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OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

December 11, 2006

VIA US MAIL

Office of the Secretary of the Commission
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Re: *Southern Nuclear Operating Company, Inc., Plant Vogtle Early Site Permit; Docket No. 52-011*

To The Rulemaking and Adjudications Staff:

Enclosed please find a Petition for Intervention submitted by Center for a Sustainable Coast, Savannah Riverkeeper, Southern Alliance for Clean Energy ("SACE"), Atlanta Women's Action for New Direction ("WAND"), and Blue Ridge Environmental Defense Fund ("BREDL").

Sincerely,

Mary Maclean Asbill
Director

cc: Office of General Counsel
~~Office of the Secretary~~
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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
	)	
Early Site Permit for Plant Vogtle ESP Site	)	
	)	

PETITION FOR INTERVENTION

I. INTRODUCTION

Pursuant to 10 C.F.R. § 2.309, 10 C.F.R. § 52.21, and a notice published by the Nuclear Regulatory Commission ("NRC" or "Commission") at 71 Fed. Reg. 60,195 (October 12, 2006), Petitioners Center for a Sustainable Coast, Savannah Riverkeeper, Southern Alliance for Clean Energy ("SACE"), Atlanta Women's Action for New Directions ("WAND"), and Blue Ridge Environmental Defense League ("BREDL), hereby submit their contentions regarding Southern Nuclear Operating Company, Inc. ("SNC") application for an Early Site Permit ("ESP") that would allow it to build and operate two new nuclear reactors on the site of the Plant Vogtle nuclear power plant ("Plant Vogtle"). As demonstrated below, these contentions should be admitted because they satisfy the NRC's admissibility requirements in 10 C.F.R. § 2.309.

Description of the Proceeding

This proceeding concerns an application by SNC for an ESP for construction of two additional nuclear reactors on the Plant Vogtle site. SNC submitted its ESP application on August 15, 2006. Notice of Receipt and Availability of the Application was published in 71 Fed. Reg. 51,222 (August 29, 2006). The application requested approval of two nuclear reactors located at the Plant Vogtle site in Waynesboro, Georgia. The application was accepted for docketing on September 19, 2006 and Notice of Acceptance for Docketing of Application for Early Site Permit (ESP) for the Vogtle ESP Site was published in 71 Fed. Reg. 56,187 (September 26, 2006).

Description of Petitioners

Center for Sustainable Coast is a non-profit membership-supported organization defending the public interest in issues related to coastal Georgia's growth, economy, and environment. The Center combines education, advocacy, technical assistance, and legal action to implement its comprehensive mission, which is the conservation and sustainable use of the region's resources – natural, historic, and economic.

Savannah Riverkeeper is a private, non-profit, advocacy group dedicated to preserving, protecting and restoring the Savannah River. Savannah Riverkeeper's mission is to protect the water quality of the Savannah River and the integrity of its watershed. Savannah Riverkeeper has approximately 100 members, with an additional 400-500 volunteers.

SACE is a nonprofit, nonpartisan membership organization that promotes responsible energy choices that solve global warming problems and ensure clean, safe and healthy communities throughout the Southeast. SACE has staff and members throughout the Southeast, including offices in Atlanta and Savannah, Georgia.

WAND is a non-profit, membership organization incorporated in the state of Georgia. It is also a chapter of a national organization, Women's Action for New Directions. WAND's mission is to act politically to reduce violence, and to redirect excessive military resources toward unmet human and environmental needs. WAND also works on issues surrounding health and social justice.

BREDL is a regional, community-based non-profit environmental organization whose founding principles are earth stewardship, environmental democracy, social justice, and community empowerment. BREDL encourages government agencies and citizens to take responsibility for conserving and protecting our natural resources. BREDL advocates grassroots involvement to empower whole communities in environmental issues. BREDL also functions as a "watchdog" of the environment, monitoring issues and holding government officials accountable for their actions.

Standing

Pursuant to 10 CFR § 2.309, a request for hearing must:

> set forth with particularity the interest of the petitioner in the proceeding, how that interest may be affected by the results of the proceeding, including the reasons why the petitioner should be permitted to intervene with particular reference to the factors set forth in 10 CFR § 2.309 (d)(1), and the specific aspect or aspects of the subject matter of the proceeding as to which the petitioner wishes to intervene.

In addition, the request for hearing must address: (1) the nature of the petitioner's right under the Atomic Energy Act to be made a party to the proceeding, (2) the nature and extent of the petitioner's property, financial, or other interest in the proceeding, and (3) the possible effect of any order that may be entered in the proceeding on the petitioner's interest. *Id*

The Atomic Safety and Licensing Board ("ASLB") summarized these standing requirements as follows:

> In determining whether a petitioner has sufficient interest to intervene in a proceeding, the Commission has traditionally applied judicial concepts of standing. *See Metropolitan Edison Co.* (Three Mile Island Nuclear station, Unit l), CLI-83-25, 18 NRC 327, 332 (1983) (citing *Portland General Electric Co.* (Pebble Springs Nuclear Plant, Units 1 and 2), CLI-76-27, 4 NRC 610 (1976)). Contemporaneous judicial standards for standing require a petitioner to demonstrate that (1) it has suffered or will suffer a distinct and palpable harm that constitutes injury-in-fact within the zone of interests arguably protected by the

governing statutes (e.g., the Atomic Energy Act of 1954 (AEA), the National Environmental Policy Act of 1969 (NEPA)); (2) the injury can be fairly traced to the challenged action; and (3) the injury is likely to be redressed by a favorable decision. *See Carolina Power & Light Co.* (Shearon Harris Nuclear Power Plants), LBP-99-25, 50 NRC 25, 29 (1999). An organization that wishes to intervene in a proceeding may do so either in its own right by demonstrating harm to its organizational interests, or in a representational capacity by demonstrating harm to its members. *See Hydro Resources, Inc.* (2929 Coors Road, Suite 101, Albuquerque, NM 87120), LBP-98-9,47 NRC 261,271 (1998). To intervene in a representational capacity, an organization must show not only that at least one of its members would fulfill the standing requirements, but also that he or she has authorized the organization to represent his or her interests. *See Private Fuel 3 Storage, L. L. C.* (Independent Fuel Storage Installation), LBP-98-7, 47 NRC 142, 168, *a f d on other grounds,* CLI-98- 13,48 NRC 26 (1998).

Pacific Gas & Electric Co. (Diablo Canyon Power Plant Independent Spent Fuel Storage Installation), LBP-02-23,56 NRC 4 13,426 (2002) (hereinafter *"Diablo Canyon*").

Petitioners' standing to participate in this proceeding is demonstrated by the declarations of the following members of Petitioner organizations, who have authorized Petitioners to represent their interests in this proceeding.

Susan Bloomfield, SACE member
David Matos, SACE member
William J. Mareska, SACE member and Savannah Riverkeeper member
Frank Carl, Savannah Riverkeeper member, and Executive Director
Mike Stacy, Savannah Riverkeeper member
Sam Booher, Center for a Sustainable Coast member
Judy Jennings, Center for a Sustainable Coast member
Karen Grainey, Center for a Sustainable Coast member
Terence Alton Dicks, Atlanta WAND member
Judith Lorraine Stocker, Altanta WAND member
Gwendolyn Walker, Atlanta WAND member
Carey K. Barber, BREDL member
Audra Roper, BREDL member
Kia Luke, BREDL member
Charles W. Barber, Sr., BREDL member
Mildred L. Walker, BREDL member
Cicero Luke, BREDL member
Cynthia Richardson, BREDL member
Shirley Coleman, BREDL member
Heather Oglesby, BREDL member
Clarence Guidry, BREDL member

Holice C. McClain, Sr., BREDL member
Marvin McRae, BREDL member
Cora L. Moore, BREDL member
Melvin Lee Avery, BREDL member
Bernice Bussey, BREDL member
Rosalyn Conyers, BREDL member

The attached declarations demonstrate that Petitioners' members live near the proposed site, i.e., within 50 miles. Therefore, Petitioners have presumptive standing by virtue of their proximity to the new nuclear plant that may be constructed on the site. *Diablo Canyon, supra,* 56 NRC at 426-427, citing *Florida Power & Light Co.* (Turkey Point Nuclear Generating Plant, Units 3 and 4), LBP-01-6, 53 NRC 138, 146, *aff'd,* CLI-01-17, 54 NRC 3 (2001) (hereinafter *"Florida Power & Light"*).[1]

Petitioners seek to protect their members' health, safety and lives, as well as the health and safety of the general public and the environment by opposing construction of any new reactors at Plant Vogtle through intervention in the Vogtle ESP proceeding. Petitioners seek to ensure that no ESP is issued by the NRC unless SNC demonstrates full compliance with the Atomic Energy Act, National Environmental Policy Act ("NEPA"), the Endangered Species Act ("ESA"), as well as with applicable Georgia state law.

Specific Aspects of the Subject Matter As To Which Petitioner Seeks to Intervene

As required by the Federal Register notice, Petitioners set forth below the specific aspects of the subject matter of this proceeding as to which they wish to intervene:

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[1] In *Diablo Canyon,* the Licensing Board noted that petitioners who live within 50 miles of a proposed nuclear power plant are presumed to have standing in reactor construction permit and operating license cases because there is an "obvious potential for offsite consequences" within that distance. *Id.* Here, the granting of an Early Site Permit to Exelon would facilitate the granting of a construction permit and operating license for a new reactor on the Clinton site. Thus, the same standing concepts apply.

1) Whether SNC has adequately assessed the impacts of the ESP on fishery resources of the Savannah River;
2) Whether SNC has adequately assessed the impacts of the ESP on the minority and low-income populations of the area surrounding Plant Vogtle;
3) Whether SNC failed to evaluate whether and in what time frame spent fuel generated by the proposed reactors can be safely disposed of;
4) Whether SNC failed to address environmental impacts of intentional attacks; and
5) Whether SNC failed to adequately evaluate energy alternatives.

Contention 1: Impacts of the ESP on aquatic resources of the Savannah River

The ER does not adequately address the adverse impacts of the proposed cooling water intake and discharge structures on the fishery resources of the Savannah River. In particular, the ER does not assess: (1) The current species diversity, abundance, and habitat utilization in the vicinity of the proposed intake and discharge points; (2) Habitat conditions and flow/habitat relationships in the project area; (3) Cumulative impacts of the existing intake and discharge combined with the proposed new intake and discharge; and (4) Fishery impacts and benefits of alternatives to the proposed action. Thus, the ER does not "contain sufficient data to aid the Commission in its development of an independent analysis" of environmental impacts pursuant to NEPA. 10 C.F.R. § 51.45(b).

The Savannah River supports at least 98 fish species representing 24 families including anadromous, diadromous and resident fish.[2] Some common freshwater resident fish in the

[2] Marcy, B. C., D. E. Fletcher, F. D. Martin, M. H. Paller, and M. Reichert. 2005. Fishes of the Middle Savannah River Basin. The University of Georgia Press. Athens, GA, Table 3 (Exhibit 1.1)

project area include largemouth bass, bluegill, redbreast sunfish, channel catfish, golden shiner, longnose gar, chain pickerel, white bass, pickerel, northern hogsucker, spotted suckers, notched-lip sucker, brown bullhead, yellow bullhead, redeye bass, white crappie and black crappie. The Savannah River is the only area of the redeye bass' range that is below the Fall Line.[3] Another freshwater resident, the robust redhorse, was recently rediscovered after being deemed extinct.[4] The Savannah River population is only one of three small sub-populations known to exist. Anadromous and diadromous fish that migrate past the VGEP site include striped bass, American Shad, blueback herring, American eel, Atlantic sturgeon and shortnose sturgeon, a federally listed endangered species.

Contention 1.1: The ER fails to use quantitative analysis and field surveys to assess baseline habitat conditions and species diversity and abundance in the projects area.

Basis:

Every application for a NRC permit, including an ESP, must be accompanied by an ER, which shall discuss: (1) The impacts of the proposed action; (2) Adverse environmental effects that cannot be avoided; (3) Alternatives to the proposed action; (4) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity; and (5) Any irreversible and irretrievable of resources associated with the proposed action. 10 C.F.R. § 51.45(b). The ER "shall include an analysis that considers and balances the environmental effects of the proposed action, the environmental impacts of alternatives to the proposed action, and alternatives available for reducing or avoiding adverse environmental

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[3] *Id.*

[4] *See* Hendricks, A.S. 1998. The conservation and restoration of the robust redhorse, moxostoma robustum, Volume 1. Report to the Federal Energy Regulatory Commission prepared by Georgia Power Company, Environmental Laboratory. Atlanta, GA. at 6-8 (Exhibit 1.2)

impacts." 10 C.F.R. § 51.45(c); 10 C.F.R. § 51.71(d). Further, the environmental analysis "*shall, to the fullest extent practicable, quantify the various factors considered.*" *Id.* (emphasis added).

The ER concludes that impacts to fishery resources are small or non-existent, and do not warrant mitigation. ER § 10.1.3; ER § 5.3.1.2; ER § 5.3.2.2. This conclusion is based on a general description of the Savannah River fishery and does not include a site-specific description of the reach of the Savannah River adjacent to Plant Vogtle where the new intake and discharge structures are proposed. ER § 2.4.2.2. Rather than conducting field studies at the proposed intake and discharge sites, the ER makes selective use of long-term studies of the Savannah River Site ("SRS") that collected data in the vicinity of Plant Vogtle. Declaration of Shawn Young ("Young Declaration") at ¶¶ 6, 9-11, 17, 18. (Exhibit 1.3). Thus, the ER fails to establish an environmental baseline that is the basis for evaluating impacts and alternatives. *Id.*

The ER's analysis of the cooling system intake and discharge structures and operation is not based on field surveys or quantitative analysis. ER § 5.3; 10 C.F.R. § 51.45(c). Thus, the ER fails to identify the current aquatic species assemblage or the presence or absence of threatened, endangered, or rare species in the project area. Similarly, the ER contains no data concerning upstream and downstream migration of anadromous and diadromous species in this section of the Savannah River or their habitat utilization within the project area. Likewise, the ER does not address specific habitat types and utilization by resident and anadromous fish in the project area. Nor does the ER examine flow-habitat relationships and the potential impacts of the project on habitat availability.

The discussion of aquatic species in Chapter 2 of the ER discusses the diverse macroinvertebrate and ichthyofauna of the Middle Savannah River found in the vicinity of VEGP, including resident and diadromous fish species. ER § 2.4.2.2. In contrast, the impacts analysis of the cooling system addresses only a handful of species that are unlikely to be impacted and ignores species with a greater likelihood of adverse impacts. Young Declaration at ¶¶ 16, 17. For example, the ER reveals:

> During spring (March-April), when important anadromous species such as American shad, hickory shad, and blueback herring ascend the Savannah River to spawn, approximately 0.9 to 1.2 percent of the river's average flow and 2.7 to 2.8 percent of the river's 7Q10 flow will pass through the new units.

ER at 5.3-2. However, this discussion fails to mention other times of year when these species may also be present and fails to analyze the impacts of diverting between 0.9 and 2.8 percent of the river's flow on these species.

Analysis of entrainment at intake structures "needs to be performed for specific water bodies."[5] Without detailed, site specific information about species abundance and flow/habitat relationships, it is not possible to evaluate the impacts of the cooling system:

> Evaluation of entrainment in absolute terms of numbers of organisms lost requires coupling the estimates of entrainment from standing crop and the rates of entrainment with data on the organisms obtained in the field. Different fish species will use a different habitat for spawning and in different seasons. The egg and larval densities will vary with habitat and location throughout the water body. Potentially high entrainment from a region determined by the hydrodynamic computations is not important if that region is not used for spawning. Additionally, organisms may not be in that region because of the entrainment. Eggs and larvae of different species will have different natural mortality rates, and mortality rates for the same species can vary with life stage.[6]

The ER fails to evaluate entrainment potential of the proposed intake. The ER's discussion of the potential impacts of the proposed discharge structure is similarly flawed. Although the ER does include a summary of computer modeling of the heat plume, the analysis is not supported by field studies or data that assesses site-specific and species-specific factors.

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[5] Edinger, J.E., *Power Plant Intake Entrainment Analysis*, Journal of Energy Engineering, Vol. 126, Vol. 126, No. 1, April, 2000. pp. 1-2. (Exhibit 1.4).
[6] *Id.*

Contention 1.2: The ER fails to identify and consider direct, indirect, and cumulative impacts of the proposed cooling system intake and discharge structures on aquatic resources.

Basis:

The ER must describe and analyze the environmental impacts of the proposed new ESP. 10 C.F.R. § 51.45(b). Impacts that must be discussed include direct and indirect impacts, and cumulative impacts of the proposed reactors. Cumulative impacts result from the "incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions." 40 C.F.R. § 1508.7.

The ER does not estimate the level of mortality from impingement and entrainment in the new intake structure. As discussed above, the ER does not quantify or describe systematically the species composition and habitat in the vicinity of the intake and cooling structures. As a result, the ER fails to analyze the nature and extent of impacts on aquatic species expected from the new reactors. Instead, the ER mistakenly relies on the performance standards that will be imposed under state-issued water quality permits. Both the intake and discharge are subject to regulation under the Clean Water Act; however, the mere fact that the new structures will comply with the regulatory requirements of the Clean Water Act does not mean that they will not cause significant impacts on aquatic species. The ER must describe and analyze the impacts of the proposed action, as well as the applicable regulatory requirements.

Section 316(b) of the Clean Water Act requires that the location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact. 33 U.S.C. § 1326(b). In 2004, EPA promulgated rules implementing § 316(b) for large existing electric generating plants. 69 Fed. Reg. 41576; 40

C.F.R. § 125.94. Compliance with the performance standards in the regulations is deemed to meet the "best available technology" mandate of the CWA. *Id.* However, more stringent standards may be required if "compliance with the applicable requirements of this section would not meet the requirements of applicable State and Tribal law, or other Federal law." 40 C.F.R. § 125.94(e). Thus, even if the new intake structure complies with the "best available technology" mandate of section 316(b), that does not alleviate the need to analyze the impacts of the intake on aquatic species. The ER must still comply with the Commission's rules that require analysis of environmental impacts, as well as disclosure of regulatory requirements imposed by other state and federal laws. 10 C.F.R. §51.45.

The ER's treatment of impacts on aquatic species resulting from effluent discharges to the Savannah River is similarly flawed. Rather than disclosing and analyzing the potential impacts from the discharge structure, the ER focuses on its design specifications and compliance with state and federal regulations of industrial effluent discharges. Proposed discharge to the river includes radiological, non-radiological and thermal pollution. ER § 5.2.3. Yet, the ER does not evaluate potential impacts on the aquatic community from this pollution source.

All cooling system discharges from the new units, including cooling tower blowdown, will be discharged to the Savannah River via a new discharge structure that will be built downstream of the existing discharge structure. ER at 2.3.3-1. The ER describes the chemical discharge associated with the proposed new units as "small" and "relatively innocuous" but fails to characterize the discharge in terms of constituents and amount. ER at 5.2-4. Operation of the cooling system requires use of anti-scaling compounds, corrosion inhibitors, and biocides, including chlorine, bromide, and chromium. ER § 3.4.2.2; ER 5.2-4; ER Table 3.6-1. The ER does not disclose whether chemical constituents in the liquid effluent will be discharged at harmful levels. Id. The ER reveals some of the chemical constituents of the proposed discharge:

Table 3.6-1 Water Treatment Chemicals that could be used in VEGP Units 3 and 4[1]

Zinc	Sodium bromide
Tolytriazole	Ammonium hydroxide
Dispersant	Soda ash
Antifoam	Ammoniium bisulfite
Hydrazine	Sodium chloride
NCS Corrosion Inhibitor	Antiscalant
Sodium hypochlorite	Coagulant
Boric acid	Stabrex ST70
Lithium hydroxide	Calcium hypochlorite (Sanuril)
Phosphate	Isothiozoline biocide
Methoxypropylamine (MPA)	
[1] Based on chemicals now used in	Units 1 and 2. This list is representative, not definitive.

The ER also fails to address potential impacts of thermal pollution on aquatic species at the point of discharge and downstream. ER § 5.3.2. Instead, the ER focuses on computer modeling of the plume and the size of the mixing zone necessary to avoid violations of water quality standards. ER § 5.2.3.2; ER Table 5.2-8. However, the ER does not acknowledge the potential impacts on aquatic species from this discharge. Young Declaration, ¶¶ 17-21. High water temperature kills the early life history stages of several highly-valued fish found near VEGP. Id. As with the intake structure, the discussion of the discharge facility suffers from the failure to perform field surveys at the proposed intake site. Id.

Additionally, the ER does not adequately address the cumulative impacts on aquatic resources of the new cooling system facilities, combined with the current impacts of the existing intake and discharge. In 1985, the NRC examined impingement and entrainment associated with the existing intake in the FES for operation of the existing units at Plant Vogtle and concluded there will be no significant impacts on the aquatic community of the Savannah River. According to the ER, "twenty years of operating experience suggest that Savannah River fish populations have not been adversely affected by operation of the existing" intake structure. ER at 5.3-3. In two decades of operation, however, SNC has not monitored impingement or entrainment associated with the existing structure. Thus, the ER fails to provide a meaningful basis to evaluate the cumulative impacts of the new and existing intake structures on aquatic species. There is no data on the rate of entrainment and impingement for any of the fish species that inhabit the Savannah River.

Similarly, the ER does not evaluate cumulative impacts from the new effluent discharge combined with the existing discharge and other sources of pollution in the area. The ER does not disclose field monitoring data from the existing discharge structure. There is no evaluation of the acute or chronic toxicity of the existing discharge. 67 Fed. Reg. 69952. There are no field surveys evaluating the existing thermal plume and its interaction with the aquatic species and habitat utilization. Young Declaration at ¶¶ 17, 18.

The ER's reliance on compliance with current and future state-issued waste discharge permits in lieu of actual analysis of impacts is unavailing. The Commission's rules require disclosure of both environmental impacts and compliance status. According to the ER, routine thermal monitoring is not required under the discharge permit for the existing facility and "it is unlikely that routine thermal monitoring will be a requirement of the new or amended permit." ER at 6.1-1. In other words, although SNC must comply with the thermal pollution standards set out in Georgia law, the waste discharge permit requires no monitoring to ensure compliance.

Contention 1.3: The ER fails to satisfy 10 C.F.R. § 51.45(b)(3) because it fails to address impacts to aquatic species in its discussion of alternatives. In particular, the ER's discussion of the no-action alternative and of alternative cooling technologies fails to consider environmental and economic benefits of avoiding construction of the proposed cooling system.

Basis:

As described above, use of Savannah River water to provide cooling water for the new units is likely to have significant impacts on fish and other aquatic life and downstream waters. Such impacts can be avoided by not constructing new reactors at Plant Vogtle (no-action alternative), or by implementing alternative cooling technology that would mitigate the impacts of the proposed operation.

The ER's discussion of the no action alternative recognizes that "environmental impacts described and predicted in this report for the new nuclear units would not occur" if the ESP is not granted. ER at 9.1-2. However, the ER fails to estimate or quantify the economic and environmental benefits of avoiding impacts to aquatic species in the Savannah River. Likewise, the ER dismisses dry cooling as an alternative cooling technology without any discussion of aquatic impacts:

> Dry cooling towers – This alternative is not suitable for the reasons discussed in EPA's preamble to the final rule addressing cooling water intake structures for new facilities (66 FR 65256; December 18, 2001). Dry cooling carries high capital and operating and maintenance costs that are sufficient to pose a barrier to entry to the marketplace for some facilities. In addition, dry cooling has a detrimental effect on electricity production by reducing the efficiency of steam turbines. Dry cooling requires the facility to use more energy than would be required with wet cooling towers to produce the same amount of electricity. This energy penalty is most significant in the warmer southern regions during summer months when the demand for electricity is at its peak. The energy penalty would result in an increase in environmental impacts as replacement generating capacity would be needed to offset the loss in efficiency from dry cooling. EPA concluded that dry cooling is appropriate in areas with limited water available for cooling or where the source of cooling water is associated with extremely sensitive

> biological resources (e.g., endangered species, specially protected areas). The conditions at the VEGP site do not warrant further consideration of dry cooling.

ER at 9.4-2.

Other than a vague reference to the preamble to an EPA rule implementing the Clean Water Act, there is no discussion or analysis of the dry cooling as an alternative to the proposed cooling system. In addition, the ER recognizes that "dry cooling is appropriate in areas with limited water available for cooling or where the source of cooling water is associated with extremely sensitive biological resources." *Id.* However, the ER ignores the fact that *there are extremely sensitive biological resources* in the Savannah River.

The ER fails to evaluate the impacts of the proposed cooling system intake and discharge on threatened and endangered species in the project area. Shortnose sturgeon, a federally endangered species, have been collected at SRS near Plant Vogtle. ER at 2.4-10. In addition, the robust redhorse, previously though to be extinct, was first documented in the middle Savannah River in 1997, when a single adult was collected near Plant Vogtle by SNC. ER at 2.4-11. The ER's failure to address potential alternatives that protect the robust redhorse is particularly ironic because SNC's parent corporation, Southern Company, is a leader in the effort to conserve this species.

Contention 2: Environmental Justice - Impact on Minority and Low-Income Populations

The ER for the proposed new reactors at Plant Vogtle is inadequate to satisfy the NEPA because it fails to provide a thorough analysis of the disparate environmental impacts of the project on the minority and low-income communities residing in close proximity to the site. The ER fails to consider factors particular to those communities which will magnify the environmental impacts of the proposed reactors in a way that is both disparate and significant. In particular, the ER fails to acknowledge the widespread practice of subsistence fishing in the

Savannah River, and the likelihood that this population's intake of radionuclides and other toxic substances generated by the proposed reactors will be significant and disproportionate to the rates of ingestion by the general population. In addition, the ER fails to address the fact that cancer rates in the minority and low-income community surrounding Plant Vogtle are already higher than for the general population, and therefore that they are more vulnerable to the adverse impacts of additional radiological and chemical pollution in the environment. Finally, the ER fails to address disparate impacts on the minority and low-income communities during a radiological emergency and evacuation.

Basis:

A. An Environmental Justice Analysis Is Required by NEPA, NRC Policy, and Executive Order 12898.

As required by NEPA, the NRC must fully assess the impacts of the proposed the Plant Vogtle ESP. 10 C.F.R. § 51.71. The NRC has delegated the first step in the NEPA evaluation process to license applicants. 10 C.F.R. § 51.45. In implementing NEPA, the NRC must take account of environmental justice, the potential for government actions to have disproportionate impacts on low income or minority communities. The EPA defines Environmental Justice as:

> [T]he fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. EPA has this goal for all communities and persons across this Nation. It will be achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.[7]

The NRC recognizes that for the impacts of its licensing decisions on some populations "may be different from impacts on the general population due to a community's distinct cultural

[7] U.S. Environmental Protection Agency, http://www.epa.gov/compliance/environmentaljustice (last visited December 5, 2006).

characteristics or practices." Policy Statement on the Treatment of Environmental Justice Matters in NRC Regulatory and Licensing Actions, 69 Fed. Reg. 52,040 at 52,049 (August 24, 2004). Thus, it is the Commission's policy that, in keeping with Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income-Populations:

> an analysis of disproportionately high and adverse impacts needs to be done as part of the agency's NEPA obligations to accurately identify and disclose all significant environmental impact associated with a proposed action.

59 Fed. Reg. 7629 (Feb. 16, 1994); *See also Louisiana Energy Services* (Claiborne Enrichment Center), CLI-98-3, 47 NRC 77, 106 (1998) ("Adverse impacts that fall heavily on minority and impoverished citizens call for particularly close scrutiny.").

NEPA further requires that that the impacts of the proposed action on low-income and minority populations be fully addressed. Executive Order 12898 directed agencies to consider environmental justice issues, that is, the particular environmental impact on minority and low-income populations. 59 Fed. Reg. 7629.

B. Environmental Report Recognizes Existence of Environmental Justice Communities

As the ER discloses, minority and low-income populations exist within a 50-mile radius around the Vogtle site, *see*, ER § 2.5.4. Namely, of the 175 block groups identified, 171 have Black races populations of 50 percent or more. ER § 2.5.4.2. Further, of the 72 census block groups identified with respect to low-income populations, 14 have 50 percent or more low-income households. ER § 2.5.4.3. Additionally, four counties within 40 miles of Vogtle have areas which are persistently distressed and suffer from unemployment and/or poverty. The census data for the region reveal the following:[8]

County	census tract	poverty	unemp.	distressed previous year
Jefferson, GA	13-163-9602.00	X	X	X
Jefferson, GA	13-163-9603.00	X	X	X
Jenkins, GA	13-165-9602.00	X		X
Allendale, SC	45-005-9703.00	X	X	X
Barnwell, SC	45-011-9701.00		X	X
Barnwell, SC	45-011-9703.00		X	X
Barnwell, SC	45-011-9704.00		X	X
Barnwell, SC	45-011-9705.00		X	X

C. Environmental Report Does Not Adequately Address Disparate Impacts on Low-Income and Minority Communities.

While the ER does address the instance of minority and low-income households within and around Burke County, it fails to take accurate account of the impact two new nuclear reactors will have on those populations based on factors particular to that area.

1. The Environmental Report Fails to Take Into Account Subsistence Fishing on the Savannah River.

The ER fails to adequately address the impact of two new nuclear reactors at Plant Vogtle because it neglects subsistence fishing along the Savannah River within minority and low-income populations. These populations are already subject to an unusual dose of radiation due to the current level of radioactive contamination in Savannah River fish. Two additional reactors at

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[8] http://132.200.33.131/cra/2006distressedorunderservedtracts.htm (last visited Dec. 6, 2006).

Plant Vogtle will increase the total radiological load of the Savannah River, which already receives radiological effluent from the existing Plant Vogtle reactors and SRS. The ER does not recognize that subsistence fishing is an exposure pathway that disproportionately impacts low-income and minority populations.

The two existing units at Plant Vogtle discharge liquid effluent, including radiological and non-radiological waste, to the Savannah at a rate of 10,000 gallons per minute (14.4 MGD). ER Table 2.9-1. The current liquid discharge includes waste from fission/activation products (0.142 curries/year), tritium (1414 curries/year), dissolved, entrained gasses (0.00172 curries/year), and gross alpha (2.98E-05 curries/year), as well as non-radiological constituents. Id. The two proposed reactors will discharge 0.52 curries per year of fission products and 2,020 curries per year of tritium. ER Table 3.0-1; ER Table 3.5-1.

SNC's radiological monitoring program reveals that Savanna River fish, particularly resident game fish species, are contaminated with cesium-137.[9] Semi-annual testing of commercially or recreationally important fish species in the vicinity of Plant Vogtle routinely find detectible levels of cesium-137 in the edible flesh of collected samples:

> Cs-137 was the only radionuclide found in the semiannual collections of a commercially or recreationally important species of fish. It has been found in all but 4 of the 125 samples collected during operation and in all but 5 of the 32 samples collected during preoperation.[10]

Significantly, in 1999 SNC collected a largemouth bass "with a concentration of 2500 Ci/kg-wet," exceeding the required reporting level of 2000 pCi/kg-wet.[11] SNC attributes the elevated cesiums-137 level in this sample to "the fact that largemouth bass are predators that concentrate

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[9] *Vogtle Electric Generating Plant, Annual Radiological Operating Report for 2005*, Southern Company (2006) (Exhibit 2.1).
[10] *Id.* at 4-28.
[11] *Id.*

Cs-137."[12] Of course, humans who eat fish are also predators that concentrate cesium-137, and largemouth bass are a target species of subsistence fishermen on the Savannah River.[13]

Although individuals from all socio-economic backgrounds engage in fishing in the area, African-Americans in particular commonly engage in subsistence fishing along the Savannah River.[14] As a recent report by the Institute for Energy and Environmental Research noted:

> Many people use the Savannah River for subsistence fishing – that is, as a primary source for food; the practice is more common among African-Americans. Fish in the Savannah River have bioaccumulated cesium, mercury, and tritium...African-American fishermen consume considerably more fish than the maximum recommended for health reasons by the South Carolina Department of Health and Environmental Control. This is clearly an environmental injustice, because people who rely routinely on the river for a large portion of their protein are disproportionately impacted by the pollution from the site.[15]

The ER is inadequate because it fails to consider the unique burdens faced by minority and low-income populations who depend on the Savannah River for food. These populations are disproportionately affected, via bioaccumulation, by increases in hazardous and radioactive material from the addition of two new nuclear reactors at Plant Vogtle. Further, the ER is inadequate because it fails to consider that impacts to important fish species targeted by subsistence fishermen results in disproportionate impacts to the minority populations that they rely on this resource as a source of nutrition. Low income and minority communities will bear the burden if target species are less abundant, smaller, or less healthy because of the proposed new units.

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[12] *Id.*

[13] Burger J (1998) *Fishing and risk along the Savannah River: Possible Intervention.* J Toxicol Environ Health 55:405–419 (Exhibit 2.2).

[14] Arjun Makhijani, Ph.D. and Michele Boyd, Institute for Energy and Environmental Research, Nuclear Dumps by the Riverside: Threats to the Savannah River From Radioactive Contamination at the Savannah River Site (2004)(Exhibit 2.3).

[15] *Id.*

Additionally, the ER fails to take account of the disproportionate impact on minority and low-income populations based on their higher-than-average consumption of fish. One study reports that "[e]thnicity and education contribute significantly to explaining variations in [the] number of fish meals per month, serving size, and [the] total quantity of fish consumed per year."[16] Not only do African-Americans consume more fish per year than Caucasians, they often eat fish in much larger portions, frequently surpassing allowable fish-consumption levels.[17] Further, low-income individuals also consume greater amounts of fish than those with higher incomes.[18] The combination of these factors means that African-Americans and low-income individuals are at specific risk from hazardous materials in the Savannah River, and that any increase in such materials from the addition of two new nuclear reactors will adversely affect those populations in particular.

Likewise, the ER is inadequate because it fails to consider the disproportionate impact on low-income and minority populations based on the cumulative effects of hazardous substances in the Savannah River, as well on the increased harm posed by certain cooking methods prevalent in the area. Both Georgia and South Carolina already issue fish consumption advisories along the Savannah River based on the presence of hazardous and radioactive material in the water. While mercury is the main threat to human health by way of fish consumption, the presence of radionuclides is also a significant factor informing the presence of these consumption

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[16] Joanna Burger, et al., *Factors in Exposure Assessment: Ethnic and Socioeconomic Differences in Fishing and Consumption of Fish Caught along the Savannah River*, Risk Analysis, Vol. 19, No. 3, p. 427, 1999. (Exhibit 2.4).
[17] *Id.* at 506.
[18] *Id.* at *431*.

advisories.[19] Radiocesium (^{137}Cs) is of particular concern because levels of ^{137}Cs actually increase when fish is cooked.[20] One study found that radiocesium levels increase by 32% when fried with breading, and by 62% when fried without breading.[21] Further, it was also noted in that same study that "over 80% of the people interviewed along the Savannah River deep-fried their fish regularly."[22]

Finally, the ER is inadequate because it fails to consider the lack of knowledge of fish consumption advisories, or awareness of associated risks, among the minority and low-income populations. Unfortunately, compliance with fish consumption advisories is quite low. This fact is based on a number of issues, including "confusion over the meaning of advisories" and lack of understanding regarding associated risks.[23] Significantly, minority and low-income populations have less awareness of the consumption advisories as compared to others groups.[24] This fact, in addition to their higher than average consumption of fish from the Savannah River, means that minority and low-income populations are particularly susceptible to health risks posed by contamination. The Environmental Report, however, fails to take this factor into account in its consideration of Environmental Justice issues.

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[19] Joanna Burger, *Science, Policy, Stakeholders, and Fish Consumption Advisories: Developing a Fish Fact Sheet for the Savannah River*, Environmental Management, Vol. 27, No. 4, p. 503, 2001. (Exhibit 2.5).
[20] Joanna Burger, et al., *Effects of Cooking on Radiocesium in Fish from the Savannah River: Exposure Differences for the Public*, Arch. Environ. Contam. Toxicol. 46, p. 231, 2004. (Exhibit 2.6).
[21] *Id.* The weight loss during cooking of a breaded fish was 25% and the weight loss of an un-breaded fish was 39%.
[22] *Id.* at 232.
[23] Burger, *Science, Policy, Stakeholders, and Fish Consumption Advisories*, note 19, *supra*, at 501 (Exhibit 2.5).
[24] *Id.* at 507.

2. The Environmental Report Fails to Consider the High Cancer Rate in Burke County.

The ER fails to adequately consider the impact two new nuclear reactors will have on the minority populations around Plant Vogtle who already suffer from higher-than-average cancer rates. One study conducted by the University of South Carolina has shown that there is a higher than average instance of cervical cancer in black women, and a higher rate of esophageal cancer in black men, within a fifty mile radius of the Savannah River Site, which lies just across the River from Plant Vogtle.[25] While the study noted that these types of cancers are not necessarily associated with exposure to radioactive materials, the impact of increased levels of hazardous and radioactive materials into the area, including into the Savannah River, on minority population already suffering from high rates of cancer should be assessed.[26]

A number of studies have shown that living near a nuclear power plant can increase certain health risks, including death. Particularly, children and fetuses are highly susceptible to the impacts of radiation. The Agency for Toxic Substances and Disease Registry (ATSDR), a federal public health agency of the U.S. Department of Health and Human Services, Toxicological Profile on Cesium reports that Cesium-137 is found in the breast milk of mothers with an internal cesium-137 burden (citing Johansson et al. 1998; Thornberg and Mattsson 2000), and can be transferred to nursing infants (citing Johansson et al. 1998).[27] Cesium-137 has also been shown to cross the placental barrier of animals.[28] Studies also indicate that subsequent

[25] 1997 FEB 3, Cancer Weekly via NewsRx.com & NewsRx.net (Exhibit 2.7).
[26] *Id.*
[27] ATSDR Toxicological Profile on Cesium, available in its entirety at www.atsdr.cdc.gov/toxprofiles/tp157.html.
[28] *Id.*

the closure of 8 U.S. nuclear plants in 1987, cancer incidence in children younger than 5 years of age in proximate areas for which data were available fell significantly after the shutdowns.[29]

Recent studies of morbidity and mortality statistics compiled by the U.S. Centers for disease Control and Prevention compare death rates before and after Plant Vogtle's existing reactors went online, and reflect that the death rate per 100,000 population from all cancers in Burke County rose 24.2 percent and that infant deaths increased by 70.1 for Burke County. [30] In light of these studies, the ER must consider the already existing negative health impacts in the Burke County area when assessing the impacts of the two new reactors.

3. The Environmental Report Fails to Consider the Inability of low-income and minority populations around Plant Vogtle to respond or evacuate in the case of a nuclear accident.

The ER is deficient because it fails to discuss or analyze the disparate impact a significant accident would have on minority and low-income populations. In the Environmental Impact Statement for the proposed Mixed Oxide Fuel Fabrication Facility at SRS, the NRC acknowledged that a significant accident would most likely affect minority or low-income communities due to the demographics and prevailing wind in the area.[31] Plant Vogtle is nearly adjacent to SRS and, therefore, a significant accident at the new reactors would have a similar disparate impact on these low-income and minority populations. The ER is deficient because it does not discuss or analyze this impact such an accident would have on these populations, nor

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[29] See Mangano, et al. 2002, *Infant Death and Childhood Cancer Reductions after Nuclear Plant Closings in the United States*, Archives of Environmental Health, Vol. 57(1), January/February 2002, pp 23-31. (Exhibit 2.7).

[30] U.S. Centers for Disease Control and Prevention (http://wonder.cdc.gov)(uses ICD-9 codes 000.1-799.9).

[31] NUREG-1767, Vol. 1, Environmental Impact Statement on the Construction and Operation of a Proposed Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina, Final Report, January 2005, Executive Summary at p. xix. Excerpt attached as Exhibit 2.8).

does it address these communities' ability to respond or evacuate in the event of a nuclear accident.

Pursuant to 10 CFR 52.17(b)(2)(ii), SNC submitted a proposed complete and integrated emergency plan to the NRC with the ESP application. Part 5, Emergency Plan; ER § 13.3. However, neither the Emergency Plan nor the section of the ER discussing emergency planning addresses the demographics of the communities within the plume exposure pathway or ingestion exposure pathway. Id. As previously discussed, low-income and minority communities dominate the area within the proposed EPZs. Despite this, and the previous NRC finding of disproportionate impacts from an accident at SRS, the ER fails to disclose and analyze potentially disparate impacts resulting from an accident or terrorist incident.

The recent Hurricane Katrina disaster revealed that low-income and minority populations are particularly vulnerable in emergency situations. Prior to Hurricane Katrina, the City of New Orleans developed and implemented an emergency plan that was well engineered and publicized. The evacuation plan functioned adequately for the population with automobiles, but utterly failed to protect the most vulnerable populations. One evaluation of the Katrina emergency response describes this disparity:

> People who had resources were served relatively because planners are familiar with their abilities and needs. People who were poor, disabled or ill were not well served, apparently because decision-makers were unfamiliar with and insensitive to their needs.[32]

Obviously, the rural are surrounding Plant Vogtle presents very different emergency planning and evacuation challenges from a major city like New Orleans. However, Hurricane

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[32] Litman, *Lessons from Katrina and Rita: What Major Disasters Can Teach Transportation Planners*, Journal of Transportation Engineering, Vol. 132, January 2006, pp. 11-18. (Exhibit 2.9).

Katrina revealed that emergency plans can overlook the most vulnerable segments of society. In order to prevent such disparate impacts, the ER must explicitly consider environmental justice.

Contention 3 : Failure to Evaluate Whether and in What Time Frame Spent Fuel Generated by Proposed Reactors Can Be Safely Disposed Of

The ER for the Vogtle ESP is deficient because it fails to discuss the environmental implications of the substantial likelihood that spent fuel generated by the new reactors will have to be stored at the Vogtle site for more than 30 years after the reactors cease to operate, and perhaps indefinitely. The Waste Confidence Decision[33] does not support SNC's failure to address this issue in the ER, because it has been outdated by changed circumstances and new and significant information. As required NEPA, the NRC may not permit construction or operation of the new Vogtle reactors unless and until it has taken into account these changed circumstances and new and significant information. 10 C.F.R. § 51.92. *See also Marsh v. Oregon Natural Resources Council,* 490 U.S. 360 (1989).

Basis:

A. Requirements of NEPA

NEPA requires the NRC to evaluate the environmental impacts of its licensing decisions. 10 C.F.R. § 51.71. The NRC has delegated the first step in the NEPA evaluation process to license applicants. 10 C.F.R. § 51.45. The environmental impacts of nuclear power plant licensing include the impacts of the uranium fuel cycle, including disposal of spent fuel. *State of Minnesota v. NRC,* 602 F.2d 412, 418 (D.C. Cir. 1979) ("*Minnesota v. NRC*"). In *Minnesota v. NRC,* the U.S. Court of Appeals for the D.C. Circuit approved the NRC's conduct of a

[33] Waste Confidence Review, 55 Fed. Reg. 38,474, 38,504 (September 18, 1990), as amended by Waste Confidence Decision Review: Status, 64 Fed. Reg. 68,005 (December 6, 1999).

rulemaking to evaluate, in compliance with NEPA, the concerns of intervenors in individual nuclear power plant licensing cases regarding:

> whether there is reasonable assurance that an off-site storage solution will be available by the years 2007-09, the expiration of the plants' operating licenses, and if not, whether there is reasonable assurance that the fuel can be stored safety at sites beyond those dates.

602 F.2d at 418. In response to the Court's decision in *State of Minnesota v. NRC*, the NRC issued its first Waste Confidence Decision in 1984. 49 Fed. Reg. 34,659 (August 31, 1984). The Waste Confidence decision was revised again in 1990 and 1999. Its findings are codified in 10 C.F.R. § 51.23.

The conclusions of the Waste Confidence Decision regarding the environmental impacts of spent fuel storage and disposal are not unassailable. They must be revisited if changed circumstances or new and significant information shows that their conclusions about environmental impacts are in error. 10 C.F.R. § 51.92, *Marsh v. Oregon Natural Resources Council,* 490 U.S. 360 (1989).

B. Waste Confidence Proceedings

The 1990 Waste Confidence Decision, the most recent comprehensive update to the 1984 Waste Confidence Decision, asserts that the Commission has:

> reasonable assurance that at least one mined geologic repository will be available within the first quarter of the twenty-first century, and that sufficient repository capacity will be available within 30 years beyond the licensed life for operation (which may include the term of a revised or renewed license) of any reactor to dispose of the commercial high-level radioactive waste and spent fuel originating in such reactor and generated up until that time. (This finding revised the finding in the original decision that a mined geologic repository would be available by the years 2007 to 2009).

55 Fed. Reg. at 38,474. The Commission repeated the same assertion in 1999. Waste Confidence Review Decision: Status, 64 Fed. Reg. 68,005-06 (December 6, 1999). The finding was codified in 10 C.F.R. § 51.23.

The 1990 Waste Confidence Decision also predicts that the first repository, now proposed for Yucca Mountain, Nevada, will not have enough capacity to handle all the spent fuel that will be generated by the current generation of nuclear reactors, or from the next generation of nuclear reactors, and therefore it "appears likely" that a second repository will be needed to accommodate all of the spent fuel from those reactors. 55 Fed. Reg. at 38,501-02. The Waste Confidence Decision does not predict the volume of spent fuel that would be generated by a new generation of reactors, but assumes that spent fuel generated by new reactors would go to a second repository, and that the repository would be available "well within" 30 years after expiration of their licenses. 55 Fed. Reg. at 38,504.

The 1990 Waste Confidence Decision also notes that in 1986, Congress had indefinitely postponed the second repository program, due to "decreasing forecasts of spent fuel discharges, as well as estimates that a second repository would not be needed as soon as originally supposed." 55 Fed. Reg. at 38,501. In 1987 amendments to the Nuclear Waste Policy Act, Congress required DOE to report to Congress on the need for a second repository between January 1, 2007, and January 1, 2010. *Id.* The Commission found it is "not clear that the institutional uncertainties arising from having to restart a second repository program should be considered in detail in the current Waste Confidence Decision review," and decided not to address them. *Id.* at 38,503-04.

In 1999, the NRC issued a "status report" on the 1990 Waste Confidence Decision, reporting that:

> no significant and unexpected events have occurred – no major shifts in national policy, no major unexpected institutional developments, no unexpected technical information – that would cast doubt on the Commission's Waste Confidence findings or warrant a detailed evaluation at this time.

64 Fed. Reg. at 68,007. Thus, the Commission decided not to modify the findings codified in 10 C.F.R. § 51.23. *Id.*

C. Changed Circumstances and New and Significant Information.

The Commission has committed to periodic review of its waste confidence findings. 55 Fed. Reg. at 38,474. In the 1999 Status Report on the Waste Confidence Review, the Commission stated that the "appropriate trigger" for the next review:

> could be a combination of events or it could be a single event. For example, *any significant delays in DOE's repository development schedule* or a decision by the Secretary of Energy to not recommend Yucca Mountain as a candidate site might necessitate a reevaluation of the Commission's Waste Confidence Decision. Thus, the Commission would consider undertaking a comprehensive reevaluation of the Waste Confidence findings when the impending repository development and regulatory activities run their course or *if significant and pertinent unexpected events occur*, raising substantial doubt about the continuing validity of the Waste Confidence findings.

64 Fed. Reg. at 68,007 (emphasis added). Petitioners submit that a number of events have occurred which call for the reevaluation of the Waste Confidence decision before any licensing decision is made with respect to new reactors, including the proposed Vogtle reactors. These changed circumstances undermine the NRC's conclusion in Finding 2 of the 1990 Waste Confidence Rule that:

> sufficient repository capacity will be available within 30 years beyond the licensed life for operation (which may include the term of a revised or renewed license) of any reactor to dispose of the commercial high-level radioactive waste and spent fuel originating in such reactor and generated up until that time.[34]

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[34] The first statement, that a repository will be available within the next 25 years, is irrelevant because the Waste Confidence Decision admits that this first repository has insufficient capacity to dispose of spent fuel from new reactors. 55 Fed. Reg. at 38,504.

55 Fed. Reg. at 38,474. The changed circumstances and new and significant information include the following:

1. The 1990 Waste Confidence Decision is based on the assumption that work on a second repository will begin in 2010, but this assumption is clearly unreasonable. It is unlikely that work on a second repository will begin while the Yucca Mountain proceeding is underway. The Yucca Mountain project has been substantially delayed, and DOE now predicts that the repository will not open until 2017.

2. When the NRC issued the 1990 Waste Confidence Decision, the prospect of new reactor licensing was virtually nonexistent. In fact, the DOE had postponed the second repository program in 1986 because of "decreasing spent fuel discharges" and "estimates that a second repository would not be needed." 55 Fed. Reg. at 38,501. In 2005, Congress changed this circumstance dramatically by approving more than $13 billion in subsidies and tax breaks for new reactors. Several applications for early site permits have are pending and a number of companies have stated that they intend to file combined construction permit/operating license applications. Now that it has become likely that many new tons of spent reactor fuel will be generated with no means of disposal, it is "clear" that the time has come to conduct a careful and thorough evaluation of the availability of a second repository. 55 Fed. Reg. at 38,502 ("[I]t is not clear that the institutional uncertainties arising from having to restart a second repository program should be considered in detail in the current [*i.e.,* 1990] Waste Confidence Review.")

3. The NRC's expression of confidence that spent fuel can be safely stored at nuclear power plant sites for lengthy period was made before the attacks of September 11, 2001, and thus does not reflect a current assessment of their vulnerability to accidents caused by intentional attack. The environmental impacts of storing spent fuel at reactor sites for any period of time,

but especially for 30 years or more, must be re-examined in light of new information regarding the threat of intentional attack against U.S. facilities, including nuclear power plants. *See* Committee on the Safety and Security of Commercial Spent Nuclear Fuel Storage, Board on Radioactive Waste Management, National Research Council, *Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report* at 12 (Washington, DC: National Academies Press, 2006)(Information gathered by this Committee "led it to conclude that there were indeed credible concerns about the safety and security of spent nuclear fuel storage in the current threat environment.").[35] Petitioners request the NRC to apply the holding of the U.S. Court of Appeals for the Ninth Circuit in *San Luis Obispo Mothers for Peace v. NRC,* 449 F.3d 1016 (9th Cir. 2006) that the NRC must consider the environmental impacts of terrorist attacks in the NEPA analyses supporting its licensing decisions.

In light of these changed circumstances and new information, the NRC no longer has any basis for refusing to prepare an EIS that addresses the environmental impacts of extended spent fuel storage at nuclear power plant sites, including the site of the proposed Vogtle reactors. The ER for the Vogtle ESP should address the issue, or it should be addressed in a generic EIS. In either event, the NRC may not issue an ESP to SNC for the Vogtle site unless and until the analysis is completed.

[35] An excerpt of this report is attached hereto as Exhibit 3.1.

Contention 4: Failure to Address Environmental Impacts of Intentional Attacks

The Environmental Report ("ER") for the Vogtle ESP application is inadequate to satisfy the National Environmental Policy Act ("NEPA") and NRC regulation 10 C.F.R. § 51.45(b) and (c) for the following reasons:

(a) it fails to address the environmental impacts of intentional attacks on the proposed nuclear power plants, or to evaluate a reasonable range of alternatives for avoiding or mitigating those impacts.

(b) it fails to address the cumulative impacts of an intentional attack on the existing Plant Vogtle, or to evaluate a reasonable range of alternatives for avoiding or mitigating those impacts.

Basis:

NRC regulations implementing NEPA, 10 C.F.R. §§ 51.45(b) and (c), require SNC's ER to address the impacts of the proposed licensing and operation of the new nuclear plants on the environment, as well as alternatives for mitigating or avoid those impacts. The ER for the Vogtle plant fails to satisfy these requirements because it does not address the environmental impacts of intentional attacks on the proposed nuclear power plants. The NRC's policies and procedures for preparing against terrorist attack, including the commencement in 2001 of a "top to bottom" review of NRC security procedures and the establishment of the Office of Nuclear Security and Incident Response, demonstrate that the NRC considers such attacks to be reasonably foreseeable for purposes of requiring a NEPA review. *San Luis Obispo Mothers for Peace v. NRC,* 449 F.3d 1016 (9th Cir. 2006) ("*Mothers for Peace*").

In *Mothers for Peace,* the U.S. Court of Appeals for the Ninth Circuit reversed the Commission's refusal, as a matter of law, to consider the environmental impacts of terrorist attacks in its licensing decisions. *See Pacific Gas & Electric Co.* (Diablo Canyon Independent Spent Fuel Storage Installation), CLI-03-01, 57 NRC 1 (2003); *Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Installation), CLI-02-25, 56 NRC 340 (2002). While the Court's decision is not binding on the NRC outside of the Ninth Circuit, the Commission should apply the decision to all of its licensing decisions, including the Vogtle ESP decision. As Commissioner Jaczko stated in a recent dissenting opinion, "the NEPA terrorism issue is a significant matter that needs resolution," and that "the current uncertainty surrounding the impact of this issue may lead to unnecessary confusion in the review of new reactor licenses." *Pacific Gas & Electric Co.* (Diablo Canyon Independent Spent Fuel Storage Installation), CLI-06-23, slip op. at 5 (September 6, 2006).

Pacific Gas & Electric Company ("PG&E") has petitioned the Supreme Court for a writ of certiorari regarding the *Mothers for Peace* decision. However, the NRC's failure to file its own petition for certiorari, or even to submit a timely response in support of PG&E's petition, indicates that the NRC does not consider the decision to warrant Supreme Court review and is prepared to carry out the Ninth Circuit's mandate.[36] Petitioners urge the Commission to follow Commissioner Jaczko's counsel and require SNC to address, in its ER, the environmental

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[36] *See* Sup.Ct.R. 12.6, which provides that:

> All parties other than the petitioner are considered respondents, but any respondent who supports the position of a petitioner shall meet the petitioner's time schedule for filing documents, except that a response supporting the petition shall be filed within 20 days after the case is placed on the docket, and that time will not be extended.

The Supreme Court docketed PG&E's petition for certiorari on October 3, 2006. *See* <u>http://www.supremecourtus.gov/docket/06-466.htm</u>. Pursuant to Sup.Ct.R. 12.6, if the government wished to file a brief in support of the petition it was required to do so by October 23. Therefore it is reasonable to expect that the government's brief, now due on December 15, 2006, will oppose the taking of certiorari.

impacts of a terrorist attack on the new reactors and the cumulative impacts of an attack on the existing Vogtle reactor. Regardless of the outcome of PG&E's petition for certiorari, the Commission may exercise its discretion to conduct such a review, thereby joining the other agencies who review the environmental impacts of terrorist attacks on their facilities.[37]

The ER should provide a full discussion of the potential consequences of a range of credible events involving destructive acts against the proposed reactors. The range of events considered in the ER should include all types of attacks that are reasonably foreseeable, including events that SNC and NRC considers to fall beyond the plant's design basis. *Limerick Ecology Action v. NRC,* 869 F.2d 719, 726 (3rd Cir. 1989).

The ER should also evaluate the potential that severe accidents caused by attacks on the existing Vogtle nuclear reactor will lead to accidents at the new nuclear reactors. SNC has notified the NRC of its intent to file a license renewal application in June of 2007, and thus it is possible that the existing nuclear reactor will continue to operate alongside two new nuclear reactors for a lengthy period.[38] The ER's analysis of cumulative impacts should include a

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[37] The U.S. Department of Energy, for example, has evaluated the environmental impacts of terrorist attacks in numerous EISs. *See, e.g.,* DOE/EIS-0250F, Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada at H-1 (February 2002); DOE/EIS-0161, Final Programmatic Environmental Impact Statement for Tritium Supply and Recycling, Vol. I at 2-1 (October 1995) (evaluating environmental impacts of recycling and production of tritium for nuclear weapons); DOE/EIS-0319, Final Environmental Impact Statement for the Proposed Relocation of Technical Area 18 Capabilities and Materials at the Los Alamos National Laboratory at iii, 5-1 (August 2002) (evaluating environmental impacts of sabotage on a DOE research facility).

It also must be noted that the DOE recently issued guidance specifically directing that "each DOE EIS and EA should explicitly consider intentional destructive acts. This applies to all DOE proposed actions, including both nuclear and non-nuclear proposals." December 1, 2006 Memorandum from Department of Energy to DOE NEPA Community. (Exhibit 4.1).

[38] Letter from Jeffrey T. Gasser, SNC, to U.S. Nuclear Regulatory Commission re: Vogtle Electric Generating Plant, Application for License Renewal (June 20, 2003). A copy of the letter

discussion of the potential impacts on the new reactors if the existing reactor or its spent fuel pool is successfully attacked. For example, if the Vogtle site is surrounded by high levels of radiation as a result of an attack, and the new reactors are rendered inaccessible, could the safety of the new reactors be compromised? Or, might a new reactor be required to be shut down for many years or permanently because the site is contaminated, causing huge economic and social impacts?

Finally, the ER should evaluate a range of reasonable design alternatives to the proposed action that would protect the environment from the potentially catastrophic environmental impacts of a successful attack. Such alternatives should include below-ground construction, recommended as a prudent design feature over 50 years ago by Dr. Edward Teller, one of the founders of the U.S. nuclear industry.[39] Alternatives could also include passive safety features

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(Accession # ML031760547) can be found on the NRC's website at: http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html.

[39] In a July 23, 1953, letter to the Joint Committee on Atomic Energy, Dr. Teller noted:

> [t]he various committees dealing with reactor safety have come to the conclusion that none of the powerful reactors built or suggested up to the present time are absolutely safe. Though the possibility of an accident seems small, a release of the active products in a city or densely populated area would lead to disastrous results. It has been therefore the practice of these committees to recommend the observance of exclusion distances, that is, to exclude the public from areas around reactors, the size of the area varying in appropriate manner with the amount of radioactive poison that the reactor might release. Rigid enforcement of such exclusion distances might hamper future development of reactors to an unreasonable extent. In particular, the danger that a reactor might malfunction and release its radioactive poison differs for different kinds of reactors. It is my opinion that reactors of sufficiently safe types might be developed in the near future. *Apart from the basic construction of the reactor, underground location or particularly thought-fully constructed safety devices might be considered.*

Letter from Dr. Edward Teller to the Honorable Sterling Cole, Chairman of the Joint Committee on Atomic Energy, United States Congress (emphasis added). A copy can be found on the website of the Nuclear Age Peace Foundation at: www.nuclearfiles.org/menu/library/correspondence/teller-edward/corr_teller_1953-07-23.htm.

advocated by Dr. Alvin Weinberg, a major contributor to the design of today's pressurized water and boiling water reactors, for the next generation of nuclear reactors. As described in Dr. Weinberg's paper, *The Second Nuclear Era,* these features, as included in the design for the advanced "PIUS" reactor, can be relied on "without calling into action any active safety equipment and without any human actions" and allow the plant to operate safely without human attendance for an extended period.[40] Additionally, a panel of industry experts drafted an 800 page report in 1980 addressing designing future reactors to be more secure.[41] This report offered a number of feasible, low-cost design changes to make nuclear plants less vulnerable to sabotage and acts of terror. As not one of these low-cost changes appear in the so-called advanced reactor designs, Petitioners request that SNC and NRC refer to this report and take these low-cost changes into account.

Contention 5: Failure to evaluate energy alternatives

The ER for the Vogtle ESP is deficient because the Alternatives analysis is flawed on two accounts: First, it is based on premature and incomplete information that cannot be adequately assessed at this point in time, as Georgia Power has been ordered to submit a detailed assessment of the maximum achievable cost effective potential for energy efficiency and demand response

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Petitioners note that they were unable to obtain a copy of the original letter. The copy that is attached is was retyped and posted on the website of the Nuclear Age Peace Foundation. (Exhibit 4.2).

[40] Alvin M. Weinberg, *The Second Nuclear Era,* Institute for Energy Analysis, Oak Ridge Associated Universities at 35-26 (1984). *The Second Nuclear Era* can be found on the website of the U.S. Office of Science and Technical Information at: http://www.osti.gov/featuredsites/weinberg.shtml.

[41] U.S. N.R.C., NUREG/CR-1345, Nuclear Power Plant Design Concepts for Sabotage Protection, Vol. 1 & 2, January 1981. (excerpt attached as Exhibit 4.3)

programs in its service area in 2007.[42] Second, it lacks a full and objective evaluation of all reasonable alternatives.

Basis:

Even the very summary information contained in the ER regarding alternatives is premature, and necessarily incomplete, as Georgia Power's upcoming Integrated Resource Plan to be filed with the Georgia Public Service Commission in January 2007 will not be fully reviewed and analyzed until later in 2007. The ER is therefore also deficient because it fails to state the degree to which energy efficiency can meet projected demand. Indeed, Georgia Power Company (co-owner of Plant Vogtle) did not include nuclear power as an option for meeting future demand in its 2004 Integrated Resource Plan. Its next Integrated Resource Plan has not been filed yet and will not even be reviewed by the Georgia Public Service Commission until 2007.[43] Additionally, claims surrounding the need for power linked to the target value of 2,234 MWe for net electrical output for a proposed two-unit facility at VEGP have not been reviewed by the Georgia Public Service Commission. The ER for the Vogtle ESP refers to the fact that no determination of participation percentages of each co-owner has been made and that such

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[42]Docket No. 22449-U, Georgia Power Company Request for an Accounting Order, Final Order, June 22, 2006, page 4. (Exhibit 5.1). Additionally, Georgia Power used planning procedures to develop its 2004 Integrated Resource Plan that significantly understated the achievable cost effective potential for energy efficiency in the utility's service area. This flaw was serious enough that the Georgia Public Service Commission decided to establish a Demand Side Working Group to more fully assess demand side options. This Group is still operating and ongoing data collection for Georgia Power's upcoming 2007 Integrated Resource Plan review is underway now. This data will not be available until at least next year.

[43] There are other supply options available that have not been reviewed yet and cannot be adequately reviewed until the 2007 Integrated Resource Planning process is completed. Therefore, evaluation of supply alternatives is premature at this time. <u>See</u> <u>Environmental Law and Policy Center v. U.S. Nuclear Regulatory</u> Commission, ___ F.3d ___, 2006 WL 3490839 *7 (7th Cir. 2006)(indicating that it is reasonable for an applicant to defer such analysis until the combined license application).

determination is not likely to be made until 2008. Only a vague, uncertain summary of who will use the additional, proposed new capacity is included in the ER. This is simply insufficient.

Further, no specific proposal for building new nuclear reactors has been filed with or approved by the Georgia Public Service Commission.[44] Another example of a deficiency in the ER is that there is significant, untapped energy efficiency potential in the service territory of the applicant utilities. The 2005 study by ICF[45], cited in the ER at p. 9.2-4, documents significant under-utilization of demand side resources that are readily available.[46] If deployed, these demand side resources could significantly offset the need for new capacity in the future. Of note, the ICF study done for Georgia is recognized to be conservative in its estimates and is also not reflective of recent fuel price increases that Georgia utilities have experienced which in turn make the cost effective potential for energy efficiency higher. It is recognized that the ICF study produced energy efficiency results at the low end of other energy efficiency potential studies. The ER fails to present the fuller scenario and analyses for demand side options available to the Georgia utilities and focuses instead on the limited and inadequate information that Georgia

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[44] In response to Georgia Power Company's request for an accounting order to record certain early site permitting and construction operation license costs, the Georgia Public Service Commission stated the following in its order of June 22, 2006: "The Commission will complete its examination of the prudence of GPC's costs before rates are adjusted to reflect the costs incurred and accumulated in Account 183. Nothing in this Accounting Order shall be construed as prejudging the prudence of the decision to incur preliminary survey and investigatory charges. Nor shall anything in this Accounting Order be construed as prejudging the prudence of the individual charges incurred in pursuit of the preliminary survey and investigation of nuclear power or the outcome of the 2007 Integrated Resource Planning proceeding or any subsequent certification proceedings." In Re: Georgia Power Company Request for an Accounting Order, *supra.* (Exhibit 5.1).

[45] ICF Consulting, Georgia Environmental Facilities Authority Assessment of Energy Efficiency Potential in Georgia Final Report, May 5, 2005 at Chapter 3. (excerpt attached as Exhibit 5.2).

[46] See ICF Consulting, Georgia Environmental Facilities Authority Assessment of Energy Efficiency Potential in Georgia Final Report, May 5, 2005 at Chapter 3. (excerpt attached as Exhibit 5.2).

Power presented to the Georgia Public Service Commission during the last Integrated Resource Plan proceedings held in 2004.[47]

Conclusion

For the foregoing reasons, the petition and contentions should be admitted.

Respectfully submitted this 11th day of December, 2006,

Mary Maclean D. Asbill
Lawrence D. Sanders
Turner Environmental Law Clinic
Emory University School of Law
1301 Clifton Road
Atlanta, GA 30322
(404) 727-3432
Email: masbill@law.emory.edu

[47] The ER ignores Combined Heat & Power potential and makes no mention of this resource. A 2005 Energy and Environmental Analysis (EEA) study done on combined heat & power (CHP) in the Southeast estimated that Georgia has the technical potential for an additional 6,445 MW of combined heat & power capacity (2,615 commercial and 3,830 industrial) based on existing facilities only. Bruce Hedman, Energy and Environmental Analysis (EEA), Southeast Planning Session: CHP Market Review, July 6, 2005 at p.22. A significant percentage of the technical potential for CHP is estimated to be economic. Further, Section 9.2.2.6 of the ER fails to identify which biomass energy generating technologies and biomass feedstocks were analyzed. In Georgia, some biomass energy technologies, particularly those utilizing gasification technologies, along with some existing biomass feedstocks, such as pecan hulls, pine bark, and poultry litter, among others, could be more cost effective and should be studied as alternatives to new nuclear reactors. Also, claims made in Section 9.2.2.11 Integrated Gasification Combined Cycle (IGCC) presume that the stated risks for cost-of-service utilities of new IGCC facilities are greater than the risks of building new nuclear reactors whereas an overall risk comparison has not been made available nor has it been reviewed yet by the Georgia Public Service Commission. Lastly, Section 10.4 Benefit-Cost Balance, Section 10.4.1.2 of the ER only analyzes the option of natural gas. Other baseload options including biomass and IGCC should be analyzed, and until they are, the ER remains deficient. See fn 1, *supra*, discussing inadequacies of the 2004 Integrated Resource Plan.

Diane Curran [signature, per Morrison]

Diane Curran
Harmon, Curran, Speilberg & Eisenberg, LLP
1726 M Street N.W., Suite 600
Washington, D.C. 20036
(202) 328-3500
Email: dcurran@harmoncurran.com

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF SUSAN BLOOMFIELD

Under penalty of perjury, Susan Bloomfield declares as follows:

1. My name is Susan Bloomfield. I am a member of the Southern Alliance for Clean Energy ("SACE").

2. I live at 14 Raintree Place, Augusta, GA 30309. My home lies within 35 to 36 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized the Southern Alliance for Clean Energy to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Susan Bloomfield (signature)

Susan Bloomfield

Dated: 11/15/06

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
Early Site Permit for Plant Vogtle ESP Site	)	

DECLARATION OF DAVID J. MATOS

Under penalty of perjury, David J. Matos declares as follows:

1. My name is David J. Matos. I am a member of the Southern Alliance for Clean Energy ("SACE")..

2. I live at 707 Palm Drive, Aiken, South Carolina 29803. My home lies within 50 to 51 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized SACE to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

[signature]
David J. Matos

Dated: 12/8/06

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF WILLIAM J. MARESKA

Under penalty of perjury, William J. Mareska declares as follows.

1. My name is William J. Mareska. I am a member of the Southern Alliance for Clean Energy ("SACE"). I am also a member of Savannah Riverkeeper.

2. I live at 14 Raintree Place, Augusta, GA 30309. My home lies within 35 to 36 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I work at 3802 Washington Road, Martinez, GA 30307. My business lies within 36 to 37 miles of the Plant Vogtle site in Burke County, GA.

4. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

5. Therefore, I have authorized the Southern Alliance for Clean Energy and Savannah Riverkeeper to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

William J. Mareska DDS.

William J. Mareska

Dated: December 08, 2006

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF FRANK CARL

Under penalty of perjury, Frank Carl declares as follows:

1. My name is Frank Carl. I am a member, and Executive Director, of Savannah Riverkeeper.

2. I live at 1226 River Ridge Road, Augusta, GA 30909. My home lies within 39 and 40 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized the Savannah Riverkeeper to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Frank Carl

Frank Carl

Dated: 12/4/06

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF MIKE STACY

Under penalty of perjury, Mike Stacy declares as follows:

1. My name is Mike Stacy, and I am a member of Savannah Riverkeeper.

2. I live at 298 Prep Phillips Drive, Augusta, GA 30901. My home lies within 33 to 34 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Savannah Riverkeeper to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Mike Stacy

Dated: Dec 7, 2006

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF SAM BOOHER

Under penalty of perjury, Sam Booher declares as follows:

1. My name is Sam Booher. I am a member of the Center for a Sustainable Coast.

2. I live at 4387 Roswell Drive, Augusta, GA 30907. My home lies within 38 to 39 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized the Center for a Sustainable Coast to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Sam Booher (signature)

Sam Booher

Dated: 2 Dec, 2006

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF JUDY JENNINGS

Under penalty of perjury, Judy Jennings declares as follows:

1. My name is Judy Jennings. I am a member of the Center for a Sustainable Coast.

2. I live at 7609 La Roche Avenue, Savannah, GA 31406. My home lies off the Savannah River and downstream of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. My family and I spend many hours recreating in and by the Savannah River. I am concerned that the increase in hazardous material, and the increased cumulative impacts, in the Savannah River caused by one or more new nuclear reactors at the Plant Vogtle site will impact me and my family's recreational enjoyment of the Savannah River and its downstream tributaries.

4. The Savannah River provides drinking water for the town of Savannah, and my family and I drink this municipal water. I am concerned that the increase in hazardous materials in the water due to the new reactor, including tritium, will be harmful to our health.

5. In the event of a nuclear emergency at the Plant Vogtle site, my health and safety, and that of my family, would be affected by the radiological exposure, particularly because of my location downstream of the Plant Vogtle site.

4. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new

nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

5. Therefore, I have authorized the Center for a Sustainable Coast to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Judy Jennings

Dated: 12-26-06

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF KAREN GRAINEY

Under penalty of perjury, Karen Grainey declares as follows:

1. My name is Karen Grainey. I am a member of the Center for a Sustainable Coast.

2. I live at 316 Tanglewood Road, Savannah, GA 31419. My home lies off the Savannah River and downstream of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. My family and I spend many hours recreating in and by the Savannah River. I am concerned that the increase in hazardous material, and the increased cumulative impacts, in the Savannah River caused by one or more new nuclear reactors at the Plant Vogtle site will impact me and my family's recreational enjoyment of the Savannah River and its downstream tributaries.

4. The Savannah River provides drinking water for the town of Savannah, and my family and I drink this municipal water. I am concerned that the increase in hazardous materials in the water due to the new reactor, including tritium, will be harmful to our health.

5. In the event of a nuclear emergency at the Plant Vogtle site, my health and safety, and that of my family, would be affected by the radiological exposure, particularly because of my location downstream of the Plant Vogtle site.

4. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new

nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

5. Therefore, I have authorized the Center for a Sustainable Coast to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Karen Grainey

Dated: 12/6/2006

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
	)	
Early Site Permit for Plant Vogtle ESP Site	)	

DECLARATION OF TERENCE ALTON DICKS

Under penalty of perjury Terence Alton Dicks declared as follows:

1. My name is Terence Alton Dicks. I am a member of Atlanta Women's Action for New Directions (WAND), which is the only Georgia chapter of WAND.

2. I live at 2007-A Steiner Ave., Augusta, GA 30901. My home lies within 29 to 30 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Atlanta WAND to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Terence Alton Dicks [signature]

Dated: Dec -7- 2006

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
Early Site Permit for Plant Vogtle ESP Site	)	

DECLARATION OF JUDITH LORRAINE STOCKER

Under penalty of perjury Judith Lorraine Stocker declared as follows:

1. My name is Judith Lorraine Stocker. I am a member of Atlanta Women's Action for New Directions (WAND), which is the only Georgia chapter of WAND.

2. I live at 108 Rhodes Lee Street, Keysville, Georgia, 30816-4413. My home lies within 36 to 37 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

3. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Atlanta WAND to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Judith Lorraine Stocker

Judith Lorraine Stocker

Dated: December 7, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of Southern Nuclear Operating Company, Inc. Early Site Permit for Plant Vogtle ESP Site	Docket No. 52-011

DECLARATION OF GWENDOLYN WALKER

Under penalty of perjury, Gwendolyn Walker declares as follows:

1. My name is Gwendolyn Walker. I am a member of Atlanta WAND, which is the only Georgia chapter of WAND.

2. I live at 1108 Allen Street, Allendale, SC 29810. My home lies within 40 miles of the Plant Vogtle site in Burke County, GA, owned by Georgia Power Company, Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit to construct one or more new nuclear power reactors.

4. I believe that the Plant Vogtle ESP application is inadequate as written and that my interests will not be adequately represented in this action without the opportunity of Petitioner to intervene as a party in the proceeding on my behalf. Further, I also believe that these facilities are inherently dangerous, and that construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

5. Therefore. I have authorized Atlanta WAND to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to the Southern Nuclear Operating Company, Inc.

Gwendolyn R. Walker
Gwendolyn Walker

Dated: 12/11/06

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of
Southern Nuclear Operating Company, Inc.
Early Site Permit for Vogtle ESP Site
Docket No. 52-011

DECLARATION OF CAREY K. BARBER

Under penalty of perjury, Carey K. Barber declares as follows:

1. My name is Carey K. Barber. I am a member of Blue Ridge Environmental Defense League.

2. I live at 2689 Teakwood Dr Hephzibah, GA 30815
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Carey K Barber
(Signature)

Dated: 01 dec 2006

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of
Southern Nuclear Operating Company, Inc.
Early Site Permit for Vogtle ESP Site
Docket No. 52-011

DECLARATION OF AUDRA ROPER

Under penalty of perjury, Audra Roper declares as follows:

1. My name is AUDRA ROPER. I am a member of Blue Ridge Environmental Defense League.

2. I live at 1445 Aylesbury Drive, Evans, GA 30809
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Audra Roper
(Signature)

Dated: 12-1-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of
Southern Nuclear Operating Company, Inc.
Early Site Permit for Vogtle ESP Site
Docket No. 52-011

DECLARATION OF KIA LUKE

Under penalty of perjury, Kia Luke declares as follows:

1. My name is Kia Luke. I am a member of Blue Ridge Environmental Defense League.

2. I live at 4331 Woodvalley Pl, Augusta GA 30906. My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Kia G. P Luke
(Signature)

Dated: 11-12-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)
Southern Nuclear Operating Company, Inc.	)
Early Site Permit for Vogtle ESP Site	)
Docket No. 52-011	)

DECLARATION OF CHARLES W. BARBER, SR.

Under penalty of perjury, Charles W. Barber Sr declares as follows:

1. My name is Charles W. Barber Sr. I am a member of Blue Ridge Environmental Defense League.

2. I live at 2689 Teakwood Dr Hephzibah GA 30815
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

[signature]
(Signature)

Dated: 01 Dec 2006

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)
Southern Nuclear Operating Company, Inc.	)
Early Site Permit for Vogtle ESP Site	)
Docket No. 52-011	)

DECLARATION OF MILDRED L. WALKER

Under penalty of perjury, Mildred L. Walker declares as follows:

1. My name is Mildred L. Walker. I am a member of Blue Ridge Environmental Defense League.

2. I live at 2503 Patterson bdg Rd Hephzibah, GA 30815
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Mildred L. Walker
(Signature)

Dated: 11-12-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)
Southern Nuclear Operating Company, Inc.	)
Early Site Permit for Vogtle ESP Site	)
Docket No. 52-011	)

DECLARATION OF CICERO LUKE

Under penalty of perjury, Cicero Luke declares as follows:

1. My name is Cicero Luke. I am a member of Blue Ridge Environmental Defense League.

2. I live at 4338 Woodvalley Place Augusta, Ga. 30906. My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Cicero Luke
(Signature)

Dated: 11-12-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)
Southern Nuclear Operating Company, Inc.)
Early Site Permit for Vogtle ESP Site)
Docket No. 52-011)

DECLARATION OF CYNTHIA RICHARDSON

Under penalty of perjury, Cynthia Richardson declares as follows:

1. My name is Cynthia Richardson. I am a member of Blue Ridge Environmental Defense League.

2. I live at 1826 Cooney Cir Augusta GA 30904
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Cynthia Richardson
(Signature)

Dated: 11-09-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)
Southern Nuclear Operating Company, Inc.)
Early Site Permit for Vogtle ESP Site)
Docket No. 52-011)

DECLARATION OF SHIRLEY COLEMAN

Under penalty of perjury, Shirley Coleman declares as follows:

1. My name is Shirley Coleman. I am a member of Blue Ridge Environmental Defense League.

2. I live at 4352 CreeKview Dr. CreeKview Dr. Heph. Ga 30815
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Shirley Coleman
(Signature)

Dated: 11-09-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)
Southern Nuclear Operating Company, Inc.)
Early Site Permit for Vogtle ESP Site)
Docket No. 52-011)

DECLARATION OF HEATHER OGLESBY

Under penalty of perjury, Heather Oglesby declares as follows:

1. My name is Heather Oglesby. I am a member of Blue Ridge Environmental Defense League.

2. I live at 2509 Church St. Hephzibah, GA.
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

[signature]
(Signature)

Dated: 110906

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)
Southern Nuclear Operating Company, Inc.	)
Early Site Permit for Vogtle ESP Site	)
Docket No. 52-011	)

DECLARATION OF CLARENCE GUIDRY

Under penalty of perjury, Clarence Guidry declares as follows:

1. My name is Clarence GUIDRY. I am a member of Blue Ridge Environmental Defense League.

2. I live at 391 Barnsley DR. Evans GA 30809
My home lies within ________ miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

(Signature)

Dated: 11-9-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)
Southern Nuclear Operating Company, Inc.)
Early Site Permit for Vogtle ESP Site)
Docket No. 52-011)

DECLARATION OF HOLICE C. McCLAIN, Sr.

Under penalty of perjury, Holice C. McClain, Sr declares as follows:

1. My name is Holice C. McClain Sr. I am a member of Blue Ridge Environmental Defense League.

2. I live at 3721 Beacon Hill Dr. Hephzibah, GA 30815
My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Holice C. McClain Sr.
(Signature)

Dated: 11-09-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)
Southern Nuclear Operating Company, Inc.)
Early Site Permit for Vogtle ESP Site)
Docket No. 52-011)

DECLARATION OF MARVIN McRAE

Under penalty of perjury, Marvin McRae declares as follows:

1. My name is Marvin McRae. I am a member of Blue Ridge Environmental Defense League.

2. I live at 710 Hudgens Ct Evans, Ga. 30809.
My home lies within ________ miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Marvin McRae
(Signature)

Dated: 11/9/06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)
Southern Nuclear Operating Company, Inc.)
Early Site Permit for Vogtle ESP Site)
Docket No. 52-011)

DECLARATION OF CORA L. MOORE

Under penalty of perjury, Cora L. Moore declares as follows:

1. My name is Cora L. Moore. I am a member of Blue Ridge Environmental Defense League.

2. I live at 4243 Windsor Springs Rd Hephzibah, GA
My home lies within 56 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Cora L. Moore
(Signature)

Dated: 11-07-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)
Southern Nuclear Operating Company, Inc.	)
Early Site Permit for Vogtle ESP Site	)
Docket No. 52-011	)

DECLARATION OF MELVIN LEE AVERY

Under penalty of perjury, Melvin Lee Avery declares as follows:

1. My name is Melvin Lee Avery. I am a member of Blue Ridge Environmental Defense League.

2. I live at 2907 Shadow Ridge Dr. apt-5, Augusta, GA. My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Melvin Lee Avery
(Signature)

Dated: 11-9-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of)
Southern Nuclear Operating Company, Inc.)
Early Site Permit for Vogtle ESP Site)
Docket No. 52-011)

DECLARATION OF BERNICE BUSSEY

Under penalty of perjury, Bernice Bussey declares as follows:

1. My name is Bernice Bussey. I am a member of Blue Ridge Environmental Defense League.

2. I live at 4010 Apt B Wheeler Woods Rd Augusta, Ga 30909. My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Bernice Bussey
(Signature)

Dated: 11-9-06

061012

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)
Southern Nuclear Operating Company, Inc.	)
Early Site Permit for Vogtle ESP Site	)
Docket No. 52-011	)

DECLARATION OF ROSALYN CONYERS

Under penalty of perjury, Rosalyn Conyers declares as follows:

1. My name is Rosalyn Conyers. I am a member of Blue Ridge Environmental Defense League.

2. I live at 3205 Riley Ct. Hephzibah, GA 30815. My home lies within 50 miles of the site in Burke County, Georgia, jointly owned by Georgia Power, Oglethorpe Power Corporation, Municipal Electric Authority of Georgia and the City of Dalton for which Southern Nuclear Operating Company, Inc. has applied to the U.S. Nuclear Regulatory Commission ("NRC") for an Early Site Permit for the construction of one or more new nuclear power plants.

3. Although no design for a new nuclear plant has been submitted, based on historical experience with nuclear reactors to date, I believe that these facilities are inherently dangerous. Therefore, construction of one or more new nuclear reactors so close to my home could pose a grave risk to my health and safety. In particular, I am concerned that if an accident involving atmospheric release of radiological material were to occur, I could be killed or become very ill.

4. Therefore, I have authorized Blue Ridge Environmental Defense League to represent my interests in this proceeding by opposing the issuance of an Early Site Permit to Southern Nuclear Operating Company, Inc.

Rosalyn Conyers
(Signature)

Dated: Nov. 9, 2006

061012

EXHIBIT 1.1

TABLE 3. Native resident, diadromous, marine, and upland fish species of the MSRB (listed in phylogenetic order).

	Scientific name	Common name
Resident species		
Lepisosteidae	*Lepisosteus osseus*	longnose gar
	Lepisosteus platyrhincus	Florida gar
Amiidae	*Amia calva*	bowfin
Clupeidae	*Dorosoma cepedianum*	gizzard shad
Cyprinidae	*Cyprinella leedsi*	bannerfin shiner
	Cyprinella nivea	whitefin shiner
	Hybognathus regius	eastern silvery minnow
	Hybopsis rubrifrons	rosyface chub
	Nocomis leptocephalus	blueheaded chub
	Notemigonus crysoleucas	golden shiner
	Notropis chalybaeus	ironcolor shiner
	Notropis cummingsae	dusky shiner
	Notropis hudsonius	spottail shiner
	Notropis lutipinnis	yellowfin shiner
	Notropis maculatus	taillight shiner
	Notropis petersoni	coastal shiner
	Opsopoeodus emiliae	pugnose shiner
	Pteronotropis stonei	lowland shiner
	Semotilus atromaculatus	creek chub
Catostomidae	*Carpiodes cyprinus*	quillback
	Carpiodes velifer	highfin carpsucker
	Erimyzon oblongus	creek chubsucker
	Erimyzon sucetta	lake chubsucker
	Hypentelium nigricans	northern hogsucker
	Minytrema melanops	spotted sucker
	Moxostoma collapsum	notchlip redhorse
	Moxostoma robustum	robust redhorse
	Scartomyzon sp. cf. *lachneri*	brassy jumprock
Ictaluridae	*Ameiurus brunneus*	snail bullhead
	Ameiurus catus	white catfish
	Ameiurus natalis	yellow bullhead
	Ameiurus nebulosus	brown bullhead
	Ameiurus platycephalus	flat bullhead
	Noturus gyrinus	tadpole madtom
	Noturus insignis	margined madtom
	Noturus leptacanthus	speckled madtom
Esocidae	*Esox americanus*	redfin pickerel
	Esox niger	chain pickerel
Umbridae	*Umbra pygmaea*	eastern mudminnow
Aphredoderidae	*Aphredoderus sayanus*	pirate perch
Amblyopsidae	*Chologaster cornuta*	swampfish
Fundulidae	*Fundulus chrysotus*	golden topminnow
	Fundulus lineolatus	lined topminnow
Poeciliidae	*Gambusia holbrooki*	eastern mosquitofish
Atherinopsidae	*Labidesthes sicculus*	brook silverside
Centrarchidae	*Acantharchus pomotis*	mud sunfish
	Centrarchus macropterus	flier
	Enneacanthus chaetodon	blackbanded sunfish

TABLE 3. (continued)

	Scientific name	Common name
Resident species		
Centrarchidae	*Enneacanthus gloriosus*	bluespotted sunfish
	Enneacanthus obesus	banded sunfish
	Lepomis auritus	redbreast sunfish
	Lepomis gibbosus	pumpkinseed
	Lepomis gulosus	warmouth
	Lepomis macrochirus	bluegill
	Lepomis marginatus	dollar sunfish
	Lepomis microlophus	redear sunfish
	Lepomis punctatus	spotted sunfish
	Micropterus salmoides	largemouth bass
	Pomoxis nigromaculatus	black crappie
Elassomatidae	*Elassoma evergladei*	Everglades pygmy sunfish
	Elassoma okatie	bluebarred pygmy sunfish
	Elassoma zonatum	banded pigmy sunfish
Percidae	*Etheostoma fricksium*	Savannah darter
	Etheostoma fusiforme	swamp darter
	Etheostoma hopkinsi	Christmas darter
	Etheostoma inscriptum	turquoise darter
	Etheostoma olmstedi	tessellated darter
	Etheostoma serrifer	sawcheek darter
	Percina nigrofasciata	blackbanded darter
Diadromous species		
Acipenseridae	*Acipenser brevirostrum*	shortnose sturgeon
	Acipenser oxyrinchus	Atlantic sturgeon
Anguillidae	*Anguilla rostrata*	American eel
Clupeidae	*Alosa aestivalis*	blueback herring
	Alosa mediocris	hickory shad
	Alosa sapidissima	American shad
Moronidae	*Morone saxatilis*	striped bass
Marine species		
Megalopidae	*Megalops atlanticus*	tarpon
Belonidae	*Strongylura marina*	Atlantic needlefish
Mugilidae	*Agonostomus monticola*	mountain mullet
	Mugil cephalus	striped mullet
Achiridae	*Trinectes maculatus*	hogchoker
Upland species		
	Micropterus coosae	redeye bass[1]

[1] The Savannah River is the only area of the redeye bass's range where it occurs below the Fall Line.

EXHIBIT 1.2

The
Conservation and Restoration of the Robust Redhorse
Moxostoma robustum

Volume 1

June 1998

prepared for the

Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

prepared by

A.S. Hendricks
Georgia Power Company
Environmental Laboratory
Smyrna, Georgia 30080

GEORGIA POWER
A SOUTHERN COMPANY

ACKNOWLEDGEMENTS

This report, and more importantly the conservation and restoration efforts for the robust redhorse described herein, could not have been possible without the cooperation and contributions of many agencies, private companies, environmental organizations, and individuals. The list of cooperators for this project would necessarily be long and most likely incomplete. The author has attempted to identify cooperating organizations, but not necessarily individuals, where appropriate within the body of this report.

The material for this report was gathered from a multitude of sources, including licensing documents and reports, complete and incomplete project reports, Robust Redhorse Conservation Committee updates, letters, personal communications, and oral presentations. Some of the study summaries presented were necessarily based on draft reports or incomplete data. These instances were identified where appropriate. The reader should exercise appropriate judgment regarding the interpretation and distribution of that material. To decrease possible confusion that may result from the author's personal interpretation of some events or study results, some portions of text in this report were adopted in whole or part, exactly as it appeared in the original document.

TABLE OF CONTENTS

1. INTRODUCTION

From 1991 - 1996, Georgia Power's Sinclair Hydroelectric Project (FERC No. 1951) was relicensed through the Federal Energy Regulatory Commission (FERC). Sinclair Dam impounds the Oconee River in central Georgia to form Lake Sinclair. The Sinclair Project is primarily used to provide generation capacity during peak demand periods, and to serve as the lower reservoir for Georgia Power's Wallace Dam pumped storage project.

This relicensing effort represented the first hydro project relicensing using the new Applicant Prepared Environmental Assessment Process (APEA), as authorized by the Energy Policy Act of 1992. This process included the submission of a Draft Environmental Assessment (DEA) with the final license application, in lieu of the usual Exhibit E, or Environmental Report.

During the beginning of the licensing process a rare fish was "rediscovered" in the Oconee River, downstream of the Sinclair Project by biologists working for the Georgia Department of Natural Resources, Wildlife Resources Division. The fish was eventually identified as the robust redhorse *Moxostoma robustum*. Subsequent reviews by many agencies and individuals suggested that conservation and restoration actions should begin immediately for this species. The APEA process fostered stakeholder inputs and agreements during licensing, and the Endangered Species Act contained provisions to encourage stakeholder partnerships to conserve imperiled species and their habitats.

Several stakeholder partnerships and agreements were formulated during and independent of the licensing process. The first, and perhaps most important of these to be covered in this report, was the creation of the Robust Redhorse Conservation Committee (RRCC). The RRCC was given the responsibility to implement research, conservation, and restoration actions for the robust redhorse. Other agreements included a negotiated flow agreement for the Oconee River designed primarily to enhance habitat for the robust redhorse, and the Robust Redhorse Flow Advisory Team for the Oconee River (Advisory Team). The Advisory Team was given the responsibility of reviewing data to monitor the effectiveness of the new flows and if necessary, make recommendations to the FERC regarding any future flow modifications for the Oconee River.

The new license for the Sinclair Project, issued by the FERC on 19 March 1996, required the submission of a report every two years to the FERC. The license stated that these reports should document the status of the robust redhorse and provide a determination regarding the adequacy of flow releases in meeting the needs of the robust redhorse. Per license requirements, this document represents the first of such reports.

This report is not intended to be a fully detailed accounting of every aspect of the conservation and restoration of the robust redhorse. However, much progress has been made during the last few years and many organizations and individuals have contributed to the project. Some progress has been made through trial and error. It is reasonable to expect mixed success during the early years of a conservation effort for a largely unknown species.

The author believed that it is necessary, at least for this initial report, to provide enough background and appropriate details to enable the reader to fully understand the magnitude of this conservation effort, as well as the growing base of knowledge and the logical progression of work. This report begins with the discovery of the robust redhorse, and some coverage is given to the early years of the conservation effort. The bulk of this report is devoted to actions that have occurred since the creation of the RRCC in 1995.

2. REDISCOVERY AND COOPERATION

2.1 Rediscovery of the Robust Redhorse *Moxostoma robustum* in the Oconee River, Georgia

The following information regarding the rediscovery of the robust redhorse was reprinted almost verbatim from a fact sheet detailing the collection and early extent of knowledge about the species. This information can be located in many reports and publications written by many individuals during the last few years, although the original fact sheet continues to be one of the more complete and explanatory sources on the rediscovery of this species. Mr. James Evans of the GA Department of Natural Resources, Wildlife Resources Division (GDNR) initially drafted the fact sheet, relying on his extensive personal experience with the robust redhorse, personal communication with other scientists, and the following unpublished manuscripts:

Jenkins, R.E., and B.J. Freeman. Systematics of the molar-toothed redhorse suckers (Moxostoma carinatum) and the rediscovered M. robustum of the south Atlantic slope (Pisces: Catostomidae).

Jenkins, R.E. Systematics of the brassy jumprock (Scartomyzon braesius, new species; formerly called Moxostoma robustum) of the south Atlantic slope (Pisces, Catostomidae).

"Five large catostomids were collected from the Oconee River below Sinclair Dam near the mouth of Commissioner Creek on 8 August 1991. Meristic characteristics did not correspond precisely to any known species and average length exceeded that of all catostomid species known to occur in the Altamaha River drainage. Preserved specimens were sent to Dr. Henry Bart, then curator of the Auburn University fish collection. He indicated that these fish might belong to what was then believed to be an undescribed species known to ichthyologists by only two existing specimens - one collected from the Savannah River, Georgia/South Carolina in 1980, and a second from the Pee Dee River, North Carolina in 1985. Informal names applied at the time to the species represented by the two Savannah/Pee Dee specimens were the bighead redhorse and the Savannah River redhorse."

"The status of this species was being investigated by Dr. Robert Jenkins of Roanoke College, Virginia; by personnel from the National Fisheries Research Center in Gainesville, Florida; and by Dr. Byron Freeman, curator of the University of Georgia fish collection. All investigators subsequently concluded that the Oconee, Savannah, and Pee Dee river specimens represented a single species. Prior to the discovery of the Oconee River population, during the period 1981 - 1990, ichthyologists, biologists, and consultants in Georgia and the Carolinas had been consulted and portions of the Savannah River were sampled in an effort to obtain more specimens. None were found."

"Initially, the Oconee, Pee Dee, and Savannah River specimens were believed to represent a new species, probably an Atlantic slope form of the river redhorse *Moxostoma carinatum*. The species is now believed to have been described by master naturalist Edward Cope in 1870 from specimens collected from the Yadkin River, North Carolina and given the scientific name *Ptychostomus robustus* (*Ptychostomus* is synonymous with the present genus designation *Moxostoma*). Cope's original type specimens were apparently lost and later workers erroneously labeled specimens of other species as types. The scientific *P. robustus*, which Cope had intended to be applied to the robust species represented by the Oconee, Pee Dee, and Savannah river specimens, was instead misapplied by later revisionists of the Catostomidae to a smaller species. This smaller species, sympatric with the larger more robust form, has since 1956 been known in the scientific literature, incorrectly, as *Moxostoma robustum* - the smallfin redhorse. As a result of these investigations, the scientific name *Ptychostomus* (*Moxostoma*) *robustus* will be transferred as *Moxostoma robustum* (Cope) (robust redhorse) to the species known from the Oconee, Pee Dee, and Savannah river specimens. The smallfin redhorse will be placed in the jumprock genus (*Scartomyzon*) and given the common name brassy jumprock (Jenkins and Freeman, in preparation)."

"Subsequent to the discovery of the Oconee River population of robust redhorse, investigations by Jenkins and Freeman into the status of this species included a review of "gray literature" such as federal aid reports, state fisheries reports, and biological surveys as well as studies of museum fish collections. In a further attempt to locate other remnant populations, the Pee Dee and Yadkin rivers in North Carolina, the Ogeechee and Broad rivers in Georgia, and the Savannah River, Georgia/South Carolina, were sampled by personnel from a variety of agencies as well as by companies with hydropower interests in these rivers."

To date, the only one other population of robust redhorse outside the Oconee River has been discovered. In October 1997, a single adult robust redhorse was caught from the Savannah River about 50 river miles downstream from Augusta, GA. During a June, 1998 survey of the Savannah River near Augusta, GA, four adult robust redhorse were captured. A more detailed accounting of this discovery is presented in a later section of this report.

"Skeletal remains of an additional specimen from the Savannah River were discovered at the University of Georgia. Pharyngeal teeth from the robust redhorse have also been found at an archeological site near Brier Creek, Georgia (Savannah River drainage). Anecdotal reports of large redhorse suckers persist from portions of the species former range, specifically from the Pee Dee and Yadkin rivers, North Carolina, and from the Savannah, Ogeechee, and Ohoopee rivers in Georgia. The general consensus of most authorities is that small, isolated remnant populations of the species could exist in one of these rivers, or perhaps elsewhere. All authorities agree that the species is in danger of extinction, perhaps within the next decade, and that recovery efforts should be initiated as soon as feasible (Jenkins and Freeman, in preparation)."

Some literature indicates that spawning runs of catostomids, and probably the robust redhorse, were declining in the late 1800s. Scientists believe that the most likely early causes for these declines may have been overfishing and excessive siltation from wide-spread land clearing and related agricultural practices. In more recent times, threats to native riverine fish populations have been associated with pollution and continued sedimentation of spawning and rearing habitats, construction of dams and associated changes in hydrologic regimes, and rapidly expanding populations of introduced predator species, including flathead *Pylodictis olivaris* and blue *Ictalurus furcatus* catfishes. The exact reasons for the apparent decline and range restriction of the robust redhorse are as yet unknown.

"Other significant findings to date from literature reviews, museum research, and field investigations on the Oconee River and elsewhere are outlined below.

1). The historic range of the species is believed to be the Piedmont and upper Coastal Plain areas from the Altamaha River drainage in Georgia through the Carolinas to at least the Pee Dee River, North and South Carolina. The known range of the Oconee River population is from approximately 1.6 km below the GA Hwy. 22 bridge at Milledgeville downstream to about 18 km above Dublin, a distance of approximately 85 km. Several attempts to collect additional specimens from the Oconee River below Dublin were unsuccessful. A review of available data and anecdotal information from throughout the Altamaha River drainage, including the Oconee River above Lake Sinclair, has produced no verifiable evidence of the presence of this species outside the area delineated above. It is probably reasonable to assume, however, that isolated individuals could exist in the Oconee River below Dublin or perhaps even in the Altamaha River.

2). Preferred habitat for non-spawning adults is typically in deeper, moderately swift areas in or near outside bends, often in association with accumulations of woody debris. Spawning behavior is apparently similar to that of the river redhorse and seems to occur over both deep and shallow water gravel patches from late April to early June at water temperatures from 18 - 24 C.

3). Recaptures of tagged fish indicate significant variability in movement patterns among individuals. Most individuals seem to migrate very little but movements of up to 27 km have been noted. Estimated population size is 1,000 - 3,000 adults based on Peterson and Chapman mark-recapture estimates.

4). Analysis of stomach contents indicates a diet consisting almost entirely of Asiatic clams (*Corbicula* sp.) which are crushed with large molariform pharyngeal teeth. Similar dentition is found in two other species of redhorse, the river redhorse (*Moxostoma carinatum*) and the copper redhorse *(M. hubbsi*).

5). A preliminary age and growth investigation indicated that over 90% of the population is between 15 and 26 years of age although a few fish as young as 5 - 6 years of age have been collected. Age and growth studies using various bony structures have shown other members of this family to be generally long-lived.

6). Length-frequency analysis of 239 robust redhorse collected from August 1991 to June 1994 shows little evidence of significant recruitment in recent years. Total length range is 424 to 722 mm, yet about 75% of the sample lies between 600 and 660 mm, or within a 60 mm (2.4 inch) range. Four individuals from this group (506, 492, 482, and 424 mm) may have been juveniles with the remainder clearly adults."

2.2 The Robust Redhorse Conservation Committee

The Robust Redhorse Conservation Committee (RRCC) was formed by the signing of a Memorandum of Understanding (MOU) in 1995. The RRCC was designed as a stakeholder partnership to restore the robust redhorse throughout its former range. The primary goals of the RRCC are to implement research and conservation measures, enhance recruitment in the existing Oconee River population, and re-establish robust redhorse populations in several river systems within the species' former range.

This stakeholder partnership approach to recovery was selected in lieu of possible listing under the Endangered Species Act (ESA) in part because a large number of private landowners and companies would necessarily be involved in the conservation of this species. Another partial reason for this approach was that conservation actions have often been delayed for various reasons upon the announcement of a proposal to federally list a species under the ESA. With this partnership approach, however, research and conservation actions could begin almost immediately, saving potentially invaluable time for the robust redhorse. Other advantages to this approach include a cooperative, instead of confrontational, environment for the parties involved. This appears to foster more rapid and efficient conservation actions. The MOU provides that the USFWS would ultimately evaluate the effectiveness of these recovery efforts. If the USFWS determines that the survival and enhancement of the robust redhorse can not be accomplished with this or other similar approaches, the USFWS may initiate listing action under the ESA.

Membership of the RRCC is representative of a diverse group of interests and expertise. Current members of the RRCC include the Georgia Department of Natural Resources (GDNR), South Carolina Department of Natural Resources (SCDNR), North Carolina Wildlife Resources Commission (NCWRC), U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey - Biological Resources Division (USGS), U.S. Forest Service (USFS), U.S. Army Corps of Engineers (USACOE), Georgia Power Company, Duke Power Company, Carolina Power and Light, and the Georgia Wildlife Federation. The MOU provides for "cooperator" status to be assigned to agencies, organizations, or individuals that are interested in the conservation of the robust redhorse but do not want formal representation on the RRCC.

The RRCC is the overall vehicle directing recovery of the robust redhorse, and has determined priority avenues for necessary research and action. Through formal annual meetings and innumerable informal meetings among members and other interested parties, the RRCC has identified impediments to the recovery effort, designed and conducted research related to those impediments, and formulated solutions or plans for dealing with those impediments. The RRCC has also been very effective in publicizing the recovery effort. As originally intended, the RRCC has been the driving force behind the conservation and restoration of the robust redhorse.

Most of the contents of this report are the direct result of actions taken or directed by the RRCC or its members. Several work items are being planned and conducted at present, which will be discussed during later sections of this report.

2.3 The Flow Advisory Team For the Oconee River

Negotiated Flow Agreement for the Oconee River

The primary focus of negotiations during the relicensing of the Sinclair Project was the potential flow requirements of the robust redhorse, especially the early life stages. During the relicensing of the Sinclair Hydroelectric Project, Georgia Power and EA Engineering, Science, and Technology had completed numerous studies on the robust redhorse. These included surveys for the availability of gravel spawning substrates, monitoring of spawning activity, surveys for young-of-year and juvenile robust redhorse, characterization of spawning habitat, and the development of habitat suitability criteria for the Oconee River. Other studies conducted during relicensing that were useful in these negotiations were an assessment of the fluvial geomorphology of the Oconee River, a description and evaluation of the floodplain, wetlands, and oxbow connectivity, boat passage, and a comprehensive instream flow study that utilized the Instream Flow Incremental Methodology (IFIM). Primary negotiating parties included Georgia Power Company, the Wildlife Resources Division and the Coastal Resources Division of the GDNR, the USFWS, and the National Marine Fisheries Service (NMFS).

The negotiating parties realized that even though there was little evidence of recent recruitment, the only population of robust redhorse known at that time persisted, for unknown reason(s) downstream of the Sinclair Project. The general consensus among the negotiating parties was that little information was available that pointed to specific causes for the apparent lack of recruitment in the Oconee River population. The FERC staff encouraged a tiered, incremental approach to a flow agreement for the Sinclair Project, instead of large-scale, sweeping changes to the existing flow regime. Initial flow modifications would need to be evaluated with respect to the robust redhorse and other fish species. Future modifications of the flow regime would necessarily be based on the best available information, and all members of the Advisory Team would need to agree on the best course of action.

A negotiated flow agreement was finalized in 1995 prior to the submittal of the license application. The negotiated flow agreement, outlined in Table 1 below, was designed primarily to enhance reproductive success of the robust redhorse. Specifically, the flow agreement provides: 1) significant increases in minimum flows throughout the year, 2) a significant increase in flow stability throughout the year, and 3) run-of-river flows for spawning and early rearing for robust redhorse and anadromous species.

Table 1. Negotiated flow agreement for Sinclair Hydroelectric Project.

MONTH	FLOW and OPERATION
Dec - Feb	500 cfs minimum, normal peaking
Mar - Apr	1500 cfs minimum, modified peaking[A]
May	run-of-river
Jun[B] - Nov	700 cfs minimum, normal peaking

[A] - modified peaking refers to the number of units (1 or 2) to be utilized depending on the amount of inflow to the reservoir

[B] - From June 1 -10, units will be operated run-of-river unless electric system demands necessitate normal peaking operation

The agreement also provided for an increase in generation scheduling from 5 to 7 days per week. This was done to reduce the extended low flow periods that previously resulted from little weekend generation.

The Flow Advisory Team

The MOU that established the RRCC included provisions for creating additional working groups to address specific issues related to the conservation and restoration of robust redhorse. The first of such groups, created by an agreement drafted largely by Georgia Power Company, was the Robust Redhorse Flow Advisory Team for the Oconee River (Advisory Team). The Advisory Team functions under the overall umbrella of the RRCC with shared memberships and administration. The current members of the Advisory Team are the GDNR, USFWS, USGS, Georgia Wildlife Federation, and Georgia Power. The Advisory Team is to be coordinated by Georgia Power Company for the life of the license, unless it is determined that the Advisory Team is no longer necessary. This may occur if the appropriate federal agency declares the robust redhorse extinct, or recovered and no longer in need of special protection.

The primary responsibilities of the Advisory Team are to monitor the effectiveness of the flow changes and other environmental conditions on the robust redhorse in the Oconee River. The agreement provides that the Advisory Team may review flow data from the Oconee River, studies developed by the RRCC, and other pertinent information related to the robust redhorse to help determine any necessary changes to the negotiated flow agreement. If studies suggest that flow changes are needed for the Oconee River, the Advisory Team may petition the FERC with its recommendations. These recommendations would then be subject to appropriate FERC evaluation and approval.

The Advisory Team has not yet made any formal determinations regarding the adequacy of the negotiated flow agreement for the Oconee River with respect to the robust redhorse. It would be difficult to attempt to make such a determination at the present time, partially because of the short time the flow agreement has been in effect. The following paragraphs explain the rationale behind the previous statement.

The flow agreement was finalized during 1995, the same year that formal studies began investigating hypotheses relating to robust redhorse recruitment in the Oconee River. The Reproductive and Recruitment Success studies that involve collection of larval and juvenile fishes from the Oconee River have been ongoing since 1995. Data collected during 1995 under the previous Sinclair flow regime suggested very low abundance of larval robust redhorse. It was unclear, however, whether the observed abundance was an accurate representation of the population of larval fishes in the river, or if some unknown sampling deficiency could have influenced the catch.

Although finalized in 1995, the flow agreement for the Oconee River was not actually implemented until June 1996, as requested by the RRCC. This request was made largely because of the natural variability associated with aquatic systems. It was believed that one year of data under the existing flow regime would not be representative of baseline conditions, making it difficult to fairly evaluate the new flow regime. By delaying the implementation of the flow agreement, it was possible to collect additional year of reproductive and recruitment success data under the existing flow regime.

Consequently, 1997 was the first year of data collection under the new flow agreement. At the conclusion of sampling this fall (1998), the Advisory Team will have 2 years each of pre- and post-flow agreement data available on larval and juvenile robust redhorse abundance and distribution in the Oconee River. Temperature and flow data from several locations in the Oconee River will also be available, as will the results of many other studies that have been directed at the requirements of the early life stages of robust redhorse. Thus, it is anticipated that the Advisory Team will begin formal analysis and decision making at the conclusion of the 1998 recruitment study.

Preliminary results of the larval fish collections and other studies have been encouraging. During 1997, the first year fully under the new flow regime, sampling results suggested relatively large increases in larval robust redhorse abundance compared to 1995 and 1996 (research summaries provided in later sections of this report). The reader is cautioned that the numbers of robust redhorse larvae captured still seem very low, and some aspects of sampling equipment and locations are still under development. These results, though encouraging, should not yet be interpreted as evidence of definitive improvement in the reproductive success of the Oconee River population.
Flow stability may be important for the successful completion of spawning and survival of early life stages of many riverine species. The negotiated flow agreement provides higher minimum flows throughout the year and run-of-river flows during May and early June. This schedule was designed to provide maximum flow stability during spawning and early rearing for the robust redhorse. In addition, spawning conditions for other species such as striped bass should be improved. Although studies to date have not revealed the exact causes or mechanisms affecting robust redhorse recruitment in the Oconee River, run-of-river flows during the May and early June should be suitable for riverine species.

Research projects have attempted a logical and systematic testing of early hypotheses potentially related to reproduction and recruitment of robust redhorse in the Oconee River. Research summaries presented later in this report indicate that a few hypotheses relating to the potential direct effects of the operation of Sinclair Dam on robust redhorse have been at least partially refuted. Of course, much research remains to be conducted to determine specific mechanisms that influence recruitment, possibly through discreet and indirect effects.

Although much data will soon be available to the Advisory Team, several factors can not be overlooked that may contribute some confusion to the analysis. One factor is the natural variability in both hydrologic regimes and fish populations. As an example, the second year of the new flow regime (1998) was probably influenced by the global weather phenomenon known as El Nino, which contributed to prolonged high water conditions during the winter and spring throughout the southeastern United States.

Another factor that the Advisory Team may need to consider when evaluating the new data is the interruption of run-of-river flows for collection of broodfish during the May spawning season (on the Oconee River) of robust redhorse. Low flows for broodfish collection are currently critical to the overall recovery efforts for the robust redhorse, and every attempt is made to minimize the duration and frequency of these events. It is unknown, however, whether any effects associated with the interruptions of run-of-river flows are positive or negative, although it is clear that the provision of low flows can contribute to more rapid warming of river temperatures than would be the case under run-of-river conditions.

3. CONSERVATION STATUS AND ACTIONS

3.1 Status of the Oconee River Population of Robust Redhorse

The age and size structure of the Oconee River population appears to have advanced slightly, but remains similar to original estimates made in 1994. Most of the data available for this population has been gathered in conjunction with broodfish collection efforts. Fish collected are double anchor tagged, measured, weighed, the location noted, and other items of interest recorded. The population evidently remains mostly composed of older adult individuals about 60 - 70 cm total length, with little evidence of recruitment into the population. However, 1 - 3 immature specimens of about 42 cm total length have been captured each year since 1992. This work and work by other researchers has to date failed to capture robust redhorse less than 42 cm.

Population estimates based on mark-recapture studies conducted during 1995 and 1996 estimated the adult population to be 2,439 and 1,746, respectively. These data appeared to indicate a decline in numbers, but this conclusion could not be made with confidence because of the high variance associated with the estimates. Survival estimates from 1995 to 1996 were nearly 1, which indicated excellent survival between years. Electrofishing catch rates have declined since 1994. However, many factors, including water stage and temperature at the time of sampling can influence catch rates of robust redhorse and contribute to variance.

These data suggest that the Oconee River robust redhorse has not begun a drastic decline. Length-frequency analysis continues to indicate a cause for concern, as was the case during the early years of this project. Robust redhorse remain the number one species in terms of abundance in certain sections of the Oconee River. However, the catch may be biased as the researchers were usually targeting robust redhorse. Unfortunately, flathead catfish are regularly collected within these same sections, and may eventually pose predation problem for juvenile robust redhorse.

Plans are to continue monitoring the Oconee River population for significant recruitment. The projects currently funded and planned for the near future will hopefully discover the reasons for the lack of juvenile fish in the Oconee River, and shed light on the most likely causes for the widespread decline of this species throughout the Atlantic slope drainages. With this information and knowledge of specific requirements of the early life stages and productive hatchery techniques, it is hoped that enhancement of the Oconee River population and the eventual recovery of the robust redhorse will be realized.

3.2 Research Summary

The following section summarizes formal research that has been aimed along two basic lines of investigation: 1) culture techniques for robust redhorse, and 2) the ecology and biology of the robust redhorse in the Oconee River. No effort was made to distinguish projects among these two investigation lines for this report because in many cases, information gained was relevant to both. These summaries are not intended to be detailed reports, but simply to provide the reader with sufficient information to understand the need and rationale for each project as related to the overall goals of the recovery effort, and to present significant results of each project. Many projects were continued for multiple years, but these summaries are presented in chronological order to enable the reader to understand the logical progression of the projects based on knowledge gained and the systematic testing of early hypotheses.

In addition to formally funded research, much less-publicized investigation and observation has been conducted within the laboratories at the USFWS Warm Springs (GA) Regional Fish Technology Center, the Institute of Ecology at the University of Georgia, and at the Georgia Cooperative Fish and Wildlife Research Unit, also located at the University of Georgia. Sperm cryopreservation, nutrient requirements of early life stages, and water quality for production are just a few examples. Other informal studies have undoubtedly been conducted at the many hatcheries that have served as rearing centers for robust redhorse. Although little information regarding much of this work is provided in this report, the information gained from this work is potentially critical for formulating relevant and efficient research plans.

The bulk of the funding for the following research projects was provided by Georgia Power Company. The bulk of the research was conducted by Dr. Cecil A. Jennings of the Georgia Cooperative Fish and Wildlife Research Unit (UGA), Dr. James L. Shelton of the Warnell School of Forest Resources (UGA), Dr. Byron J. Freeman of the Institute of Ecology (UGA), and Gregory L. Looney of the Warm Springs Fish Technology Center (USFWS). Dr. Robert E. Jenkins of Roanoke College, Virginia was also contracted for the age, growth, and maturation studies. It is doubtful that many of these projects could have been successfully completed without the additional funds and enormous amount of in-kind services provided by the Georgia Department of Natural Resources, the United States Fish and Wildlife Service, the University of Georgia, and volunteer participation. Duke Power, Carolina Power and Light, and the Electric Power Research Institute also contracted with Dr. Ike Wirgin of New York University for genetic research.

Many portions of the following text were included verbatim from submitted research reports, summaries, and electronic communications.

3.2.1 1995 Research Summaries

Project 1. Hormone Induced Ovulation of Robust Redhorse *Moxostoma robustum*

To facilitate recovery of the robust redhorse, adult broodfish from the only known Oconee River population were used to produce offspring for research and reintroduction purposes. However, initial attempts to spawn robust redhorse, by both natural and artificial means, were largely unsuccessful. Some eggs were produced from female fish that were "running ripe" at the time of collection, but these numbers were far below what was needed for a valid effort at recovery. It became apparent that artificial spawning, and the development of a reliable and efficient hormone treatment regime was vital to the success of the recovery program.

The initial research project for developing a hormone treatment regime for robust redhorse propagation was conducted during spring, 1995. The objectives of this project were to:
1) evaluate the effectiveness of five different hormones in inducing robust redhorse to ovulate,
2) determine the optimum treatment dosage for the most effective hormones or hormone combination, and
3) determine if robust redhorse spawn intermittently.

A temporary broodfish holding and spawning facility was constructed on the banks of the Oconee River at Beaverdam Wildlife Management Area (WMA). The spawning facility originally included nine circular holding tanks that were aerated and supplied with a continuous flow of river water from electrical pumps. The site at Beaverdam WMA was selected because it was relatively close to the area of broodfish collection, which would greatly minimize transport and holding times of adult broodfish.

The study involved testing five hormone treatments, administered via injection, on female robust redhorse, along with a control group that were subjected to injections of a sterile saline solution. Hormones and dosage rates were selected based on a review of scientific literature, personal communication with other researchers, and product information provided by the manufacturers. Broodfish were returned to the Oconee River upon completion of each spawning trial.

Broodfish were collected with boat-mounted electrofishing gear from May 1 to May 3, 1995. A total of 33 females were collected, but only 21 of these were used in the study, based on a determination of appropriate spawning condition for hormone treatments. A total of 58 males were collected, all with free flowing milt. Seventeen males were transferred to holding tanks for egg fertilization.

Nine of the 17 females injected with hormones ovulated, but none of the fish in the control group ovulated. Eggs collected per female ranged from 1,485 to 86,295. It appeared that robust redhorse are capable of intermittent spawning, as some of the females released additional eggs one day after initial collection.

This work indicated that Ovaprim, Carp Pituitary Extract (CPE), and Human Chorionic Gonadotropin (HCG) were effective for inducing ovulation and increasing spawning success of broodfish. However, specific dosage rates and treatment intervals needed to provide optimum results were unknown.

About 800,000 eggs were produced from both natural and artificially induced females. The eggs were transported to McDuffie Fish Hatchery, Warm Springs Fish Hatchery, and Whitehall Fisheries Lab for incubation. About 71,000 fry were produced and shipped to grow-out ponds at various hatcheries. Pond inventory from November 30 - December 1, 1995 indicated that about 40,000 (56%) fry had survived to fingerling stage.

Project 2. Spawning Behavior of Robust Redhorse in the Oconee River, Georgia

Some field observations from the Oconee River indicated that the robust redhorse may construct redds in gravel substrate, but these observations were not thoroughly documented. Whether robust redhorse construct redds or not could be important in determining reasons for limited recruitment in the Oconee River population. The specific objectives of this project were to:
1) document spawning-related behavior prior to and during the spawning act, and
2) identify specific habitat conditions associated with the spawning sites.

Three reaches of the Oconee River were surveyed by boat for spawning robust redhorse and/or suitable spawning sites. These surveys focused on known gravel deposits and areas that were shallow enough to allow direct observation. High flows and turbidity hindered the survey effort. However, spawning robust redhorse were observed from 14-22 May 1995, at a gravel bar near the Avant Mine site at about river mile 120. Documentation of spawning behavior was recorded with both video and still photography. Water velocity, depth, substrate, water temperature, and other variables were recorded at spawning sites.

Spawning was observed from dawn to dusk, and occurred over small to medium-sized gravel. Water velocity ranged from 35 - 60 cms and daytime water temperature fluctuated around 25 C during observation. It appeared that male robust redhorse were very territorial and would actively defend their staging position on the gravel bar against other males. Females staged in a pool upstream of the gravel bar, and when ready, moved onto the gravel bar between two males. Gametes were released as the three fish pressed into each other, with caudal and anal fins plowing into the gravel substrate. One group of spawning fish included three males and two females, and spawning behavior was often violent and aggressive as non-participating males butted participating males with their snouts. This behavior was consistent with some other species of the genus *Moxostoma*.

The Laurens County section of the Oconee River has at least one active spawning population and suitable habitat to support other breeding groups. Spawning habitat, based on observable activity, is moderate to swift, shallow water over loose gravel substratum.

