NUREG–1437
Vol. 1

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Main Report

Final Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research

AVAILABILITY NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 2120 L Street, NW., Lower Level, Washington, DC 20555-0001
2. The Superintendent of Documents, U.S. Government Printing Office, P. O. Box 37082, Washington, DC 20402-9328
3. The National Technical Information Service, Springfield, VA 22161-0002

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC bulletins, circulars, information notices, inspection and investigation notices; licensee event reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the Government Printing Office: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, international agreement reports, grantee reports, and NRC booklets and brochures. Also available are regulatory guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG-series reports and technical reports prepared by other Federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal articles, and transactions. *Federal Register* notices, Federal and State legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Office of Administration, Distribution and Mail Services Section, U.S. Nuclear Regulatory Commission, Washington DC 20555-0001.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, Two White Flint North, 11545 Rockville Pike, Rockville, MD 20852-2738, for use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018-3308.

NUREG-1437
Vol. 1

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Main Report

Final Report

Manuscript Completed: April 1996
Date Published: May 1996

Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

ABSTRACT

The Nuclear Regulatory Commission (NRC) anticipates that it will receive applications for renewal of the operating licenses of a significant portion of existing nuclear power plants. This Generic Environmental Impact Statement (GEIS) examines the possible environmental impacts that could occur as a result of renewing licenses of individual nuclear power plants under 10 CFR 54. The GEIS, to the extent possible, establishes the bounds and significance of these potential impacts. The analyses in the GEIS encompass all operating light-water reactors. For each type of environmental impact the GEIS attempts to establish generic findings covering as many plants as possible. While plant and site-specific information is used in developing the generic findings, the NRC does not intend for the GEIS to be a compilation of individual plant environmental impact statements.

This GEIS has three principal objectives: (1) to provide an understanding of the types and severity of environmental impacts that may occur as a result of license renewal of nuclear power plants under 10 CFR Part 54, (2) to identify and assess those impacts that are expected to be generic to license renewal, and (3) to support a rulemaking (10 CFR Part 51) to define the number and scope of issues that need to be addressed by the applicants in plant-by-plant license renewal proceedings. To accomplish these objectives, the GEIS makes maximum use of environmental and safety documentation from original licensing proceedings and information from state and federal regulatory agencies, the nuclear utility industry, the open literature, and professional contacts.

CONTENTS

FIGURES

TABLES

TABLES

ACRONYMS AND ABBREVIATIONS

ADS	automatic depressurization system
AEA	Atomic Energy Act of 1954
AEC	U.S. Atomic Energy Commission
AEO	*Atomic Energy Outlook 1990*
AFUDC	allowance for funds used during construction
AGA	American Gas Association
AGR	advanced gas-cooled reactor
AIRFA	American Indian Religious Freedom Act
ALARA	as low as reasonably achievable
ALI	annual limits on intake
A/m	amps per meter
AML	acute myelogenous leukemia
ANO	Arkansas Nuclear One
ANOVA	analysis of variance
ANSI	American National Standards Institute
AP&L	Arkansas Power and Light
ASME	American Society of Mechanical Engineers
ATWS	anticipated transit without scram
BAU	business-as-usual
BEIR	Biological Effects of Ionizing Radiation
BIG/GT	biomass-gasifier/gas turbine
BRC	below regulatory concern
BSD	Burlington School District
B&W	Babcock and Wilcox
BWR	boiling-water reactor
°C	degrees centigrade (Celsius)
CAA	Clean Air Act
CAAA	Clean Air Act Amendments of 1990
CCC	California Coastal Commission
CDE	committed dose equivalent
CDF	core damage frequencies
CE	Combustion Engineering
CEDE	committed effective dose equivalent
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	chlorofluorocarbon
CFR	Code of Federal Regulations
Ci	curie
CML	chronic myelogenous leukemia
CMSA	consolidated metropolitan statistical area
CNS	central nervous system
CO	carbon monoxide

