increase by nearly 50 percent between the years 2000 and 2045 (Castro and Foster, 2000; Figure 14).

Table 2. Estimated water use (million gallons per day) in South Carolina, by county, for the year 2000

County	Hydro-electric	Thermo-electric	Public supply	Industry	Irrigation	Golf course	Domestic	Subtotal
Abbeville	3,273		3.41	1.67	1.08	0.30	0.73	7
Aiken		161	19.32	81.71	5.85	3.00	0.80	111
Allendale			1.20	2.95	14.94	0.10	0.27	19
Anderson	2,232	75	20.41	2.09	1.61	2.30	0.36	27
Bamberg			0.79	0.08	12.94	0.40	0.41	15
Barnwell			3.20	0.91	16.46	0.50	0.63	22
Beaufort			23.50	0.89	5.06	15.20	0.52	45
Berkeley	5,222	585	12.77	11.77	1.83	1.50	3.60	31
Calhoun			0.91	90.20	21.20	0.30	0.61	113
Charleston			53.38	39.29	8.04	6.00	2.56	109
Cherokee	1,022		12.03	2.30	1.75	0.60	0.37	17
Chester	3,105		3.52	0.79	0.31	0.60	1.45	7
Chesterfield			5.89	1.53	1.50	1.00	0.84	11
Clarendon			1.83	0.10	5.72	1.50	1.07	10
Colleton		3	2.35	0.13	3.69	0.40	1.30	8
Darlington		824	6.27	18.10	3.53	1.50	0.42	30
Dillon			4.87	2.21	1.80	0.20	0.40	9
Dorchester			7.49	3.33	0.60	1.50	1.92	15
Edgefield	2,660		3.60	0.10	7.33	0.50	0.11	12
Fairfield	4,825	803	2.29	0.10	2.46	0.20	0.50	6
Florence			14.82	37.84	5.29	1.30	2.81	62
Georgetown		12	7.43	32.03	4.79	4.20	0.43	49
Greenville	571		56.57	0.76	5.11	6.20	2.87	72
Greenwood	477		13.18	0.40	0.09	1.90	1.33	17
Hampton			1.80	1.76	5.68	0.70	0.47	10
Horry		104	30.24	3.10	3.14	19.40	1.44	57
Jasper			1.26	0.15	2.16	0.40	0.18	4
Kershaw	1,652		7.28	13.30	0.45	0.80	0.40	22
Lancaster	1,165		11.84	13.75	0.95	1.30	0.68	29
Laurens	295		5.96	0.13	3.17	0.80	0.90	11
Lee			1.58	1.93	0.77	0.20	1.25	6
Lexington	288	146	18.24	44.10	18.30	2.30	8.46	91
McCormick	3,266		1.71	0.01	1.34	0.90	0.08	4
Marion			4.71	2.43	1.90	0.30	0.59	10
Marlboro			3.10	9.66	2.92	0.40	0.81	17
Newberry			5.16	0.38	0.87	0.60	1.05	8
Oconee	32	2,596	10.12	2.33	1.44	1.50	0.53	16
Orangeburg			9.60	8.80	47.60	1.50	1.29	69
Pickens	492		13.18	1.58	0.71	1.60	1.86	19
Richland	1,222	438	57.61	29.62	1.77	4.30	1.65	95
Saluda			0.63	0.15	6.07	0.30	0.95	8
Spartanburg	46		39.80	3.82	3.13	3.30	3.53	54
Sumter			16.13	2.59	13.18	1.30	2.53	36
Union	3,047		4.46	3.65	0.76	0.40	0.25	10
Williamsburg			1.64	4.77	2.31	0.30	1.93	11
York	1,283	93	14.68	86.50	1.00	3.20	6.41	112
South Carolina	36,175	5,840	542	566	253	97	64	1,522

* Subtotals do not include hydroelectric or thermoelectric uses.

Table 3. Estimated water use (million gallons per day) in South Carolina, by basin, for the year 2000

	Basin	Hydro-electric	Thermo-electric	Public supply	Industry	Irrigation	Golf course	Domestic	Subtotal
Surface water	Savannah	11,626	2,757	53	81	16	7	0	157
	ACE	2,926	588	92	53	58	20	0	223
	Santee	21,621	1,554	251	283	32	21	0	587
	Pee Dee	0	940	41	103	20	23	0	186
	Statewide	36,173	5,839	437	519	126	71	0	1,153
Ground water	Savannah	0	0	6	9	16	2	5	38
	ACE	0	4	29	15	58	9	15	127
	Santee	0	0	11	7	32	7	30	87
	Pee Dee	0	0	58	20	20	8	13	119
	Statewide	0	4	104	51	126	26	64	371
Total water	Savannah	11,626	2,757	59	90	33	9	5	195
	ACE	2,926	592	121	68	116	29	15	350
	Santee	21,621	1,554	262	290	64	28	30	675
	Pee Dee	0	940	99	123	40	31	13	305
	Statewide	36,173	5,843	541	570	253	97	64	1,525

* Subtotals do not include hydroelectric or thermoelectric uses.

** Irrigation use estimates are based on a 5-month growing season. The source of irrigation water is assumed to be half surface water and half ground water.

*** Some values do not equal those of Table 2 because of rounding errors.

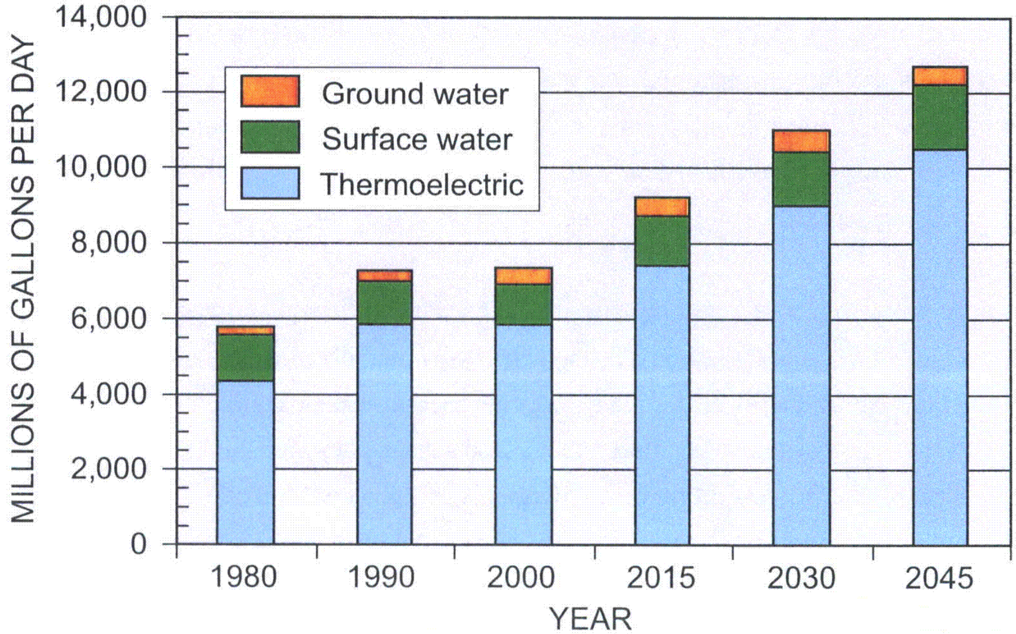


Figure 14. Past water use and projected water demand for South Carolina (Castro and Foster, 2000).

WATER RESOURCES MANAGEMENT

Early in this State's history, rivers were used for transportation, irrigation, and drinking water. Over time, rivers were harnessed to provide mechanical power for mills, and in the 20^{th} century, water wheels gave way to hydroelectric turbines, as massive dams were built to generate electricity and provide some degree of flood control. By the end of the 20^{th} century, most of South Carolina's larger rivers were regulated by releases from impoundments, several of which are located in North Carolina. Only in the ACE basin (see Figure 1) are any major rivers in South Carolina still unregulated and flowing naturally.

The regulation of South Carolina's rivers was by far the most important water resources management decision in the State's history. Dams and reservoirs provided many benefits, such as electricity, flood control, water supply, sustained flow during dry periods, and increased recreational and tourism opportunities. But the dams also created some problems, such as altered flow regimes, interrupted fish passage, destroyed and altered habitats, and changes in water chemistry.

In the later part of the 20^{th} century, the water demands of an increasing population and growing industrial base, as well as greater environmental awareness, led to an increasing need for effective water resources management. The South Carolina Water Resources Commission (SCWRC) was established in 1967 to provide the State with an assessment of its water resources and to offer management guidelines for sustaining the State's water resources for future generations.

Today, water resources planners and managers are faced with many issues, such as monitoring and protecting water quality and quantity, determining and maintaining appropriate flows in rivers, protecting riverine habitats and ecosystems, regulating releases from reservoirs, allocating water during shortages, maintaining navigation, and managing flood plain development. Many of these issues stem from an increasing population making increasing demands on the finite water resources of the State.

In addition to problems caused by competing demands, the withdrawal or diversion of water from a lake, stream, or aquifer may cause undesired effects, such as saltwater intrusion, lowering of water level in a lake or wetland, diminishing the flow to a stream, reducing the ability of an aquifer to produce water, lowering the water level in nearby wells (well interference), land subsidence, or sinkhole formation. These adverse effects can be mitigated by restricting withdrawals, diverting water from other areas, withdrawing water from a stream rather than from an aquifer or vice versa, or taking water from water storage facilities such as lakes or reservoirs.

The effective management of South Carolina's water resources—finding ways to satisfy the many competing demands while still protecting the resource for future generations—is beyond the capability of any one agency or organization; it will require cooperation and shared responsibility among public and private parties.

Effective resource management requires the increased utilization of regulatory science—research directed to provide useful information for regulators facing specific choices. Research institutes and universities should be encouraged to work with State resource agencies and become integrated into the decision-making processes of the State. South Carolina needs integrated, long-term research projects to answer specific regulatory questions.

The management of South Carolina's water resources is a task made difficult by the complexity of the system and the interconnection of its components. Water quantity affects water quality; water quality affects the quantity of usable water; lakes affect rivers; ground water affects surface water; surface water affects ground water; and climatic conditions ultimately control all these components. Because of the complex interaction of all the components of the State's water resources system, management strategies must be flexible, responsive to trial, monitoring, and feedback, and should change in response to new scientific information and technical knowledge. This "adaptive management" approach provides a process for continually improving management practices and policies.

Whether dealing with surface water or ground water, there are two major issues facing water resource managers: *water quantity*—making sure there is enough water at the right place at the right time; and *water quality*—making sure the available water is suitable for use.

SURFACE WATER QUANTITY

The flow of unregulated streams is essentially controlled by climatic and geographic conditions, outside the influence of man. Quantity management programs for these rivers are therefore limited primarily to water allocation and conservation mechanisms. Regulated streams, on the other hand, are strongly controlled by man and, as such, offer a much better opportunity to manage the quantity and location of the surface water. The management of the reservoirs that control South Carolina's rivers is the key to the effective management of the State's surface water resources.

An essential element of any successful water quantity management program is knowing how much water there is, and where it is, at any given time. To that end, a good monitoring network is a requirement for an effective surface water management program.

South Carolina's Streams

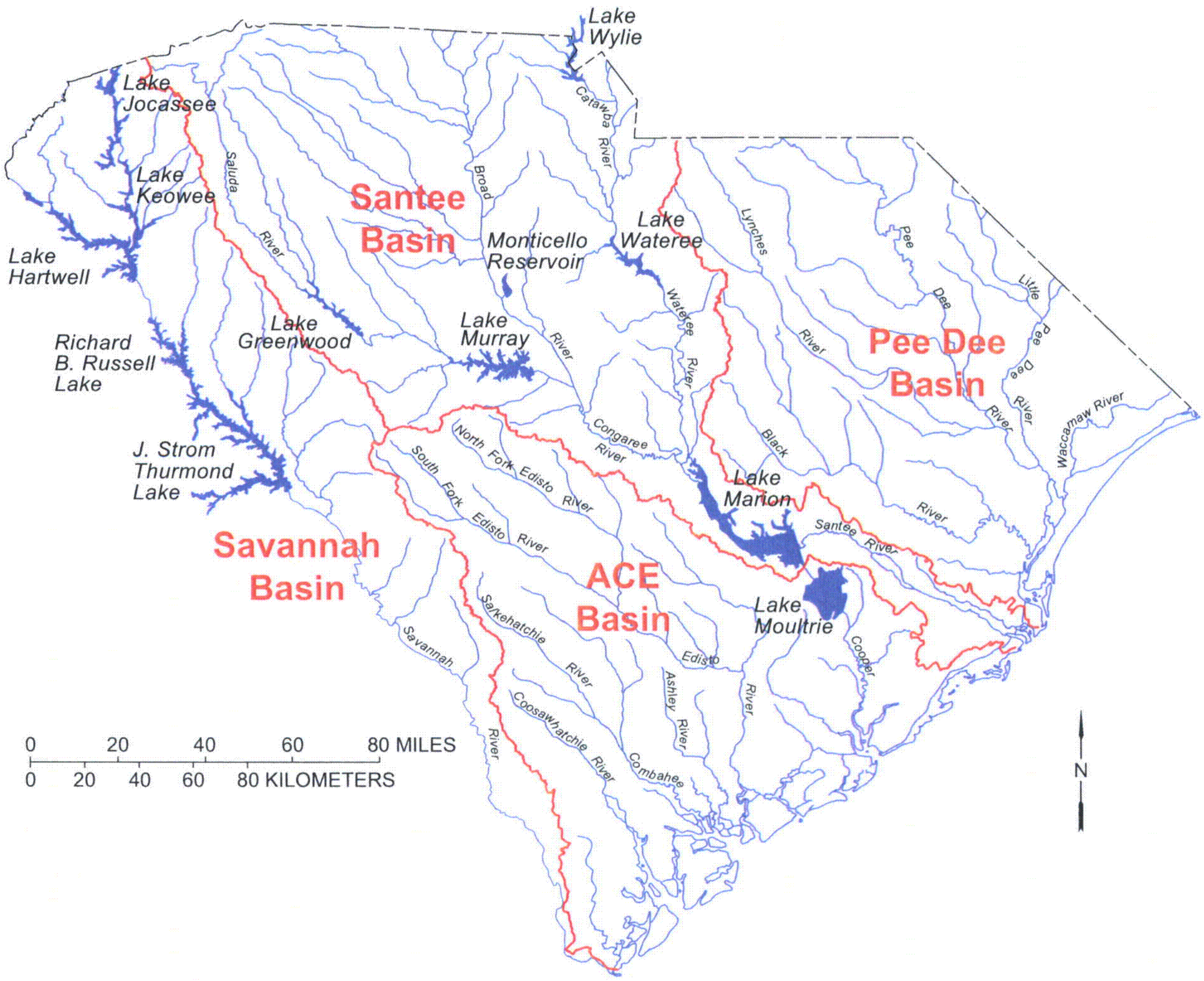
There are more than 11,000 miles of permanently flowing streams in South Carolina (Beasley and others, 1988), having an average flow of about 33 billion gallons per day (SCWRC, 1983). Four major drainage basins contain the State's streams (Figure 15), and 3 of these are shared with Georgia or North Carolina. Most of South Carolina's major rivers are highly regulated by releases from instream reservoirs.

The Savannah River, which forms the Georgia-South Carolina border, is the dominant river in the Savannah basin, and is heavily regulated by releases from Lakes Hartwell, Russell, and Thurmond.

In the Santee basin, the Saluda River and Broad River enter South Carolina from North Carolina and converge to form the Congaree River at Columbia. The Catawba River, entering South Carolina near Charlotte, N.C., becomes the Wateree River before merging with the Congaree to form the Santee River just above Lake Marion. All of these rivers are controlled by releases from reservoirs in South Carolina and North Carolina.

Most of the major rivers of the Pee Dee basin—the Pee Dee, Little Pee Dee, Lynches, and Waccamaw—originate in North Carolina and receive much of their flow from drainage in that state. The Black River is the largest river in this basin that originates within South Carolina. There are no major reservoirs in this basin in South Carolina, but the flow of the Pee Dee River is controlled by reservoir operations in North Carolina.

The ACE basin is the only major drainage basin located entirely within South Carolina, and most of its major rivers—the Ashley, Edisto, Salkehatchie, Coosawhatchie, and Combahee—are essentially unregulated. Only the Cooper River, which flows from Lake Moultrie to the Charleston Harbor, is significantly regulated.



Rank	Lake	Drainage basin	Lake operator	Surface area (acres)	Volume (acre-feet)
1	Hartwell	Savannah	Corps of Engineers	56,000	2,549,000
2	Thurmond	Savannah	Corps of Engineers	70,000	2,510,000
3	Murray	Santee	SCE&G	51,000	2,114,000
4	Marion	Santee	Santee-Cooper	110,000	1,400,000
5	Moultrie	ACE	Santee-Cooper	60,000	1,211,000
6	Jocassee	Savannah	Duke Power	7,565	1,185,000
7	Russell	Savannah	Corps of Engineers	26,650	1,026,000
8	Keowee	Savannah	Duke Power	18,372	1,000,000
9	Monticello	Santee	SCE&G	6,800	431,050
10	Wateree	Santee	Duke Power	13,710	310,000
11	Wylie	Santee	Duke Power	12,455	281,900
12	Greenwood	Santee	Duke Power	11,400	270,000

Figure 15. Major rivers and the 12 largest lakes, by volume, in South Carolina.

South Carolina's Lakes

There are more than 1,600 lakes in South Carolina that cover an area of 10 acres or more (SCWRC, 1991). They impound more than 15 million acre-feet of water, 95 percent of which is contained in the State's 12 largest reservoirs (Figure 15), and releases from these manmade lakes control the flow of many of the State's rivers.

All of these major reservoirs were constructed for the primary purpose of hydroelectric power generation, and that function is still the guiding force behind reservoir operations. The lakes also provide some flood control by reducing the severity of peak flood flows, and they help to supplement low flows during extended dry periods. Reservoirs also serve as reliable sources of water for many cities and water companies across the State.

In the years since they were constructed, South Carolina's lakes have become nationally known for their boating, fishing, and recreational opportunities. Recreational use of lakes has become an important economic asset, and this use needs to be given important consideration in any lake management program.

In the Savannah basin, Lakes Thurmond, Russell, and Hartwell dominate the upper Savannah River and effectively control the flow of the lower Savannah River. These reservoirs, operated by the U. S. Army Corps of Engineers, are located on the Georgia-South Carolina border, and are shared by the two states. Lakes Jocassee and Keowee, both located entirely within South Carolina, flow into Lake Hartwell via the Seneca River.

The Santee basin contains 6 of the 12 largest lakes in South Carolina: Lakes Murray and Greenwood on the Saluda River; Lakes Wylie and Wateree on the Catawba/Wateree River; Monticello Reservoir off the Broad River; and Lake Marion on the Santee River. (Although Lake Moultrie gets its water from the Santee River via Lake Marion, the reservoir itself is located in the ACE basin.) In addition to these South Carolina lakes, there are several more reservoirs in North Carolina that regulate flows of the Broad River and Catawba River before they enter South Carolina.

Although there are no major reservoirs on the rivers of the Pee Dee basin in South Carolina, this basin is influenced by reservoirs located in North Carolina. The Pee Dee River, for example, is controlled by 6 reservoirs in North Carolina.

Only in the ACE basin are most of the rivers undammed and in a relatively "natural" condition. But even this basin contains one major reservoir: Lake Moultrie, which gets its water from Lake Marion via a cross-basin canal. Lake Moultrie discharges some of its water into the Cooper River, enhancing natural flows into the Charleston Harbor, while the rest of its discharge is returned to the Santee River.

Lakes and Rivers are Interconnected

Lakes and rivers are inherently connected and interdependent. What happens in a river affects every lake downstream, and what happens in a lake affects the river downstream. Management of the State's surface water system requires a coordinated management of its lakes and rivers in order to balance the needs of lake users with the needs of river users. Lakes cannot be operated without regard for the needs of downstream users, with respect to both water quantity and water quality. Likewise, the needs of river users cannot necessarily outweigh the needs of lake users.

The construction of an instream reservoir has a profound impact on the river in which it is constructed. Some of the impacts are beneficial, such as sustaining streamflows during extended dry periods, whereas other impacts are detrimental, such as decreasing the downstream river's dissolved-oxygen concentrations, hindering navigation, altering habitats, and preventing fish passage past the dam. Perhaps the most significant impact a reservoir has on its river is the change in the downstream flow regime.

Management Guidelines for Streams

South Carolina's streams are one of its most important resources, and their wise use and management is clearly in the State's interest. The complexity of South Carolina's river systems, their dependence on unpredictable and uncontrollable weather patterns, and the diverse multitude of users and their demands all contribute to the complexity of managing South Carolina's streams.

Some of the major issues facing resource managers are developing appropriate release schedules for reservoirs, establishing desired and minimum allowable flows, monitoring both water quantity and water quality, protecting habitats and ecosystems, maintaining and restoring water quality, controlling point and nonpoint sources of pollution, allocating water during times of shortage, managing flood-plain development, dredging channels, controlling invasive exotic species, and maintaining navigation.

Many of these issues are being addressed, to some extent, by Federal, State, and local government agencies, as well as by private organizations, particularly the environmental issues. For example, the DNR's Scenic Rivers Program works to conserve unique ecological, cultural, recreational, and scenic resource values in South Carolina's rivers. Through a cooperative, voluntary management process involving landowners, community interests, and the DNR working together for common river-management goals, more than 250 miles along segments of eight rivers are being managed and protected as State Scenic Rivers.

Minimum Required Flows

Minimum required flows for streams need to be established to protect public health and safety, maintain fish and wildlife, and provide recreation, while promoting aesthetic and ecological values. The minimum required flow for a stream is the greatest of the minimum flows required for:

1. Protection of water quality;
2. Protection of fish and wildlife habitats;
3. Maintenance of navigability;
4. Estuary maintenance and prevention of saltwater intrusion.

Protection of water quality—Streamflows must be maintained to protect human health and safety and to prevent irreversible damage to the ecosystem.

The *assimilative capacity* of a stream refers to the amount of wastewater and other pollutants a stream can receive without causing harmful effects to aquatic life or humans who consume the water. The assimilative capacity is directly related to how much water is in the stream; higher flows can handle larger amounts of pollutants before becoming adversely affected.

Although a stream's assimilative capacity is proportional to its flow, it is usually impractical to permit all wastewater discharges as a function of streamflow. A more manageable approach is to determine a low-flow value for the stream—a flow that is almost always met or exceeded—and determine the assimilative capacity of the stream for that low flow. Permits to discharge are then issued based on the assimilative capacity for that low flow. By doing this, the assimilative capacity of the stream will almost always be greater than the permitted wasteload, so the stream's water quality standards will almost always be met without curtailing normal discharges.

DHEC, the State agency responsible for overseeing and regulating wastewater discharge, uses the "7Q10" flow as the low flow value to determine the wasteload capacity of a stream. The 7Q10 flow is a statistically determined value and is defined as the lowest mean streamflow over 7 consecutive days that can be expected to occur once in a 10-year period. In any year, there is a 10-percent probability that the average flow for 7 consecutive days will be equal to or less than the 7Q10. The 7Q10 flow is usually met or exceeded about 95 percent of the time. In general, DHEC allows treated waste discharges into a stream only to the extent that, under 7Q10 conditions, all water quality standards will be met.

7Q10 values are not fixed numbers, and should not be thought of as fixed values; they can vary over time as water availability changes during wet and dry periods. Because of this variability, if 7Q10 values are used for comparison of the assimilative capacity of different drainage areas, they should each be calculated from the same period of record. To maintain water quality during prolonged dry periods, when flows frequently drop below established 7Q10 values, regulatory programs should have the flexibility and authority to reduce permitted waste discharges or improve waste treatment in order to maintain water quality standards.

Protection of fish and wildlife habitats— Reduced flows decrease the amount of habitat available to aquatic biota and can restrict the movement of resident and migratory fish species. Reduced flows also intensify pollution, inflate water temperature, and exacerbate dissolved-oxygen problems, all of which can damage riverine habitats and ecosystems.

It is the responsibility of the DNR to determine the minimum flow required to protect the State's aquatic resources. The current policy for determining instream flow requirements for fishery resources can be found in *South Carolina Instream Flow Studies: A Status Report* (Bulak and Jöbsis, 1989). Work is currently underway to determine if it is more appropriate to prescribe minimum flows based on a percentage of mean monthly flows rather than mean annual flow as employed by Bulak and Jöbsis (1989). Basing minimum flows on mean monthly flows has the advantage of a closer adherence to a stream's natural flow pattern. This methodology would require a technique for estimating the natural flow pattern of regulated rivers, and it would also require an evaluation of the change in habitat at various percentages of mean monthly flow.

Maintenance of navigability—Minimum-flow requirements for navigation are based on either one-way or two-way navigation. The minimum flow for one-way passage by boat for a given stream segment will provide a minimum depth of 1 foot across a channel 10 feet wide or across 10 percent of the total stream width, whichever is greater. The minimum flow for two-way passage by boat would provide a minimum depth of 2 feet across a channel 20 feet wide, or across 20 percent of the total stream width, whichever is greater (de Kozlowski, 1988).

Prevention of saltwater intrusion—Estuaries are essential habitats for numerous marine resources, and adequate freshwater flow into estuaries is necessary to maintain the ecological functions that support recruitment of important recreational finfish and shellfish populations. Freshwater flow in coastal rivers must also be maintained to keep saltwater away from the intake structures of water supplies. Measured data of saltwater advances into rivers during different flows should be used to build and verify simulation models to enhance the management of flow regimes in rivers in order to control the saltwater wedge and maintain the ecological functions of estuaries. Minimum flows required to prevent undesirable saltwater intrusion should be determined by the DNR.

Allocation of Stream Water

South Carolina's streams usually have more than enough water to satisfy the demands of all water users. During dry summers or prolonged droughts, however, streamflows can become unusually low, and demands for water can exceed the available supply. To maximize water availability at all times and to protect human and economic needs, surface water use must be regulated. An allocation mechanism must be established to control the distribution of water so that all users have a reliable water supply. Variations in surface water availability and the location of withdrawals must play major roles in the allocation of water.

At any given withdrawal point, there is a quantifiable amount of *available water* that can be removed from a stream without adversely impacting downstream users. This available water is the difference between how much water is in a stream at the withdrawal point and how much water must be left instream for downstream use. Any withdrawals, discharges, and drainage recruitments occurring upstream from the withdrawal point are incorporated into the measured flow at the withdrawal point. The amount of water needed for downstream use is the sum of all downstream permitted withdrawals and required instream flows minus local discharges and recruitments. The amount of available water will vary with changes in streamflow or offstream use.

Many users of stream water—in particular public suppliers and industries—return much of their withdrawn water back into the stream, usually in the form of treated wastewater. This nonconsumptive use results in a net withdrawn amount (the total withdrawn amount minus the returned amount) that is often considerably less than the total withdrawn amount. For these cases in which a portion of the withdrawn water is returned to its source, both the amount of total withdrawal and net withdrawal need to be considered. Between the point of withdrawal and the point of return, the stream must be able to adequately accommodate the loss of the amount of total withdrawal. Downstream from the point of return, however, the stream must be able to accommodate the loss of only the amount of net withdrawal. In order to minimize the impact of the withdrawal on the stream between the withdrawal point and the return point, water should be returned as near to the point of withdrawal as is practical.

There will be times when the available water is less than the desired withdrawal amount. How often this is likely to occur can be determined by examining the stream's historical measured-flow data. A duration curve—a statistical analysis of how often various flows occur—can provide an estimate of how often the desired withdrawal amount will be available, and the stream's measured flow history can provide an estimate of the longest continuous period during which the streamflow will be inadequate to provide to desired withdrawal amount. The summation of flow deficit during this period represents how much additional water would be needed from other sources to supplement the natural flow in order to meet the user's demands during this dry period. This supplemental water can come from storage facilities, ground water, or other water suppliers.

During extended dry periods, reduced water availability may necessitate a reduction in offstream withdrawals, resulting in a shortage of water for some users. Economic, social, and environmental considerations must be weighed against overall fairness when imposing water restrictions.

Management Guidelines for Lakes

A properly managed reservoir can be a valuable asset to the State, providing a reliable supply of water, generating electricity, and offering numerous recreational and economic opportunities. An improperly managed reservoir, however, can become a liability, disrupting lake and downstream ecosystems, failing as a reliable source of water, and reducing the potential economic benefits a reservoir can offer. The goal of lake management is to satisfy as many demands as possible while protecting the resource for future use.

A multitude of issues face lake managers and water resources planners. Some issues, such as water quality or allocation programs, are similar to those associated with river management. Other issues, such as hydroelectric power generation, are specific to lake management. Many problems stem from competing demands for the same limited resource. Complicating the management task is the fact that many of the reservoirs that control South Carolina's surface water system are partly or entirely located in other states. Further complicating matters is the fact that the State has little direct control over the operation of these reservoirs.

Lake Levels and Rule Curves

From the point of view of a reservoir manager (and most lake users), an important operating goal is to keep the lake level at a desired elevation, usually the "full pool" level. There are many benefits to maintaining a full-pool lake level: more efficient hydroelectric power generation; consistent boating and fishing conditions; a consistent shoreline (important to lakeside property owners); and a maximized supply of water for offstream use.

Seasonal variations in the desired lake elevations are normal. Lake levels are usually lowered from full pool during the early winter in anticipation of high inflows expected during the spring. Capturing high springtime flows provides some flood protection downstream from the lake, while returning the reservoir to its full pool level. The desired, or target, lake elevation over the course of a year is known as a rule curve or guide curve. Reservoir releases are adjusted in order to keep the lake level as close to the rule curve as possible: If the lake level is too high, release more water; if it is too low, release less water.

Reservoir Release Schedules

The DNR should evaluate each regulated river in the State to determine the desired and minimum required flows just downstream from each impoundment. These flows are determined on the basis of permitted offstream withdrawals and required instream flows. During nondrought conditions, reservoirs should be operated so that releases are sufficient to ensure that desired downstream flows are always met. During droughts, the reservoir's drought contingency plan must be activated, and releases made according to the drought plan and the severity of the drought.

Most reservoirs are obligated, by permit or license, to release a minimum flow volume over some period of time, typically one week. While these releases usually average more than the minimum required downstream flow, the timing of the releases is often highly variable: most of a week's allocation of water can be released in only three or four days (because releases are made with consideration only for hydroelectric power generation), leaving very little water for release during the remaining days of the week. Although the required weekly average release is met, instantaneous flows or average daily flows can be significantly less than the minimum required flow for several days each week. Reservoir operations should be planned to ensure adequate average daily or instantaneous flows, rather than weekly releases.

Another conflict between reservoir operations and downstream flow requirements stems from a reservoir's tendency to smooth out seasonal fluctuations in flows. To reduce a reservoir's potential negative impact on aquatic populations, consideration should be given to releasing water in such a way as to mimic natural seasonal fluctuations, where appropriate.

One of the most important issues in water resources management is balancing reservoir operations with the demands of upstream and downstream uses. Although lake uses are important, consideration must also be given to the many downstream uses as well. Specific release schedules designed to meet downstream requirements must be incorporated into the Federal license, State operating permit, or Corps of Engineers operating plan that specifies release schedules.

The State should use its authority under Section 401 of the Federal Clean Water Act to ensure that any proposed releases will not result in violations of State water quality standards nor in an unacceptable degradation of water quality.

FERC Licenses—With the exception of the reservoirs operated by the U.S. Army Corps of Engineers (COE), all of the major hydropower reservoirs in South Carolina and North Carolina are licensed by FERC, the Federal Energy Regulatory Commission. FERC licenses specify operational plans, including required minimum releases. The best way to guarantee downstream flow protection is to incorporate the appropriate release conditions into the FERC licenses.

FERC licenses are usually issued for long periods of time—typically 30 to 50 years. When licenses are reissued, changes in reservoir operating plans can be made. Relicensing, therefore, offers an excellent opportunity to incorporate strategies for managing not just the reservoir, but the entire river system, into the reservoir operating plans. Although relicensing opportunities are rare, many lakes in South Carolina and North Carolina will be relicensed within the next few years, providing important opportunities to adjust release schedules for the betterment of all the lake and river users. DNR and DHEC need to be involved in the relicensing of these reservoirs so that these rare opportunities for change are not missed.

Over time, significant changes may occur in the lake and downstream river uses, perhaps because of increasing populations or changing climatic conditions. Because of the length of time between relicensing opportunities, it is important that the reservoir operating plans detailed in the FERC licenses allow for some flexibility in reservoir operations, so that resource managers can react to changes in either water availability or demands for the water.

COE Lakes—Because the U.S. Army Corps of Engineers operates the major reservoirs on the Savannah River (Lakes Thurmond, Russell, and Hartwell), these reservoirs do not fall under the jurisdiction of FERC, and are therefore not licensed by FERC. These lakes are operated according to plans developed and implemented by the COE.

Because Georgia and South Carolina share the Savannah River lakes, both states must work together to determine downstream water demands and to incorporate appropriate release schedules into the COE operational plans. The need for this cooperation has been recognized on a political level, with the proposed (but unrealized) *Savannah River Compact*, a formal agreement between Georgia, South Carolina and the Federal government to work together to manage the Savannah River. On a technical level, the *Savannah River Basin Comprehensive Water Resources Study* is an ongoing cooperative project between Georgia, South Carolina, and the Corps of Engineers, with the goal of balancing the many uses and demands for the entire Savannah River with the operation of the Corps' reservoirs.

The Southeastern Power Administration (SEPA), a division of the U. S. Department of Energy, has the responsibility to market electricity generated by the reservoirs operated by the U. S. Army Corps of Engineers in the southeastern part of the country. On average, the three reservoirs on the Savannah River—Hartwell, Russell, and Thurmond—generate more than half of the total power from SEPA's ten multipurpose reservoirs within the Mobile, Savannah, and Wilmington Districts in the Southeast.

Although the U. S. Fish and Wildlife Service (FWS), a division of the Interior Department, does not have direct authority over reservoir operations, this agency develops and enforces legislation to protect and maintain riverine ecosystems, primarily concerning minimum required flows and habitat protection. Federal environmental laws are important in ensuring that aquatic and other ecosystems are protected. Many aquatic systems in South Carolina should be restored so that important functions of those systems can be recovered and benefits can be realized and sustained. Restoring aquatic systems does not necessarily mean returning those systems to predisturbance or predevelopment conditions. State agencies should establish and maintain a strong cooperation with the Fish and Wildlife Service in order to coordinate activities relating to water resources in the State.

Water-Shortage Contingency Plans

Water-shortage contingency plans must be developed by the lake owners for all Federally-operated, FERC-licensed, or State-permitted lakes in the State. These plans should be developed and coordinated with the appropriate Federal and State agencies, local governments, and all other stakeholders, and should include water-shortage severity levels, the water releases associated with each severity level, and a public-information program. The State Drought Response Committee should approve these plans.

During water shortages, reservoir releases (outflows) should be reduced as the volume of water in the lake declines (Figure 16). As long as the water level in a regulated lake is above the first water-shortage severity level, as described in the lake's operating plan, water releases from the lake should equal or exceed the downstream desired flow requirements as defined by DNR.

If the lake level declines to less than the first water-shortage severity level because of low inflow, downstream releases and lake withdrawals should both be reduced, but downstream releases must always meet minimum flow requirements.

If the volume of usable storage in the lake is reduced so much that running out of water becomes a realistic concern—for example, if the volume of usable storage is equivalent to only 100 days of lake withdrawals—downstream releases should be set equal to the inflow into the lake. By setting outflow equal to inflow, the entire volume of water remaining in the lake's usable storage becomes available to lake users.

Evaporation from a lake can be thought of as a type of withdrawal; water is removed from the lake and does not enter the downstream system. Evaporative losses, therefore, must be included in the 100-day withdrawal-volume calculations.

If a drought persists to the extent that the water level nears the bottom of the conservation pool, and the volume of usable storage in the lake is almost exhausted—for example, equivalent to 10 days of lake withdrawals—further reductions in both lake withdrawals and downstream uses should be required. The lake's outflow should be set equal to the lake's inflow minus the newly-reduced lake withdrawals.

Uncertainty in estimates of drought severity and duration, the tolerance for water-use curtailment, and the probability of system failures all need to be considered by lake managers. Drought contingency plans need to be specific to the particular uses and conditions of each lake.

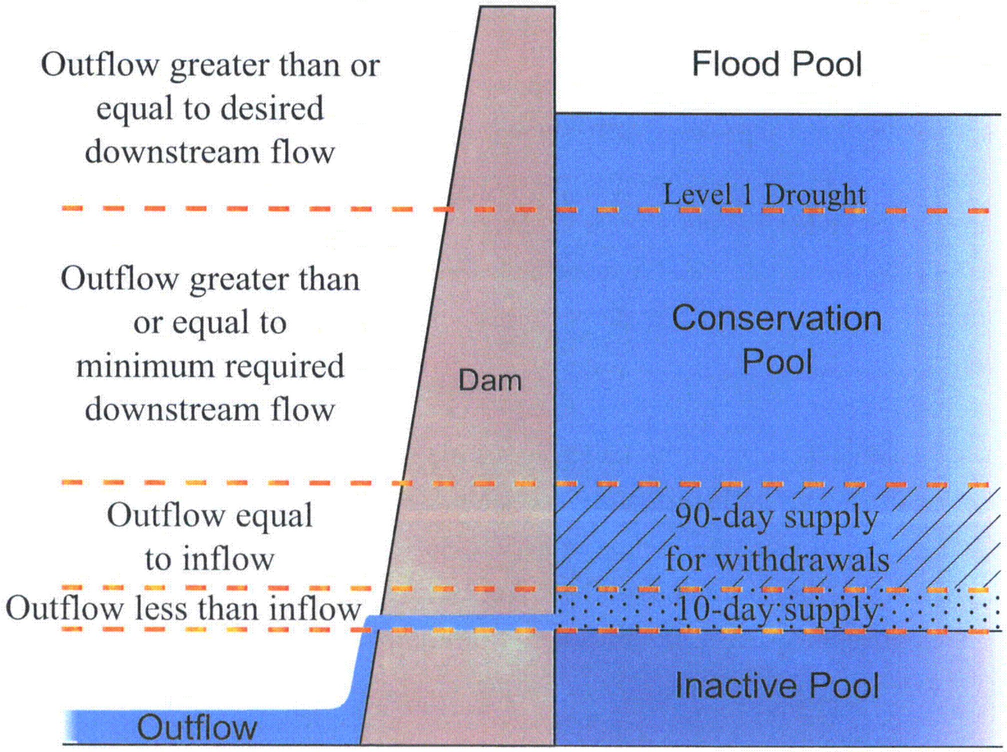


Figure 16. Illustration showing how the recommended reservoir release (outflow) is reduced as lake levels decrease due to drought.

Surface Water Quantity Monitoring Network

Perhaps the most important tool available to help manage the State's surface-water resources is a good monitoring network. Without an accurate knowledge of how much water is on the ground and where it is, no water-resources management program can be successful.

Continuous monitoring of streamflow is necessary to collect enough flow data to develop a statistically meaningful understanding of flow regimes and to determine accurate relationships between precipitation, soil-moisture conditions, and streamflows. These relationships are crucial for modeling and predicting future flows, in normal conditions as well as during droughts or floods.

Water quantity should be monitored in all the larger streams and lakes throughout the State. Streams originating outside South Carolina should be monitored at sites near the point of entry into the State, near midstate (Fall Line), and at sites just upstream of tidal waters. Streams located entirely within the State should be monitored at sites representative of the upper, middle, and lower areas of the Piedmont and Coastal Plain. Streams should also be monitored near sites of significant net withdrawal or discharge. In addition, many gages are installed at other locations for site-specific reasons, such as local hydrologic studies. For example, note the many streamflow gages located near the Savannah River Site (see Figure 17).

The current surface-water quantity-monitoring network consists of streamflow gages, stage-only gages, and crest-stage gages (Figures 17-19). Streamflow gages continuously measure river stage, from which flow volumes are calculated, and stage-only gages continuously record lake levels and river stages without making flow calculations. Crest-stage gages record only a single high-water level resulting from a significant flood event. Many of these gaging stations operate on a near-real-time basis and, as such, play an important role in the State's management of extreme-flow conditions. The gages in this surface-water network are operated and maintained by the USGS, with financial assistance from DNR, DHEC, and other government and private organizations.

Having an adequate number of properly located gages is vital to the effectiveness of this monitoring network, but it is also very important that these gages are continuously operated at the same location for a long period of time. Long-term flow records—preferably in excess of 20 years—are necessary in order to produce statistically meaningful flow histories, as well as to accurately evaluate trends in flow rates. Reduced funding has led to the elimination of several streamflow gages in each of the last few years. It is imperative that this monitoring program receives adequate funding to prevent the loss of any more gages, in particular those having been in service for many years or those installed at important locations.

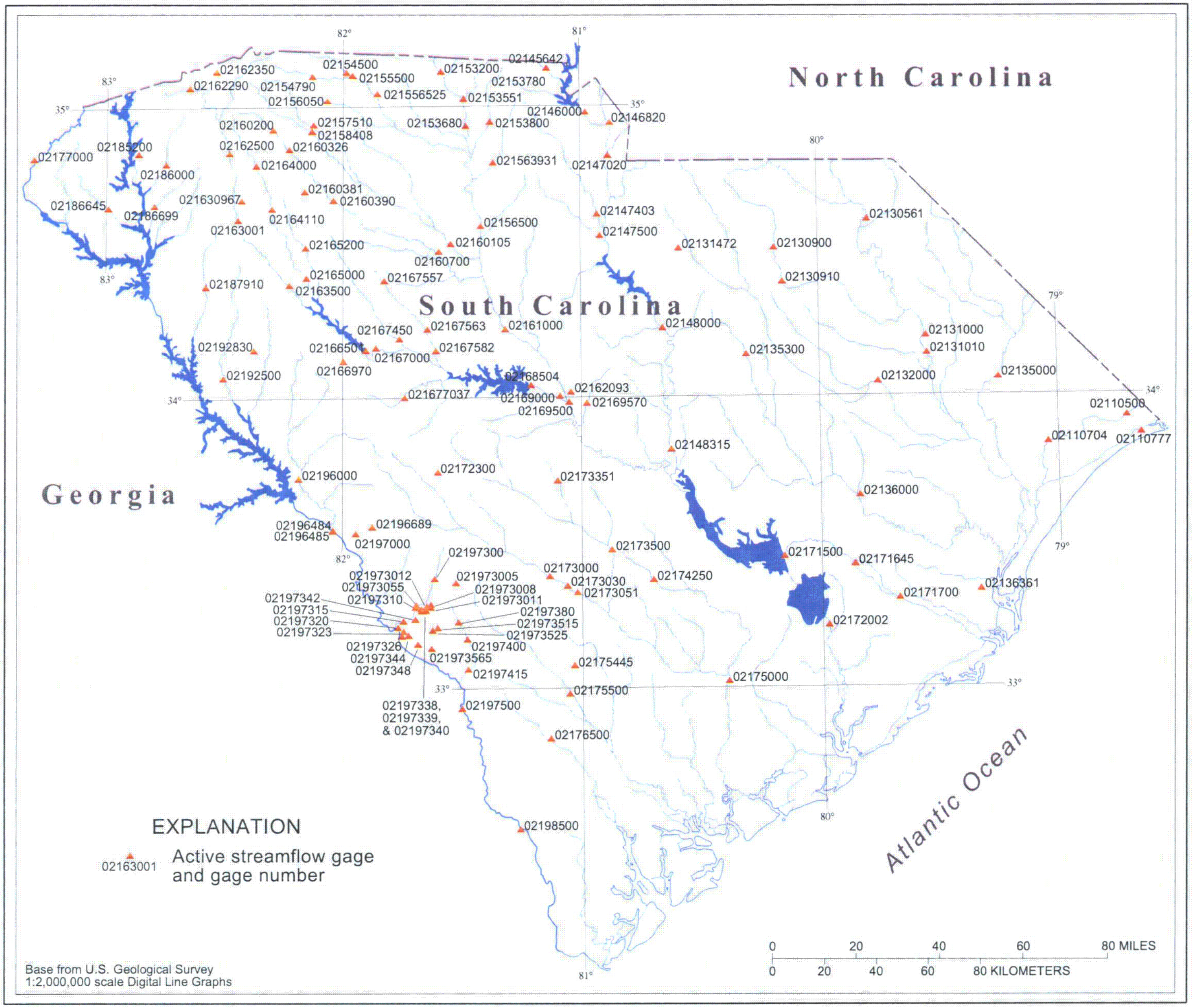


Figure 17. Current network of USGS streamflow gaging stations in South Carolina.

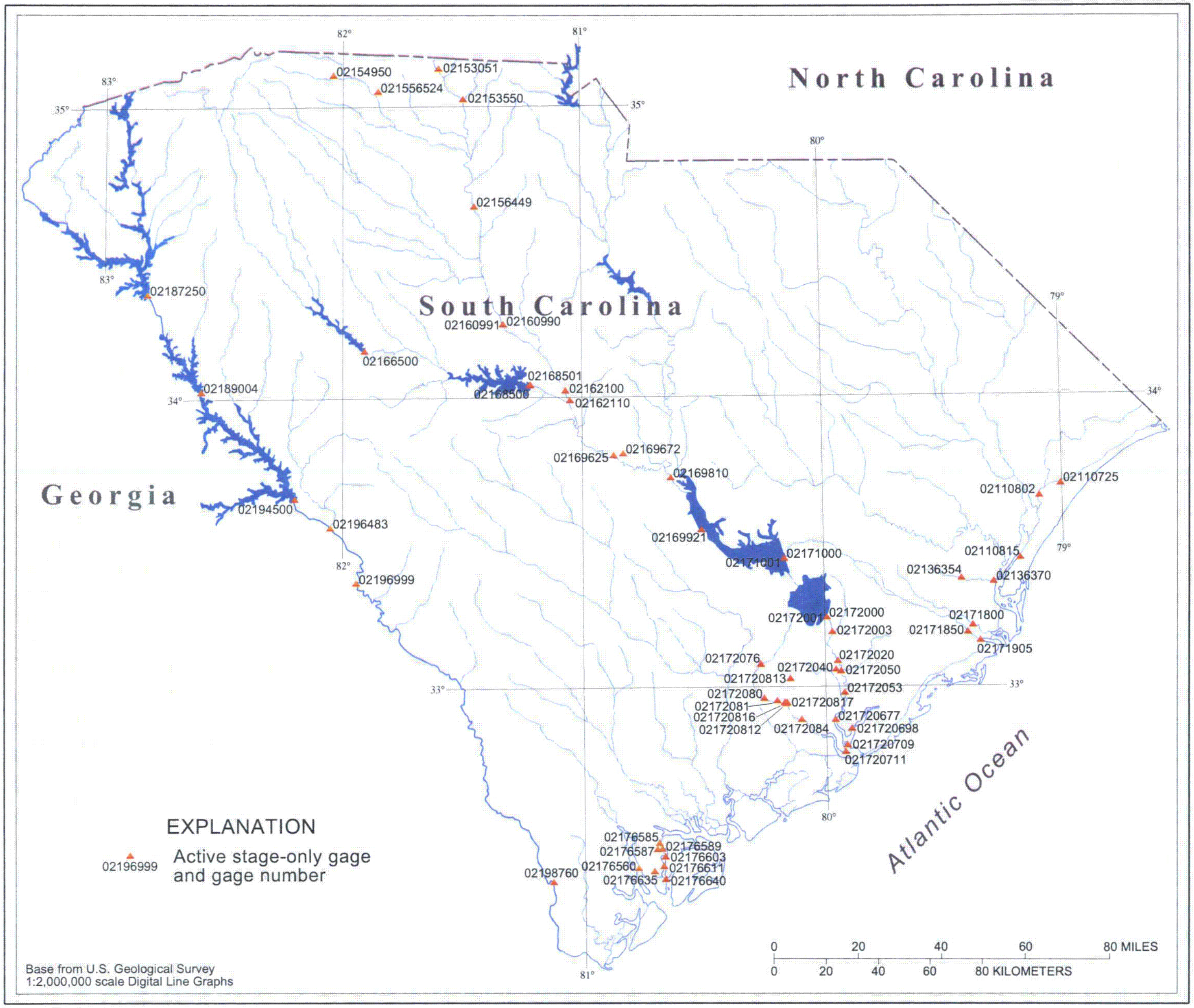


Figure 18. Current network of USGS stage-only gaging stations in South Carolina.

Figure 19. Current network of USGS crest-stage gaging stations in South Carolina.

SURFACE WATER QUALITY

"It is declared to be the public policy of the State to maintain reasonable standards of purity of the air and water resources of the State, consistent with the public health, safety and welfare of its citizens, maximum employment, the industrial development of the State, the propagation and protection of terrestrial and marine flora and fauna, and the protection of physical property and other resources." S.C. POLLUTION CONTROL ACT

From agriculture and manufacturing, to recreation and tourism, clean water is essential to the economy and to the health and welfare of the citizens of South Carolina. Over the years, Congress has promulgated, and Federal and State agencies have implemented, effective water quality management laws, such as the Clean Water Act and the Safe Drinking Water Act. These laws have significantly reduced surface water pollution and improved drinking water quality by regulating point source discharges and by establishing and enforcing strict standards for safe drinking water. As a result, the water in our lakes, streams, and estuaries is now cleaner than it was 30 years ago, and tap water is now safer to drink. These gains should not be lost, and a strong commitment to clean water must continue.

Polluted runoff, also known as nonpoint-source pollution, is now the leading cause of water pollution in the Nation and in the State. Pollutants, such as bacteria and fertilizers from farms and chemicals and oils from cities, wash into our waterways after rainstorms and adversely impact water quality. Sources of this pollution are numerous, widespread, hard to detect, and often unregulated, making them more difficult to manage than point-source discharges. Preventing and reducing polluted runoff is the collective responsibility of all levels of government, agriculture, industry, landowners, and citizens alike and is best achieved at the watershed level by enhancing stewardship, forging partnerships, and increasing public education and participation.

South Carolina Pollution Control Act

South Carolina is fortunate to have an abundance of water. Most of it is clean enough to support desired uses such as fishing and swimming. Urbanization, land development, and the extensive use of fertilizers and pesticides, coupled with increased demands for water to meet population growth and industrial and agricultural needs, place added pressures on the resource, making it increasingly difficult to meet and maintain water quality standards. Protecting, improving, and restoring water quality are goals of the State. Waters that meet State standards must be protected to ensure that quality will not be compromised in the future. Waters that do not meet standards must be restored for the intrinsic benefits that clean waters afford the citizens of the State.

The principal law governing pollution in South Carolina is the S.C. Pollution Control Act (SCPCA). In accordance with the SCPCA, DHEC abates, controls, and prevents pollution of all bodies of surface and ground water, natural or artificial, public or private, inland or coastal, fresh or salt, which are wholly or partially within or bordering South Carolina or within its jurisdiction. DHEC's goal is to maintain and improve all surface waters to a level that provides for the survival and reproduction of a balanced community of plants and animals, recreation in and on the water, and, where appropriate, drinking water after conventional treatment, shellfish harvesting, and industrial and agricultural uses. Other Federal and State agencies have interests and programs involving water quality protection, including the South Carolina Department of Natural Resources, U.S. Army Corps of Engineers, and U.S. Geological Survey, as well as county and city governments.

Federal Clean Water Act

The principal law governing pollution of the Nation's surface waters is the Federal Water Pollution Control Act Amendments of 1972, commonly known as the Federal Clean Water Act (CWA). The CWA provides for a variety of regulatory and nonregulatory programs to reduce direct pollutant discharges into waterways and to manage polluted runoff. Administered by the Environmental Protection Agency (EPA), the goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters so they can support the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water.

DHEC has been delegated authority by the EPA to implement the Federal Clean Water Act in South Carolina. Under Section 106 of the CWA, in order to receive funding to prevent and reduce water pollution in South Carolina, DHEC must monitor, and compile and analyze data on, surface and ground water quality.

Water Quality Standards

Under the CWA and SCPCA, DHEC is required to classify South Carolina's waters and develop water quality standards. Beneficial uses are designated for each water body, and water quality standards are established that will protect the uses of the water (S.C. Regulation 61-68, *Water Classifications and Standards*; SCDHEC, 2001a). A requirement of the CWA is that State water quality standards be at least as stringent as those established by the EPA. Standards include three major components: (1) designated uses of a water body; (2) water quality criteria necessary to support those uses; and (3) antidegradation rules to maintain good water quality.