Project 3. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River, GA

From the first efforts to document the status of the robust redhorse in the Oconee River, it appeared that the population was skewed toward larger, older individuals. Robust redhorse had been observed spawning in the Oconee River, however, many efforts directed at collecting juvenile or young-of-year (YOY) fish were unsuccessful. This combination of circumstances suggested reproductive or recruitment failure in recent years. Data regarding spawning success, distribution and abundance of larvae, and estimates of larval growth and mortality were needed to determine if the scarcity of juvenile robust redhorse is related to recruitment failure or other non-biological factors. Specific objectives for this task were to:

1) document spawning activity,
2) determine reproductive success,
3) determine growth and mortality of larval life stages sampled from the Oconee River

Pushnets, D-ring nets, light traps, and seines were used to sample larval fishes from about a 51 km reach of the Oconee River from May 10 to December 8, 1995. Depth, water velocity, turbidity, water temperature, and dissolved oxygen were recorded for each sample. Fish samples were preserved in 10% buffered formalin and returned to the laboratory where they were examined for the presence of larval and juvenile robust redhorse. After picking, twenty percent of the sample residues were re-examined to determine to efficiency of project personnel extracting larval fish.

Six hundred twenty-two samples were collected from the Oconee River that contained 45,698 larval and juvenile fishes, representing 11 families. Six larval robust redhorse were identified from these samples. Most of these (5) robust redhorse were caught in late May with pushnets. These larvae were 13-14 mm total length, with five being collected at night, directly upstream of a suspected spawning site.

Larval and juvenile suckers of other species were relatively abundant in the samples. However, density estimates for robust redhorse larvae ranged from 0.0 to 13.4 per 1000 m^3 of water sampled. It appeared that the chosen gear types were effective at sampling larval fishes from the Oconee River. Each gear seemed to work better during different flow conditions, but based on the numbers and diversity of fishes collected, it seemed that most of the sampling gear worked well most of the time.

A D-ring net was deployed nine times about 1-3 m downstream of spawning fish at the Avant Mine site. Four nets contained no eggs, the other nets contained 81, 1, 1, 9, and 2 eggs. Considering the known fecundity of robust redhorse from Project 1, it appeared that the eggs may be buried in the gravel during the spawning act, preventing most egg drift. This also suggested that newly hatched larvae would probably also remain buried in interstitial spaces within the gravel substrate until all yolk material had been absorbed.

This study suggested that larval and juvenile life stages of robust redhorse were rare in the Oconee River. However, it was unclear whether the scarcity of larval and juvenile robust redhorse in the samples was strictly a function of abundance, or if other sampling and biological considerations contributed to the low catch rates. Growth and mortality of larval robust redhorse could not be estimated because of insufficient numbers of larvae collected.

Project 4. Surveys for Additional Populations of Robust Redhorse

Robust redhorse were known only from a small reach of the Oconee River between Milledgeville and Dublin, Georgia. Recovery efforts would benefit from the discovery of other remnant populations within the suspected former range of this species. Such a population would provide additional information about the habitat requirements, and possibly lend clues regarding the apparent recruitment failure in the Oconee River. These status surveys may also provide information on the occurrence of flathead and blue catfish, two recently introduced, highly predatory species that are expanding their range. Introduced catfish predation can negatively affect native sucker populations. The primary objective of this project was to locate other remnant populations of robust redhorse.

Preliminary surveys for robust redhorse were planned for the Broad River and Brier Creek, two major tributaries of the Savannah River. Historical collections of robust redhorse are known from the Savannah River near Augusta. Robust redhorse remains were also identified from a shell midden in the floodplain of Brier Creek. However, only the Broad River could be sampled during 1995 because of time constraints associated with fund availability and acquiring the necessary sampling gear.

Eight collections were made with boat-mounted electrofishing gear in Madison and Elbert Counties, GA, during December 1995 and January 1996. Several sucker species were collected including silver redhorse, northern hogsucker, and jumprock, but no robust redhorse were collected. Carpsuckers were seen but not captured. Silver redhorse were particularly abundant, as were Asiatic clam *Corbicula* sp. *Corbicula* sp. are a food item of robust redhorse. Flathead catfish were also collected, having been introduced into Clarks Hill Reservoir in 1964. However, most individuals were small and flathead density appeared low. The existence of flathead catfish within the drainage for many years, and the abundant and diverse sucker population in the Broad River, suggested that flathead catfish may have limited success colonizing the upper Broad River system.

Preliminary sampling in the Broad River indicated that suitable habitat and a forage base were available for robust redhorse. Brier Creek was believed large enough to support robust redhorse, and records exist of a prehistoric population. The researchers suggested Brier Creek should remain a priority for future robust redhorse surveys.

3.2.2 1996 Research Summaries

Project 1. Effects of Temperature and Water Flow on the Incubation and Survival of Robust Redhorse eggs and larvae

Although robust redhorse spawning was documented in the Oconee River, it appeared that the abundance of larvae and juveniles was low. This suggested that environmental conditions may be unsuitable for incubation of eggs and larvae. Little was known about the early life history requirements of robust redhorse, and temperature and water flow are two of the most critical factors influencing the survival of fishes during early life stages.

This project was designed to provide information regarding optimum incubation parameters for robust redhorse eggs and larvae. If temperature and/or flow conditions were problematic within the Oconee River, this project could help provide information for a solution, and help determine factors needed in other rivers that are prospective stocking sites for establishing reproducing populations.

In addition, egg to fry survival rates had been very low under laboratory conditions. Data gathered from this project could be useful in establishing more efficient hatchery protocols for producing robust redhorse fingerlings. Specific objectives of this project were to:

1) examine incubation success through a range of flow rates and turbulence levels, and
2) examine the effects of water temperature on incubation success.

Fertilized robust redhorse embryos obtained from the hormone-induced ovulation work conducted earlier in the spring were used for this study. An incubation system that allowed control of water temperature and flow velocity for replicate groups of embryos was constructed. Water flow treatments ranged from a low flow rate that produced no turbulence to a high flow rate that produced high turbulence for the incubating eggs. Five temperature treatments were used, which included 15, 19, 23, 27, and 30 °C. Six replicates were to be used for each flow rate at each temperature. Surviving larvae were counted and examined for deformities immediately after each trial was completed.

Surprisingly, the robust redhorse embryos were positively buoyant when introduced to the study chambers. This was the first, and only, time that positive buoyancy had been noted during incubation. A control group of embryos placed in McDonald hatching jars also floated. It was thought this buoyancy could have occurred as a result of changes in internal gas pressures within the embryos during transport or tempering. Because of this buoyancy problem, data regarding temperature effects reflect all flow treatments combined. Data collected on the effects of flow and turbulence was deemed not statistically defensible by the researchers, and was presented only in support of, and as a guide to, future studies dealing with temperature and flow effects on incubation.

The highest survival was encountered at 23 °C and decreased as water temperature increased or decreased. None of the 4,800 embryos subjected to 30 °C survived, and deformities were most prevalent at 27 °C and 15 °C. Incomplete spinal development was the most common deformity. This type of deformity would almost certainly result in death.

In sustained flow treatments survival was extremely low for the high-flow, high-turbulence levels. No strong relationship was observed between survival and flow rate when embryos were transferred to low turbulence treatments at the start of hatching.

The highest survival rates occurred at 23 °C (32%) and 19 °C (23%). Similarly, deformities were lowest at 19 °C (3%) and 23 °C (4%). These data suggest possible optimum incubation temperature around 23 °C, and that temperatures higher than 27 °C or lower than 19 °C would likely contribute to significant mortality. Water temperature data collected at the spawning facility during broodfish collection efforts ranged from 17.3 to 26.1 °C. Therefore, it is possible for wild-spawned robust redhorse larvae to be exposed to high, possibly detrimental water temperatures in late May.

Sustained flow versus reduced flow treatments indicated robust redhorse fry may experience higher mortalities when exposed to adverse conditions after hatching. This research indicated that yolk-sac fry may be a critical developmental stage relative to environmental conditions. This suggested that robust redhorse fry could be susceptible to mortality if displaced from the gravel before the yolk-sac is fully absorbed.

Even though unexpected problems affected this study, the information provided was useful in many ways to the overall goals of the recovery effort. The results of this project suggested that yolk-sac fry are the most vulnerable life stage, and that physical and/or biological processes affecting the substrate during their presence is worthy of future study.

Project 2. Swimming Performance of Larval and Juvenile Robust Redhorse: Implications for recruitment in the Oconee River, GA

One hypothesis for the apparent lack of recruitment in the Oconee River robust redhorse population was negative impacts of hydropeaking flows on early life stages. Hydrological conditions downstream of peaking facilities can be highly variable, and may influence water depth, velocity, and temperature, and possibly other factors involving the spawning substrate. The variability in depth and velocity is of particular importance, especially for those fishes that may require relatively shallow and slow habitat conditions during early life stages. Therefore, the swimming ability of a species, and its ability to maintain position in desired habitats, may be a critical factor to survival.

Through laboratory experiments, this project attempted to document the swimming ability of three size classes of larval robust redhorse under varying flow conditions. A literature review provided information regarding the swimming ability of robust redhorse relative to other fishes. The overall goal of this project was to test the hypothesis that larval robust redhorse could tolerate typical low-velocity currents that occurred during power generation at Sinclair Dam. Specific objectives were to:
1)measure prolonged swimming speeds of three size-classes of larval and juvenile robust redhorse in a gravity-flow current flume, and
2)determine the availability of larval fish rearing habitat, defined by current velocity, varied between minimum and peaking flow releases at Sinclair Dam during May and June when early life stages of robust redhorse would be most vulnerable to flow.

Swimming Performance
About 1,000 newly hatched robust redhorse larvae were randomly selected from those available from the artificial spawning efforts. Swimming performance was measured by determining the failure velocity (FV50). Mean total length of the three size classes was 13.1, 16.2, and 20.4 mm. Swim-up typically occurred at about 11 mm total length. Water temperature was kept constant for each size class of fish tested, but was increased with increasing size classes to simulate water temperature that the specific size class would have experienced in the Oconee River during May and June. The range of current velocities tested was 3.6 - 6.7 cm/s, and the mean increment between test velocities was 1.1 cm/s. For this project, current velocity and fish score (pass/fail) were synonymous with toxin dosage and animal survival in toxicity experiments.

Larval and juvenile robust redhorse often responded to increases in current velocity by laying on the bottom of the swim tube. Once the fish started swimming, swimming behavior was more similar to striped bass *Morone saxatilis* than larval and juvenile Colorado squawfish *Ptychocheilus lucius*. Robust redhorse exhibited photopositive behavior when positioning within the swim tube.

The proportion of robust redhorse that successfully completed a 1 hour swimming trial at a prescribed velocity decreased as velocity increased for each size class tested. Prolonged swimming speeds increased with length for larval and juvenile fish. However, the increase in swimming performance from 13.1 to 16.2 mm fish was greater than the increase from 16.2 to 20.4 mm fish. FV50 values were estimated for both 30 minute and 60 minute intervals.

Swimming speeds of yolk-sac (13.1 mm = 6.9 cm/s, 5.3 BL/s) and larval robust redhorse (16.2 mm = 10.6 cm/s, 6.5 BL/s; 20.4 mm = 11.7 cm/s, 5.7 BL/s) were among the highest reported for early life stages. Prolonged swimming speeds were greater than striped bass (lowest reported), but less than Colorado squawfish (highest reported). Swimming performance of larval robust redhorse was high, as expected.

Rearing Habitat Modeling
Four study sites were used to assess the effects of peaking flow releases on rearing habitat availability in the Oconee River at seven river discharges (500 - 6,000 cfs). PHABSIM models developed by EA Engineering during relicensing studies for Sinclair Dam were used to estimate robust redhorse rearing habitat, using swimming performance data gathered as part of this project. Mean Weighted Usable Habitat (WUH) was calculated at seven discharges for each of the four study sites, and was based on the swimming performance of the 13.1 mm size class larvae. Regression analysis was used to evaluate the relationship between discharge and rearing habitat.

Availability of larval robust redhorse rearing habitat was relatively low at the Avant Mine, Georgia Railroad Bridge, and Highway 57 study sites at all river discharges. The greatest mean WUH estimates were calculated for the Dublin site at 4,000 - 6,000 cfs. Relationships between mean WUH and discharge were not significant at the Avant Mine, Georgia Railroad Bridge, or the Highway 57 study sites. However, a positive relationship was evident between discharge and habitat availability for Dublin study site. These data suggested that peaking flows did not cause current velocity to limit larval robust redhorse rearing habitat in the Oconee River. High discharge was actually related to increased rearing habitat at Dublin, the furthest site downstream from Sinclair Dam.

These results indicated that even though WUH was not correlated with discharge (at three sites), the position of appropriate rearing habitat was dynamic during changing discharges. The conclusion that hydropeaking events at Sinclair Dam did not limit available larval habitat assumes that larval fish can move as the habitat moves within the River. Although the quantity of larval robust redhorse habitat (based on depth and current velocity) was estimated during this project, the quality of this habitat remains unknown.

Project 3. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River, GA (Year 2)

This project was a continuation of similar work performed during 1995, with intentions to build on information learned during the initial phase of this project. The objectives for this project were modified slightly, based on 1995 sampling results and new hypotheses regarding the fate of eggs and larvae within the gravel substrate. The 1996 objectives for this project were:

1) document continued spawning activity,
2) determine abundance of larvae in spawning sites, and
3) determine the abundance of larvae in the Oconee River

Weekly sampling of larval and juvenile fishes was conducted during approximately the same time frame as 1995, again using pushnets, D-ring nets, light traps, and seines. A benthic pump was used at the spawning site to determine if eggs were being deposited in the gravel, and to quantify the abundance of eggs and larvae. Water depth, velocity, temperature, turbidity, and dissolved oxygen were again collected for each fish sample. Handling of samples was similar to the previous study. Twenty percent of the sample residues were re-examined to determine to efficiency of project personnel extracting larval fish.

The catch of larval and juvenile fishes in 1996 was similar to, but slightly lower than the catch from the same reach of river during 1995. Four hundred twenty-two samples were collected that contained 38,715 larval and juvenile fishes that represented 11 families. Cyprinids comprised about 90% of the sample by number, and as in 1995, Catostomids were well represented in the catch.

Some robust redhorse eggs and larvae were collected at the spawning site with the benthic pump, but in very low numbers. A laboratory experiment helped determine that the benthic pump was about 33% effective in sampling fertilized robust redhorse eggs from gravel substrate, which may partially explain the low catch.

Only three larval robust redhorse were caught in icthyoplankton drift samples, which led to much lower estimates of density (1.5 - 3.5 per 1000 m3 of water) than in 1995 (0.0 - 13.4 per m3 of water). The 1995 density estimates were obtained during early to mid May, and the density estimates for 1996 were obtained during late May and early June. Whether these density estimates represented actual differences in larval robust redhorse abundance, or the estimates reflected temporal differences in fish collection was unclear. Densities of larval robust redhorse sampled from the gravel substrate also appeared low. These low estimates may have been be a reflection of sampling efficiency, however, overall densities of larval robust redhorse in the Oconee River seemed low relative to the large numbers of spawning adults frequenting gravel areas.

Thirty-six juvenile silver redhorse were collected during 1996, but no robust redhorse juveniles were collected. Early assumptions were that robust redhorse and silver redhorse occupied the same or similar habitats, and would behave similarly with regard to avoidance of sampling gears. If these assumptions were true, differences in catch rates should reflect actual differences in species abundance. However, juvenile robust redhorse have demonstrated extremely wary behavior in the laboratory, and have proven difficult to capture in hatchery ponds. Differences in behavior and/or habitat preference may partially explain reduced catch rates of robust redhorse juveniles from the Oconee River, or the actual numbers of juvenile robust redhorse may be extremely low.

Another possibility for the apparent differences in abundance may be spawning time as related to river conditions. Silver redhorse spawn earlier in the spring than robust redhorse, possibly when river conditions would be less affected by hydro operations. During May when robust redhorse typically begin spawning, peaking ability at Sinclair Dam can be extremely important to the Southern Electric system. Other projects conducted during 1996 attempted to determine the possible relation between generation flows, habitat stability, and robust redhorse recruitment.

3.2.3 1997 Research Summaries

Project 1. Effects of Temperature and Water Flow on the Incubation and Survival of Robust Redhorse Eggs and Larvae (year 2)

Initial work for this project was begun in 1996, however, unexpected problems with egg buoyancy prevented statistical analysis and confidence in portions of the study. This project was designed to repeat the initial flow and temperature study with redesigned flow chambers, as well as confirm and refine results obtained during 1996. Specific objectives were to:

1) refine estimates of optimum temperature for incubation of eggs and fry,
2) determine optimum flow rate for hatching success of eggs and development of larvae,
3) evaluate interactive effects of flow and temperature on survival of eggs and larvae,
4) determine if eggs from early-, peak-, and late-spawning fish, and from different parental crosses, respond similarly to the effects of temperature and flow.

Complete analysis of this project was not available for this report, however, preliminary data appeared to confirm earlier results. Narrower ranges of temperatures tested indicated that water temperatures around 21 - 23 °C may be optimum for survival of eggs and larvae. These data also showed that higher tested flows resulted in higher mortalities to both eggs and larvae than the lower flows tested. In addition, some flow trials resulted in good egg incubation, but were lethal to fry. These results appeared to confirm earlier suspicions that yolk-sac fry were more fragile than either eggs or swim-up fry.

Project 2. Effects of Gravel Quality and Percent Fine Sediment on the Hatching and Survival of Robust Redhorse Eggs

This project represented the next logical step in a series of studies designed to address the apparent lack of recruitment of robust redhorse in the Oconee River. Previous projects have documented continued spawning, egg deposition in the gravel, and that survival to emergence (STE) was low. Sedimentation has been shown to negatively affect survival of salmonid eggs and larvae. It was believed that examination of some of these same factors in the Oconee River could further narrow the possible causes for low STE of robust redhorse. The goal of this project was to determine if the low abundance of larvae and observed absence of juvenile robust redhorse were related to poor incubation habitat

in terms of gravel quality and percent fine sediment. The specific objectives of the project were to:
1) determine the size(s) of gravel most suitable for survival of robust redhorse larvae,
2) evaluate the effects of fine sediment on STE,
3) determine if suitable-sized gravel is present in the Oconee River in high enough concentrations to permit high STE.

To determine gravel size most suitable for survival of larvae, five treatments of various-sized gravel were used that represented the range of gravel sizes available in the Oconee River. A fixed volume of fertilized robust redhorse eggs would be incubated in each gravel treatment. The substrate producing the highest percentage of larval emergence would be considered optimum size for robust redhorse STE.

To determine the effects of percent fine sediment on STE, treatments would involve fixed volumes of fertilized eggs placed 6 - 15 cm deep in separate trays of optimum-sized gravel. Other projects have determined that robust redhorse eggs are usually buried between 6 - 15 cm in the gravel substrates during the spawning events. These treatments were inoculated with 25%, 50%, or 75% fines. Three replicates of each treatment combination were evaluated. Water temperature and flow was be controlled to mimic the conditions present in the Oconee River during the time of the experiment.

Preliminary results indicated that peak emergence occurred on day 16, somewhat later than occurred during normal hatchery operations. Results also indicated that lower percentages of fines in the gravel contributed to greater STE. Preliminary conclusions of this project were that gravel quality, in terms of size and amount of fine sediments present in the Oconee River, may affect STE of robust redhorse.

Project 3. Substrate Stability and Spawning Behavior of Robust Redhorse in the Oconee River

Substrate Stability

The purpose of this project was to continue narrowing the focus of the research into the possible causes of low recruitment in the Oconee River, based on what had been learned from previous projects. Other projects have pointed to the early life stages of robust redhorse as the possible bottleneck for this population. The physical characteristics of spawning sites and the stability of these areas during spawning may be important factors in recruitment process from yolk-sac larvae to emergent fry. Specific objectives of this project were to:
1) characterize physical attributes of known spawning sites,
2) estimate potential change in physical habitat from hydropower operations at Sinclair Dam,
3) estimate the potential for physical movement of gravel to reduce STE,

Gravel mobility was assessed by calculating and comparing shear stresses on the gravel bed during various hydropower operations. United States Geological Survey rating curves for the Avant Mine site were collected, and additional channel and bed composition surveys were conducted. Direct observations of particle movements were conducted with tracer gravel studies, and evaluated across a range of hydro operations. In addition, scour chains were used to assess the amount of scour and fill that might occur during hydro operations. A model was developed to help describe potential gravel movements at various flow regimes.

This project also attempted to assess any change in fine sediment composition of gravel areas during hydro operations. Freeze core substrate samples were used to describe these changes. Bed sediment transport was measured with pit-fall traps and modified Whitlock-Vibert boxes. Suspended sediment was measured with rising stage samplers.

Preliminary results of this study indicated that gravel patches were relatively stable across a 2,000 cfs flow event. Habitat modeling of the study site showed that shear velocities remained relatively low over gravel habitat, although shear velocities at higher modeled discharges could pose problems for emerging larval suckers. Freeze core samples documented that robust redhorse eggs are distributed to depths greater than 9 cm below the substrate surface. Fine sediments within the core samples were not abundant, although it appeared the repeated spawning acts may help to displace much of the finer sediments from the substrate.

Spawning Behavior of Robust Redhorse

Results of previous studies suggested that robust eggs were buried in gravel substrates during spawning events. The possibility that repeated spawning events at the same site may dislodge or damage already deposited eggs was worthy of investigation. This project was to document the mechanics of egg burial, and further characterize microhabitat of known spawning areas. Specific objectives of this project were to:

1) determine the mechanics of egg burial and any effects of repeated spawning acts on the same site,
2) identify the commencement of spawning at known and suspected spawning sites in the Oconee River,
3) determine if shifts in spawning activity occur with changes in water stage,
4) determine if cyprinids previously seen near spawning areas were feeding on drifting eggs or larvae.

During April and May, 1997, at the Avant Mine site, robust redhorse were observed exhibiting pre-spawning behavior (swirling and porpoising). Frequent high flows associated with rainfall events and the usually high spring turbidity hindered efforts at direct visual observation. At times, hydro-acoustic equipment was used to monitor robust redhorse activity. Most spawning activity was observed in water less than 75 cm deep, although the researchers were unable to directly observe fish in deeper water.

An underwater microphone was used to record sounds made by spawning redhorse. Recordings were made during observed spawning events, and were diagnostic for the presence/absence of spawning fish. Sounds result from the displacement and agitation of gravel during the spawning act. The sounds were usually intense enough to be heard out of water. Some investigators could feel the vibrations in the gravel bed. The microphone has the potential to help monitor spawning activity during conditions where direct observation is impossible.

Bannerfin shiners *Cyprinella leedsi* observed near the spawning site were collected with seines. Bannerfin shiners appear to be drift feeders, and stomach content analysis of the captured fish indicated that the shiners were actively feeding on robust redhorse eggs and larvae.

Preliminary data indicated robust redhorse eggs were usually highly concentrated in localized areas. These data also suggested at least some eggs were not buried during spawning events, or were possibly dislodged by other spawning events.

Researchers determined that robust redhorse were spawning during times of high flow and turbidity that would have prevented direct observation. These data also suggested that robust redhorse were spawning during discharges in excess of 2,300 cfs. This preliminary evaluation indicated that robust redhorse may successfully spawn in a wide range of flow conditions.

Project 4. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River (year 3)

This project was a continuation of larval fish sampling that began in 1995. The purpose of this project was to help determine whether the causes of the apparent recruitment failure in the Oconee population is biological or environmental. Monitoring the abundance and distribution of larval and juvenile robust redhorse in the Oconee River is also a critical component of the work necessary for determining the effects of the new flow regime at Sinclair Dam. The specific objectives for this project were to:
1) determine abundance of larval robust redhorse in spawning sites, and
2) determine the abundance of larval and juvenile robust redhorse in the Oconee River.

As in the previous two years, this project involved the use of multiple gear types to collect larval and juvenile fishes from the Oconee River, including pushnets, light traps, and seines. Water temperature, depth, velocity, turbidity, and dissolved oxygen were again measured for each sample collection.

Preliminary results for this project indicated that 25 larval and post-larval robust redhorse were captured. Nineteen were caught with pushnets, five with seines, and one was caught in a light trap. This catch, during the first year under the new flow regime, more than doubled the highest abundance estimate from previous years. Peak density (# per 1000 m3 of water) estimates for 1995, 1996, and 1997 were 13.4, 3.4, and 32.1, respectively. No YOY robust redhorse were captured, so there was still little evidence of recruitment to the adult population. It could not be determined whether the observed increase in larval density was a true reflection of larval abundance, or if sampling efficiency improved. However, these results were encouraging.

Project 5. Age, Growth, and Maturation of Robust Redhorse

Age, growth, and age at maturation data were lacking for the robust redhorse, and also for its believed closest relative, the river redhorse *Moxostoma carinatum*. This project would help determine some critical aspects of robust redhorse biology, including the age of sexual maturity, typical and maximum longevity, reproductive potential of the species during a given year, and reproductive potential over the life span of individuals. These data would also provide valuable information on the age structure of the Oconee River population. Accurate age structure information could be important by allowing determination of environmental conditions in the Oconee River when strong and weak year-classes were produced. The river redhorse was included in this study partially because large sample numbers of robust redhorse of varying sizes are not currently available, and it was suspected that published accounts of age, growth, and maturation of river redhorse were erroneous.

Other researchers have demonstrated the validity of using opercles for long-lived fish. Opercles were the primary hard structures used during this project for aging redhorse, although a few lapillus otoliths were aged to determine similarity with opercles. Preliminary work by Dr. R.E. Jenkins on robust and river redhorse opercle bones indicated that one major annulus was formed on the opercle during each year. All available (38), wild-caught, adult specimens of robust redhorse were used for developing age-growth relationships, in addition to pond-reared juveniles. About 500 specimens of river redhorse were to be used. The opercle method was validated using 1) known-age fish, 2) marginal increment analysis, and length-frequency analysis. Length-frequency analysis may only be useful for younger redhorse because of extensive overlap in adult fish size. Specific objectives of this project were to:

1) determine year-class of all wild caught robust redhorse,
2) age at each annulus,
3) sexual differences in growth, if any,
4) age and size at maturation by sex,
5) length-weight relationship,
6) geographic variation in growth,
7) comparison of ages determined by opercles, otoliths, and scales, and
8) morphological growth trajectories

This project is currently incomplete, but preliminary results indicated that opercles were a valid structure for aging robust redhorse. For fish age 10 years and older, scale ages were slightly to grossly underestimated relative to opercle ages. Scales may be acceptable to about age 5. Beyond age 5, the use of scales may lead to underestimation of robust redhorse ages.

Mean age of the 34 Oconee River specimens used for aging was 18; 17.4 for males and 19.1 for females. The youngest fish were an age 4 male and an age 10 male. Ages 11-15 were represented by 6 fish, ages 16-20 by 14, and ages 21-25 by 12 fish. These data suggested an older-aged population with little recruitment. Survival to adulthood occurred unevenly across years. Year classes of the 34 fish span 1967 - 1988. Of these 22 years, 13 are represented by 1-5 fish. Age at maturation is probably 4-5 for males and 5-6 for females.

Back-calculation of lengths-at-age indicated length increase to be moderate in year 1, relatively rapid in years 2-5, and generally slowing to little or no advancement of length in ages 15-25.

The heaviest fish, a gravid female, was collected by EA Engineering, Science, and Technology on 22 May 1993. This fish was reported to be 8 kg (17.64 lb) and 682 mm TL. The longest robust redhorse was 732 mm TL, caught during spring 1995. The largest reported river redhorse was a female taken from the Elk River, Missouri, in April, 1986. That fish weighed 7.743 kg (17 lb 1.12 oz) and was 812.8 mm in total length.

Oconee River adult females were larger than males on average, which is typical of redhorses. The quadratic equation for the length-weight relationship of the 38 fish was: $Wt = 729.3805 - 11.2276(SL) + 0.0333\ SL^2$, $R^2 = 0.733$.

Project 6. Genetic Investigation of the Oconee River Robust Redhorse Population

One of the original questions concerning the lack of recruitment in the Oconee River population centered around the numbers (est 1,000 - 3,000) of adults using a few known and suspected spawning sites. There seemed to be a good possibility for inbreeding, or at least a probability of low genetic diversity, within the Oconee River robust redhorse population. Recovery efforts for other species have often been heavily criticized for initiating stocking programs without genetic characterization of wild and hatchery stocks. In order to successfully establish other reproducing populations, or restock the Oconee River if necessary, answers regarding of the genetic diversity of the robust redhorse could be valuable. Specific objectives of this project were to:

1) determine if the Oconee population contains single or multiple genetic stocks,
2) compare nuclear DNA of hatchery and native stock,
3) determine the extent of inbreeding within the Oconee River population.
4) Develop rapid and sensitive PCR-based approach to identify young life stages of robust redhorse from a mixed sucker species, early life stage collection.

Preliminary results indicated genetic diversity of the Oconee River robust redhorse population to be on the low end of normal range when compared to other species. As of October, 1997, no significant evidence of inbreeding in the Oconee population.

Investigators continue to collect tissues samples for use in this project. Funding for this project was provided to Dr. Ike Wirgin of New York University by EPRI, Duke Power, and Carolina Power and Light.

Project 7. Surveys for Additional Populations of Robust Redhorse

Candidate stream reaches within the hypothesized historic range of the robust redhorse were prioritized using a variety of data sources. Based on the initial work, the Savannah River system and the Ohoopee River in Georgia, and the Broad River system in North Carolina emerged as primary candidates for remaining populations. Streams would be surveyed with electrofishing gear. The objectives of this project were to:

1) survey likely stream reaches for other remnant populations of robust redhorse.
2) conduct habitat assessments of stream reaches.

Surveys of the stream reaches included assessment of access potential, gross habitat assessment, and fish collection. One sampling trip was made to the Savannah River in the vicinity of U.S. Highway 301. High water levels prevented a thorough habitat assessment, and hindered fish collection efforts. A few spotted suckers *Minytrema melanops* were collected, but no robust redhorse.

Brier Creek in the Savannah River system was sampled in the fall. Fish abundance appeared low, and no suckers were captured. Relatively high water levels may have influenced electrofishing catch rates, but were suitable for a general habitat assessment. This reach was characterized as a lowland river swamp, with a poorly defined and braided channel. Little habitat was encountered that would be considered suitable robust redhorse spawning habitat.

The Ohoopee River was scheduled for survey, but high flow conditions prevented sampling efforts. However, information regarding boat and vehicle access was noted, as were reports of potential spawning shoals.

The upper Broad River system (Santee River drainage) in North Carolina was also sampled. Anecdotal reports of "large, redhorse suckers" spawning in the Rocky Broad River had been received. Spawning redhorse were observed in May, 1997, in the Rocky Broad River, but were identified as black redhorse *Moxostoma duquesnei*. No robust redhorse were observed.

The Green and Rocky Broad Rivers in North Carolina was sampled in November, 1997. This was actually part of a large, cooperative effort involving several individuals, agencies, and private companies. No robust redhorse were captured, although several other species of suckers were collected.

3.2.4 1998 Research Summaries

The following projects are either ongoing or will be attempted during 1998.

<u>Project 1. Effects of Temperature and Flow on Incubation of Robust Redhorse Eggs and Larvae</u>

This project is a partial continuation of work done in 1996 and 1997 aimed at developing more efficient techniques for hatchery production of robust redhorse. In addition, this project would have some applicability to the success of early life stages of robust redhorse in the Oconee River. Early attempts at some portions of this project achieved varied success. Less successful attempts often resulted from unforeseen and/or uncontrollable factors. Slight modifications and refinements were made to these studies based on information gained during previous studies. Modifications include a narrowing of the range of temperatures tested, and further investigation into the interactive effects of water temperature and flow on early life stages.

Project 2. Effects of Gravel Quality and Percent Fine Sediment on the Hatching success of Robust Redhorse Eggs

This project is a continuation of a similar project conducted during 1997. During 1997, the percentages of fine sediment inoculated into the gravel treatments were 25, 50, and 75%. To determine the critical level of percent fines in the spawning substrate this project will focus on substrate composition containing 5, 10, 15, and 20% fine sediment.

Project 3. Reproductive and Recruitment Success of Robust Redhorse in the Oconee River (Year 4)

This project is a continuation of earlier work to document the abundance and distribution and larval and juvenile robust redhorse in the Oconee River. This project is also of fundamental importance for documenting any changes in recruitment that may result from the new flow regime at Sinclair Dam or other unknown and possibly uncontrollable factors. Modifications to this project for 1998 include sampling of tributary streams to the Oconee River, and deep water, main channel seining. Other aspects of larval and juvenile fish collection will remain essentially the same.

Project 4. Age, Growth, and Maturation of Robust Redhorse

This project is a continuation of the age and growth project described in the previous section. The goals and objectives remain unchanged. The continuation is primarily to allow time for dealing with many new specimens of river redhorse, juvenile (pond reared) robust redhorse, and developing adequate age-growth relationships for these species.

Project 5. Genetic Investigation of the Oconee River Population of Robust Redhorse

This project is a continuation of the project started in 1997 by Dr. Ike Wirgin at New York University, and is again funded by Duke Power, CP&L, and EPRI. The goals and objectives of this project are essentially unchanged from those described in the previous section of this report, although samples from the Savannah River will be included.

Project 6. Surveys for Additional Populations of Robust Redhorse

A Georgia Power crew collecting fish samples for routine radiological analysis near Plant Vogtle downstream of Augusta GA, captured a single adult robust redhorse from the Savannah River in October, 1997. In addition, a South Carolina Department of Natural Resources biologist reported the probable, but unconfirmed, observation of a robust redhorse during fish sampling on the Savannah River near Augusta, GA. These occurrences prompted the RRCC to organize large-scale sampling efforts to determine the location and extent of any native robust redhorse population in the Savannah River. Sampling was planned to be conducted during two separate occasions for different reaches of the Savannah River during spring 1998.

On 20 - 21 May 1998, seven electrofishing boats sampled primarily two areas: from the New Savannah Bluff Lock and Dam to about 12 river miles downstream, and from Vogtle Electric Generating Plant downstream to about Little Hell Landing. These reaches of the Savannah River are typically wide and deep, and represented a much more difficult sampling task than the Oconee River. The Georgia Department of Natural Resources, the Institute of Ecology and the Cooperative Fish and Wildlife Research Unit at the UGA, Georgia Power Company, Army Corps of Engineers, Tulane University (LA), Kleinschmidt Associates, and Roanoke College (VA) supplied equipment and/or personnel for these surveys.

During the two days, the boats accumulated more than 15 hours (total pedal time) of electrofishing effort in search of robust redhorse. Effort was concentrated on sections with meander bends, areas as similar as possible to those areas in the Oconee River where robust redhorse occur. V-lip redhorse and spotted suckers were relatively abundant, and a few carpsuckers were captured from furthest downstream location on 20 May. No robust redhorse were captured. Some boats working the upper area just downstream from the New Savannah Bluff Lock and Dam reported observing a few large suckers in the electrical field, but these fish were not be captured. It is possible, but unknown, if these observations were robust redhorse. Another, but probably less intensive survey of these reaches will most likely be conducted in 1998 during the typically low-flow period of September - November.

On 3- 4 June 1998, the Savannah River was sampled in the Augusta shoals area between the City of August diversion dam and the New Savannah Bluff Lock and Dam. This reach of the Savannah River is characterized by shallower water and more shoals and rocky/gravely substrate than the downstream reaches sampled. The Corps of Engineers provided low flows of about 6500 cfs during the sampling period, about half of which would flow through the sampling area. The Georgia and South Carolina Departments of Natural Resources, the UGA Institute of Ecology, EDAW, Inc, Georgia Power Company, Duke Power, Roanoke College, and the North Carolina Museum of Natural Science provided equipment and/or personnel to assist in these surveys. A total of five electrofishing boats participated during the two day search for robust redhorse.

Four adult female robust redhorse were captured during the two days sampling, with a few additional reports of large suckers seen escaping the electric field. The captured fish were transported to McDuffie Hatchery for spawning attempts. It appeared that these fish were overripe, and no usable eggs were collected. The fish were scheduled to be released at the capture site on 8 June 1998.

The location of other robust redhorse in the Savannah River is significant. The extent and condition of this population is unknown at present, but it is encouraging that other individuals exist outside the Oconee River. The discovery of this population will undoubtedly be a topic requiring much discussion of the RRCC, and some effort will most likely be directed at broodfish collection from Savannah River during 1999.

3.3 Broodfish Collection, Fingerling Production, and Reintroduction

After the robust redhorse was rediscovered in the Oconee River in 1991 and the significance of this discovery was established, attempts were made to spawn this species during the springs of 1992, 1993, and 1994. Obviously, dealing with a fish whose biology and early life history requirements were almost completely unknown to the scientific community was a daunting task, even with the depth of professional and experienced personnel that participated in the early years of this project.

Some (400) fertilized eggs were obtained during 1992 after holding a few adult robust redhorse in tanks at Warm Spring Regional Fisheries Center. All eggs died within two days. During spring 1994, the focus was on collecting ripe broodfish for transportation to Warm Springs. Again, some eggs were produced and hatched, but none survived to fingerling stage. It was not until the spring of 1995 and more formal experiments with hormone induced ovulation that significant robust redhorse production was realized. The following section provides summary information regarding the production of eggs, fry, and stockable fish. In most cases, very detailed records were kept regarding production, pond stocking, pond harvest, transport, and reintroduction to other streams.

3.3.1 1993 year-class

A small number of eggs and fry were produced in the spring of 1993 and survived in ponds to the fingerling stage. The RRCC decided that better survival in the wild might be achieved if these fish were raised in captivity for two growing seasons, believing that the larger size of phase II fish would reduce vulnerability to predation.

From 9 March to 9 August 1995, About 545 robust redhorse juveniles from the 1993 year-class were reintroduced into the Broad River system, Georgia, at several locations. More specifically, 250 juveniles were released into the South Fork of the Broad River at Georgia Hwy 22, 195 juveniles were released into the North Fork of the Broad River at Highway 51, and 100 juveniles were released into the South Fork of the Broad River at Watson Mill State Park. The Broad River system was chosen as the initial reintroduction site primarily for the following reasons: 1) suitable habitat and food source, 2) non-existent or reduced densities of introduced catfish predators, 3) adequate access for future sampling to determine survival, 4) local support from environmental organizations, and 6) relatively undeveloped watershed with good water quality and no hydropower development.

Another creek within the Oconee River drainage was inadvertently stocked with a small number of fish from the 1993 year-class. During June 1995, the dam on a rearing pond at Walton State Hatchery broke and released about 200 juveniles into Dennis Creek. Dennis Creek is a tributary of Little River, which ultimately flows into Lake Sinclair.

These juveniles were apparently from a single mating. This occurrence prompted the consideration of Little River as a site for future stockings to enhance the gene pool, making the assumption that some of these original fish would survive to reproducing age.

3.3.2 1995 year class

The primary goal of the broodfish collection efforts during the spring 1995 was to provide enough adult robust redhorse to meet requirements of the new hormone induced ovulation studies. A specific fry production goal was not established prior to this work, largely because rearing space was not a limiting factor.

A single electrofishing boat was used to collect broodfish from the Oconee River. Two additional boats were used to transport broodfish from the capture site to the temporary hatchery and holding facility near the boat ramp at Beaverdam Wildlife Management Area. Previous work indicated that catch rates increased at low flows, and flows necessary for broodfish collection efforts were coordinated through the Georgia Power Company Control Center in Atlanta, Georgia.

From 1 - 3 May 1995, 58 male and 33 female robust redhorse (that appeared to be good candidates for spawning) were collected. Fertilized eggs (about 800,000) from 17 matings were transported to three hatchery facilities for incubation. These facilities were the McDuffie State Fish Hatchery (GA WRD), Warm Springs Regional Fish Technology Center (USFWS) and Whitehall Fisheries Laboratory (UGA). Attempts were made to maintain incubation temperatures at 22 - 24 °C. From these eggs, about 73,000 fry were produced. Overall survival from egg to swim-up fry was about 9%. Survival at the three hatcheries varied from 18% at Warm Springs to less than 1% at McDuffie. The exact causes for the high mortalities remain unknown, although it is suspected that one incident of rapid temperature elevation at the McDuffie hatchery may have resulted in the loss of almost all fry from this facility.

From 19 May to 26 June, about 70,000 fry were transported to rearing ponds at the Walton and McDuffie State Hatcheries and the USFWS Bo Ginn hatchery in Georgia, and to the McKinney Lake hatchery in North Carolina.

During 30 November and 1 December 1995, all ponds were drained and about 40,000 robust redhorse fingerlings were recovered for an overall survival rate of about 57%. Survival rate varied among the ponds and ranged from 39 - 84%. Survival did not appear correlated to stocking rate. These fingerlings were restocked at reduced densities to be grown a second year. It was believed that an additional year of growth, and thus additional size, would reduce the fingerling's vulnerability to predators and enhance overall survival when reintroduced to wild streams in the fall of 1996.

During November 1996, only about 3,104 phase II robust redhorse fingerlings were harvested from the grow-out ponds at the various hatcheries. Overall survival from phase I to phase II was about 8%, and individual pond survival ranged from 86% at

Walton hatchery to less than 1% at several ponds at the McDuffie and BoGinn hatcheries.

Varyied mortality was experienced at all ponds under various environmental conditions and handling procedures. No consistent pattern was revealed among the different hatcheries and ponds, and the primary causes of mortality were unknown.

During November, 1996, about 1,424 total robust redhorse juveniles (1995 year class) were stocked into the Broad River system, Georgia. More specifically, 150 juveniles were released into the South Fork of the Broad River upstream from Watson Mill State Park, and 150 juveniles were released into the North Fork of the Broad River near the community of Franklin Springs, GA. About 1,124 juveniles were released into the Hudson River near its junction with the Broad River.

About 1,377 juveniles were stocked into ponds at the Piedmont Wildlife Refuge to start building a refugial population of robust redhorse. The small number of remaining fingerlings were retained at McDuffie hatchery or sent to the UGA.

3.3.3 1996 year class

Collection and transportation of broodfish to the temporary spawning facility was conducted as in 1995. Flows for broodfish collection were again coordinated through the Georgia Power. Broodfish were collected and spawned on three occasions from 29 April to 23 May 1996. A total of 12 females and 21 males were used to produce a total of 477,119 eggs. (Twenty-four crosses were made, but some of these crosses experienced high mortalities for unknown reasons. It was unclear how many crosses contributed significantly to the fry production. It appeared that the third spawning attempt near the close of the natural spawning window produced the fewest fry). A portion of the total egg production was used in various early life history studies.

After incubation, about 98,000 (about 30% survival from egg to swim-up) fry were collected for transport to Walton and McDuffie State Fish Hatcheries. About 2,000 fry were retained by the UGA for use in ongoing studies. The bulk of the fry were stocked into four rearing ponds at the two hatcheries during June, 1996. These ponds were harvested during February, 1997, and there was essentially no survival from any of the ponds. About 400 fingerlings reared at UGA's Whitehall Lab represented the only production for the 1996 year class. Most of these fingerlings were transferred to the SCDNR hatchery at Cheraw in March, and a small number were retained at Whitehall Lab for use in other research.

3.3.4 1997 year class

Broodfish collection resumed during 12 - 14 May and 19 - 22 May 1997 and methods were similar to previous years. Fish were spawned at the Beaverdam WMA temporary hatchery using the hormone induced ovulation techniques developed through research projects. Largely because of the widespread failures of the 1996 year-class, the fry production goal was increased to 200,000.

A total of 126 robust redhorse were collected during May, 1997, and 61 (48%) fish were female and two (1.6%) were juveniles. Fifty-three fish were recaptures from previous collection efforts. A total of 30 females and 45 males were transported to the spawning facility. Eight females were spawned without the use of hormones and produced 79,491 eggs. Eight females also underwent hormone treatments (Ovaprim), and the spawning rate for these fish was 100%. Artificially induced ovulation produced 280,683 eggs, for a total 1997 egg production of 360,174. About 65,000 of these eggs were shipped to UGA and Warm Springs Fish Technology Center for use in various research projects. The remaining eggs were shipped to McDuffie hatchery, UGA, and Warm Springs. A portion of these eggs were also used for early life history studies.

From the eggs used solely for production purposes, about 189,167 fry were produced. This represented a tremendous improvement in production efficiency since work was begun with egg and larval rearing requirements. Survival from egg to emergent fry was 11% in 1995, 30% in 1996, and 67% in 1997.

Greg Looney of the USFWS, in cooperation with other researchers, developed handling procedures and hatchery protocol for use in robust redhorse production. These procedures should prove valuable for hatchery managers and others involved in rearing this species, and will hopefully contribute to greater survival rates from egg to fingerling.

During late May and early June, 1997, 182,127 fry were transferred to 12 grow-out ponds at Burton, McDuffie, Walton, and Richmond Hill State Fish Hatcheries in Georgia, and Dennis Center and Campbell hatcheries in South Carolina. After one growing season, about 34,974 fingerlings were harvested from these ponds, resulting in an overall survival rate of about 19%. Individual pond survival ranged from 76% to 0%.

Because earlier attempts at rearing these fish to phase II for reintroduction were not successful, only about 20% of the 1997 year class was held back for a second growing season. An additional 1,770 fingerlings were stocked into ponds at the Piedmont Wildlife Refuge to supplement the existing refuge population of robust redhorse. All remaining fish were reintroduced to the wild.

During November, 1997, about 24,256 fingerlings of the 1997 year-class were reintroduced to the Broad River system, GA. Original sites stocked during previous years were restocked, and several new sites within this river system were stocked for the first time. New sites were selected in the North and South Forks of the Broad River, Hudson River, and Hannah Creek.

The Ogeechee River was a new reintroduction drainage for 1997. The Ogeechee River was originally selected as a potential stocking site because it remains the largest Georgia river without significant, current predation issues. In addition, the Ogeechee has a diverse sucker population, good water quality, and a good mussel population. However, the Ogeechee River may be more suitable as a site for raising future broodfish than developing a reproducing population because of limited spawning habitat for robust redhorse. During December, 1997, about 1,762 fingerlings were reintroduced to the Ogeechee River at Mayfield and Jewell Mill.

3.3.5 1998 year-class

Attempts at broodfish collection during 1998 were met with many difficulties. The far-reaching weather phenomenon know as El Nino most likely influenced the abnormally high amounts of rainfall in Georgia during the winter and early spring 1997-98. The Oconee drainage seemed particularly wet, as the Oconee River reached flood stage on several occasions. Extended high reservoir inflows and expectations of continued rainfall within the basin prevented the provision of low flows from Sinclair Dam for most of the spring. These conditions made it impossible to conduct the usual early surveys to check the location and spawning condition of robust redhorse. Only one broodfish collection and spawning effort was possible beginning on 18 May. By the end of this period, low flows provided from Sinclair Dam enabled river temperatures to approach 25 C or higher. Earlier experience indicated that these river temperatures may not be conducive to successful artificial spawning.

During the broodfish collection effort between 18 - 20 May, 14 female and 17 male robust redhorse were transported to the temporary hatchery at Beaverdam WMA. Some females were overripe or had other problems, and only four were successfully spawned. Of these four females, one fish spawned three times, and the other three fish spawned twice each. A total of 142,662 fertilized eggs were produced from 10 matings. These eggs were then transported to McDuffie, Warm Springs, Dennis Center, and the UGA for rearing and research.

4. REINTRODUCTION MONITORING

A critical component in the recovery effort for the robust redhorse is to monitor the success of the re-introduced populations. The Broad River system has received the most significant stockings over the last few years and was the first system to be checked for success. The upper sections of the Broad River have received slightly more effort than the lower sections. During 1997, investigators collected silver redhorse, but could find no robust redhorse. Flathead catfish were also absent from the collection in the upper Broad River which was encouraging.

On 10 October 1997, about 200 Phase I fingerlings were stocked into Hannah Creek below a low-head dam. The next morning, investigators made a search of the creek. A total of 30 fingerlings were located within 2,610 feet downstream of the release site. The largest fingerling was found the furthest downstream, and had moved through a beaverdam and pool. Fingerlings were found in both slow and fast current areas, so a preliminary estimate of juvenile habitat preference could not be made. However, there were few predators present.

As of May 1998 monitoring is continuing on the Broad River system with a variety of gears. Investigators have delineated 500 m reaches of this system with GIS, and are systematically sampling these reaches on a weekly basis. No robust redhorse juveniles have been captured. However, two fish were momentarily stunned, but not captured during recent sampling that are believed to have been robust redhorse juveniles. One fish was estimated to be about 15 inches long and the other fish was about 6 inches in length (Dr. B.J. Freeman, personal communication). The Broad River system has thusfar received fish from the 1993, 1995, and 1997 year-classes. Although not conclusive, this report, indicating potential survival from two separate year-classes, was encouraging.

The lack of positively locating stocked fish during the early monitoring efforts should not necessarily be interpreted as non-survival. Juvenile robust redhorse have proven difficult to capture in closed systems even when their presence is certain. Additionally, the apparent lack of juvenile robust redhorse in the Oconee River has prevented researchers from developing a clear sense of preferred habitat for early life stages of this species. The Broad River system still appears to be one of the better introduction sites.

5. PUBLICITY, EDUCATION, AND OUTREACH

All parties involved with this project realized during the early stages that publicity, education, and outreach could be critical to helping the recovery effort succeed. Because this was a relatively new approach to conservation of imperiled species, it was necessary to attempt to fully explain the rationale and methods of this approach to the media and the public. Effective publicity regarding the robust redhorse recovery would help heighten awareness of imperiled species and the importance of aquatic habitats, and hopefully showcase the effectiveness of diverse stakeholder partnerships for conservation and management of wildlife. Fortunately, media interest regarding this recovery effort remains high.

The following is a short listing of some of the written publicity efforts to date. The intent is not to document all articles, but simply to provide the reader information regarding the extent and diversity of publicity efforts.

- *Back from the brink.* Atlanta Journal-Constitution
- *Monumental effort gives robust redhorse a chance.* Macon Telegraph
- *Agencies out to save states' robust redhorse.* Atlanta Journal-Constitution
- *Robust redhorse conservation committee organized.* Bulletin of the Edison Electric Institute
- *Cooperative effort aimed at rare fish.* Royston News Leader
- *Robust redhorse may be coming back.* The Clayton Tribune
- *Georgia Power making progress protecting rare fish species.* The Citizen Weekly
- *Robust redhorse fingerlings.* Southern Company Environmental Review
- *A rosier future for the robust redhorse.* Athens Daily News
- *The mystery fish.* 10-page feature article in Southern Wildlife Magazine
- *Cooperative recovery effort aimed at rare fish.* Highlights, an internal publication of the Georgia Wildlife Resources Division
- *Developing stakeholder partnerships for the management of imperiled fish species: a case study.* Proceedings of the Waterpower '97 conference, Atlanta, Georgia
- Short article in Popular Mechanics magazine

Numerous oral reports have been presented for professional societies, civic clubs and organizations, and internal planning and review meetings by nearly every individual involved with the recovery effort. It would be nearly impossible to keep track of each and every presentation, particularly those made for university student classes and other internal agency/company updates. The following is a sampling of the types and diversity of known organizations that have received presentations about the robust redhorse. Presentations have been made more than once to many of these organizations.

- American Fisheries Society (AFS)
- Southern Division AFS
- Georgia Chapter AFS
- Alabama Chapter AFS
- South Carolina Chapter AFS
- North Carolina Chapter AFS
- North American Lake Management Society
- Southeastern Fishes Council
- Waterpower '97
- Edison Electric Institute Biologists' Task Force
- Auburn University Student Seminars
- The University of Georgia Student Seminars
- Quad-utility Biologist Meetings
- Villa Rica, GA Lions Club
- Roswell, GA Garden Club
- Camp Creek Middle School, Atlanta, GA
- Peach County High School
- Bryan Middle School

As stated earlier, media interest regarding the robust redhorse remains high and publicity has been considerable. In addition to the items listed above several television spots have been aired by local stations, and the Georgia Public Television network included the robust redhorse in a documentary of the state's rare and endangered wildlife. Coverage of some aspects of the recovery effort could also be viewed on multiple occasions on Cable News Network (CNN) during 1997. The Georgia Department of Natural Resources is also producing documentary films on the historic decline and recovery efforts, with funding provided by the Georgia Wildlife Resources Division Fisheries Section, GA WRD Non-game program, and Georgia Power Company. Copies of these videos should be available in the near future.

6. WHERE DO WE GO FROM HERE?

During the past few years, the RRCC has learned a great deal about the biology and requirements of the robust redhorse through the cooperative efforts of many agencies, universities, private utilities, conservation groups, and individuals. We have learned how to produce eggs through hormone-induced ovulation, have achieved greater survival rates from egg to fry, and are working to find solutions to other problems with fingerling production. Numerous studies have and are being conducted on age and growth, genetics, and the early life stage requirements of this species in relation to Sinclair Dam and other environmental factors that are necessary for evaluating the new flow regime. Reintroduction sites continue to be evaluated, and several reintroductions have been made within the historic range of this species. A Candidate Conservation Agreement is currently being developed to help facilitate reintroduction efforts in other drainages. Another population of robust redhorse has been located in the Savannah River that could serve as another source of broodfish for the recovery efforts, although the status and extent of this population is presently unknown. While we can not yet say that this species is recovered, we can say that significant progress has been made in the conservation and restoration of robust redhorse. The RRCC should be able to proceed with the knowledge gained during these initial efforts and hopefully accelerate the recovery process.

For 1998 and beyond, it is anticipated that the RRCC will continue to identify impediments to the recovery, and create task groups and formulate solutions to effectively deal with those impediments. The Advisory Team should soon have sufficient data to begin formal analysis of the flows for the Oconee River, and make decisions regarding the adequacy of present flows or the need for modifications in the flow regime.

Primary issues for focus in the near future are the recently discovered Savannah River population, reintroduction site evaluation and monitoring survival of stocked populations, predation, habitat degradation, more efficient culture of fingerlings, and enhancing communication among participating organizations and individuals.

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EXHIBIT 1.3

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of SOUTHERN NUCLEAR OPERATING COMPANY (Early Site Permit-Vogtle Electric Generating Plant)	Docket No. 52-011

DECLARATION OF SHAWN PAUL YOUNG, PH.D.

I, Shawn Paul Young, do hereby declare and say as follows:

Background

1. My name is Shawn Paul Young, Ph.D. I am currently a Post Doctoral Fellow and Adjunct Faculty at Clemson University, Clemson, South Carolina. My business address is 261 Lehotsky Hall, Clemson University, Clemson, SC 29634. I submit this affidavit as a private consultant to the Intervenors in this matter.

2. My professional and educational experience is summarized in the curriculum vitae attached to this affidavit. I received a B.S. in Environmental Studies from Northland College; a M.S. in Aquaculture, Fisheries, and Wildlife Biology from Clemson University; and a Ph.D. in Fisheries and Wildlife Sciences from Clemson University. I have ten years experience researching the effects of human activities on fisheries and aquatic ecosystems, including six years experience studying fisheries in the Savannah River Basin. In addition to my professional qualifications, I have been an avid outdoorsman, fishing, hunting, and enjoying nature in every manner since my early childhood.

3. I have completed 15 peer-reviewed publications relevant to fisheries and aquatic ecology. I have been consulted by public, state, federal, and academic sectors in the subject area of fish and aquatic ecology. I have presented scientific presentations at numerous professional meetings, academic seminars, and citizen fishing association functions. At Clemson University, I was honored with an outstanding employee award in 2003, and the fisheries research facility previously under my management twice received facilities excellence awards.

4. I am familiar with the application of Southern Nuclear Operating Company ("Applicant" or "SNC") for an Early Site Permit ("ESP") at the Vogtle Electric Generating Plant ESP site, and SNC's Environmental Review ("ER"). I have reviewed materials and data provided within the documents describing the additional two units' water intake, water consumption, and thermal discharge into Savannah River, and subsequent potential impacts on the fish assemblage of the Savannah River.

5. I am providing this affidavit in support of Intervenors' contentions outlined in Contention 1 -- Impacts on Fishery Resources of the Savannah River. The opinions and conclusions I express in this affidavit are my own and should not be attributed to Clemson University. My affidavit explains justification for the contentions stated and the request that additional data be collected and modeling be performed to properly evaluate potential effects of the proposed additional reactor units at Vogtle Electric Generation Plant (VEGP) on fishery resources of the Savannah River. I have extrapolated my knowledge and experience in this subject matter to the scenarios and data explained and detailed within Southern Nuclear Operating Company's (SNC) Early Site Permit Application and related documentation. I have arrived at conclusions dealing with the matters stated herein and believe them to be true and correct.

<u>In the ER, SNC's conclusions that impacts to fishery resources are small or non-existent, and do not warrant mitigation, are unfounded. Impacts from proposed additional units and cumulative effects of proposed units combined with existing unit operation should be substantiated and may be large.</u>

6. An additional two units, especially in conjunction with operation of existing units, have the potential for large cumulative impacts on the Savannah River fish assemblage. SNC fails to provide an adequate analysis or evidence to support their assertions that impacts will be small or non-existent. At one point, SNC states that twenty years of operating experience should be taken as factual basis to suggest that Savannah River fish populations have not been adversely affected by the operation of VEGP units and impact from additional units would be small. The only analysis provided in the ER utilizes improper assumptions to model entrainment for the existing intake structure. The additional units may pose higher impact levels than those assumed by SNC in the ER. Without proper scientific study and analysis, there is no basis to conclude the proposed new intake and discharge structures, alone or in combination with the existing facility, will not have significant impacts on the Savannah River fish assemblage.

7. Many fish populations in the middle Savannah River are greatly reduced from their historical numbers. The declines cited by fisheries experts are due to the incremental impacts from dams, urbanization, industrialization, and nuclear power facilities, including the operation of the Vogtle Plant (Marcy et al. 2005). Recently, several populations appear to be exhibiting some recovery or at least a halt in decline, which is likely due to increased awareness of fish ecology and of human impacts on fish populations, prompting conservation and management actions. For instance, the moratorium on striped bass harvest was lifted in 2005 (Georgia and South Carolina Departments of Natural Resources), and American shad populations appear to have stabilized (Bailey et al. 2004). However, the moratorium on shortnose sturgeon and Atlantic sturgeon remains due to severely depleted sub-populations in the Savannah River; the

recovery of the robust redhorse, a sucker once proclaimed extinct, is still in the early stages; and status of several species (American eel, quill-back sucker, and brassy jumprock sucker) are still undetermined.

8. Additional units at VEGP will increase the stress that the Savannah River ecosystem is already experiencing. Increasing the potential for entrainment at intake structures and thermal discharge will perpetuate the poor condition of several Savannah River fishes.

The ER does not adequately address potential impacts to increased water intake and increased thermal discharge on fish in the Savannah River.

A. The ER's conclusion regarding potential impacts of entrainment and impingement as a consequence of increasing water intake is based on improper assumptions and lacks appropriate analysis.

9. The ER states that 40 CFR § 125.94(a)(1)(i) indicates that if a facility's flow is commensurate with a closed-cycle recirculating system, the facility has met the applicable performance standards and is not required to demonstrate that it meets impingement mortality and entrainment performance standards. (ER at 5.3-1). The ER discusses the 1985 FES for operation of VEGP Units 1 and 2, which evaluated entrainment at the existing intake structure and concluded that there will be no significant effects on Savannah River fishes. (ER at 5.3-2). From this, the ER concludes that the existing structure actually performs as predicted in the FES and has no significant impacts. Based on the record of performance (or lack thereof), the ER extrapolates that the new intake structure will likewise have insignificant impacts. Neither of these conclusions is supported by empirical data and unwarranted based on the evidence at hand.

10. At minimum, a study of entrainment and impingement associated with the existing intake structure is necessary to determine the cumulative withdrawal effects. The assumptions made in this previous modeling of entrainment at intakes for existing units, discussed in the FES, are improper and misleading. Without actual field study of the existing intake it is not possible to

determine the level of impacts. SNC should undertake seasonal field studies to determine species composition, distribution, and vulnerability to entrainment at the existing intake structures.

11. There is potential for large impacts to fish and invertebrate populations in the Middle Savannah River near the VGEP site. Larval shortnose sturgeon, a federally endangered species, and a high number of American shad and blueback herring larvae have been captured at the Savannah River Site (SRS) intake structures (Paller et al. 1986; Wike 1998), which are in the general area of the VEGP intake structures. SRS has conducted numerous field surveys to determine entrainment in this area; yet, no data is provided in the ER. The ER contains no data for seasonal or total entrainment losses by species or by life history stage. Based on my knowledge of the area and review of the existing reported studies, I conclude that entrainment is occurring at the existing intake structure, but at an unknown level of significance. Similarly, there will be entrainment associated with the proposed new intake structure, but it is impossible to determine the significance of the impact without additional study.

12. The assumptions for the previous entrainment model developed in 1985 for the existing units, discussed in § 5.3.1.2, are improper. First, the assumption of a uniformly distributed drift community is invalid. The pattern of drift community distribution (i.e. the pattern of egg, larval, and early juvenile stages of fishes) would vary in time and space due to river flow fluctuations. The Savannah River fish assemblage utilizes several life history strategies to survive the inherent temporal and spatial heterogeneity of riverine habitats. Also, dispersal mechanisms also vary from species to species and also across life history stages of each species. Differences in physiology make some species more susceptible to entrainment than others. Some examples are (a) adhesive versus buoyant eggs; (b) immobile larvae versus highly mobile larvae; and, (c)

resident fish with small home ranges (that may avoid VEGP) versus migratory fish that ultimately must pass VEGP during vulnerable early life history stages on their journey down the Savannah River to the Atlantic Ocean. Second, the entrainment analysis also assumes a minimum guaranteed river flow of 5,800 cfs instead of the 7Q10 flow of 3,828 cfs.(ER at 5.3-2).

13. Entrainment rates will vary depending on the river flow. The maximum level of entrainment occurs during low flow periods because reduced flow concentrates the drift community due to river channel confinement. Low water levels confine organisms to smaller habitat concentrating the number of organisms per unit of area in the vicinity of the intake structures. This confinement increases the vulnerability to entrainment, and could have differential impact from species to species. That is, some species may still avoid entrainment while others suffer high mortality. The ER does not calculate normal and worst case scenarios based upon species composition in the river channel at different flows.

14. Using the 7Q10 flow of 3,828 cfs, the ER calculates the current maximum withdrawal at 3% of total river volume. (ER at 5.3-2). In contrast, Marcy et al. (2005) report that 4.2% of the Savannah River is withdrawn by the existing units (citing Wiltz 1981, DOE 1990). This discrepancy may be due to the fact that the ER bases its calculation on the maximum withdrawal rate of 120 cfs (53,860 gpm) assumed by the NRC in the FES for Units 1 and 2. The ER does not include actual withdrawal data for Units 1 and 2, which may be higher than the rate used in the FES.

15. The expected rate of withdrawal of Savannah River water to replace water losses from the circulating water system will be 18,612 and 37,224 gpm for one and two-unit operations, respectively (see Table 3.0-1). The maximum rate of withdrawal during two-unit operation will be 57,784 gpm (128.8 cfs). (ER § 3.4.2.1). This is equivalent to 3.4% of the total 7Q10

Savannah River flow. Assuming the maximum intake for the existing intake structure is 120 cfs (53,860 gpm), then the existing structure currently withdraws up to 3.1% of the 7Q10 flow. (ER at 5.3-2). Thus, the two intake structures will cumulatively withdraw up to 6.5% of the 7Q10 flow of the Savannah River.

16. Finally, the analysis of the intake structure is flawed because it provides only a vague summary of some fish species and life histories, rather than a comprehensive discussion of all of the species likely to inhabit this reach of the Savannah River at different times of year. (ER § 5.3.1.2). In fact, the ER discusses only those species and their life stages that have a lower probability of entrainment and neglect to address those with high susceptibility. In particular, the ER fails to discuss the potential impact on important and commercially valuable species such as shortnose sturgeon, American shad and blueback herring. As mentioned above, these species have been collected in surveys of the reactor intake structure at SRS.

B. <u>The ER's conclusion regarding potential impacts of increased thermal discharge is not supported by any evidence.</u>

17. The ER provides no scientific studies or field observations to support conclusions that "cumulative impacts of the plumes from existing discharge and the proposed discharge on the Savannah River will be small and will not warrant mitigation" and "neither plume is large enough to affect the water quality or biota of the river" (ER at 10.5-2). First, the ER concedes that no data on actual plume size has been collected since operation of the existing units commenced. (ER at 10.5-2). Second, the computer modeling indicates the existing thermal plume will mingle with the new plume, resulting in an increased volume of the river affected by thermal discharge. Third, the ER only discusses fish species and life history stages that provide supportive argument that additional units will not affect fish species. For instance, SNC only

states that American shad spawning migration does not appear to be blocked by the thermal-plume, and spawn farther upstream with egg and larval development also occurring upstream, all facts favorable to their application. However, they fail to include that American shad may also spawn in the vicinity near VEGP and Savannah River Site (Paller et al. 1986), and larvae and juveniles will be migrating downstream during their first summer and will migrate through the vicinity of VEGP thermal discharge and intakes. No discussion or assessment of larval and juvenile American shad behavior passing VEGP affected area is included. SNC's failure to adequately list, discuss, and assess potential impacts on the vulnerable life history stages of fishes of the Savannah River warrants further investigation.

18. Similar to the entrainment discussion, no modeling or data are presented for thermal discharge impacts at the variable river-flows that occur on the Middle Savannah River. Again, a worst case scenario that produces a maximum impact from thermal discharge would be the 7Q10 flow of 3,828. Reduced flow places more of the drift community at danger of thermal impacts due to river channel confinement. That is, low water levels confine organisms to a smaller habitat, concentrating the number of organisms per unit of area in the vicinity of the thermal plume. Further, low-flow reduces the river volume, and thus, the ability for the heat to be dissipated across time and space. This confinement increases the vulnerability to thermal stress and mortality, and could have differential impact from species to species. Thermal tolerance varies from species to species, and also across life history stages of individual species. Some species may suffer high mortality. The ER fails to provide any such data to evaluate impacts of thermal discharge at VEGP. Without data collected from the site, it is not possible to assess the impacts from the current or proposed discharge.

19. The maximum blowdown temperature at the point of discharge to the Savannah River from the two new units is predicted to be 91°F (ER Table 3.0-1) and the existing discharge is stated as 89°F (ER Table 2.9-1).

20. High water temperature kills the early life history stages of several highly-valued fish found near VEGP, and most likely also causes mortality in many less-studied and less-desired Savannah River fish species. American shad eggs suffer mortality at 80.1 °F, and larvae suffer mortality at 87 °F (Stier and Crance 1985). Blueback herring eggs and larvae suffer mortality at 85.5°F (Pardue 1983). The federally endangered shortnose sturgeon's eggs suffer mortality at 75°F, and larvae suffer mortality at 85 °F (Crance 1986). Striped bass eggs suffer mortality at 75°F, and larvae suffer mortality at 85°F (Bain and Bain 1982; Fay et al. 1983). Fay et al. (1983) also provides data and synthesis from a number of studies on the effects of thermal pollution discharge on early life stages of striped bass, "Most early striped bass life stages show significant elevated mortality when exposed to rapid changes in water temperature (such as that in a thermal discharge plume) ." The studies found in Fay et al. (1983) provide evidence that striped bass larval survival is significantly affected by sudden temperature elevations of 18 °F, and mortality exceeds 50% when water temperatures reach 90°F.

21. The computer modeling reported in the ER indicates that additional thermal discharge from the new units is not likely to cause a significant increase in downstream water temperature or violation of water quality standards. (ER § 5.3.2). Even if this is the case, however, there may still be significant impacts to species within the drift community.

I declare under penalty of perjury that the foregoing is true and correct.

Date: 12-7-06

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Education

PhD Fisheries and Wildlife Biology (Fisheries Emphasis). May 2005. Clemson University. Clemson, SC. Dissertation: *Behavior and mortality of adult striped bass in J. Strom Thurmond Reservoir, South Carolina-Georgia.*

MS Aquaculture, Fisheries, and Wildlife Biology (Fisheries Emphasis). August 2001. Clemson University. Clemson, SC. Thesis: *Habitat utilization by striped bass in J. Strom Thurmond Reservoir, South Carolina-Georgia.*

BS Environmental Studies. May 1996. Northland College. Ashland, WI.

Academic Experience

Post-doctoral Researcher (November 2006 – Present)
Department of Forestry and Natural Resources; Clemson University, Clemson, SC
My main research field is in fish ecology and behavior in altered river-systems. I will be conducting research on migratory anadromous and resident fish species in the Apalachicola River during Spring 2006. This will include population estimation, behavior/movement during spawning migration and the effects of hydroelectric and lock-and-dam facilities, and age-growth studies. I plan to also conduct lab experiments examining retention of internally-implanted telemetry devices with several construction designs and short-term effects of implantation on behavior. Other research may include paleoecology of fish species of coastal North Carolina, native mussel / fish host dynamics in the Apalachicola River, and studies of potential self-cognition by fish.

Adjunct Professor – Fisheries/Aquatic Ecology/Aquaculture (August 2005 – Present)
Department of Biological Sciences; Clemson University, Clemson, SC

Interim Lecturer – Aquatic Ecology (August 2005 – May 2006)
Department of Forestry and Natural Resources; Clemson University, Clemson, SC
WFB 300 Wildlife and Fisheries Biology (Team-taught course): My lectures focused on aquatic animal ecology and taxonomy. Lecture topics included fish, crocodilians, sea turtles, pinnipeds, sirenians, and cetaceans.
ENR 302 Natural Resource Measurements (Team-taught course w/ labs): My lectures focused on aquatic survey methods and techniques. Lecture/Lab topics included biotelemetry, water quality/environmental monitoring, capture and tagging methods for fish and aquatic

invertebrates, population estimation of fish and aquatic invertebrates, and stream habitat surveying.

Research Biologist/Facility Manager (June 2000 – May 2006)
Aquatic Animal Research Laboratory; Clemson University, Clemson, SC
I conducted research and managed facilities at a leading fisheries/aquaculture research laboratory. Our research specialized in identifying factors that affect fish and aquatic invertebrate physiology, behavior, and population dynamics. I conducted research on habitat requirements of marine, estuarine, anadromous, and freshwater species at the larval, juvenile, and adult life-history stages. I studied the effects of biotic and abiotic factors such as temperature, salinity, dissolved oxygen, total ammonia, nitrite, metals toxicity, feed rations, and population density on the health, survival, growth, condition, and behavior of fish and aquatic invertebrates.
Knowledge, Skills, and Abilities:

- Knowledge of fish and aquatic invertebrate physiology, ecology, health, and care.
- Aquaculture methodology, operation, and water quality monitoring.
- Supervise/assist primary researchers, graduate assistants, and student workers.
- Experimental techniques - tissue sampling, blood chemistry and osmolality.
- Statistical analysis and technical writing for publication of research and for oral presentation of research at professional meetings *(please refer to Publications and Presentations)*.
- Construct and repair re-circulating and flow-through culture systems; plumbing, electrical, carpentry, general construction, and mechanical repair.
- Budgeting; record and data storage; maintain lab protocols and operating procedures.

Graduate Research Assistant (June 1999 – May 2005)
SC Cooperative Fish and Wildlife Research Unit, Clemson University
My dissertation and thesis culminated several telemetry field studies of behavior, mortality, and habitat selection of reservoir striped bass coupled with extensive water quality monitoring. The research identified seasonal migration patterns, daily movement patterns, and seasonal habitat selection in relation to water quality; sources and magnitude of mortality; temporal and spatial patterns of mortality; and, potential to successfully live-release striped bass angled during fishing tournaments. Through graduate coursework, I also acquired extensive knowledge of fisheries science and management; physiology, ecology and conservation of aquatic organisms; limnology and hydrology; and experimental statistics *(please refer to transcripts)*.
Knowledge, Skills, and Abilities:

- Assisted with the following research projects:
    - Striped bass habitat use in Lake Murray, SC.
    - Largemouth bass movement in Steele Creek - Savannah River Nuclear Reservation.
    - American shad population estimation and passage at Savannah River Lock and Dam.
    - Robust redhorse/Savannah River sucker species ecology: Behavior and habitat use.
    - Shortnose sturgeon ecology in lower Savannah River: Behavior and habitat use.
- Supervise and conduct long-term telemetry studies.
- Surgical implantation of telemetry devices and fish tagging methods.
- Procedures and methodology for long-term habitat/ water-quality modeling and monitoring.
- Data management, statistical analysis, technical writing for dissertation and thesis completion, publication in peer-reviewed journals, and presentation of project results at

professional and public meetings *(please refer to Publications and Presentations).*

Other Professional Experience

Aquatic Ecology / Fisheries Expert (November 2006 – Present)
Turner Environmental Law Clinic; Emory University, Atlanta, GA
I am assisting with the review and comment on the Draft Environmental Impact Statements and Environmental Reviews pertaining to potential impacts of nuclear power-plant expansion on the middle Savannah River ecosystem.

Aquatic Ecology / Fisheries Expert (January 2005 – August 2006)
Southern Environmental Law Center and Public Citizen; Charlottesville, VA
I provided scientific review and affidavit opinion of Environmental Impact Statements and Environmental Reviews pertaining to potential impacts of nuclear expansion on the North Anna/Pamunkey River ecosystem.

Contract Fish Biologist (June 2006 – October 2006)
Portland General Electric; Madras, OR
I conducted annual monitoring activities investigating the native fish assemblage within the middle Deschutes River Basin and Lake Billy Chinook. Duties included estimating rainbow trout population density and spawning adult abundance; kokanee spawning adult abundance, fecundity, and age composition; and bull trout spawning adult abundance.

Fisheries Field Technician (October 1997 - May 1999) Idaho Department of Fish and Game
Position Description: I conducted research on the effects of hydroelectric generation on behavior and survival of salmonids (rainbow trout and bull trout), burbot, and white sturgeon in the Kootenai River, ID-MT. Major responsibility was to conduct large-scale radio-telemetry studies to acquire knowledge of seasonal movements and migratory behavior to and from spawning grounds, and determine affect of flow fluctuation on behavior. I captured the above species using screw-traps, gill-nets, hoop-nets, set-lines, angling and electrofishing (back-pack and boat).

Fisheries Bio-Aide (April 1997 – September 1997) Idaho Department of Fish and Game
Position Description: I conducted numerous salmonid (rainbow/steelhead, king salmon, bull trout, cutthroat trout, and brook trout) population estimates through back-country snorkel surveys and electro-fishing in rivers, streams and reservoirs with backpack units and boat units.

Fisheries Volunteer (Sept 1996 – Dec 1996) USGS-BRD, Great Lakes Division
Position Description: I assisted with assessment of Lake Trout restoration efforts in western Lake Superior by using large-scale gill netting from a research vessel. Subsequent laboratory duties involved stomach diet analysis of Lake Herring by zooplankton and benthic organism identification.

Fisheries Aide (June 1996 – Sept 1996) US Forest Service, Superior National Forest
Position Description: I conducted stream habitat surveys for creation of a GIS database of brook trout habitat and abundance throughout watersheds within the Superior National Forest.

Publications

Burkey, K. B., **S. P. Young**, J. R. Tomasso, and T. I. J. Smith. (In Press). 2006. Low-salinity resistance of juvenile cobia. North American Journal of Aquaculture.

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In Preparation:

Young, S. P., J.J. Isely, W.C. Bridges, and J. R. Tomasso. Response-surface analysis of temperature and dissolved oxygen interactions affecting selection of habitat by striped bass.

Young, S. P., S. M. Welch, and A. G. Eversole. Survival and injury to crayfish subjected to electrofishing.

Welch, S. M., **S. P. Young**, and A. G. Eversole. Evaluation of capture methods in determining aquatic and burrowing crayfish species richness.

Selected Presentations

Young, S.P. 2006. Behavioral Thermoregulation and Metabolic Scope of striped bass in various aquatic environments. Austin Peay University. Clarksville, TN.

Young, S.P. 2006. Behavioral Thermoregulation and Metabolic Scope – Lecture for comparative anatomy and physiology. Clemson University. Clemson, SC.

Young, S.P. and J.J. Isely. 2005. Post-tournament live-release survival, dispersal, and behavior of adult striped bass. American Fisheries Society annual meeting. Anchorage, AK.

Young, S.P and J.J. Isely. 2005. Post-tournament live-release survival, dispersal, and behavior of adult striped bass. Trout Unlimited. Clemson, SC.

Young, S.P and J.J. Isely. 2005. Behavior and mortality of adult striped bass in J. Strom Thurmond Reservoir, South Carolina-Georgia. Dissertation Seminar. Clemson University. Clemson, SC.

Young, S.P. and J.J. Isely. 2004. Temporal and spatial estimates of adult striped bass mortality from telemetry and transmitter return data. Annual meeting of the American Fisheries Society. Madison, WI.

Atwood, H.L.; **S.P. Young**, J.R. Tomasso, and T.I.J. Smith. 2004. Effect of temperature and salinity on survival, growth, and condition of juvenile black sea bass. 28^{th} Annual Larval Fish Conference, Early Life History Section, American Fisheries Society. Clemson, SC.

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Young, S.P. 2003. Life skills training for hatchery fish: Social Learning and Survival. Department of Biological Sciences. Clemson University.

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Young, S.P. 2002. Strain-specific characteristics to manage sub-populations of fish species. Department of Biological Sciences. Clemson University.

Awards

- 2004 Animal Research Committee Excellence Award, Clemson University.
- 2003 Outstanding Classified Employee Award - Clemson University
- 2003 Employee Performance Award, Clemson University.
- 2003 Animal Research Committee Excellence Award, Clemson University

Professional Membership

- American Fisheries Society (General Member)
  - Fisheries Management Section, Physiology Section, Fish Health Section, Water Quality Section, Early Life History Section, and Fish Culture Section Member

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EXHIBIT 1.4

Power Plant Intake Entrainment Analysis

By John Eric Edinger,[1] Member, ASCE, and Venkat S. Kolluru[2]

Abstract: Power plant condenser cooling water intake entrainment of fish eggs and larvae is becoming an issue in evaluating environmental impacts around the plants. Methods are required to evaluate intake entrainment on different types of water bodies. Presented in this paper is a derivation of the basic relationships for evaluating entrainment from the standing crop of fish eggs and larvae for different regions of a water body, and evaluating the rate of entrainment from the standing crop. These relationships are coupled with a 3D hydrodynamic and transport model that provides the currents and flows required to complete the entrainment evaluation. Case examples are presented for a simple river system, and for the more complex Delaware River Estuary with multiple intakes. Example evaluations are made for individual intakes, and for the cumulative impacts of multiple intakes.

INTRODUCTION

Power plant condenser cooling water intakes can entrain fish eggs and larvae from different parts of the water body on which the plant is located. The evaluation and permitting of intakes comes under Section 316(b) of the Clean Water Act (*CFR* 1999). EPA is presently developing regulations for implementing Section 316(b) (*USDC* 1999). The impact of entrainment on fish eggs and larvae is usually examined using two parameters. The first parameter is the percentage of entrainment from the standing crop of organisms located in a particular region of a water body. The second parameter is the rate of entrainment of organisms from that region of water body.

The percentage of entrainment from the standing crop of organisms can be compared to the size of the standing crop itself. A 5 or 10% entrainment from a very large standing crop may not be considered significant because enough fish eggs and larvae will survive to produce a sufficient number of adults for continual propagation of the population. A 1 or 2% entrainment from a small standing crop may, however, be critical.

The rate of entrainment, usually expressed in terms of percent per day, is the rate of loss of organisms due to the intake. It can be compared to the natural mortality rate of the organisms. If the rate of entrainment is small and less than the natural mortality rate, then the impact of the entrainment will not be appreciably noticeable. If, however, the rate of entrainment is significant compared to the natural mortality rate, then there could be a bigger impact. If the entrainment rate exceeds the rate of natural mortality, then the population may not be able to sustain itself.

Intake entrainment evaluation needs to be performed for specific water bodies. Hydrodynamic and transport modeling can determine the percentage of entrainment from a standing crop and the rate of entrainment from different regions of a water body for each intake on that water body. The analysis can also determine the cumulative impact of several intakes on the same water

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Note. Discussion open until September 1, 2000. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on May 18, 1998. This paper is part of the ***Journal of Energy Engineering***, Vol. 126, No. 1, April, 2000. ©ASCE, ISSN 0733-9402/00/0001-0001–0014/$8.00 + $.50 per page. Paper No. 18440.

body. The results of the analysis can be used in the design of field sampling programs to show what regions of a water body might be most vulnerable and require more detailed and frequent sampling.

Evaluation of entrainment in absolute terms of numbers of organisms lost requires coupling the estimates of entrainment from standing crop and the rates of entrainment with data on the organisms obtained in the field. Different fish species will use a different habitat for spawning and in different seasons. The egg and larval densities will vary with habitat and location throughout the water body. Potentially high entrainment from a region determined by the hydrodynamic computations is not important if that region is not used for spawning. Additionally, organisms may not be in that region because of the entrainment. Eggs and larvae of different species will have different natural mortality rates, and mortality rates for the same species can vary with life stage.

Formulation of Entrainment Parameters

The formulation of the entrainment parameters depends on simulating a dye release into different volumes of the water body. Fish eggs and larvae are more like particles and have mobility, and their entrainment may not be completely represented by a dye withdrawal. However, the dye simulation does represent the mass of water that would be entrained from a given region, and performing a dye simulation is similar to the methods used by Boreman and Goodyear (1988) and Versar (1990) in their formulations.

The percentage of entrainment of the standing crop and the entrainment rate from a volume V is determined by releasing the dye into the volume of the water body at an initial concentration C_0. Over time the dye from the volume will spread and reach the intake where its concentration at the intake, $C_I(t)$, will decrease approximately as

$$C_I(t) = C_{\mathrm{int}}e^{-rt} \tag{1}$$

where C_{int} = peak concentration of the dye at the intake and is less than C_0; and r = flushing rate for that volume of the water body.

Let Q_p be the withdrawal rate at the intake. Then the cumulative mass of the dye initially in volume V withdrawn at the intake, $M(t)$, will be

$$M(t) = Q_p \int C_I(t)\, dt \tag{2}$$

which is integrated from $t = 0$ to t to give

$$M(t) = Q_p C_{\mathrm{int}}/r(1 - e^{-rt}) \tag{3}$$

for the condition that $M(t) = 0$ at $t = 0$. The initial mass of dye, M_0 in the water body volume, V, is equal to C_0V. Thus

$$M(t)/M_0 = (Q_p C_{\mathrm{int}}/rVC_0)(1 - e^{-rt}) \tag{4}$$

The $M(t)$ can be evaluated at the intake from the hydrodynamic modeling used for the dye simulations.

Letting $e(t)$ be defined as $M(t)/M_0$ the following relationship is fit to the cumulative mass of dye at the intake over time to give the empirical parameters e_0 and r:

$$e(t) = e_0(1 - e^{-rt}) \tag{5}$$

The $e(t)$ is computed from the model results so that all the dye that could enter the intake is captured.

Comparing (4) and (5) gives

$$e_0r = Q_pC_{int}/VC_0 \tag{6}$$

where e_0r is the rate, day^{-1}, at which organisms initially in volume V are entrained at the intake.

The biological assessment of intake entrainment is often based on the entrainment mortality formula such as developed by Boreman and Goodyear (1988) or the Spawning and Nursery Area of Consequence formula used by Versar (1990). These formula require assessing the fractional entrainment rate per unit volume, P/V (day^{-1}), where P is the rate of intake withdrawal from volume V for different regions of the water body. The P/V as used in Boreman and Goodyear (1988) and Versar (1990) formulas is the fractional rate at which organisms are entrained from the region with volume V. The dye concentration in the volume would decrease approximately as

$$C_v(t) = C_0e^{-rt} \tag{7}$$

where $C_v(t)$ = concentration in the volume as a function of time. For the mass withdrawal over time to be conserved it is required that PC_0 equals Q_pC_{int}. Substituting PC_0 into (6) for Q_pC_{int} gives

$$P/V = e_0r \tag{8}$$

Eq. (8) shows the e_0r is identical to P/V in the Boreman and Goodyear (1988) and Versar (1990) relationship.

In the above formulations, $100e_0r$ is the percentage of standing crop entrained from volume V, and e_0r is the rate per day of entrainment from volume V.

Evaluation of Entrainment Parameters

Evaluation of the entrainment parameters for a water body requires applying a hydrodynamic and transport model to that water body to simulate the entrainment of the dye from various regions within the water body.

The evaluation can be carried out using the time varying 3D Generalized Longitudinal Lateral and Vertical Hydrodynamic and Transport Model (GLLVHT) (Edinger et al. 1993; Edinger and Buchak 1995).

As illustrated in Fig. 1 the water body is first set up and grided for the hydrodynamic and transport computations. The time varying inflows for a river system and the boundary conditions of tidal elevations, and salinity boundary conditions for estuaries and coastal waters are then set up so that the hydrodynamic model can compute the time varying currents and circulation from model cell to model cell. The intake withdrawal is also included in the model set up. The modeled currents transport the fish eggs and larvae from different regions through the water body and toward the intake.

Shown in Fig. 1 are the regions for which the intake entrainment is to be evaluated. The illustrated regions are at the near shore region near the intake, the channel, and far shore going laterally across the water body. The regions extend from above, at and below the intake and discharge location. The regions can encompass any number of the detailed hydrodynamic model cells in any configuration.

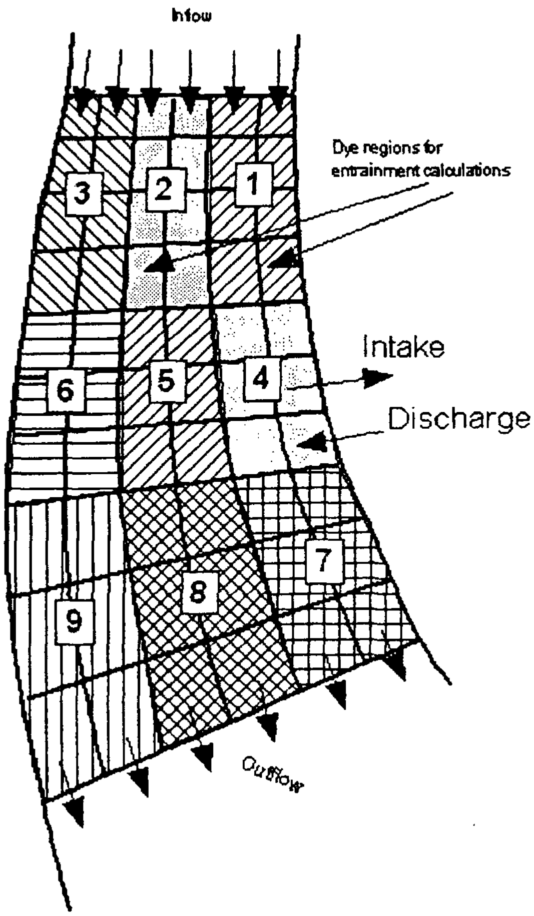

FIG. 1. GLLVHT Computational Grid for Dundee Pool on Passiac River, N.J., and Entrainment Regions

The locations and sizes of the model cells might be determined from the biological sampling that identifies specific areas for detailed evaluation. The entrainment regions can include individual portions of the vertical water column, where for example, it might be useful to distinguish between surface or benthic organisms.

Each region is dyed instantaneously, and separately, to evaluate the percentage of standing crop that could be entrained from that region, e_0, and the entrainment rate, e_0r. The simulation is run for a long enough period of time to establish the currents within the water body and to withdraw sufficient dye to evaluate e_0 and e_0r using (5) for each region.

A simple river case is illustrated for a small industrial cooling water intake located on the Dundee Pool of the Passiac River in New Jersey. The analysis is for a low river flow condition of 0.87 m^3/s, an average spring river flow of 6.0 m^3/s, and an intake withdrawal rate of 0.31 m^3/s. There is a discharge back into the river that results in recirculation between the intake and the discharge. Recirculation can increase entrainment from the intake region and reduce entrainment from other portions of the water body.

Table 1 gives the percentage entrainment and the entrainment rate as determined for the regions surrounding the intake illustrated in Fig. 1. Table 1(a) shows that the standing crop is most vulnerable for the region just upriver from the intake and at the intake. This is because most of water from the region just upriver from the intake enters into the intake region with the river flow while those in the intake region are carried out of that region with the river flow.

Table 1(b) shows the entrainment rates from the different regions. The entrainment rate is high where the entrainment from the standing crop is high. The results for the fall low flow condition show that the natural rates are exceeded in the immediate vicinity of the intake, but the entrainment rates are less downriver and across river in the far shoreline region. Generally, on rivers, it is necessary to conduct seasonal evaluations relative to the spawning seasons.

Table 2 gives the percentage of entrainment from the standing crop and entrainment rates for the average spring river flow. It shows that both parameters decrease with river flow, but not necessarily in proportion to river flow. It also shows that the entrainment decreases more rapidly across the river for the average flow case than for the low flow case.

TABLE 1. Percent of Standing Crop Entrained ($100xe_0$) and Entrainment Rate, e_0r, for Intake on Dundee Pool of Passiac River, N.J. during Fall Low Flow Conditions

Region (1)	Near shore (2)	Channel (3)	Far shore (4)
(a) Percentage of Standing Crop Entrained (%)			
Upstream of intake	57.4	19.9	7.0
At intake	21.8	7.1	2.4
Downstream of intake	2.1	1.0	0.5
(b) Entrainment Rate, e_0r (day^{-1})			
Upstream of intake	3.14	0.38	0.07
At intake	0.84	0.11	0.02
Downstream of intake	0.04	0.01	0.00

TABLE 2. Percent of Standing Crop Entrained ($100xe_0$) and Entrainment Rate, e_0r, for Average Spring Flow Condition

Region (1)	Near shore (2)	Channel (3)	Far shore (4)
(a) Percentage of Standing Crop Entrained (%)			
Upstream of intake	21.4	0.87	0.04
At intake	4.10	0.09	0.01
Downstream of intake	0.01	0.0	0.0
(b) Entrainment Rate, e_0r (day^{-1})			
Upstream of intake	3.55	0.06	0.002
At intake	1.70	0.006	<0.001
Downstream of intake	<0.001	—	—

Application to the Delaware River Estuary

The entrainment analysis can be applied to complex tidal water bodies with numerous intakes. Not only is it necessary to evaluate the impact of individual intakes, but it is also necessary to evaluate cumulative impacts. The Delaware River Estuary, shown in Fig. 2, has about 60 intakes along its industrialized reach and is illustrative of a water body with the potential for cumulative impacts. A large number of the intakes are for municipal and industrial water supplies as well as industrial and power plant cooling water usage. The GLLVHT hydrodynamic model and entrainment modeling has been applied for the river-estuary reach from Trenton to Reedy Island, or River Mile (RM) 130 to about RM 60. The Delaware River Estuary is tidal up estuary to Trenton.

For the entrainment analysis the GLLVHT model was set up with 26 5-km longitudinal segments, five lateral segments, with 2 m thick layers. The width increases in the down estuary direction. The geometry was mapped to have a middle channel section and tidal overbank areas on either side. A tidal boundary condition was applied at the most down estuary end of the model segment. A freshwater inflow was placed at the head of the estuary. The hydrodynamic computations were qualitatively verified by comparison to graphical tidal elevation and velocity data presented in HydroQual, Inc. (1997). The Delaware River Estuary has a freshwater inflow of 85 m^3/s during low flow conditions and an average annual flow of 283 m^3/s.

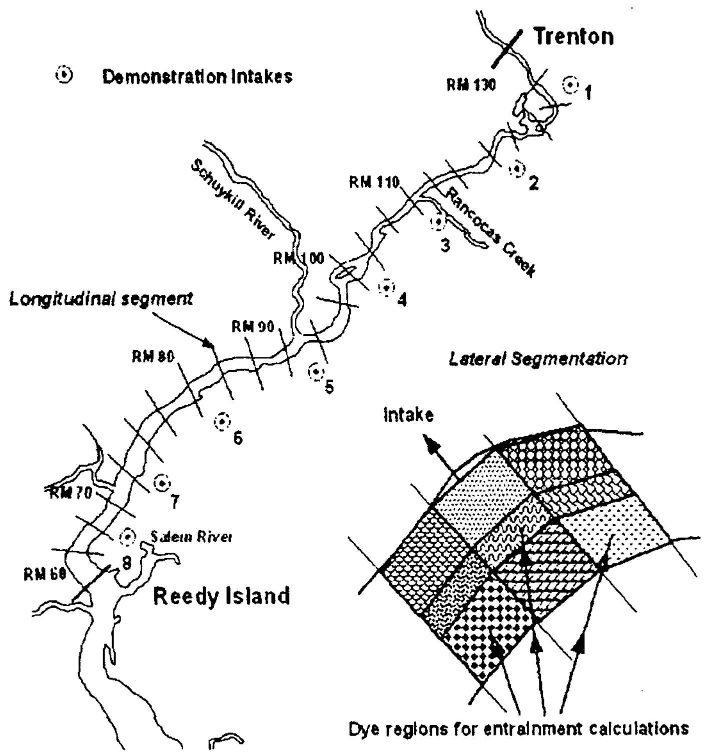

FIG. 2. Delaware River Estuary Showing Hydrodynamic Model Grid, Entrainment Regions, and Location of Intakes

The detailed hydrodynamic grid was overlain with 24 entrainment regions consisting of 8 along the estuary and 3 laterally. The lateral regions consisted of a near shore over bank region, a channel region, and a far shore over bank region. Hypothetical intakes were located in the center of each near shore over bank region. This gave eight intakes for which the percentage entrainment and the entrainment rate could be evaluated as a function of intake location along the estuary, for different freshwater inflows, different intake withdrawal rates, and cumulative impact estimates.

The Delaware River Estuary entrainment analysis illustrates a number of properties of the entrainment parameters along and across an estuary including percentage entrainment from standing crop, the effects of river flows on entrainment, the effects of withdrawal rates on entrainment, and the cumulative effects of multiple intakes.

Percentage Entrainment along the Estuary

The percentage entrainment from the standing crop for the near shore, channel and far shore regions along the estuary are shown for different intake locations in Fig. 3. In Fig. 3, the longitudinal locations of the entrainment regions along the estuary are numbered 1 through 8. Each intake was assumed to withdraw 10 m^3/s. For a particular intake, the percentage entrainment was highest at the intake location, and decreases across and up and down the estuary from the intake. Most of the entrainment is from up and down estuary rather than from across the estuary. There is entrainment down estuary from the intake, as well as from above, because the tides move water masses containing the fish eggs and larvae past the intake. The percentage entrainment from standing crop decreases the further down estuary the intake is located because of the increasingly larger volume of tidal flow in the estuary.

Effects of River Flows on Percentage of Entrainment

The effects of river flow on the percentage of entrainment from the standing crop are shown in Fig. 4 for the low flow of the Delaware and the average flow of the Delaware for an intake located at RM 117. It generally shows that there is little change with river flow except from the entrainment regions near the head of the estuary. For the regions near the head of the estuary, the increased river flow tends to move more organisms through the estuary toward the intakes. For the nontidal river case results given in Tables 1 and 2, the entrainment parameters are sensitive to river flow.

Effects of Intake Withdrawal Rates on Percentage of Entrainment

The effects of different withdrawal rates on entrainment from the standing crop are shown in Fig. 5 for an intake located at RM 117. It shows that the percentage of entrainment from standing crop increases with the intake withdrawal rate. The increase is not proportional to the withdrawal rate, but rather increases asymtotically to some upper limit. Fig. 5 shows at the intake, for example, that the percentage of entrainment from standing crop is 1.0% for an intake withdrawal rate of 5 m^3/s, 1.9% for a withdrawal of 10 m^3/s, and 3.7% for a withdrawal of 20 m^3/s.

Entrainment Rates along the Estuary

Fig. 6 shows the entrainment rate as percent per day for the near shore, channel and far shore regions along the estuary for different intake locations. The rates are computed for a low river flow and an intake withdrawal rate of 10 m^3/s. The entrainment rate is high near the intake location, but decreases

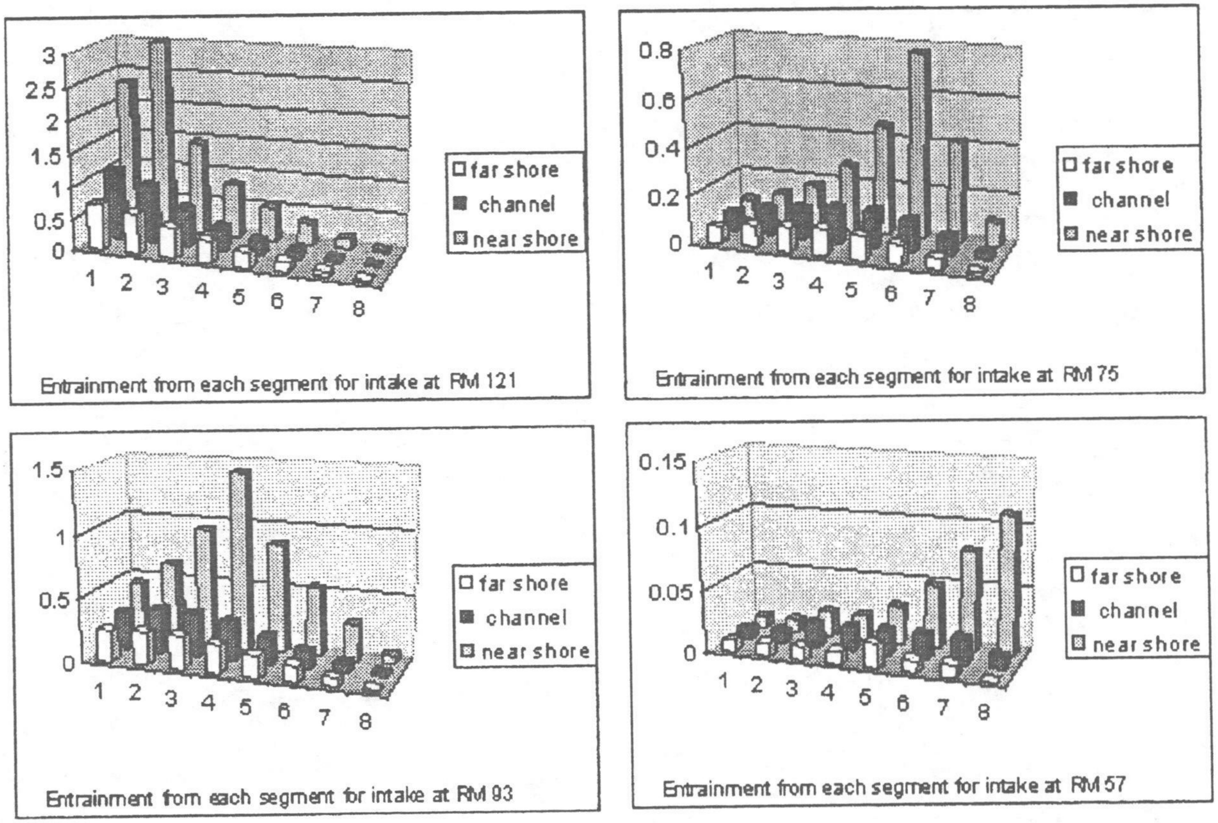

FIG. 3. Percent Entrainment from Standing Crop from Near Shore, Channel, and Far Shore Regions along Estuary for Intakes at Different RM Locations

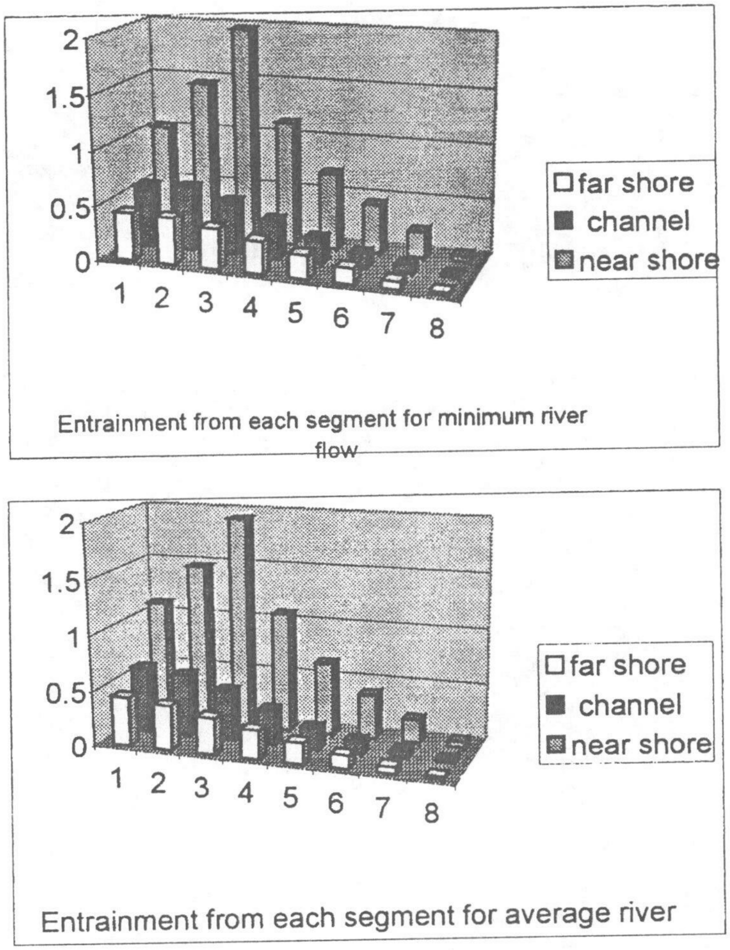

FIG. 4. Effects of River Flow on Percent Entrainment for Intake Located at RM 112

rapidly away from the intake. The magnitudes of the individual intake entrainment rates for the Delaware River Estuary are small when compared to the results for the river case shown in Table 1.

Cumulative Percentage of Entrainment

Although the percentage of entrainment of standing crop by individual intakes might be low, in cases like the Delaware River Estuary, the cumulative effects of the multiple intakes along the river could be high. Fig. 7 shows the cumulative entrainment from each region due to all of the intakes included in the study. The cumulative impact is highest in the near shore area near the head of the estuary, and decreases down estuary. The contribution of each individual plant to the cumulative impact can be assessed by comparing the results in Fig. 3 with Fig. 7.

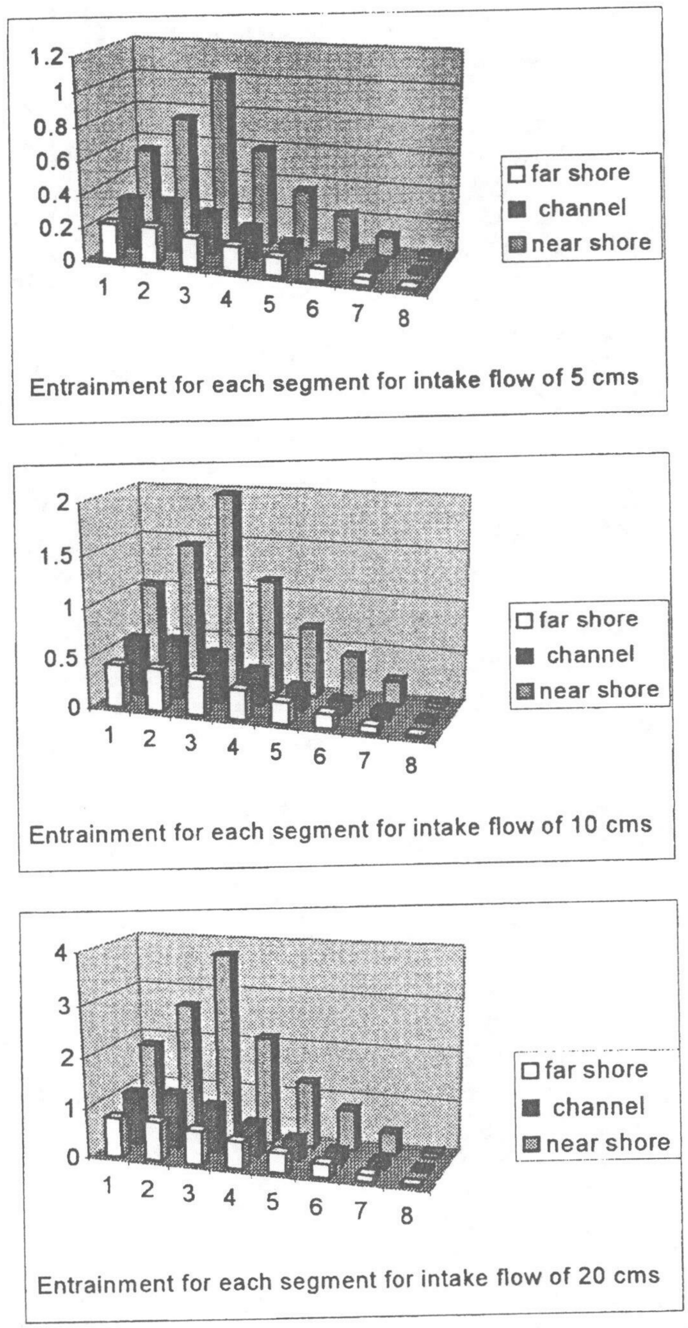

FIG. 5. Effects of Intake Pumping Rate on Percent Entrainment for Intake Located at RM 112

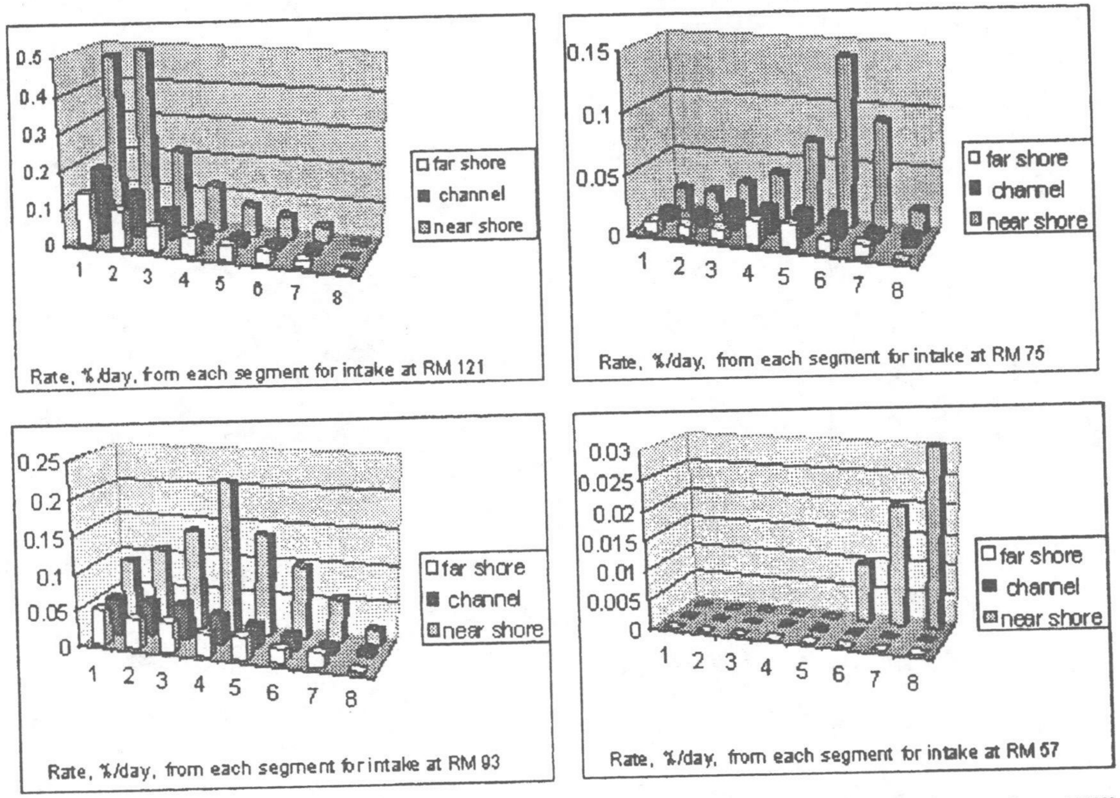

FIG. 6. Rate of Entrainment, day^{-1}, from Near Shore, Channel, and Far Shore Regions along Estuary for Intakes at Different RM Locations

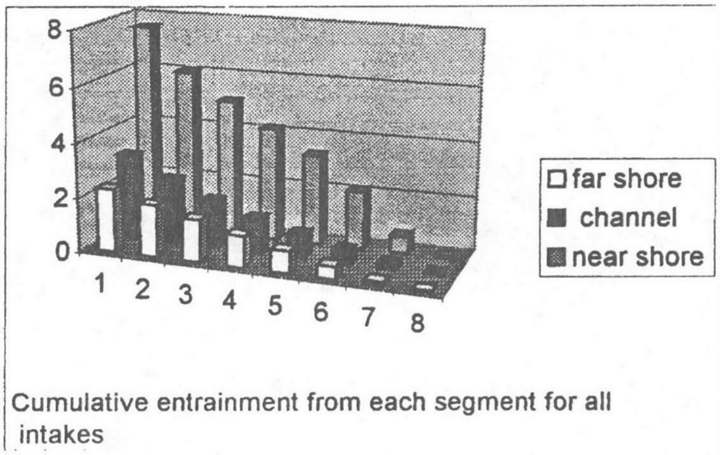

FIG. 7. Cumulative Percent Entrainment from Near Shore, Channel, and Far Shore Regions along Estuary

Cumulative Entrainment Rates

Similar to the cumulative percentage of entrainment from standing crop, the entrainment rate might be low for individual intakes, but could be high cumulatively. Fig. 8 shows the cumulative entrainment rate from each region due to all of the intakes included in the study. Typically for estuarine species, the natural mortality rate may range from 2%/day to 7%/day (Edinger et al. 1993) depending on the species and the season and may approach 10–50%/day in the more freshwater portions of the estuary. Fig. 8 shows that the cumulative impact is highest in the near shore area near the head of the estuary. These values approach or exceed the natural mortality rates and decrease down estuary. The contribution of each individual intake to the cu-

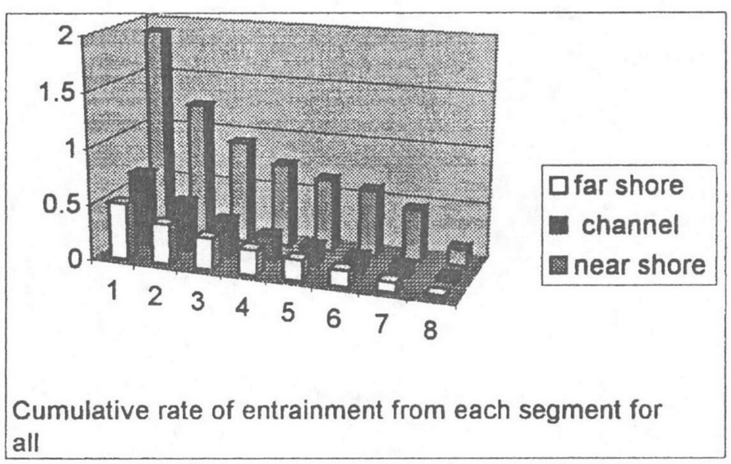

FIG. 8. Cumulative Entrainment Rate, day^{-1}, from Near Shore, Channel, and Far Shore Regions along Estuary

mulative impact can be assessed by comparing the results in Fig. 6 with Fig. 8.

CONCLUSIONS

Hydrodynamic and transport modeling can be used to evaluate two key parameters required to assess the impact of cooling water intakes on organism entrainment. These types of assessments show how the entrainment would vary throughout a water body, vary with flows and tides, and vary with intake sizes. The modeling can be used to assess entrainment due to individual intakes, and the cumulative impact of multiple intakes on the same water body. The modeling results can be used to evaluate where in the water body there might be problems due to entrainment, which can, in turn, be used to guide field study programs to identify the overlap of areas of potentially high entrainment with possible spawning areas.

ACKNOWLEDGEMENT

Jian Wu of J. E. Edinger Associates, Inc., helped perform the model simulations, prepare diagrams, and review and prepare the manuscript.

APPENDIX I. REFERENCES

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APPENDIX II. NOTATION

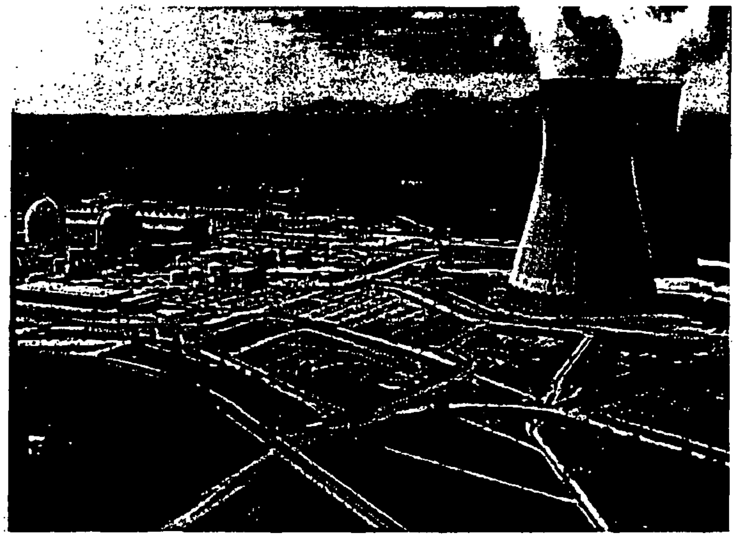
The following symbols are used in this paper:

C_{int} = maximum concentration of dye from entrainment region at intake (kg/m^3);
$C_I(t)$ = concentration of dye at intake as function of time (kg/m^3);
$C_r(t)$ = concentration of dye in entrainment region as function of time (kg/m^3);
C_0 = initial concentration of dye in entrainment region (kg/m^3);
$e(t)$ = $M(t)/M_0$;
e_0 = fractional entrainment from standing crop in volume V;

e_0r = entrainment rate from volume V (day^{-1});
$M(t)$ = cumulative mass of dye at intake over time (kg);
M_0 = total cumulative mass of dye at intake (kg);
P = rate of intake withdrawal from volume V as used in Boreman and Goodyear (1988) formula (m^3/day);
Q_p = intake withdrawal rate (m^3/s or m^3/day);
r = entrainment rate from entrainment region (day^{-1});
t = time (days); and
V = volume of entrainment region (m^3).

EXHIBIT 2.1

VOGTLE ELECTRIC GENERATING PLANT ANNUAL RADIOLOGICAL ENVIRONMENTAL OPERATING REPORT FOR 2005



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LIST OF ACRONYMS

Acronyms presented in alphabetical order.

Acronym	Definition
ASTM	American Society for Testing and Materials
CL	Confidence Level
EL	Georgia Power Company Environmental Laboratory
EPA	Environmental Protection Agency
GPC	Georgia Power Company
ICP	Interlaboratory Comparison Program
MDC	Minimum Detectable Concentration
MDD	Minimum Detectable Difference
MWe	MegaWatts Electric
NA	Not Applicable
NDM	No Detectable Measurement(s)
NRC	Nuclear Regulatory Commission
ODCM	Offsite Dose Calculation Manual
Po	Preoperation
PWR	Pressurized Water Reactor
REMP	Radiological Environmental Monitoring Program
RL	Reporting Level
RM	River Mile
TLD	Thermoluminescent Dosimeter
TS	Technical Specification
VEGP	Alvin W. Vogtle Electric Generating Plant

1.0 INTRODUCTION

The Radiological Environmental Monitoring Program (REMP) is conducted in accordance with Chapter 4 of the Offsite Dose Calculation Manual (ODCM). The REMP activities for 2005 are reported herein in accordance with Technical Specification (TS) 5.6.2 and ODCM 7.1.

The objectives of the REMP are to:

1) Determine the levels of radiation and the concentrations of radioactivity in the environs and;

2) Assess the radiological impact (if any) to the environment due to the operation of the Alvin W. Vogtle Electric Generating Plant (VEGP).

The assessments include comparisons between results of analyses of samples obtained at locations where radiological levels are not expected to be affected by plant operation (control stations) and at locations where radiological levels are more likely to be affected by plant operation (indicator stations), as well as comparisons between preoperational and operational sample results.

VEGP is owned by Georgia Power Company (GPC), Oglethorpe Power Corporation, the Municipal Electric Authority of Georgia, and the City of Dalton, Georgia. It is located on the southwest side of the Savannah River approximately 23 river miles upstream from the intersection of the Savannah River and U.S. Highway 301. The site is in the eastern sector of Burke County, Georgia, and across the river from Barnwell County, South Carolina. The VEGP site is directly across the Savannah River from the Department of Energy Savannah River Site. Unit 1, a Westinghouse Electric Corporation Pressurized Water Reactor (PWR), with a licensed core thermal power of 3565 MegaWatts (MWt), received its operating license on January 16, 1987 and commercial operation started on May 31, 1987. Unit 2, also a Westinghouse PWR rated for 3565 MWt, received its operating license on February 9, 1989 and began commercial operation on May 19, 1989.

The pre-operational stage of the REMP began with initial sample collections in August of 1981. The transition from the pre-operational to the operational stage of the REMP occurred as Unit 1 reached initial criticality on March 9, 1987.

A description of the REMP is provided in Section 2 of this report. Maps showing the sampling stations are keyed to a table which indicates the direction and distance of each station from a point midway between the two reactors. Section 3 provides a summary of the results of the analyses of REMP samples for the year. The results are discussed, including an assessment of any radiological impacts upon the environment and the results of the land use census and the river survey, in Section 4. The results of the Interlaboratory Comparison Program (ICP) are provided in Section 5. Conclusions are provided in Section 6.