ConEd	Consolidated Edison
CPI	containment performance improvement
CPW	continuous polymer wire
CRAC	Consequence (of) Reactor Accident Code
CRD	control rod drive
CWA	Clean Water Act of 1977
CZMA	Coastal Zone Management Act
DAC	derived air concentrations
DAW	dry active waste
DE	dose equivalent
DECON	a nuclear plant decommissioning method
DER	Florida Department of Environmental Regulation
DFA	direct fluorescent antibody
DMBA	dimethylbenzanthracene
DNR	Florida Department of Natural Resources
DO	dissolved oxygen
DOE	U.S. Department of Energy
DOI	Department of Interior
DRBC	Delaware River Basin Commission
DREF	dose rate effectiveness factor
DRI	Data Resources Incorporated
DSC	dry shielded canister
DSM	demand-side management
E	electric field
EA	environmental assessment
EAB	exclusion area boundary
EDE	effective dose equivalent
EEC	European Economic Community
EEDB	Energy Economic Data Base
EEG	electroencephalogram
EEI	Edison Electric Institute
E-field	electric-field
EI	exposure index
EIA	Energy Information Administration
EIS	environmental impact statement
EKG	electrocardiogram
ELF	extremely low frequency
EM	electromagnetic
EMF	electromagnetic field
ENTOMB	a nuclear plant decommissioning method
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act of 1992
EPCRA	Emergency Planning and and Community Right-to-Know Act

EPRI	Electric Power Research Institute
EPZ	emergency planning zone
ESA	Endangered Species Act
ESEERCO	Empire State Electric Energy Research Corporation
FDA	U.S. Food and Drug Administration
FEMA	U.S. Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FES	final environmental statement
FFCA	Federal Facilities Compliance Agreement
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FIS	federal interim storage
FONSI	finding of low significant impact
FPC	Florida Power Commission
FP&L	Florida Power & Light
FR	Federal Register
FSAR	final safety analysis report
FWCA	Fish and Wildlife Coordination Act
FWS	U.S. Fish and Wildlife Service
GBD	gas bubble disease
GCHWR	gas-cooled heavy-water-moderated reactor
GCR	gas-cooled reactor
GE	General Electric Company
GEIS	generic environmental impact statement
$g/m^2/s$	gallons per square meter per second
GNP	gross national product
GNSI	General Nuclear Systems, Inc.
GPU	General Public Utilities Corporation
GRI	Gas Research Institute
GTCC	greater-than-class-C
GW	gigawatt
GWd	gigawatt-days
HC	hydrocarbons
HL&P	Houston Lighting and Power Company
HLW	high-level radioactive waste
HP	health physics
HPOF	high-pressure oil-filled
HRS	hazard ranking system
HSM	horizontal storage module
HSWA	Hazardous and Solid Waste Amendments of 1984
HWR	heavy-water reactor
ICRP	International Commission on Radiological Protection
IGSCC	intergranular stress-cracking corrosion

IMP	intramembranous protein particle
INIRC	International Non-Ionizing Radiation Protection Association
INPO	Institute of Nuclear Power Operations
IOR	ion exchange resin
IPA	integrated plant assessment
IPE	individual plant examination
IRPA	International Radiation Protection Association
ISFSI	independent spent-fuel storage installation
ISI	in-service inspection
ISTM	inspection, surveillance, testing, and maintenance
kV	kilovolt
kV/m	kilovolts per meter
kW	kilowatt
kWh	kilowatt-hour
LD	Legionnaires' disease
LDR	land disposal restrictions
LDSD	Lower Dauphin School District
LET	linear energy transfer
LLRWPAA	Low-Level Radioactive Waste Policy Amendments Act of 1985
LLW	low-level radioactive waste
LMFBR	liquid-metal first breeder reactor
LOCA	loss-of-coolant accident
LOS	level of service
LPGS	Liquid Pathway Generic Study
LPZ	low population zone
LWR	light-water reactor
m	meter
mA	milliamperes
MACCS	MELCOR Accident Consequence Code System
MANOVA	multivariate analyses of covariance
MAP	Methodologies Applications Program
MASD	Middletown Area School District
mCi	milliCurie
MCLG	maximum contaminant goal levels
MDNR	Maryland Department of Natural Resources
MFD	magnetic flux density
mG	milligauss
mM	millimole
MMPA	Marine Mammals Protection Act
MPC	maximum permissible concentration
MPRSA	Marine Protection, Research, and Sanctuaries Act
MPOB	maximum permissible organ burden
MRC	Marine Review Committee