"Designated uses" are the desired uses of a water body that, at a minimum, meet the fishable/swimmable standard of the Clean Water Act. Examples of designated uses are aquatic life support, shellfish harvesting, drinking water, primary contact (swimming), and secondary contact (boating). All surface waters in South Carolina are classified on the basis of their designated uses (S.C. Regulation 61-69, *Classified Waters*; SCDHEC, 2002d), which must be approved by the South Carolina General Assembly and the EPA.

Water quality criteria describe the conditions that are necessary to support the designated uses. Numeric water quality criteria are expressed as quantitative units, such as concentration of pollutants, temperature, or pH. Narrative water quality criteria are general statements made to protect a specific designated use or set of uses.

Antidegradation policies are a set of rules that restrict or prohibit activities that could result in the degradation of high-quality waters. Under provisions of the Clean Water Act, conditions of a water body must not be allowed to deteriorate to such a degree that one or more of the designated uses can no longer be supported. Antidegradation policies apply to point-sources and nonpoint-sources of pollution (SCDHEC, 1998b and 1999c).

Water quality standards—designated uses, water quality criteria, and antidegradation policies—are the foundation of an effective water quality management program and are essential for protecting the quality of the State's surface waters. They establish water quality goals for specific water bodies and provide the regulatory basis for implementing treatment strategies to meet these goals. They are used to determine permit limits for treated wastewater discharges and any other activity that may impact water quality. Under provisions of the Clean Water Act, water quality standards are reviewed and revised every three years.

Areawide Water Quality Management Planning

The South Carolina Department of Health and Environmental Control was designated by Governor Edwards in 1976 as the State Planning Agency for water quality and, as such, is responsible for Areawide Water Quality Management Planning in South Carolina pursuant to Section 208 of the CWA. Six Councils of Government (COG) have been designated by the Governor to provide specific areawide water-quality management-planning functions in areas of the State within their jurisdictions. These COGs are Appalachian, Central Midlands, Waccamaw Regional, Lowcountry, Berkeley-Charleston-Dorchester, and Santee-Lynches Regional. DHEC provides specific areawide water-quality management-planning functions for those counties not serviced by the named COGs.

The 208 Water Quality Management Plan prepared by DHEC is updated on an as-needed basis. The process for updating or amending the plan is described in it. As the State water quality planning agency, DHEC reviews and, where applicable, certifies, approves, and submits Water Quality Management Plans and updates prepared by other areawide planning agencies to EPA for approval.

Intergovernmental and Interagency Cooperation

Enabling intergovernmental and interagency cooperation is important for several reasons. It allows for the sharing of information and expertise, helps to prevent the duplication of effort, and ensures consistency between State and Federal programs. In the case of nonpoint-source pollution that does not remain within political boundaries, intergovernmental cooperation is essential. Interagency cooperation must also occur in order to streamline regulatory activities. Achieving consistency with Federal programs involves cooperation with the U.S. Fish and Wildlife Service, Department of Defense, Federal Highway Administration, U.S. Geological Survey, and the National Resource Conservation Service, among others. Councils of Government, designated management agencies, the DNR, and the S.C. Forestry Commission are key local and State partners in water quality management.

Pollution Control Programs

DHEC is authorized to implement and enforce key pollution control programs created by the Federal Clean Water Act. Five of the most important of these programs are described below:

Section 303(d) (Total Maximum Daily Load)—Section 303(d) requires that every 2 years the State inventories waters and identifies those that do not meet water quality standards. For these impaired water bodies, a Total Maximum Daily Load (TMDL) must be developed for the pollutant(s) causing the water quality violation. States are required to identify high priority waters targeted for TMDL development over the next 2 years. TMDLs includes both nonpoint sources and point sources of pollutants in the calculations used to determine how much of the pollutant can be assimilated by the receiving body of water. The TMDL must also include a margin of safety. TMDLs are developed by DHEC's Bureau of Water, approved by EPA and then implemented by reissuing or modifying permits, and through voluntary pollution reduction measures.

Section 402 (National Pollutant Discharge Elimination System)—Section 402 of the Clean Water Act creates the National Pollutant Discharge Elimination System (NPDES). All facilities that discharge pollutants from any point source to waters of the United States must obtain a permit through the NPDES. These permits state the limits placed on discharges, as well as monitoring and reporting requirements. Any permit limit must be stringent enough to ensure that the discharge will not cause a violation of the water quality standards. NPDES permits are issued for a period of up to 5 years.

DHEC will not issue an NPDES or wastewater construction permit unless it has been certified by the applicable areawide water quality management agency that the permit will be consistent with the applicable plan. South Carolina has six separate areawide wastewater treatment plans as described in the 208 Water Quality Management Plan produced by DHEC. This document describes how agencies are authorized to administer wastewater issues. It also provides an inventory of the publicly owned wastewater treatment works in the area of the State where DHEC provides specific areawide water quality management functions.

Residual waste is the solid material, or sludge, remaining after wastewater treatment. Disposal and use of sludge is regulated by DHEC's Bureau of Water as part of the NPDES or land application permitting process.

Section 319 (Nonpoint Source Pollution Program)—Section 319 of the Clean Water Act requires the State to produce a nonpoint-source pollution (NPS) assessment report and to develop a Statewide NPS pollution management program.

NPS is the leading cause of water pollution in the nation and in the South Carolina. The State's NPS Assessment Report describes existing and potential NPS problems for more than 300 water bodies in the State. To address this growing problem, the S.C. NPS Management Program was developed by DHEC, approved by the EPA in 1990, and was updated in 1999. The NPS Management Program provides a framework for managing NPS pollution and for restoring water bodies impacted by it. It relies on regulatory and nonregulatory programs and on the implementation of Best Management Practices (BMP).

Water pollution caused by atmospheric (wind-borne) deposition is a growing problem in the Nation. The National Air Deposition Program monitors mercury, nitrogen compounds, phosphate, sulfur oxides, and acid rain at more than 200 stations Nationwide, 5 of which are located in South Carolina. Mercury is a naturally occurring element that is commonly found in coal. When coal is burned at power plants, mercury is emitted with the smoke and is directly deposited in water bodies or washed into streams or lakes by runoff. Microorganisms convert elemental mercury to methylmercury, a highly toxic form that accumulates in fish tissue. Samples collected from blackwater streams in the Santee basin by the USGS indicate the greatest ratio of methylmercury to total mercury in the Nation (Hughes and others, 2000). This suggests that conditions in the Santee basin are conducive to converting a relatively small amount of elemental mercury into high concentrations of methylmercury. Additional studies should be made to address the high levels of methylmercury concentrations found in fish-tissue samples in the State.

Section 401 (Water quality certification)—Section 401(a) of the Clean Water Act requires that an applicant must receive approval from the State certifying that the proposed activity will not violate water quality standards before it can receive a Federal license.

This section provides protection around and downstream from Federally permitted projects, such as hydroelectric generation. Applications for wetland alterations can be denied under provisions of this section. Certification issued by the State is contingent upon meeting water quality standards. S.C. Regulation 61-101 (*Water Quality Certification*; SCDHEC, 1995) establishes procedures and policies for implementing certification.

Section 404 (Placement of dredged materials into waters)—Under Section 404 of the Clean Water Act, a Federal permit is required to discharge dredged or fill material into waters of the United States, including wetlands. This program is administered jointly by EPA and the U.S. Army Corps of Engineers, but the Federal permit cannot be issued if the State (DHEC) denies 401 water quality certification.

Activities that are regulated under this program include fills for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and conversion of wetlands to uplands for farming and forestry. No discharge of dredged or fill material is permitted if a practical alternative exists that is less damaging to the environment or if the State's waters would be significantly degraded.

Wetlands contribute to the health and safety of the public by controlling floods and by intercepting and storing polluted stormwater runoff before it reaches other waterways. They also serve as important habitats for plants and animals. Small, isolated freshwater wetlands in the State continue to be lost to development by being either filled or ditched. At the present time, the State has no authority to prevent this from occurring. The State must remain committed to the protection and restoration of its wetlands and to the concept of no-net-loss of wetlands.

Watershed-based Water Quality Management

A watershed-protection approach focuses all water-quality management activities—such as monitoring, assessment, NPDES permitting, and TMDL restoration studies—in a single watershed. Such an approach recognizes that water pollution in a watershed is a function of land-use activities that are occurring in the watershed.

In 1991, DHEC implemented the State's Watershed Water Quality Management Strategy to increase the efficiency and effectiveness of programs that protect and improve the quality of South Carolina's surface and ground water resources. The strategy recognizes the interdependence of water quality and all the activities that occur in the associated watershed. Water quality monitoring, assessment, modeling, planning, permitting, and other DHEC initiatives are coordinated within the framework of a watershed management approach. Such an approach fosters stewardship and volunteerism by allowing stakeholders to participate in decisions and actions that will protect and restore the watershed in which they work and live.

Watershed Water Quality Assessment reports are prepared for all of the major river basins on a 5-year rotating basis. These comprehensive reports include information about a watershed's water chemistry, biological monitoring, physical characteristics, natural resources, growth potential, potential nonpoint-source contributions, ground water concerns, and point-source discharges.

Water Quality Planning

Section 303(e) of the CWA requires that each state establish and maintain a continuing planning process (CPP) consistent with the Act. The CPP explains South Carolina's approach to implementing Federal and State laws and regulations on water quality. It describes processes for developing and updating water quality management programs and their implementation and public participation requirements. DHEC is responsible for routinely updating South Carolina's CPP.

Programs of the U.S. Geological Survey

As the primary Federal science agency for water-resources information, the U.S. Geological Survey (USGS) monitors the quantity and quality of water in the Nation's rivers and aquifers. The Cooperative Water Program has been a successful cost-sharing partnership between the USGS and water-resources agencies at the State and local levels. Most work in the Cooperative Water Program is directed toward potential and emerging long-term problems, such as water supply, waste disposal, ground-water quality, effect of agricultural chemicals, floods, droughts, and environmental protection.

The National Water Quality Assessment Program (NAWQA) is a USGS program that collects and assesses information on water chemistry, hydrology, land use, stream habitat, and aquatic life from more than 50 major river basins and aquifers across the Nation. This information supports the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies, and assesses water quality conditions Nationwide.

The USGS Toxic Substances Hydrology Program was initiated in 1982, with the goal of providing scientific information on the behavior of toxic substances in the Nation's hydrologic environments. Investigations occur over a wide range of scales; from point sources such as leaks or discharges from industrial facilities, to multiple, closely-spaced releases such as domestic septic systems, to relatively uniform releases that occur over broad areas such as agricultural and residential land uses.

Drinking Water

The Federal Safe Drinking Water Act (SDWA) of 1974 authorizes the EPA to set National health-based standards for drinking water to control the levels of naturally occurring and manmade contaminants in the Nation's drinking-water supply. These standards are a key component of the EPA's comprehensive approach to drinking water protection, which includes assessing and protecting drinking-water sources, protecting wells and collection systems, making sure water is treated by qualified operators, ensuring the integrity of distribution systems, and making information available to the general public about the quality of their drinking water. Under provisions of the Federal Safe Drinking Water Act, EPA authorized DHEC to implement and enforce programs of the SDWA to ensure that the public water systems in the State provide safe drinking water.

Amendments to the SDWA in 1996 place a priority on prevention activities as an approach to improving drinking water supplies. The amendments require the State to provide Source Water Assessments for each Federally defined public water supply system. These assessments include the *Source Water Protection Area (SWPA)*—a description of the drinking-water source and the land area that contributes water to that source; a *Potential Contaminant Source Inventory*—a listing of the land uses and activities within the SWPA that could potentially release contaminants to the source water; and a *Susceptibility Analysis*—an evaluation of the contaminant inventory to determine the likelihood that a potential contaminant source will affect a nearby drinking-water source. These assessments should be used by public water systems to determine what preventive actions are needed to protect drinking-water sources from contamination.

The "Capacity Development" initiative requires states to develop and implement (1) a strategy to ensure that all public water systems have the technical, managerial, and financial capability to reliably deliver safe water to the public and (2) a plan to identify and assist those water systems that need improvements. South Carolina had already initiated such an effort in 1993 and received early approval from the EPA. Components of the program include construction-permitting requirements for new water systems or for modifications or expansions of existing systems; sanitary surveys that evaluate a system's technical, managerial, and financial capacity to comply with the State Safe Drinking Water Act; and an operating permit program requiring systems that fail sanitary surveys to prepare and submit a business plan to DHEC. To strengthen drinking-water safety, DHEC has the legal authority to deny business plans or construction permits to any public water system that is unable to demonstrate the capacity to comply with State drinking water standards.

States are required to submit an annual report on public water system violations to EPA. These reports must address violations of drinking water standards with respect to maximum contaminant levels, treatment techniques, monitoring requirements, and variances and exemptions. As of 1999, all community water systems are required to prepare and distribute an annual "Consumer Confidence Report" documenting the quality of water delivered by the system. The report includes information about the type of contaminants that were detected and the health risks associated with those contaminants. Public water systems must also notify their customers when they violate EPA or State drinking water standards. Any violation of a standard "that has the potential to have serious adverse effects on human health as a result of short-term exposure" must be reported within 24 hours.

Surface Water Quality Monitoring Networks

The Clean Water Act of 1972 gives states the primary responsibility for implementing programs to protect and restore water quality, including monitoring. Under the provisions of both the South Carolina Pollution Control Act and the Clean Water Act, DHEC is the State agency delegated responsibility for monitoring the quality of water in the State's streams, lakes, and estuaries. Monitoring is done in order to determine water quality status and trends, identify emerging water-quality problems, identify water bodies that are not supporting designated uses, determine if remediation and management programs are effective, issue permits for effluent discharge and determine if dischargers are in compliance with pollution regulations, and evaluate the impacts of environmental emergencies such as spills.

The primary monitoring network in the State is the Ambient Surface Water Quality Monitoring Network (DHEC, 2003b). This network, operated by DHEC, is used to assess the overall physical, chemical, and biological integrity of the State's streams, lakes, and estuaries. The core of this statewide network consists of Integrator Sites, which are 314 permanent, fixed-location monitoring sites that are sampled monthly (Figure 20). Sites are targeted for the farthest downstream access of each of the Natural Resource Conservation Service 11-digit watershed units, as well as the major lakes, reservoirs, and estuarine areas in each watershed unit.

Special Purpose Sites of the ambient network are also permanent, fixed-location sites, but they do not meet the location criteria of the Integrator Sites (Figure 20). These sites represent locations that are of special interest to the State, such as areas used to track the progress of specific remediation activities, or

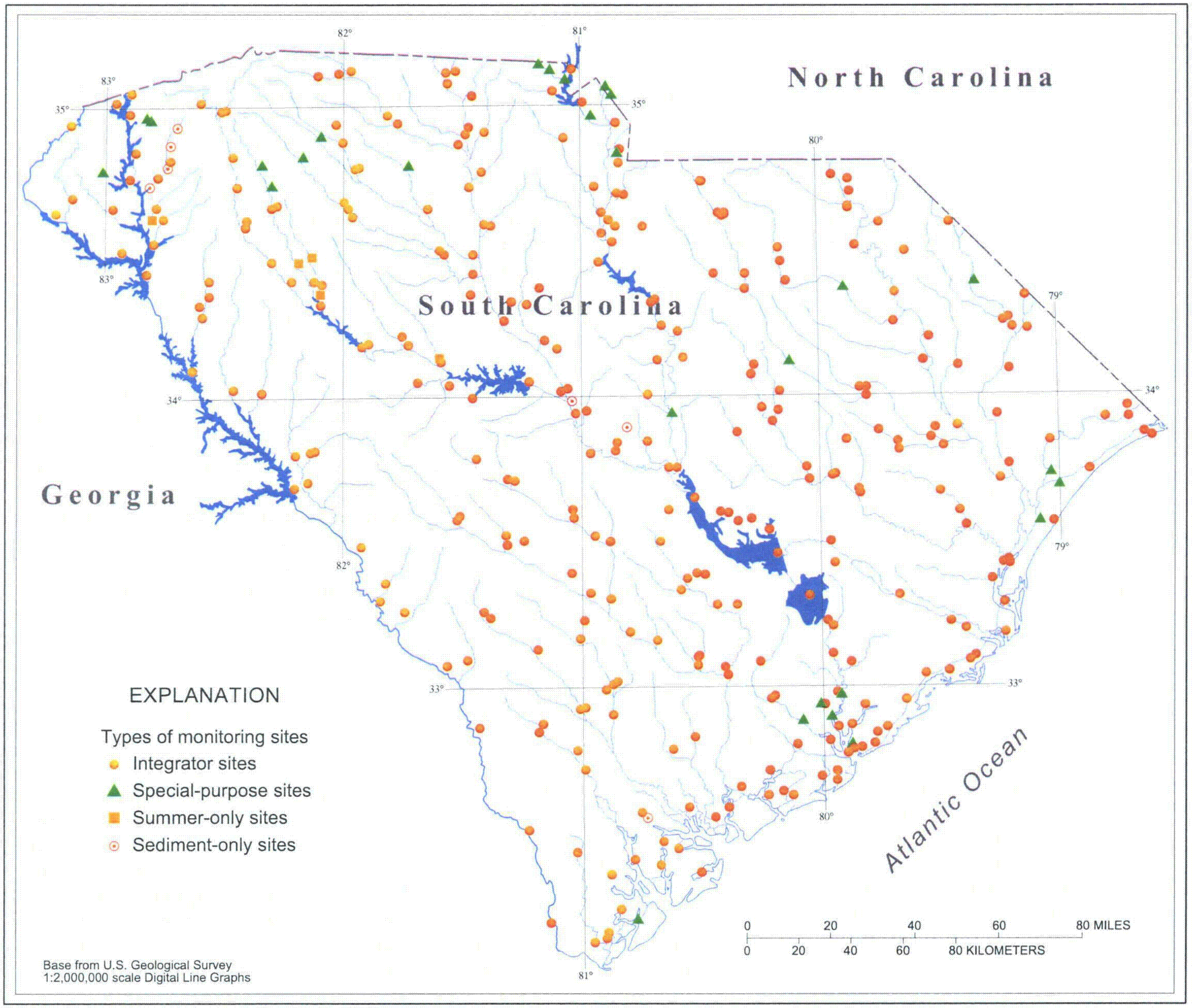


Figure 20. DHEC's Ambient Surface Water Quality Monitoring Network (modified from SCDHEC, 2003b).

where additional data are needed in large watersheds. Currently, there are 28 Special Purpose Sites, sampled monthly. In addition, there are 5 Summer-Only Sites that are sampled monthly from May through October to measure specific reservoir eutrophication conditions.

Watershed Water Quality Management Sites constitute a monitoring network that supplements the Integrator and Special Purpose stations on a 5-year rotating schedule (Figure 21). Each major watershed is sampled once every 5 years to provide additional information for various programs and to assess results of remediation activities. There are 80 to 100 monitoring sites within a given watershed, sampled monthly for a year.

A statewide random sampling of streams, lakes, and estuaries is done each year as part of the Ambient Surface Water Quality program. These samples are collected in order to make statistically valid statements about the water quality of large areas on the basis of a relatively small subset of sampling points. Each year, approximately 30 randomly selected sites are sampled in streams, and about 30 sites are sampled in lakes or reservoirs. Each of these sites is sampled monthly for 1 year.

The South Carolina Estuarine and Coastal Assessment Program was developed by DHEC, DNR, and the Marine Resources Research Institute (MRRI) to assess water quality of coastal estuaries. Water samples at 30 Core Sites in tidal creeks and open-water environments are sampled monthly by DHEC as part of the Ambient Surface Water Quality Monitoring Network. Sediment samples at the Core Sites are collected annually by DNR and MRRI for sediment chemistry and toxicity analyses. Sediment and water samples are also collected from 30 Supplemental Sites on a yearly basis.

Pollutants that are discharged at low concentrations or during storm runoff events may be undetectable or absent during normal sampling intervals. These pollutants bind to organic matter in the water column and settle to the bottom where they become part of the sediments composing the streambed. Sediment samples are collected at each randomly selected site, as described above, and at 87 permanent, fixed-location sites and analyzed for the presence of pollutants.

In the course of a complete 5-year Watershed cycle, data are collected at more than 1,250 monitoring locations across the State through the Ambient Surface Water Quality Monitoring Network.

The Ocean Water Monitoring Program is administered by DHEC and is designed to protect the health of beachgoers. Water samples are collected from 112 sites along the coast on a monthly basis from April through October and on a biweekly basis from May through September. Samples are also collected after rain, sewage spills, or excessively high tides. Swimming advisories are issued if samples are found to contain elevated counts of bacteria.

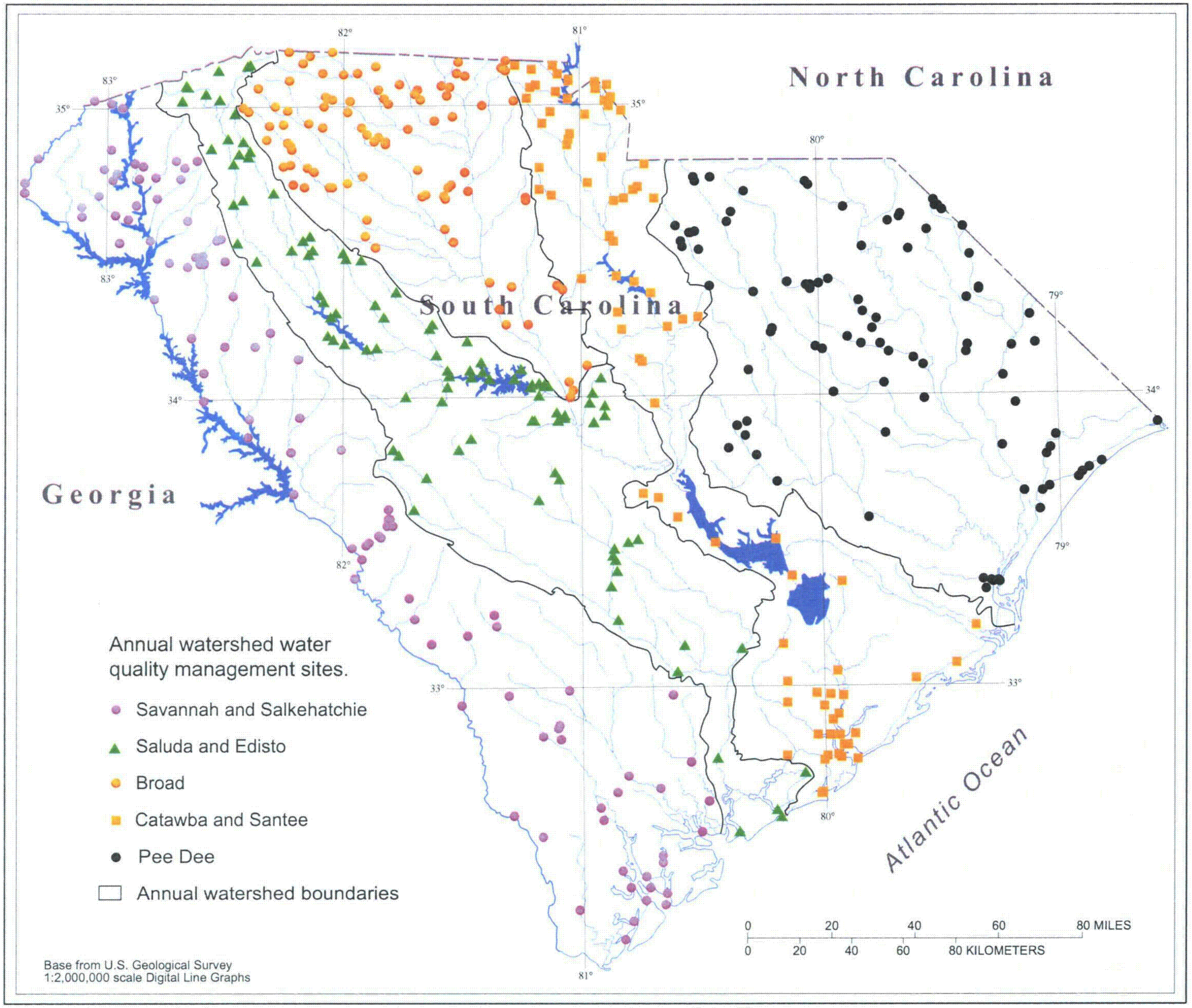


Figure 21. DHEC's Watershed Water Quality Monitoring Network (modified from SCDHEC, 2003b).

The U.S. Geological Survey maintains a network of water quality stations near several of their stream gages (Figure 22). Continuous-record stations at fixed locations monitor water quality on a regularly scheduled basis, where the frequency of sampling can be one or more times daily, weekly, monthly, or quarterly. Partial-record stations are maintained at fixed locations for a period of years but record limited water-quality data at a sampling interval that is usually less than quarterly. Other stations collect random samples from locations other than the continuous- and partial-record sites. Properties and constituents measured at these stations generally include water temperature, specific conductance, dissolved oxygen, pH, and turbidity.

Figure 22. Current network of USGS surface water quality stations in South Carolina.

GROUND WATER QUANTITY

Ground water is a significant source of drinking water in the State, supplying about 40 percent of the population, including virtually all of the rural population. It is also an important source of water for manufacturing, irrigation, and power generation and is vital for maintaining aquatic ecosystems by recharging streams, lakes, and wetlands and for sustaining surface water supplies during droughts. It is estimated that about 60 percent of the water in South Carolina's streams originates as ground water (Winter and others, 1998).

Aquifers of South Carolina

Ground water occurs everywhere in the State but is most abundant in the Coastal Plain province. The Coastal Plain contains a wedge of unconsolidated sand, clay, and limestone that thickens from zero at the Fall Line to about 3,800 feet near Hilton Head Island. The sand and limestone beds are permeable and constitute the aquifers of the Coastal Plain; clay layers are relatively impermeable and constitute the confining units. Wells in the Coastal Plain aquifers can produce as much as 3,000 gpm (gallons per minute).

Aquifers that are bounded above and below by clay or rock, and which contain water under pressure, are called "confined aquifers." Wells constructed in such aquifers are termed "artesian wells" because the water level in the wells rises above the top of the aquifer. The wells may or may not flow at the land surface; wells that do flow are referred to as "flowing artesian wells." Some confined aquifers of the Coastal Plain can be mapped for tens, and even hundreds, of square miles.

Aquifers that lack confinement are called "unconfined" or "water-table aquifers," and wells tapping such aquifers are referred to as "water-table wells." Water in unconfined aquifers is under only atmospheric pressure and stands at the top of the saturated zone, or "water table." Water-table aquifers occur throughout the Coastal Plain, but they locally discharge to streams and other surface-water bodies, thereby limiting their lateral continuity and size. Where the water table coincides with the land surface, a swamp results.

The Piedmont and Blue Ridge provinces consist of hard, metamorphic and igneous rock overlain by a layer of sand and clay called saprolite. Saprolite is the weathered by-product of Piedmont rocks and serves as a storage reservoir for ground water. Although relatively impermeable, compared to Coastal Plain deposits, saprolite slowly transmits water downward wherever the hard rock is fractured.

Water in the saprolite is generally under atmospheric pressure; as such, wells constructed in saprolite are similar to water-table wells of the Coastal Plain. For the purposes of this discussion, both the unconfined aquifers of the Coastal Plain and the saprolitic layer of the Piedmont and Blue Ridge are considered to be the water-table aquifers of the State.

Water that occurs in fractured bedrock can either be under atmospheric pressure or artesian pressure. Unlike confined aquifers of the Coastal Plain, however, fracture zones are typically connected only over short distances. As such, there is little hydraulic continuity to the aquifers of the Piedmont province. Wells constructed in the fractured bedrock are referred to as rock wells, and the aquifers they tap are collectively called "bedrock aquifers." Wells in bedrock aquifers typically yield only between 5 and 15 gpm.

Groundwater Use and Reporting Act

The principal law governing the management of ground water quantity in the State is the Groundwater Use and Reporting Act, which states that "the general welfare and public interest require that the groundwater resources of the State be put to beneficial use to the fullest extent to which they are capable, subject to reasonable regulation, in order to conserve and protect these resources, prevent waste, and to provide and maintain conditions which are conducive to the development and use of water resources."

The act also establishes conditions for the designation of Capacity Use Areas: "In the State where excessive groundwater withdrawal presents potential adverse effects to the natural resources or poses a threat to public health, safety, or economic welfare or where conditions pose a significant threat to the long-term integrity of a groundwater source, including salt water intrusion, the board, after notice and public hearing, in accordance with the Administrative Procedures Act, shall designate a capacity use area."

In Capacity Use Areas, permits are required for large-scale (3 million gallons or more in any month) ground water withdrawals. Each permit must comply with the construction, operation, and special conditions as set forth in the regulations. DHEC has the authority to modify, revoke, or deny permits and can set limits on pumping rates and on the number of wells withdrawing from an aquifer.

Ground Water Programs

The occurrence and movement of ground water are not completely understood. Water wells offer the primary means of studying ground water. Tens of thousands of wells have been drilled in the State, and they have provided much information on the resource, but much more is needed in the form of geophysical logs, surface geophysics, water-level data, hydraulics tests, cores, and water-quality analyses.

The USGS, DNR, and DHEC all play key roles in the collection, management, and analysis of ground water data. Advancing our understanding of this resource must continue with routine data collection, county and statewide ground water investigations, and with programs like DNR's surface geophysics and borehole geophysical logging programs. New test holes, core holes, and well clusters should be drilled in areas that are deficient in subsurface data. State colleges and universities should play a larger role in addressing State ground water issues.

A key to understanding the ground water resources is having accurate information about the location, thickness, and continuity of aquifers and confining units. The DNR, in cooperation with the USGS and DHEC, should reevaluate the State's existing hydrogeologic framework and revise it where necessary. Aquifers and confining units should be delineated, mapped, and characterized with respect to their hydraulic properties. Recharge areas should also be delineated and mapped. New water wells and test holes should be added on an ongoing basis to continually improve the accuracy of the framework.

Geophysical logs are an important source of subsurface data and are used for delineating aquifer boundaries, assessing water salinity, and determining well-screen locations to optimize ground water development. Efforts should be coordinated between DHEC and DNR to ensure that geophysical logs are obtained from all new public-supply wells.

Ground water flow models are important management tools for allocating and optimizing ground water withdrawals, for evaluating conjunctive use strategies and interactions between ground water and surface water, for predicting the effect of future pumping scenarios, and for determining optimal well spacings. The USGS, DNR, and DHEC should develop a comprehensive ground water flow model of the Coastal Plain. The model should incorporate the best scientific data available and should be revised periodically as new data or modeling techniques warrant.

Accurate water use data are important when developing a ground water management plan and for evaluating water use trends. Historically, only large ground water users in Capacity Use Areas were required to report their water use. The Groundwater Use and Reporting Act was amended in 2000 to require anyone in the State who withdraws 3 million gallons or more in any single month to register and annually report their water use to DHEC. This applies to ground water users in Capacity Use Areas and those outside Capacity Use Areas. This program should be strictly enforced to ensure compliance with metering requirements and reporting requirements. Unscheduled field checks should be made to ensure compliance.

Because the State does not have the financial resources to drill the number of deep wells that are needed to implement and maintain the potentiometric mapping program and other ground water investigations, existing municipal, irrigation, industrial, and other deep wells are used in these programs. These non-State-owned wells are sometimes abandoned by their owners when the wells are no longer needed or used, resulting in the permanent loss of the wells and of any future information they might provide. To prevent such losses, the DNR and USGS should be given 60 days advance notice of any well that is being considered for abandonment. If deemed important to the State's ground water monitoring programs, a variance should be granted to keep wells from being permanently plugged. In all other cases, wells should be abandoned in accordance with the law as described in the *State Primary Drinking Water Regulation* (S.C. Regulation 61-58; SCDHEC, 2003c) and in the *Well Standards* (S.C. Regulation 61-71; SCDHEC, 2002e).

Managing Ground Water Withdrawals

Although ground water is a renewable resource, pumping water from wells at rates that exceed natural replenishment will deplete the resource and cause ground water levels to decline. Consequences of overpumping include reductions in well yield, increased pumping costs, reduced flow rates in streams, altered ground water flow patterns, water-level declines in lakes and wetlands, land subsidence, sinkholes, and saltwater intrusion.

"Cones of depression" develop where aquifers are stressed by pumping. When water is pumped from a well, it is replaced with water from the aquifer. As pumping continues, water levels in the aquifer continue to decline and take on the shape of an inverted cone, the apex of which is centered at the well. Water levels are at their deepest near the well and gradually become shallower away from the well. Deep and areally extensive cones of depression often develop where excessive, long-term pumping occurs.

Identifying and mapping the extent of these cones is critical for evaluating ground water conditions. Potentiometric maps are used to detect changes in aquifer storage by evaluating the expansion or contraction of cones, and to assess the effectiveness of ground water management practices. Potentiometric maps of each major aquifer in the State should be constructed at least every 5 years to identify those areas where overpumping is occurring and to determine how conditions are changing with time.

Overpumping has caused significant regional water-level declines in nearly half (13) of the counties in the Coastal Plain. Declines have been documented in Beaufort, Berkeley, Charleston, Colleton, Darlington, Dorchester, Florence, Georgetown, Horry, Jasper, Marion, Sumter, and Williamsburg Counties. Cones of depression can impact large areas, affect hundreds of well owners, and can take decades to recover. For example, separate cones of depression in Georgetown and eastern Williamsburg Counties have coalesced to form a large cone that covers an area of about 700 square miles; water levels in that area have declined more than 200 feet from predevelopment levels (Hockensmith, 2003).

Although cones of depression are reversible—reduced pumping will result in a return to higher water levels—significant overpumping of an aquifer can also cause permanent damage to the aquifer or the overlying land. The water level in a confined aquifer can decline to a point at which the increased stress on the aquifer system causes a rearrangement of the grains that form the aquifer skeleton, resulting in an irreversible reduction in the aquifer's water-storing capacity. Excessive pumping can also lead to the dewatering of clay layers within the aquifer system, which can cause land subsidence. This is of particular concern in South Carolina because of the large number of clay beds in the Coastal Plain aquifer systems. A study should be made by DNR and the South Carolina Geodetic Survey to determine if, and to what extent, subsidence has occurred in the Coastal Plain.

In addition to a gradual and regional subsidence of land surface, overpumping in areas of the State that are underlain by limestone aquifers can also cause a sudden and localized collapse of land surface, resulting in sinkholes. Sinkholes have been documented throughout much of the lower Coastal Plain, particularly in Orangeburg and Berkeley Counties (Spigner, 1978; Hockensmith, 1989). A study should be made to identify existing sinkholes and areas susceptible to sinkhole development.

To protect aquifer systems from permanent damage due to overpumping and to ensure the long-term usefulness of the ground water resources, ground water withdrawals exceeding 3 million gallons per month should be regulated throughout the Coastal Plain. Currently, only the coastal counties and a small portion of southern Marion County are regulated as Capacity Use Areas. The Capacity Use Area should be expanded to include all Coastal Plain counties.

One of the challenges of ground water management is determining when withdrawals should be restricted. The 1998 Water Plan (Cherry and Badr, 1998) called for a water-level trigger mechanism for each aquifer in the State; when the water level in an aquifer drops below the trigger level, restrictions would be activated. In the 1998 Water Plan, water-level declines of 150 feet for the Black Creek and Middendorf aquifers and 75 feet for the Floridan aquifer were the trigger levels. The large areal extent of these aquifers and their wide range of hydrologic and physical properties may limit the application of such generalized triggers. Withdrawal-restriction criteria that are effective for an aquifer in one location may be inappropriate for that same aquifer in another location. Further studies are needed to refine this water-level index and establish additional indices for initiating withdrawal restrictions; until that is done, water levels should be maintained at least above the 1998 trigger levels. Resource managers should also consider policies—such as mandatory well spacing, or the reservation of certain aquifers for a given use or uses—to minimize the need for restricted withdrawals.

Ground water withdrawals should be managed to address the following goals:

1. Withdrawals should be managed so as to minimize their impacts on other users of the aquifer. Large-capacity wells, for example, should be placed suitably far from existing wells, and they should not be screened or gravel-packed in aquifers used primarily for domestic supply.

2. Withdrawals during droughts should be managed to protect drinking-water supplies.

3. Withdrawals should be managed to prevent land subsidence and sinkholes.

4. Withdrawals from water-table aquifers should be managed to minimize their impact on wetlands, surface water, and confined aquifers.

5. Withdrawals should not cause saltwater intrusion.

6. Withdrawals should not cause a degradation of an aquifer's water quality, which can occur when pumping-related changes in water pressure between two aquifers causes water from an adjacent aquifer with lower-quality water to move into the pumping aquifer.

An effective ground water management plan that involves the regulation of withdrawals should incorporate elements of adaptive management. Programs that restrict withdrawals should be monitored, evaluated, and adjusted as needed. This approach allows for the continual improvement of practices by learning from the outcome of operational programs.

Ground Water Quantity Monitoring Networks

Ground-water levels should be monitored throughout the State to determine the effects that withdrawals and droughts have on the State's ground-water resources. Water-level data indicate seasonal and long-term changes in ground water storage and can be evaluated to determine the general conditions of the State's ground-water resources.

Seven confined aquifers can be delineated and mapped across the Coastal Plain. In each county, water levels in a minimum of two wells per aquifer should be monitored with automatic data loggers. In those counties where water-level declines have been documented, or where a single aquifer is heavily utilized, a minimum of three wells should be monitored per aquifer. Monitor wells should have screens set adjacent only to the aquifer that is being monitored; wells with screens set adjacent to two or more aquifers should not be included in the monitoring network. Figure 23 shows the current ground-water monitoring network for the confined aquifers of the Coastal Plain, and Table 4 lists the number of additional wells required to complete the network.

In addition to the confined aquifers of the Coastal Plain, water levels in at least one well per county should be monitored in the bedrock aquifers of the Piedmont and Blue Ridge, using automatic data loggers. The current ground-water monitoring network for the State's bedrock aquifers is shown on Figure 23, and Table 4 lists the number of additional wells required to complete this network.

Owing to their shallow depths and low yields, water-table aquifers typically are not used as a source for water-supply systems; however, they are important because they contribute significantly to base flow and evapotranspiration; they are in direct contact with other surface-water bodies such as wetlands, springs, streams, ponds, and lakes; and they recharge the deeper, confined aquifers. A rise in the water table generally results in an increase in soil moisture content, but it also results in a reduction in storage capacity, rendering the area more susceptible to flooding. On the other hand, a drop in the water table leads to an increase in storage capacity, but generally causes a reduction in soil moisture content, rendering the area more susceptible to drought. As such, the water level in the water-table aquifer serves as an index for evaluating the severity of both droughts and floods.

Figure 23. Current network of ground-water monitor wells in South Carolina.

Table 4. Number of required and existing monitor wells for confined aquifers of the Coastal Plain and bedrock aquifers of the Piedmont and Blue Ridge

County	Number of aquifers	Number of monitor wells required	Number of existing monitor wells	Number of additional monitor wells required
Abbeville	1	1	0	1
Aiken	3	6	2	4
Allendale[1]	5	10	14	0
Anderson	1	1	1	0
Bamberg	5	10	0	10
Barnwell	4	8	0	8
Beaufort[2,4]	4	8	7	4
Berkeley[4]	5	10	2	8
Calhoun	4	8	0	8
Charleston[2]	4	8	5	5
Cherokee	1	1	1	0
Chester	1	1	1	0
Chesterfield[3]	3	5	1	4
Clarendon	4	8	0	8
Colleton[4]	6	12	4	8
Darlington[4]	2	4	1	3
Dillon	3	6	1	5
Dorchester[4]	5	10	0	10
Edgefield[3]	2	3	0	3
Fairfield	1	1	0	1
Florence[4]	3	6	4	2
Georgetown[4]	4	8	0	8
Greenville	1	1	2	0
Greenwood	1	1	0	1
Hampton	5	10	3	7
Horry[4]	3	6	5	1
Jasper[4]	5	10	1	9
Kershaw[3]	3	5	1	4
Lancaster	1	1	0	1
Laurens	1	1	0	1
Lee	3	6	1	5
Lexington[3]	4	7	1	6
McCormick	1	1	1	0
Marion[4]	3	6	2	4
Marlboro	2	4	2	2
Newberry	1	1	0	1
Oconee	1	1	1	0
Orangeburg	5	10	3	7
Pickens	1	1	0	1
Richland[3]	4	7	2	5
Saluda	1	1	1	0
Spartanburg	1	1	1	0
Sumter[4]	3	6	0	6
Union	1	1	0	1
Williamsburg[4]	5	10	0	10
York	1	1	1	0
Total		**234**	**72**	**172**

[1] Allendale County currently has more monitor wells than required.
[2] County with more than 2 existing monitor wells in some aquifers.
[3] County is in both the Coastal Plain and Piedmont provinces. Only 1 well required for bedrock aquifer.
[4] County has documented water-level declines in 1 or more aquifers and may require additional monitor wells.

Because the movement of water in water-table aquifers is strongly influenced by topography, the location and number of water-table monitor wells should be based on the location and size of drainage subbasins within the State. Water-table monitor wells should be sited near surface drainage divides rather than near streams for two reasons: (1) the water table near a drainage divide changes gradually compared to the water table near a stream; and (2) the overall range of water levels near a divide will be greater than that near a stream. As such, the water table measured near a divide provides a better measure of the volume of water available for base flow and evapotranspiration, and it provides a better indication of the rate and direction of water movement between the water table aquifer and the underlying confined aquifer. No wells are currently available for continuously monitoring the water-table aquifers of the State. Figure 24 shows proposed locations of monitoring stations for these aquifers.

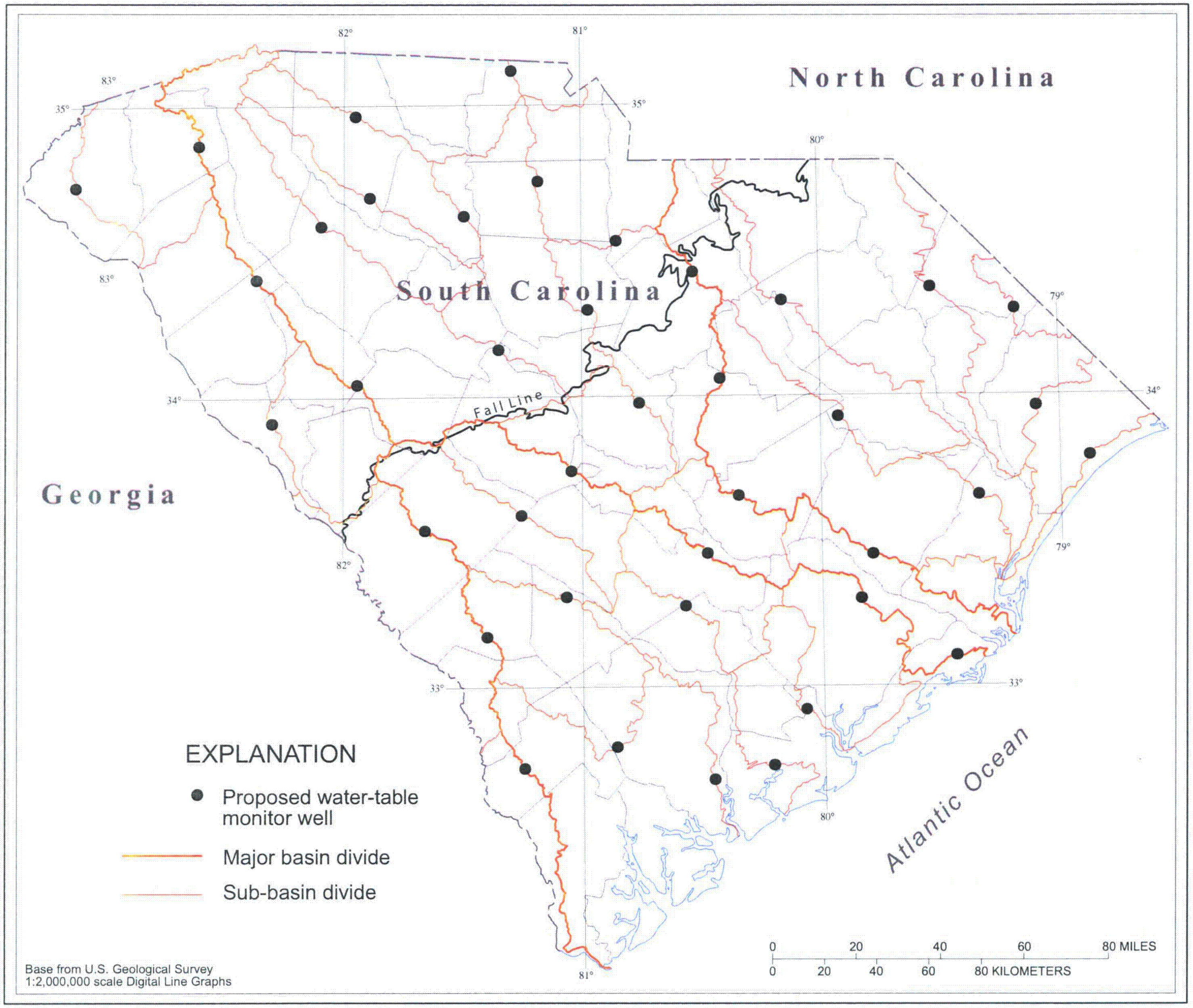


Figure 24. Proposed network of water-table monitor wells in South Carolina.

GROUND WATER QUALITY

Like surface water, ground water is vulnerable to contamination and must be protected. Contrary to popular belief, sand and soil do not completely "filter out" all pollutants; even pathogens such as bacteria and viruses are found in ground water. This contamination occurs mainly from improper fuel storage and waste disposal and from agricultural and industrial practices. Natural processes, however, can also degrade water quality. Elevated metal concentrations can result when metals, such as iron, are leached into ground water from minerals present in the earth. Naturally-occurring radionuclides (uranium and radium) have also been detected in ground water in some areas of the State.

Pollutants are numerous, but they commonly consist of nitrates, pathogens, petroleum products, metals, volatile organic compounds, fertilizers, pesticides, and radionuclides. In general, water-table aquifers are more susceptible to surface contamination than are confined aquifers, and therefore should not be used as potable sources without appropriate water-quality monitoring, analysis, and treatment. Because shallow ground water and surface water are hydraulically connected, contaminated ground water that is discharging into surface waters can also degrade the water in streams, lakes, and wetlands.

Contamination can originate from point sources and form well-defined, localized plumes beneath leaking tanks or industrial spills, or it can occur over wide areas from diffuse, nonpoint sources such as from the improper application of fertilizers and pesticides or from urban runoff. Remediation of ground water is costly, time consuming, and often ineffective at restoring water to its original condition. Consequently, efforts must be focused on preventing ground water contamination rather than on treating contamination after it occurs.

Water Quality Standards

Water quality standards promulgated in S.C. Regulation 61-68 (*Water Classification and Standards*; SCDHEC, 2001a) are applicable for both surface water and ground water. Because most of the ground water in the State "is presently suitable for drinking water without treatment ... all South Carolina ground water is classified Class GB effective June 28, 1985," unless otherwise classified (SCDHEC, 2001a). Class GB is ground water that is suitable for drinking and meets safe-drinking-water standards set forth in S.C. Regulation 61-58 (*State Primary Drinking Water Regulation*; SCDHEC, 2003c).

The State recognizes that Class GB may not be suitable for some ground water. Ground water can also be classified as Class GA, which is exceptionally valuable ground water that is vulnerable to contamination due to hydrological characteristics, or Class GC, which is ground water not suitable for drinking. The State has the right to require that an owner or operator of a contaminated site restore the ground water quality to a level that maintains and supports the classified use.

Pollution Control Programs

Federal, State, and local government agencies are responsible for enacting laws and regulations that protect ground water resources, but it is the responsibility of each citizen to do his part. The State's goal is "to maintain or restore ground water quality so it is suitable as a drinking water source without any treatment" (SCDHEC, 2001a). DHEC administers most of the programs involving ground water quality, including the Clean Water Act and the Safe Drinking Water Act (SDWA). Section 102 of the Clean Water Act authorizes states to "develop comprehensive programs for preventing, reducing, or eliminating the pollution of navigable waters and ground waters and improving the sanitary condition of surface and underground waters." Under this authority, South Carolina is currently developing a Comprehensive State Ground Water Protection Program that will provide a framework for protecting the ground water resources.

The SDWA of 1974 protects public health by regulating public drinking water supplies. One of the most effective ways to ensure safe drinking water is to protect the source of the water. Source water protection is achieved through four programs provided under the SDWA: (1) the Wellhead Protection Program; (2) the Sole Source Aquifer Program; (3) the Underground Injection Control Program; and (4) the Source Water Assessment Program.

The Wellhead Protection Program is voluntary and allows for increased protection of source areas that supply water to public supply wells. Potential sources of contamination that threaten the wells are identified and the water system's susceptibility to each source of contamination is quantified. Amendments to the SDWA in 1996 essentially expanded this program to include surface-water supply systems as well as ground water systems.

Under provisions of the Sole Source Aquifer Program, communities or individuals can petition the EPA for an added degree of protection for an aquifer that is the "sole or principal" source of drinking water for the community. A region is eligible to participate in this program if 50 percent or more of the population in the defined area relies on the designated aquifer as a source of drinking water. If the sole source aquifer is threatened by a project that is financed by the Federal government, the EPA can modify the project to reduce the potential for contamination.

The Underground Injection Control Program regulates injection wells to ensure that they do not contaminate aquifers. Injection wells used to inject municipal and industrial wastes and to dispose of hazardous or radioactive waste are prohibited in the State. The majority of injection wells permitted in the State are used for aquifer remediation.

The Federal Resource Conservation and Recovery Act regulates monitoring, investigation, and remediation activities at currently operating hazardous treatment, storage, and disposal facilities. Underground storage tanks are regulated under this act. Storage tanks that leak gasoline are the leading cause of ground water pollution in the State.

The Federal Comprehensive Environmental Response, Compensation, and Liability Act provides a "Superfund" to clean up soil and ground water contaminated by uncontrolled and abandoned hazardous-waste sites or by accidents, spills, and emergency releases of contaminants into the ground. Sites typically include industrial and municipal landfills and dump sites at military installations and manufacturing plants.

The Federal Insecticide, Fungicide, and Rodenticide Act protects human health and the environment by requiring the testing and registration of all chemicals used as active ingredients of pesticides and pesticide products.

Saltwater contamination of ground water is a concern in coastal counties of South Carolina. Overpumping can induce saltwater into freshwater aquifers, contaminating the aquifers for years or even decades. The Groundwater Use and Reporting Act allows for areas threatened by overpumping to be designated as Capacity Use Areas. In these areas, ground water withdrawals are regulated by the State, either by limiting the amount of water that can be pumped from a well or by limiting the number of wells that can be drilled into a specific aquifer. This act allows the State to minimize damages caused by saltwater contamination. Currently, all coastal counties in the State are designated as Capacity Use Areas.

Ground Water Quality Monitoring Networks

The State's ambient ground-water-quality monitoring network, operated by DHEC, consists of 115 wells located throughout the State (Figure 25). The objectives of this monitoring program are to determine the baseline values of ground water quality, to determine geographic and temporal variations in ground water quality, and to provide ground water quality data for specific aquifers, especially those that are in the initial phases of contamination studies.

Public-supply wells constitute the majority of the wells in this network; however, in rural areas where public-supply wells do not exist, privately owned wells are used. Wells are sampled in one or two of the major river basins each year and then are resampled on a 5-year rotating cycle. This sampling schedule corresponds to the watershed water-quality management schedule for surface water sampling. As such, both surface and ground water are sampled from the same watershed in the same year.

Other State and Federal agencies, such as DNR and the USGS, measure ground water quality for investigations related to specific study areas or to specific aquifers.

Some wells in coastal counties are already being continuously checked for specific conductance (a measure of salinity) to monitor saltwater intrusion, but saltwater intrusion should be monitored in aquifers along the entire coast with automated recording devices. Well-cluster sites in six coastal zones should be constructed, each consisting of three or four wells (one per aquifer) that monitor specific conductance and water chemistry for saltwater contamination. Changes in conductance or chemistry within any well should be examined as an indication of possible saltwater intrusion. In areas where saltwater problems are known to exist, more monitor wells may be needed. Existing wells in the saltwater contamination monitoring network and proposed cluster sites are shown on Figure 26.