2.0 REMP DESCRIPTION

A summary description of the REMP is provided in Table 2-1. This table summarizes the program as it meets the requirements outlined in ODCM Table 4-1. It details the sample types to be collected and the analyses to be performed in order to monitor the airborne, direct radiation, waterborne and ingestion pathways, and also delineates the collection and analysis frequencies. In addition, Table 2-1 references the locations of stations as described in ODCM Section 4.2 and in Table 2-2 of this report. The stations are also depicted on maps in Figures 2-1 through 2-3.

REMP samples are collected by Georgia Power Company's (GPC) Environmental Laboratory (EL) personnel. The same lab performs all the laboratory analyses at their headquarters in Smyrna, Georgia.

TABLE 2-1 (SHEET 1 of 5)

SUMMARY DESCRIPTION OF RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Exposure Pathway and/or Sample	Number of Representative Samples and Sample Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
1. Direct Radiation	Thirty nine routine monitoring stations with two or more dosimeters placed as follows: An inner ring of stations, one in each compass sector in the general area of the site boundary; An outer ring of stations, one in each compass sector at approximately 5 miles from the site; and Special interest areas, such as population centers, nearby recreation areas, and control stations.	Quarterly	Gamma dose, quarterly
2. Airborne Radioiodine and Particulates	Samples from seven locations: Five locations close to the site boundary in different sectors; A community having the highest calculated annual average ground level D/Q; and	Continuous sampler operation with sample collection weekly, or more frequently if required by dust loading.	Radioiodine canister: I-131 analysis, weekly. Particulate sampler; Gross beta analysis[1] following filter change and gamma isotopic analysis[2] of composite (by location), quarterly.

TABLE 2-1 (SHEET 2 of 5)

SUMMARY DESCRIPTION OF RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Exposure Pathway and/or Sample	Number of Representative Samples and Sample Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
2. Airborne Radioiodine and Particulates (cont.)	A control location near a population center at a distance of about 14 miles.		
3. Waterborne			
a. Surface[3]	One sample upriver. Two samples downriver.	Composite sample over one month period[4].	Gamma isotopic analysis[2], monthly. Composite for tritium analysis, quarterly.
b. Drinking	Two samples at each of the two nearest water treatment plants that could be affected by plant discharges. Two samples at a control location.	Composite sample of river water near the intake of each water treatment plant over two week period[4] when I-131 analysis is required for each sample; monthly composite otherwise; and grab sample of finished water at each water treatment plant every two weeks or monthly, as appropriate.	I-131 analysis on each sample when the dose calculated for the consumption of the water is greater than 1 mrem per year[5]. Composite for gross beta and gamma isotopic analysis[2] on raw water, monthly. Gross beta, gamma isotopic and I-131 analyses on grab sample of finished water, monthly. Composite for tritium analysis on raw and finished water, quarterly.
c. Sediment from Shoreline	One sample from downriver area with existing or potential recreational value.	Semiannually	Gamma isotopic analysis[2], semiannually.

TABLE 2-1 (SHEET 3 of 5)

SUMMARY DESCRIPTION OF RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Exposure Pathway and/or Sample	Number of Representative Samples and Sample Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
c. Sediment from Shoreline (cont.)	One sample from upriver area with existing or potential recreational value.		
4. Ingestion			
a. Milk	Two samples from milking animals[6] at control locations at a distance of about 10 miles or more.	Biweekly	Gamma isotopic analysis[2,7], biweekly.
b. Fish	At least one sample of any commercially or recreationally important species near the plant discharge. At least one sample of any commercially or recreationally important species in an area not influenced by plant discharges.	Semiannually	Gamma isotopic analysis[2] on edible portions, semiannually.
	At least one sample of any anadromous species near the plant discharge.	During the spring spawning season.	Gamma isotopic analysis[2] on edible portions, annually.

TABLE 2-1 (SHEET 4 of 5)

SUMMARY DESCRIPTION OF RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Exposure Pathway and/or Sample	Number of Representative Samples and Sample Locations	Sampling and Collection Frequency	Type and Frequency of Analysis
c. Grass or Leafy Vegetation	One sample from two onsite locations near the site boundary in different sectors. One sample from a control location at a distance of about 17 miles.	Monthly during growing season.	Gamma isotopic analysis[2,7], monthly.

TABLE 2-1 (SHEET 5 of 5)

SUMMARY DESCRIPTION OF RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

Notes:

(1) Airborne particulate sample filters shall be analyzed for gross beta radioactivity 24 hours or more after sampling to allow for radon and thoron daughter decay. If gross beta activity in air particulate samples is greater than 10 times the yearly mean of control samples, gamma isotopic analysis shall be performed on the individual samples.

(2) Gamma isotopic analysis means the identification and quantification of gamma-emitting radionuclides that may be attributable to the effluents from the facility.

(3) Upriver sample is taken at a distance beyond significant influence of the discharge. Downriver samples are taken beyond but near the mixing zone.

(4) Composite sample aliquots shall be collected at time intervals that are very short (e.g., hourly) relative to the compositing period (e.g., monthly) to assure obtaining a representative sample.

(5) The dose shall be calculated for the maximum organ and age group, using the methodology and parameters in the ODCM.

(6) A milking animal is a cow or goat producing milk for human consumption.

(7) If the gamma isotopic analysis is not sensitive enough to meet the Minimum Detectable Concentration (MDC) for I-131, a separate analysis for I-131 may be performed.

TABLE 2-2 (SHEET 1 of 3)

RADIOLOGICAL ENVIRONMENTAL SAMPLING LOCATIONS

Station Number	Station Type	Descriptive Location	Direction[1]	Distance (miles)[1]	Sample Type
1	Indicator	River Bank	N	1.1	Direct Rad.
2	Indicator	River Bank	NNE	0.8	Direct Rad.
3	Indicator	Discharge Area	NE	0.6	Airborne Rad.
3	Indicator	River Bank	NE	0.7	Direct Rad
4	Indicator	River Bank	ENE	0.8	Direct Rad.
5	Indicator	River Bank	E	1.0	Direct Rad.
6	Indicator	Plant Wilson	ESE	1.1	Direct Rad.
7	Indicator	Simulator Building	SE	1.7	Airborne Rad. Direct Rad. Vegetation
8	Indicator	River Road	SSE	1.1	Direct Rad.
9	Indicator	River Road	S	1.1	Direct Rad.
10	Indicator	Met Tower	SSW	0.9	Airborne Rad.
10	Indicator	River Road	SSW	1.1	Direct Rad.
11	Indicator	River Road	SW	1.2	Direct Rad.
12	Indicator	River Road	WSW	1.2	Airborne Rad. Direct Rad.
13	Indicator	River Road	W	1.3	Direct Rad.
14	Indicator	River Road	WNW	1.8	Direct Rad.
15	Indicator	Hancock Landing Road	NW	1.5	Direct Rad. Vegetation
16	Indicator	Hancock Landing Road	NNW	1.4	Airborne Rad. Direct Rad.
17	Other	Sav. River Site (SRS), River Road	N	5.4	Direct Rad.
18	Other	SRS, D Area	NNE	5.0	Direct Rad.
19	Other	SRS, Road A.13	NE	4.6	Direct Rad.
20	Other	SRS, Road A.13.1	ENE	4.8	Direct Rad.
21	Other	SRS, Road A.17	E	5.3	Direct Rad.
22	Other	River Bank	ESE	5.2	Direct Rad.
23	Other	River Road	SE	4.6	Direct Rad.
24	Other	Chance Road	SSE	4.9	Direct Rad.
25	Other	Chance Road near Highway 23	S	5.2	Direct Rad.
26	Other	Highway 23 and Ebenezer Church Road	SSW	4.6	Direct Rad.
27	Other	Highway 23 opposite Boll Weevil Road	SW	4.7	Direct Rad.
28	Other	Thomas Road	WSW	5.0	Direct Rad.

TABLE 2-2 (SHEET 2 of 3)

RADIOLOGICAL ENVIRONMENTAL SAMPLING LOCATIONS

Station Number	Station Type	Descriptive Location	Direction[1]	Distance (miles)[1]	Sample Type
29	Other	Claxton-Lively Road	W	5.1	Direct Rad.
30	Other	Nathaniel Howard Road	WNW	5.0	Direct Rad.
31	Other	River Road at Allen's Chapel Fork	NW	5.0	Direct Rad.
32	Other	River Bank	NNW	4.7	Direct Rad.
35	Other	Girard	SSE	6.6	Airborne Rad. Direct Rad.
36	Control	GPC Waynesboro Op. HQ	WSW	13.9	Airborne Rad. Direct Rad.
37	Control	Substation Waynesboro, GA	WSW	16.7	Direct Rad Vegetation
43	Other	Employee's Rec. Center	SW	2.2	Direct Rad.
47	Control	Oak Grove Church	SE	10.4	Direct Rad.
48	Control	McBean Cemetery	NW	10.2	Direct Rad.
51	Control	SGA School Sardis, GA	S	11.0	Direct Rad.
52	Control	Oglethorpe Substation; Alexander, GA	SW	10.7	Direct Rad.
80	Control	Augusta Water Treatment Plant	NNW	29.0	Drinking Water[2]
81	Control	Sav River	N	2.5	Fish[3] Sediment[4]
82	Control	Sav River (RM 151.2)	NNE	0.8	River Water
83	Indicator	Sav River (RM 150.4)	ENE	0.8	River Water Sediment[4]
84	Other	Sav River (RM 149.5)	ESE	1.6	River Water
85	Indicator	Sav River	ESE	4.3	Fish[3]
87	Indicator	Beaufort-Jasper County Water Treatment Plant	SE	76	Drinking Water[5]
88	Indicator	Cherokee Hill Water Treatment Plant, Port Wentworth, Ga	SSE	72	Drinking Water[6]
98	Control	W.C. Dixon Dairy	SE	9.8	Milk
99[7]	Control	Boyceland Dairy	W	20.9	Milk
100[8]	Control	Coble Dairy	WNW	16.2	Milk

TABLE 2-2 (SHEET 3 of 3)

RADIOLOGICAL ENVIRONMENTAL SAMPLING LOCATIONS

Notes:

(1) Direction and distance are determined from a point midway between the two reactors.

(2) The intake for the Augusta Water Treatment Plant is located on the Augusta Canal. The entrance to the canal is at River Mile (RM) 207 on the Savannah River. The canal effectively parallels the river. The intake to the pumping station is about 4 miles down the canal.

(3) A 5 mile stretch of the river is generally needed to obtain adequate fish samples. Samples are normally gathered between RM 153 and 158 for upriver collections and between RM 144 and 149.4 for downriver collections.

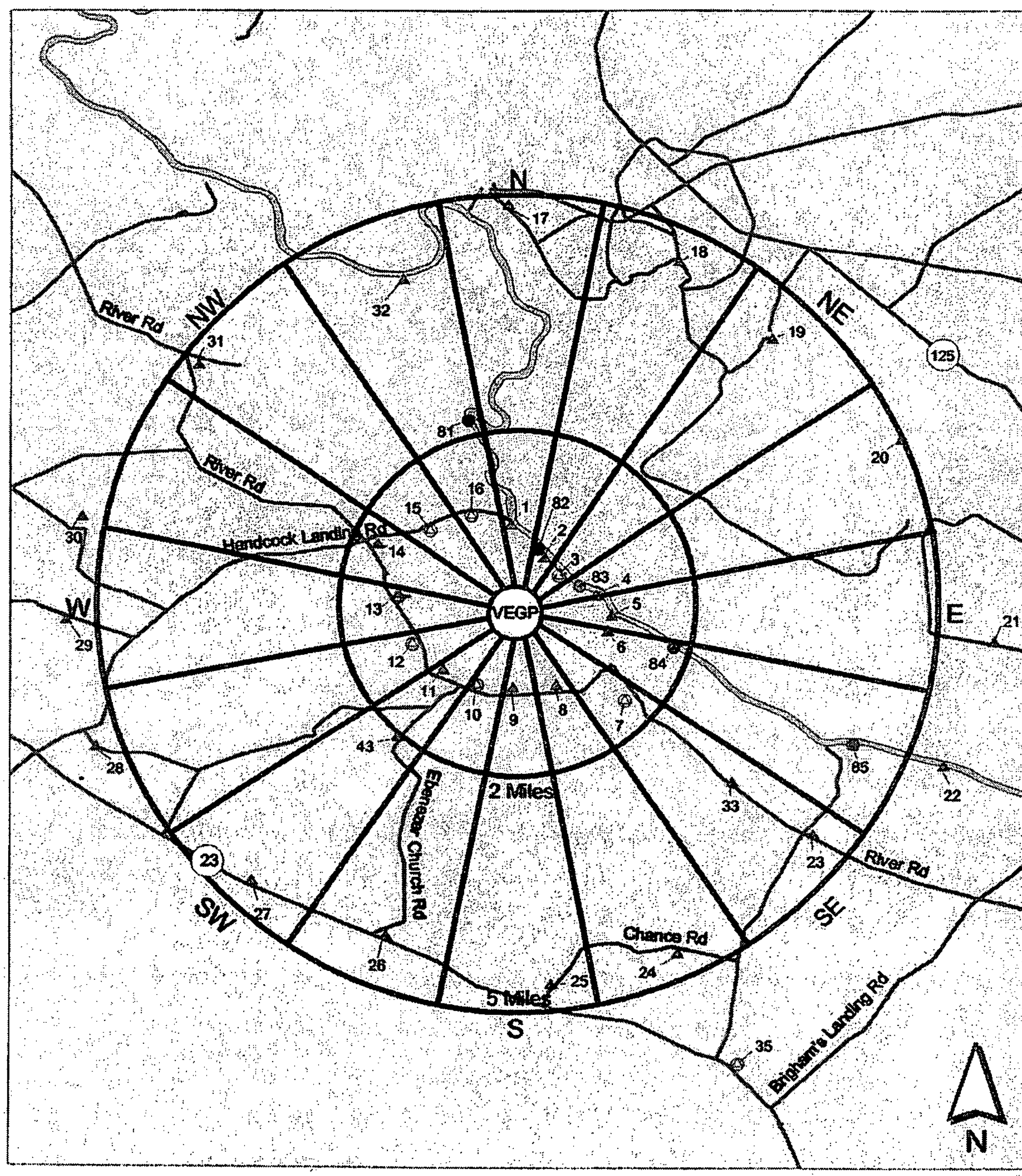
(4) Sediment is collected at locations with existing or potential recreational value. Because high water, shifting of the river bottom, or other reasons could cause a suitable location for sediment collections to become unavailable or unsuitable, a stretch of the river between RM 148.5 and 150.5 was designated for downriver collections while a stretch between RM 153 and 154 was designated for upriver collections. In practice, collections are normally made at RM 150.2 for downriver collections and RM 153.3 for upriver collections.

(5) The intake for the Beaufort-Jasper County Water Treatment Plant is located at the end of canal that begins at RM 39.3 on the Savannah River. This intake is about 16 miles by line of sight down the canal from its beginning on the Savannah River.

(6) The intake for the Cherokee Hill Water Treatment Plant is located on Abercorn Creek which is about one and a quarter creek miles from its mouth on the Savannah River at RM 29.

(7) Dairy operations ceased and milk sampling was discontinued at location 99 on September 3, 2003.

(8) Milk sample collection began at location 100 on September 30, 2003.

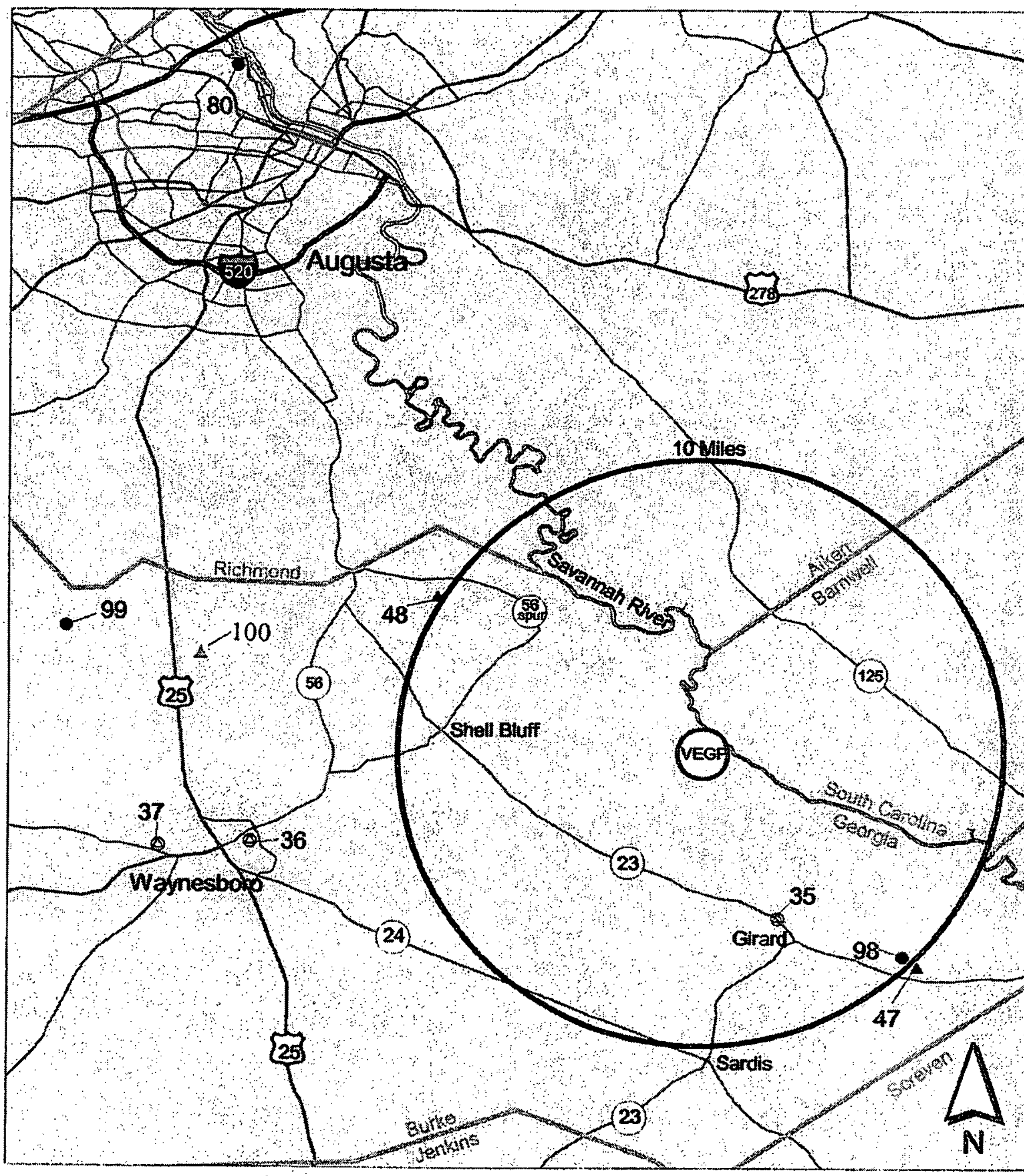


Radiological Environmental Sampling Locations	Indicator	Control	Additional
TLD	▲	▲	▲
Other	●	●	●
TLD & Other	◬	◬	◬

REMP Stations in the Plant Vicinity

Figure 2-1

C32

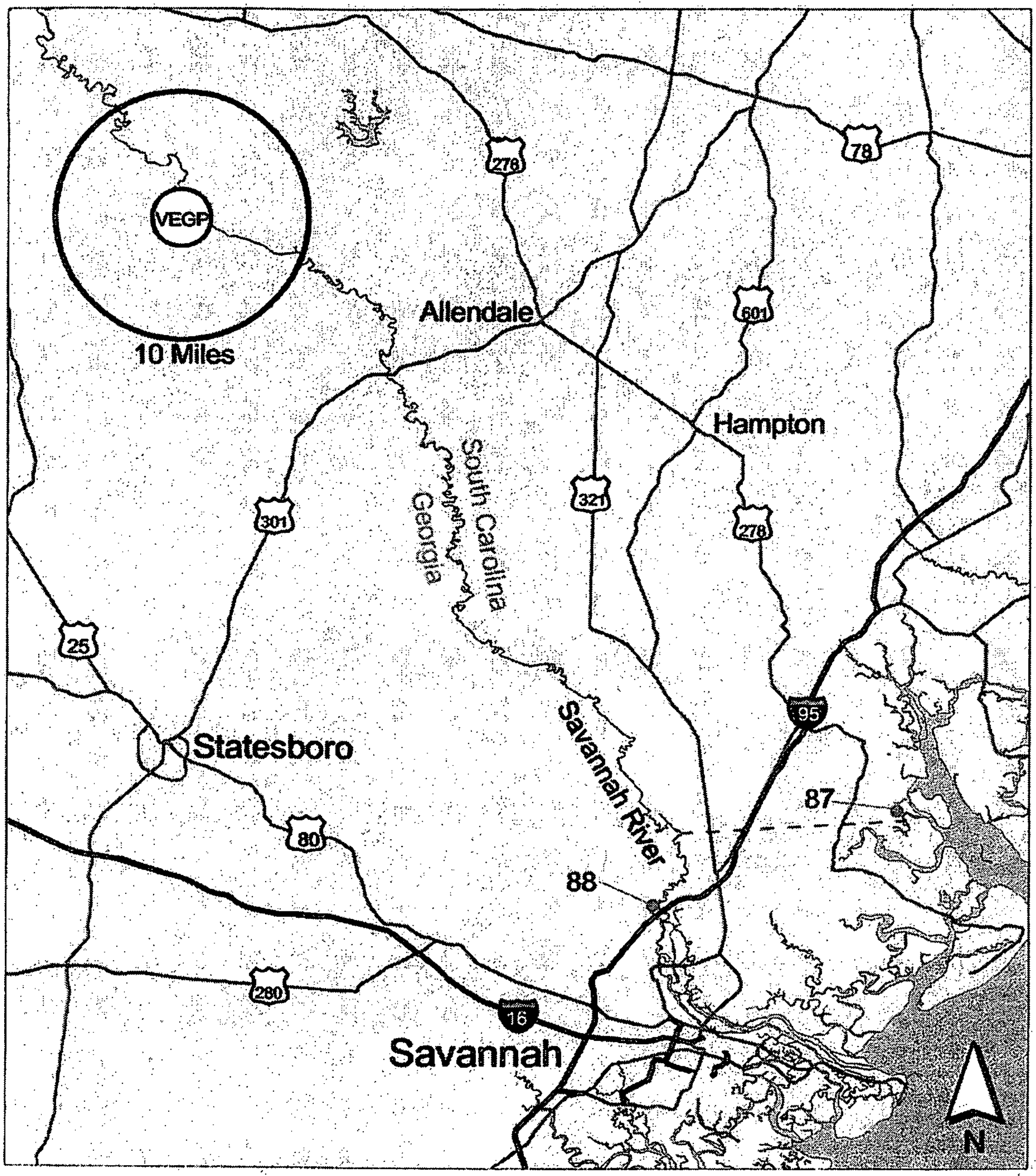


Radiological Environmental Sampling Locations	Indicator	Control	Additional
TLD	▲	▲	▲
Other	●	●	●
TLD & Other	⊚	⊚	⊚

REMP Control Stations for the Plant

Figure 2-2

C33



Radiological Environmental Sampling Locations

	Indicator	Control	Additional
TLD	▲	▲	△
Other	●	●	●
TLD & Other	●	●	●

REMP Indicator Drinking Water Stations

Figure 2-3

C34

3.0 RESULTS SUMMARY

In accordance with ODCM 7.1.2.1, the summarized and tabulated results for all of the regular samples collected for the year at the designated indicator and control stations are presented in Table 3-1. The format of Table 3-1 is similar to Table 3 of the Nuclear Regulatory Commission (NRC) Branch Technical Position, "An Acceptable Radiological Environmental Monitoring Program", Revision 1, November 1979. Results for samples collected at locations other than indicator or control stations are discussed in Section 4 under the particular sample type.

As indicated in ODCM 7.1.2.1, the results for naturally occurring radionuclides that are also found in plant effluents must be reported along with man-made radionuclides. The radionuclide Be-7 which occurs abundantly in nature is found in some years in the plant's liquid and gaseous effluent. No other naturally occurring radionuclides are found in the plant's effluent releases. Therefore, the only radionuclides of interest in the REMP samples are the man-made radionuclides and Be-7, when it is detected in the effluent. Be-7 was not detected in plant effluents in 2005.

TABLE 3-1 (SHEET 1 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY

Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Minimum Detectable Concentration (MDC) (a)	Indicator Locations Mean (b), Range (Fraction)	Location with the Highest Annual Mean		Other Stations (g) Mean (b), Range (Fraction)	Control Locations Mean (b), Range (Fraction)
				Name Distance & Direction	Mean (b), Range (Fraction)		
Airborne Particulates (fCi/m3)	Gross Beta 361	10	20.5 1.6-39.3 (259/259)	Station 16 Hancock Landing Road 1.4 miles NNW	20.9 1.7-33.3 (51/51)	19.4 1.9-34.2 (52/52)	20.4 1.9-39.0 (50/50)
	Gamma Isotopic 28						
	Cs-134	50	NDM (c)		NDM	NDM	NDM
	Cs-137	60	NDM		NDM	NDM	NDM
Airborne Radioiodine (fCi/m3)	I-131 361	70	NDM		NDM	NDM	NDM
Direct Radiation (mR/91 days)	Gamma Dose 157	NA (d)	12.5 7.7-17.2 (62/62)	Station 29 Claxton-Lively Road 5.1 miles W	16.3 15.3-16.9 (4/4)	13.0 9.8-16.9 (72/72)	13.2 10.7-16.3 (23/23)

TABLE 3-1 (SHEET 2 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY

Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Minimum Detectable Concentration (MDC) (a)	Indicator Locations Mean (b), Range (Fraction)	Location with the Highest Annual Mean		Other Stations (g) Mean (b), Range (Fraction)	Control Locations Mean (b), Range (Fraction)
				Name Distance & Direction	Mean (b), Range (Fraction)		
Milk (pCi/l)	Gamma Isotopic 46						
	Cs-134	15	NA		NDM	NA	NDM
	Cs-137	18	NA		NDM	NA	NDM
	Ba-140	60	NA		NDM	NA	NDM
	La-140	15	NA		NDM	NA	NDM
	I-131 46	1	NA		NDM	NA	NDM
Vegetation (pCi/kg-wet)	Gamma Isotopic 36						
	I-131	60	NDM		NDM	NA	NDM
	Cs-134	60	NDM		NDM	NA	NDM
	Cs-137	80	49.5 23.5-75.6 (2/24)	Station 16 Hancock Landing Road 1.4 miles NNW	75.6 (1/12)	NA	NDM

TABLE 3-1 (SHEET 3 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY
Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Minimum Detectable Concentration (MDC) (a)	Indicator Locations Mean (b), Range (Fraction)	Location with the Highest Annual Mean		Other Stations (g) Mean (b), Range (Fraction)	Control Locations Mean (b), Range (Fraction)
				Name Distance & Direction	Mean (b), Range (Fraction)		
River Water (pCi/l)	Gamma Isotopic 36						
	Be-7	124(e)	NDM		NDM	NDM	NDM
	Mn-54	15	NDM		NDM	NDM	NDM
	Fe-59	30	NDM		NDM	NDM	NDM
	Co-58	15	NDM		NDM	NDM	NDM
	Co-60	15	NDM		NDM	NDM	NDM
	Zn-65	30	NDM		NDM	NDM	NDM
	Zr-95	30	NDM		NDM	NDM	NDM
	Nb-95	15	NDM		NDM	NDM	NDM
	I-131	15	NDM		NDM	NDM	NDM
	Cs-134	15	NDM		NDM	NDM	NDM
	Cs-137	18	NDM		NDM	NDM	NDM
	Ba-140	60	NDM		NDM	NDM	NDM
	La-140	15	NDM		NDM	NDM	NDM
	Tritium 12	3000	800 334-1420 (4/4)	Station 83 RM 150.4 0.8 miles ENE	800 334-1420 (4/4)	712 276-1400 (4/4)	458 306-610 (2/4)

TABLE 3-1 (SHEET 4 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY

Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Minimum Detectable Concentration (MDC) (a)	Indicator Locations Mean (b), Range (Fraction)	Location with the Highest Annual Mean		Other Stations (g) Mean (b), Range (Fraction)	Control Locations Mean (b), Range (Fraction)
				Name Distance & Direction	Mean (b), Range (Fraction)		
Water Near Intakes to Water Treatment Plants (pCi/l)	Gross Beta 36	4	3.75 1.32-11.04 (23/24)	Station 87 Beaufort 76 miles SE	4.53 1.43-11.04 (12/12)	NA	2.48 1.28-3.39 (11/12)
	Gamma Isotopic 36						
	Be-7	124(e)	NDM		NDM	NA	NDM
	Mn-54	15	NDM		NDM	NA	NDM
	Fe-59	30	NDM		NDM	NA	NDM
	Co-58	15	NDM		NDM	NA	NDM
	Co-60	15	NDM		NDM	NA	NDM
	Zn-65	30	NDM		NDM	NA	NDM
	Zr-95	30	NDM		NDM	NA	NDM
	Nb-95	15	NDM		NDM	NA	NDM
	I-131(f)	15	NDM		NDM	NA	NDM
	Cs-134	15	NDM		NDM	NA	NDM
	Cs-137	18	NDM		NDM	NA	NDM
	Ba-140	60	NDM		NDM	NA	NDM
	La-140	15	NDM		NDM	NA	NDM
	Tritium 12	3000	463 259-677 (8/8)	Station 87 Beaufort 76 miles SE	483 363-600 (4/4)	NA	393 344-442 (2/4)

TABLE 3-1 (SHEET 5 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY

Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Minimum Detectable Concentration (MDC) (a)	Indicator Locations Mean (b), Range (Fraction)	Location with the Highest Annual Mean Name Distance & Direction	Location with the Highest Annual Mean Mean (b), Range (Fraction)	Other Stations (g) Mean (b), Range (Fraction)	Control Locations Mean (b), Range (Fraction)
Finished Water at Water Treatment Plants (pCi/l)	Gross Beta 36	4	2.61 1.66-5.19 (24/24)	Station 87 Beaufort 76 miles SE	2.74 1.92-5.19 (12/12)	NA	2.00 1.01-3.80 (11/12)
	Gamma Isotopic 36						
	Be-7	124(e)	NDM		NDM	NA	NDM
	Mn-54	15	NDM		NDM	NA	NDM
	Fe-59	30	NDM		NDM	NA	NDM
	Co-58	15	NDM		NDM	NA	NDM
	Co-60	15	NDM		NDM	NA	NDM
	Zn-65	30	NDM		NDM	NA	NDM
	Zr-95	30	NDM		NDM	NA	NDM
	Nb-95	15	NDM		NDM	NA	NDM
	I-131	1	NDM		NDM	NA	NDM
	Cs-134	15	NDM		NDM	NA	NDM
	Cs-137	18	NDM		NDM	NA	NDM
	Ba-140	60	NDM		NDM	NA	NDM
	La-140	15	NDM		NDM	NA	NDM
	Tritium 12	2000	546 435-735 (8/8)	Station 87 Beaufort 76 miles SE	564 435-724 (4/4)	NA	223 (1/4)

TABLE 3-1 (SHEET 6 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY

Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Minimum Detectable Concentration (MDC) (a)	Indicator Locations Mean (b), Range (Fraction)	Location with the Highest Annual Mean		Other Stations (g) Mean (b), Range (Fraction)	Control Locations Mean (b), Range (Fraction)
				Name Distance & Direction	Mean (b), Range (Fraction)		
Anadromous Fish (pCi/kg-wet)	Gamma Isotopic 1						
	Be-7	655(e)	NDM		NDM	NA	NA
	Mn-54	130	NDM		NDM	NA	NA
	Fe-59	260	NDM		NDM	NA	NA
	Co-58	130	NDM		NDM	NA	NA
	Co-60	130	NDM		NDM	NA	NA
	Zn-65	260	NDM		NDM	NA	NA
	Cs-134	130	NDM		NDM	NA	NA
	Cs-137	150	28.8 (1/1)		NDM	NA	NA
Fish (pCi/kg-wet)	Gamma Isotopic 2						
	Be-7	655(e)	NDM		NDM	NA	NDM
	Mn-54	130	NDM		NDM	NA	NDM
	Fe-59	260	NDM		NDM	NA	NDM
	Co-58	130	NDM		NDM	NA	NDM
	Co-60	130	NDM		NDM	NA	NDM
	Zn-65	260	NDM		NDM	NA	NDM
	Cs-134	130	NDM		NDM	NA	NDM
	Cs-137	150	39.3 (1/1)	Station 81 2.5 miles N	40.2 (1/1)	NA	40.2 (1/1)

TABLE 3-1 (SHEET 7 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY

Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Medium or Pathway Sampled (Unit of Measurement)	Type and Total Number of Analyses Performed	Minimum Detectable Concentration (MDC) (a)	Indicator Locations Mean (b), Range (Fraction)	Location with the Highest Annual Mean		Other Stations (g) Mean (b), Range (Fraction)	Control Locations Mean (b), Range (Fraction)
				Name Distance & Direction	Mean (b), Range (Fraction)		
Sediment (pCi/kg-dry)	Gamma Isotopic 4						
	Be-7	655(e)	1931 1325-2538 (2/2)	Station 83 0.8 miles ENE	1931 1325-2538 (2/2)	NA	1086 556-1616 (2/2)
	Co-60	70(e)	146 (1/2)	Station 83 0.8 miles ENE	146 (1/2)	NA	NDM
	Cs-134	150	NDM		NDM	NA	NDM
	Cs-137	180	263 135-391 (2/2)	Station 83 0.8 miles ENE	263 135-391 (2/2)	NA	89 80-99 (2/2)

TABLE 3-1 (SHEET 8 of 8)

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM ANNUAL SUMMARY

Vogtle Electric Generating Plant, Docket Nos. 50-424 and 50-425
Burke County, Georgia

Notes:

a. The MDC is defined in ODCM 10.1. Except as noted otherwise, the values listed in this column are the detection capabilities required by ODCM Table 4-3. The values listed in this column are a priori (before the fact) MDCs. In practice, the a posteriori (after the fact) MDCs are generally lower than the values listed. Any a posteriori MDC greater than the value listed in this column is discussed in Section 4.

b. Mean and range are based upon detectable measurements only. The fraction of all measurements at a specified location that are detectable is placed in parenthesis.

c. No Detectable Measurement(s).

d. Not Applicable.

e. The EL has determined that this value may be routinely attained under normal conditions. No value is provided in ODCM Table 4-3.

f. Item 3 of ODCM Table 4-1 implies that an I-131 analysis is not required to be performed on water samples when the dose calculated from the consumption of water is less then 1 mrem per year. However, I-131 analyses have been performed on the finished drinking water samples.

g. "Other" stations, as identified in the "Station Type" column of Table 2-2, are "Community" and/or "Special" stations.

4.0 DISCUSSION OF RESULTS

Included in this section are evaluations of the laboratory results for the various sample types. Comparisons were made between the difference in mean values for pairs of station groups (e.g., indicator and control stations) and the calculated Minimum Detectable Difference (MDD) between these pairs at the 99% Confidence Level (CL). The MDD was determined using the standard Student's t-test. A difference in the mean values that was less than the MDD was considered to be statistically indiscernible.

The 2005 results were compared with past results, including those obtained during preoperation. As appropriate, results were compared with their Minimum Detectable Concentrations (MDC) and Reporting Levels (RL) which are listed in Tables 4-1 and 4-2 of this report, respectively. The required MDCs were achieved during laboratory sample analysis. Any anomalous results are explained within this report.

Results of interest are graphed to show historical trends. The data points are tabulated and included in this report. The points plotted and provided in the tables represent mean values of only detectable results. Periods for which no detectable measurements (NDM) were observed or periods for which values were not applicable (e.g., milk indicator, etc.) are listed as NDM and are plotted in the tables as 0's.

Table 4-1

Minimum Detectable Concentrations (MDC)

Analysis	Water (pCi/l)	Airborne Particulate or Gases (fCi/m3)	Fish (pCi/kg-wet)	Milk (pCi/l)	Grass or Leafy Vegetation (pCi/kg-wet)	Sediment (pCi/kg)
Gross Beta	4	10				
H-3	2000 (a)					
Mn-54	15		130			
Fe-59	30		260			
Co-58	15		130			
Co-60	15		130			
Zn-65	30		260			
Zr-95	30					
Nb-95	15					
I-131	1 (b)	70		1	60	
Cs-134	15	50	130	15	60	150
Cs-137	18	60	150	18	80	180
Ba-140	60			60		
La-140	15			15		

(a) If no drinking water pathway exists, a value of 3000 pCi/l may be used.

(b) If no drinking water pathway exists, a value of 15 pCi/l may be used.

Table 4-2
Reporting Levels (RL)

Analysis	Water (pCi/l)	Airborne Particulate or Gases (fCi/m3)	Fish (pCi/kg-wet)	Milk (pCi/l)	Grass or Leafy Vegetation (pCi/kg-wet)
H-3	20,000 (a)				
Mn-54	1000		30,000		
Fe-59	400		10,000		
Co-58	1000		30,000		
Co-60	300		10,000		
Zn-65	300		20,000		
Zr-95	400				
Nb-95	700				
I-131	2 (b)	900		3	100
Cs-134	30	10,000	1000	60	1000
Cs-137	50	20,000	2000	70	2000
Ba-140	200			300	
La-140	100			400	

(a) This is the 40 CFR 141 value for drinking water samples. If no drinking water pathway exists, a value of 30,000 may be used.

(b) If no drinking water pathway exists, a value of 20 pCi/l may be used.

Atmospheric nuclear weapons tests from the mid 1940s through 1980 distributed man-made nuclides around the world. The most recent atmospheric tests in the 1970s and in 1980 had a significant impact upon the radiological concentrations found in the environment prior to and during preoperation, and the earlier years of operation. Some long lived radionuclides, such as Cs-137, continue to have some impact. A significant component of the Cs-137 which has often been found in various samples over the years (and continues to be found) is attributed to the nuclear weapons tests.

Data in this section has been modified to remove any obvious non-plant short term impacts. The specific short term impact data that has been removed includes: the nuclear atmospheric weapon test in the fall of 1980; abnormal releases from the Savannah River Site (SRS) during 1987 and 1991; and the Chernobyl incident in the spring of 1986.

In accordance with ODCM 4.1.1.2.1, deviations from the required sampling schedule are permitted, if samples are unobtainable due to hazardous conditions, unavailability, inclement weather, equipment malfunction or other just reasons. Deviations from conducting the REMP as described in Table 2-1 are summarized in Table 4-3 along with their causes and resolutions. As discussed in Section 4.2, during 2005 there were four deviations which resulted in loss of data.

All results were tested for conformance with Chauvenet's criterion (G. D. Chase and J. L. Rabinowitz, Principles of Radioisotope Methodology, Burgess Publishing Company, 1962, pages 87-90) to identify values which differed from the mean of a set by a statistically significant amount. Identified outliers were investigated to determine the reason(s) for the difference. If equipment malfunction or other valid physical reasons were identified as causing the variation, the anomalous result was excluded from the data set as non-representative. No data were excluded exclusively for failing Chauvenet's criterion. Data exclusions are discussed in this section under the appropriate sample type.

TABLE 4-3

DEVIATIONS FROM RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

COLLECTION PERIOD	AFFECTED SAMPLES	DEVIATION	CAUSE	RESOLUTION
1st Quarter 2005	TLD Station #1	No direct radiation data.	Unable to collect TLDs because station was underwater due to high river level.	Replaced TLDs when water level receded.
1st Quarter 2005	TLD Station #47	No direct radiation data.	Tree where TLDs were in attached was cut down.	TLDs were replaced with blanks at mid-quarter.
5/3/05-5/10/05	Girard AF/AC Station 35	Non-representative sample of airborne particulates.	Small hole found in air filter.	Replaced filter at beginning of week.
7/27/05-8/2/05	Waynesboro AF/AC Station 36	Non-representative sample of airborne particulates.	Power loss at air station.	Contacted Distribution about power loss.
8/2/05-8/9/05	Waynesboro AF/AC Station 36	Non-representative sample of airborne particulates.	Power loss at air station.	Power restored on 8/10/05 at 12:56pm.
8/2/05-8/9/05	River Road AF/AC Station 12	Non-representative sample of airborne particulates.	Station only ran 55 hours due to storm.	Station operation satisfactory after sample change out.
8/2/05-8/9/05	Hancock Landing AF/AC Station 16	Non-representative sample of airborne particulates.	Station only ran 55 hours due to storm.	Station operation satisfactory after sample change out.
8/9/05-8/16/05	Girard AF/AC Station 35	Non-representative sample of airborne particulates.	Sample time short 85 hours.	Total volume was calculated. Station operation satisfactory after sample change out.
8/9/05-8/16/05	Waynesboro AF/AC Station 36	Non-representative sample of airborne particulates.	Power loss at air station.	Power restored on 8/10/05 at 12:56pm.
1st Semi-Annual Period of 2005	Fish Collection	Unable to obtain fish samples.	High river levels existed up until next sample collection period.	Performed fish sampling when water levels permitted during second semi-annual period.
10/4/05-10/11/05	Hancock Landing AF/AC Station 16	Non-representative sample of airborne particulates.	Filter apparatus not completely attached:	Double check connections to ensure proper installation.
10/25/05-12/31/05	W. C. Dixon Dairy	No milk samples available.	Cows were sold. Owner may purchase more cows in the future.	Will keep in contact with owner to find out when/if milk samples will be available.
11/8/05-11/22/05	Coble Dairy	No milk samples available.	Coble moved cows to new location.	Dairy employees will start providing samples on 12/6/05.
11/22/05-11/29/05	Waynesboro AF/AC Station 36	Non-representative sample of airborne particulates.	Air filter not centered in sample holder.	Double check filter placement during change out.
4th Quarter 2005	TLD Station #14	Non-representative sample of airborne particulates.	TLDs missing at the end of the quarter.	TLDs replaced at the beginning of the next quarter.

4.1 Land Use Census and River Survey

In accordance with ODCM 4.1.2, a land use census was conducted on November 15, 2005 to determine the locations of the nearest permanent residence, milk animal, and garden of greater than 500 square feet producing broad leaf vegetation, in each of the 16 compass sectors within a distance of 5 miles; the locations of the nearest beef cattle in each sector were also determined. A milk animal is a cow or goat producing milk for human consumption. Land within SRS was excluded from the census. The census results are tabulated in Table 4.1-1.

Table 4.1-1

LAND USE CENSUS RESULTS

Distance in Miles to the Nearest Location in Each Sector

SECTOR	RESIDENCE	MILK ANIMAL	BEEF CATTLE	GARDEN
N	None	None	None	None
NNE	None	None	None	None
NE	None	None	None	None
ENE	None	None	None	None
E	None	None	None	None
ESE	4.2	None	None	None
SE	4.4	None	5.0	None
SSE	4.6	None	4.6	None
S	4.4	None	None	None
SSW	4.7	None	4.5	None
SW	2.7	None	4.9	None
WSW	1.2	None	2.7	3.2
W	3.7	None	4.4	None
WNW	1.8	None	None	3.3
NW	1.6	None	1.9	None
NNW	1.5	None	None	None

ODCM 4.1.2.2.1 requires a new controlling receptor to be identified, if the land use census identifies a location that yields a calculated receptor dose greater than the one in current use. It was determined that no change in the controlling receptor was required in 2005.

ODCM 4.1.2.2.2 requires that whenever the land use census identifies a location which yields a calculated dose (via the same ingestion pathway) 20% greater than that of a current indicator station, the new location must become a REMP station (if samples are available). None of the identified locations yielded a calculated dose 20% greater than that for any of the current indicator stations. No milk animals were identified within five miles of the plant.

A survey of the Savannah River downstream of the plant for approximately 100 miles was conducted on September 20, 2005 to identify any withdrawal of water from the river for drinking or irrigation purposes. No such usage was identified. These results were corroborated by checking with the Georgia Department of Natural Resources on October 31, 2005 and the South Carolina Department of Health and Environmental Control on September 22, 2005. Each of these agencies confirmed that no water withdrawal permits for drinking or irrigation purposes had been issued for this stretch of the Savannah River. The two water treatment plants used as indicator stations for drinking water are located farther downriver.

4.2 Airborne

As specified in Table 2-1 and shown in Figures 2-1 through 2-3, airborne particulate filters and charcoal canisters are collected weekly at 5 indicator stations (Stations 3, 7, 10, 12 and 16) which encircle the plant at the site periphery, at a nearby community station (Station 35) approximately 7 miles from the plant, and at a control station (Station 36) which is approximately 14 miles from the plant. At each location, air is continuously drawn through a glass fiber filter to retain airborne particulate and an activated charcoal canister is placed in series with the filter to adsorb radioiodine.

Each particulate filter is counted for gross beta activity. A quarterly gamma isotopic analysis is performed on a composite of the air particulate filters for each station. Each charcoal canister is analyzed for I-131.

As provided in Table 3-1, the 2005 annual average weekly gross beta activity was 20.5 fCi/m^3 for the indicator stations. It was 0.1 fCi/m^3 greater than the control station average of 20.4 fCi/m^3 for the year. This difference is not statistically discernible, since it is less than the calculated MDD of 2.7 fCi/m^3.

The 2005 annual average weekly gross beta activity at the Girard community station was 19.4 fCi/m^3 which was 1.0 fCi/m^3 less than the control station average. This difference is not statistically discernible since it is less than the calculated MDD of fCi/m^3.

The historical trending of the average weekly gross beta air concentrations for each year of operation and the preoperational period (September, 1981 to January, 1987) at the indicator, control and community stations is plotted in Figure 4.2-1 and listed in Table 4.2-1. In general, there is close agreement between the results for the indicator, control and community stations. This close agreement supports the position that the plant is not contributing significantly to the gross beta concentrations in air.

Figure 4.2-1

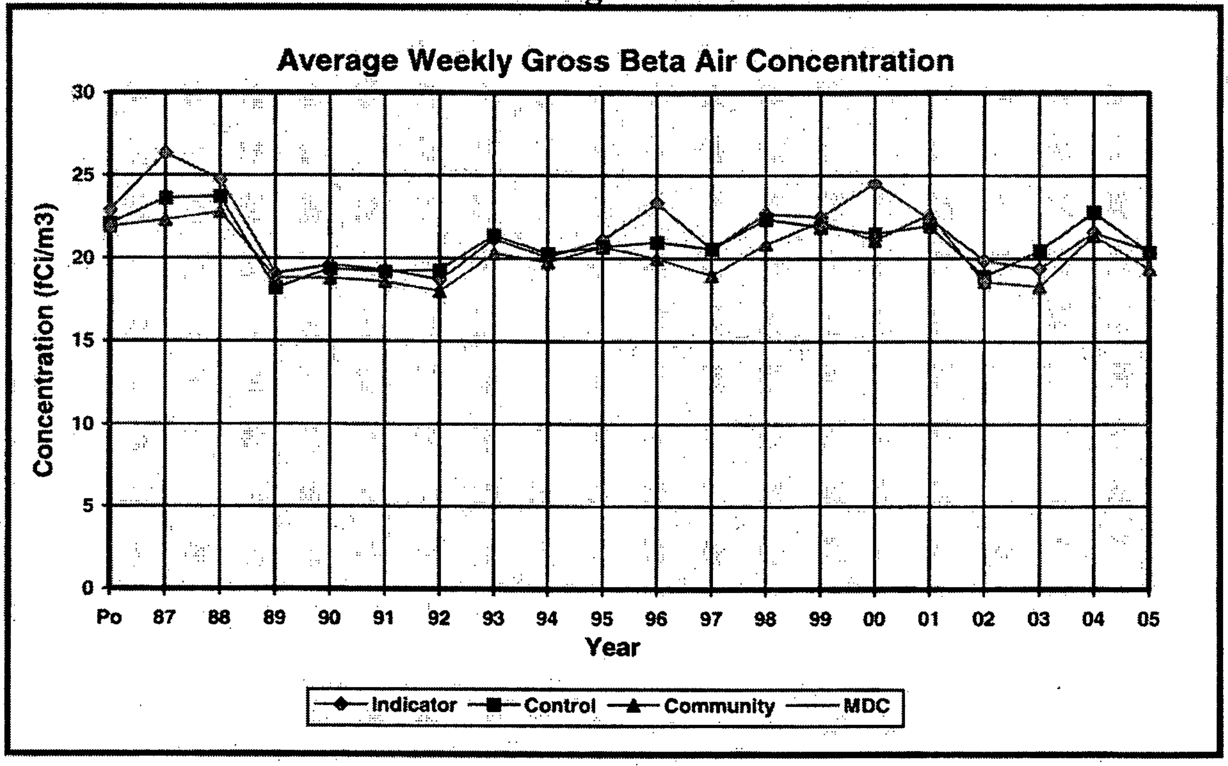


Table 4.2-1
Average Weekly Gross Beta Air Concentration

Period	Indicator (fCi/m3)	Control (fCi/m3)	Community (fCi/m3)
Pre-op	22.9	22.1	21.9
1987	26.3	23.6	22.3
1988	24.7	23.7	22.8
1989	19.1	18.2	18.8
1990	19.6	19.4	18.8
1991	19.3	19.2	18.6
1992	18.7	19.3	18.0
1993	21.2	21.4	20.3
1994	20.1	20.3	19.8
1995	21.1	20.7	20.7
1996	23.3	21.0	20.0
1997	20.6	20.6	19.0
1998	22.7	22.4	20.9
1999	22.5	21.9	22.2
2000	24.5	21.5	21.1
2001	22.4	22.0	22.7
2002	19.9	18.9	18.6
2003	19.4	20.5	18.3
2004	21.6	22.8	21.4
2005	20.5	20.4	19.4

C35

During 2005, no man-made radionuclides were detected from the gamma isotopic analysis of the quarterly composites of the air particulate filters. In 1987, Cs-137 was found in one indicator composite at a concentration of 1.7 fCi/m^3. During pre-operation, Cs-137 was found in approximately 12% of the indicator composites and 14% of the control composites with average concentrations of 1.7 and 1.0 fCi/m^3, respectively. The MDC for airborne Cs-137 is 60 fCi/m^3. Also, during pre-operation, Cs-134 was found in about 8% of the indicator composites at an average concentration of 1.2 fCi/m3. The MDC for Cs-134 is 50 fCi/m3.

The naturally occurring radionuclide Be-7 is typically detected in all indicator and control station gamma isotopic analysis of the quarterly composites of the air particulate filters. In 2005, Be-7 was not identified in plant gaseous effluents therefore it is not included in the 2005 REMP summary table for the airborne pathway samples. Be-7 has been detected in gaseous effluents eight of the eighteen years of plant operation. However, there was not a statistically discernible difference between the indicator and control station Be-7 concentrations in air samples in any of the years.

Airborne I-131 was not detected in any sample during 2005. During pre-operation, positive results were obtained only during the Chernobyl incident when concentrations as high as 182 fCi/m^3 were observed. The MDC and RL for airborne I-131 are 70 and 900 fCi/m^3, respectively.

Table 4-3 lists REMP deviations that occurred in 2005. There were nine air sampling deviations. Six of these involved power losses to the air station; at least two of the six were storm related outages. Two of the nine deviations involved errors in placement of filters/filter holders. One deviation was due to a hole in the air filter. The sample results of six of the nine deviations passed Chauvenet's Criterion and were retained in the air sample database. Three of the deviations resulted in data exclusions from the database.

4.3 Direct Radiation

Direct (external) radiation is measured with thermoluminescent dosimeters (TLDs). Two Panasonic UD-814 TLD badges are placed at each station. Each badge contains three phosphors composed of calcium sulfate crystals (with thulium impurity). The gamma dose at each station is based upon the average readings of the phosphors from the two badges. The badges for each station are placed in thin plastic bags for protection from moisture while in the field. The badges are nominally exposed for periods of a quarter of a year (91 days). An inspection is performed near mid-quarter to assure that all badges are on-station and to replace any missing or damaged badges.

Two TLD stations are established in each of the 16 compass sectors, to form 2 concentric rings. The inner ring (Stations 1 through 16) is located near the plant perimeter as shown in Figure 2-1 and the outer ring (Stations 17 through 32) is located at a distance of approximately 5 miles from the plant as shown in Figure 2-2. The 16 stations forming the inner ring are designated as the indicator stations. The two ring configuration of stations was established in accordance with NRC Branch Technical Position "An Acceptable Radiological Environmental Monitoring Program", Revision 1, November 1979. The 6 control stations (Stations 36, 37, 47, 48, 51 and 52) are located at distances greater than 10 miles from the plant as shown in Figure 2-2. Monitored special interest areas consist of the following: Station 35 at the town of Girard, and Station 43 at the employee recreational area. The TLD mean and range values presented in the "Other" column in Table 3-1 (page 1 of 8) includes the outer ring stations (stations 17 through 32) as well as stations 35 and 43.

As provided in Table 3-1 the average quarterly exposure measured at the indicator stations was 12.5 mR with a range of 7.7 to 17.2 mR. This average was 0.7 mR less than the average quarterly exposure measured at the control stations (13.2 mR). This difference is not statistically discernible since it is less than the MDD of 1.0 mR. Over the operational history of the site, the annual average quarterly exposures shows a variation of no more than 0.7 mR difference between the indicator and control stations. The overall average quarterly exposure for the control stations during preoperation was 1.2 mR greater than that for the indicator stations.

The quarterly exposures acquired at the outer ring stations during 2005 ranged from 9.8 to 16.9 mR with an average of 12.9 mR which was 0.3 mR less than that for the control stations. However, this difference is not discernible since it is less than the MDD of 1.0 mR. For the entire period of operation, the annual average quarterly exposures at the outer ring stations vary by no more than 1.2 mR from those at the control stations. The overall average quarterly exposure for the outer ring stations during preoperation was 1.8 mR less than that for the control stations.

The historical trending of the average quarterly exposures for the indicator inner ring, outer ring, and the control stations are plotted in Figure 4.3-1 and listed in Table 4.3-1. The decrease between 1991 and 1992 values is attributed to a change in TLDs from Teledyne to Panasonic. It should be noted however that the differences between indicator and control and outer ring values did not change. The close agreement between the station groups supports the position that the plant is not contributing significantly to direct radiation in the environment.

Figure 4.3-1

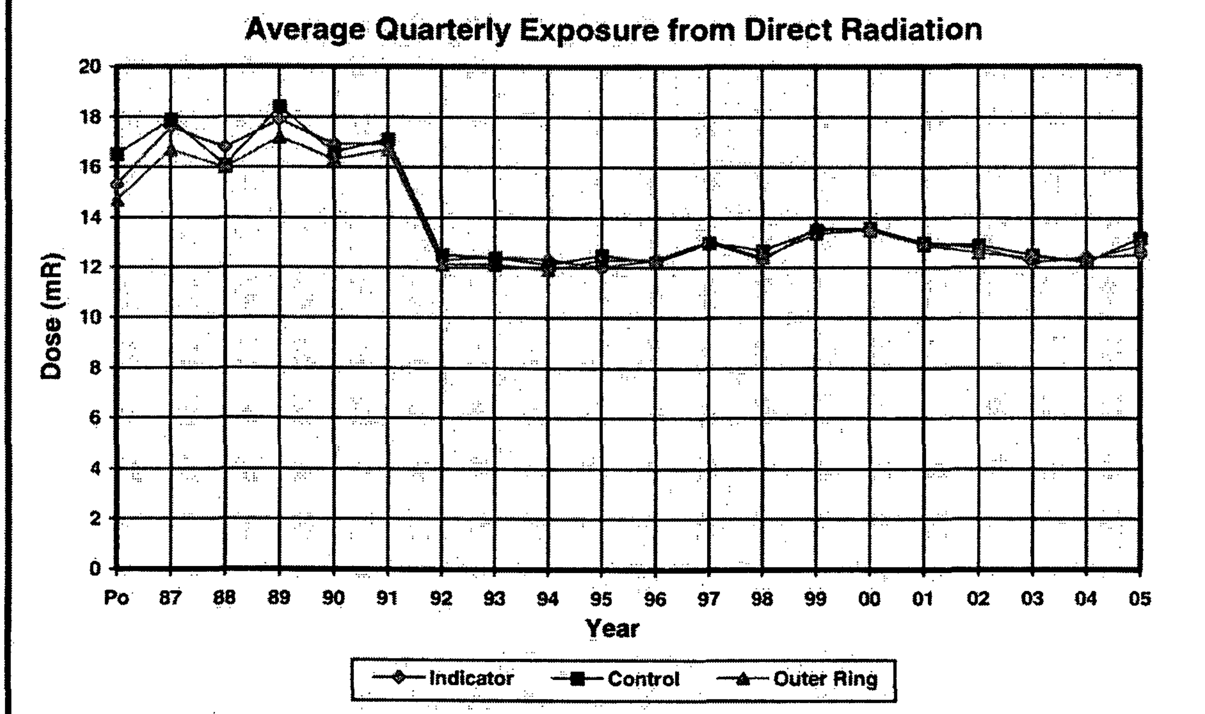


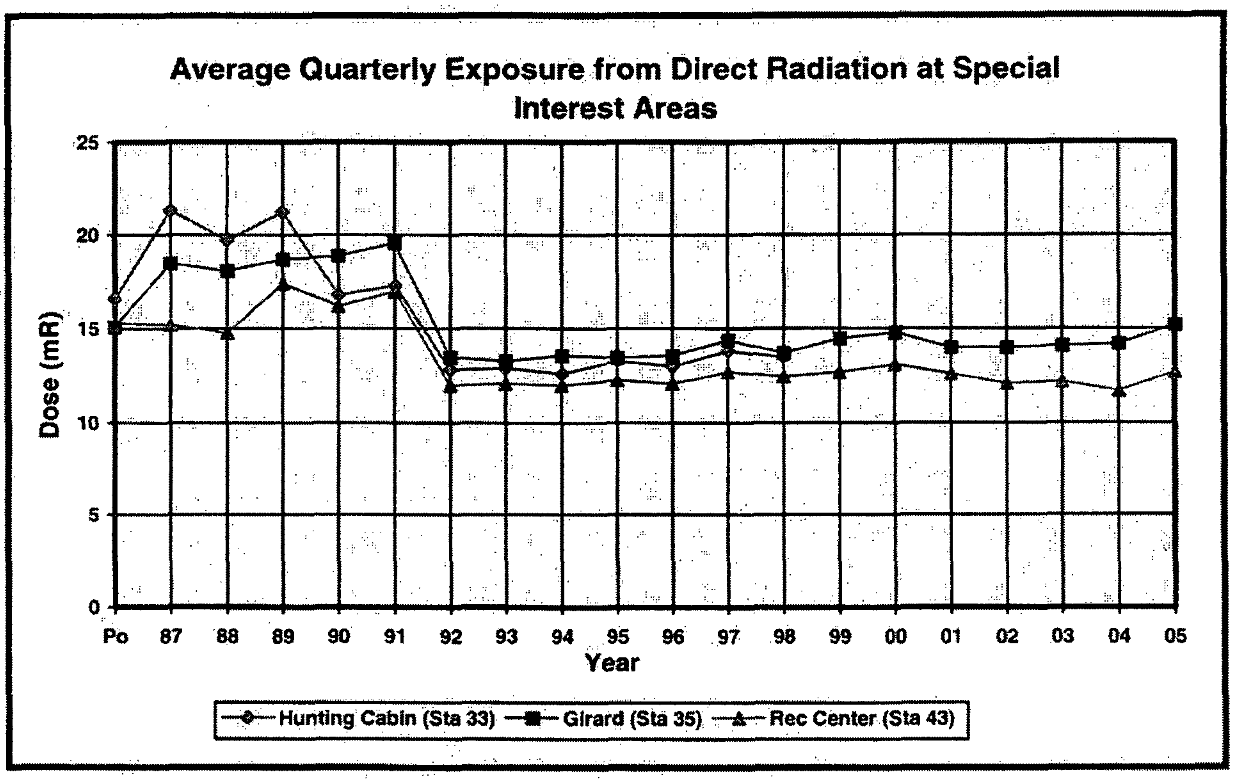
Table 4.3-1
Average Quarterly Exposure from Direct Radiation

Period	Indicator (mR)	Control (mR)	Outer Ring (mR)
Pre-op	15.3	16.5	14.7
1987	17.6	17.9	16.7
1988	16.8	16.1	16.0
1989	17.9	18.4	17.2
1990	16.9	16.6	16.3
1991	16.9	17.1	16.7
1992	12.3	12.5	12.1
1993	12.4	12.4	12.1
1994	12.3	12.1	11.9
1995	12.0	12.5	12.3
1996	12.3	12.2	12.3
1997	13.0	13.0	13.1
1998	12.3	12.7	12.4
1999	13.6	13.5	13.4
2000	13.5	13.6	13.5
2001	12.9	13.0	12.9
2002	12.8	12.9	12.6
2003	12.2	12.5	12.4
2004	12.4	12.2	12.3
2005	12.5	13.2	12.9

C36

The historical trending of the average quarterly exposures at the special interest areas for the same periods are provided in Figure 4.3-2 and listed in Table 4.3-2. These exposures are within the range of those acquired at the other stations. They too, show that the plant is not contributing significantly to direct radiation at the special interest areas.

Figure 4.3-2



C37

Table 4.3-2

Average Quarterly Exposure from Direct Radiation at Special Interest Areas

Period	Station 33 (mR)	Station 35 (mR)	Station 43 (mR)
Pre-op	16.6	15.1	15.3
1987	21.3	18.5	15.2
1988	19.7	18.1	14.8
1989	21.2	18.7	17.4
1990	16.8	18.9	16.2
1991	17.3	19.6	17.0
1992	12.8	13.5	12.0
1993	12.9	13.3	12.1
1994	12.6	13.6	12.0
1995	13.3	13.5	12.3
1996	13.0	13.6	12.1
1997	13.8	14.4	12.7
1998	13.5	13.7	12.5
1999	NA	14.5	12.7
2000	NA	14.8	13.1
2001	NA	14.0	12.6
2002	NA	14.0	12.1
2003	NA	14.1	12.2
2004	NA	14.2	11.7
2005	NA	15.2	12.7

The hunting cabin activities at Station 33 have been discontinued and, consequently, this location is no longer considered as an area of special interest. Monitoring at this location was discontinued at the end of 1998.

There were three deviations from the REMP pertaining to measuring quarterly gamma doses during 2005. These deviations are listed in Table 4-3. All three deviations led to data exclusions from the database. In two of these cases, the TLDs were missing or destroyed therefore no data was available for those stations. In one case, blanks were put in place at mid-quarter and the results failed Chauvenet's Criterion.

The standard deviation for the quarterly result for each badge was subjected to a self imposed limit of 1.4. This limit is based upon the standard deviations obtained with the Panasonic UD-814 badges during 1992 and is calculated using a method developed by the American Society of Testing and Materials (ASTM Special Technical Publication 15D, ASTM Manual on Presentation of Data and Control Chart Analysis, Fourth Revision, Philadelphia, PA, October 1976).

The limit serves as a flag to initiate an investigation. To be conservative, readings with a standard deviation greater than 1.4 are excluded since the high standard deviation is interpreted as an indication of unacceptable variation in TLD response.

The readings for the following badges were deemed unacceptable since the standard deviation for each badge was greater than the self-imposed limit of 1.4:

First Quarter:	V30A, V32B, V45B, V47A
Second Quarter:	V16B, V23A, V31B, V37B
Third Quarter:	None
Fourth Quarter:	None

However, for these cases when only one badge exceeded a standard deviation of 1.4, the companion badges were available and were used for determining the quarterly doses. The badges exceeding the self-imposed limit were visually inspected under a microscope and the glow curve and test results for the anneal data and the element correction factors were reviewed. No reason was evident for the high standard deviation.

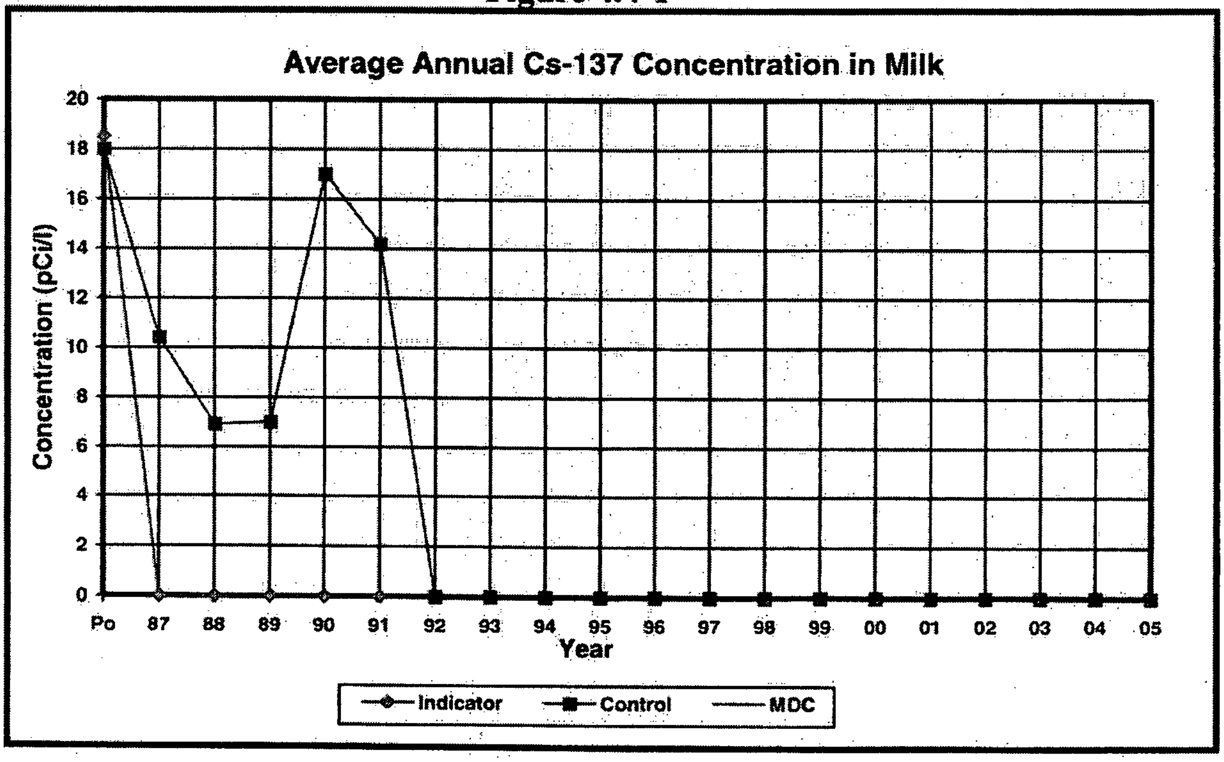
4.4 Milk

In accordance with Tables 2-1 and 2-2, milk samples are collected biweekly from two control locations, the W. C. Dixon Dairy (Station 98) and the Boyceland Dairy (Station 99). The Boyceland Dairy discontinued operations in 2003. The last sample was collected on September 3, 2003, and Coble Dairy (Station 100) was added soon after as a replacement location. In the fall of 2005, W. C. Dixon Dairy sold his cows but indicated that he may purchase more cows in 2006. Coble Dairy also had some business changes. The cows were moved in November 2005 from the location on Hwy. 25 to a nearby location on Hwy. 80 north of Waynesboro. No milk samples were available for the two collection periods in November due to milking and processing activities in the new location. A schedule was agreed upon by the Coble employees to provide samples twice a month. Gamma isotopic and I-131 analyses are performed on each milk sample.

No indicator station (a location within 5 miles of the plant) for milk has been available since April 1986. As discussed in Section 4.1, no milk animal was found during the 2005 land use census.

No man-made radionuclide was identified during the gamma isotopic analysis of the milk samples in 2005. The MDC and RL for Cs-137 in milk are 18 and 70 pCi/l, respectively. During preoperation and each year of operation through 1991, Cs-137 was found in 2 to 6% of the samples at concentrations ranging from 5 to 27 pCi/l. During preoperation, Cs-134 was detected in one sample and in the first year of operation, Zn-65 was detected in one sample. Figure 4.4-1 and Table 4.4-1 provide the historical trending of the Cs-137 concentration in milk.

Figure 4.4-1



C38

Table 4.4-1

Average Annual Cs-137 Concentration in Milk

Year	Indicator (pCi/l)	Control (pCi/l)
Pre-op	18.5	18
1987	NDM	10.4
1988	NDM	6.9
1989	NDM	7
1990	NDM	17
1991	NDM	14.2
1992	NDM	NDM
1993	NDM	NDM
1994	NDM	NDM
1995	NDM	NDM
1996	NDM	NDM
1997	NDM	NDM
1998	NDM	NDM
1999	NDM	NDM
2000	NDM	NDM
2001	NDM	NDM
2002	NDM	NDM
2003	NDM	NDM
2004	NDM	NDM
2005	NDM	NDM

During 2005, I-131 was not detected in any of the milk samples. Since operations began in 1987, I-131 may have been detected in one sample in 1996 and two during 1990; however, its presence in these cases was questionable, due to large counting uncertainties. During preoperation, positive I-131 results were found only during the Chernobyl incident with concentrations ranging from 0.53 to 5.07 pCi/l. The MDC and RL for I-131 in milk are 1 and 3 pCi/l, respectively.

4.5 Vegetation

In accordance with Tables 2-1 and 2-2, grass samples are collected monthly at two indicator locations onsite near the site boundary (Stations 7 and 15) and at one control station located about 17 miles WSW from the plant (Station 37). Gamma isotopic analyses are performed on the samples. During 2005, two samples out of the 24 samples collected at the indicator stations were positive for the man-made radionuclide, Cs-137. The average of the two positive indicator samples was 49.5 pCi/kg-wet. None of the 12 samples collected at the control stations were positive for Cs-137. The levels seen at the indicator stations could potentially be attributed to plant effluents. However, Cs-137 is sometimes detected in environmental samples as a result of atmospheric weapons testing and the Chernobyl incident.

The historical trending of the average concentration of Cs-137 at the indicator and control stations is provided in Figure 4.5-1 and listed in Table 4.5-1. No trend is recognized in this data. The MDC and RL for Cs-137 in vegetation samples are 80 and 2000 pCi/kg-wet, respectively. Cs-137 is the only man-made radionuclide that has been identified in vegetation samples during the operational history of the plant. During preoperation, Cs-137 was found in approximately 60% of the samples from indicator stations and in approximately 20% of the samples from the control station. These percentages have generally decreased during operation.

The naturally occurring radionuclide Be-7 is typically detected in indicator and control station vegetation samples. Be-7 was not detected in gaseous effluents in 2005, therefore it is not included in the REMP summary table for the airborne pathway samples. Be-7 has been detected in gaseous effluents eight of the eighteen years of plant operation and is therefore of interest in the REMP program. However, the levels of Be-7 found in the REMP make no significant contribution to dose.

In May and June of 1986 during preoperation, as a consequence of the Chernobyl incident, I-131 was found in nearly all the samples collected for a period of several weeks in the range of 200 to 500 pCi/kg-wet. The MDC and RL for I-131 in vegetation are 60 and 100 pCi/kg-wet, respectively. Also during this time period, Co-60 was found in one of the samples at a concentration of 62.5 pCi/kg-wet. There is no specified MDC or RL for Co-60 in vegetation.

Figure 4.5-1

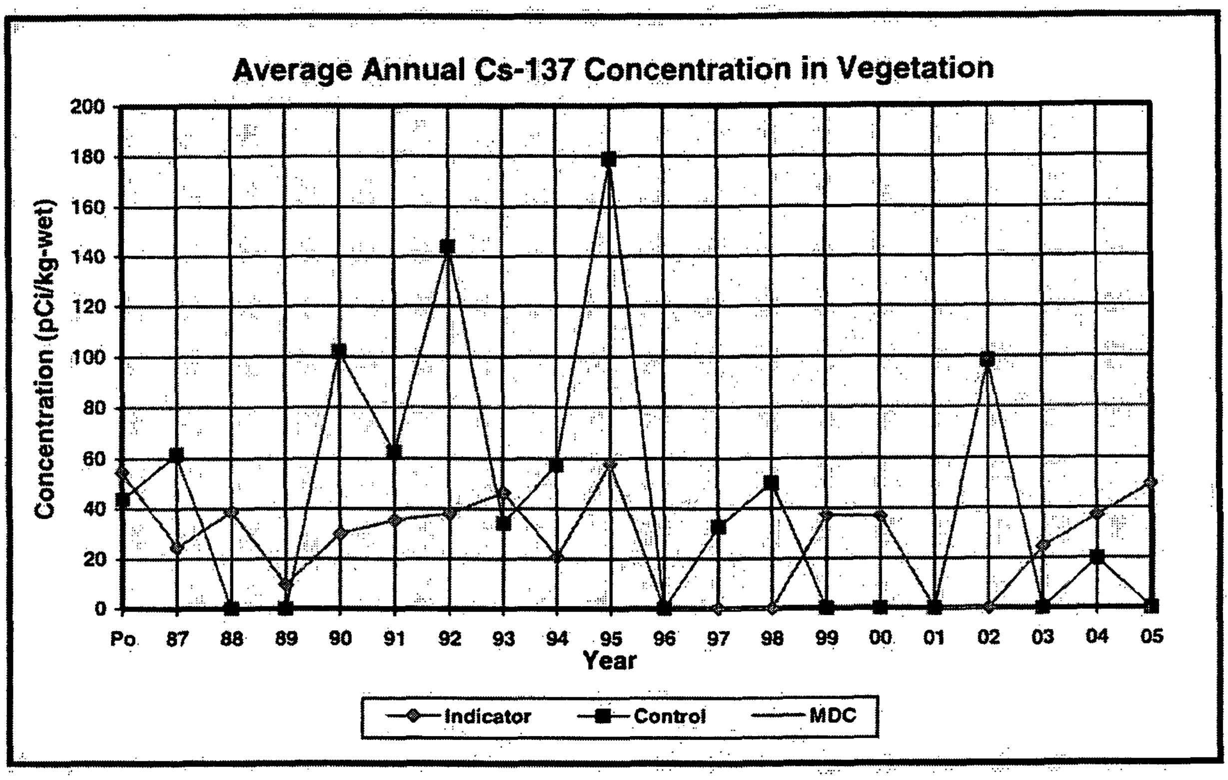


Table 4.5-1
Average Annual Cs-137 Concentration in Vegetation

Year	Indicator (pCi/kg-wet)	Control (pCi/kg-wet)
Pre-op	54.6	43.7
1987	24.4	61.5
1988	38.7	NDM
1989	9.7	NDM
1990	30.0	102.0
1991	35.3	62.4
1992	38.1	144.0
1993	46.4	34.1
1994	20.7	57.4
1995	57.8	179.0
1996	NDM	NDM
1997	NDM	32.6
1998	NDM	50.1
1999	37.2	NDM
2000	36.6	NDM
2001	NDM	NDM
2002	NDM	98.3
2003	24.5	NDM
2004	36.8	19.7
2005	49.5	NDM

C39

4.6 River Water

Surface water from the Savannah River is obtained at three locations using automatic samplers. Small quantities are drawn at intervals not exceeding a few hours. The samples drawn are collected monthly; quarterly composites are produced from the monthly collections.

The collection points consist of a control location (Station 82) which is located about 0.4 miles upriver of the plant intake structure, an indicator location (Station 83) which is located about 0.4 miles downriver of the plant discharge structure, and a special location (Station 84) which is located approximately 1.3 miles downriver of the plant discharge structure. A statistically significant increase in the concentrations found in samples collected at the indicator station compared to those collected at the control station could be indicative of plant releases. Concentrations found at the special station are more likely to represent the activity in the river as a whole, which might include plant releases combined with those from other sources along the river.

A gamma isotopic analysis is conducted on each monthly sample. As in all previous years, there were no gamma emitting radionuclides of interest detected in the 2005 river water samples.

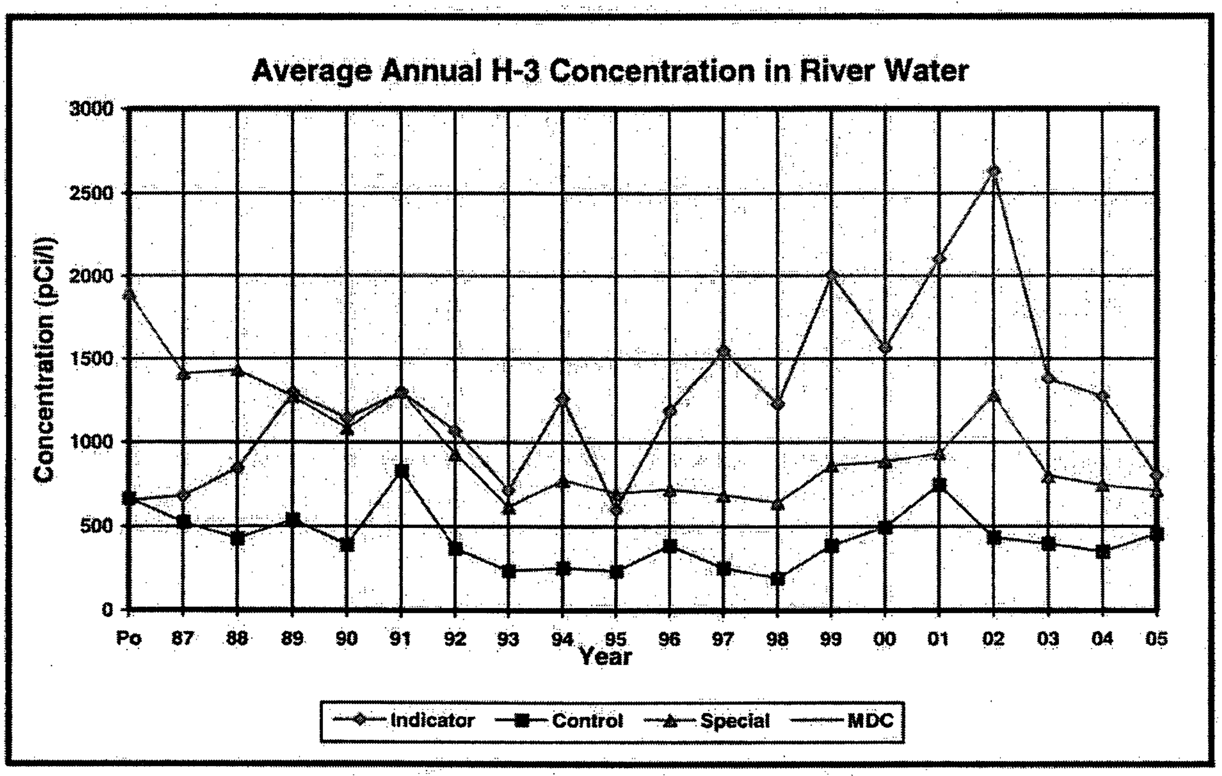
Each quarterly composite is analyzed for tritium. As indicated in Table 3-1, the average concentration found at the indicator station was 800 pCi/l which was 342 pCi/l greater than that found at the control station (458 pCi/l). This difference is not statistically discernible since it is less than the calculated MDD of 1333 pCi/l. The MDC for tritium in river water used to supply drinking water is 2000 pCi/l and the RL is 20,000 pCi/l.

At the special river water sampling station, the results ranged from 276 pCi/l to 1400 pCi/l with an average of 713 pCi/l. The decrease in tritium concentration between the indicator station and the special station is due to the additional dispersion over the 0.9 miles that separates the two stations. In the first two years of operation, the tritium concentration at the special station was somewhat greater than that at the indicator station. In recent years, the level at the special station has generally become less than the level at the indicator station.

The historical trending of the average tritium concentrations found at the special, indicator, and control stations along with the MDC for tritium is plotted on Figure 4.6-1. The data for the plot is listed in Table 4.6-1. Also included in the table are data from the calculated difference between the indicator and control stations; the MDD between the indicator and control stations; and the total curies of tritium released from the plant in liquid effluents.

The annual downriver survey of the Savannah River showed that river water is not being used for purposes of drinking or irrigation for at least 100 miles downriver (discussed in Section 4.1).

Figure 4.6-1



C40

Table 4.6-1

Average Annual H-3 Concentration in River Water

Year	Special (pCi/l)	Indicator (pCi/l)	Control (pCi/l)	Difference Between Indicator and Control (pCi/l)	MDD (pCi/l)	Annual Site Tritium Released (Ci)
Pre-op	1900	650	665	-15	145	NA
1987	1411	680	524	156	416	321
1988	1430	843	427	416	271	390
1989	1268	1293	538	755	518	918
1990	1081	1142	392	750	766	1172
1991	1298	1299	828	471	626	1094
1992	929	1064	371	693	714	1481
1993	616	712	238	474	1526	761
1994	774	1258	257	1001	2009	1052
1995	699	597	236	361	766	968
1996	719	1187	387	800	2147	1637
1997	686	1547	254	1293	1566	1449
1998	640	1226	196	1030	1313	1669
1999	859	2005	389	1616	1079	1674
2000	885	1564	496	1068	1786	869
2001	931	2101	743	1358	1696	1492
2002	1280	2628	437	2190	1211	1566
2003	800	1376	399	977	1706	1932
2004	743	1269	351	918	1061	1212
2005	713	800	458	342	1333	1860

4.7 Drinking Water

Samples are collected at a control location (Station 80 - the Augusta Water Treatment Plant in Augusta, Georgia located about 56 river miles upriver), and at two indicator locations (Station 87 - the Beaufort-Jasper County Water Treatment Plant near Beaufort, South Carolina, 112 river miles downriver; and Station 88 - the Cherokee Hill Water Treatment Plant near Port Wentworth, Georgia, 122 river miles downriver). These upriver and downriver distances in river miles are the distances from the plant to the point on the river where water is diverted to the intake for each of these water treatment plants.

Water samples are taken near the intake of each water treatment plant (raw drinking water) using automatic samplers that take periodical small aliquots from the stream. These composite samples are collected monthly along with a grab sample of the processed water coming from the treatment plants (finished drinking water). Quarterly composites are made from these monthly collections for both raw and processed river water. Gross beta and gamma isotopic analyses are performed on each of the monthly samples while tritium analysis is conducted on the quarterly composites. An I-131 analysis is not required to be conducted on these samples, since the dose calculated from the consumption of water is less than 1 mrem per year (see ODCM Table 4-1). However, an I-131 analysis is conducted on each of the monthly finished water grab samples, since a drinking water pathway exists.

Provided in Figures 4.7-1 and 4.7-2 and Tables 4.7-1 and 4.7-2, are the historical trends of the average gross beta concentrations found in the monthly collections of raw and finished drinking water.

For 2005, the indicator station average gross beta concentration in the raw drinking water was 3.75 pCi/l which was 1.27 pCi/l greater than the average gross beta concentration at the control station (2.48 pCi/l). This difference is not statistically discernible, since it is less than the calculated MDD of 1.29 pCi/l. The required MDC for gross beta in water is 4.0 pCi/l. There is no RL for gross beta in water.

For 2005, the indicator station average gross beta concentration in the finished drinking water was 2.61 pCi/l which was 0.61 pCi/l greater than the average gross beta concentration at the control station (2.00 pCi/l). This difference is less than the MDD of 0.79 pCi/l and not statistically discernible. The gross beta concentrations at the indicator stations ranged from 1.66 to 5.19 pCi/l while the concentrations at the control station ranged from 1.01 to 3.80 pCi/l. The required MDC for gross beta in water is 4.0 pCi/l. There is no RL for gross beta in water.

Figure 4.7-1

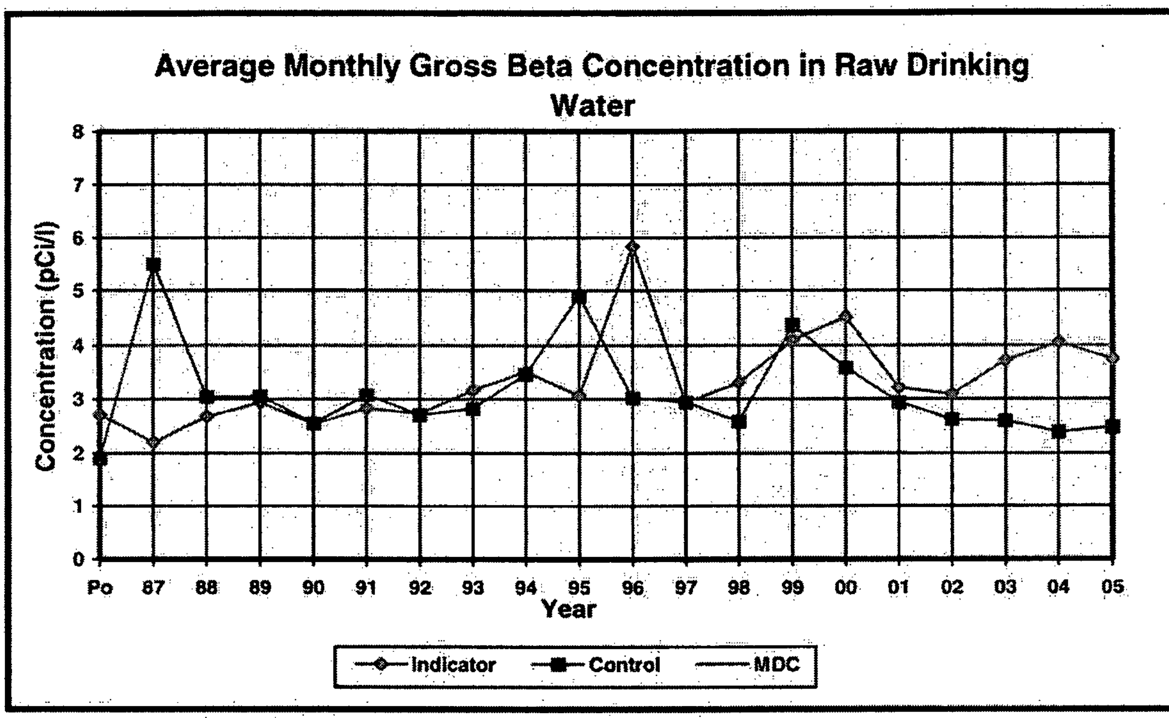


Table 4.7-1
Average Monthly Gross Beta Concentration in Raw Drinking Water

Period	Indicator (pCi/l)	Control (pCi/l)
Pre-op	2.70	1.90
1987	2.20	5.50
1988	2.67	3.04
1989	2.93	3.05
1990	2.53	2.55
1991	2.83	3.08
1992	2.73	2.70
1993	3.17	2.83
1994	3.51	3.47
1995	3.06	4.90
1996	5.83	3.02
1997	2.93	2.94
1998	3.31	2.58
1999	4.10	4.37
2000	4.52	3.59
2001	3.21	2.94
2002	3.09	2.61
2003	3.73	2.59
2004	4.06	2.39
2005	3.75	2.48

C41

Figure 4.7-2

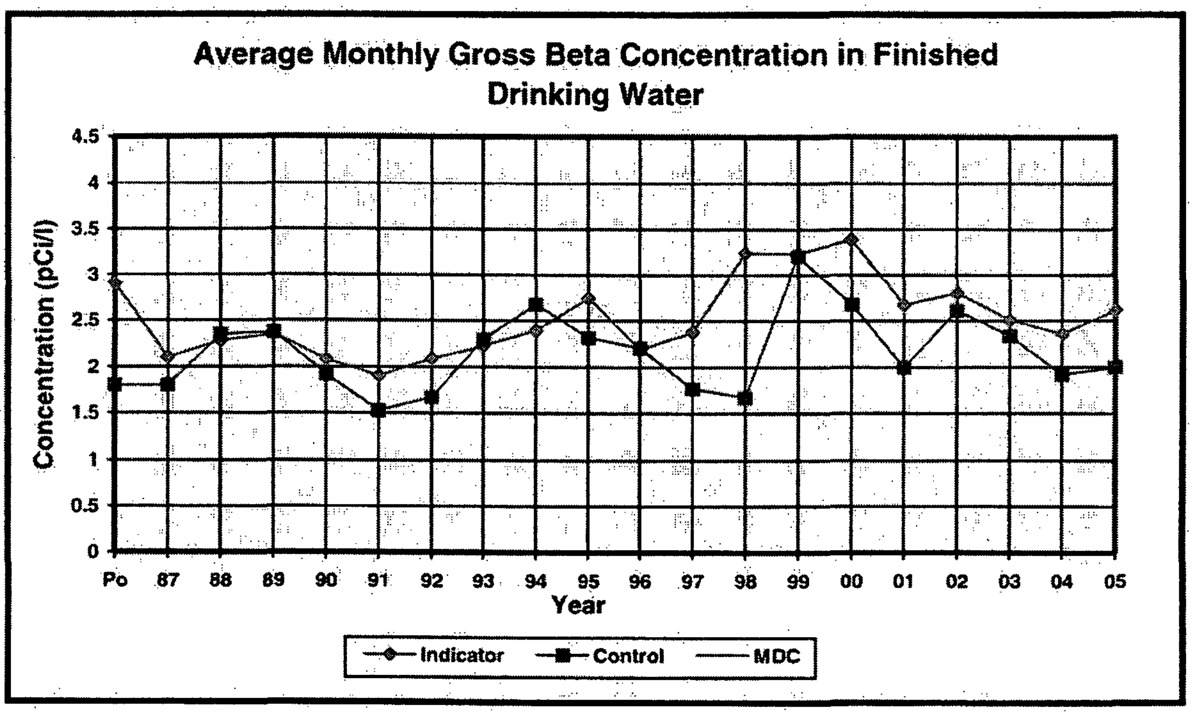


Table 4.7-2
Average Monthly Gross Beta Concentration in Finished Drinking Water

Period	Indicator (pCi/l)	Control (pCi/l)
Pre-op	2.90	1.80
1987	2.10	1.80
1988	2.28	2.35
1989	2.36	2.38
1990	2.08	1.92
1991	1.90	1.53
1992	2.09	1.67
1993	2.23	2.30
1994	2.40	2.68
1995	2.74	2.32
1996	2.19	2.21
1997	2.38	1.77
1998	3.23	1.67
1999	3.23	3.21
2000	3.39	2.68
2001	2.67	2.00
2002	2.80	2.61
2003	2.51	2.34
2004	2.36	1.92
2005	2.61	2.00

C42

As provided in Table 3-1, there were no positive results during 2005 for the radionuclides of interest from the gamma isotopic analysis of the monthly collections for both raw and finished drinking water. Only one positive result has been found since operation began. Be-7 was found at a concentration of 68.2 pCi/l in the sample collected for September 1987 at Station 87. During preoperation Be-7 was found in about 5% of the samples at concentrations ranging from 50 to 80 pCi/l. The MDC assigned for Be-7 in water is 124 pCi/l. Also during preoperation, Cs-134 and Cs-137 were detected in about 7% of the samples at concentrations on the order of their MDCs which are 15 and 18 pCi/l, respectively.

I-131 was detected in finished drinking water in 1997 at levels near the MDC. This was the first occurrence for detecting I-131 in finished drinking water since operation began. During preoperation, it was detected in only one of 73 samples at a concentration of 0.77 pCi/l at Port Wentworth. The MDC and RL for I-131 in drinking water are 1 and 2 pCi/l, respectively.

Figures 4.7-3 and 4.7-4 and Tables 4.7-3 and 4.7-4 provide historical trending for the average tritium concentrations found in the quarterly composites of raw and finished drinking water collected at the indicator and control stations. The tables also list the calculated differences between the indicator and control stations, and list the MDDs between these two station groups.

The graphs and tables show that the tritium concentrations in the drinking water samples, both raw and finished, have been gradually trending downward since 1988. The small increase in average concentrations at the indicator stations for 1991 and 1992 reflect the impact of the inadvertent release from SRS of 7,500 Ci of tritium to the Savannah River about 10 miles downriver of VEGP, in December 1991 (SRS release data was obtained from "Release of 7,500 Curies of Tritium to the Savannah River from the Savannah River Site", Georgia Department of National Resources, Environmental Protection Division, Environmental Radiation Program, January 1992).

The 2005 raw drinking water indicator stations average tritium was 463 pCi/l which was 70 pCi/l greater than the concentration determined at the control station (393 pCi/l). The difference between the average at the indicator stations and the average at the control station is less than the calculated MDD of 301 pCi/l and therefore is not statistically discernible. For the past 3 years, the average tritium concentration seen at the indicator stations has been less than all prior years (pre-op to present) and was approximately 75% less than the pre-op average tritium concentration seen at the indicator stations (2300 pCi/l). The MDC and RL for tritium in drinking water are 2000 pCi/l and 20,000 pCi/l, respectively.

The finished drinking water average tritium concentration at the indicator stations during 2005 was 546 pCi/l which was 323 pCi/l greater than that found at the control station (223 pCi/l). Application of the modified Student's t-test shows that the difference between the average at the indicator stations and the single positive value at the control station is not statistically discernible.

Figure 4.7-3

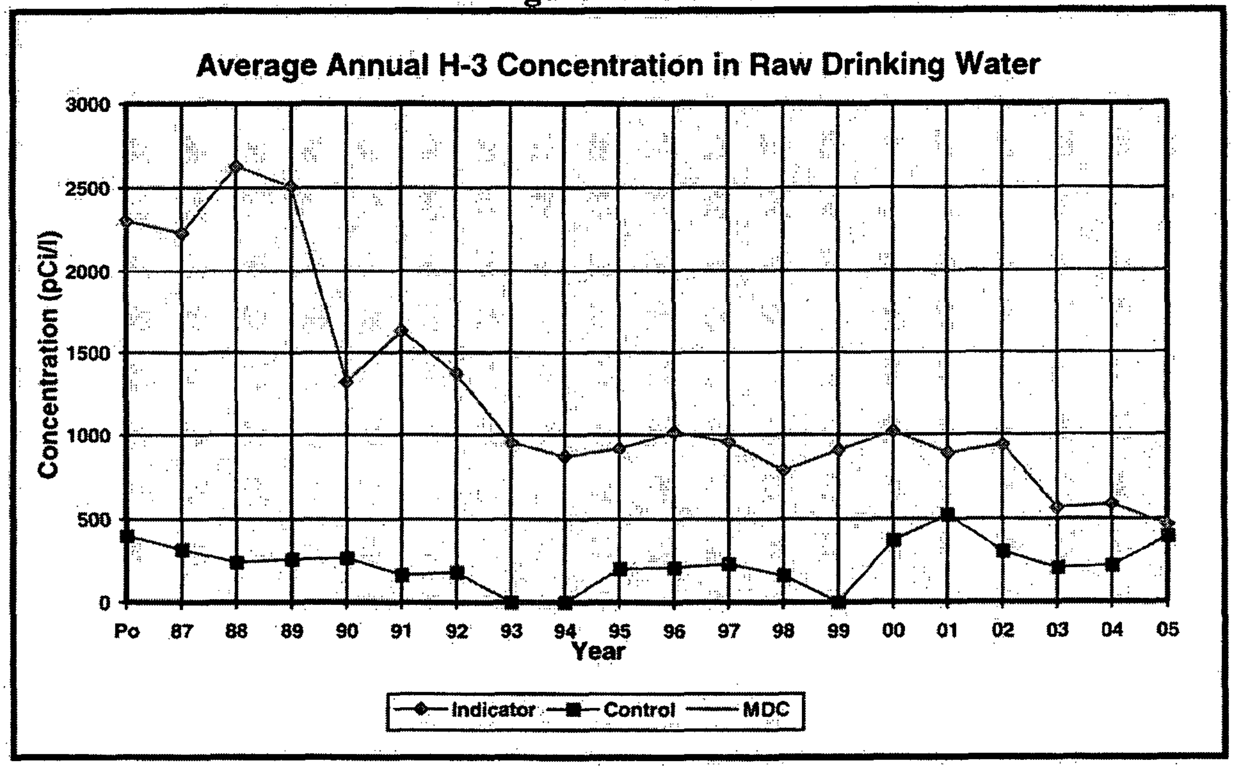


Table 4.7-3
Average Annual H-3 Concentration in Raw Drinking Water

Period	Indicator (pCi/l)	Control (pCi/l)	Difference Between Indicator and Control (pCi/l)	MDD (pCi/l)
Pre-op	2300	400	1900	
1987	2229	316	1913	793
1988	2630	240	2390	580
1989	2508	259	2249	1000
1990	1320	266	1054	572
1991	1626	165	1461	834
1992	1373	179	1194	353
1993	955	NDM	955	NA
1994	871	NDM	871	NA
1995	917	201	716	NA
1996	1014	207	807	151
1997	956	230	726	61
1998	791	160	631	NA
1999	908	NDM	908	NA
2000	1020	373	647	704
2001	889	525	364	NA
2002	938	304	634	284
2003	563	203	360	NA
2004	585	220	365	204
2005	463	393	70	301

C43

Figure 4.7-4

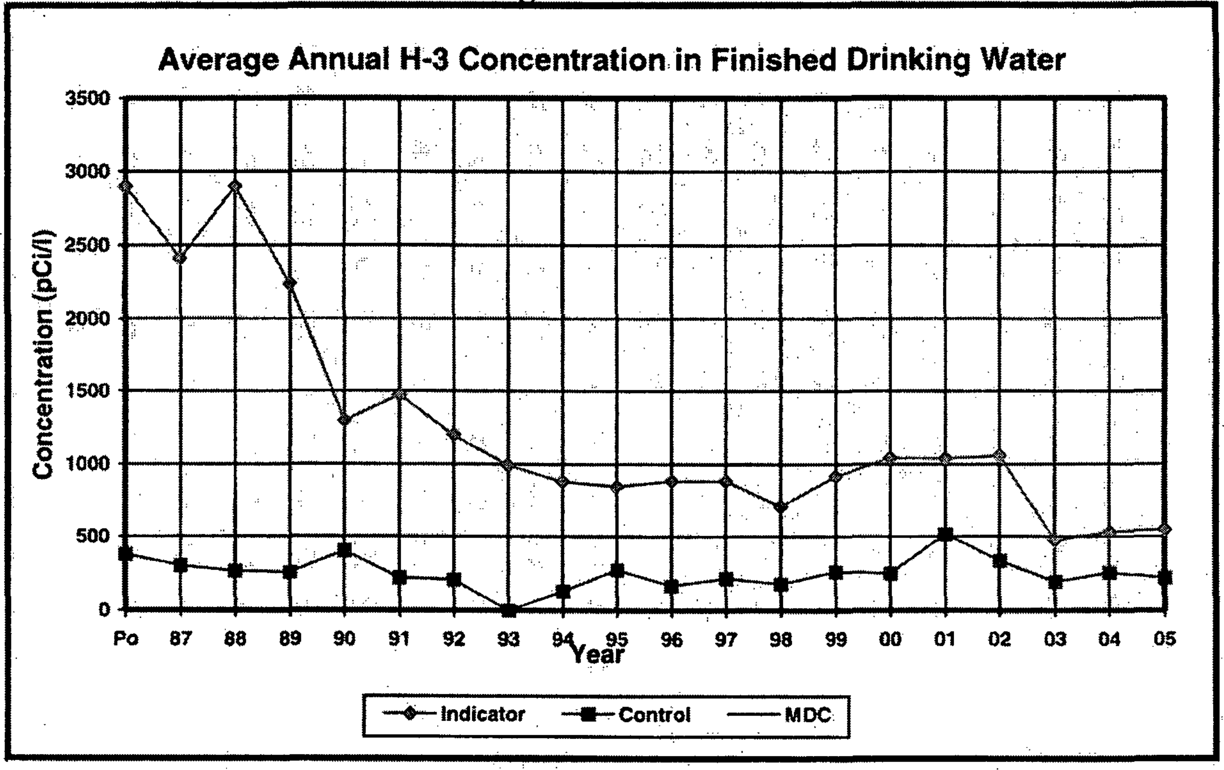


Table 4.7-4
Average Annual H-3 Concentration in Finished Drinking Water

Period	Indicator (pCi/l)	Control (pCi/l)	Difference Between Indicator and Control (pCi/l)	MDD (pCi/l)
Pre-op	2900	380	2520	
1987	2406	305	2101	1007
1988	2900	270	2630	830
1989	2236	259	1977	627
1990	1299	404	895	1131
1991	1471	225	1246	647
1992	1195	211	984	427
1993	993	0	993	NA
1994	880	131	749	270
1995	847	279	568	NA
1996	884	168	716	NA
1997	887	221	666	383
1998	713	180	533	NA
1999	920	263	657	NA
2000	1043	251	792	833
2001	1037	516	521	NA
2002	1060	340	720	416
2003	473	196	277	NA
2004	531	255	276	314
2005	546	223	323	NA

C44

4.8 Fish

Table 2-1 requires the collection of at least one sample of any anadromous species of fish in the vicinity of the plant discharge during the spring spawning season, and for the semi-annual collection of at least one sample of any commercially or recreationally important species in the vicinity of the plant discharge area and in an area not influenced by plant discharges. Table 2-1 specifies that a gamma isotopic analysis be performed on the edible portions of each sample collected.

As provided in Table 2-2, a 5-mile stretch of the river is generally needed to obtain adequate fish samples. For the semiannual collections, the control location (Station 81) extends from approximately 2 to 7 miles upriver of the plant intake structure, and the indicator location (Station 85) extends from about 1.4 to 7 miles downriver of the plant discharge structure. For anadromous species, all collection points can be considered as indicator stations.

The anadromous fish sample was collected on April 26, 2005 during the spring spawning season. In all but two previous years of operation, no radionuclides were detected. In 2005, Cs-137 was detected in the anadromous fish sample at a low level of 28.8 pCi/kg-wet. In 1987, as well as in 1991, Cs-137 was found in a single sample of American shad at concentrations of 10 and 12 pCi/kg-wet, respectively.

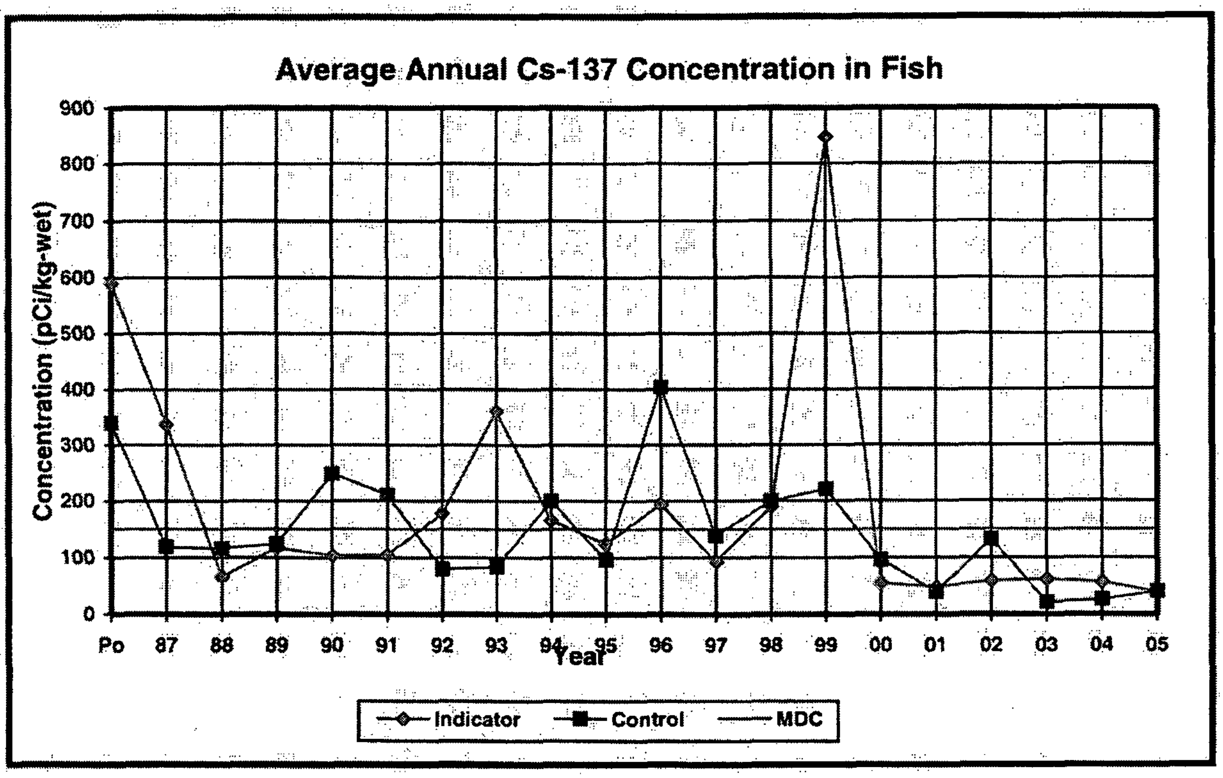
The dates and compositions of the semi-annual catches at the indicator and control stations during 2005 are shown below. During the first semi-annual period, river levels were extremely high and electrofishing was not possible.

Date	Indicator	Control
Could not collect during first semi-annual period due to high river levels	NA	NA
November 4	Largemouth Bass	Largemouth Bass

As indicated in Table 3-1, Cs-137 was the only radionuclide found in the semiannual collections of a commercially or recreationally important species of fish. It has been found in all but 4 of the 125 samples collected during operation and in all but 5 of the 32 samples collected during preoperation. As provided in Table 3-1, the concentration at the indicator station for the second semi-annual collection was 39.3 pCi/kg-wet which was 0.9 pCi/kg-wet less than that at the control station (40.2 pCi/kg-wet). No statistical analysis can be performed since there is only a single positive value at each station. No discernible difference has occurred for any year of operation or during pre-operation.

Figure 4.8-1 and Table 4.8-1 provide the historical trending of the average concentrations of Cs-137 in units of pCi/kg-wet found in fish samples at the indicator and control stations. The indicator station fish sample concentration of Cs-137 in 1999 was greatly influenced by a largemouth bass collected in October with a concentration of 2500 pCi/kg-wet. Other than the fact that largemouth bass are predators that concentrate Cs-137, no specific cause for the elevated concentration in this sample is known. No trend is recognized in this data. The MDC and RL for Cs-137 in fish are 150 and 2000 pCi/kg-wet, respectively.

Figure 4.8-1



C45

Table 4.8-1
Average Annual Cs-137 Concentration in Fish

Year	Indicator (pCi/kg-wet)	Control (pCi/kg-wet)
Pre-op	590	340
1987	337	119
1988	66	116
1989	117	125
1990	103	249
1991	105	211
1992	178	80
1993	360	84
1994	165	200
1995	125	96
1996	194	404
1997	93	139
1998	190	200
1999	848	221
2000	55	96
2001	48	39
2002	59	133
2003	62	21
2004	56.4	26.0
2005	39.3	40.2

The only other radionuclide found in fish samples during operation is I-131. In 1989, it was found in one sample at the indicator station at a concentration of 18 pCi/kg-wet. In 1990, it was found in one sample at the indicator station and in one sample at the control station, at concentrations of 13 and 12 pCi/kg-wet, respectively. The MDC assigned to I-131 in fish is 53 pCi/kg-wet.

During preoperation, Cs-134 was found in two of the 17 samples collected at the control station at concentrations of 23 and 190 pCi/kg-wet. The MDC and RL for Cs-134 are 130 and 1000 pCi/kg-wet, respectively. Nb-95 was also found in one of the control station samples at a concentration of 34 pCi/kg-wet. The assigned MDC and calculated RL for Nb-95 are 50 and 70,000 pCi/kg-wet, respectively.

4.9 Sediment

Sediment was collected along the shoreline of the Savannah River on July 6 and October 4, 2005 at Stations 81 and 83. Station 81 is a control station located about 2.5 miles upriver of the plant intake structure while Station 83 is an indicator station located about 0.6 miles downriver of the plant discharge structure. A gamma isotopic analysis was performed on each sample. The radionuclides of interest identified in 2005 samples were Be-7, Co-60, and Cs-137.

Be-7, which is abundant in nature, was not identified in plant liquid effluents during 2005. However, it continues to be trended in river sediment in the REMP report. In 2005, the average level at the indicator station was 1931 pCi/kg-dry and at the control station it was 1086 pCi/kg-dry. The difference between the average at the indicator and the control station (845 pCi/kg-dry) is not statistically discernible since it is less that the MDD of 5612 pCi/kg-dry. Because there continues to be no significant difference between the indicator and control station, the Be-7 found at the indicator station is not attributed to plant releases.

For Cs-137, the average concentration at the indicator station during 2005 was 263 pCi/kg-dry which was 174 pCi/kg-dry greater than that at the control station (89 pCi/kg-dry). The calculated MDD is 889 pCi/kg-dry. Therefore, there is no discernible difference between Cs-137 concentration in sediment at the indicator and control stations. The Cs-137 level at the indicator station has averaged nearly 100 pCi/kg-dry greater than that at the control station over the entire period of operation. During preoperation, the Cs-137 was 170 pCi/kg-dry greater at the indicator station than at the control station.

During 2005, Co-60 was detected in one of two sediment samples at the indicator station. The concentration of the single positive sample was 146 pCi/kg-dry. Since no Co-60 was detected in sediment collected at the control station, this concentration of Co-60 could be attributed to plant releases or, potentially, to other facilities that release radioactive effluents in the vicinity of the plant.

The historical average concentrations of Be-7, Co-58, Co-60, and Cs-137 in sediment are plotted in Figures 4.9-1 through 4.9-4 along with listings of their concentrations in Tables 4.9-1 through 4.9-4. The concentrations of the solely man-made nuclides (Co-58, Co-60, & Cs-137) are consistent with past average concentrations. No pattern has been detected. Be-7, produced by man and nature, is also within the range that is typically seen.

During preoperation, Zr-95, Nb-95, Cs-134, and Ce-141 were detected in at least one of the control station samples and Nb-95 was detected in one of the indicator station samples. Be-7 and Cs-137 were found in several of the samples. The concentrations of these preoperational nuclides were on the order of their respective MDC values. The presence of these preoperational nuclides could be attributed to atmospheric weapons testing and the Chernobyl incident.

Mn-54 and I-131 were found sporadically over several years of operation. A summary of the positive results for these nuclides along with their applicable MDCs is provided in Table 4.9-5.

Figure 4.9-1

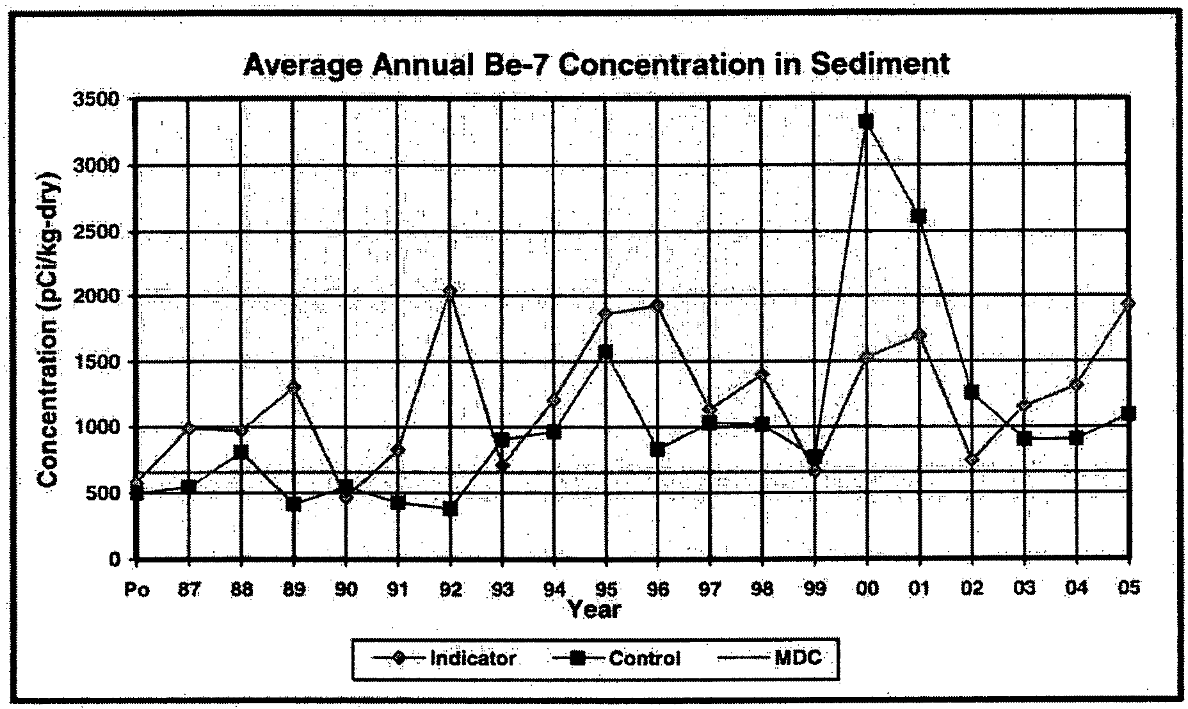


Table 4.9-1
Average Annual Be-7 Concentration in Sediment

MDC=655 pCi/kg-dry		
Year	**Indicator (pCi/kg-dry)**	**Control (pCi/kg-dry)**
Pre-op	580	500
1987	987	543
1988	970	810
1989	1300	415
1990	465	545
1991	826	427
1992	2038	380
1993	711	902
1994	1203	964
1995	1865	1575
1996	1925	831
1997	1130	1028
1998	1396	1016
1999	662	769
2000	1526	3324
2001	1697	2614
2002	742	1254
2003	1150	903
2004	1309	905
2005	1931	1086

C46

Figure 4.9-2

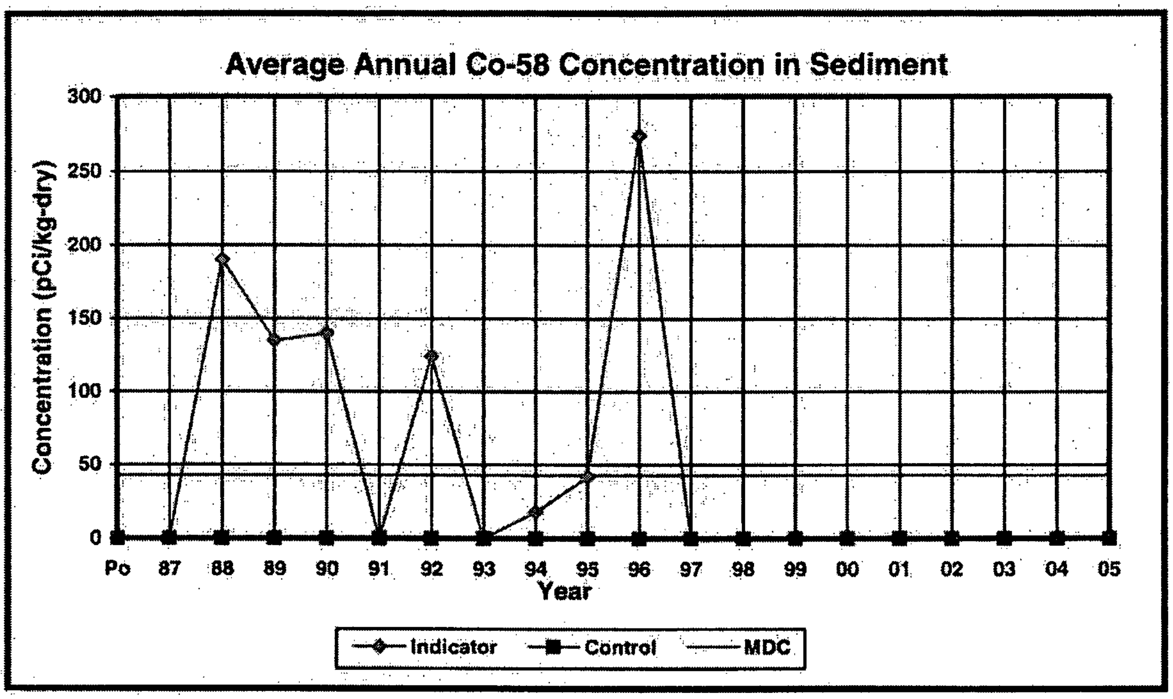


Table 4.9-2
Average Annual Co-58 Concentration in Sediment

MDC=43 pCi/kg-dry		
Year	**Indicator (pCi/kg-dry)**	**Control (pCi/kg-dry)**
Pre-op	NDM	NDM
1987	NDM	NDM
1988	190	NDM
1989	135	NDM
1990	140	NDM
1991	NDM	NDM
1992	124	NDM
1993	NDM	NDM
1994	18.4	NDM
1995	42.4	NDM
1996	274	NDM
1997	NDM	NDM
1998	NDM	NDM
1999	NDM	NDM
2000	NDM	NDM
2001	NDM	NDM
2002	NDM	NDM
2003	NDM	NDM
2004	NDM	NDM
2005	NDM	NDM

C47

Figure 4.9-3

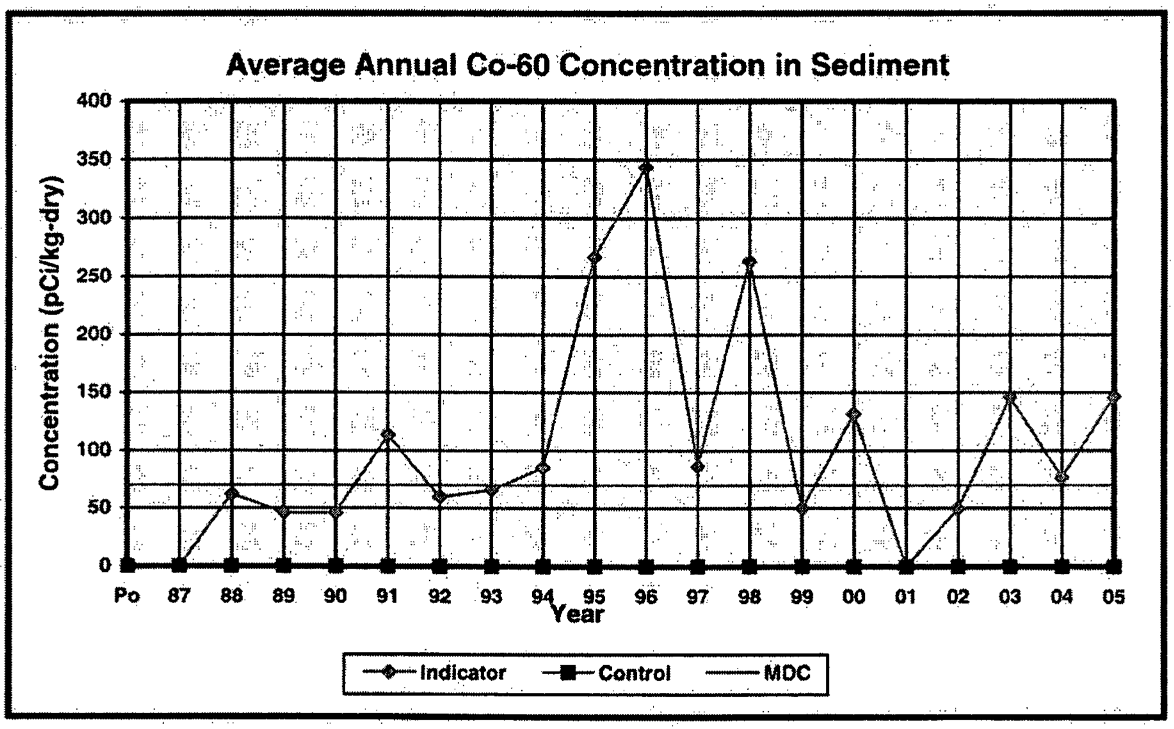


Table 4.9-3
Average Annual Co-60 Concentration in Sediment

MDC=70 pCi/kg-dry

Year	Indicator (pCi/kg-dry)	Control (pCi/kg-dry)
Pre-op	NDM	NDM
1987	NDM	NDM
1988	62	NDM
1989	46	NDM
1990	46	NDM
1991	113	NDM
1992	59.5	NDM
1993	65.9	NDM
1994	85.2	NDM
1995	267	NDM
1996	344	NDM
1997	86	NDM
1998	263	NDM
1999	49.5	NDM
2000	131.3	NDM
2001	NDM	NDM
2002	49.7	NDM
2003	146	NDM
2004	77	NDM
2005	146	NDM

C48

Figure 4.9-4

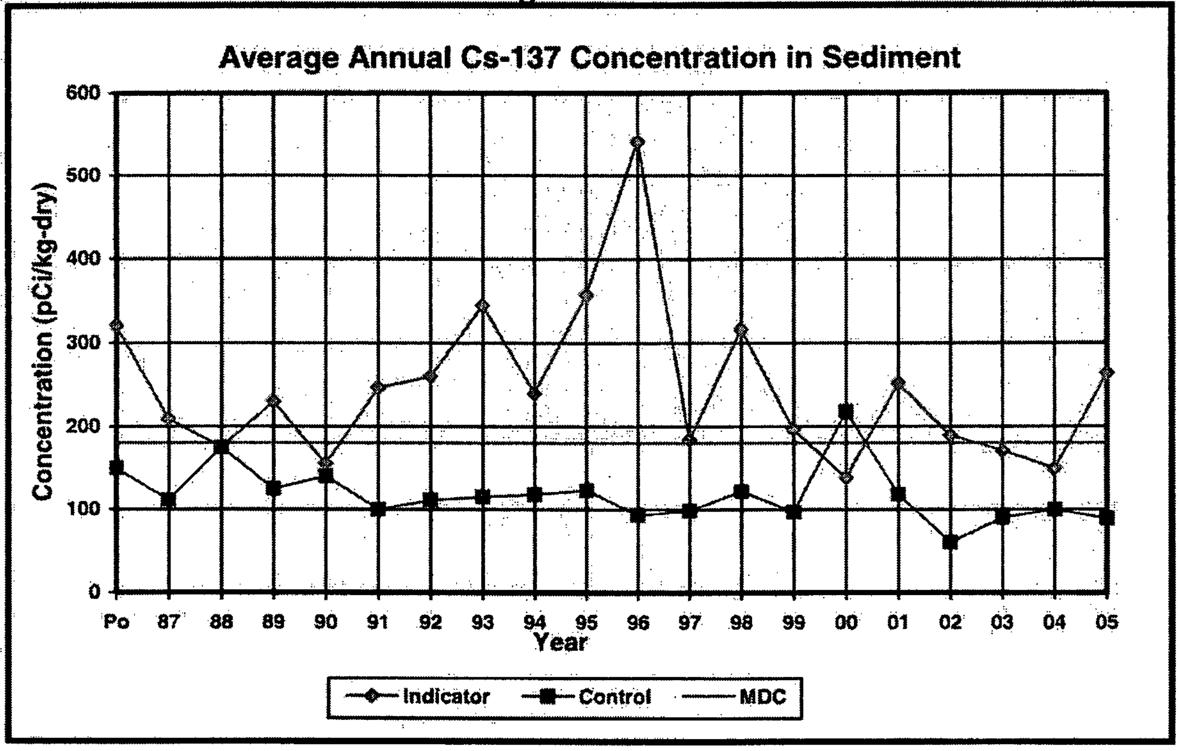


Table 4.9-4
Average Annual Cs-137 Concentration in Sediment

MDC=180 pCi/kg		
Year	**Indicator (pCi/kg)**	**Control (pCi/kg)**
Pre-op	320	150
1987	209	111
1988	175	175
1989	230	125
1990	155	140
1991	246	100
1992	259	111
1993	345	115
1994	240	118
1995	357	123
1996	541	93
1997	184	98
1998	316	122
1999	197	97
2000	138	218
2001	252	118
2002	189	60
2003	171	90
2004	149	100
2005	263	89

C49

Table 4.9-5

Additional Sediment Nuclide Concentrations

Nuclide	YEAR	Indicator (pCi/kg-dry)	Control (pCi/kg-dry)	MDC (pCi/kg-dry)
Mn-54	1988	22	NDM	42
	1989	18	NDM	
	1994	32	NDM	
I-131	1992	194	20	53
	1994	51	41	

5.0 INTERLABORATORY COMPARISON PROGRAM

In accordance with ODCM 4.1.3, the EL participates in an ICP that satisfies the requirements of Regulatory Guide 4.15, Revision 1, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment", February 1979. The guide indicates the ICP is to be conducted with the Environmental Protection Agency (EPA) Environmental Radioactivity Laboratory Intercomparison Studies (Cross-check) Program or an equivalent program, and the ICP should include all of the determinations (sample medium/radionuclide combinations) that are offered by the EPA and included in the REMP.