mrem	millirem
MRS	monitored retrievable storage
m^3/s	cubic meters per second
MSA	metropolitan statistical area
MSW	municipal solid waste
mT	millitesla
MTIHM	metric tons of initial heavy metal
MTU	metric tons of uranium
mV/m	millivolts per meter
MW	megawatt
MWd	megawatt-days
MW(e)	megawatt (electrical)
MW(t)	megawatt (thermal)
MYL	middle year of license
MYR	middle year of relicense
µg/g	micrograms per gram
µm	micron
NAA	nonattainment area
NAAQS	National Ambient Air Quality Standards
NAS	National Academy of Sciences
NBS	National Bureau of Standards (now NIST)
NCA	National Coal Association
NCRP	National Council on Radiation Protection and Measurements
NEC	normalized expected cost
NEPA	National Environmental Policy Act of 1969
NERC	North American Electric Reliability Council
NESC	National Electric Safety Code
NESHAP	National Emission Standards for Hazardous Air Pollutants
NGS	nuclear generating station
NHPA	National Historic Preservation Act of 1966
NIEHS	National Institute of Environmental Health Sciences
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NLF	normalized latent facility
NMFS	National Marine Fisheries Service
NMR	nuclear magnetic resonance
NO_x	nitrogen oxide(s)
NPA	National Planning Association
NPDES	National Pollutant Discharge Elimination System
NPP	nuclear power plant
NRC	U.S. Nuclear Regulatory Commission
NSPS	new source performance standards
NSSS	nuclear steam supply system
NTD	normalized total dose
NUHOMS	Nutech Horizontal Modular System

NUMARC	Nuclear Utilities Management and Resources Council
NUREG	an NRC reports category
NUS	NUS Corporation
NWPA	Nuclear Waste Policy Act of 1982
NYSDEC	New York State Department of Environmental Conservation
ODC	ornithine decarboxylase
OHMS	hydroxy melatonin sulfate
OL	operating license
O&M	operation and maintenance
ONS	Oconee Nuclear Station
OPEC	Organization of Petroleum Exporting Countries
OR	odds ratio
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OTA	Office of Technology Assessment
OTEC	ocean thermal energy conversion
PAME	primary amoebic meningoencephalitis
PASNY	Power Authority for the State of New York
PCB	polychlorinated biphenyl
PG&E	Pacific Gas and Electric
pH	hydrogen-ion concentration
PHWR	pressurized heavy-water reactor
PLEX	plant life extension
PM	particulate matter
PMR	proportionate mortality ratios
ppm	parts per million
PSD	prevention of significant deterioration
PRA	probabilistic risk assessment
PTH	parathyroid hormone
PURPA	Public Utility Regulatory Policies Act of 1978
PURTA	Public Utilities Realty Tax Assessment of 1970
PV	solar photovoltaic
PWR	pressurized-water reactor
QA	quality assurance
RBE	relative biological effectiveness
RCB	reactor containment building
RCRA	Resource Conservation and Recovery Act of 1976
RD&D	1. research, design, and development 2. research, development, and demonstration
RERF	Radiation Effects Research Council
RET	renewable energy technology
RF	radio frequency

RHR	residual heat removal
RIMS	Regional Industrial Multiplier System
rms	root mean square
ROW	right(s) of way
RPV	reactor pressure vessel
RRY	reference reactor year
RSD	Russellville (Ark.) School District
RSS	Reactor Safety Study
RV	recreational vehicle
RY	reactor-year
SAFSTOR	a nuclear plant decommissioning method
SAMDA	severe accident mitigation design alternative
SAND	Data Resource Incorporated's detailed electricity sector model
SAND NUPLEX	SAND generating capacity projections
SAR	safety analysis report
SARA	Superfund Amendments and Reauthorization Act
SCE	Southern California Edison
SCM	Surface Compartment Model
SDG&E	San Diego Gas & Electric Company
SDWA	Safe Drinking Water Act
SEA	Science and Engineering Associates, Inc.
SER	safety evaluation report
SERI	Solar Energy Research Institute
SEV	state equalized value
SF	spent fuel
SHPO	state historic preservation office
SI	International System
SIR	standardized incidence ratio
SLB	shallow land burial
SMR	standardized mortality ratio
SMITTR	surveillance, on-line monitoring, inspections, testing, trending, and recordkeeping
SMSA	standard metropolitan statistical area
SO_2	sulfur dioxide
SOK	San Onofre kelp bed
SONGS	San Onofre Nuclear Generating Station
SRBC	Susquehanna River Basin Commission
SSC	systems, structures, and components
t	metric tons
TDE	total dose equivalent
TDS	total dissolved solids
TEDE	total effective dose equivalent
TMI	Three Mile Island (nuclear plant)
TRU	transuranic

TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
UCB	upper confidence bound
UFC	uranium fuel cycle
UHV	ultra-high voltage
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
USD	Unified School District
USGS	U.S. Geological Survey
USI	unresolved safety issue
VDT	video display terminal
VR	volume reduction
VRF	volume reduction factor
W	watt
WCGS	Wolf Creek Generating Station
WHO	World Health Organization
WNP-2	Washington Nuclear Project
WTE®	Whole Tree Energy®

EXECUTIVE SUMMARY

This Generic Environmental Impact Statement (GEIS) for license renewal of nuclear power plants was undertaken to (1) assess the environmental impacts that could be associated with nuclear power plant license renewal and an additional 20 years of operation of individual plants and (2) provide the technical basis for an amendment to the Nuclear Regulatory Commission's (NRC's) regulations, 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," with regard to the renewal of nuclear power plant operating licenses. The rule amendment and this document were initiated to enhance the efficiency of the license renewal process by documenting in this GEIS and codifying in the Commission's regulations the environmental impacts that are well understood.

Under NRC's environmental protection regulations in 10 CFR Part 51, renewal of a nuclear power plant operating license is identified as a major federal action significantly affecting the quality of the human environment, and thus an environmental impact statement (EIS) is required for a plant license renewal review. The EIS requirements for a plant-specific license renewal review are specified in 10 CFR Part 51. Operating licenses may be renewed for up to 20 years beyond the 40-year term of the initial license. License renewal applicants perform evaluations and assessments of their facility to provide sufficient information for the NRC to determine whether continued operation of the facility during the renewal term will endanger public health and safety or the environment. The assessments also help to determine what activities and modifications are necessary at the time of license renewal and throughout the renewal term to ensure continued safe operation of the plant. Most utilities are expected to begin preparation for license renewal about 10 to 20 years before expiration of their original operating licenses. For the analysis in this GEIS, the staff anticipates that plant refurbishment undertaken specifically for license renewal would probably be completed during normal plant outage cycles, beginning 8 years before the original license expires, and during one longer outage, if a major refurbishment item is involved.

The Commission will act on an application for license renewal submitted by a licensee of an operating nuclear power plant. Although a licensee must have a renewed license to operate a plant beyond the term of the existing operating license, the possession of that license is just one of a number of conditions that must be met for the licensee to continue plant operation during the term of the renewed license. If the Commission grants a license renewal for a plant, state regulatory agencies and the owners of the plant would ultimately decide whether the plant will continue to operate based on factors such as need for power or other matters within the state's jurisdiction or the purview of the owners. Economic considerations will play a primary role in the decision made by state regulatory agencies and the owners of the plant. Thus, for license renewal reviews, the Commission has adopted the following definition of purpose and need:

> The purpose and need for the proposed action (renewal of an operating license) is to provide an option that allows for power generation capability beyond the term of a current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by State, utility, and, where authorized, Federal (other than NRC) decisionmakers.

In Chapter 8, the Commission considers the environmental consequences of the no-action alternative (i.e., denying a license renewal application) and the environmental consequences of the various alternatives for replacing lost generating capacity that would be available to a utility and other responsible energy planners. No conclusions are made in this document about the relative environmental consequences of license renewal or the construction and operation of alternative facilities for generating electric energy. The information in the GEIS is available for use by the NRC and the licensee in performing the site-specific analysis of alternatives. This information will be updated periodically, as appropriate.