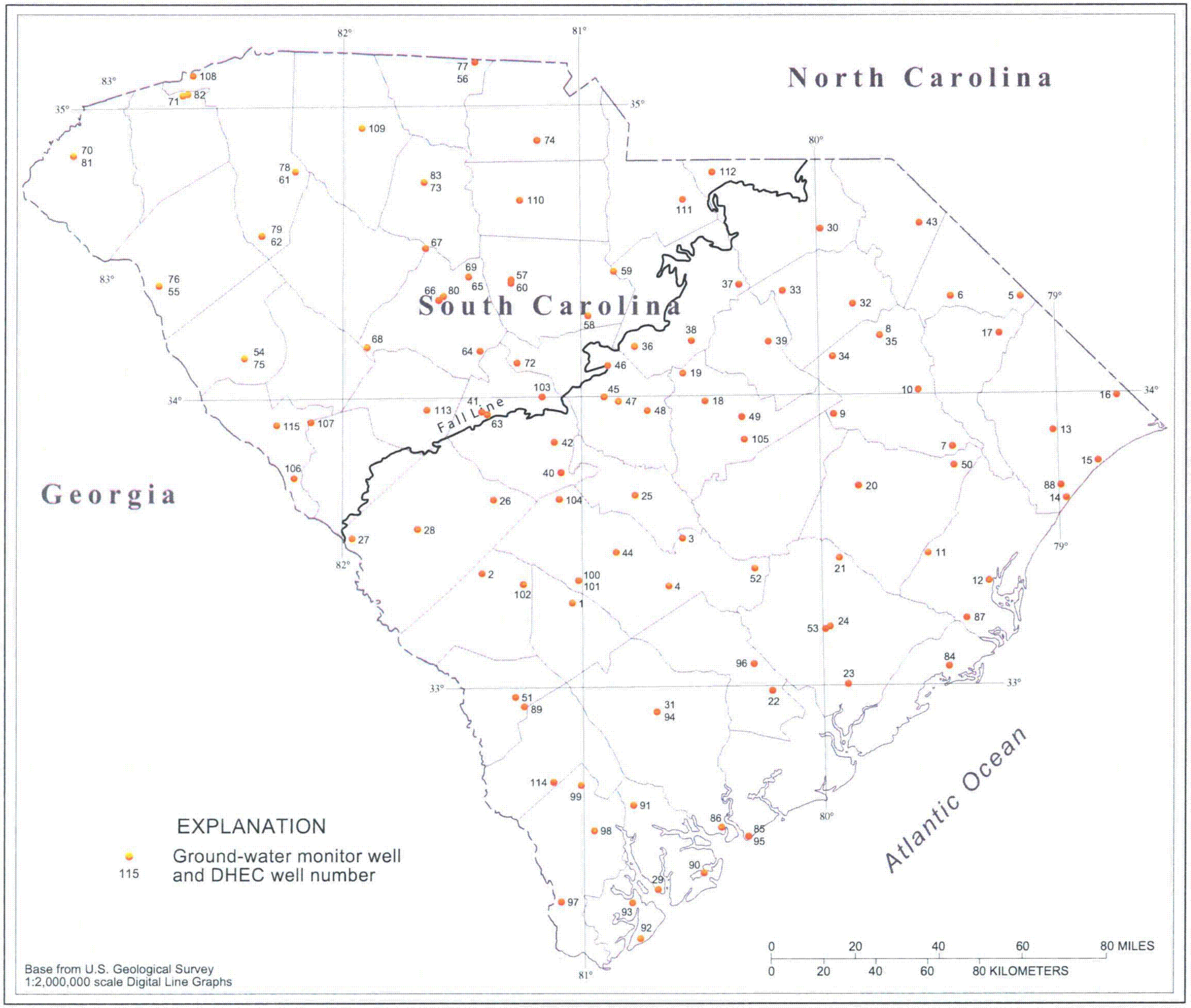


Figure 25. Location of wells in DHEC's Ambient Ground Water Quality Monitoring Network (modified from Reihm, 2002).

Figure 26. Location of saltwater intrusion monitor wells.

DROUGHT MANAGEMENT AND MITIGATION

Deficient precipitation for extended periods can cause an agricultural drought during the growing season and a lack of water to meet other demands. The State should have a statewide drought management and mitigation plan to help sustain all water uses in the State during water shortage periods. The available water during dry periods should be allocated among all uses in such a way as to minimize adverse economic and health-related problems, but all users within the drought-affected area should share the burden.

The Drought Response Committee was established by the South Carolina Drought Response Act of 1985 and includes State and local representation. The Committee has the authority to declare a drought based on climatic conditions, soil moisture, streamflows, and water levels in lakes and aquifers. The specific drought indices used in declaring a drought, and the corresponding drought levels, are the responsibility of the Drought Response Committee. Drought declarations should not be made prematurely or so frequently that the public becomes unresponsive. The Committee may request that State and Federal water resource agencies provide additional monitoring of streamflows, water levels, and water quality to ascertain the adequacy of drought mitigation practices. The DNR serves as the primary agency to monitor drought conditions throughout the State and coordinate the State's response.

An updated status of soil moisture, streamflows, aquifer water levels, lake levels, and overall climate must be issued periodically for as long as the drought exists. Notification of water-shortage conditions is to be provided by the DNR by letter and/or public communication through such media as newspaper, radio, television, and the Internet. The Drought Response Committee can recommend that the Governor issue a public statement imposing mandatory water-use restrictions. Economic, social, and environmental considerations should be used to help prioritize water use in order to enhance the recommendations of the Drought Response Committee and the Governor's Office.

A proactive approach to drought management is required to lessen the economic, social, and environmental impacts of drought. Federal and State funds should be used for drought mitigation, and cooperation among Federal, State, and local agencies, as well as private interests, is essential for sustaining all uses during dry periods. An assessment is needed of how droughts impact the State and of how vulnerability to droughts can be reduced. The following recommendations should be considered for inclusion into a drought mitigation plan:

- DHEC and DNR should develop allocation mechanisms for surface and ground water to ensure water availability and minimize conflicts during water shortages.

- DHEC and DNR should establish and enforce minimum required flows and water levels to protect water quality for the designated uses of surface water.

- Resource agencies should promote measures to increase water availability, as described in the "Maximizing Water Availability" section later in this report.

- Farmers should invest, with Federal and State support, in efficient irrigation systems where adequate surface or ground water supplies are available.

- Farmers, especially those not using irrigation systems, should select varieties of crops that have a high tolerance for dry weather.

- Federal and State resource agencies should improve research programs to increase the accuracy of drought predictions. Earlier warnings will enhance drought management and mitigation.

- A Statewide shallow-ground-water monitoring network should be developed to monitor the effects of drought on water-table aquifers.

- Statistical analyses of water-level data should be made from long-term surface- and ground-water records to determine the relative severity and recurrence interval of droughts.

- All water suppliers should prepare drought response plans, specifying water reduction schedules, alternate supply sources, and backup systems.

- Victims of drought should seek relief from the nearly 50 federal programs that have some element of drought relief, primarily for agricultural droughts. Federal and State agencies should improve programs that assist businesses that suffer drought-related losses. Also, the Emergency Board of each county in the State should help alleviate the impacts of extreme droughts on farmers, ranchers, local businesses, and communities.

- During the 1998-2002 drought, many owners of private wells had to deepen their wells or lower their pumps in reaction to water-level declines caused by the drought. No State or Federal assistance was available to help these citizens maintain their water supply. A program should be developed to provide financial assistance to low-income households in order to help them maintain their wells during prolonged or severe droughts.

FLOOD PLAIN MANAGEMENT AND MITIGATION

The ancient Egyptians built their agriculture and social system around periodic flooding. Although floods are natural events necessary for healthy ecosystems, modern man tends to regard floods as natural disasters to be prevented if at all possible. Since the 1930's, the approach to flood control has been to build reservoirs capable of holding large volumes of water, while also building levees to prevent high streamflows from escaping the river channel. While this structural approach has been successful in reducing some flooding and flood damage, it has become very expensive, and it does not guarantee protection: levees and floodwalls can fail or be overwhelmed by storms that exceed the design limits of the protective structures.

Because flood plains and wetlands provide important ecological and hydrological functions, an important goal of a flood plain management program should be to preserve natural flood plains and wetlands, not only by limiting development in those areas but also by allowing flooding to occur. The goal of flood plain management is not necessarily to reduce or eliminate flooding, but to reduce or eliminate the dangers and damages associated with floods. Flood plain management is most effective at the local level, but it requires the cooperation of all levels of government, as well as those at risk from flooding.

Flood damage can be reduced by minimizing the potential for damage. Highly vulnerable structures and critical facilities, as well as large population groups, should be relocated out of potential flood areas. Levees and floodwalls can protect heavily developed areas, but these structures are expensive and provide a false sense of security. Because all developments have the potential to increase flood damage by increasing flood stage, flood flow, and flood velocity, or by altering erosion rates, new developments can increase the flood risk for existing structures previously thought to be adequately protected. It is important that new developments are designed to minimize any flood impact they may have on existing structures.

With the goal of protecting the public and minimizing flood damages, DNR developed the *South Carolina Flood Mitigation Plan* (SCDNR, 1999). Both State and Federal governments should encourage and provide incentives for communities that participate in flood management planning while discouraging behavior likely to result in future loss of property and life. The State should also oversee flood plain and floodway delineation, and verify the hydrologic and hydraulic analyses used to make those delineations. Because DNR administers the National Flood Insurance Program, the Flood Mitigation Program, and the Federal Emergency Management Agency (FEMA) Map Modernization Program for South Carolina, it should be the State agency spearheading the implementation of these management and mitigation practices.

BASINWIDE MANAGEMENT AND INTERSTATE COOPERATION

Conflicting jurisdictions, authorities, and program objectives of the various government agencies and private organizations that have interests in the water resources of a basin greatly compound the complexity of effective water resources management. The State should work to establish a river basin advisory committee for each of its four major basins. Each committee, made up of representatives from Federal, State, and local agencies and stakeholders, would develop a basinwide comprehensive water resources plan to optimize water use throughout that basin.

The water in three of the four major basins in South Carolina is shared with either Georgia or North Carolina. To promote interstate coordination and reduce potential disputes among these States, formal mechanisms meant to provide equitable water apportionment, such as interstate compacts or memoranda of agreement, should be developed among these States. These mechanisms also provide the means for active programs for basinwide water conservation, flood protection, improved water quality, dependable navigation, and protection of fish and wildlife habitats.

DNR, DHEC, other State resource agencies, the State Legislature, and the Governor must work together with their counterparts in Georgia and North Carolina to develop these formal mechanisms. The United States government, including the Corps of Engineers and FERC, should also be involved in developing these mechanisms whenever appropriate.

MAXIMIZING WATER AVAILABILITY

South Carolina ordinarily receives ample water to meet its present and future needs, but because of its temporal and spatial distribution, water is sometimes unavailable in the right place at the right time and of the right quality. This variability in the water supply is controlled to a large extent by climatic factors over which man has no influence. Water shortages, droughts, and increasing populations are driving nations, states, and municipalities to investigate better ways of conserving water and to find new and alternative water supply technologies. South Carolina needs to join this quest for a sustainable water supply.

The amount of time required for surface water to travel through the hydrologic cycle before being discharged to the ocean is significantly less than that needed for ground water. If water in a stream is not utilized before reaching the ocean, it is no longer available as a supply source. As such, water availability can be enhanced by withdrawing water in the following order of source preference: (1) streams; (2) lakes; and (3) aquifers.

Consideration must be given to resource management policies that can help maximize water availability. DNR, in cooperation with other government and private agencies, should investigate the economic feasibility and overall practicality of the following practices and encourage their implementation where appropriate:

1. Water conservation
2. Optimization of water use in reservoirs
3. Construction of new reservoirs
4. Agricultural water-table management
5. Aquifer storage and recovery
6. Interbasin transfer of water
7. Conjunctive water use
8. Desalination
9. Gray water
10. Recycled wastewater

Water Conservation

Water conservation and improved efficiency of use can have many benefits and should be the first approach for extending or augmenting available supplies. Conservation has a limited impact on the overall water supply, however, unless consumptive use is reduced. Conservation can significantly extend water supply availability and can also reduce costs to municipal facilities.

Water conservation must become an integral component of effective water resource management. Water should be conserved at all times rather than only as a last resort during times of crisis. Initiatives to manage water resources effectively can be achieved only through cooperation and collaboration among all water users—individuals, businesses, industries, farmers, and government. Individuals must conserve water at home and at work. Businesses and industries across the State must find more efficient ways to use water and eliminate waste. Farmers must help find solutions that reduce their irrigation needs while protecting their crops. And all water supply systems must develop interconnections with neighboring systems, increase storage capacity when possible, and establish aggressive conservation programs.

Water conservation can be achieved through more efficient operation of storage and delivery facilities (to increase supply) and more efficient use by users (to reduce demand). Implementation of many conservation measures will present new challenges in securing authorizing legislation and funding, developing integrated policies, setting an appropriate balance of government and the private sector, and integrating research and education for technology transfer.

The key to making water conservation work is education. Significant water use reductions can be achieved when people understand the reasons to conserve. South Carolina needs a multifaceted water conservation campaign with voluntary, incentive, and regulatory mechanisms to address both supply-side and demand-side conservation.

Optimization of Water Use in Reservoirs

The State should play a major role in managing existing lakes to maximize the mix of benefits from the lake water and to minimize conflicts among all upstream, downstream, and lake uses. Lake management should give equal consideration to all uses, including but not limited to, water supplies, hydroelectric power, fish and wildlife, water quality, recreation, flood control, and real estate. During water shortages, all users should share the burden based upon economic, social, and environmental impacts.

Each reservoir should have a drought contingency plan that associates reservoir water levels, drought conditions, and natural inflows with the allocation of water for all uses, including downstream releases. These plans should be developed in coordination with State resource agencies, Federal agencies, stakeholders, and all interested parties in the basin. The drought contingency plan should minimize the likelihood of a reservoir's conservation pool becoming so depleted that no more water is available for withdrawal for public supplies. State resource agencies should take an active role in developing and enforcing these plans to maximize water supplies for all uses.

Construction of New Reservoirs

Although there is usually more than enough water in South Carolina to satisfy all the demands for it, shortages can occur when water availability is low. One method for improving water availability is to capture excess water during wet periods and store it in reservoirs for use during dry periods. Water stored in reservoirs in South Carolina and its neighboring states played a major role in alleviating the drought of 1998-2002; very low natural flows in the streams were supplemented by releases of water stored in those reservoirs.

Instream Reservoirs

An instream reservoir is built by damming a stream to store water. The reservoir changes the natural flow of a stream, reduces flooding, provides water for generation of hydroelectric power and other uses, and can augment the streamflow below the dam during low-flow periods. When instream reservoirs are constructed, stream and wetland ecosystems are altered in the reservoir area, upstream from the reservoir, and downstream from the dam. Because instream reservoirs tend to reduce downstream flooding, flood-plain wetlands adjacent to streams receive less water and often undergo significant ecosystem changes. The migration of fish and other aquatic organisms across dams decreases or ceases, altering ecosystems both above and below the dam. There may be a gain or loss in the diversity of organisms. Vegetation in a lake is different from vegetation in streams, and terrestrial and wetland wildlife habitats are converted to open-water habitats. Instream reservoirs also serve as traps for sediment and nutrients, and while nutrient concentrations may be greater in the reservoir than downstream, dissolved-oxygen levels are often much lower in reservoirs than in flowing streams. Recreational opportunities for reservoirs and those for free-flowing streams are different, and use of the reservoir is dependent upon ownership and provision for public access to the reservoir.

Offstream Reservoirs

An offstream reservoir is an artificial lake positioned adjacent to a stream rather than in the stream channel, made without damming the stream or altering the watercourse. An offstream reservoir can still modify the natural flow of a stream, however; water diversion and storage can reduce downstream flows and lessen flooding when streamflows are high, and reservoir releases can augment naturally low streamflows during extended dry periods. An offstream reservoir has considerably less impact on riverine ecosystems than does an instream reservoir, and because the stream remains unimpeded, navigational and recreational uses of the stream are generally not significantly changed. Some terrestrial habitat will be replaced by aquatic habitat, increasing the diversity of aquatic organisms.

The diversion of water from a stream into an offstream reservoir should be treated like any other offstream withdrawal; permitted and subject to curtailment during extended periods of low streamflow. Because offstream reservoirs do not control streamflow as do instream reservoirs, releases from offstream reservoirs should not be determined by minimum downstream flow requirements.

Agricultural Water-Table Management

Agricultural water-table management is the management, control, and regulation of soil-water conditions in the profile of agricultural soils: excess and deficit soil-water conditions can be managed to provide better plant growth conditions, with the benefit of more efficient water use. Agricultural water-table management also provides an added level of protection to farmers from drought conditions by artificially maintaining the water content in the soil and reducing water loss through drainage. The key elements of effective water-table management are controlled subsurface drainage and subirrigation.

The addition of properly designed and constructed water-control structures to a subsurface drainage system allows the drainage outlet to be artificially set at any level between the ground surface and the drain depth. Raising the outlet after planting helps keep water available for plant use longer than does uncontrolled subsurface drainage. This practice also can be used to recharge the water table between growing seasons by capturing water that would normally drain into local streams.

With subirrigation, water is supplied through the subsurface drainage system by using control structures to regulate the water table in the field. Irrigation water is applied below the ground surface, thus raising and maintaining a water table at an appropriate depth in the crop root zone. The pumping system and water control structure can be managed to create a constant or fluctuating water table. If the system is properly designed for the site and soil conditions, loss of water through deep seepage is negligible, and runoff of irrigation water rarely occurs. Water is always applied where the crop needs it most. A water supply such as a deep well, farm pond, or stream can be used to supply adequate supplemental water when needed for subirrigation.

Together with the U.S. Department of Agriculture's South Carolina Natural Resources Conservation Service and other agricultural research institutes, the DNR should promote these techniques and provide design and operational guidance and, if possible, financial incentives to farmers implementing these practices.

Aquifer Storage and Recovery

Underground water storage involves the injection or infiltration of water into an aquifer for future use. In effect, it makes use of an underground reservoir to store water in much the same way that surface water reservoirs are used. This technique has advantages over storage in surface water reservoirs because water stored underground is not subject to evaporation and is less easily contaminated. Artificial aquifer recharge holds significant potential for the storage of surplus, good-quality water for future use.

Aquifer storage and recovery (ASR) projects take advantage of a water supplier's unused treatment capacity during times of low water demand (usually in the winter) to treat surface water and then pump it into an aquifer for storage until later recovery during times of peak demand or low flow (typically a few days during the summer). ASR helps water suppliers meet peak summer demands by providing pretreated water to augment surface supplies without the need for increased treatment capacity.

ASR programs are already in use throughout the United States. In South Carolina, ASR programs are operating in Horry, Charleston, Beaufort, and Jasper Counties. An ASR program is being considered in Orangeburg County, and the South Carolina DNR is currently studying the feasibility of using ASR techniques in the Piedmont province.

Interbasin Transfer of Water

In some areas, the demand for water may exceed the natural availability, resulting in a water shortage. One solution to this problem is to transfer water from an area that has an excess of water into the area that has the deficit. The interbasin transfer of water involves moving water from one hydrologic basin (the origin basin) into another basin (the receiving basin), where it is used and discharged. The significant feature of interbasin transfer is that the water is completely removed from the origin basin, preventing its use by anyone downstream of the withdrawal point.

The Interbasin Transfer Act of 1985 gave DHEC the authority to regulate and permit interbasin transfers in South Carolina. Permit conditions should reflect a scientific understanding of the water availability, and protect both basins of origin and receipt. Interbasin transfer permit conditions should also consider the flow frequency and magnitude of the source stream, as well as the volume of stored water needed to supplement natural low flows in the origin basin.

Normally, there will be adequate excess water in the origin basin, so that transferring water to another basin will not result in detrimental water shortages in the origin basin. If the origin basin is experiencing a water shortage, however, there may not be enough water available for transfer without aggravating the water shortage in the origin basin. A trigger mechanism should be designed into special-permit conditions to make transferable volumes proportional to the available water volume in the origin basin: the less water available, the less water transferred. In that way, both the origin and receiving basins share the burden during water shortages.

Conjunctive Water Use

Conjunctive water use is the combined use of ground- and surface-water resources in order to optimize the water availability, increase the reliability of the water supply, or to offset the negative impacts of using a single source. Water planners should consider the implementation of conjunctive strategies—that is, using both surface water and ground water—for the following conditions:

- If withdrawals from a single source are limited or are unreliable;
- If heavy withdrawals from aquifers are substantially altering horizontal or vertical flow patterns or are causing land subsidence or irreversible damage to the aquifers;
- If withdrawals from aquifers are negatively impacting domestic ground-water users;
- If withdrawals from streams are destructive to aquatic ecosystems;
- If water quality from a single source is inconsistent or undesirable.

The combined use of ground water and surface water should be optimized to reduce the effects that withdrawals have on either source and on the environment.

Desalination

Desalination is the process in which dissolved minerals—primarily salt—are removed from seawater or brackish water, making the saltwater or brackish water suitable for use in public supply systems. Desalination plants are becoming increasingly common, primarily in high-growth coastal areas of Florida and California. While only Florida is currently desalting seawater for drinking-water use, more than 20 states employ technologies such as reverse osmosis to desalt brackish water. South Carolina is one of those states: in 1991, Mount Pleasant Waterworks became the first municipal water system in South Carolina to provide drinking water treated with reverse-osmosis technology.

The most common objection to using desalted water to help meet municipal water needs is that the process is expensive; however, developments in technology and improvements in desalting processes have dramatically reduced the cost of desalination over the past 30 years. When considering new sources for public supplies near the coast, State and local governments, as well as private water companies, should consider the feasibility of desalination by making cost comparisons to other sources of suitable water, such as surface water impoundments, remote well fields, and long-distance pipelines.

Gray Water

Gray water is water that can be used twice; it includes the discharge from kitchen sinks and dishwashers (*not* garbage disposals); bathtubs, showers and lavatories (*not* toilets); and household laundry (*not* diaper water). Using gray water can almost double home water-use efficiency and provide a water source for landscape irrigation. Although properly treated and continuously monitored gray water can be a valuable and safe resource for landscape irrigation, poor maintenance or system neglect can lead to human health problems and maintenance difficulties. Currently, South Carolina's health codes do not allow the use of gray water because of possible health risks.

Recycled Wastewater

Treated municipal wastewater can be recycled for irrigation, industry, and fire-control purposes. The use of reclaimed water is less expensive, optimizes the resource, provides nutrients to crops, reduces surface-water pollution, and conserves freshwater. Because effluent can contain pathogens and harmful chemicals, however, it must be carefully applied and monitored in order to prevent direct human contact and contamination of ground-water resources. Only effluent that has passed through a secondary treatment phase and that has been approved by public health officials should be recycled. A separate delivery system must be constructed to prevent contamination to the public water system. If effluent is used for irrigation, monitor wells should be constructed to evaluate the long-term effects on ground-water quality. Effluent irrigation should not be used on row crops or crops that are eaten raw, such as fruits and nuts, but can be used on grasslands such as turf farms, pastures, golf courses, parks, athletic fields, and cemeteries. The State encourages the use of recycled water as long as it is adequately treated to ensure water quality appropriate for the use.

RECOMMENDATIONS

WATER RESOURCES MANAGEMENT

The effective management of South Carolina's water resources is beyond the scope of any one agency or organization and will require cooperation and shared responsibility among Federal, State, and local agencies, as well as public and private parties.

Management strategies must be flexible, responsive to trial, monitoring, and feedback, and should change in response to new scientific information and technical knowledge. This "adaptive management" approach provides a process for continually improving management practices and policies.

Effective resource management requires the increased utilization of regulatory science. Research institutes and universities should be encouraged to work with State resource agencies to advance regulatory science and become integrated into the decision-making processes of the State.

The State should work to establish a river basin advisory committee for each of its four major basins. Each committee, made up of representatives from Federal, State, and local agencies and stakeholders, would provide a basinwide comprehensive water resources plan to optimize water use throughout that basin. These plans should be approved and adopted by the appropriate Federal, State, and local agencies.

Formal mechanisms such as interstate compacts, memoranda of agreement, or protocols should be developed with Georgia and North Carolina to provide equitable water apportionment.

Consideration must be given to resource management policies that can help maximize water availability. The State, in cooperation with other government and private agencies, should investigate the economic feasibility and overall practicality of these policies.

Water availability can be enhanced by withdrawing water in the following order of source preference: (1) streams; (2) lakes; and (3) aquifers.

In order to effectively manage the State's water resources, comprehensive and accurate monitoring of water use is needed.

Preventing and reducing water pollution is the collective responsibility of all levels of government, agriculture, industry, landowners, and citizens alike, and it is best achieved at the watershed level, by enhancing stewardship, forging partnerships, and increasing public education and participation.

Source Water Assessments should be used by public water systems to determine what preventive actions are needed to protect drinking-water sources from contamination.

The State must remain committed to the protection and restoration of its wetlands and to the concept of no-net-loss of wetlands. Legislation should be enacted to establish a Statewide wetlands protection program.

Water conservation and improved efficiency of use can have many benefits and should be the first approach for extending or augmenting available supplies. Water should be conserved at all times rather than only as a last resort during times of crisis. South Carolina needs a multifaceted water-conservation campaign with voluntary, incentive, and regulatory mechanisms to address both supply-side and demand-side conservation.

Water planners should consider the implementation of conjunctive strategies—that is, using both surface water and ground water. The combined use of ground water and surface water should be optimized to reduce the effects that withdrawals have on either source and on the environment.

All water supply systems should develop interconnections with neighboring systems, increase storage capacity when needed, and establish aggressive conservation programs.

The State should promote efficient irrigation and agricultural water table management techniques and provide design and operational guidance and, if possible, financial incentives to farmers implementing these practices.

Interbasin-transfer permits should allow for restrictions on the volume of transferable water during water shortages in the origin basin.

Water suppliers near the coast should consider the technical and economic feasibility, as well as the ecological impact, of desalination as a source of water.

Treated municipal wastewater should be recycled for irrigation use on grasslands such as turf farms, pastures, parks, athletic fields, and golf courses.

SURFACE WATER

The effective management of the State's surface water system requires a coordinated management of its lakes and rivers in order to balance the needs of lake users with the needs of river users.

To maximize water availability at all times and to protect human and economic needs, surface water use must be regulated. An allocation mechanism must be established to control the distribution of water so that all users have a reliable water supply. Variations in surface water availability and the location of demands must play major roles in the water allocation.

Desired flows and minimum required flows for streams should be established to protect public health and safety, maintain fish and wildlife, and provide recreation and navigation while promoting aesthetic and ecological values. It is the responsibility of the DNR to determine the minimum flow required to protect the State's aquatic resources.

The DNR should evaluate each regulated river in the State to determine the desired flows and minimum required flows just downstream from each reservoir.

The State should determine the minimum streamflow needed to maintain ecological functions of estuaries and to prevent saltwater contamination of water-supply intakes.

Permitted discharges should be adjusted as needed to reflect variability in the assimilative capacity of a river, which will change over time due to the cyclic nature of wet and dry periods.

When water is being discharged back into a stream, it should be returned as near to the point of withdrawal as is practical in order to minimize the impact of the withdrawal on the stream between the withdrawal point and the return point.

Reservoir operations should be planned to ensure adequate instantaneous or average daily flows, rather than average weekly flows.

Releases from reservoirs should be conducted in such a way as to mimic natural seasonal fluctuations in streamflow, where appropriate.

During nondrought conditions, reservoirs should be operated so that releases are sufficient to ensure that desired downstream flows are always met. During droughts, the reservoir's drought contingency plan must be enforced.

Downstream minimum required flows can be achieved by incorporating the appropriate releases into the FERC license, State operating permit, or Corps of Engineers operating plan.

The State needs to be involved in the issuing and reissuing of FERC reservoir operating licenses, which offer excellent opportunities to incorporate strategies for managing the entire river system into the reservoir operating plans.

It is important that reservoir operating plans detailed in FERC licenses allow for some flexibility in reservoir operations so that resource managers can react to changes in either water availability or demands for water without having to wait for the next relicensing opportunity.

The State should continue to use its authority under Section 401 of the Federal Clean Water Act to ensure that any proposed releases will not result in violations of State water quality standards, nor result in an unacceptable degradation of water quality. The 401 Certification can also be used to require minimum flow releases.

Because Georgia and South Carolina share the Savannah River and its lakes, these States must work together to incorporate appropriate release schedules into the Corps of Engineers operating plans for these lakes.

State Legislatures should authorize the development of a formal agreement between Georgia and South Carolina to work together to manage the Savannah River basin.

South Carolina and Georgia should continue to support the *Savannah River Basin Comprehensive Water Resources Study*, an ongoing cooperative technical project of Georgia, South Carolina, and the Corps of Engineers.

State agencies should work with relevant Federal agencies in order to coordinate activities relating to the water resources of the State.

When reservoir water levels are above the first water-shortage severity level, releases from the reservoir should equal or exceed the downstream desired-flow requirements.

When lake levels decline to less than the first water-shortage severity level because of low inflow, downstream releases and lake withdrawals should both be reduced, but downstream releases must always meet minimum flow requirements.

If the volume of usable storage in a lake is reduced so much because of drought that running out of water becomes a realistic concern—for example, if the volume of usable storage is equivalent to only 100 days of lake withdrawals—downstream releases should be set equal to the inflow into the lake. All regulated lakes must be studied to determine if this 100-day level is an appropriate trigger for this action.

If a drought persists to the extent that the water level nears the bottom of the conservation pool, and the volume of usable storage in the lake is almost exhausted—for example, equivalent to 10 days of lake withdrawals—further reductions in both lake withdrawals and downstream uses should be required. The lake's outflow should be set equal to the lake's inflow minus the newly-reduced lake withdrawals.

Having an adequate number of properly located gages is vital to the effectiveness of the surface-water monitoring network. The State should provide adequate funding to support this monitoring program and to prevent the loss of existing gages.

Protecting, improving, and restoring water quality are goals of the State. The State should continue to develop and improve water-quality standards that will meet the goals of South Carolina and the Clean Water Act. Waters that do not meet standards must be restored.

The State should continue to revise and refine water-quality monitoring programs to address additional potential impacts on water quality from increasing population and development. It should increase analytical capabilities to measure the presence of chemicals at very low concentrations, strengthen monitoring programs that assess biological integrity of water bodies, and improve lake-quality monitoring programs.

The State should continue to develop and implement Total Maximum Daily Loads for all waters on the 303(d) list. This includes waters impaired solely or primarily by nonpoint-source pollution.

The State should continue efforts to reduce point-source pollution by issuing water-quality based National Pollutant Discharge Elimination System permits.

The State should continue to seek additional resources and technology to identify and reduce nonpoint sources of pollution.

The State should investigate the elevated mercury levels found in fish tissue samples.

The State should continue to conduct water-quality assessment and protection at the watershed level. It should continue to increase watershed partnerships among government, the private sector, and stakeholders and encourage resource stewardship through education and outreach.

GROUND WATER

Advancing our knowledge of the State's ground water resources must continue with routine data collection, county, regional, and Statewide ground water investigations, and with programs like the surface geophysics and borehole geophysical logging programs.

To protect aquifer systems and to ensure the long-term sustainability of the ground water resources, the entire Coastal Plain province should be designated a Capacity Use Area.

Efforts should be coordinated between DHEC and DNR to ensure that geophysical logs are obtained from all new public-supply wells.

The State, in cooperation with the USGS, should reevaluate the existing hydrogeologic framework and improve it where necessary. New test holes should be drilled in areas that lack substantial subsurface data.

A comprehensive ground-water flow model of the Coastal Plain should be developed and used to predict the effect of future pumping and to determine optimal well spacings.

Potentiometric maps of each major aquifer in the State should be constructed at least every 5 years to identify those areas where overpumping is occurring and to determine how ground water levels are changing with time.

The DNR and USGS should be given 60 days advance notice of any well that is being considered for abandonment. If deemed important to the State's ground-water monitoring programs, a variance should be granted to keep a well from being permanently plugged.

A study should be made by the State to determine if, and to what extent, subsidence has occurred in the Coastal Plain. Withdrawal rates should be managed so as to prevent land subsidence and sinkholes.

In areas where water-level declines are or may become troublesome, withdrawals should be restricted in order to minimize further declines and allow ground-water levels to recover.

Ground-water levels in the Coastal Plain aquifers should be kept above the trigger levels described in the 1998 *South Carolina Water Plan*. More studies are needed to refine this water-level index and to establish additional indices for initiating withdrawal restrictions.

Resource managers should develop ground water policies—such as mandatory well spacing, or the reservation of certain aquifers for specific uses—to minimize the need for restricting ground-water withdrawals. Withdrawals should be managed so as to minimize their impacts on other users of the aquifer.

Withdrawals should be managed so as to prevent degradation of aquifer water quality. Efforts must focus on preventing ground-water contamination as well as treating it.

The State should continue to investigate elevated levels of uranium and radium found in some aquifers.

Withdrawals from an aquifer should not result in saltwater intrusion.

Withdrawals from water-table aquifers should be managed with consideration for the impact these aquifers have on wetlands, surface water, and confined aquifers.

Withdrawals should be managed to protect drinking-water supplies obtained from public-supply wells or private domestic wells.

Ground-water quantity should be monitored throughout South Carolina to determine the effects that withdrawals and droughts have on the State's ground-water resources.

In each county, water levels in a minimum of two wells per aquifer should be monitored with automatic data loggers. In those counties where water-level declines are or may become troublesome, or where a single aquifer is heavily utilized, a minimum of three wells per aquifer should be monitored.

Water levels in a minimum of one well per county should be monitored in the bedrock aquifers of the Piedmont province.

A Statewide water-table monitoring network should be established. Each monitor well should be sited near a drainage divide.

Saltwater intrusion should be monitored in aquifers along the entire coast; each major aquifer should have at least two monitor wells.

DROUGHT MANAGEMENT AND MITIGATION

The State should have a drought management and mitigation plan to enhance current drought-related legislation and to help sustain all water uses in the State during water shortages.

Water available during dry periods should be allocated among all uses in such a way as to minimize adverse economic, environmental, and health-related problems, but all users within the drought-affected area should share the burden. Economic, social, and environmental impacts should be considered when prioritizing water use.

Drought-contingency plans must be developed by lake owners for all Federally operated, FERC-licensed, or State-permitted lakes.

All water suppliers and industries should prepare drought response plans, specifying system-specific triggers or indicators, predrought planning efforts, water reduction schedules, alternate supply sources, and backup systems. These plans should be filed with and approved by the State Drought Response Committee.

Federal and State agencies should improve research programs to increase the accuracy of drought predictions and should improve programs to assist businesses that suffer drought-related losses.

Farmers should invest in efficient irrigation systems if adequate surface- or ground-water supplies are available, and they should select varieties of crops that have a high tolerance for dry weather.

During the 1998-2002 drought, many owners of private wells had to deepen their wells or lower their pumps in reaction to water-level declines caused by the drought. No State or Federal assistance was available to help these citizens maintain their water supply. A program should be developed to provide financial assistance to low-income households.

FLOOD PLAIN MANAGEMENT AND MITIGATION

An important goal of a flood-plain management program should be to preserve natural flood plains, not only by limiting development in those areas but also by allowing flooding to occur.

Highly vulnerable structures and critical facilities, as well as large population groups, should be relocated out of flood-hazard areas.

New developments should be designed to minimize any flood impact they may have on existing structures.

State and Federal governments should encourage and provide incentives for communities that participate in flood-management planning while discouraging behavior likely to result in future loss of property and life.

The State should oversee flood-plain and floodway delineation and verify the hydrologic and hydraulic analyses used to make those delineations.

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GLOSSARY

Abandoned well—A well whose use has been permanently discontinued or which is in a state of such disrepair that it cannot be used for its intended purpose. Generally, abandoned wells will be filled with cement to protect ground water from waste and contamination.

Adaptive management—A process for implementing policy decisions as an ongoing activity that requires monitoring and adjustment. Adaptive management applies scientific principals and methods to improve resource management incrementally as managers learn from experience and as new scientific findings and social changes demand.

Agricultural water-table management—Modification and management of the water table to maintain the water level at a depth favorable for optimum crop growth. Also referred to as controlled drainage.

Antidegradation policy—Rules or guidelines that are required of each state by Federal regulations implementing the Clean Water Act, stating that existing water quality be maintained even if the current water quality in an area is higher than the minimum permitted as defined by Federal ambient water quality standards.

Aquatic life—All forms of living things found in water, ranging from bacteria to fish and rooted plants. Insect larvae and zooplankton are also included.

Aquifer—(1) A geologic formation, a group of formations, or a part of a formation that is water bearing. (2) A geological formation or structure that stores or transmits water, or both, such as to wells and springs. (3) A layer of sediments or rock that is sufficiently permeable to conduct ground water and to yield significant quantities of water to wells and springs. Aquifers can lie close to the surface or at great depths, and can occur over areas of hundreds of square miles.

Aquifer storage and recovery—The process of pumping and storing treated water in an aquifer for recovery and use at a later time. During periods of low demand, treated water is pumped into an aquifer; water is then recovered during periods of high demand. In coastal counties, for example, treated water can be pumped into an aquifer during the winter and recovered during the summer months when demand is greatest.

Aquifer test—See *Pumping test.*

Artesian aquifer—See *Confined aquifer*.

Artesian well—A well drilled into an artesian aquifer that has enough hydraulic pressure for water to rise above the top of the aquifer.

Assimilative capacity—The capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects and without damage to aquatic life or humans who consume the water.

Base flow—(1) The flow in a channel that is sustained by ground-water discharge in the absence of direct runoff. (2) The flow that a perennial stream reduces to during the dry season. (3) That part of stream discharge derived from ground water seeping into the stream.

Basement—See *Bedrock*.

Basin—A geographic area drained by a single major river; consists of a drainage system comprised of streams and often natural or man-made lakes. There are four major basins in South Carolina: Ashepoo-Edisto-Combahee (ACE), Catawba-Santee, Savannah, and Yadkin-Pee Dee.

Basin of origin—See *Origin basin*.

Bedrock—A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material. In the Piedmont and Blue Ridge provinces of South Carolina, bedrock occurs below the saprolite layer, about 0 to 100 feet below land surface. In the Coastal Plain region of the State, bedrock occurs below layers of sediments, from 0 to 3,800 feet below land surface.

Bedrock aquifer—An aquifer composed of solid rock, in which most water flows through cracks and fractures in the rock instead of through pore spaces between sand grains.

Beneficial use (of water)—A use of water resulting in an appreciable gain or benefit to the user, consistent with State law. Most states recognize the following as beneficial uses: domestic, municipal, industrial, irrigation, mining, hydroelectric power, navigation, recreation, stock raising, public parks, wildlife, and game preserves.

Best management practice (BMP)—Methods that have been determined to be the most effective and practical means of preventing or reducing nonpoint-source pollution.

Blue Ridge province—A mountainous area in the northwest corner of South Carolina with elevations generally greater than 1,000 feet. Blue Ridge refers to a mountain range in the United States, extending from northern Georgia across western North Carolina and into West Virginia. It is the easternmost range of the Appalachian Mountains and consists mainly of igneous and high-grade metamorphic rocks.

Borehole—A hole bored or drilled into the earth for exploratory purposes or to obtain water.

Brackish—Water containing 1,000 to 3,000 parts per million total dissolved solids. Brackish water, a mixture of seawater and freshwater, is generally unsuitable for municipal, domestic, and irrigation uses and has a salty taste.

Capacity use area—An area in the State where ground water withdrawals are regulated. Overpumping of aquifers in some areas has depleted the ground water resources or has caused saltwater intrusion. In such areas, water wells are permitted and ground water withdrawals are regulated by the State. Currently, all the coastal counties and a small part of Marion County are designated as Capacity Use Areas.

CFS—Cubic feet per second. The common unit for measuring streamflow. One cfs is equivalent to about 448 gallons per minute.

Chlorides—Negative chlorine ions found naturally in surface and ground water and in high concentrations in seawater. Elevated levels of chlorides in ground water near coastlines may indicate saltwater intrusion.

Clay—A fine-grained earth material with grains smaller than 0.2 millimeters in diameter. Beds of clay form confining units in the Coastal Plain.

Clean Water Act (CWA)—A pollution-control program administered by the EPA that regulates the discharge of pollutants from point- and nonpoint-sources into waters of the United States. Originally established in 1972 under the name Federal Water Pollution Control Act Amendments.

Coastal Plain province—An area of the State which extends from the Fall Line to the coast that is characterized by a low, broad plain consisting of layers of sand, clay, and limestone. The Coastal Plain thickens from zero feet at the Fall Line to about 3,800 feet at Hilton Head Island.

Commercial water use—Water used for motels, hotels, restaurants, office buildings, and other commercial facilities and institutions.

COE—The United States Army Corps of Engineers. Provides engineering services to the Nation, including planning, designing, building, and operating water resources projects.

Compact—See *Interstate water compact.*

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)—Provides the EPA with authority for emergency response and cleanup of hazardous substances that been spilled, improperly disposed of, or released into the environment. Also referred to as the Superfund Law.

Cone of depression—A depression in the water table or potentiometric surface of a body of ground water that has the shape of an inverted cone and that develops in the vicinity of a well by withdrawal of water. The surface area included in the cone is known as the area of influence of the well.

Confined aquifer—An aquifer bounded above and below by impermeable beds, such as clay or rock, and which contains water that is under pressure. Also referred to as an artesian aquifer.

Confined ground water—Water in an artesian or confined aquifer.

Conjunctive water use—The combined use of surface and ground water systems and sources to optimize the resource and to prevent or minimize adverse effects of using a single source.

Conservation storage—The portion of water stored in a reservoir that can be released for all useful purposes, such as municipal water supply, power, irrigation, recreation, and fish and wildlife demands. Conservation storage is the volume of water stored between the inactive pool elevation and flood-control stage. Also referred to as active conservation storage, conservation pool, and usable storage.

Consumptive water use—(1) A use of water that lessons the amount of water available for another use (e.g., water that is consumed by humans or animals). (2) A portion of water withdrawn from a surface or ground water source that is consumed and does not return to its original source or to another body of water. This includes water that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.

Contaminant—Any physical, chemical, biological, or radiological substance or material that has an adverse effect on air, water, or soil.

Contamination—The introduction of microorganisms, chemicals, toxic substances, or wastes into water in a concentration that makes the water unfit for its next intended use.

Core drilling—Cylindrical samples of earth materials obtained by drilling into the earth. The resulting samples (cores) are circular sections of each layer of sediment or rock. Cores are used to delineate and characterize aquifers and confining units and to identify and map geologic formations.

Crest-stage gage—An instrument used to obtain a record of flood crests (peak height).

Dam—(1) A structure of earth, rock, or concrete designed to form a basin and hold water back to make a pond, lake, or reservoir. (2) A barrier built for impounding or diverting the flow of water.

Datum—An elevation to which gage-height readings are referenced.

Dead storage—See *Inactive Pool.*

Depletion—The progressive withdrawal of water from reservoirs or aquifers at a rate greater than that of replenishment.

Desalination—Removal of dissolved salts from saltwater or brackish water to make it usable.

Designated uses—Those water uses identified in State water quality standards that must be achieved and maintained as required under the Clean Water Act. Such uses may include primary contact (swimming), secondary contact (boating), drinking water, shellfish harvesting, and aquatic life support.

Desired flow—A streamflow, greater than the minimum required streamflow, that enhances all instream water-uses.

DHEC—The South Carolina Department of Health and Environmental Control. The State agency responsible for implementing and enforcing State and Federal pollution control programs. http://www.scdhec.net/

Discharge—(1) The flow of surface water in a stream or the flow of ground water from a spring or well. (2) The volume of water that passes a given point in a given period of time.

Discharge point—A location at which effluent is released into a receiving stream or body of water.

Dissolved oxygen (DO)—The concentration of free (not chemically combined) oxygen dissolved in water and readily available to fish and other aquatic organisms. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms. Usually expressed in milligrams per liter or parts per million.

Dissolved solids—Minerals and organic matter dissolved in water, including salt. Excessive amounts make water unfit to drink or use in industrial processes.

Distribution system—Any combination of pipes, tanks, pumps, and so forth that delivers water from water sources or treatment facilities to the consumer.

Divide—See *Drainage divide*.

DNR—The South Carolina Department of Natural Resources. The State agency responsible for preserving, protecting, and enhancing the natural resources of the State. http://water.dnr.state.sc.us/

Domestic water use—Water used normally for residential purposes, including household use, personal hygiene, drinking, washing clothes, flushing toilets, washing cars, and for lawns, gardens, trees and shrubs. Also referred to as residential water use.

Domestic well—A water well used solely for domestic use.

Drainage area—(1) An area enclosed by a drainage divide from which direct surface runoff from precipitation normally drains by gravity into a common stream. (2) An area having a common outlet for its surface runoff.

Drainage basin—(1) The land area drained by a river. (2) Part of the Earth's surface that is occupied by a drainage system with a common outlet for its surface runoff. The term is used synonymously with *watershed*, *river basin*, and catchment.

Drainage divide—The line of highest elevations that separates adjoining drainage basins.

Drawdown—(1) The act or process of the lowering of the water surface level due to release of water from a reservoir. (2) The magnitude of the lowering of a water surface or a potentiometric surface. (3) The decline of water below the static level during pumping from a well.

Dredging—The process of digging up and removing material from wetlands or from the bottoms of waterways to clear them or make them deeper or wider.

Drought—A period of diminished precipitation that results in negative impacts upon the hydrology, agriculture, biota, energy, and economy of the State. The following are three broad categories of drought:

> ***Meteorological drought*** – such a drought is considered to occur when rainfall is less than the long-term average rainfall over a given time interval.
>
> ***Agricultural drought*** – this type of drought occurs when soil moisture availability to agricultural crops is reduced to a level causing adverse effects on the agricultural production of a region.
>
> ***Hydrological drought*** – the onset of such a drought is signified by the occurrence and/or persistence of meteorological drought causing a shortage of surface water in streams, lakes, and/or ground-water supplies.

Drought contingency plan—A document setting out an organized, planned, and coordinated course of action to be followed in case of a drought.

Drought index—An indicator of drought, or below-normal precipitation conditions. Drought indices are most typically represented as numeric values and are useful for planning. Indices used by the State include sustained decline in water levels of natural flowing streams and other natural bodies of water, decline in water tables, forest fire indices, sustained decline in potable drinking water supplies, agricultural stress, low soil moisture, and low precipitation.

Duration curve—A cumulative frequency curve that shows the percentage of time during which a specified value of a measurable property (e.g., streamflow, discharge, or power) was equaled or exceeded in a given period. Commonly referred to as flow duration curve.

Ecological impact—The effect that a human or natural activity has on living organisms and their environment.

Ecosystem—The interacting system of a biological community and its environmental surroundings.

Effluent—Treated or untreated wastewater that flows out of a treatment plant, sewer, or industrial outfall. Generally, refers to wastes discharged into surface waters.

Elevation—The variation in the height of the earth's surface as measured by the vertical distance from a known datum plane, typically mean sea level (MSL).

EPA—The United States Environmental Protection Agency. Responsible for implementing Federal laws designed to protect the environment. http://www.epa.gov/

Estuary—A region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix freshwater and saltwater. Such areas include bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife.

Evaporation—The process by which liquid water is converted into water vapor.

Evaporation rate—The quantity of water that is evaporated from a given surface per unit of time. It is usually expressed in inches or depth per day, month, or year.

Evapotranspiration—The loss of water to the atmosphere from water bodies or soil by evaporation and by transpiration from the plants.

Fall Line—An line marking the boundary between igneous and metamorphic rocks of the Piedmont province and sediments of the Coastal Plain province.

FEMA—The Federal Emergency Management Agency. FEMA is responsible for reducing the loss of life and property and protecting our Nation's critical infrastructure from all types of hazards. http://www.fema.gov/

FERC—The Federal Energy Regulatory Commission. FERC regulates and oversees energy industries in the economic and environmental interest of the American public. http://www.ferc.gov/

Flood—Temporary inundation of a normally dry area caused by high flow or overflow of water in an established watercourse, such as a river or stream.

Flood control storage—The control of floodwaters by the construction of flood storage reservoirs, floodwater retaining structures, channel improvements, levees, bypass channels, or other engineering works.

Flood crest—The maximum height of a flood at a particular location.

Flood plain—The flat or nearly flat land along a river or stream or in a tidal area that is covered by water during a flood.

Flood plain management—The operation of an overall program of corrective and preventive measures for reducing flood damage, including flood control projects, flood-plain land-use regulations, flood-proofing of buildings, and emergency preparedness plans.

Flood prevention—Measures that are taken in order to keep flood problems from getting worse. Planning, land acquisition, river channel maintenance, wetlands protection, and other regulations all help modify development on flood plains and watersheds to reduce their susceptibility to flood damage.

Flood stage—A gage height at which a watercourse overtops its banks and begins to cause damage to any portion of the defined reach.

Floodway—(1) The channel and that portion of the adjacent land area that is required through regulations to pass flood flows without increasing the water surface elevation more than a designated height. (2) Defined by FEMA as the stream channel plus that portion of the overbanks that must be kept free from encroachment in order to discharge the 1-percent annual chance of flood without increasing flood levels by more than 1 foot.

Flowing well—A well drilled into a confined aquifer that has enough hydraulic pressure for the water to flow to the surface without pumping. Also called a flowing artesian well.

Fracture—A break in a rock formation due to structural stresses.

Freshwater—Water that generally contains less than 1,000 milligrams per liter of dissolved solids.

Full pool—Maximum water surface elevation of a reservoir under normal operating conditions.

FWS—The United States Fish and Wildlife Service. An agency of the U.S. Department of Interior that is responsible for acquiring, protecting, and managing unique ecosystems necessary to sustain fish and wildlife, operating fish hatcheries, conducting research on fish and wildlife, developing recovery plans for endangered and threatened species, and other responsibilities related to fish and wildlife ecosystems. http://www.fws.gov/

Gaging station—A site on a stream, canal, lake, or reservoir where systematic observations of stage, discharge, or other hydrologic data are obtained. The USGS maintains most of the gaging stations in South Carolina.

Geophysical log—A record of the structure and composition of the earth obtained by lowering probes into a well or test hole.

Gray water—Domestic wastewater composed of wash water from washing machines, showers, bathtubs, and laundry sinks.

Ground water—Water within the earth that seeps downward and saturates the soil or rock, supplying wells and springs.

Ground water flow model—A computer model that uses numerical methods to estimate ground water flow directions and rates.

Ground water level—The elevation of the water table or potentiometric surface at a particular location.

Hazardous waste—Solid, liquid, or gaseous substances that are classified under State or Federal law as potentially dangerous and are subject to special handling, shipping, and disposal requirements.

Headwaters—The source and upper reaches of a stream or reservoir.

Hydraulic head—(1) The height of the surface of a water body above a given point. (2) The difference in water level at two given points.

Hydraulics test—See *Pumping test.*

Hydroelectric plant—Electric power plant in which the energy of falling water is used to spin a turbine generator to produce electricity.

Hydroelectric power—Electricity produced using falling water as a source of energy.

Hydrograph—(1) A graphical representation or plot of changes in the flow of water or in the elevation of water level plotted against time. (2) A graph showing stage, flow, velocity or other hydraulic properties of water with respect to time.

Hydrologic cycle—Movement or exchange of water between the atmosphere and earth.

Igneous rock—A rock formed by the solidification of molten rock.

Impermeable—Unable to transmit water; not easily penetrated. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water.

Impoundment—A body of water, such as a pond, confined by a dam, dike, floodgate, or other barrier. It is used to collect and store water for future use.

Inactive pool—(1) The volume of water in a reservoir stored below the lowest outlet or operating level. (2) Storage in a reservoir that cannot be released by the dam. Also referred to as dead pool or dead storage.

Industrial water use—Water used for industrial purposes such as fabricating, manufacturing, processing, washing, and cooling, and includes industries as steel, chemical, paper, mining, and petroleum refining.

Infiltration—(1) That portion of rainfall that moves downward into the subsurface rock and soil. (2) The process by which water moves from the surface into the soil.

Inflow—(1) The act or process of flowing in or into, such as water flowing into a reservoir. (2) The volume of water flowing into a reservoir, including precipitation falling onto the surface of the reservoir.

Injection well—A well constructed for the purpose of injecting treated water into the ground.

Instantaneous discharge—The discharge rate at a particular instant of time.

Instream flow—(1) The amount of water remaining in a stream that is required to satisfy a particular water use. (2) Nonconsumptive water in a stream.

Instream reservoir—A lake that is created by impounding a stream channel for use in collecting and storing water for future use. Unlike offstream reservoirs, instream reservoirs dam the stream and interrupt fish and boat passage along the stream.

Instream use—(1) Nonconsumptive uses of water in a stream. (2) Water use that takes place within a stream channel (e.g., hydroelectric power generation, navigation, water quality improvement, fish propagation, and recreation).

Interbasin transfer—The physical transfer of water from one watershed to another.

Interstate water compact—(1) Broadly, an agreement between two or more states regarding competing demands for water resources that are beyond the legal authority of one state alone to solve. (2) An agreement negotiated between states, adopted by their state legislatures, and approved by Congress.

