

December 28, 1989

Docket No. 50-395

Mr. O. S. Bradham
Vice President, Nuclear Operations
South Carolina Electric & Gas Company
Virgil C. Summer Nuclear Station
Post Office Box 88 (Mail Code)
Jenkinsville, South Carolina 29065

SUBJECT: ENVIRONMENTAL ASSESSMENT FOR EXTENSION OF LICENSE EXPIRATION DATE -
V. C. SUMMER NUCLEAR STATION, UNIT NO. 1 (TAC NO. 59402)

Dear Mr. Bradham:

Enclosed for your information is a copy of the Environmental Assessment associated with the extension of the V. C. Summer Nuclear Station, Unit No. 1, Operating License expiration date and a copy of a "Notice of Environmental Assessment and Finding of No Significant Impact" which will be published in the Federal Register. These documents relate to your request dated August 2, 1985, as supplemented March 30, 1988, June 15, 1989 and September 1, 1989, for a license amendment for the V.C. Summer Nuclear Station, Unit No. 1, to change the expiration date of Facility Operating License NPF-12 from March 21, 2013 to August 6, 2022.

Sincerely,

JJH
John J. Hayes, Jr., Project Manager
Project Directorate II-1
Division of Reactor Projects - I/II

Enclosure:
As stated

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Mr. O. S. Bradham
South Carolina Electric & Gas Company

Virgil C. Summer Nuclear Station

cc:

Mr. William A. Williams, Jr.
Technical Assistant - Nuclear Operations
Santee Cooper
P. O. Box 764 (Mail Code 153)
Columbia, South Carolina 29218

J. B. Knotts, Jr., Esq.
Bishop, Cook, Purcell
and Reynolds
1400 L Street, N.W.
Washington, D. C. 20005-3502

Resident Inspector/Summer NPS
c/o U.S. Nuclear Regulatory Commission
Route 1, Box 64
Jenkinsville, South Carolina 29065

Regional Administrator, Region II
U.S. Nuclear Regulatory Commission,
101 Marietta Street, N.W., Suite 2900
Atlanta, Georgia 30323

Chairman, Fairfield County Council
P. O. Box 293
Winnsboro, South Carolina 29180

Mr. Heyward G. Shealy, Chief
Bureau of Radiological Health
South Carolina Department of Health
and Environmental Control
2600 Bull Street
Columbia, South Carolina 29201

South Carolina Electric & Gas Company
Mr. A. R. Koon, Jr., Manager
Nuclear Licensing
Virgil C. Summer Nuclear Station
P. O. Box 88
Jenkinsville, South Carolina 29065

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SUMMER FILE

ENVIRONMENTAL ASSESSMENT
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
RELATING TO THE CHANGE IN EXPIRATION DATE OF
FACILITY OPERATING LICENSE NO. NPF-12
V.C. SUMMER NUCLEAR POWER STATION, UNIT 1
DOCKET NO. 50-395

1.0 INTRODUCTION

The V.C. Summer Nuclear Station, Unit No. 1 (Summer Station, Summer or the plant) is currently licensed for operation for 40 years commencing with the issuance of the construction permit. The license expires on March 21, 2013. By letter dated August 2, 1985, as supplemented March 30, 1988, June 15, 1989, and September 1, 1989, South Carolina Electric & Gas Company (the licensee) requested that the license expiration date for Summer be extended to August 6, 2022 or 40 years after the date of issuance of the operating license.

2.0 NEED FOR THE PROPOSED ACTION

The granting of this request would allow the licensee to operate the plant for nine years and four months beyond the current license expiration date. This extension would permit the plant to operate for the full 40 year design basis lifetime, consistent with previously issued Commission policy (Memorandum dated August 16, 1982 from William J. Dircks to the Commissioners), as evidenced by issuance of similar extensions to other licensees, e.g. March 17, 1987 License Amendment Nos. 107 and 110 issued to Wisconsin Electric Power Company for the Point Beach Nuclear Plant, Units 1 and 2.

3.0 ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

In May 1981, the Nuclear Regulatory Commission issued the "Final - Environmental Statement Related to the Operation of the Virgil C. Summer Nuclear Station, Unit No. 1," NUREG-0719 (FES). The staff has reviewed the FES and the additional information provided by the licensee to determine the environmental impact of operation of the Summer Station for an additional nine years.