The GEIS summarizes the findings of a systematic inquiry into the potential environmental consequences of renewing the licenses of and operating individual nuclear power plants for an additional 20 years. The inquiry identifies the attributes of the nuclear power plants, such as major features and plant systems, and the ways the plants can affect the environment. The inquiry also identifies the possible refurbishment activities and modifications to maintenance and operating procedures that might be undertaken given the requirements of the safety review as provided for in the Commission's regulations in 10 CFR Part 54, or given a utility's motivation to increase economic efficiency. Two scenarios were developed to identify possible initiators of environmental impacts from the possible set of refurbishment activities and continuation of plant operation during the renewal term. One scenario was developed as a typical but somewhat conservative scenario for license renewal, intended to be representative of the type of program that many licensees seeking license renewal might implement. The other scenario is highly conservative, encompassing considerably more activities, and is intended to characterize a reasonable upper bound of impact initiators that might result from license renewal.

The general analytical approach to each environmental issue is to (1) describe the activity that affects the environment, (2) identify the population or resource that is affected, (3) assess the nature and magnitude of the impact on the affected population or resource, (4) characterize the significance of the effect for both beneficial and adverse effects, (5) determine whether the results of the analysis apply to all plants, and (6) consider whether additional mitigation measures would be warranted for impacts that would have the same significance level for all plants.

A standard of significance was established for assessing environmental issues; and, because significance and severity of an impact can vary with the setting of a proposed action, both "context" and "intensity" as defined in the Council on Environmental Quality regulations (40 CFR 1508.27) were considered. With these standards as a basis, each impact was assigned to one of three significance levels:

Small: For the issue, environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.

Moderate: For the issue, environmental effects are sufficient to alter noticeably but not to destabilize important attributes of the resource.

Large: For the issue, environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

The discussion of each environmental issue in the GEIS includes an explanation of how the significance category was determined. For issues in which probability of occurrence is a key consideration (i.e., accident consequences), the probability of occurrence is factored into the determination of significance. In determining the significance levels, it is assumed that ongoing mitigation measures would continue and that mitigation measures employed during plant construction would be employed during refurbishment, as appropriate. The potential benefits of additional mitigation measures are not considered in determining significance levels.

In addition to determining the significance of environmental impacts associated with an issue for that issue, a determination was made whether the analysis in the GEIS could be applied to all plants and whether additional mitigation measures would be warranted. The categories to which an issue may be assigned follow.

Category 1: For the issue, the analysis reported in the GEIS has shown the following:

(1) the environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics;
(2) a single significance level (i.e., small, moderate, or large) has been assigned to the impacts (except for collective off-site radiological impacts from the fuel cycle and from high-level-waste and spent-fuel disposal); and
(3) mitigation of adverse impacts associated with the issue has been considered in the analysis, and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

Category 2: For the issue, the analysis reported in the GEIS has shown that one or more of the criteria of Category 1 cannot be met, and therefore, additional plant-specific review is required.

This final GEIS assesses 92 environmental issues. Sixty-eight of these issues are found to be Category 1 and are identified in 10 CFR Part 51 as not requiring additional plant-specific analysis. Guidance on the analyses required for each of the other 24 issues is provided in 10 CFR Part 51. A summary of the findings for the 92 environmental issues is provided in Table 9.1 of this GEIS and summarized in narrative below.

IMPACTS OF REFURBISHMENT

- On-site land use impacts are expected to be of small significance at all sites. Temporary disturbance of land may be mitigated by restoration to its original condition after refurbishment. This is a Category 1 issue.

- Nuclear power plant atmospheric emissions would either remain constant during refurbishment or decrease if the plant were partially or totally shut down. Small quantities of fugitive dust and gaseous exhaust emissions from motorized equipment operation during construction and refurbishment would temporarily increase ambient concentrations of particulate matter and gaseous pollutants in the vicinity of the activity but would not be expected to measurably affect ambient concentrations of regulated pollutants off-site. Additional exhaust emissions from the vehicles of up to 2300 personnel could be cause for some concern in geographical areas of poor or marginal air quality, but a general conclusion about the significance of the potential impact cannot be drawn without considering the compliance status of each site and the numbers of workers to be employed during the outage. This is a Category 2 issue.

- Proven erosion control measures such as best management practices are expected to be implemented at all plants and to minimize impacts to local water quality from runoff in disturbed areas. Consequently, impacts of refurbishment on surface water quality are expected to be of small significance at all plants. Because the effects of refurbishment are considered to be of small significance and potential mitigation measures are likely to be costly, the staff does not consider implementation of mitigation measures beyond best management practices to be warranted. This is a Category 1 issue.