Irrigation—The controlled application of water to soil when rainfall is insufficient to maintain desirable soil moisture for plant growth.

Land application—The discharge of treated effluent onto the ground for reuse, typically for irrigation.

Landfill—(1) Sanitary landfills are disposal sites for non-hazardous solid wastes spread in layers, compacted to the smallest practical volume, and covered by material applied at the end of each operating day. (2) Secure chemical landfills are disposal sites for hazardous waste, selected and designed to minimize the chance of release of hazardous substances into the environment.

Limestone—A sedimentary rock composed of calcium carbonate, and sometimes containing shells and other hard parts of prehistoric water animals and plants.

Maximum Contaminant Level (MCL)—Legally enforceable standards regulating the maximum allowed amount of certain chemicals in drinking water. The MCL is the greatest amount of a contaminant that can be present in drinking water without causing a risk to human health. MCLs are set for certain inorganic and organic chemicals, turbidity, coliform bacteria, and certain radioactive materials.

Mercury—A heavy metal that can accumulate in the environment and is highly toxic if inhaled or ingested.

Metamorphic rock—A sedimentary or igneous rock that has been changed by pressure, heat, or chemical action. For example, limestone, a sedimentary rock, is converted to marble, a metamorphic rock.

Methylmercury—An organic compound formed by the action of certain bacteria on available supplies of inorganic mercury in stream-bottom sediments containing low concentrations of dissolved oxygen. Has known neurological toxicity effects in humans.

Minimum required streamflow—The minimum amount of water required in a stream to protect fish and wildlife, protect water quality, meet navigation needs, and to prevent saltwater intrusion. Also referred to as minimum instream flow.

Mitigation—Actions designed to lessen or reduce adverse impacts.

Monitor well—(1) A well used to obtain water quality samples or measure ground water levels. (2) A well drilled at a landfill or hazardous waste management facility to collect ground-water samples for the purpose of physical, chemical, or biological analysis to determine the amounts, types, and distribution of contaminants in the ground water beneath the site.

Municipal water use—Water supplied for municipal uses through a distribution system.

National Flood Insurance Program (NFIP)—A federal program enabling property owners in participating communities to purchase insurance for the protection against losses from flooding.

National Pollutant Discharge Elimination System (NPDES)—A program established by the Clean Water Act that requires all point sources of pollution discharging into any "waters of the United States" to obtain a permit from the EPA or the State. The permit lists permissible discharges and/or the level of cleanup technology required for wastewater.

Navigable—Waters which are now navigable, or have been navigable at any time, or are capable of being rendered navigable by the removal of accidental obstructions, by small pleasure or sport fishing boats or by rafts of lumber or timber.

Nitrates—Nitrates are chemical compounds used as fertilizers to supply a source of nitrogen for plant growth. Nitrates washed into surface waters can lead to excessive growth of aquatic plants and can cause dissolved-oxygen levels to decrease.

Nonconsumptive water use—Water use in which the water is not consumed or lost from the system. Examples include hydropower generation, boating, and fishing.

Nonpoint-source (NPS) pollution—(1) Pollution discharged over a wide land area, not from a specific location. (2) Water pollution caused by diffuse sources with no discernable distinct point of source, often referred to as runoff or polluted runoff from agriculture, urban areas, mining, construction sites, and other sites. The pollutants are generally carried off the land by storm water.

NRCS—The Natural Resources Conservation Service. An agency of the U.S. Department of Agriculture, the Natural Resources Conservation Service works in soil and water conservation, resource inventories, and rural community development. Formerly known as the Soil Conservation Service.
http://www.nrcs.usda.gov/

Nutrient pollution—Contamination of water resources by excessive inputs of nutrients, usually nitrogen and phosphorus. In surface waters, excess algal production is a major concern of nutrient pollution.

Offstream reservoir—A reservoir built adjacent to a stream in which water is diverted from the stream and stored in the reservoir for later use. Unlike instream reservoirs, offstream reservoirs do not dam the stream and interrupt fish and boat passage along the stream.

Offstream use—Water withdrawn or diverted from surface or ground water sources for use at another place. Examples of offstream use include public-water supply, industry, irrigation, thermoelectric power generation, and other uses.

Origin basin—The basin from which water is removed during an interbasin transfer.

Outcrop—(1) Subsurface formations that become exposed at the surface. (2) An area where subsurface formations are exposed at the surface.

Outflow— (1) The act or process of flowing out, such as water being released from a reservoir. (2) The volume of water leaving a hydrologic system, such as a reservoir, including evaporation and seepage.

Overpumping—Pumping a well at a rate that causes a significant decline in the potentiometric surface, subsidence of the land surface, or a degradation of water quality.

Partial-record station—A gaging station at which discrete measurements of one or more hydrologic parameters are obtained over time without continuous data being recorded. A common example is a crest-stage gage, at which only peak stages are recorded.

Pathogens—Microorganisms (e.g., bacteria, viruses, or parasites) that can cause disease in humans, animals, and plants.

Period of record—The period of time during which hydrological measurements have been collected at a given location; such as the period of time that a streamflow gage has been in operation at a specific site.

Permeability—(1) The capacity of soil, sediment, or porous rock to transmit water. (2) For a rock or earth material, the ability to transmit fluids or the rate at which fluids pass through soil. Hydraulic conductivity and permeability are typically used synonymously in water-related studies.

Physiographic province—A region of which all parts are similar in geologic structure and climate and which has consequently had a unified geomorphic history; a region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

Piedmont province—An area of the State northwest of the Fall Line that is characterized by rolling hills and elevations which range from about 500 to 1,000 feet. Piedmont refers to an area or plain at the base of a mountain. In the United States, the Piedmont province is a plateau extending from New Jersey to Alabama and lying east of the Appalachian Mountains.

Plume—A relatively concentrated mass of chemical contaminants spreading in the environment that were released from a point source into either a surface water body or an aquifer.

Point-source—A stationary location or fixed facility from which pollutants are discharged; any single identifiable source of pollution, such as a pipe, ditch, ship, pit, or factory smokestack.

Point-source pollution—Pollution originating from any discrete source, such as a pipe, ditch, or sewer.

Pollutant—Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.

Pollution—Generally, the presence of a substance in the environment that because of its chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Potable water—Water that is safe for drinking and cooking.

Potentiometric surface—A surface that represents the static head of ground water in tightly cased wells that tap a confined aquifer. The potentiometric surface is defined by the levels to which water will rise in these wells.

Predevelopment—Refers to the potentiometric-surface or water-table elevation of an aquifer before ground water was withdrawn from the aquifer. Predevelopment water levels are estimated with computer modeling programs.

Primary drinking water regulation—A regulation applying to public water systems that specifies a contaminant level that, in the judgment of the EPA, will not adversely affect human health.

Primary drinking water standards—Enforceable regulations applying to public water systems and specifying the maximum contamination levels that, in the judgment of the EPA, are required to protect the public welfare.

Public supply water—Water withdrawn by public and private water suppliers and delivered to users who do not supply their own water.

Public Trust Doctrine—A judicial doctrine under which the State holds its navigable waters and underlying beds in trust for the public and is required or authorized to protect the public interest in such waters.

Public water system—A system that provides piped water for human consumption to at least 15 service connections or regularly serves 25 individuals for at least 60 days per year.

Pumping test—A test involving the withdrawal of a fixed quantity of water from a well to determine the hydraulic properties of an aquifer. Also referred to as an aquifer test or hydraulics test.

Radionuclide—Radioactive chemicals that usually occur naturally and are found in drinking water supplies. Radium and uranium are examples of radionuclides found South Carolina.

Receiving basin—The basin that receives water from another basin (origin basin) during an interbasin transfer.

Recharge—The downward movement of water through soil to ground water. There are three types of recharge:

> ***Natural recharge*** – precipitation or other natural surface flows making their way into ground water supplies.
>
> ***Artificial or induced recharge*** – actions by man specifically designed to increase supplies in an aquifer through various methods, such as water spreading (flooding), ditching, or pumping.
>
> ***Incidental recharge*** – actions such as irrigation and water diversion that add to ground water supplies but are intended for other purposes.

Recharge area—The land area over which precipitation infiltrates into soil and percolates downward to replenish an aquifer. Also referred to as recharge zone.

Recharge rate—The quantity of water per unit of time that replenishes or refills an aquifer.

Recorder—A mechanical apparatus that records measured hydrologic parameters, such as streamflow rates or aquifer water levels.

Recurrence interval—A statistical expression of the average time between floods or other hydrologic events that equal or exceed a given magnitude. For example, a flood that would be equaled or exceeded on the average of once in 100 years would have a recurrence interval of 100 years, or a 1-percent chance of occurring in any year. The actual times between occurrences vary randomly. Also referred to as the return period.

Recycled water—Water that is used more than one time before it passes back into the natural hydrologic system. Also referred to as recirculated water.

Recycled wastewater—Wastewater that becomes suitable for a specific beneficial use (such as irrigation) as a result of treatment. Also referred to as reclaimed wastewater.

Regulated stream—A stream whose flow has been manipulated either by a dam or by diversion.

Release schedule—A schedule of when and how much water will be released from a reservoir.

Relicensing—The process of renewing a license previously issued by the Federal government (commonly involving the Federal Energy Regulatory Commission) to operate a hydroelectric power plant.

Renewable resource—A natural resource that can be continuously replenished in the course of natural events and within the limits of human time. Water is an example of a renewable resource.

Resource Conservation and Recovery Act (RCRA)—Federal legislation requiring that hazardous wastes be tracked from generation to disposal.

Reservoir—(1) Any natural or artificial holding area used to store, regulate, or control water. (2) An artificially created lake in which water is collected and stored for future use.

Reverse osmosis—The process of removing salts from water using a membrane.

Riparian—Pertaining to the banks of a river, stream, waterway, or other typically flowing body of water. Also commonly used in reference to other water bodies such as ponds and lakes.

Riparian Rights Doctrine—The system for allocating water used in England and the eastern United States, in which owners of land along the banks of a stream or water body have the right to reasonable use of the waters and a correlative right protecting against unreasonable use by others that substantially diminishes the quantity or quality of water.

Riparian owner—One who owns land on the bank of a river or on other water bodies.

River basin—(1) A term used to designate the area drained by a river and its tributaries. (2) The area from which water drains to a single point. Also referred to as a watershed.

River stage—The elevation of a stream's water surface at a specified location. Usually referenced to an arbitrary zero datum or to mean sea level.

Rule curve—A graphical representation of the desired operating water level of a reservoir throughout a year. Also known as a guide curve.

Runoff—(1) That portion of precipitation that moves over the land into surface water bodies. (2) That portion of precipitation not intercepted by vegetation, absorbed by the land surface, or evaporated, and thus flows overland into a stream, lake, pond, or ocean.

Safe Drinking Water Act (SDWA)—A water-related program administered by the EPA that protects public health by ensuring that the source of drinking water as well as the system storage distribution and service lines are free and protected from contamination. Establishes uniform drinking water standards for the Nation.

Saltwater—Water that contains a relatively high percentage of dissolved solids. Generally, there are four categories, based on the dissolved solids concentration in parts per million (ppm):

Brackish water – 1,000 to 3,000 ppm
Moderately saline water – 3,000 to 10,000 ppm
Very saline water – 10,000 to 35,000 ppm
Brine – more than 35,000 ppm. Seawater has a concentration of 33,000 to 36,000 ppm.

Saltwater intrusion—The invasion of a body of freshwater by a body of saltwater. It can occur either in surface-water bodies or in aquifers. The term is applied to the flooding of freshwater marshes by seawater, the migration of seawater up rivers and navigation channels, and the movement of seawater into freshwater aquifers in coastal areas.

Sanitary survey—An onsite review of the water resources, facilities, equipment, operation, and maintenance of a public water system.

Saprolite—A soft, clay-rich, thoroughly decomposed rock formed in place by chemical weathering of igneous or metamorphic rock. Forms in humid, tropical, or subtropical climates.

Scenic Rivers Program—Created by the South Carolina Scenic Rivers Act of 1989, this program has the purpose of protecting "unique or outstanding scenic, recreational, geologic, botanical, fish, wildlife, historic or cultural values" of selected rivers or river segments in the state. The goal of the program is the conservation of South Carolina's river heritage through the proper management of the natural and cultural character of the State's river corridors.

Sediment—Soil particles that have been transported from their original location by wind or water action. Most particles originate from disintegrated rocks, such as sand and clay, but some are derived from chemical or biochemical precipitates, such as limestone, and some from decomposed organic material, such as humus.

Seepage—(1) The passage of water or other fluid through a porous medium. (2) The slow movement of water through small cracks, pores, or interstices of a material into or out of a body of surface or subsurface water. (3) The interstitial movement of water that may take place through a dam, its foundation, or abutments.

Self-supplied water—Water withdrawn from a surface or ground water source by a user rather than being obtained from a public water-supply system.

Southeastern Power Administration (SEPA)—Federal power administration that markets electricity (mainly hydroelectric power generated from dams and reservoirs operated by the U.S. Corps of Engineers) to utilities companies in West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Kentucky, and southern Illinois.

7Q10—Seven-day, 10-year low flow of a stream. The minimum flow averaged over 7 consecutive days that is expected to occur, on average, once in any 10-year period. The 7Q10 has a 10-percent chance of occurring in any given year.

Sewage sludge—Settled sewage solids combined with varying amounts of water and dissolved materials that are removed by screening, sedimentation, chemical precipitation, or bacterial digestion. The disposal of sewage sludge is regulated under the Clean Water Act. Also referred to as biosolids or sludge.

Sinkhole—A depression in the earth's surface caused by dissolving of underlying limestone, salt, or gypsum.

Soil Conservation Service—The former name of a branch of the United States Department of Agriculture, renamed the Natural Resources Conservation Service (NRCS). See *NRCS*.

Sole-source aquifer—An aquifer that is the sole or principal source (50-percent or more) of drinking water for a geographic area, as established by the Safe Drinking Water Act.

Source Water Assessment Program (SWAP)—A requirement established under the 1996 amendments to the Safe Drinking Water Act that requires each state to develop and implement a program to identify ground and surface waters that supply drinking water for public water systems. Once a source area is identified or delineated, a state must then locate contaminants within the delineated area that could potentially degrade source water.

Source Water Protection Area (SWPA)—A description of the drinking-water source and the land area that contributes water to that source.

Specific conductance—A measure of the ability to conduct an electrical current. It is commonly used as a field method of estimating the dissolved solids content water. Specific conductance is measured in wells along the coast to detect saltwater intrusion.

Spillway—A channel or passageway around or over a dam through which excess water or flood flows are discharged. If gates control the flow, it is a controlled spillway; if the elevation of the spillway crest is the only control, it is an uncontrolled spillway.

Spring—A place where ground water flows naturally from a rock or the soil onto the land surface or into a body of water.

Stage—The level of the water surface above a given datum at a given location. Generally refers to the level of water in a stream.

Stage-only gage—An instrument used to measure the stage (height) of the water in a stream, canal, lake, or reservoir. The USGS maintains most of the stage-only gages in South Carolina.

Stakeholders—Individuals and organizations with an interest in a particular area, issue, or project. Stakeholders may include public agencies at all levels, non-profit organizations, private landowners, and industries.

State Drought Response Committee—A committee authorized by the South Carolina Drought Response Act that analyzes drought conditions and makes recommendations as to the severity of droughts. It consists of representatives from the S.C. Department of Natural Resources, S.C. Emergency Preparedness Division of the Office of the Adjutant General, S.C. Department of Health and Environmental Control, S.C. Department of Agriculture, and S.C. Forestry Commission.

Storage—(1) Water artificially impounded in surface or underground reservoirs for future use. (2) Water naturally detained in a drainage basin, such as ground water, channel storage, and depression storage.

Static level—The level of water in a non-pumping or non-flowing well.

Storage capacity—The total volume of a reservoir, exclusive of surcharge.

Streamflow—(1) Water flowing in the stream channel. (2) The discharge that occurs in a natural channel. (3) The amount of water that moves past a fixed point during a given period of time.

Streamflow gage—An instrument used to measure the volume of water flowing in a stream or canal. The USGS maintains most of the streamflow gages in South Carolina.

Sub-basin—A portion of a basin drained by a single stream or group of minor streams.

Subirrigation—(1) Irrigation below the land surface (as by periodic rise in water table). (2) Irrigation from the water table that is supplied by seepage from overlying canals, reservoirs, or irrigated fields.

Subsidence—The sinking or settling of land due to a number of factors, one of which is the pumping of ground water.

Surface water—(1) All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.). (2) Water that remains on the earth's surface. (3) A source of drinking water that originates in rivers, lakes, and reservoirs.

Thermoelectric power—Electrical power generated using fossil fuels (coal, oil, or natural gas), geothermal heat, or nuclear energy.

Total Maximum Daily Load (TMDL)—The maximum quantity of a particular water pollutant that can be discharged into a body of water without violating a water quality standard.

Transmissivity—(1) The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. (2) The ability of an aquifer to transmit water.

Transpiration—(1) The movement of water from the soil or ground water to the atmosphere via plant cells. (2) The process by which water vapor escapes from a living plant, principally through the leaves, and enters the atmosphere. Transpiration, combined with evaporation, is referred to as evapotranspiration.

Unconfined aquifer—An aquifer containing water that is under atmospheric pressure. The water level in a well that penetrates an unconfined aquifer is the same as the water table outside the well.

Underground Injection Control Program (UIC)—A program required in each state by a provision of the Safe Drinking Water Act for the regulation of injection wells, including a permit system.

Unregulated stream—A stream that has not been dammed or diverted.

Unsaturated zone—The ground above the water table in which soil pores are not fully saturated, although some water may be present.

USGS—The United States Geological Survey. An agency of the U.S. Department of the Interior, responsible for extensive earth-science studies of the Nation's land, water, and mineral resources. http://www.usgs.gov/

Volatile Organic Compounds (VOC)—Organic compounds, most of which are man-made, that are used and produced in the manufacture of paints, adhesives, petroleum products, pharmaceuticals, and refrigerants. They are often compounds of fuels, solvents, hydraulic fluids, paint thinners, and dry cleaning agents. VOC contamination of drinking-water supplies is a human health concern because many are toxic and are known or suspected human carcinogens.

Wastewater—A combination of liquid and water-carried pollutants from homes, businesses, industries, or farms; the spent or used water that contains dissolved or suspended solids.

Wastewater treatment plant—A water effluent treatment facility containing a series of tanks, screens, filters, and other mechanical, biological, and chemical processes by which pollutants are removed from water.

Water budget—An accounting of the inflows to, the outflows from, and the storage changes of water in a hydrologic system.

Water demand—The water requirements for a particular purpose, such as irrigation, power production, municipal supply, or storage.

Water level—(1) A measurement of the height of the surface of still water. (2) The water-surface elevation or stage of the free surface of a body of water above or below any datum, or the surface of water standing in a well, which is usually indicative of the position of the water table or potentiometric surface.

Water-quality criteria—A specific level or range of levels of water quality necessary for the protection of a water use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.

Water-quality standards—State-adopted and EPA-approved ambient standards for water bodies. The standards prescribe the use of the water body and establish the water-quality criteria that must be met to protect designated uses.

Watershed—(1) An area that, because of topographic slope, contributes water to a specified surface-water drainage system, such as a stream or river. The watershed for a major river may encompass a number of smaller watersheds that ultimately combine at a common point. (2) An area confined by topographic divides that drains a given stream or river. Also referred to as a *drainage basin.*

Watershed Protection Approach (WPA)—A type of pollution management program supported by the EPA as being the most effective mechanism for achieving clean water. The WPA is an approach that integrates water quality management activities within hydrologically-defined drainage basins, or watersheds, as opposed to conventional, politically-defined boundaries. Public participation is emphasized and stakeholders can tailor management activities to local concerns within the watershed.

Water supply system—The infrastructure used for the collection, treatment, storage, and distribution of potable water from source to consumer.

Water table—(1) The water level in an unconfined aquifer at which the pressure is atmospheric. It is found at the level at which water stands in wells that penetrate the aquifer just far enough to hold standing water. (2) The upper surface of the saturated zone in an unconfined aquifer.

Water-table aquifer—An unconfined aquifer within which the water table occurs.

Water well—An excavation drilled, dug, bored, driven, or jetted into the ground where the intended use is for the location, acquisition, development, or artificial recharge of ground water.

Wellhead—(1) The source of a well or stream. (2) The physical structure, facility, or device at the land surface from or through which ground water flows or is pumped.

Wellhead protection area—A protected surface and subsurface zone surrounding a well or well field supplying a public water system to prevent contaminants from reaching the well water.

Wellhead Protection Program—A program intended to protect and preserve the quality of ground water that is used as a source of drinking water.

Wetland—An area that is periodically inundated or saturated by surface or ground water on an annual or seasonal basis, that displays hydric soils, and that typically supports or is capable of supporting hydrophytic vegetation. Other common names for wetlands are sloughs, ponds, swamps, bogs, and marshes. All definitions of wetlands generally require that at least one of the following attributes be met:

> ***Wetland hydrology*** – at some time in the growing season, the substrate is periodically or permanently saturated with or covered by water.
>
> ***Hydrophytic vegetation*** – at least periodically, the land supports predominantly water-loving plants such as cattails, rushes, or sedges.
>
> ***Hydric soils*** – the area contains undrained, wet soil that is anaerobic, or lacks oxygen in its upper levels.

This glossary was compiled from numerous sources including the *Glossary of Geology* (Bates and Jackson, 1987) and online glossaries provided by the Nevada Division of Water Resources, U.S. Environmental Protection Agency, National Weather Service, and United States Geological Survey.

Nevada Division of Water Resources:
http://water.nv.gov/Water%20planning/dict-1/ww-index.htm

National Weather Service:
http://www.srh.noaa.gov/wgrfc/resources/glossary/a.html

U.S. Environmental Protection Agency:
http://www.epa.gov/OCEPAterms/

United States Geological Survey:
http://search.usgs.gov/query.html?qt=glossary

ABBREVIATIONS and ACRONYMS

ACE	Ashepoo-Combahee-Edisto river basin
ASR	Aquifer Storage and Recovery
BMP	Best Management Practice
CFS	Cubic feet per second
COE	United States Army Corps of Engineers
COG	Council of Governments
CPP	Continuing Planning Process
CWA	Federal Clean Water Act
DHEC	South Carolina Department of Health and Environmental Control
DNR	South Carolina Department of Natural Resources
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FWS	United States Fish and Wildlife Service
GPM	Gallons per minute
MGD	Million gallons per day
MRRI	Marine Resources Research Institute
NAWQA	National Water Quality Assessment Program
NFIP	National Flood Insurance Program
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint-Source Pollution
NRCS	Natural Resources Conservation Service
SCE&G	South Carolina Electric and Gas
SCPCA	South Carolina Pollution Control Act
SCWRC	South Carolina Water Resources Commission
SDWA	Safe Drinking Water Act
SEPA	Southeastern Power Administration
SWAP	Source Water Assessment Program
SWPA	Source Water Protection Area
TMDL	Total Maximum Daily Load
UIC	Underground Injection Control Program
USGS	United States Geological Survey
7Q10	Seven-day, 10-year low flow

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CHAPTER 9

ALTERNATIVES TO THE PROPOSED ACTION

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9.0 ALTERNATIVES TO THE PROPOSED ACTION

The proposed action is the U.S. Nuclear Regulatory Commission (NRC) issuance of a combined construction and operating license (combined license) to Duke Energy for the Lee Nuclear Station, in Cherokee County, South Carolina. This action includes the construction and operation of the Lee Nuclear Station and its associated support facilities, including electric transmission lines to connect the Lee Nuclear Station to the Duke Energy transmission system.

Chapter 9 describes the alternatives to construction and operation of new nuclear units at the Lee Nuclear Site and alternative plant and transmission systems. The descriptions provide sufficient detail for the reader to evaluate the effects of these alternative generation options or plant and transmission systems relative to those of the proposed action.

The chapter is divided into four sections:

- No-Action Alternative (Section 9.1)
- Energy Alternatives (Section 9.2)
- Alternative Sites (Section 9.3)
- Alternative Plant and Transmission Systems (Section 9.4)

9.1 NO-ACTION ALTERNATIVE

9.1.1 INTRODUCTION

The purpose of this section is to examine the consequences should Duke Energy, for whatever reason, not build the Lee Nuclear Station and no other action is taken, hereafter referred to as the "no-action" alternative. To be precise, as directed by NUREG-1555, the no-action alternative means the following:

- the facility is not built and no other generating facility would be built,
- there is no other generation purchase strategy implemented to take the facility's place,
- there are no additional conservation measures that could be enacted to decrease the amount of electrical capacity that would otherwise be required.

Simply put, the output of the proposed generating facility would not become available to either Duke Energy or the region's electrical system. However, as proposed by NUREG-1555, the no action alternative does leave open the potential for either power-reduction measures or purchase power from other suppliers.

This review of the no-action alternative has five components, all discussed in the following subsections of this report. First, there is the initial consideration of exactly what happens to the electric supply/demand balance should the facility not be built and no other action taken. Next, given that Duke Energy is a regulated provider of electric services in North Carolina and South Carolina, there is the consideration of Duke Energy's regulatory and statutory consequences from such an alternative. Third, there is the consideration of what happens, from an energy supply perspective, to the Duke Energy electric system and its customers if the no-action alternative be taken. Fourth, there is the consequence of what should occur to regional energy supplies given the no-action alternative, and finally, what happens with respect to environmental impacts given the no-action alternative.

9.1.2 DUKE ENERGY'S SUPPLY – DEMAND ENERGY BALANCE ASSUMING NO-ACTION ALTERNATIVE

This section presents data relating the consequences of the no-action alternative with respect to Duke Energy's electric supply-demand balance. The need for this facility has been documented and thoroughly demonstrated in Chapter 8. Consequently, based on current and future electric supply and customer demand within Duke Energy's service areas, there is a demonstrated need for the electric output from this or a similar generation source in Duke Energy's franchise service areas. In addition, as discussed in Section 8.4, the demonstrated need for power is for power produced by a baseload facility such as the proposed Lee Nuclear Station.

Given this demand forecast, there are a number of implications should the Lee Nuclear Station not be built and no other actions taken in response. The first and most obvious is that the load projected to be served in the Duke Energy service territory from the unit would not be served and Duke Energy will experience a shortage of energy and capacity.

Referring to Table 8.2-1, Duke Energy's expected peak is forecasted to be approximately 21,000 MW in the 2016-2018 timeframe and its expected energy consumption approximately

105,000 – 107,000 GWh. The output of the Lee Nuclear Station (at an assumed 90 percent capacity factor) would be expected to provide almost 11 percent of the projected capacity need and 16 percent of the projected energy need.

Duke Energy's current future electric service forecasts and the resources necessary to maintain its reserve margin requirement (Section 8.1.4) are reflected in Tables 8.2-1 and 8.3-13, respectively. Table 8.4-1 shows the proposed additional generating units. Assuming the proposed 800 MW Cliffside coal unit and the proposed peaking intermediate units shown in Table 8.4-1 are built, and that the Lee Nuclear Station is not built, then Duke Energy would fail to meet its 17 percent planning reserve margin in the summer of 2018. For example, Duke Energy's projected peak demand for the summer of 2018 is 20,915 MWs (Table 8.2-1). A 17 percent reserve margin represents 3550 MWs. To the extent the Lee Nuclear Station was planned as part of the overall resource mix to meet the 17 percent reserve margin but does not materialize, Duke Energy's reserve margin would drop to 11.6 percent. At this point in time, absent any other alternative, Duke Energy would not have met its 2018 target planning reserve margin. Should this occur without mitigation, Duke Energy would be in danger of being in breach of its statutory obligation to provide adequate and reliable electric service in its North and South Carolina service areas.

9.1.3 STATUTORY AND REGULATORY CONSEQUENCES ASSUMING NO-ACTION ALTERNATIVE

Given the fact that the need for this electric supply in Duke Energy's franchise service area has been demonstrated in Chapter 8, the next question to consider is what are Duke Energy's obligations with respect to the provision of this electric service? As discussed in Section 8.1.2 Duke Energy has both statutory and regulatory responsibilities in both North and South Carolina to provide adequate and reliable electric service in its franchised service areas. For example, the North Carolina General Statutes declare that North Carolina Utilities Commission (NCUC) has the authority to regulate electric utilities in accordance with the policy of the state which provides:

> § 62- 2(a) ... it has been determined that the rates, services and operations of public utilities as defined herein, are affected with the public interest and that the availability of *an adequate and reliable supply of electric power* ..... to the people, economy and government of North Carolina is a matter of public policy. (emphasis added)

Similarly, South Carolina Code of Laws (Reference 1) requires that Duke Energy has an obligation to provide adequate and reliable electric service to all customers in its service area under the following state law:

> Section 58-27-1510. Service shall be adequate, efficient and reasonable. *Every electrical utility shall furnish adequate, efficient and reasonable service.* (emphasis added)

PSCSC rules reiterate this requirement (Reference 2) that Duke Energy provide adequate and reliable electric service to all customers in its service area under the regulatory rules.

Based on these service obligations under the laws governing the states of North Carolina and South Carolina, Duke Energy has an obligation to provide adequate and reliable electric service to its customers in its franchise service areas in both states. If Duke Energy took the no-action alternative, as demonstrated in Subsection 9.1.2, Duke Energy by 2018 would face both energy and capacity shortages. *Therefore, for Duke Energy to retain its franchise service rights in North*

Carolina and South Carolina, it must provide adequate and reliable electric service to meet its future electric demand, and, as will be demonstrated later in this chapter, the only viable option to meet these statutory obligations requires the construction of the Lee Nuclear facility or an equivalent regulatory acceptable electric supply option.

Given this situation, there are only three alternatives available to Duke Energy to meet its North Carolina and South Carolina statutory obligations to provide adequate and reliable electric service. The first option would be the construction by Duke Energy of a similar but different baseload facility, an option considered in Subsection 9.2.2 but not an option considered under the "no-action alternative". A second option would be some modifications to Duke Energy's current system or customer demands sufficient to "make-up" for the un-built facility (discussed in Subsection 9.1.4 below). A third option would be for Duke Energy to obtain purchased power from other utilities or suppliers (discussed in Subsection 9.1.5 below). As will be demonstrated in the sections below, these latter two alternatives are also not viable alternatives to the proposed generating facility.

9.1.4 REGIONAL ELECTRIC SUPPLY CONSEQUENCES ASSUMING NO-ACTION ALTERNATIVE

The no-action alternative as defined in Subsection 9.1.1 is taken here to mean that the facility is not built, and no other facility would be built or other strategy implemented to take its place. This would mean that the electrical capacity to be provided by the project would not become available. The no-action alternative also presupposes that no additional conservation measures would be enacted to decrease the amount of electrical capacity that would otherwise be required.

As discussed in Subsection 8.3.2, the capacity margin projections include the planned addition of 37,000 MWs of capacity in the Southeast Electric Reliability Council (SERC) Region, indicating a need for additional generation to maintain acceptable capacity reserve margins across the region. In and of itself, assuming other states in the SERC region required similar reserve margin, this level of reserves in the SERC region would indicate that Duke Energy would not likely be able to purchase, on a long-term basis, any baseload capacity from other potential suppliers in the SERC region. Consequently, Duke Energy would have to buy short term power if it is available. Assuming short term power is available in the region, hour to hour, its costs can be $100 to 200 per MWH. The cost to replace all of the nuclear energy based upon an average of $150/MWH could exceed $1 billion per year. Given this situation, as discussed in Subsection 9.1.2, Duke Energy would face energy and capacity shortages and Duke Energy would have no choices other than to buy power at prevailing wholesale market rates or implement rolling blackouts for customers. In addition, although Duke Energy has agreements in place with neighboring utilities for emergency power, the provisions are to use this power for true emergencies, not as a remedy for failure to build adequate generating resources. If emergency energy were not available, Duke Energy would have no option other than to face rolling blackouts.

There are additional regional effects. Duke Energy plans generation capacity additions to meet three reserve margin requirements - 1) long term reserve margin requirements, 2) contingency reserve requirements and 3) reactive reserve requirements. The long term planning reserve margin requirement of 17 percent, which is a state regulatory supported requirement, is discussed in Subsection 8.1.4. To the extent the Lee Nuclear Station were planned as part of the overall resource mix to meet the 17 percent reserve margin but does not materialize, Duke Energy's reserve margin would drop to 7 percent. From a long term generation reserves requirement, if another large unit is out of service or if load is above forecast, Duke would not be able to meet its load at times of peak demand. It would need to implement load reductions in some fashion to maintain viable operation.

With respect to the contingency reserve requirement, as a member of the SERC Reliability Region and the VACAR sub-region within SERC, Duke Energy has several reliability agreements with the other VACAR members including an agreement to share generation reserves. (Reference 3) Under the agreement Duke Energy has a commitment under SERC implementation of the Federal Power Act (16 U.S. C. Chapter 12) to provide its proportionate share of 1.5 times the largest generating resource in VACAR. This value changes annually. Presently, Duke's share is 515 MW of contingency reserves to VACAR.

Contingency reserves of this nature serve a different purpose than that of the reserve margin. Contingency reserves are reserves that must be made available within fifteen minutes of a VACAR system need usually brought about by the loss of a large generation unit within VACAR[1]. While nuclear unit capacity would not serve as contingency reserve, it makes other generation available to serve as contingency reserve as that generation is unloaded and available in a capacity emergency. If Duke has insufficient baseload generating reserves, all of its generation capacity will be employed to serve load at times of high system demand and no generation will be available to come on line in the event of the loss of a generation unit within VACAR.

Additionally, not all generating units are suitable to provide contingency reserves. The contingency reserve units must be able to ramp their output quickly. Because of the need for rapid start-up or ramp-up, baseload units, which generally require an extended start-up and ramp-up and are typically operated at full output, are not suitable. If the Lee Station is not built, then more non-baseload units must be utilized to meet load thus depleting the inventory of units suitable for supplying contingency reserves. Absent the construction of the Lee Nuclear Station or similar resources, Duke Energy may not have adequate contingency reserves to meet its VACAR reserve sharing obligations.

Should Duke/VACAR lack sufficient contingency reserves, it puts the reliability of the grid in jeopardy. Any system that cannot supply short term contingency reserves is susceptible to cascading blackouts. If a system loses a large generating unit and cannot replace its output within fifteen minutes, the system becomes highly stressed. Frequency will decline, transmission lines may become overloaded and relays may operate to protect those lines. Under-frequency relays may actuate to remove load from the system. These are the initial steps of every major cascading blackout since 1965. Some systems avert blackouts at this point. Others continue into a chaotic disaggregation of the system. The provision of contingency reserves is critical to system reliability. This is why, on June 18, 2007, the NERC Reliability Standards became

1. Contingency reserves are reserves that can be brought on line quickly to avoid a cascading blackout. When a system loses a large generation unit, operators must act quickly to replace it. The situation is much different than that of growing load and the potential inability to balance load with generation at a later hour in the day. These load balancing situations allow time to purchase generation, make public appeals or plan rotating blackouts. In the case of the sudden loss of generation, operators must respond within minutes and typically utilize predetermined procedures, one of which is to have in place and call upon contingency reserves.

mandatory and enforceable under provisions of the Energy Policy Act of 2005. These standards make the provision of contingency reserves mandatory. The requirements are detailed in NERC Reliability Standard BAL-002-0. (Reference 4)

With respect to reactive reserves, there are reliability ramifications beyond the effects of not serving Duke territorial load or meeting contingency reserves. These reliability implications impact Duke, VACAR and SERC. To explain, all load on an AC power system has two components: real power load (conventional load) and reactive load (VARS). The real power load is addressed in load forecasts. Typically, if one builds generation to meet real power load, the reactive power load will be met as AC generators are an excellent source of reactive power. Reactive power is needed to maintain the proper voltage schedule on the AC system. The danger of not meeting reactive load can be greater than the perils of not meeting real power load. This is exacerbated by the fact that substitute reactive power cannot be shipped effectively over AC transmission lines. In fact, purchased power usually consumes more reactive power than it can provide further exacerbating the situation.

The lack of reactive power to meet reactive load requirements means that voltage profiles will be lower than desired. Lowered voltage profiles coincident with system contingencies (as they do occur daily) can lead to even lower voltage profiles, which eventually lead to more VAR consumption on transmission lines which lead to a downward spiral effect causing cascading blackouts and the domino effect seen in all of the other major blackouts that have occurred since the Northeast Blackout in 1965. The single most important asset in preventing major cascading blackouts is reactive power from generating units on Automatic Voltage Regulation. FERC has implemented through NERC, mandatory and enforceable Reliability Standards effective June 18, 2007, addressing both reactive reserve requirements (Reference 5) and automatic voltage regulation requirements (Reference 6).

If Duke Energy was to not build the Lee Nuclear Station for whatever reason and take no other action, it would likely be in violation of these federally mandated Reliability Standards. Violation of NERC Reliability Standards is subject to a maximum fine of $1,000,000 per day per violation.

Based upon regional system reliability requirements, the no action alternative is not acceptable, in light of the fact that Duke Energy has no alternative but to comply with its contingency and reactive reserve commitments, which, under current load forecasts, will require the construction of the Lee Nuclear Station or resources with equivalent capacity.

9.1.5 ENVIRONMENTAL CONSEQUENCES ASSUMING NO-ACTION ALTERNATIVE

Under the No-Action Alternative the environmental impacts described in Chapters 4 and 5 would not occur. However, the electric demand would have to be met by some other generation source, even if this power was purchased from another utility. This alternative has implications in terms of both environmental and monetary costs. With no marked change in diversity of fuel supply, the regional supply portfolio would remain heavily dependent on coal and natural gas. Under this scenario, the region might be adversely affected by increased air pollutants and increased fuel costs. The environmental impacts of increased electric generation using coal or gas are discussed in Subsection 9.2.3.

9.1.6 REFERENCES

1. South Carolina, Code of Laws, Title 58, Public Utilities, Services and Carriers, http://www.scstatehouse.net/code/titl58.htm
2. South Carolina Code of Regulations, Chapter 103, Public Service Commission, http://www.scstatehouse.net/regs/103.doc
3. Operating Manual for the VACAR Reserve Sharing Agreement
4. NERC Reliability Standard BAL-002-0 http://www.nerc.com/~filez/standards/Reliability_Standards.html
5. NERC Reliability Standard VAR-001 Requirement 2 http://www.nerc.com/~filez/standards/Reliability_Standards.html
6. NERC Reliability Standard VAR-002-1Requirement 1 http://www.nerc.com/~filez/standards/Reliability_Standards.html

9.2 ALTERNATIVE ENERGY SOURCES

The purpose of this section is to explore alternative electric energy sources rather than completing the construction of the proposed nuclear facility. As directed by NUREG-1555, there are essentially three options that can be explored in this alternative. First are alternatives not requiring new generating capacity, examined in Subsection 9.2.1. Second are alternatives requiring new generation, examined in Subsection 9.2.2. Third are competitive market options, considered in Subsection 9.2.3.

While there are several potential sources for electric service in lieu of the proposed generating facility, there are several fundamental decision criteria that these potential sources must meet in order to be equivalent in energy supply to the proposed facility and in order to satisfy the regulatory and statutory obligations under which Duke Energy must plan and build its electric supply resources. These decision criteria include:

1. Regulatory acceptability - The proposed alternative must be acceptable to Duke Energy's utility commissions in North Carolina and South Carolina,

2. Baseload equivalent - The alternative electric resource must be equivalent to a baseload resource in terms of both supply availability (both amount of energy, capacity, and timing of availability) and reliability (the need for this type resource was demonstrated in Subsection 8.4), and

3. Risks avoidance - The alternative must not introduce supply risks, such as marginal or uncertain transmission capability, uncertainty of fuel supplies, insufficient or uncertain financial capabilities of the potential supplier, unknown or uncertain capabilities of the potential supply resource, or any other risk or uncertainty.

These decision criteria will be used, in part, along with criteria established by NUREG-1555, to evaluate the alternative resource options explored in this chapter.

9.2.1 ALTERNATIVES NOT REQUIRING NEW GENERATING CAPACITY

NUREG-1555 directs this subsection of the Environmental Report to examine the "economic and technical feasibility of (1) supplying the electrical energy from the proposed plant without constructing new generating capacity, or (2) initiating energy conservation measures that would avoid the need for the plant." While there are several potential sources for electric service in lieu of the proposed generating facility, any acceptable option must meet the criteria established in the introduction to this section. As directed by NUREG-1555 there are three basic options to consider in this subsection, (1) power purchases, (2) plant reactivation or extended service life, and (3) conservation. All three alternatives are explored below.

Purchased Power

NUREG-1555 directs the analysis of alternatives to the Lee Nuclear Station to evaluate the potential of a purchase power option. As discussed in Chapter 8, projected demand in the SERC Region exceeds current generation capacity. Consequently, there is a low likelihood that baseload power would be available under a purchase agreement. Furthermore, as discussed in Subsection 8.1.4, the risk that purchased power could be terminated for a variety of reasons is not an acceptable business risk to Duke Energy. Therefore, Duke Energy does not rely upon purchase power for baseload needs. This option fails the "baseload equivalent" business criteria established in the introduction to this subsection. It is also likely that such an option would be unacceptable to state utility regulators as it might present risks and uncertainties to the long-term supply of power to Duke Energy's service area, violating both the "regulatory acceptability" and the "unacceptable risks" criteria established in the introduction.

As noted in Subsection 8.1.4, the NCUC supported Duke Energy's policy of not using generation sources from outside its service area for baseload generation in the approval of Duke Energy's Integrated Resource Plan (IRP) (p. 29). In the Order Approving Integrated Resource Plans And Requiring Additional Information In Future Reports, Docket No. E-100, Sub 103, August 31, 2006 (Reference 1), in a discussion about future nuclear and fossil fuel generating plants, the NCUC held;

> *"Using power generated in other states in place of power generated in North Carolina would not result in any major reduction in electric usage or in any meaningful environmental benefits and would have at least one serious adverse affect.* During periods of peak consumption, the state's utilities might have to pay extremely high rates to purchase power from other utilities; in some case they may be unable to import sufficient power at all because of the limitations of the transmission system or for other reasons. Consequently, a policy prohibiting the construction of all nuclear and fossil-fired plants may create risks of both excessive electric rates and unreliable service. Such a policy would contravene G.S. 62-2(a)(3), which provides that a primary purpose of utility regulation is "[t]o promote adequate, reliable, and economical utility service to all of the citizens and residents of the State." (emphasis added)

Conclusion: Purchase power is not an acceptable option to replace the need for the Lee Nuclear Station.

Reactivation or Life Extension of Existing Plants

NUREG-1555 directs the analysis of alternatives to the Lee Nuclear Station to evaluate the potential of a plant reactivation option in the "relevant region." As demonstrated in Subsection 8.1, Duke's relevant market area is its franchise service territory. Also, as discussed in the introduction to this subsection and in Subsection 8.1.4, (discussion entitled Regional Market Based Considerations), Duke Energy and its state utility commissions are reluctant to rely upon baseload generation from resources outside Duke Energy's relevant market area. These considerations restrict the analysis, from a geographic perspective, to Duke Energy's franchise service areas in North and South Carolina.

Duke Energy has received permission from the NRC to extend the life of its three existing nuclear stations, Oconee, McGuire, and Catawba. In addition, Duke Energy is seeking relicensing of the hydroelectric units with FERC licenses that would expire in the planning horizon. All generation listed in Tables 8.3-1, 8.3-2 and 8.3-3, other than those listed as scheduled for potential retirement as shown in Table 8.3-6, are included in Duke Energy's resource planning process. The units scheduled for retirement are older single-cycle combustion turbines and old coal-fired units that meet intermediate and peaking needs, not baseload needs. Thus, even if these units were to be reactivated or their life extended, it would not impact the need for the Lee Nuclear Station. Reactivation of any of these older coal-fired units would initiate the application of new more stringent air emissions controls, thus adversely affecting the cost competitiveness of the units. No units are anticipated for retirement beyond 2017 at this stage of planning.

Conclusion: Within the relevant market area there is no known additional generating units that might be considered viable candidates for extended service or reactivation and thereby avoiding the need for the Lee Nuclear Station.

Potential for Supplying the Electrical Energy Through Conservation

NUREG-1555 requires the analysis of alternatives to the Lee Nuclear Station to evaluate the potential for conservation to replace the need for the proposed facility. As directed by NUREG-1555, "except for unusual circumstances, no additional review should be required to complete this portion of this ESRP, since the reviewers for ESRP (Subsection 8.2.2 and Section 8.4), in the process of analyzing and evaluating the need for the plant, should make a determination that conservation is or is not a practical alternative to the proposed plant."

Given this direction, the review and evaluation of Duke Energy's forecasting process and inclusion of conservation in this forecast was discussed in Subsection 8.2.2. The evaluation concluded that the forecast provided in the Duke Energy Carolinas Annual Plan (Integrated Resource Plan or IRP) properly incorporates demand-side options, energy efficiency, and fuel substitution, which was identified in NUREG-1555 as factors to consider in developing an electric energy forecast.

In addition, the need-for-power analysis presented in Subsection 8.4 concluded that the 2007 IRP suggested that a combination of additional baseload, intermediate and/or peaking generation and energy efficiency and demand response programs is required over the next fifteen years to reliably and cost effectively meet customer demand (Reference 3).

Duke Energy has increased its emphasis and financial commitment to conservation activities with a pledge to spend as much as 1% of its retail electric revenues in new energy efficiency and demand side programs (Reference 2).

The 2008 IRP documents the extensive demand-side and conservation activities (Reference 3). As shown in Table 8.3-12, the 2008 IRP resource plan includes projections of 1800 MWs and 2,226,770 MWHs of EE/DSM in addition to new renewable, coal, gas-fired, and nuclear generation (Reference 3). Despite aggressive efforts on EE/DSM, Duke is only projecting to obtain enough DSM equal to 12% of the Lee Nuclear Station output (Reference 3).

Conclusion: Duke Energy has a strong commitment to energy conservation and has properly accounted for these type activities in its energy resource plan. As such, there are no additional energy conservation activities that could be employed and offset the need for the Lee Nuclear Station.

9.2.2 ALTERNATIVES REQUIRING NEW GENERATING CAPACITY

NUREG-1555 directs this subsection of the Environmental Report to review the potential for alternative generation energy sources that could meet the demonstrated forecast demand from both a load and economic standpoint and thereby obviate the need for the proposed Lee Nuclear Station. As directed by NUREG-1555 there are three basic options to consider in this subsection, alternatives not yet commercially available, fossil fuels, taking into account national policy regarding their use as fuels, and alternatives uniquely available within the region. As directed by NUREG-1555, these options are categorized and evaluated in two distinct categories, (1) competitive -an option that is feasible and compares favorably to the proposed project in terms of environment and health impacts, (2) noncompetitive. Both categories are evaluated in this subsection.

In this evaluation, the capacity and energy requirements developed in Section 8.2 are used as a basis for the need for power. While there are several potential sources for electric service in lieu of the proposed generating facility, any acceptable option must meet the criteria, established in the introduction to Section 9.2. With respect to the "baseload equivalent" criteria, NUREG-1555 specifically agrees with and addresses this criteria in this subsection, stating that "If the proposed project is intended to supply base load power, a competitive alternative would also need to be capable of supplying base load power." Therefore, any potential alternative generating resource must, as an initial criteria, be comparable to a baseload facility, while at the same time passing the additional business criteria of "regulatory acceptance" and no "unacceptable risks."

Generation Alternatives Explored

As presented in Duke Energy's 2008 IRP (Reference 3), data for a wide range of competitive technologies were explored.

As described in the 2007 Annual Plan filing (Reference 4) where it outlined the fact that in developing the 2006 IRP, a list of eighty-eight supply-side resources was compiled of potential alternatives for the IRP process, this learning and experience from the 2006 analyses allowed a more focused approach to resource screening that carries forward for this IRP. As a result, less effort was spent on economically screening the multiple sizes and similar technology variants such as greenfield/brownfield, single rail/dual rail and single/multiple units of the specific technologies. As was shown in the 2006 IRP, the largest sizes of each technology were the lowest cost due to economies of scale, and the differences caused by the other variations were minor. As in the 2007 IRP analyses, the elimination of some of these variations allowed more time to concentrate on ensuring consistency of treatment across the technologies. This approach also allows the Company to examine renewable technologies such as wind, biomass, hydro, animal waste, and solar in more depth.

From the remaining subset of alternatives, several additional technologies were eliminated from further consideration. A brief explanation of the technologies excluded and the logic for their exclusion follows:

- Coal fired Circulating Fluidized Bed combustion is a conventional commercially proven technology in utility use. However, boiler size remains generally limited to the 300-350 MW. In addition, the new source performance standards (NSPS) generally dictate that post-boiler clean-up equipment must be installed to meet the standards when burning coal, which effectively eliminates one of the advantages of this technology. Both of these issues cause it to be one of the higher-cost baseload alternatives available on a utility scale.

- Advanced Battery storage technologies remain relatively expensive and are generally suitable for small-scale emergency back-up and/or power quality applications with short-term duty cycles of three hours or less. In addition, the current energy storage capability is 100 MWh or less. Research, development, and demonstration continue, but this technology is generally not commercially available on a larger supply-side utility scale. Small-scale substation pilots are being studied to assist in increasing distribution system reliability.

- Compressed Air Energy Storage (CAES), although demonstrated on a utility scale and generally commercially available, is not a widely applied technology. This is due to the fact that suitable sites that possess the proper geological formations and conditions necessary for the compressed air storage reservoir are relatively scarce. The capacity and energy available from CAES is also very site geologically specific. There are no viable sites in the Duke Energy Carolinas service territory to support the application of this technology.

- Fuel Cells, although originally envisioned as being a competitor for combustion turbines and central power plants, are now targeted to mostly distributed power generation systems. The size of the distributed generation applications ranges from a few kilowatts to tens of megawatts in the long-term. Fuel gas (hydrogen) purity, cost and performance issues have generally limited their application to niche markets and/or subsidized installations. While a medium level of research and development continues, this technology is not commercially available for utility scale application.

Below is a listing of the technologies screened and placed into general Conventional and Demonstrated category classes:

Conventional Technologies (technologies in common use):

Baseload Technologies

800 MW class Supercritical Coal (Greenfield)

2-1117 MW Nuclear units, AP1000

2410 MW Natural Gas Combined Cycle

Peak / Intermediate Technologies

4-160 MW Combustion Turbines – GE 7FA

460 MW Unfired + 40 MW Inlet Chilling Combined Cycle - 7FA

460 MW Unfired + 120 MW Duct Fired + 40 MW Inlet Chilling Combined Cycle – 7FA

Demonstrated Technologies (technologies with limited acceptance and not in widespread use):

Base Load Technologies

630 MW class IGCC (Brownfield)

In anticipation of the state of North Carolina passing RPS legislation, Duke Energy Carolinas issued an RFP for renewable resources on April 20, 2007; bids were received at the end of July 2007. The bids were of the following types:

- On-Shore Wind
- Off-Shore Wind
- Biomass
  - Biomass Firing
  - Poultry Waste Firing
  - Digester Biogas Firing
  - Hog Digester Biogas Firing
- Solar PV
- Landfill Gas
- Biodiesel Firing

The analysis for the IRP utilized an average composite of the bids to perform the renewables screening since this was the most up-to-date information available.

Renewable technologies were screened within their own category, rather than being screened together with conventional technologies within the baseload or peaking/intermediate categories in order to identify the most attractive options to satisfy the NC REPS requirement.

Additional information on these demonstrated technologies is presented below:

Integrated Gasification Combined Cycle (IGCC)

Integrated Gasification Combined Cycle (IGCC) is an emerging, advanced technology that combines modern coal gasification technology with both gas turbine and steam turbine power generation. Compared to conventional pulverized coal plants, the technology is substantially cleaner because major pollutants can be removed from the gas stream prior to combustion.

The IGCC process generates much less solid waste than the pulverized-coal-fired alternative. The largest solid waste stream produced by IGCC installations is slag, a sand-like marketable byproduct. Slag production is a function of the fuel ash content. The other large-volume byproduct produced by IGCC plants is sulfur, which is extracted during the gasification process and can be marketed rather than placed in a landfill. IGCC units do not produce ash or scrubber wastes.

Today's IGCC technology still needs operating experience for widespread expansion into commercial-scale, utility applications. Each major component of IGCC has been broadly utilized in industrial and power generation applications. But the joining of coal gasification with a combined cycle power block to produce commercial electricity as a primary output is relatively new. This has been demonstrated at only a handful of facilities around the world, including five in the U.S. Experience has been gained with the chemical processes of gasification and the impact of coal properties on the IGCC areas of design, efficiency, economics, etc. Duke Energy Indiana received regulatory approval on November 20, 2007 to construct a 630 MW IGCC facility at its existing Edwardsport coal plant. IGCC was the preferred choice for Indiana based on the proximity to coal and the federal, state, and local incentives to construct the facility in Indiana. Those factors are not available in the Carolinas for IGCC.