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The FES for the Summer Station projected the impact of the operation of the station on the surrounding environment. Impacts included those associated with radiological and non-radiological areas. As a result of the request for the extension, the licensee had to compare actual impacts of operation of the Summer Station with those projected in the FES. In addition, the licensee had to project what the impact would be as a result of the additional years of operation. The staff has evaluated this information and the conclusions follow.

4.0 RADIOLOGICAL IMPACTS

The staff has compared previous estimates of offsite radiological impacts for 30 years of operation with the impact of 40 years of operation derived from estimates for similar light water reactors. The following is the staff's evaluation.

4.1 Radiological Impacts - General Public

In the FES, the staff calculated dose commitments to the human population residing around the Summer Station to assess the impact on nearby residents from radioactive material released to the environment. As used in the FES, the dose commitment estimated was that dose which would be received over a 50-year period following the intake of radioactive materials for one year, based on the environmental concentrations that would exist 15 years after the plant began operation. The 15 year period was chosen as representing the midpoint of plant operation and was incorporated into the dose models to allow for buildup of long-lived radionuclides in the environment (e.g., soil and shoreline sediments). For a plant licensed for 40 years, increasing the buildup period from 15 to 20 years would increase the dose from long-lived radionuclides via the ingestion pathways by about one-third. It would have much less effect on the projected dose from shorter-lived radionuclides.

Maximum doses projected for a critical receptor were a thyroid dose of 0.17 rem per year, via the inhalation pathway, for a child located 1.2 miles east of the plant, and 0.01 mrem per year, via the water ingestion pathway. The thyroid dose is principally due to I-131, a radionuclide with a relatively short half-life. The water ingestion dose is due to both long- and short-lived nuclides. Table 4-1 presents offsite dose calculations based on actual effluent releases for the period January 1, 1982, through December 31, 1988. The calculated offsite doses (Reference 1) are typical of each year of operation of Summer and are expected to remain typical of plant operations through the year 2022.

The staff considered the radiological impacts expected as a result of hypothetical design basis accidents at Summer and from normal plant operation. The estimated impacts of postulated design basis accidents are related to power level and short-lived radionuclides, rather than to length of operation; thus, the results presented in the FES are not changed.

In the Summer Safety Evaluation Report (SER) for operation (Reference 2) and the FES, the staff evaluated the regional demography for Summer and found the land area within a 25 mile radius, as indicated by the population statistics, to be about 91 percent woodlands and 7 percent agriculture. The remaining area is devoted primarily to general farming and small industry. The FES projected a 14.5 percent increase in population within 50 miles of the facility from 1970 to 1979, and a 63 percent increase from 1979 to 2010. Based on 1980 census data, the level of population projected in the FES for 1980 is close to the 1980 census data. The staff also projected in the FES an upward trend in the population of the region for the years 1990 and 2000. For example, FES Table 2.1, projected for the years 1990 and 2000 a population increase from 566,750 to 753,000. However, based on the 1980 census data, the licensee's projected populations for these years are 523,220 and 587,000, respectively.

The staff, therefore, concludes that projected population distributions, as related to the requested extension of the Summer operating license, are adequately bounded by the FES. The staff further concludes, based upon these population estimates, that the current Exclusion Area Boundary, Low Population Zone, and nearest population center distance will likely remain unchanged in the foreseeable future. Therefore, the conclusion reached in the SER that Summer meets the requirements of 10 CFR Part 100, remains unchanged.

4.2 Environmental Impacts-Uranium Fuel Cycle

The impacts of the uranium fuel cycle as considered for the FES were originally based on 30 years of operation of a model light water reactor (LWR). The fuel requirements for the model LWR were assumed to be one initial core load and 29 annual refuelings (approximately 1/3 core per refueling). In considering the annual fuel requirement for 40 years of operation for the model LWR, fuel use is averaged over a 40-year operating life, which results in a slight reduction compared to the annual fuel requirement averaged for a 30-year operating life. The net result is an approximately 1.5 percent reduction in the annual fuel requirements for the model LWR, due to averaging of the initial core load over 40 years, instead of 30 years. This small reduction in fuel requirements would not lead to significant changes in the annual impacts of the uranium fuel cycle.

The Summer Station switched to 18 months refueling outages following the second refueling outage in September 1985. The switch to the longer operating cycle does not change the above conclusions.

4.3 Environmental Impacts - Occupational Exposures

The staff has evaluated the licensee's occupational dose assessment for the additional years during which Summer would operate and compared it with current Summer and overall industry occupational dose experience.