The ICP is conducted by Analytics, Inc. of Atlanta, Georgia. Analytics has a documented Quality Assurance (QA) program and the capability to prepare Quality Control (QC) materials traceable to the National Institute of Standards and Technology. The ICP is a third party blind testing program which provides a means to ensure independent checks are performed on the accuracy and precision of the measurements of radioactive materials in environmental sample matrices. Analytics supplies the crosscheck samples to the EL which performs the laboratory analyses in a normal manner. Each of the specified analyses is performed three times. The results are then sent to Analytics who performs an evaluation which may be helpful to the EL in the identification of instrument or procedural problems.

The samples offered by Analytics and included in the EL analyses are gross beta and gamma isotopic analyses of an air filter; gamma isotopic analyses of milk samples; and gross beta, tritium and gamma isotopic analyses of water samples.

The accuracy of each result is measured by the normalized deviation, which is the ratio of the reported average less the known value to the total error. The total error is the square root of the sum of the squares of the uncertainties of the known value and of the reported average. The uncertainty of the known value includes all analytical uncertainties as reported by Analytics. The uncertainty of the reported average is the propagated error of the values in the reported average by the EL. The precision of each result is measured by the coefficient of variation, which is defined as the standard deviation of the reported result divided by the reported average. An investigation is undertaken whenever the absolute value of the normalized deviation is greater than three or whenever the coefficient of variation is greater than 15% for all radionuclides other than Cr-51 and Fe-59. For Cr-51 and Fe-59, an investigation is undertaken when the coefficient of variation exceeds the values shown as follows:

Nuclide	Concentration *	Total Sample Activity (pCi)	Percent Coefficient of Variation
Cr-51	<300	NA	25
Cr-51	NA	>1000	25
Cr-51	>300	<1000	15
Fe-59	<80	NA	25
Fe-59	>80	NA	15

* For air filters, concentration units are pCi/filter. For all other media, concentration units are pCi/liter (pCi/l).

As required by ODCM 4.1.3.3 and 7.1.2.3, a summary of the results of the EL's participation in the ICP is provided in Table 5-1 for: the gross beta and gamma isotopic analyses of an air filter; gamma isotopic analyses of milk samples; and gross beta, tritium and gamma isotopic analyses of water samples. Delineated in this table for each of the media/analysis combinations, are: the specific radionuclides; Analytics' preparation dates; the known values with their uncertainties supplied by Analytics; the reported averages with their standard deviations; and the resultant normalized deviations and coefficients of variation expressed as a percentage.

In 2005, the laboratory analyzed 9 samples for 46 parameters and completed a gamma analysis investigation of Fe-59 in water. The 2005 analyses included tritium, gross beta, Fe-55, Sr-89/90 and gamma emitting radio-nuclides in different matrices. Two analyses were outside the control limit for precision. The precision deviations were for the determination of gross alpha in water and Sr-90 in an air filter.

The gross alpha in water was analyzed in triplicate with an average value reported. The high range may be attributed to one of the samples not dispersing evenly in the planchet causing alpha absorption. The second quarter alpha sample was in control so no further investigation will be performed. The second quarter air filter sample analyzed for Sr-90 had a high precision value. The low activity in the sample produced small detector counts, thus causing the elevated error. No further investigation will be performed.

The 2004 Fe-59 analysis in water investigation was completed. The efficiencies used in determining the activity were obtained from a calibration curve. The curve was determined to be lower at higher energies due to summing effects from the calibration nuclides. A curve will be produced using a standard containing nuclides without summing gamma energies. The difference in efficiencies of the curves will be applied to the analysis to compensate for the summing losses. This is a known bias for gamma spectroscopy measurements and does not significantly effect radiological environmental monitoring measurements.

TABLE 5-1 (SHEET 1 of 3)

INTERLABORATORY COMPARISON PROGRAM RESULTS

GROSS BETA ANALYSIS OF AN AIR FILTER (pCi/filter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
Gross Beta	09/15/05	75.00	71.80	2.90	0.80	5.60	0.77

GAMMA ISOTOPIC ANALYSIS OF AN AIR FILTER (pCi/filter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
Ce-141	09/15/05	161.80	163.00	5.42	1.82	4.69	-0.16
Co-58	09/15/05	46.30	44.50	4.79	0.49	12.39	0.31
Co-60	09/15/05	113.20	117.00	1.06	1.30	3.80	-0.88
Cr-51	09/15/05	260.80	237.00	6.53	2.63	8.14	1.12
Cs-134	09/15/05	80.00	85.70	3.86	0.95	6.27	-1.14
Cs-137	09/15/05	145.60	137.00	8.07	1.52	6.67	0.89
Fe-59	09/15/05	53.40	42.70	3.91	0.49	11.03	1.82
Mn-54	09/15/05	70.40	64.50	1.22	0.72	5.11	1.65
Zn-65	09/15/05	105.10	86.50	5.51	0.96	7.88	2.24

GAMMA ISOTOPIC ANALYSIS OF A MILK SAMPLE (pCi/liter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
Ce-141	06/09/05	97.60	92.40	12.37	1.03	7.95	0.67
Co-58	06/09/05	NA	NA	NA	NA	NA	NA
Co-60	06/09/05	144.20	145.00	5.62	1.61	5.94	-0.09
Cr-51	06/09/05	286.60	303.00	28.38	3.37	15.87	-0.36
Cs-134	06/09/05	93.10	95.00	6.43	1.06	8.75	-0.24
Cs-137	06/09/05	194.30	189.00	6.24	2.10	5.60	0.49

TABLE 5-1 (SHEET 2 of 3)

INTERLABORATORY COMPARISON PROGRAM RESULTS

GAMMA ISOTOPIC ANALYSIS OF A MILK SAMPLE (pCi/liter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
Fe-59	06/09/05	70.30	63.90	8.92	0.71	17.92	0.51
I-131	06/09/05	93.00	86.90	6.93	0.97	10.63	0.61
Mn-54	06/09/05	127.70	125.00	3.73	1.39	6.61	0.31
Zn-65	06/09/05	163.50	155.00	12.09	1.72	10.90	0.48

GROSS BETA ANALYSIS OF WATER SAMPLE (pCi/liter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
Gross Beta	03/17/05	276.00	268.00	4.66	2.98	6.00	0.45
	06/09/05	214.20	214.00	17.96	2.37	8.39	0.01

GAMMA ISOTOPIC ANALYSIS OF WATER SAMPLES (pCi/liter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
Ce-141	03/17/05	222.00	221.00	9.6	2.46	5.13	0.09
Co-58	03/17/05	115.40	111.00	7.4	1.24	9.21	0.41
Co-60	03/17/05	142.80	139.00	6.4	1.54	7.91	0.34
Cr-51	03/17/05	370.30	322.00	46.1	3.57	14.70	0.89
Cs-134	03/17/05	138.60	134.00	6.1	1.49	5.46	0.61

TABLE 5-1 (SHEET 3 of 3)

INTERLABORATORY COMPARISON PROGRAM RESULTS

GAMMA ISOTOPIC ANALYSIS OF WATER SAMPLES (pCi/liter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
Cs-137	03/17/05	131.40	125.00	7.3	1.39	6.53	0.75
Fe-59	03/17/05	125.60	107.00	9.5	1.19	12.06	1.23
I-131	03/17/05	76.10	65.90	7.1	0.73	11.84	1.13
Mn-54	03/17/05	157.00	154.00	8	1.71	5.63	0.34
Zn-65	03/17/05	219.60	191.00	14.9	2.12	10.82	1.20

TRITIUM ANALYSIS OF WATER SAMPLES (pCi/liter)

Analysis or Radionuclide	Date Prepared	Reported Average	Known Value	Standard Deviation EL	Uncertainty Analytics (3S)	Percent Coef of Variation	Normalized Deviation
H-3	03/17/05	5388.00	6040.00	132.04	133.33	4.10	-2.96
	06/09/05	9879.10	9100.00	133.48	200.00	2.60	2.62

6.0 CONCLUSIONS

This report confirms the licensee's conformance with the requirements of Chapter 4 of the ODCM during 2005. It provides a summary and discussion of the results of the laboratory analyses for each type of sample.

All of the radiological levels were low and generally trending downward.

In 2005, there were two instances in which the indicator station readings were greater than the control station readings. These are discussed in the following paragraphs.

Cesium-137 was identified in vegetation in two of 24 samples at the indicator station and in none of the 12 samples at the control station. The average of the two positive samples from the indicator station was 49.5 pCi/kg-wet. The potential dose to a member of the public who would receive the highest dose (an adult) due to regular consumption of leafy vegetation containing Cs-137 at the concentration identified at the indicator station would be 0.17 mrem in one year. This dose is less than 2% of the regulatory limit of 15 mrem per year to any organ due to gaseous effluents. As discussed in the vegetation section of the report, low levels of Cs-137 in vegetation samples is attributed primarily to fallout from nuclear weapons testing and from the Chernobyl incident.

Cobalt-60 was identified in river sediment at the indicator station in one of two samples but not at the control station. The activity found at the indicator station was 146 pCi/kg-dry and could be attributed to plant releases. The consequent total body dose to a member of the public expected to receive the highest dose was determined to be approximately 0.0067 mrem in one year or approximately 0.22% of the ODCM limit.

No discernible radiological impact upon the environment or the public as a consequence of plant discharges to the atmosphere and to the river was established for any other REMP samples.

EXHIBIT 2.2

FISHING AND RISK ALONG THE SAVANNAH RIVER: POSSIBLE INTERVENTION

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Fishing is often perceived as an enjoyable activity, and eating fish is viewed as safe and healthful. However, with recent increases in consumption advisories because of contamination, the public is faced with whether to eat fish or not. In this article I examine the knowledge base of people fishing along the Savannah River, where South Carolina has issued consumption advisories because of mercury and radionuclides. Over 250 people fishing from the Augusta lock and dam to south of the Department of Energy's Savannah River Site (SRS) were interviewed from early April until late November 1997. Overall 82% of the fishermen thought the fish were safe to eat, even though 62% had heard some warnings about eating the fish. There were significant differences in whether people thought the fish were safe to eat as a function of income, age, education, and whether they were employed at the Savannah River Site. Significantly more fishermen thought the fish were safe who made more than $20,000/year, were over 34 yr of age, worked at SRS, and had no college or technical training, compared to others. Significantly fewer blacks had heard of consumption advisories than whites, fewer low-income people had heard, and fewer people who had not worked at SRS had heard, compared to others. Most people heard about the advisories from television, newspapers, and other people, although more blacks than whites heard about advisories from the radio. There were also significant ethnic differences in distance traveled, and in whether specific fish were frozen for later consumption. These data can be used to design an information program to target the people who may be most at risk from eating fish obtained from the Savannah River.

The general public and governmental agencies are interested in the safety of both commercial and noncommercial foods, including recreational and subsistence fishing. The U.S. Environmental Protection Agency (1996) reported that from 1994 to 1995 there was a 14% increase in the number of water bodies in the United States with fishing or consumption

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advisories. Over 15% of the nation's lakes and 4% of the rivers have advisories, mostly as a result of mercury, polychlorinated biphenyls (PCBs), chlordane, dioxins, and DDT (U.S. EPA, 1996). The increase in advisories reflects cause for concern, although the increase could be due to a real increase in contamination levels, an increase in public concern, or merely an increase in monitoring or the levels that generate advisories. Further, the mean per capita freshwater/estuarine fish consumption in the United States rose from 6.5 g/d in 1973–1974 to 16.6 g/d in 1989–1991 (Jacobs et al., 1998). Thus, there is a need to understand fishing behavior, knowledge of advisories, and compliance of people fishing in waters with consumption advisories.

This article examines whether people had heard of consumption advisories, their sources of information, and aspects of fishing behavior that relate to risk reduction or information transfer to people fishing on the Savannah River along the Savannah River Site (SRS), a Department of Energy (DOE) facility in South Carolina. The DOE's Savannah River Site (SRS, 310 sq mi, 806 km^2) is situated in South Carolina. During the DOE tenure the land has been off limits to the public except for controlled game hunting. Fishing along the site is often perceived as excellent by the local people. This article concentrates on perceptions of safety of eating fish, information sources of fishermen, and risk reduction. Data on fishing behavior and consumption patterns are presented elsewhere (Burger et al., in press).

The state of South Carolina has issued fishing advisories for the Savannah River (SCDHEC, 1996), based on mercury levels and radionuclides. Burger et al. (in press) reported significant differences in fishing and consumption patterns of black and white fishermen along the Savannah River, but did not report on knowledge about the advisories or sources of information, which would allow further intervention or modifications to reduce risk in this population. Further, the need to place stakeholder concerns at the beginning of any effective risk assessment and risk management process (Commission on Risk Assessment and Risk Management, 1996) means, in this case, that it is critical to understand how the fishing public perceives fishing and consumption advisories.

The primary advisories for the Savannah River are for mercury. Mercury accounts for 46% of the fishing and consumption advisories in the United States (U.S. EPA, 1996). There is an extensive series of studies on the relationship between fish consumption, mercury levels, and child neurobehavioral development (Ratcliffe et al., 1996; Weiss & Elsner, 1996; Weihe et al., 1996). Stern (1993) has recommended that the reference dose for any nonoccupational population be lowered to 0.07 μg/kg/d to protect the developing fetus. Since fisherman may consume large quantities of fish, they and their offspring may be particularly at risk. Understanding fishing, consumption, and cooking patterns may lead to more accurate risk assessments and more effective risk management strategies.

This study was undertaken as part of the Consortium for Risk Evaluation with Stakeholder Participation's (CRESP) work to develop risk methodologies for humans and ecosystems.

It is, however, also important to bear in mind that fish provide many benefits such as a source of protein that has the potential for reduction of cholesterol (Hunter et al., 1988; Horn, 1992; Anderson & Wiener, 1995), and it is an enjoyable activity that has many social benefits (Toth & Brown, 1997).

MATERIALS AND METHODS

Under a Rutgers University-approved protocol, 258 people were interviewed who were actually fishing on the Savannah River, above, along, and below the Department of Energy (DOE) Savannah River Site (SRS, Figure 1). The length of the river surveyed was about 90 km.

Interviews were conducted from 3 April until 22 November 1997. Most interviews were conducted by the same people, who had lived and worked in the region their entire lives. The protocol was to alternate interviewing people in the three sections of the river (above, along, and below SRS), depending upon weather, water level, and fishing conditions. Upon reaching a fishing site along the river, all the fishermen who were present were interviewed. Interviews were conducted on 54 separate days. The same fishermen were frequently encountered, although each person was interviewed only once. People were interviewed while they fished from the shore (47%) or from a boat (53%). Fewer than 10 people refused to be interviewed, largely because they were talking with other people or were intent on pulling in a fish. Most interviews required 30–45 min to complete.

The questionnaire contained several sections, including demographics, fishing behavior, consumption patterns, cooking patterns, warnings and safety of the fish, and personal data (income, education, and employment). Individuals were also asked to list the fish they most often caught (most mentioned one to three species). We asked whether they ate fish as fillets, whole, in stews, or by other methods; whole fish was defined as including the entire fish except for the organs or scales (people who ate whole fish said they removed the scales and organs, and then either fried or stewed them). Most demographic (sex, age, ethnicity, residence) questions were at the beginning of the questionnaire, but income, education and employment were asked at the end because prior surveys had indicated that some people are reluctant to disclose their income or education.

Of the subjects, 70% were white, 28% were black, and 2% were other; 89% were men, and 29 (11%) had ever worked at SRS. The average age of those interviewed was 43 ± 1 yr. The average number of years people had fished on the Savannah River was 24 ± 1 yr, although some people had fished for over 50 yr. The average income of those interviewed was $21,490/yr (range of 0 to $60,000); the blacks who were interviewed

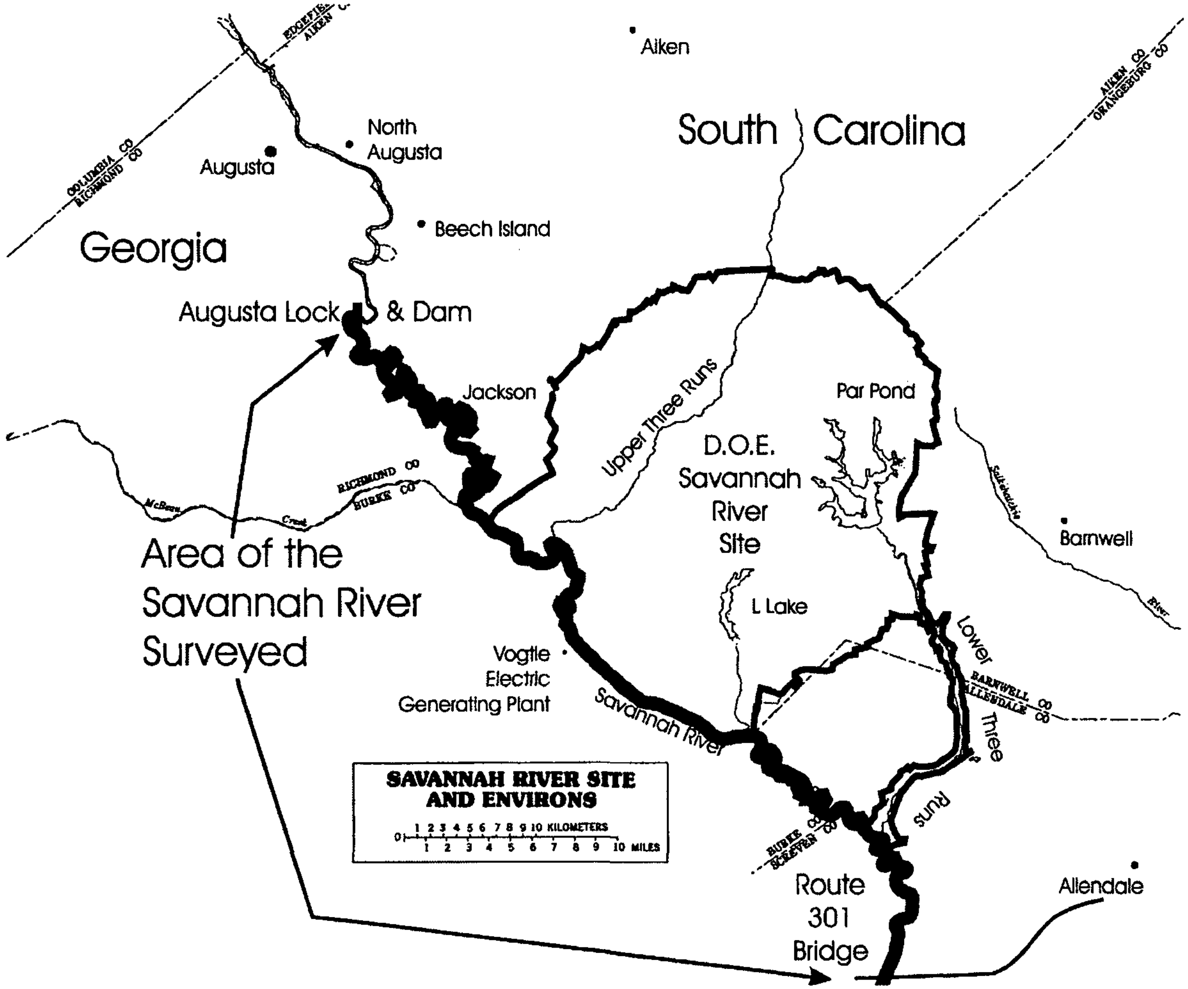


FIGURE 1. Map of Savannah River Site showing Savannah River and area sampled.

made significantly less money per year than did the whites ($\chi^2 = 7.7$, $p < .006$).

For comparison, the regional median income around SRS is approximately $27,647 (U.S. Census Bureau). Although 34% of the local population is black, 28% of the population in Georgia and South Carolina is black (U.S. Census Bureau).

Wilcoxon χ^2 tests were used to examine differences between groups, and analysis of variance (ANOVA) to determine whether there were differences among variables as a function of ethnicity, age, and income (SAS Institute, Inc., 1988). A level of $p < .05$ was accepted as significant.

RESULTS

Information Sources and Knowledge about Advisories

Overall 82% of the people interviewed believed the fish were safe to eat, and this varied by income, educational level, age, and whether people were employed at SRS (Table 1). In general, people with higher incomes and those who were over 34 yr of age believed the fish were safer to eat than people with lower incomes or who were younger. Fewer people with a college or technical education believed the fish were safe to eat than people with less education.

Sixty-two percent of the people had heard of fishing or consumption advisories for the Savannah River. There were significant differences in the percent that had heard warnings as a function of ethnicity, income, and SRS employment. Significantly more people who worked at SRS had heard warnings than those who did not work there (Table 1).

There were also significant differences in where people had heard about consumption advisories ($\chi^2 = 185$, df = 4, $p < .005$); fewer people learned about the advisories from radio and signs than from other sources, such as newspapers, television, and other people. There were significant ethnic differences ($\chi^2 = 116$, df = 4, $p < .005$), with more blacks hearing about advisories from radio than whites (Figure 2). Of those that had heard warnings, 57% mentioned mercury, 24% mentioned pollution, and 14% mentioned restricting fish intake. About the same number of blacks and whites reported hearing about mercury (42% vs. 54%), and about the same number knew to limit fish consumption (14% black vs. 8% white). Only one person mentioned that pregnant women and children should restrict fish intake, one person mentioned tritium, and no one mentioned cesium.

Information on whether people had heard consumption advisories as a function of income, age, and education is shown in Table 2.

Fishing Behavior and Consumption

Several aspects of fishing behavior and consumption could be modified to reduce risk from contaminants in fish, or can be used to target popula-

TABLE 1. Relationships of Ethnicity, Income, Employment, and Age on Perceptions

	Sample size	Percent that say the fish are safe to eat	Percent that have heard of advisories
Ethnicity			
Black	72	81	50
White	179	83	66
χ^2 (*p*)		0.08 (NS)	5.49 (.02)
Income			
Less than $20,000	137	79	56
Over $20,000	99	90	69
χ^2 (*p*)		4.66 (.03)	3.78 (.05)
SRS employment			
Employed at SRS	29	97	83
Not employed at SRS	228	80	60
χ^2 (*p*)		4.67 (.03)	5.85 (.01)
Age			
Under 34 yr	81	70	59
35–49 yr	92	88	65
Over 50 yr	75	86	65
χ^2 (*p*)		10.73 (.005)	0.85 (NS)
Education			
Not high school graduate	45	86	49
High school graduate	153	86	65
College or tech. training	59	70	66
χ^2 (*p*)		7.22 (.03)	4.18 (NS)

Note. Values are means ± SE; NE, not significant; Wilcoxon χ^2 given, with *p* in parentheses.

tions at risk: distance traveled, fish species caught and eaten, cooking methods, and the age children begin eating fish. There were significant ethnic differences in how far people traveled to fish on the river ($\chi^2 = 5.8$, $p < .02$, Figure 3). Over 85% ate only fish they caught themselves or that were given to them by other fishermen; they said they did not eat fish in restaurants or buy fish in stores.

The main fish caught were bream (the local term for sunfish, *Lepomis auritus*), catfish (*Ictalurus punctatus*), bass (*Micropterus salmoides*), crappie (*Pomoxis nigromaculatus*), and bowfin (*Amia calva*, Figure 4); panfish usually refers to sunfish. Few people mentioned pickerel (*Esox niger*). Although people did not catch the same amount of each species of fish (χ^2 = 491, df = 6, $p < .005$), there were no ethnic differences in the fish caught. Both black and white fishermen froze most fish (except shad) for later consumption, increasing potential exposure time for mercury since they could eat the fish throughout the year. People froze significantly less shad and pickerel ($\chi^2 = 185$, df = 4, $p < .005$) than the other species (Figure 4); there

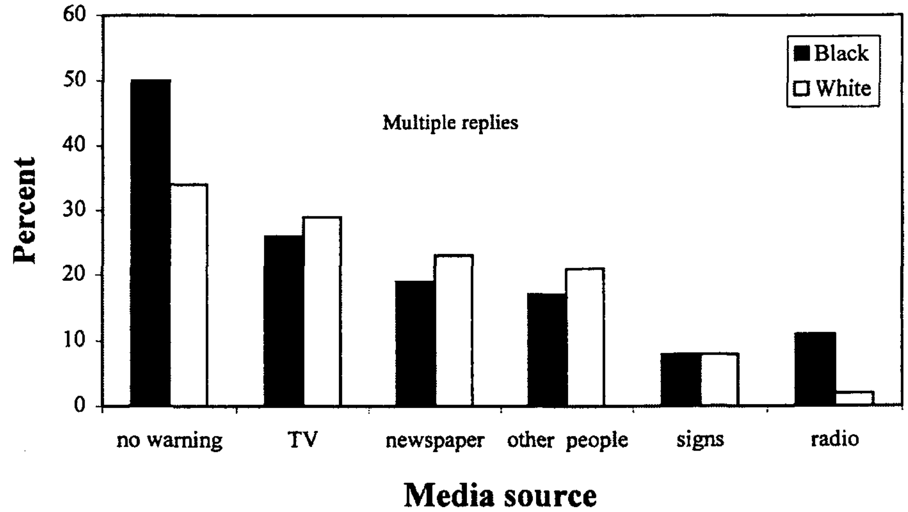


FIGURE 2. Media sources for information on fishing advisories for blacks and whites interviewed while fishing along the Savannah River.

were significant ethnic differences ($\chi^2 = 383$, df = 4, $p < .005$), with blacks freezing more shad and pickerel and less bass than whites.

Over 65% of the fishermen interviewed ate whole fish, and they ate whole fish 68 ± 3% of the time. A significantly higher proportion of blacks ate whole fish, compared to whites ($\chi^2 = 8.5$, $p < .04$).

Deep frying was significantly more common as a cooking method than the other methods ($\chi^2 = 464$, df = 4, $p < .005$, Figure 5). There were no significant ethnic differences in cooking methods.

DISCUSSION

Knowledge About Risk from Fish Consumption

The results from this study indicate that only about 60% of the people surveyed had heard any warnings, and this varied as a function of ethnicity, income, and employment. Thus, 40% had not heard warnings. However,

TABLE 2. Mean Income, Age, and Education as a Function of Having Heard Advisories

	Black				White			
	Heard		Not heard		Heard		Not heard	
	N	Mean SE	N	Mean SE	N	Mean SE	N	Mean SE
Income	31	20,347 ± 1856	36	17,042 ± 1369	109	22,625 ± 1189	55	22,182 ± 1647
Age	36	45.17 ± 2.09	35	47.94 ± 2.83	115	43.1 ± 1.48	56	39.11 ± 1.81
Education	35	12.19 ± 0.37	35	11.17 ± 0.43	115	12.37 ± 0.14	58	12.64 ± 0.29

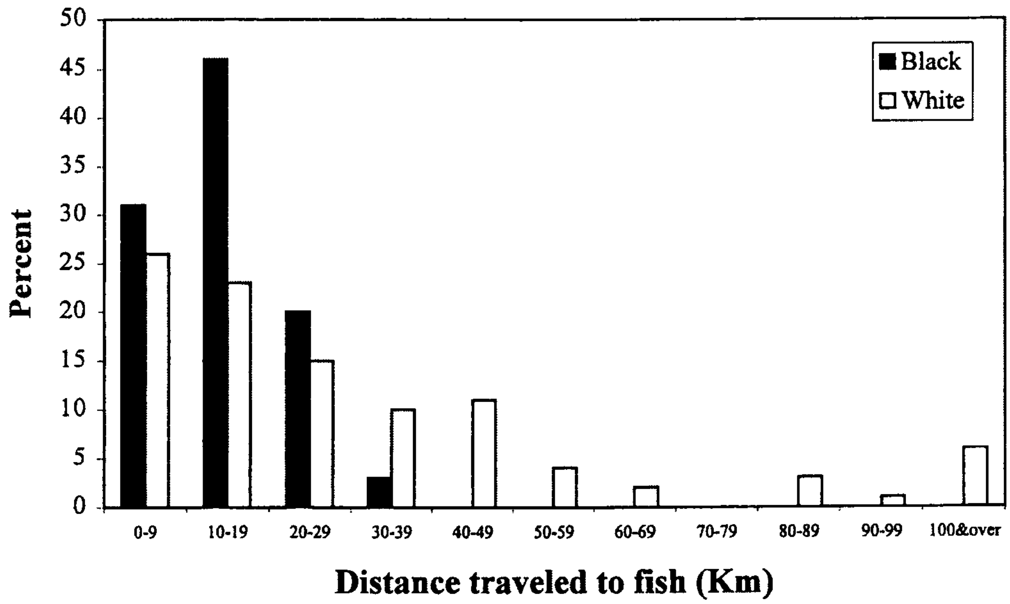


FIGURE 3. Distances traveled by blacks and whites to fish along the Savannah River, indicative of the area to cover when disseminating information.

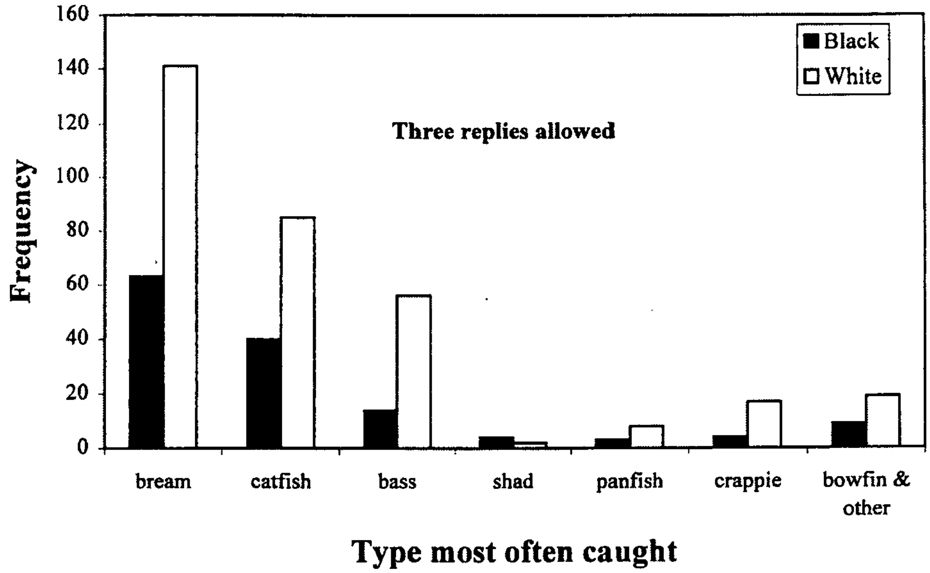
these data apply to people fishing along the Savannah River, and the percent who have heard warnings among the general public in Georgia and South Carolina may be different.

When the people fishing had heard warnings, 57% had heard something about mercury, and none reported hearing about strontium or cesium. Despite the regular release of information warning about consumption of fish from the Savannah River and elsewhere in South Carolina, no one reported the correct consumption advisories, and only one person reported the importance of pregnant women limiting consumption. These data suggest that detailed consumption advisory information is not reaching the people who regularly fish along the Savannah River.

In a similar study in the Everglades, Fleming et al. (1995) reported that 71% of the fishermen were aware of mercury warnings for fish from the Everglades, although 74% of these people stated they did not change their fishing behavior because of it. It is not unusual for people to be aware of the warnings, but to believe the fish are safe to eat anyway. Similar results were found for people fishing in the Newark Bay Complex in New Jersey (Burger et al., 1998), Raritan Bay and the New Jersey coast (May & Burger, 1996), Jamaica Bay in New York (Burger et al., 1993), and Puerto Rico (Burger et al., 1992).

There are two interesting aspects to these data: (1) There is a discrepancy between knowledge of consumption advisories and a belief that the fish are safe to eat, and (2) even people who have heard consumption advisories are generally not aware of the correct advisory or the population that is most at risk. The causes for the discrepancy between knowledge of the advisories and the belief that the fish are safe to eat are unclear.

Several authors have suggested that the discrepancies derive from the familiarity of fishing (Lowrance, 1976), the lack of overt health problems associated with eating fish (Burger et al., 1993), distrust of government



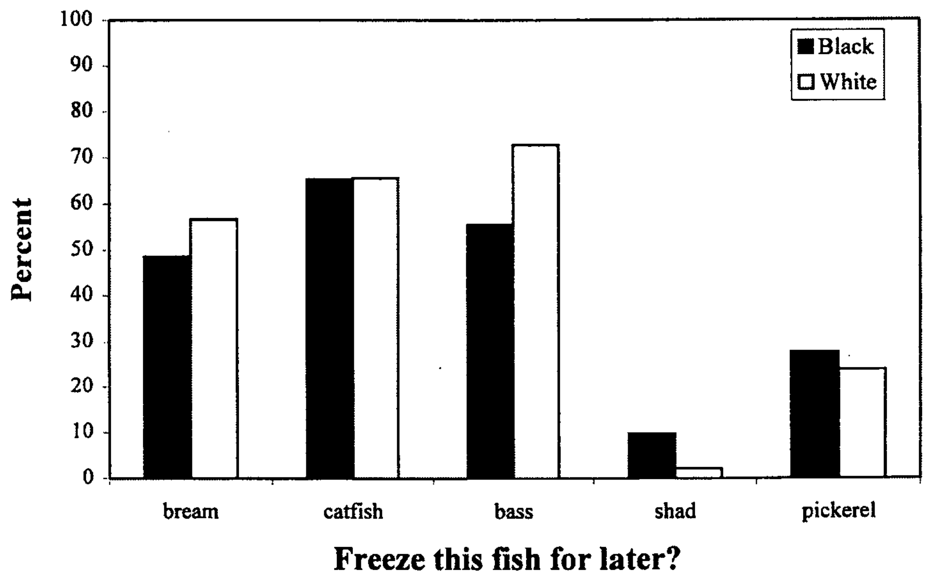


FIGURE 4. Types of fish caught by blacks and whites, and percent of the time the fish are frozen for later use.

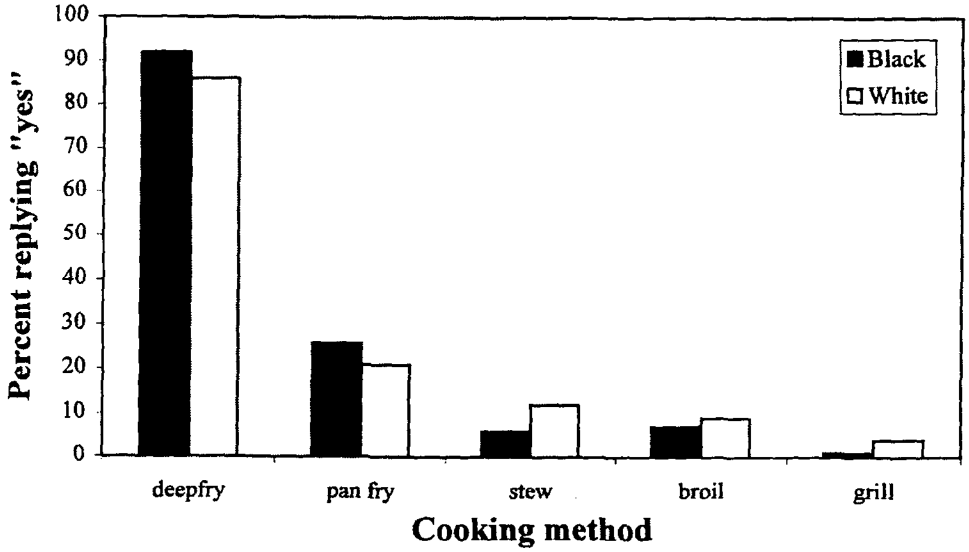


FIGURE 5. Cooking methods employed by blacks and whites for fish obtained from the Savannah River.

agencies issuing advisories (May & Burger, 1996), and confusion over discrepancies in advisories between agencies or states (Reinert et al., 1991; Cunningham et al., 1994). As an example, the discrepancy between the states bordering the river regarding consumption advisories (South Carolina issues them, while Georgia does not) may provide a conflicting message, allowing people to ignore the advisory. Moreover, the importance of fishing to both social and economic needs contributes to continued interest in fishing (Diana et al., 1993; Toth & Brown, 1997). In many societies, fishing may be an integral part of the culture (Murphy & Murphy, 1960; Cornell, 1994). Although considerable attention has been devoted to the importance of fishing to Native American cultures (Murphy & Murphy, 1960), it may be equally important for other ethnic groups, as Toth and Brown (1997) reported for people living in the South.

Fishing was an important activity for many of the people we interviewed who were fishing along the Savannah River. People had fished there for many decades without experiencing any obvious ill health effects. Fishing serves an important social function. Many people noted that they went fishing in groups, and it was important to catch fish for fish fries (an aspect also noted by Toth & Brown, 1997).

Ethnic Differences

There have been a number of studies that indicate differences in environmental attitudes between blacks and whites (Bullard & Wright, 1986; Taylor, 1989; Flynn et al., 1994). There are data showing differences in participation in recreational activities (Burger, 1997). In a general population attending a Mayfest celebration in Columbia, SC, there were significant differences in fishing rates, with black men fishing on significantly more days a year than whites (Burger, 1997). In the present study, black men also fished significantly more than white men; this suggests that the ethnic differences in participation in South Carolina are real, potentially increasing differences in exposure.

One key finding of the present study, however, is the ethnic differences in knowledge about fishing advisories for the people fishing along the Savannah River. Velicer and Knuth (1994) also found differences in knowledge about fish safety, with migrant workers being less aware of advisories than were others fishing on Lake Ontario (New York). While in their study the transient nature of the workers may be partly to blame, this is not the case with the fishermen interviewed in this study since fishermen had fished on the Savannah River an average of 24 years. Similarly, Burger et al. (1998) reported differences in knowledge about consumption advisories between hispanics and others (blacks and whites) in the Newark Bay complex (NJ); hispanics were much less aware of the warnings than were other fishermen.

Overall, people who had heard advisories had higher incomes. However, the relationship between income and age differed for blacks and whites: Income and years in school were both negatively correlated with age for blacks, while income (but not years in school) was positively correlated for whites; income increased with age for white men, but decreased with age for black men (Burger et al., unpublished data). Since education, income, and age are not related in the same way, this suggests that different strategies are required for each ethnic group fishing along the river. Increasing knowledge among white fishermen may require reaching younger men with less education; however, increasing knowledge among black fisherman may require reaching older men with less education.

Risk Reduction

One approach to risk reduction from eating Savannah River fish is to understand three factors: (1) the characteristics of people who are not aware of the consumption advisories, (2) the sources of information that people use to obtain information about fishing and consumption advisories, and (3) the aspects of fishing that could be modified to reduce risk while not necessarily limiting fishing behavior.

Overall, a higher proportion of people who had not heard advisories were black, had incomes less than $20,000, were not employed at SRS, and tended to be under 34 yr of age, with less than a high school education. Further, data from this survey show that most people travel less than 30 km to fish along the Savannah River. There were ethnic differences in how people fishing along the Savannah River obtained information about advisories, but most people heard about them from television, newspapers, and other people. Despite the difficulty of placing such information on television and in newspapers, the wide reliance on these sources suggests these are useful avenues. Significantly more blacks than whites heard about the advisories from radio.

Behaviors that could be undertaken to reduce risk without altering how much fish are eaten include changing the species of fish consumed (some fish have higher contaminant loads than others), changing the size of the fish consumed (larger fish have higher contaminant loads), and altering cooking methods (Morgan et al., 1997).

Opportunities for Enhancing Risk Communication with the Public

There are specific opportunities for reaching the public that fish along the Savannah River, and these might be suitable for other populations elsewhere. From a risk perception perspective, it is important to know the characteristics of people who had heard (and not heard) advisories as a function of income, age and education since this information might help direct an information campaign. This information was shown in Table 2, and only income affected whether people had heard the advisories, although all three factors affected whether people believed the fish were safe to eat. The differences, however, were not great, indicating an opportunity to better inform the whole population.

Black men fished significantly more often than white men, increasing the importance of targeting black populations about information on any risks from fishing. Since this population relied more heavily on information from radio, this medium could also be pursued, including using radio stations or programs that are particularly popular. The ethnic difference in knowledge of advisories suggests that methods could be developed for different ethnic groups (Velicer & Knuth, 1994). At the very least, this might involve targeting the people who actually fish on the river. Many fishermen fish from shore at a few designated spots, such as the Augusta Lock and Dam, and a directed information campaign at these sites might reach a number of people. Another avenue might be to target black leaders within the fishing community, or to provide people who fish frequently along the river with additional information. During the present survey, many of the same people were encountered throughout the fishing season, suggesting that they may be an important source of information for others. Additional consumption advisory information could also be provided to black women, who may become pregnant and who may be responsible for preparing and cooking fish.

Information could be made available in the small towns and villages that border the river, since most people traveled less than 30 km to fish along the river. Information could also be made available at small business and other workplaces, as well as in all small convenience stores near the Savannah River.

In addition to providing consumption advisory information in the usual places, a program to distribute information directly to the public fishing along the river might be the most effective method of risk communication. There are several boat landings and other concentration points where a large number of people could be reached. Such a campaign could be conducted throughout the fishing season to reach people who fish for different species of fish. That is, some people fish for shad early in the season, while others engage in fishing more often later in the season.

Providing usable information to people fishing along the river, as well as elsewhere in the region, entails communication methods that are brief, straightforward, and easy to understand. Partly as a result of the information acquired in this survey, the relevant agencies (South Carolina Department of Health and Environmental Control, Georgia Department of Natural Resources, U.S. Environmental Protection Agency, U.S. Department of Energy) cooperatively produced a fish fact sheet, called "Eating Fish from the Savannah River," aimed at the people fishing along the river. This was a major step in interstate cooperation that could serve as a model for other regions, particularly since conflicting information from different states and agencies provides confusion to the general public (Reinert et al., 1991; Cunningham et al., 1994). There are several other regions of the United States where two or more states border on a river, estuary, or harbor with sufficient pollution warranting fish consumption advisories, and the issuance of a joint fish fact sheet on both the benefits and potential risks from eating fish could greatly reduce confusion, providing a clearer understanding of fish consumption.

Compared to the general public, significantly more of the employees of SRS had heard of the consumption advisory, but not all had. Noting an opportunity for improvement, the fish fact sheet mentioned earlier was made available to SRS employees at the SRS medical facilities (W. Whitaker, personal communication). Information on the risk from consuming fish was also placed in the SRS environmental bulletin and on their homepage.

Finally, there are positive benefits from consuming fish. Fish are a good source of protein because of the potential for reduction of cholesterol (Horn, 1992; Anderson & Wiener, 1995). Epidemiologic studies often support the hypothesis that moderate fish consumption reduces the risk of sudden cardiac death in humans (Sheard, 1998). Failure of consumption advisories to acknowledge this fact adds to confusion, and might allow people to disregard the advisories. Fishing is an enjoyable pastime, and people engage in fishing for a variety of reasons. Toth and Brown (1997) recently showed significant differences in the attitudes of blacks and whites toward fishing in the southeastern United States, with subsistence playing a greater role for blacks than whites. Yet perceptions may well differ from region to region, and site-specific information is required both to understand the local situation and to form a basis for a more general theory of risk perception and ethnic differences with respect to fishing. Although perceptions are correlated with a number of factors, such as age, gender, and ethnicity (Taylor, 1989; Stern, 1993; Arp & Kenny, 1996), as well as trust and optimism, perceived hazards are often more important than are personal demographic characteristics or community resources (Barke & Jenkins-Smith, 1993; Greenberg & Schneider, 1997).

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EXHIBIT 2.3

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Nuclear Dumps by the Riverside:

Threats to the Savannah River from Radioactive Contamination at the Savannah River Site

Arjun Makhijani, Ph.D.
Michele Boyd

March 11, 2004

Nuclear Dumps by the Riverside

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Arjun Makhijani
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March 5, 2004

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Preface

This report is the third in IEER's series of reports concerning threats to water resources from wastes dumped at nuclear weapons complex sites.[2] We chose to focus on the Savannah River Site (SRS) in South Carolina because waste management and disposal practices at SRS have created risks for future water resource integrity and have already led to severe contamination of the surface and groundwater onsite with radionuclides and hazardous chemicals. The site sits above the most important aquifer system in the southeast United States--the Dublin-Midville Aquifer System (also called the Tuscaloosa aquifer)--and borders the Savannah River, which provides drinking water, fishing, and recreation to residents in both South Carolina and Georgia.

No single report, including this one, can provide a comprehensive evaluation of the past contamination of the SRS site or of all the actual and potential threats that it poses to the surface and groundwater resources of the region. Such a study is well beyond the time and financial resources of IEER. We focus on the sources of radioactivity currently at SRS that pose the most serious threats to the environment, and especially to the water resources of the region.

This report does not cover contamination from continuing, proposed or possible future activities at the site, including the current operation of one reprocessing plant, a new tritium separation facility being built there, a proposed plant to make reactor fuel from a mixture of weapon-grade plutonium oxide and depleted uranium oxide, and possibly a plant to mass manufacture plutonium pits for nuclear weapons. These projects will not enhance national or global security; rather they will aggravate present problems and further jeopardize the Nuclear Non-Proliferation Treaty, as IEER has argued in other reports and studies. These prior recommendations are on grounds quite independent of the issues that we have analyzed here. However, as this report shows, the problems of managing the wastes and implementing a cleanup program from the legacy of the Cold War is daunting enough without adding the financial, technical, human resource, and managerial complexities associated with new nuclear weapons or nuclear fuel production programs, not to speak of the diversion of focus from the protection of future generations from the vast amounts of radioactivity at SRS.

We have also not covered environmental aspects of the continued operation of the reprocessing plants at SRS under the guise of waste management. It has even been put in the cleanup budget and has, over the past decade, diverted literally billions of dollars of scarce resources from urgent cleanup priorities, while at the same time aggravating the problem of high-level waste management by generating even more liquid high-level waste. We have previously addressed the issue of reprocessing at SRS.[3]

Democracy and openness are crucial to reducing the risks to human health and the environment posed by nuclear weapons production. For example, for long-term stewardship to be effective, adequate information (e.g., detailed data, including maps, showing the location of contamination)

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[2] The first report, *Poison in the Vadose Zone: An Examination of the Threats to the Snake River Plain Aquifer from the Idaho National Engineering and Environmental Laboratory*, by Arjun Makhijani and Michele Boyd was released in October 2001 and is available at http://www.ieer.org/reports/poison/pvz.pdf. The second report, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of the Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats*, by Arjun Makhijani and Sriram Gopal, was released in December 2001 and is available at http://www.ieer.org/reports/rocky/fullrpt.pdf.

[3] Sachs, 1996

must be widely available to the general public, local and state governments, and prospective site developers to allow them to protect themselves from being exposed to chemical or radioactive contamination during well drilling and soil excavation (exposures due to inadvertent exhumation). Workers involved with future uses of the site after institutional memory has been lost (which is very likely given the long periods involved) could also be harmed more than estimates that presume institutional memory and control.

Also, detailed information on the sources of contamination should be developed and made available so that the same costly mistakes will not be repeated. However, the gates of information that were opened at the end of the Cold War are being slammed shut in the name of the War on Terrorism. There is no credible evidence that the proliferation of nuclear weapons, for instance, has been promoted by openness in regard to information on waste, cleanup, environmental and health data and related issues. There is evidence that safety, health, and environmental protection, and even security, in terms of better plutonium accounting, for instance, have been promoted by openness. The terrorist attacks of September 11 appear to have provided an excuse for the DOE to greatly restrict information about the site that has no relationship to national security, but that does fit in with the decades-old DOE habit of operating in secret outside of independent scrutiny.

Arjun Makhijani
March 5, 2004

Executive Summary

The Savannah River Site (SRS) is an 803-square kilometer (310-square mile) nuclear weapons plant located in South Carolina on the northeast bank of the Savannah River and above the most important aquifer system in the southeastern United States, commonly called the Tuscaloosa aquifer. The plant was constructed in the early 1950s, mainly to produce plutonium and tritium for nuclear weapons. The availability of ample water resources was one important reason that the site was selected. These same resources are vitally important to the region for drinking, agriculture, fishing, industry, and recreation to residents in both South Carolina and Georgia.

The long-term health of the water resources in the region depends, among other things, on keeping the vast amount of radioactivity at SRS, which amounts to about two-thirds of the total radioactivity in the whole U.S. nuclear weapons complex, out of the surface and groundwater, and, hence, also out of the Savannah River. This report focuses on three areas:

1. High-level radioactive waste in storage tanks (SRS has the largest amount of radioactivity in high-level waste of any site in the United States).
2. Buried wastes, including plutonium-contaminated wastes, which DOE plans to leave at SRS, which pose potentially significant threats to water resources.
3. Some aspects of current water resource contamination that will continue to pose significant threats, with a special focus on tritium contamination.

A. Most Important Findings

1. *Water contamination at SRS*: Waste disposal practices at SRS have led to severe contamination of portions of the surface and groundwater at SRS, especially with tritium and trichloroethylene (TCE). This contamination in the ground and surface water often greatly exceeds safe drinking water limits with both radioactive and non-radioactive toxic materials.
2. *Threats to regional water resources*: The main threats to the Savannah River and possibly other water resources in the region due to SRS come from radioactive and hazardous wastes that were dumped in shallow trenches and pits, contaminated soil, contaminated water that is flowing in the Savannah River, and high-level wastes in tanks that are not being retrieved.
3. *Pollution of the Savannah River*: The Savannah River is contaminated as a result of highly contaminated surface water flowing into it from SRS, though the pollution level is low enough to keep the water well within present safe drinking water limits. However, there are spots, notably near the outfall of Four Mile Creek, where contamination may exceed those limits
4. *Tritium contamination*: Tritium, a radioactive isotope of hydrogen, is the most common radioactive pollutant at SRS that flows into offsite water. Radioactive waste from SRS has caused tritium contamination of the Savannah River. Tritium is present at levels of about 5 percent of the drinking water limit in the Savannah River in the environs of SRS. Though there is some further reduction of this by dilution, elevated tritium levels due to SRS are present all the way to the mouth of the Savannah River at Savannah, Georgia.

5. *Tritium contamination in Georgia*: Rainfall and groundwater in parts of Georgia across the river from the Savannah River Site are contaminated with air emissions of tritiated water from SRS, though well below safe drinking water limits. Rainfall carries this contamination across the river. There may or may not be groundwater pathways from the site under the Savannah River that may also carry tritium to Georgia. Investigations have been inconclusive. If pathways under the river exist, they may pose a long-term risk to groundwater in Georgia in the environs of SRS. As of this writing (mid-February 2004), DOE funding to the State of Georgia for environmental monitoring related to SRS is set to expire April 30, 2004.

6. *Tritium in drinking water standards:* Tritiated water is far more dangerous to children and developing fetuses than to adults. Recent research indicates that current safe drinking water standards for tritium are not adequate to protect developing fetuses to a level comparable to that for non-pregnant adults.

7. *Subsistence fishing*: Many people use the Savannah River for subsistence fishing – that is, as a primary source of food; the practice is more common among African-Americans. Fish in the Savannah River have bioaccumulated cesium, mercury, and tritium from SRS. Studies have found that African-American fishermen consume considerably more fish than the maximum recommended for health reasons by the South Carolina Department of Health and Environmental Control. This is clearly an environmental injustice, because people who rely routinely on the river for a large portion of their protein are disportionately impacted by the pollution from the site. A sound and stringent cleanup plan must be implemented at SRS in order to address this environmental injustice and to protect the health of anyone who depends on the river for their subsistence.

8. *Inadequate cleanup plans:* The DOE practice of capping shallow dumps and seepage basins is not suited to long-term protection of the water resources of the region, unless there is some provision for recovery of the wastes in the medium term. Grouting and/or capping waste are stopgap measures that will likely lead to problems once the grout and the caps start to break down. It will be even more technically difficult and expensive, and perhaps impossible, to remediate grouted material should contaminants leak from it. Provision for recovering the buried waste is essential to a sound long-term stewardship program, which must have as its basic assumption that there will be an eventual loss of institutional control over the site.

9. *Unsafe and illegal high-level waste management*: DOE is leaving large amounts of residual radioactivity from high-level waste in tanks that are being "closed" by pouring grout into them. The total amount of residue left in the ground from such practice, if extended to all 51 high-level waste tanks may eventually amount to a million or more curies and include significant amounts of plutonium-238 and plutonium-239. The concentration of alpha-emitting plutonium isotopes in the two closed tanks (17 and 20) is well above the maximum allowed for shallow land diposal of radioactive waste and generally required by regulations to be disposed of in a deep geologic repository. DOE has diluted this waste by grouting. This means that grouting is being used to create *de facto* shallow high-level waste dumps at SRS, treating high-level waste as if it were low-level waste. This practice violates the 1982 Nuclear Waste Policy Act. Even if the practice were to be declared legal, it would pose a significant threat to the Savannah River over the long term. The closure plan for Tank 19 is another example of this

dangerous DOE policy. The residual waste would be more than 14 times greater than the highest limit allowed for the most radioactive waste permitted for shallow land burial. DOE plans to dilute the waste with grout so that the net result would squeak in under the low-level waste limit (0.997 times the limit for Class C waste). This will create another *de facto* high-level nuclear waste dump by the riverside.

B. Key Recommendations

1. *Recover buried wastes and highly contaminated soil*: DOE should urgently develop plans to recover buried wastes and highly contaminated soil at SRS, so that the main sources of water pollution over the long-term are minimized.
2. *Stop grouting residual waste*: DOE should stop grouting of residual radioactive materials in high-level waste tanks so as not to abandon vast amounts of radioactivity near the Savannah River. It should make a commitment to removing nearly all the radioactivity from the tanks and to decommissioning the tanks by removing them from the ground for safer, retrievable storage. (It should be noted that these underground tanks are, in some cases, partially below the shallow water table).
3. *Restore funding for monitoring to Georgia*: DOE should restore funding for water monitoring to the State of Georgia and expand such funding. It should also provide funds for an independent investigation of long-term threats to the Tuscaloosa aquifer if large amounts of residual radioactivity are left at SRS.
4. *Commission a conclusive study of groundwater pathways*: The U.S. government should provide sufficient funds for a geological investigation that would be thorough enough to settle conclusively the question of whether radioactivity is migrating into Georgia groundwater by pathway(s) under the Savannah River. This could be crucial to understanding what needs to be done to protect groundwater from SRS contamination both in Georgia and South Carolina.
5. *Retrieve wastes and inform the subsistence fishing population*: The States of Georgia and South Carolina, as well as the federal government and local governments, should initiate efforts to inform those who rely on subsistence fishing of the risks of large-scale fish consumption from the Savannah River and of efforts being made to reduce those risks. More complete studies of diets of the people, especially African Americans, living along the Savannah River are needed. These should be done with the involvement of local communities, historically Black colleges, the states of Georgia and South Carolina, with technical assistance as needed from the federal Centers for Disease Control and Prevention, which is headquartered in Atlanta, Georgia, and funding from the federal government. The DOE should take urgent steps to develop a plan to recover the buried wastes and contaminated soil that are the main sources of contamination of the Savannah River.
6. *Address tritium risks*: The National Academy of Sciences panel on the effects of low-level radiation (called the BEIR VII panel) should fully address the non-cancer risks of tritium and the risks of tritium to pregnant women and developing fetuses, as well as risks from combined exposure to tritium and non-radioactive toxic materials.
7. *Tighten tritium standards*: The EPA should tighten current standards for tritium contamination of drinking water so as to protect pregnant women and developing fetuses,

with due regard for the fact that the nourishment of the fetuses comes via the woman, so that protecting both is essential.

8. *Investigate Iodine-129 risks*: More extensive monitoring of I-129 in Savannah River water and fish should be conducted. The health implications of I-129 contamination of the Savannah River should be studied, including its effect on pregnant women, and communicated to the public.

C. Other Findings and Recommendations

1. Other Findings

a. DOE does not have a reliable inventory of how much waste and contamination is at SRS. Monitoring data taken by numerous entities on and near SRS is not comprehensively reviewed, evaluated, and interpreted.

Estimating and controlling future releases of contamination from SRS requires knowing, among other things, how much waste there is at SRS and in what condition. However, DOE does not have a reliable inventory of how much waste and contamination is at SRS. DOE's own assessment of its buried transuranic inventories concludes that the lack of adequate records and the lack of formal waste characterization of these wastes means that DOE has "generally low confidence in the reported numbers."[4] Nor is there information on volumes of soil contaminated by leaching from the buried solid wastes.

b. DOE's cleanup plan depends unrealistically on long-term institutional controls.

DOE plans to abandon large amounts of waste at SRS by grouting waste tanks or leaving buried waste in place by capping dumps and seepage basins. The grouting of some tanks containing large amounts of residual radioactivity is already being carried out. Given the half-life of many of the radionuclides, including plutonium-239, DOE must maintain institutional control in perpetuity to monitor the effectiveness of the barriers and prevent human intrusion. It is unrealistic to expect such control over hundreds of years, much less the tens of thousands of years that the wastes will pose risks to human health.

c. DOE is continuing to dispose of low-level waste in unlined and unregulated trenches at SRS.

DOE is continuing to dispose of low-level waste in shallow, unlined trenches in the E-Area, which are exempt from independent external regulation. Such ongoing disposal of low-level waste could result in two potentially significant groundwater contamination problems. First, this disposal of low-level waste increases the inventory of waste in the ground at SRS that could later migrate to groundwater or surface water, resulting in increased contamination. Second, continuing to have the trenches open causes existing contamination to be driven further into the ground. As water collects in trenches from rainfall and percolates downward, it can remobilize contamination in the soil from prior releases, and carry them to the aquifer.

[4] Huntoon, July 2000

d. The Defense Waste Processing Plant (DWPF) has not made adequate progress in vitrifying radioactivity in the high-level waste tanks

The DWPF was started in 1996 to vitrify essentially all the radioactivity in the high-level waste tanks at Savannah River Site in about 6,000 glass logs cast into steel canisters. After six years of operation more than 1,200 canisters, that is, over 20 percent of the total planned number, of glass logs had been cast. But only about one percent of the radioactivity in the tanks was in these logs. This progress is inadequate and a cause for concern both as regards the number of glass logs that might be needed and the potential that a large amount of radioactivity may be left in the tanks for the long term. A larger number of logs would create larger demands on repository space in any eventual geologic disposal site. Leaving larger amounts of radioactivity at SRS would create larger risks to the region's water resources. Another problem is that there is as yet no replacement technology for extracting cesium-137 from the saltcake in the tanks, which creates additional uncertainties for the vitrification program and for the management of the liquids in the high-level waste tanks. The technology chosen for cesium-137 extraction was written off as a failure in 1998, after 16 years of development and $500 million in expenses.[5]

e. Cleanup technologies are lacking for trace water contaminants of significant health and environmental concern, notably tritium.

There are currently no adequate cleanup technologies for trace contamination of water, notably for tritium. Remediation by using trees as an evapo-transpiration medium, as DOE is currently doing at SRS, could present long-term genetic risks to forests and hence ecosystems that have not been evaluated. DOE should set 500 picocuries per liter as an action level for tritium contamination at SRS, which it has already adopted at Rocky Flats.

2. Other Recommendations

a. DOE should develop a reliable inventory of how much waste and contamination is at SRS, and publish a full and accurate inventory of volumes and radioactivity in the Central Internet Database.

It will be difficult or impossible to devise sound cleanup plans and waste management strategies without accurate waste inventories, both in terms of radioactivity and volume. DOE's data improved (under pressure from IEER) in the period 1997-2000 but the quality remains inadequate to provide a technically sufficient basis for decision-making. Creating accurate and sufficiently precise waste inventories should be a high priority.

b. Cleanup standards should be based on the subsistence farmer exposure scenario.

At SRS, current remediation goals are based on the industrial worker scenario for soil and on drinking water standards for groundwater. This scenario assumes unrealistically that DOE will control land use in perpetuity or at least for hundreds or thousands of years. Long-term cleanup

[5] Wald, 1999

standards for soil and groundwater at SRS should be based on the subsistence farmer exposure scenario, which assumes that a person who grows all of his or her own food would unknowingly use contaminated water for drinking and farming. Further, this scenario assumes that such exposure would last a lifetime, and not just a few years. It assumes that the people in the critical group spend most of their time on the contaminated site. In addition, it assumes that the diets of future populations will be similar to those of today.

As with other risk-based standards, the subsistence farmer scenario assumes that people's health is protected if their lifetime exposure is less than an assigned limit. The reasoning is that in such a case all other people would be protected because their doses would be lower than that of the hypothetical subsistence farmer. The subsistence farmer scenario complies with the recommendations made by the International Commission on Radiological Protection (ICRP) for exposure, risk estimation procedure, and definition of the critical group. DOE should not rely on long-term institutional controls to prevent exposure to future generations.

c. DOE should stop disposing of low-level radioactive wastes by burial.

It is important to the future of protection of water resources that shallow-land burial of low-level radioactive wastes be stopped. Such wastes should be retrievably stored.

d. A new, sustained national R&D program aimed at trace contaminants should be created.

The federal government should create a well-funded basic science research program and a technology development program linked to it through the National Science Foundation to address the issue of cleaning up trace contaminants in soil and water. Such a program, if properly conceived and implemented, could be of immense value in long-term protection of water resources from the threats posed by radioactive wastes in the nuclear weapons complex, and probably also in many other industrial pollution situations.

e. Congress should request two investigations of the Defense Waste Processing Facility

The small amount of radioactivity that has been vitrified in the Defense Waste Processing Facility to date should be investigated because it poses a number of potential problems for waste management, for repository planning, and for long-term threats to southeastern water resources. Because of the vast budgetary, economic, health, and environmental implications, Congress should authorize two separate investigations of the issue – one by the General Accounting Office and one by a specially constituted panel of the National Academy of Sciences. Input and review by environmental officials and experts designated by the States of South Carolina and Georgia should be included as a prominent part of the scope of work of both investigations.

Chapter I: The Site

A. Background[6]

The Savannah River Site (SRS) is a nuclear weapons material production facility located in South Carolina adjacent to the Savannah River. Its area is about 310 square miles (about 800 square kilometers). Originally called the Savannah River Plant, the site was built by the U.S. government in the early 1950s to produce plutonium-239 and tritium for the U.S. nuclear weapons program. SRS also produced plutonium-238 for both nuclear weapons and civilian applications (including space program applications). Neptunium-237, which is irradiated to produce plutonium-238, was also produced at SRS. The site also produced other nuclear materials, including californium-252 and americium-241, for research and commercial applications.[7] Plutonium-242, a non-fissile isotope of plutonium that is used to study the properties of plutonium-239 in sub-critical experiments, was also made at SRS.

SRS has had three main missions:

1. Nuclear materials production
2. Environmental management
3. Nuclear materials disposition

SRS produced 36 metric tons of plutonium, or somewhat more than one-third of the U.S. plutonium-239 stock during the Cold War.[8] SRS also produced essentially all the tritium used in the nuclear weapons program. In this report we will focus on the present contamination of water resources on and off the Savannah River Site and the main threats to those resources from the large amount of radioactive and hazardous waste at the site. Each discrete area within SRS is named by the operations performed in that area and a code letter.

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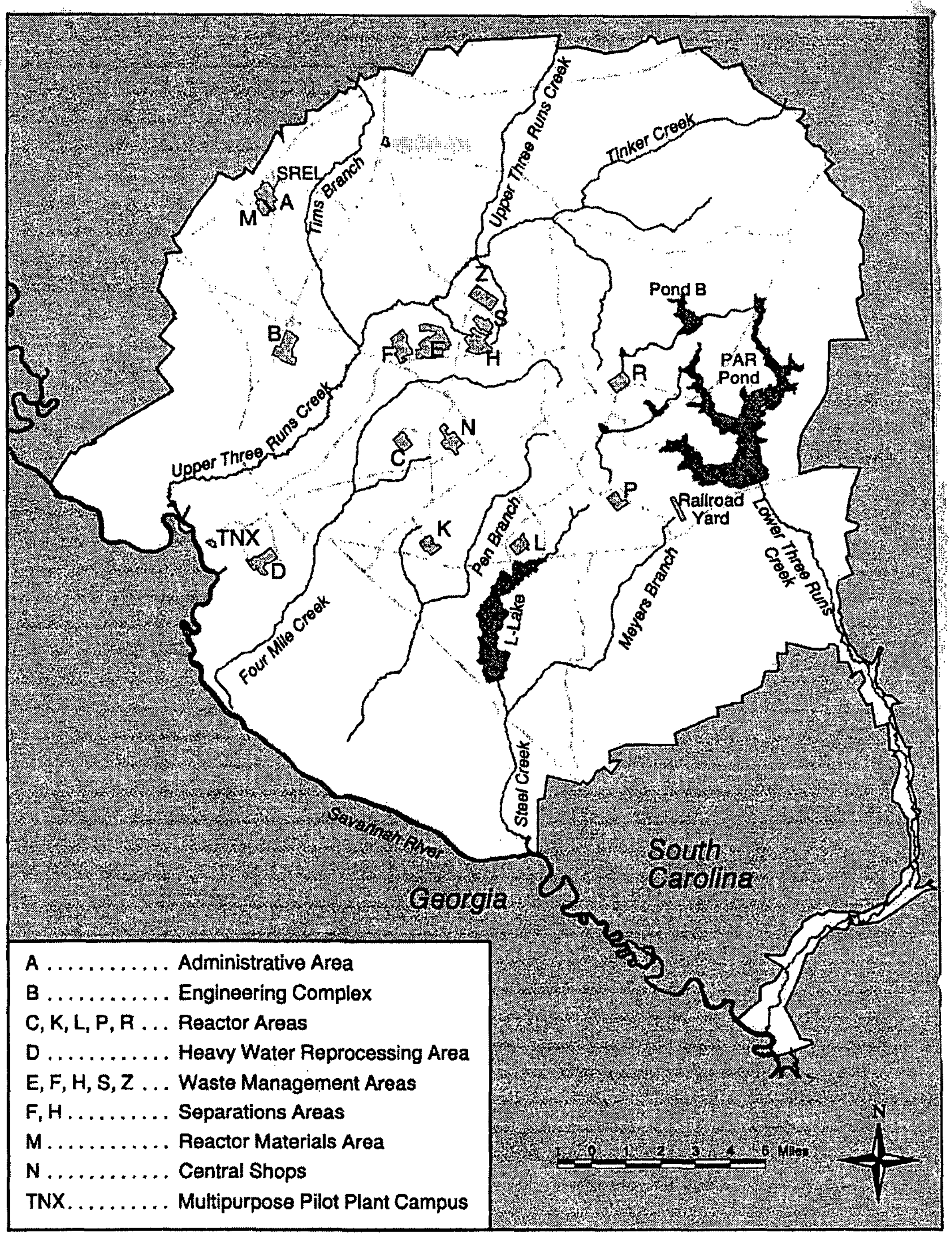
[6] For general background on the site, see Makhijani, Hu, and Yih, eds., 2000, pages 246 to 253; NRDC, 1987, pages 98 to 124, including descriptions of the facilities onsite and periods of operation.

[7] DOE, January 2001, Vol II, South Carolina section, page 3

[8] DOE, February 1996, page 25

Figure 1: SRS map with operational areas and surface water.



Source: Based on WSRC, 2000b, page 6

The main activities at SRS were:

- **Five nuclear materials production reactors**: These were heavy-water-moderated production reactors (C, K, L, P, and R reactors, located in areas named with those letters), which operated for a variety of periods, ranging from 1953 to past the end of the Cold War. See Figure 1 above. All the reactors are now closed. The heavy water moderator in these reactors was a primary source of tritium contamination, since the heavy hydrogen (deuterium) in the heavy water is transmuted to tritium during reactor operation.
- **Two reprocessing plants**: These are integrated complexes of large industrial buildings centered around huge "canyon" buildings, designated F- and H-canyons, used to separate specific nuclear materials from the fission products created in the reactors during operation and also from unused uranium. The separated materials were: plutonium-239 (and associated isotopes), tritium, plutonium-238, neptunium-237, plutonium-242, and uranium of various enrichments, including highly enriched uranium (from the driver rods that were used to fuel the reactors) and depleted uranium (from the target rods used to produce plutonium-239). One of the reprocessing plants continues to operate ostensibly to process irradiated materials for the purpose of waste management. In 2001, a comprehensive study of the need for nuclear materials stabilization published by DOE found that the chemical separation activities for currently identified canyon missions in the F- and H-Canyons would be completed by the end of Fiscal Year 2002 and in 2008, respectively.[9] As of early 2003, all chemical separation operations were completed in F-Canyon and all related operations are undergoing suspension and "de-activation" has been authorized. However, decommissioning has not been authorized.[10] It appears that F-canyon will continue to be a drain on cleanup resources for a considerable time, without progress on actual decommissioning.
- **Waste management activities**: These included transferring highly radioactive waste from separations activities to the high-level waste "tank farms" (the F and H Tank Farms), inter-tank transfers of high-level waste, evaporation to reduce waste volume, operation of the vitrification plant for high-level waste, discharge of "low-level" liquid waste into seepage basins, dumping of radioactive waste in unlined pits and trenches, often packaged in nothing more than cardboard boxes, and open burning of radioactive and mixed waste.

B. Water Resources at SRS

SRS is located in a coastal plain ecosystem with shallow groundwater. It is "covered by hardwood and pine forests and contains lakes, streams, and Carolina bays and other wetlands".[11] Natural and artificial surface-water bodies on or adjacent to SRS are shown in Figure 1 above.

Several layers of aquifers are separated by clay-rich confining units under SRS. The principal aquifer is the Dublin-Midville Aquifer System (also called the Tuscaloosa aquifer). The vadose zone (the unsaturated zone between the ground surface and the water table) under SRS is very

[9] DOE-EM, February 2001
[10] DOE-EM, Spring 2003. See also SRS CAB, February 2004
[11] DOE, January 2001, Vol. II, South Carolina section, page 3

thin. In fact, in some areas, the groundwater discharges to the surface water.[12] The proximity of groundwater and surface water bodies and the outcropping of groundwater into surface streams plays a crucial role in the continuing contamination of the Savannah River originating in the waste disposal areas at SRS.

SRS is located in one of the wettest areas of the United States, with annual rainfall averaging about 120 centimeters (48 inches).[13] About 42 centimeters (16.5 inches) of annual precipitation, which is about one-third of the total, traverses the vadose zone and goes into the upper aquifer.[14] The Savannah River as well as the Tuscaloosa aquifer are used for drinking, agricultural, industrial, and other uses.

1. The Savannah River

The Savannah River, on the southwest border of SRS, is the most prominent geographic feature in the area. With a watershed larger than 27,400 square kilometers,[15] the Savannah River basin is one of the major river systems in the southeastern United States, flowing southeast from North Carolina, forming the border between South Carolina and Georgia, and emptying into the Atlantic Ocean. Approximately 21 percent of SRS (182 square kilometers) consists of wetlands.[16]

The Savannah River Swamp is a 3,020-hectare (about 30 square kilometer) "forested wetland on the floodplain of the Savannah River", [17] along the southeast border of SRS. It "is separated from the main flow of the Savannah River by a 3-meter-high natural levee along the river bank." An area of the Savannah River Swamp, called Creek Plantation Swamp, is outside the SRS boundary, located between Steel Creek Landing and the Little Hell Landing. The Creek Plantation Swamp is "mostly uninhabited" and "access is limited to occasional hunters and fishers."[18]

The Savannah River is classified as "Freshwaters,"[19] by the South Carolina Department of Health and Environmental Control. The regulation in Chapter 61, R.61-68 covers water Classifications and Standards and defines "Freshwaters" as water "suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment," and for fishing, industrial, and agricultural uses.[20]

The Beaufort-Jasper Water Treatment Plant (also known as the Beaufort Public Water Works Plant or the Chelsea Water Treatment Plant), in South Carolina, is approximately 120 river miles downstream from SRS and provides drinking water to about 97,000 people. The City of Savannah Industrial and Domestic Water Supply Plant (also known as the Cherokee Hill plant)

[12] DOE, May 2002b, Section 3.2; and DOE, September 2000
[13] WSRC, 2000b, page 2
[14] DOE, September 2000, page 1
[15] DOE, August 1987, page 3-87
[16] McAllister, et al., September 1996, page 9.8
[17] Nelson, et al., 2000, page S23
[18] DOE, August 1987, page 3-90
[19] WSRC, 2000b, page 216
[20] SCDHEC Regulation R.61-68, Section G.10; DOE, August 1987, page 3-90

in Port Wentworth, Georgia, is approximately 130 river miles downstream from SRS and a few miles upstream of Savannah, Georgia. This plant provides water largely for industrial and manufacturing purposes, but also potable water for approximately 11,000 people.[21]

Water from the Savannah River has been used extensively in SRS operations. Beginning in the 1950s, SRS withdrew about 28.3 cubic meters per second (about 450,000 gallons per minute) of water from the river for cooling purposes, an amount equal to about 10 percent of the entire river flow. "This secondary cooling water [was] used mainly to cool the reactor primary coolant (heavy water, D_2O)" and was "returned to the Savannah River" via SRS streams. These discharges amounted to "10 to 20 times the natural flows of these streams" and regularly caused them to "overflow their original banks along much of their length."[22] The secondary water was not in direct contact with the radioactivity in the reactors.

All of the major surface water streams on or adjacent to SRS flow into the Savannah River, including the following six streams:[23]

- ***Upper Three Runs Creek:*** It traverses SRS but originates outside the SRS boundary, Upper Three runs has two principal tributaries: Tim's Branch and Tinker Creek. It has the largest watershed of any stream at SRS.
- ***Beaver Dam Creek:*** This is a small stream that joins Four Mile Creek before reaching the Savannah River via the swamp.
- ***Four Mile Creek*** (also known as Fourmile Branch): It flows 24 kilometers on the SRS site and drains into the Savannah River via the swamp.
- ***Pen Branch:*** This creek and Grave Branch together have a watershed area of55 square kilometers."
- ***Steel Creek***: The main tributary of Steel Creek is Meyers Branch.
- ***Lower Three Runs Creek:*** It drains an area second only to that of Upper Three Runs Creek. It was dammed in 1958 to create PAR Pond.

Surface water bodies at SRS have been used for the discharge of effluent from the SRS operations since the early 1950s. "Consequently, thermal, biological, chemical, and radiochemical effects have been observed in the SRS streams."[24] About 200 "Carolina bays, which are naturally occurring pond formations found in parts of the southeast, are scattered throughout the site," covering a total of about 472 hectares (about 1,100 acres). These bays "serve as natural habitats for many species of wildlife on the site," and have not been used for effluent discharge.[25]

[21] WSRC, 2000b, pages 2 and 111. A river mile is a mile as measured along the navigation channel of a river.
[22] DOE, August 1987, page 3-93
[23] DOE, August 1987, pages 3-93, 3-96, 3-97, and 3-98
[24] DOE, August 1987, page 3-87
[25] WSRC, 2000b, page 2; McAllister, et al., September 1996, page 9.4; DOE, August 1987, page 3-87

2. Artificial Surface-Water Bodies

There are two major artificial bodies of water on the SRS site: PAR Pond and L-Lake. PAR Pond was created in 1958 by the construction of an earthen dam on Lower Three Runs Creek to provide cooling water for, and to receive cooling water from, the P- and R-Reactors (hence the name PAR).[26] The pond covers 10.7 square kilometers (2,640 acres) and has an average depth of 6.2 meters (20 feet) and a maximum depth of 18 meters (59 feet).[27]

L-Lake, which covers about 4 square kilometers (1,000 acres), was created in 1985 by an earthen dam across Steel Creek to receive cooling water discharges from the L-Reactor. In addition to Steel Creek waters, the "lake was filled with 110 million gallons of water diverted from Par Pond." The object was "to provide L-Lake with an initial source of lake species" and to help accelerate "the development of a biologically balanced community. Water from L-Lake flows to Steel Creek and eventually to the Savannah River."[28]

Both PAR Pond and L-Lake are contaminated. Before they were constructed, cooling water was discharged directly to Lower Three Runs Creek (from P- and R-Reactors) and to Steel Creek (from L-Reactor).[29]

3. Groundwater

The hydrogeology under SRS is complex due to heterogeneities in the vadose zone and in the multilayer aquifer system. There are several productive aquifers that drain into the Savannah River, its tributaries, and the Savannah River Swamp. Groundwater velocities in SRS aquifers range "from tens to hundreds of feet per year." While the aquifers are, broadly speaking, separated by relatively impermeable confining layers, water does move slowly between them, at a rate of "several inches to several feet per year."[30]

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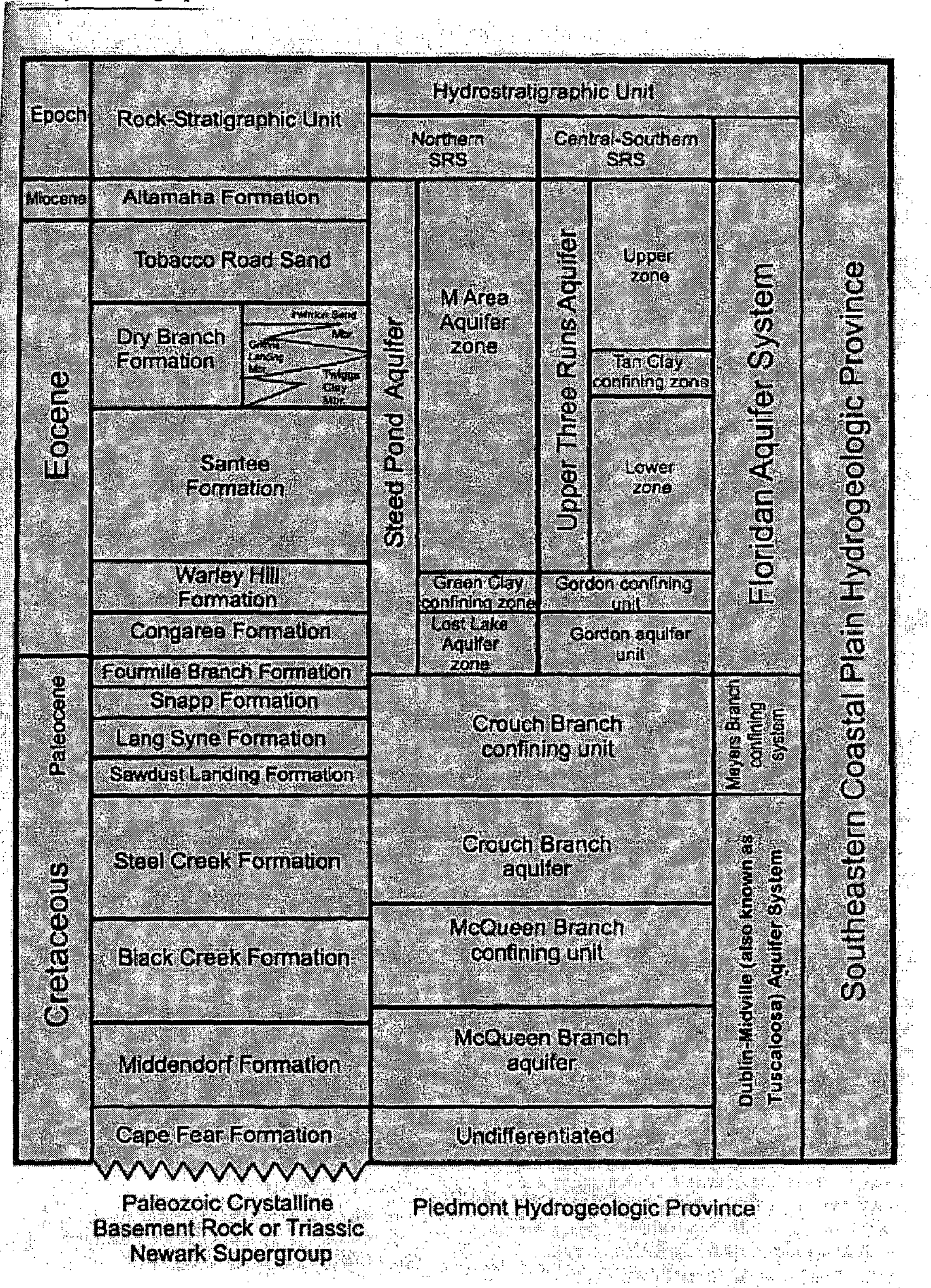
[26] Dunn et al., March 2000
[27] DOE, May 1997, page S-3
[28] DOE, August 1987, page 3-99
[29] RAC, April 2001, page 5-2
[30] WSRC, 2000b, page 156

Figure 2: Hydrostratigraphic units at SRS



Source: Based on WSRC, 2000b, page 157

Groundwater in the area can occur as perched water, normal aquifers, and artesian aquifers.[31] Deeper aquifers flow toward the major streams. The deepest aquifers (the Dublin and Midville aquifers) flow toward the Savannah River. The vertical groundwater flow can change or even reverse in successively deeper aquifers. Under most of the site, vertical flow of water is downward, so water flows from shallower to deeper zones. In some areas, however, groundwater flows up towards the upper aquifers. The complexities of the regional geology are considerable and there can be no assurance of long-term integrity of the deep aquifers if large amounts of long-lived radioactive wastes are abandoned on site.

The vadose zone at SRS is relatively thin, ranging from zero to 37 meters (120 feet) thick, so groundwater regularly intercepts surface water bodies (e.g., streams, Carolina bays and the Savannah River).[32] This has important consequences for contaminant migration at SRS, because contaminants can and do migrate from groundwater to SRS streams.

Groundwater is widely used throughout South Carolina. Over half of the people of the state rely on it for their drinking water, via public water supplies or individual wells. Groundwater is also widely used in industry. [33]

SRS uses approximately 5.3 million gallons of groundwater per day. This includes withdrawal of water for drinking, and for sanitary and industrial processing purposes. SRS is the largest self-supplied industrial consumer of groundwater in South Carolina.[34]

[31] RAC, April 2001, page 5-7
[32] DOE, May 2002b, Section 3.2; DOE, September 2000
[33] RAC, April 2001, page J-3 and SCDHEC, May 2001
[34] WSRC, 2002b, page 55

Chapter II: Sources of Contamination

The Savannah River Site contains the largest amount of radioactivity in waste of any nuclear weapons site in the United States. Roughly 99 percent of this radioactivity is in 49 high-level waste tanks that contain fission products as well as plutonium, uranium and other radionuclides comprising the main waste discharges from the reprocessing plants (F and H canyons). The largest volume of discharged waste was in liquid form into seepage basins. Solid radioactive waste was buried in landfills and trenches at the site. The largest volume of solid radioactive waste is in a catch-all category called "low-level" waste. Broadly speaking, the main threats to water resources arise from the long-lived radionuclides in the waste, which includes the high-level waste in the tanks, the radioactivity in buried wastes and seepage basins, the radioactivity in the vadose zone, and radionuclides already in the groundwater under SRS. These risks from radioactivity are compounded by the presence of toxic non-radioactive contaminants.

Table 1 shows official estimates of the amounts of radioactive waste, both in terms of volume and of total radioactivity content.

Table 1: Official estimates of waste at SRS resulting from nuclear weapons production, as of mid-2001 or early 2002.

Type of waste	Volume (cubic meters)	Radioactivity (curies)
Total high-level waste	144,000	484,200,000
Comprised of:		
sludge in tanks	10,600	320,000,000
salt cake & supernate in tanks	133,500	160,000,000
vitrified waste in canisters	1221 canisters	4,200,000
Stored transuranic	15,000	560,000
Buried transuranic	4,530	21,900
Active low-level	680,000	Not given
Mixed low-level	7,300	Not given
Stored low-level	1,600	Not given
TOTAL (rounded)	**~852,000**	**~490,000,000**

Sources: HLW: Caldwell et. al, 2002, pp. 1, 2, and 80 and DOE-SRS, June 2001, p. 2-1. Sources for the rest: DOE, June 2000 and DOE-EM, January 1997, Chapter 3. HLW waste volume changes due to increasing from sludge washing operations.

Note: All numbers are rounded. DOE sources are not internally consistent regarding waste data. We have used what appears to be the best available data. In some cases, such as additions to high-level waste tanks arising from sludge washing, the waste volumes change from year to year considerably, leading to difficulties in creating a single date for compiling all the waste data.

The risks to water resources can also be viewed in terms of the various waste disposal and discharge methods, because the disposal method determines how the waste enters the watershed and its contribution to groundwater and surface water contamination. These disposal and discharge methods may be put into the following categories for the purpose of compiling data:

1. Landfills/Trenches/Pits
2. Seepage basins
3. Ponds (PAR Pond/L-Lake)
4. Tanks (F- and H-Area high-level waste tanks and smaller tanks)
5. Direct discharge to streams

A. Landfills/Trenches/Pits, Seepage Basins, and Ponds

SRS used trenches, rubble and burning pits, and landfills to dispose of radioactive and mixed wastes. Much of the buried waste has been left in the ground and capped. Table 2 summarizes the major landfills, trenches, and pits that have contaminated both groundwater and surface water at SRS.

Table 2: Summary of major landfills, trenches, and pits contaminating water at SRS

Landfill/Trench/Pit	Affected water system	Contaminants
Burial Ground Complex • Old Radioactive Waste Burial Ground • Low-Level Radioactive Waste Disposal Facility	Four distinct groundwater plumes • Southwest plume contaminated with tritium outcropping into Four Mile Creek • Northern plumes outcropping into Upper Three Runs Creek	Tritium and other radionuclides, volatile organic compounds (primarily trichloroethylene), metals
TNX Burial Ground	Groundwater; discharges to the Savannah River Swamp and the Savannah River	Trichloroethylene; radionuclides, including uranium and radium-226
A-Area Burning/Rubble Pits	Groundwater	Trichloroethylene, tetrachloroethylene, methylene chloride
C-Area Burning/Rubble Pit	Groundwater; outcrops to Four Mile Creek	Trichloroethylene, tetrachloroethylene, vinyl chloride, tritium (the tritium is from other sources in C-Area)
Chemical, Metals, and Pesticides Pits	Groundwater; outcrops to Pen Branch	Trichloroethylene, tetrachloroethylene, metals

Sources: WSRC, 2000a and DOE, January 2001, Vol. II, South Carolina section

One of the largest and most contaminated areas at SRS is the Burial Ground Complex, which is located between the F-Area and H-Area reprocessing plants. Its principal use was for the disposal of low-level radioactive and mixed wastes.[35] DOE estimates that there are more than 1.3 million curies of low-level waste (decay-corrected to 2001) and about 18,500 curies of transuranic waste (decay-corrected to 2006) in the Burial Grounds.[36] "The Burial Ground Complex is divided into a southern area and a northern area." The Old Radioactive Waste Burial Ground, in the southern section, was the first part of the "Burial Ground Complex to receive waste and was filled to capacity." As an interim remediation action, it was "covered with a low-permeability interim cap" that is supposed to reduce "water infiltration by 70 percent."[37] The Old Radioactive Waste Burial Ground may be the most important source of future contamination among the various burial and burning sites because of the large quantity and variety of waste,

[35] WSRC, 2000b, page 55. Also see Chapter V below.
[36] WSRC, August 2002, page 35; WSRC, December 2000, pages ES-11 to ES-16; DOE, June 2000, page 21
[37] DOE, January 2001, Vol. II, South Carolina section, page 37

including radioactive and non-radioactive toxic materials dumped there.

SRS also used a dozen seepage basins for the discharge of billions of gallons of liquid wastes contaminated with radionuclides, organic toxic chemicals, and heavy metals. The largest amount of liquid wastes came from the two reprocessing plants (F- and H-canyons).

Table 3: Summary of the primary seepage basins contaminating water at SRS

Basin	Affected water system	Contaminants
F-Area Seepage Basins	Groundwater; outcrops into Four Mile Creek	Tritium, uranium-238, iodine-129, strontium-90, curium-244, americium-241, technitium-99, cadmium, aluminum
H-Area Seepage Basins	Groundwater; outcrops into Four Mile Creek	Tritium, strontium-90, mercury
Old TNX Seepage Basin	Groundwater; Savannah River and swamp	Trichloroethylene
New TNX Seepage Basin	Groundwater; Savannah River and swamp	Trichloroethylene
M-Area Seepage Basin	Groundwater; outcrops into Upper Three Runs Creek	Trichloroethylene, tetrachlorethylene
Old F-Area Seepage Basin	Groundwater	Tritium, iodine-129, uranium
K-Area Seepage Basin	Groundwater; outcrops into Indian Grave Branch	Tritium
R-Area Reactor Seepage Basins	Groundwater	Strontium-90, VOCs
L-Area Reactor Seepage Basin	Groundwater	Trichloroethylene, tetrachloroethylene, tritium
P-Area Reactor Seepage Basins	Groundwater; outcrops into Steel Creek	Tritium, trichloroethylene
Ford Building Seepage Basin	Groundwater	Lead, mercury, nitrates
C-Area Reactor Seepage Basins	Groundwater	Tritium, trichloroethylene

Sources: DOE SRS fact sheets; WSRC, 2000a.

Finally, there are also artificial ponds on the site, with the largest being PAR Pond. PAR Pond and L-Lake are no longer actively used because all reactors at SRS are permanently shutdown. However, they remain contaminated. The sediment in PAR Pond is contaminated primarily with cesium-137. There are also smaller concentrations of strontium-90, plutonium-238/239, americium-241, curium-244. There is also tritium in the water. The total inventory of cesium-137 was estimated to be 44 curies in 1991. Non-radioactive contaminants include mercury.[38]

B. High-Level Waste Tanks

The largest inventory of radioactivity at SRS is in the high-level waste tanks in the F- and H-Areas. As noted in Table 1, as of mid-2001, 49 tanks contained 144,000 cubic meters (about 38 million gallons) of liquid waste with approximately 480 million curies of radioactivity (decay-corrected). The high-level waste in the tanks is in the form of sludge waste and salt waste. The sludge contains about two-thirds of the radioactivity and represents about 7 percent of the volume; the salt and supernate contain almost all the rest. Less than one percent of the

[38] Whicker, Niquette, and Hinton, January 1993, pages 475 and 478; Whicker et al., October 1993, pages 619 and 620

radioactivity had been vitrified as of early 2002. Two additional tanks that still contain residual high-level waste have been "closed" with grout (see below).

The potential sources of groundwater contamination from the high-level waste tanks are

- leakage of operational tanks through the primary and secondary containment as well as associated equipment (e.g., pipelines and valves),
- leakage and spills during withdrawal and transfers of wastes from the tanks,
- migration of contaminants from the "closed" tanks in which residual high-level waste has been left in place and grouted,
- contamination resulting from disposal of wastes deriving from high-level waste processing, and
- migration of any high-level radioactive waste that might be abandoned on the site in grouted or other form.

The past history of the tanks is mixed so far as tank integrity is concerned. Two of the four types of high-level waste tanks at SRS have leaked radioactive waste, while another type has had in-leakage of water. One type, the latest, has performed well thus far and is not known to have leaked:

- Twelve Type I tanks were built between 1952 and 1953. Five of these tanks have leak sites through which waste leaked from the primary containment to the secondary containment (i.e., 5-foot high annulus "pans"). In one case, the secondary containment of the tank was observed to be generally corroded "creating the potential for significant degradation of the tank secondary containment."[39] Four of the leaking Type I tanks, including the tank with corroded secondary containment, sit in the water table.[40]

- Four Type II tanks were built in 1956. Like Type I tanks, these also have 5-foot high annulus "pans" as secondary containment. All Type II tanks have leak sites through which waste leaked from the primary containment to the secondary containment. In one case, "tens of gallons of waste overflowed" the secondary containment and leaked into the soil.[41]

- Eight Type IV tanks at Savannah River were built between 1958 and 1962. This type has a single steel wall. Two of these tanks have known cracks and small amounts of groundwater have leaked into the tanks. Four of the Type IV tanks are in a perched water body "caused by the original construction of the tank area."[42]

- None of the 27 Type III tanks have currently known leak sites. These tanks are of the newest design, built between 1969 and 1986, with full-height secondary containment. Although the probability of a significant release may be relatively low compared to other sources of contamination, the consequences are higher than most other sources because the waste has

[39] DNFSB, April 1999
[40] DOE-SRS, May 2002b, page S-4; Caldwell, et al., 2002, page 75
[41] DOE-SRS, May 2002b, page S-4; Caldwell, et al., 2002, page 75
[42] DOE-SRS, May 2002b, page S-4; Caldwell, et al., 2002, page 75

decayed less than in the older tanks.[43] This difference is likely to disappear over time periods that are well short of the very long-lived components of the waste, like plutonium-239.

By 2022, DOE is required to close all of the tanks that have leaked or that do not have full-height secondary containment, which includes all the Type I, II, and IV tanks. Type III tanks are projected to be in use until almost 2030.[44]

As of 2002, DOE had completed "closure" of two tanks in the F-Area, numbers 17 and 20.[45] The bulk waste was removed, but the residual waste, which consists of solids firmly attached to the tank surfaces as a "crust" or "heel," was left in the tanks.[46] Grout was pumped into the tanks using a "three-layered backfill system" consisting of a "chemically reducing grout at the bottom of the tank, a controlled low-strength material in most of the empty space, and a high-strength grout at the top of the tank." Grout is a filler material consisting of sand and gravel with a cement binder that sets after it is poured. The chemical composition of the grout is reducing because such a composition would "reduce the mobility of technetium-99."[47] Of course, the degree to which this design function succeeds will depend, in part, on the integrity of the grout over the long-term.

The grouting of two tanks still containing residual wastes has already created a *de facto* high-level nuclear waste dump on the site. The main radionuclides remaining in the tanks are strontium-90, cesium-137, technetium-99, and cobalt-60, but the residual waste also includes selenium-79, carbon-14, iodine-129, plutonium-238, -239, -240, -241 and -242, neptunium-237, americium-241, and curium-244 and -245.

The residual radioactivity level in Tank 20 is estimated to be about a quarter of a curie per gallon and that in Tank 17 almost half a curie per gallon.[48] The total plutonium concentration of the residual wastes in both tanks (for isotopes 238, 239 and 240) is well above the limit for Class C low-level waste, putting the waste in the category that must generally be disposed of in a deep geologic repository. The total residual volume was estimated at 1000 gallons in Tank 20. DOE estimates of residual volume in Tank 17 appear to be inconsistent. Caldwell, et al. reported the residual volume as 2,200 gallons of sludge in a 2002 publication, while a DOE tank closure report published in the same year reported the volume to be 4,000 gallons.[49] It is not clear whether the Caldwell et al. estimate included the volume of interstitial liquid.

C. Other Wastes

The waste management practices over time at SRS have caused extensive contamination of surface and groundwater, and some migration of contamination outside the present SRS boundary, including into the Savannah River. There is extensive documentation of such

[43] DOE-SRS, May 2002b, page S-9
[44] DOE-SRS, May 2002b, page 1-9
[45] See Caldwell et al., 2002, for details on "closure" of Tanks 17 and 20
[46] DOE-SRS, May 2002b, page 1-9
[47] NRC-NAS, 2001, page 72
[48] NRC-NAS, 2001, pages 70-71
[49] Caldwell et al., 2002, pages 77 to 78. DOE-SRS, May 2002b, page 2-1

contamination, which includes both radioactive and non-radioactive components. For example, groundwater underlying the Burial Ground Complex, has been highly contaminated with tritium, other radionuclides, volatile organic compounds (primarily trichloroethylene), and metals. Short-term threats to the groundwater include tritium and volatile organic compounds, strontium-90, mercury, cadmium, and lead. Long-term threats include iodine-129, technetium-99, neptunium-237, uranium isotopes, and plutonium-239.[50]

The burning and rubble pits also pose environmental risks. SRS burned a variety of wastes every month in the A-Area Burning/Rubble Pits, including wastes contaminated with hazardous materials like solvents and waste oils. In 1973, SRS stopped burning the wastes and added a layer of soil over the "debris." However, SRS continued to dump paper, wood, empty steel barrels, and cans into the pits until they were filled to capacity.[51] This continued use of the pits is another example of exacerbating a waste and contamination problem even after ceasing hazardous substance disposal. Groundwater beneath the area is contaminated with trichloroethylene, tetrachloroethylene, and methylene chloride.[52] The soil under the C-Area Burning/Rubble Pit, which was built in the early 1960s, and similarly used until 1973, is contaminated with trichloroethylene, tetrachloroethylene, and dioxins. The groundwater is contaminated with trichloroethylene, tetrachloroethylene, and tritium (the tritium is from other sources in C-Area).[53]

As discussed Chapter 1, the groundwater is so shallow at SRS that it commonly breaks out into surface streams, where it eventually flows to the Savannah River. In most natural hydrological systems, groundwater, which is filtered by nature, provides a cleansing effect when it flows into surface waters. However, after several decades of nuclear weapons materials production and poor waste disposal practices at SRS, the groundwater is severely contaminated under the industrial areas of the site, which cover 5 to 10 percent of the total area.[54] This contaminated groundwater affects the entire Savannah River watershed in this area.

D. Water Monitoring

Several organizations are involved in environmental monitoring of surface water and groundwater on or near SRS, including the U.S. Department of Energy site management contractor, the Westinghouse Savannah River Company, the South Carolina Department of Health and Environmental Control (SCDHEC), the Georgia Department of Natural Resources (GDNR), the U.S. Geological Survey, and the Georgia Geologic Survey.

The Westinghouse Savannah River Company conducts water sampling programs to monitor a variety of contaminants including mercury, lead, organics, and a variety of radionuclides.[55]

Through its Environmental Surveillance and Oversight Program, the South Carolina Department of Health and Environmental Control (SCDHEC) monitors 75 groundwater wells, consisting of

[50] WSRC, August 2000, pages 2-23 to 2-24
[51] DOE-SRS, December 2001a
[52] DOE-SRS, December 2001a
[53] DOE-SRS, September 2003
[54] DOE, May 2002b, page 3-13
[55] WSRC, 2000b, page 163

public supply wells, irrigation wells, and monitoring wells within 10-miles of the SRS boundary.[56] SCDHEC also collects "monthly raw drinking water samples from water treatment plants that use the lower portion of the Savannah River as a source, and quarterly grab samples from selected municipal and large community drinking water systems within 30 miles of SRS. Samples are analyzed for gross alpha, nonvolatile beta, and beta-gamma emitting radionuclides, and tritium."[57]

The Georgia Department of Natural Resources, Environmental Protection Division, "regularly monitors drinking water from the [City of Savannah Industrial and Domestic Water Supply Plant], as well as seven ... locations on the Savannah River." The Georgia Department of Natural Resources planned to install a continuous water monitor at River Mile 120 (at U.S. Highway 301) during 2003, but could not do so because DOE refused to fund it.[58] "The City of Savannah also monitors surface water from U.S. Highway 301 on a daily basis, and both raw and finished water on a once-per-shift basis."[59] DOE funding to the State of Georgia for environmental monitoring related to SRS is set to expire April 30, 2004, as of this writing (mid-February 2004).[60] In the absence of state and federal funding, the people of Georgia will not have adequate knowledge of the risks to which they are being subjected from contamination originating at SRS. The federal government is, in effect, imposing an unfunded fedral mandate on Georgia. The State of Georgia has the responsibility to protect the health of its people, and the federal government is imposing risks on those people via radioactive contamination. At the same time it is refusing to provide funds to Georgia to monitor that contamination.

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[56] SCDHEC, December 2001, page 7
[57] SCDHEC, December 2001, page 7
[58] Hardeman, 2004b
[59] Hardeman, 2002
[60] Hardeman, 2004a

Chapter III: Tritium and Radioactive Water

Tritium is radioactive hydrogen. Tritium in gaseous form generally presents a low health risk because it is exhaled before it can deliver substantial radiation doses to the body. However, tritium can displace one or both of the hydrogen atoms in water, thereby creating radioactive water (see box), which behaves chemically like ordinary water. Since water is essential to life, radioactive water means that radioactivity seeps into all parts of the body and its constituents – cells, as well as DNA and proteins, for instance. Tritium that is in organic materials is called organically-bound tritium (OBT). Both tritiated water and organically-bound tritium can cross the placenta and irradiate developing fetuses *in utero*, thereby raising the risk of birth defects, miscarriages, and other problems (see below). Tritium discussed in this report is either in the form of tritiated water or OBT, unless otherwise specified.

About Tritium

Tritium is a radioactive form of hydrogen with two neutrons, resulting in a total atomic weight of 3 (1 proton and 2 neutrons). Most tritium is man-made. Some tritium occurs naturally due to interactions between the atmosphere and cosmic radiation. With its relatively short half-life (12.3 years), tritium decays at about 5.5 percent annually.

As a gas, tritium is a light and small atom and hence diffuses readily through all but the most highly engineered containment vessel and mixes freely with the other forms of hydrogen in water and water vapor. It forms tritiated water by replacing one or both atoms of non-radioactive hydrogen in water. Tritiated water is often designated as HTO and T_2O, depending on whether it has one or two atoms of tritium in the water molecule respectively. When tritium is generated by neutron absorption in heavy water (D_2O), it is DTO. All these forms of water containing tritium are rendered radioactive as a result. They behave in a manner that is chemically the same as ordinary water. The pervasiveness of tritium is due to the mobility of tritiated water in the environment along with non-radioactive water (both H_2O and D_2O).

The specific activity of tritium is very high – almost 10,000 curies per gram. Hence a small amount (weight) of tritium can contaminate a large amount of water. The combination of these two properties -- tritiated water is chemically like ordinary water and tritium is highly radioactive – makes tritium a very pernicious pollutant that is difficult to contain and, once in the water difficult to remediate, especially when in trace amounts.

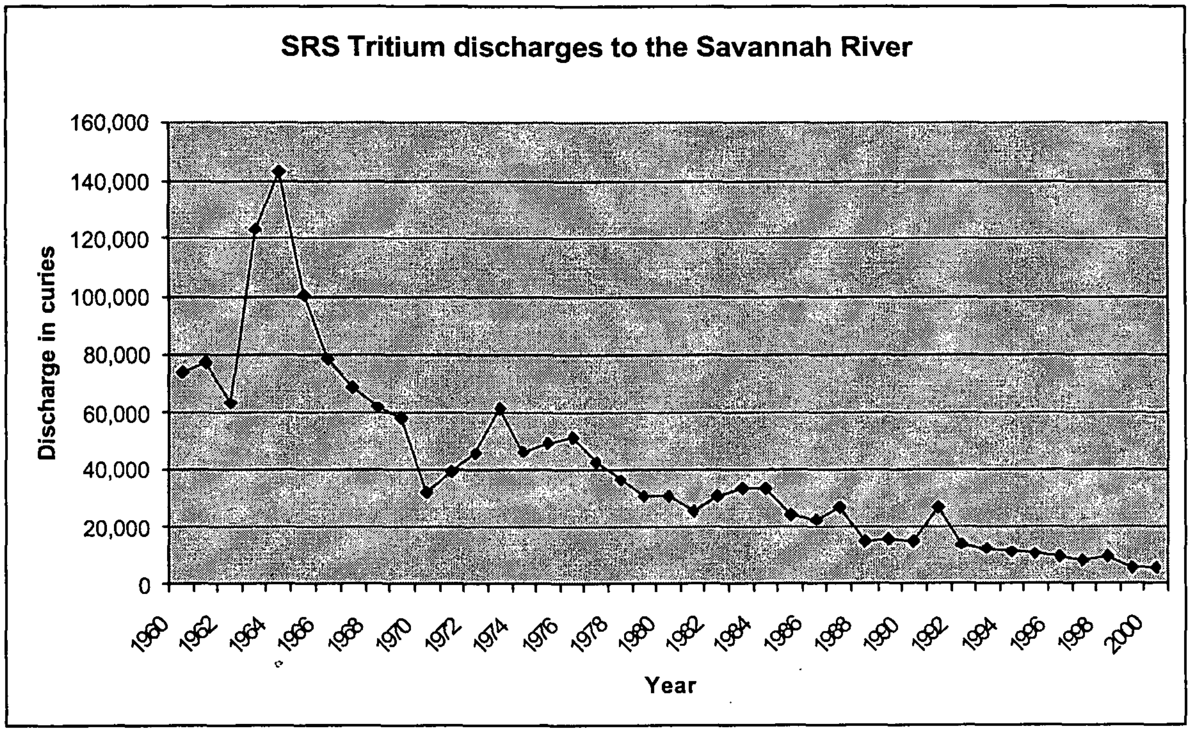
Tritium's primary function in a nuclear weapon is to boost the yield of the fissile material used both in pure fission weapons and in the primary of thermonuclear weapons. Contained in removable and refillable reservoirs in the warhead, it increases the efficiency with which the nuclear fissile materials are used. Although no official data are publicly available, each warhead is estimated to require an average of approximately four grams of tritium. However, neutron bombs, designed to release more radiation, have been estimated to require more tritium (10-30 grams).[1]

1. Reproduced from Zerriffi, January 1996, page 1

There are two types of tritium releases from SRS: (1) direct releases into streams; and (2) migration of tritium from seepage basins, buried wastes, and the K-Area containment basin to groundwater and outcropping to SRS streams. At first direct releases, mainly from reactors and the reprocessing plants, accounted for almost all tritium releases to streams. Since the mid-1970s, however, groundwater outcropping to streams has been the major source of tritium releases to the streams.[61] The amount of tritium discharged to the river has declined substantially over the years as the reactors have been shut down.

Annual releases of tritium to SRS streams from both direct releases and migration ranged from more than 100,000 curies per year in the mid-1960s to about 3,100 curies in 2002.[62] The highest estimated release of tritium to surface water was about 143,000 curies in 1964.[63] Figure 3 shows the annual tritium transport summary from both direct releases and migration from 1960 to 2000, as well as the resulting tritium transport in SRS streams and in the Savannah River downriver of SRS.

Figure 3. Tritium Discharges into the Savannah River – Historical Data



Source: WSRC, 2000a, Table 20. pages 72 and 73. These estimates are based on tritium measurements in the Savannah River. Other methods of estimation yield somewhat different results.

[61] RAC, April 2001, page 5-43. Also see WSRC, 2000a.
[62] WSRC, 2002d
[63] WSRC, 2002a

Between 1954 and 1988, a total of 1.5 million curies of tritium were released directly into SRS streams and 7.2 million curies of tritium were released into seepage basins and burial grounds. Of the tritium released directly into the streams, about three-fourths was from the reactors, about 15 percent from the F- and H- canyons, and the rest from other facilities. Much of this tritium has decayed into non-radioactive helium-3; about 5.5 percent of the tritium inventories decays each year. But there is still enough for tritium to be the most ubiquitous contaminant at SRS.

Table 4: Sources and activities of cumulative tritium discharges at SRS, 1954-1988 (not decay-corrected)

Facility	Amount discharged to streams (curies)
Reactors	1,144,000
Separations	237,000
D-Area	145,000
Subtotal	**1,526,000**
	Amount discharged to the ground, curies
Seepage basins (See Note 1)	3,015,000
Burial grounds	4,200,000
Subtotal	**7,215,000**
Total	8,741,000

Source: Murphy *et al.*, May 1991, pages i, 16.
* Note 1: In this case, as with other waste data, DOE data are internally inconsistent. The seepage basins number above is taken from page 16 of Murphy et al.; it differs from the number given in the table on page 17, which is 1,208,000 curies. But the subtotal, 7,215,00, is more in line with the number, "about 7 million," given on page i of Murphy.

Currently, most of the tritium released directly to SRS streams comes from the Effluent Treatment Facility, which discharges wastewater into Upper Three Runs Creek.[64] In 2000, the Effluent Treatment Facility accounted for about 94 percent (by activity) of the direct releases of tritium at SRS. The releases from this facility have varied in recent years, increasing from 308 curies in 1996 to 1,680 curies in 2000 and back down to 989 curies for 2002.[65] This indicates that discharges probably depend on rainfall and other factors that are mobilizing tritium at varying rates. Approximately 30 percent of the tritium released to the seepage basins evaporated; the remaining tritium decays or percolates through the soil to the shallow aquifer.[66] Table 4 lists the sources and activities of tritium discharges to streams and to the ground at SRS from 1954 to 1988. In addition, about 25 million curies of tritium was discharged into the atmosphere between 1954 and 1992.[67]

[64] WSRC, 2002d; DOE-SRS, April 2002a
[65] WSRC, 2000a, Table 18, page 66 and WSRC 2002d
[66] Murphy et al., May 1991, pages i and 11
[67] GDNR, 1994, Table 2, page 8. This table does not specify the partition between tritiated water and tritium gas

The shallow groundwater at SRS is contaminated to levels far above the drinking water standard. Shallow groundwater at SRS is generally not used for drinking or process water,[68] but the tritium in it migrates into SRS streams that flow into the Savannah River, which is used for drinking. The U.S. Environmental Protection Administration regulation, pursuant to the federal Safe Drinking Water Act (SDWA), establishes a concentration of 20,000 picocuries/liter (pCi/L) for tritium.[69] Although it is not accurate to say that tritium concentrations in water exceeding 20,000 pCi/L violates the safe drinking water act, the limit is a useful basis of comparison for measuring a legally established concentrations level for what is considered "safe." The EPA regulation applies to public drinking water supplies for the concentrations of contaminants in drinking water at the point of delivery (i.e., at the kitchen sink tap). It does not, strictly speaking, apply at the point of intake before treatment and polishing, but because there is no practical and effective treatment method for removing tritium from water, the same concentrations found at the point of intake should be assumed to be present at the point of delivery, unless dilution with uncontaminated water supplies occurs. The drinking water limit is enforced on the water supply system operator, rather than the polluter who contaminated the water (in this case, the DOE). Therefore, we use Safe Drinking Water regulations as a benchmark for comparison, and not as a conclusion of a violation of law or present-day risk. (The Department of Energy and the State of Georgia use the same benchmark in their environmental monitoring reports).

Tritium is the most widespread radioactive contaminant in groundwater under SRS. More than half of all shallow groundwater monitoring wells at SRS indicate tritium contamination at concentrations exceeding drinking water standards in the separations (F- and H-Areas) and the waste management areas (E-, F-, H-, S- and Z-Areas). Some of the wells in the F and H separations areas have tritium concentrations hundreds and even thousands of times above the drinking water limit. The proportion of wells contaminated with tritium above the drinking water limit went up in the separations and waste management areas from 51 percent in 1998 to 63 percent in the year 2000. It has gone up from 60 percent to 100 percent of wells in the K-area in the same period.[70] The most contaminated well in SRS in the year 2002 with regard to tritium had a level of 78.2 million picocuries per liter, up from 64.2 million in the year 2001. Groundwater under the L and P reactor areas is also highly contaminated.[71]

Because the groundwater is so shallow at SRS, the tritium-contaminated groundwater outcrops into streams along seeplines. Tritium migration from seepage basins and the Solid Waste Disposal Facility accounts for most of the tritium in SRS streams.[72] In 1995, an independent group of technical, health and legal experts hired by the SRS Citizens' Advisory Board, called the Independent Scientific Peer Review (ISPR), indicated that, "Concentrations of tritium exceeding 10,000 picocuries per milliliter (10 million picocuries per liter) have been measured in the groundwater in the vicinity of Fourmile Branch."[73]

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discharges to the atmosphere.