Overall, experience with IGCC still shows generation costs are more expensive than comparably sized pulverized coal plants, due in part to the coal gasifier and other specialized equipment.

Natural Gas Combined Cycle (NGCC)

Natural-gas-fired generation using combined-cycle turbines is a technology that is available and economical. Current estimates indicate that capital costs for natural-gas-fired power plants average $575/kW.

Electrical generation with natural gas has a higher cost due to fuel costs rather than capital costs. It has been indicated that if the fuel prices increase 100 percent, this would result in a 16 percent increase in the cost of nuclear generation, a 55 percent increase for coal, and a 79 percent increase for natural gas. Further, the overall costs for generation of electricity gave costs of $0.0266/kWh for nuclear, $0.0328/kWh for coal, and $0.0353/kWh for natural gas.

Existing manufacturers' standard-sized units include a natural-gas-fired combined-cycle plant of 482 MW net capacity, consisting of two 172 MW natural gas turbines (e.g., General Electric Frame 7FA) and 138 MW of heat recovery capacity. Duke Energy assumed five 482 MWe units, having a total capacity of 2410 MWe, as the natural-gas-fired alternative at the Lee Nuclear Site capacity of two AP1000 units. The total generation from this replacement power source is 2410 MWe and would only slightly overestimate the impacts from an exact replacement of Lee Nuclear Station Units 1 and 2. Table 9.2-4 shows the amounts of the 2410 MWe natural gas-fired plant emissions. Table 9.2-5 presents the assumed basic operational characteristics of the natural-gas-fired units. For the purposes of analysis, Duke Energy has assumed that there would be sufficient natural gas availability.

Based on the well-known technology, fuel availability, and generally understood environmental impacts associated with constructing and operating a natural-gas-fired power generation plant, it is considered a competitive alternative and is therefore examined further in Subsection 9.2.3.

Wind

Wind power systems produce power intermittently, depending upon when the wind is blowing at sufficient velocity and duration. Despite advances in technology and reliability, capacity factors for wind power systems remain relatively low (29 to 32 percent for North Carolina, Reference 14) compared to the 90 to 95 percent industry average for a baseload plant such as a nuclear plant. Therefore, wind power alone is not capable of producing baseload power, and is not a reasonable alternative by itself.

Biomass

Biomass combustion is a current significant energy source for electrical generation. Supplying almost 850 gigawatt hours (GWh) (2.9 quadrillion British thermal units [Btu] [quads]) of energy in 2003 (including municipal solid waste), it has surpassed hydropower as the largest domestic source of renewable energy. Biomass fired facilities generate electricity using available equipment and well-established technology. This energy is dispatchable on demand because it is combustion based.

The energy content of dry biomass ranges from 7000 Btu per pound (Btu/lb) for straws to 8500 Btu/lb for wood. However, the cost of switchgrass and other energy crops currently is almost twice the cost of coal on an energy basis. Furthermore, the lack of adequate infrastructure, along with transportation and handling costs, are primary obstacles when considering the economic and technical feasibility of this renewable energy source.

Most of the biomass fueled generation facilities in the U.S. use steam turbine conversion technology, and can accept a wide variety of biomass fuels. However, at the scale appropriate for biomass (the largest biomass power plants are 40 to 50 MW in size), the technology is expensive and inefficient. Biomass is much less dense than coal, requiring a greater volume of fuel to be handled per megawatt. Greater areas of biomass storage and additional handling are required to accommodate the lower-density materials. Therefore, the technology is relegated to more cost effective applications where there is a readily available supply of low-, zero-, or negative-cost delivered feedstocks.

Solar Technologies

There are currently two practical methods to produce electricity from solar energy: photovoltaic and solar thermal power. Photovoltaics ("solar cells") convert sunlight directly into electricity using semiconducting materials. Solar thermal power systems convert sunlight into electricity using heat as an intermediate step. These systems generate electricity from this heat with various methods. For this discussion, the different methodologies of nonphotovoltaic systems are grouped together.

Some solar thermal systems can also be equipped with a thermal storage tank to store heated transfer fluid. These solar thermal plants can then dispatch electric power on demand using this stored heat.

Solar technologies produce more electricity with more intense and direct sunlight. Cloudy days can significantly reduce output. To work effectively, solar installations require consistent levels of sunlight (solar insolation). The lands with the best solar resources are usually arid or semi-arid.

While photovoltaic systems use both diffuse and direct radiation, solar thermal power plants can only use the direct component of the sunlight. This makes solar thermal power less suitable for areas like the Southeastern U.S. with high humidity and frequent cloud cover, both of which diffuse solar energy and reduce its intensity. In addition, the average annual amount of solar energy reaching the ground needs to be 64 kWh per square foot per day (kWh/ft^2/day) or higher for solar thermal power systems. The Southeast receives an annual average of 32 to 43 kWh/ft^2/day of solar radiation.

Like wind, capacity factors are too low to meet baseload requirements. Average annual capacity factors for solar power systems are relatively low (24 percent for photovoltaics and 30 to 32 percent for solar thermal power) compared to 90 to 95 percent for a baseload plant such as a nuclear plant.

Land use requirements (and associated construction and ecological impacts) are also much greater for solar technologies than for a nuclear plant. The area of land required depends on the available solar insolation and type of plant, but is about 8 ac/MW for photovoltaic systems and 3.8 ac/MW for solar thermal power plants. Assuming capacity factors of 24 percent for photovoltaics and 32 percent for solar thermal power, facilities having a 2234 MW net capacity are estimated to require 74,467 ac. (116 sq. mi.), if powered by photovoltaic cells, and 26,529 ac. (41 sq. mi.), if powered by solar thermal power.

Landfill Gas

Under the NC GreenPower program, landfill methane projects qualify as a renewable resource. The methane production at waste landfill sites can be a valuable fuel for either direct thermal applications or for electricity generation. North Carolina is part of the EPA's Landfill Methane Outreach Program (LMOP) and is actively promoting the development of landfill gas-to-energy (LGTE) projects (Reference 14).

By way of background, seventeen LGTE projects are currently operating in North Carolina and several more are under consideration. Some of these projects are operating at closed sites while other sites continue to accept waste. North Carolina has six landfill gas projects that are generating electricity, totaling over 15 MW of capacity. Additionally, eleven other landfill projects currently consume the landfill gas directly for thermal applications.

The EPA estimates a total electric generation potential in North Carolina of around 60-70 MW. Reference 14 provides an estimate of 150 MW total generation capacity from 2008 through 2017. This capacity is insufficient to support baseload generation.

The Duke Energy resource model discussed in Subsection 8.4 considers various generating resources. Using decision criteria, similar to the criteria used by Duke Energy to dispatch power, the model selects and designates various resources to be installed and used as either baseload, intermediate, or peaking units. This assignment is based on the decision criteria, rather than a *prima facie* definition of the unit as baseload, intermediate, or peaking. The decision criteria are sensitive to economic and regulatory environments and may change from year to year as the model re-evaluates the appropriateness of the resource mix."

In the above list of generating alternatives Duke Energy considered, the only technologically feasible, baseload-comparable alternatives to the Lee Nuclear Station are coal-fired facilities and NGCC units.

Conclusion: Duke Energy identified and evaluated a comprehensive set of alternative generation technologies, both fossil fuel and renewables, and properly concluded that coal-fired and NGCC facilities are the potential alternatives to the Lee Nuclear Station that are acceptable from a regulatory and risk standpoint and can serve baseload needs. Therefore, Subsection 9.2.3 assesses these alternative technologies.

9.2.3 ASSESSMENT OF COMPETITIVE ALTERNATIVE ENERGY SOURCES AND SYSTEMS

As discussed in Subsection 9.2.2, the only technologically feasible, baseload-comparable alternatives to the Lee Nuclear Station are coal-fired and NGCC facilities.

9.2.3.1 Coal-Fired Facility

Duke Energy reviewed the NRC analysis of environmental effects from coal-fired generation alternatives in NUREG-1437 (Reference 5) and found it to be a reasonable description of impacts associated with this alternative energy source. Construction effects are substantial, due in part to the large land area required (which can result in natural habitat loss) and the large workforce needed. NRC pointed out that siting a new coal-fired plant where an existing nuclear plant is located reduces many construction effects. NRC identified major adverse effects from operations as human health concerns associated with air emissions, waste generation, and losses of aquatic biota due to cooling water withdrawals and discharges.

For purposes of this analysis, Duke Energy defined the pulverized coal-fired alternative as consisting of four conventional boiler units, each with a net capacity of 530 MW for a combined capacity of 2120 MW. This coal-fired alternative, for purposes of this analysis, is located at the proposed project site. Table 9.2-1 presents the assumed basic operational characteristics of the coal-fired units.

In a pulverized coal-fired generation system, pieces of coal are crushed between balls or cylindrical rollers. The crushed coal is then fed into the pulverizer along with air heated to about 650°F from the boiler. As the coal is pulverized to the consistency of talcum powder by the rolling action, the hot air both dries it and moves the usable fine coal powder to a burner in the boiler, where it is combusted.

The overall effects associated with the construction and operation of the coal-fired alternative using closed-cycle cooling are discussed in the following subsections and compared to the Lee Nuclear Station in Table 9.2-3.

9.2.3.1.1 Air Quality

The air quality effects of coal-fired generation vary considerably from those of nuclear generation due to emissions of SO2, NOX, particulates, carbon dioxide (CO2), hazardous air pollutants such as mercury, and naturally occurring radioactive materials.

Duke Energy assumed a plant design that minimizes air emissions through a combination of boiler technology and post-combustion pollutant removal. Duke Energy estimated the 2120-MW coal-fired alternative emissions as summarized in Table 9.2-2.

A new coal-fired generating plant needs to meet the new source review requirements in Title I of the Clean Air Act (Reference 6). The plant also needs to comply with the new source performance standards for new generating plants in 40 CFR 60, Subpart Da. The standards establish limits for particulate matter and opacity (40 CFR 60.42(a)), SO2 (40 CFR 60.43(a)), NOX (40 CFR 60.44(a)), and mercury (40 CFR 60.45Da). More stringent control for these and other criteria pollutants may be required under the BACT or LAER provisions as part of the New

Source Review analysis, unless the project will net out of review through other reductions at the same facility.

EPA has various regulatory requirements for visibility protection in 40 CFR 51, Subpart P, including a specific requirement for review of any new major stationary source in an area designated as attainment or unclassified under the Clean Air Act. Section 169A of the Clean Air Act establishes a national goal of preventing future and remedying existing impairment of visibility in mandatory Class I federal areas when impairment results from air pollution caused by human activities. In addition, EPA issued new regional haze requirements in 1999 (64 FR 35713-35774). The requirements specify that state agencies must establish goals for reasonable progress toward achieving natural visibility conditions for each mandatory Class I federal area located within a state. The reasonable progress goals must provide for an improvement in visibility for the most-impaired days over the period of the implementation plan and ensure no degradation in visibility for the least-impaired days over the same period (40 CFR 51.308(d)(1)). If a new coal-fired power plant is located close to a mandatory Class I federal area and is determined to have a significant impact, additional air pollution control requirements may be imposed.

A new coal-fired power plant is subject to the requirements in Title IV of the Clean Air Act. Title IV was enacted to reduce emissions of SO2 and NOX, the two principal precursors of acid rain, by restricting emissions of these pollutants from power plants. Title IV caps aggregate annual power plant SO2 emissions and imposes control on SO2 emissions through a system of marketable allowances. EPA issues an allowance for each ton of SO2 that a generating unit is allowed to emit: new units do not receive allowances but are required to have allowances to cover their SO2 emissions. Owners of new units must therefore acquire allowances from owners of other power plants by purchase or reduce SO2 emissions at other power plants they own. Allowances can be banked for use in future years. Thus, a new coal-fired power plant does not add to net regional SO2 emissions, although it might do so locally. Regardless, SO2 emissions are greater for the coal alternative than the proposed project alternative because a nuclear power plant releases almost no SO2 during normal operations.

EPA issued the Clean Air Interstate Rule (CAIR) in 2005 (70 FR 25162-25405). CAIR provides a federal framework requiring certain states to reduce emissions of SO2 and NOX. EPA anticipates that states achieve this reduction primarily by limiting emissions from the power generation sector. CAIR covers 28 eastern states, including South Carolina, and the District of Columbia. Any new fossil fuel fired power plant sited in South Carolina is subject to the CAIR limitations.

In 2005, EPA issued a final rule limiting mercury emissions from coal-fired power plants. Emissions are capped at specified, nationwide levels. A first-phase cap of 38 tons per year (Tpy) becomes effective in 2010 and a second-phase cap of 15 Tpy becomes effective in 2018. Plant owners must demonstrate compliance with the standard by holding one “allowance” for each ounce of mercury emitted in any given year. Allowances are transferable among regulated plants. Any new coal-fired power plant sited in South Carolina is subject to this rule. The new facility also has to meet regulatory levels under the latest EPA regulations.

Coal contains uranium and thorium. Uranium concentrations are generally in the range of 1 to 10 parts per million (ppm). Thorium concentrations are generally about 2.5 times greater than uranium concentrations. One estimate is that a 1000 megawatts electric (MWe) coal-fired plant had an annual release of approximately 5.2 T. of uranium and 12.8 T. of thorium in 1982. The population dose equivalent from the uranium and thorium releases and daughter products produced by the decay of these isotopes has been calculated to be significantly higher than that from nuclear power plants (Reference 7).

A coal-fired plant also has unregulated carbon dioxide emissions. Duke Energy Carolinas estimates that pulverized coal-fired plants sufficient to substitute for the power that is generated by the proposed project emit approximately 19 million Tpy of carbon dioxide (Reference 8).

During the construction of a coal-fired plant, temporary fugitive dust is generated. Exhaust emissions come from vehicles and motorized equipment used during the construction process. In addition, coal-handling equipment introduces fugitive particulate emissions.

The NUREG-1437 analysis did not quantify emissions from coal-fired power plants but implied that air quality effects are substantial. NUREG-1437 also identifies global warming from unregulated carbon dioxide emissions and acid rain from SOX and NOX emissions as potential effects. Adverse human health effects, such as cancer and emphysema, have been associated with the products of coal combustion.

Overall, the air quality effects associated with the 2120-MW coal-fired alternative are MODERATE.

9.2.3.1.2 Waste Management

Coal combustion generates waste in the form of ash, and equipment for controlling air pollution generates additional ash, spent selective catalytic reduction (SCR) catalyst, and scrubber sludge.

This coal-fired alternative facility, using coal having an ash content of 9.84 percent, consumes approximately 6,633,000 Tpy of coal. Particulate control equipment collects ±99.9 percent of this ash, approximately 652,000 Tpy.

Other types and amounts of waste include:

- Flue gas desulfurization sludge (gypsum): 1,137,478 Tpy.
- Raw water treatment sludges: 1160 Tpy.
- General water treatment sludges: 726 Tpy.

Portions of the ash and gypsum may be recycled. These by-product and waste streams are classified as non-hazardous, as determined by the Resource Conservation and Recovery Act (RCRA) toxicity characteristic leaching procedure.

Provision is made to store fly ash, bottom ash, and scrubber by-products on-site indefinitely. Duke Energy currently markets much of the ash and scrubber by-products to building product manufacturers and as makeup products for the construction industry. Water treatment sludges are disposed at a state-approved landfill, either on-site or off-site. Spent SCR catalyst is regenerated or disposed off-site. Waste effects to groundwater and surface water extend beyond the operating life of the plant if leachate and runoff from the waste storage area occur. Disposal of the waste noticeably affects land use and groundwater quality, but with appropriate management and monitoring, it does not destabilize any resources. After closure of the waste site and revegetation, the land is available for other uses.

In May 2000, EPA issued a "Notice of Regulatory Determination on Wastes from the Combustion of Fossil Fuels" (65 FR 32213-32237). EPA concluded that some form of national regulation is warranted to address coal combustion waste products. Accordingly, EPA announced its intention to issue regulations for disposal of coal-combustion wastes under Subtitle D of RCRA.

Debris is generated during construction activities on the coal-fired alternative units. Such debris is disposed of in landfills.

For the preceding reasons, the appropriate characterization of effects from waste generated from the coal-fired alternative is MODERATE.

9.2.3.1.3 Other Effects

Land - In NUREG-1437, the NRC staff estimated that approximately 1700 ac. are needed for a 1000-MW coal-fired plant. Duke Energy experience indicates that a 2120-MWe coal-fired plant requires approximately 2000 ac. This area includes land for the coal pile, a limestone pile, an ash and scrubber solids disposal area, and plant buildings and structures, but it does not include land for an associated coal mine, access road, and railroad spur.

NUREG-1437 estimated that approximately 22,000 ac. of land are affected for mining the coal and disposing of the waste to support a 1000-MW coal-fired plant during its operational life. A replacement 2120-MWe coal-fired plant to substitute for the proposed project affects approximately 46,640 ac. of land.

Construction of the alternative permanently changes the land use at the site, and most likely involves an irretrievable but moderate loss of forest land and/or farmland. No significant effects to plant site soils are anticipated because of the use of erosion control practices during and following construction.

The effect of the coal-fired alternative on land use is best characterized as SMALL, similar to the proposed project.

Ecology - The coal-fired generation alternative introduces construction effects and new incremental operational effects. Even assuming siting at a previously disturbed area, the effects alter the ecology. Ecological effects to a plant site and utility easements include effects on threatened or endangered species, wildlife habitat loss, reduced wildlife reproduction, habitat fragmentation, and a local reduction in biological diversity. Use of cooling makeup water from a nearby surface water body has adverse aquatic resource effects. If needed, maintenance of a transmission line and a rail spur has ecological effects. There are effects to terrestrial ecology from cooling tower drift. Overall, the ecological effects are SMALL, similar to the proposed project.

Water Use and Quality - Construction of each power station (including access roads) affects surface water hydrology, but sites are chosen to avoid extensive site excavation, filling, or grading. New construction disturbs the land surface, which may temporarily affect surface water quality. Potential water quality effects consist of suspended solids from disturbed soils, biochemical oxygen demand, nutrient loading from disturbed vegetation, and oil and grease from construction equipment. New construction activities that disturb 1 ac. or more require a National Pollutant Discharge Elimination System (NPDES) permit for stormwater discharges from the site to ensure the implementation of best management practices and to minimize effects to surface waters during construction. To minimize the effects of stormwater flow erosion during construction, on-site retention areas (stormwater detention ponds) are designed to detain storm water from the 25-year, 24-hour rainfall event. Runoff detention ponds are designed to detain runoff within the containment areas to allow for settling and to reduce peak discharges. Best management practices are also required during construction to minimize water quality effects. Construction causes no significant consumption of surface water resources. Sanitary waste water is most likely routed to a publicly owned treatment works, if available. If a sanitary waste treatment system is not available, one is constructed.

During operation, a fraction of the plant intake water requirement for each station is for cooling tower makeup water flow. Consumptive water use through evaporation is small. If the amount of water consumption is moderated through the use of a local reservoir, effect on water availability downstream or in the vicinity of the plant would be negligible. Cooling water for the main condensers and miscellaneous components is recirculated through the cooling towers, with the blowdown (i.e.; the fraction of circulated water that is discharged to prevent the buildup of dissolved salts and minerals) and other plant operational wastewater streams subsequently being discharged through diffusers.

A biocide is used to protect the cooling water system from biological growths. Cooling tower blowdown is expected to be several times larger than any other wastewater stream, but it does not contain any detectable amounts of priority pollutants. Plant process wastewater streams include demineralizer regeneration wastes, steam cycle blowdown, and service water/ pretreatment waste and chemical drains. Plant wastewater outfalls also require a NPDES permit, with established treatment standards and discharge limits. To prevent leachate in stormwater runoff from entering the surficial aquifer, the coal storage area and the runoff basin are lined with low-permeability materials. Runoff streams from the coal pile, fly ash and bottom ash piles, and gypsum storage area is collected in the lined recycle basin for reuse (which is sized to exceed capacity requirements for the 25-year, 24-hour storm event), with no direct discharge to the surface water.

Overall, water use and quality effects can be characterized as SMALL, similar to the proposed project.

Human Health - Coal-fired power generation introduces worker risks from coal and limestone mining, worker and public risks from coal and lime/limestone transportation, worker and public risks from disposal of coal combustion wastes, and public risks from inhalation of stack emissions.

Emission effects can be widespread and health risks are difficult to quantify. The NRC staff stated in NUREG-1437 that there are human health effects (cancer and emphysema) from inhalation of toxins and particulates from a coal-fired plant, but did not identify the significance of these effects.

Regulatory agencies, including EPA and state agencies, set air emissions standards and requirements based on human health effects. These agencies also impose site-specific emissions limits as needed to protect human health. EPA has recently concluded that mercury emissions of power plants should be controlled (under the Clean Air Mercury Rule). Certain segments of the U.S. population (e.g., the developing fetus and subsistence fish-eating populations) may be at potential risk of adverse health effects at high levels of consumption of fish containing methyl mercury accumulated from the aquatic food chain. However, human health effects from radiological doses and inhaling toxins and particulates generated by burning coal at a newly constructed coal-fired plant are characterized as SMALL.

Socioeconomics –During the four-year construction period of the coal-fired Big Stone II Power Plant near Milbank, South Dakota, this single 500-580 MW plant is estimated to employ an average of 625 construction workers, with a peak workforce of 1500. Once online, it is likely to employ 30 to 40 operational workers at the site (Reference 9). Construction of the Duke Energy 800 MW Cliffside unit is expected to peak at 1800 workers. The 2120-MW coal-fired alternative, if constructed on a staggered timeline, could be expected to employ more workers, with an average of 1250 construction workers and a peak workforce of 2000. The peak number of workers noticeably affects the local workforce for most sites, but the jobs are temporary and many of the workers commute from surrounding areas. The influx of workers noticeably affects local school systems and other social services.

The coal-fired plants provide a new tax base for the local communities in which they are sited through the in-lieu-of-tax payments made by Duke Energy Carolinas. For these reasons, the non-transportation socioeconomic effects for new pulverized coal-fired plants are noticeable, but are unlikely to destabilize the area.

For transportation related to commuting of plant operating personnel for the coal- fired alternative, the effects are considered negligible. Transportation effects are temporary, noticeable, but not destabilizing during plant construction.

In NUREG-1437, the NRC states that socioeconomic effects at a rural site are greater than at an urban site, because more of the peak construction workforce need to move to the area to work.

Coal and lime/limestone are likely delivered by rail to each power plant, although barge delivery is feasible for a site located on a navigable body of water. Socioeconomic effects associated with rail transportation likely have some effect to the community. Barge delivery of coal and lime/ limestone likely have minor socioeconomic effects.

Overall, Duke Energy concludes that the socioeconomic effects associated with constructing and operating the 2120-MW coal-fired alternative are SMALL (Adverse) to LARGE (Beneficial), similar to the proposed project.

Aesthetics - The coal-fired power block is as much as 200-ft. tall and is visible off-site during daylight hours. The exhaust stack is as high as 650 ft. Also present are 100-ft. high mechanical draft cooling towers or 600-ft. high natural-draft cooling towers, if required. The stack and cooling towers would likely be highly visible in daylight hours for distances greater than 10 mi. These structures are also visible at night because of outside lighting. The Federal Aviation Administration (FAA) generally requires that structures exceeding an overall height of 200 ft. above ground level have markings and/or lighting so as not to impair aviation safety. Visual effects of a new coal-fired plant are mitigated by landscaping and color selection for buildings that are consistent with the environment. Visual effects at night are mitigated by reduced use of lighting, provided the lighting meets FAA requirements, and appropriate use of shielding. Overall, the addition of the coal-fired unit likely has some aesthetic effect. There is a significant aesthetic effect if construction of a new rail spur is needed.

Coal-fired generation introduces mechanical sources of noise that are audible off-site. Sources contributing to total noise produced by plant operation are classified as continuous or intermittent. Continuous sources include the mechanical equipment associated with normal plant operations. Intermittent sources include the equipment related to coal handling, solid waste disposal, transportation related to coal and lime/limestone delivery, use of outside loudspeakers, and the commuting of plant employees. The noise effects of a coal-fired plant are slightly greater than those of expected operation of the proposed project. Noise effects associated with rail delivery of coal and lime/limestone are most significant for residents living in the vicinity of the facility and along the rail route. Although noise from passing trains significantly raises noise levels near the rail line, the short duration of the noise reduces the effect. Nevertheless, given the frequency of train transport and the fact that many people are likely to be within hearing distance of the rail route, the effects of noise on residents in the vicinity of the facility and the rail line are noticeable. Noise associated with barge transportation of coal and lime/limestone are minimal. Noise and light from the pulverized coal-fired power plants are detectable off-site.

Aesthetic effects at the plant site are mitigated if the plant is located in an industrial area adjacent to other power plants.

Overall, the aesthetic effects associated with new pulverized coal-fired power plants can be categorized as SMALL, but substantially greater than the proposed project.

Cultural Resources - Studies likely are needed to identify, evaluate, and address mitigation of the potential effects of new plant construction on historic and archaeological resources before construction begins at any site. The studies likely are needed for areas of potential disturbance at the proposed plant site and along associated corridors where new construction occurs (e.g., roads, rail lines, or other rights-of-way). Historic and archaeological resource effects can generally be effectively managed and as such are considered SMALL.

Environmental Justice - Environmental justice effects depend upon the nearby population distribution. Construction activities offer new employment possibilities, but have negative effects on the availability and cost of housing, which disproportionately affect low-income populations. Overall, environmental justice effects are likely to be SMALL, similar to the proposed project.

Conclusion: Duke Energy identified and evaluated a coal-fired facility as an alternative to the Lee Nuclear Station and concludes that it is not an environmentally superior alternative to the chosen resource, the Lee Nuclear Station.

9.2.3.2 Natural Gas Generation (Combined Cycle)

A 482 MWe NGCC unit has been identified as a probable standard size unit to be used. This alternative would require five 482 MWe units to adequately replace the Lee Nuclear Station's generating capacity. The total generation from this replacement power source is 2410 MWe and would only slightly overestimate the impacts from an exact replacement of the Lee Nuclear Station's 2400 MWe.

The economics of combined cycle technology are largely dependent on the price of natural gas, which is highly volatile. As noted in Subsection 9.2.2, the overall cost of generating electricity from natural gas is currently higher than the costs for nuclear generation ($0.0353/kWh vs. $0.0266/kWh).

Construction of a natural gas pipeline from the plant location to a supply point where a firm supply of gas is available would be needed. There is currently no gas pipeline to the Lee Nuclear Site. It is anticipated that the environmental impacts of constructing a gas pipeline to the Lee Nuclear Site would be similar to those associated with constructing a new transmission line right-of-way. Soil impacts from construction of the natural gas pipeline are considered MODERATE because of the disturbance to the topsoil along its route.

The overall impacts associated with the construction and operation of the natural-gas-fired alternative using a closed-cycle cooling system are summarized in Table 9.2-3 and discussed in the following subsections.

9.2.3.2.1 Water Use and Quality

A trade-off of water quality impacts would be associated with a large baseload NGCC plant. Though water requirements are less for combined cycle plants than for conventional steam electric plants, the site would require the construction of a new intake structure to provide water needs for the facility. New base gas combined cycle units would likely utilize closed-loop cooling towers. Because water requirements for combined cycle generation are less than for conventional steam electric generation, evaporation from combined cycle cooling towers would be less than the anticipated evaporation associated with the Lee Nuclear Station's cooling tower system. Sediment caused by construction activities would impact adjacent waters. Plant discharges would comply with all appropriate permits. No low-level radioactive waste discharges to surface water are associated with a combined cycle unit. The overall impacts are characterized as SMALL.

9.2.3.2.2 Waste Management

The solid waste generated from this type of facility would be minimal. The only significant waste would be from spent SCR catalyst used for NOx control. The SCR process would generate approximately 1500 cubic feet (cu. ft.) of spent catalyst material per year. The overall impacts are characterized as SMALL.

9.2.3.2.3 Air Quality

Natural gas is a relatively clean-burning fuel. The combined-cycle operation is highly efficient (60 percent versus 33 percent for the coal-fired alternative) because the heat recovery steam generator does not receive supplemental fuel. The natural-gas-fired alternative would release similar types of emissions, but in lesser quantities than the coal-fired alternative, and in much larger quantities than the nuclear alternative.

The largest environmental impact from this type of facility would result from the air emissions. The emissions resulting from burning natural gas only would be 34.4 T. per year of SO_2, 517 T. per year of NO_x, 287 T. per year of particulate matter (PM), and 482 T. per year of carbon monoxide (CO). A facility of this size would add 6,755,712 T. per year of CO_2 to the environment. Assumptions and calculations for these emissions are provided in Table 9.2-5 and Table 9.2-4 respectively. The $PM_{2.5}$ and regional haze rules would not be of concern with NGCC generation because these units have minimal SO_2 emissions. The overall impacts are characterized as SMALL to MODERATE.

9.2.3.2.4 Other Impacts

Land - Use of the Lee Nuclear Site for a natural-gas-fired combined cycle plant would require no new lands. A major combined cycle generation station can be located on less than 200 ac.

One obstacle to the consideration of combined cycle generation using only natural gas is the availability of the gas. Based on current technology, a facility of this size would require in excess of 100 billion cu. ft. per year of natural gas. If legislation is passed, requiring the reduction of CO_2 levels, increased use of natural gas in the generation mix would be required in order to meet these standards, resulting in reduced availability of natural gas. There are four natural gas pipelines, all located in the same right-of-way, approximately 4 mi. northwest of the site. A large, new baseload combined cycle facility would require extending one or more of the existing gas pipelines to the site, which would disturb significant acreage between the right-of-way and the plant site. This assumes that the current gas supply is adequate to fuel a new facility along with the current users. If these lines do not have adequate capacity to service the current users as well as the new site, a new pipeline would need to be run, which would have a larger impact than assumed here. The overall impacts are characterized as MODERATE.

Ecology - Locating a new combined cycle facility at the Lee Nuclear Site would alter the ecology. On-site impacts would likely not be as significant as with coal-fired generation due to the smaller footprint requirement. However, ecological impacts created by new gas transmission needs could create significant off-site issues. Impacts would include wildlife habitat loss and reduced productivity, and could include habitat fragmentation and a local reduction in biological diversity. Impacts from a new intake (impingement and entrainment) and discharge (waste heat to a receiving water body) would be created. These ecological impacts would vary depending upon the corridor selected for the gas pipeline. However, the overall impacts are characterized as SMALL to MODERATE.

Human Health - A new combined cycle power plant introduces small risks to workers and the public. The generic environmental impact statement (GEIS) analysis noted that there could be human health impacts from the inhalation of toxins and particulates. Regulatory agencies, such as the EPA, have established regulatory requirements for power plant emissions and discharges to protect human health. A new combined cycle plant would comply with these regulatory requirements. The overall impacts are characterized as SMALL.

Socioeconomics - Construction of a major combined cycle plant would take approximately 2 – 3 years. Construction of a new combined cycle station of this size would employ a construction workforce of approximately 800, which would stimulate the economy of the region. The surrounding communities would experience demands on housing and public services. After construction, the workers would leave, and the operating plant would provide new jobs. However, long-term job opportunities would be less than for a coal-fired station and substantially less than those during operation of the Lee Nuclear Station.

Operational impacts could result in moderate socioeconomic benefits in the form of jobs, tax revenue, and plant expenditures. However, by comparison, these benefits will be less than those achieved through operation of the Lee Nuclear Station.

The size of the construction workforce for a combined cycle plant and plant-related spending during construction could be substantial. Operational impacts, once the combined cycle plant is constructed, would result in approximately 807 fewer jobs available to the regional economy (Lee Nuclear Station Units 1 and 2 would employ 957 workers compared to a projected 150 for the combined cycle plant). The overall impacts are characterized as MODERATE.

Aesthetics - The five power plant units with their approximately 200-ft. stacks could be visible at a distance of several miles. Combined cycle generation would introduce additional mechanical sources of noise that would be audible off-site. Sources contributing to total noise produced by plant operation are classified as continuous or intermittent. Continuous sources include the mechanical equipment (e.g., combustion turbine units and mechanical-draft cooling towers) associated with normal plant operations. Intermittent sources include the equipment related to ammonia handling and solid waste disposal. Noise levels associated with a combined cycle generation facility are expected to be similar to those of a nuclear facility as discussed in Subsection 5.8.1.5. The overall impacts are characterized as SMALL to MODERATE.

Cultural Resources - The GEIS analysis concluded that impacts to cultural resources would be relatively small unless important site-specific resources were affected. Construction impacts would be similar to those for construction of two nuclear units, which have been discussed and evaluated for the Lee Nuclear Site in Subsections 2.5.3 and 4.1.3. The overall impacts are characterized as SMALL.

Environmental Justice - Environmental justice effects depend upon the nearby population distribution. Construction activities offer new employment possibilities, but have negative effects on the availability and cost of housing, which disproportionately affects low-income populations. The overall impacts are characterized as SMALL.

9.2.3.2.5 Conclusion

A natural gas-fired combined cycle facility would be a viable replacement for Lee Nuclear Station baseload generation. However, the air quality, land, ecology, socioeconomic, and aesthetic impacts would be greater than the impacts from construction and operation of the Lee Nuclear Station.

9.2.4 REFERENCES

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TABLE 9.2-1 (Sheet 1 of 2)
COAL FIRED ALTERNATIVE

Characteristic	Basis
Unit size - 530 MW ISO rating net [(a)]	Assumed
Unit size - 562 MW ISO rating gross [(a)]	Calculated based on 6 percent onsite power
Number of Units - 4	Assumed
Boiler Type - tangentially fired, dry bottom	Minimizes NOX emissions (Reference 10)
Fuel Type - bituminous, pulverized coal	Typical for coal used in South Carolina
Fuel Heating Value - 12,617 Btu/lb	2005 value for coal used in South Carolina (Reference 11)
Fuel Ash Content by weight - 9.84%	2005 value for coal used in South Carolina (Reference 11)
Fuel Sulfur content by weight - 1.24%	2005 value for coal used in South Carolina (Reference 11)
Uncontrolled NOX emission - 10 lb/T	Typical for pulverized coal, tangentially fired dry bottom NSPS (Reference 10)
Uncontrolled CO emission - 0.5 lb/T	Typical for pulverized coal. Tangentially fired dry bottom NSPS (Reference 10)
Heat rate - 10,000 Btu/kWh	Typical for pulverized coal. Tangentially fired dry bottom NSPS (Reference 12)
Capacity factor - 0.85	Typical large coal-fired units (Reference 13)
Fuel Consumption - 6,633,000 Tpy	Calculated from the above values
NOX control - Low NOX burners, overfire air and selective catalytic reduction (95% reduction)	Best available for minimizing particulate emissions (Reference 10)
Particulate control - fabric filters (baghouse-99.9% removal efficiency)	Best available for minimizing particulate emissions (Reference 10)
SOX control - Wet scrubber-limestone (95% removal efficiency)	Best available for minimizing SOX emissions (Reference 10)

TABLE 9.2-1 (Sheet 2 of 2)
COAL FIRED ALTERNATIVE

Notes:

Btu = British thermal unit

ISO rating = International Standards Organization rating at standard atmospheric conditions of 59°F, 60 percent relative humidity and 14.696 pounds of atmospheric pressure per square inch

Heat Rate (a measure of efficiency) = the reciprocal of thermal efficiency, units of Btu/kWh.

kWh = kilowatt hour

NSPS = New Source Performance Standard

lb = pound

MW = megawatt

NOX = nitrogen oxides

SOX = sulfur oxides

T = ton

Tpy = Tons per year

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a) The difference between “net” and “gross” is electricity consumed on-site

TABLE 9.2-2
AIR EMISSIONS FROM THE 2120-MW COAL-FIRED ALTERNATIVE

Pollutant	Tons/Year
Annual Coal Consumption	6,633,000
SO_X	7,814
NO_X	1658
CO	1658
Particulate Matter	64
Particulate Matter <10 microns in diameter	17

Calculated from data in Table 9.2-1

TABLE 9.2-3
COMPARISON OF THE ENVIRONMENTAL IMPACTS OF THE COAL-FIRED AND NATURAL GAS ALTERNATIVES TO THE LEE NUCLEAR STATION

Attribute	Environmental Impacts		
	Lee Nuclear Station	Coal-Fired Alternative	Natural Gas Generation
Air Quality	SMALL	MODERATE	SMALL to MODERATE
Waste Management	SMALL	MODERATE	SMALL
Land	SMALL	SMALL	MODERATE
Ecology	SMALL	SMALL	SMALL to MODERATE
Water Use & Quality	SMALL	SMALL	SMALL
Human Health	SMALL	SMALL	SMALL
Socioeconomics	SMALL	SMALL	MODERATE
Aesthetics	SMALL	SMALL	SMALL to MODERATE
Cultural Resources	SMALL	SMALL	SMALL
Environmental Justice	SMALL	SMALL	SMALL

TABLE 9.2-4 (Sheet 1 of 2)
AIR EMISSIONS FROM GAS-FIRED ALTERNATIVE

Pollutant	Emission
SO_x[c]	34.4 T. SO_2 per year
NO_x[d]	517 T. NO_x per year
CO_x[d]	482 T.CO per year
PM_x[c]	287 T. filterable TSP per year
PM_{10x}[c]	287 T. filterable PM_{10} per year

Notes:

a. Assumes annual gas consumption of 2,404,470 T. per year

b. Assumes annual Btu input of 114,847,104 MMBtu per year

c. Recent CT application

d. 2.5 parts per million (ppm) recent NC combined cycle air permit

Btu British thermal unit

CO Carbon monoxide

kWh Kilowatt hour

TABLE 9.2-4 (Sheet 2 of 2)
AIR EMISSIONS FROM GAS-FIRED ALTERNATIVE

lb.	Pound
MW	Megawatt
NO_x	Oxides of Nitrogen
PM	Total particulate matter
PM_{10}	Particulates having diameter less than 10 microns
SO_2	Sulfur dioxide
T.	Ton
yr.	Year

TABLE 9.2-5
GAS-FIRED ALTERNATIVE CHARACTERISTICS

Characteristic	Basis
Unit size = 482 MW ISO rating net [(a)] Two 112 MW-combustion turbines 138 MW-heat recovery boiler	Standard size (Duke Energy experience)
Number of units = 5	Approximate capacity to replace 2400 MWe net
Fuel type = natural gas	Assumed
Fuel heating value = 23,882 Btu/lb (HHV)	Typical for natural gas used in NC (Duke Energy experience)
Fuel sulfur content = 0.0006 lb/MMBtu	Used when sulfur content is not available
NOx control = selective catalytic reduction (SCR) with water injection	Best available for minimizing NOx emissions
Fuel NOx content = 0.009 lb/MBtu (2.5 ppm)	Typical for large SCR-controlled combined cycle gas-fired units (EPA BACT Clearinghouse)
Fuel CO content = 0.0084 lb/MMBtu (9 ppm)	Typical for large SCR-controlled gas fired units
Heat rate = 6800 Btu/kWh	Typical for combined cycle gas-fired turbines (@ ISO)
Capacity factor = 0.8	Typical for baseload units

a) The difference between "net" and "gross" is electricity consumed on-site.

Notes

Btu	British thermal unit
ISO rating	International Standards Organization rating at standard atmospheric conditions of 59°F 60% relative humidity and 14.696 lb. of atmospheric pressure per sq. in.
kWh	Kilowatt hour
MM	Million
MW	Megawatt
MWe	Megawatts electric
NOx	Nitrogen oxides
HHV	High Heating Value

9.3 ALTERNATIVE SITES

As directed by 10 CFR 51.45(b)(3), the ER should present, "appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." The NRC, in Regulatory Guide 4.2, "Preparation of Environmental Reports for Nuclear Power Stations," directs license applicants to include a discussion of the site selection process, the purpose of which is to, "provide a condensed description of the major considerations that led to the final selection ... " The Regulatory Guide also directs that, "The applicant is not expected to conduct detailed environmental studies at alternative sites; only preliminary reconnaissance-type investigations need be conducted."

The Duke Energy site selection process utilized the guidance provided in NUREG-1555 and the Electric Power Research Institute's (EPRI) Siting Guide and site suitability considerations set forth in NRC Regulatory Guide 4.7, Revision 2, "General Site Suitability Criteria for Nuclear Power Stations."

The Duke Energy site selection process for the Lee Nuclear Station broadly considered potential sites for future nuclear and fossil-fired power generating stations. Consequently, specific descriptions for many of the potential sites are proprietary. The following description of the site selection process describes the process without providing specifics for any sites except the final four candidate sites.

In addition to the guidance previously noted, Duke Energy applied the following business goals to the site selection process:

- Site a proposed nuclear plant to provide baseload power for the Duke Energy Carolinas Service Area.
- Identify sites in both North Carolina and South Carolina that are suitable for nuclear power plants.
- Select only sites capable of being acquired and characterized in time to meet the schedule of submitting a combined license application by the end of 2007.
- Minimize transmission line energy losses.
- Minimize capital and operating costs.

Subsection 9.3.1 describes the site selection process utilized by Duke Energy to select the following four candidate sites:

- Lee Site (Cherokee County, South Carolina)
- Keowee Site (Oconee County, South Carolina)
- Perkins Site (Davie County, North Carolina)
- Middleton Shoals Site (Anderson County, South Carolina)

Subsection 9.3.2 provides a comparison of the potential environmental impacts of constructing and operating a nuclear plant at each of these four candidate sites.

9.3.1 SITE SELECTION PROCESS

Site selection was conducted in accordance with the general process outlined in the Electric Power Research Institute's (EPRI) Siting Guide and site suitability considerations set forth in NRC Regulatory Guide 4.7, Revision 2, "General Site Suitability Criteria for Nuclear Power Stations." The general site selection process is depicted in Figure 9.3-1. The site selection process began by screening the Region of Interest (ROI) (defined in Subsection 9.3.1.1) and then reducing the number of sites under consideration in successive steps. This process proceeded through the following steps which successively reduced the number of sites down to a final proposed site:

- Identifying the region of interest
- Identifying candidate areas
- Identifying potential sites
- Identifying candidate sites (coarse screen)
- Identifying candidate sites (fine screen)
- Selecting the final proposed site

Site suitability criteria listed in Chapter 3 of the EPRI Siting Guide were used as the overall framework for these evaluations.

Evaluations of potential and candidate sites using the screening criteria and general siting criteria (described in Subsection 9.3.1.4) were based on publicly available data sources only. Evaluation of the final four candidate sites also had the advantage of first-hand observations.

9.3.1.1 Defining the Region of Interest

As discussed in Chapter 8, Duke Energy is an electric power company operating under franchises from the North Carolina Utilities Commission (NCUC) and the Public Service Commission of South Carolina (PSCSC). Under their statutory authority, the two utility commissions have granted Duke Energy a franchised area in each respective state to serve. These two franchised service areas combined are the Duke Energy Carolinas Service Area.

As also discussed in Chapter 8, the underlying need for the proposed plant is to provide baseload power for the Duke Energy Carolinas Service Area. Consequently, the plant should be located as close as possible to the Duke Energy load centers so as to minimize energy losses from transmission over long distances. Additionally, it is unlikely that the two utility commissions would approve construction of a plant located outside the service area as a financially prudent decision. Consequently, the Region of Interest (ROI) identified for site selection is the Duke Energy Carolinas Service Area as depicted in Figure 9.3-2. Prospective sites were reviewed based on the assumption that a twin-unit plant, using the Westinghouse AP1000 certified design, would be built and operated.

9.3.1.1.1 Description of the Region of Interest

As discussed above, the ROI is the Duke Energy Carolinas Service Area illustrated in Figure 9.3-2. Areas of high population are also shown in Figure 9.3-2. These high population centers also represent the major electric load centers.

The ROI is geographically part of the Piedmont, characterized by rolling hills with a gradual increase in elevation from southeast to northwest. The northwestern portion of the ROI encompasses part of Blue Ridge Mountains and eastern slope of the Appalachian Mountains. East of the ROI is the Atlantic Coastal Plain. Interstate 85 runs from the southwestern edge of the ROI to the northeastern edge connecting the major population centers shown on Figure 9.3-2. Duke Energy maintains two 525 kV transmission lines, one north and one south of, and parallel to, the Interstate 85 corridor. There are four major rivers flowing generally from the north-northwest to south through the ROI. The Yadkin-Pee Dee River basin is in the eastern part of the ROI. The Catawba River and Broad River basins cover the central portion of the ROI and the Savannah River basin is along the western edge of the ROI. The ROI is rural and population density is generally less than 300 individuals per square mile except in the high population centers noted on Figure 9.3-2.

9.3.1.2 Process for Identifying Candidate Areas

The first step in the site selection process was to screen the ROI to eliminate those areas of the Duke Energy service area that were either unsuitable or significantly less suitable than other potential siting areas. Exclusionary and avoidance criteria identified in the EPRI Siting Guide were reviewed to identify applicable criteria and related physical features within the ROI that would provide insight into site suitability.

Criteria applied to initial screening of the ROI are listed in Table 9.3-1. Specific screening criteria for each category are provided in the second column. Explanations/rationales for the use of these criteria are provided in the third column of Table 9.3-1. Information pertaining to the aforementioned initial screening criteria listed in Table 9.3-1 was displayed on separate maps of the Duke Energy service area. These maps were combined using a simple overlaying technique to produce a composite screening map of the ROI.

Areas that remained eligible on the composite map (i.e., those not affected by any of the screening criteria) were reviewed to verify that the area remaining provided:

- Adequate land acreage for a reasonable number of potential sites.
- Reasonable diversity in potential sites, in terms of alternative settings within the ROI.
- Potential sites capable of satisfying Duke Energy's business objectives for the proposed nuclear plant.

Once this process was completed, the final composite screening result formed the basis for identification of candidate areas for potential sites. This regional screening effort yielded six general candidate areas across the Duke Energy service area that were subsequently examined for potential site locations (Figure 9.3-3). The six areas span across most of the Duke Energy service area. Two of the areas are located in North Carolina, three are located in South Carolina, and one, located near the center of the service area, extends across both North and South

Carolina. These candidate areas generally take the form of land lying along linear segments of the water bodies that are candidate cooling water sources, interrupted by areas excluded due to population density, distance to transmission lines, and/or distance to rail lines.

9.3.1.3 Potential Site Identification Process

A two-track process was used to identify potential sites within the above candidate areas.

The first track consisted of Duke Energy reviewing previous siting studies for both fossil and nuclear siting efforts to identify potential sites within the candidate areas. Seventeen sites were identified in the candidate areas. This list of 17 sites included Duke Energy's three existing nuclear sites; McGuire Nuclear Station, Catawba Nuclear Station, and Oconee Nuclear Station. However, after a review of these existing nuclear sites, two were eliminated prior to the potential site screening effort. McGuire Nuclear Station and Catawba Nuclear Station were eliminated based on insufficient land area to accommodate the new units, significant population growth concerns, transmission challenges, and water quality/thermal concerns. While the existing Oconee Nuclear Station does not have sufficient land area to accommodate the new units, Duke Energy property located adjacent to the site was identified as a potential site. Removing McGuire Nuclear Station and Catawba Nuclear Station from the list and substituting the new potential site adjacent to Oconee in place of Oconee reduced the number of potential sites to 15. After reviewing the remaining 15 sites, five additional sites were eliminated prior to the potential site screening effort due to significant on-going residential development in these areas which would make siting a nuclear plant difficult. These included two sites on Lake Keowee, one site on Lake Norman and two sites on Lake Hartwell that were eliminated from the list reducing the number of potential sites to 10.

The second track consisted of an entirely new exercise in potential site identification within the candidate areas. Starting with the areas remaining after ROI screening, general siting areas were identified that allowed evaluation of siting trade-offs within the Duke Energy service area.

Criteria applied in selecting these areas were:

- At least one siting area for each major water source.
- Proximity to load and transmission.
- Avoidance of high population areas.
- Avoidance of areas with significant ongoing development.
- Proximity to transportation, e.g., railroads.
- Diversity of siting areas between the two states in the Duke Energy service area.
- Areas particularly compatible with Duke Energy business objectives.

Areas identified using the considerations outlined above defined the geographic basis for delineating potential greenfield sites. Aerial photographs and other available geographic information were used in defining potential sites. Potential sites were defined to be approximately 6000 ac. in size, although favorable sites as small as 2000 ac. were considered. Thirteen sites were identified in the candidate areas as a result of this second independent effort. Since this second effort was independent of the previous review there was some overlap in the sites that were identified.

The two lists of potential sites were consolidated and duplicate sites were removed resulting in a total of 15 potential sites.

9.3.1.4 Screening Process to Identify Candidate Sites

A two-phased screening process was used to identify candidate sites. The first phase is a coarse screen using nine criteria to identify a smaller set of potential sites to be sent through the second phase, fine screening process. The fine screening process uses a much larger set of criteria (Table 9.3-2) to further evaluate the remaining potential sites that passed the coarse screening process to select the candidate sites.

The 15 potential sites were evaluated against the following set of nine coarse screening criteria to identify a smaller set of sites to be sent through the second phase, fine screening process:

- Water supply availability
- Flooding potential
- Distance to population centers
- Known hazardous land uses near the site
- Protected species or habitat near the site
- Acres of identified wetlands on the site
- Cost to construct access to nearest rail line
- Cost to construct transmission to nearest node
- Land acquisition costs

Screening criteria used in this evaluation were derived from those discussed in Section 4.2 of the EPRI Siting Guide. These screening criteria provided insights into the overall site suitability tradeoffs inherent in the available sites within the Duke Energy service area and were designed to take advantage of data available at this stage of the site selection process.

The overall process for applying the coarse screening criteria was composed of the following elements:

- **Criterion Ratings**: The sites were assigned a rating of 1 to 5 (1 = least suitable, 5 = most suitable) for each of the screening criteria.
- **Weight Factors**: Weight factors reflecting the relative importance of these criteria were developed consistent with the modified Delphi method suggested in the EPRI Siting Guide. Weight factors were developed before sites were evaluated so that participants

could provide an independent view of weights for nuclear power plant site screening before screening results were known. These weight factors were developed by a multidisciplinary committee of Duke Energy employees experienced with areas of nuclear power plant site suitability issues; it was composed of subject matter experts in water use and availability, real estate, ecology, transmission, land use, health and safety, socioeconomics, and public relations.

- **Composite Suitability Ratings**: Ratings reflecting the overall suitability of each site were developed by multiplying criterion ratings by the criterion weight factors, and summing overall criteria for each site.

Based on the coarse screening ratings results, a total of seven sites, roughly half the number reviewed in the first phase, coarse screening, were identified for further, more detailed evaluation in the fine screening process.

NUREG-1555 recommends at least four candidate sites for evaluation. The objective of this next phase of the site selection process was to further evaluate these seven remaining potential sites in order to select a smaller set of four candidate sites to be evaluated to determine the preferred site and the three alternate sites.

General siting criteria used in the fine screening process to evaluate the seven remaining potential sites were derived from those presented in Chapter 3.0 of the EPRI Siting Guide; criteria from the siting guide were tailored to reflect issues applicable to, and data available for, the Duke Energy service area candidate sites. General siting criteria used in evaluating the candidate sites are listed in Table 9.3-2.

The overall process for applying the general siting criteria was composed of the following elements:

- **Criterion Ratings**: Each site was assigned a rating of 1 to 5 (1 = least suitable, 5 = most suitable) for each of the siting criteria. Information sources for these evaluations included (1) publicly available data, (2) information available from Duke Energy files and personnel, (3) U.S. Geological Survey (USGS) topographic maps, and (4) information derived from site flyovers, windshield surveys, and site visits.

- **Weight Factors**: Weight factors reflecting the relative importance of these criteria were synthesized from those developed for previous nuclear power plant siting studies. The weight factors (1 = least important, 10 = most important) were derived using a methodology consistent with the modified Delphi process specified in the Siting Guide.

- **Composite Suitability Ratings**: Ratings reflecting the overall suitability of each site were developed by multiplying criterion ratings by the criterion weight factors and summing overall criteria for each site.

On completing this evaluation, the following four candidate sites were identified:

- **Lee Site**: The Lee Site is located in the south-central portion of the Duke Energy service area, near the northeast border of South Carolina. The site is in a rural area about 6 miles south of Blacksburg and Gaffney, on the west side of the Broad River. The site is located off McKowns Mountain Road, which connects to Road 105, leading to Gaffney, and

Highway 329, that leads north to US 29 (Gaffney and Blacksburg) and I-85 (about 6 – 8 miles to the north). Distance to an area with a population density greater than 300 persons per sq. mi., Gaffney, South Carolina, is 6.3 mi. The distance to the nearest population center, which is Gastonia, North Carolina, is 19.8 mi.