The FES stated that it was impossible to determine in advance a specific year to year or average annual occupational radiation dose for a particular plant over its operating lifetime. However, the staff projected that the occupational doses at Summer could average as much as 1300 person-rem/yr. when averaged over the life-of-the-plant.

The average occupational collective dose at Summer over the recent six year period covering 1982-1988 is 354 person-rem per year (Reference 3). By comparison, the annual collective dose per reactor unit for other U.S. pressurized water reactors during this same period averaged 450 person-rem per reactor-year (Reference 3).

The licensee has projected that an average annual collective dose of 400 person-rem will be incurred for each additional year of operation. The total occupational dose expected over the period of the operating license extension is 3600 person-rem and is based on additional refuelings during this period, with no major unanticipated maintenance. The licensee expects that increased doses from increased maintenance and corrosion product build-up will be offset by a continually improving ALARA (as low as reasonable achievable) program, dose-saving plant modifications, reduced requirements for TMI-required modifications and the use of robotics.

The staff concludes that the licensee's occupational dose assessment is reasonable, and their radiation protection program is adequate to ensure that occupational radiation exposures will be maintained ALARA, in continued compliance with the requirements of 10 CFR Part 20, and enveloped by the values projected in the FES.

4.4 Environmental Impacts - Transportation of Fuel and Waste

The staff reviewed the environmental impacts attributable to the transportation of fuel waste to and from the Summer site. With respect to the normal conditions of transport and possible accidents in transport, the staff concludes that the environmental impacts are adequately bounded by those identified in Table S-4, "Environmental Impact of Transportation of Fuel and Waste To and From One Light Water-Cooled Nuclear Power Reactor," of 10 CFR 51.52. Table S-4 represents the contribution of such transportation to annual radiation dose per reactor year to exposed transportation workers and to the general public. Table S-4 is based on an annual refueling and an assumption of 60 spent-fuel shipments per reactor year. Presently, Summer is on a 18-month refueling cycle, which would require less than 30 spent fuel shipments per reactor year. Reducing the number of fuel shipments will reduce the overall impacts related to population exposure and accidents discussed in Table S-4.

Spent fuel will be stored in the reracked, high density spent fuel pool (previously evaluated by the staff for radiological environmental consequences). This will reduce offsite exposures since the radioactivity in the fuel will decay longer before shipment than originally stated in the FES. Any further expansion of onsite spent fuel storage capacity (such as through rod-consolidation) will be further evaluated for radiological environmental effects by the NRC staff when and if it is proposed.

The licensee's radioactive waste (radwaste) shipments have been only slightly higher than the PWR industry average (278.6 m³/year versus 223.9 m³/year) (Reference 1). Moreover, the recent installation of a "super compactor" is a commitment by SCE&G to reduce the volume of annual radioactive waste shipments to ALARA levels. Based on this information, the volume of radioactive waste shipped in the years of the extension should remain significantly lower than the FES predictions and represents a small percentage of the total volume generated over the life of the plant.

4.5 Decommissioning

The staff has evaluated the impact of the proposed extension on decommissioning of the unit and concludes that there will be no significant impact. SCE&G will submit an initial decommissioning report to the NRC by July 26, 1990. Also, it will submit its proposed decommissioning plan for review at or about five years before the expected termination of operations. The staff will review these at the appropriate time.

4.6 Conclusions

Based on the above considerations, the projected annual radiation dose to individuals and populations would not be changed significantly over the proposed extended period of operation. Therefore, the staff concludes that the environmental impacts associated with extending the operating license duration by about 10 years are not significantly different from those previously assessed in the FES and are acceptable.

5.0 NON-RADIOLOGICAL ENVIRONMENTAL IMPACTS

5.1 Land Use

The FES addressed the impact of operation of the Summer Station in terms of the amount of acreage committed to the project, the land which would be taken out of production, and population growth resulting from the operation of the Summer Station.

As a result of the operation of the Summer Station the amount of land committed to the project has not increased. Therefore, the amount of land taken out of production remains the same as that projected in the FES. The estimate in the FES of the population growth resulting from the in-migration of workers both for jobs at the plant itself and for service related industries stimulated by plant operations has been small compared to the related existing population in the Central Midlands region of South Carolina. Land which was utilized for transmission line corridors has

not resulted in the permanent loss of farmland since farming activities have been able to continue during this period. The licensee has evaluated the impact of the license extension and has determined that there will not be any additional land use impacts as a result of the extension.

The staff has reviewed the above information and has concluded that the extension of the operating license is not expected to have a significant environmental impact on land use.