68 DOE, May 2002b, page 3-13

69 EPA, 2003

70 WSRC, 2000b, pages 181, 182, and 184

71 WSRC, 2002b, Table 6-1, page 59.

72 WSRC, 2000b, pages. 88 to 89. See Figures 6-7 and 6-8.

73 ISPR, October 1995, page 14

Table 5 lists the main sources of tritium and the annual total tritium migration to surface water from 1996 to 2002.

Table 5: Main sources of tritium and annual total tritium migration to surface water, 1996-2002

Source	Surface water outcrop	Radioactive migration (curies)						
		1996	1997	1998	1999	2000	2001	2002
Solid Waste Disposal Facility and General Separations Area*	Upper Three Runs	164	267	386	467	483	470	275
Solid Waste Disposal Facility and H-Area seepage basin*	Four Mile Creek	3,200	2,960	3,488	2,090	1,920	411	381
F-Area seepage basin	Four Mile Creek	1,620	1,000	1,477	648	353	284	226
H-Area seepage basin	Four Mile Creek	505	400	515	258	139	161	95
K-Area disassembly basin, reactor seepage basin, and retention basin	Indian Grave Branch, a tributary of Pen Branch	1,290	2,150	3,090	1,160	1,040	1,040	853
P-Area seepage basin	Steel Creek	320	393	507	369	265	309	177
Sub-Total		7,099	7,170	9,463	4,992	4,200	2,675	2,007
Total direct releases and migration		**7,560**	**8,350**	**10,555**	**6,111**	**5,995**	**4,423**	**3,096**

Source: WSRC, 2002d
Note: * It is not possible to distinguish between the two sources at the outcrop point.

The Georgia Department of Natural Resources (GDNR) monitors tritium concentrations along the Savannah River and at the Four Mile Creek outfall to the Savannah River.[74] The maximum concentration at the Four Mile Creek outfall between 1997 and mid-1999 was 220,000 picocuries per liter in April 1999.[75] According to GDNR, between 1997 and mid-1999 "positive tritium results, attributable mostly to SRS, were found in most types of samples and at most locations, within 30 miles of SRS."[76]

Historically, the highest tritium concentrations at the Savannah River have been those due to discharges from Four Mile Creek. The South Carolina Department of Health and Environmental Control (SCDHEC) also monitors the SRS streams and the outfalls to the Savannah River. These 1999 data, in Table 6, show that water entering the Savannah River from Four Mile Creek

[74] GDNR, 1999, pages A-10 and D-58
[75] GDNR, 1999, pages A-10 and D-58
[76] GDNR, 1999, page A-10

was contaminated well above drinking water standards.

Table 6: Maximum and mean tritium concentrations at outfalls to the Savannah River, South Carolina Department of Health and Environmental Control data, 1999

Sample location	**Maximum concentration** (picocuries per liter)	**Mean concentration** (picocuries per liter)	**Percent of drinking water standard** (mean concentration)
Upper Three Runs	34,649	4,189	21
Four Mile Creek	213,646	176,767	884
Four Mile Creek (30 feet from creek mouth)	206,764	127,599	638
Four Mile Creek (150 feet from creek mouth)	132,286	57,722	229
Beaver Dam Creek	1,788	797	4
Steel Creek	34,466	13,060	65
Lower Three Runs	1,576	973	5

Source: SCDHEC, 1999, Appendix D, pages 13, D-24 and D-25

The relatively large flow of the Savannah River dilutes the tritium and lowers its concentration, normally to below the drinking water standard, as can be seen in Table 7 below. Yet, it is clear that SRS operations and past dumping have a significant effect on levels of tritium in the river, with concentrations downstream being ten to twenty times those upstream from SRS discharge points. It must be noted that the portion of the Savannah River that is close to the Four Mile Creek discharge point is significantly above the safe drinking water limit of 20,000 picocuries per liter (Table 6).

Table 7: Mean concentration of tritium in the Savannah River, 2000 to 2002, picocuries per liter

River Mile (description)	**Tritium concentration 2000**	**Tritium concentration 2001**	**Tritium concentration 2002**
160.0 (upstream of SRS)	110	82.3	171
150.4 (at Four Mile Creek)	2,220	2,280	2530
150.0 (south of Four Mile Creek mouth)	2,130	1,230	1080
141.5 (south of Steel Creek mouth)	1,420	1,220	1120
118.8 (south of the swamp and SRS)	1,180	1,020	1010

Source: WSRC, 2000a, page 69, for Year 2000; WSRC, 2001a, Excel Table "Radioactivity in Savannah River Water, for Year 2001; WSRC, 2002f, Excel Table in CD entitled "Radioactivity in Savannah River Water," for Year 2002.

The concentration at the mouth of the river at Savannah, Georgia, in 2002, was 774 picocuries per liter (see Table 8 below).[77] This means that the entire length of the Savannah River from the south end of SRS to the Atlantic Ocean is affected by SRS tritium discharges. In the past few years, the concentrations of tritium in the Savannah River have been at about 5 percent of the present safe drinking water standard -- that is, it is well within the regulatory limit. While we may conclude from this that the cancer risk to adults from Savannah River water is very low (i.e., well below regulatory limits), it does not put to rest all the essential health-risk-related questions such as non-cancer risks and risks to children and fetuses (see Chapter V).

A. SRS Tritium in Georgia

Tritium from SRS affects Georgia in several ways:

- SRS discharges pollutants, including tritium into the Savannah River, which means that river water is polluted with tritium, though at levels that are well below safe drinking water limits.
- Rainwater on the Georgia side of the Savannah River contains levels of tritium that are attributed to SRS air emissions.
- The groundwater from the Upper Three Runs Aquifer in Georgia is contaminated with tritium attributed to rainfall contaminated by SRS emissions (see below).
- The fish in Savannah River are contaminated with tritium and other radionuclides from SRS (see Chapter IV).

None of these sources of contamination give radiation doses that are near or above present regulatory limits.

In 1991, tritium was discovered in drinking water wells in Burke County, Georgia, which borders the Savannah River across from SRS. A subsequent study found tritium contamination in 15 wells with an average of 500 picocuries per liter and a maximum of 3,500 picocuries per liter. The latter figure is almost 18 percent of the regulatory limit for drinking water. Data indicate that the wells drew water from the Upper Three Runs Aquifer, where the contamination appears to be centered in Georgia groundwater.[78]

There has been considerable investigation of the source of tritium contamination in Georgia groundwater. As we have discussed, SRS is the principal source of tritium discharges to the Savannah River. The issue that has been investigated is how the contamination gets from SRS, which is on the South Carolina side of the Savannah River, to the Georgia side. These investigations have led to a generally accepted conclusion that at least some of the contamination in Georgia groundwater comes from the contamination of rainwater by SRS air emissions (evaporation of tritiated water). Isopleths of the tritium content of rainwater clearly show the highest levels of tritium closest to the site, declining with distance.[79]

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[77] WSRC, 2002d

[78] GDNR, 1994, pages i and p. 44

[79] GDNR, 1999, pages A-11 to A-12. A 2002 report of an official investigation also concluded that contaminated

The Georgia Department of Natural Resources has summarized data for tritium in rainfall on the Georgia side of the Savannah River. Their summaries show rainwater contamination of several thousand picocuries per liter in the 1980s, declining to several hundred to 1,000 or more picocuries per liter in the 1990s.

The issue that remains unresolved is whether tritium migrates directly from contaminated aquifers at SRS beneath the Savannah River into Georgia (called transriver flow). In 1991, DOE asked the U.S. Geological Survey to study the groundwater flow and stream-aquifer relations in the Savannah River basin near SRS to determine whether transriver flow is occurring. The first part of the study, which included drilling wells and water quality analysis, was completed. The study was published in 1994.[80]

In 2001, DOE funded a panel of four scientists to determine whether "tritium-contaminated water from SRS releases can migrate and/or have migrated" into Georgia aquifers.[81] In January 2002, the panel released its report, which concluded that based "on the available data, there is insufficient evidence to confirm or refute whether tritium has or may in the future migrate under the Savannah River from the SRS site."[82] It recommended that the U.S. Geological Survey (USGS) be funded to complete the studies that it was conducting under DOE, including "more localized groundwater modeling" and "a more thorough evaluation of the impact of different groundwater withdrawal scenarios."[83] In late 2002, DOE "contracted with the USGS to continue looking at groundwater flow on the SRS plant site, but many of the recommendations of the [panel] are not included within the scope of work and thus are going unfunded."[84] DOE funding to the State of Georgia for environmental monitoring related to SRS is set to expire April 30, 2004, as of this writing (mid-February 2004).[85]

B. Tritium in Drinking Water

SRS drinking water is supplied by 18 separate systems, all of which use groundwater. Only three of the systems, A-Area, D-Area, and K-Area, are classified as "nontransient/noncommunity systems" and thus "are actively regulated by SCDHEC [South Carolina Department of Health and Environment Control]."[86] Many of the water systems require treatment to meet the SCDHEC and U.S. Environmental Protection Administration (EPA) drinking water standards.[87] Treatment includes "aeration to remove dissolved gases; filtration to remove iron; and addition of ... chemicals to adjust pH, prevent piping corrosion, and prevent bacterial growth." The biological

atmospheric tritiumtransport from South Carolina contributed to the well water contamination in Burke County. (See Moeller et al., 2002, page 4)

[80] GDNR, 1994

[81] Moeller et al., 2002, page 2

[82] Moeller et al., 2002, page 4

[83] Moeller et al., 2002, page 7

[84] Setser and Hardeman, 2002

[85] Hardeman, 2004a.

[86] WSRC, 2000b, pages 23, 138, and 139. The three nontransient/noncommunity systems serve more than 25 people.

[87] SCDHEC Regulation R.61-58 and EPA, 2003

and chemical compliance samples were below maximum contaminant levels in 2000.[88]

Municipal drinking water systems near SRS, in South Carolina, use both groundwater and surface water, with 25 of 28 depending on groundwater. However, about 57 percent of the customers depend on the 3 surface water systems.[89] Table 8 shows the mean concentration of tritium in one upstream and two downstream drinking water systems in 2000 and 2002.

Table 8: Mean concentration of tritium in drinking water systems offsite, finished water, in 2000 and 2002

Treatment plants	Tritium, finished water, pCi/liter, 2000	Tritium, finished water, pCi/liter, 2002
North Augusta Public Water Works (upstream of SRS)	41.2	132
Beaufort Public Water Works	1030	824
City of Savannah Industrial and Domestic Water Supply Plant	950	774

Source: WSRC, 2000a, Table 21, p. 75; WSRC, 2002e. The EPA safe drinking water limit is 20,000 picocuries per liter.

C. Comments on tritium contamination

DOE argues that there is not a problem with tritium contamination, because the concentration of tritium is ten times lower than the drinking water standard for tritium (20,000 picocuries per liter). But DOE must also adhere to keeping releases "as low as reasonably achievable" (the ALARA principle), so the fact that the level is below the maximum limit is not a sufficient argument for meeting regulations or public safety requirements.

For reference, it is important not only to note that while the levels of contamination of some groundwater are well below the safe drinking water limit, they are well above natural background. The natural concentration of tritium in lakes, rivers, and potable waters was 5 to 25 picocuries per liter prior to nuclear weapons testing.[90] Nuclear weapons testing greatly increased the amount of tritium in the atmosphere and though most of this has decayed away, there is still sufficient tritium from bomb testing to elevate global tritium levels. Rainwater over Atlanta in the early 1990s was about 39 picocuries per liter. For purposes of analysis, this might be considered as background (natural and bomb-testing) unaffected by SRS operations.[91] The figure of 1,000 picocuries per liter is 20 times below the safe drinking water limit; however, it is also more than 25 times above the rainwater tritium content in Atlanta.

The South Carolina Department of Health and Environmental Control allows for the use of

[88] WSRC, 2000b, pages 138 and 24
[89] SCDHEC, December 2001, page 7
[90] Eisenbud and Gesell, 1997, page 18
[91] GDNR, 1994, pp. 13-14

groundwater mixing zones only under certain situations.[92] Specifically, all of the following requirements must be met:

1. The contamination source must be under control and/or commitments have been made and steps implemented "to minimize the addition of contaminants to ground water."
2. The contaminated shallow aquifer is unlikely to be used or will not be used as a source of drinking water and discharges of pollutants to surface water will not result in violation of applicable standards.
3. The contaminants will likely remain within the property and are unlikely to flow offsite.
4. "The contaminants in question are not dangerously toxic, mobile, nor persistent."[93]

These criteria are not met with the tritium contamination at SRS for the following reasons:

1. Capping has slowed but not stopped the release of contamination from seepage basins and landfills.
2. The contamination flows offsite, via surface streams, to the Savannah River.
3. The contamination is toxic and mobile. While tritium does decay, its half-life of 12.3 years is long enough and the source of contamination large enough that the contamination persists and continues to migrate offsite and contaminate the Savannah River.
4. Some contaminants are very long-lived and DOE is highly unlikely to be able to ensure that the shallow groundwater will never be used for drinking (see Chapters V and VI).

[92] SCDHEC Regulation R.61-68, Section C.11, page 10
[93] SRS CAB, October 2001

Chapter IV: Other Radioactive and Non-Radioactive Contamination

A. Radionuclides

In addition to tritium, other radionuclides also migrate from the burial grounds and seepage basins to the groundwater. Concentrations of some radionuclides are above drinking water standards in the groundwater under many of the site areas. Currently, concentrations of these radionuclides are low both in the SRS streams and in the Savannah River. However, large source terms– that is, sources from which radioactivity could migrate into water – remain in the buried wastes and contaminated soils at SRS.

For instance, in the F- and H-Areas, migration from the burial grounds and seepage basins has led to highly contaminated groundwater, especially with strontium-90 and iodine-129, which have half-lives of 28.1 years and 16 million years, respectively. Radium-226, uranium isotopes, iodine-129, and strontium-90 are significantly above drinking water standards in the groundwater. Some of these radionuclides have migrated from the groundwater under the seepage basins to Four Mile Creek. Iodine-129 concentration at point of discharge into the Savannah River averaged 40 percent of the drinking water standard in 1998.[94] Technetium-99 migration from the F- and H-areas also contributes to groundwater contamination. Alpha and beta-emitting radionuclides are also present in other SRS surface streams.[95] Those concentrations are generally measured to be below current drinking water standards.

B. Organic Toxic Compounds

Volatile organic compounds, particularly trichloroethylene (TCE) and tetrachloroethylene (PCE), were used as degreasers throughout SRS. TCE is one of the primary groundwater contaminants throughout the site. "The highest concentrations of volatile organics ...generally are found under seepage and settling basins in central and southern portions of the [A-Area and M-Area]."[96]

TCE and PCE are also classified as dense non-aqueous phase liquids (DNAPL), because they are more dense than water and relatively insoluble in it. DNAPLs are particularly difficult to remove from groundwater, because they tend to migrate along vertical fractures and form lateral structures of pollution when they encounter less permeable layers. DNAPLs trapped in pore space slowly dissolve into the groundwater over a long period of time. These "sinks" of DNAPLs found in pockets and pore spaces are particularly difficult to locate and remove.

Large amounts of solvents were discharged into unlined basins in the 350-acre A/M-Area.[97] And although DOE ceased it massive dumping of toxic chemicals years ago, there are some locations at SRS where concentrations of TCE in groundwater are increasing. For example, the TCE concentration in a southwestern well (MSB 2B) increased nearly three-fold from 1996 to 2000 (4,880 micrograms per liter to 13,000 micrograms per liter). The highest concentration in the

[94] GDNR, 1999, pages A-4 and D-58
[95] WSRC, 2001b, pages 49 and 53
[96] WSRC, 2000b, page 166
[97] Massman, November 1999, page 1 and DOE-SRS, January 2002d

year 2000 was in a northern well with a concentration of 40,300 micrograms per liter. The drinking water standard for TCE is 5 micrograms per liter.[98]

In order to slow the spread of contamination, the basins in the A/M-Area have been capped[99] and a program of pump-and-treat with air strippers is being used to remove the volatile organic compounds from the groundwater. One air-stripper is located in the northern section of the A/M-Area and the other is located south of the M-Area Hazardous Waste Management Facility. According to Westinghouse, "The two ... air strippers have removed more than 400,000 pounds of solvent from over 4.3 billion gallons of groundwater."[100]

Since 1995, DOE has also been using another method, called "soil vapor extraction" or "soil vacuum extraction" to clean out solvents from the vadose zone. There are currently six vapor extraction systems operating in the A/M-Area. Soil vapor extraction has been used to remove almost 600,000 pounds of solvents from the vadose zone.[101] Monitored natural attenuation is planned for the most dilute portion of the plume.[102]

The total amount of solvent that had been removed from both the groundwater and the soil was about 950,000 pounds as of January 2002.[103] Uncertainties in the amount and the distribution of the solvents in the soil mean that the total time and resources that will be required to clean up the contamination are essentially unknown. Vapor extraction suffers from a problem similar to pump-and-treat systems for water: the cleaner the soil becomes., the more difficult it is to extract the remainder of the contamination with vapor extraction.[104]

TCE is also present in the D-Area and in the TNX shallow aquifers[105] The plume of TCE contamination in the TNX area seems to be moving via the Savannah River Swamp and was within a several hundred feet of the Savannah River by 1990.[106] The groundwater pump-and-treat system at TNX has decreased TCE concentrations over time, but concentrations exceed drinking water standards in seven wells.[107]

TCE concentrations above the drinking water standard are also found in the groundwater in the E-, F-, and H-Areas. The range of contamination in these Areas is between 14.7 and 1,160 micrograms per liter.[108] The drinking water standard for TCE is 5 micrograms per liter.

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[98] WSRC, 2000b, pages 166 and 169
[99] DOE-SRS, January 2002d
[100] DOE-SRS, January 2002e. "An air stripping system works bypumping contaminated groundwater to the top of an air stripping column. As the groundwater cascades downward through the column, pumped air is forced upward from the bottom of the column. When the water mixes with air, solvents in the groundwater move from a liquid phase into a vapor phase, and volatile contaminants are stripped and released to the atmosphere. The cleaned water is discharged through a permitted outfall to a nearby stream at levels less than 1 part per billion." (DOE-SRS, January 2002e)
[101] DOE-SRS, January 2002e, page 2; WSRC, 2000b, page 169
[102] Bergren and Huber, 1999, page [8]
[103] DOE-SRS, January 2002e, page 2
[104] Massman, November 1999, pages 2 and 29
[105] WSRC, 2000b, page 174
[106] RAC, April 2001, page J-8, citing Cummins, et al. 1991
[107] WSRC, 2000b, pages 174 to 176;DOE-SRS, March 2002b
[108] DOE, May 2002b, page 3-17 to 3-19

Volatile organic compounds, especially TCE and PCE, are also in the groundwater under other areas at SRS, such as the K- and L-areas and the Burning/Rubble Pits.[109] In the case of the K- and L-areas, the TCE and PCE contamination exists along with the tritium in the groundwater.[110]

C. Mercury and Cadmium

Mercury was used at SRS mainly to produce lithium-6, which is the material irradiated in a reactor to produce tritium. It was also used for other purposes, such as a sealant in tritium gas pumps.[111] Specifically, mercury was used to separate lithium-6 from lithium-7, with the former being used as target material in reactors for producing tritium. Over 10 metric tons (about 24,000 pounds) of mercury are mixed in the waste in the Burial Ground.[112] Mercury and cadmium appear to be migrating into the groundwater in the F- and H-areas. The average concentration of cadmium in the F-area shallow groundwater and for mercury below the H-area exceeded maximum allowable concentrations in 1999.

Table 9: Cadmium and mercury in F- and H-Area groundwater, 1999

Metal	Concentrations (micrograms per liter)				
	F-Area		H-Area		Regulatory limit
	Average	Maximum	Average	Maximum	
Cadmium	7.8	37	BAL	BAL	5
Mercury	0.63	7.4	2.4	16	2

Source: Serkiz et al., 2000, page 3
Note: BAL=Below allowable limit

The solubility of mercury in water depends on a variety of conditions, including the chemical form of the mercury and parameters (such as pH) of the solvent water. In the Burial Grounds, average mercury concentrations have exceeded 3 micrograms per liter in at least four areas of the site.[113]

D. Contaminant Levels in Fish

Fish bioaccumulate certain elements, especially cesium-137 and mercury.[114] By the mid-1950s,

[109] WSRC, 2000b pages 183 to 187
[110] WSRC, 2002b, Table 6-1, page 59
[111] WSRC, August 2000, pages C-1 to C-3
[112] WSRC, August 2000, page C-1
[113] WSRC, August 2000, page 2-64
[114] WSRC, 2000b, page 114 and 141. "Cesium is chemically similar to potassium and tends to replace potassium in animal flesh. (Connor, 1996). Mercury in streams and rivers is "converted to ... methylmercury by bacteria l and other processes ....Fish absorb methylmercury from food they ingest and from water as it passes over their gills; the methylmercury then is bound in their tissues." (WSRC, 2000b, page 142). "High-dose human exposure of mercury results in mental retardation, cerebral palsy, deafness, blindness, and dysarthria in utero and in sensory and motor impairment in adults .... Data on cardiovascular and immunological effects are also beginning to be reported and provide more evidence for toxicity from low-dose methylmercury exposure." (EPA-OST, January 2001, pages ix to x).

it was evident that fish in the Savannah River were impacted by SRS activities, including bass, bream, and catfish.[115]

Fish in the Savannah River have concentrated about 3,000 times more cesium than levels found in the water.[116] The highest level of Cs-137 was 1.58 picocuries per gram of fresh weight. Most measurements are an order of magnitude below this.[117]

Neither South Carolina nor Georgia has issued fish consumption guidelines based on cesium-137 concentrations in fish.[118] The Georgia Department of Natural Resources found a maximum of 2 picocuries of cesium-137 per gram (fresh weight) in SRS outfalls, with a mean of 0.200 picocuries per gram (fresh weight).[119] According to Georgia's Department of Natural Resources, the mercury guidelines are sufficient to be protective for cesium-137.[120] Given the present mix of contaminants, limiting fish consumption based on the mercury guidelines would keep doses from cesium-137 below 1 millirem and therefore under any applicable standards. However, DOE is leaving an enormous amount of residual cesium-137 and other radionuclides in the tanks, which may create a greater threat in the future. This problem will be multiplied many fold if DOE does not implement some method to extract most of the cesium-137 from the tank waste (see Chapter V). Further, the problem of cesium-137 in the river and the fish should be evaluated together with that of Iodine-129 (see below), tritium, and mercury. Further, the issue of subsistence fishing needs to be addressed. Current standards and guidelines may not be sufficient to protect some populations when all pollutants and vulnerabilities are taken into account.

Tritium, some of it organically bound (and hence with a longer residence time in the body relative to tritiated water), is also found in the area's fish. The Georgia Department of Natural Resources found a maximum of 13 picocuries of tritium per gram (fresh weight) in SRS outfalls, with a mean of 2.1 picocuries per gram (fresh weight).[121]

Although it is illegal to fish within the SRS boundary, some people may poach fish from within its boundary.[122] Over the long run it would be virtually impossible to guarantee that areas currently within the SRS boundary will remain so and be off-limits to fishing. Radionuclide concentrations in fish from SRS locations have been consistently higher than offsite locations.[123]

According to Westinghouse: "Mercury concentrations in offsite fish ranged from a high of 1.629 [micrograms per gram] in a bass ... to a low of 0.016 [micrograms per gram] in a mullet." Mercury concentrations in fish caught at SRS "ranged from a high of 1.817 [micrograms per gram] in a bass from Par-Pond to a low of 0.094 [micrograms per gram] in a bream in L-Lake."

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[115] RAC, April 2001, pages 14-2 and 14-3. "Routine collection of fish began in July 1957," though limited sampling was conducted prior to 1957.
[116] WSRC, 2000b, page 114
[117] WSRC, 2000a, pages 94 to 96
[118] SCDHEC, 2003a, SCDHEC, 2003b
[119] GDNR, 1999, page A-18
[120] GDNR, 2003, page 39
[121] GDNR, 1999, page A-10
[122] RAC, April 2001, page 14-1
[123] RAC, April 2001, page 14-21

Bass were found to accumulate the highest levels of mercury.[124]

According to the South Carolina Department of Health and Environmental Control, bluegill, sunfish, catfish and crappie from the Savannah River along SRS should be limited to one meal (8-ounces or 0.227 kg) a week (1.14 0z./day), while largemouth bass and bowfin from the Savannah River along SRS should be limited to one meal per month. This is based on the mercury content of the fish, and not on the radionuclide levels.[125]

Social research indicates that some people use the Savannah River for subsistence fishing, usually defined to include those individuals who consume approximately 50 kilograms (110 pounds) of fish per year (about 2 pounds per week). A 1996 survey by Morris, Samuel, and students of Benedict College indicated that people fish near the SRS outfalls that are contaminated.[126] A 1999 survey of people fishing along the Savannah River found that some individuals eat as much as 50 to 100 kilograms of fish from the Savannah River per year.[127] There are people from various segments of the population who practice subsistence fishing, including Whites, but both surveys found that the practice is more common among African-Americans, who, on average, also eat more fish from the river than Whites. The average daily consumption among African-Americans indicated by the 1999 survey was about four ounces, or four times the maximum limit recommended by the South Carolina Department of Health and Environmental Control. *Reducing pollution in the Savannah River along SRS is therefore an essential aspect of environmental justice as well as of protecting the health of all people who depend on the river for their subsistence and as an important source of protein.*

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[124] WSRC, 2000b, page 141

[125] SCDHEC, 2003b, Table II

[126] Milton Morris and May Linda Samuel, *A Study of Factors Relating to Fish Subsistence/Consumption Within Communities Near the Savannah River Site* (Benedict College, Columbia, South Carolina), November 26, 1996, pages 29, 89, and 91. See answers to questions 10 and 21. Benedict College is an historically Black college in Columbia, South Carolina. IEER thanks Dr. May Linda Samuel for providing us with the research data and making a presentation on the subject at an IEER workshop.

[127] Burger et al., 1999, pages 432 and 433

Chapter V: Remediation of SRS

There are four threats to the water resources of South Carolina and Georgia from SRS:

1. Migration of radionuclides from shallow land disposal of wastes at SRS due to processing of existing waste, such as that now stored in high-level waste tanks and other containment structures.
2. Flow of contaminants from plumes presently onsite into offsite water bodies, both via groundwater and surface water transport.
3. Migration of radionuclides from dumps and burial grounds into aquifers onsite and from there to offsite groundwater and surface water.
4. Migration of waste disposed of onsite from future production or processing activities.

We will discuss the first three items in this chapter. The last is beyond the scope of this report.

A. High-level waste tanks

More than 99 percent of the radioactivity in the waste at SRS is contained in the high level waste. Of this only about one percent (about 4.2 million curies) has been extracted from the tanks, mixed with molten glass and cast into glass logs at a vitrification plant for high-level waste, called the Defense Waste Processing Facility, which was opened in 1996. The 1221 glass logs that have been cast are in steel-alloy canisters, and are stored onsite pending disposal in a high-level waste repository. In the short- and medium-term, this vitrified waste poses the least risk of contaminating the environment at the site. In the long term, it must be disposed of in a deep geologic repository.[128]

DOE has not yet determined how the bulk of the waste from the tanks will be disposed of. The original waste management plan, adopted in the 1980s was to treat the salt and supernate wastes, which is about 90 percent of the volume, remove the key radionuclides (especially cesium-137) and vitrify almost all the radioactivity. The bulk liquid that would remain was planned to be mixed with cement and disposed of onsite as low-level waste called saltstone.

DOE's original plan to separate the cesium-137 from the salt wastes ran into severe technical difficulties. The method originally chosen, large-scale in-tank precipitation (ITP) using tetraphenyl borate, was abandoned in 1998.[129] The main problem was that the residual waste generated benzene, a flammable and toxic gas whose presence in the tanks gave rise to risks of fire in radioactive wastes.

[128] The only high-level waste repository being investigated in the United States at present is the site at Yucca Mountain, Nevada. Laboratory experiments have shown that the geology of this site is not compatible with glass as a waste form. (See Makhijani, January 1991). DOE's own modeling shows that the geology of the site is not estimated to play a significant role in retaining the wastes, leaving almost the entire function of radionuclide containment to be performed by metal canisters into which spent fuel or the SRS high-level waste would be inserted. (See DOE charts in Makhijani, 1999). But Yucca Mountain is an oxidizing environment, raising the possibility that the canisters may corrode faster than the DOE projects.

[129] NRC-NAS, 2001, page 24

In July 2001, DOE announced that it had decided to extract cesium-137 from the salt solution using specific organic solvents with a technology called Caustic Side Solvent Extraction.[130] Currently, DOE is researching this technology, as well as back-up technologies, including an ion-exchange method and small tank tetraphenylborate precipitation.[131] This latter approach is chemically identical to the earlier in-tank precipitation method, with the main exception that smaller tanks are to be used in this version. The extracted cesium-137 waste would be vitrified.

In its August 2002 Record of Decision, DOE decided to follow the same procedure to close the remaining 49 tanks as it has with the two tanks it has closed so far -- filling the tanks with grout after the bulk of the waste has been removed.[132] As we have noted in Chapter II, the "heels" of radioactive materials left in these tanks contain substantial amounts of radionuclides. The residual cesium-137 activity of the residual waste in Tank 19 *alone*, over 48,000 curies,[133] exceeds the *total estimated* cesium-137 activity for the residual waste in *all* the tanks in the F- and H-Area Tank Farms (9,900 curies) in the High-Level Waste Tank Closure Final Environmental Impact Statement.[134] The tank waste that remains to be vitrified contains far more radioactivity than the tanks that have been emptied so far. The Tank Closure EIS estimates the residual radioactivity in the F and H Tank Farms as about 170,000 curies; the far higher actual residual waste means that closure of over four dozen high-level waste tanks may result in a million curies or more remaining onsite as a future threat to the groundwater and streams onsite and, therefore, to the Savannah River

In fact, the closure plan for Tank 19 is a blatant, illegal, and dangerous example of "dilution is the solution to pollution." The residual waste in the tank is estimated to have a concentration of radioactivity over 14 times the Class C low-level waste limit, which defines the most radioactive waste allowed to be put into shallow land burial. The Class C limit is exceeded for each one of four radionuclides by itself: plutonium-238, plutonium-239, plutonium-240, and americium-241. The tank residuals are therefore "Greater than Class C waste," or equivalently, transuranic waste, of the type that is generally required to be disposed of in a deep geologic repository. But once the tank residual wastes are diluted with a huge amount of grout, the closure document estimates that the resultant waste will be 0.997 times the Class C limit – that is, it would squeak under the wire of present "low-level" waste rules. Allowing such dilution and dumping could open the door to diluting even more radioactive wastes and leaving them by the riverside to threaten people far into the future.[135]

Plutonium is another concern. The "emptied" Tank 19 is estimated to contain 30 curies of plutonium-239, and almost 11 curies of plutonium-240.[136] This Pu-239/240 inventory amounts to about half a kilogram. Given that less than two percent of the radioactivity in all of the sludge has been vitrified (4.2 million curies out of 320 million curies) and that almost all of the

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[130] DOE, July 2001

[131] Contardi, July 2001, page 2

[132] DOE, August 2002. Residual waste consists of solids firmly attached to the tank surfaces as a "crust" or "hard-heel," which is more difficult to remove from the tanks than the bulk of waste, as well as interstial liquids.

[133] d'Entremont and Thomas, November 2002, Table 3, page 16

[134] DOE, May 2002b, page C-18, Table C.3.1-1

[135] d'Entremont and Thomas, November 2002, Table 6, page 19

[136] d'Entremont and Thomas, November 2002, Table 3, page 16

plutonium is in the sludge, the eventual residual plutonium-239/240 in the tank farm may be very substantial. In addition, the Tank Farms contain well over a million curies of plutonium-238,[137] which has a half life of about 87 years. Residual radioactivity of even one or two percent in these tanks would leave a vast amount of total alpha-emitting plutonium radioactivity in the tanks as low-level waste.

DOE is planning to evaluate each tank on a case-by-case basis, in what DOE calls "Closure Modules."

> Each tank system or group of tank systems would be evaluated to determine the inventory of radiological and nonradiological contaminants remaining after bulk waste removal. This information would be used to conduct a performance evaluation as part of the preparation of a Closure Module. In the evaluation DOE would consider (1) the types of contamination in the tank and configuration of the tank system, and (2) the hydrogeologic conditions at and near the tank location, such as the distance from the water table and distance to nearby streams.[138]

Therefore, "the closure configuration for each tank or group of tanks would be determined on a case-by-case basis through the development of the Closure Module."[139] The South Carolina Department of Health and Environmental Control must approve the Closure Modules, but it is unclear how SCDHEC could make such a determination on a case-by-case basis. The General Closure Plan involves estimating the performance of all tank closure together. For example, a total 4 millirem-per-year limit in drinking water in the receiving stream from all tanks and all radionuclides must be premised upon some overall plan that includes a tank by tank evaluation, and adds it up for all tanks. The DOE approach cannot provide a basis for such an evaluation, especially since the actual tank-by-tank plans indicate that there will be far more residual radioactivity than that estimated in the Final Closure EIS. The DOE plan is risky, to say the least. A large part of the risk lies in the fact that the preferred alternative is closure of the tanks by grouting. If grouting is found to be unsatisfactory from the point of view of a 4 millirem drinking water standard in the receiving stream, it cannot be undone or remediated.

1. DOE Contingencies

DOE broached the possibility of abandoning most high-level waste onsite in November 2001:

> HLW [High-level waste] processing is the single largest cost element in the EM [Environmental Management] program today. Eliminate the need to vitrify at least 75 percent of the waste scheduled for vitrification today. Develop at least two (2) proven, cost effective solutions to every high-level waste stream in the complex.[140]

[137] DOE's then-contractor for SRS, Dupont, listed the Pu-238 content of the Tank Farm in 1986 as being 1.5 million curies. See Makhijani, Alvarez, and Blackwelder, 1987, Table 1, and associated discussion. This would have decayed to about 1.3 million curies by 2003.

[138] DOE, August 2002

[139] DOE, August 2002

[140] Roberson, November 2001

DOE's initial approach to getting around the high-level waste act, which requires deep geologic disposal of high-level waste, was to redefine the waste from high-level to a newly created category, not established in law: "waste incidental to reprocessing." DOE laid the basis for this new waste classification in 1999 in Order 435.1 and in its Radioactive Waste Management Manual, DOE M 435.1-1.[141] DOE acknowledged in DOE G 435.1-1 that its definition of high-level waste is "slightly modified from the Nuclear Waste Policy Act of 1982."[142] However, the change is much larger than this phrase would imply, because DOE has introduced the criteria of technical and economic practicality of processing into its definition. DOE claims that incidental wastes that can be managed as low-level wastes "may include, but are not limited to, spent nuclear fuel reprocessing plant wastes that ...[h]ave been processed, or will be processed, to remove key radionuclides to the maximum extent that is technically and economically practical."[143]

DOE claims that the waste left in the two closed tanks is "incidental waste," even though in the past DOE itself had classified it as high-level waste. According to a 2000 report by the National Academy of Sciences (NAS), there are several obstacles to reclassifying the high-level waste as waste incidental to reprocessing. To declare the waste as incidental, DOE Order 435.1 in Appendix D requires that the "waste must receive processing to remove key radionuclides to the maximum extent that is technically and economically practical." However, the authors reasoned that the evidence indicates that the waste is practically and economically treatable, though the costs are slightly higher than with direct grouting. In addition, the level of cesium-137 that would be incorporated in the grout is several orders of magnitude higher than the current state permit limits. Further, in Tank 19, the residual radioactivity is well beyond Class C waste limits. It will have high residual plutonium content, which puts it in the category of waste that must be disposed of in a deep geologic repository. Finally, SRS would also have to demonstrate that the waste would meet the long-term performance objectives in DOE Order 435.1. The authors of the NAS report concluded that the direct grout waste stream is high in long-lived radionuclides and "the ability of the site to reliably meet long-term safety performance objectives remains uncertain."[144]

The Natural Resources Defense Council, the Confederated Tribes & Bands of the Yakama Nation, and the Snake River Alliance filed a lawsuit against DOE alleging that reclassification is in contravention of the Nuclear Waste Policy Act.[145] In July 2003, the court ruled in favor of the plaintiffs that the redefinition is illegal.[146] DOE is appealing. Thereafter, DOE has attempted to get Congress to give it clear authority to make such classification changes, but, as of this writing (mid-February 2004), without success.

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[141] DOE, July 1999, page II-3. It could be argued that the foundation for the new waste category was in DOE Order 5820.2A, which preceded DOE Order 435.1, because DOE's closure of Tank 20 was based on performance assessment objectives contained in DOE Order 5820.2A. This allowed DOE to determine that the residuals in the tank after repeated cleaning are "incidental wastes" that could be disposed of as low-level waste as long as they were not greater than Class C wastes.
[142] DOE, July 1999, page II-1
[143] DOE, July 1999, page II-13
[144] NRC-NAS, 2000b, pages 76-79
[145] NRDC v. DOE, 2002
[146] NRDC v. DOE, 2003

2. Performance of Grout

There is insufficient understanding of the long-term risks to groundwater and surface water from shallow land burial of grouted wastes. Given past experience with grouting of wastes (discussed below), these contaminants could leach out into the groundwater much faster than anticipated and add to the existing contamination in the groundwater, and eventually to the surface water. Moreover, grouting the tanks in place would put the residual wastes in a form that would be very difficult or impossible to retrieve were they found to be leaking. Grouting would also make remediation of the vadose zone even more difficult. DOE admits that "tank closure is, for all practical purposes, irreversible. DOE would have great difficulty undoing a closure [with grout] if it were later discovered that [a dose] estimate had been improperly developed, or that the performance had been improperly evaluated."[147]

According to a report on long-term stewardship by the National Academy of Sciences:

> Predicting performance in resisting water infiltration can be difficult because of uncertainties that include the degree to which the first layers of grout take up the residue, the water pathway effects of the cold joints between successive pours of grout, and the effects of preferential corrosion of the tank metal and penetrating structures (thereby offering a partial bypass path). Moreover, waste tank residue is likely to be highly radioactive and not taken up in the grout, so there is substantial uncertainty associated with the volumetric classification and average concentration of the waste and prediction of the isolation performance of the system.[148]

While experience at other sites with grout does not correspond in its details with that at SRS, it is indicative of the kinds of problems that have already been experienced with grouting. We examine two such cases here.

DOE sponsored studies on grout durability in the context of a grouting program at Hanford. The durability of grout depends on many factors, such as temperature and moisture, and the composition of the grout. The heat due to radioactive decay, for instance, and/or the heat that is released when the grout sets can raise the temperature above 90° Celsius (194° F). At such temperatures the grout may not set properly, and hence it may subsequently crack. According to a 1992 study of the durability of double-shell tank waste grouts at Hanford:

> The grouts will remain at elevated temperatures for many years. The high temperatures expected during the first few decades after disposal will increase the driving force for water vapor transport away from the grouts; the loss of water may result in cracking, dehydration of hydrated phases, and precipitation of salts from saturated pore solution. As the grout cools, osmotic pressure caused by the high salt content may draw moisture back into the grout mass. The uptake of moisture may have detrimental impacts on the behavior of the grout.[149]

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[147] DOE-SRS, November 2001
[148] NRC-NAS, 2000c, page 40
[149] Lokken, Martin, and Shade, December 1992, page 2

The history of grout at Rocky Flats, the nearly decommissioned DOE plant near Denver, Colorado, where plutonoium pits for nuclear bombs were made, indicates the risks in the real world, even in the absence of elevated temperatures.

Rocky Flats operations resulted in the generation of liquid and solid wastes containing radioactive and hazardous materials and large quantities of contaminated soil and groundwater. From 1953 to 1986, five ponds lined with asphalt and concrete (called Solar Ponds) were used to store and evaporate low-level waste contaminated with nitrates and radionuclides. Other waste was also dumped in the ponds from time to time.[150] The linings were ineffective, as demonstrated by the fact that the shallow groundwater in the area became contaminated with radioactive materials, nitrates, VOCs, and heavy metals.[151]

Because of the existing contamination and possible further contamination, DOE began phasing out the use of the ponds in early 1980s; it soon began another experiment with cement. In 1985, sludge from the solar evaporation ponds began to be mixed with cement to form large blocks of "pondcrete," which were packaged in fiberglass boxes and shipped to the Nevada Test Site for disposal. Soon after the project began, the waste had to be reclassified from low-level to mixed waste, because it was determined that the waste contained hazardous chemicals, regulated under the Resource Conservation and Recovery Act (RCRA). Over 16,500 pondcrete blocks of mixed waste were manufactured and stored onsite, outdoors, for nearly two years, while the permitting necessary for offsite shipment was being pursued.[152]

In 1988, it was discovered that some of the fiberglass boxes on the outdoor pad had deteriorated while exposed to the weather and some of the pondcrete blocks had crumbled and cracked. At least one box had spilled open. It was later determined that the ratio of cement to sludge waste in making the pondcrete was incorrect. The problem apparently arose because the equipment used to introduce cement plugged up intermittently. Over 8,000 pondcrete blocks, that is, about half of the blocks stored outdoors, had to be remixed and repackaged.[153]

The Nevada Test Site found that 25 of the 28 blocks of pondcrete that had not yet been buried were, contrary to specifications, with surfaces soft enough to be scored by a stick; it was decided to bury them anyway because no liquids were found. The Nevada Test Site determined that the approximately 2,000 blocks that had already been buried posed little threat of contaminant migration, based on its assessment of the 28 blocks, the distribution of the containers throughout the burial ground, and the dryness of the soil. However, in October 1988, the Nevada Test Site changed its acceptance criteria for the pondcrete. It required that the pondcrete be packaged in plywood boxes with a compressive strength of 4,000 pounds per square foot.[154]

Rocky Flats has been left with some of the legacy of the mess as well, despite the shipment of the pondcrete blocks to Nevada. The quantity of underlying contaminated soil under the Solar Ponds has not been fully determined, but is estimated to be slightly less than 153,000 cubic

[150] BEMR, 1996. Rocky Flats Environmental Technology Site section
[151] GAO, January 1991, page 3
[152] GAO, January 1991, pages 1 to 6
[153] GAO, January 1991, pages 2 to 4
[154] GAO, January 1991, page 5

meters (200,000 cubic yards) in that general vicinity.[155]

DOE is pursuing a cleanup program under which soil with contaminant concentrations greater than specified radionuclide soil action levels (RSALs) will be removed. However, the proposed RSALs at Rocky Flats are quite high: 50 picocuries per gram of plutonium in the top three feet, and 3000 pCi/g (based upon concentration and area/volume) in the three to six foot depth range.[156] These levels are far too lax and represent an unacceptable risk to future generations by traditional radiation protection standards, which aim at protecting future farmers or ranchers who might settle on the site, in case site control and information about the contamination are lost.[157]

In sum, grouting residual high-level waste in tanks that contains significant quantities of long-lived radionuclides (including cesium-137 and plutonium-238, and plutonium-239/240) is a policy that poses considerable risks to the long-term health of the water resources in the region.

B. Buried Waste

A variety of wastes have been buried, often literally dumped, at SRS. These include what came to be defined as transuranic waste (with high levels of alpha-emtting plutonium and/or other transuranic radionuclides), low-level radioactive waste, and mixed radioactive and non-radioactive toxic waste.

1. Transuranic Waste

Even though the TRU waste category was created in 1970 and TRU waste was designated for repository disposal, DOE buried transuranic (TRU) waste at SRS well into the 1970s. While the intent of these burials may have been retrievable storage, most of these wastes are currently believed to be essentially irretrievably buried.[158] Approximately 17,100 curies (4,530 cubic meters) of transuranic wastes are buried in the Old Radioactive Waste Burial Ground at SRS. Transuranic waste is also buried at the Low-Level Radioactive Waste Disposal Facility (38 curies) and the Mixed Waste Management Facility (1,390 curies).[159] The TRU activity associated with the buried TRU-contaminated wastes at the three locations at SRS is approximately 18,500 curies (decay-corrected to 2006).[160] The DOE Field Offices ranked the level of confidence associated with these data as "generally low to medium." At SRS, the estimates of the activity of the transuranic waste at the three locations are considered to be "reasonably good," but volume estimates for the Low-Level Radioactive Waste Disposal Facility and the Mixed Waste Management Facility are not known.[161]

The volume of transuranic-contaminated soil associated with buried transuranic wastes is highly uncertain. DOE has estimated that the volume is 38,000 cubic meters, but this value is more than

[155] BEMR, 1996. Rocky Flats Environmental Technology Site section
[156] Rocky Flats, 2003 , General Response, page 1
[157] See Makhijani and Gopal, December 2001, for further discussion of setting radionuclide soil action levels for Rocky Flats.
[158] Fioravanti and Makhijani 1997, pages 110 to 113
[159] Decay-corrected to 2006. DOE, June 2000, pages 22 and 23
[160] DOE, June 2000, page 12
[161] DOE, June 2000, page 12

10 years old and was derived by reviewing historical disposal records or from pit and/or trench dimensions rather than from field characterization activities.[162]

There is a huge area of 195 acres (78 hectares) called the Burial Ground Complex, where radioactive and mixed radioactive and non-radioactive hazardous wastes were dumped. A part of this, including 58 acres involving mixed wastes, has been closed and capped. Another 25 acres are also capped. Because of the hazardous materials, it is required to be, and is, regulated under the Resource Conservation and Recovery Act.[163]

The purpose of surface caps is to reduce water infiltration and hence the leaching of contaminants from the buried waste and the contaminated vadose zone to the groundwater. They are not a remediation method for already contaminated groundwater. Vegetation planted on the caps increases evapotranspiration and hence can reduce water infiltration. But vegetation also reduces runoff and may therefore sometimes increase water infiltration. In any case, caps are a short term palliative, not a long-term remedy. Physical and biological processes can also decrease the long-term performance of compacted soil caps. They include wetting and drying cycles, soil erosion, root intrusion, worms, and burrowing animals. Table 10 lists some of the main physical and biological processes that can decrease the long-term performance of compacted soil caps.

Table 10: Physical and Biological Processes Influencing Long-Term Performance of Compacted Soil Caps

Physical Processes	Biological Processes
Wetting and drying cycles	Root intrusion
Freeze-thaw effects	Worms
Soil erosion	Insects
Subsidence	Burrowing animals

Source: Smith, Luxmoore, and Suter, 1997, pages D-61 to D-67

The way in which physical, chemical, and biological processes interact to disperse radionuclides in the environment over the long term is not very well understood. For instance, it is often assumed that clay acts as a strong retardant for radionuclides through ion-exchange that binds metal cations in the waste to the soil. This assumption has been shown not to apply under certain field circumstances, as for instance when organic materials from decaying leaves accelerate the movement of radionuclides.[164] As for biological processes and radioactivity dispersal, DOE is sponsoring research on how bacteria might be used to concentrate radioactivity for the purpose of remediation.[165] But if bacteria can, under controlled circumstances, be used for remediation, they may equally well disperse radioactivity under natural circumstances where there are no means to prevent the microorganisms from spreading in the environment.

[162] DOE, June 2000, page 14
[163] DOE, January 2001, Vol. II, South Carolina section, page 26
[164] For more discussion and evidence, see Makhijani and Boyd, 2001, Fioravanti and Makhijani, 1997, and Makhijani and Gopal, December 2001.
[165] LBL, 2000

2. Low-level waste

In addition to transuranic wastes, DOE is planning to leave almost 1.4 million cubic meters of in-situ media contaminated with low-level waste in place, most of which will be covered with a surface cap or grouted.[166] (See Table 11).

Table 11: SRS management of in-situ media contaminated with low-level waste

Method	Volume (cubic meters)	Radioactivity (curies)*
Cap in place	898,576	Not given
Soil mixing/grouting	431,770	Not given
Monitoring	27,799	Not given
TOTAL	**1,358,145**	1,326,000

Source: DOE-EM, April 2001, page 10-19
Note: * Decay corrected to 2002: 571,000 curies in the Old Radioactive Waste Burial Ground. Decay corrected to: 755,000 curies in the Low-Level Radioactive Waste Disposal Facility. WSRC, August 2002, page 35; WSRC, December 2000, pages ES-11 to ES-16

In addition to the threat to surface and groundwater from the low-level waste in the Burial Grounds, DOE is continuing to dispose of low-level waste in unlined trenches in E-Area, which are exempt from independent external regulation. In the February 2000 Record of Decision for low-level waste disposal, DOE specified regional disposal sites at the Hanford Site and Nevada Test Site, with continued disposal of wastes generated onsite at SRS in E-Area Trenches, the Low Activity Waste Vaults, and the Intermediate-Level Waste Vaults.[167]

DOE's ongoing disposal of low-level waste using shallow unlined trenches could aggravate groundwater contamination problems in two ways. First, this disposal of low-level waste increases the inventory of waste in the ground that could later migrate to groundwater and/or surface water. Second, continuing to have the trenches open causes existing contamination to be driven further towards the aquifers. As rainwater collects in trenches and percolates downward, it can dissolve chemicals in the waste, as well as remobilize vadose zone contaminants, and carry them to the aquifer.

According to the original Performance Assessment for the E-Area Low-Level Waste Facility, which was issued in 1994, the trenches could only be used for radioactively contaminated soil. In 2000, the Performance Assessment was revised to include disposal of grouted radioactive ash and other grouted waste.[168] Disposal of waste is continuing despite the paost record of substantial groundwater pollution from past dumping.[169]

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[166] DOE-EM, April 2001, pages 10-18 and 10-19
[167] DOE, February 2000 and DOE-SRS, April 2002a
[168] "Components in grout" means placing the item on a one-foot thick grout base, filling any void space with grout, and grouting around the item using the trench walls as a form. (DOE-SRS, April 2002a, pages 2-3)
[169] DOE, January 1998b and WSRC, 2000b, pages 177 and 179

C. Tritium

As discussed in Chapter III, the principal radioactive surface discharge from SRS into the Savannah River is tritium, both now - 13 years after the last reactor start-up attempt at SRS - and for the immediate future.[170] The long-term threat that the serious shallow aquifer contamination on the SRS site poses to the deeper aquifers needs to be carefully and independently evaluated, given the importance of this aquifer to the southeastern United States.

Currently, tritiated water plumes are being managed with hydraulic pumping. In order to reduce the amount of tritium-contaminated water discharging through the seepline to Four Mile Creek, DOE installed a small dam, creating a small pond. An irrigation system pumps water from the pond to 30 acres of adjacent pine and hardwood-mixed forest. The trees and other plants take up the tritium-contaminated water and release some to the atmosphere through transpiration. DOE is calling this the "tritium phytoremediation project." The dam, completed in October 2000, and the irrigation system, operating since February 2001, have reduced tritium discharges to Four Mile Creek by about 50 percent.[171] However, equipment failure caused three large releases of tritium into the creek in 2001. While DOE states that this remediation is an "interim measure" there are no other specific plans to reduce tritium discharges to the river, other than simply waiting for it to decay, which will take many decades.[172]

Phytoremediation may reduce the pollution of SRS streams but it may carry a stiff, but, at present, unquantifible penalty because it may compromise the genetic integrity of the forest. Some of the tritiated water will become incorporated into the DNA of the trees and into seeds with unknown long-term effects.[173] The main approach to reducing tritium must be to remove the primary source: the solid waste in the burial grounds. While there is currently no technology to remove the relatively highly dilute levels of tritium found in the surface water at SRS, it may be possible to strip some of the tritium from the most contaminated water. DOE does not plan to do this because the technology is not considered practical on a large scale.

We will deal with tritium in more detail in the policy chapter (Chapter VI), since the problem is connected to the issue of the adequacy of present safe drinking water standards to protect public health.

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[170] The last tritium production reactor to operate at the SRS shut down in August 1988, for safety upgrades and repairs. The K-reactor restarted briefly for a test in 1991, but shut down immediately and permanently when tritium leakage into the Savannah River was discovered.
[171] DOE-SRS, October 2003
[172] WRSC, 2001b, page 47
[173] Makhijani 2001, Chapter 5. See discussion of the genetic uncertainty principle.

Chapter VI: Policy Considerations for Cleanup[174]

DOE plans for SRS, which involve leaving significant amounts of waste and contamination in place, are dependent on the use of long-term stewardship, including institutional controls, for protection of human health and the environment.[175] DOE's general cleanup strategy for SRS to leave waste and contamination in place, grout it and/or put a cap over it, declare the site cleaned up, and assume that institutional controls will be effective in preventing inadvertent exhumation of the site. Meanwhile, DOE plans continuing non-environmental management missions, such as the mixed oxide plutonium-uranium (MOX) fuel fabrication plant, in the central industrial area for the foreseeable future.

This chapter will focus on policy changes that are essential for protecting surface and groundwater resources at SRS from further contamination. The measures discussed here as essential to protecting the Savannah River and possibly also the deep aquifers in the region. Most of our recommendations focus on preventing radioactive contaminants from migrating to the groundwater, because contaminants, notably tritium, are extremely difficult to remove once they reach the aquifer.

A. Assume Long-Term Stewardship Will Eventually Fail

DOE has pursued a course for "cleanup" at SRS that will result in the grouting and/or capping of substantial amounts of waste and contamination in place. DOE assumes that this waste and contamination will not present a risk to human health and the environment because the federal government will provide institutional and land use controls at SRS in perpetuity. According to its 2001 publication, *A Report to Congress on Long-Term Stewardship*:

> DOE anticipates that DOE/EM [Environmental Management] Environmental Restoration operating activities at SRS, including well monitoring, maintenance of treatment facilities, maintenance of institutional and engineered controls, and compliance support will be completed by 2047. Following the operating period, the remediated release sites will be monitored and maintained in perpetuity (estimated, for the purposes of this report, through 2070) to ensure the containment of any residual contamination.[176]

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[174] In 2003, the DOE announced a policy of using "risk-based end states" to set the approach and goals for clean-up. This new formulation of an old approach is being used to try to relax cleanup criteria and reduce costs. It is widely opposed, including by the U.S. and Ohio Environmental Protection Agencies, both of whom rejected the proposed document for Fernald (See EPA Region 5, 2003 and Ohio EPA, 2003). For the DOE Risk-Based End States Cleanup Project policy see http://www.em.doe.gov/doe/em/cda/channel_front_door/0,2116,68296_69747,00.html. The new policy is likely to increase risks rather than reduce them. We will not consider it explicitly in this report.

[175] Long-term stewardship is "the physical controls, institutions, information and other mechanisms needed to ensure protection of people and the environment at sites where DOE has completed or plans to complete 'cleanup' (e.g., landfill closures, remedial actions, removal actions, and facility stabilization)." (NRC-NAS, 2000c, page 11, quoting DOE in 64 FR 54280, October 6, 1999) Institutional controls, often an element of stewardship, "consist mainly of land use or access restrictions, and they can take the form either of legal restrictions imposed through covenants, easements, and the like, or of physical restrictions, such as fences, warning signs, or the posting of guards." (NRC-NAS, 2000c, page 7)

[176] DOE, January 2001, Vol. II, South Carolina section, page 10

"Perpetuity" means for an eternal or unlimited duration – surely far longer than recorded history. Planning for a few decades does not begin to cover the number of years that the radioactive waste in the ground at SRS will remain dangerous. DOE does recognize in its June 2002 Predecisional Draft of its *Long-Term Stewardship Strategic Plan* that, "Given the long-lived nature of radionuclides and other residual hazards, it is reasonable to assume that, at some sites, long-term stewardship will be required for centuries or millennia."[177] Yet, DOE fails to analyze how maintaining stewardship for this length of time is possible, or what will be the consequences of failure.

There is simply no factual or analytical basis for DOE's assumption that federal control or any form of continuous institutional control of SRS can be maintained for hundreds of years or thousands of years, not to speak of "in perpetuity." The reality is that DOE is faced with the normal and unpredictable changes in government missions and priorities, in which land use and budget priorities shift, and government and contractor staffing shifts, and records and institutional memory are lost over time. In its draft *Strategic Plan*, DOE recognizes that some factors, such as regulatory structures, demographic and political changes, climate or geological changes, and economic changes could impact long-term stewardship. However, DOE does not acknowledge that any institutional controls put in place today will lapse with time from fallibility of memory or from political and economic pressures.

According to a 2000 study on long-term stewardship by the National Research Council:

> The Committee on Remediation of Buried and Tank Wastes finds that much regarding DOE's intended reliance on long-term stewardship is at this point problematic. The details of long-term stewardship planning are yet to be specified, the adequacy of funding is not assured, and there is no convincing evidence that institutional controls and other stewardship measures are reliable over the long term. Scientific understanding of the factors that govern the long-term behavior of residual contaminants in the environment is not adequate. Yet, the likelihood that institutional management measures will fail at some point is relatively high, underscoring the need to assure that decisions made in the near term are based on the best available science.
>
> [...]
>
> Other things being equal, contaminant reduction is preferred to contaminant isolation and imposition of stewardship measures whose risk of failure is high.
>
> [...]
>
> *The committee believes that the working assumption of DOE planners must be that many contamination isolation barriers and stewardship measures at sites where wastes are left in place will eventually fail, and that much of our current knowledge of the long-term behavior of wastes in environmental media may eventually be proven wrong. Planning and implementation at these sites must proceed in ways that are cognizant of this potential fallibility and uncertainty.*[178] [Original emphasis.]

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[177] DOE, June 2002, page 3

[178] NRC-NAS, 2000c, pages 3 and 5

Many types of failures in "institutional controls" can occur. For example, the definition and standards for "institutional control" may be changed or reinterpreted over time, such as with zoning laws, which are subject to change through local government ordinances or even by court order. Other problems with institutional control include maintaining institutional consistency, preventing the deterioration of oversight, and sustaining follow-up and enforcement. According to the 2000 National Research Council report, "Often the real issue is not ***whether*** use restrictions will eventually fail, but when and what the ***consequences*** will be when they do." [Original emphasis] For example, in the early 1990s, the federal government sold land near the DOE Oak Ridge Reservation in Tennessee to be used as a golf course. Although the deed prohibited the use of groundwater, which was contaminated with trichloroethylene (TCE) from the Y-12 plant, a well was drilled within only a few years to irrigate the course. Fortunately, the problem was discovered before the well was completed.[179]

In some cases, the relevant information is not disseminated to the appropriate people. For instance, at the Oak Ridge Reservation, a contaminated building in the K-25 facility was decontaminated up to eight feet from the floor and leased to a private company, with the stipulation that no activities would be allowed above that height. According to an IEER analysis, the Occupational Safety and Health Administration (OSHA) found that, "some tenants had not been informed about all of the hazards present in the facilities" and "some of the information" that OSHA had "received about the condition of these facilities was 'out of date, inaccurate, and/or incomplete.'"[180]

DOE should not use long-term stewardship as a substitute for cleanup. Long-term stewardship is useful only if the threat is reduced enough that even a complete failure of the stewardship program would not result in grave harm. It is a backup in case we are wrong in our estimates of the effects of the very low-levels of residual radioactivity that would inevitably remain even after thorough cleanup. When technologies do not exist for such cleanup, technology development to get that cleanup is needed, with careful monitoring and other measures being carried out as interim steps. Thorough cleanup is a *prerequisite* of a successful long-term stewardship program.

Hand-in-hand with an effective cleanup program (see specific recommendations below), DOE should seek to develop the elements of long-term stewardship that delay and reduce the impact of the failure of long-term stewardship. In developing this program, the DOE should assume that institutional controls will eventually fail. Therefore, the most optimistic scenarios (i.e. all wastes will be contained and human intrusion will be prevented) are unrealistic. DOE needs to build "failure scenarios" into the long-term stewardship program.

The cleanup strategy at the Savannah River Site is part of DOE's current policy to declare "cleanup" or "closure" to be completed as soon and as cheaply as possible, then transfer the highly uncertain and not-well-defined long-term responsibility to another federal or local entity if possible. For example, the Rocky Flats site in Colorado is slated to be turned over the Fish and

[179] NRC-NAS, 2000c, page 52
[180] Ledwidge, May 1999, pages 3 and 4

Wildlife Service after DOE has declared "closure" complete.[181] DOE has also sought to abandon its long-term stewardship responsibilities altogether, in which case state and local governments would be stuck with them. The most compelling example of DOE's plans for sites after "closure" is the Weldon Spring site, just outside St. Louis, Missouri.[182] This site was used to process uranium for nuclear weapons in the 1950s and 60s. The DOE spent more than $900 million on cleanup at the site, constructing a 45-acre disposal cell now containing more than 1.5 million cubic meters of radioactive waste. DOE removed additional radioactive waste that was previously disposed of in a nearby rock quarry, which is within a few hundred yards of the Missouri River. Now with the waste in place and "cleanup" declared "complete" despite residual ground water contamination, there is serious concern about whether the site will be cared for in the future. The future for the Weldon Spring site is incomprehensibly long, given that the cell entombs uranium-238, which has a half-life of more than 4.4 billion years.

The need for long-term stewardship and the federal government's responsibility in this regard was stressed in clear terms by Missouri Department of Natural Resources Director, Stephen M. Mahfood, the state's top environmental official, in a 2001 letter to Assistant Secretary Jessie Roberson. He warned that other states may not be able to trust the DOE if it failed to act on its promises at Weldon Spring:

> Since the Weldon Spring site is the first large and technically complex site where DOE will complete cleanup and begin long-term stewardship, we believe you will share our interest in assuring the processes work effectively. Other states may look to Weldon Spring to gauge whether the strategy of on-site capping of waste is prudent, based on the robustness of DOE's commitment to ensure post-closure protection of human health and the environment. Unfortunately, the inadequacy of DOE's draft Weldon Spring plan sends a clear message: any state considering a DOE proposal to leave waste on-site should think long and hard about accepting DOE's assurances the site will not present any risk to human health and the environment. DOE's long-term stewardship planning promises appear to be empty, based on the draft Weldon Spring plan. Their promise to provide an effective long-term stewardship program and to also continue investing in science and technology is unreliable.
>
> Pursuant to the state of Missouri's duty to protect the health and environment of all Missourians, we are concerned the [Department of Energy] appears to be committing the same fundamental lapse which occurred during the Cold War: waiting until the project is done to consider the full, long-term and life-cycle environmental implications of the decisions that are made. We cannot stand idly by and allow the same mistake to be repeated. Those mistakes left us with the terrible environmental legacy from shortsighted decision-making that occurred during the perceived urgency of the Cold War.[183]

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[181] FWS, 2004
[182] For information on Weldon Spring, see the website of the State of Missouri on the subject: http://www.dnr.state.mo.us/alpd/hwp/ws-special/ws-toc.htm (Missouri, 2004).
[183] Mahfood, 2001

A year later, he again stressed the state's determination in this regard:

> We do not intend to allow the federal government to walk away from its responsibility for perpetual stewardship of the site.[184]

But the fact is that DOE is ignoring the state's concerns about the need of an effective long-term stewardship plan. The state does not have an effective decision-making role as a partner of the federal government. On the contrary, the DOE has cut funding to the state for performing even minimal monitoring of the site. By leaving waste in place, but cutting funds needed to independently monitor the site, DOE has, in effect, imposed an "unfunded mandate" on the state and its residents. Last year Missouri State Geologist, Mimi Garstang, R.G., wrote to DOE asking for DOE to involve the State of Missouri in decisions affecting future generations of Missourians:

> I have grave concerns over DOE's position to exclude the state of Missouri in a legally binding agreement executed concurrent with this final [Record of Decision]...[185]

Despite this objection, DOE and EPA signed the final Record of Decision for the site in February 2004, "without the concurrence by the state of Missouri..." and despite the fact that "[I]nstitutional controls on impacted property remain unresolved."[186]

The Weldon Spring site provides a useful cautionary tale for other states and communities around other sites because it is the first large industrial scale nuclear weapons site where DOE has declared cleanup "complete." The question here is: "Will DOE honor its commitment to provide adequate long-term stewardship for sites where residual contamination and waste is left after cleanup is declared 'complete'?" The Weldon Spring experience indicates the drift of the answer: No. This bodes ill for SRS and other DOE sites. This is already in evidence in the cut-off of Georgia's funds for environmental monitoring with the argument that South Carolina is doing sufficient monitoring. But it is not and cannot, because some of the contamination is in Georgia groundwater, as we have discussed.

Grouting residual waste in high-level waste tanks is another egregious example of DOE's neglect of the long-term in its rush for cheap short-term solutions. There is no firm process to assure that there will be an iterative cycle for continuing to improve conditions where contamination remains. One reason for a lack of confidence is that the details about post-closure care, in most enforceable agreements, are limited. The Weldon Spring, Missouri, example cited above further erodes that confidence.

Finally, DOE cannot rely on the annual appropriations process to ensure adequate funding in the long-term. As priorities shift in Washington, sites could face insufficient funds to do basic monitoring and maintenance. Over time, this possibility becomes more likely as institutional memory is lost. The government should establish funding mechanisms that will enable the long-

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[184] Mahfood, 2002
[185] Garstang, 2003
[186] Garstang, 2004

term stewardship program to be maintained without relying on annual appropriations. These would be similar in concept to entitlement programs, such as social security or the nuclear weapons workers compensation programs that are not subject to annual appropriations. Rather, a formula for meeting expenses that are needed to fulfill the purposes of the laws is used to determine the level of expenditures in any given year.

B. Manage Wastes at SRS

Given the findings of this report, the following are IEER's recommendations for managing wastes at SRS.

1. Close the reprocessing canyons; cease generating new wastes

DOE should permanently shut down and decommission both reprocessing canyons, which generate high-level, transuranic, and low-level wastes, and cost hundreds of millions of dollars annually to operate. Millions of additional gallons of liquid waste and large volume of solid radioactive low-level wastes from reprocessing are still being added to existing stocks.

In 1992, the first Bush administration decided to phase out reprocessing.[187] Since this decision to phase out reprocessing, the SRS canyons have been used to stabilize nuclear material. The original rationale for operating the canyons had some basis in a safety rationale. However the most dangerous materials left over from SRS production (the liquids and corroded irradiated materials) have already been reprocessed. DOE has closed the F-canyon, but it has not yet declared that it will permanently shut and decommission it. F-canyon continues to be a drain on the cleanup budget, as does H-canyon, which is to continue operating until 2008.

2. Empty and decommission the high-level waste tanks

The sludge from the high-level waste tanks is being vitrified at SRS. The radioactivity content of the first 1,200 or so canisters of vitrified waste is far lower than the projected average for the 6,000 glass logs that are eventually to be produced. Part of the problem is that the process for extracting cesium-137 from the salt and supernate failed after $500 million in costs. A replacement process has not yet been decided upon.

Whatever the process, the residual waste in the tanks needs to be minimized, monitored and maintained in a state that will allow it to be retrieved at a later date. DOE should give up its attempts to redefine this waste as "incidental waste" that can be disposed of in shallow land burial in some form, whether by fiat or via getting the authority to do so through legislation.

We recognize that it will not be possible to remove all of the high-level waste from the tanks with present technology. However, grouting the residual waste, as has been done with Tanks 17 and 20, will make it essentially impossible to remediate them and will create a de facto high-level waste dump on the site in the vicinity of the Savannah River. Moreover, the radioactivity content of the residual waste is likely to be higher in the tanks that have not yet been washed,

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[187] Claytor, 1992

because the wastes in most remaining tanks contain higher concentrations of fission products, especially if they continue to be washed with supernate (see Chapter V).

3. Recover and stabilize buried wastes

The low-level and transuranic wastes as well as associated contaminated soil should be recovered and stabilized. As discussed in Chapter III, grouting and capping waste is only a stopgap measure that will likely lead to long-term problems once the grout and the caps start to break down. It will be even more technically difficult and expensive, than it is today to dig up the grouted material and remediate the tank sites once contaminants start leaking. Such barriers have limited lifetimes compared to the time periods over which the wastes will remain hazardous. Recovering the buried waste is essential to establishing any long-term stewardship program, which must have as its basic assumption that there will be an eventual loss of institutional control over the site. Moreover, the problem of tritium contamination can only be realistically alleviated by recovering as much of the dumped waste as possible to strict standards.

4. Stop dumping low-level waste into unlined and unregulated trenches

The ongoing practice of disposing of low-level radioactive waste in unlined trenches must be ended. DOE could make greater use of existing above-grade vaults that are similar to the management technique used by most European states for low-level waste.[188] This disposal option would provide a greater degree of confidence in long-term protection of human health and the environment. Transuranic waste and all wastes that are equivalent to Class B, Class C, or greater than-Class C low-level waste should be designated for deep geologic disposal. This would correspond approximately to the European regulatory practice of designating such wastes for deep disposal rather than disposal in shallow, low-level waste dumps.

5. Research cleanup technologies for groundwater and soil

More research needs to be done on technologies to cleanup contaminants in groundwater and soil. According to the National Research Council, "Pump and treat systems ... are by far the most commonly used and proposed ... treatment method for contaminated groundwater." However, "pump and treat systems may be unable ... to remove enough contamination to restore groundwater to drinking water standards, or ... removal may require a very long time - in some cases centuries."[189]

C. Minimize Health Risks from Tritium

Tritium in the burial grounds and in the soil under the seepage basins will remain a threat to water resources at SRS for at least two generations since its half-life is 12.3 years. In order to

[188] The vaults in E-Area include a Low Activity Waste (LAW) vault, an Intermediate-Level Non-Tritium (ILNT) vault, an Intermediate-Level Tritium (ILTV) vault. (DOE, January 1998b; DOE-SRS, April 2002a)
[189] NRC-NAS, 2000c, page 31

address the current source terms of tritium described in Chapters II and III, DOE should (1) stop the direct discharge of tritium-contaminated wastes to onsite streams; (2) retrieve tritium-tainted wastes in the burial grounds and seepage basins; and (3) continue the hydraulic pumping program to reduce tritium discharges in a manner that does not increase uptake of tritium by trees.

As we have discussed in Chapter III, tritium contamination of the Savannah River as well as offsite groundwater is well below the safe drinking water standards. Moreover, the EPA safe drinking water standard is somewhat more stringent for tritium than it is for other beta emitters, since the dose from the latter is restricted to 4 millirem per year (from drinking 2 liters of water per day), while the dose implied by a limit of 20,000 picocuries is just under one millirem per year.[190]

However, there are questions that need to be addressed regarding the health risks from tritium that go well beyond cancer risks to adults. These include non-cancer risks, risks to children and developing fetuses regarding both cancer as well as non-cancer health effects, and synergistic effects of toxic non-radioactive materials with tritium.

1. Overview of tritium-related radiological issues

Tritium can be ingested in two forms: tritiated water or organically bound tritium (OBT). Due to its chemical properties, tritiated water can replace ordinary water in human cells (approximately 70 percent of the soft tissue in the human body is water). When tritium replaces hydrogen in a carbon-hydrogen bond, it is difficult to remove and is referred to as nonexchangeable organically bound tritium. Animal studies indicate that 1-5 percent of the tritiated water in a body is incorporated into biomolecules. Direct intake of organically bound tritium, for example through food, is more likely to be incorporated as organically bound tritium in biomolecules than tritiated water. However, organically bound tritium is a heterogeneous group of compounds that can behave very differently in metabolic processes, and more research is needed to understand the incorporation of tritium from a variety of compounds.[191]

Current radiation protection standards assume that exposure to beta radiation (such as that from tritium) causes the same biological damage as whole-body exposure to gamma and x-rays. But the cancer risk from tritum per unit of radiation energy can be far higher. A 2002 study examined uncertainties in the assumptions of the International Commission on Radiological Protection (ICRP) models for calculating the dose of radiation from the intake of tritiated water and organically bound tritium. It also estimated dose conversion factors for tritated water and for OBT. It found the relative biological effectiveness (RBE) of both tritiated water and OBT to be higher than ICRP models.[192] This means that tritium is much more effective per unit of radation energy deposited in the body than gamma rays or than assumed in ICRP models. It is also more effective in producing cancer in fetuses than it is in adults. The (RBE) of a unit of beta particle

[190] We have used a dose conversion factor of 1.73*10-11 sieverts per becqueral, which is the EPA guideline for tritium ingestion, to estimate this dose.
[191] Harrison, Khursheed and Lambert, 2002, pages 300, 303, and 304
[192] Harrison, Khursheed and Lambert, 2002, page 308

energy from tritium decay for tritiated water and for organically bound tritium for adults and for fetuses relative to the values used by the EPA in current regulations can be estimated from the research of Harrison, Khursheed and Lambert. Our estimates based on their analysis are shown in Table 12 below:

Table 12: Relative Biological Effectiveness of Tritiated Water and Organically Bound Tritium

Age	Form of tritium	5% Confidence limit	median	95% confidence limit
Adult	HTO	1.2	2.3	3.8
Adult	OBT	2.3	5.0	11.6
Fetus (maternal ingestion during pregnancy)	HTO	2.1	4.4	8.1
Fetus (maternal ingestion during pregnancy)	OBT	4.0	9.8	23.1

Source: Estimated from Harrison, Khursheed, and Lambert 2002, Table 8. The RBEs shown above were calculated by dividing the tritium doses in sieverts per Becquerel shown in this table by $1.73*10^{-11}$, which is the dose conversion factor for tritiated water in sieverts per Becquerel in the prevailing regulatory guide of the Environmental Protection Agency (EPA, 1988).
Note: HTO = tritiated water in which one atom of ordinary hydrogen has been replaced by an atom of tritium. OBT = organically bound tritium. The numbers in the columns for confidence intervals mean that the RBEs would be less than the cited number for the percent of times indicated by the confidence interval were a series of identical experiments to be performed.

The increased risks to pregnant women and fetuses do not stop at cancer. As discussed previously, the risks of tritium exposure to pregnant women and fetuses include miscarragies and genetic defects, as discussed below. The risks can be multi-generational.

2. The standard for tritium in drinking water

Recent research clearly indicates that the maximum contaminant level for tritium in drinking water should be re-evaluated in light of the significantly higher cancer risk created by fetal exposure, especially in regard to organically bound tritium. Rivers can be and are used by large numbers of people for drinking water, as is the case with the Savannah River. This indicates that the higher health risk created by organically bound tritium must be taken into account by creating more stringent drinking water standards.

Furthermore, current estimates of the health risks from exposure to organically bound tritium may underestimate the actual health impacts. Tritiated water is considered to be uniformly distributed throughout the body although at different concentrations (for example bone and fat have lower concentrations due to their relatively lower water content[193]), but organically bound tritium can localize in relatively small numbers of cells at relatively high concentrations. Therefore, while the average dose to the tissues may be low, the dose to cells where the organically bound tritium is concentrated may be large. For example, when tritium is

[193] Harrison, Khursheed and Lambert, 2002, page 305

incorporated into DNA, it does not uniformly irradiate the whole cells, but selectively irradiates the nucleus. The resulting risk to the cell could be greater than if tritium were incorporated more uniformly throughout the cell.[194] Moreover, organically bound tritium is generally retained in the body longer than tritiated water, because biomolecules have a slower turnover than water.[195] Human studies indicate that tritiated water has a biological half-life of 10 days, and non-exchangeable organically bound tritium has a biological half-life of 21 to 76 days. For tritiated organic molecules with very slow turnover rates, the biological half-life has been found to be 280 to 550 days.[196] This last is comparable to the biological half-life of some metals in insoluble form.

The health impacts on fetuses from exposures to tritium also need further research. Both tritiated water and organically bound tritium can enter the fetus through the placenta. Animal studies have found that tritiated water has a greater average concentration in fetal tissues than maternal tissues, due to the relatively higher water content in a fetus. Organically bound tritium from food ingested by the mother also can be incorporated into the fetal tissues.[197] The health effects on the developing fetus itself (e.g. miscarriages, malformations, and developmental effects other than mental retardation) and on relevant organs at critical periods of fetal development are not well known. Further, the incorporation of tritium into biomolecules of long-lived cells of a fetus, such as neurons or oocytes could result in large doses over the lifetime of the cells.[198] Considering that ova are formed once per lifetime during females' fetal development, the effects of radiation on the reproductive system of female fetuses and the possible effect of such radiation on the children of females irradiated in the womb could be significant.[199] In addition, the combined effects of *in utero* exposure to tritium combined with endocrine disrupting chemicals, such as dioxins or PCBs, need to be studied.

Another issue that needs further research is the transmutation of organically bound tritium into helium-3 during decay. If the tritium is in a biologically important molecule, such as DNA, its decay to helium may result in biological damage that would not be fully accounted for by the emission of a beta ray.[200] Since helium atoms do not bond to carbon, a free helium ion and a reactive carbon ion are left. The carbon ion can lead to single-strand break in the DNA, an interstrand cross-link, or even to a mutation, depending where it happens to be in the DNA.[201]

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[194] Hill and Johnson, December 1993, page 632

[195] Straume, February 1991, page 4

[196] Hill and Johnson, December 1993, page 638. The International Commission on Radiological Protection (ICRP) assumes a biological half-life of 10 days for tritiated water and 40 days for organically bound tritium in adults. For a 3-month-old child, ICRP assumes a biological half-life of tritiated water and organically bound tritium of 3 and 8 days, respectively. (Harrison, Khursheed and Lambert, 2002, page 300)

[197] Harrison, Khursheed and Lambert, 2002, page 305

[198] Straume, February 1991, page 5

[199] Straume and Carsten, December 1993. These observations are based on experiments with mice. On p. 661-662 they note: "Of particular concern for genetic risk assessment has been the incorporation of tritiated nucleotides into DNA during oogenesis (*in utero*)....It can be inferred from these mouse data that 37kBq/g of body weight of ^{3}H [Tritium]-Tdr administered i.p. [by intraperitoeal injections] will result in ~5 Gray/y.... Because ingestion of ^{3}H [Tritium]-Tdr results in about 1/5 of the dose compared to that from i.p. injections in rodents (NCRP 1979), ingestion of such compounds by women during critical development *in utero* could perhaps result in ~ 20 mGy/y (or 600 mGy in a 30-y-old woman) to oocyte nuclei per 37 MBq (1 mCi) ingested."

[200] Straume, February 1991, page 5

[201] Hill and Johnson, December 1993, page 632

This assumption is based on the low number of hydrogen atoms in the DNA for which transmutations have been found. However, there is no threshold dose for the effects of radiation from a non-lethal dose to a single cell. For example, according to Professor David Close, "mutations can be caused by a single tritium replacement of hydrogen in the C5 position of the DNA base cytosine. After the tritium decays, the cytosine is mistaken for thymine. This ... leads to a point mutation with a thymine-adenine pair for the original cytosine-guanine pair in DNA."[202] The potential health effects of such transmutations need to be further researched. IEER and others have appealed to the National Academy of Sciences Panel on the Biological Effects of Ionizing Radiation (the "BEIR VII" panel) to present an analysis of and some conclusions on this issue[203] so that science and public health may both be better served in this regard than they are now.

The Department of Energy has agreed to an action level for tritium in surface water of only 500 picocuries per liter in the context of its clean up at Rocky Flats.[204] This level corresponds to a lifetime risk of cancer for an adult of just under one in a million from drinking two liters of water per day. There is no *a priori* reason why this should not be adopted as an action level for cleanup throughout the nuclear weapons complex. In fact, there is a persuasive case that if such an action level is adopted anywhere, it should be at SRS because of the far larger number of people who use the river and the far larger volume of water involved.

D. Base Cleanup Standards on the Subsistence Farmer Scenario

Long-term cleanup standards for soil and groundwater at SRS should be based on the subsistence farmer exposure scenario, which assumes that a person who grows all his/her own food would unknowingly use contaminated water for drinking and farming. Further, it assumes that such exposure would last a lifetime, and not just a few years. The people in the critical group spend most of their time on the contaminated site. In addition, this scenario assumes that the diets of future populations, as well as the water intake, will be similar to those of today. People are considered protected if their lifetime exposure is less than an assigned limit. The reasoning is that in such a case all other people would be protected since their doses would be lower than that of the hypothetical subsistence farmer. While there is no expectation that such a conservative "worst case" exposure scenario is likely in the foreseeable future, much of the future, especially beyond a few generations, is not foreseeable. Hence, it is prudent to plan for such a land use scenario to be protective. The subsistence farmer scenario complies with the recommendations made by the International Commission on Radiological Protection for exposure, risk estimation procedure, and definition of the critical group.[205]

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[202] Close, 2001

[203] BEIR stands for the Biological Effects of Ionizing Radiation. The National Academy of Sciences and a Committee on this subject issues periodic reports. The current committee is considering the seventh in the series, hence the term BEIR VII. The report is due to be issued in December 2004. The Institute for Energy and Environmental Research and others have asked the BEIR VII panel to consider these aspects of tritium radiation risk, as well as other related issues. See IEER's web site, at http://www.ieer.org/comments/beir/

[204] Rocky Flats, 2003. Attachment 5, Table 1, page 5-25

[205] Makhijani and Gopal, December 2001

E. Use Cleanup Budget Exclusively For Cleanup Tasks

Although the budget for the Office of Environmental Management (EM) activities at SRS increased by nearly a billion dollars in 1995 (when SRS was transferred to the responsibility of EM), the actual EM activities remain virtually unchanged. Much EM funding is devoted to "cleanup"tasks that are actually just part of "overhead" and "indirect costs" requirements, such as site security, road repair, and administration. In addition, EM funding appears far larger than funds used for clean up especially because of the inclusion of funds for operating the F- and H-canyons.

This funding shift at SRS has been part of a larger pattern: when the Cold War ended, Congress began shifting funding from nuclear weapons to the environmental cleanup and radioactive waste management. Though the funding levels for accounts changed significantly, the change in specific facility operations and individual personnel was much less significant. Consequently, much of DOE's environmental budget has essentially been used to support nuclear weapons facility infrastructure and operations, notably the F- and H-canyons.

The budget from the Environmental Management program should be used to fund only legitimate cleanup related tasks, not general site facility support and infrastructure maintenance. Moreover, cleanup activities that are a result of other national security or materials disposition programs should be included in those budgets. As the cleanup functions are then carried out by EM, the funds can be transferred. This would be a more transparent and accountable way to show the total lifecycle cost of weapons programs.

There is a growing recognition of a serious problem in the direction of the DOE cleanup program that increasingly allows large amounts of waste and contamination to remain onsite. At the same time, there is a lack of confidence in the ability of any institution, especially one with credibility as low as the DOE, to provide effective long-term stewardship for the residual contamination and waste for such long periods of time.

Our conclusion, presented in IEER's 1997 report, *Containing the Cold War Mess,* that DOE is not the right agency for cleanup has, unfortunately, been repeatedly confirmed over the years. We strongly recommend that, instead of abandoning cleanup, policymakers should abandon DOE and move cleanup to an independent agency or to states.[206] Congress should create an escrow fund or an entitlement program (see above) for cleanup so states or the independent agency can actually carry out cleanup with confidence. There should be strict national cleanup standards enforced by the Environmental Protection Agency (EPA) to ensure that the funds are properly used.

At the Savannah River Site, it is highly unlikely that the entire site can be returned to background levels of contamination or even very close to that with existing technology. But a great deal more can be done to restore the Savannah River to a better state than it is now and to ensure that programs that are being done in the name of cleanup and waste management do not increase risks to groundwater and surface water in the future. Leaving a million or more curies of waste

[206] Fioravanti and Makhijani, 1997; Makhijani and Gopal, December 2001

buried in the ground, grouted and covered with a surface cap is incompatible with and even inimical to this goal. Buried waste must be recovered and high-level waste must be vitrified and prepared for deep geologic disposal.

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EXHIBIT 2.4

Risk Analysis, Vol. 19, No. 3, 1999

Factors in Exposure Assessment: Ethnic and Socioeconomic Differences in Fishing and Consumption of Fish Caught along the Savannah River

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South Carolina has issued fish consumption advisories for the Savannah River based on mercury and radionuclide levels. We examine differences in fishing rates and fish consumption of 258 people interviewed while fishing along the Savannah River, as a function of age, education, ethnicity, employment history, and income, and test the assumption that the average consumption of fish is less than the recreational value of 19 kg/year assumed by risk assessors. Ethnicity and education contributed significantly to explaining variations in number of fish meals per month, serving size, and total quantity of fish consumed per year. Blacks fished more often, ate more fish meals of slightly larger serving sizes, and consumed more fish per year than did Whites. Although education and income were correlated, education contributed most significantly to behavior; people who did not graduate from high school ate fish more often, ate more fish per year, and ate more whole fish than people who graduated from high school. Computing consumption of fish for each person individually indicates that (1) people who eat fish more often also eat larger portions, (2) a substantial number of people consume more than the amount of fish used to compute risk to recreational fishermen, (3) some people consume more than the subsistence level default assumption (50 kg/year) and (4) Blacks consume more fish per year than Whites, putting them at greater risk from contaminants in fish. Overall, ethnicity, age, and education contributed to variations in fishing behavior and consumption.

KEY WORDS: Ethnicity; fish consumption; advisories; Savannah River; methylmercury; risk perception.

1. INTRODUCTION

Recreational and subsistence fishing are important aspects of rural culture and tradition, particularly in the southern United States, where the fishing season extends for many months.[1] Fish can provide an important source of low-fat protein and contribute to lowering blood cholesterol.[2] However, the presence of contaminants in fish may pose a health hazard, particularly for high risk groups such as pregnant women and their fetuses, and young children.

There are concerns about the safety of non-commercial fish, shellfish and wildlife.[3-5] From 1994 to 1995, 15% of the nation's lake acres and 4% of the river miles were under fishing or consumption advisories, an increase of 14% over the previous year. Mercury accounts for 46% of the advisories; other contaminants of concern are PCBs, chlordane, dioxins, and DDT.[6] Although some of the apparent in-

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crease may be due to increased monitoring, there is still cause for concern. A relationship exists between mercury levels, fish consumption, and deficits in neurobehavioral development in children,[7-9] although the positive benefits with respect to cardiovascular health must also be considered.[10-12]

Because fishermen may consume large quantities of fish (in excess of 0.35 kg/day),[13,14] it is critical to examine fishing behavior, fish consumption, and cooking patterns among fishermen in places with consumption advisories. An effective risk reduction and risk management strategy can be implemented only with site-specific information. Furthermore, such information from many sites can lead to both an empirical and theoretical understanding of the risk from fish consumption.

There is often a discrepancy between knowledge about fish advisories and the behavior of the fishing public.[15,16] The public does not know about the warnings, they do not know about the *correct* warnings, or they are choosing not to follow them. People may choose not to follow advisories because they do not believe them, they do not agree with the advice, or they have no alternative if fish is their main or only source of protein.[17] However, the failure of the public to follow consumption advisories or select fish or cooking methods to reduce risk may be due partially to the failure of risk communicators or state agencies to reach the appropriate target audiences.[18]

Designing an appropriate risk communication strategy requires understanding how ethnicity, income, and age relate to differences in fishing behavior, consumption patterns, and potential risk. Fleming et al.,[19] working in the Florida Everglades, reported that Blacks were less likely to know about health advisories than were other ethnic groups. Considering the significant social role fishing plays within some Black communities (e.g., Mississippi Delta[1]), it appears critical to understand fishing and consumption behavior of Blacks in a variety of communities in order to develop an overall risk management strategy.

In this paper we examine the fishing and consumption patterns of Black and White persons fishing along the Savannah River. We examine differences in fishing and consumption patterns as a function of ethnicity, income, education, age, and employment to provide a framework for designing a risk management strategy. There are few studies of fishing behavior and consumption patterns that are able to separate the effects of income, ethnicity, and education, and our study was designed to address this. Based on mercury, the state of South Carolina has issued fish consumption advisories for waters of the state, including the Savannah River.[20] South Carolina updated the advisories for the Savannah River to include risks from radionuclides. The portion of the river with the most stringent advisories is adjacent to the Department of Energy's (DOE) Savannah River Site (SRS).

2. METHODS

Under a university-approved protocol, 258 people who were fishing on the Savannah River were interviewed. We sampled three sections of river: along SRS, upriver from the site to the Augusta Lock and Dam, and downriver from the site to Barton's Landing (301 bridge (Fig. 1, about 90 km of river). The DOE's SRS (SRS, 310 sq mi, 803 sq km) is situated in South Carolina. Before the DOE purchased the site in 1952, much of the site had been cleared for agriculture, except for the bottomland swamps along the Savannah River. During the DOE tenure, the land was off limits to the public except for controlled game hunting. Pine and other forests have grown up, and many populations of amphibians, reptiles, birds, and mammals, including some endangered species, increased since the late 1950s.[21]

Interviews were conducted both on land and on the water (by boat) from 3 April until 22 November 1997. To ensure a wide distribution of people and fishing methods, interviews were conducted nearly every week, and each person was interviewed only once. We interviewed fishermen on 54 days, including weekdays and weekend days, and conducted interviews from dawn to dusk. Our overall design was to move systematically down the river from the Augusta Lock and Dam, interviewing at all locations where we found fishermen, before beginning again at the dam. We often saw the same people at the same fishing sites, and they expressed interest in the progress of the survey work. Most interviews were conducted by the same two people who had lived and worked in the region their entire lives.

The protocol was to alternate interviewing people along the three sections of the river, depending on weather, water level, and fishing conditions. That is, when people were fishing for a particular fish, they often concentrated in some regions of the river in preference to others. Furthermore, we could not interview people when the water level was high because the fishing was poor, and we encountered no one

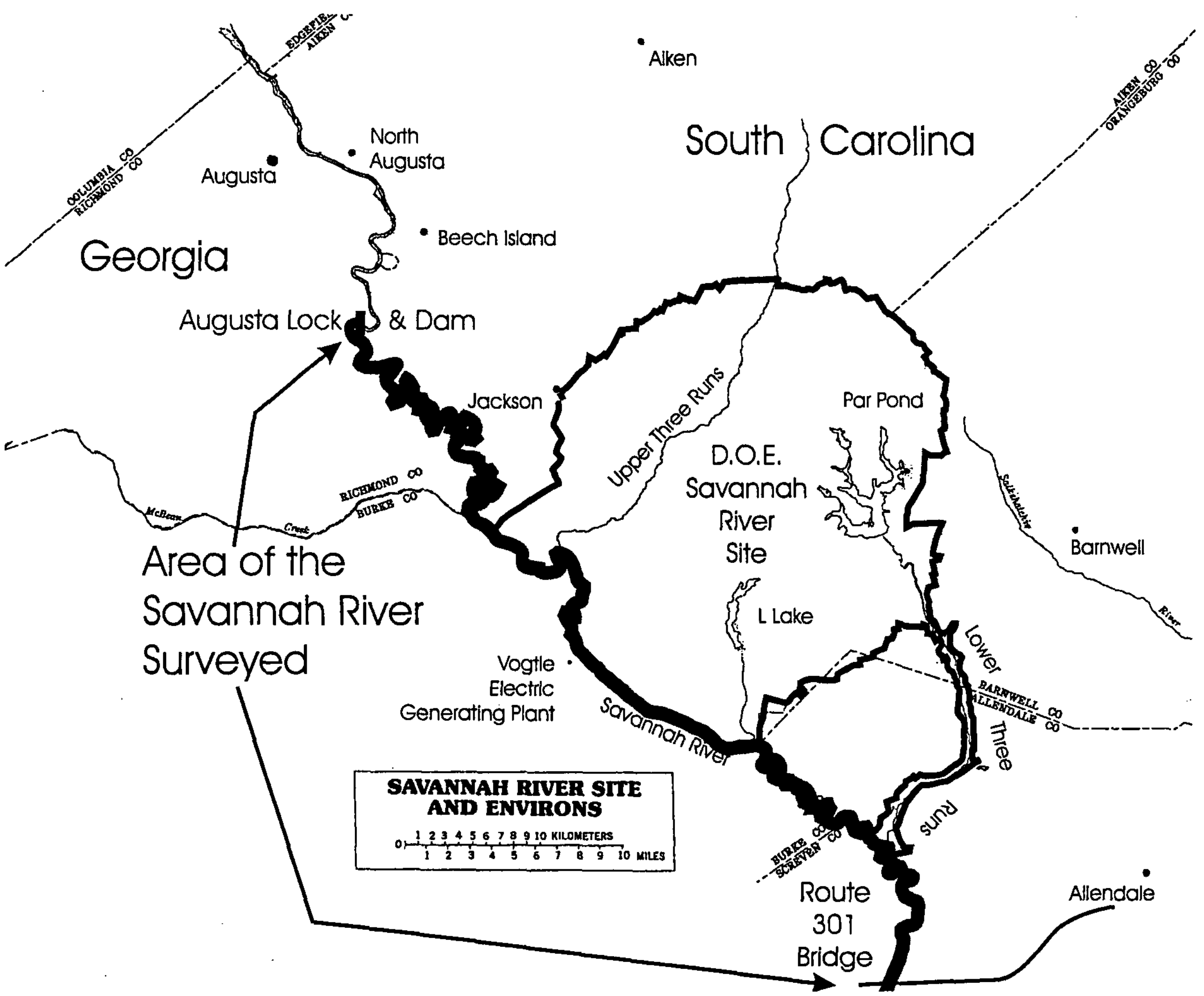

Fig. 1. Map of the Savannah River Site and the Savannah River showing the Augusta Lock and Dam and the Interstate-95 bridge that bound the study area.

fishing. Upon reaching a sampling site, we interviewed all the fishermen. Only 10 people out of 268 approached refused to be interviewed, largely because they did not have the time to participate. Most interviews took 30–45 min because people wanted to talk about fishing, their catch, and how they prepared fish.

The questionnaire contained questions about fishing behavior, consumption patterns, cooking patterns, warnings and safety of the fish, and personal demographics. Some demographics questions (sex, age, ethnicity, residence) were asked at the beginning, and more sensitive questions (income, education, and employment) were asked at the end to reduce rejection rates. Because our sample was largely male, we did not examine the data by gender except in our initial model-building (see below). Prior surveys had indicated that some people are reluctant to disclose their income or education. However, after a friendly and lengthy interview with local interviewers, most people were willing to give this information at the end of the survey. People were asked to give their household income. Information on fishing behavior, consumption patterns, and knowledge of consumption advisories is presented in this paper; data on sources of information is presented elsewhere.[22]

We used nonparametric analysis of variance (SAS Proc NPAR1WAY with Wilcoxon option), yielding a χ^2 statistic to examine differences among groups. We also used ANOVA with Duncan Multiple

Range Test to identify which groups differed from each other (SAS GLM procedure[22]). We use a significance level of $p < 0.05$.

We used multiple regression procedures (SAS PROC GLM) to examine the relative contribution of the independent variables (ethnicity, income, age, and education) to the dependent variables that we were most interested in from a risk perspective (years fished on the Savannah River, serving size, meals/month, and total ounces of fish consumed per year).[23] This procedure allows for interactions among variables. Other questions dealt with fishing behavior patterns, and these data are presented descriptively to aid in risk management.

Initially, we developed models for each of the four dependent variables, using each independent variable separately. This allowed us to determine that gender did not enter significantly in any of the models, and was not used further. All other independent variables were used in the models. We used a models-building procedure in which we added the dependent variable that contributed the most to explaining the variation, and then again developed models using each of the other four variables. In this manner, we determined the best models. We continued until all significant variables were added. Because we had already assessed the correlation among variables (Table I), and the independent variables were not highly correlated, we did not see collinearity as a problem. We also constructed models with all the interaction terms (i.e., education × income) to determine if any would contribute significantly to explaining the variation (in addition to each variable separately); no interactions were significant. Education was also added as a squared value to evaluate a nonlinear effect.

3. STUDY POPULATION

Our population was drawn from people fishing along a 90 km segment of the Savannah River, upriver, along, and downriver from the SRS, and was meant to be representative of fishermen anywhere along the Savannah River or similar fishing areas in the region.

Of the 258 people interviewed, 89% were men; 70% were White, 28% were Black, and 2% were other. Thirty-four percent of the population in the counties adjacent to the stretch of river surveyed is Black, compared with 28% of the population of Georgia and South Carolina.[24] Only 29 (11%) people worked or had worked at SRS. The age range of those interviewed was from 16 to 82 years (mean = 43 ± 1).

The average income of those interviewed was $21,490/year (range of $0 to $60,000), compared to the regional income around SRS of approximately $27,647.[24] The Blacks who were interviewed had lower annual income than the Whites. For Blacks, age was negatively correlated with both income and years in school (Table I), whereas for Whites, age and income were positively correlated. However, for both Blacks and Whites, income and schooling were only very weakly correlated.

Of those interviewed, only 14% had less than a high school education, compared to 21% for Georgia and 23% for South Carolina generally[24]; conversely only 11% of our sample graduated from college, compared to 19.8% for South Carolina and 21.8% for Georgia.[25]

4. RESULTS

Although most of those interviewed were men, they indicated that their wives and children ate fish as often as they did, and children began eating fish at 3–5 years of age, depending on species of fish. Preferred fish in descending order of frequency were bream (the local term for sunfish; *Lepomis* spp), catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis nigromaculatus*), and bowfin (*Amia calva*). These accounted for most of the fish caught.

4.1. Factors Affecting Fishing and Consumption

Fishing behavior and consumption rates for the study population are shown in Table II. People fishing along this stretch of the Savannah River eat an average of 1.4 kg of fish per month, mainly deep fried (not including pan fried). The average number of years people had fished on the Savannah River was 24 years, although some people had fished for more than 50 years (Fig. 2). For both Blacks and Whites, serving size and number of fish meals per month were positively correlated (Table I).

After assessing variables individually, we developed multivariate linear regression models for the dependent variables: number of years fished on the Savannah River, fish meals per month, serving size, and ounces of fish per year. The best models explained variation in average years fished by educa-

Table I. Correlations between Demographic and Fish Consumption Questions Asked of Black and White Fishermen along the Savannah River. Blacks are Above and Whites Are Below the Line. Given are Kendall-Tau Probabilities. (NS = not significant)

	(1) Age	(2) Income	(3) School	(4) Fished	(5) Distance	(6) Meals	(7) Serving	(8) Deep fry	(9) Oz.
1)Age	—	−0.16 (0.07)	−0.18 (0.048)	0.36 (0.001)	NS	NS	NS	NS	NS
2)Income	0.14 (0.01)	—	0.37 (0.001)	NS	NS	NS	NS	NS	NS
3)Years of schooling	NS	0.18 (0.003)	—	−0.18 (0.08)	NS	NS	NS	NS	NS
4)Years fished Savannah River	0.39 (0.001)	0.12 (0.03)	−0.12 (0.048)	—	NS	NS	NS	NS	NS
5)Distance traveled	NS	NS	NS	NS	—	NS	NS	NS	NS
6)Fish meals/month	NS	−0.15 (0.02)	−0.13 (0.044)	NS	NS	—	NS	−0.18 (0.07)	0.92 (0.001)
7)Average fish serving	NS	NS	0.17 (0.01)	NS	NS	0.17 (0.02)	—	NS	0.26 (0.007)
8)Percent fish deep fry	NS	NS	−0.19 (0.007)	0.13 (0.042)	NS	NS	NS	—	0.19 (0.058)
9)Oz. of fish/year	NS	−0.11 (0.09)	NS	NS	NS	0.91 (0.001)	0.33 (0.001)	NS	—

tion, age, and income. The best models explained variations in serving size, fish meals per month, and total kg of fish consumed per year as a function of ethnicity and education (neither age or income entered significantly; Table III). The independent variables explained only 5% of the variation in serving size, but from 15% to 33% of the variation in total consumption per year, number of fish meals/month, and years fished on the Savannah River.

4.2. Ethnic Differences in Fishing

There were significant differences in nearly all measures of fishing behavior, consumption, and cooking methods as a function of ethnicity (Table IV). Blacks ate larger portions of fish and ate fish more often than did Whites (Fig. 3). The higher number of meals per month that Blacks consumed resulted in significant differences in the average consumption of fish per year. Figure 4 shows the distribution by race of people consuming fish in both pounds and kilograms, with the vertical lines indicating the recreational (19 kg/year) and subsistence (50 kg/year) consumption levels used as the default exposure assumptions for risk assessments by South Carolina (SC DHEC, pers. comm.). Furthermore, a significantly higher proportion of Blacks than Whites ate whole fish rather than fillets (Table IV).

Table II. Mean and Standard Error of Select Questions Asked of Fishermen along the Savannah River

	Mean	Range
Number of years fished	31 ± 1	(1–73)
Years fished Savannah River	24 ± 1	(1–73)
Distance traveled (km)	37 ± 7	(2–960)
How often they eat fish/month	3.61 ± 0.28	(0–24)
Serving size of fish (g)	376.1 ± 5.45	(0–625)
Fish/month (kg)	1.46 ± 0.13	(0–9.55)
Fish/year (kg)	17.60 ± 1.51	(0–114.5)
Percent that deep fry	82 ± 2	(0–100)
Percent that eat whole fish	85 ± 2	(50–100)
Age	43 ± 1	(16–82)
Years of schooling	12 ± 0.1	(6–18)
Income	$21,491 ± $758 ($0–$60,000)	

4.3. Income and Education Differences

There were few significant differences as a function of income, although people with lower incomes ate fish significantly more often than those with higher incomes (Table V). There were significant differences as a function of education (Table VI). Fishermen who had not graduated from high school ate fish more often, consumed more fish per month and per year, deep fried more often, and had lower incomes than people with more education. The subgroup with a high school education, however, had fished for significantly longer than the subgroups with

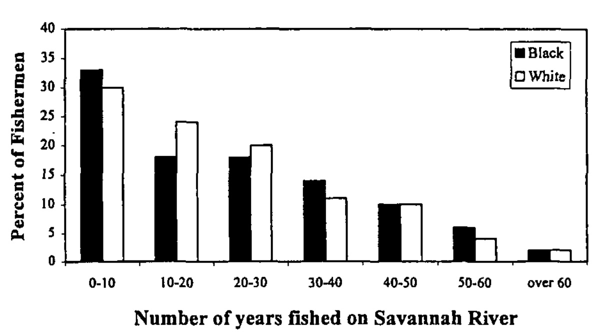

Fig. 2. Number of years subjects had fished on the Savannah River by race.

Table III. Models Explaining Variation in Fishing Behavior and Consumption of Fishermen along the Savannah River. No Interactions Were Significant. Values Shown $F(p)$

	Years fished Savannah River	Serving size	Fish meals per month	Total grams of fish per year
Model				
F	19.4	2.0	6.9	7.3
dF	5,206	5,194	5,199	5,179
p	0.0001	0.08	0.0001	0.0001
r^2	0.33	0.05	0.15	0.18
Factors entering (F, p)				
Ethnicity	NS	3.5 (0.06)	13.2 (0.004)	12.2 (0.0006)
Education	2.9 (0.09)	NS	14.0 (0.0002)	17.7 (0.0001)
Age	72.3 (0.0001)	NS	NS	NS
Income	3.0 (0.08)	NS	NS	NS
Education^2	5.6 (0.02)	3.1 (0.08)	13.8 (0.0003)	18.1 (0.0001)

less than or more than a high school education (Table VI).

The relationship between total fish consumption (kg/year) and education, however, was also explained by a nonlinear function (see Table II), shown in Fig. 5. There are two curves for total fish consumption as a function of education, one for Whites and one for Blacks. At all education levels, Blacks ate more fish than Whites.

4.4. Employment at SRS

There were a number of significant differences as a function of employment (Table VII). People who currently worked at SRS had fished on the river for fewer years, ate fish less often per month, and consumed less fish per year than did people who did not work at SRS.

5. DISCUSSION

Because fish consumption is a major pathway of exposure to a number of environmental contaminants (e.g., methylmercury, polychlorinated biphenyls), risk assessors must take consumption of "local" fish into account when estimating risk or crafting consumption advisories. Different assumptions are made for fish consumption by recreational (19 kg/year) and subsistence (50 kg/year) fishermen. This study illustrates two aspects of fishing behavior and consumption by people fishing along the Savannah River that bear on exposure and risk. We investigated the pro-

Table IV. Differences as a Function of Ethnicity for Fisherman Interviewed along the Savannah River (mean ± SE; NS = not significant)

	Black	White	Kruskal–Wallix χ^2 $(p)^a$
Number interviewed	72 (28%)	180 (70%)	
Number of years fished	34 ± 2 (1–73)	31 ± 1 (1–70)	NS
Years fished Savannah River	24 ± 2 (1–73)	24 ± 1 (1–70)	NS
Distance traveled (km)	15 ± 1 (5–32)	42 ± 9 (2–960)	5.84 (0.02)
How often they eat fish/month	5.37 ± 0.57 (0–20)	2.88 ± 0.30 (0–24)	16.97 (0.001)
Serving size of fish (g)	387 ± 10.2 (0–597)	370.53 ± 6.60 (199–625)	3.73 (0.05)
Fish/month (kg)	2.13 ± 0.24 (0–7.96)	1.17 ± 0.14 (0–9.56)	12.38 (0.001)
Fish/year (kg)	25.55 ± 2.92 (0–95.46)	14.03 ± 1.70 (0–114.5)	12.38 (0.001)
Percent that deep fry	81 ± 4 (0–100)	75 ± 2 (0–100)	NS
Percent that eat whole fish	79 ± 4 (0–100)	64 ± 3 (0–100)	8.46 (0.004)
Age	47 ± 2 (23–77)	42 ± 1 (16–82)	NS
Years of schooling	12 ± 0.3 (3–18)	12 ± 0.1 (5–18)	12.99 (0.002)
Income	$18,571 ± $1,140 ($0–$49,000)	$22,431 ± $957 ($0–$60,000)	7.69 (0.006)

[a] Based on the Kruskal–Wallis nonparametric analysis of variance.

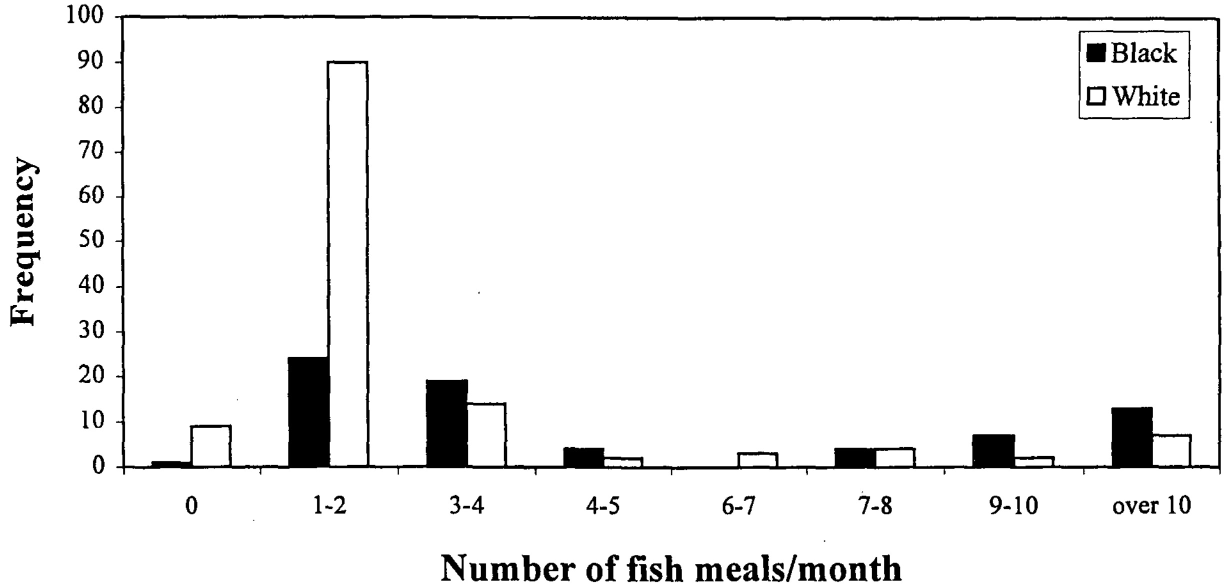

Fig. 3. Number of fish meals eaten per month by race.

portion of our Savannah River fishing sample that might be significantly exposed to potentially harmful chemicals because they are consuming more than 19 kg/year of fish from the Savannah River, and also the demographic variables (ethnicity, education, income) that explain variations in exposure.

5.1. Methodological Considerations

Information on sport fish consumers has been obtained by at least two methods (and combinations, thereof): surveys based on fishing license holders, and surveys of anglers while they are fishing (often

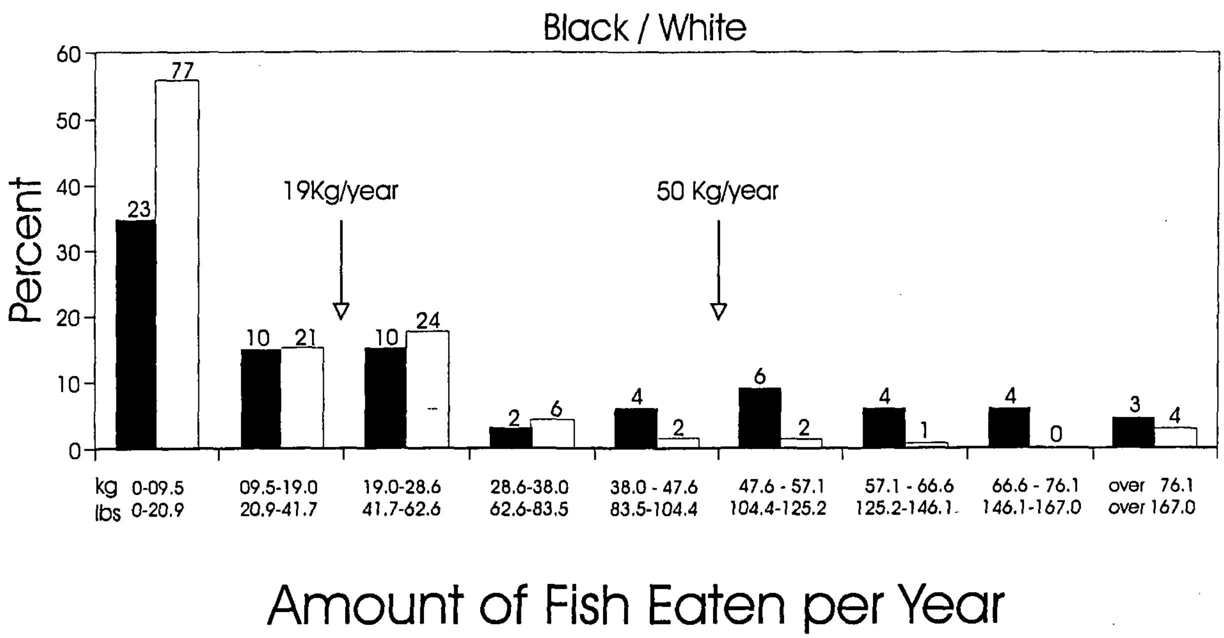

Fig. 4. Amount of fish consumed per year by race; 19 kg/year and 50 kg/year are the values used by South Carolina in its risk assessment for recreational and subsistence fishermen.

Table V. Differences as a Function of Income for Fishermen along the Savannah River (mean ± SE; NS = not significant)

	Income less than or equal to $20,000	Income greater than $20,000	Kruskal–Wallis χ^2 (p)
Number interviewed	138 (54%)	99 (38%)	
Number of years fished	30 ± 1 (1–73)	32 ± 2 (1–70)	NS
Years fished Savannah River	22 ± 2 (1–73)	24 ± 2 (1–60)	NS
Distance traveled (km)	32 ± 9 (2–800)	31 ± 4 (3–160)	NS
How often they eat fish/month	3.97 ± 0.36 (0–20)	3.39 ± 0.52 (0–24)	5.31 (0.02)
Serving size of fish (g)	375.00 ± 8.10 (0–625)	379.05 ± 7.27 (199–568)	NS
Fish/month (kg)	1.58 ± 0.16 (0–8.00)	1.44 ± 0.24 (0–9.55)	NS
Fish/year (kg)	18.93 ± 1.88 (0–95.46)	17.25 ± 2.82 (0–114.5)	NS
Percent that deep fry	77 ± 3 (0–100)	76 ± 3 (0–100)	NS
Percent that eat whole fish	72 ± 3 (0–100)	64 ± 4 (0–100)	NS
Age	42 ± 1 (16–82)	43 ± 1 (19–75)	NS
Years of schooling	12 ± 0.2 (3–16)	13 ± 0.2 (5–18)	20.20 (0.001)

called "creel surveys"). The former has the advantage of being truly population-based, whereas the latter may lack external validity because they depend on a convenience sample. However, creel surveys have the advantage of obtaining information on unlicensed, subsistence anglers and those who might not otherwise answer a mail or telephone survey.

There are inevitably sampling biases in any design that depends on the presence of people at designated places.[26] In this study, we interviewed people who were fishing on the river, and were therefore limited to those people we found. We tried to reduce this bias by conducting our interviews at all times of the day, on all days of the week, along different sections of the river. Furthermore, we approached everyone we encountered and experienced a very low refusal rate (4%), thus reducing any bias due to selection of people to interview.

There is a potential recall bias with respect to the frequency of eating fish and the size of a fish meal. We dealt with the latter by providing them with a reference for quantity (a 6.5-oz. can of tuna). We dealt with the former by asking them in three different places about consumption rates, thereby providing an internal validity check. For example, everyone who said that they did *not* consume fish on one part of the questionnaire later gave their fish meal size as zero when asked about specific species of fish. The correlation between average serving size reported for eating fish on one part of the survey compared to the average serving size reported for specific fish species on the questionnaire was over 0.9. Although it

Table VI. Differences as a Function of Education for Fishermen Interviewed along Savannah River (mean ± SE; NS = not significant; significant differences between means found by Duncan Test indicated by letters)

	Not high school graduate	High school graduate	College or technical training	Wilcoxon χ^2 (p)
Number interviewed	45 (17%)	154 (60%)	59 (23%)	
Number of years fished	36 ± 2 (8–68) A	31 ± 1 (1–73) A,B	28 ± 2 (1–70) B	NS
Years fished Savannah River	23 ± 3 (1–60) A,B	26 ± 1 (1–73) A	17 ± 2 (1–52) B	9.69 (0.008)
Distance traveled (km)	24 ± 4 (2–96)	36 ± 9 (2–960)	54 ± 24 (5–800)	NS
How often they eat fish/month	5.93 ± 0.85 (0–24) A	3.02 ± 0.27 (0–20) B	3.36 ± 0.67 (0–24) B	11.96 (0.003)
Serving size of fish (g)	383.12 ± 13.30 (227–625)	366.10 ± 6.81 (0–597)	397.73 ± 11.78 (199–597)	NS
Fish/month (kg)	2.61 ± 0.44 (0.02–9.55) A	1.15 ± 0.11 (0–8.00) B	1.52 ± 0.31 (0.20–9.55) B	9.45 (0.009)
Fish/year (kg)	31.30 ± 5.26 A (0.18–114.55)	13.79 ± 1.36 B (0–95.46)	18.20 ± 3.66 B (0.23–114.5)	9.45 (0.009)
Percent that deep fry	77 ± 5 (0–100)	80 ± 3 (0–100)	70 ± 4 (0–100)	NS
Percent that eat whole fish	75 ± 6 (0–100) A	76 ± 3 (0–100) A	44 ± 6 (0–100) B	25.35 (0.0001)
Age	49 ± 2 (16–82) A	43 ± 1 (16–82) B	41 ± 2 (20–75) B	NS
Income	$14,359 ± $1,183 A ($0–$32,000)	$21,347 ± 897 B ($0–$55,000)	$27,134 ± 1,864 C ($0–$60,000)	28.41 (0.0001)

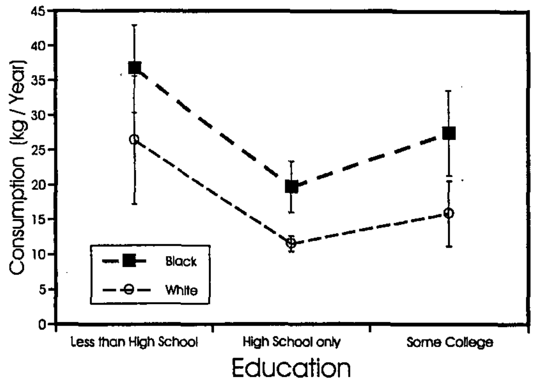

Fig. 5. Curvilinear relationship between educational level and fish consumption by race. Shown are mean ± standard error.

is difficult to obtain accurate information about fishing and consumption and about contaminants in the fish consumed, this information is critical for estimating risk and determining whether advisories are warranted.[27]

An additional aspect deals with the form of questions. Our experience indicates that minimizing the total length of the survey is important and, also, asking similar questions two or more different ways in the questionnaire is helpful in showing internal consistency. When asking about the portion size of fish, we used a standard 6.5-oz can of tuna as a model; this proved to be very helpful in obtaining consistency of results among people. The questions that proved most difficult to answer related to the percent of time people cooked fish by different methods. We suggest that it was difficult to distinguish between deep fry and fry, largely because some people pan fry with a substantial quantity of oil.

We had two categories for how people obtained the fish they ate: self-caught and bought. After completion of the survey we concluded that it would have been useful to distinguish between fish obtained directly from the wild by themselves, friends, or family, and store-bought or restaurant fish. Several people mentioned that attending fish fries held by neighbors and family was an important and frequent social event.