- **Keowee Site**: The Keowee site is located in the southwest portion of the Duke Energy service area, near the northwest border of South Carolina. The Keowee site is located adjacent to the existing Oconee Nuclear Station. The Keowee site is bounded on the west side by Highway 130 and on the north side by Highway 183 and on the east side by the Keowee River. Distance to population density greater than 300 persons per sq. mi., which is Clemson, South Carolina, is 7 miles (mi.). The distance to the nearest population center, which is Anderson, South Carolina, is 21 mi.

- **Perkins Site**: The Perkins Site is located in the northeast portion of the Duke Energy service area, near the north-central border of North Carolina. The site is close to Mocksville, N.C. where US highways, 158, 64 and 601 meet. Access to the site is via Route 801 just to north of site, which connects with SR 601 and also connects with SR 64 about 4 miles north. Interstate 85 lies about 9 miles southeast of site. Distance to an area with a population density greater than 300 persons per sq. mi. (Salisbury, North Carolina) is 11 mi. The distance to the nearest population center, which is Winston-Salem, North Carolina, is 15.4 mi.

- **Middleton Shoals Site**: The Middleton Shoals Site is located in the southwest portion of the Duke Energy service area, near the northwest border of South Carolina. Routes 187 and 184 converge near the site and connect to SC 81 to the east (Iva) and 181 to the north (into Anderson). Distance to a population area with a density greater than 300 persons per sq. mi. is 9.7 mi. The distance to the nearest population center, which is Anderson, South Carolina, is 15 mi.

9.3.2 CANDIDATE SITES COMPARISON

In this subsection, the potential environmental impacts of constructing and operating the Lee Nuclear Station at each of four candidate sites (Lee Site, Keowee Site, Perkins Site, and Middleton Shoals Site) are discussed and compared against each other. The comparison of the candidate sites utilizes the impact significance defined in 10 CFR 51, Appendix B, Table B-1, Footnote 3. Unless the significance level is identified as beneficial, the effect is adverse, or in the case of SMALL it may be negligible. These definitions of significance are as follows:

SMALL — Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.

MODERATE — Environmental effects are sufficient to alter noticeably, but not to destabilize, any important attribute of the resource,

LARGE — Environmental effects are clearly noticeable and are sufficient to destabilize any important attributes of the resource.

The comparison of potential environmental impacts for the four candidate sites are summarized in Table 9.3-3. This table illustrates that, although each of the candidate sites is a viable location for a nuclear power plant, none of the alternative sites were deemed environmentally superior to the Lee Site.

9.3.2.1 Land Use Impacts

The objective of this criterion was to evaluate the suitability of the four candidate sites with respect to potential conflicts in existing land uses at each site. Impacts include the amount of clearing and grading necessary to place the proposed AP1000 standard plant on the site, including any supporting infrastructure. Information sources include USGS topographic maps and first-hand observations from helicopter over-flights.

Lee Site

The Lee Site was previously owned by Duke Energy and was available for purchase at the time of the site selection study. Duke Energy has subsequently purchased the site. The site was developed as an industrial site (the former Cherokee Nuclear Site) and extensive rough grading, including the construction of two reservoirs, was completed in the 1970's. The surrounding land is rural and sparsely populated. An existing 8-mile rail spur to the site will need a small re-route (approximately 1800 feet) and the rail bed will need vegetation cleared, new ballast, rail ties and rails added to become operational for transporting materials and equipment to the site. Land use impacts would be SMALL.

Keowee Site

The Keowee site is owned by Duke Energy and is located adjacent to the Oconee Nuclear Station. The site is a wooded greenfield site, requiring extensive rough grading that would include the construction of a supplemental water reservoir. Residential development is absent on the site, but the surrounding area has a low level of development. There is a high level of residential development at the area where a water intake structure would be constructed. A 5.4-mile rail spur would be constructed to the site to transport materials and equipment to the site. Land use impacts would be MODERATE.

Perkins Site

Duke Energy currently owns the Perkins Site that was originally characterized for the Perkins Nuclear Station in the 1970's. The site remains a wooded greenfield site and is managed as a wildlife management area by the NC Fish and Wildlife Service under an agreement with Duke Energy. The site would require extensive rough grading. There is no residential development on the site but the surrounding area is undergoing a moderate amount of residential development particularly in the area proposed for a supplemental water reservoir. A 5.6-mile rail spur would be constructed to the site to transport materials and equipment to the site. Land use impacts would be MODERATE.

Middleton Shoals Site

This site is currently owned by Duke Energy. The site is a wooded greenfield site requiring extensive rough grading that would include the construction of a supplemental water reservoir. There is no residential development on the site and sparse residential development in the vicinity of the site. A 14-mile rail spur would be constructed to the site to transport materials and equipment to the site. Land use impacts would be MODERATE.

9.3.2.2 Hydrology and Water Quality Impacts

The four sites were compared based on impacts to water supply, water quality and potential for flooding.

Water Supply

The four sites were evaluated with respect to the cooling water assuming that each site would use cooling towers. The average cooling water consumptive water use for all plant needs would be 55 cfs. Total average water withdrawal for plant needs would be 78 cfs with 23 cfs being returned to the river or reservoir. Using groundwater to supply cooling needs is not an option at any of these sites as any wells drilled in these areas would have low yields.

Each site was also evaluated assuming augmentation as needed to yield an equivalent amount of cooling water during assumed low flow conditions. In each case, the amount of augmentation and reason for the assumed augmentation is provided below, in order to provide a basis for comparison. Impacts of such augmentation is comparable for all four sites. However, as a result of the inherent attributes of the AP1000 reactor design, offsite cooling water is not required for safe operation, and curtailment of operations is an equally viable option; relative impacts on water supply are considered under scenarios involving both normal flow and curtailed operation during low flow conditions.

Lee Nuclear Site

The Lee Nuclear Site is located on the Broad River. All the water needed to support plant needs at the Lee Nuclear Site during normal operations would be withdrawn from the Broad River. The closest USGS gauging station is at Gaffney, just above the Lee Nuclear Site, but this gauge ceased operation in 1991. Consequently, other gauges in North and South Carolina along the Broad River were used to augment the data after 1991. The average flow is calculated to be 2538 cfs (1926 – 2006), and the FERC regulatory low-flow release at the Ninety-Nine Islands Hydroelectric Station is required to be 483 cfs. The Broad River has adequate flow under average flow conditions to support the requirements of a closed cycle cooling water system. Low-flow conditions (e.g., drought) could require supplemental water storage or curtailment of operations. Supplemental water storage for low-flow periods is estimated to be 7301 ac.-ft. in addition to the capacity of existing ponds on the site. A withdrawal of 55 cfs for consumptive water use under normal flow conditions would be SMALL since this represents 2 percent of the average mean flow. Under low-flow conditions, the impact should still be SMALL because consumptive withdrawal would be curtailed.

Keowee Site

All the water needed to support plant needs at the Keowee Site will be withdrawn from Lake Keowee. The Lake Keowee – Lake Jocassee storage would be sufficient to supply the additional cooling requirements of a second nuclear station near Oconee Nuclear Station if agreements could be reached with the U.S. Army Corps of Engineers (USACE) to reduce the amount of water that is required to be released from Lake Keowee during low flow events. However, successful negotiation of such an agreement is not guaranteed. Therefore, a supplemental water storage reservoir for low-flow periods with an estimated volume of 4,800 ac-ft is assumed for comparison. A withdrawal of 55 cfs for consumptive water use under normal flow conditions will be SMALL. Under low flow conditions, the impact should still be SMALL even without the supplemental reservoir if withdrawal is agreed to, or as a result of curtailed consumptive use.

Perkins Site

The Perkins Site is located on the Yadkin River. All the water required to support plant needs at the Perkins Site will be withdrawn from the Yadkin River. The closest USGS gaging station is at Yadkin College, 3 miles upstream of the Perkins Site. Flow data for the Yadkin River at this station shows an average flow of 3031 cfs and a 7Q10 flow of 595 cfs for the period of 1963 – 2003. The Yadkin River has adequate flow under average flow conditions to support the requirements of a closed cycle cooling water system. Low flow conditions (e.g., drought) could require supplemental water storage or curtailment of operations. A supplemental reservoir, if used for low-flow periods, is estimated to be 8,635 ac-ft. A withdrawal of 55 cfs for consumptive water use under normal flow conditions will be SMALL since this represents < 2 percent of the average mean flow. Under low flow conditions, the impact should still be SMALL since consumptive withdrawal would be curtailed.

Middleton Shoals Site

The Middleton Shoals Site is located on the Savannah River/Russell Reservoir, just downstream of Hartwell Dam. All the water needed to support plant needs at the Middleton Shoals site will be withdrawn from Russell Reservoir. The USACE controls the water supply and flow in the Russell Reservoir at Middleton Shoals. Russell Reservoir should have an adequate supply, although an agreement would be needed with the USACE to allow continued use of the reservoir under low flow conditions. However, successful negotiation of such an agreement is not guaranteed. Therefore, a 4,800 ac-ft supplemental reservoir would be constructed for low flow events. A withdrawal of 55 cfs for consumptive water use under normal flow conditions will be SMALL. Under low flow conditions, the impact should still be SMALL even without the supplemental reservoir.

Water Quality

All four sites would operate under a National Pollutant Discharge Elimination System (NPDES) permit. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating discharges into the waters of the United States. The permit contains limits on what can be discharged, monitoring and reporting requirements, and other provisions to ensure that the discharge does not hurt water quality or human health. Any releases of contaminants to rivers or reservoirs as a result of construction or operation of a nuclear plant at the four sites would be regulated through the NPDES permit process to ensure water quality is protected. Therefore, impacts to water quality at all four sites would be SMALL.

Flooding

To estimate flood potential, a comparison was conducted between site grade elevation (based on suggested plant layout locations for the four sites, as shown on USGS Topographic maps at 1:24,000 scale) and the 100-year flood elevation for the major river on which the site is located. The 100-year flood elevations were based on Flood Insurance Rate Maps (FIRM) from FEMA for the respective counties in which the sites are located. Primary emphasis was on flood elevations for the main water bodies (rivers and reservoirs) and their major tributaries where flood elevations were identified. Onsite tributaries were noted but were typically identified as flood hazard free, based on the FEMA maps. FIRM maps also include 500-year floodplain, although none of the sites appear to be located within the 500-year floodplain.

Site	Site Grade Elevation	Maximum Flood Elevation (from main water body)	Difference in Elevation
Lee	590 ft	520 ft	70 ft
Keowee	800 ft	680 ft or lower (Keowee River)	120 ft
Perkins	720-730 ft	650-660 ft	70 ft (minimum)
Middleton Shoals	550 ft	450 ft	100 ft

Based on the above results, the risk for flooding to the four sites is rated as SMALL.

9.3.2.3 Terrestrial Ecology Resources

The objective of this criterion is to evaluate the candidate sites with respect to potential construction and operation related impacts on important terrestrial species and ecology. Data were obtained from the South Carolina Rare, Threatened & Endangered Species Inventory (Reference 1) and North Carolina Natural Heritage Program (Reference 2), listing of rare plant and animal species. Wetland information was obtained from the National Wetlands Inventory (NWI) maps published by U.S. Fish and Wildlife Service or other existing environmental documentation for the candidate sites.

In addition to the above, aerial photographs were obtained for the Lee Nuclear Site and the Perkins, Keowee, and Middleton Shoals candidate sites. The aerial photographs were subjected to image interpretation to identify cover or habitat types within a core area of the central portion of each site. This core area is described by a circle with a radius of 2500 ft. centered on the coordinates for the proposed reactor units. A circle with a radius of 2500 ft. defines an area of about 450 ac. (Table 9.3-4).

Undisturbed temperate broadleaf and mixed forests like the MH, MHP, and PMH types on the candidate sites generally constitute high-quality wildlife habitat. In addition to high species diversity in the plant community, these forests typically develop vertical structure that includes four layers. The uppermost layer is the canopy, which is composed of tall mature trees. Below the canopy is the three-layered, shade tolerant understory. The top layer of the understory is the subcanopy which is composed of smaller mature trees, saplings, and suppressed juveniles awaiting an opening in the canopy. Below the subcanopy is the shrub layer, composed of low-growing woody plants. Typically the lowest growing (and most diverse) stratum is the ground cover or herbaceous layer.

Species diversity and structural diversity in forests increase the number of ecological niches available for occupation by a correspondingly larger number of more diverse animal species.

Niche is a term describing the relational position of a species or population in its ecosystem. It describes how an organism or population responds to the distribution of resources and competitors (e. g., by growing when resources are abundant and predators, parasites and pathogens are scarce) and how it in turn alters those same factors (e.g., by limiting access to resources by other organisms, by acting as a food source for predators, or as a consumer of prey). The abundant and varied animal community occupying upland hardwood and mixed forests includes a large number of common bird, mammal, and herptile species, as well as members of "important" groups as defined in NUREG-1555. Lesser numbers of these species occupy cover types of lower habitat value, including monotypic Pine plantations and less stratified shrub-forb-herb habitats like the USC and OFM types.

Sixty-four percent, 66 percent, and 59 percent of the cover in the core area at the Perkins, Keowee, and Middleton Shoals sites, respectively, consist of high-quality deciduous and mixed forest habitat (Table 9.3-4). This compares to only 14 percent at the Lee Nuclear Site. In contrast, the lower quality Pine, USC, and OFM habitat types comprise 36 percent, 30 percent, and 39 percent, respectively, at the Perkins, Keowee, and Middleton Shoals sites but almost 70 percent of the habitat at the Lee Nuclear Site. These data reflect the relative lack of previous disturbance at the Perkins, Keowee, and Middleton Shoals sites and the high degree of disturbance at the Lee Nuclear Site. The core area of the Lee Nuclear Site was extensively cleared and graded for the Cherokee Project but was cancelled in the 1980s.

Selecting the Lee Nuclear Site greatly reduces the adverse impact from additional clearing of upland forest habitat in comparison to the other three candidate sites. Accordingly, the Lee Nuclear Site is the preferred alternate site when considering the impact of the project on high quality terrestrial resources.

Lee Nuclear Site

There are no documented rare, threatened or endangered (RTE) species on the Lee Nuclear Site, according to References 1 and 2. There are no documented occurrences of RTE in the vicinity of the site. However, field reconnaissance at the site revealed the presence of habitat suitable for several state and federally listed species outside of the core area. Field reconnaissance also revealed a small population of adder's tongue fern (*Ophioglossum vulgatum*), a state-listed species of concern, also outside the core area (Subsection 2.4.1.3.1).

NWI maps did not reveal significant wetland acreage on the Lee Nuclear Site, although, wetlands identified through interpretation of aerial photographs total about 35 ac. (Table 9.3-4). Only about 2.5 ac. of these wetlands are under the regulatory jurisdiction of the U.S. Army Corps of Engineers. The Lee Nuclear site is already partially cleared. It was determined that using 65 ac. of high quality habitat (Table 9.3-4) for plant facilities in the 450-ac. core area of the site would have minimal impacts on terrestrial ecosystems.

In NUREG 1437, NRC concludes potential adverse impacts due to drift from cooling towers to surrounding plants, primarily trees in this case, is minor. This potential impact can be minimized with the use of drift eliminators on the cooling towers.

Impacts to terrestrial ecology resources at the Lee Nuclear Site are estimated to be SMALL.

Keowee Site

There are no documented RTE species on the Keowee site. The federally listed endangered peregrine falcon (*Falco peregrinus*) has been occasionally sighted near the Oconee Nuclear Station (which is located next to the Keowee site). There are four state-listed plant species (species of concern) in the vicinity of Lake Keowee: *Nestronia umbellula* (Indian Olive), *Viola tripartita* (three-parted violet), *Carex laxiflora* (loose-flowered sedge), and *Carex prasina* (drooping sedge). The NWI maps and aerial photograph interpretation did not reveal significant wetland acreage on the Keowee site. The site is mostly wooded. Using 450 ac. in the core area of the site for the plant facilities would require removal of 297 ac of high quality wooded habitat (Table 9.3-4).

In NUREG 1437, NRC concludes potential adverse impacts due to drift from cooling towers to surrounding plants, primarily trees in this case, is minor. This potential impact can be minimized with the use of drift eliminators on the cooling towers.

Impacts to terrestrial ecology resources at the Keowee site are estimated to be MODERATE.

Perkins Site

There are no documented RTE species at the Perkins site. There are no documented occurrences of RTE species in the vicinity of the site. NWI maps and aerial photo interpretation did not reveal significant wetland acreage on the Perkins site. The site is mostly wooded. Using 450 ac. for the plant facilities in the core area of the site would require removal of 288 ac. of high quality wooded habitat (Table 9.3-4).

In NUREG 1437, NRC concludes potential adverse impacts due to drift from cooling towers to surrounding plants, primarily trees in this case, is minor. This potential impact can be minimized with the use of drift eliminators on the cooling towers.

Impacts to terrestrial ecology at the Perkins site are estimated to be SMALL to MODERATE.

Middleton Shoals Site

There are no documented RTE species on the Middleton Shoals site. There are no documented occurrences of RTE species in the vicinity of the site. NWI maps and aerial photograph interpretation did not reveal significant wetland acreage on the Middleton Shoals site. The site is mostly wooded. Using 450 ac. in the core area of the site for the plant facilities would require removal of 265 ac. of high quality wooded habitat (Table 9.3-4).

In NUREG 1437, NRC concludes potential adverse impacts due to drift from cooling towers to surrounding plants, primarily trees in this case, is minor. This potential impact can be minimized with the use of drift eliminators on the cooling towers.

Impacts to terrestrial ecology at the Middleton Shoals site are estimated to be SMALL to MODERATE.

9.3.2.4 Aquatic Ecology Resources

The objective of this evaluation is to compare the candidate sites with respect to impacts to aquatic ecology resources from thermal discharges, entrainment and impingement. Data were obtained from the South Carolina Rare, Threatened & Endangered Species Inventory (Reference 1) and North Carolina Natural Heritage Program (Reference 2), listing of rare plant and animal species. Previous NRC evaluations of aquatic ecology impacts at operating power plants from NUREG-1437 were coupled with observations from helicopter flyovers of the sites and plant design considerations.

Lee Site

There are no documented occurrences of aquatic RTE species in the vicinity of the Lee Site. The Lee Site is located on a river which would likely provide sufficient heat rejection capacity for the proposed plant, using a closed cooling water system, without having significant thermal impacts to aquatic ecology. No information was discovered during the evaluation which revealed any concerns with significant thermal impacts at the site.

The proposed plant will include cooling towers that will reduce the amount of cooling water withdrawal required for plant operation. In NUREG 1437, NRC concluded that, with cooling towers and appropriate intake design, potential adverse impacts due to entrainment or impingement of aquatic organism are minor and do not significantly disrupt existing populations. Assuming a two unit closed-cycle plant at the site, and 100 percent of the local plankton passing through the plant, it appears that there would be no discernible effect on the plankton population in the existing water source. This is due to the very small volume of water used by the plant relative to the total volume available from the water source. Because of the low flow velocities of a closed cycle plant at the site, impingement of adult fish would be expected to be minimal.

Impacts to aquatic ecology resources were estimated to be SMALL.

Keowee Site

There are no documented occurrences of aquatic RTE species in the vicinity of the Keowee Site. The Keowee Site is located on a reservoir which would likely provide sufficient heat rejection capacity for the proposed plant, using a closed cooling water system, without having significant thermal impacts to aquatic ecology. No information was discovered during the evaluation which revealed any concerns with significant thermal impacts at the site.

The proposed plant will include cooling towers that will reduce the amount of cooling water withdrawal required for plant operation. In NUREG 1437, NRC concluded that, with cooling towers and appropriate intake design, potential adverse impacts due to entrainment or impingement of aquatic organism are minor and do not significantly disrupt existing populations. Assuming a two unit closed-cycle plant at the site, and 100 percent of the local plankton passing through the plant, it appears that there would be no discernible effect on the plankton population in the existing water source. This is due to the very small volume of water used by the plant relative to the total volume available from the water source. Because of the low flow velocities of a closed cycle plant at the site, impingement of adult fish would be expected to be minimal.

Impacts to aquatic ecology resources were estimated to be SMALL.

Perkins Site

There are no documented occurrences of aquatic RTE species in the vicinity of the Perkins Site. The Perkins Site is located on a river which would likely provide sufficient heat rejection capacity for the proposed plant, using a closed cooling water system, without having significant thermal impacts to aquatic ecology. No information was discovered during the evaluation which revealed any concerns with significant thermal impacts at the site.

The proposed plant will include cooling towers that will reduce the amount of cooling water withdrawal required for plant operation. In NUREG 1437, NRC concluded that, with cooling towers and appropriate intake design, potential adverse impacts due to entrainment or impingement of aquatic organism are minor and do not significantly disrupt existing populations. Assuming a two unit closed-cycle plant at the site, and 100 percent of the local plankton passing through the plant, it appears that there would be no discernible effect on the plankton population in the existing water source. This is due to the very small volume of water used by the plant relative to the total volume available from the water source. Because of the low flow velocities of a closed cycle plant at the site, impingement of adult fish would be expected to be minimal.

Impacts to aquatic ecology resources were estimated to be SMALL.

Middleton Shoals Site

There are no documented occurrences of aquatic RTE species in the vicinity of the Middleton Shoals Site. The Middleton Shoals Site is located on a reservoir which would likely provide sufficient heat rejection capacity for the proposed plant, using a closed cooling water system, without having significant thermal impacts to aquatic ecology. No information was discovered during the evaluation which revealed any concerns with significant thermal impacts at the site.

The proposed plant will include cooling towers that will reduce the amount of cooling water withdrawal required for plant operation. In NUREG 1437, NRC concluded that, with cooling towers and appropriate intake design, potential adverse impacts due to entrainment or impingement of aquatic organism are minor and do not significantly disrupt existing populations. Assuming a two unit closed-cycle plant at the site, and 100 percent of the local plankton passing through the plant, it appears that there would be no discernible effect on the plankton population in the existing water source. This is due to the very small volume of water used by the plant relative to the total volume available from the water source. Because of the low flow velocities of a closed cycle plant at the site, impingement of adult fish would be expected to be minimal.

Impacts to aquatic ecology resources were estimated to be SMALL.

9.3.2.5 Socioeconomics

Construction Related Effects

The capacity of the communities surrounding the plant site to absorb temporary construction population was estimated.

It is assumed that construction requires a peak on-site workforce of 4512 workers and that no other major construction project would occur in the site vicinity concurrently with construction of the plant.

Available population and economic data were obtained from the U.S. Census Bureau for each site (Reference 3). The data were collected by county to determine availability of an adequate labor force within commuting distance (based on an assumed location of the labor pool). Data relating to population and labor force, primarily the construction industry, were compared with the expected construction labor requirements to determine availability of labor.

Because the preferred and alternative sites are all located in similar rural settings in the same general region of the southeastern United States, the assumptions used for the Lee Nuclear Station regarding an in-migrating workforce are also applied to the three alternative sites.

To address potential impacts on local community services, the following assumptions were used:

- During the construction phase, an estimated peak workforce of 4512 is expected to be present on-site and include both construction workers (4398) and a small number of operations workers (114) whose presence is expected to overlap with peak construction activity.
- Seventy percent of the 4398 construction workers will in-migrate (3079 construction workers), and 36 percent of the 114 operations workers will in-migrate (41 operations workers).
- Twenty-five percent of these in-migrating construction workers (770) will bring their families (3 additional persons per family equals 2309 additional people), resulting in a total in-migrating construction population of 5388 (3079 in-migrating workers plus 2309 additional people).
- One hundred percent of in-migrating operations workers (41) will bring their families (3 additional persons per family equals 123 additional people), resulting in a total in-migrating operations population of 164.
- An influx of direct workers also will bring in an influx of indirect jobs. The U.S. Department of Commerce, Bureau of Economic Analysis, Economics and Statistics Division, provides multipliers for industry jobs and earnings based on their economic model, the Regional Input-Output Modeling System (RIMS II). During the peak construction time period, for every construction job, an estimated additional 0.45 jobs are created, resulting in 1385 indirect jobs (based on 70 percent of the construction workforce in-migrating). For every operations job on-site at the peak construction phase, an estimated additional 0.95 jobs are created, resulting in 39 additional indirect jobs (based on 36 percent of the operations workforce in-migrating). The total number of indirect jobs created during the peak construction phase is estimated at 1424. Because most indirect jobs are service-related and not highly specialized, it is assumed that most, if not all, indirect jobs are filled by the existing workforce within the 50-mi. region.

The result is a total population influx into the region at the peak construction phase of 5552 persons, including construction and operations workers and their families (3120 in-migrating workers plus 2432 additional family members).

The preferred and alternative sites currently meet the population requirements of 10 CFR 100. The population distribution near each site is low with typically rural characteristics.

Demography

Based on the estimated in-migrating population (5552) and the U.S Census Bureau 2000 population levels for the study area and host county for each site, the percent increases in population would be as shown in Table 9.3-5.

Potential increases in population during construction for the proposed project within the multi-county study area would represent a less than 1 percent increase in population for each site area, and impacts would be expected to be SMALL. Under the most conservative scenario, where all in-migrating workers and their families choose to reside in the host county at each site, the potential impacts on the existing population in each host county would be SMALL to MODERATE at Middleton Shoals, where the population in Anderson County would increase by 3.3 percent, and MODERATE to LARGE at the other three sites, based on a host county population increase ranging from 8.4 percent (Keowee) to 15.9 percent (Perkins). Note that all impacts would be temporary and are based on conservative 2000 U.S. Census Bureau population levels. A comparison to 2006 estimated populations for the host counties resulted in slightly reduced percentage increases for all sites, with the greatest change occurring for Davie County, which experienced a 14.9 percent population increase between 2000 and 2006. However, factoring in 2006 population estimates, even for the Perkins Site, which showed the greatest change, would still result in a MODERATE to LARGE impact on the host county for the Lee, Keowee, and Perkins sites. Finally, it should be noted that expanding the in-migration to a two-county area for each site, including the significantly more populated York County for Lee; Pickens County for Keowee; and Davidson County for Perkins (Abbeville County for Middleton Shoals is less populated than host Anderson County), would result in decreased impacts at each site. The in-migrating population would represent a smaller percentage increase to these more highly populated counties, which are also likely to offer more amenities. Based on the percentage increase in population for a two-county area, which ranges between 2.5 and 3.1 percent, the impacts at all sites would be expected to be SMALL to MODERATE.

Local Economy

As described in Subsection 4.4.2.2, the wages and salary of the construction and operations workforce would have a multiplier effect that could result in an increase in business activity, particularly in the retail and service sectors. This would have a positive impact on the business community and could provide opportunities for new business and increased job opportunities for residents. The economic effect in the study area would be beneficial for each site. Duke Energy assumes that direct jobs would be filled by an in-migrating workforce, but most indirect jobs would be service-related, not highly specialized, and filled by the existing workforce in the study area at each site. As discussed in Subsection 4.4.1.1, Duke Energy estimates that an in-migrating workforce of 3120 (70 percent of 4398 construction workers plus 36 percent of 114 operation workers) during peak construction would create 1424 indirect jobs for a total of 4544 new jobs in the region. Expenditures made by the direct and indirect workforce would strengthen the regional economy. Unemployment rates in 2000 within each of the host counties were 3.8 percent in Cherokee County (Lee Nuclear Site), 2.6 percent in Oconee County (Keowee Site), 2.7 percent in Anderson County (Middleton Shoals Site), and 2.4 percent in Davie County (Perkins Site). The impacts of the proposed project on the economy would be beneficial and SMALL in the region of all of the sites, and beneficial and MODERATE to LARGE in the host counties for each site.

Taxes

The tax structure and revenue categories for South Carolina are described in detail for the Lee Nuclear Site in Subsection 2.5.2.3 and are expected to also apply to the Keowee and Middleton Shoals sites because they are located in South Carolina. The Perkins Site is located in North Carolina, and the types of taxes generated by construction activities and purchases, and by site workforce expenditures, are expected to be similar as well. Duke Energy currently operates the existing McGuire Nuclear Station, Units 1 and 2, in Mecklenburg County, North Carolina, and pays property taxes to both Mecklenburg County and the town of Huntersville, which benefits the total operating budget of Mecklenburg County. Because host Davie County for the Perkins Site is significantly less populated than Mecklenberg County, the benefits to Davie County are expected to be even greater than those realized by Mecklenburg County for McGuire. In summary, the increase in collected taxes as a result of constructing and operating the proposed project would be viewed as a benefit to the state and local taxing jurisdictions for the preferred site and for each of the alternative sites. It is expected that the impacts on the economy of the region would be beneficial and SMALL, while the impacts to the host county for each site are expected to be beneficial and LARGE.

Transportation

The existing transportation network surrounding the Lee Nuclear Site has been described previously in Subsection 2.5.2.2, and impacts to this network from construction activities have been described in Subsection 4.4.1.3. Cherokee County sits just off Interstate-85 between Charlotte-Gastonia and Greenville-Spartanburg. The Lee Nuclear Site is located off McKowns Mountain Road, which connects to Road 105 leading into Gaffney, and Highway 329, which leads north to U.S. Highway 29 (Gaffney and Blacksburg) and I-85.(about 6 - 8 mi. to the north). Upgrades would be required if the site is developed. Based on the size of the construction workforce and the associated number of vehicles added to the roadways, the impacts from construction workers and deliveries on smaller two-lane state and county highways and local roads, primarily McKowns Mountain Road, are MODERATE to LARGE within the immediate vicinity of the site. Mitigation measures would be required and could include the following:

- Widening of McKowns Mountain Road to accommodate the additional traffic.
- Installing traffic-control lighting and directional signage.
- Creating an additional entrance to the site to alleviate traffic at the primary plant entrance.
- Shuttling construction workers to and from the site.
- Encouraging carpooling.
- Staggering shifts to avoid traditional traffic congestion time periods.

The Keowee Site is located in Oconee County, which is served by I-85 in the southeast corner, as well as U.S. Highways 76 and 123, State Highway 28, and State Scenic Highway 11. The proposed site is on a two-lane highway with service to the site being convenient from four main directions. Highway 123 runs the length of adjacent Pickens County from east to west with four-lane service to Greenville. State Highway 133 (which runs north-south on the east side of Lake Keowee) and State Highway 183 from Pickens serve as commuting highways from Pickens

County to the existing Oconee Nuclear Station, which is adjacent to the proposed Keowee Site. Adjacent Pickens County is not served by the Interstate Highway System, but has ready access to the I-85 corridor via U.S. 76, 123, and 178. State Highways 8, 96, 135, 137, 124, and State Scenic Highway 11 complete the major road network. The existing transportation routes adequately serve the site area, which includes the existing Oconee Nuclear Station, located approximately 1 mi. to the north. However, development of the Keowee Site would likely require the widening of Highway 183, the relocation of an existing road that currently runs next to the Keowee Site and connects to Highway 183 at the existing Oconee Nuclear Station, and development of a new access road to the site. In addition, development at the Keowee Site would add commuters, deliveries, and congestion to the existing and significant workforce and delivery system associated with the nearby Oconee Nuclear Station, local residents, and recreational users of Lake Keowee. Impacts, particularly potential cumulative impacts from activities at both plants, would be MODERATE to LARGE. Mitigation measures for the access road and surrounding roads would be required, and these measures would be similar to those identified for the Lee Nuclear Site.

There is good access to the Middleton Shoals Site from local roads on the east side of the Savannah River. Routes 187 and 184 converge near the site and connect to SC Highways 81 to the east (Iva) and 181 to the north (into Anderson). Larger routes include State Road (SR) 72 to the south (15 mi.) and U.S. Highway 29 to the north (7-8 mi.). The closest interstate is I-85 to the north (5 mi. north of Anderson), which connects to the Greenville-Spartanburg area. Similar to that at the Lee and Keowee sites, development of the Middleton Shoals Site, which is currently served by 2-lane roads, would require widening of some surrounding roads. This could include the widening of Highways 181 (coming in from Anderson) and 187, both of which access the site from the north, as well as construction of a new road for direct site access. Impacts would be MODERATE to LARGE and would require mitigation measures similar to those for the Lee Nuclear Site.

The Perkins Site is close to Mocksville, which is where U.S. Highways 158, 64, and 601 meet. These highways join Interstate-40 approximately 9 mi. to the northwest of the site. Access from the site (Davie County) is via Route 801 just to the north of site. This route then connects with SR 601 (runs north-south west of site) and also connects with SR 64 about 4 mi. north (east-west route). Interstate-85 is about 9 mi. southeast of the site. The primary site access from I-85 would be via U.S. Highways 64 and 801, which are also two-lane roads. Development of the Perkins Site would require similar road widening and site access. Impacts would be MODERATE to LARGE and would require similar mitigation measures, as described for the Lee Nuclear Site.

In summary, the preferred site and all three alternative sites are greenfield sites located along two-lane roads that would require upgrading for site development. Impacts at all sites are expected to be the same (MODERATE to LARGE). While Keowee has the advantage of being near the existing Oconee Nuclear Station and an already developed infrastructure, the site itself is undeveloped and would require new access roads. The potential cumulative impacts from continued operation of Oconee and new construction and operations at Keowee need to be recognized. In addition, significant upgrading of most arterial links and main highways is likely to be required within both North and South Carolina, including areas around each of the sites, in order to accommodate projected growth over the next 10 - 20 years.

Recreation

Nearby recreational facilities at the Lee Nuclear Site have been described previously in Subsection 2.5.2.5 and include Kings Mountain State Park and the adjoining Kings Mountain National Military Park, which are located approximately 8 mi. northeast of the site center point. A comparison of nearby state parks and game preserves at the three alternative sites reveals the following:

Keowee: Oconee State Park is located to the west (over 5 mi.), Keowee Toxaway State Natural Area to the north (10 mi.); and Lake Keowee with a shoreline located approximately 1 mi. from the site.

Lake Keowee is smaller than Lake Hartwell on which the Middleton Shoals site is located, but it supports similar activities, including boating, skiing and fishing. Lake Keowee was formed by damming the water of the Little River and Keowee River above the Hartwell Reservoir. Hartwell Reservoir, a U.S. Army Corps of Engineers reservoir, is located south and downstream of the site. Keowee Lake covers about 18,500 ac. and has 300 mi. of shoreline, which is developed with both permanent and vacation residences, along with campgrounds, boat launch areas, marinas, golf courses, and some small retail establishments. Lake Keowee is used as a source of municipal drinking water by Greenville and Seneca and is extensively used for recreation by fishermen, swimmers, skiers, and boaters (Reference 6).

Middleton Shoals: Saddler's Creek State Recreation Area (approximately 10 mi. to the north) and 56,000-ac. Lake Hartwell in Anderson County, on which the site is located.

The lake includes 962 mi. of shoreline and has over 80 public boat launch, recreation, and park areas. One of the boat launches, located at the Highway 368 crossing of the Savannah River into Anderson County, SC, is located immediately south of the site.

Perkins: Boone's Cave State Park located in adjacent Davidson County to the southeast (approximately 5 mi.), which has never been intensely developed as a recreation site; Perkins State Game Preserve to the east (approximately 1.3 mi.), and Alcoa State Game Lands to the south of the site (approximately 5 mi.).

Impacts to recreational areas near the Lee Nuclear Site were addressed in Subsection 4.4.2.6. Given the distance to the nearest state park, impacts to recreational facilities for the Lee Nuclear Site are expected to be SMALL. Impacts to recreational areas at the Perkins Site are also expected to be SMALL, given the distance to the nearest state park and the nature of activities that occur at the nearby game preserve. Impacts to recreation at Keowee and Middleton Shoals would be expected to be SMALL to MODERATE, given their proximity to reservoirs that support recreational use. In addition, development of the Middleton Shoals Site would adversely impact the existing boat launch located next to the site. Mitigation would be required and would likely include relocation of the boat launch to a different location.

Housing

The impacts of plant construction on housing depend upon the number of workers already residing in the study area and the number that would relocate and require housing. As discussed previously, Duke Energy estimates that approximately 3120 workers and their families (for a total of 5552 persons) would migrate into the region. Assuming these workers are dispersed throughout the multi-county region, the impacts on housing at each site are expected to be SMALL, based on the small percentage increases in total study area population occurring at each site. However, under a more conservative assumption that all of the in-migrating workers and their families would prefer to live close to the site in a two-county area, the percentage use of the existing vacant housing inventory is provided in Table 9.3-5. These numbers are based on housing data for 2000 (vacant) and assume one housing unit per worker.

Based on absolute numbers, the available housing would be sufficient to house the workforce at the preferred and alternative sites, with the lowest available housing found near the Perkins Site (although also note that the Perkins Site is within 20 mi. of the large metropolitan area of Winston-Salem in Forsyth County, which had 9242 vacant housing units in 2000). The available housing may not be sufficient, however, in terms of the type, size, and pricing desired by the workers. In this case, workers could relocate to other areas in the region, such as to larger metropolitan areas within commuting distance; have new homes constructed; bring their own homes; or live in hotels and motels. Single workers could also share apartments, which would reduce the total number of housing units needed. An increase in housing demand could result in an increase in housing prices and rent, which could result in pricing some low-income populations out of their rental housing. In the long-term, however, the study area, and particularly the host county of each site, would benefit from increased property values and the addition of new houses to the tax rolls.

In general, impacts on housing are considered to be SMALL when a small change in housing availability occurs and MODERATE when there is a discernable but temporary reduction in the availability of housing units. Duke Energy concludes that the potential impacts on housing could be MODERATE to LARGE if the majority of workers choose to reside in the small towns closest to the Lee Nuclear Site and SMALL if the workers are dispersed throughout the larger study area. These findings are applicable to the preferred site and the three alternative sites.

Public Services

Public services include water supply and wastewater treatment facilities, police, fire and medical facilities; and social services. New construction or operations workers relocating from outside the region would most likely live in residentially developed areas where adequate water supply and wastewater treatment facilities already exist. Small increases in the regional population would not materially affect the availability of police, fire, or medical services. It is not expected that public services would be materially impacted by new construction or operations employees relocating into the region. Therefore, the impacts on public services would be SMALL at the preferred and alternative sites.

Schools

According to the 2000 census estimate, the percentages of school age children between the ages of 5 and 19 in South Carolina and North Carolina are 21.7 percent and 20.5 percent, respectively. Applying the same two-state average percentage of 21.1 percent to the total in-migrating population at the preferred and alternative sites, based on the assumption that most of these workers would come from the two-state area, the anticipated school age population derived from the in-migrating family total is 1171 (total in-migrating population of 5552 x 21.1 percent:). [Note that this works out to 1.4 school-age children per family, based on the assumption that a total of 811 in-migrating construction and operation workers would bring families.] Further assuming a conservative scenario where the majority of workers would in-migrate into a two-county area, with half residing in each county, an additional 586 children would be added to the existing county school district system. The percentage increases for each county are identified in Table 9.3-6.

The projected increase in school age children within the two-county area is very similar across the sites, ranging from 2.4 percent (Lee) to 3.2 percent (Perkins), and is expected to result in SMALL to MODERATE impacts. Impacts on the educational systems of individual counties are more variable. For each site, the increase in one county is low (2.0 percent or less) and would likely result in SMALL impacts, but in the other county, the projected increase is significantly higher and would likely result in MODERATE to LARGE impacts. Specifically, impacts on Cherokee County with a 5.2 percent increase (Lee Nuclear Site), and on Oconee and Pickens counties with 4.6 and 2.4 percent increases, respectively (Keowee Site) would be expected to be MODERATE. Impacts on Davie County with an 8.5 percent increase (Perkins Site) and Abbeville County with a 10.4 percent increase (Middleton Shoals) would be expected to be LARGE. The quickest mitigation measure would be to hire additional teachers and move modular classrooms to existing schools. Increased property and sales tax revenues as a result of the increased population would fund additional teachers and facilities. It should also be noted that while this is a conservative estimate, in the case of Middleton Shoals, more than 50 percent of the in-migrating workers and their families are likely to reside in the more populated Anderson County. The educational school district system of Anderson County is expected to more easily absorb an influx of school age children than the less populated Abbeville County, even at a greater than 50-50 split. In the case of the Perkins Site, the large metropolitan area of Winston-Salem, located in a third county (Forsyth County) approximately 20 mi. to the north of the site, is likely to draw some percentage of workers and their school-age children, thereby helping to further reduce the impacts on Davie and Davidson counties, as analyzed in this conservative scenario.

Operation Related Effects

The anticipated operational plant staff is 957 individuals. Based on the previous analysis that indicated construction related socioeconomic impacts for all four sites are SMALL, it may also be assumed that operation related socioeconomic impacts would also be SMALL.

9.3.2.6 Environmental Justice

The objective of this criterion is to ensure that the effects of proposed actions do not result in disproportionate adverse impacts to minority and low-income communities. In comparing sites, this principle is evaluated on the basis of whether any disproportionate impacts to these communities are significantly different when comparing one site to another.

The NRC guidance for determining if potential environmental justice conditions exist is:

- The minority populations of a census block or the environmental impact area exceed 50 percent.
- The minority population percentage of the environmental impact area is significantly greater (typically at least 20 percentage points) than the minority population percentage in the geographic area chosen for the comparative analysis.

Environmental justice data for the host county and surrounding counties for the four sites are summarized below.

Site	Population (2000)	White	Minority*	Low Income*
Lee (SC)	1,419,710	69.8 %	30.2 %	10.8 %
Keowee (SC)	1,019,627	79.5 %	20.5 %	11.7 %
Perkins (NC)	1,287,650	65.7 %	34.3 %	10.2 %
Middleton Shoals (SC)	1,045,794	79.2 %	20.8 %	11.8 %

*State Average for NC is 27.9 percent minority and 12.3 percent below poverty line. State Average for SC is 32.3 percent minority and 14.1 percent below poverty line.

- The Lee, Keowee and Middleton Shoals sites are all below 50 percent minority and below the South Carolina average percent minority.
- The Perkins Site is below 50 percent minority but above the North Carolina average of 27.9 percent minority. However, it is not more than 20 percent above the North Carolina average.
- Low-income populations at all sites are below the respective state average.

Based on the NRC guidance, it is not likely that there are environmental justice issues at any of the four sites.

Environmental justice consequences of the construction and operation of a nuclear plant at any of the four sites would be SMALL.

9.3.2.7 Historic and Cultural Resources

Lee Site

There are no documented sites eligible for listing on the National Register of Historic Places (NRHP) on the Lee Site. The Ninety-Nine Islands Hydroelectric Station and Dam near the Lee Site are eligible for listing on the NRHP but are not likely to be impacted by the construction or operation of a nuclear power plant.

Keowee Site

There are no documented sites eligible for listing on the NRHP on the Keowee Site. There are no documented sites eligible for listing on the NRHP in the vicinity of the Keowee Site.

Perkins Site

There are no documented sites eligible for listing on the NRHP on the Perkins Site. The NC Department of Cultural Resources lists a possible historic Indian circle (eligible for the NRHP listing) in the vicinity of the site.

Middleton Shoals Site

There are no documented sites eligible for listing on the NRHP on the Middleton Shoals Site. There are no documented sites eligible for listing on the NRHP in the vicinity of the Middleton Shoals Site.

Siting a nuclear plant at any of the four sites would require a formal cultural resources survey be conducted so that no archeological or historic resources would be damaged during plant construction. Mitigative measures would be performed to prevent permanent damage and ensure that any impacts to cultural resources from construction or operation at any of the four sites would be SMALL.

9.3.2.8 Air Quality

Air pollutant emissions from construction will be temporary and will be similar to any large-scale construction project. Particulate emissions in the form of dust from disturbed land, roads, and construction activities would be generated in proportion to the amount of grading needed for a specific site. Air pollutants emitted from the exhaust systems of construction vehicles and equipment and from vehicles used by construction workers to commute to the site are governed by mobile emission standards and should be similar for all sites. The amount of pollutants emitted in this way would be small compared to total vehicular emissions in the region.

During station operation, standby diesel generators would be used for auxiliary power. It is expected that these generators would see limited use and, when used, they would operate for short time periods. A nuclear plant at any of the four sites would be subject to a Synthetic Minor Operating Permit to ensure that the facility operations would not interfere with attaining or maintaining Primary and Secondary National Air Quality Standards (NAAQS). Therefore, air pollutant emissions from the standby diesel generators are expected to be minimal and would not result in any violation of NAAQS. Therefore the air quality impacts from operation of a nuclear plant at any of the four sites would be SMALL.

Lee Site

The counties surrounding the Lee Site were designated, at the time of the site selection study, as being unclassified or in attainment of the NAAQS. It is not expected that construction-related emissions would result in any violation of NAAQS. Because the Lee site does not require extensive rough grading, impacts from fugitive dust are estimated to be SMALL.

Keowee Site

The counties surrounding the Keowee Site are designated, at the time of the site selection study, as being unclassified or in attainment of the NAAQS. It is not expected that construction-related emissions would result in any violation of NAAQS. Because the Keowee Site would require extensive rough grading, impacts from fugitive dust are estimated to be SMALL to MODERATE.

Perkins Site

The counties surrounding the Perkins Site are designated, at the time of the site selection study, as being unclassified or in attainment of the NAAQS. It is not expected that construction-related emissions would result in any violation of NAAQS. Because the Perkins Site would require extensive rough grading, impacts from fugitive dust are estimated to be SMALL to MODERATE.

Middleton Shoals Site

The counties surrounding the Middleton Shoals Site are designated, at the time of the site selection study, as being unclassified or in attainment of the NAAQS. It is not expected that construction-related emissions would result in any violation of NAAQS. Because the Middleton Shoals Site would require extensive rough grading, impacts from fugitive dust are estimated to be SMALL to MODERATE.

9.3.2.9 Human Health

For this analysis, it was assumed that each site was capable of supporting the NRC requirements for an exclusion area and low-population zone, since these were exclusionary criteria used in ruling out sites early in the site selection process. Consequently, it is assumed that this fact coupled with the AP1000 design would ensure that all the candidate sites could meet NRC requirements for dose to individual members of the public.

This evaluation looked at the probable impacts to population dose considering the distribution of population in the vicinity of each candidate site and any susceptibility due to the pathways for radiological contamination at each site.

Data used were census estimates at the time of the site selection study, population projections for 2010, and distance to a public water supply. Hydro-geologic data from publicly available documents were used as input to the EPA DRASTIC groundwater model. The EPA DRASTIC groundwater model (Reference 4) was used to estimate a site's susceptibility to groundwater contamination. The higher the DRASTIC ranking the more vulnerable the site is to groundwater contamination.

Data from the National Agriculture Statistics Service (Reference 5) were used to estimate the contribution of potential radiological contamination through the food pathway for each site.

Lee Site

Population density in Cherokee County was estimated as 134 individuals per square mile and population in adjoining York County was estimated as 241 individuals per square mile. Projected 2010 population for Cherokee County is 62,000. The nearest population center (>25,000 people) is 19.8 miles away.

The closest downstream public water supply intake is the city of Union, 21 miles downstream. Using data from the Catawba Nuclear Station Environmental Report, V.C. Summer Nuclear Station Final Safety Analysis Report, and USGS geological maps, a DRASTIC index of 83-128 was estimated for the Lee Site indicating a low to moderate vulnerability to groundwater contamination.

Agriculture (farmland) represents 64,020 acres of total Cherokee county area of 251,520 acres (25 percent). Out of total farmland, 25,279 acres are planted in crop (39 percent); other farmland is used for cattle (beef and milk) (9,468 head), hogs and pigs (57), sheep/lambs (187) and no poultry. The Lee site was estimated to have a low potential of contamination through the food pathway.

Because of low population, distance to downstream water and relatively small agricultural production, the overall risk of impacts to Human Health for the Lee Site was estimated to be SMALL.

Keowee Site

Population in Oconee County was estimated as 106 individuals per square mile and population in adjoining Pickins County was estimated as 223 individuals per square mile. Projected 2010 population for Oconee County is 100,000. The nearest population center (>25,000 people) is 21 miles away. However, population within 10 miles of the site will exceed 25,000 people seasonally during summer due to summer homes on Lake Keowee and Lake Hartwell.

The closest downstream public water supply intake is the city of Clemson, two miles downstream. Using data from the V.C. Summer Nuclear Station Environmental Report and Final Safety Analysis Report, and USGS geological maps, a DRASTIC index of 75-120 was estimated for the Keowee Site indicating a low to moderate vulnerability to groundwater contamination.

Agriculture (farmland) represents 78,349 acres out of 400,000 acres in Oconee County (19 percent). Out of total farmland, 31,949 acres are planted in crop (40.8 percent). Other farmland is used for cattle (19,828 head), hogs and pigs (1266), sheep/lambs (110), and 27 million poultry (sold in 2002). The Keowee site was estimated to have a moderate to high potential of contamination through the food pathway.

Because of moderate population levels, relatively close proximity to a downstream drinking water intake and moderate agricultural production, overall risk of impacts to Human Health was estimated to be SMALL to MODERATE for the Keowee Site.

Perkins Site

Population in Davie County was estimated as 131 individuals per square mile. Projected 2010 population for Davie County is 44,000. The nearest population center (>25,000 people) is 15.4 miles away.

The closest public water supply intake is Salisbury, nine miles downstream. Using data from the McGuire Nuclear Station Environmental Report and Final Safety Analysis Report, Shearon Harris Nuclear Station Final Safety Analysis Report, and USGS geological maps, a DRASTIC index of 77-124 was estimated for the Perkins Site indicating a low to moderate vulnerability to groundwater contamination.

Agriculture (farmland) represents 76,295 acres of total county area of 169,600 acres (45 percent). Out of total farmland, 43,056 acres are planted in crop (56 percent); other farmland is used for cattle (beef and milk) (15,120 head), sheep/lambs (99) and no poultry. The Perkins Site was estimated to have a moderate potential of contamination contribution via the food pathway.

Because of low population, distance to a downstream water intake and moderate level of agricultural production, overall risk of impacts to Human Health was estimated for the Perkins Site as SMALL.

Middleton Shoals Site

Population in Anderson County was estimated as 231 individuals per square mile. Projected 2010 population for Anderson County is 189,000. The nearest population center (>25,000 people) is 15 miles away.

The closest public water supply intake is Abbeville, eight miles downstream. Using data from the V.C. Summer Nuclear Station Final Safety Analysis Report, and USGS geological maps, a DRASTIC index of 75-124 was estimated for the Lee Site indicating a low to moderate vulnerability to groundwater contamination.

Agriculture (farmland) represents 176,947 acres of total Anderson county area of 459,520 acres (38 percent). Out of total farmland, 87,393 acres are planted in crop (49 percent); other farmland is used for cattle (beef and milk) (40,505 head), hogs and pigs (1787), sheep/lambs (422) and over 5 million poultry (sold in 2002). The potential for contamination through the food pathway was estimated as moderate to high for the Middleton Shoals Site.

Because of higher population and the highest levels of agricultural production, the overall risk of impacts to Human Health for the Middleton Shoals Site was estimated as SMALL to MODERATE.

9.3.2.10 Accidents

Impacts from accidents were evaluated based on population distribution and ability to evacuate the area in the event of an accident.

Lee Site

Population density in Cherokee County was estimated as 134 individuals per square mile and population in adjoining York County was estimated as 241 individuals per square mile. Projected 2010 population for Cherokee County is 62,000. The nearest population center (>25,000 people) is 19.8 miles away.

Cherokee County sits just off I-85 between Charlotte/Gastonia and Greenville-Spartanburg. The site is in a rural area about 6 miles south of Blacksburg and Gaffney, on west side of river. The site is located off McKowns Mountain Road, which leads west to Road 105/329 that in turn leads north to US 29 (Gaffney and Blacksburg) and I-85 (about 6-8 miles to the north). No close access (bridge) to the east side of the river exists, but SR 5 in Blacksburg lies to the north and runs south into York County east of site.

Impacts related to potential accidents were estimated as SMALL to MODERATE.

Keowee Site

Population in Oconee County was estimated as 106 individuals per square mile and population in adjoining Pickens County was estimated as 223 individuals per square mile. Projected

2010 population for Oconee County is 100,000. The nearest population center (>25,000 people) is 21 miles away. However, population within 10 miles of the site will exceed 25,000 people seasonally during summer with summer homes on Lake Keowee and Lake Hartwell.

Oconee County is served by I-85 at its southeast corner, plus U.S. highways 76 and 123 and State highways 28 and Scenic 11. The Keowee Site is on a two-lane highway with service to the site being convenient from four main directions. There are no limiting climate or terrain conditions.

Oconee Nuclear Station is adjacent to the Keowee Site, and brings the advantage of already having an existing Emergency Plan that could be easily adapted to include the Keowee Site. However, both sites would require evacuation under emergency conditions.