5.2 Hydrological Impacts of Operation

The FES for Summer addressed the impact of operation on surface water, ground water, with respect to the discharge of sanitary and chemical wastes, water quality, and thermal effects on the Monticello Reservoir.

Discharges from the Summer Station are limited by the National Pollutant Discharge Elimination System (NPDES) permit issued by the South Carolina Department of Health and Environmental Control (DHEC). The permit expired in June 1989 and a renewal application was forwarded in December 1988.

The licensee has confirmed in thermal mapping studies that the evaporative losses resulting from operation of the Summer Station are bounded by the information presented in their Operating License Environmental Report and the FES. The thermal plume area limits imposed by the Summer NPDES Permit have never been exceeded. Under the worse meteorological conditions the evaporative water losses would be equal to those presented in the FES.

A study by the licensee indicated that there has not been any significant reduction in water quality as a result of the operation of the Summer Station. Turbidity levels of the Monticello Reservoir are lower than those of the Parr Reservoir which is located adjacent to the Monticello Reservoir.

The discharge of chemical and sanitary wastes is controlled by the Summer NPDES permit. The effluent levels of this permit are routinely met. However, there has been some growth of algae and rapid photosynthesis in the treatment ponds which has caused the pH limit to be exceeded during certain times in the summer months. The licensee has requested and has received approval from DHEC to utilize chemicals to control the growth of algae. The licensee has also received permission from DHEC to use boric acid on the secondary side of the plant to control corrosion. The discharge of the boron is monitored.

The licensee indicated that there was a rise in the groundwater level onsite as a result of the filling of Monticello Reservoir. They have assumed that similar increases in level have been experienced in groundwater of adjacent properties which are not owned by the licensee. However, as noted in the FES, the main hydrological impact of the site is a result of the operation of the Fairfield Pump Storage Facility. Therefore, irrespective of the extension of the operating license, reservoir levels necessary to support the operation of the Fairfield Pump Storage Facility

would still affect groundwater levels and wells adjacent to the reservoir. Measurement of radioactivity from two onsite and offsite wells has not shown any radiological contamination of groundwater. However, one onsite well has shown low level contamination due to surface run-off of rain water containing airborne emissions.

The licensee has projected that the hydrological impact as a result of the extension would be no different than that which has occurred as a result of the present operation of the Summer Station. In addition, discharges are limited by the requirements of DHEC.

The staff has reviewed the information and analyses provided by the licensee and has concluded that the extension of the operating license is not expected to have a significant environmental impact.

5.3. Impact on Biota

5.3.1 Terrestrial

The FES discussed the impact of operation on the terrestrial biota. This impact assessment included the impact of the Summer Station and the transmission lines.

The licensee indicated that infrared photography had revealed no loss of plant vigor around the station. Bird surveys revealed no differences between the preoperational and operational data with the exception of the composition and numbers of waterfowl and wading birds due to the creation of the Monticello Reservoir. The licensee has altered their transmission line corridor maintenance to limit the use of broadcast herbicides to those areas where it is impractical to mow. The effects of operation have been determined to be minimal, as was predicted by the FES.

The licensee has determined that the extension is not likely to result in a change in the impact on terrestrial biota from that which has occurred during past operation.

The staff has reviewed the licensee's evaluation and analyses and has concluded that the extension of the operating license is not likely to result in a significant environmental impact.

5.3.2 Aquatic Biota

The FES addressed the impact of discharges from the Summer Station on phytoplankton, zooplankton, benthic invertebrates, and fish. In addition, the impact of the thermal discharges on the Broad/Congaree River were projected. The impact of cooling water system impingement and entrainment were projected as were the levels of dissolved oxygen (DO) in the Monticello Reservoir.

The licensee conducted preoperational and operational studies of the aquatic biota in the Parr and Monticello Reservoirs. Operational data indicate that the effects of the thermal discharge are limited to the southeast portion of the Monticello Reservoir and away from the discharge into the Parr Reservoir and the Broad River. Thermal limits, as stated in the NPDES permit, have never been exceeded in the discharge temperature, the plume measured at the Fairfield Pump Storage Facility, or in the plume temperature rise. A thermal plume study indicated that the thermal discharge into the Parr Reservoir should not affect the striped bass spawning downstream in the Congaree River. However, the thermal discharge may result in a general trend of earlier fish spawning in the Monticello Reservoir. Benthic organism densities are lower in the vicinity of the thermal discharge. Hot weather fish kills have occurred in the discharge canal and when the plant has experienced a reactor trip with the kill number ranging from several up to several hundred. Discussions have been held with DHEC and the South Carolina Wildlife and Marine Resources Department on possible mitigative actions.