5.2. Advisories and Exposure

The Savannah River runs between South Carolina and Georgia. Georgia has not issued any consumption advisories, although they have pamphlets that explain to the public how to reduce any risk from eating fish. However, South Carolina has issued a fish consumption advisory for the Savannah River from the Augusta Lock and Dam to the I-95 bridge,[20] beyond our interview area. Mercury concentrations provided the basis for the recommended consumption amounts, although specific ingestion levels were also based on cesium-137 and strontium-90. Pregnant women, women planning to get pregnant, and infants and children are advised not to eat fish from the river.[20] Thus, fishermen must decide whether to follow the advice of South Carolina (consumption advisory) or Georgia (no advisory). Whenever two states share waters, but give conflicting advice, confusion can result.[27,28]

Recommended adult consumption limits, according to South Carolina, range from 1 to 4.7 lbs

Table VII. Differences as a Function of SRS Employment for Fishermen Interviewed along Savannah River (mean ± SE; NS = not significant)

	SRS	Non SRS	Kruskal–Wallis X^2 (*p*)
Number interviewed	29 (11%)	229 (89%)	
Number of years fished	25 ± 2 (2–50)	32 ± 1 (1–73)	3.04 (0.05)
Years fished Savannah River	22 ± 3 (1–50)	24 ± 1 (1–73)	NS
Distance traveled (km)	42 ± 9 (5–160)	36 ± 8 (2–960)	NS
How often they eat fish/month	1.38 ± 0.24 (0–4)	3.83 ± 0.30 (0–24)	9.42 (0.002)
Serving size of fish (g)	373.30 ± 14.75 (199–597)	376.46 ± 5.86 (0–625)	NS
Fish/month (kg)	0.62 ± 0.14 (0.02–2.39)	1.55 ± 0.14 (0–9.55)	5.36 (0.02)
Fish/year (kg)	7.41 ± 1.63 (0.23–28.64)	18.59 ± 1.63 (0–114.5)	5.36 (0.02)
Percent that deep fry	84 ± 5 (0–100)	76 ± 2 (0–100)	NS
Percent that eat whole fish	71 ± 7 (0–100)	68 ± 3 (0–100)	NS
Age	38 ± 2 (21–60)	44 ± 1 (16–82)	7.37 (0.03)
Years of schooling	13 ± 0.3 (12–16)	12 ± 0.1 (3–18)	7.81 (0.02)
Income	$32,172 ± 2,552 ($2,000–$60,000)	$20,002 ± $732 ($0–$60,000)	23.34 (0.001)

(0.45–2.14 kg) of fish per month (up to 25.7 kg/yr) of largemouth bass and from 1.5 lbs (680 g) to no limit for other fish (depending on river segment). Our consumption rate for fishermen along the Savannah River (number of meals per month × average serving size) ranged up to 49.1 kg/per year (mean of 2.82 kg) for Blacks, and ranged up to 9.5 kg/year (mean of 1.17 kg) for Whites. It is highly unlikely for any one fishermen to eat only largemouth bass (the species with the most stringent advisories),[20] because they are difficult to catch consistently, and other species of fish caught are brought home for consumption. Even so, these data indicate that some fishermen are exceeding the limits advised by South Carolina.

Long-term risk, however, is a function of the amount of fish eaten, the contaminants therein, and the number of years of exposure. The average time fished in this study was 32 years, with an average of 24 years fished on the Savannah River. This is high, particularly because some people had fished the Savannah River for 50 to 73 years. In our study, Whites fished an average of 2.9 times per month and Blacks 5.4 times per month. In a comparable study in the Everglades, Fleming et al.[19] reported that fishermen had fished an average of 16 years and 1.8 times/month.

Most of our subjects were men, but one of the questions dealt with the amount of fish their wives and children ate. Women and children ate the fish as often as men, and children began to eat the fish at 3–5 years of age. Thus, women and children are clearly eating the fish from the Savannah River. Although we did not specifically ask about pregnancy, only one person mentioned limiting fish consumption during pregnancy, and everyone said their wives ate the fish, all the time, whenever they themselves ate fish. Our data suggest, therefore, that women are not avoiding the fish, nor are they avoiding feeding the fish to children.

Nervous system development in the fetus is the most sensitive endpoint for organic mercury,[13] and is now used in risk assessments to develop reference doses (RfDs) or their equivalent. Data sources used are based on the Iraq organomercury epidemic,[13] and on prospective longitudinal studies in the Seychelles[8] and the Faroe Islands.[9] The EPA IRIS data base lists an RfD of 0.1 μg/kg/day,[29] but the EPA Division of Water has based its fish advisories on an oral RfD = 0.06. The Agency for Toxic Substances and Disease Registry has proposed an RfD of 0.5[30] based on the Seychelles neurodevelopmental study[8] without incorporating an uncertainty factor for inter-individual variation. The data from the Faroe Island study[9] would support a lower value and, indeed, Stern[13] computed an RfD of 0.07 based on data from Iraq. Thus, there is still disagreement about the RfD, with a range of slightly less than an order of magnitude.

5.3. Fish Consumption: Frequency and Amount

Since detailed individual data on fish consumption frequency and serving size are seldom available, most studies examine fish consumption by multiplying the average number of meals per month times the average serving size to obtain the amount of fish eaten, although nutritional epideiologists recognize that this method may underestimate consumption.[31] In this study, computing average fish consumption by this method would yield a rate of 16.2 kg/yr for Blacks (instead of the actual value of 17.6 kg/yr). However, we found that the people who ate fish the most often also ate the largest fish meals, increasing their total consumption over a year. This has the effect of placing more people at greater risk than would appear from examining only averages (see Table IV). This supports the importance of understanding the distribution of exposure variables rather than merely their parameters. Furthermore, there were significantly more Blacks at the high consumption levels than Whites.

These data indicate that studies of fish consumption should take into account individual differences in both rate of fish consumption and quantity of fish consumed per meal. Examining only averages does not give a complete picture of the consumption patterns of those potentially most at risk, but systematically biases towards a low estimate. The data further suggest that the factors that contribute to the total amount of fish eaten per year (= exposure) include ethnicity, education, and age. Income did not enter any of the models independently as a significant variable.

5.4. Ethnic and Socioeconomic Differences and Risk

There is a growing literature on ethnic differences in environmental attitudes and risk, although much of this literature deals with environmental hazards, such as hazardous wastes,[32-34] rather than the health risks from consuming fish. Several studies have indicated that Blacks are generally less concerned than Whites[32–35] about environmental hazards. However, Burby and Strong[36] reported that Blacks were more concerned about environmental pollution than Whites, and Burger[37] found that Blacks living near SRS in Columbia, South Carolina, were equally or more concerned about environmental problems than Whites in the same area. Furthermore, a number of studies have shown differences in fishing behavior between Blacks and Whites, at least with respect to attitudes toward fishing,[1] but little attention has been directed to studies of exposure differences. Fleming et al.[19] working in the Florida Everglades, noted that Blacks were less likely to know about the health advisories than other ethnic groups examined, and Toth and Brown[1] reported higher levels of consumption of fish among Blacks compared to Whites. Furthermore, in their models, economic and subsistence came out as more important contributors to the reasons Blacks gave for fishing than for Whites.

It is important to provide good communication with regard to risk balancing because the beneficial qualities of fish may offset the harm from contaminants. The Alaska Division of Public Health, for example, reached this conclusion with regard to traditional food consumption in Alaska.[38,39] Their reports concluded that the contaminant levels in traditional foods were sufficiently low that the benefits to the native population outweighed the risks.

In this study from the Savannah River, there were significant ethnic differences in nearly all measures of fishing and consumption, and these differences were not attributable to income. However, there was a clear relationship between educational level, ethnicity, age, and fish consumption. On average, the Blacks in our sample had less education and ate more fish per year than did the Whites. The relationship is nonlinear, however in that people, both Black and White who had a high school education ate significantly less fish than people with more or less education (refer to Table V). The reasons for the high fish consumption in people with less and more education is interesting, and may relate to knowledge levels: people with less education (who tend to make less money) may eat more fish because it is a cheap and good source of protein, and people with more education may be more aware of the positive cholesterol-reducing benefits of fish. We cannot separate these two explanations from our data, but suggest that it is important to do so.

In general, Blacks ate larger meals of fish and ate fish more often than did Whites. This suggests that potential exposure is higher for Blacks than for Whites, although the risk depends on the levels of contaminants in the fish. However, given that South Carolina has issued consumption advisories for this portion of the Savannah River, these data suggest that Blacks consuming fish from the study area have a potentially greater exposure to contaminants than do Whites.

The fishermen examined from Savannah River differed considerably from several studies that indicate that the "average" angler is middle-class, White, male, between the ages of 30 and 40 (reviewed in Ebert[12]). The use of general demographics to determine the potential risk of fish consumption patterns for specific waters may seriously miss the mark. For example, Jacobs *et al.*[40] showed that the per capita consumption of fish for the United States was only 0.016 kg/day, far lower than the 0.048 kg/day for the present study. Site-specific information on both demographics and fish consumption is essential to the development of both risk assessment and risk management. It is impossible to target the population at risk if sufficient information on the population is not available.

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EXHIBIT 2.5

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Science, Policy, Stakeholders, and Fish Consumption Advisories: Developing a Fish Fact Sheet for the Savannah River

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ABSTRACT / In recent years there has been a startling rise in the issuance of fish consumption advisories. Unfortunately, compliance by the public is often low. Low compliance can be due to a number of factors, including confusion over the meaning of advisories, conflicting advisories issued by different agencies, controversies involving health benefits versus the risks from consuming fish, and an unwillingness to act on the advisories because of personal beliefs. In some places, such as along the Savannah River, one state (South Carolina) had issued a consumption advisory while the other (Georgia) had not, although at present, both states now issue consumption advisories for the Savannah River. Herein we report on the development of a fish fact sheet to address the confusing and conflicting information available to the public about consuming fish from the Savannah River. The process involved interviewing fishers to ascertain fishing and consumption patterns, evaluating contaminant levels and exposure pathways, discussing common grounds for the provision of information, and consensus-building among different regulatory agencies (US Environmental Protection Agency, South Carolina Department of Health and Environmental Control, Georgia Department of Natural Resources) and the Department of Energy. Consensus, a key ingredient in solving many different types of "commons" problems, was aided by an outside organization, the Consortium for Risk Evaluation with Stakeholder Participation (CRESP). The initial role for CRESP was to offer scientific data as a basis for groups with different assumptions about risks to reach agreement on a regulatory response action. The process was an example of how credible science can be used to implement management and policies and provide a basis for consensus-building on difficult risk communication issues. The paper provides several lessons for improving the risk process from stakeholder conflicts, through risk assessment, to risk management. It also suggests that consensus-building and risk communication are continuing processes that involve assimilation of new information on contaminants and food-chain processes, state and federal law, public policy, and public response.

Hunting and fishing are important activities for many Americans, both for recreation and for food. Public understanding of potential contamination of self-caught food is essential for successful management of exposure and, ultimately, of health effects. Only recently has the scientific community begun to realize that exposure to contaminant levels in some fish are sufficiently high to produce potential adverse health effects, particularly for developing fetuses and young children (Jacobson and others 1989, 1990, Institute of Medicine 1991, Sparks and Shepherd 1994, ATSDR 1995, Jacobson and Jacobson 1996, Schantz 1996). This potential for health effects has led to management of the risk by issuing consumption advisories for some waters and has resulted in cleanup directives from state

KEY WORDS: Fishing; Consumption advisories; Conflict; Consensus-building; Environmental planning; Human health; Risk assessment; Mercury; Cesium; Remediation; Risk communication

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and federal agencies, as well as natural resource damage claims against the responsible parties. The consumption advisories stimulated a flurry of studies to determine the perceptions of risk and compliance by the fishing public.

It is also important to bear in mind that fish and fishing provide many benefits, both nutritional and social (Toth and Brown 1997). For subsistence fishers, fish may be the main affordable source of protein. For others, it may be the healthiest source of protein as well as omega-3 oils, which offer the potential for reduction of cholesterol levels (Hunter and others 1988, Kimbrough 1991, Horn 1992, Anderson and Wiener 1995). Moreover, it is an enjoyable activity that has many social and cultural benefits (Toth and Brown 1997), particularly for Native Americans (Harris and Harper 1997, Burger 1999). The importance of viewing fishing within an integrated context of culture and life-style should not be underestimated.

The US Environmental Protection Agency (EPA 1998a) reported that the number of waterbodies under fishing advisories rose by 9% from 1997 to 1998, and this represents 16% of the nation's total lake acres and 7% of the nation's total river miles. Large portions of US coastal waters, as well as all of the Great Lakes and their connecting waters, are under advisories (EPA 1998a). Mercury accounts for 1931 of the advisories, an increase of 115% from 1993 to 1998; other contaminants with increased numbers of advisories were PCBs, chlordane, dioxins, and DDT. Although the rise in the number of advisories may be due to changes in monitoring or changes in regulatory attention, the sharp rise is cause for concern.

EPA provides guidance both for conducting fish consumption studies and for assessing chemical contaminants data for use in fish advisories (EPA 1998b, 1999). Furthermore, several other regulators have provided insights on the development of plans for fish tissue monitoring, issuance of consumption advisories, and a unified approach to such advisories (Dourson and Clark 1990, Manning 1993).

There is often a gap between the perception of risk by the fish-consuming public and the views on fish consumption expressed by the agencies issuing the advisories (Belton and others 1986, Fiore and others 1989, Reinert and others 1991 Anderson and Wiener 1995, Ebert 1996). The public frequently views eating fish as posing a less serious hazard than does the scientist or environmental manager. People often are aware of advisories, but continue to consume the fish nonetheless (Reinert and others 1991, Burger and Gochfeld 1991, Burger and others 1992, 1993, Velicer and Knuth 1994, May and Burger 1996).

One of the most difficult situations for the fishing public occurs when there is a discrepancy between the information provided by different agencies (Cunningham and others 1994). Such a situation occurs frequently when two or more states are responsible for the same water system, as occurs in the Great Lakes (Foran and VanderPloeg 1989) and along the Savannah River, where for some years, South Carolina issued consumption advisories, but Georgia did not (SCDHEC 1996). In the latter situation, the agencies, along with the US Environmental Protection Agency, recognized the need to provide credible information to local populations to enable effective decision-making when considering the risks and benefits of consuming fish from the Savannah River. The initial discrepancy developed because of different assumptions regarding risk assessment in regard to fish consumption. Although at present both states issue some consumption advisories for the Savannah River, they differ with respect to some of the species of fish covered.

In this paper, we report on the process of developing a fish fact sheet for people fishing along the Savannah River. The overall objective was to produce a one-page fact sheet that all relevant regulatory and compliance agencies could agree on, in terms of content and presentation, distribution, and sources of follow-up information. The process was one of conflict resolution, consensus-building, and overall agreement on a message that was driven and accomplished by a variety of stakeholders. Because of the evolving nature of information on consumption patterns, contaminant levels, and federal and state legislation and regulation (including environmental justice issues), the process is necessarily iterative and on-going. Thus we examine the consensus process to provide insights about a dynamic process.

While several governmental agencies as well as the public have recognized the importance of stakeholder input (NRC 1993, 1995, Commission on Risk Assessment and Risk Management 1996), there are few published papers detailing the inclusion and importance of stakeholders in the process (see Boiko and others 1996, Jacobson and Marynowski 1997, Harris and Harper 1997). Pittinger (1998) emphasized the importance of involving both risk assessors and risk managers right from the start. For the purposes of this project, we define stakeholders as any individuals, organizations, or agencies that have an interest in the maximization of public health through wise patterns of fish consumption.

Background: Contamination, Conflicts, and Consumption Advisories

The Savannah River originates in the southern Appalachians of North Carolina, passes through South Carolina and Georgia, and flows to the Atlantic Ocean near Savannah. On its winding path it flows through several large reservoirs and past various industrial sites, including chemical factories, nuclear power plants, and the Savannah River Site. The Savannah River Site (SRS) of the Department of Energy is a 780-km^2 nuclear production and research facility. The nuclear reactors were operated from the early 1950s until 1988. Water from the Savannah River was used for cooling the reactors and was deposited in thermal cooling reservoirs on site. Radionuclides were released during this period (Ashley and Zeigler 1980). While there is the potential for contamination of fish from radionuclides (^{90}Sr, ^{137}Cs), mercury is the primary contaminant of concern in fish from the Savannah River (SCDHEC 1996).

The original source of mercury in the Savannah River was from upstream contamination from a chemical plant, although some came from SRS (Kartek and others 1994). However, the problem is of interest to the Department of Energy since they pumped water from the Savannah River to cool their nuclear reactors and so have redistributed and concentrated the mercury both on SRS lands and in the swamplands and streams that run into the Savannah River. DOE is mindful of its economic and social role in the region, since SRS is one of the largest local employers (Greenberg and others 1998). EPA, with a concern both for risk associated with fish consumption patterns and possible equity issues associated with higher consumption rates by minorities, initiated discussions with DOE concerning contaminants in fish, risk from fish consumption, and methods of risk reduction.

The South Carolina Department of Health and Environmental Control (SCDHEC) has issued fish consumption advisories for some time that include the Savannah River from the Augusta Lock and Dam to the Rt. 301 bridge, and includes the river bordering the SRS (SCDHEC 1996, 1999) (Figure 1). The advisories state clearly how much can safely be eaten and what species of fish to avoid. Initially the advisories were driven by mercury contamination; however, radionuclides were also taken into account (SCDHEC 1996, 1999). Georgia did not initially issue advisories, although each year they issued a "Guidelines for Eating Fish from Georgia Waters," which includes a discussion of contaminants, risk, and risk reduction. Georgia now issues recommendations (or advisories) for consumption of some species of fish from the Savannah River (GDNR 1999). At present, there are still discrepancies between the species of fish under advisories and the target population.

EPA, through its regional office in Atlanta, Georgia, provides CERCLA oversight for all federal facilities in the eight-state southeast region. This office had determined significant risk existed for certain populations. However, the coordination among the two states and another powerful federal agency (DOE) required a more thoughtful strategy to ensure better public information regarding risk, without creating other institutional conflicts. The EPA desired that each state maintain its jurisdictional primacy with respect to public health, while insisting that a tangible form of risk communication resulted. EPA is also mandated by a Federal Executive Order 12898 to address environmental justice issues, particularly in regard to its oversight of federal facilities (such as DOE).

When it became apparent that there was confusion regarding the appropriate public response to the consumption advisories and that there may be people eating considerable quantities of fish from the Savannah River, the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) offered to help the EPA regional office, the two states, and DOE by obtaining credible data on fish consumption patterns and by acting as a facilitator to help reach consensus among the state and federal regulators on the appropriate public message concerning the consumption of fish from the Savannah River. This is an on-going process because of the evolving nature of new information on contaminants, consumption patterns, receptor pathways, and public response.

The Role of Science in the Process

Although both South Carolina and Georgia used the same data on levels of contaminants in fish to conduct their human health risk assessment, they arrived at different management strategies. There were several areas of uncertainty about fishing and fish consumption on the Savannah River. One important uncertainty concerned the patterns of consumption of local fishers; there was little information on consumption rates and cooking methods (Burger 1998). Such information is best gathered by interviewing the fishers who are most at risk (Velicer and Knuth 1994)—those actually fishing on the Savannah River.

A key aspect of obtaining information on fish consumption on the Savannah River was the inclusion of a wide range of stakeholders. They were involved in the kinds of information solicited, the design of the questionnaire, the design of the sample, the region and

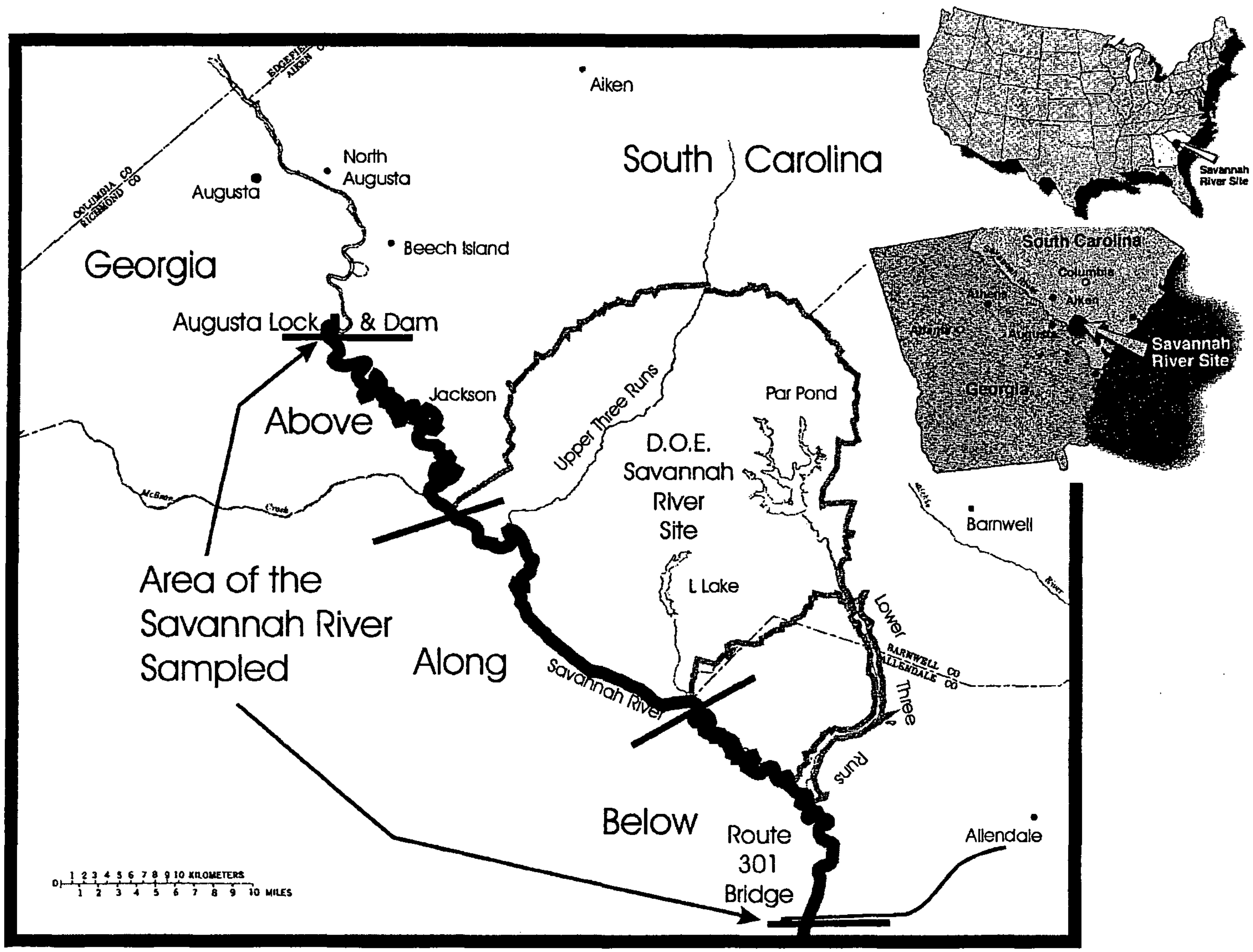


Figure 1. Map of the Savannah River indicating areas where fishermen were surveyed.

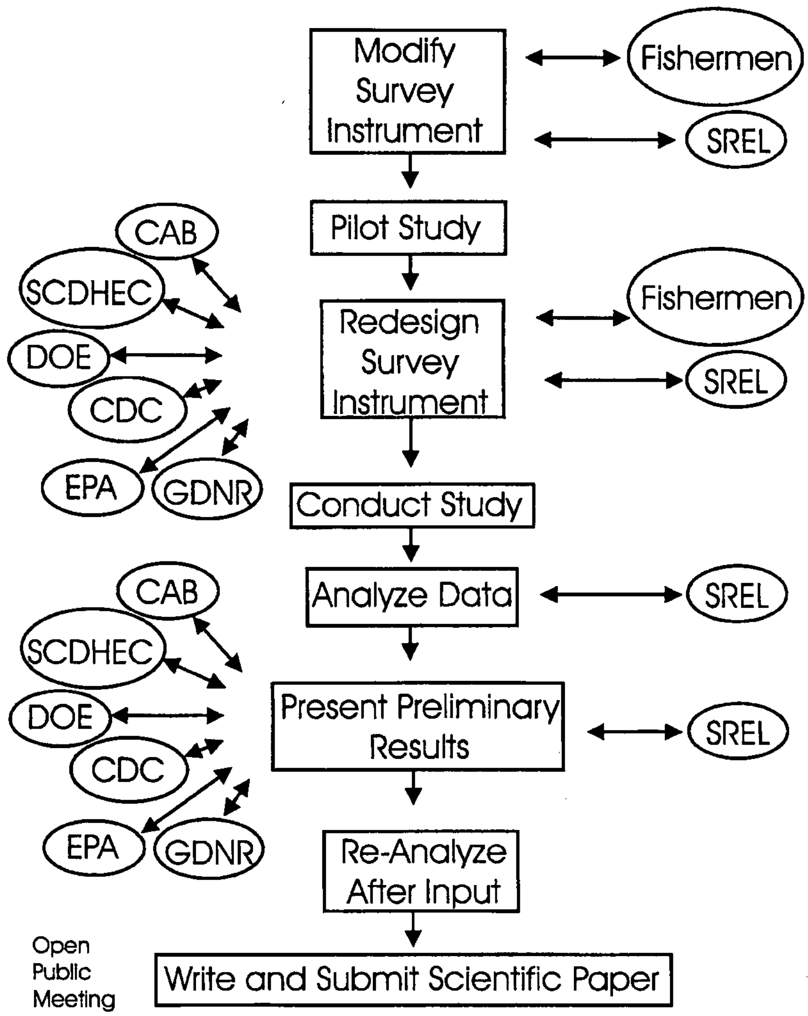


Figure 2. Schematic of the process involved in conducting a stakeholder-driven survey of fishing behavior and consumption patterns for fishermen along the Savannah River by CRESP (Consortium for Risk Evaluation with Stakeholder Participation). EPA = U.S. Environmental Protection Agency, SCDHEC = South Carolina Department of Health and Environmental Control, GDNR = Georgia Department of Natural Resources, DOE = U.S. Department of Energy, CDC = Centers for Disease Control and Prevention: Subcommittee for Health Effects, CAB = Citizens Advisory Board for the Savannah River Site, SREL = Savannah River Ecology Laboratory.

population to be sampled, and the analysis of the data. While the research design is the responsibility of the scientists involved, the information gathered can best inform the regulatory agencies if the data are what they need for appropriate response actions. Since CRESP is committed to undertaking studies with input from a wide variety of stakeholders, consultation was elicited at every stage in the process.

The fishing and consumption survey conducted by CRESP involved the following steps (shown in Figure 2) (Burger 1998, Burger and others 1999):

1. Modifying a previously used and tested questionnaire on fishing and consumption to make it relevant to the Savannah River (after Burger and Gochfeld 1991).
2. Collaborating with the Savannah River Ecology Laboratory (SREL), located on the SRS, concerning all aspects of the research, particularly with regard to the local fish fauna and contaminants.
3. Conducting a pilot study of 40 fishers along the Savannah River to elicit their responses to the survey questions and other reactions and information about fishing that might be critical to understanding fish consumption patterns.
4. Presenting the results of the pilot study to the Centers for Disease Control and Prevention (CDC) Subcommittee for Health Effects for comments, suggestions, and modifications.
5. Soliciting informal comments from members of the Citizens Advisory Board for SRS, and from EPA, DOE, and the relevant state agencies.
6. Redesigning the questionnaire and extending the survey region as a result of the pilot study and the input of various stakeholders.

7. Conducting the survey.
8. Analyzing the data.
9. Presenting the preliminary results to regulatory agencies (SCDHEC, Georgia Department of Natural Resources, EPA), DOE, a subcommittee of the Citizen's Advisory Board, and the SRS-CDC health effects subcommittee.
10. Refining the analysis to reflect additional concerns, questions, and information needs of the stakeholders. This aspect of the study is continuing as the state and federal agencies refine their needs.
11. Writing up the study for publication in scientific journals, as well as responding to requests for accounts in the popular press.

While most of the above steps do not need further explanation, several do. Developing a suitable questionnaire on fishing and consumption patterns is critical because site-specific information on exposure is essential for risk assessment, and its relevance is also germane to eliciting cooperation (Velicer and Knuth 1994, Anderson and Wiener 1995). The total design for the project included evaluating the importance and role of fishing and hunting in the local cultures (Burger 1997, 2000, Burger and others 1997).

We feel strongly that the inclusion of a variety of stakeholders in the pilot study and redesign of the questionnaire, while it undoubtedly took more time, was essential to providing the best information, as well as ensuring that the information was later deemed credible by the relevant regulatory agencies and the public.

Two other aspects were essential to the success of the fishing and consumption study: (1) the inclusion of scientists from the SREL in all phases of the research, and (2) the use of local interviewers familiar with the culture and locations. Inclusion of scientists from SREL ensured that local viewpoints and existing local information were incorporated at all stages. The use of local people to conduct the interviews ensured a very high response rate, enabled interpretation of local customs regarding cooking, and ensured more accurate information.

Conducting a pilot study allowed us to determine whether any questions were confusing and what information might be lacking, as well as allowing for a power analysis to determine the sample size necessary for appropriate statistical analysis. Furthermore, results from the pilot were discussed with various stakeholders, allowing them to suggest further questions. For example, following the pilot study, members of the SRS-CDC health effects committee recommended the addition of questions regarding cooking practices and the age at which children first begin eating fish. Other stakeholders suggested adding questions about the sources of information people used in making decisions about fish consumption.

Finally, the presentation of draft results to several stakeholder groups (regulatory agencies, DOE, SRS-CDC health effects subcommittee and the SRS citizen's advisory board subcommittee) allowed us to examine other questions they felt were relevant to decisions about risk management and the fish fact sheet. Recognition of the need to negotiate and reach a consensus is key to conflict resolution (Fisher and Ury 1981, Burkardt and others 1998) and is particularly important where there may be differences in both the methods and assumptions of risk analysis. The assumptions of risk management are, by their very nature, value-laden (Silbergeld 1991), and this also must be taken into account.

The Role of Science: Providing Exposure Assessment Data

The overall results of the fishing and consumption study can be summarized as follows (Burger 1998, Burger and others 1999): Ethnicity and education were the two factors that contributed the most to explaining variations in the number of fish meals per month, serving size, and total quantity of fish consumed per year. Blacks fished more often, ate more fish meals, ate larger serving sizes, and consumed more fish per year than did whites. Although few women were interviewed, their consumption patterns did not differ markedly from the men. Blacks also traveled shorter distances to fish, had significantly lower incomes, and spent fewer years in school than whites. Fishers with incomes below $20,000 ate fish slightly more times per year than those with higher incomes. Although education and income were correlated, education contributed more to explaining differences in fishing and consumption behavior than did income. Fishers who did not graduate from high school ate fish more often, ate more fish per year, ate more whole fish, and had lower incomes than those who graduated from high school. Depending upon the species of fish, children began to eat fish between the ages of 3 and 5 years.

Using the data on meal size and fish consumption rates for each individual indicates that: (1) people who eat fish more often also eat larger portions, (2) a substantial number of people (72 of 258) exceed the fish consumption threshold (19 kg/year) used by the SCDHEC to compute risk to recreational fishers, (3) some people (24 of 258) consume more than the subsistence

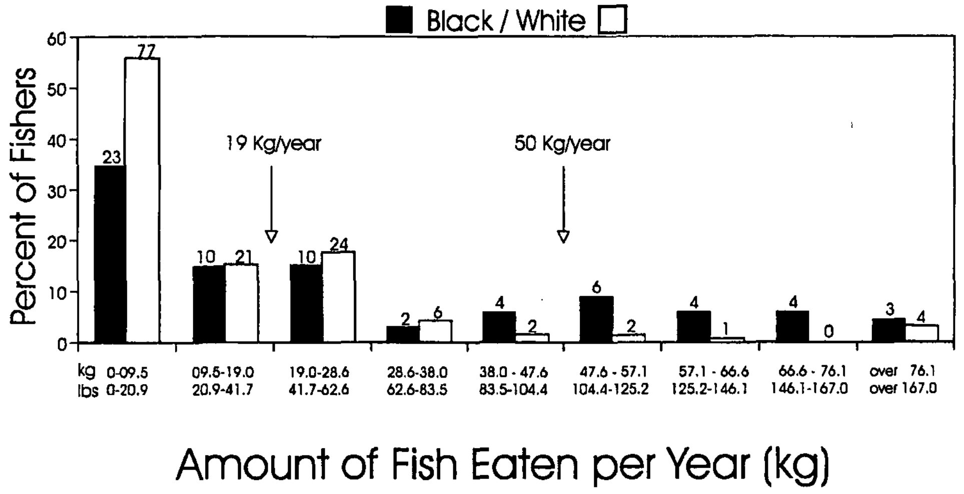


Figure 3. Fish consumption rates of black (black bar) and white (white bar) fishermen interviewed along the Savannah River (after Burger and others 1999).

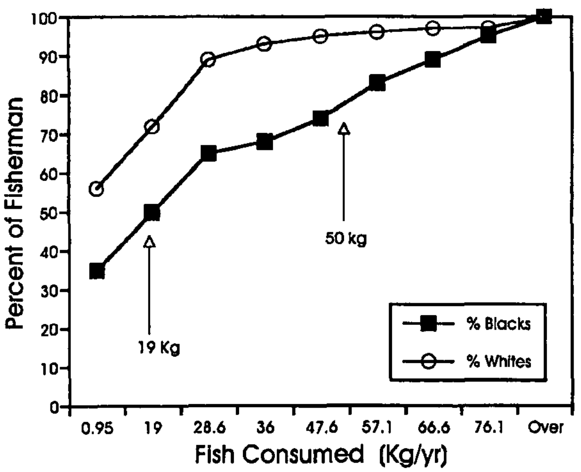


Figure 4. Cumulative percent of people consuming fish as a function of ethnicity.

level default assumption (50 kg/year) used by SCDHEC (1996), and (4) blacks consume more fish per year than whites, putting them at greater risk from potential contaminants in fish (Figure 3). Overall, ethnicity, age, and education (but not income) contributed to variations in fishing behavior and consumption. Clearly, a higher proportion of blacks are consuming more than 19 kg/year, compared to whites (Figure 4).

Even though 62% of the fishers were aware of the advisories issued by SCDHEC, over 80% believed the fish were safe to eat. Fewer blacks, low-income people, and people who had never worked at SRS knew about the consumption advisories, compared to others. Sources of information about the contents of the advisories included newspapers, television, and other people. Few people said they learned about the advisories from doctors, public health officials, or the printed brochures (Burger 1998).

The information provided by the interviews of people fishing along the Savannah River served as a common base for further discussion, and reinforced the mandate of EPA to ensure that affected communities were aware of the risks attendant with fish consumption. EPA's regulatory role in relation to DOE served as a stimulus for further discussion among DOE and the state regulatory agencies.

The Role of Interdisciplinary Information

While information on fishing and consumption patterns was key to providing a solid base for discussions among the agency stakeholders about a common fish consumption message, data and review from many other disciplines were essential to evaluate the potential risk from consuming fish from the Savannah River. This included evaluation of contaminant data on fish and pathways of exposure and involved scientists in exposure assessment and remediation technologies. It was essential to bring several other aspects of risk assessment and management to bear in evaluating the information to use in a fish fact sheet, including aspects of ecological health, public and worker health and safety, data characterization, and outreach and communication.

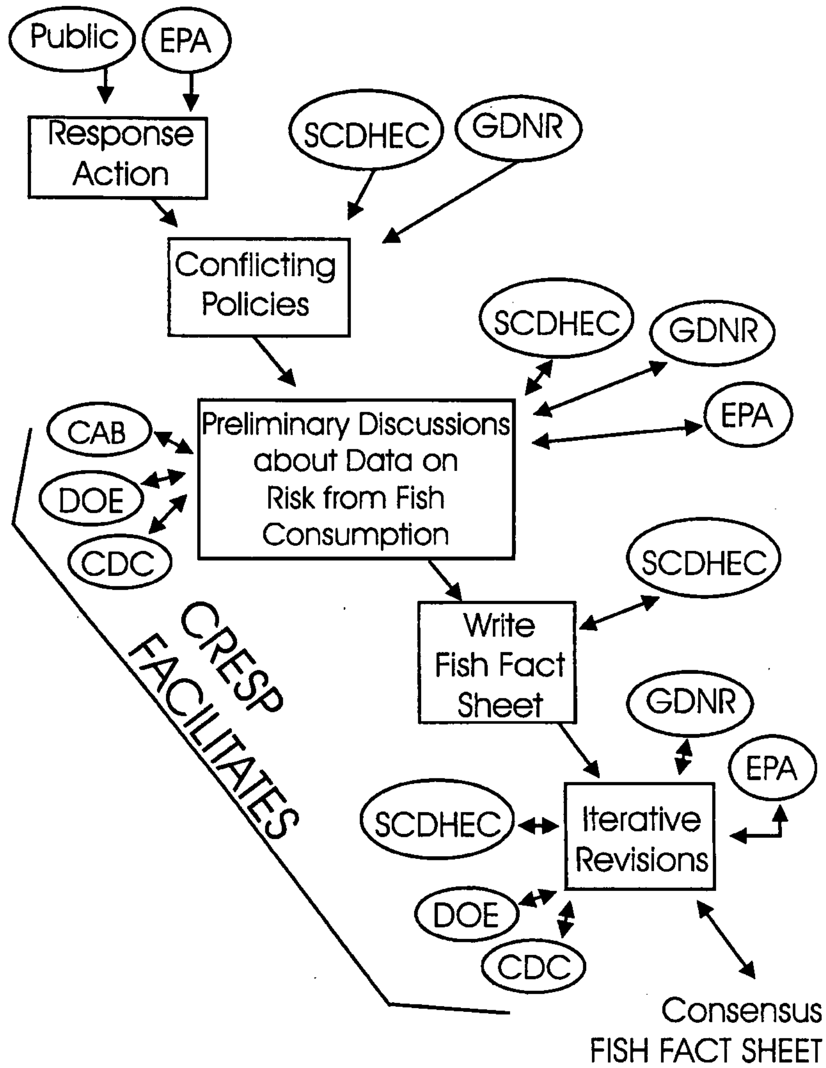


Figure 5. Schematic of the process involved in developing the fish fact sheet. CRESP (Consortium for Risk Evaluation with Stakeholder Participation). EPA = U.S. Environmental Protection Agency, SCDHEC = South Carolina Department of Heath and Environmental Control, GDNR = Georgia Department of Natural Resources, DOE = U.S. Department of Energy, CDC = Centers for Disease Control and Prevention: Subcommittee for Health Effects, CAB = Citizens Advisory Board for the Savannah River Site.

Facilitation Leads to Consensus Among Agency Stakeholders

With the data provided by the fishing and consumption study, it became apparent that it was essential to develop a simple, readable and attractive fish fact sheet that contained information on consuming fish from the Savannah River. While the two state agencies still have differing viewpoints on the issuance of fishing advisories concerning fish species, it was clear that a common message could be developed that would provide necessary information to fishers.

Considerable discussion took place among all the relevant agencies (SCDHEC, GDNR, DOE, EPA) about the kinds of information to present in the fact sheet, EPA provided initial content, and then South Carolina took the lead in writing the initial draft. This was followed by numerous communications concerning the intent and wording of the draft, including conference calls where representatives from all agencies and CRESP were involved. The draft was also reviewed by the relevant citizens advisory board, and the SRS-CDC health effects subcommittee, both for content and presentation. While CRESP facilitated this process, it was the hard work on the part of all involved that resulted in a consensus on the information to provide in the fact sheet, as well as the wording and presentation. This consensus process is shown in Figure 5.

Several principles guided our deliberation, including:

1. Fish are a good source of protein (Hunter and others 1988, Kimbrough 1991, Horn 1992, Anderson and Wiener 1995), and the benefits of fish

consumption must be clear in the fish fact sheet. In addition to direct health benefits of fish consumption, fish also play a key role in social and cultural practices (Toth and Brown 1997).

2. The realization that there was a population of fishers that ate substantially more fish than was previously thought provided justification for the development of the fish fact sheet and motivated the group to reach a consensus.
3. Information on the demographics of the population of fishers and credible sources of information helped outreach and communication specialists design the format and content of the fish fact sheet.
4. Since both radionuclides and mercury are contaminants that can increase the risk of developmental effects, the focus should be on pregnant women and young children.
5. Complete site characterization and extensive knowledge of the sources and pathways is not required to communicate about the potential risks of fish consumption.
6. It should be clear to the public that the fish fact sheet represents consensus among both state regulatory agencies, as well as EPA. This was accomplished by the inclusion of appropriate logos from each agency, with contact numbers where the public can find out more information.

With these in mind, it was possible to provide a message that focused risk reduction for fish consumers overall, on a sensitive target group (pregnant or soon-to-be pregnant women), and to recommend switching to fish species with lower contaminant levels.

Efficacy of the Fish Fact Sheet and Risk Communication

One commitment made by the researchers in their survey protocol, approved by Rutgers University Human Subjects Review Board, was to provide information to the original subjects of the study. The mechanism selected was to distribute the fish fact sheet to people fishing along the Savannah River, ask them some risk communication questions about the sheet, and provide answers to their questions regarding fish consumption (Burger and Waishwell, unpublished data). Nearly everyone we approached agreed to answer our questions, and 90 of 93 people took the fact sheet home. Over 40% of those interviewed correctly identified the target audience, and over 80% understood that they could reduce their risk from eating fish by limiting fish intake in some way. When asked whether they had other comments or would like other information, 50% of black people interviewed asked where they could get the fish fact sheet or when more would be available, indicating an interest in such information. White fishers asked about the levels of contaminants in fish (50%), and both groups asked who was going to clean up the river. These interviews indicated the importance of continuing to refine the fish fact sheet as information becomes available and documented the interest of the fishers in receiving such information.

Lessons for the Future

State agencies have a clear responsibility to provide information to the public about the safety of self-caught foods, including fish (Manning 1993, EPA 1999). While the US EPA provides general information on national consumption rates of fish, contaminant levels of concern, and summaries of water bodies with consumption advisories (EPA 1999), it is still the responsibility of individual states to obtain site-specific information on consumption rates and contaminant levels and to issue advisories where appropriate.

Where there is disagreement between two or more states about the issuance of advisories, the suitable levels of consumption, or the fish species of interest, the development of a fish fact sheet aimed at providing the public with consensus information may be the best solution. It removes the discussion from the necessity to agree on the exact risk methodologies used, and the assumption used, to reaching consensus on the key points the fishing public should be aware of in making their own decisions about how much fish to consume. In contrast, a fish advisory is driven by specific risk assessments, which may involve a number of disputed assumptions.

It is important to stress both the benefits and the risks of consuming fish. Fish clearly provide a good and healthy source of protein (Hunter and others 1988, Kimbrough 1991, Horn 1992, Anderson and Wiener 1995), although some chemicals in contaminated fish have the potential to cause adverse developmental effects (see Jacobson and others 1989, 1990, Institute of Medicine 1991, Sparks and Shepherd 1994, ATSDR 1995, Jacobson and Jacobson 1996, Schantz 1996). The importance of providing both types of information should not be underestimated because the public is surely aware of it (Egeland and Middaugh 1997).

The input of stakeholders was essential to the consensus necessary to produce the fish fact sheet. Many different agencies have recognized the importance of including stakeholders at an early stage in the decision-

Eating Fish from the Savannah River

Did you know...

- Some fish from the Savannah River have chemicals in them that can cause health problems.
- Fish caught in the Savannah River may contain mercury.
- Fish caught in Steel Creek, Lower Three Runs Creek, and Fourmile Branch may also contain cesium and strontium.
- Fish that contain these chemicals do not look, smell, or taste different.

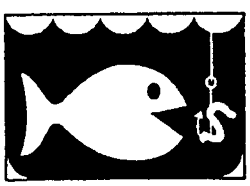
Why is this important to me?

Eating fish with mercury, cesium, and strontium will not make you sick right away. But as you eat more and more, they may build up in your body.

Mercury is more harmful to babies and children than adults. Unborn babies and children have nervous systems that are still forming. Pregnant women can pass mercury to their unborn babies. Mothers can pass it to their babies through breast milk.

Can I still eat fish?

Fish is a healthy, low-fat source of protein. There is no way to clean or cook the fish to get rid of mercury and cesium. This is because they are stored mostly in the meat of the fish, and not in the fat or skin. You can reduce strontium by



removing the scales and bones before cooking. You can further reduce health risks from eating fish by doing these things:

- Follow the advice in this fact sheet.
- Eat smaller fish.
- Eat smaller amounts of fish.
- Eat fish from places like markets and restaurants, and from lakes and rivers without fish advisories.
- Eat crappie, pickerel, and sunfish which have lower levels of chemicals.

How much fish can I eat?

Most people should not eat more than one meal a week of largemouth bass or bowfin from the Savannah River. Unborn babies, infants, and children can be more easily harmed by mercury. If you are pregnant, planning a pregnancy, breast-feeding, or have young children, please call one of the telephone numbers on the back of this page for more information.

Remember...

- Mercury is more harmful to babies and children.
- Pregnant women and women with young children should call for more information before eating fish.
- Most people can still eat up to one meal a week of largemouth bass or bowfin.
- The Savannah River is safe for boating and swimming.

Figure 6. The fish fact sheet developed through the process described in this paper.

Will eating fish affect my health?

If large amounts of mercury, cesium, or strontium get into your body, they may cause health problems.

Mercury collects in fish meat and may build up in people who eat fish. It is harmful to the kidneys and nervous system (brain, spinal cord, and nerves). In most cases, health effects from mercury in adults go away as the body gets rid of it.

Cesium collects in fish meat and, when eaten, may build up in your muscles. Cesium is a radioactive substance which can injure cells. It may increase the risk of developing cancer.

Strontium collects in the scales and bones of fish and, when eaten, may build up in your bones. Strontium is a radioactive substance which can injure cells. It may increase the risk of developing cancer.

Is catching and releasing O.K.?

People who want to continue to enjoy fishing, but also want to avoid any risks from eating fish containing the chemicals, should consider catching and releasing. Catching and releasing is a good way to preserve your local fishery.

How can I get more information?

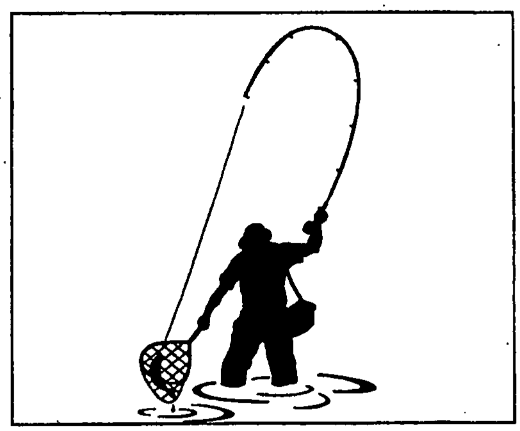
If you have questions or need more information, please call:

(803) 641-7670
Local DHEC Office in Aiken

(888) 849-7241 (toll-free)
DHEC Division of Health Hazard Evaluation

(706) 369-6376 or (404) 656-4713
Georgia Department of Natural Resources

(800) 241-1754
U.S. Environmental Protection Agency



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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY making process (NRC 1993, Commission on Risk Assessment and Risk Management 1996), particularly for agencies such as the DOE (NRC 1995, Jacobson and Marynowski 1997) where the magnitude and costs of the decisions are so great. While the creation of citizens advisory boards was an excellent first step (Boiko and others 1996), inclusion of an even broader range of stakeholders was an important part of the process of consensus-building about the fish fact sheet. We note in passing that two groups that were not involved in the process were downstream residents and local elected officials, who are particularly important in addressing environmental equity issues (Greenberg and Cidon 1997).

In the development of the fish fact sheet reported here, we found several things to be essential: (1) the acquisition of credible data on fishing and consumption patterns, (2) the inclusion of a wide range of stakeholders in the study design and development, (3) the willingness of all agencies to reach consensus on a message about fish consumption, and (4) the presence of an outside entity (CRESP) that could facilitate the process, while not being previously or directly related to the local situation. Further, evolving information on fishing and consumption patterns (which may change over time), contaminant levels, food-chain effects, federal and state regulations and laws, and environmental justice concerns will force the process to be dynamic and iterative. Because of their commitment to providing appropriate risk information and developing sound public policy, all parties are willing to continue the dialog, based on sound science and equity concerns. Willingness to reach a consensus is a key ingredient of conflict resolution (Fisher and Ury 1981, Kriesberg and Thorson 1991, Burkardt and others 1998). All of these aspects played a critical role in our ability to reach consensus on both the fish fact sheet itself and on a suitable distribution plan and public outreach. Evaluation of the impact of fish fact sheet is a necessary follow-up to a public outreach approach.

Acknowledgments

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EXHIBIT 2.6

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Effects of Cooking on Radiocesium in Fish from the Savannah River: Exposure Differences for the Public

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Abstract. Understanding the factors that contribute to the risk from fish consumption is an important public health concern because of potential adverse effects of radionuclides, organochlorines, other pesticides, and mercury. Risk from consumption is normally computed on the basis of contaminant levels in fish, meal frequency, and meal size, yet cooking practices may also affect risk. This study examines the effect of deep-frying on radiocesium (^{137}Cs) levels and risk to people fishing along the Savannah River. South Carolina and Georgia have issued consumption advisories for the Savannah River, based partly on ^{137}Cs. ^{137}Cs levels were significantly higher in the cooked fish compared to the raw fish on a wet weight basis. Mean ^{137}Cs levels were 0.61 pCi/g (wet weight basis) in raw fish, 0.81 pCi/g in cooked–breaded, and 0.99 pCi/g in cooked–unbreaded fish. Deep-frying with and without breading resulted in a weight loss of 25 and 39%, while ^{137}Cs levels increased by 32 and 62%, respectively. Therefore, the differences were due mainly to weight loss during cooking. However, the data suggest that risk assessments should be based on cooked portion size for contaminant analysis, or the risk from ^{137}Cs in fish will be underestimated. People are likely to estimate the amounts of fish they eat based on a meal size of the cooked portion, while risk assessors determine ^{137}Cs levels in raw fish. A conversion factor of at least two for ^{137}Cs increase during cooking is reasonable and conservative, given the variability in ^{137}Cs levels. The data also suggest that surveys determining consumption should specifically ask about portion size before or after cooking and state which was used in their methods.

Protecting human health involves assessing hazards and understanding how to avoid or mitigate harm. Scientists have devoted considerable time to assessing the hazards posed to organisms by metals, organochlorines, other pesticides, and radionuclides, often using bioindicators and biomarkers of exposure (Kolehmainen 1972; Sheehan *et al.* 1984; Whicker *et al.* 1990; Brisbin 1991; Burger 1993; Renzoni 1994; Hoffman *et al.* 1995; Linthurst *et al.* 1995) Fish are particularly useful as bioindicators of contamination because of their role in the food chain, for both humans and other organisms.

Fishing is an important aspect of culture and tradition in much of the United States, particularly in the Southeast (Fleming *et al.* 1995; Toth and Brown 1997; Burger *et al.* 1999a, b). Contaminants, such as mercury and polychlorinated biphenyls (PCBs), as well as radionuclides, are sufficiently high in some fish and seafood to pose a potential risk to human consumers (ATSDR 1996; IOM 1996; Ratcliffe *et al.* 1996; Kamrin and Fischer 1999; Burger *et al.* 2001). Concern about such health risks has led to the issuing of consumption advisories for some waters (EPA 2000). Fetuses, neonates, and young children are the group most at risk (Ratcliffe *et al.* 1996; Weiss and Elsner 1996; Weihe *et al.* 1996; Jacobson and Jacobson 1996). Risk reduction for fetuses and neonates often involves calculating the appropriate consumption for pregnant women, combined with appropriate risk communication (Knuth 1996; Ebert 1996).

Risk from fish consumption involves data on contaminant loads of fish, meal frequency, and meal size. Yet other factors may affect the risk from fish consumption, including cooking practices (Zabik and Zabik 1995; Zabik *et al.* 1995; Morgan *et al.* 1997; Wilson *et al.* 1998). Several studies have examined the effect of trimming fat, removing skin, and cooking on mercury, PCBs, and other fat-soluble contaminants (Morgan *et al.* 1997; Burger 1998) and on pesticides (Zabik and Zabik 1995; Zabik *et al.* 1995), but no attention has been devoted to ^{137}Cs. Trimming and cooking of fish by various means reduces the levels of fat-soluble contaminants but not mercury (Burger *et al.* 2003). The effect on ^{137}Cs is unclear.

This article examines the effect of deep-frying on radiocesium (^{137}Cs) levels in largemouth bass (*Micropterus salmoides*), a preferred fish of people in South Carolina and else-

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where in the South (Fleming *et al.* 1995; Burger 1998). It is important to understand the effects of cooking and the use of batter on ^{137}Cs levels in fish because over 80% of the people interviewed along the Savannah River deep-fried their fish regularly (Burger *et al.* 1999), and when asked, 90% said that they were basing it on how their fried fish looked. Additionally, in a survey of students at Rutgers University, nearly 98% said that they were basing consumption on broiled or cooked fish (Burger, unpublished data).

We test the hypothesis that the levels of ^{137}Cs in raw and deep-fried fish (with and without a batter) does not differ. If the levels of ^{137}Cs differ in cooked and raw fish, this has major implications for risk assessment because most consumption studies report consumption on the basis of cooked fish (Fleming *et al.* 1995; Kamrin and Fischer 1999; Burger *et al.* 1999), yet contaminant data are reported for raw fish (Morgan *et al.* 1997; Wilson *et al.* 1998; Burger *et al.* 2001a, b).

Our overall objective was to determine whether deep-frying affects the resultant risk assessment for fish consumption. There are consumption advisories for largemouth bass from the Savannah River (SCDHEC 1996; GDNR 2001), and the inclusion of cooking effects will help clarify risk associated with bass consumption in this region.

Materials and Methods

Fish (N = 39) were collected from L Lake on the Savannah River Site (SRS; 33.1°N, 81.3°W) (Fig. 1), a 780-km^2 nuclear weapons production and research facility operated by the U.S. government since the early 1950s. L Lake was constructed in 1985 to serve as a source of cooling water for the reactor but was used infrequently (Kennamer *et al.* 1998). Prior to the construction of the lake, there was some ecosystem contamination of streams and the floodplain (Ashley and Zeigler 1980; Whicker *et al.* 1990). Some contaminants came from industrial activities upstream from SRS, activities on-site also resulted in contamination by a wide range of heavy metals and radionuclides (Kvartek *et al.* 1994; Sugg *et al.* 1995), and atmospheric deposition also contributed contaminants to SRS.

The SRS produced plutonium and tritium and processed other nuclear materials for nuclear weapons and other governmental and private industrial purposes. Radiocesium was released to the environment during the operation of a high-level waste storage system, two radiochemical processing facilities, and five production reactors (Cummins *et al.* 1991). Carlton *et al.* (1994) estimated that 65% of the released Cs remained on site. Impoundments on SRS were used as thermal cooling reservoirs for nuclear production reactors (Asley and Zeigler 1980; Whicker *et al.* 1990.

Fish were collected from L Lake under appropriate state permits and with protocol approvals from the University of Georgia Institutional Animal Care and Use Committee (A960205) and Rutgers University Institutional Review Board (07-017). Fish were collected using a rod and reel, placed on ice, and immediately dissected upon return to the laboratory at the Savannah River Ecology Laboratory (SREL).

Dissected fish were immediately frozen (−4°C) and labeled by date and collection location. The fillet from one side of the fish was designated for frying, while that from the other side was designated as raw. The side that was chosen for cooking was then divided longitudinally for a breaded and nonbreaded treatment. The designation of the side for the raw and breading treatment was done at random.

Fillets were cooked either with or without batter. Batter was applied by dusting the wet fillet with dry breading mixture (Zatarain's Seasoned Fish Fry, New Orleans, LA). Cooking was done according to local customs using local deep-frying vats and using the same oil (Dukes Peanut Oil) as is the local custom. However, we cooked all the unbattered fish first to avoid cross-contamination. Fillets were weighed before and after cooking. Fillets were submerged in the hot oil until the fillet began to float, indicating that cooking was complete. It was then patted dry and frozen for later analysis.

We determined ^{137}Cs count rates of wet muscle tissue using a Gamma-X HPGe High-Purity Germanium Coaxial Photon Detector System with a 56.7 × 77.3-mm crystal. An EG&G Ortec 92 × Spectrum Master integrated spectroscopy system with associated Gamma Vision Software was used for data acquisition. A counting window of approximately 658–666 keV was used after a peak region of interest was acquired after calibration with a known ^{137}Cs standard to record total absorptions from the ^{137}Cs emission of 662-keV photons. Counting time per sample was 500 min. Simultaneous background counts were performed for each sample. Count rates of standards were determined weekly before or after every counting sequence. The minimal detectable activity (MDA) was calculated using a 2-σ detection limit where the peak count is equal to twice the sum of 1 plus the square root of the sum of 1 plus the background divided by the live time (Currie 1968). All values are pCi/g (wet weight basis).

We used the Kruskal-Wallis non-parametric one-way analysis of variance (Wilcoxon option in the Statistical Analysis System PROC NPARIWAY) to examine differences among treatments (SAS 1995). The level for significance was designated as < 0.05.

Results

The moisture content of fish ranged from 67 to 77%. Mean ^{137}Cs levels were 0.61 pCi/g in raw fish and 0.81 and 0.99 pCi/g in breaded and unbreaded cooked fish. There were significant differences in ^{137}Cs levels (wet weight basis) as a function of treatment (Table 1) (χ^2 = 53.5, df = 2, $p <$ 0.0001). ^{137}Cs levels were 32% (breaded) and 62% (nonbreaded) higher in cooked than raw fish.

Discussion

The source of the ^{137}Cs in the fish was industrial pollution, since L Lake was used as a source of cooling water for a nuclear reactor when it was functioning (Kennamer *et al.* 1998). Prior to the construction of the cooling ponds, there was some ecosystem contamination of streams and the floodplain, and small quantities of radionuclides were released subsequently (Ashley and Zeigler 1980; Whicker *et al.* 1990; Kennamer *et al.* 1998). There is no controversy about the source of ^{137}Cs contamination in L Lake, although there is some limited atmospheric deposition of ^{137}Cs on-site.

Contaminants and radionuclides in fish are usually calculated on a wet weight basis, rather than a dry weight basis. While drying fish for dry weight analysis results in complete moisture loss, cooking for human consumption removes only some of the moisture. For fish (N = 11 species) collected in the Savannah River, the dry weight ranged from 23 to 33% of the corresponding wet weight (i.e., water content of 67–77%). Thus for the same samples, levels expressed on a wet weight basis are 1/4 to 1/3 of the same content expressed on a dry weight basis, although in some fish the ratio may be as high as 1/5 (Burger *et al.* 2001a). As has been found previously, the differences between raw and cooked fish are largely due to

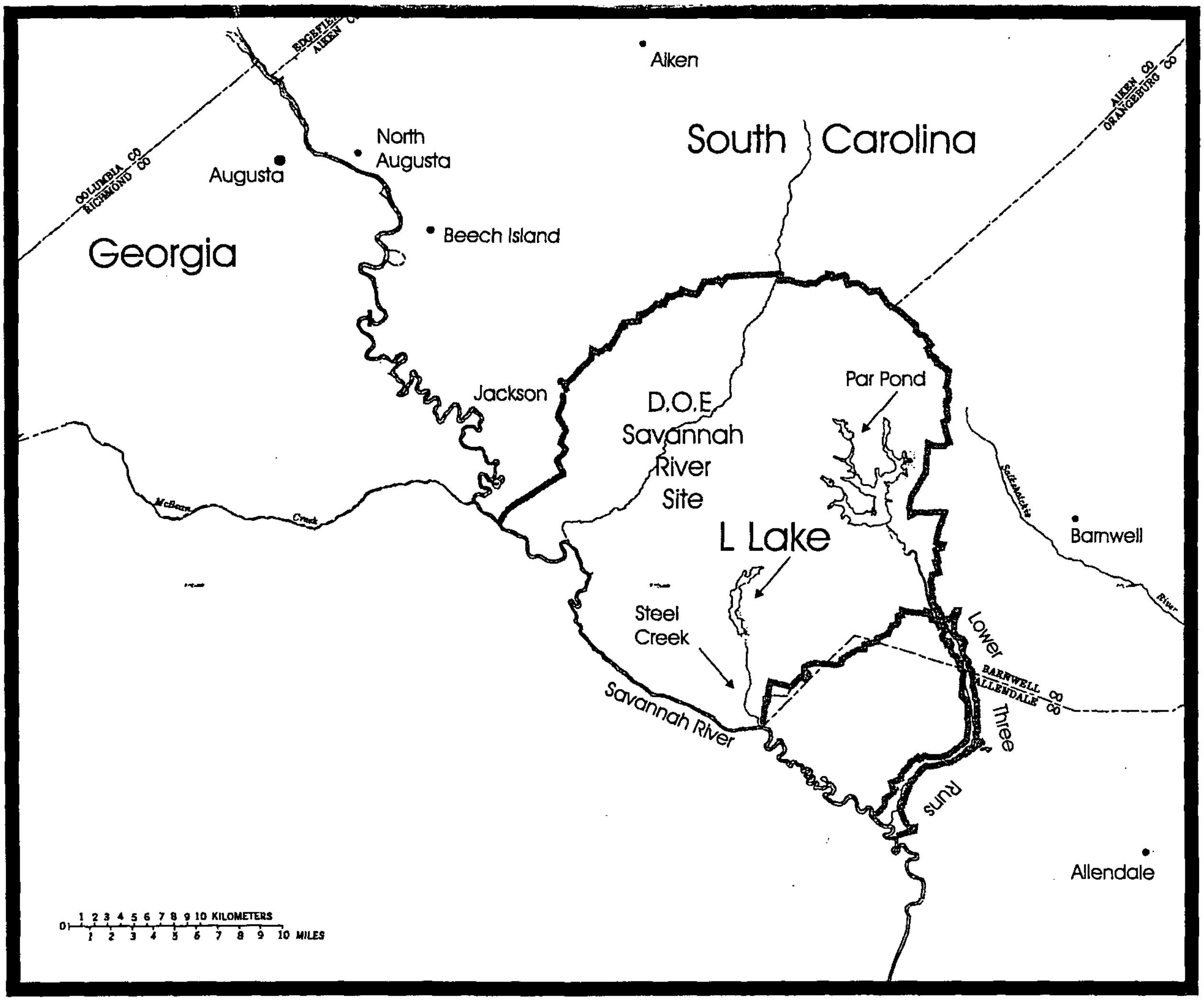

Fig. 1. Map showing the Savannah River Site and L Lake, where Largemouth Bass were collected.

Table 1. Concentrations of radiocesium (^{137}Cs) in raw and cooked largemouth bass with and without breading[a]

	Picocuries per gram		
	Arithmetic mean	SE	Range of values
Raw	0.61	0.02	0.38–0.97
Cooked–breaded	0.81	0.02	0.51–1.13
Cooked–unbreaded	0.99	0.10	0.62–4.50

[a] Fish ($N = 39$) were collected from the cesium-contaminated L Lake on the Savannah River Site in South Carolina. All means are statistically different ($p < 0.05$) from each other.

moisture loss (Zabik and Zabik 1995; Zabik *et al.* 1995; Burger *et al.* 2003).

Few studies have examined how cooking affects the amount of contaminants in fish. In largemouth bass, mercury levels were 45–75% higher in cooked fillets compared to uncooked fillets (on a wet weight basis [Burger *et al.* 2003]), which is slightly higher than the range reported by Morgan *et al.* (1997) for fish from Lake Superior. In some of the samples, mercury concentrations were twice as high in cooked as in uncooked fish. The primary objective of this study was to understand the effect of local cooking methods on ^{137}Cs in largemouth bass, one of the preferred local fish (Burger 1998). The data from this study clearly indicate that the concentration of ^{137}Cs (on a wet weight basis) in uncooked fish is less than in cooked fish (for the same portion size). The actual conversion factor will depend upon the species of fish and the cooking method. In this study, ^{137}Cs concentrations were up to 1.6 times higher in cooked compared to raw fish. However, when the maximum values are considered, the Cs concentrations were up to 115% higher in the cooked (nonbreaded) compared to the raw fish. This suggests that a conversion factor of at least 2 is required. While exposure to contaminants in fish will generally approach the mean values in fish for chronic consumers, high-end values are of interest for pregnant women because of sensitive periods in neurobehavioral development and our lack of knowledge of the specific effects of one or two meals with high levels during these sensitive periods. Clearly these data suggest that a conversion factor should be used in risk assessment. However, several issues should be examined before performing risk assessments and developing risk management plans, including (1) Are estimates of amount eaten based on cooked or uncooked portions of fish? (2) Are contaminant levels based on cooked or uncooked fish? (3) Are the conversion values for a specific fish and a specific cooking method known? (4) What are the ranges or uncertainties in the first three factors? and (5) What are the relative contributions of the different fish species and cooking methods to the total fish consumption of people eating wild-caught fish?

Morgan *et al.* (1997) suggested using food preparation factors in risk assessment, but these have generally not been applied because they are not generally known for specific fish. Preparation factors (mercury concentration in cooked fish/ mercury concentration in raw fish) in their study generally ranged from 1.3 to 1.6 for fillets from Great Lakes fish, compared to 1.5 to 1.8 for largemouth bass in another study (Burger *et al.* 2003). These two studies suggest that a preparation conversion factor of 2 would be a suitable, protective default for mercury. However, there are no data for ^{137}Cs. ^{137}Cs data from this study suggest that the conversion factor should be at least 2 based on the maximum levels of ^{137}Cs in cooked and uncooked fish. The similarity of the conversion factor is based on the fact that the main difference is one of moisture loss in cooking.

Overall, the study suggests that risk assessors who do not take cooking method into account, but use contaminant data from raw fish, may be overestimating safe consumption levels. This factor should be considered by state agencies setting consumption levels for high risk populations. However, most consumption studies do not examine the species of fish eaten, making it difficult to use species-specific conversion factors. At the least, risk assessors should determine whether estimates of intake were made on a cooked or a raw fish basis.

Finally, it is clear that the mass of ^{137}Cs in the fillet itself has not changed; what has changed between raw and cooked fish is the perception of the quantity of fish consumed. The perceptual problem is faced by both the consumer (who often estimates intake based on cooked fish) and the risk assessor (who estimates risk based on contaminants levels in raw fish because contaminant levels are usually measured in raw fish). The human health risk is based on the dose (mass of ^{137}Cs). However, if people estimate their consumption based on cooked fish, but risk assessors compute risk on raw fish, the estimates are underestimates of the actual risk. Another implication of this research is that when people are asked about fish consumption, whether their answers are based on cooked or uncooked fish should be clearly stated.

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EXHIBIT 2.7

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Epidemiology

Researchers Find Cancer Rates Normal Near Nuclear Plant

1997 FEB 03 -- After years of concern about unsafe living conditions around the Savannah River Site, which produces material for nuclear weapons, researchers announced that most cancer rates in the area are about the same as in similar communities.

The University of South Carolina study did find more cases of cervical cancer among black women and cancer of the esophagus among black men than expected in a 22-county area in South Carolina and Georgia. And while researchers said more study is needed, neither cancer is generally associated with exposure to radiation.

The results are the first from a six-year study of cancer within a 50 mile radius of the facility on the Savannah River.

The area includes ten South Carolina counties and 12 in Georgia. It has a population of about 1.1 million and includes the cities of Aiken, South Carolina, as well as Augusta and Savannah, Georgia.

"If you went back into the 1980s, 70s, and 60s, people always said they thought there would be more cancer," said Daniel Lackland, Medical University of South Carolina. "In general, the rates of cancer are what you would expect to see in a non-metropolitan area."

The study, conducted in conjunction with Emory University in Atlanta, Georgia, was financed by the U.S. Energy Department. Figures released include new cancer cases for 1991-93.

Jonathan Liff, Emory, said there were about 4,000 new cases each year, about what would be expected.

The incidence of both cervical cancers and cancer of the esophagus were higher on the South Carolina side of the river than in Georgia.

Tobacco and alcohol use are thought to contribute cancer of the esophagus. Poor nutrition, including diets low in fruits and vegetables, may also be a factor.

Viral infection spread through sexual contact is an important cause of cervical cancer. Early sexual activity and multiple partners are risk factors, the study said.

Lackland said some studies in Europe found a higher rates of cancers like leukemia near nuclear facilities. "We have looked at that in great detail. We don't see the excessive rates like we do in Europe," Lackland said.

Now the research turns to determining whether there is a difference in cancer rates closer to the plant than in other places in the study area.

Dean Moss, Beaufort-Jasper Water-Sewer Authority in South Carolina, said people have been concerned for years about drawing drinking water downstream from the plant. Five years ago, the water supply was shut down for a time after a tritium release.

Moss said the research seems to confirm the results of other studies that found no higher incidence of cancer cases. "Having this report and study confirm that is reassuring," he said.

Moss said some people in Beaufort will always be suspicious about the plant and its effect on the environment. Others, he said, can look at studies and assure themselves there is little danger. "For the people who are concerned but have an open mind, to them this information will be important," he said.

This article was prepared by Cancer Weekly Plus editors from staff and other reports.

Cancer Weekly, February 3, 1997, page 13-14

EXHIBIT 2.8

Archives of Environmental Health

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Infant Death and Childhood Cancer Reductions after Nuclear Plant Closings in the United States

[Articles]

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ABSTRACT.

Subsequent to 1987, 8 U.S. nuclear plants located at least 113 km from other reactors ceased operations. Strontium-90 levels in local milk declined sharply after closings, as did deaths among infants who had lived downwind and within 64 km of each plant. These reductions occurred during the first 2 yr that followed closing of the plants, were sustained for at least 6 yr, and were especially pronounced for birth defects. Trends in infant deaths in proximate areas not downwind, and more than 64 km from the closed plants, were not different from the national patterns. In proximate areas for which data were available, cancer incidence in children younger than 5 yr of age fell significantly after the shutdowns. Changes in health following nuclear reactor closings may help elucidate the relationship between low-dose radiation exposure and disease.

THERE IS A RELATIVE PAUCITY of research that documents the beneficial health effects to humans following a reduction in the level of environmental toxins. Existing data provide evidence for immediate responses, as well as for responses with longer latencies. Motor vehicle restrictions during the 1996 Summer Olympic Games resulted in a 28% drop in peak ozone concentration and a more than 40% reduction in asthma admissions/emergency room visits among Atlanta children.[1] The decline in smoking for U.S. adult males, from 52% in 1965 to 28% in 1990,[2] was not followed by a reduction in age-adjusted incidence of lung-bronchial cancers until 1984.[3]

Reduction of ionizing radiation in the environment, and hence in the food chain, occurred after enactment of the Partial Test Ban Treaty of 1963 that prohibited atmospheric atomic weapons testing by the United States, the (then) Soviet Union, and Great Britain. In the United States, dietary levels of short-lived isotopes, such as iodine-131 (I-131) and strontium-89 (Sr-89), with respective biological half-lives of 8 and 50 days, fell dramatically. Even concentrations of a long-lived isotope such as strontium-90 (half-life = 28.7 yr) in raw milk declined by one-half in 9 U.S. cities from the peak of April/May 1964 to November/December 1965. This decline, from an average of 30 to 15 picocuries per liter, fell further to 6 by 1970.[4,5]

Diminishing radioactivity levels in the diet were accompanied by immediate and significant morbidity and mortality reductions among infants and young children. U.S. infant deaths per 1,000 births fell from 24.7 to 19.1 from 1965 to 1971, respectively-a rate of decrease more than 4 times greater than for 1951-1965,[6] respectively. (Note: Atmospheric bomb testing in Nevada began in January 1951.[7]) Cancer incidence in children who were younger than 5 yr of age and who lived in Connecticut-the only U.S. state that operated a comprehensive tumor registry-dropped 30% from the 1962-1964 peak of 20.38 cases/100,000 to 14.21 by 1967-1969, following a 40% rise during the time of atmospheric bomb testing.[8]

Although most permanent shutdowns of nuclear power reactors are relatively recent, periods that follow unexpectedly large releases of airborne emissions offer an example of reduced environmental radioactivity. In the 1960s, declines in local infant mortality were documented after substantial reductions in gaseous emissions from several nuclear facilities.[9] In downwind areas within 64 km of 5 closed reactors, infant deaths declined at an unexpectedly rapid rate in the first 2 yr that followed closing.[10] We propose to extend that report by presenting data on all reactors for which post-shutdown data are currently available. Mortality 2 yr and 6 yr after reactor closings will be reviewed, the purpose of which will be assessment of whether immediate reductions are sustained over longer periods of time. Proximate areas that are not downwind from closed reactors and 64-129 km downwind will be examined. Finally, childhood cancer incidence trends near closed reactors will also be considered.

Method

Subsequent to 1987, 13 nuclear power reactors in the United States have been closed permanently. In addition, 5 other reactors have been nonoperational for at least 2 consecutive calendar years (see Table 1). The 8 regions in which closings left no operating power reactor within a 112-km radius of the closed facility are the focus of this report. Preliminary data have already been presented for 5 of the 8 regions.[10] Of these 8 regions, 6 have involved permanent shutdowns. The Pilgrim reactor in Massachusetts did not operate from April 1986 until late 1988. During the winter of 1995-1996, all 4 Connecticut reactors-3 at Millstone in Waterford and 1 in Haddam Neck, 29 km to the northwest-were closed. Millstone units 2 and 3 resumed operations in July 1999 and July 1998, respectively.

Reactor name (location)	Started/ closed	Prevailing wind direction*	Cities located downwind (< 64 km from closed reactor)	1990 Population (n)
LaCrosse	07/11/67	South	LaCrosse, WI	97,904
(Genoa, WI)	04/30/87	(LaCrosse)	Vernon, WI	25,617
Rancho Seco	09/16/74	Southwest	Amador, CA	30,039
(Clay Station, CA)	06/07/89	(Sacramento, CA)	El Dorado, CA	125,995
			Placer, CA	172,796
			Sacramento, CA	1,041,219
Fort St. Vrain	01/31/74	South	Larimer, CO	186,136
(Platteville, CO)	08/18/89	(Denver, CO)	Weld, CO	131,821
Trojan	12/15/75	East-southeast/ northwest	Columbia, OR	37,557
(Prescott, OR)	11/09/92	(Portland, OR)	Clark, WA	238,053
			Cowlitz, WA	82,119
			Multnomah, OR	583,887
			Wahkiakum, WA	3,832
Maine Yankee	10/23/72	South	Kennebec, ME	115,904
(Wiscasset, ME)	08/05/97	(Portland, ME)	Knox, ME	36,310
			Lincoln, ME	30,357
Big Rock Point	09/27/62	West-northwest	Antrim, MI	18,185
(Charlevoix, MI)	08/29/97	(Sault Ste. Marie, MI)	Charlevoix, MI	21,468
		Southwest	Cheboygan, MI	21,400
		(Alpena, MI)	Emmet, MI	25,040
			Otsego, MI	17,957
Temporary shutdowns				
Haddam Neck	07/24/67	South	Middlesex, CT	143,196
(Haddam Neck, CT)	—	(Hartford, CT)	New London, CT	254,957
Millstone 1,2,3	10/26/70	Southwest	Tolland, CT	128,699
(Waterford, CT)	—	(Providence, RI)	Windham, CT	102,525
			Kent, RI	161,135
			Washington, RI	110,006
Pilgrim	06/16/72	Southwest	Plymouth, MA	435,276
(Plymouth, MA)	04/30/86	(Boston, MA)		

Comparison of reactors closed subsequent to 1987 with physical locations of additional operating reactors located < 113 km from closed reactor specified

Reactor name (location)	Date closed	Reactor name and distance/direction from closed reactor
Hanford-N (Richmond, WA)	02/01/88	Washington Nuclear 2; same site as closed reactor
Yankee Rowe (Rowe, MA)	10/01/91	Vermont Yankee; 24 km northeast
San Onofre (San Clemente, CA)	11/30/92	San Onofre 2 and 3; all 3 reactors located at same site
Clinton (Clinton, IL)	Autumn of 1996	LaSalle 1; 113 km north
LaSalle County 2 (Seneca, IL)	Autumn of 1996	LaSalle 2; same site as closed reactor
Zion 1,2 (Zion, IL)	01/16/98	Byron 1; 104 km west

Notes: WI = Wisconsin, CA = California, CO = Colorado, OR = Oregon, WA = Washington, ME = Maine, MI = Michigan, CT = Connecticut, MA = Massachusetts, IL = Illinois, and RI = Rhode Island.
*In this column, specific cities that appear within parentheses are located downwind in the wind direction cited.

Table 1.-U.S. Nuclear Reactors Closed Subsequent to 1987

Demographic characteristics of the 8 areas are presented in Table 2. Population density varied greatly; some regions were urban settings, and some were sparsely populated areas. Poverty rates and percentages of Blacks and Hispanics in the population were less than the U.S. standard in each area.

Reactor name	Population per km^2 in 1997	Percentage		
		Black (1995)	Hispanic (1995)	Low SES persons (%) (1995)
U.S.	29.2	12.7	11.0	13.8
LaCrosse	40.1	0.5	0.8	10.2
Rancho Seco	127.0	7.4	13.6	13.6
Fort St. Vrain	22.3	6.6	14.4	10.8
Trojan	133.5	4.5	4.2	12.0
Maine Yankee	42.3	0.2	0.5	11.7
Big Rock Point	17.6	0.3	1.4	10.5
Haddam Neck/Millstone	144.3	3.0	2.3	6.5
Pilgrim	270.1	5.1	2.8	7.8
Areas with higher concentrations than U.S.	6	0	2	0
Areas with lower concentrations than U.S.	2	8	6	8

Notes: SES = socioeconomic status; low SES refers to those individuals whose incomes were below the poverty line.

Table 2.-Demographic Data and Downwind Counties Located < 64 km from Nuclear Reactors that Had Closed

An approximation of change in environmental radioactivity before and after a reactor shutdown may be observed with annual measures of Sr-90 in pasteurized milk, reported each July by the U.S. Environmental Protection Agency in 60 U.S. cities.[11] Readings for cities located within 64 km of closed reactors are also provided. The analysis of levels of long-lived Sr-90 has likely underestimated the reduction in environmental radioactivity inasmuch as short-lived isotopes emitted by reactors would no longer be present after a shutdown.

Short-lived airborne radioactive particulates often decay before entering the food chain. However, they can enter the body through inhalation. Persons with the greatest uptake from this vector are those who live downwind from the source, inasmuch as prevailing winds carry the majority of particles in the downwind direction. Longer-lived isotopes can also be inhaled, but they are also returned to earth by precipitation, after which they are again consumed in the diet. Again, levels are most likely highest in downwind, rainy areas. This principle is illustrated in the patterns of fallout from atmospheric atomic bomb tests in Nevada. For example, after the large "Smoky" test on August 31, 1957, U.S. government officials documented elevated levels of radioisotopes in raw milk. The typical concentration of Sr-89 (< 5 picocuries/l) was exceeded in Cincinnati, Ohio (i.e., 150 picocuries/l); in New York (160 picocuries/l); in Sacramento, California (30 picocuries/l); in Saint Louis, Missouri (290 picocuries/l); and in Salt Lake City, Utah (120 picocuries/l).[12] The only upwind city-Sacramento-had the lowest concentration of Sr-89. In addition, the total in Salt Lake City (i.e., city closest to Nevada) was exceeded by the much rainier Cincinnati (Ohio), New York, and Saint Louis (Missouri) areas.

Given that airborne radioactive particulates are propelled by prevailing winds, in this analysis we focused on counties located downwind and mostly or totally within 64 km of the closed reactors. Prevailing wind directions for the large city or cities nearest to each closed reactor were used.[13] Winds in Portland, Oregon-near the closed Trojan reactor-emanate from the east-southeast and northwest during 6 individual months; therefore, "downwind" counties are situated in both directions.

Infant deaths that occurred during the first year of life were obtained from the National Center for Health Statistics. County-specific deaths and population information were available on the world wide web (http://elib2.cdc.gov:2087/data and statistics/CDC Wonder). The accuracy of the count of infant deaths is likely very high; all U.S. states have reported death data to the federal government, subject to reliability tests since 1933. Coding the reason for death should also be consistent over time; the 9th revision of the International Classification of Diseases (ICD) coding system was used for the classification of all deaths from 1979 to 1998. The county of residence for an infant death (i.e., mother's residence) has been a standard data element collected in the hospital medical record for many years.

Infant mortality rates before and after reactors ceased operations were compared. The period before a reactor is closed is defined as the last 2 yr of operation, including the year of closing. For example, the LaCrosse reactor ceased operations on April 30, 1987; therefore, the "before" period of operation is 1986-1987. Given that cellular damage from radioactive exposures is most pronounced in the fetal period, many births that followed the closing of a reactor (but in the same year) were subject to exposures from reactor operations *prior to birth.* Rates for the 2 yr before closing are contrasted with rates for the subsequent 2- and 6-yr periods.

The report also reviewed infant mortality from congenital anomalies (ICD codes 740.0-759.9) known to be sensitive to the effects of radiation. Approximately 1 of every 4 deaths in the first year of life results from a birth defect. Approximately one-half of the infant congenital anomaly deaths involves heart defects. Chromosomal defects (including Down's, Edwards', and Patau's syndromes), and nervous system defects (including anencephalus and spina bifida) account for another quarter of deaths.[6]

Childhood cancer data were also analyzed because of the increased sensitivity of the developing fetus to the carcinogenic effects of ionizing radiation. Cancer incidence data were available only from state registries of California, Colorado, and Wisconsin. These states operated comprehensive tumor registries before and after closings (i.e., reporting of cancer cases was mandated by state law, reporting originated from several sources, and the reporting system was complete and accurate). Cases diagnosed before an individual's 5th birthday, which likely represented a fetal origin, were analyzed.

Trends in infant mortality near closed nuclear facilities were compared with U.S. patterns. Aggregated data (i.e., 1988-1996) from states and cities that made up approximately 47% of the U.S. population were used for cancer incidence because no national registry exists. (Areas include the states of California, Connecticut, Florida, Hawaii, Iowa, Massachusetts, New Jersey, New Mexico, New York, Pennsylvania, Utah, and Wisconsin; and the Standard Metropolitan Statistical Areas of Atlanta, Denver, and Seattle.) Infant mortality and childhood cancer trends in counties near nuclear plants were also compared with all other counties in the state. For Millstone, "other state" represents Connecticut and Rhode Island combined, whereas for Trojan, "other state" represents Oregon and Washington combined.

Results

Change in environmental radioactivity. Sr-90 concentrations in pasteurized milk over a 12-yr period before and after shutdown were available for 3 cities within 64 km of closed nuclear plants. These were compared with trends in 23 U.S. cities for which an annual reading was reported each year from 1983-1994 (Table 3). In each area near a closed reactor, the average Sr-90 concentration fell by more than the U.S. decline (67.1%, 48.0%, and 47.1%, compared with 34.0%). This comparison was hampered by the availability of only 1 annual measurement, thus raising the chance of random fluctuation.

City/state	Closest reactor	Years included		Average strontium-90 concentration*				
		BC	AC	BC	*n*	AC	*n*	Change (%)
Sacramento, CA	Rancho Seco, CA	1983–1988	1989–1994	0.92	6	0.48	6	−47.1
Denver, CO	Fort St. Vrain, CO	1983–1988	1989–1994	1.52	6	0.50	2	−67.1
Portland, OR	Trojan, OR	1987–1992	1993–1994	1.25	6	0.65	2	−48.0
U.S. (23 cities)		1983–1988	1989–1994	1.97		1.30		−34.0

Notes: BC = before closing reactor, AC = after closing reactor, CA = California, CO = Colorado, and OR = Oregon.
*Concentrations of strontium-90 are expressed in picocuries of Sr-90 per liter of milk.

Table 3.-Change in Average Strontium-90 Concentrations in Pasteurized Milk in Cities Located < 64 km from Nuclear Plants that Had Closed

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Infant mortality-all causes. Infant mortality in each of the 8 downwind areas decreased during the first 2 yr following closing (Table 4). Each decline exceeded the U.S. average 2-yr reduction of 6.4%, and the total decline of 17.4% was significant ($p < .01$). Each decline also exceeded the trend for other counties in the state; the total reduction in other counties of 6.7% was significantly different from the "nuclear" counties ($p < .01$).

Reactor	Year closed	Infant deaths		Live births		Deaths/1,000		Change (%)	
		BC	AC	BC	AC	BC	AC	Local	Other state
LaCrosse, WI	1987	36	30	3,507	3,452	10.27	8.69	−15.4	−1.9
Rancho Seco, CA	1989	418	390	44,500	49,414	9.39	7.89	−16.0	−9.2
Ft. St. Vrain, CO	1989	83	72	9,725	9,977	8.53	7.22	−15.4	−5.2
Trojan, OR	1992	253	204	30,320	29,799	8.34	6.85	−17.9	−5.9
Big Rock Point, MI	1997	25	15	2,922	3,040	8.56	4.93	−42.4	+2.0
Maine Yankee, ME	1997	19	18	3,841	4,013	4.95	4.49	−9.3	+22.8
Pilgrim, MA	1986	97	76	12,956	13,412	7.49	5.67	−24.3	−13.1
Millstone, CT	1995	166	130	22,261	21,093	7.46	6.16	−17.4	−5.4
Totals for 8 areas		1,097	935	130,032	134,200	8.44	7.00	−17.4*	−6.7
U.S. average for 2-yr change	1986–1998							−6.4	

Notes: BC = 2 yr before closing reactor, AC = 2 yr after closing reactor, WI = Wisconsin, CA = California, CO = Colorado, OR = Oregon, MI = Michigan, ME = Maine, MA = Massachusetts, and CT = Connecticut.
*$p < .01$ (nuclear counties vs. both U.S. and other state totals).

Table 4.-Change in "All-Causes" Death Rates of Infants during Their First Year of Life and Who Were Located < 64 km Downwind of Reactors, 2 Years before vs. 2 Years after Nuclear Plant Closings

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Infant mortality data for 6 yr post-shutdown were available for counties near 4 of the 8 plants; the other plants closed too recently or they were re-started (Table 5). In each of the 4 areas, reductions continued to exceed the U.S. standard, and the total decline of 26.9% was significantly greater than the national trend ($p < .0001$). Reductions near the Rancho Seco and Trojan plants were also significant. Rates also fell faster than in other counties in respective states.

Reactor	Year closed	Infant deaths		Live births		Deaths/1,000		Change (%)	
		BC	AC	BC	AC	BC	AC	Local	Other state
LaCrosse, WI	1987	36	69	3,507	10,302	10.27	6.70	−34.8	−7.7
Rancho Seco, CA	1989	418	1,038	44,500	144,770	9.39	7.17	−23.6	−16.5
Ft. St. Vrain, CO	1989	83	192	9,725	30,129	8.53	6.37	−25.3	−15.2
Trojan, OR	1992	253	523	30,320	92,649	8.34	5.64	−32.4	−12.7
Totals for 4 areas		790	1,822	88,052	277,880	8.97	6.56	−26.9*	−15.1
U.S. average for 6-yr change	1986–1998							−11.9	

Notes: BC = 2 yr before closing reactor, AC = 6 yr after closing reactor, WI = Wisconsin, CA = California, CO = Colorado, and OR = Oregon.

*$p < .0001$ (nuclear counties vs. both U.S. and other state totals). Rancho Seco difference ($p < .05$) and Trojan difference ($p < .0001$) were significant.

Table 5.-Change in "All-Causes" Death Rates of Infants during Their First Year of Life and Who Were Located < 64 km Downwind of Reactors, 2 Years before vs. 6 Years after Nuclear Plant Closings

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Infant mortality-congenital anomalies. During the first 2 yr following reactor shutdown, infant deaths from congenital anomalies declined 22.4%, compared with an average 2-yr decline in the U.S. of 5.5% ($p < .05$) and a total decline of 5.6% combined for other counties in the state where reactors were located. Declines in 7 of the 8 areas exceeded that of the U.S.; declines in 6 of the 8 areas exceeded those of other counties in the state (Table 6). During the first 6 yr following the closing of the reactor (for the 4 areas for which data were available), declines near each reactor continued. The change near the Trojan reactor in Oregon is significant, compared with both the U.S. and other counties in Oregon and Washington (Table 7).

Reactor	Year closed	Infant deaths		Live births		Deaths/1,000		Change (%)	
		BC	AC	BC	AC	BC	AC	Local	Other state
LaCrosse, WI	1987	7	4	3,507	3,452	2.00	1.16	–42.0	+1.3
Rancho Seco, CA	1989	90	79	44,500	49,414	2.02	1.60	–20.8	–10.1
Ft. St. Vrain, CO	1989	20	24	9,725	9,977	2.06	2.41	+17.0	–6.6
Trojan, OR	1992	61	41	30,320	29,799	2.01	1.38	–31.3	–1.0
Big Rock Pt., MI	1997	10	4	2,922	3,040	3.42	1.32	–61.5	+1.0
Maine Yankee, ME	1997	6	5	3,841	4,013	1.36	1.25	20.2	+5.4
Pilgrim, MA	1986	26	23	12,956	13,412	2.01	1.71	–14.9	–32.5
Millstone, CT	1995	51	37	22,261	21,093	2.29	1.75	–23.6	–7.7
Totals for 8 areas		271	217	130,032	134,200	2.08	1.62	–22.4*	–5.6
U.S. average for 2-yr change	1986–1998							–5.5	

Notes: BC = 2 yr before closing reactor, AC = 2 yr after closing reactor, WI = Wisconsin, CA = California, CO = Colorado, OR = Oregon, MI = Michigan, ME = Maine, MA = Massachusetts, and CT = Connecticut.
*$p < .05$ (nuclear counties vs. both U.S. and other state totals).

Table 6.-Change in "Congenital Anomalies" Death Rates of Infants during Their First Year of Life and Who Were Located < 64 km Downwind of Reactors, 2 Years before vs. 2 Years after Nuclear Plant Closings

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Reactor	Year closed	Infant deaths		Live births		Deaths/1,000		Change (%)	
		BC	AC	BC	AC	BC	AC	Local	Other state
LaCrosse, WI	1987	7	17	3,507	10,302	2.00	1.65	–17.5	–7.7
Rancho Seco, CA	1989	90	228	44,500	144,770	2.02	1.57	–22.3	–17.4
Ft. St. Vrain, CO	1989	20	52	9,725	30,129	2.06	1.73	–16.0	–14.3
Trojan, OR	1992	61	123	30,320	92,649	2.01	1.33	–34.0	–4.9
Totals for 4 areas		178	420	88,052	277,850	2.02	1.51	–25.2*	–14.8
U.S. average for 6-yr change	1986–1998							–10.9	

Notes: BC = 2 yr before closing reactor, AC = 6 yr after closing reactor, WI = Wisconsin, CA = California, CO = Colorado, and OR = Oregon.
*$p < .02$ (nuclear counties vs. U.S.), and $p < .08$ (nuclear counties vs. other state totals). The Trojan trend was significantly different from those for U.S. ($p < .03$) and for other state ($p < .006$).

Table 7.-Change in "Congenital Anomalies" Death Rates of Infants during Their First Year of Life and Who Were Located < 64 km Downwind of Reactors, 2 Years before vs. 6 Years after Nuclear Plant Closings

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Infant mortality-downwind 64-129 km from the plant. Infant mortality in downwind counties located 64-129 km from the closed reactors rose near 5 of the 7 plants (the area downwind from the Pilgrim reactor is the Atlantic Ocean). The overall increase of 5.4% was not significantly different from the 6.4% average national decrease. The 39.3% rise near the Rancho Seco reactor was significant at $p < .01$ (Table 8).

Reactor	Year closed	Infant deaths		Live births		Deaths/1,000		Change (%)
		BC	AC	BC	AC	BC	AC	
LaCrosse, WI	1987	13	14	1,570	1,467	8.28	9.54	+15.3
Rancho Seco, CA	1989	67	101	9,637	10,426	6.95	9.68	+39.3 ($p < .01$)
Ft. St. Vrain, CO	1989	33	28	3,347	3,229	9.86	8.67	−12.1
Trojan, OR	1992	9	11	1,605	1,608	5.61	6.84	+22.0
Big Rock Pt., MI	1997	5	16	1,131	1,180	4.42	13.56	+206.8
Maine Yankee, ME	1997	7	7	1,778	1,762	3.94	3.97	+0.8
Pilgrim, MA	1986	No data: Atlantic Ocean is downwind area						
Millstone, CT	1995	312	285	53,078	51,247	5.88	5.56	−5.4
Totals for 8 areas		446	462	72,146	70,890	6.18	6.52	+5.4

Notes: BC = 2 yr before closing reactor, AC = 2 yr after closing reactor, WI = Wisconsin, CA = California, CO = Colorado, OR = Oregon, MI = Michigan, ME = Maine, MA = Massachusetts, and CT = Connecticut.
Counties included Buffalo (Wisconsin); Jackson (Michigan), Trempealeau (Wisconsin)—*LaCrosse reactor*; Douglas (Nevada), Lyon (Nevada), Story (Nevada), Washoe (Nevada)—*Rancho Seco reactor*; Albany (Wyoming), Laramie (Wyoming)—*Fort St. Vrain reactor*; Hood River (Oregon), Wasco (Oregon), Pacific (Washington)—*Trojan reactor*; Alpena (Michigan), Montmorency (Michigan), Presque Isle (Michigan)—*Big Rock Point reactor*; Franklin (Maine), Somerset (Maine)—*Maine Yankee reactor*; Norfolk (Massachusetts), Worcester (Maine), Providence (Rhode Island)—*Millstone reactor*.

Table 8.-Change in "All Causes" Death Rates of Infants during Their First Year of Life and Who Were Located 64-129 km Downwind of Reactors, 2 Years before vs. 2 Years after Nuclear Plant Closings

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Infant mortality-counties not downwind. In 6 of 8 regions, reductions in infant mortality rates occurred in the first 2 yr following shutdown in non-downwind counties located less than 64 km from closed facilities. However, none of the reductions were significant, and the combined change of 7.1% was equivalent to the average U.S. 2-yr decline (Table 9).

Reactor	Year closed	Infant deaths BC	Infant deaths AC	Live births BC	Live births AC	Deaths/1,000 BC	Deaths/1,000 AC	Change (%)
LaCrosse, WI	1987	57	63	7,431	7,176	7.67	8.78	+14.4
Rancho Seco, CA	1989	310	324	36,944	40,073	8.39	8.09	−3.6
Ft. St. Vrain, CO	1989	537	530	58,790	59,923	9.13	8.84	−3.2
Trojan, OR	1992	66	73	11,826	12,296	5.58	5.94	+ 6.4
Big Rock Pt., MI	1997	13	12	2,184	2,288	5.95	5.24	−11.9
Maine Yankee, ME	1997	45	37	9,254	8,990	4.86	4.12	−15.4
Pilgrim, MA	1986	579	528	57,466	60,619	10.08	8.71	−13.6
Millstone, CT	1995	637	555	86,642	83,920	7.35	6.61	−10.0
Totals for 8 areas		2,244	2,122	270,537	275,285	8.29	7.71	−7.1

Notes: BC = 2 yr before closing reactor, AC = 2 yr after closing reactor, WI = Wisconsin, CA = California, CO = Colorado, OR = Oregon, MI = Michigan, ME = Maine, MA = Massachusetts, and CT = Connecticut.
Counties included Allamakee (Iowa), Clayton (Iowa), Winnishiek (Iowa), Fillmore (Minnesota), Houston (Minnesota), Winona (Minnesota), Crawford (Wisconsin), Grant (Wisconsin), Monroe (Wisconsin), Richland (Wisconsin)—*LaCrosse reactor;* San Joaquin (California), Solano (California), Sutter (California), Yolo (California)—*Rancho Seco reactor;* Adams (Colorado), Arapahoe (Colorado), Boulder (Colorado), Gilpin (Colorado), Grand (Colorado), Jefferson (Colorado)—*Fort St. Vrain reactor;* Clatsop (Oregon), Washington (Oregon)—*Trojan reactor;* Grand Traverse (Michigan), Leelanau (Michigan)—*Big Rock Point reactor;* Androscoggin (Maine), Cumberland (Maine), Sagadahoc (Maine)—*Maine Yankee reactor;* Barnstable (Massachusetts), Bristol (Massachusetts), Dukes (Massachusetts), Norfolk (Massachusetts), Suffolk (Massachusetts), Bristol (Rhode Island), Newport (Rhode Island)—*Pilgrim reactor;* and Hartford (Connecticut), New Haven (Connecticut), and Suffolk (New York)—*Millstone reactor.*

Table 9.-Change in "All Causes": Death Rates of Infants during Their First Year of Life and Who Were Located < 64 km-and Not Downwind-from Reactors, 2 Years before vs. 2 Years after Nuclear Plant Closings

Incidence-childhood cancer. In the states that operated comprehensive cancer registries at the time of reactor shutdown, incidence of newly diagnosed cancers in children under age 5 yr declined in downwind counties within 64 km. The decline measures the 2 yr prior to closing with 7 yr post-shutdown. The total reduction of 25.0% was significantly different from the stable U.S. trend ($p < .005$) and from the trend in other counties in the state ($p < .006$) (Table 10). The reduction near the Rancho Seco plant in California was significant, compared with the reduction in the United States ($p < .02$) and in the remainder of the state ($p < .004$).

Reactor	Year closed permanently	Cancer cases (n)		Population 0–4 yr of age		Cases/100,000		Change (%)	
		BC	AC	BC	AC	BC	AC	Local	Other state*
LaCrosse, WI	1987	7	15	17,492	61,053	40.02	24.57	−38.6	−5.1
Rancho Seco, CA	1989	50	153	208,302	854,118	24.00	17.91	−25.4	−1.0
Ft. St. Vrain, CO	1989	10	32	49,156	178,742	20.34	17.90	−12.0	+32.9
Total for 3 areas		67	200	274,950	1,093,913	24.36	18.28	−25.0†	−0.5
U.S. change	1988–1989 to 1990–1996							+0.3	

Notes: BC = 2 yr before the reactor was closed, AC = 7 yr after the reactor was closed, WI = Wisconsin, CA = California, and CO = Colorado.
*"Other" category for Colorado includes Denver area (i.e., Adams, Arapahoe, Boulder, Denver, Douglas, and Jefferson counties), approximately 55% of the state's population 0–4 yr of age.
†$p < .005$ (nuclear counties vs. U.S.), and $p < .006$ (nuclear counties vs. other state total). Rancho Seco trend differed significantly from trends from U.S. ($p < .02$) and other state ($p < .004$).

Table 10.-Changes in the Incidence Rates of All Cancers during the First 5 Yr of Life of Children Who Lived in Counties that Were Downwind 64 km from Closed Nuclear Plants at 2 Years before vs. 7 Years after Closure of Reactors

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Discussion

Research on changes in health in populations exposed to reduced levels of radioactivity has been scant. However, falling infant mortality and a decrease in childhood cancer immediately after atmospheric nuclear weapons testing was halted in 1963 suggest that "smaller" exposures may result in measurable improvements in health, especially in infants and young children.

In each of 8 areas downwind and proximate to closed nuclear power plants, infant deaths declined in excess of national trends during the first 2 yr following shutdown. Declines in mortality from congenital anomalies among local infants were particularly sharp. These trends were consistent for 2-yr and 6-yr periods after plant closings. Although declines near each reactor have fallen short of statistical significance, the possibility that similar trends should occur in each area by random chance is low.

The unexpectedly large decline in infant mortality occurred only in downwind counties that were located less than 64 km from closed nuclear facilities. Nondownwind counties located less than 64 km from reactors have nonsignificant declines in infant deaths. In downwind counties located 64-129 km from the plants, infant death rates increased, but the increases were not significant. Therefore, any beneficial effect of reactor shutdowns may apply only to the closest downwind counties. This finding illustrates the importance of analyzing the health of populations that live near nuclear facilities by *direction,* rather than as a whole. It also suggests that inhalation of airborne radioactive gases and particles, by which process the fetus absorbs radioactivity through the placenta,[14] may be a significant vector of exposure, along with dietary intake.

Cancer diagnosed in children under the age of 5 yr was also reduced in proximate downwind counties with available data. This trend is meaningful because it takes into account disease incidence, which cannot be affected by life-saving technological innovations, and may, therefore, be a more sensitive indicator of radiation effects than mortality.

No demographic characteristic predisposes these areas to health improvements. Reduced infant mortality rates occurred in both rural and urban regions. The relatively small proportions of minorities and poor individuals should not affect short-term changes inasmuch as it is unlikely that the racial distribution of studied counties changed appreciably in 2 yr. In addition, during the 20th century, improvements in infant health have yielded relatively equal benefits for all races and socioeconomic classes (i.e., similar reductions in infant mortality have occurred for all races).

The data support prior research that has shown that in utero exposures to radioactivity are most deleterious given the heightened sensitivity of the developing fetus and newborn infant. In the United States, infant deaths have been linked to exposure to fission products from atmospheric weapons tests.[15] In both Germany [16] and the United States,[17] increases in infant mortality have been attributed to fallout from the 1986 Chernobyl accident. Increased incidences of various congenital malformations have been documented in several European nations after Chernobyl.[18-21] Elevated rates of childhood cancer near U.S. nuclear reactors have also been reported.[22-24]

In addition to reduced exposures to fission products, there may be other explanations for the decline. One such possibility is a demographic shift (i.e., closing of a nuclear power facility results in loss of employment for plant workers, who leave the area in search of work). Although some nuclear workers remain after reactors are closed to assist in deactivating the plant, many, in fact, lose their jobs.

The processes of operating a reactor and deactivating it are distinctly different.

Some evidence, however, suggests that this population shift may not account for the unexpectedly large infant death and childhood cancer decreases in their entirety.

1. Nuclear plant workers are generally healthier than other workers of childbearing age. They are sufficiently healthy to hold full-time jobs, and their employer-based health insurance allows them access to medical care (including prenatal care-an important determinant of infant mortality risk). Thus, any departure of these workers from a downwind county after reactor closing would leave a higher-risk population than existed prior to closing of the reactor.

2. In urban areas, such as Sacramento, California, and Portland, Oregon, workers at the nuclear plant likely represent a small percentage of the overall workforce, and they have little impact on the postclosing infant death and cancer rates. Even in rural areas, numbers of live births did not decline rapidly following the closure of the reactor.

3. Workers are as likely to live upwind as they are to live downwind from the plant; however, consistent improvements in infant health occurred only in downwind areas.

4. Two of the plants were closed only temporarily. They did not lay off large numbers of workers, yet disease and death trends were similar to those obtained for the permanently closed reactors.

Whereas a substantial lag period between exposure and disease manifestation may be observed for adult cancers exposed to external x-rays, a much shorter lag period has been documented for very young individuals. Pelvic x-rays administered in utero are linked with increased cancer deaths before an individual's 10th birthday,[25] and 2/3 of these malignancies are diagnosed before the age of 5 yr. Thyroid cancer among children under 15 yr of age who lived near the Chernobyl facility began a sustained increase just 4 yr after the April 26, 1986, accident.[26-28] In 3 Pennsylvania counties located closest to the Three Mile Island facility, cancer deaths in persons under the age of 10 yr jumped from 28 to 36 in the 5 yr following the March 28, 1979, accident.[29]

A relatively short latency period that followed the addition of radioactivity raises the question of whether a similarly short lag exists between reduced exposures and declining disease rates. Short-lived airborne radioisotopes emitted from reactors are completely removed from the environment/diet within several months of the plant shutdown. Long-lived isotopes decay slowly, but existing data on dietary levels of Sr-90 suggest that these may be reduced substantially within several years after plant closing.

The data indicate that improvements in health occur after relatively slight reductions in dietary radioactivity. Sr-90 concentrations measured in milk samples in 9 U.S. cities fell from 30 to 15 picocuries per liter over an 18-mo period following cessation of large-scale atmospheric nuclear weapons tests in the mid-1960s. In contrast, Sr-90 reductions in milk near closed nuclear reactors fell from approximately 1.0 to 0.5 picocuries after shutdown. Changes in health status after a relatively small reduction support the effects of low-dose exposures on laboratory animals.[30] In light of these data, the current understanding of the relationship between low-dose radiation exposure and disease should be reconsidered.

Several factors limit this study from being more meaningful. There is a dearth of research on health effects of reduced exposures to ionizing radiation and other toxic substances with which to compare results. Small population sizes in several of the areas near closed facilities make significant findings elusive. The 60 cities with federally reported dietary levels of radioactivity are often not proximate to nuclear sites. Moreover, routine reports of particular isotopes (e.g., barium-140, cesium-137, iodine-131, strontium-89) are no longer available. Reliance on annual strontium-90 levels in milk is a relatively basic measure of radiation burden on local residents. The use of weekly or monthly levels of a variety of isotopes (i.e., both short- and long-lived) would make dose estimates more meaningful. Moreover, given that locally consumed milk is often not produced locally, radioisotope concentrations in air and water would be useful.

The current report was based on aggregate data. In this report, we did not measure levels of radioactivity in the bodies of individual decedents or of infants who survived the first year of life. More dose information-not just in environmental/dietary levels-but *in vivo,* is needed. U.S. government programs that measure Sr-90 in deciduous teeth, children's vertebrae, and adult vertebrae were discontinued in the 1970s and early 1980s.[31] A recent project in which Sr-90 concentrations were measured in deciduous teeth of persons living near nuclear reactors indicated a link between Sr-90 levels and childhood cancer incidence.[32]

More research on how intrauterine exposure to radiation affects health in later life is critical in understanding effects of nuclear reactors. With more than 400 such facilities operating worldwide, such data can play a vital role in any program of disease prevention and health promotion.

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Key words: childhood cancer; downwind; infant death; nuclear plant closings; nuclear reactors; radioactivity

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EXHIBIT 2.9

NUREG-1767, Vol. 1

Environmental Impact Statement on the Construction and Operation of a Proposed Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina

Chapters 1 through 8 and Appendices A through E

Final Report

U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555-0001

NUREG-1767, Vol. 1

Environmental Impact Statement on the Construction and Operation of a Proposed Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina

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Final Report

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Division of Waste Management and Environmental Protection
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

ABSTRACT

The U.S. Department of Energy (DOE) has contracted with Duke Cogema Stone & Webster (DCS) to design, construct, and operate a proposed Mixed Oxide (MOX) Fuel Fabrication Facility that would convert depleted uranium and weapons-grade plutonium into MOX fuel. The proposed MOX facility would be located on the DOE's Savannah River Site in South Carolina. Use of the proposed facility to produce MOX fuel would be part of the DOE's surplus plutonium disposition program. The purpose of the DOE program is to ensure that plutonium produced for nuclear weapons and declared excess to national security is converted to proliferation-resistant forms.

This final environmental impact statement (FEIS) was prepared in compliance with the National Environmental Policy Act (NEPA), the U.S. Nuclear Regulatory Commission's (NRC's) regulations for implementing NEPA, and the guidance provided by the Council on Environmental Quality regulations implementing the procedural provisions of NEPA. This FEIS evaluates the potential environmental impacts of the proposed action. The document discusses the purpose and need for the proposed action, describes the proposed action and its reasonable alternatives, describes the environment potentially affected by the proposal, presents and compares the potential environmental impacts resulting from the proposed action and its alternatives, and identifies mitigation measures that could eliminate or lessen the potential environmental impacts. The document also includes comments received on the draft environmental impact statement and NRC's responses.

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EXECUTIVE SUMMARY

The consortium of Duke Project Services Group, Inc., COGEMA, Inc., and Stone & Webster, Inc., has formed a Limited Liability Company called Duke Cogema Stone & Webster (DCS). DCS has been hired by the U.S. Department of Energy (DOE) to design, construct, and operate a facility (the proposed MOX facility) that would convert depleted uranium and surplus weapons-grade plutonium into mixed oxide (MOX) fuel. The DOE is responsible for the surplus plutonium disposition program for the United States. Within this program, the U.S. Nuclear Regulatory Commission (NRC) has the independent responsibility of determining whether the proposed MOX facility can be built and operated in a safe and environmentally acceptable manner. The proposed action requiring the February 2003 draft environmental impact statement (DEIS) and this NRC final environmental impact statement (FEIS) involves a decision by the NRC whether to authorize DCS to construct and later operate the proposed MOX facility at DOE's Savannah River Site (SRS) in South Carolina. DCS has submitted to the NRC, among other documents, a revised Construction Authorization Request (CAR) and a revised environmental report (ER), in seeking authority to begin constructing the proposed MOX facility.

This FEIS was prepared by the staff of the NRC and its contractor, Argonne National Laboratory, and complies with the National Environmental Policy Act (NEPA), NRC regulations for implementing NEPA (Title 10, Part 51 of the *Code of Federal Regulations* [10 CFR Part 51]), and the applicable Council on Environmental Quality (CEQ) regulations.

The proposed MOX facility would convert 34 metric tons (MT) (37.5 tons) of surplus weapons-grade plutonium into MOX fuel. This facility would be built on 16.6 ha (41 acres) of land in the F-Area of the SRS. If the NRC approves the CAR, DCS plans to request a 10 CFR Part 70 license to possess and use special nuclear material at the proposed MOX facility. Such a license would allow DCS to operate the proposed MOX facility for 20 years. The facility would be designed for a maximum annual throughput of 3.5 MT (3.9 tons) of plutonium.

Feedstock (surplus plutonium dioxide and depleted uranium dioxide) would be required to be transported to the SRS to make the MOX fuel. The surplus plutonium is currently stored at seven DOE facilities at various locations in the United States. Additionally, depleted uranium hexafluoride would need to be transported from a DOE site (assumed to be the gaseous diffusion uranium enrichment facility in Portsmouth, Ohio) to a commercial fuel fabrication facility (assumed to be the Global Nuclear Fuel Americas, LLC, in Wilmington, North Carolina), where it would be converted to depleted uranium dioxide, which would then be transported to the SRS. Once manufactured, the MOX fuel would be transported to mission reactors, where it would be irradiated. For purposes of complying with NEPA's requirements, it is assumed that one or more reactors will later be authorized by the NRC to use MOX fuel, and the FEIS includes a generic evaluation of using MOX fuel in a reactor. In order for a specific commercial reactor to use MOX fuel, an amendment to its 10 CFR Part 50 NRC license would be required. The NRC would analyze the site-specific environmental impacts related to such an amendment if and when such a request was made to the NRC. Following irradiation and storage at reactor sites, the spent MOX fuel would be transported to a geologic repository (assuming one is later licensed by the NRC to operate) for final disposal, and the FEIS includes a discussion of spent MOX fuel transportation impacts.

In addition to presenting the potential environmental impacts of the proposed MOX facility and the related fuel cycle impacts, this FEIS discusses two proposed DOE facilities — the Pit Disassembly and Conversion Facility (PDCF) and the Waste Solidification Building (WSB) — which would also be located at the SRS, that would be required to support operation of the proposed MOX facility. The PDCF would be required to convert approximately 25.6 MT (28.2 tons) of surplus plutonium from a metallic form to plutonium dioxide powder. The remaining quantity of surplus plutonium, called "alternate feedstock," would be in a form that would be suitable to go directly to the proposed MOX facility. The proposed MOX facility would remove impurities from the plutonium dioxide and mix it with depleted uranium dioxide to make MOX fuel.

The WSB would process liquid waste streams from the PDCF and proposed MOX facility. The WSB may also be used for temporary storage and processing of other waste forms generated at the proposed MOX facility and the PDCF before such wastes are transferred to the SRS waste management system or shipped off-site for disposition. In addition, infrastructure upgrades would be needed to support the proposed MOX facility. These upgrades would include constructing waste transfer pipelines, realigning electric utility lines, and adding access roads.

A brief summary of FEIS Chapters 1-6 follows. Chapter 1 of the FEIS discusses the purpose and need for this action and its relationship to the DOE's surplus plutonium disposition program. The fundamental purpose of this DOE program is to ensure that surplus weapons-grade plutonium is converted to proliferation-resistant forms. The DOE's program is intended to lay the foundation for parallel disposition of excess Russian plutonium, thereby protecting against proliferation of materials capable of making weapons of mass destruction.

Chapter 2 of this FEIS describes the proposed action and alternatives to the proposed action, including the no-action alternative. The no-action alternative consists of the continued storage of surplus plutonium at various locations throughout the DOE complex, in the event the NRC does not approve the proposed MOX facility. This alternative is evaluated in detail in Chapter 4. Other alternatives to the proposed action discussed in Chapter 2 include alternate locations for the proposed MOX facility in the F-Area, alternate technology and design options, immobilizing surplus plutonium instead of producing MOX fuel, deliberately making off-specification MOX fuel, the "MIX MOX" alternative, and the Parallex Project (which involves irradiating the MOX fuel in Canadian deuterium uranium reactors).

Chapter 3 describes the environment that would be affected by the proposed action and includes discussions on soils, hydrology, air quality, local ecology, waste management, risks to human health, and socioeconomic issues.

Chapter 4 evaluates and compares the environmental effects of the proposed action and the no-action alternative. Significant or more important potential impacts are discussed in Chapter 4, which includes the following topics: (1) human health, (2) air quality, (3) hydrology,

(4) waste management, (5) accident impacts, (6) decommissioning, and (7) environmental justice. Indirect impacts of transportation of radioactive materials, conversion of depleted uranium, and reactor use are discussed in Chapter 4. The following potential impacts for the no-action alternative and proposed action are considered to be less significant and are discussed in Appendixes G and H: (1) geology, seismology, and soils; (2) noise; (3) ecology; (4) land use; (5) cultural and paleontological resources; (6) infrastructure; and (7) socioeconomics. A summary of the significant or more important potential impacts discussed in Chapter 4 is presented below.

The annual collective dose to members of the public (i.e., those living and working within 80 km [50 mi] of the SRS) produced by routine operation of the proposed MOX facility, the PDCF, and the WSB would be expected to result in a latent cancer fatality (LCF) rate of approximately 0.0009/yr or less. Routine operation of the proposed MOX facility, the PDCF, and the WSB is expected to produce small air quality impacts and would not cause exceedance of any ambient air quality standard level for criteria pollutants at the SRS.

Construction and routine operation of the proposed facilities would not be expected to cause any disproportionately high and adverse impacts to low-income or minority populations in the SRS vicinity. Of the accidents evaluated, a hypothetical PDCF tritium release accident had the highest estimated short-term impacts, approximately 3 LCFs among members of the off-site public. Such an accident also had the highest estimated 1-year exposure impact, including the ingestion dose, of up to 100 LCFs among members of the off-site public. However, it is regarded as highly unlikely that such an accident would occur, and the risk to any population, including low-income and minority communities, is considered to be low. Nevertheless, the communities most likely to be affected by a significant accident would be minority or low-income, given the demographics and prevailing wind direction. The extent to which low-income or minority population groups would be affected would depend on the amount of material released and the direction and speed of the wind.

Transportation of uranium and plutonium feedstock materials, transuranic waste, fresh MOX fuel, and spent MOX fuel would result in approximately 3,300,000 to 8,200,000 km (2,050,000 to 5,100,000 mi) traveled by 1,497 to 3,512 truck shipments over the operations period of the proposed MOX facility. Up to 1 LCF might be expected from the radioactive nature of the cargo. (Estimated LCFs for members of the public and the transportation crews were 0.2 to 0.4 and 0.1 to 0.3, respectively.) One to two latent fatalities from vehicle emissions were estimated, and no fatalities (0.078 to 0.20 fatality) from the physical trauma of potential vehicle accidents were estimated.

Chapter 4 of the FEIS also evaluates the use of MOX fuel in a generic reactor using a 40% MOX fuel core. For both normal operations and design-basis accidents, the impacts of using MOX fuel in a reactor would not be significantly different from the impacts of a reactor using 100% low-enriched uranium fuel. For highly unlikely beyond-design-basis accidents, the impacts for a reactor using a 40% MOX fuel core could be up to 14% greater than for a reactor using 100% low-enriched uranium fuel. Since no reactor licensee has yet sought the authority to use MOX fuel, the transportation of fresh MOX fuel is also evaluated on a generic basis, using a surrogate reactor located in the Midwest.

Chapter 4 also presents the costs and benefits of the proposed action. The primary benefit of operating the proposed MOX facility would be the resulting reduction in the supply of weapons-grade plutonium available for unauthorized use. Converting surplus plutonium in this manner is viewed as being a safer use/disposition strategy than the DOE's continued storage of surplus plutonium, as would occur under the no-action alternative, because it would reduce the number of locations where the various forms of plutonium are stored. Further, converting weapons-grade plutonium into MOX fuel in the United States — as opposed to immobilizing a portion of it as the DOE had previously planned to do — lays the foundation for parallel disposition of weapons-grade plutonium in Russia, which distrusts immobilization because of its failure to degrade the plutonium's isotopic composition. Converting surplus plutonium into MOX fuel is thus viewed as a better way of ensuring that weapons-usable material will not be obtained by rogue states and terrorist groups. Implementing the proposed action is expected to promote the above nonproliferation objectives.