Adjacent Pickens County is not served by the Interstate Highway system, but has ready access to the I-85 corridor via U.S. 76, 123, and 178. State Highways 8, 96, 135, 137, 124, and Scenic 11 complete the major road net. Highway 123 runs the length of Pickens County from east to west with four-lane service to Greenville. State Highway 133 (which runs north-south on the east side of Lake Keowee) and State Highway 183 from Pickens serve as commuting highways from Pickens County to Oconee Nuclear Station. Although several of the residential communities on both sides of Lake Keowee have long, narrow access roads, none of these roads has been identified as seriously congested.

Impacts related to potential accidents were estimated as SMALL.

Perkins Site

Population in Davie County was estimated as 131 individuals per square mile. Projected 2010 population for Davie County is 44,000. The nearest population center (>25,000 people) is 15.4 miles away.

The Perkins Site is close to Mocksville, which is an important center for highway transportation – where US highways, 158, 64 and 601 meet. These highways join Interstate 40 which is approximately 9 miles to the northwest of the site. Access from the site (Davie County) is via Route 801 just to north of site; connects with SR 601 (runs north-south west of site); also connects with SR 64 about 4 miles north (east-west route); I-85 lies about 9 miles southeast of site; no bridges across river; only way out is 801 to 64 to I-85.

Impacts related to potential accidents were estimated as SMALL.

Middleton Shoals Site

Population in Anderson County was estimated as 231 individuals per square mile. Projected 2010 population for Anderson County is 189,000. The nearest population center (>25,000 people) is 15 miles away.

Good access to the site from local roads on east side of Savannah River. Routes 187 and 184 converge near the site and connect to SC 81 to the east (Iva) and 181 to the north (into Anderson). Larger Routes include (SR) 72 to the south (15 miles) and US 29 to the north (7-8 miles). Closest interstate is I-85 to the north [5 miles north of Anderson] that connects to the

Greenville–Spartanburg area. Anderson County includes 37 miles of I-85 frontage. City of Anderson is 30 miles south of I-385 and 50 miles south of I-26.

No limiting climate or terrain conditions.

Impacts related to potential accidents were estimated as SMALL.

9.3.2.11 Transmission Corridors

Lee Site

Seven miles of 230 kV transmission line and fifteen miles of 525 kV transmission line would be needed to connect the site to the transmission system. Route selection would avoid populated areas and residences to the extent possible. The use of lands currently used for forests or timber production would be altered. Trees would be replaced by grasses and other low-growing types of ground cover. The new transmission corridor would not be expected to permanently affect agricultural areas, but has the potential to affect residents along the right-of-way. For this reason, impacts to land use along the right-of-way would be MODERATE.

Keowee Site

Due to close proximity of the Oconee switchyard, only very short runs would be needed to connect the site to the transmission system. For this reason, impacts to land use along the right-of-way would be SMALL.

Perkins Site

Seven and half miles of 230 kV transmission line and fifteen miles of 525 kV transmission line would be needed to connect the site to the transmission system. Route selection would avoid populated areas and residences to the extent possible. The use of lands currently used for forests or timber production would be altered. Trees would be replaced by grasses and other low-growing types of ground cover. The new transmission corridor would not be expected to permanently affect agricultural areas, but has the potential to affect residents along the right-of-way. For this reason, impacts to land use along the right-of-way would be MODERATE.

Middleton Shoals Site

Fifteen miles of 230 kV transmission line would be needed to connect the site to the transmission system. Route selection would avoid populated areas and residences to the extent possible. The use of lands currently used for forests or timber production would be altered. Trees would be replaced by grasses and other low-growing types of ground cover. The new transmission corridor would not be expected to permanently affect agricultural areas, but has the potential to affect residents along the right-of-way. For this reason, impacts to land use along the right-of-way would be MODERATE.

9.3.2.12 Conclusion

Table 9.3-3 summarizes the comparison of the candidate sites. Although all four candidate sites are suitable for construction and operation of twin AP1000 nuclear units, no site was deemed superior to the Lee Site.

9.3.2.13 References

1. South Carolina Department of Natural Resources (SCDNR). 2003. South Carolina Rare, Threatened & Endangered Species Inventory. Accessed at http://www.dnr.state.sc.us / heritage/owa/species.login. Note: This is a protected website that is accessible only through SCDNR authorization.

2. North Carolina Natural Heritage Program, 2005. Listing of rare plant and animal species. NC NHP database updated: July 2005. Accessed at http://207.4.179.38/nhp/quad.html.

3. U.S.Census Bureau, http://quickfacts.census.gov/qfd/ for SC and GA.

4. U.S. Environmental Protection Agency, "DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings", EPA Manual, 1987.

5. National Agricultures Statistics Service, 2002 Census of Agriculture for North and South Carolina, Web Site: http://151.121.3.33:8080/Census/Create_Census_US_CNTY.jsp.

6. U.S. Nuclear Regulatory Commission, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, NUREG-1437, Supplement 2, Washington, DC, 1999.

TABLE 9.3-1 (Sheet 1 of 2)
CRITERIA APPLIED TO INITIAL SCREENING OF THE REGION OF INTEREST

Criteria Data Category	Screening Criteria	Explanation/Rationale
Seismic	Exclude areas < 25 mi. from capable faults Exclude areas < 5 mi. from surface faults	An examination of geology/seismology information for the Duke Energy service area indicated that there are no capable or surface faults that would affect the suitability of sites for a nuclear power plant. Accordingly, this criterion was eliminated from the ROI screening process.
Population	Exclude counties where population density > 300 persons per sq. mi	Counties with > 300 persons per sq. mi. likely have multiple imbedded areas > 500 persons per sq. mi. Siting within these areas would place the plant within an unacceptable distance of high population density areas.
Water Availability	Exclude areas not within 5 mi. of water bodies that support AP1000 water requirements	Rivers for which more than 10% of the average flow would be required for makeup water may present permitting or operational water supply problems. Pumping makeup water more than 5 mi. imposes significant construction and operational costs and can result in operational risks.
Dedicated Land Use	Exclude federal & state parks, monuments, wildlife areas, wilderness areas	Lands in the identified categories have been formally designated for uses that are not compatible with use as a power plant site.

TABLE 9.3-1 (Sheet 2 of 2)
CRITERIA APPLIED TO INITIAL SCREENING OF THE REGION OF INTEREST

Criteria Data Category	Screening Criteria	Explanation/Rationale
Regional Ecological Features	Exclude significant known, mapped wetlands, threatened & endangered species habitat	Development of a plant at the location of significant known areas of ecological importance could result in unacceptable environmental impacts and/or challenges as to whether obviously superior alternatives are available. Other than ecological areas associated with dedicated land uses, no known ecologically sensitive areas were identified at a regional scale. Site suitability from an ecological perspective was evaluated on a site-specific basis.
Transmission	Exclude areas > 15 mi. from 525 kV lines and/or 230 kV nodes	Sites at large distances from the existing grid require large transmission construction costs and result in additional operational line losses. Long interconnects also decrease redundancy and increase the potential for operational interruptions.
Rail	Exclude areas > 10 mi. from existing lines	Sites at large distances from existing lines require large rail spur construction costs to provide for delivery of large plant components and construction modules.

TABLE 9.3-2 (Sheet 1 of 2)
GENERAL SITING CRITERIA USED FOR SECOND PHASE FINE SCREENING OF SITES

Siting Criteria
Health and Safety Criteria: Accident Cause-Related Criteria
Geology and Seismology
Cooling System Requirements: Cooling Water Supply
Cooling Water System: Ambient Temperature Requirements
Flooding
Nearby Hazardous Land Uses
Health and Safety Criteria: Accident Effects-Related
Extreme Weather Conditions
Population
Emergency Planning
Atmospheric Dispersion
Health and Safety Criteria: Operational Effects-Related
Surface Water- Radionuclide Pathway
Groundwater - Radionuclide Pathway
Air - Radionuclide Pathway
Air-Food Ingestion Pathway
Surface Water – Food Radionuclide Pathway
Transportation Safety
Environmental Criteria: Construction-Related Effects on Aquatic Ecology
Disruption of Important Species/Habitats
Bottom Sediment Disruption Effects
Environmental Criteria: Construction-Related Effects on Terrestrial
Disruption of Important Species/Habitats and Wetlands
Dewatering Effects on Adjacent Wetlands
Environmental Criteria: Operational-Related Effects on Aquatic Ecology
Thermal Discharge Effects
Entrainment/Impingement Effects
Dredging/Disposal Effects

TABLE 9.3-2 (Sheet 2 of 2)
GENERAL SITING CRITERIA USED FOR SECOND PHASE FINE SCREENING OF SITES

Siting Criteria
Environmental Criteria: Operational-Related Effects on Terrestrial Ecology
Drift Effects on Surrounding Areas
Socioeconomic Criteria
Socioeconomics – Construction Related Effects
Environmental Justice
Land Use
Engineering and Cost Related Criteria: Health and Safety Related Criteria
Water Supply
Pumping Distance
Flooding
Civil Works
Engineering and Cost: Transportation or Transmission Related Criteria
Railroad Access
Highway Access
Barge Access
Transmission Cost and Market Price Differentials
Engineering and Cost- Related Criteria: Related to Socioeconomic & Land Use
Topography
Land Rights
Labor Rates

TABLE 9.3-3
SUMMARY OF POTENTIAL ENVIRONMENTAL IMPACTS AT CANDIDATE SITES

Potential Environmental Impact Area	Lee Site	Keowee Site	Perkins Site	Middleton Shoals Site
Land Use	SMALL	MODERATE	MODERATE	MODERATE
Hydrology and Water Quality	SMALL	SMALL	SMALL	SMALL
Terrestrial Ecology Resources	SMALL	MODERATE	SMALL - MODERATE	SMALL - MODERATE
Aquatic Ecology Resources	SMALL	SMALL	SMALL	SMALL
Socioeconomics	SMALL	SMALL	SMALL	SMALL
Environmental Justice	SMALL	SMALL	SMALL	SMALL
Historic and Cultural Resources	SMALL	SMALL	SMALL	SMALL
Air Quality	SMALL	SMALL - MODERATE	SMALL - MODERATE	SMALL - MODERATE
Human Health	SMALL	SMALL - MODERATE	SMALL	SMALL - MODERATE
Accidents	SMALL - MODERATE	SMALL	SMALL	SMALL
Transmission Corridors	MODERATE	SMALL	MODERATE	MODERATE

TABLE 9.3-4 (Sheet 1 of 2)
COVER (HABITAT) TYPES PRESENT ON THE PERKINS, KEOWEE, MIDDLETON SHOALS, AND LEE NUCLEAR CANDIDATE SITES[a]

	Name of Candidate Site							
	Perkins		Keowee		Middleton Shoals		Lee Nuclear Site	
Cover or Habitat Type	Acres	%	Acres	%	Acres	%	Acres	%
Mixed Hardwood (MH) - Stands dominated by mixed hardwoods with little or no pine in the canopy.	0	0.0	212	47.0	99	22.1	38	8.6
Mixed Hardwood Pine (MHP) - Stands dominated by mixed hardwood with pine in the canopy.	177	39.3	46	10.2	21	4.7	12	2.6
Pine Mixed Hardwood (PMH) - Stands dominated by pine with mixed hardwood in the canopy and understory.	111	24.7	39	8.7	144	31.9	14	3.2
Pine - Young to mid-aged pine stands or plantations with no hardwoods in canopy.	3	0.7	122	27.1	58	13.0	0	0.0
Upland Scrub (USC) - Partially forested early successional, scrubby areas.	79	17.6	0	0.0	104	23.1	29	6.3
Open/Field/Meadow (OFM) - Non-forested areas dominated by grasses, herbs, or bare soil maintained by cattle grazing and/or mowing.	80	17.7	13	2.9	13	2.8	280	62.3

TABLE 9.3-4 (Sheet 2 of 2)
COVER (HABITAT) TYPES PRESENT ON THE PERKINS, KEOWEE, MIDDLETON SHOALS, AND LEE NUCLEAR CANDIDATE SITES[a]

	Name of Candidate Site							
	Perkins		Keowee		Middleton Shoals		Lee Nuclear Site	
Cover or Habitat Type	Acres	%	Acres	%	Acres	%	Acres	%
Wetland	0	0.0	0	0.0	0	0.0	35	7.7
Open Water	0	0.0	18	4.1	11	2.4	42	9.3
Total	450	100.0	450	100.0	450	100.0	450	100.0

a) Based on cover type analysis within a circle with a radius of 2500 ft. centered on the coordinates of the proposed reactor units.

TABLE 9.3-5
PERCENT INCREASE IN POPULATION FOR STUDY AREA AND HOST COUNTY FOR EACH SITE

	Total Study Area[a] Population (2000)	Percentage Increase	Host County Population (2000)	Percentage Increase	Two-County Population (2000)	Percentage Increase
Lee Nuclear Site (SC)	1,419,710	0.39%	Cherokee 52,537	10.6%	217,151 (Cherokee and York)	2.5%
Keowee Site (SC)	1,019,627	0.54%	Oconoee 66,215	8.4%	176,972 (Oconee and Pickens)	3.1%
Middleton Shoals Site (SC)	1,045,794	0.53%	Anderson 165,740	3.3%	191,907 (Anderson and Abbeville)	2.9%
Perkins Site (NC)	1,287,650	0.43%	Davie 34,835	15.9%	182,081 Davie and Davidson)	3.0%

a) Study Areas for each site are defined as follows:

Lee Nuclear Site - Cherokee, York, Union, Chester, and Spartanburg counties, SC, and Gaston and Mecklenberg counties, NC.

Keowee Site - Oconee, Pickens, Anderson, Greenville and Spartanburg counties, SC; and Elbert and Hart counties, GA.

Middleton Shoals Site - Anderson, Abbeville, Oconee, Pickens, Greenville, and Spartanburg counties, SC, and Elbert and Hart counties, GA.

Perkins Site - Davie, Davidson, Rowan, Forsyth, Guilford, Randolph, and Stanly counties

TABLE 9.3-6
PERCENTAGE USE OF EXISTING VACANT HOUSING

Site	Two-County Area	Required Housing Units (assuming 1 per worker)	Total Housing Available[a] (Vacant) (2000)	Percent Utilized
Lee Nuclear Site	Cherokee and York	3120	6915	45%
Keowee Site	Oconee and Pickens		9794	32%
Middleton Shoals Site	Anderson and Abbeville		9089	34%
Perkins Site	Davie and Davidson		5479	57%

a) Vacant housing units available for sale or rent by county.

TABLE 9.3-7
PROJECTED INCREASE IN SCHOOL-AGE CHILDREN WITHIN THE TWO-COUNTY AREA

Site	County	Percent School Age Children (Ages 5-19) (2000)	Total Population School Age Children (5-19) (2000)[a]	Percent Increase in School-Age Children by County	Percent Increase for Two-County Area
Lee Nuclear Site	Cherokee (host county)	21.5%	11,277	5.2%	2.4% (48,311)
	York	22.5%	37,034	1.6%	
Keowee Site	Oconee (host county)	19.2%	12,675	4.6%	3.1% (36,981)
	Pickens	22%	24,306	2.4%	
Middleton Shoals Site	Anderson (host county)	20.4%	33,802	1.7%	3.0% (39,451)
	Abbeville	21.6%	5649	10.4%	
Perkins Site	Davie (host county)	19.9%	6913	8.5%	3.2% (36,370)
	Davidson	19.9%	29,457	2.0%	

a) Population estimates for school age children, including age brackets 5-9, 10-14, and 15-19.

9.4 ALTERNATIVE PLANT AND TRANSMISSION SYSTEMS

This section discusses alternatives in each of three system areas for the Lee Nuclear Station. This information is provided to enable a comparison of the environmental impacts of each alternative to those of the selected system.

Subsection 9.4.1 presents alternatives to the plant heat dissipation system. Subsection 9.4.2 evaluates alternatives to the circulating water system. These are presented as alternatives in the areas of intake designs and locations, discharge designs and locations, water supplies, and water treatment. Subsection 9.4.3 presents alternatives to the transmission system. These include alternative corridor routes and alternatives to the selected transmission system design, construction, and maintenance practices.

Each subsection provides an evaluation of alternatives to the selected system based on the guidance provided in NUREG-1555, "Standard Review Plans for Environmental Reviews for Nuclear Power Plants," for that subsection. Each evaluation identifies those system alternatives that are either environmentally preferable or equivalent to the selected system. Environmentally preferable alternatives are then compared with the selected system on a benefit-cost basis to determine their need to be considered as a preferred alternative. Only systems considered feasible for construction and operation at the Lee Nuclear Site are considered, provided that they:

- Are not prohibited by federal, state, regional, or local regulations, or Native American tribal agreements.
- Are consistent, where applicable, with any findings of the National Pollutant Discharge Elimination System (NPDES) (Reference 3) or the Federal Water Pollution Control Act (FWPCA), commonly referred to as the Clean Water Act (CWA) (Reference 4).
- Are judged as practical from a technical standpoint with respect to the proposed dates of plant construction and operation.
- Are applicable to and compatible with the plant, the service area, and the regional transmission network, where appropriate.

This analysis has two objectives. The first is to identify and verify means to mitigate adverse impacts associated with the selected system. The second is to identify and analyze reasonable alternatives to the selected system and rank them as environmentally preferable, equivalent, or inferior to the selected system. The selected system, with any verified mitigation applied (i.e., measures and controls to limit adverse impacts, if any), is the baseline system against which alternative systems are compared. If no adverse impacts are predicted for the selected system, the review is limited to analyzing the alternative systems to determine their environmental equivalence to the selected system.

9.4.1 HEAT DISSIPATION SYSTEMS

The purpose of the plant cooling system is to dissipate energy to the environment. The condenser creates the low pressure required to drag steam through and increase the efficiency of the turbines. The lower the pressure of the exhaust steam leaving the low-pressure turbine, the more efficiency is gained. The limiting factor is the temperature of the cooling water.

The various heat dissipation system options differ in how the energy transfer takes place and, therefore, have different environmental impacts. Potential alternatives considered are those generally included in the broad categories of "once-through" and "closed-cycle" systems. The once-through method involves the use of large quantities of cooling water, withdrawn from and returned to a large water source after circulating through the main condenser. Closed-cycle cooling systems involve substantially less water usage, because the water performing the cooling is continually recirculated through the main condenser and only makeup water for normal system losses is required. Normal system losses can include evaporation, blowdown, and drift. Evaporation occurs as part of the cooling process in wet systems. The purpose of blowdown is to control solids in the water that accumulate due to evaporation, which helps protect surfaces from scaling or corrosion problems. Drift is liquid water that escapes from the heat dissipation system in the form of unevaporated droplets during operation.

Open-mode systems, discussed here as once-through cooling, are excluded per the discussion in Subsection 9.4.1.2.1.

The analysis of each alternative heat dissipation system considers various factors during construction and operation. These factors are discussed below for the selected Lee Nuclear Station heat dissipation system and for alternative designs, and a summary comparison is presented in Table 9.4-1.

9.4.1.1 Selected Heat Dissipation System

This subsection describes the selected heat dissipation system, identifies any associated adverse impacts, and addresses the expected mitigation.

Lee Nuclear Station has two cooling systems that transfer heat to the environment during normal modes of plant operation. These systems are the service water system (SWS) and the circulating water system (CWS), as described in Sections 3.4 and 5.3. Heat generated during each operational mode can be released by these systems to the atmosphere and to the Broad River. Operation outside of normal modes of plant operation is not covered in this subsection.

The CWS uses three mechanical-draft cooling towers per unit to dissipate heat. The mechanical-draft cooling towers use fans to force convection within the cooling tower. These cooling towers discharge to the outfall structure on the Broad River via the blowdown pipe.

The CWS makeup is provided by the raw water system that pumps makeup water from the Make-Up Pond A to the CWS, and makeup water to the clarification system used in the service and demineralized water systems. Water chemistry is maintained in the circulating water by the turbine island chemical feed system. The normal concentration of dissolved solids in the circulating water is four cycles of concentration (Section 5.2.3.1).

The environmental impacts of the selected heat dissipation system on the atmosphere and terrestrial ecosystems during unit operation, as described in Subsection 5.3.3, include:

- Heat dissipation to the atmosphere.
- Length and frequency of elevated plumes.
- Frequency and extent of ground level fogging and icing in the site vicinity.

- Solids deposition (i.e., drift deposition) in the site vicinity.
- Cloud formation, cloud shadowing, and additional precipitation.
- Interaction of vapor plume with existing pollutant sources located within 1.25 miles (mi) of the Lee Nuclear Site.
- Ground level humidity increase in the site vicinity.

9.4.1.2 Screening of Alternatives to the Selected Heat Dissipation System

Due to the nature of the site selected, only a limited number of cooling system alternatives is feasible. An initial environmental screening of the alternative designs eliminated those systems that are obviously unsuitable for use in a new facility. The screening criteria include on-site land use requirements and terrain conditions, water use requirements, and legislative restrictions that might preclude the use of any of the alternatives.

The AP1000 standardized design utilizes a turbine exhausting to a shell-and-tube surface condenser. Circulating water is used for the condenser cooling medium. For maximum thermal performance, the AP1000 turbine low pressure stage design requires operation at an average condenser backpressure of 3 inches (in.) Hg absolute.

Because the AP1000 standardized design uses a specific condenser and turbine design, the compatibility of tower technology with the AP1000 design is an essential element of the alternative evaluation screening. In addition, it is important to consider that the fundamental goal of the 10CFR Part 52 process is to maintain standardization in plant design.

The following alternative heat dissipation systems have been identified for screening:

- Once-through systems.
- Closed-cycle systems.
- Cooling ponds.
  - Dry cooling towers.
  - Wet dry cooling towers.
  - Spray systems.
  - Natural draft wet cooling towers.
  - Mechanical draft wet cooling towers.

9.4.1.2.1 Once-through Systems

Based on the relatively low flow in the Broad River, a once-through cooling system is not considered feasible for the Lee Nuclear Station. EPA 316 regulatory limits for cooling water withdrawal and thermal releases would severely impact plant operation during most months of the year. Therefore, this system is inferior to the selected heat dissipation system.

9.4.1.2.2 Cooling Ponds

A cooling pond is not considered feasible at the Lee Nuclear Site because the surrounding topography does not lend itself to construction of a pond of adequate size (approximately 7000 acres [ac.]) to dissipate the waste heat from the units. Therefore, cooling system alternatives are limited to a closed-cycle cooling tower or spray system with makeup from the Broad River.

9.4.1.2.3 Dry Cooling Towers

Dry cooling is an alternative cooling method in which heat is dissipated directly to the atmosphere using a tower. This tower transfers the heat to the air by conduction and convection rather than by evaporation. Heat transfer is then based on the dry-bulb temperature of the air and the thermal transport properties of the piping material. A natural- or mechanical-draft configuration can be used to move the air.

Because there are no evaporative or drift losses in this type of system, many of the problems of conventional cooling systems are eliminated. For example, there are no problems with blowdown disposal, chemical treatment, fogging, or icing when dry cooling towers are utilized. Although elimination of such problems is beneficial, most currently available dry tower technologies require condenser and turbine designs outside the scope of the AP1000 standardized design.

While a wet tower uses the processes of evaporation, convection and conduction to reject heat, a dry tower is dependent on conduction and convection only. As a result, heat rejection is limited by the dry bulb temperature at the site. The higher the ambient temperature at the site, the higher the steam saturation pressure, and consequently, the higher the turbine backpressure will be.

Since dry towers do not rely on the process of evaporative cooling as does the wet tower, larger volumes of air must be passed through the tower compared to the volume of air used in wet cooling towers. As a result, dry cooling towers need larger heat transfer surfaces and must be larger in size than comparable wet towers.

The U.S. Environmental Protection Agency (EPA) rejects dry cooling as the best available technology for a national requirement because the technology carries costs that are sufficient to pose a barrier to its entry to the marketplace for some projected new facilities. Dry cooling technology also poses some detrimental effects on electricity production by reducing the energy efficiency of steam turbines.

The increased exhaust gas emissions of dry cooling tower systems as compared with wet cooling tower systems provide additional support for EPA's rejection of dry cooling as the best available technology. Dry cooling technology results in a performance penalty for electricity generation that is likely to be significant under certain climatic conditions. A performance penalty is applied by the EPA to any technology (i.e., dry cooling) that requires the power producer to use more energy than would be required by another available technology (i.e., recirculating wet cooling) to produce the same amount of energy. Therefore, EPA does not consider dry cooling technology as the best available technology for minimizing adverse environmental impacts.

Two technologies are used in dry coolers: the air-cooled condenser and the indirect dry cooling tower.

The most common form of dry cooling tower technology is the air-cooled condenser (ACC). In this design, steam from the turbine exhaust is piped through large ducts to a separate air-cooled condenser located next to the turbine building. Fans draw air through cooling coils to reject heat from the exhaust steam. As the steam loses its heat, it condenses to water and is returned as steam generator feedwater.

Incorporation of the ACC technology would require large-scale changes to the standardized design. The ACC is not compatible with the condenser and turbine design described in the certified design and would require extensive revision to fundamental design elements of the main steam, feedwater and heater drains systems. Essential elements of the turbine building foundation, structure and turbine missile evaluation would require revision.

The cooling units for an ACC must be located in immediate proximity to the turbine building and the size of the units requires extensive land use. As stated previously, dry towers require much larger heat transfer surfaces and are much larger in size than comparable wet towers. Extensive changes to the AP1000 turbine building footprint would be required to accommodate this design.

Because of the larger volume of air required for heat rejection, fan horsepower requirements for the ACC are typically 3 to 4 times higher than wet towers. This will significantly decrease the net electrical output of the unit. In addition, the AP1000 standardized electrical distribution design is not sized to accommodate these additional loads.

In addition to the impact on the AP1000 design, an ACC is not as thermally efficient as a wet cooling tower system, which would have a negative impact on plant performance. Dry cooling designs are unable to maintain design plant thermal performance during the hottest months of the year. Depending on weather conditions and the design heat rate, a plant can experience capacity reductions of up to 10 to 25 percent on the steam side alone, because of increased turbine backpressure.

As previously stated, the AP1000 turbine low pressure stage design requires operation at an average condenser backpressure of 3 inches (in.) Hg absolute to maintain design electrical output and has operational limits at 5 inches Hg absolute. State-of-the-art ACC designs can not operate within these parameters during the summer temperature conditions expected at the Lee Nuclear Station. This would increase the probability of forced down powers and turbine trips. It is important to note that ACC designs in current use in the United States are combined with turbines specially designed to operate at these higher backpressures.

Incorporation of the ACC technology at the Lee Nuclear Station would extensively revise the AP1000 design reviewed during the 10CFR 52 Design Certification process. The revisions would impact safety-related design attributes, such as the offsite dose analysis. An ACC can not be integrated with the standardized turbine generator design without greatly increasing the probability of plant transients during summer operation. Therefore, this system is inferior to the selected heat dissipation system.

The second type of dry cooling tower technology is the indirect dry tower. In this design, the wet tower in the AP1000 standardized design is replaced with a large air-water heat exchanger.

Circulating water from the condenser is piped through metal-finned tubes and fans force air over the tubes to reject heat to the air and atmosphere.

The advantages of indirect dry cooling towers are the same as the ACC design. The requirement for cooling water is eliminated and there are no problems with blowdown disposal, chemical treatment, icing or fogging.

The most significant disadvantage of indirect dry cooling towers is the size of the units. Indirect dry cooling is much less efficient than air cooled condensers because heat rejection is dependent on two thermal interfaces (steam/CWS/air), rather than the single interface used in the ACC (steam/air). Since indirect cooling has never been utilized at a 1000 MWe fossil or nuclear unit in the United States, establishing the actual size of the unit is difficult. However, based on relative efficiencies, an indirect dry cooling tower would require much more space than an ACC and would dwarf the footprint of a wet cooling tower.

Because of the loss of efficiency, the indirect dry cooling tower requires an even larger volume of air for heat rejection than the ACC. Therefore, fan horsepower requirements would increase beyond the ACC design, which is already 3 to 4 times greater than wet towers. An indirect cooling tower would decrease the plant net electrical output even more than an ACC. And as stated previously, the standardized electrical distribution design for the AP1000 is not sized to accommodate either the ACC or indirect dry cooling tower fan horsepower requirements.

The ACC and indirect dry cooling towers both rely upon sensible heat rejection for cooling, so the turbine backpressure limitations in the ACC technology discussion are applicable to the indirect dry cooling design. Like the ACC, indirect dry cooling towers in current use are combined with turbines specially designed to operate at higher backpressures than the AP1000 standard design.

Incorporation of the indirect dry cooling tower technology at the Lee Nuclear Station is not possible because the site cannot provide the land usage required for the towers. The tower fan horsepower requirements greatly exceed the AP1000 standardized electrical distribution design and would substantially decrease the net electrical output of the plant. The indirect dry cooling towers would also require changes to the AP1000 design that would impact the 10CFR 52 certification of the plant design and negatively impact utility efforts towards plant standardization. Therefore, this system is inferior to the selected heat dissipation system.

9.4.1.2.4 Wet Dry Cooling Towers

Wet-dry or hybrid cooling towers use a combination of wet and dry cooling technologies. If a hybrid design is used in conjunction with the AP1000 design, it will need to be a wet and indirect dry cooling combination to satisfy the design requirements for the turbine/condenser package specified in the Design Control Document certified by the NRC, because the AP1000 design has a surface condenser.

Hybrid cooling technologies that combine wet and indirect dry cooling technologies are composed of two configurations: a single tower equipped with integrated wet and dry cooling sections and a design that uses the combination of a separate wet tower and air-cooled heat exchangers.

The single tower with wet and dry cooling capability operates in a manner similar to that of a wet cooling tower. The additional dry section, typically located in the upper part of the cooling tower, transfers heat from the circulating water into an air stream that is then mixed with the moist air exiting the wet tower section. This increases the temperature and lowers the humidity of the air leaving the tower, suppressing formation of a visible plume. The plume abatement feature is the primary reason for selecting this technology as the decrease in tower consumptive water use is limited by the size of the dry cooling section. Consumptive water savings from this design are achieved through the decreased heat load on the wet section of the tower due to sensible heat rejection in the dry section. In addition, sensible heat rejection is dependent on the temperature of the ambient air, and during summer conditions, the heat rejection (and therefore consumptive water savings) decreases substantially. Therefore, these towers are not a good choice for sites with high ambient conditions during the summer, like those experienced at the Lee Nuclear Station.

Further reductions in consumptive water use would require increasing the size of the dry section. However, because the tower structure must support both wet and dry sections, there is a physical limitation to the size of the dry cooling sections that can be housed in a single tower arrangement. For decreased consumptive water use, a second wet-dry cooling tower design that utilizes a separate wet tower and air-cooled heat exchangers is available. In this design, circulating water is routed to the wet and dry systems in a series or parallel flow arrangement to provide operating flexibility. Because the indirect dry cooling section can be located at a significant distance away from the wet tower, it can be sized large enough to accommodate a significant portion of the heat rejection requirements for the station.

Like the integrated wet-dry tower, consumptive water use savings from the separate tower design are still dependent on the temperature of the ambient air. During hot weather conditions, heat rejection from the air-cooled heat exchangers decreases substantially, with the wet tower rejecting most of the heat load and a limited decrease in consumptive water usage.

Wet-dry cooling technologies have higher capital costs, land use, and consumptive power requirements than other technologies, such as wet mechanical draft cooling towers.

As discussed in ER Subsection 5.3.3, the design and environmental impacts from cooling tower plumes are considered SMALL or non-existent. Therefore, the selection of a plume-abatement technology is not indicated for the Lee site.

Although the average flow on the Broad River will support station operation with minimal effects on the downstream environment or users, the flow is subject to seasonal variations. As described in ER Subsection 5.2.1.3, the station plans to limit withdrawal from the Broad River during low-flow conditions, utilizing water stored in on-site impoundments to supplement or replace withdrawals from the river.

The Lee Nuclear Station has evaluated the use of wet-dry towers, based on their ability to reduce consumptive water use at the site and extend the availability of the water stored in on-site impoundments during extended periods of low-flow conditions on the river. However, the water-saving features of the wet-dry technologies decrease markedly during hot weather operation, which is the time when low-flow conditions occur on the Broad River. During the months that favor operation of the wet-dry technologies for consumptive water savings, ample flow is available in the Broad River to support station operation with minimal effects on the downstream environment or users. While wet-dry tower technologies have the ability to reduce consumptive water use, the timing of the water conservation feature does not align with the need for this feature at the Lee Nuclear Site. Specifically, a hybrid tower configuration sized to conserve enough water to preclude shutdown during all historical low-flow) river conditions would require a footprint that would be prohibitive for the site as it currently exists. Based on this discussion, and giving due consideration to the higher capital costs and consumptive power requirements of the wet-tower technologies, the systems are considered inferior to the selected heat dissipation system.

9.4.1.2.5 Closed Cycle Spray Systems

A closed-cycle spray system is composed of a spray canal system approximately 2.5-mi. long and 200-ft. wide. During operation, water is sprayed upward at between 15 and 20 ft. The system's efficiency is a very strong function of the wet-bulb temperature alone. Because heat transfer coefficients vary as much as 50 percent for wet-bulb temperature variations between 40°F and 80°F, winter use requires a minimum canal size large enough for the system to operate in the low winter wet-bulb temperatures. Hourly wet-bulb temperature variations change the condenser intake temperature, and thus affect the power production efficiency.

The atmospheric effects of closed-cycle spray systems are fogging and icing. These effects are largely dependent on the quantity of evaporation of the spray effluent and the absolute humidity deficit of the atmosphere. Therefore, the expected plume lengths are greater than those estimated for cooling towers because of the usually lower ambient temperature and greater amount of moisture within the near-surface layer, where most of the effluent is dispersed.

The aesthetics of closed-cycle spray systems are reasonable. The operation of a spray canal increases noise levels at the plant site by a small amount. This increase is due to motors and the falling water. Normally acceptable noise levels occur at the site boundary.

Closed-cycle spray systems were not considered as an alternative cooling means for the Lee Nuclear Site because of the large land requirements for canals or spray ponds, which can only be used as a cooling medium. Therefore, this system is inferior to the selected heat dissipation system.

9.4.1.3 Potential Alternatives to the Selected Heat Dissipation System

Based on the results of the screening, the following alternatives are evaluated in more detail for use at the Lee Nuclear Site:

- Circular mechanical-draft cooling towers (selected).
- Rectangular mechanical-draft cooling towers.
- Natural-draft cooling towers.

A summary of the screening is presented in Table 9.4-1. Table 9.4-5 provides a cost comparison of the alternative heat dissipation systems. The Lee Nuclear Station heat dissipation system design, circular mechanical-draft cooling towers, is described in Subsection 9.4.1.1.

Rectangular mechanical-draft cooling towers have features similar to those of circular mechanical-draft cooling towers. The two mechanical-draft towers have the same makeup and intake velocity requirements, blowdown requirements, chemical concentration of blowdown water, consumptive use of river water, fogging/icing issues, noise considerations, and salt discharges. Also, the efficiency of the circular and rectangular mechanical-draft cooling towers is very similar. Land use for rectangular mechanical-draft cooling towers is 93 ac. larger than for circular mechanical-draft cooling towers. In addition, economic costs for the rectangular cooling towers are greater than for the selected heat dissipation system (rectangular mechanical-draft cooling towers cost approximately $22,881,425 more than circular mechanical-draft cooling towers, in 2007 dollars). The increase in necessary land use ultimately increases the effect on nearby wildlife and could cause increased land erosion, which increases the amount of silt in the river. The increases in erosion, silt, and harmful effects on wildlife make this alternative environmentally inferior to the selected system.

The natural-draft cooling towers have features similar to those of the circular mechanical-draft cooling towers. Makeup requirements, intake velocities, river consumptive use, construction land needs, and length/frequency of plumes are all similar for both options. Natural-draft cooling towers are more efficient as compared to circular mechanical-draft cooling towers, due to the power penalty associated with supplying electricity to the fan motors of the mechanical-draft cooling towers (natural-draft towers do not have such mechanical needs). However, this difference does not warrant the selection of natural-draft towers over the selected system. The natural-draft cooling towers cost more than the selected system (natural-draft cooling towers cost approximately $5,459,265 more than circular mechanical-draft cooling towers, in 2007 dollars). In addition, the visual impact of the cooling towers is much greater for the natural-draft design (approximately 500-ft. tall) than for the mechanical-draft design. The increased discharge temperatures and visual disturbance caused by the natural-draft cooling towers being taller than the circular mechanical-draft cooling towers makes this alternative environmentally inferior compared to the selected circular mechanical-draft cooling towers.

9.4.2 CIRCULATING WATER SYSTEMS

The CWS is an integral part of the heat dissipation system discussed in Subsection 9.4.1. The CWS provides the interface between the main condenser and the heat dissipation system. This subsection describes the selected CWS design configuration and alternatives to the following components of the Lee Nuclear Station CWS:

- Intake systems
- Discharge systems
- Water supply
- Water treatment

9.4.2.1 Selected Circulating Water System

The selected intake system for the CWS is described in Subsections 3.4.2.1 and 5.3.1. The selected water intake system is composed of four parts: (1) a river intake structure, (2) piping from the river intake structure to the Make-Up Pond A, (3) the Make-Up Pond A, and (4) a makeup intake structure for pumping water to the plant from the Make-Up Pond A. The following discussion focuses only on the river intake structure and the piping to the Make-Up Pond A because the other design features of the selected CWS and the alternative systems are identical.

The environmental effects of the selected intake system on the aquatic ecology and the physical impacts, such as scouring, silt build-up, and shoreline erosion caused by the flow field during unit operation are discussed in Subsection 5.3.1. Environmental impacts for the intake system portion of the selected CWS are SMALL, and no mitigation is warranted.

The selected discharge system for the Lee Nuclear Station CWS is described in Subsections 3.4.2.2 and 5.3.2. Evaporation from the cooling towers is discharged to the atmosphere, while blowdown from the cooling towers is discharged to the Broad River. This discharge meets the thermal and chemical requirements of state and federal regulations, as discussed in Subsections 3.4.2.2 and 5.3.2.

The environmental effects of the selected discharge system on the physical impacts and the aquatic ecology are discussed in Subsection 5.3.2. Environmental impacts for the discharge system portion of the selected CWS are SMALL, and no mitigation is warranted.

The raw water supply for the Lee Nuclear Station is from the Broad River. Sufficient volume is provided for maximum system requirements, and intake structure geometry is designed to function under the worst expected river and reservoir conditions, as described in Subsection 9.4.2.2.4.

As discussed above, environmental impacts for the water supply for the selected intake system of the CWS are SMALL, and no mitigation is warranted.

The selected water treatment, or circulating water chemistry, for the Lee Nuclear Station CWS is maintained by the turbine island chemical feed system, as described in Subsection 3.3.2. Turbine island chemical equipment injects the required chemicals into the circulating water downstream of the CWS pumps. The chemicals used can be divided into three categories based on function: (1) biocide/algaecide, (2) pH adjuster, and (3) silt dispersant. The biocide/algaecide, pH adjuster, and dispersant are metered into the system continuously or as required to maintain proper concentrations. The biocide and algaecide application frequency may vary with seasons.

9.4.2.2 Alternatives to the Selected Circulating Water System

The purpose of this subsection is to identify and analyze reasonable alternatives to the selected intake, discharge, water supply, and water treatment systems of the CWS. These alternatives are ranked as environmentally preferable, equivalent, or inferior to the selected system. Account is taken of the kind and magnitude of environmental impacts and the efficiencies and economics of the alternatives.

The analysis of each alternative system considers various factors during construction and operation, for comparison with those of the selected system. This subsection provides separate descriptions of the alternative intake system, discharge system, water supply, and water treatment system features, including comparative evaluation summary data for each alternative.

9.4.2.2.1 Alternatives to the Selected Intake System

The following river intake facilities are considered:

- Bankside river intake structure (selected).
- Off-river intake structure on an open-ended approach canal.
- Perforated pipe intake with off-river pump structure.
- Infiltration bed intake with off-river pump structure.

In the process of considering alternative intake systems, the following six methods for screening fish and debris are considered:

- Vertical traveling screens (selected)
- Fixed screens
- Revolving drum screens
- Psychological screens
- Perforated pipe
- Infiltration bed

The first four screening systems are applicable to intake structures with integral screening devices.

Any alternative intake system design withdraws makeup water from the same source body as does the selected intake system design, i.e., the Broad River. To avoid recirculation, the intake structure for the Lee Nuclear Station units is located upstream of the discharge point. Alternative intake system locations that were evaluated include placement at the shoreline or in an offshore intake structure. A detailed comparative evaluation of the intake systems has been performed and reported in, "Duke Power Company Project 81, Cherokee Nuclear Station, Environmental Report," Amendment 4 (Reference 1). A summary comparison of the alternative intake systems is provided in Table 9.4-2. No environmentally preferable alternative to the selected intake structure was identified.

No improvements are apparent where substitution of components or modifications to the size or function of components would improve the operability of the system for its intended purpose.

The hydrodynamics of the selected intake system are planned to generate a smooth, continuous source of water to the intake structure. Additional precautions were incorporated into the intake canal so that water would flow under the worst combination of river supply and weather conditions expected. The intake structure is located on the west bank of the Broad River, approximately 1.5 mi. upstream from the Ninety-Nine Islands Dam. This location ensures river flows that are sufficient for cooling purposes in the event that the dam fails and river flow decreases. The only other location considered for the intake structure was a position 800 ft.

upstream from the Ninety-Nine Islands Dam. However, after considering the channel stability experienced in the vicinity of this location and the cost of constructing and maintaining a control dike, this alternative location was not selected.

The physical effects of the selected water intake system are addressed in Subsection 5.3.1. Construction and operation of this system have SMALL environmental impacts on groundwater, physical alterations of local streams and wetlands, and downstream water quality as a result of erosion and sedimentation.

The selected system's pumping facilities present SMALL environmental impacts, as described in Subsection 5.3.1. No environmentally superior or equivalent alternative method of intake defouling, including chemicals, has been identified. No adverse impacts are identified, and no mitigation is warranted.

The selected bankside river intake structure requires only 1 ac. of land and disturbs only 0.5 ac. during construction. Due to the orientation of the structure, silt and debris do not present issues requiring mitigation. Also, river channel integrity is protected by constructing an artificial vertical bank. Industry long-term operating experience with structures essentially of this type allows prediction of maintenance and operating characteristics. Because no alternative design is environmentally desirable, costs were not quantified. For these reasons, the bankside river intake structure is the selected system for Lee Nuclear Station.

9.4.2.2.1.1 Bankside River Intake Structure (Selected)

This selected system design and environmental impacts are described in Subsections 3.4.2.1 and 5.3.1.

The makeup water system replaces water lost from the cooling towers due to evaporation and blowdown. The intake structure is located on the west bank of the Broad River, approximately 1.5 mi. upstream from the Ninety-Nine Islands Dam. This location ensures river flows sufficient for cooling purposes in the event that the dam fails and the river flow decreases. The river intake structure serves as a platform to support trash racks, traveling screens, pumps, motors, and other equipment. As described in Section 3.4, the pumps located at the river intake structure transfer maximum flow of 60,000 gallons-per-minute (gpm) to the intake Make-Up Pond A, where a second set of pumps is located. These pumps are sized to supply the required makeup water to the cooling tower basin. The maximum flow rate through the traveling screens located in front of each pump is 20,000 gpm, with a maximum velocity of less than 0.5 foot-per-second (ft/sec) for all river flows above the 508 ft. mean sea level (msl) elevation, which is the approximate low-water pumping elevation. All intake water pumped from the Broad River passes through a curtain wall, stop log assemblies, bar screens, and traveling screens designed to minimize uptake of aquatic biota and debris. Each traveling screen has fish collection and return capability. The screens are sized so that the average through-screen velocity is in accordance with Section 316(b) of the Clean Water Act (Reference 4). The traveling screens are modified "Ristroph" design (or equivalent) fish-handling screens with Fetcher-type fish-friendly buckets on each screen basket. The screens are equipped with dual-pressure spray header systems and separate fish and debris troughs. The fish and debris troughs are supplied with a supplemental flow sufficient to move the fish through a fish return trough. The fish return trough exits the intake structure on the downriver side, and returns the fish to the riverine section of the Broad River downstream of the intake structure. Debris collected by the trash racks and traveling screens is collected and disposed of as solid waste by other commercial means. Water from screen backwashing is returned to the structure at the screen forebay.

The traveling screens are protected by a rack structure. The upstream rack is situated at a shallow angle to the river flow and consists of closely spaced, heavy horizontal bars, allowing easy deflection of large debris. Racks parallel to the river flow consist of closely spaced, heavy horizontal bars, again allowing for large debris to be deflected. The downstream rack consists of widely spaced bars that provide nominal protection from debris and allow easy passage of fish and other swimming organisms. The effect of the sweeping river current through the rack structure and the low approach velocity to the traveling screens provides for minimum fish impingement. Three other features that reduce fish impingement are appropriate location, location of traveling screens flush with the river bank, and an approach velocity to the screen of 0.5 ft/sec or less. For these reasons, the bankside structure has a negligible effect on fish entrapment or impingement. For additional details, see Figures 3.4-1 and 5.3-1.

Costs of this system include the rack structure, river intake structure including pumps and screens, piping to the Make-Up Pond A, access road, construction cofferdam, and excavation.

A cellular sheet-pile cofferdam or similar structure is built out from the river bank so that the intake structure is constructed in the dry with no adverse impact on the river water during construction. A major portion of the slope protection around the structure is completed before the cofferdam is removed. No permanent or temporary adverse environmental impacts on the river are expected. The effect of increased noise and movement of men, materials, and machines during construction is essentially the same as that of construction of the remainder of the plant. In addition, any slight increase in the noise level by any alternative is caused mainly by operation of the water pumps and is not expected to adversely affect the surrounding area.

As discussed above, the selected intake structure is located on the west bank of the Broad River, approximately 1.5 mi. upstream from Ninety-Nine Islands Dam. This location provides river flows that are sufficient for cooling purposes in the event that the dam fails and river flow decreases.

The bankside river intake structure requires approximately 1 ac. of land and disturbs less than 0.5 ac. of river bottom during construction. Negligible problems with silt and debris are anticipated due to orientation and location. River channel stability is also assured by use of an artificially created vertical bank. Long-term operating experience with structures essentially of this type allow prediction of maintenance and operating characteristics. For these reasons, the bankside river intake structure is the selected intake facility.

9.4.2.2.1.2 Off-River Intake Structure on an Open-Ended Approach Canal

The river intake structure is located at the end of an intake canal. A submerged weir and training wall are located at the canal entrance, and the intake structure is equipped with trash racks and traveling screens to handle debris. The submerged weir is necessary to route the stream bed load by the canal entrance. Use of the approach canal without the weir would result in extreme silt accumulation in the canal. The velocity in the 700-ft.-long canal is less than 0.5 ft/sec and allows most fish that swim in to also swim out. The canal allows some silt to settle before it reaches the intake structure and, therefore, requires periodic silt removal during operation. Use of the canal situates the intake structure closer to the plant yard, resulting in better protection from floodwaters, a shorter piping system, lower pumping costs, improved construction conditions, and easier access. For location and details, see Figure 9.4-1.

Costs of this system include the submerged weir, training wall, canal, intake structure including pumps and screens, piping to the Make-Up Pond A, access road, periodic silt removal operation, and cofferdams for canal entrance facilities.

The alternative off-river intake structure incorporates a submerged weir and training wall, which directs the river stream away from the intake waterway. This device should aid in carrying fish past the entrance. Most fish that enter the canal can swim against its current of less than 0.5 ft/sec and reenter the flow of the river just as they would at any other inlet on the river. The intake structure has an inlet velocity of less than 0.5 ft/sec and also has bar racks to help keep larger fish and debris out. The traveling screens keep all but the smallest fish from entering the pump well.

Because the structure is connected to the river by the canal, it can be built in the dry with no effect on the river. Construction of the canal entrance facilities requires less temporary river protection than the selected facility, because the canal can also be built in the dry before it is connected to the river channel. When the mouth of the canal is opened, the turbidity of the river is slightly increased for only a short time with no permanent adverse impact on the river. The effect of increased noise and movement of men, materials, and machines during construction is essentially the same as that of construction of the remainder of the plant. In addition, any slight increase in the noise level by any alternative is caused mainly by operation of the water pumps and is not expected to adversely affect the surrounding area.

The off-river intake structure on an open-ended approach canal requires 4 ac. of land and does not disturb more than 0.5 ac. of river bottom during construction. Problems with silt are anticipated in the canal and periodic dredging operations are required. Possible problems with river channel stability and silt removal operations are the primary reasons for not selecting this system.

The greater land requirements associated with an open-ended canal, as compared with the selected system, adversely impact the surrounding environment. Silt removal and dredging operations for an open-ended canal increase the monetary and time costs as compared to the selected system. For these reasons this system is not selected.

9.4.2.2.1.3 Perforated Pipe Intake with Off-River Pump Structure

The perforated pipe intake with off-river pump structure consists of a perforated pipe intake located in the river channel, piping to a pump structure, the pump structure, and the intake water pumps including piping for backwashing the perforated pipe. The currents of the river carry both fish and debris past the openings in the perforated pipe. Inlet velocities of less than 0.5 ft/sec assure sufficient protection for all fish against impingement on the pipes. Stability for the channel in this area is provided by a thick concrete mat, which anchors the pipes in the river. This concrete mat is anchored into the rock underlying the river bed. Stiffened and streamlined pipe heads provide protection from floodwater debris loading. Four steel pipes, each with a diameter of 3 ft., carry water to the pumping structure. These pipes are fully encased in concrete in the river channel. The concrete pumping structure supports the intake pumps and is located approximately 150 ft. from the water's edge. The frequency of backwashing the perforated pipes is determined by head loss due to debris loading. The location is at the same point of the river as the selected intake system. For details, see Figure 9.4-2.

Costs of this system include perforated pipe, concrete foundation, piping to the pump structure, the pumping structure including pumps and backwash piping, piping to the Make-Up Pond A, access road, and construction cofferdam.

The perforated pipe intake with off-river pump structure utilizes river currents to sweep fish past the plotted openings in the pipe. With an inlet velocity of less than 0.5 ft/sec, fish entrapment should not occur.

A cellular sheet-pile cofferdam or similar structure is constructed out from the river bank so that the anchorage system, concrete mat, perforated pipe, and piping to the pump structure can be built in the dry with no adverse impact on the river water during construction. Temporary adverse impacts on the river are SMALL. The effect of increased noise and movement of men, materials, and machines during construction is essentially the same as that of construction of the remainder of the plant. In addition, any slight increase in the noise level by any alternative is caused mainly by operation of the water pumps and is not expected to adversely affect the surroundings.

The perforated pipe intake with off-river pump structure has SMALL impacts on fish and plankton. Turbidity of the river may increase slightly during backwash operations. The facility requires approximately 1 ac. of land and disturbs less than 0.5 ac. of river bottom during construction. River currents are expected to keep problems with silt to a minimum. Debris may cause some damage to the intake during flood conditions. The presence of the perforated pipe in the channel causes localized stream flow alterations, which may affect sediment distribution in the channel bottom. No effective means is available to inspect and repair the perforated pipe intake and no operating experience is available for prediction of such maintenance. Lack of operating experience within the industry, possible damage by debris, and lack of inspection and maintenance capability are the primary reasons for not selecting this system.

9.4.2.2.1.4 Infiltration Bed Intake with Off-River Pump Structure

The infiltration bed intake with off-river pump structure consists of an infiltration bed, piping to the pump structure, the pump structure, and the intake water pumps including piping for backwashing the infiltration bed. Negligible intake velocities assure no impingement of free-swimming organisms. Backwashing of the bed forces entrapped sediment and debris up into the river current, allowing it to continue downstream. Water from numerous smaller, perforated pipes in the bed is collected into four 3-ft.-diameter steel pipes, which carry water to the pumping structure. These pipes are fully encased in concrete in the river channel. The concrete pumping structure supports the intake pumps and is located approximately 150 ft. from the water's edge. The frequency of backwashing the perforated pipes is determined by head loss due to debris loading. The location is at the same point of the river as the selected intake system. For details, see Figure 9.4-3.

Costs of this system include washed crushed stone, perforated pipe and headers, piping to the pump structure, the pumping structure including pumps and backwash piping, piping to the Make-Up Pond A, access road, and construction cofferdam.

The infiltration bed intake with off-river pump structure utilizes low inlet velocities during intake of river water. Due to these low velocities, no problem is foreseen with fish entrapment.