The thermal discharges have had no apparent effect on the DO level in the Monticello Reservoir although low DO levels were found in deep, stratified areas of the reservoir, but this is unrelated to the operation of the Summer Station. Chemical discharges have been as projected in the FES. The licensee has received approval from DHEC to use a biocide to treat the Summer Station's service water system for Asiatic clams.

The licensee conducted impingement and entrainment studies of their circulating water system. As a result of these studies, they determined that, although fish were being removed through impingement, the overall effect on the adult fish population was minimal. Entrainment losses were determined to have no apparent ill effects on the fish population of the Monticello Reservoir.

The licensee has assessed the impact of the additional years of operation associated with the license extension. They have concluded that the impact of the additional years of operation should be no different than that associated with the present operation of the Summer Station.

The staff has evaluated the licensee's assessment and has concluded that the impact on aquatic biota as a result of the extension of the operating license does not impose a significant environmental impact.

6.0 OTHER NON-RADIOLOGICAL IMPACTS

6.1 Socioeconomic Impacts

The FES projected the impact of the operation of the Summer Station on the labor force and the economics of the area. In addition, the impact on recreational activities was also assessed, as well as the impact on historic and archaeological sites.

The number of employees at the Summer Station was 660 as of June 1989. This compares to a figure of 213 as projected by the FES. Some of the increase can be attributed to the relocation of management, licensing, and engineering staff from the company headquarters in Columbia to the site. The operation of the plant has not resulted in an influx of people into the area around the plant. The growth has been moderate as predicted by the FES.

The amount of taxes paid to Fairfield County as a result of the operation of the Summer Station is almost \$8 million which represents almost 70% of the total property taxes collected by the county. In addition, the amount paid is expected to increase by \$2 million due to the expiration of the manufacturers' five year exemption. The existing contribution is significantly more than that projected in the FES.

The FES indicated that the operation of the Summer Station created a 300 acre sub-impoundment for a fishing lake and swimming, boating, and picnic activities. However, the FES predicted that this area would only have minimal use. The licensee has confirmed that utilization has been minimal.

The licensee indicated that there were no new historical or archaeological sites identified since the issuance of the FES. In addition, they indicated that the license extension will not affect the historic character or the public use of the three sites located near the Summer Station.

The licensee has indicated that the extension of the operating license for the Summer Station is not anticipated to change the socioeconomic impact on the area.

The staff has reviewed the licensee's evaluation and has concluded that the impact on the socioeconomics of the area will not be a significant impact as a result of the extension.

6.2 Short Term Uses Versus Long Term Productivity

The FES indicated that the evaluation of short term uses would be that associated with the period of construction and operation of the station and that long term productivity would be that period beyond the service life of the facility. The FES stated that short term uses would involve forest land and agricultural productivity with no serious impacts. The FES also indicated for the long-term approximately 200 acres would be affected with the remaining portion of the land restored to its natural vegetation. The licensee determined that the impact of the extension was already covered by the FES.

The staff has reviewed the licensee's determination and has concluded that the short-term uses versus long-term productivity remain virtually unchanged and will not result in a significant impact as a result of the extension.

6.3 Irreversible and Irretrievable Commitment of Resources

The FES indicated that the resources that may be irreversibly committed by operation are: (1) biological species or species populations destroyed, (2) unrecoverable construction materials, (3) materials rendered radioactive that cannot be decontaminated or uranium fuel consumed, (4) air and water resources lost, and (5) land areas rendered permanently unfit for other uses.

The licensee determined that the proposed extension in the operating license will not result in any significant irreversible impact on biotic resources or on water and air resources, nor will it require additional construction materials. Most of the radioactive contamination of structures, systems, and components occurred relatively early in the facility life so that the extended period of operation should not cause significant additional material to become permanently contaminated. With respect to land resources, the land utilized for the site, as well as transmission corridors, is not generally considered irreversible or irretrievably committed in the long-term. The only irreversible and irretrievable commitment of resources that would result from the extended period of operation is the additional uranium fuel that would be consumed or reduced to unrecoverable waste.

The staff has reviewed the licensee's determination and has concluded that the irreversible and irretrievable commitment of resources as a result of the extension will not result in a significant impact.