In addition to the above primary benefits, there would be secondary economic benefits of the proposed action. Impacts of construction on the regional economic area (REA) and region of influence (ROI) would be beneficial with respect to jobs and income. During operations, the proposed MOX facility, PDCF, and WSB would be expected to generate 490 direct and 780 indirect jobs, producing a total income of $64 million a year in the REA. The economic cost benefit analysis for the proposed action shows an overall net benefit to the ROI and REA of $1,940 million. National economic costs for the proposed MOX facility, PDCF, and WSB are estimated to be $4,064 million (in 2003 dollars). The national economic benefits would include adding employment and income in various sectors of the economy through the purchase of goods and services required during construction and operation.

Chapter 5 of the FEIS identifies mitigation measures that could eliminate or lessen the potential environmental impacts of the proposed action. The NRC evaluated proposed mitigation measures identified by DCS and identified additional measures that could reduce or eliminate adverse environmental impacts of the proposed action. On the basis of its independent review, the NRC is making a preliminary conclusion that the potential significant impacts of the proposed action can be mitigated. However, any possession and use license issued to DCS should be conditioned on the commitments made by DCS and the various proposed NRC mitigation requirements discussed in Chapter 5.

Chapter 6 presents the many federal, state, and local environmental requirements that would be applicable to the proposed MOX facility.

After weighing the costs and benefits of the proposed action, comparing alternatives, and considering the comments received on the DEIS (see FEIS Appendix J), the NRC staff, in accordance with 10 CFR 51.91(d), includes in this FEIS its final NEPA recommendation regarding the proposed action. As discussed further in Chapter 2, the NRC staff continues to recommend that, unless safety issues mandate otherwise, the action called for is the issuance of the proposed license to DCS, with conditions to protect environmental values. As stated in Chapter 2, the NRC staff concludes that (1) the applicable environmental requirements presented in FEIS Chapter 6 and (2) the proposed mitigation measures discussed in FEIS

Chapter 5 would eliminate or substantially lessen any potential adverse environmental impacts associated with the proposed action.

Appendix J includes a summary of the comments and responses received on the DEIS. Ninety-four commenters submitted about 750 comments on the DEIS. Appendix J also identifies changes in the FEIS text based on the comments and revised accident analyses from new design information for the WSB provided by DCS since publication of the DEIS.

ACRONYMS AND ABBREVIATIONS

The following is a list of the acronyms, initialisms, abbreviations, and units of measure used in this document. Some acronyms and abbreviations used only in tables, figures, equations, or as reference callouts are defined in the respective tables, figures, equations, and reference lists.

Acronyms, Initialisms, and Abbreviations

7Q10	7-day low flow, 10-year recurrence flow
AADT	average annual daily traffic
ADU	ammonium diuranate
AEA	Atomic Energy Act
Ag	silver
$AgNO_3$	silver nitrate
ALARA	as low as reasonably achievable
ALI	annual limit on intake
ALOHA	Areal Locations of Hazardous Atmospheres (computer code)
Am	americium
ANL-W	Argonne National Laboratory-West
ANSI	American National Standards Institute
APA	aqueous polishing area
APSF	Actinide Packaging and Storage Facility
AQCR	Air Quality Control Region
BPIP	Building Profile Input Program
BRP	Reagents Processing Building
CAA	Clean Air Act
CANDU	Canadian Deuterium Uranium (reactor)
CAR	Construction Authorization Request
CAS	Chemical Abstract Services
CEDE	committed effective dose equivalent
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CH-TRU	contact-handled transuranic (waste)
CIESIN	Center for International Earth Science Information Network
CIF	Consolidated Incineration Facility
CO	carbon monoxide
CO_2	carbon dioxide
CPT	cone-penetration test
CSWTF	Central Sanitary Wastewater Treatment Facility
CWA	Clean Water Act

D&D	deactivation and decommissioning
DCP	dry conversion process
DCS	Duke Cogema Stone & Webster
DDE	deep dose equivalent
DEIS	draft environmental impact statement
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DWPF	Defense Waste Processing Facility
EA	environmental assessment
EBR-II	Experimental Breeder Reactor-II
EDE	effective dose equivalent
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ER	Environmental Report
ERPG	Emergency Response Planning Guideline
ETF	Effluent Treatment Facility
FEIS	final environmental impact statement
FGR	Federal Guidance Report
FOF	F-Area Outside Facility
FONSI	Finding of No Significant Impact
FR	*Federal Register*
FSER	final safety evaluation report
FTE	full-time equivalent
FY	fiscal year
Ga	gallium
GE	General Electric
GENII	Generation II (computer code)
GRP	gross regional product
$H_2C_2O_4$	oxalic acid
HEPA	high-efficiency particulate air (filter)
HEU	highly enriched uranium
HF	hydrogen fluoride
HI	hazard index
HLW	high-level (radioactive) waste
HQ	hazard quotient
HRCQ	highway route controlled quantity
HSWA	Hazardous and Solid Waste Amendments
HVAC	heating, ventilation, and air conditioning
HYDOX	hydride-oxidation
ICRP	International Commission on Radiological Protection
IMPLAN	Intelligent Multi-Resource Planning (computer code)

INEEL	Idaho National Engineering and Environmental Laboratory
ISA	integrated safety analysis
ISCST3	Industrial Source Complex Short-Term (version 3) model
ISFSI	interim spent fuel storage installation
ITP	in-tank precipitation
KAMS	K-Area Material Storage (SRS)
LANL	Los Alamos National Laboratory
LCF	latent cancer fatality
L_{dn}	day-night average sound level
L_{eq}	equivalent sound pressure level
LEU	low-enriched uranium
LLC	Limited Liability Company
LLNL	Lawrence Livermore National Laboratory
LLW	low-level (radioactive) waste
LSA	low specific activity
LTA	lead test assembly
MAR	material at risk
MBTA	Migratory Bird Treaty Act
MC&A	material control and accounting
MEI	maximally exposed individual
MMI	Modified Mercalli Intensity (earthquake intensity scale)
MOX	mixed oxide (plutonium dioxide and uranium dioxide)
MPQAP	MOX Project Quality Assurance Plan
MSL	mean sea level
MWMF	Mixed Waste Management Facility
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NMSS	Office of Nuclear Material Safety and Safeguards (NRC)
NNSA	National Nuclear Security Administration
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NO_x	nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
NRHP	*National Register of Historic Places*
NSC	National Safety Council
NSPS	New Source Performance Standards

O_3	ozone
OAQPS	Office of Air Quality Planning and Standards (EPA)
OFASB	Old F-Area Seepage Basin
OHER	Office of Health and Environmental Research (DOE)
OML	oxalic mother liquor
ORR	Oak Ridge Reservation
OSHA	Occupational Health and Safety Administration
PAG	protective action guide
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PDCF	Pit Disassembly and Conversion Facility
PEIS	programmatic environmental impact statement
PM	particulate matter
PM_{10}	particulate matter with a diameter less than or equal to 10 micrometers
$PM_{2.5}$	particulate matter with a diameter less than or equal to 2.5 micrometers
PMF	probable maximum flood
PSD	Prevention of Significant Deterioration
PSSCs	principal structures, systems, and components
Pu	plutonium
Pu (IV)	tetravalent plutonium
Pu (III)	trivalent plutonium
PuO_2	plutonium oxide
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
REA	regional economic area
REG	mitigation measures instituted to ensure compliance with regulations, permits, and guidelines
RFETS	Rocky Flats Environmental Technology Site
ROD	Record of Decision
ROI	region of influence
S&D PEIS	Storage and Disposition Programmatic Environmental Impact Statement
SA	Supplement Analysis
SAAQS	State Ambient Air Quality Standard
SC	South Carolina; state route
SCAPA	Subcommittee on Consequence Assessment and Protective Action (DOE)
SCDHEC	South Carolina Department of Health and Environmental Control
SCDNR	South Carolina Department of Natural Resources
SCSHPO	South Carolina State Historic Preservation Officer
SER	safety evaluation report
SGT	Safeguards Transporter
SHPO	State Historic Preservation Office
SIP	state implementation plan

SNF	spent nuclear fuel
SNM	special nuclear material
SO_2	sulfur dioxide
SO_x	sulfur oxides
SPCC	spill prevention control and countermeasures
SPD	surplus plutonium disposition
SPD EIS	Surplus Plutonium Disposition Environmental Impact Statement
SPL	sound pressure level
SR	State Route
SRARP	Savannah River Archaeological Research Program
SREL	Savannah River Ecology Laboratory
SRS	Savannah River Site
SWB	standard waste box
TAP	toxic air pollutant
TCDD	tetrachlorodibenzo-para-dioxin
TEDE	total effective dose equivalent
TEEL	temporary emergency exposure limit
TI	transport index
TIGR	thermally induced gallium removal
TRAGIS	Transportation Routing Analysis Geographic Information System
TRU	transuranic (radioactive waste)
TRUPACT	transuranic package transporter
TSCA	Toxic Substances Control Act
TSD	Transportation Safeguards Division (DOE Albuquerque Operations Office)
TSP	total suspended particulates
U	uranium
UF_6	uranium hexafluoride
UO_2	uranium dioxide
U.S.C.	*United States Code*
VOC	volatile organic compound
VRM	visual resource management
WAC	waste acceptance criteria
WIPP	Waste Isolation Pilot Plant
WM PEIS	*Final Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*
WMA	Wildlife Management Area
WSB	Waste Solidification Building

Units of Measure

Bq	becquerel(s)	km^2	square kilometer(s)
Btu	British thermal unit(s)	kV	kilovolt(s)
Ci	curie(s)	L	liter(s)
µCi	microcurie(s)	lb	pound(s)
cm	centimeter(s)	m	meter(s)
d	day(s)	m^2	square meter(s)
dB	decibel(s)	m^3	cubic meter(s)
dBA	A-weighted decibel(s)	µm	micrometer(s)
dps	disintegration(s) per second	mg	milligram(s)
°C	degree(s) Celsius	mi	mile(s)
°F	degree(s) Fahrenheit	mi^2	square mile(s)
ft	foot (feet)	min	minutes
ft^2	square foot (feet)	mm	millimeter(s)
ft^3	cubic foot (feet)	mo	month(s)
g	gram(s) or gravitational acceleration	mph	mile(s) per hour
		mrem	millirem(s)
µg	microgram(s)	mSv	millisievert(s)
gal	gallon(s)	MT	metric ton(s)
gpm	gallon(s) per minute	MWh	megawatt-hour(s)
h	hour(s)	nCi	nanocurie(s)
ha	hectare(s)	Pa	Pascal(s)
hg	mercury	ppb	part(s) per billion
Hz	hertz	ppm	part(s) per million
in.	inch(es)	s	second(s)
K	kelvin degrees (temperature)	Sv	sievert(s)
kg	kilogram(s)	yd^3	cubic yard(s)
km	kilometer(s)	yr	year(s)

EXHIBIT 2.10

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Lessons From Katrina and Rita

What Major Disasters Can Teach Transportation Planners

Todd Litman
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13 April, 2006

Abstract

This paper examines failures in hurricane Katrina and Rita emergency response and their lessons for transportation planning in other communities. Katrina's evacuation plan functioned relatively well for motorists but failed to serve people who depend on public transit. Rita's evacuation plan failed because of excessive reliance on automobiles, resulting in traffic congestion and fuel shortages. Equitable and compassionate emergency response requires special efforts to address the needs of vulnerable residents. Improved emergency response planning can result in more efficient use of available resources. This paper identifies various policy and planning strategies that can help create a more efficient, equitable and resilient transport system.

A version of this paper was published as,
"Lessons From Katrina and Rita: What Major Disasters Can Teach Transportation Planners," *Journal of Transportation Engineering* (http://scitation.aip.org/teo), Vol. 132, January 2006, pp. 11-18.
It was also presented at the 85th Transportation Research Board Annual Meeting, January, 2006.

Preface

I recently purchased a fascinating book, *The San Francisco Calamity by Earthquake and Fire*, published in 1906, just a few months after that disaster occurred. There are interesting similarities between the problems described in that book and those reported 99 years later from the Katrina and Rita disasters: general panic and confusion, uncontrolled fires, reports of lawlessness that justified martial law (police and soldiers were instructed to shoot looters on sight) leading to accusations of brutality, severe thirst although fresh water was available nearby, overwhelmed medical services, homelessness and inadequate shelter, hunger and fear of starvation, overwhelmed transportation services, failing communication systems, and stories of racism and excessive suffering by poor people. Society's ability to respond to major disasters seems to have progressed little in a century.

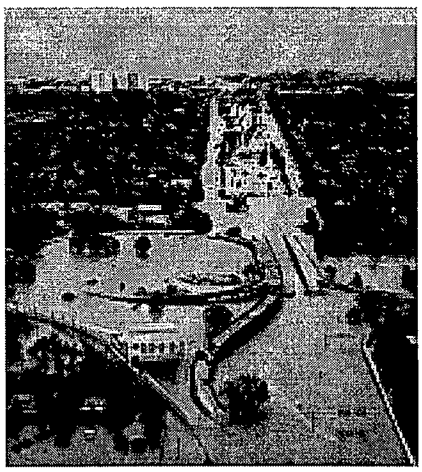
Intelligence is reflected in our ability to learn from past events and apply general concepts to specific situations. We cannot predict the exact type of disaster that will occur in the future and the specific problems it will create, but we can develop general principles and guidance for better emergency response. It is my hope that this paper will help planners do a better job of preparing for the next major disaster, thereby reducing damage and suffering.

1906 San Francisco Earthquake and Fire Evacuation (Carleton Emmons Watkins)

Introduction

A good planning principle is to "hope for the best but prepare for the worst." We often have trouble imagining the worst scenario until the terrible event occurs. Only then can we evaluate our emergency response preparations. This paper examines lessons transportation planners can learn from two recent disasters: hurricanes Katrina and Rita. Planners can use this information to improve the quality of services they provide under emergency conditions and avoid repeating past mistakes.

Every disaster presents a unique combination of problems. Katrina, which hit the Gulf Coast August 29, 2005, began with a hurricane, which lead to infrastructure damage, flooding, civil disorder, fires, toxic chemical dispersion, disease risk, and thousands of people isolated for days without water, food or medical care. Rita, which hit the Coast September 24, 2005, created huge traffic congestion and fuel supply problems. There is much such disasters can teach us.



This analysis is not intended to fault individuals. Rather, it is intended to honestly examine planning failures. We can assume that nearly everybody involved in emergency response sincerely wants to do their best; after all, they and their loved ones may also require emergency services. Many emergency responders make significant personal sacrifices. If we are to make any judgments, it would be against anybody who hides, denies or understates mistakes and so prevents society from learning to avoid such errors in the future. This paper attempts to identify ways to better allow individuals to help people in emergencies.

Various long-term planning errors contributed to these disasters: the concentration of poverty in New Orleans neighborhoods vulnerable to flooding, allowing shoreline development that eliminated protective barrier islands and wetlands, and underfunding levee maintenance (Bourne, 2004; Begley, 2005). There is also evidence that global warming exacerbated hurricane impacts by increasing ocean surface temperatures. Federal security planning may have focused excessively on terrorist risks at the expense of natural risks. These are all important issues to explore, and where appropriate, correct. However, this paper focuses only on transport policy and planning issues.

It is worth noting that these disasters could have been worse. Hurricanes follow a predictable path and provide considerable warning. These cities have well-established hurricane response plans and there was ample warning. Travel conditions were good during the evacuation periods. The hurricanes did not follow the most damaging possible course, and much infrastructure survived. Although delayed, extensive emergency response and relief was provided. Actual deaths were a fraction of what could have occurred. Other conditions could result in far more deadly and damaging events.

What Failed

Katrina

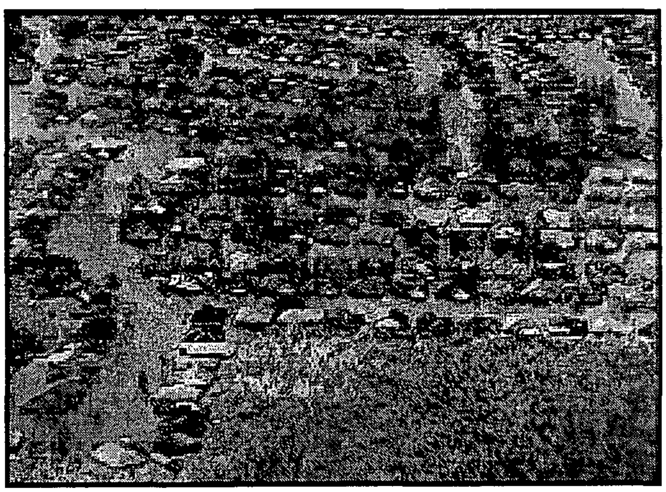
It would be wrong to claim that this disaster was an unavoidable "act of god." Katrina began as a hurricane but only became a disaster because of significant, preventable planning and management failures. By most accounts, automobile evacuation functioned adequately. The plan, which involved using all lanes on major highways to accommodate outbound vehicle traffic, was well engineered and publicized (Wolshon, 2002). Motorists were able to flee the city, although congestion resulted in very slow traffic speeds and problems when vehicles ran out of fuel or had other mechanical problems.

However, there was no effective plan to evacuate transit dependent residents. In an article titled "Planning for the Evacuation of New Orleans" published in the *Institute of Transportation Engineers Journal* (Wolshon, 2002, p. 45) the author explains,

> Of the 1.4 million inhabitants in the high-threat areas, it is assumed only approximately 60 percent of the population or about 850,000 people will want, or be able, to leave the city. The reasons are numerous. Although the primary reasons are a lack of transportation (it is estimated that about 200,000 to 300,000 people do not have access to reliable personal transportation), an unwillingness to leave homes and property (estimated to be at least 100,000 people) and a lack of outbound roadway capacity.

This indicates that public officials were aware of and willing to accept significant risk to hundreds of thousands of residents unable to evacuate because they lacked transportation. The little effort that was made to assist non-drivers was careless and incompetent. Public officials provided little guidance or assistance to people who lacked automobiles (Renne, 2005). The city established ten pickup locations where city buses were to take people to emergency shelters, but the service was unreliable. Transit dependent people were directed to the Superdome, although it had insufficient water, food, medical care and security. This lead to a medical and humanitarian crisis.

New Orleans officials were aware of the risks facing transit-dependent residents. These had been described in recent articles in *Scientific American* (Fischett, 2001) and *National Geographic* (Bourne, 2004) magazines, and from previous experience (see box on the next page). A July 2004 simulation of a Category 3 "Hurricane Pam" on the southern Louisiana coast by the Federal Emergency Management Agency (FEMA), projected 61,290 dead and 384,257 injured or sick in a catastrophic flood of New Orleans. City and regional emergency plans describe likely problems in detail (Louisiana, 2000; New Orleans, 2005).



Coastal communities flooded by Hurricane Katrina.

The *City of New Orleans Comprehensive Emergency Management Plan* (New Orleans, 2005) states:

> The city of New Orleans will utilize all available resources to quickly and safely evacuate threatened areas. ...Special arrangements will be made to evacuate persons unable to transport themselves or who require specific life-saving assistance. Additional personnel will be recruited to assist in evacuation procedure as needed. ...Approximately 100,000 citizens of New Orleans do not have means of personal transportation.

The *Southeast Louisiana Hurricane Evacuation and Sheltering Plan* specifies that school and municipal buses should be used to evacuate people who lack access to private transportation (Louisiana, 2000, p. 13):

> The primary means of hurricane evacuation will be personal vehicles. School and municipal buses, government-owned vehicles and vehicles provided by volunteer agencies may be used to provide transportation for individuals who lack transportation and require assistance in evacuating.

Some Can't Evacuate New Orleans for Ivan (A Year Before Katrina)
Free Republic (www.freerepublic.com/focus/f-news/1477282/posts), by Mary Foster, Sept. 2004.

NEW ORLEANS - Fleeing to safety was not an option for some people as 140-mph Hurricane Ivan churned toward the Gulf Coast, threatening to submerge the below-sea-level city in what could be the most disastrous storm to hit in nearly 40 years.

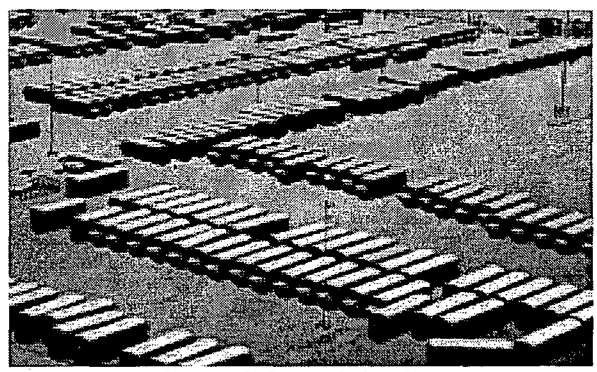
Latonya Hill, who waited out the dangerous storm sitting on her stoop Tuesday, said the official pleas for residents to pack up and leave meant little to her. "Got no place to go and no way to get there," said the 57-year-old grandmother, who lives on a disability check and money she picks up cleaning houses or baby sitting. "They say evacuate, but they don't say how I'm supposed to do that," Hill said. "If I can't walk it or get there on the bus, I don't go. I don't got a car. My daughter don't either."

Hill is among the estimated 100,000 people in New Orleans who rely on city transportation to get around, making evacuation impossible for them. Yet, no shelters were open in the city as of Tuesday night and there were no plans to open any. The city was working on setting up a shelter of "last resort," Mayor Ray Nagin said. No shelters had been set up yet because of concerns about flooding and capacity, Nagin added.

At 5 a.m. Wednesday, Ivan was about 220 miles from the city and moving at 12 mph. Forecasters said Ivan could bring a coastal storm surge of 10 to 16 feet, topped by large, battering waves. More than 1.2 million people in metropolitan New Orleans were warned to get out as Ivan approached, and those who could streamed inland in bumper-to-bumper traffic in an agonizingly slow exodus, spurred by dire warnings that the hurricane could overwhelm New Orleans with up to 20 feet of water.

The New Orleans Regional Transit Authority (RTA) had a hurricane evacuation policy: Drivers should evacuate buses and other agency vehicles with their families and transit-dependent residents, thereby protecting people and vehicles. There are unconfirmed stories that Amtrak offered use of a train for evacuation that was not accepted by local officials. But neither public buses nor trains were deployed to evacuate people out of the city (Murdock, 2005). Residents who wanted to leave the area by public transport were expected to pay for commercial services, a major barrier to many low-income residents. New Orleans Mayor Ray Nagin later explained that, in his interpretation, using buses to transport residents to the Superdome reflected the emergency plans' intent, and there were insufficient buses to evacuate everybody who needed assistance.

The city had approximately 500 transit and school buses, a quarter of the estimated 2,000 buses needed to evacuate residents who wanted transport (even more buses would have been needed to carry *all* residents who needed transport, since under emergency conditions it is unrealistic for a bus to carry 50 passengers). However, if given priority in traffic buses could have made multiple trips out of the city during the 48-hour evacuation period, and even evacuating 10,000 to 30,000 people would have reduced emergency shelter overcrowding. Many public buses were subsequently ruined by the flooding (Preston, 2005).



Flooded New Orleans School Buses

Federal emergency officials also failed to deploy buses for evacuation as planned. A top FEMA staff described his surprise and frustration at the agency's inadequate preparation before Katrina struck, despite his urgent warnings to agency executives (Bosner, 2005). He says that at the time he wondered, "Where are the buses to get people out of there?"

The importance of buses for evacuation of the city became clear soon after the hurricane hit. On September 1 Mayor Nagin said on a local radio station, "I need 500 buses...This is a national disaster. Get every doggone Greyhound bus line in the country and get their asses moving to New Orleans." Two weeks after the hurricane he explained on NBC's *Meet the Press* (www.msnbc.msn.com/id/9240461):

> "Sure, there was [sic] lots of buses out there, but guess what? You can't find drivers that would stay behind with a Category 5 hurricane, you know, pending down on New Orleans. We barely got enough drivers to move people on Sunday, or Saturday and Sunday, to move them to the Superdome. We barely had enough drivers for that. So sure, we had the assets, but the drivers just weren't available."

This indicates that bus deployment was ad hoc, implemented by officials during the emergency without a detailed action plan. Such a plan would include the designation of certain staff as *essential,* meaning that they are expected to work during emergency situations. Transit agency staff would have an incentive to volunteer for such a role because they would be allowed to evacuate their own families.

It is unsurprising that public officials directed transit-dependent residents to local emergency shelters, since that strategy had worked successfully during previous hurricanes. They appeared to be unaware of Katrina's greater severity, and insensitive to the risks and discomfort shelter occupants faced. A more cautious and compassionate plan would have offered all residents the option of free transport out of the city.

This situation is simply an extreme example of the problems non-drivers face every day. In most North American cities, New Orleans included, public transit is considered a mode of last resort or a novelty for tourists. Service quality is minimal, and poorly integrated into the overall transport system. The result is a huge difference in convenience, comfort and safety between motorists and non-motorists (and therefore between wealthy and poor, white and black, able and disabled), which is degrading and inequitable ("Evaluating Transportation Equity," VTPI, 2005). It is also inefficient and leads to additional problems, such as costly and dangerous rescue efforts, health problems, and distrust of authority.

After the hurricane there was no lack of material or human resources ready for deployment. Water, food, state-of-the-art equipment, and skilled rescuers were available and waiting, but were turned back, misdirected or misused (Murdock, 2005). Civil organizations were not allowed into the city to provide assistance. The American Red Cross explained soon after the hurricane struck (2005),

> Access to New Orleans is controlled by the National Guard and local authorities and while we are in constant contact with them, we simply cannot enter New Orleans against their orders. The state Homeland Security Department had requested--and continues to request--that the American Red Cross not come back into New Orleans following the hurricane. Our presence would keep people from evacuating and encourage others to come into the city.

The official response, when it came, was slow and confused, leaving tens of thousands of people without food, water, medical treatment or public services. Civil disorder developed, with reports of looting and violence, and poor coordination among public officials (Bradshaw and Slonsky, 2005).

With better planning, hundreds of deaths could have been avoided and billions of dollars in property and productivity could have been preserved. Better planning could also have greatly reduced the fear, discomfort, frustration and violence experienced by residents.

Rita

Hurricane Rita hit the Louisiana and Texas coasts September 24. Public officials ordered evacuations of coastal cities, and provided free bus transportation for non-drivers. More residents responded to evacuation instructions. This resulted in significant problems automobile traffic problems (Blumenthal, 2005).

An estimated three million people evacuated the Texas coast, creating colossal 100-mile-long traffic jams that left many stranded and out of fuel. Drivers heeding the call to evacuate Galveston Island and other low-lying areas took 4 and 5 hours to cover the 50 miles to Houston, and from there roadway conditions were even worse, with traffic crawling at just a few miles per hour.

Many fuel stations ran out of gasoline, because fuel truck drivers did not report to work. Some evacuees spent hours searching for fuel. Despite high heat and humidity, many evacuees did not use their vehicle air conditioning to save fuel. Vehicles failed along the way due to overheating and running out of fuel, further increasing congestion. There were inadequate washrooms and emergency services. After crawling only 10 or 20 miles in nine hours, some drivers turned around to take their chances at home rather than risk being caught in the open when the hurricane struck.

Timothy Adcock, 48, a Houston landscaper in the 15th hour of inching to north a companion's truck after his car broke down under the grueling conditions, said, "I never saw anything so disorganized. We did everything we were supposed to do; secure our house, left early, checked routes, checked on our neighbors, but when we got out there we were totally on our own." A high-occupancy vehicle lane went unused, he said, and they saw no police officers. At one point, Mr. Adcock said, he called the Texas DOT for an alternate route, but the woman who answered could not find a map.

Many stranded drivers said they had responded to official pleas to flee made by Mayor White and Judge Eckels, who often invoked the specter of Hurricane Katrina. "Don't wait, the time for waiting is over," Mr. White urged Wednesday. "Don't follow the example of New Orleans and think someone's going to get you." But Thursday as the traffic chaos worsened, he and Judge Eckels appeared to back off their dire warnings, saying that the only mandatory evacuation order concerned those in flood-prone areas along the coast. "The biggest flaw in this plan was communications," Judge Eckels said. "They didn't understand what could happen. We did not do a good enough job of telling people that you get on the road, it may take 20 hours."

County officials admitted that their plans had not anticipated the volume of traffic. They maintained that they had not urged such a widespread evacuation, although only a day earlier they invoked the specter of Hurricane Katrina to urge all residents to leave. Officials also made matters worse by announcing at one point that they would use inbound lanes on one highway to ease the outbound crush, only to abort the plan later, saying it was impractical, because the route was still needed to get resources into the city.

Educated by Rita – Editorial
New York Times (www.nytimes.com), 24 Sept. 2005.

Three weeks after the nation was shocked to realize how little the government knew about emergency management in New Orleans, another hurricane has hit the South and made it clear that the learning curve is still daunting.

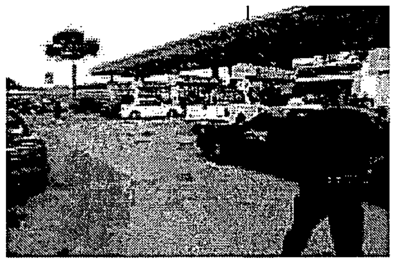
There was little danger that Rita would fail to get the authorities' full attention, or that people in the potential path of danger would not heed warnings to evacuate. But when Houston residents were told to leave, they found themselves stranded and sweltering in 90-degree heat in colossal traffic jams.

High-occupancy-vehicle lanes went unused, as did many inbound lanes of highways, because authorities inexplicably waited until late Thursday to open some up. Some motorists discovered, in terror, that they were stuck in what could be the hurricane's path. Tragically, one bus carrying elderly nursing home residents caught fire, killing 24.

If Katrina exposed what happens when many people have no cars to escape danger, Rita seemed to show the other side of the coin. The authorities are going to have to become much more sophisticated about developing evacuation plans that do not put every family on the highway in its own vehicle. But the car-obsessed American public is going to require a lot of education before many will accept the idea that they should flee disaster via mass transit.

Some Rita-related failures seemed inexplicable. A dearth of federal security screeners at Houston's airports led to long lines for passengers trying get out of the city. The Homeland Security Department should have anticipated that problem. Houston's shortage of emergency shelters and the local officials' apparent reluctance to let the public know where space was available were hard to comprehend.

Traffic congestion leaving Houston during Rita evacuation.



Police maintain order at gas stations.

Fuel was difficult to find.

Harris County emergency management coordinator Frank E. Gutierrez, explained that their evacuation models envisioned 0.8 to 1.2 million people but more than 2.5 million fled Rita. State officials promised to send gas trucks to relieve fuel shortages but their mobilization was slow. Gutierrez said the city intended to send out vans and buses with water for stranded people, and to evacuate people by buses, as needed. City officials put out a call for volunteers to help load vans and buses with water.

As congestion worsened state officials announced that contraflow lanes would be established on I-45, 290 and I-10. But by mid-afternoon, with traffic immobile on 290, the plan was dropped, stranding many and prompting other to reverse course. "We need that route so resources can still get into the city," explained an agency spokeswoman.

The Houston area's two major air gateways, Hobby Airport and Bush Intercontinental, suffered major delays when more than 150 screeners from the Transportation Security Administration, facing their own evacuation concerns, did not show up for work. The agency later rushed in replacements, but passengers, already burdening the system with extra luggage for their trips to safety, waited for hours to go through security.

Evacuation Picked Apart In Houston: Task Force Zeroes In On Traffic Flow, Fuel Supplies, Communication And Special Needs, by Rad Sallee, *Houston Chronicle* (www.chron.com), 27 Oct. 2005

Who should evacuate, when should they go, and how can their safety be guaranteed along the way were among the issues discussed at the governor's evacuation task force meeting Wednesday. Jack Little, chairman of the Task Force on Evacuation Transportation and Logistics, said the group will focus on "four very large, overarching needs":

- Traffic flow, from the surge zones to shelter destinations.
- Fuel availability along the evacuation routes.
- Evacuation of those with special needs such as hospital and nursing home patients.
- Communication and coordination among governmental bodies and with the public.

The public meeting in Houston is the first of several statewide. The task force will probably report its findings before June 1, when next year's hurricane season begins, said Kathy Walt, spokeswoman for Gov. Rick Perry. Mayor Bill White said the most urgent needs that local governments cannot provide are "fuel ... and incident management along the highways."

County Judge Robert Eckels said "communication was probably the biggest failure." During Hurricane Rita, he said, many evacuees hit the road without knowing how long the trip would take or how much fuel, food and water they would need.

Task force member Bill King, former mayor of Kemah, noted that centralizing authority for evacuation had been "resisted" by local governments and asked Galveston City Manager Steve LeBlanc if some might welcome such centralization now. Le- Blanc said he thought they would. "We have to get out first," LeBlanc said. He noted that the plan called for a sequenced evacuation, but "it just didn't get followed."

Shoreacres Mayor Nancy Edmonson echoed LeBlanc in saying the critical problem was "to keep people off the road who don't need to be there." She said west Houston and other inland areas are unlikely to be flooded, and their residents should shelter in place. Instead of controlling the lights, she said, police in some towns seemed focused on keeping evacuees from leaving the roadway. She said some people need to pick up relatives along the way.

Mayor Bill Jackson of Bayou Vista recommended posting National Guard troops to help police at barricades, which would free law officers to patrol the routes. Houston did not need to evacuate, Jackson said, "but my city would be totally and completely destroyed."

Bellaire Mayor Cindy Siegel disagreed. Although her city is not in a storm-surge zone, 80% of its homes flooded during Tropical Storm Allison, she said. And it has two large nursing homes with patients who would die if power were cut off for a long time, as in New Orleans after Hurricane Katrina, she said.

Galveston Mayor Lyda Ann Thomas said finding shelters was as big a problem as transportation. She said Galveston residents spent 18 hours getting to Huntsville, their initial destination, only to be "shuffled off" to Buffalo, Centerville and other towns. "What I'm looking for is specific shelters for Galveston and Galveston County," she said.

Houston METRO's described his agency's response to Hurricane Rita (Wilson, 2005).

> Public transit is an extremely versatile and flexible asset that can provide on-demand, custom services tailored to the unplanned needs of tens of thousands of people. We became, in effect, the means by which thousands of people, who had no way out, actually got out or got to safety in area shelters. METRO deployed multi-purpose services, including round trip transit, rescue of evacuees, humanitarian lifeline services, and demand response emergency relief.
>
> Specifically, during Hurricane Rita, METRO used over 1,000 vehicles to transport more than 20,000 people during 4,500 trips. We also used 18 METRO buses, plus operators and police – along with 350 wonderful volunteers – to load and dispense 45,000 bottles of water to stranded motorists along area freeways. METRO conducted last minute "sweeps" of the freeways to rescue motorists and residents seeking shelter. We suspended bus service at 2 pm on Thursday, Sept. 22, the day before Rita landed, to use as many vehicles as necessary for the evacuation.

Summary of Planning Problems

Table 1 summarizes various problems encountered during Katrina and Rita.

Table 1 **Examples of Poor Decision-Making**

General	Transportation
• Failure to track the number of people at emergency shelters, and provide adequate facilities and resources. • Failure to define who is in charge, conflicts over authority, and inadequate communication among top-level decision-makers. • Failure to distribute food and water immediately after the hurricane. • Waiting until the fourth day to deploy the National Guard and supply ships waiting nearby. • Failure to provide security to rescue teams. • Failure to help evacuate families of essential staff (police, fire, transit, healthcare, utility, etc.) so they could concentrate on emergency response. • Failure of communications systems (telephone service stopped) and backup generators at critical facilities. • Official overreaction to reports of violence, and so failing to provide help or allow evacuation of some people, particularly African-Americans. • Failure to show respect and compassion to disadvantaged people.	• Failure to have an effective evacuation plan for non-drivers. • Failure to prioritize evacuation to insure that the most vulnerable (residents of the riskiest areas and people with special needs) leave first. • Failure to understand and address the reasons that discourage people from evacuating. • Failure to offer free or subsidized evacuation transport to people who need it. • Failure to prioritize evacuation traffic to favor buses, HOVs and service vehicles. • Failure to implement a transit and school bus "evacuation action plan." • Failure to use counterflow lanes and road shoulders for evacuation traffic, in some cases where it was possible. • Failure to coordinate vehicle rentals, fuel distribution and services along evacuation route. • Failure to use public transit, school buses, charter buses and trains for evacuation. • Failure to accommodate pets.

Other countries have more effective disaster response than the U.S. For example, by all accounts Cuba has an outstanding system to alert residents, organize evacuations, maintain public services during evacuation periods, and repair damages (Cohn, 2005; Martin, 2005). It accommodates special needs, such as medical services for evacuees. Cuba is a socialist dictatorship. Its economic policies are not an attractive model. But it demonstrates that financial or technical resources are not the key to effective emergency response. Rather than dismissing Cuba's disaster response programs because the government is communist, it would be better to learn from them and do even better.

Overcoming Resistance to Evacuation

It is important to understand why some people refused to evacuate when ordered before and after Katrina struck. Interviews indicated various reasons:

- Many lower income people lacked a vehicle and money.
- Many had no place to go and were fearful of conditions in emergency shelters.
- Many had survived previous hurricanes safely in their homes.
- Many did not expect the hurricane to be as bad as it was.
- Some wanted to protect their homes or pets.
- Some were proud of their ability to endure disaster risks and discomfort.

Various strategies could be used to increase evacuation rates, including more information on the risks facing people who stay, subsidized transportation, more comfortable and secure shelters, and better protection of homes. Had residents been offered free transportation out of and back to the city, and assurance of a relatively comfortable and safe refuge, perhaps half of those who stayed would have left. This would have greatly reduced crowding at emergency shelters and subsequent rescue problems. Assuming 200,000 residents had accepted free evacuation transportation at a cost of $100 each, it would have required $20 million in subsidy. This may seem costly for a single city (it represents about 20% of the regional transit agency annual budget), but is tiny compared with the costs it would have avoided.

Pets present a particular challenge. Before a disaster strikes it seems unreasonable to abandon or destroy pets. It is therefore important to try to accommodate pets, by allowing animals to accompany evacuees (perhaps only small animals in a carrying cage) or by having special SPCA services to collect pets and house them in kennels.

Caring For The Most Vulnerable

An important test of a transportation system's effectiveness and fairness is its ability to accommodate the needs of the most vulnerable users under extreme conditions (Litman, 2004). Katrina disaster response failed in those terms. People who had resources were served relatively well because planners are familiar with their abilities and needs. People who were poor, disabled or ill were not well served, apparently because decision-makers were unfamiliar with and insensitive to their needs.

The City of New Orleans does provided a section on "Emergency Guide for Citizens with Disabilities" in its *Comprehensive Emergency Management Plan* posted on the City's website (New Orleans, 2005), but it contains little practical support, placing most of the responsibility for safety and evacuation on individuals. The Guide recommends that people with disabilities develop a "support system" to provide help during disasters. The "General Evacuation Guidelines" advises, "If you need a ride, try to go with a neighbor, friend, or relative," but provides no directions for people who lack neighbors, friends or relatives who have extra capacity in their evacuation vehicles, which is likely to be common in areas were poverty is concentrated.

Non-drivers include a diverse group of people who face various combinations of physical, economic and social disadvantages. A system designed for non-drivers must therefore be able to accommodate a wide range of needs, including poverty, physical and mental disabilities (Access Board, 2005), illnesses, inability to speak or read English, parents with young children, distrust of authority, frustration and anger. Many non-drivers lack convenient access to the Internet, and some lack regular telephone and mail service. Many had nowhere to stay outside of the city and no money to pay for housing, food or return transportation. Understanding and responding to these diverse needs is therefore important for effective disaster management and evacuation planning.

Under emergency conditions public infrastructure may be stressed. For example, a typical bus can normally carry about 50 passengers, but in an emergency, with evacuees carrying baggage, some in wheelchairs, and communication systems overwhelmed, 30-40 passengers is a more realistic load. It will therefore be important to provide a generous amount of overcapacity and redundancy.

Planning For Resilience

A key concept recognized by engineers and planners is the value of *resilience* ("Evaluating Transportation Resilience," VTPI, 2005), which refers to a system's ability to accommodate variable and unexpected conditions without catastrophic failure, or "the capacity to absorb shocks gracefully" (Foster, 1993).

Resilience acknowledges *uncertainty*, our inability to know what combination of conditions will occur in the future. If the future were predictable, resilience would lose its importance: individuals and communities would simply need to plan for a single set of conditions. But since the future is unpredictable, it is necessary to plan for a wide range of possible conditions, including some that may be unlikely but which could result in significant harm if they are not anticipated.

Resilience tends to increase if a system has diversity, redundancy, efficiency, autonomy and strength in its critical components. This allows the system to continue functioning if a link is broken, if a particular resource becomes scarce, if a particular decision-maker is unavailable, etc. Resilience is affected by a system's ability to collect and distribute critical information under extreme conditions. Resilience tends to increase if a system has effective ways to prioritize resources. For example, evacuations could be more efficient if buses and trains were given priority where needed to avoid congestion and bottlenecks, or to use limited fuel resources most efficiently.

A single highway lane can typically accommodate a maximum of about 2,000 vehicles per hour, but less under mass evacuation conditions because of congestion, diverse and overloaded vehicles (many tow heavily loaded trailers), weather (rain and flooding), infrastructure failures (such as earthquake damage), and vehicle mechanical problems, crashes and driver confusion. Assuming that each highway lane accommodates 1,000 vehicles per hour under such conditions and vehicles carry an average of 2.5 passengers, each lane accommodates 2,500 passengers per hour. A four-lane highway can therefore evacuate about 10,000 people per hour, or 20,000 if inbound lanes are reversed. A city with one million residents and two four-lane highways in functional conditions would therefore require about 50 hours to evacuate all residents by automobile.

Assuming that a highway lane can accommodate 600 buses per hour (according to the *Highway Capacity Manual* a bus or truck represents 1.5 Passenger Car Equivalents on level highway conditions, and 2.5 under rolling conditions) and buses carry an average of 25 passengers, each bus lane accommodates 15,000 passengers per hour, the same as six lanes of automobile traffic. Highway capacity can therefore more than double by dedicating one lane to buses and encouraging residents to use buses and other high occupant vehicles such as vans with more than six passengers ("HOV Priority," VTPI, 2005). A city with one million residents and two four-lane highways in functional conditions would therefore require only about 24 hours to evacuate all residents if about half are transported by bus and other high occupancy vehicles. In some situations trains may also be useful for mass evacuations. Urban light rail lines can carry 20,000 passengers per hour, and heavy rail lines even with good management.

Mobility management has other applications in emergency situations. During Oakland, California wildfires in 2004, residents who walked down the hills survived but many who tried to drive were delayed and perished. During disasters, emergency responders are sometimes more mobile using bicycles than motor vehicles. Evacuation congestion is often exacerbated by households that drive multiple vehicles, some towing trailers filled with household goods; traffic would flow more efficiently if evacuees have instructions and incentives to use minimal vehicles and limit the amount of goods they carry.

Resilience is also important for addressing long-term changes, such as traffic problems resulting from roadway damage (Giuliano and Golog, 1998), and increasing fuel prices. For example, the financial burden of increased fuel prices is reduced if a community has good travel alternatives (walking and cycling conditions, rideshare and public transit services, telecommuting, delivery services, etc), and so can reduce vehicle use with minimal problem. This flexibility benefits not only people who shift mode and reduce their automobile travel, but also those who continue driving, due to reduced congestion and reduced fuel demand, which reduces price increases.

Below are examples of specific ways to increase transportation system resilience ("Evaluating Transportation Resilience," VTPI, 2005).

- Value diversity, flexibility and redundancy ("Evaluating Transport Diversity," VTPI, 2005). Develop a multi-modal transportation system that provides a variety of mobility options.
- Design transportation facilities to withstand extreme conditions (earthquakes, storms, etc.).
- Create transportation system networks that provide multiple links to each destination, including multiple rail lines, roads, paths and bridges.
- Plan transportation systems to provide *basic mobility* ("Basic Mobility," VTPI, 2005). Insure that transport planning takes into account people with special needs (physical disabilities, low incomes, inability to speak the local language, etc.). Work with community organizations to identify their needs and maintain effective communications with vulnerable groups.
- Develop effective ways to maintain information and communication systems among transport system managers, staff and users under normal and extreme conditions. Develop ways to communicate with residents and travelers under emergency conditions.
- Develop ways to prioritize transport system resources when necessary. For example, design systems to allow emergency, service and freight vehicles priority over general traffic. Maintain contingency plans to allocate fuel and other resources in emergencies.
- Maintain ongoing transportation systems evaluation to provide early detection of possible problems and inefficiencies.
- Design critical components of the transportation system to be fail-safe, self-correcting, repairable, redundant and autonomous. For example, where possible use roundabouts instead of traffic signals, since they function without electricity.
- Cross-train staff to perform critical management and repair services.
- Encourage efficient use of resources, including traffic management, energy efficiency and accessible land use.

Disaster Transportation Issues

Disasters can present various transportation issues:

- Evacuations before, during or after an event, and adequate accommodation of evacuees at refuge destinations.
- Delivery of emergency supplies and services, including water, food, medical care, utility maintenance, law enforcement, etc.
- Search and rescue operations.
- Quarantine.
- Transportation infrastructure repair.

Many disasters involve a variety of catastrophes, such as an earthquake that causes fires and toxic chemical release. Specific transport issues vary depending on the type and scale of disaster, as summarized below. Major emergencies require regional planning and coordination, since disasters do not recognize jurisdictional boundaries.

Table 2 **Major Transportation Issues**

	Geographic Scale	Warning	Evacu-Ation	Emerg. Services	Search & Rescue	Quar-antine	Infrast. Repair
Hurricane	Very large	Days	✓	✓	✓		✓
Earthquake	Large	None	✓	✓	✓		✓
Tsunami	Very large	Short	✓	✓	✓		✓
Flooding	Large	Days	✓	✓	✓		✓
Forest fire	Small to large	Usually	✓	✓	✓		✓
Volcano	Small to large	Usually	✓	✓	✓		✓
Blizzard/ice storm	Very large	Usually		✓	✓		✓
Building fire	Small	Seldom		✓	✓		
Explosion	Small to large	Seldom	✓	✓	✓		✓
Bus/train/aircraft crash	Small	Seldom		✓	✓		✓
Radiation/toxic release	Small to large	Sometimes	✓	✓	✓	✓	
Plague	Small to large	Usually		✓		✓	
Riot	Small to large	Sometimes	✓	✓			
War	Small to large	Usually	✓	✓			✓
Landslide or avalanche	Small to medium	Sometimes	✓	✓	✓		✓

Different types of disasters present different types of transportation issues.

Evacuation activities can vary depending on the type and scale of disaster. Some disasters require mass evacuations. Others, such as earthquakes and fires, require evacuation from collapsed structures to local hospitals and shelters. Even a small building fire, such as an apartment building, might require evacuation of residents to hospitals and temporarily shelters. Emergency transportation and public transit services are therefore an important component of all emergency preparedness efforts.

Role of Automobile Transportation

Some critics argue that the best way to improve emergency transportation is to increase automobile ownership and roadway capacity. In a message distributed after Katrina but before Rita, O'Toole (2005) pointed out most New Orleans residents with automobiles could evacuate with relative convenience and comfort, and so argues that the best evacuation strategy is to subsidize car ownership for households that lack vehicles. But such arguments ignore several important points (Litman, 2005).

- Many people cannot drive due to disabilities, age, addictions, legal restrictions, or other problems. Encouraging such people to drive is impractical and dangerous.
- Many vehicles, particularly the older vehicles typically owned by lower-income people, tend to be unreliable and unsafe. Even people who own a car need backup transport options.
- Automobiles cannot be used in some disaster situations. Earthquakes, storms and floods often damage vehicles, highways and bridges (Giuliano and Golog, 1998).
- Increased automobile ownership would exacerbate traffic congestion. Hurricane Rita evacuation failed due to too many private vehicles.
- The reduction in hurricane deaths cited by O'Toole has been offset many times over by increased automobile traffic deaths.

O'Toole argues that it would be cheaper to purchase cars for nonmotorists than to build New Orleans' streetcar system, but his accounting ignores many costs (operating expenses, parking, road capacity, crash damages, etc.), and the used vehicles he proposes purchasing would require frequent repairs and only last a few more years, compared with the 20-40 year operating life of a train and 50+ years of a rail line. The gift of a "free" car can be a curse to financially struggling families since it adds hundreds of dollars in annual expenses for insurance, fuel, tires and repairs. At $3,500 annually ($1,000 in capital and $2,500 in operating expenses), providing cars to 100,000 New Orleans households that lack vehicles would cost $350 million, more than three times the regional transit budget, plus large additional costs to expand road and parking capacity.

Cox (2005) argues that urban national highways should be expanded to facilitate automobile evacuations, but the costs would be immense since expanding urban highways is particularly costly. Current roadway funding is hardly adequate to maintain the current system and there appears to be little public support for tax increases. It would be inefficient to size all roadways for evacuations that only occur once a century at any particular location, if other strategies can accommodate such needs at lower cost.

Described differently, emergency response requires *mobility*. Automobiles provide mobility, but have high total costs and constraints that limit their use in some situations and for some people, particularly those most vulnerable. Although it makes sense to increase automobile affordability through true cost-saving strategies such as carsharing and Pay-As-You-Drive insurance ("Affordability," VTPI, 2005), it is wrong to assume that automobile solutions are most appropriate or cost effective in every situation.

Best Practices

Many jurisdictions and agencies have emergency response plans, but they often lack details. Emergency action plans are needed that specify exactly who will do what, when. Such plans must be tested occasional with multi-agency practice sessions. Below are recommendations for effective emergency transportation plans (TRB, 2005):

- Include disaster response as part of all transportation planning (local, regional, national, transit, etc.). Consider the widest possible range of possible disasters and stresses on the transport system, and consider the widest possible range of possible solutions.
- Identify exactly who will do what during disasters.
- Update emergency response plans regularly, particularly after a disaster tests its effectiveness.
- Establish a system to prioritize evacuations based on factors such as geographic location (evacuate the highest risk areas first), and individual need and ability.
- Use counterflow and highway shoulders for evacuation routes, and apply other traffic management strategies where appropriate.
- Coordinate vehicle rentals and fuel supplies, provide special services (information, water, food, washrooms, medical services, vehicle repairs, etc.) along evacuation routes,
- Create communication and support networks that serve the most vulnerable people. Establish a system to identify and contact vulnerable people, provide individualized directions for their care and evacuation, and establish a chain of responsibility for caregivers. Provide instructions on pickup locations and what evacuees should bring. This information should be distributed regularly, not just when major emergencies occur.
- Give buses and other high occupancy vehicles priority where critical resources (road space, ferry capacity, fuel, repair services, etc.) are limited.
- Be ready to quickly deploy buses, vans and trains. This requires an inventory of such vehicles and their drivers, and clearly established instructions for their use.
- Coordinate fuel, emergency repair and other support services.

Developing communication and support networks that serve vulnerable people requires effective community outreach. Each neighborhood should have an inventory of people who may need assistance, ways to contact them, directions for their evacuation, and a list of their friends and family who can provide emergency support. If possible, social service agency staff or volunteer community leaders should travel with vulnerable evacuees to provide information and reassurance to people who may be frustrated and frightened. Implementing such a system requires that planning professionals work with a broad range of community groups, professionals and social service organizations.

There are often years or even decades between major disasters, so it is important to preserve institutional memory by documenting successes and failures, and updating emergency plans while the experience is still fresh.

Conclusions

This paper identifies ways to improve emergency response transportation services based on experience gained during two recent hurricanes. Katrina and Rita provide important and different lessons. Katrina's evacuation was relatively effective for people with automobiles but failed transit-dependent residents. Non-drivers received better services during Rita's evacuation, but excessive vehicle traffic created problems for motorists. Counterflow lanes were not implemented, fuel was poorly distributed, basic services (such as washrooms) were not provided along the evacuation route, and traffic was poorly managed.

This experience indicates that the best way to quickly evacuate a large city is to give buses, and perhaps private high occupancy vehicles, priority in traffic and fuel access, and then accommodate as many low-occupancy vehicles as resources allow. Individuals can choose between accepting a free and fast bus ride, or driving a private vehicle and facing congestion delays.

Planners can help prevent future disasters by demanding that emergency response plans devote at least as much attention to non-automobile evacuation as to automobile-based evacuation, and by developing ways to prioritize use of critical transportation resources, such as road capacity and fuel, during emergencies. Planners need to anticipate the needs of non-drivers, who include many people with various physical, economic and social problems. This may require community outreach to build understanding and trust among public officials and the people they serve before an emergency occurs. Extra effort should be made to offer comfort to evacuees, for example, by providing washrooms and information stations along evacuation routes, and having public officials and community volunteers accompany evacuation buses to provide physical and emotional support.

It is important to understand why many people ignore evacuation orders. Some face logistical or financial barriers obtaining transportation. Some had nowhere to go and are fearful of emergency shelter conditions. Some stay to protect their property or pets, or out of bravado. Addressing these objections can increase evacuation rates.

Katrina evacuation problems are simply extreme examples of the day-to-day problems facing non-drivers due to inadequate and poorly integrated transportation services. Rita evacuation problems are simply extreme examples of the day-to-day traffic problems that result from excessive reliance on automobile transport without efficient management. Transportation professionals can play an important role in creating a more equitable and efficient transportation system. It would be helpful for all transportation professionals to spend at least two weeks each year without driving so they can directly experience the non-automobile transportation system that they help create.

A variety of planning policies and programs can help create a more resilient transport system. These increase system diversity and integration, improve user information, prioritize resource use, and provide coordinated services during special events and emergencies. Such policies can save lives, reduce suffering, and provide substantial savings and benefits to society.

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EXHIBIT 3.1

SAFETY AND SECURITY
OF
COMMERCIAL
SPENT NUCLEAR FUEL STORAGE

Public Report

Committee on the Safety and Security of Commercial Spent Nuclear Fuel Storage

Board on Radioactive Waste Management

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
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- German organizations and individuals who helped organize a tour of spent fuel storage facilities in Germany. These organizations and individuals are explicitly acknowledged in Appendix C.
- Speakers (see Appendix A) and participants at committee meetings as well as those who sent written comments for providing their knowledge and perspectives on this important matter.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

John F. Ahearne, Sigma Xi and Duke University
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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the report's conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Chris G. Whipple, ENVIRON International Corporation, and R. Stephen Berry, University of Chicago. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

CONTENTS

NOTE TO READERS

This report is based on a classified report that was developed at the request of the U.S. Congress with sponsorship from the Nuclear Regulatory Commission and the Department of Homeland Security. This report contains all of the findings and recommendations that appear in the classified report. Some have been slightly reworded and other sensitive information that might allow terrorists to exploit potential vulnerabilities has been redacted to protect national security. Nevertheless, the National Research Council and the authoring committee believe that this report provides an accurate summary of the classified report, including its findings and recommendations.

The authoring committee for this report examined the potential consequences of a large number of scenarios for attacking spent fuel storage facilities at commercial nuclear power plants. Some of these scenarios were developed by the Nuclear Regulatory Commission as part of its ongoing vulnerability analyses, whereas others were developed by the committee based upon the expertise of its members or suggestions from participants at the committee's open meetings. The committee focused its discussions about terrorist attacks on the concept of *maximum credible scenarios*. These are defined by the committee to be physically realistic classes of attacks that, if carried out successfully, would produce *the most serious potential consequences within that class. In a practical sense they can be* said to *bound* the consequences for a given type of attack. Such scenarios could in some cases be very difficult to carry out because they require a high level of skill and knowledge or luck on the part of the attackers. It was nevertheless useful to analyze these scenarios because they provide decision makers with a better understanding of the full range of potential consequences from terrorist attacks.

The committee uses the term *potential consequences* advisedly. It is important to recognize that a terrorist attack on a spent fuel storage facility would not necessarily result in the release of any radioactivity to the environment. The consequences of such an attack would depend not only on the nature of the attack itself, but also on the construction of the spent fuel storage facility; its location relative to surrounding features that might shield it from the attack; and the ability of the guards and operators at the facility to respond to the attack and/or mitigate its consequences. Facility-specific analyses are required to determine the potential vulnerability of a given facility to a given type of terrorist attack.

Congress asked the National Research Council for technical advice related to the vulnerability of spent fuel storage facilities to terrorist attacks. Congress, the Nuclear Regulatory Commission, and the Department of Homeland Security are responsible for translating this advice into policy actions. This will require the balancing of costs, risks, and benefits across the nation's industrial infrastructure. The committee was not asked to examine the potential vulnerabilities of other types of infrastructure to terrorist attacks or the consequences of such attacks. While such comparisons will likely be difficult, they will be essential for ensuring that the nation's limited resources are used judiciously in protecting its citizens from terrorist attacks.

SUMMARY FOR CONGRESS

The U.S. Congress asked the National Academies to provide independent scientific and technical advice on the safety and security of commercial spent nuclear fuel storage in the United States, specifically with respect to the following charges:

- Potential safety and security risks of spent nuclear fuel presently stored in cooling pools at commercial nuclear reactor sites.
- Safety and security advantages, if any, of dry cask storage versus wet pool storage at these reactor sites.
- Potential safety and security advantages, if any, of dry cask storage using various single-, dual-, and multi-purpose cask designs.
- The risks of terrorist attacks on these materials and the risk these materials might be used to construct a radiological dispersal device.

Congress requested that the National Academies produce a classified report that addresses these charges within 6 months and also provide an unclassified summary for unlimited public distribution. The first request was fulfilled in July 2004. This report fulfills the second request.

The highlights of the report are as follows:

(1) Spent fuel pools are necessary at all operating nuclear power plants to store recently discharged fuel.

(2) The committee judges that successful terrorist attacks on spent fuel pools, though difficult, are possible.

(3) If an attack leads to a propagating zirconium cladding fire, it could result in the release of large amounts of radioactive material.

(4) Additional analyses are needed to understand more fully the vulnerabilities and consequences of events that could lead to propagating zirconium cladding fires.

(5) It appears to be feasible to reduce the likelihood of a zirconium cladding fire by rearranging spent fuel assemblies in the pool and making provision for water-spray systems that would be able to cool the fuel, even if the pool or overlying building were severely damaged.

(6) Dry cask storage has inherent security advantages over spent fuel pool storage, but it can only be used to store older spent fuel.

(7) There are no large security differences among different storage-cask designs.

(8) It would be difficult for terrorists to steal enough spent fuel from storage facilities for use in significant radiological dispersal devices (dirty bombs).

The statement of task does not direct the committee to recommend whether the transfer of spent fuel from pool to dry cask storage should be accelerated. The committee judges, however, that further engineering analyses and cost-benefit studies would be needed before decisions on this and other mitigative measures are taken. The report contains detailed recommendations for improving the security of spent fuel storage regardless of how it is stored.

EXECUTIVE SUMMARY

In the Fiscal Year 2004 Energy and Water Development Conference Report, the U.S. Congress asked the National Academies to provide independent scientific and technical advice on the safety and security[1] of commercial spent nuclear fuel storage in the United States, specifically with respect to the following four charges:

(1) Potential safety and security risks of spent nuclear fuel presently stored in cooling pools at commercial reactor sites.
(2) Safety and security advantages, if any, of dry cask storage versus wet pool storage at these reactor sites.
(3) Potential safety and security advantages, if any, of dry cask storage using various single-, dual-, and multi-purpose cask designs.
(4) The risks of terrorist attacks on these materials and the risk these materials might be used to construct a radiological dispersal device.

Congress requested that the National Academies produce a classified report that addresses these charges within 6 months and also provide an unclassified summary for unlimited public distribution. The first request was fulfilled in July 2004. This report fulfills the second request.

Spent nuclear fuel is stored at commercial nuclear power plant sites in two configurations:

- In water-filled pools, referred to as *spent fuel pools*.
- In *dry casks* that are designed either for storage (single-purpose casks) or both storage and transportation (dual-purpose casks). There are two basic cask designs: bare-fuel casks and canister-based casks, which can be licensed for either single- or dual-purpose use, depending on their design.

Spent fuel pools are currently in use at all 65 sites with operating commercial nuclear power reactors, at 8 sites where commercial power reactors have been shut down, and at one site not associated with an operating or shutdown power reactor. Dry-cask storage facilities have been established at 28 operating, shutdown, or decommissioned power plants. The nuclear industry projects that up to three or four nuclear power plants will reach full capacity in their spent fuel pools each year for at least the next 17 years.

The congressional request for this study was prompted by conflicting public claims about the safety and security of commercial spent nuclear fuel storage at nuclear power plants. Some analysts have argued that the dense packing of spent fuel in cooling pools at nuclear power plants does not allow a sufficient safety margin in the event of a loss-of-pool-coolant event from an accident or terrorist attack. They assert that such events could result in the release of large quantities of radioactive material to the environment if the zirconium cladding of the spent fuel overheats and ignites. To reduce the potential for such fires, these

[1] In the context of this study, *safety* refers to measures that protect spent nuclear fuel storage facilities against failure, damage, human error, or other accidents that would disperse radioactivity in the environment. *Security* refers to measures to protect spent fuel storage facilities against sabotage, attacks, or theft.

analysts have suggested that spent fuel more than five years old be removed from the pool and stored in dry casks, and that the remaining younger fuel be reconfigured in the pool to allow more space for air cooling in the event of a loss-of-pool-coolant event.

The committee that was appointed to perform the present study examined the vulnerability of spent fuel stored in pools and dry casks to accidents and terrorist attacks. Any event that results in the breach of a spent fuel pool or a dry cask, whether accidental or intentional, has the potential to release radioactive material to the environment. The committee therefore focused its limited time on understanding two issues: (1) Under what circumstances could pools or casks be breached? And (2) what would be the radioactive releases from such breaches?

To address these questions, the committee performed a critical review of the security analyses that have been carried out by the Nuclear Regulatory Commission and its contractors, the Department of Homeland Security, industry, and other independent experts to determine if they are objective, complete, and credible. The committee was unable to examine several important issues related to these questions either because it was unable to obtain needed information from the Nuclear Regulatory Commission or because of time constraints. Details are provided in Chapters 1 and 2.

The committee's findings and recommendations from this analysis are provided below, organized by the four charges of the study task. The ordering of the charges has been rearranged to provide a more logical exposition of results.

CHARGE 4: RISKS OF TERRORIST ATTACKS ON THESE MATERIALS AND THE RISK THESE MATERIALS MIGHT BE USED TO CONSTRUCT A RADIOLOGICAL DISPERSAL DEVICE

The concept of *risk* as applied to terrorist attacks underpins the entire statement of task for this study. Therefore, the committee examined this final charge first to provide the basis for addressing the remainder of the task statement. The committee's examination of Charge 4 is provided in Chapter 2. On the basis of this examination, the committee offers the following findings and recommendations numbered according to the chapters in which they appear:

FINDING 2A: The probability of terrorist attacks on spent fuel storage cannot be assessed quantitatively or comparatively. Spent fuel storage facilities cannot be dismissed as targets for such attacks because it is not possible to predict the behavior and motivations of terrorists, and because of the attractiveness of spent fuel as a terrorist target given the well known public dread of radiation. Terrorists view nuclear power plant facilities as desirable targets because of the large inventories of radioactivity they contain. While it would be difficult to attack such facilities, the committee judges that attacks by knowledgeable terrorists with access to appropriate technical means are possible. It is important to recognize, however, that an attack that damages a power plant or its spent fuel storage facilities would not necessarily result in the release of *any* radioactivity to the environment. There are potential steps that can be taken to lower the potential consequences of such attacks.

FINDING 2B: The committee judges that the likelihood terrorists could steal enough spent fuel for use in a significant radiological dispersal device is small. Removal of a spent fuel assembly from the pool or dry cask would prove extremely difficult under almost any terrorist attack scenario. Attempts by a knowledgeable insider(s) to remove single rods and related debris from the pool might prove easier, but the amount of material that could be removed would be small. Moreover, superior materials could be stolen or purchased more easily from other sources. Even though the likelihood of spent fuel theft appears to be small, it is nevertheless important that the protection of these materials be maintained and improved as vulnerabilities are identified.

> **RECOMMENDATION: The Nuclear Regulatory Commission should review and upgrade, where necessary, its security requirements for protecting spent fuel rods not contained in fuel assemblies from theft by knowledgeable insiders, especially in facilities where individual fuel rods or portions of rods are being stored in pools.**

FINDING 2C: A number of security improvements at nuclear power plants have been instituted since the events of September 11, 2001. However, the Nuclear Regulatory Commission did not provide the committee with enough information to evaluate the effectiveness of these procedures for protecting stored spent fuel. Surveillance and other human-factors related security procedures are just as important as the physical barriers in preventing and mitigating terrorist attacks. Although the committee did learn about some of the changes that have been instituted since the September 11, 2001, attacks, it was not provided with enough information to evaluate the effectiveness of procedures now in place.

> **RECOMMENDATION: Although the committee did not specifically investigate the effectiveness and adequacy of improved surveillance and security measures for protecting stored spent fuel, an assessment of current measures should be performed by an independent[2] organization.**

CHARGE 1: POTENTIAL SAFETY AND SECURITY RISKS OF SPENT NUCLEAR FUEL STORED IN POOLS

The committee's examination of Charge 1 is provided in Chapter 3. On the basis of this examination, the committee offers the following findings and recommendations:

FINDING 3A: Pool storage is required at all operating commercial nuclear power plants to cool newly discharged spent fuel. Freshly discharged spent fuel generates too much decay heat to be passively air cooled. This fuel must be stored in a pool that has an active heat removal system (i.e., water pumps and heat exchangers) for at least one year before being moved to dry storage. Most dry storage systems are licensed to store fuel that has been out of the reactor for at least five years. Although spent fuel younger than five years could be stored in dry casks, the changes required for shielding and heat-removal

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[2] That is, independent of the Nuclear Regulatory Commission and the nuclear industry.

could be substantial, especially for fuel that has been discharged for less than about three years.

FINDING 3B: The committee finds that, under some conditions, a terrorist attack that partially or completely drained a spent fuel pool could lead to a propagating zirconium cladding fire and the release of large quantities of radioactive materials to the environment. Details are provided in the committee's classified report.

FINDING 3C: It appears to be feasible to reduce the likelihood of a zirconium cladding fire following a loss-of-pool-coolant event using readily implemented measures. The following measures appear to have particular merit: Reconfiguring the spent fuel in the pools (i.e., redistribution of high decay-heat assemblies so that they are surrounded by low decay-heat assemblies) to more evenly distribute decay-heat loads and enhance radiative heat transfer; limiting the frequency of offloads of full reactor cores into spent fuel pools, requiring longer shutdowns of the reactor before any fuel is offloaded, and providing enhanced security when such offloads must be made; and development of a redundant and diverse response system to mitigate loss-of-pool-coolant events that would be capable of operation even if the pool or overlying building were severely damaged.

FINDING 3D: The potential vulnerabilities of spent fuel pools to terrorist attacks are plant-design specific. Therefore, specific vulnerabilities can be understood only by examining the characteristics of spent fuel storage at each plant. As described in Chapter 3, there are substantial differences in the designs of spent fuel pools that make them more or less vulnerable to certain types of terrorist attacks.

FINDING 3E: The Nuclear Regulatory Commission and independent analysts have made progress in understanding some vulnerabilities of spent fuel pools to certain terrorist attacks and the consequences of such attacks for releases of radioactivity to the environment. However, additional work on specific issues is needed urgently. The analyses carried out to date provide a general understanding of spent fuel behavior in a loss-of-pool-coolant event and the vulnerability of spent fuel pools to certain terrorist attacks that could cause such events to occur. The work to date, however, has not been sufficient to adequately understand the vulnerabilities and consequences of such events. Additional analyses are needed to fill in the knowledge gaps so that well-informed policy decisions can be made.

> **RECOMMENDATION: The Nuclear Regulatory Commission should undertake additional best-estimate analyses to more fully understand the vulnerabilities and consequences of loss-of-pool-coolant events that could lead to a zirconium cladding fire. Based on these analyses, the Commission should take appropriate actions to address any significant vulnerabilities that are identified.** The committee provides details on additional analyses that should be carried out in its classified report. Cost-benefit considerations will be an important part of such decisions.

> **RECOMMENDATION: While the work described in the previous recommendation under Finding 3E, above, is being carried out, the Nuclear Regulatory Commission should ensure that power plant operators take prompt and effective measures to reduce the consequences of loss-of-pool-coolant**

events in spent fuel pools that could result in propagating zirconium cladding fires. The committee judges that there are at least two such measures that should be implemented promptly:

- Reconfiguring of fuel in the pools so that high decay-heat fuel assemblies are surrounded by low decay-heat assemblies. This will more evenly distribute decay-heat loads, thus enhancing radiative heat transfer in the event of a loss of pool coolant.
- Provision for water-spray systems that would be able to cool the fuel even if the pool or overlying building were severely damaged.

Reconfiguring of fuel in the pool would be a prudent measure that could probably be implemented at all plants at little cost, time, or exposure of workers to radiation. The second measure would probably be more expensive to implement and may not be needed at all plants, particularly plants in which spent fuel pools are located below grade or are protected from external line-of-sight attacks by exterior walls and other structures.

The committee anticipates that the costs and benefits of options for implementing the second measure would be examined to help decide what requirements would be imposed. Further, the committee does not presume to anticipate the best design of such a system—whether it should be installed on the walls of a pool or deployed from a location where it is unlikely to be compromised by the same attack—but simply notes the demanding requirements such a system must meet.

CHARGE 3: POTENTIAL SAFETY AND SECURITY ADVANTAGES, IF ANY, OF DIFFERENT DRY CASK STORAGE DESIGNS

The third charge to the committee focuses exclusively on the safety and security of dry casks. The committee addressed this charge first in Chapter 4 to provide the basis for the comparative analysis between dry casks and pools as called for in Charge 2.

FINDING 4A: Although there are differences in the robustness of different dry cask designs (e.g., bare-fuel versus canister-based), the differences are not large when measured by the absolute magnitudes of radionuclide releases in the event of a breach. All storage cask designs are vulnerable to some types of terrorist attacks, but the quantity of radioactive material releases predicted from such attacks is relatively small. These releases are not easily dispersed in the environment.

FINDING 4B: Additional steps can be taken to make dry casks less vulnerable to potential terrorist attacks. Although the vulnerabilities of current cask designs are already small, additional, relatively simple steps can be taken to reduce them as discussed in Chapter 4.

> **RECOMMENDATION: The Nuclear Regulatory Commission should consider using the results of the vulnerability analyses for possible upgrades of requirements in 10 CFR 72 for dry casks, specifically to *improve their resistance to terrorist attacks.*** The committee was told by

Nuclear Regulatory Commission staff that such a step is already under consideration.

CHARGE 2: SAFETY AND SECURITY ADVANTAGES, IF ANY, OF DRY CASK STORAGE VERSUS WET POOL STORAGE

In Chapter 4, the committee offers the following findings and recommendations with respect to the comparative component of Charge 2:

FINDING 4C: Dry cask storage does not eliminate the need for pool storage at operating commercial reactors. Under present U.S. practices, dry cask storage can only be used to store fuel that has been out of the reactor long enough (generally greater than five years under current practices) to be passively air cooled.

FINDING 4D: Dry cask storage for older, cooler spent fuel has two inherent advantages over pool storage: (1) It is a passive system that relies on natural air circulation for cooling; and (2) it divides the inventory of that spent fuel among a large number of discrete, robust containers. These factors make it more difficult to attack a large amount of spent fuel at one time and also reduce the consequences of such attacks. The robust construction of these casks prevents large-scale releases of radioactivity in all of the attack scenarios examined by the committee in its classified report.

FINDING 4E: Depending on the outcome of plant-specific vulnerability analyses described in the committee's classified report, the Nuclear Regulatory Commission might determine that earlier movements of spent fuel from pools into dry cask storage would be prudent to reduce the potential consequences of terrorist attacks on pools at some commercial nuclear plants. The statement of task directs the committee to examine the risks of spent fuel storage options and alternatives for decision makers, not to recommend whether any spent fuel should be transferred from pool storage to cask storage. In fact, there may be some commercial plants that, because of pool designs or fuel loadings, may require some removal of spent fuel from their pools. If there is a need to remove spent fuel from the pools it should become clearer once the vulnerability and consequence analyses described in the classified report are completed. The committee expects that cost-benefit considerations would be a part of these analyses.

IMPLEMENTATION ISSUES

Implementation of the recommendations in Chapters 2-4 will require action and cooperation by a large number of parties. The final chapter of the report provides a brief discussion of two implementation issues that the committee believes are of special interest to Congress: *Timing Issues*: Ensuring that high-quality, expert analyses are completed in a timely manner; and *Communications Issues*: Ensuring that the results of the analyses are communicated to relevant parties so that appropriate and timely mitigating actions can be taken. This discussion leads to the following finding and recommendation.

FINDING 5A: Security restrictions on sharing of information and analyses are hindering progress in addressing potential vulnerabilities of spent fuel storage to

terrorist attacks. Current classification and security practices appear to discourage information sharing between the Nuclear Regulatory Commission and industry. They impede the review and feedback processes that can enhance the technical soundness of the analyses being carried out; they make it difficult to build support within the industry for potential mitigative measures; and they may undermine the confidence that the industry, expert panels such as this one, and the public place in the adequacy of such measures.

> **RECOMMENDATION: The Nuclear Regulatory Commission should improve the sharing of pertinent information on vulnerability and consequence analyses of spent fuel storage with nuclear power plant operators and dry cask storage system vendors on a timely basis.**

The committee also believes that the public is an important audience for the work being carried out to assess and mitigate vulnerabilities of spent fuel storage facilities. While it would be inappropriate to share all information publicly, more constructive interaction with the public and independent analysts could improve the work being carried out and also increase public confidence in Nuclear Regulatory Commission and industry decisions and actions to reduce the vulnerability of spent fuel storage to terrorist threats.

INTRODUCTION AND BACKGROUND

In the Fiscal Year 2004 Energy and Water Development Conference Report, the U.S. Congress asked the National Academies to provide independent scientific and technical advice on the safety and security[1] of commercial spent nuclear fuel storage in the United States (see Box 1.1). The Nuclear Regulatory Commission and the Department of Homeland Security jointly sponsored this study, as directed by Congress.

Awareness and concerns about the threat of high-impact terrorism have become acute and pervasive since the attacks on September 11, 2001. The information gathered by the committee during this study led it to conclude that there were indeed credible concerns about the safety and security of spent nuclear fuel storage in the current threat environment. From the outset the committee believed that safety and security issues must be addressed quickly to determine whether additional measures are needed to prevent or mitigate attacks that could cause grave harm to people and cause widespread fear, disruption, and economic loss. The information gathered during this study reinforced that view. Any concern related to nuclear power plants[2] has added stakes: Many people fear radiation more than they fear exposure to other physical insults. This amplifies the concern over a potential terrorist attack involving radioactive materials beyond the physical injuries it might cause, and beyond the economic costs of the cleanup.

1.1 CONTEXT FOR THIS STUDY

The congressional request for this study was prompted by conflicting public claims about the safety and security of commercial spent nuclear fuel storage at nuclear power plants. Some have argued that the dense packing used for storing spent fuel in cooling pools at nearly every nuclear power plant does not provide a sufficient safety margin in the event of a pool breach and consequent water loss from an accident or terrorist attack.[3] In such cases, the potential exists for the fuel most recently discharged from a reactor to heat up sufficiently for its zirconium cladding to ignite, possibly resulting in the release of large amounts of radioactivity to the environment (Alvarez et al., 2003a). The Nuclear Regulatory Commission's own analyses have suggested that such zirconium cladding fires and releases of radioactivity are possible (e.g., USNRC, 2001a).

To reduce the potential for such an event, Alvarez et al. (2003a) suggested that spent fuel more than five years old be removed from the pool and stored in dry casks, and

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[1] In the context of this study, *safety* refers to measures that protect spent nuclear fuel storage facilities against failure, damage, human error, or other accidents that would disperse radioactivity in the environment. *Security* refers to measures to protect spent fuel storage facilities against sabotage, attacks, or theft.

[2] Safety and security of reactors at nuclear power plants are outside of the committee's statement of task and have been addressed only where they could not be separated from spent fuel storage. The distinctions between spent fuel storage and operating nuclear power reactors are sometimes blurred in public discussions of nuclear and radiological concerns.

[3] The committee refers to such occurrences as *loss-of-pool-coolant events* in this report.

BOX 1.1 STATEMENT OF TASK

The issues to be addressed by this study are specified in the Energy and Water Development Conference Report and are as follows:

(1) potential safety and security risks of spent nuclear fuel presently stored in cooling pools at commercial reactor sites (see Chapter 2)

[illegible]

that the remaining younger fuel be rearranged in the pool to allow more space for cooling (see also Marsh and Stanford, 2001; Thompson, 2003). The Nuclear Regulatory Commission staff, the nuclear industry, and some others have argued that densely packed pool storage can be carried out both safely and securely (USNRC, 2003a).

Policy actions to improve the safety and security of spent fuel storage could have significant national consequences. Nuclear power plants generate approximately 20 percent of the electricity produced in the United States. The issue of its future availability and use is critical to our nation's present and future energy security. The safety and security of spent fuel storage is an important aspect of the acceptability of nuclear power. Decisions that affect such a large portion of our nation's electricity supply must be considered carefully, wisely, and with a balanced view.

1.2 STRATEGY TO ADDRESS THE STUDY CHARGES

Congress directed the National Academies to produce a classified report that addresses the statement of task shown in Box 1.1 within 6 months and an unclassified summary for unlimited public dissemination within 12 months. This report, which has undergone a security review by the Nuclear Regulatory Commission and found to contain no classified national security or safeguards information, fulfills the second request.[4]

The National Research Council of the National Academies appointed a committee of 15 experts to carry out this study. Biographical sketches of the committee members are provided in Appendix B. The committee met six times from February to June 2004 to gather information and complete its classified report. The committee met again in August, October, and November 2004 and in January 2005 to develop this public report.

Details on the information-gathering sessions and speakers are provided in Appendix A. Most of the information-gathering sessions were not open to the public because they involved presentations and discussions of classified information. The committee recognized, however, that important contributions to this study could be made by industry representatives, independent analysts, and the public, so it scheduled open, unclassified

[4] The classified report was briefed to the agencies and Congress on July 15, 2004.

sessions at three of its meetings to obtain comments from interested organizations and individuals. Public comments at these meetings were encouraged and considered.

Subgroups of the committee visited several nuclear power plants to learn first-hand how spent fuel is being managed in wet and dry storage: the Dresden and Braidwood Nuclear Generating Stations in Illinois, which are owned and operated by Exelon Nuclear Corp.; the Indian Point Nuclear Generating Station in New York, which is owned and operated by ENTERGY Corp.; and the Palo Verde Nuclear Generating Station in Arizona, which is operated by Arizona Public Service Corp. A subgroup of committee members also traveled to Germany to visit spent fuel storage installations at Ahaus and Lingen and to talk with experts about the safety and security of German spent fuel storage. The German government has been concerned about security for a long time, and the German nuclear industry has made adjustments to spent fuel storage designs and operations that reduce their vulnerability to accidents and terrorist attacks. A summary of the trip to Germany is provided in Appendix C.

The statement of task for this study directed the committee to examine both the safety and the security of spent fuel storage. It is important to recognize that these are two sides of the same coin in the sense that any event that results in the breach of a spent fuel pool or a dry cask, whether accidental or intentional, has the potential to release radioactive material to the environment. The committee therefore focused its limited time on understanding two issues: (1) Under what circumstances could pools or casks be breached? And (2) what would be the radioactive releases from such breaches?

The initiating events that could lead to the *accidental* breach of a spent fuel pool are well known: A large seismic event or the accidental drop of a cask on the pool wall that could lead to the loss of pool coolant. The condition that could lead to an accidental breach of a dry storage cask is similarly well known: an accidental drop of the cask during handling operations. Current Nuclear Regulatory Commission regulations are designed to prevent such accidental conditions by imposing requirements on the design and operation of spent fuel storage facilities. These regulations have been in place for decades and have so far been effective in preventing accidental releases of radioactive materials from these facilities into the environment.

The initiating events that could lead to the *intentional* breach of a spent fuel pool or dry storage cask are not as well understood. The Nuclear Regulatory Commission has had long-standing requirements in place to deal with radiological sabotage (included in the "design basis threat"; see Chapter 2), but the September 11, 2001, terrorist attacks provided a graphic demonstration of a much broader array of potential threats. As described in the following chapters, the Nuclear Regulatory Commission is currently sponsoring studies to better understand the potential consequences of such terrorist attacks on spent fuel storage facilities.

Early on in this study, the committee made a judgment that it should focus most of its attention concerning such initiating events on the security aspects of its task statement. Many of the phenomena that follow an initiating event (e.g., loss of pool coolant or cask breach) would be the same whether it arose from an accident or terrorist attack, as noted previously. While the mitigation strategies for such events might be similar, they would require different kinds of preparation.

Given the relatively short time frame for this study, the committee focused its efforts on performing a critical review of the security analyses that have been carried out by the Nuclear Regulatory Commission and its contractors, the Department of Homeland Security, industry (i.e., EPRI, formerly named the Electric Power Research Institute; ENTERGY Corp.; and dry cask vendors), and other independent experts to determine if they are objective, complete, and credible. The committee could only perform limited independent safety and security analyses based on the information it gathered.

The committee made many requests for information from the Nuclear Regulatory Commission, its Sandia National Laboratories contractor, and other organizations and individuals, often with little advance notice. For the most part, all parties responded well to these requests. The committee was able to access experts who could answer its technical questions and was pleased with the cooperation and information it received during its visits to spent fuel storage facilities. This cooperation was essential in enabling the committee to complete its task within the requested six-month timeframe.

The committee was forced to circumscribe some aspects of its examinations, however, due to time and/or information constraints. In particular, the committee did not pursue in-depth examinations of the following topics:

- Human factors issues involved in responding to terrorist attacks on spent fuel storage. These include surveillance activities to identify potential threats (both inside and outside the plant); the response of security forces; and the preparation of plant personnel to deploy mitigative measures in the event of an attack.
- The behavior of radioactive material after it enters the environment from a spent fuel pool or dry cask. The committee assumed that any large release of radioactivity from a spent fuel storage facility would be problematic even in the absence of knowledge of how it would disperse in the environment. The committee instead focused its efforts on understanding how much radioactive material would be released, if any, in the case of an attack.
- The economic consequences of potential terrorist attacks, except insofar as noting the possible magnitude of cleanup costs after a catastrophic release of radioactivity.
- The costs of potential measures to mitigate spent fuel storage vulnerabilities. The committee understands that the Nuclear Regulatory Commission would include cost-benefit considerations in decisions to impose any new requirements on industry for such measures.

The committee also did not examine the potential vulnerability of commercial spent fuel while being transported. That topic is not only outside of the committee's task, but there is another National Academies study currently underway to examine transportation issues.[5]

Because most of the studies on spent fuel storage vulnerabilities undertaken for the Nuclear Regulatory Commission are still in progress, the committee was not able to review completed technical documents. Instead, the committee had to rely on presentations by and discussions with technical experts. The committee does not believe that these difficulties prevented it from developing sound findings and recommendations from the information it

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[5] Committee on Transportation of Radioactive Waste. See *http://national-academies.org/transportofradwaste*. That committee's final report is now planned for completion in the late summer of 2005.

did receive. The committee was able to draw upon other information sources both domestic and foreign,[6] including the experience and expertise of its members, to fill some of the information gaps.

1.3 REPORT ROADMAP

The sections that follow in this chapter provide background on storage of spent nuclear fuel, which may be helpful to non-experts in understanding the issues discussed in the following chapters. The other chapters are organized to explicitly address the four charges of the committee's statement of task:

- Chapter 2 addresses the last charge to the committee to "explicitly consider the risks of terrorist attacks on these materials and the risk these materials might be used to construct a radiological dispersal device."
- Chapter 3 addresses the first charge to the committee to examine the "potential safety and security risks of spent nuclear fuel presently stored in cooling pools at commercial reactor sites."
- Chapter 4 addresses the second and third charges to examine the "safety and security advantages, if any, of dry cask storage versus wet pool storage at these reactor sites" and the "potential safety and security advantages, if any, of dry cask storage using various single-, dual-, and multi-purpose cask designs."
- Chapter 5 concerns implementation of the recommendations in this report, specifically concerning timing and communication issues.

The appendixes provide supporting information, including a glossary and acronym list, descriptions of the committee's meetings, and biographical sketches of the committee members.

1.4 BACKGROUND ON SPENT NUCLEAR FUEL AND ITS STORAGE

This section is provided for readers who are not familiar with the technical features of spent nuclear fuel and its storage. Other readers should skip directly to Chapter 2.

Spent nuclear fuel is fuel that has been irradiated or "burned" in the core of a nuclear reactor. In power reactors, the energy released from fission reactions in the nuclear fuel heats water[7] to produce steam that drives turbines to generate electricity. Spent nuclear fuel from non-commercial reactors (such as research reactors, naval propulsion reactors, and plutonium production reactors) is not considered in this study.

1.4.1 Nuclear Fuel

Almost all commercial reactor fuel in the United States is in the form of solid, cylindrical pellets of uranium dioxide. The pellets are about 0.4 to 0.65 inch (1.0 to 1.65 centimeters) in length and about 0.3 to 0.5 inch (0.8 to 1.25 centimeters) in diameter. The

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[6] For example, the aforementioned visits to Lingen and Ahaus, in Germany.

[7] A different coolant can be used, but all power reactors now operating in the United States are water cooled.

pellets are loaded into tubes, called *fuel cladding*, made of a zirconium metal alloy, called zircaloy. A loaded tube, which is typically 11.5 to 14.75 feet (3.5 to 4.5 meters) in length, is called a *fuel rod* (also referred to as a *fuel pin* or *fuel element*). Fuel rods are bundled together, with a 0.12 to 0.18 inch (0.3 to 0.45 centimeter) space left between each for coolant to flow, to form a square fuel assembly (see FIGURE 1.1) measuring about 6 to 9 inches (15 to 23 centimeters) on a side.

Typical fuel assemblies for boiling water nuclear reactors (BWRs) hold 49 to 63 fuel rods, and fuel assemblies for pressurized water nuclear reactors (PWRs) hold 164 to 264 fuel rods.[8] Depending on reactor design, typically between 190 and 750 assemblies, each weighing from 275 to 685 kg (600 to 1500 pounds), make up a power reactor core. New fuel assemblies (i.e., those that have not been irradiated in a reactor) do not require special cooling or radiation shielding; they can be moved with a crane in open air. Once in the reactor, however, the fuel undergoes nuclear fission and begins to generate the radioactive fission products and activation products that require shielding and cooling.

The uranium oxide fuel essentially is composed of two isotopes of uranium: Initially, about 3-5 percent[9] by weight is fissile uranium (uranium-235), which is the component that sustains the fission chain reaction; and about 95-97 percent is uranium-238, which can capture a neutron to produce fissile plutonium and other radioactive heavy isotopes (actinides). Each fission event, whether in uranium or plutonium, releases energy and neutrons as the fissioning nucleus splits into two (and infrequently three) radioactive fragments, called fission products.

When the fissile material has been consumed to a level where it is no longer economically viable (typically 4.5 to 6 years of operation for current fuel designs), the fuel is considered *spent* and is removed from the reactor core. Spent fuel assemblies are highly radioactive. The decay of radioactive fission products and other constituents generates heat (called *decay heat*) and penetrating (gamma and neutron) radiation. Therefore cooling, shielding, and remote handling are required for spent nuclear fuel.

The amount of heat and radiation generated by a spent fuel assembly after its removal from a reactor depends on the number of fissions that have occurred in the fuel, called the *burn-up*, and the time that has elapsed since the fuel was removed from the reactor. The rate of decay-heat generation by spent reactor fuel and how it will change with time after the fuel is removed from the reactor can be calculated. The results of an example calculation are shown in FIGURE 1.2.

At discharge from the reactor, a spent fuel assembly generates on the order of tens of kilowatts of heat. Decay-heat production diminishes as very short-lived radionuclides decay away, dropping heat generation by a factor of 100 during the first year; dropping by another factor of 5 between year one and year five; and dropping about 40 percent between year five and year ten (see FIGURE 1.2). Within a year of discharge from the reactor, decay-heat production in spent nuclear fuel is dominated by four radionuclides: Ruthenium-106 (with a 372.6-day half-life), cerium-144 (284.4-day half-life), cesium-137 (30.2-year half-life),

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[8] Technical specifications for the fuel assemblies are taken from the American National Standard document for pool storage of spent nuclear fuel (American Nuclear Society, 1988).

[9] With only a few exceptions, commercial nuclear power reactors in the United States have been fueled with low-enriched uranium, that is, less than 20 percent of the uranium is uranium-235. Uranium found in nature has about 0.71 percent uranium-235 by weight.

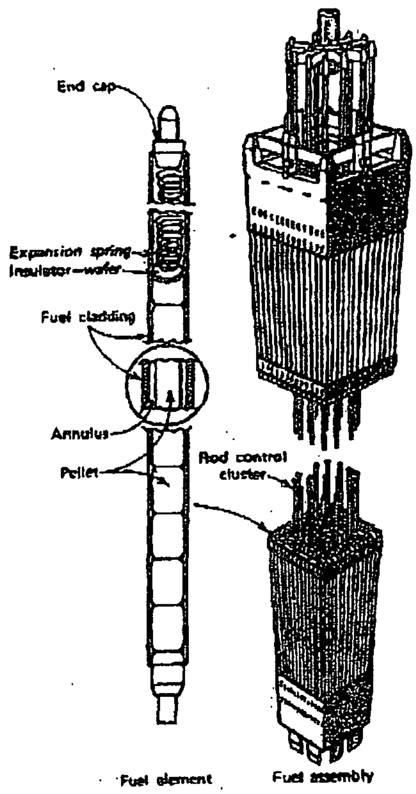

FIGURE 1.1 Fuel rods, also called fuel pins or elements, are bundled together into fuel assemblies as shown here. This fuel assembly is for a PWR reactor. SOURCE: Duderstadt and Hamilton (1976; Figure 3-7).

and cesium-134 (2.1-year half-life) and their short-lived decay products contribute nearly 90 percent of the decay heat from a spent fuel assembly.

Longer-lived radionuclides persist in the spent fuel even as the decay heat drops further. Cesium-137 decays to barium-137, emitting a beta particle and a high-energy gamma ray. The cesium-137 half-life of 30.2 years is sufficiently long to ensure that this radionuclide will persist during storage. It and other materials present in the fuel will form small particles, called *aerosols*, in a zirconium cladding fire.

Shorter-lived radionuclides decay away rapidly after removal of the spent fuel from the reactor. One of these is iodine-131, which is of particular concern in reactor core accidents because it can be taken up in large quantities by the human thyroid. This radionuclide has a half-life of about 8 days and typically persists in significant quantities in spent fuel only on the order of a few months.

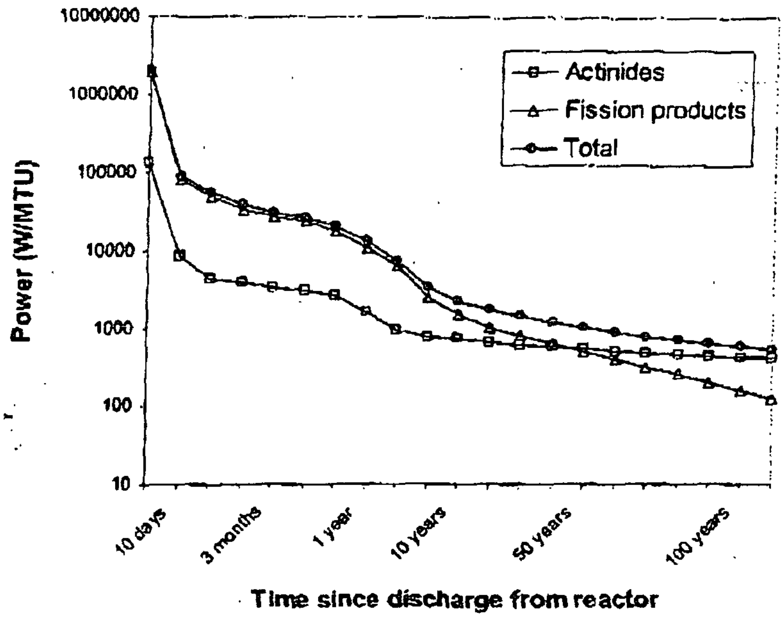

FIGURE 1.2 Decay-heat power for spent fuel (measured in watts per metric ton of uranium) plotted on a logarithmic scale as a function of time after reactor discharge. Note that the horizontal axis is a data series, not a scale. SOURCE: Based on data from USNRC (1984).

1.4.2 Storage of Spent Nuclear Fuel

Storage technologies for spent nuclear fuel have three primary objectives:

- Cool the fuel to prevent heat-up to high temperatures from radioactive decay.
- Shield workers and the public from the radiation emitted by radioactive decay in the spent fuel and provide a barrier for any releases of radioactivity.
- Prevent criticality accidents (uncontrolled fission chain reactions).

After the fuel assemblies are unloaded from the reactor they are stored in water pools, called *spent fuel pools*. The water in the pools provides radiation shielding and cooling and captures all but noble gas radionuclides in case of fuel rod leaks.[10] The geometry of the fuel and neutron absorbers (such as boron, hafnium, and cadmium) within the racks that hold the spent fuel or in the cooling water help prevent criticality events.[11] The water in the pool is circulated through heat exchangers for cooling and ion exchange filters to capture any radionuclides and other contaminants that get into the water. Makeup water is also added to the pool to replace pool water lost to evaporation. The operation of the pumps and heat exchangers is especially important during and immediately after reactor

[10] If the cladding in the fuel rods is breached some radioactive materials will be released into the pool.
[11] See the Glossary (Appendix E) for a definition of criticality. Most of the fuel's capacity for sustaining criticality is expended in the reactor as the uranium and plutonium are fissioned.

refueling operations, because this is when larger quantities of higher heat-generating spent fuel are placed into the pool.

Current U.S. regulations require that spent fuel be stored in the power plant's fuel pool for at least one year after its discharge from the reactor before being moved to dry storage. After that time the spent fuel can be moved, but only with active cooling. Active cooling is generally necessary for about three years after the spent fuel is removed from the reactor core (USNRC, 2003b).

When a spent fuel pool is filled to capacity, older fuel, which has lower decay-heat, is moved to other pools or placed into dry casks. Heat generated in the loaded dry casks is removed by air convection and thermal radiation. The cask provides shielding of penetrating radiation and confinement of the radionuclides in the spent fuel. As with pool storage, criticality control is accomplished by placing the fuel in a fixed geometry and separating individual fuel assemblies with neutron absorbers. Standard industry practice is to place in dry storage only spent fuel that has cooled for five years or more after discharge from the reactor.[12] Most spent fuel in wet or dry storage is located at nuclear power plant sites (i.e., on-site storage).

There are significant differences in the design and construction of wet and dry storage installations at commercial nuclear power plants. The characteristics depend on the type of the nuclear power plant, the age of the spent fuel storage installation, or the type of dry casks used. The design and features of spent fuel pools and dry storage facilities are discussed in Chapters 3 and 4, respectively.

1.4.3 Spent Fuel Inventories

As of 2003, approximately 50,000 MTU (metric tons of uranium) of spent fuel have been generated over the past four decades in the United States. A typical nuclear power plant generates about 20 MTU per year. The entire U.S. nuclear industry generates about 2000 MTU per year.

Of the approximately 50,000 MTU of commercial spent fuel in the United States, 43,600 MTU are currently stored in pools and 6200 MTU are in dry storage. Pool storage exists at all 65 sites with operating commercial nuclear power reactors[13] and at 8 sites where commercial power reactors are no longer operating (i.e., they have been shut down or decommissioned) (FIGURE 1.3). Additionally, there is an away-from-reactor spent fuel pool operating at the G.E. Morris Facility in Illinois (see Appendix D).

Of the spent fuel in dry storage, 4500 MTU are in storage at 22 sites with operating commercial nuclear power reactors, and 1700 MTU are in storage at 6 sites where the commercial reactors are no longer operating. An additional dry-storage facility is operated by the federal government at the Idaho National Laboratory. It stores most of the damaged fuel from the Three Mile Island Unit 2 reactor accident.

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[12] Fuel aged as little as three years could be stored in passively cooled casks, but fewer assemblies could be accommodated in each cask because of the higher heat load.

[13] There are 103 operating commercial nuclear power reactors in the United States. Many sites have more than one operating reactor.

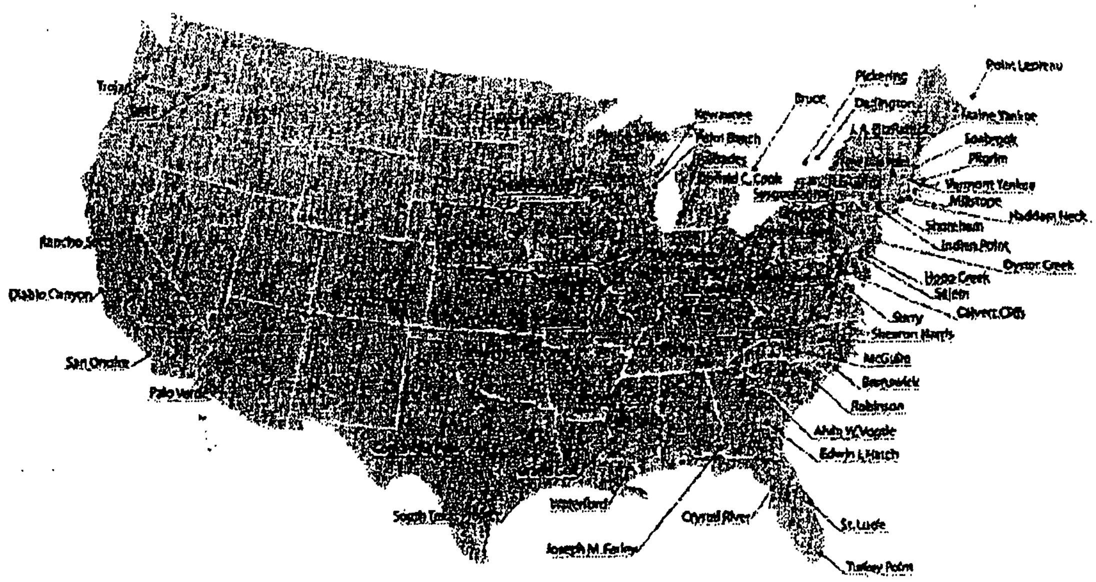

FIGURE 1.3 Locations of spent fuel storage facilities in the United States.

TABLE 1.1 provides a listing of the 30 operating Independent Spent Fuel Storage Installations (ISFSIs[14]) in the United States. These ISFSIs include the dry storage facilities at operating and shutdown commercial power reactor sites as well as the storage facilities at the Morris and Idaho sites, as described above. The committee did not examine the Morris and Idaho facilities as part of this study. At-reactor pool storage is not considered to be an ISFSI because it operates under the power reactor license.

1.4.4 History of Spent Fuel Storage

Spent fuel pools at commercial nuclear power plants were not designed to accommodate all the fuel used during the operating lifetime of the reactors they service. Most commercial power plants were designed with small pools under the assumption that fuel would be cooled for a short period of time after discharge from the reactor and then be sent offsite for recycling (i.e., reprocessing).[15] A commercial reprocessing industry never developed, however, for the reasons discussed in Appendix D. Newer power plants were designed with larger pool storage capacities. Even plants with larger-capacity pools will run out of pool space if they operate beyond their initial 40-year licenses. In 2000, the nuclear power industry projected that roughly three or four plants per year would run out of needed storage space in their pools without additional interim storage capacity (see FIGURE 1.4).

Another development that logically could reduce the demand for storage of spent nuclear fuel at the sites of power plants is the availability of a geologic repository for

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[14] An ISFSI is a facility for storing spent fuel in wet pools or dry casks and is defined in Title 10, Part 72 of the Code of Federal Regulations.

[15] Residual uranium-235 and plutonium in the spent fuel would be recovered for the manufacture of new fuel. The waste products in the fuel, principally the fission products, would be immobilized in solid matrices and stored for eventual disposal.

TABLE 1.1: Operating ISFSIs in the United States as of July 2004

Name	Location
Palo Verde	Arizona
Arkansas Nuclear One	Arkansas
Rancho Seco	California
San Onofre	California
Diablo Canyon	California
Fort St. Vrain [1]	Colorado
Edwin L. Hatch	Georgia
DOE-INL [2]	Idaho
G.E. Morris [3]	Illinois
Dresden	Illinois
Duane Arnold	Iowa
Maine Yankee	Maine
Calvert Cliffs	Maryland
Big Rock Point	Michigan
Palisades	Michigan
Prairie Island	Minnesota
Yankee Rowe	Massachusetts
Oyster Creek	New Jersey
J.A. FitzPatrick	New York
McGuire	North Carolina
Davis-Besse	Ohio
Trojan	Oregon
Susquehanna	Pennsylvania
Peach Bottom	Pennsylvania
Robinson	South Carolina
Oconee	South Carolina
North Anna	Virginia
Surry	Virginia
Columbia Gen. Station	Washington
Point Beach	Wisconsin

NOTES:

[1]The Fort St. Vrain ISFSI stores fuel from a commercial gas-cooled reactor. The facility is operated by the Department of Energy.

[2]The DOE-INL facility stores fuel from the Three-Mile Island Unit 2 reactor. The facility is operated by the Department of Energy.

[3]The G.E. Morris ISFSI is a wet storage facility.

SOURCES: Data from the USNRC (2004).

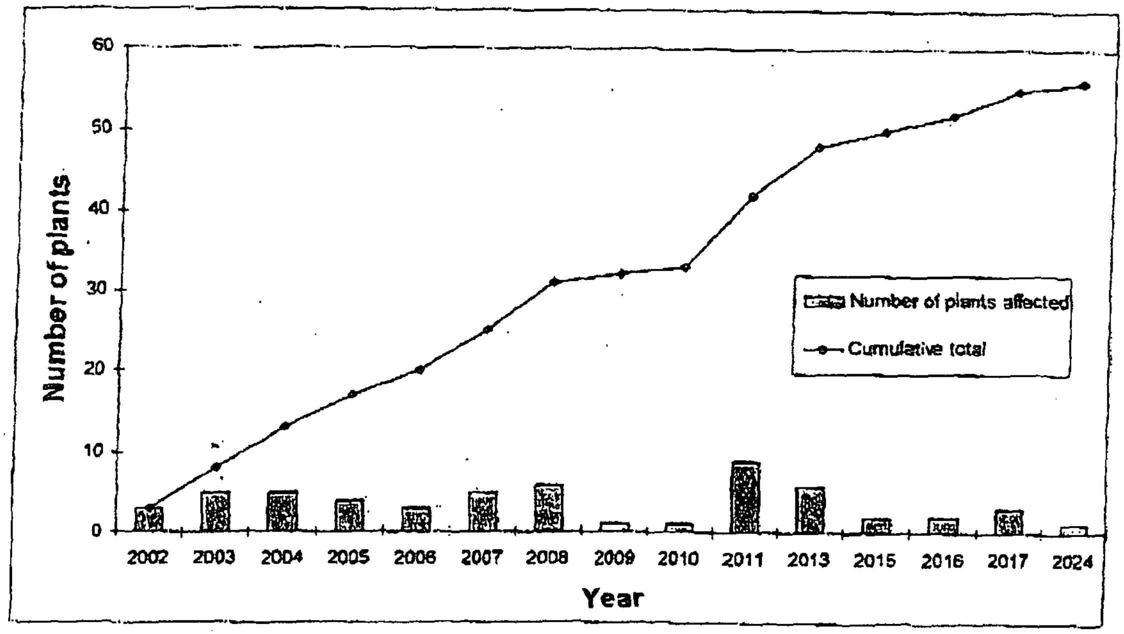

FIGURE 1.4 Projection of the number of commercial nuclear power plants that will run out of needed space in their spent fuel pools in coming years if they do not add interim storage. These data, looking only at plants that did not already use dry cask storage, were provided to the Nuclear Regulatory Commission in 2000. SOURCE: USNRC (2001b).

disposal of spent nuclear fuel. But a nuclear waste repository is not expected to be in operation until at least 2010, and even then it will take several decades for all of the spent fuel to be shipped for disposal. Thus, onsite storage of spent fuel is likely to continue for at least several decades.

Power plant operators have made two changes in spent fuel storage procedures to increase the capacity of onsite storage. First, starting in the late 1970s, plant operators began to install high-density racks that enable more spent fuel to be stored in the pools. This has increased storage capacities in some pools by up to about a factor of five (USNRC, 2003b). Second, as noted above, many plant operators have moved older spent fuel from the pools into dry cask storage systems (see Chapter 4) or into other pools when available to make room for freshly discharged spent fuel and to maintain the capacity for a full-core offload.[16]

The original spent fuel racks, sometimes called "open racks," were designed to store spent fuel in an open array, with open vertical and lateral channels between the fuel assemblies to promote water circulation. The high-density storage racks eliminated many of the channels so that the fuel assemblies could be packed closer together (FIGURE 1.5). This configuration does not allow as much water (or air circulation in loss-of-pool-coolant events) through the spent fuel assemblies as the original open-rack design.

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[16] Although not required by regulation, it is standard practice in the nuclear industry to maintain enough open space in the spent fuel pool to hold the entire core of the nuclear reactor. This provides an additional margin of safety should the fuel have to be removed from the reactor core in an emergency or for maintenance purposes.

Several nuclear utilities have already submitted license applications to the Nuclear Regulatory Commission to build 16 new ISFSIs. Among the potential new ISFSIs, a consortium of utilities has submitted a license for a private fuel storage facility (PFS) in Utah for interim dry storage of up to 40,000 metric tons of spent fuel.

Most or all pools store some spent fuel that has aged more than five years after discharge from the reactor, and so could be transferred to dry-cask storage. The amount that could be transferred depends on plant-specific information such as pool size and configuration, operating history of the reactor, the enrichment and burn-up level in the fuel, and availability of an ISFSI.

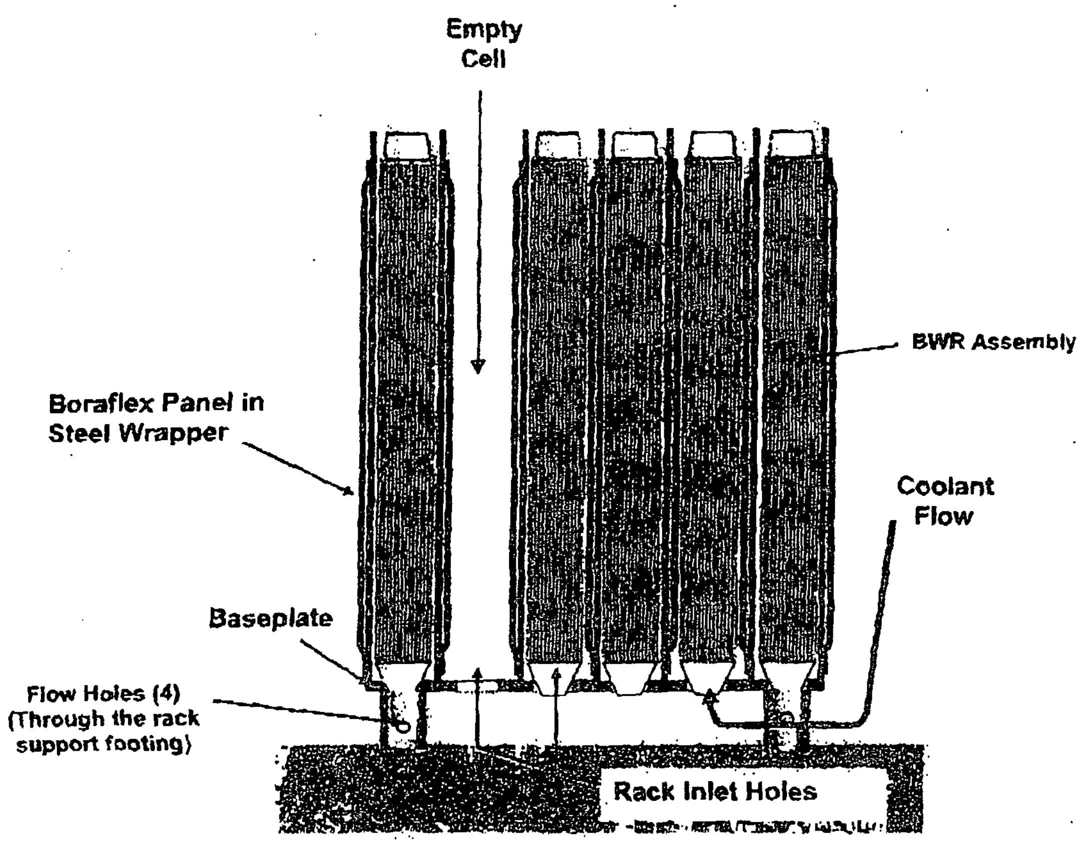

FIGURE 1.5 Dense spent fuel pool storage racks for BWR fuel. This cross-sectional illustration shows the principal elements of the spent fuel rack, which sits on the bottom of the pool. SOURCE: Nuclear Regulatory Commission briefing materials (2004).

EXHIBIT 4.1

DOE F 1325.8
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United States Government — **Department of Energy**

memorandum

DATE: December 1, 2006

REPLY TO ATTN OF: Office of NEPA Policy and Compliance (ECohen: 202-586-7684)

SUBJECT: Need to Consider Intentional Destructive Acts in NEPA Documents

TO: DOE NEPA Community
(list attached)

In light of two recent decisions by the United States Court of Appeals for the Ninth Circuit, DOE National Environmental Policy Act (NEPA) documents, including environmental impact statements (EISs) and environmental assessments (EAs), should explicitly address potential environmental consequences of intentional destructive acts (i.e., acts of sabotage or terrorism). This interim guidance has been developed by the Office of NEPA Policy and Compliance, in consultation with the Assistant General Counsel for Environment and the Deputy General Counsel of the National Nuclear Security Administration. More detailed guidance on this matter is in preparation.

The more recent of the court's two decisions involved DOE's EA for *Construction and Operation of a Biosafety Level-3 Facility at Lawrence Livermore National Laboratory* (DOE/EA-1442, 2002). In that October 16, 2006, decision, *Tri-Valley CAREs v. Department of Energy*, the court wrote:

> Concerning the DOE's conclusion that consideration of the effects of a terrorist attack is not required in its Environmental Assessment, we recently held to the contrary in *San Luis Obispo Mothers for Peace v. Nuclear Regulatory Commission*, 449 F.3d 1016 (9th Cir. 2006). In *Mothers for Peace*, we held that an Environmental Assessment that does not consider the possibility of a terrorist attack is inadequate. Id. at 1035. Similarly here, we remand for the DOE to consider whether the threat of terrorist activity necessitates the preparation of an Environmental Impact Statement. As in *Mothers for Peace*, we caution that there "remain open to the agency a wide variety of actions it may take on remand [and]. . . [w]e do not prejudge those alternatives." Id.

A summary of the court's decision in *Mothers for Peace* is contained in DOE's NEPA *Lessons Learned Quarterly Report*, September 2006, page 19 (available on the DOE NEPA website at *www.eh.doe.gov/nepa* under Lessons Learned Quarterly Reports).

Each DOE EIS and EA should explicitly consider intentional destructive acts. This applies to all DOE proposed actions, including both nuclear and non-nuclear proposals.

Partial guidance on analyzing intentional destructive acts in NEPA documents is contained in *Recommendations for Analyzing Accidents under NEPA* (July 2002;

available on the DOE NEPA website under Selected Guidance Tools). This guidance includes example language and a discussion of ways to apply an analysis of accidents to an analysis of the potential consequences of acts of sabotage or terrorism. This approach may be appropriate for many, if not most, situations where the potential sabotage or terrorist scenarios and the accident scenarios involve similar physical initiating events or forces (e.g., fires, explosions, drops, punctures, aircraft crashes). This approach may not be adequate for all situations, however, because accident scenarios may not fully encompass potential threats posed by intentional destructive acts. For example, this approach may not adequately reflect the threat assessments for facilities with inventories of special nuclear materials. Each EIS and EA should explicitly consider whether the accident scenarios are truly bounding of intentional destructive acts. Regardless of whether additional analysis is necessary, each EIS and EA should contain a section demonstrating explicit consideration of sabotage and terrorism.

The Department is developing new guidance on considering intentional destructive acts in NEPA documents, and expects that the guidance will address such topics as:

- Determining the appropriate level of detail for analysis, consistent with the "sliding-scale" principle (e.g., a more detailed threat analysis is appropriate for a special nuclear material management facility, or for a non-nuclear facility with a significant amount of material at risk; a less detailed analysis may be adequate for a proposed office complex).
- Determining when a finding of no significant impact for an EA is appropriate in view of potential large impacts from terrorist acts.
- Determining what information regarding analyses of these threats can be released to the public.
- Considering intentional destructive acts even when some or all of the analyses may be classified; protecting classified security information through the use of classified appendices and unclassified summaries.
- Timing considerations for cases where threat analyses are needed.

While this further guidance is in preparation, DOE NEPA practitioners should immediately implement the guidance in this notice to explicitly consider the potential impacts of intentional destructive acts in NEPA documents, and should consult with the Office of NEPA Policy and Compliance and, depending on the organization that is preparing the NEPA document, either the DOE or NNSA Office of the General Counsel.

Carol Borgstrom

Carol M. Borgstrom
Director
Office of NEPA Policy and Compliance

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EXHIBIT 4.2

Letter on Dangers and Military Applications of Nuclear Energy

From:Edward Teller
To: Sterling Cole, United States Congressman
Date: July 23, 1953

E-mail this Page
Printer Friendly
1953

Edward Teller to Sterling Cole
July 23 1953

The Honorable Sterling Cole
Chairman
Joint Committee on Atomic Energy
The Congress of the United States
Washington, D. C.

Dear Sir:

In response to your invitation to make a statement in connection with the development of atomic energy by private enterprise, I should like to discuss two topics concerning which I have some specific experience. These are the safety of nuclear reactors and the connection between power production and military application.

Briefly, my opinion can be stated as follows. First, nuclear power-producing units will be dangerous instruments and careful thought will have to be given to their safe construction and operation and, second, there is a great and increasing need for fissionable materials in the military field.

I should like to recommend:

First, that an advisory committee should be set up to review planned reactors and supervise functioning reactors under the control of private enterprise. Instead of setting up a new committee, the present Advisory Committee on Reactor Safeguards of the Atomic Energy Commission might serve this purpose, and Second, that the Government stimulate power production by private enterprise by guaranteeing to buy militarily useful by-products at a pre-determined price and in limited but large quantities for a period of five or ten years.

Safety of Nuclear Reactors
For the past six years I have served as the Chairman of the Reactor Safeguard Committee. Recently, this committee and the Industrial Committee on Reactor Location problems have been merged into the Advisory Committee on Reactor Safeguards, and I am participating in the work of this new committee.

Up to the present time we have been extremely fortunate in that accidents in nuclear reactors have not caused any fatalities. With expanding applications of nuclear reactions and nuclear power, it can not be expected that this unbroken record will be maintained. It must be realized that this good record was achieved to a considerable extent because of safety measures which have necessarily retarded development.

The main factors which influence reactor safety are, in my opinion, reasonably well understood. There have been in the past years a few minor incidents, all of which have been caused by neglect of clearly formulated safety rules. Such occasional accidents can not be avoided. It is rather remarkable that they have occurred in such a small number of instances. I want to emphasize in particular that the operation of nuclear reactors is not mysterious and that the irregularities are no more unexpected than accidents which happen on account of disregard of traffic regulations.

In the popular opinion, the main danger of a nuclear pile is due to the possibility that it may explode. It should be pointed out, however, that such an explosion, although possible, is likely to be harmful only in the immediate surroundings and will probably be limited in its destructive effects to the operators. A much greater public hazard is due to the fact that nuclear plants contain radioactive poisons. In a nuclear accident, these poisons may be liberated into the atmosphere or into the water supply. In fact, the radioactive poisons produced in a powerful nuclear reactor will retain a dangerous concentration even after they have been carried downwind to a distance of ten miles. Some danger might possibly persist to distances as great as 100 miles. It would seem appropriate that Federal regulations should apply to a hazard which is not confined by state boundaries. The various committees dealing with reactor safety have come to the conclusion that none of the powerful reactors built or suggested up to the present time are absolutely safe. Though the possibility of an accident seems small, a release of the active products in a city or densely populated area would lead to disastrous results. It has been therefore the practice of these committees to recommend the observance of exclusion distances, that is, to exclude the public from areas around reactors, the size of the area varying in appropriate manner with the amount of radioactive poison that the reactor might release. Rigid enforcement of such exclusion distances might hamper future development of reactors to an unreasonable extent. In particular, the danger that a reactor might malfunction and release its radioactive poison differs for different kinds of reactors. It is my opinion that reactors of sufficiently safe types might be developed in the near future. Apart from the basic construction of the reactor, underground location or particularly thought-fully constructed safety devices might be considered.

It is clear that no legislation will be able to stop future accidents and avoid completely occasional loss of life. It is my opinion that the unavoidable danger which will remain after all reasonable controls have been employed must not stand in the way of rapid development of nuclear power. It also would seem that proper legislation at the present time might make provisions for safe construction and safe operation of nuclear reactors. In case an accident should occur which involved the lives of many people, pressure for such legislation would become overwhelming. Proper steps taken at the present time could reasonably prepare for accidents and minimize the suffering that is caused, when and if they should occur.