A cellular sheet-pile cofferdam or similar structure is constructed out from the river bank so that the perforated pipe, gravel filter, and piping to the pump structure can be built in the dry. Slightly less than one acre of the river bottom is excavated, approximately 6 ft. deep, for use as the filter bed. Due to the large cofferdam size for this alternative, some additional scour of the river bottom is anticipated adjacent to the cofferdam. No permanent impacts on the river are expected. The effect of increased noise and movement of men, materials, and machines during construction is essentially the same as that of construction of the remainder of the plant. In addition, any slight increase in the noise level by any alternative is caused mainly by operation of the water pumps and is not expected to adversely affect the surroundings.

The infiltration bed intake with off-river pump structure has SMALL effects on fish and plankton. Heavy sediment load in the river is expected to require frequent backwashing, which causes a significant increase in turbidity downstream of the intake. The facility requires approximately 1.5 ac. of land and disturbs less than 1.5 ac. of river bottom during construction. Additional scour may also result from use of the large cofferdam. Additional problems include possible scour of the bed by river currents. No operating experience is available with this system and no backwash system has been demonstrated to effectively cleanse such an infiltration bed in a turbid river. For the above reasons, this system is not selected.

9.4.2.2.2 Screening Alternatives

9.4.2.2.2.1 Vertical Traveling Screens (Selected)

The design and operation of the selected traveling screens are described in Section 3.4. The screen is an endless belt of 3/8-in. mesh panels that travel vertically, enabling the panels to pass through a backwash jet spray for cleaning. The debris is washed into a trough and collected at one end of the structure. The collected debris is transported away from the structure for appropriate disposal. The mesh is sized by the maximum particle size that can be tolerated by the system, and by the size of the smallest fish to be protected.

9.4.2.2.2.2 Fixed Screens

This system is practicable only where suspended debris is negligible, so that cleaning requirements are minimal. When the screen is lifted out for spray cleaning, a backup screen must be dropped into place just behind the screen raised for cleaning. The process of cleaning the fixed screens is very time-consuming and not cost-effective as compared to the selected system.

9.4.2.2.2.3 Revolving Drum Screens

The normal operation of this system prevents fish from entering the system but discharges debris into the downstream flow. Discharged debris into the downstream flow negatively impacts the intake structure and allows debris to enter various pumps and components. This alternative system is not selected due to its inability to adequately obstruct debris, as compared to the selected system.

9.4.2.2.2.4 Psychological Screens

These systems, such as electrically charged screens, air bubble screens, sound screens, and light screens, aid somewhat in diverting fish away from the intake but do not prevent debris from entering the structure. This alternative system is not selected due to its inability to adequately obstruct debris, as compared to the selected system.

9.4.2.2.2.5 Perforated Pipe

This system consists of perforated pipe placed in the river channel and oriented in such a manner that the passing current sweeps debris and most suspended solids downstream. Approximately 25 percent of the pipe area is utilized for water intake. Debris larger than the 3/8-in.-wide inlet slots is excluded from the pipe. Construction and implementation of this system disrupt the riverbed, presenting negative impacts on the environment. Therefore, a perforated pipe system is not a preferable screening system alternative to the selected system.

9.4.2.2.2.6 Infiltration Bed

This system consists of perforated pipe embedded in a gravel bed beneath the river bottom. The size of particle screened depends upon gradation of the filter medium and pipe perforation size. Trapped particles are removed by backwashing the system and allowing the river flow to carry the particles downstream. Construction and implementation of this system disrupt the riverbed, presenting negative impacts on the environment. Therefore, an infiltration bed is not a preferable screening system alternative to the selected system.

9.4.2.2.2.7 Selected Screening System

The vertical traveling screen system is the proposed screening system for the site. The rotation allows for aquatic life to be safely washed away by backwash into a trough that leads back to the river. The mesh spacing of the screens is small enough to block all but the smallest fish from entering the system. The other screening alternatives have been rejected for the following reasons:

- Fixed screens would require more maintenance than the proposed system.
- Revolving drum screens would displace debris into the downstream flow.
- Psychological screens do not guarantee that fish would be diverted from the intake and they have no means of stopping debris.
- Perforated pipe and infiltration bed construction would cause more of an environmental impact than the selected system.

For all of these reasons, the vertical traveling screen system has been selected for the site.

9.4.2.2.3 Alternatives to the Selected Discharge System

The primary purpose of the discharge system is to disperse cooling tower blowdown into the Broad River to limit the concentration of dissolved solids in the heat dissipation system. The heated water discharge tends to remain at (or move toward) the surface of the Broad River. The discharge forms plumes of warm water that dissipate with distance from the source by rejecting heat to the atmosphere or mixing with cooler ambient waters. Mixing tends to occur more rapidly in rivers than in lakes or reservoirs because of increased turbulence. Also because of turbulence, rivers do not naturally thermally stratify and, as a result, alteration of temperature stratification caused by nuclear power plant water discharges is not an issue. The selected discharge system design is described in Subsections 3.4.2.2 and 5.3.2. The evaluation results for the alternative discharge systems screening are presented in Table 9.4-3. The environmental effects of the selected discharge system are discussed in detail in Subsection 5.3.2.

In general, for plant designs that include cooling towers, the effects were found to be minor. The thermal plume discharged by the Lee Nuclear Station in particular is so small that adverse impacts to biota are not expected.

In winter, fish attracted to the elevated temperature of the Lee Nuclear Station plume could stay an extended time. This could result in accelerated spawning and increased larval mortality from asynchrony with food source development or cold shock of migrant larvae. Drifting benthos, plankton, and larval fish may be impacted passing through the thermal plume at the site during the winter. Any resulting impact is considered SMALL due to the plume size and considering the total populations.

The selected closed-cycle system employing cooling towers is discussed in Subsection 9.4.1. Evaporation from the cooling towers discharges to the atmosphere. Blowdown from the cooling towers is discharged to the Broad River. This discharge meets the thermal and chemical requirements of the state and federal regulations.

The following discharge options are considered:

- Single port spillway apron discharge structure.
- Bankside single port discharge structure.
- River bottom single port diffuser structure.
- Mid river single port diffuser structure (selected).

The Ninety-Nine Islands Dam has eliminated fish migration on this reach of the Broad River. The systems, therefore, have no impact on fish migration. There is also no increase in noise level expected from the discharge structure for this application. Detailed descriptions of the alternative discharge systems evaluated for use at Lee Nuclear Station are provided in the following subsections.

9.4.2.2.3.1 Single Port Spillway Apron Discharge Structure

The single port spillway apron discharge structure consists of a single pipe anchored through a concrete headwall and emptying onto a rocky ledge leading to the river adjacent to the west abutment of the Ninety-Nine Islands Dam spillway apron. Recirculation of water to the intake is prevented by the dam. Average blowdown from the cooling towers is discharged into the Broad River at a rate of approximately 4040 gpm per unit, and the maximum approximate blowdown rate per unit is 14,000 gpm. The alternative discharge structure is shown in Figure 9.4-4.

Construction of the single port spillway apron discharge structure has SMALL effects on the natural surface water body. All construction related to this structure is in the dry and is located outside of the normal water course. The effect of increased noise and movement of men, materials, and machines during construction is essentially the same as that of construction of the rest of the plant.

The blowdown discharge structure is located below the Ninety-Nine Islands Dam at a point where the river bed consists of mainly bedrock. For this reason, river bed scour is not considered to be a problem. The single port spillway apron discharge structure has negligible impacts on the river and the surrounding environment. The economics and simplicity of the selected structure, with its adequate dispersion pattern, lend themselves favorably to a blowdown discharge application. Because construction is accomplished in the dry, this design does not disturb the river bottom. However, the Ninety-Nine Islands Dam is considered a historical site and the addition of a single port spillway apron discharge structure would negatively affect the aesthetics of the historical site. In addition, CORMIX modeling indicates that the single port spillway apron discharge structure alternative does not meet temperature requirements.

9.4.2.2.3.2 Bankside Single Port Discharge Structure

The bankside single port discharge structure consists of a single pipe anchored through a concrete headwall and emptying into the river at or about the water surface of the river. The discharge pipe is sized for an effluent velocity of approximately 5 ft/sec. The structure is located approximately 1200 ft. downstream of the Ninety-Nine Islands Dam.

Sheet-pile cofferdams or similar type structures are built out from the river bank so the discharge structure can be built in the dry with no adverse impact on the river water during construction. A major portion of the slope protection around the structure is expected to be completed before the cofferdam is removed. Permanent or temporary adverse impacts on the river are expected to be SMALL. The effect of increased noise and movement of men, materials, and machines during construction is essentially the same as that of construction of the rest of the plant.

The bankside single port structure is similar to the selected structure in most aspects. Location of the structure approximately 1200 ft. downstream increases the costs compared with those of the selected system. In addition, cofferdam requirements disturb a portion of the river bottom not required for the selected system. Also, CORMIX modeling indicates that the bankside single port discharge structure alternative does not meet temperature requirements. The practicability of the bankside single port discharge structure is so low that a sketch of the preliminary design is not warranted.

9.4.2.2.3.3 River Bottom Single Port Diffuser Structure

The river bottom single port diffuser structure consists of a single exit pipe anchored to the river bottom. Discharge is perpendicular to river flow. The structure is located approximately 1200 ft. downstream of the Ninety-Nine Islands Dam.

Sheet-pile cofferdams or similar type structures are built out from the river bank so the discharge structure can be built in the dry with no adverse impact on the river water during construction. A major portion of the slope protection around the structure is expected to be completed before the cofferdam is removed. No permanent or temporary adverse impacts on the river are expected. The effect of increased noise and movement of men, materials, and machines during construction is essentially the same as that of construction of the rest of the plant.

The river bottom single port diffuser structure has SMALL impacts on the river and the surrounding environment. Its capabilities for mixing are approximately the same as for the previously discussed structures. Additional protected piping is required for this application. Larger cofferdam requirements also disturb a larger portion of the river bottom. Construction and implementation of this discharge system require use of larger cofferdams and disturb a larger portion of the river bottom than required for the selected system, increasing the negative impacts on the environment. For these reasons, this alternative discharge system is not selected. The practicability of the river bottom single port diffuser structure is so low that a sketch of the preliminary design is not warranted.

9.4.2.2.3.4 Mid River Single Port Diffuser Structure (Selected)

The mid river single port diffuser structure consists of a single, 3-ft.-diameter exit pipe that extends into the Broad River at an approximate elevation of 505.1 ft. above msl. This places the diffuser approximately 6 ft. under the normal water level of the river. The diffuser is composed of a steel pipe with sixteen 1-in.-diameter holes per foot over a length of 65 ft., which provides more than 1000 holes. The port is located immediately upstream of the Ninety-Nine Islands Dam, at a position which allows the discharged water to flow directly into the turbine of the hydroelectric station. The selected discharge structure is shown in Figure 5.3-4 Sheets 1 and 2.

The discharge line is installed by divers. Any permanent or temporary adverse impacts on the river are expected to be SMALL. The effects of increased noise and movement of people, materials, and machines during construction are essentially the same as for construction of the other portions of the plant.

The flow from the diffuser exits the pipe at such a position where it immediately mixes into the intake water of the Ninety-Nine Islands turbine structure, and therefore has SMALL impacts on the aquatic life and river temperature. This discharge structure also has a SMALL differentiating impact on river water use because it mixes into the turbine intake. The aesthetic impact on the historical Ninety-Nine Islands Dam is also SMALL, because the discharge structure is located approximately 6 ft. below the normal water level of the Broad River. For these reasons, the mid river single port diffuser structure is the selected system for the site.

9.4.2.2.4 Alternatives to the Selected Water Supply

The selected water supply for the heat dissipation system at the Lee Nuclear Station is the Broad River. No alternative sources of water supply are available. This selected water supply system is designed so that the bottom of the intake channel is at sufficient depth to ensure direct flow from the main river channel to the water intake. As described in Section 5.3, the maximum amount of water introduced into the system from the Broad River is approximately 60,000 gpm for the two operating units. The annual mean flow at the Broad River is 2538 cubic feet per second (cfs). Based on the anticipated maximum intake flow of 60,000 gpm for both operating units, the intake withdraws approximately 5 percent of the annual mean river flow. During low-flow conditions in the river, raw water is pumped from the Make-Up Pond B intake structure to the Make-Up Pond A. For further discussion of the Make-Up Pond B and the Make-Up Pond A, see Section 5.3.

Groundwater was evaluated and not considered a viable alternative water source because the groundwater would not be able to support the large component cooling makeup water requirement of 60,000 gpm for both units.

The environmental impact of using the Broad River water supply during times of normal flow is SMALL. However, low river flow may not supply enough water to the CWS, and therefore, during low-flow conditions in the river, raw water is pumped from the Make-Up Pond B intake structure to the Make-Up Pond A. No environmentally equivalent or superior alternative raw water source is identified. Environmental impacts are SMALL, and no mitigation is needed.

9.4.2.2.5 Alternatives to the Selected Water Treatment System

Evaporation of water from cooling towers leads to an increase in chemical and solids concentrations in the circulating water, which in turn increases the scaling tendencies of the water. The Lee Nuclear Station CWS is operated so that the concentration of total dissolved solids in the cooling tower blowdown is monitored to meet the values on the NPDES permit. The selected water treatment system is described in Subsection 3.3.2. The Broad River is the source of the makeup water for the CWS. Circulating water chemistry, including blowdown and makeup water from the Broad River, is maintained by the turbine island chemical feed system. Turbine island chemical feed equipment injects the required chemicals into the circulating water downstream of the CWS pumps. This maintains a noncorrosive, nonscale-forming condition and limits the biological film formation. This formation reduces the heat transfer rate in the condenser and heat exchangers supplied by the CWS. The SWS cooling towers use the same water treatment chemicals as the CWS.

The chemicals used can be divided into six categories based upon function: (1) biocide, (2) algaeecide, (3) pH adjuster, (4) corrosion inhibitor, (5) scale inhibitor, and (6) silt dispersant. The pH adjuster, corrosion inhibitor, scale inhibitor, and dispersant are metered into the system continuously or as required to maintain proper concentrations. The biocide application frequency may vary with seasons. The algaecide is applied, as necessary, to control algae formation on the cooling water.

Additional treatment for biofouling, scaling, or suspended matter reduction through the addition of biocides, antiscalants, and dispersants occurs in the cooling tower basin. Sodium hypochlorite and bromine can be used to control biological growth in the CWS. Sodium hypochlorite is as effective a biocide and alleviates some of the safety concerns associated with storing and using gaseous chlorine. Alternative biocides include hydrogen peroxide or ozone. The final choice of chemicals or combination of chemicals is dictated by makeup water conditions, technical feasibility, economics, and discharge permit requirements. Because the discharges from CWS and the SWS are subject to NPDES permit limitations that consider aquatic impacts, different water treatment chemicals used in the system would be environmentally equivalent.

Because of strict regulation of chemical discharges from steam electric power plants (e.g., EPA regulations at Title 40 Code of Federal Regulations [CFR] 423), water treatment systems for cooling tower blowdown have been developed. All nuclear power plants are required to obtain an NPDES permit to discharge effluents. These permits are renewed every five years by the regulatory agency, either EPA or, more commonly, the state's water quality permitting agency. The periodic NPDES permit renewals provide the opportunity for the issuing agency to require modification of power plant discharges or to alter discharge monitoring in response to water quality concerns. A more detailed discussion of this subject is provided in Section 3.6.

A detailed description of treatment system operating procedures, including plant operational and seasonal variations, is provided in Section 3.6. The frequency of treatment for each of the normal modes of operation is described in Table 3.6-1, as well as the quantities and points of addition of the chemical additives. All methods of chemical use are monitored.

Duke Power Company evaluated alternative water treatment systems to prepare for the construction of the previous Cherokee Nuclear Station Units 1, 2, and 3. Most of the evaluation still applies to the Lee Nuclear Station units. The water treatment system has been evaluated, and the results are provided in Reference 2. The summary results of the alternative water treatment systems screening are presented in Table 9.4-4.

The Westinghouse water treatment chemical addition strategy for the CWS and SWS cooling towers consists of:

- Biocide: sodium hypochlorite
- Algaecide: quarternary amine
- pH adjuster: sulfuric acid
- Corrosion inhibitor: polyphosphate
- Scale inhibitor: phosphonate
- Silt dispersant: polyacrylate

The Duke Energy water treatment chemical addition strategy for the Lee Nuclear Station CWS and SWS cooling towers (i.e., the Lee water treatment chemical addition strategy) consists of:

- Biocide/algaecide: sodium hypochlorite and sodium bromide
- pH adjuster: sulfuric acid
- Silt dispersant: polyacrylate

The following additional factors were considered in selecting water treatment alternatives:

- Biocide/algaecide - This chemical treatment creates an oxidizing biocide based on chlorine and hypobromous acid that is expected to control biofouling and underdeposit corrosion. No amine-based algaecide is utilized, due to current NPDES permitting guidelines.
- Corrosion inhibitor - The selection of non-corrosive tower materials, pH control, and the maintenance of a bromine residual provide the required corrosion control. No phosphate-based corrosion inhibitor is utilized, due to current NPDES permitting guidelines.
- Scale inhibitor - pH control is used to maintain a non-scaling water chemistry in the cooling towers. No phosphate-based scale inhibitor is utilized, due to current NPDES permitting guidelines.

Based on the above comparison and the comparison made in Table 9.4-4, the Lee water treatment chemical addition strategy is the selected strategy for the CWS and SWS cooling towers.

9.4.3 TRANSMISSION SYSTEMS

Duke Energy's electrical system planners are conducting a comprehensive siting study to determine the routes for new electrical transmission lines to connect the Lee Nuclear Station to the existing electric transmission grid within the Duke Energy service area in North and South Carolina.

After conducting a review of the existing transmission grid in the vicinity of the Lee Nuclear Station, including current loads and available capacity, Duke Energy determined that two existing overhead transmission lines should be "folded-in" to the station's proposed switchyard. The use of two existing transmission lines allows for more than one pathway to move power from the Lee Nuclear Station to existing load centers in the Duke Energy service area. A fold-in configuration requires that each of the existing lines be diverted from its current route at two points to (1) depart the existing line and enter the switchyard, and then (2) exit the switchyard and return to the existing line. The segment of the existing line between the diversions is de-energized.

The two existing transmission lines selected for the fold-in are the Asbury 525-kilovolt (kV) line that generally runs east to west about 16 mi. south of the Lee Nuclear Station and the Roddey 230 kV line that generally runs east to west about 8 mi. south of the station. The fold-in configuration as planned adheres to the following requirements:

- The two new 525 kV lines to and from the Asbury route are separated by a minimum of 1 mi. to reduce the possibility that a single unanticipated event such as a storm, plane crash, or sabotage could simultaneously interrupt service on both lines.
- The two 230 kV lines from the Roddey route are similarly separated for the same reason.
- One 230 kV line can parallel one 525 kV line within a common right-of-way (ROW) 325-ft. wide. The ROW for a single 230 kV line is 150-ft. wide and the ROW for a single 525 kV line is 200-ft. wide.

Thus, the overall objective of the study is to select two transmission line routes that are separated by a minimum of 1 mi. Along the first route, a single-circuit 525 kV line would run northward within a 200-ft.-wide ROW from the existing Asbury 525 kV line to intersect the existing Roddey 230 kV line. Thereafter, the 525 kV line and a double-circuit 230 kV line would continue parallel to each other within a 325-ft. ROW to the Lee Nuclear Station switchyard. Along the second route, the new 230 kV and 525 kV lines would exit the switchyard in parallel, continue southerly to tie-in to the Roddey 230 kV line, after which the 525 kV line would continue southward to its termination at the existing Asbury 525 kV line.

The siting study is being conducted in three phases (Figure 9.4-5). They are:

- Alternate route development.
- Alternate route evaluation and comparison.
- Study documentation and agency approvals.

The first phase of the study is now complete. Selection of preferred alternative routes is in progress. Each of these phases is discussed in greater detail in the following subsections.

9.4.3.1 Siting Study Area

Duke Energy defined a 284-square mile (sq. mi.) siting study area (Figure 9.4-6) located within Cherokee, York, and Union counties. The study area was selected based on consideration of the proposed location of the Lee Nuclear Station, the presence of existing 230 kV and 525 kV lines, topography, the Broad River, land use and development patterns, and transportation corridors. Field reconnaissance of the general area between the proposed site and the existing transmission lines indicated that expanding the area shown on Figure 9.4-6 from west to east would be counterproductive. Expansion would dictate increasingly longer ROW with a correspondingly greater potential for environmental and land use impacts and higher overall cost.

Once defined, Duke Energy collected aerial photographs and topographic maps and conducted extensive field reconnaissance visits to gather data including, but not limited to, land use, aesthetics, cultural resources, natural resources, and development and infrastructure in the study area. This information was supplemented by contacting federal, state, and local natural resource and planning agencies for pertinent environmental information and records.

Data were then grouped into 12 data layers for manipulation by a Geographical Information System (GIS). The data layers are:

- Cultural resources
- Rare, threatened, and endangered species
- Land cover
- Prime farmland soils and soils of statewide importance
- Land use
- Future land use
- Zoning
- Occupied buildings
- Public visibility
- Federal Emergency Management Agency (FEMA) floodzones
- Hydrography
- Wetlands

Figure 9.4-7 is a sample data layer illustrating the application of public visibility factors to the study area. Once all twelve data layers were mapped in a manner similar to Figure 9.4-7, Duke Energy held two community workshops, in April 2007. Two weeks before the workshops, Duke Energy mailed invitations to 4182 property owners of record in the siting study area along with Community Questionnaires designed to solicit substantive information to support the siting process. The Community Questionnaires were also available at the workshop. The workshops were designed to inform local residents about the project, explain the siting process, and solicit public feedback that might influence the selection of alternative routes within the study area and Duke Energy's final evaluation of those alternatives. Held in Union, South Carolina, and York, South Carolina, the workshops were attended by a total of 116 people and 348 Community Questionnaires were completed and returned. In addition to local residents, Duke Energy invited elected public officials, governmental agency personnel, and local community leaders to attend.

Feedback at the workshops, upon review and discussion of the data layers, revealed several issues of special concern to the attendees. Included were protection of water resources (including the Broad River, a state-designated scenic river downstream of the Ninety-Nine Islands Dam) and historic structures, potential effects on and visibility of the new lines from residences, and the presence of a local wildlife management area. The wildlife management area encompasses a geographic feature known as Worth Mountain that was identified by numerous attendees as an area of special concern to local residents and landowners. The data layers were then augmented to reflect any pertinent new information generated during the workshops.

9.4.3.2 Alternative Corridors

After adjusting the data layers to reflect public feedback, Duke Energy assigned numeric weights to each of the factors included within a data layer to represent the relative influence of each on and the sensitivity of each to transmission line routing. The weighted data were then combined in the GIS to produce a single map representing the cumulative effect of all data layers to transmission line routing. This map, called a Suitability Composite, displays a range of low constraints (i.e., high suitability) to high constraints (i.e., low suitability) on transmission line routing alternatives within the study area.

Duke Energy then used the composite to identify a series of 21 alternative routes (identified as Alternate Routes A-U), largely confined to low-constraint areas, for additional analysis and evaluation (Figure 9.4-8). Although the GIS algorithm produces direct routes, Duke Energy converted these routes to 1500-ft.-wide corridors for purposes of future real estate and engineering analysis and to allow flexibility when selecting actual ROW. Table 9.4-6 illustrates the twelve data layers, and results for selective individual criteria within the data layers.

Once mapped, the alternative routes were again presented to the public and local decision-makers, at community workshops held in June 2007. Duke Energy again solicited feedback. The purposes of these workshops were to provide complete information about the project and the transmission line siting process, and to offer the public an opportunity to inspect the alternative routes and provide additional information that could affect evaluation of the 21 alternatives directly to Duke Energy's siting team.

9.4.3.3 Preferred Alternatives

The data gathered during the siting study and public feedback were used to regroup factors contained in the 12 data layers discussed above into nine route evaluation categories for additional analysis by GIS of the viable alternatives. The categories are:

- Cultural and natural resources
- Land cover

- Soil
- Property ownership
- Land use
- Occupied buildings
- Public visibility
- Residential visibility
- Water quality

Within each of the above categories, criteria are developed to allow qualitative and quantitative comparisons of the alternative route combinations based on the sensitivity of each data factor to transmission line construction and long-term operation. As part of this comparative analysis a weight ranging from 1-10 is assigned to each data factor, with a value of 10 assigned to the most sensitive factors. For example, the number of homes within 200 ft. of the proposed route where the new line(s) would not be parallel and adjacent to an existing line would be assigned a weight of 10.

The factor weights are then multiplied by the factor score (e.g., units, miles, acres) in each category for each alternative route to calculate individual factor scores. Individual factor scores for each route are then added to compile a total evaluation category score for each of the alternative combinations.

Once so calculated, the total evaluation category scores are normalized on a scale of 1-10. Normalizing the category scores prevents any single evaluation category from unjustifiably influencing the overall alternative route score. For example, the unit of measure in the Occupied Buildings category is the actual number of buildings within a certain distance of the route, and the unit of measure in the Land Cover category is acres. The total evaluation score in the Occupied Buildings category is often low (e.g., no more than tens of units) compared to scores an order of magnitude greater (e.g., hundreds of acres) in the Land Cover category. Without score normalization, the larger Land Cover scores would render the lower Occupied Buildings scores (and other categories with low numeric values) unimportant in the comparative analysis.

The normalized evaluation scores for each of the nine categories are added to compile a total route evaluation score for each of the alternative route combinations. Alternative route combinations with the lowest total evaluation score (i.e., highest suitability) are those that minimize impacts over the broadest range of environmental, land use, cultural, and aesthetic factors used in the analysis. Duke Energy then performs a comprehensive cost estimate for each alternative route combination. The preferred routes are those with high suitability ratings in the evaluation categories and reasonable, but not necessarily lowest overall cost.

Once selected, the preferred alternative routes are subjected to a further field evaluation designed to detect any fatal flaws not evident in the data collected to date. The selected routes, along with a summary of the siting study, are then submitted to the Public Service Commission of South Carolina (PSCSC) in compliance with the Utility Facility Siting Act. The PSCSC will hold public hearings and issue a decision on Duke Energy's request to construct a transmission line along the selected route. Upon completion, the results of the corridor selection process will be submitted as a supplement to this Environmental Report.

9.4.3.4 Rights-of-Way

As the final step in the process, Duke Energy would select an actual ROW within each corridor and apply for the necessary permits to construct and operate the new transmission lines in accordance with all applicable laws and regulations.

Once Duke Energy secures the right to enter a property, the ROW is subjected to site-specific pre-construction investigations, possibly including but not limited to a cultural resource field survey and reconnaissance to ascertain the presence or absence of plant species of special concern, as required by permitting or review agencies at the federal or state level.

9.4.4 REFERENCES

1. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, *Final Environmental Statement Related to Construction of Cherokee Nuclear Station, Units 1, 2, and 3, Duke Power Company, Docket Nos. STN 50-491, STN 50-492, and STN 50-493*, NUREG-75/089, Washington, DC, October 1975.

2. Duke Power Company, *Project 81, Cherokee Nuclear Station, Environmental Report, Amendment 4*, Charlotte, NC, October 13, 1975.

3. 40 CFR 122, "EPA Administered Permit Programs: The National Pollutant Discharge Elimination System."

4. Federal Water Pollution Control Act (Clean Water Act), 33 USC 1251 et seq.

TABLE 9.4-1 (Sheet 1 of 3)
SCREENING OF ALTERNATIVE HEAT DISSIPATION SYSTEMS

Factors Affecting System Selection	Circular Mechanical-draft Cooling Towers (Selected)	Rectangular Mechanical-draft Cooling Towers	Natural-draft Cooling Towers
On-site Land Requirements	Construction activities would expose 100 ac. of forest and other lands to erosion (Reference 2).	Construction activities would expose 193 ac. of forest and other lands to erosion (Reference 2).	Construction activities would expose 99 ac. of forest and other lands to erosion (Reference 2).
Terrain Considerations	Terrain features of the Lee Nuclear Site are suitable for this system.	Terrain features of the Lee Nuclear Site are suitable for this system.	Terrain features of the Lee Nuclear Site are suitable for this system.
Water Use	20,820 gpm per unit	20,820 gpm per unit	20,820 gpm per unit
Atmospheric Effects	No adverse effects due to fogging or icing from the tower to off-site activities. No chemical discharge other than salt and no odors attributed to the system.	No adverse effects due to fogging or icing from the tower to off-site activities. No chemical discharge other than salt and no odors attributed to the system.	No adverse effects due to fogging or icing from the tower to off-site activities. No chemical discharge other than salt and no odors attributed to the system.
Thermal and Physical Effects	Discharge and site construction add some turbidity to the water, but have no overall adverse effects.	Discharge and site construction add some turbidity to the water, but have no overall adverse effects.	Discharge and site construction add some turbidity to the water, but have no overall adverse effects. Natural-draft cooling towers also have a slightly higher discharge temperature, which causes a slight increase to the river temperature as compared to the other alternatives.

TABLE 9.4-1 (Sheet 2 of 3)
SCREENING OF ALTERNATIVE HEAT DISSIPATION SYSTEMS

Factors Affecting System Selection	Circular Mechanical-draft Cooling Towers (Selected)	Rectangular Mechanical-draft Cooling Towers	Natural-draft Cooling Towers
Noise Levels	Some noise is attributed to the mechanical portions of the tower, however, these disturbances are unobtrusive to the surroundings (Reference 2).	Some noise is attributed to the mechanical portions of the tower, however, these disturbances are unobtrusive to the surroundings (Reference 2).	Because there are no mechanized parts, there is no significant noise related to this system, other than falling water (Reference 2).
Aesthetic and Recreational Benefits	Consumptive water use for this system is consistent with minimum stream flow requirements for the Broad River, environmental maintenance of fish and wildlife water demand, and recreation. Any plumes are visible, but resemble clouds and do not disrupt the surroundings. Each tower is approximately 60-ft. tall.	Consumptive water use for this system would be consistent with minimum stream flow requirements for the Broad River, environmental maintenance of fish and wildlife water demand, and recreation. Any plumes are visible, but they resemble clouds and do not disrupt the surroundings. Each tower is approximately 60-ft. tall.	Consumptive water use for this system is consistent with minimum stream flow requirements for the Broad River, environmental maintenance of fish and wildlife water demand, and recreation. The tall towers (500 ft.) are visible for longer distances. Plumes are also more visible.
Legislative Restrictions	An intake structure for this system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The NPDES discharge permit thermal discharge limitation addresses the additional thermal loads from the blowdown. These regulatory restrictions have a small impact on this heat dissipation system.	An intake structure for this system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The NPDES discharge permit thermal discharge limitation addresses the additional thermal loads from the blowdown. These regulatory restrictions have a small impact on this heat dissipation system.	An intake structure for this system would meet Section 316(b) of the CWA and the implementing regulations, as applicable. The NPDES discharge permit thermal discharge limitation addresses the additional thermal loads from the blowdown. These regulatory restrictions have a small impact on this heat dissipation system.

TABLE 9.4-1 (Sheet 3 of 3)
SCREENING OF ALTERNATIVE HEAT DISSIPATION SYSTEMS

Factors Affecting System Selection	Circular Mechanical-draft Cooling Towers (Selected)	Rectangular Mechanical-draft Cooling Towers	Natural-draft Cooling Towers
Operating and Maintenance Experience	Mechanical-draft cooling tower systems are common to power plants (both fossil and nuclear) and are considered highly reliable.	Mechanical-draft cooling tower systems are common to power plants (both fossil and nuclear) and are considered highly reliable.	Natural-draft cooling tower systems are common to power plants (both fossil and nuclear) and are considered highly reliable.
Generating Efficiencies	The energy requirements for mechanical-draft cooling towers would be more than natural-draft cooling tower systems.	The energy requirements for mechanical-draft cooling towers would be more than natural-draft cooling tower systems.	Natural-draft cooling tower energy requirements would be less than the mechanical-draft systems.
Other Considerations	NA	NA	NA
Cost[(a)(b)(c)]	$204,912,575	$227,794,000	$210,371,840
Is this a suitable alternative for the Lee Nuclear Site?	Yes	Yes	Yes

a) Estimated cost in 2007 dollars per Table 10.1.0-1 of Reference 2.

b) The 1986 dollars from Reference 2, Table 10.1.0-1, were converted to 2007 dollars. The dollar values were converted by applying the Consumer Price Index (CPI) ratio of the June 2007 southern region value (201.675) to the June 1986 value (108.7). CPI data are from the U.S. Department of Labor, Bureau of Labor Statistics.

c) See Table 9.4-5 for more details on Cost.

TABLE 9.4-2 (Sheet 1 of 4)
SCREENING OF ALTERNATIVE INTAKE SYSTEMS

Factors Affecting System Selection	Bankside River Intake Structure (Selected)	Off-River Intake Structure on an Open-Ended Approach Canal	Perforated Pipe Intake with Off-River Pump Structure	Infiltration Bed Intake with Off-River Pump Structure
Construction Impacts	A cellular sheet pile cofferdam or similar structure is built out from the river bank so that the intake structure is built in the dry with no adverse effect on the river water during construction. Noise disruption is slight.	Because the structure is connected to the river by a canal, it can be built on dry land with no effect on the river. Canal entrance facilities require less temporary river protection than the selected facility. Noise disruption is slight.	A cellular sheet pile cofferdam or similar structure is built out from the river bank so that the anchorage system, concrete mat, perforated pipe, and piping to the pump structure can be built in the dry with no adverse effect on the river water during construction. Noise disruption is slight.	A cellular sheet pile cofferdam or similar structure is built out from the river bank so that the perforated pipe, gravel filter, and piping to the pump structure can be built in the dry. About 1 ac. of river bottom is excavated approximately 6-ft.-deep for use as the filter bed. Due to the large cofferdam size for this alternative, some additional scour of the river bottom is anticipated adjacent to the cofferdam. No permanent effects on the river are expected. Noise disruption is slight.

TABLE 9.4-2 (Sheet 2 of 4)
SCREENING OF ALTERNATIVE INTAKE SYSTEMS

Factors Affecting System Selection	Bankside River Intake Structure (Selected)	Off-River Intake Structure on an Open-Ended Approach Canal	Perforated Pipe Intake with Off-River Pump Structure	Infiltration Bed Intake with Off-River Pump Structure
Aquatic Impacts	All intake water taken from the Broad River passes through a curtain wall, stop log assemblies, bar screens, and traveling screen designed to minimize uptake of aquatic biota and debris. Maximum velocities for all river flows are less than 0.5 ft/sec. (Reference 2).	Structure incorporates a submerged weir and training wall, which directs the river stream away from the intake waterway, to aid in carrying fish past the entrance. The canal current is less 0.5 ft/sec, which should allow fish to swim out of the canal. In addition, structure has bar racks and traveling screens to keep fish and debris out of the pump well (Reference 2).	Provides negligible effects on fish and plankton. Intake velocity of less than 0.5 ft/sec assures sufficient protection for all fish against impingement on the pipes. Turbidity of the river may increase slightly during backwash operations (Reference 2).	Negligible intake velocities assure no impingement of free-swimming organisms. Heavy sediment load in the river requires frequent backwashing, which causes a significant increase in turbidity downstream of the intake (Reference 2).
Land Use Impacts	Requires approximately 1 ac. of land and disturbs less than 0.5 ac. of river bottom during construction. Negligible problems with silt and debris are anticipated.	Requires 4 ac. of land and does not disturb more than 0.5 ac. of the river bottom during construction. Problems with silt are anticipated in the canal and periodic dredging operations are required.	Requires approximately 1 ac. of land and disturbs less than 0.5 ac. of river bottom during construction.	The facility requires 1.5 ac. of land for operation, of which approximately 1 ac. is river bed. During construction, approximately 1.5 ac. of river bottom are disturbed.

TABLE 9.4-2 (Sheet 3 of 4)
SCREENING OF ALTERNATIVE INTAKE SYSTEMS

Factors Affecting System Selection	Bankside River Intake Structure (Selected)	Off-River Intake Structure on an Open-Ended Approach Canal	Perforated Pipe Intake with Off-River Pump Structure	Infiltration Bed Intake with Off-River Pump Structure
Water Use Impacts	The relative position of the intake (shoreline or offshore) would have no differentiating impact on the water use requirements, and, therefore, it would not be an important factor.	The relative position of the intake (shoreline or offshore) would have no differentiating impact on the water use requirements, and, therefore, it would not be an important factor.	The relative position of the intake (shoreline or offshore) would have no differentiating impact on the water use requirements, and, therefore, it would not be an important factor.	The relative position of the intake (shoreline or offshore) would have no differentiating impact on the water use requirements, and, therefore, it would not be an important factor.
Compliance with Regulations	The intake structure meets CWA Section 316(b) requirements and the implementing regulations, as applicable.	The intake structure meets CWA Section 316(b) requirements and the implementing regulations, as applicable.	The intake structure meets CWA Section 316(b) requirements and the implementing regulations, as applicable.	The intake structure meets CWA Section 316(b) requirements and the implementing regulations, as applicable.

TABLE 9.4-2 (Sheet 4 of 4)
SCREENING OF ALTERNATIVE INTAKE SYSTEMS

Factors Affecting System Selection	Bankside River Intake Structure (Selected)	Off-River Intake Structure on an Open-Ended Approach Canal	Perforated Pipe Intake with Off-River Pump Structure	Infiltration Bed Intake with Off-River Pump Structure
Total Annual Costs	Costs include the rack structure, river intake structure including pumps and screens, piping to the Make-Up Pond A, access road, construction cofferdam, and excavation. Cost comparison of alternative intake systems is shown in Table 10.2.4-1 of Reference 2.	Costs include the submerged weir, training wall, canal, intake structure including pumps and screens, piping to the Make-Up Pond A, access road, periodic silt removal operations, and cofferdams for canal entrance facilities. Cost comparison of alternative intake systems is shown in Table 10.2.4-1 of Reference 2.	Costs include perforated pipe, concrete foundation, piping to the pump structure, pumping structure including pumps and backwash piping, piping to the Make-Up Pond A, access road, and construction cofferdam. Cost comparison of alternative intake systems is shown in Table 10.2.4-1 of Reference 2.	Costs include washed crushed stone, perforated pipe and headers, piping to the pump structure, pumping structure including pumps and backwash piping, piping to the Make-Up Pond A, access road, and cofferdam. Cost comparison of alternative intake systems is shown in Table 10.2.4-1 of Reference 2.

TABLE 9.4-3 (Sheet 1 of 3)
SCREENING OF ALTERNATIVE DISCHARGE SYSTEMS

Factors Affecting System Selection	Single Port Spillway Apron Discharge Structure	Bankside Single Port Discharge Structure	River Bottom Single Port Diffuser Structure	Mid River Single Port Diffuser Structure (Selected)
Construction Impacts	Construction of structure has negligible effect on the natural surface water body. All construction related to this structure is in the dry and located outside the normal water course. Noise disruption impacts are SMALL. The aesthetic appearance of the Ninety-Nine Islands Dam is negatively impacted by this system.	Sheet-pile cofferdams or similar structures are built out from the river bank so the discharge structure can be built in the dry with SMALL adverse effects on the river water during construction. Noise disruption impacts are SMALL.	Sheet-pile cofferdams or similar type structures are built out from the river bank so the discharge structure can be built in the dry with SMALL adverse effects on the river water during construction. Noise disruption impacts are SMALL.	The discharge line is installed by divers. Any permanent or temporary adverse impacts on the river are expected to be SMALL. Noise disruption impacts are SMALL. The aesthetics impacts of this system on the historical Ninety-Nine Islands Dam are SMALL.

TABLE 9.4-3 (Sheet 2 of 3)
SCREENING OF ALTERNATIVE DISCHARGE SYSTEMS

Factors Affecting System Selection	Single Port Spillway Apron Discharge Structure	Bankside Single Port Discharge Structure	River Bottom Single Port Diffuser Structure	Mid River Single Port Diffuser Structure (Selected)
Impacts on Aquatic Ecology	The blowdown discharges below the Ninety-Nine Islands Dam. This dam has eliminated fish migration on this reach of the Broad River. The system, therefore, has SMALL effects on fish migration. System has MODERATE effects on the river and the surrounding environment based on not meeting temperature requirements per CORMIX modeling.	The blowdown discharges below the Ninety-Nine Islands Dam. This dam has eliminated fish migration on this reach of the Broad River. The system, therefore, has SMALL effects on fish migration. System has MODERATE effects on the river and the surrounding environment based on not meeting temperature requirements per CORMIX modeling.	The blowdown discharges below the Ninety-Nine Islands Dam. This dam has eliminated fish migration on this reach of the Broad River. The system, therefore, has SMALL effects on fish migration. System has SMALL effects on the river and the surrounding environment.	The blowdown discharges directly upstream from the Ninety-Nine Islands Dam. This location allows for flow to adequately mix with the intake to the turbine of the hydroelectric station. The system, therefore, has SMALL impacts on fish migration, the river, and the surrounding environment.
Water Use Impacts	The position of the discharge would have SMALL differentiating impacts on the water use requirements, and, therefore, it would not be an important factor.	The position of the discharge would have SMALL differentiating impacts on the water use requirements, and, therefore, it would not be an important factor.	The position of the discharge would have SMALL differentiating impacts on the water use requirements, and, therefore, it would not be an important factor.	The position of the discharge has SMALL differentiating impacts on the water use requirements, and, therefore, it would not be an important factor.

TABLE 9.4-3 (Sheet 3 of 3)
SCREENING OF ALTERNATIVE DISCHARGE SYSTEMS

Factors Affecting System Selection	Single Port Spillway Apron Discharge Structure	Bankside Single Port Discharge Structure	River Bottom Single Port Diffuser Structure	Mid River Single Port Diffuser Structure (Selected)
Compliance with Regulations	Per CORMIX modeling, the structure **would not** meet the National Pollutant Discharge Elimination System (NPDES) temperature requirements as mandated by the South Carolina Department of Health and Environmental Control (SCDHEC).	Per CORMIX modeling, the structure **would not** meet the NPDES temperature requirements as mandated by the SCDHEC.	Per CORMIX modeling, the structure **would** meet the NPDES temperature requirements as mandated by the SCDHEC.	The structure **would** meet the NPDES temperature requirements as mandated by the SCDHEC.

TABLE 9.4-4 (Sheet 1 of 2)
SCREENING OF ALTERNATIVE WATER TREATMENT SYSTEMS

Factors Affecting System Selection	Westinghouse Water Treatment Chemical Addition Strategy for the CWS and SWS	Lee Water Treatment Chemical Addition Strategy for the CWS and SWS (Selected)
Chemicals Used	Biocide: sodium hypochlorite Algaecide: quarternary amine pH adjuster: sulfuric acid Corrosion inhibitor: polyphosphate Scale inhibitor: phosphonate Silt dispersant: polyacrylate	Biocide/algaecide: sodium hypochlorite and sodium bromide pH adjuster: sulfuric acid Silt dispersant: polyacrylate
Construction Impacts	Installation of the chemical treatment systems would result in additional commitments of land. Associated soil erosion and sediment impacts, however, would be SMALL.	Installation of the chemical treatment systems would result in additional commitments of land. Associated soil erosion and sediment impacts, however, would be SMALL.
Aquatic Impacts	Residual chemicals from this treatment process could affect aquatic resources in the downstream Broad River. Biocides, corrosion inhibitors, and pH adjustment chemicals are potentially toxic to aquatic life.	Residual chemicals from this treatment process could affect aquatic resources in the downstream Broad River. Biocides, and pH adjustment chemicals are potentially toxic to aquatic life.
Land Use Impacts	There would be no appreciable land use impacts.	There would be no appreciable land use impacts.

TABLE 9.4-4 (Sheet 2 of 2)
SCREENING OF ALTERNATIVE WATER TREATMENT SYSTEMS

Factors Affecting System Selection	Westinghouse Water Treatment Chemical Addition Strategy for the CWS and SWS	Lee Water Treatment Chemical Addition Strategy for the CWS and SWS (Selected)
Water Use Impacts	Chemical treatment systems would not impact water withdrawal requirements.	Chemical treatment systems would not impact water withdrawal requirements.
Compliance with Regulations	An amine-based algaecide cannot be utilized due to current NPDES permitting guidelines. Phosphate-based corrosion or scale inhibitor cannot be utilized, due to current NPDES permit guidelines.	Permits may have to be revised to account for the chemically treated cooling system effluent.

TABLE 9.4-5
COST[a] COMPARISON – COOLING SYSTEM ALTERNATIVES

Component	Circular Mechanical-draft Cooling Towers (Selected)	Rectangular Mechanical-draft Cooling Towers	Natural-draft Cooling Towers
Cooling Towers[b]	$54,919,130	$63,802,725	$74,910,465
Fan Motors and Switchgear	$7,694,540	$8,508,885	---
CWS Pumps	$8,382,745	$8,382,745	$8,382,745
CWS Pump Motors	$6,540,730	$6,540,730	$6,540,730
Piping	$31,074,960	$44,748,165	$28,589,260
Penalties	$96,300,470	$95,827,445	$91,948,640
Total	$204,912,575	$227,794,000	$210,371,840

a) Estimated cost in 2007 dollars per Table 10.1.0-1 of Reference 2. The 1986 dollars from Reference 2, Table 10.1.0-1, were converted to 2007 dollars. The dollar values were converted by applying the Consumer Price Index (CPI) ratio of the June 2007 southern region value (201.675) to the June 1986 value (108.7). CPI data are from the U.S. Department of Labor, Bureau of Labor Statistics.

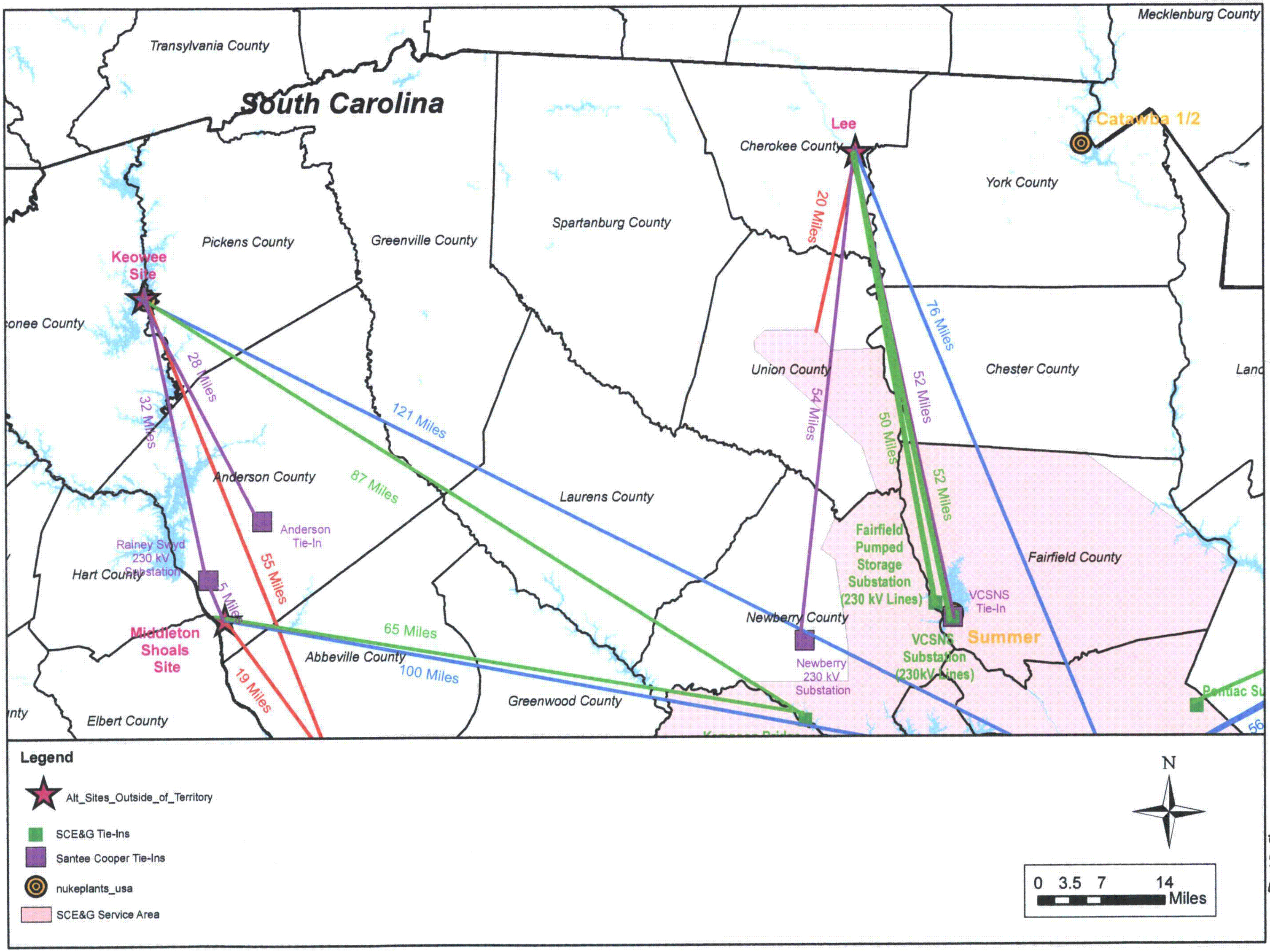
b) Includes cooling tower, precast concrete, erection, and basin.

TABLE 9.4-6 (Sheet 1 of 2)
SUMMARY OF TRANSMISSION LINE SITING CRITERIA RESULTS

		Alternate Routes										
Criterion	Units	A	B	C	D	E	F	G	H	I	J	K
Total Length	Miles	18.54	18.72	18.98	17.46	17.72	16.67	18.22	18.40	18.66	17.14	17.40
Recorded Cultural Resources within 1000 ft.	Count	0	0	0	0	0	0	0	0	0	0	0
Recorded Cultural Resources within 1.2 mi.	Count	0	0	0	0	0	0	0	0	0	0	0
Recorded Rare, Threatened or Endangered Species within 50 ft.	Count	0	0	0	0	0	0	0	0	0	0	0
Lake or Pond	Acres	4.68	4.43	4.49	2.70	2.70	2.47	4.68	4.48	4.49	2.70	2.70
Wetlands, Emergent	Acres	0.48	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00
Wetlands, Forested	Acres	8.81	7.96	8.04	7.06	7.06	6.52	8.81	8.01	8.04	7.06	7.06
Bottomland Forest	Acres	41.76	18.93	20.18	20.01	21.19	14.66	39.29	16.50	17.68	17.55	18.72
Grassland/Pasture	Acres	127.48	159.50	131.26	119.42	90.59	68.39	125.36	157.49	129.10	117.31	88.48
Prime Farmland	Acres	29.66	22.85	21.34	20.42	18.86	14.00	29.66	22.86	21.34	20.42	18.86
Occupied Buildings within 200 ft.	Count	0	0	0	0	0	0	0	0	0	0	0
Future Land Use Agriculture	Acres	458.37	456.12	458.81	391.69	391.69	461.28	445.22	443.79	444.85	378.69	378.69
Future Land Use Industrial	Acres	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

TABLE 9.4-6 (Sheet 2 of 2)
SUMMARY OF TRANSMISSION LINE SITING CRITERIA RESULTS

Criterion	Units	Alternate Routes									
		L	M	N	O	P	Q	R	S	T	U
Total Length	Miles	16.35	13.78	14.37	13.90	13.55	14.78	13.73	16.93	17.22	16.71
Recorded Cultural Resources within 1000 ft.	Count	0	0	0	0	1	1	1	0	2	2
Recorded Cultural Resources within 1.2 mi.	Count	0	0	3	3	5	5	7	12	18	11
Recorded Rare, Threatened or Endangered Species within 50 ft.	Count	0	0	0	0	0	0	0	0	0	0
Lake or Pond	Acres	2.47	0.91	2.97	1.72	5.76	5.73	2.89	3.59	2.45	2.45
Wetlands, Emergent	Acres	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	2.26
Wetlands, Forested	Acres	6.52	15.72	15.72	0.00	7.69	6.01	7.27	28.86	12.32	5.83
Bottomland Forest	Acres	12.20	38.94	30.95	6.33	25.15	23.11	32.57	36.10	24.98	23.00
Grassland/Pasture	Acres	66.28	72.85	66.20	91.52	139.19	154.96	109.39	139.67	99.32	98.60
Prime Farmland	Acres	14.00	12.42	12.42	24.96	19.14	31.35	35.28	33.40	25.33	12.48
Occupied Buildings within 200 ft.	Count	0	0	0	0	0	0	0	0	0	0
Future Land Use Agriculture	Acres	448.26	366.18	390.74	379.73	422.55	541.59	404.94	538.58	549.38	552.01
Future Land Use Industrial	Acres	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00



ALT 2-1
Duke Sites