7.0 PLANT MODIFICATIONS

The Summer Station has procedures which govern the manner in which modifications are made to the facility under 10 CFR 50.59. This procedure calls for the determination of whether the proposed modification will result in an increase in radiation doses or will alter chemical or thermal releases to the environment. Where necessary environmental approvals or permits are required, DHEC is the typical agency from which approval is requested. If the proposed modification involves an "unreviewed safety question" or a change in the Technical Specifications, then NRC approval is required. The NRC is annually updated with respect to the changes made under 10 CFR 50.59. Those modifications which have been made and are environmental in nature include:

- 1) change of the water supply to the circulating water pump motor bearing coolers from raw water to filtered water;
- 2) addition of a 5,000 gallon collection tank for collection and holdup of water from the refueling water storage tank;
- 3) addition of two buildings within the protected area for computer office space and maintenance activities; and

- 4) a monitoring system to detect water accumulation in underground tanks as well as leakage.

Other modifications which are being considered include:

- 1) steam generators replacement due to their continually degrading condition;
- 2) installation of a biocide treatment system to the service water system to prevent Asiatic clam growth;
- 3) installation of an oil incinerator to reduce the amount of radioactive waste required to be disposed; and
- 4) removal of the RTD manifold system with replacement using wall-mounted RTD's to reduce occupational doses.

While it is recognized that the requested license extension could possibly cause further routine design changes and modifications similar in nature to those already conducted, it is not anticipated that these would have an adverse effect on the environment. Those that possibly could, would be reviewed by the NRC or the appropriate state, local, or Federal agency prior to implementation.

8.0 CONCLUSION ON ENVIRONMENTAL IMPACTS

Based on the above, the staff concludes that the proposed extension would not have any significant impact on the environment.

9.0 ALTERNATIVES TO THE PROPOSED ACTION

One alternative to issuance of the proposed license extension would be to deny the application. This would require the plant to shut down upon expiration of the current operating license. Another alternative, is the construction of a fluidized bed coal plant to replace the Summer Station. Extension of the operating license would involve little or no additional capital costs for the period of the extension, whereas capital costs associated with new fossil fuel replacement generating stations would be significant. Environmental impacts related to extending the operating life of the plant, including the fuel cycle and transportation impacts, remain small when compared to impacts related to fossil plant electrical generation.

10.0 ALTERNATIVE USE OF RESOURCES

This action does not involve the use of resources not previously related to the operation of the plant.

11.0 AGENCIES AND PERSONS CONSULTED

In the course of our review of licensee's request, the staff contacted the South Carolina Department of Health and Environmental Control.

12.0 BASIS AND CONCLUSION FOR NOT PREPARING AN ENVIRONMENTAL IMPACT STATEMENT

The staff has reviewed the proposed license amendment relative to the requirements set forth in 10 CFR Part 51. Based on this assessment, the staff concludes that there are no significant radiological or non-radiological impacts associated with the proposed action and that the issuance of the proposed license amendment will have no significant impact on the quality of the human environment. Therefore, pursuant to 10 CFR 51.31, an environmental impact statement need not be prepared for this action.

Principal Contributors: J. Minns
J. Hayes, Jr.

Dated: December 28, 1989

REFERENCES

1. Semiannual Effluent and Waste Disposal Report for Operating Period January 1981 to December 1988, V. C. Summer Nuclear Station, South Carolina Electric & Gas Company
2. Safety Evaluation Report Related to the Operation of Summer Unit 1, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, February 1981. (NUREG-0717).
3. NUREG/CR-1850, Volume 6, "Occupational Radiation Exposure at Commercial Nuclear Power Plants and Other Facilities," January 1988.
4. NRC's Decommissioning Rule, 10 CFR Part 50.33(k), and 10 CFR Part 50.75, "Reporting and Recordkeeping for Decommissioning Planning."

Table 4-1

Comparison Between Summer Average Annual Offsite Individual Doses
and

FES Projections and 10 CFR 50 Appendix I Dose Design Objectives

Doses (mrem/year or mrad/year)

<u>Gaseous Effluents</u>	<u>Summer Average</u>	<u>FES Table 4.8</u>	<u>10 CFR 50 Appendix I</u>
<u>Noble Gases</u>			
Gamma Air Dose	0.019	0.23	10
Beta Air Dose	0.063	0.57	20
<u>Iodines and Particulates</u>			
Organ	0.0074	0.75	15
<u>Liquid Effluent</u>			
Total Body	0.064	0.05	3
Organ ¹	0.15	0.06	10

1. Includes thyroid, liver and bone; by water and fish ingestion pathways.