It would seem reasonable to extend the Atomic Energy Commission procedures on reviewing planned reactors and supervising functioning reactors to nuclear plants under the control of private enterprise.

To what extent these functions should be advisory or regulatory is a difficult question. I feel that ultimate responsibility for safe operation will have to be placed on the shoulders of the men and the organization most closely connected with the construction and the operation of the reactor.

Power Production and Military Application

The first and best known military application of atomic energy was con-nected with strategic bombing. In the popular mind, such strategic bombing has been identified with the destruction of cities. The belief is widely held that a relatively limited number of atomic bombs can not only cause terrifying destruction but would produce saturation, that is, only a limited number of atomic bombs would be needed. It is my conviction that this opinion is based on a misconception and that indeed a great stockpile of fissionable material could be usefully applied in warfare. Furthermore, it seems to me that a more general use of fission weapons will not result necessarily in a more thorough destruction of cities but might rather be used against military targets of the more conventional type. It seems to me therefore that a less expensive source of fissionable materials would be desirable. Such a less expensive source could be obtained if atomic reactors were constructed for the dual purpose of providing power and producing fissionable materials.

Strategic targets include industrial plants and military installations far behind the enemy's lines. Depending on the vulnerability of these targets and on their contribution to the enemy's war effort, one may well be justified in using atomic bombs against these targets. The size of the target need not be decisive and the number of such targets may be quite appreciable.

The possible tactical targets are even more numerous. Any concentration of fighting forces or of material near the fighting lines constitutes tactical targets. Strongly defended positions might be attacked by atomic bombs. Atomic weapons could be used against beachheads or against enemy forces attempting to cross a natural obstacle. Conversely, atomic weapons could be employed to prepare a landing on a beachhead or the attack of a parachute force. The vulnerability of naval vessels to atomic bombs has been demonstrated in the Bikini tests. Vehicles less expensive than naval units may present atomic bomb targets, particularly if the cost of the bomb is lower than the cost of the vehicle which one attempts to destroy. An enemy bomber or even an enemy fighter plane might be considered as a possible target for an atomic bomb.

It might seem extravagant to use atom bombs for all these different types of targets. The question of extravagance or of sound economy must be considered, however, in connection with the ease of delivery, with the expense of delivery and with the expense of the fissionable materials. I can think of no exception to the rule that the cost of delivery will be less if one produces a certain damage by atomic weapons rather than by more conventional means. It is therefore the cost of fissionable materials which will decide how extensively one can use atomic weapons in warfare. The more the cost of atomic weapons can be reduced, the greater will be the number of applications where relatively cheap delivery systems can replace the much more expensive conventional methods. Increase in our stockpile of fissionable materials may therefore reduce the military expenditure without reducing military potential.

It seems to be doubtful whether, on the basis of present technology, atomic energy can produce power in an economically profitable manner.

Power production can, however, be conducted in such a manner as to produce militarily useful materials. It would seem to me reasonable to stimulate the construction of power-producing reactors by guaranteeing a price at which the Government will buy the militarily useful by-products. This price should of course be set lower than the price at which the Atomic Energy Commission is producing fissionable materials at the present time. It probably will be necessary to set a limit to the amount of fissionable material which the Government is prepared to purchase and also to set a limit to the time during which such purchases will be made at the fixed price. Nevertheless, it seems probable that if a fair price is guaranteed for a period like five or ten years, this will be an effective stimulant to the nation's atomic power industry. This industry is likely to become a factor in national defense which may not be second even to the steel or aircraft industries.

The above contains the substance of the testimony which I have prepared for the joint Congressional Committee. I should like to express my very great regret that at the date set for the hearing it was completely impossible for me to leave Livermore. It would be a great pleasure to appear before the joint Congressional Committee at any time to amplify the above statements or else to help in any other way that you can think of.

Yours very truly,
Edward Teller

EXHIBIT 4.3

NUREG/CR-1345
SAND80-0477/1
RS

NUCLEAR POWER PLANT DESIGN CONCEPTS FOR SABOTAGE PROTECTION

VOLUME I

David M. Ericson, Jr.
G. Bruce Varnado
Nuclear Fuel Cycle Safety Research Department 4410

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Memorandum of Understanding DOE 40-550-75
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ABSTRACT

Using a modern design for a nuclear power plant as a point of departure, this study examines the enhancement of protection which may be achieved by changes to the design and the impacts associated with the changes. These changes include concepts such as complete physical separation of redundant trains of safety equipment, hardened enclosures for water storage tanks, and hardened shutdown heat removal systems. The study examines the enhancement (value) in terms such as the potential reduction in the number of vital areas and the increase in probability of adversary sequence interruption. The impacts considered include constraints imposed upon operations and maintenance personnel and increased capital and operating costs.

The study results indicate that design changes alone do not provide significant enhancement of protection against sabotage. However, some of the design alternatives can facilitate the implementation of effective physical protection systems for both insider and external threats. Design changes that limit access and reduce outside access are practical only for new plants. A promising alternative considered is a hardened decay heat removal system, which provides primary coolant makeup and feedwater to the steam generators of a pressurized water reactor plant. Such a system has potential fo. incorporation into new plants.

5,6

Commission (NRC) Office of Nuclear Reactor Regulation, the Advisory Committee on Reactor Safeguards,[5] and the nuclear power industry.[6]

ily and straightforwardly evaluate the relative public risk of energy alternatives. However desirable, such a study unfortunately goes far beyond the intent and scope of this program. Therefore, in this effort, only the public risk from potential malevolent acts against a single energy producer, i.e., nuclear power plants, is considered.

[a] A glossary of definitions of terms (e.g., vulnerability) used in this study and report is given in Appendix A.

A summary of the initial findings on these 29 options is presented in Table 4-2 (Table 2.2 from Appendix D). It is emphasized again that these findings reflect the subjective judgment of the authors, taking into account all the available inputs. The summary chart is set up so that an option which was considered good in all aspects would have a solid circle in every column. All 29 concepts are deemed feasible, but 3 (II.8, III.3, and IV.2) would require some technology development in order to implement them. Most of the concepts appear to have potential for improving resistance to sabotage. Hardening particular enclosures (I.6) probably does not offer much increased sabotage resistance because of the considerations mentioned above under component hardening (see page 4-2) and because hardening would not affect the "authorized insider." Moving spent fuel and ECCS components into containment may *not* offer much advantage for several reasons. For instance, although spent fuel in containment might be better protected during operation, the increase in numbers of personnel with access during outages could increase the overall vulnerability. Moving major ECCS components into containment would introduce other problems, for example, qualification of equipment for post-LOCA environments, which would work against possible improvements in protection. The ideas for additional protected trip mechanisms were not considered to add to the resistance to sabotage because there are already many conditions which will trip the plant off line. It was noted by members of the DSTSG that tripping the plant is no problem; in fact, just the opposite is true--the plants almost trip too easily.

When the remaining factors--independence, impacts, and side benefits--are considered, generalizations are no longer appropriate. Only eight of the options are considered to have independence from other aspects of the plant, a result which is perhaps not surprising given the strong interrelationships between normal plant systems. Simply making buildings harder (I.2 and I.3) does not require interaction with other plant features; however, such hardening could affect the performance of other structures under seismic disturbance. Likewise, additional physical separation (II.1 and II.5), though it may require careful engineering, is not dependent upon other systems. The same

Table 4-2

Findings on Potential for Improved Plant Sabotage Resistance

Design Alternatives		POTENTIAL IMPROVED RESISTANCE (YES ◐ NO)	FEASIBILITY (YES ◐ NO)	STATE OF THE ART (YES ◐ NO)	INDEPENDENCE (HIGH ◐ LOW)	IMPACTS (LOW ◐ HIGH)	SIDE BENEFITS (YES ◐ NO)
CATEGORY I. HARDENING CRITICAL SYSTEMS OR LOCATIONS							
Underground siting	1	●	●	●	○	○	○
Hardened containment	2	○	●	●	●	○	●
Hardened fuel bldg.	3	◐	●	●	●	◐	○
Hardened control room	4	●	●	●	○	●	○
Hardened RPS cabinets	5	○	●	●	○	●	○
Hardened ultimate heat sink	6	◐	●	●	○	◐	○
Natural protection	7	●	●	●	—	○	○
Hardened tank enclosures	8	●	●	●	○	●	●
CATEGORY II. PLANT LAYOUT MODIFICATIONS							
Separation of penetrations	1	●	●	●	●	●	●
Underground galleries	2	●	●	●	○	○	●
SF within containment	3	○	●	●	●	○	○
SF below grade	4	●	●	●	○	○	◐
Physically separated trains	5	●	●	●	●	●	●
Separate cable spreading	6	●	●	●	○	●	●
Alternate CR arrangements	7	●	●	●	○	○	○
ECCS within containment	8	○	●	○	○	○	○
Buildings outside PA	9	●	●	●	—	●	○
CATEGORY III. SYSTEM DESIGN CHANGES							
Isolation of low pressure	1	●	●	●	●	●	◐
Damage control	2	●	●	●	—	●	●
Alternate containment	3	●	●	○	○	○	●
Separate trains	4	●	●	●	●	◐	●
Protected trip	5	○	●	●	○	●	○
Additional trip	6	○	●	●	○	●	○
Turbine runback	7	●	●	●	○	○	●
Intake structures	8	◐	●	●	○	◐	○
Trip coils	9	◐	●	●	○	◐	◐
High-pressure RHRS	10	◐	●	●	○	◐	◐
CATEGORY IV. ADDITIONAL SYSTEMS							
HDHRS	1	●	●	●	●	○	●
Diverse scram	2	●	●	○	○	○	●

observation can be made for isolation of low-pressure systems and extra trains of emergency equipment (III.1 and III.4), although piping connections would require some evaluation. Adding an additional system (IV.1) is relatively independent, except that such options usually postulate and require an intact primary coolant system.

There is almost an even division between those options which are deemed to have significant impacts and those which are deemed not to. However, it should be emphasized that, in this initial analysis, the question of impacts produces widely varying opinions, even among people with similar experience. Therefore, these results are used advisedly and without forming an unchangeable position. For those options which involve layout modifications, one of the most frequently cited impacts was the increased cost of generally larger, more spread out facilities. Also, operational impacts were often cited for storing spent fuel in containment (II.3) or putting ECCS components into containment (II.8).

Although not central to the question of improved resistance to sabotage, other potential benefits of the proposed options were considered. Again, about half of the options offer some additional benefit. The most cited benefit, especially for those designs which stress separation, is the added protection against fire effects. Where additional redundancy is proposed, a significant additional benefit is the capability to have a full train of safety equipment down for maintenance or testing and still meet single-failure criteria for safety systems.

Based upon the foregoing considerations, six options from this set were selected for further conceptual development and analysis. These options were selected because, at this time, they appear to offer the most promise for enhancing protection without obvious major impacts, and they cover a spectrum of possible designs. The six options are listed in Table 4-3.

EXHIBIT 5.1

Docket No. 22449-U

In Re: Georgia Power Company Request For An Accounting Order

ORDER

Record submitted: June 2, 2006 **Decided: June 22, 2006**

APPEARANCES:

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On behalf of the Consumers' Utility Counsel:

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On behalf of Georgia Power Company:

KEVIN C. GREENE, ESQ.
BRANDO MARZO, ESQ.

On behalf of Georgia Industrial Group and Georgia Textile Manufacturers Association:

RANDALL QUINTRELL, ESQ.

On behalf of Southern Alliance for Clean Energy:

RENEE KASTANAKIS, ESQ.

I. STATEMENT OF PROCEEDINGS

This matter comes before the Georgia Public Service Commission ("Commission") on the request of Georgia Power Company ("Georgia Power" or "Company") for an Accounting Order.

On February 20, 2006, Georgia Power filed with the Commission its Request For An Accounting Order Authorizing The Use Of FERC Account 183 (Preliminary Survey and Investigation Charges) To Record Certain Early Site Permitting And Construction Operating License Costs ("Request"). In its Request, Georgia Power asked the Commission to issue an order authorizing the Company to record the Early Site Permit and Construction Operating License costs in FERC account 183 for future recovery in rates, subject to the cost recovery rules defined in the Integrated Resource Planning ("IRP") statute.

On March 21, 2006, the Commission issued its Procedural and Scheduling Order setting forth the dates for filing of testimony and briefs, as well as the date for a hearing in this matter. The Commission also set forth specific issues to be addressed by the Company in its testimony. Pursuant to the Procedural and Scheduling Order, on April 13, 2006, Georgia Power pre-filed the panel testimony of Ann P. Daiss, Jeffrey A. Burleson and Louis B. Long. On May 5, 2206, the Georgia Industrial Group and Georgia Textile Manufacturers Association ("GIG/GTMA") pre-filed the testimony of Jeffry Pollock. On that same date, the Southern Alliance for Clean Energy ("SACE") pre-filed the testimony of David Schlissel and the panel testimony of Sara Barczak, Rita Kilpatrick, Dr. Arjun Makajani and Dr. Brice Smith. On May 16, 2006, the Company filed the rebuttal testimony of the panel of Ms. Daiss, Mr. Burleson and Mr. Long.

On May 25, 2006 the Commission held a hearing to consider the Company's Request. At the outset of the hearing, the Commission granted Georgia Power's Motion to Strike portions of the testimony pre-filed by SACE. Specifically, the Commission struck an exhibit entitled DAS-2 of the testimony of Mr. Schlissel, and the testimony of the SACE panel appearing in Section II, from line twenty-three on page seven through line twelve of page twenty-eight. In addition, the Commission agreed to allow the pre-filed testimony of Mr. Pollock to be withdrawn. On June 2, 2006, the parties filed briefs and proposed orders setting forth their respective positions in this matter.

At the June 22, 2006 Administrative Session, a Stipulation executed on behalf of the Commission Staff, Georgia Power, GIG and GTMA was presented to the Commission for its consideration. A copy of the Stipulation is attached hereto as Attachment A and incorporated herein by this reference. The Commission voted to approve and adopt the Stipulation with one modification, the addition of the following Ordering Paragraph:

ORDERED FURTHER, that Georgia Power Company's filing in the 2007 IRP shall include a detailed assessment of the maximum achievable cost effective potential for energy efficiency and demand response programs in its service area. Such assessment shall follow the scope and detail used in the May 5, 2005 Georgia Environmental Facilities Authority Final Report on Assessment of Energy Efficiency Potential in Georgia.

After a recess, the signatories to the Stipulation each informed the Commission that they did not object to including the additional Ordering Paragraph in the Commission Order approving the Stipulation. The Commission hereby adopts the Stipulation and the additional Ordering Paragraph.

Therefore, the Company's request for an Accounting Order is **granted**.

WHEREFORE IT IS ORDERED, effective January 1, 2006 the Company shall record the actual costs incurred, net of any amounts billed to co-owners, in developing, filing and obtaining a federal Early Site Permit (ESP) and/or Combined Operating License (COL) and other permits required for new regulated retail nuclear generation at the Vogtle Electric Generating Plant in FERC Account 183, Preliminary Survey and Investigation Charges.

ORDERED FURTHER, that the amounts recorded in Account 183 pursuant to this Order shall not exceed $51 million plus carrying costs as allowed by this order without prior Commission approval and shall not be included in retail rate base in subsequent filings before this Commission except as provided for in this order.

ORDERED FURTHER, any incurred costs included in Account 183 pursuant to this Order for work which benefits other projects in which the Company or any affiliate is involved shall be equitably shared with such other project.

ORDERED FURTHER, that the amounts recorded in Account 183 pursuant to this order shall earn carrying costs at the Company's prevailing AFUDC rate at the time.

ORDERED FURTHER, that if new nuclear generation is certified by the Commission, the prudently incurred costs recorded in Account 183 pursuant to this order shall be transferred to Account 107, Construction Work In Progress – Electric, and accumulated with all other costs to construct the plant in the construction account (s) established for the new plant.

ORDERED FURTHER, that if new nuclear generation is not certified for the anticipated 2015 base load need of the Company, the prudently incurred ESP and COL amounts recorded in Account 183 until the time work on the ESP and COL stopped, shall be deferred until the Company's next rate case at which time the Commission will determine the appropriate retail rate making treatment for the recovery of those costs net of any income tax savings realized and any gains or losses, if any, from the disposition of these assets.

ORDERED FURTHER, the Commission will complete its examination of the prudence of GPC's costs before rates are adjusted to reflect the costs incurred and accumulated in Account 183. Nothing in this Accounting Order shall be construed as prejudging the prudence of the decision to incur preliminary survey and investigatory charges. Nor shall anything in this Accounting Order be construed as prejudging the prudence of the individual charges incurred in pursuit of the preliminary survey and investigation of nuclear power or the outcome of the 2007 Integrated Resource Planning proceeding or any subsequent certification proceedings.

ORDERED FURTHER, that for all accounting entries required by this order the Company shall file with the Commission on a quarterly basis reports showing the accumulated balance in Account 183 and providing documentation that all expenditures are directly related to ESP and COL.

ORDERED FURTHER, that all tax credits or other incentives received by Georgia Power in connection with the analysis, permitting, or construction or operation of new regulated retail generation at the Vogtle Electric Generating Plant shall be credited upon receipt, against all balances accumulated under this Order in Account 183. Where such incentives are received during or after the Commission's authorized transfer of the Account 183 balances to a CWIP or plant in service account, such incentives shall be used to otherwise reduce the annual base revenue requirement of the nuclear investments for rate-making purposes.

ORDERED FURTHER, that Georgia Power Company's filing in the 2007 IRP shall include a detailed assessment of the maximum achievable cost effective potential for energy efficiency and demand response programs in its service area. Such assessment shall follow the scope and detail used in the May 5, 2005 Georgia Environmental Facilities Authority Final Report on Assessment of Energy Efficiency Potential in Georgia.

ORDERED FURTHER, that any motion for reconsideration, rehearing or oral argument or any other motion shall not stay the effective date of this Order, unless otherwise ordered by this Commission.

ORDERED FURTHER, that jurisdiction over this matter is expressly retained for the purpose of entering such further Order or Orders as this Commission may deem just and proper.

The above by action of the Commission during its Administrative Session on the 22nd day of June, 2006.

REECE MCALISTER
EXECUTIVE SECRETARY

DATE

STAN WISE
CHAIRMAN

DATE

EXHIBIT 5.2

ICF CONSULTING

Georgia Environmental Facilities Authority

Assessment of Energy Efficiency Potential in Georgia

Final Report

May 5, 2005

05-013

powered by perspective

3. Estimates of Energy Efficiency Potential

3.1. Introduction

- Below are our estimates of current technical and economic potential as well as projections of achievable potential over the 2005-2015 period.
  - Our technical and economic potential estimates show total gross potential, including some potential that may be achieved due to naturally occurring conservation in the future. These assessments represent the full extent of technically feasible and economically viable energy efficiency potential in Georgia.
  - Achievable potential is presented as the net of naturally occurring potential, showing only what is achievable above and beyond naturally occurring conservation. These projections may be viewed as energy efficiency policy targets—incremental energy efficiency improvements attainable through policy intervention.
- Because this study considers currently available energy efficiency technologies, the projections of achievable potential are most accurate over the short- to medium-term—from present through about 2010.
  - The intent is to identify latent energy efficiency potential that can be readily captured through policy interventions in the next five to ten years.
  - Towards the later years of our projections (2010-2015), new energy efficiency technologies will be developed that supplement and/or replace the commercially available technologies we have modeled. As these technologies emerge, cost-effective and achievable potential will likely exist in excess of what we estimate here.

3.2. Technical and Economic Potential

- Before considering the magnitude of energy efficiency improvements that could realistically be achieved through policy intervention, it is useful to formally quantify what is technically and economically possible—technical and economic potential.
- Technical and economic potential estimates, as we have presented them here, have no time dimension; it is assumed that all energy efficiency technologies are installed instantaneously. To accomplish this, measure savings factors are applied to all technically or economically feasible applications for which energy efficiency upgrades have not yet been completed.
- Technical potential ranges from about 20% to 30% of overall 2004 Georgia load for electricity sales, peak demand, and gas sales. Economic potential ranges from approximately 10% to 20% of 2004 load (See Table 11). Economic potential includes only those measures with a TRC benefit-cost ratio of 1.0 or greater.
- For electricity sales, peak demand, and gas sales, the majority of technically feasible energy efficiency is also cost-effective. This is particularly true for electricity sales, where nearly 70% of technical potential is also economic.
- Table 11 shows our estimates of technical and economic potential both in absolute terms and as a percentage of 2004 load.

Table 11. Technical and Economic Potential—Total Potential and Percent of 2004 Load

Load Type	Technical Potential		Economic Potential	
Reduction in Electricity Sales (MWh)	35,492,561	29%	24,709,395	20%
Reduction in Peak Demand (MW)	7,703	33%	4,199	18%
Reduction in Gas Sales (MMcf)	63,341	19%	36,048	11%

3.2.1. Technical and Economic Potential by Sector

- The residential sector has the greatest technical and economic potential, followed by the commercial and industrial sectors.
- A very high proportion of what is technically feasible in the industrial sector is also cost-effective, whereas technical potential in the residential sector far exceeds economic potential.
- The figures below show our estimates of technical and economic potential by sector, presented in the context of 2004 load. Table 12 presents technical and economic potential by sector both as absolute potential and as a percentage of 2004 load.

Figure 18. Technical & Economic Potential by Sector (Electricity Sales)

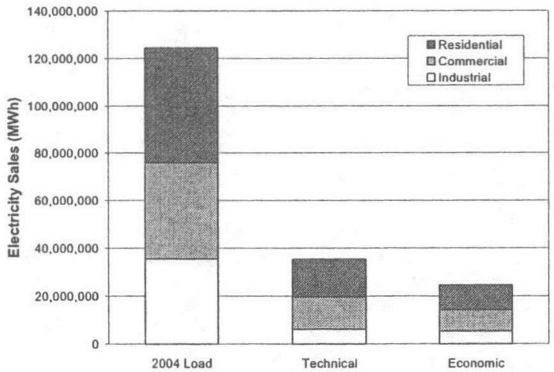


Figure 19. Technical & Economic Potential by Sector (Peak Demand)

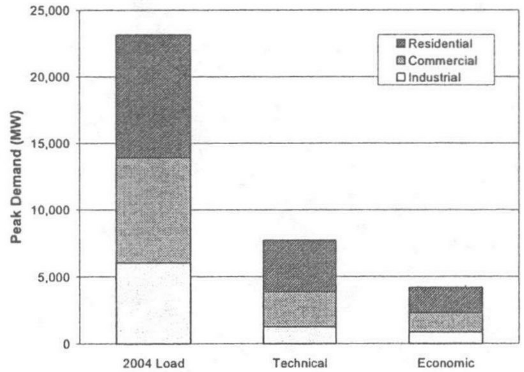


Figure 20. Technical & Economic Potential by Sector (Gas Sales)

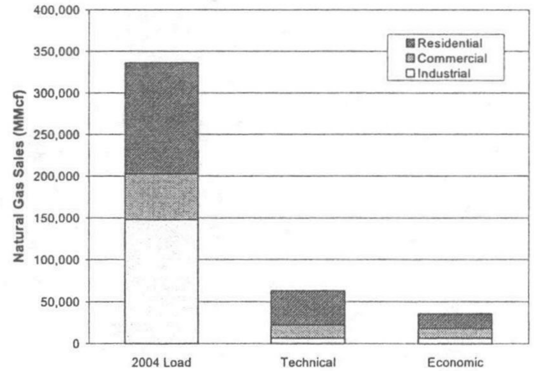


Table 12. Technical and Economic Potential by Sector—Total Potential and Percent of 2004 Load

Load Type	Technical Potential		Economic Potential	
Residential				
Reduction in Electricity Sales (MWh)	15,884,676	33%	10,396,499	21%
Reduction in Peak Demand (MW)	3,836	41%	1,882	20%
Reduction in Gas Sales (MMcf)	41,292	31%	17,833	13%
Commercial				
Reduction in Electricity Sales (MWh)	13,480,921	33%	8,947,117	22%
Reduction in Peak Demand (MW)	2,602	33%	1,432	18%
Reduction in Gas Sales (MMcf)	15,492	28%	11,747	21%
Industrial				
Reduction in Electricity Sales (MWh)	6,126,964	17%	5,365,779	15%
Reduction in Peak Demand (MW)	1,265	21%	885	15%
Reduction in Gas Sales (MMcf)	6,557	4%	6,468	4%
Total				
Reduction in Electricity Sales (MWh)	**35,492,561**	**29%**	**24,709,395**	**20%**
Reduction in Peak Demand (MW)	**7,703**	**33%**	**4,199**	**18%**
Reduction in Gas Sales (MMcf)	**63,341**	**19%**	**36,048**	**11%**

3.3. Achievable Potential

- Our estimates of achievable potential represent energy efficiency savings that could be realistically achieved through policy interventions in the 2005-2015 time period.
- As described earlier, we have calibrated EEPM's market adoption curves to several scenarios:
  - **Naturally Occurring**—This scenario reflects efficiency gains from turnover of older equipment to current standard equipment and the adoption of high-efficiency equipment due to natural market forces and existing energy efficiency programs.
  - **Minimally Aggressive**—This scenario is consistent with a portfolio of energy efficiency programs offering modest financial incentives (~25% of incremental costs) with limited marketing and outreach.
  - **Moderately Aggressive**—This scenario is consistent with a portfolio of energy efficiency programs offering more generous financial incentives (~50% of incremental costs) with more extensive marketing and outreach.
  - **Very Aggressive**—This scenario is consistent with a portfolio of energy efficiency programs offering highly aggressive incentives (~100% of incremental costs) with extensive marketing and outreach efforts. This type of scenario is considered to reflect the maximum possible achievable potential. Efficiency potential in the Very Aggressive case still does not capture all economic potential. Even with financial incentives covering the full cost of efficient equipment, some customers will not be influenced to invest in energy efficiency.
- All achievable potential estimates presented here are net of naturally occurring conservation and therefore represent the incremental savings that may be gained through targeted policy intervention.
- By 2010, we project achievable potential of between 2.3% and 8.7% of electricity sales, 1.7% and 6.1% of peak demand, and 1.8% and 5.5% of gas sales (See Table 13).

Table 13. 2010 Achievable Potential—Total Potential and Percent of 2010 Load

Load Type	Minimally Aggressive		Moderately Aggressive		Very Aggressive	
Reduction in Electricity Sales (MWh)	3,338,924	2.3%	8,704,577	6.0%	12,546,554	8.7%
Reduction in Peak Demand (MW)	447	1.7%	1,149	4.4%	1,608	6.1%
Reduction in Gas Sales (MMcf)	7,041	1.8%	16,972	4.4%	21,343	5.5%

Figure 21. Achievable Potential (Electricity Sales)

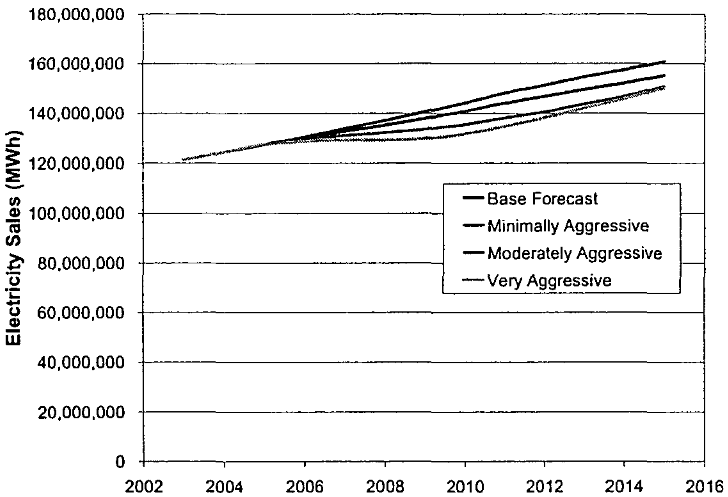


Figure 23. Achievable Potential (Gas Sales)

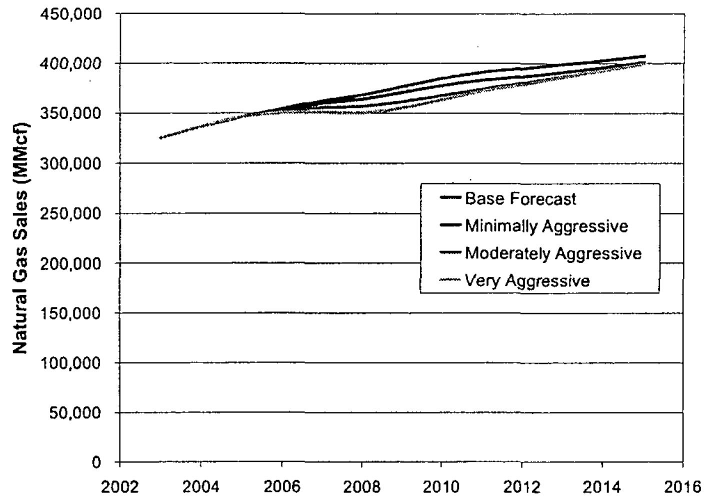
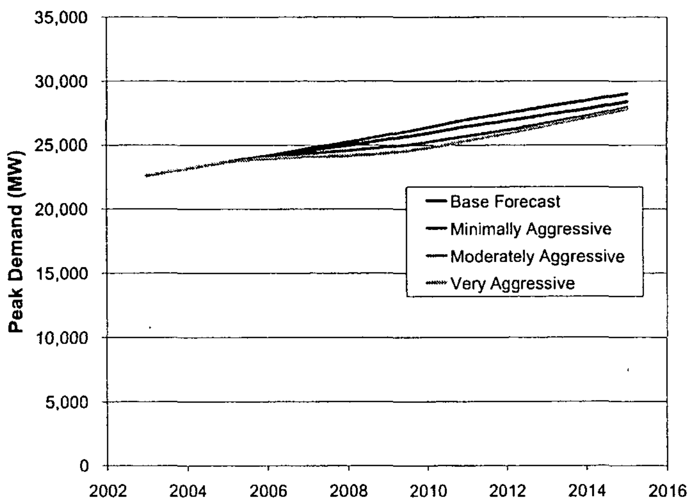


Figure 22. Achievable Potential (Peak Demand)



3.3.1. *Achievable Potential by Sector*

- Achievable potential is relatively evenly distributed across the residential, commercial, and industrial sectors, though there are a few important observations about the relative importance of the sectors to total potential (See figures below).
  - Residential sector potential is significant in electricity and gas sales savings, but nonresidential sectors dominate peak demand potential.
  - The commercial sector plays the largest role in electricity sales and peak demand potential, but the smallest role in gas sales potential.
  - Industrial sector potential is most pronounced for gas sales.

Figure 24. 2010 Achievable Potential by Sector (Electricity Sales)

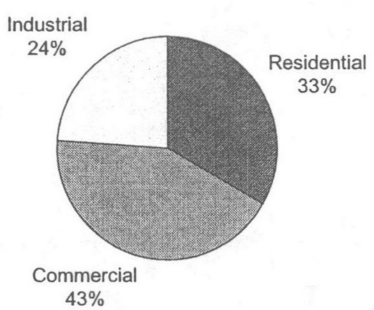


Figure 25. 2010 Achievable Potential by Sector (Peak Demand)

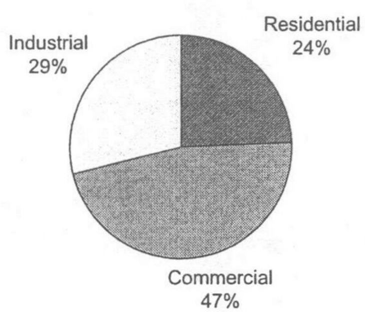
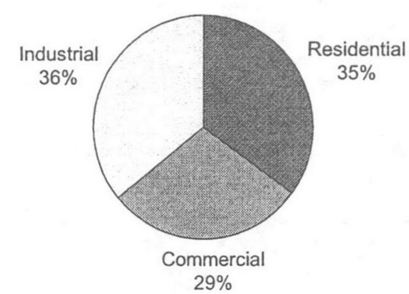


Figure 26. 2010 Achievable Potential by Sector (Gas Sales)



3.3.2. Achievable Potential by End Use

- A handful of end uses make up the majority of total potential. Please note that industrial heating, ventilation, and air conditioning end uses are combined and included in the space heat end use in the figures below.
  - **Electricity Sales**—Lighting comprises the largest share of electricity sales savings potential, making up 43% of total savings. Air conditioning is the next most significant end use with a 13% share. Commercial office equipment (12%) and a combination of all industrial process end uses (19%) also contribute substantially to total potential (See Figure 27).
  - **Peak Demand**—Air conditioning makes up 37% of total peak demand savings, reflecting the significance of cooling loads at the time of the electricity grid's summer peak. Lighting accounts for an additional 28% of potential, though because of residential lighting usage patterns, most of this savings is found in the nonresidential sectors. Industrial process end uses (21%) are also significant sources of peak savings (See Figure 28).
  - **Gas Sales**—Space heat, industrial processes, and domestic hot water make up 44%, 32%, and 24% of gas savings potential, respectively, with minor savings in other end uses (See Figure 29).
- The figures on the following pages present 2010 achievable potential by sector and end use, providing an overall context for the contribution of each sector and end use to total potential.

Figure 27. 2010 Achievable Potential by End Use (Electricity Sales)

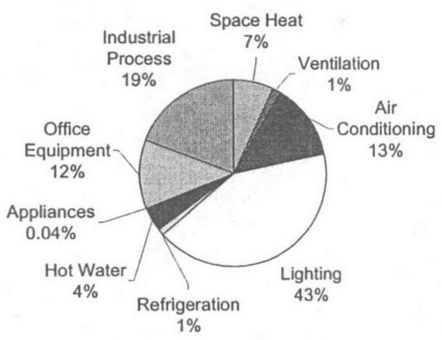


Figure 28. 2010 Achievable Potential by End Use (Peak Demand)

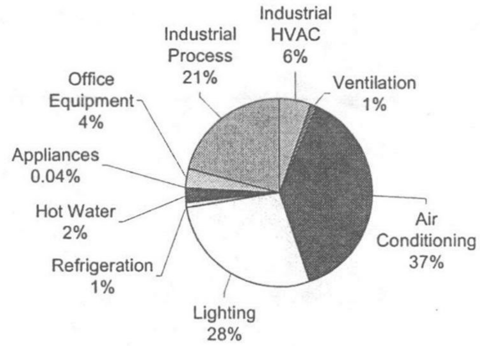


Figure 29. 2010 Achievable Potential by End Use (Gas Sales)

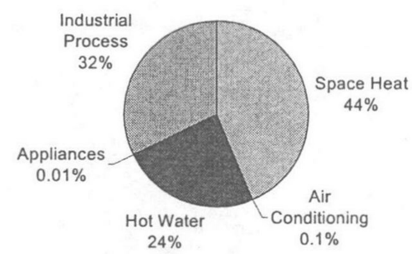


Figure 30. 2010 Achievable Potential by Sector and End Use (Electricity Sales)

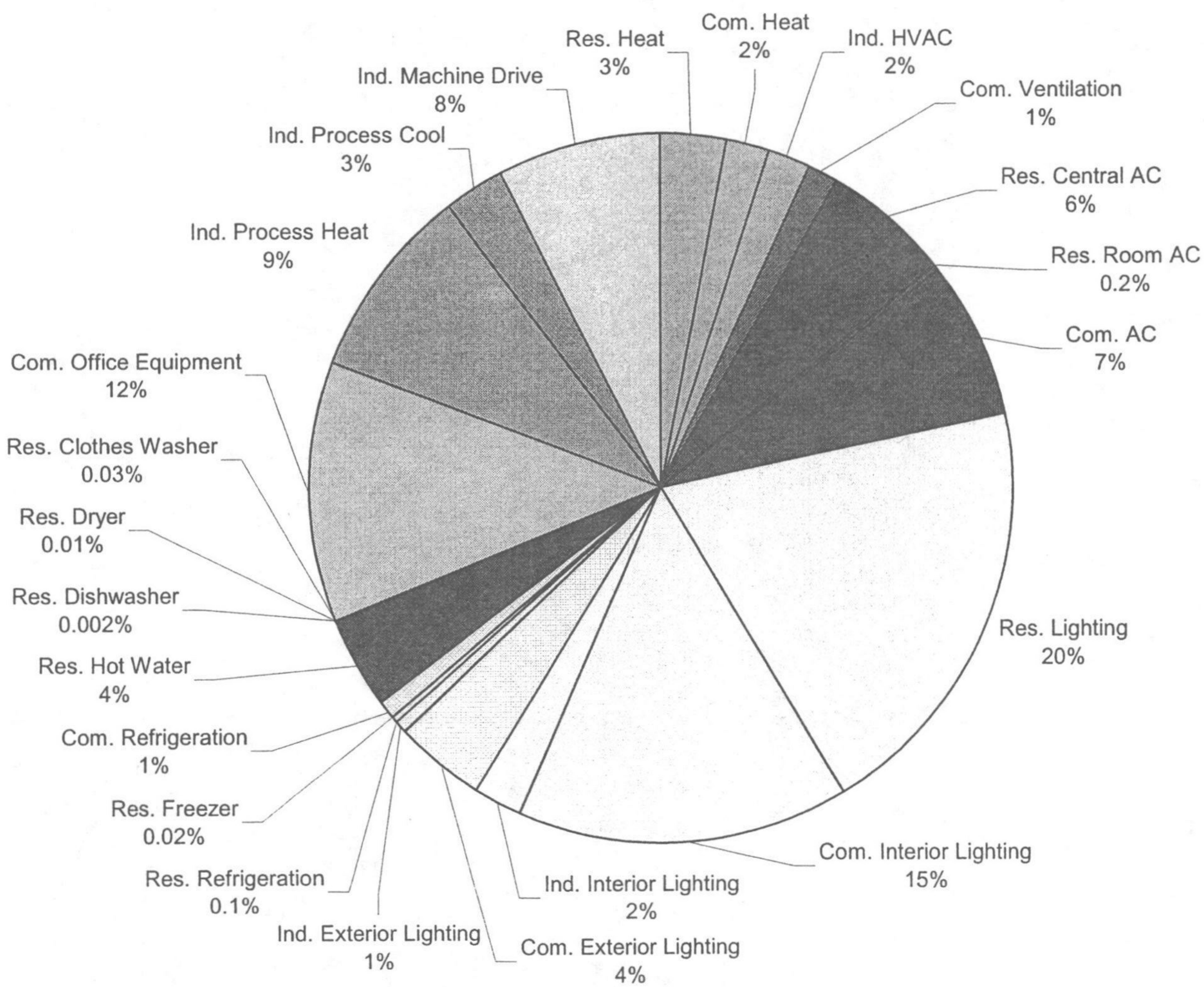


Figure 31. 2010 Achievable Potential by Sector and End Use (Peak Demand)

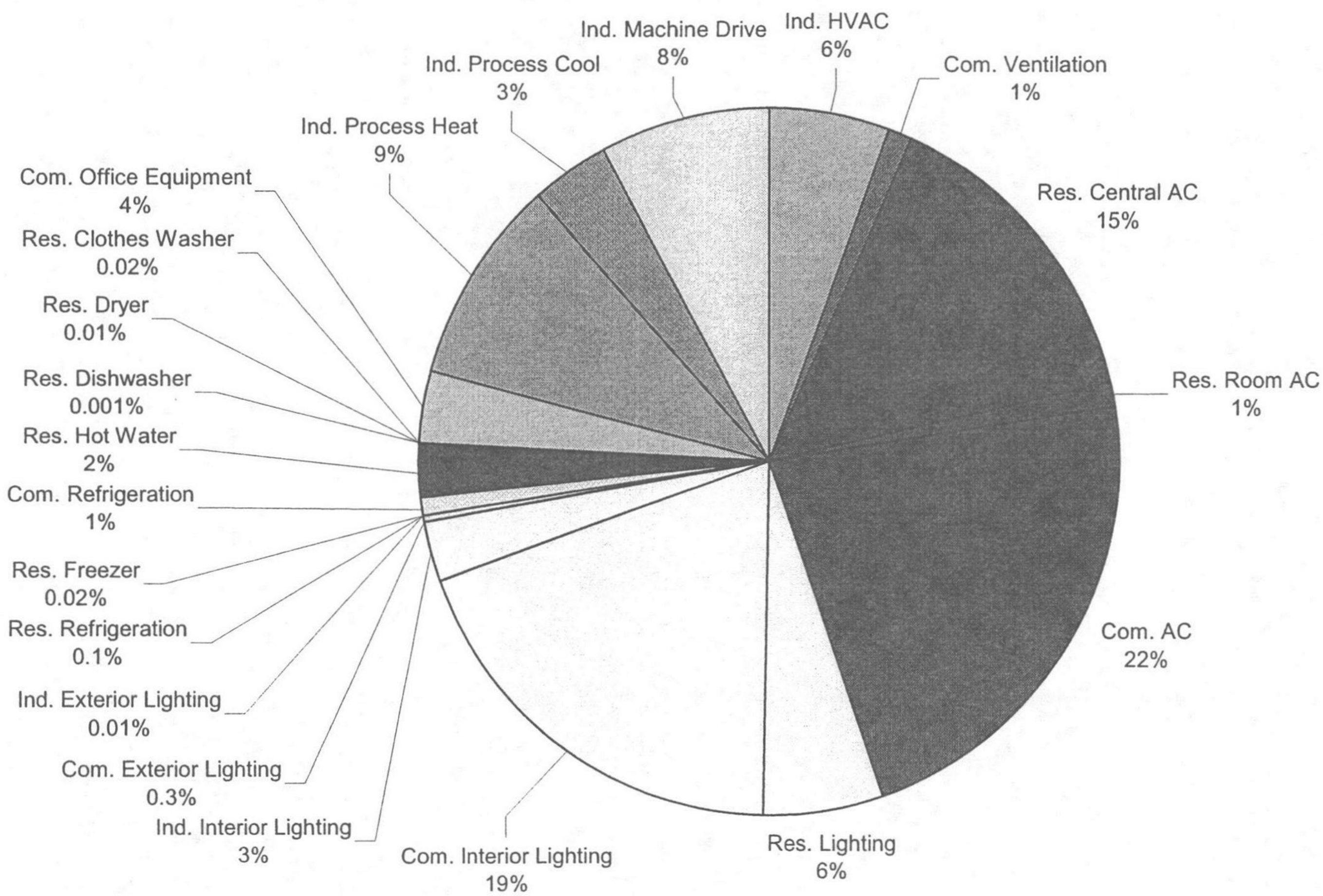
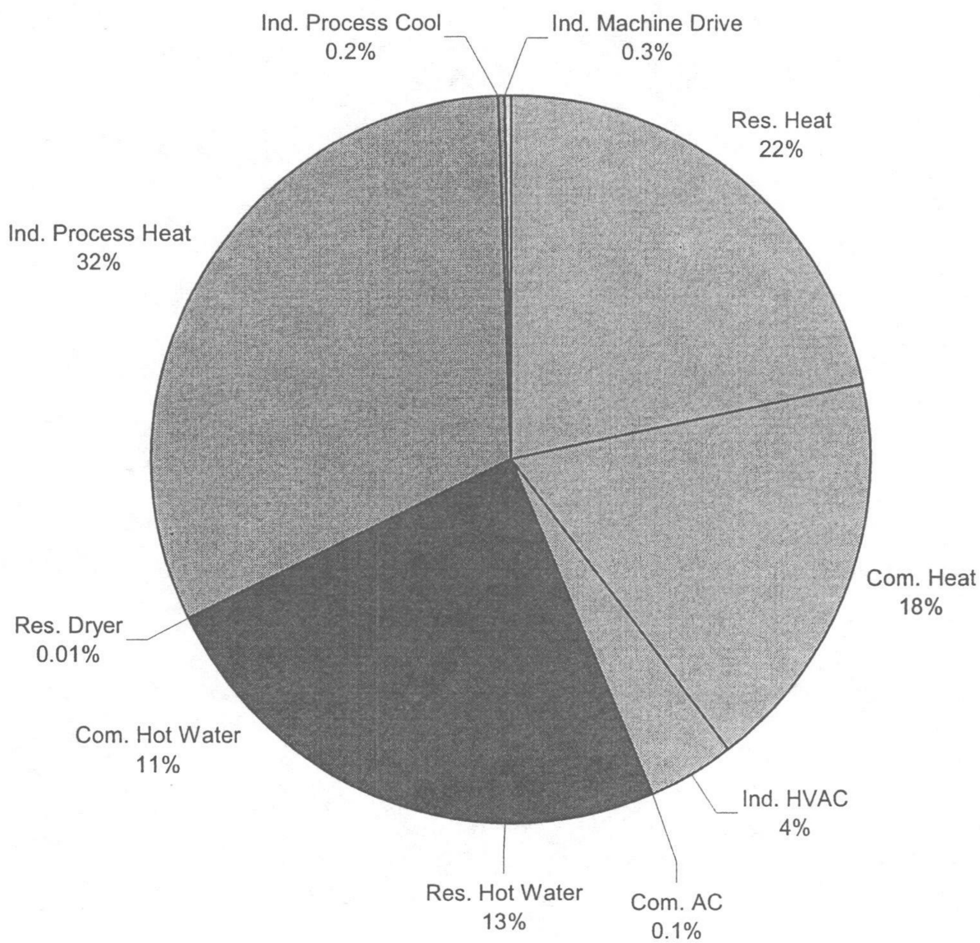


Figure 32. 2010 Achievable Potential by Sector and End Use (Gas Sales)



3.3.3. *Achievable Potential Cost-Effectiveness*[4]

- The achievable energy efficiency potential identified in this study has significant direct net economic benefits for the state of Georgia.
- From a "Total Resource Cost" or TRC perspective, the total net benefits to the state from energy efficiency improvements implemented from 2005-2015 in each of the policy intervention scenarios are between $0.9 billion and $1.6 billion in net present value dollars.
- The TRC benefit-cost ratios for the three intervention scenarios are between 1.5 and 2.2.
- Figures on the following pages assess the cost-effectiveness of each policy intervention scenario from a variety of perspectives. With each figure, there is a description of the benefit-cost perspective presented. Subsequent to these figures are three tables detailing the cost-effectiveness of each sector and end use. Each of the three tables reflects the cost-effectiveness of one policy intervention scenario.
- For all cost-effectiveness tests, dollars are presented in net present value terms, showing what future costs and savings are worth today. To clarify, money spent or saved some number of years in the future is less valued than money spent or saved today. To account for this, we have discounted future expenditures and savings at an annual rate of 8.15%.
- Table 14 shows the costs associated with each achievable potential scenario. Several types of costs are included:
  - **Participant Costs**—Incremental capital, installation, and maintenance costs incurred for energy efficiency equipment.
  - **Program Incentives**—Monetary incentives paid through energy efficiency programs to encourage the adoption of efficient equipment.
  - **Program Administration**—Any administrative, marketing, or outreach costs required to run the programs and engage customers.

Table 14. Net Present Value (Thousands) of Participant, Program Incentive, and Program Administrative Costs

Scenario	Participant Costs	Program Incentives	Program Administration
Minimally Aggressive	$655,860	$163,965	$89,192
Moderately Aggressive	$1,463,379	$731,690	$501,035
Very Aggressive	$1,825,967	$1,825,967	$1,000,910

[4] California Public Utilities Commission. *California Standard Practice Manual: Economic Analysis of Demand-Side Programs and Projects*, October 2001.

Total Resource Cost Test (TRC)

- The Total Resource Cost Test assesses the costs of an energy efficiency program relative to other energy supply options.
  - **Benefits**—TRC benefits include avoided energy supply costs.
  - **Costs**—TRC costs include the total costs of the energy efficiency measures installed plus any program administrative costs. Measure costs may be paid by any combination of program participant expenditures and program incentives.
- Figure 33 compares avoided energy supply costs with the sum of program administrative and measure costs (comprised of a combination of participant costs and program incentives).

Table 15. Total Resource Cost Test (TRC) Explained

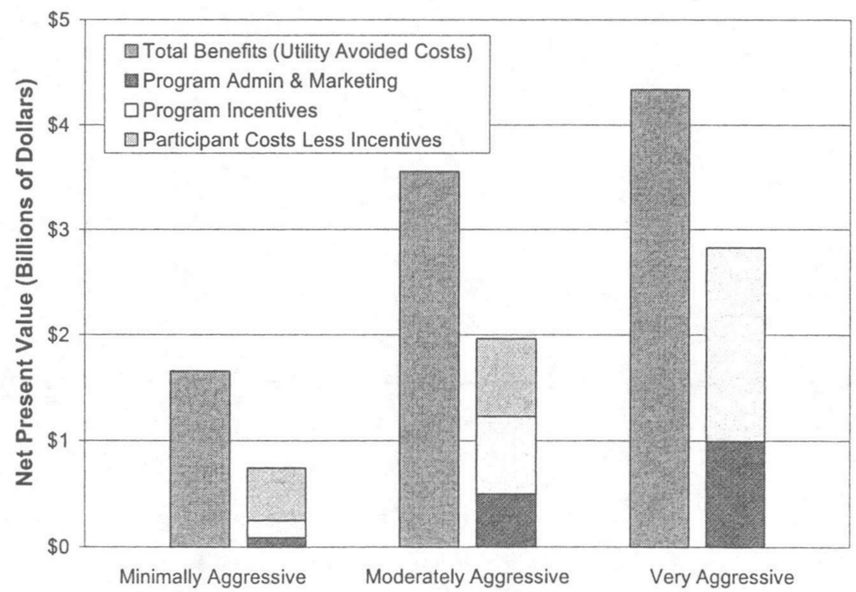
In essence, the TRC test measures whether it is more expensive to generate and deliver a given amount of energy or to implement programs to save that energy.

In Figure 33, the blue (left) bars show how much it would cost to provide the energy that could be saved through efficiency programs. This cost includes elements such as fuel costs at power plants, the cost of building new power plants, the cost of using power lines or pipelines to deliver electricity or gas, and any other costs that the energy utility could avoid by reducing the amount of energy they need to provide.

The other bars show how much it would cost to save that same amount of energy, including the total cost of energy-saving equipment and any administrative costs required to implement energy efficiency programs. The cost of efficient equipment can be paid by any combination of program participant out-of-pocket expenses and financial incentives provided by the program.

As is the case for each of the cost-effectiveness tests, the difference between the bars represents net benefits—benefits minus costs. Any program or efficiency measure for which benefits are greater than costs is considered cost-effective and passes the TRC test. These cost-effective measures and programs yield benefits to Georgia in excess of the costs of investment even without considering any additional environmental or secondary economic benefits. The TRC test does not identify specifically who will benefit from the programs, but any program or measure that passes the test will benefit customers overall.

Figure 33. TRC Benefits and Costs for Achievable Potential Scenarios



Participant Cost Test (PCT)

- The Participant Cost Test quantifies benefits and costs from the perspective of program participants.
  - **Benefits**—PCT benefits include participant energy bill savings plus any program incentives paid to the participant.
  - **Costs**—PCT costs include the total costs of the energy efficiency measures installed.
- Figure 34 compares the sum of participant energy bill savings and program incentives with total measure costs paid by the participant.

Table 16. Participant Cost Test (PCT) Explained

The PCT test measures how much program participants benefit from taking part in an energy efficiency program.

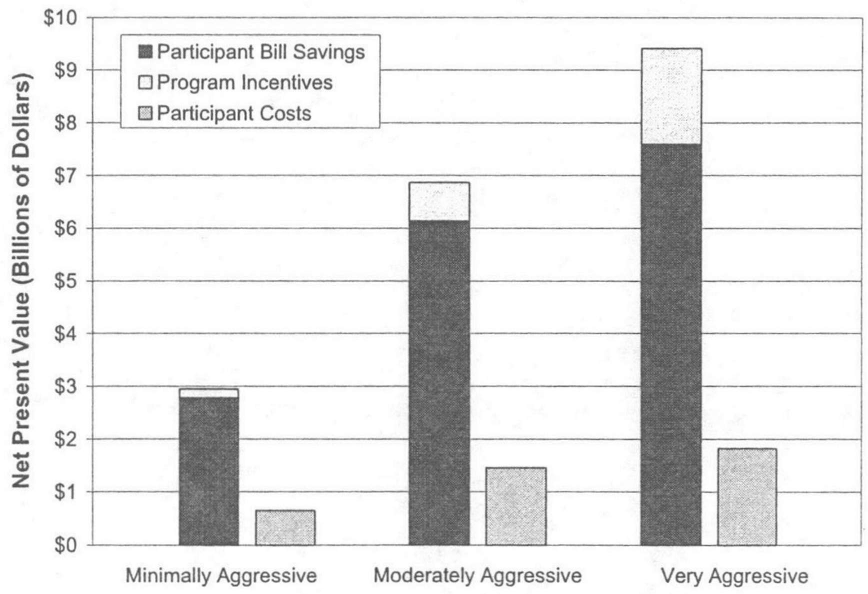
In Figure 34, the left bars show the financial benefits that participants receive as a result of taking part in energy efficiency programs. These benefits include energy bill savings resulting from installed efficient equipment and any financial incentives paid by the programs to encourage the adoption of that equipment.

The right bars show the additional costs participants must pay in order to purchase, install, and maintain high-efficiency equipment. In many instances, high-efficiency equipment costs more than its standard efficiency counterpart. This incremental cost is what participants must pay in order to achieve energy savings.

As is the case for each of the cost-effectiveness tests, the difference between the bars represents net benefits—benefits minus costs. Any program or efficiency measure for which benefits are greater than costs is considered cost-effective from a PCT perspective and passes the PCT test.

The PCT test is a reasonable estimate of the quantifiable benefits to participants in energy efficiency programs. However, because customers are also influenced by a range of unquantifiable factors, the PCT test cannot balance all of the criteria on which customers make their decisions to participate in a program.

Figure 34. PCT Benefits and Costs for Achievable Potential Scenarios



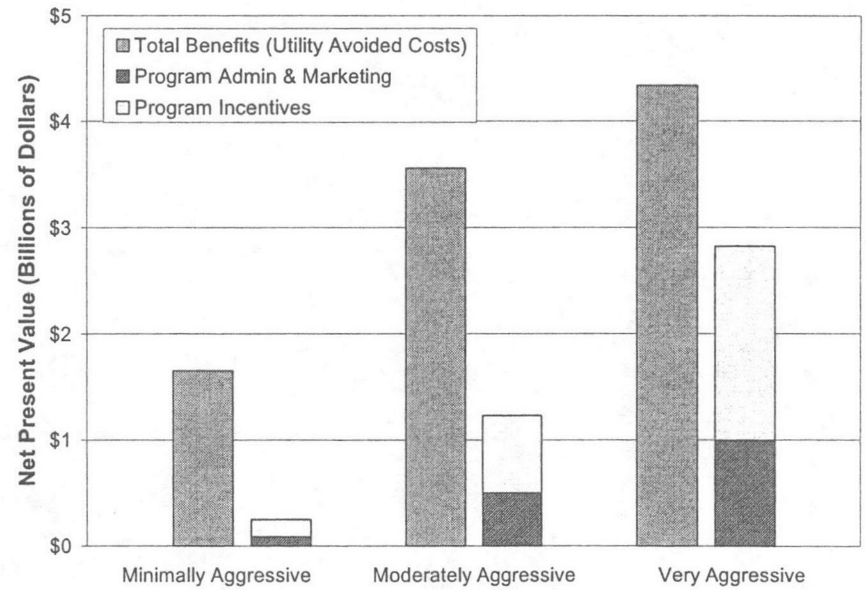
Utility Cost Test (UCT)

- The Utility Cost Test, sometimes called the Program Administrator Cost Test, measures the costs of administering an energy efficiency program relative to energy supply options.
  - **Benefits**—UCT benefits include avoided energy supply costs.
  - **Costs**—UCT costs include all costs incurred by the utility or program administrator—program administrative costs plus program incentives.
- Figure 35 compares avoided energy supply costs with the sum of program incentive and administrative costs.

Table 17. Utility Cost Test (UCT) Explained

The UCT test measures whether it is more costly for a utility to generate and deliver a given amount of energy or to implement programs to save that energy.
In Figure 35, the blue (left) bars show how much it would cost to provide the energy that could be saved through efficiency programs. This cost is identical to that used for the TRC test and includes elements such as fuel costs at power plants, the cost of building new power plants, the cost of using power lines or pipelines to deliver electricity or gas, and any other costs that the energy utility could avoid by reducing the amount of energy they need to provide.
The other bars show how much the utility would have to pay to implement programs to save that same amount of energy. This cost includes financial incentives paid to program participants to encourage the purchase of efficient equipment and any administrative costs required to implement the programs.
As is the case for each of the cost-effectiveness tests, the difference between the bars represents net benefits—benefits minus costs. Any program or efficiency measure for which benefits are greater than costs is considered cost-effective and passes the UCT test.

Figure 35. UCT Benefits and Costs for Achievable Potential Scenarios



Ratepayer Impact Measure (RIM)

- The Ratepayer Impact Measure assesses the impacts of an energy efficiency program on utility revenues in relation to utility avoided energy supply costs.
  - **Benefits**—RIM benefits include avoided energy supply costs.
  - **Costs**—RIM costs include program administrative and incentive costs plus utility lost revenues due to customer energy bill savings.
- Figure 36 compares avoided energy supply costs with the sum of program incentive/administrative costs and utility lost revenues.

Table 18. Ratepayer Impact Measure (RIM) Explained

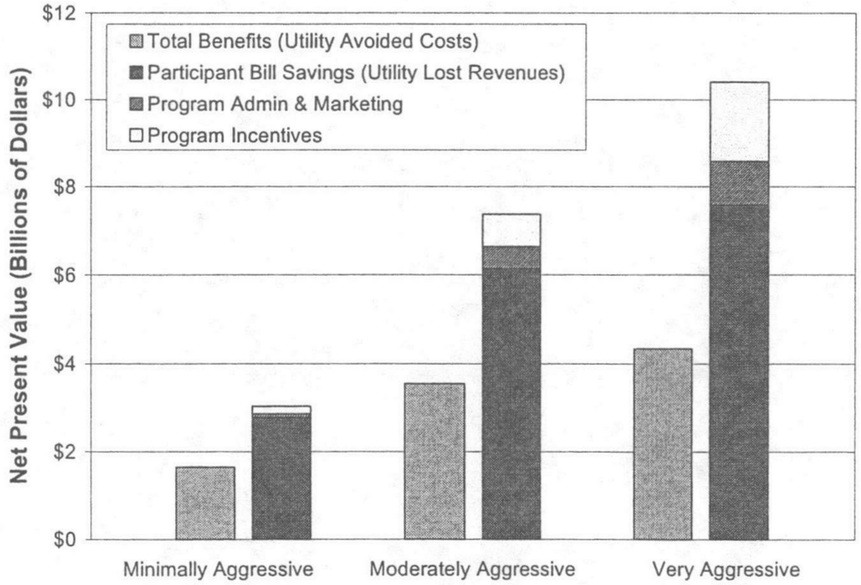
The RIM measures the amount that utility average revenue (i.e., $/kWh or $/Thm) would have to change in order to cover the costs of an energy efficiency program.

In Figure 36, the light blue (left) bars show how much it would cost to provide the energy that could be saved through efficiency programs. This cost is identical to that used for the TRC and UCT tests and includes elements such as fuel costs at power plants, the cost of building new power plants, the cost of using power lines or pipelines to deliver electricity or gas, and any other costs that the energy utility could avoid by reducing the amount of energy they need to provide.

The other bars show the cost to implement programs to save that same amount of energy and the utility sales revenue lost as a result of customer bill savings. The program implementation cost includes financial incentives paid to program participants to encourage the purchase of efficient equipment and any administrative costs required to implement the programs. Utility lost revenues are the reductions in utility bills that customers experience due to energy savings.

As is the case for each of the cost-effectiveness tests, the difference between the bars represents net benefits—benefits minus costs. Unlike other cost-effectiveness metrics, however, RIM is typically used as a program design tool for minimizing rate impacts rather than a test for screening programs or measures. For this reason, RIM is best viewed not as a cost-effectiveness test per se, but rather as an indication of how a utility's average revenue would need to change to meet its revenue requirement, all else being equal.

Figure 36. RIM Benefits and Costs for Achievable Potential Scenarios



- Table 19 shows net economic benefits and benefit-cost ratios for each achievable potential scenario from a variety of cost perspectives.
- The tables on the following pages show this same information for each sector and end use.
  - As for all estimates of economic and achievable potential, each end use includes savings and costs from measures with TRC benefit-cost ratios of 1.0 or greater.
  - These end use groupings approximate the pieces that would make up a comprehensive portfolio of energy efficiency programs across all sectors.

Table 19. Net Benefits (Billions) and Benefit-Cost Ratios for Achievable Potential Scenarios

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Minimally Aggressive	$0.9	2.2	$2.3	4.5	$1.4	6.5	-$1.4	0.5
Moderately Aggressive	$1.6	1.8	$5.4	4.7	$2.3	2.9	-$3.8	0.5
Very Aggressive	$1.5	1.5	$7.6	5.2	$1.5	1.5	-$6.1	0.4

Table 20. Net Benefits (Millions) and Benefit-Cost Ratios for Achievable Potential by Sector and End Use (Minimally Aggressive)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Residential Space Heat	$54	2.1	$172	5.1	$85	6.1	-$118	0.5
Residential Central A/C	$70	3.5	$174	8.2	$88	10.1	-$104	0.5
Residential Room A/C	$2	1.6	$6	3.8	$3	4.5	-$5	0.5
Residential Lighting	$161	1.8	$570	4.2	$293	5.2	-$409	0.5
Residential Hot Water	$50	2.7	$141	6.5	$69	7.7	-$91	0.5
Commercial Heating	$44	2.5	$111	5.3	$64	7.2	-$66	0.5
Commercial Ventilation	$8	1.8	$27	3.8	$15	5.8	-$18	0.5
Commercial Cooling	$54	3.0	$131	6.7	$71	8.7	-$77	0.5
Commercial Interior Lighting	$59	1.4	$297	3.0	$173	4.2	-$237	0.5
Commercial Exterior Lighting	$31	2.3	$87	5.0	$48	6.5	-$56	0.5
Commercial Refrigeration	$4	2.1	$12	4.7	$7	6.1	-$8	0.5
Commercial Office Equipment	$31	2.3	$100	5.9	$46	6.7	-$69	0.4
Commercial Hot Water	$14	1.5	$53	3.2	$32	4.3	-$39	0.5
Industrial HVAC	$13	1.7	$23	2.4	$25	4.9	-$10	0.8
Industrial Process Cooling	$31	5.0	$38	6.6	$36	14.5	-$7	0.9
Industrial Process Heating & Boiler Fuel	$187	4.8	$227	6.3	$219	13.8	-$40	0.9
Industrial Interior Lighting	$15	1.8	$25	2.4	$28	5.4	-$10	0.8
Industrial Exterior Lighting	$4	2.1	$6	3.0	$7	6.1	-$2	0.8
Industrial Process Machine Drive	$79	4.6	$96	6.0	$93	13.2	-$18	0.9
Total	**$911**	**2.2**	**$2,296**	**4.5**	**$1,403**	**6.5**	**-$1,385**	**0.5**

Table 21. Net Benefits (Millions) and Benefit-Cost Ratios for Achievable Potential by Sector and End Use (Moderately Aggressive)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Residential Space Heat	$92	1.7	$397	5.3	$139	2.7	-$305	0.4
Residential Central A/C	$144	2.8	$426	8.2	$174	4.4	-$282	0.4
Residential Room A/C	$2	1.3	$16	4.0	$5	2.0	-$14	0.4
Residential Lighting	$273	1.4	$1,580	4.4	$508	2.3	-$1,307	0.4
Residential Hot Water	$91	2.2	$322	6.6	$120	3.4	-$231	0.4
Commercial Heating	$79	2.1	$246	5.5	$107	3.2	-$167	0.5
Commercial Ventilation	$14	1.6	$62	4.0	$24	2.6	-$48	0.5
Commercial Cooling	$98	2.5	$284	6.8	$122	3.9	-$186	0.5
Commercial Interior Lighting	$49	1.1	$630	3.1	$197	1.9	-$581	0.4
Commercial Exterior Lighting	$50	1.8	$179	5.2	$71	2.9	-$130	0.5
Commercial Refrigeration	$7	1.7	$28	4.9	$10	2.7	-$21	0.4
Commercial Office Equipment	$48	1.9	$201	6.1	$67	2.9	-$154	0.4
Commercial Hot Water	$16	1.2	$119	3.4	$41	2.0	-$103	0.4
Industrial HVAC	$19	1.4	$56	2.6	$36	2.2	-$38	0.6
Industrial Process Cooling	$61	4.1	$82	6.8	$68	6.4	-$22	0.8
Industrial Process Heating & Boiler Fuel	$367	4.0	$496	6.6	$412	6.3	-$128	0.8
Industrial Interior Lighting	$20	1.5	$55	2.6	$38	2.4	-$35	0.7
Industrial Exterior Lighting	$7	1.7	$14	3.2	$10	2.7	-$8	0.7
Industrial Process Machine Drive	$157	3.7	$218	6.2	$178	5.8	-$61	0.8
Total	**$1,594**	**1.8**	**$5,412**	**4.7**	**$2,326**	**2.9**	**-$3,818**	**0.5**

Table 22. Net Benefits (Millions) and Benefit-Cost Ratios for Achievable Potential by Sector and End Use (Very Aggressive)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Residential Space Heat	$89	1.5	$576	5.7	$89	1.5	-$487	0.4
Residential Central A/C	$162	2.3	$598	8.6	$162	2.3	-$435	0.4
Residential Room A/C	$1	1.1	$23	4.4	$1	1.1	-$22	0.3
Residential Lighting	$125	1.1	$2,077	4.8	$125	1.1	-$1,953	0.3
Residential Hot Water	$97	1.8	$452	7.1	$97	1.8	-$355	0.4
Commercial Heating	$85	1.7	$356	5.9	$85	1.7	-$270	0.4
Commercial Ventilation	$14	1.4	$93	4.5	$14	1.4	-$79	0.4
Commercial Cooling	$108	2.1	$395	7.3	$108	2.1	-$287	0.4
Commercial Interior Lighting	-$13	1.0	$948	3.6	-$13	1.0	-$962	0.3
Commercial Exterior Lighting	$47	1.6	$250	5.6	$47	1.6	-$202	0.4
Commercial Refrigeration	$6	1.4	$41	5.4	$6	1.4	-$34	0.4
Commercial Office Equipment	$46	1.6	$274	6.5	$46	1.6	-$228	0.4
Commercial Hot Water	$6	1.1	$182	3.9	$6	1.1	-$177	0.4
Industrial HVAC	$13	1.2	$96	3.1	$13	1.2	-$83	0.5
Industrial Process Cooling	$73	3.5	$115	7.2	$73	3.5	-$42	0.7
Industrial Process Heating & Boiler Fuel	$443	3.4	$694	7.0	$443	3.4	-$251	0.7
Industrial Interior Lighting	$16	1.2	$90	3.0	$16	1.2	-$74	0.5
Industrial Exterior Lighting	$6	1.5	$22	3.7	$6	1.5	-$16	0.6
Industrial Process Machine Drive	$189	3.1	$311	6.6	$189	3.1	-$123	0.7
Total	**$1,512**	**1.5**	**$7,592**	**5.2**	**$1,512**	**1.5**	**-$6,080**	**0.4**

3.3.4. Achievable Potential in Depth

- To assist more directly in any future energy efficiency program design strategies, we have modeled the potential for energy efficiency in each sector separately and assessed the subsectors and end uses in which the greatest potential lies.
- Below are the complete results of the EEPM modeling effort for each sector. Table 23 shows 2010 achievable potential by sector both in absolute terms and as a percentage of 2010 load.

Table 23. 2010 Achievable Potential by Sector—Total Potential and Percent of 2010 Load

Load Type	Minimally Aggressive		Moderately Aggressive		Very Aggressive	
Residential						
Reduction in Electricity Sales (MWh)	806,010	1.5%	2,908,146	5.3%	5,157,717	9.4%
Reduction in Peak Demand (MW)	78	0.8%	280	2.7%	487	4.8%
Reduction in Gas Sales (MMcf)	2,378	1.6%	5,947	3.9%	7,523	4.9%
Commercial						
Reduction in Electricity Sales (MWh)	1,654,957	3.3%	3,725,692	7.5%	4,763,509	9.6%
Reduction in Peak Demand (MW)	229	2.4%	537	5.7%	698	7.4%
Reduction in Gas Sales (MMcf)	2,167	3.4%	4,928	7.7%	6,100	9.5%
Industrial						
Reduction in Electricity Sales (MWh)	877,957	2.2%	2,070,740	5.2%	2,625,327	6.6%
Reduction in Peak Demand (MW)	140	2.1%	333	4.9%	423	6.3%
Reduction in Gas Sales (MMcf)	2,496	1.5%	6,097	3.6%	7,720	4.6%
Total						
Reduction in Electricity Sales (MWh)	**3,338,924**	**2.3%**	**8,704,577**	**6.0%**	**12,546,554**	**8.7%**
Reduction in Peak Demand (MW)	**447**	**1.7%**	**1,149**	**4.4%**	**1,608**	**6.1%**
Reduction in Gas Sales (MMcf)	**7,041**	**1.8%**	**16,972**	**4.4%**	**21,343**	**5.5%**

Residential Sector Achievable Potential

OVERVIEW

- By 2010, we project achievable potential in the residential sector of between 1.5% and 9.4% of residential electricity sales, 0.8% and 4.8% of residential peak demand, and 1.6% and 4.9% of residential gas sales (See Table 24).
- Unlike the commercial and industrial sectors, the residential sector was not modeled in segregated subsectors (i.e., single- or multi-family housing). Because of the overall dominance of single-family housing to residential energy consumption, single-family energy profiles were used wherever there was a known difference between single- and multi-family measure savings characteristics.
- Because residences have a lower occupancy rate on the type of summer weekday afternoon that characterizes electricity system peak, residential sector peak demand savings are lower than electricity sales savings would seem to suggest.
- Significant natural gas savings in the space heating and hot water end uses make the residential sector a large source of gas sales potential overall.

Table 24. 2010 Residential Achievable Potential—Total Potential and Percent of 2010 Load

Load Type	Minimally Aggressive		Moderately Aggressive		Very Aggressive	
Reduction in Electricity Sales (MWh)	806,010	1.5%	2,908,146	5.3%	5,157,717	9.4%
Reduction in Peak Demand (MW)	78	0.8%	280	2.7%	487	4.8%
Reduction in Gas Sales (MMcf)	2,378	1.6%	5,947	3.9%	7,523	4.9%

RESIDENTIAL SECTOR ACHIEVABLE POTENTIAL BY END USE

- Below are descriptions of the main end uses contributing to residential savings potential. Figures on the following pages show projections of residential achievable potential and the relative shares of each end use.
- **Electricity Sales**
  - Electricity sales savings potential is dominated by the lighting end use, making up 59% of total potential. The primary measure influencing this potential is the replacement of highly inefficient but common incandescent light bulbs with compact fluorescent lights (CFLs), which use approximately 25% of the energy consumed by incandescent bulbs.
  - The central air conditioning and room air conditioning end uses follow lighting as the next most significant sources of electricity sales savings, with a combined share of 19%. Most geographical regions can gain peak demand savings from air conditioning measures, but Georgia's warm climate also makes air conditioning measures highly important to energy sales potential.
  - Water heating (13%) and space heating (9%) also contribute notable shares to total residential potential. Many households utilize natural gas as fuel for these energy services, but these end uses also make up a significant portion of residential electricity usage and savings potential.
  - Absent from this list of significant end uses are residential appliances. The high-efficiency appliances reviewed for this assessment, including refrigerators, freezers, clothes dryers, clothes washers, and dishwashers, were not cost-effective on a TRC basis and therefore were not included in policy-driven achievable potential scenarios. Some appliance savings result from an increased replacement rate of older appliances to current standard efficiency units.
- **Peak Demand**
  - Central air conditioning (61%) and room air conditioning (4%) make up the clear majority of peak demand potential. Because system peak demand typically occurs on a summer weekday afternoon, air conditioning makes up a very large proportion of total residential peak demand and savings potential.
  - Lighting plays a substantial but lesser role in peak demand savings, with a 24% share of potential. This result also reflects residential electricity usage patterns on a typical peak summer afternoon. Residential lighting is not as extensively used during this time period, so its contribution to peak demand potential is less than its contribution to energy sales potential.
  - Water heating holds a sizable portion of peak demand potential (10%), but space heating has no impact on peak demand savings.
- **Gas Sales**
  - Space heating makes up the majority of gas sales potential, with a 62% share. Programmable thermostats and infiltration reduction measures are the most important contributors to this potential.
  - Water heating accounts for nearly all other gas sales potential, contributing 38% to the total. This potential consists of measures reducing heat loss (e.g., pipe and tank insulation) and measures restricting hot water usage (e.g., faucet aerators and low flow showerheads).

Figure 37. Residential Achievable Potential (Electricity Sales)

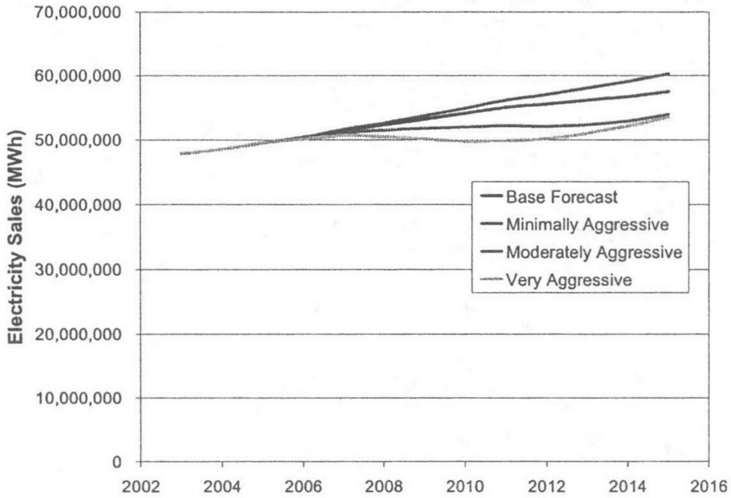


Figure 38. Residential Achievable Potential (Peak Demand)

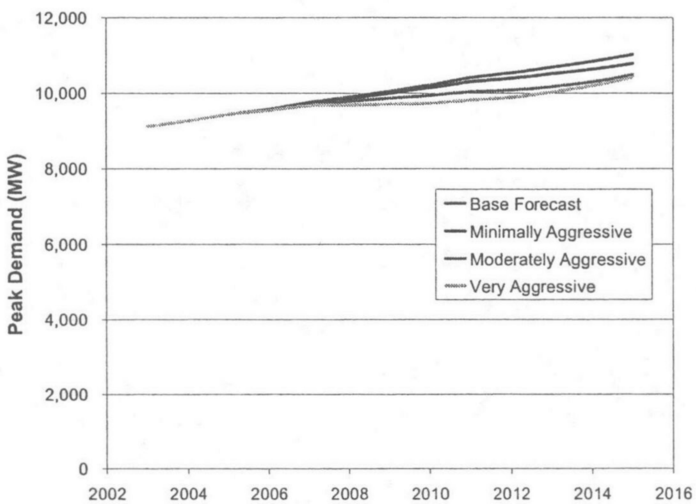


Figure 39. Residential Achievable Potential (Gas Sales)

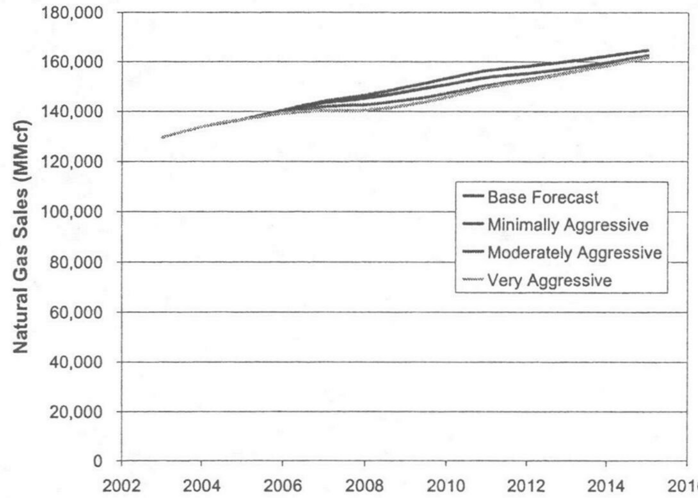


Figure 40. Residential Potential by End Use (Electricity Sales)

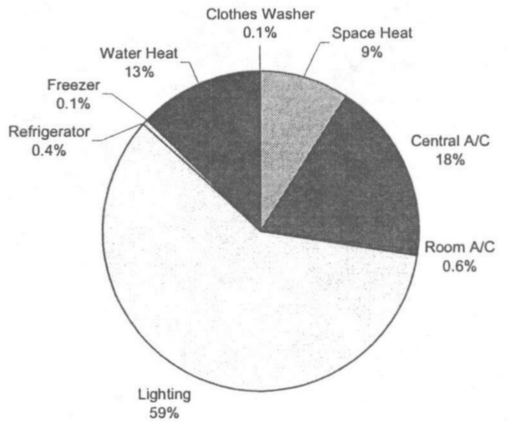


Figure 42. Residential Potential by End Use (Gas Sales)

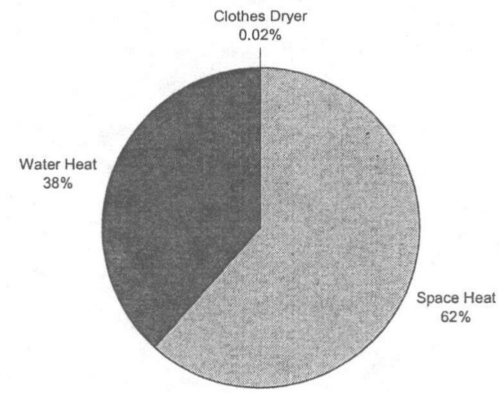
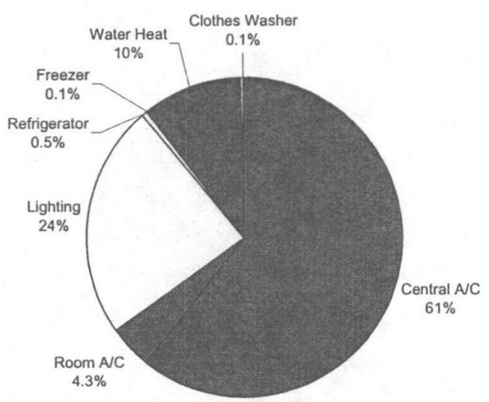


Figure 41. Residential Potential by End Use (Peak Demand)



Residential Sector Achievable Potential Cost-Effectiveness

- From a TRC perspective, the total net benefits to the state from energy efficiency improvements implemented from 2005-2015 in the residential sector are between $0.3 billion and $0.6 billion in net present value dollars.
- The TRC benefit-cost ratios for the three intervention scenarios are between 1.4 and 2.1.
- Table 25 shows the net present value of costs associated with residential sector programs.
- Table 26 shows the direct net benefits and benefit-cost ratios for each intervention scenario from a range of cost perspectives.
- The tables on the following pages present the net benefits and cost-effectiveness for each end use contributing to overall residential achievable potential.

Table 25. Net Present Value (Thousands) of Participant, Program Incentive, and Program Administrative Costs (Residential)

Scenario	Participant Costs	Program Incentives	Program Administration
Minimally Aggressive	$271,147	$67,787	$39,372
Moderately Aggressive	$683,568	$341,784	$247,718
Very Aggressive	$834,206	$834,206	$484,278

Table 26. Net Benefits (Billions) and Benefit-Cost Ratios for Residential Sector Achievable Potential Scenarios

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Minimally Aggressive	$0.3	2.1	$1.1	4.9	$0.5	6.0	-$0.7	0.5
Moderately Aggressive	$0.6	1.6	$2.7	5.0	$0.9	2.6	-$2.1	0.4
Very Aggressive	$0.5	1.4	$3.7	5.5	$0.5	1.4	-$3.3	0.4

Table 27. Net Benefits (Millions) and Benefit-Cost Ratios for Residential Achievable Potential by End Use (Minimally Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Residential Space Heat	$54	2.1	$172	5.1	$85	6.1	-$118	0.5
Residential Central A/C	$70	3.5	$174	8.2	$88	10.1	-$104	0.5
Residential Room A/C	$2	1.6	$6	3.8	$3	4.5	-$5	0.5
Residential Lighting	$161	1.8	$570	4.2	$293	5.2	-$409	0.5
Residential Hot Water	$50	2.7	$141	6.5	$69	7.7	-$91	0.5
Total	**$336**	**2.1**	**$1,063**	**4.9**	**$539**	**6.0**	**-$728**	**0.5**

Table 28. Net Benefits (Millions) and Benefit-Cost Ratios for Residential Achievable Potential by End Use (Moderately Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Residential Space Heat	$92	1.7	$397	5.3	$139	2.7	-$305	0.4
Residential Central A/C	$144	2.8	$426	8.2	$174	4.4	-$282	0.4
Residential Room A/C	$2	1.3	$16	4.0	$5	2.0	-$14	0.4
Residential Lighting	$273	1.4	$1,580	4.4	$508	2.3	-$1,307	0.4
Residential Hot Water	$91	2.2	$322	6.6	$120	3.4	-$231	0.4
Total	**$603**	**1.6**	**$2,741**	**5.0**	**$945**	**2.6**	**-$2,138**	**0.4**

Table 29. Net Benefits (Millions) and Benefit-Cost Ratios for Residential Achievable Potential by End Use (Very Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Residential Space Heat	$89	1.5	$576	5.7	$89	1.5	-$487	0.4
Residential Central A/C	$162	2.3	$598	8.6	$162	2.3	-$435	0.4
Residential Room A/C	$1	1.1	$23	4.4	$1	1.1	-$22	0.3
Residential Lighting	$125	1.1	$2,077	4.8	$125	1.1	-$1,953	0.3
Residential Hot Water	$97	1.8	$452	7.1	$97	1.8	-$355	0.4
Total	**$474**	**1.4**	**$3,726**	**5.5**	**$474**	**1.4**	**-$3,252**	**0.4**

Commercial Sector Achievable Potential

OVERVIEW

- By 2010, we project achievable potential in the commercial sector of between 3.3% and 9.6% of commercial electricity sales, 2.4% and 7.4% of commercial peak demand, and 3.4% and 9.5% of commercial gas sales (See Table 30).
- As noted above, the commercial sector is by far the most significant source of total electricity sales (43%) and peak demand (47%) potential. The sector's importance to overall gas potential is much less, representing only 29% of the total.
- The commercial sector has been segregated into eleven subsectors, defined by building type. These building types are the same as those defined in the EIA's energy consumption forecasts:
  - Education
  - Assembly
  - Food Sales
  - Food Service
  - Health Care
  - Lodging
  - Office – Large
  - Office – Small
  - Mercantile/Service
  - Warehouse
  - Other
- The large office, small office, and mercantile/service building types dominate electricity sales and peak demand potential, but natural gas savings potential is more evenly distributed among subsectors.

Table 30. 2010 Commercial Achievable Potential—Total Potential and Percent of 2010 Load

Load Type	Minimally Aggressive		Moderately Aggressive		Very Aggressive	
Reduction in Electricity Sales (MWh)	1,654,957	3.3%	3,725,692	7.5%	4,763,509	9.6%
Reduction in Peak Demand (MW)	229	2.4%	537	5.7%	698	7.4%
Reduction in Gas Sales (MMcf)	2,167	3.4%	4,928	7.7%	6,100	9.5%

COMMERCIAL SECTOR ACHIEVABLE POTENTIAL BY SUBSECTOR AND END USE

- Below are descriptions of the main end uses and building types contributing to commercial savings potential. Figures on the following pages show projections of commercial achievable potential and the relative shares of each end use and building type.
- **Electricity Sales**
  - The large office (22%), small office (13%), and mercantile/service (24%) subsectors are the principal sources of electricity savings potential.
  - Interior lighting is the largest portion of electricity sales potential, with a 35% share. These savings are derived from the installation of high-efficiency technologies in the linear fluorescent, incandescent, high-intensity discharge, and exit lighting technology types. Significant savings also exist in exterior lighting applications, which hold a 10% share of total potential.
  - Office equipment is the next most important segment of potential, making up 28% of the total. Measures for this end use principally include technologies designed to reduce electricity consumption when computers, monitors, printers, copiers, and other equipment are not in use.
  - Cooling (air conditioning) also makes up a significant percentage of potential, contributing 17% to the total.
- **Peak Demand**
  - Large office (16%), small office (14%), and mercantile/service (26%) building types also hold the most peak potential, though significant cooling savings in the lodging subsector propel it to a notably large share of potential as well (13%).
  - As is the case in the residential sector, cooling comprises the dominant share of peak demand potential, with 47% of the total.
  - In contrast to the residential sector, commercial interior lighting is used extensively during peak hours and contributes 41% to total commercial peak demand potential.
  - Despite a large contribution to overall peak usage, office equipment does not have as significant peak savings potential (8%). Because most office equipment measures save energy by reducing energy consumption while the equipment is not in use, savings potential during the peak period is small relative to overall electricity sales potential.
- **Gas Sales**
  - Gas sales potential is more evenly distributed among building types, with notable shares in the warehouse (16%), mercantile/service (15%), lodging (14%), and health care (14%) subsectors.
  - As in the residential sector, heating makes up the majority of gas savings potential, comprising 63% of the total.
  - A variety of hot water measures make up the remaining 37% of potential, with a negligible portion attributable to gas space cooling measures (0.4%).

Figure 43. Commercial Achievable Potential (Electricity Sales)

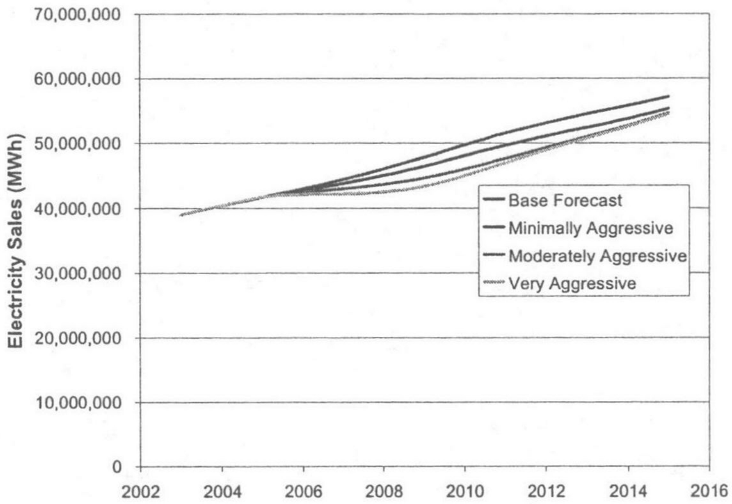


Figure 45. Commercial Achievable Potential (Gas Sales)

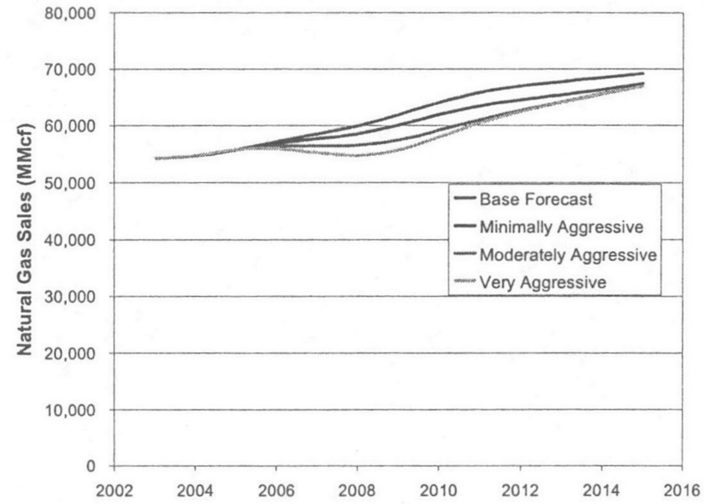


Figure 44. Commercial Achievable Potential (Peak Demand)

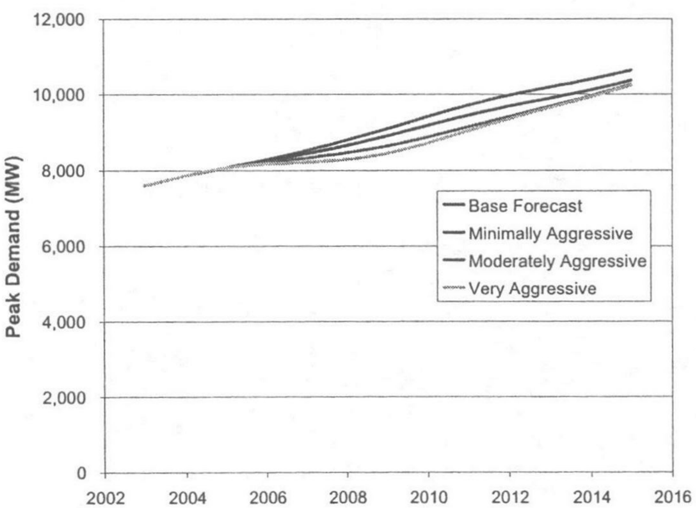


Figure 46. Commercial Potential by End Use (Electricity Sales)

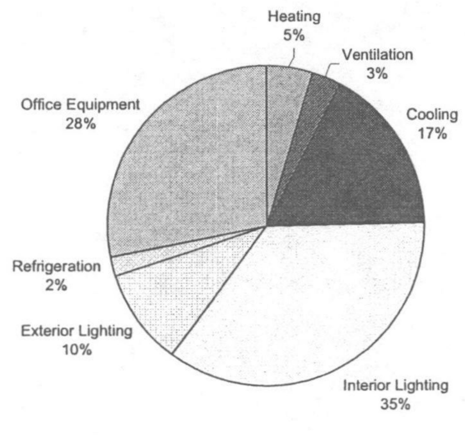


Figure 47. Commercial Potential by End Use (Peak Demand)

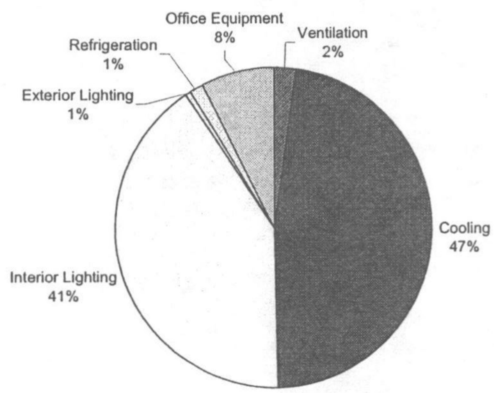


Figure 48. Commercial Potential by End Use (Gas Sales)

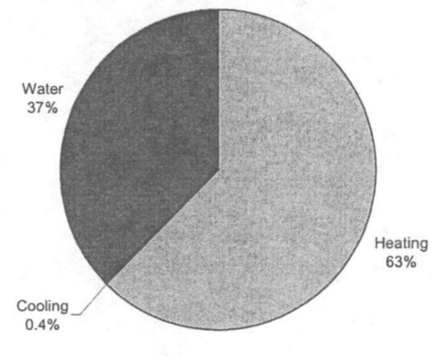


Figure 49. Commercial Potential by Building Type (Electricity Sales)

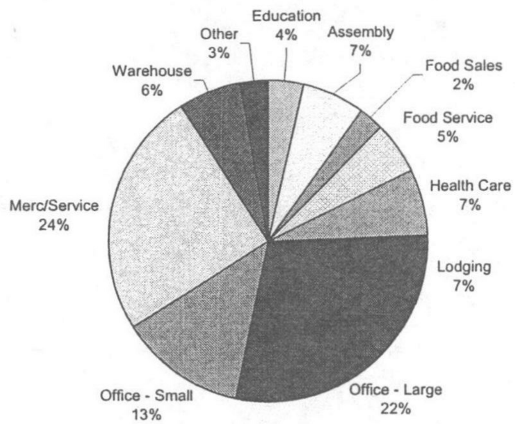


Figure 50. Commercial Potential by Building Type (Peak Demand)

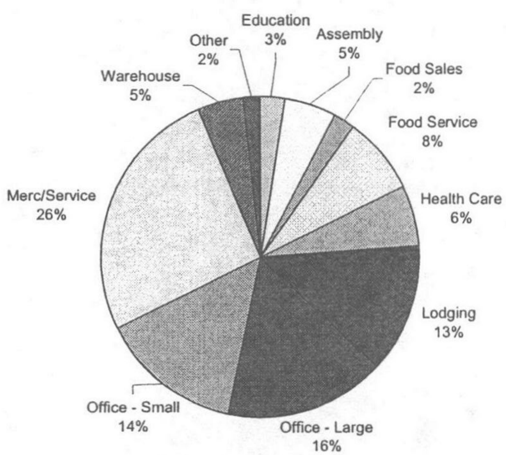
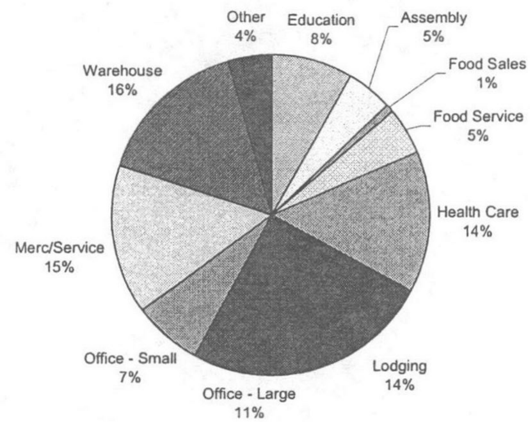


Figure 51. Commercial Potential by Building Type (Gas Sales)



COMMERCIAL SECTOR ACHIEVABLE POTENTIAL COST-EFFECTIVENESS

- From a TRC perspective, the total net benefits to the state from energy efficiency improvements implemented from 2005-2015 in the commercial sector are between $0.2 billion and $0.4 billion in net present value dollars.
- The TRC benefit-cost ratios for the three intervention scenarios are between 1.3 and 1.8.
- Table 31 shows the net present value of costs associated with commercial sector programs.
- Table 32 shows the direct net benefits and benefit-cost ratios for each intervention scenario from a range of cost perspectives.
- The tables on the following pages present the net benefits and cost-effectiveness for each end use contributing to overall commercial achievable potential.

Table 31. Net Present Value (Thousands) of Participant, Program Incentive, and Program Administrative Costs (Commercial)

Scenario	Participant Costs	Program Incentives	Program Administration
Minimally Aggressive	$278,819	$69,705	$34,829
Moderately Aggressive	$557,833	$278,917	$174,565
Very Aggressive	$703,990	$703,990	$353,116

Table 32. Net Benefits (Billions) and Benefit-Cost Ratios for Commercial Sector Achievable Potential Scenarios

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Minimally Aggressive	$0.2	1.8	$0.8	3.9	$0.5	5.4	-$0.6	0.5
Moderately Aggressive	$0.4	1.5	$1.7	4.1	$0.6	2.4	-$1.4	0.4
Very Aggressive	$0.3	1.3	$2.5	4.6	$0.3	1.3	-$2.2	0.4

Table 33. Net Benefits (Millions) and Benefit-Cost Ratios for Commercial Achievable Potential by End Use (Minimally Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Commercial Heating	$44	2.5	$111	5.3	$64	7.2	-$66	0.5
Commercial Ventilation	$8	1.8	$27	3.8	$15	5.8	-$18	0.5
Commercial Cooling	$54	3.0	$131	6.7	$71	8.7	-$77	0.5
Commercial Interior Lighting	$59	1.4	$297	3.0	$173	4.2	-$237	0.5
Commercial Exterior Lighting	$31	2.3	$87	5.0	$48	6.5	-$56	0.5
Commercial Refrigeration	$4	2.1	$12	4.7	$7	6.1	-$8	0.5
Commercial Office Equipment	$31	2.3	$100	5.9	$46	6.7	-$69	0.4
Commercial Hot Water	$14	1.5	$53	3.2	$32	4.3	-$39	0.5
Total	**$246**	**1.8**	**$818**	**3.9**	**$456**	**5.4**	**-$571**	**0.5**

Table 34. Net Benefits (Millions) and Benefit-Cost Ratios for Commercial Achievable Potential by End Use (Moderately Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Commercial Heating	$79	2.1	$246	5.5	$107	3.2	-$167	0.5
Commercial Ventilation	$14	1.6	$62	4.0	$24	2.6	-$48	0.5
Commercial Cooling	$98	2.5	$284	6.8	$122	3.9	-$186	0.5
Commercial Interior Lighting	$49	1.1	$630	3.1	$197	1.9	-$581	0.4
Commercial Exterior Lighting	$50	1.8	$179	5.2	$71	2.9	-$130	0.5
Commercial Refrigeration	$7	1.7	$28	4.9	$10	2.7	-$21	0.4
Commercial Office Equipment	$48	1.9	$201	6.1	$67	2.9	-$154	0.4
Commercial Hot Water	$16	1.2	$119	3.4	$41	2.0	-$103	0.4
Total	**$361**	**1.5**	**$1,750**	**4.1**	**$640**	**2.4**	**-$1,389**	**0.4**

Table 35. Net Benefits (Millions) and Benefit-Cost Ratios for Commercial Achievable Potential by End Use (Very Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Commercial Heating	$85	1.7	$356	5.9	$85	1.7	-$270	0.4
Commercial Ventilation	$14	1.4	$93	4.5	$14	1.4	-$79	0.4
Commercial Cooling	$108	2.1	$395	7.3	$108	2.1	-$287	0.4
Commercial Interior Lighting	-$13	1.0	$948	3.6	-$13	1.0	-$962	0.3
Commercial Exterior Lighting	$47	1.6	$250	5.6	$47	1.6	-$202	0.4
Commercial Refrigeration	$6	1.4	$41	5.4	$6	1.4	-$34	0.4
Commercial Office Equipment	$46	1.6	$274	6.5	$46	1.6	-$228	0.4
Commercial Hot Water	$6	1.1	$182	3.9	$6	1.1	-$177	0.4
Total	**$299**	**1.3**	**$2,538**	**4.6**	**$299**	**1.3**	**-$2,240**	**0.4**

Industrial Sector Achievable Potential

OVERVIEW

- By 2010, we project achievable potential in the industrial sector of between 2.2% and 6.6% of industrial electricity sales, 2.1% and 6.3% of industrial peak demand, and 1.5% and 4.6% of industrial gas sales (See Table 36).
- The industrial sector has been segregated into eleven subsectors, defined by NAICS code. These subsectors include the ten largest electricity consumers, according to EIA South Census Region data, and a compilation of all other load in other manufacturing and non-manufacturing industries:
  - 325-Chemicals
  - 331-Primary Metals
  - 322-Paper
  - 313-Textile Mills
  - 311-Food
  - 324-Petroleum and Coal Products
  - 326-Plastics and Rubber Products
  - 327-Nonmetallic Mineral Products
  - 336-Transportation Equipment
  - 332-Fabricated Metal Products
  - Other/Non-Manufacturing
- The chemical and primary metals industries are the most significant contributors to electricity sales and peak demand potential. The chemical industry is most dominant as a part of gas sales potential, comprising a 38% share of the total.

Table 36. 2010 Industrial Achievable Potential—Total Potential and Percent of 2010 Load

Load Type	Minimally Aggressive		Moderately Aggressive		Very Aggressive	
Reduction in Electricity Sales (MWh)	877,957	2.2%	2,070,740	5.2%	2,625,327	6.6%
Reduction in Peak Demand (MW)	140	2.1%	333	4.9%	423	6.3%
Reduction in Gas Sales (MMcf)	2,496	1.5%	6,097	3.6%	7,720	4.6%

Industrial Sector Achievable Potential by Subsector and End Use

- Below are descriptions of the main end uses and NAICS codes contributing to industrial savings potential. Figures on the following pages show projections of industrial achievable potential and the relative shares of each end use and NAICS code.
- Mirroring the custom nature of industrial processes, the measures considered for the process end uses in the industrial sector do not represent specific technologies or practices. Rather, based on extensive audit data collected from facilities targeted for their high energy consumption, the process measures modeled are designed to reflect a range of typical estimated implementation costs to achieve one unit of energy savings (i.e., $/kWh or $/Therm) in a certain end use.
- **Electricity Sales**
  - The chemical and primary metals industries, which are also the two largest industrial electricity consumers in Georgia according to EIA data for the South Census Region, make up the greatest single portions of electricity sales potential, with 17% and 15% shares respectively.
  - The process heating and boiler fuel (36%), process machine drive (32%), and process cooling (12%) end uses make up most of electricity savings potential in the industrial sector.
  - Non-process end uses including interior lighting (10%), HVAC (7%), and exterior lighting (3%) also contribute notably to total potential.
- **Peak Demand**
  - Peak demand savings potential is split among NAICS codes very similarly to electricity sales potential, with the chemical and primary metals industries making up 16% and 13% of total potential respectively.
  - End use distributions are also very similar to those in electricity sales potential. The HVAC end use, driven primarily by air conditioning savings, makes up a notable 19% of peak demand savings potential.
- **Gas Sales**
  - The chemical and petroleum/coal products industries contribute the most to total industrial gas sales savings potential, comprising 38% and 12% of potential respectively.
  - The process heating and boiler fuel end use makes up the vast majority of gas savings potential, with an 87% share.
  - Most of the remaining potential is derived from the HVAC end use, primarily heating, accounting for 11% of the total.

Figure 52. Industrial Achievable Potential (Electricity Sales)

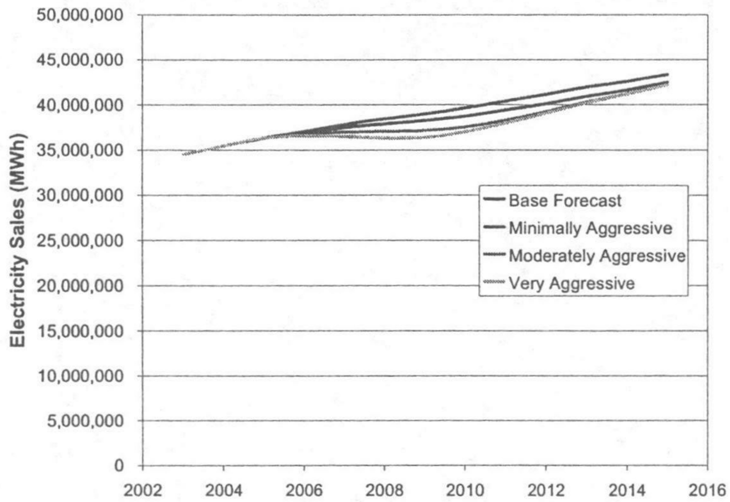


Figure 54. Industrial Achievable Potential (Gas Sales)

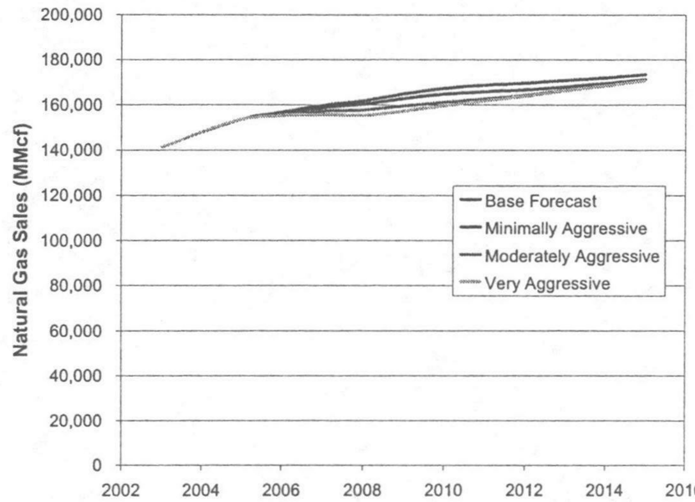


Figure 53. Industrial Achievable Potential (Peak Demand)

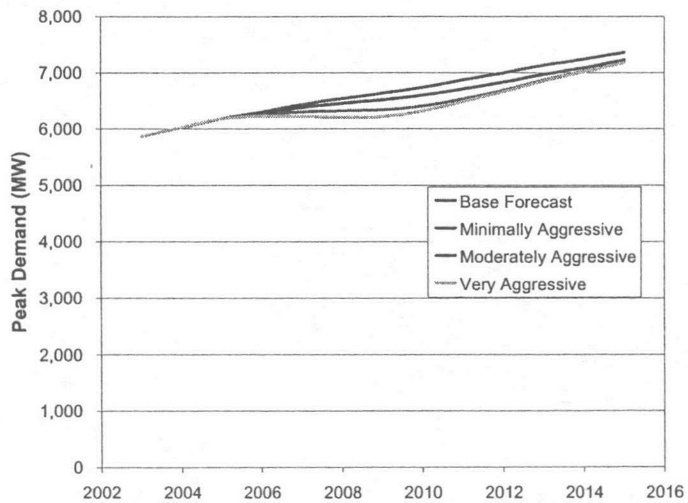


Figure 55. Industrial Potential by End Use (Electricity Sales)

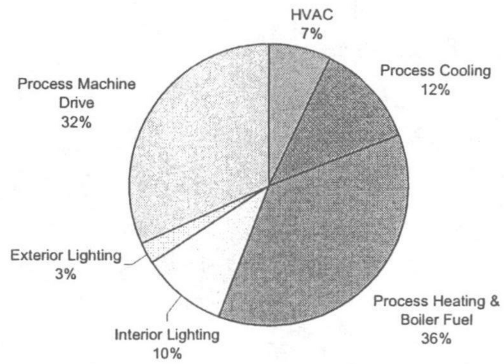


Figure 56. Industrial Potential by End Use (Peak Demand)

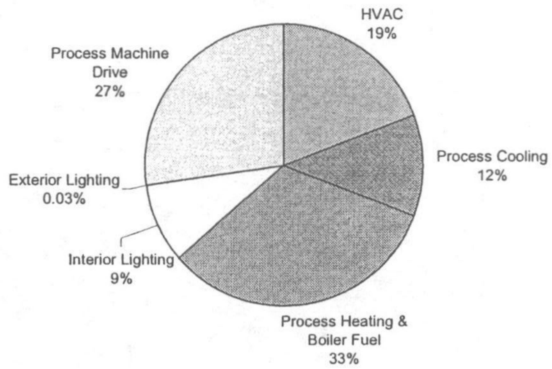


Figure 57. Industrial Potential by End Use (Gas Sales)

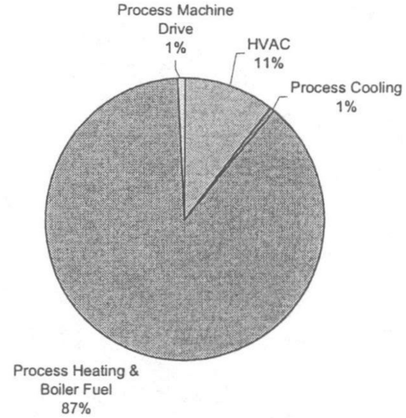


Figure 58. Industrial Potential by NAICS Code (Electricity Sales)

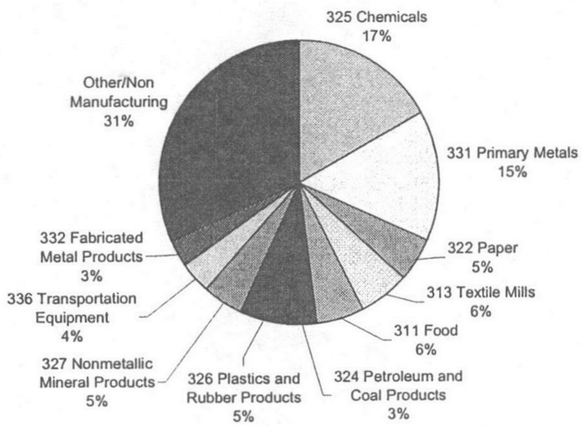


Figure 59. Industrial Potential by NAICS Code (Peak Demand)

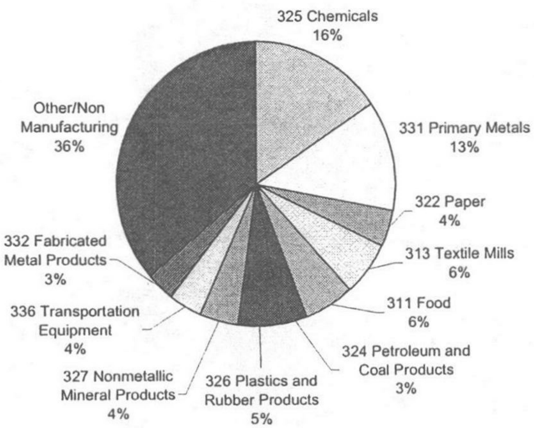
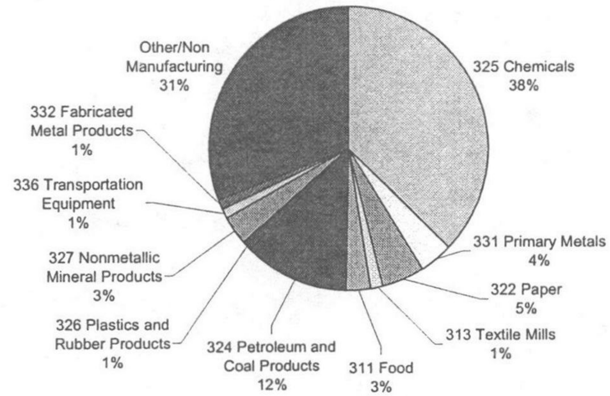


Figure 60. Industrial Potential by NAICS Code (Gas Sales)



Industrial Sector Achievable Potential Cost-Effectiveness

- From a TRC perspective, the total net benefits to the state from energy efficiency improvements implemented from 2005-2015 in the industrial sector are between $0.3 billion and $0.7 billion in net present value dollars.
- The TRC benefit-cost ratios for the three intervention scenarios are between 2.6 and 3.7.
- Table 36 shows the net present value of costs associated with industrial sector programs.
- Table 38 shows the direct net benefits and benefit-cost ratios for each intervention scenario from a range of cost perspectives.
- The tables on the following pages present the net benefits and cost-effectiveness for each end use contributing to overall industrial achievable potential.

Table 37. Net Present Value (Thousands) of Participant, Program Incentive, and Program Administrative Costs (Industrial)

Scenario	Participant Costs	Program Incentives	Program Administration
Minimally Aggressive	$105,893	$26,473	$14,991
Moderately Aggressive	$221,978	$110,989	$78,752
Very Aggressive	$287,771	$287,771	$163,516

Table 38. Net Benefits (Billions) and Benefit-Cost Ratios for Industrial Sector Achievable Potential Scenarios

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Minimally Aggressive	$0.3	3.7	$0.4	4.9	$0.4	10.8	-$0.09	0.8
Moderately Aggressive	$0.6	3.1	$0.9	5.1	$0.7	4.9	-$0.3	0.8
Very Aggressive	$0.7	2.6	$1.3	5.6	$0.7	2.6	-$0.6	0.7

Table 39. Net Benefits (Millions) and Benefit-Cost Ratios for Industrial Achievable Potential by End Use (Minimally Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Industrial HVAC	$13	1.7	$23	2.4	$25	4.9	-$10	0.8
Industrial Process Cooling	$31	5.0	$38	6.6	$36	14.5	-$7	0.9
Industrial Process Heating & Boiler Fuel	$187	4.8	$227	6.3	$219	13.8	-$40	0.9
Industrial Interior Lighting	$15	1.8	$25	2.4	$28	5.4	-$10	0.8
Industrial Exterior Lighting	$4	2.1	$6	3.0	$7	6.1	-$2	0.8
Industrial Process Machine Drive	$79	4.6	$96	6.0	$93	13.2	-$18	0.9
Total	**$329**	**3.7**	**$415**	**4.9**	**$408**	**10.8**	**-$86**	**0.8**

Table 40. Net Benefits (Millions) and Benefit-Cost Ratios for Industrial Achievable Potential by End Use (Moderately Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Industrial HVAC	$19	1.4	$56	2.6	$36	2.2	-$38	0.6
Industrial Process Cooling	$61	4.1	$82	6.8	$68	6.4	-$22	0.8
Industrial Process Heating & Boiler Fuel	$367	4.0	$496	6.6.	$412	6.3	-$128	0.8
Industrial Interior Lighting	$20	1.5	$55	2.6	$38	2.4	-$35	0.7
Industrial Exterior Lighting	$7	1.7	$14	3.2	$10	2.7	-$8	0.7
Industrial Process Machine Drive	$157	3.7	$218	6.2	$178	5.8	-$61	0.8
Total	**$630**	**3.1**	**$921**	**5.1**	**$741**	**4.9**	**-$291**	**0.8**

Table 41. Net Benefits (Millions) and Benefit-Cost Ratios for Industrial Achievable Potential by End Use (Very Aggressive Scenario)

Scenario	TRC		PCT		UCT		RIM	
	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio	Net Benefits	BC Ratio
Industrial HVAC	$13	1.2	$96	3.1	$13	1.2	-$83	0.5
Industrial Process Cooling	$73	3.5	$115	7.2	$73	3.5	-$42	0.7
Industrial Process Heating & Boiler Fuel	$443	3.4	$694	7.0	$443	3.4	-$251	0.7
Industrial Interior Lighting	$16	1.2	$90	3.0	$16	1.2	-$74	0.5
Industrial Exterior Lighting	$6	1.5	$22	3.7	$6	1.5	-$16	0.6
Industrial Process Machine Drive	$189	3.1	$311	6.6	$189	3.1	-$123	0.7
Total	**$739**	**2.6**	**$1,328**	**5.6**	**$739**	**2.6**	**-$589**	**0.7**

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
	)	
Early Site Permit for Plant Vogtle ESP Site	)	
	)	

CERTIFICATE OF SERVICE

I hereby certify that the foregoing Petition to Intervene was sent this 11th day of December, 2006 via the method indicated to each of the following:

Secretary of the Commission (Original via U.S. Mail)
United States Regulatory Commission
Washington, DC 20555-0001
Attention: Rulemaking and Adjudications Staff

Office of General Counsel (1 copy via U.S. Mail)
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Office of the Secretary (via federal express)
Sixteenth Floor
One White Flint North
11555 Rockville Pike
Rockville, Maryland 20852

Betina C. Terry
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P.O. Box 1295
Birmingham, AL 35201-1295

Stanford M. Blanton, Esq.
Balch and Bingham
P.O. Box 306
Birmingham, AL 35201

Mary Maclean D. Asbill

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
Early Site Permit for Plant Vogtle ESP Site	)	December 11, 2006

NOTICE OF APPEARANCE FOR LAWRENCE D. SANDERS, ESQ.

Pursuant to 10 C.F.R. § 2.7133(b), Lawrence D. Sanders, Esquire, hereby enters an appearance on behalf of Center for a Sustainable Coast, Savannah Riverkeeper, Southern Alliance for Clean Energy ("SACE"), Atlanta Women's Action for New Directions ("WAND"), and Blue Ridge Environmental Defense League ("BREDL) provides the following information:

1. I am an attorney licensed to practice law in Georgia and California. My offices are located at Turner Environmental Law Clinic, Emory University School of Law, 1301 Clifton Road, Atlanta, Georgia 30322. Telephone (404) 712-8008.
2. I have been appointed by the petitioners to jointly represent these organizations in this proceeding.

Lawrence D. Sanders, Esq.

12/11/2006
Date

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
Early Site Permit for Plant Vogtle ESP Site	)	December 11, 2006

NOTICE OF APPEARANCE FOR MARY MACLEAN D. ASBILL, ESQ.

Pursuant to 10 C.F.R. § 2.7133(b), Mary Maclean D. Asbill, Esquire, hereby enters an appearance on behalf of Center for a Sustainable Coast, Savannah Riverkeeper, Southern Alliance for Clean Energy ("SACE"), Atlanta Women's Action for New Directions ("WAND"), and Blue Ridge Environmental Defense League ("BREDL) provides the following information:

3. I am an attorney licensed to practice law in Georgia. My offices are located at Turner Environmental Law Clinic, Emory University School of Law, 1301 Clifton Road, Atlanta, Georgia 30322. Telephone (404) 727-3432.
4. I have been appointed by the petitioners to jointly represent these organizations in this proceeding.

Mary Maclean D. Asbill, Esq.

12/11/2006
Date

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE SECRETARY

In the Matter of	)	
	)	Docket No. 52-011
Southern Nuclear Operating Company, Inc.	)	
	)	
Early Site Permit for Plant Vogtle ESP Site	)	December 11, 2006

NOTICE OF APPEARANCE FOR DIANE CURRAN

Pursuant to 10 C.F.R. § 2.7133(b), Diane Curran Esquire, hereby enters an appearance on behalf of Center for a Sustainable Coast, Savannah Riverkeeper, Southern Alliance for Clean Energy ("SACE"), Atlanta Women's Action for New Directions ("WAND"), and Blue Ridge Environmental Defense League ("BREDL) provides the following information:

5. I am an attorney licensed to practice law in the District of Columbia. My offices are located at Harmon, Curran, Spielberg & Eisenberg, L.L.P., 1726 M Street, N.W., Suite 600, Washington, D.C., 20036. Telephone (202) 328-3500.
6. I have been appointed by the petitioners to jointly represent these organizations in this proceeding.

Diane Curran
Diane Curran, Esq. by MM/DD

12/11/2006
Date