- Additional water requirements during construction and refurbishment would be a small fraction of cooling water requirements of the operating power plant. If the plant were partially or totally shut down, cooling water use would decline. Water use during refurbishment is expected to have impacts of small significance on the local water supply. The only potential mitigation for any increase in water consumption would be to acquire the additional water from some other source. However, because this approach would provide very little, if any, environmental benefit and would be costly, the staff does not consider implementation of additional mitigation to be warranted. This is a Category 1 issue.

- Deep excavations and site dewatering would not be required during refurbishment. Consequently, the impacts of refurbishment on groundwater would be of small significance at all sites. No additional mitigation measures would be warranted because there would be no adverse impacts to mitigate. This is a Category 1 issue.

- Effluent discharges from the cooling system of a nuclear power plant would either remain constant during refurbishment or decrease if the plant were partially or totally shut down. Effects of changes in water withdrawals and discharges during refurbishment would be of small significance. No additional mitigation measures beyond those implemented during the current license term would be warranted because there would be no adverse impacts to mitigate. This is a Category 1 issue.

- The small on-site change in land use associated with refurbishment and construction could disturb or eliminate a small area of terrestrial habitat [up to 4 ha (10 acres)]. The significance of the loss of habitat depends on the importance of the plant or animal species that are displaced and on the availability of nearby replacement habitat. Impacts would be potentially significant only if they involved wetlands, staging or resting areas for large numbers of waterfowl, rookeries, restricted wintering areas for wildlife, communal roost sites, strutting or breeding grounds for gallinaceous birds, or rare plant community types. Because ecological impacts cannot be determined without considering site- and project-specific details, the potential significance of those impacts cannot be determined generically. This is a Category 2 issue.

- Because of refurbishment-related population increases, impacts on housing could be of moderate or large significance at sites located in rural and remote areas, at sites located in areas that have experienced extremely slow population growth (and thus slow or no growth in housing), or where growth control measures that limit housing development are in existence or have recently been lifted. This is a Category 2 issue.

- Tax impacts, which involve small to moderate increases in the direct and indirect tax revenues paid to local jurisdictions, are considered beneficial in all cases.

- In the area of public services, in-migrating workers could induce impacts of small to large significance to education, with the larger impacts expected to occur in sparsely populated areas. Impacts of small to moderate significance may occur to public utilities at some sites. Transportation impacts could be of large significance at some sites. These socioeconomic issues are Category 2.

- The impacts of refurbishment on other public services (public safety, social services, and tourism and recreation) are expected to be of small significance at all sites. No additional mitigation measures beyond those implemented during the current license term would be warranted because mitigation would be costly and the benefits would be small. These are Category 1 issues.

- In-migrating workers could induce impacts of small to moderate significance to off-site land use. The larger impacts are expected to occur in sparsely populated areas. This is a Category 2 issue.

- Based on the findings at the case study sites, refurbishment-related economic effects would range from small benefits to moderate benefits at all nuclear power plant sites. No adverse effects to economic structure would result from refurbishment-related employment.

- Site-specific identification of historic and archaeological resources and determination of impacts to them must occur during the consultation process with the State Historic Preservation Office (SHPO) as mandated by the National Historic Preservation Act. Impacts to historic resources could be large if the SHPO determines that significant historic resources would be disturbed or their historic character would be altered by plant refurbishment activities. The significance of potential impacts to historic and archaeological resources cannot be determined generically. This is a Category 2 issue.

- The impact on aesthetic resources is found to be of small significance at all sites. Because there will be no readily noticeable visual intrusion, consideration of mitigation is not warranted. This is a Category 1 issue.

- Radiation impacts to members of the public are considered to be of small significance because public exposures are within regulatory limits. Also, the estimated cancer risk to the average member of the public is much less than 1×10^{-6}. Because current mitigation practices have resulted in declining public radiation doses for nearly two decades, additional mitigation is not warranted. The impact on human health is a Category 1 issue.

- Occupational radiation exposure during refurbishment meets the standard of small significance. Because the as-low-as-reasonably-achievable (ALARA) program continues to reduce occupational doses, no additional mitigation program is warranted. This is a Category 1 issue.

- The significance of potential impacts to threatened and endangered species cannot be determined generically because compliance with the Endangered Species Act cannot be assessed without site-specific consideration of potential effects on threatened and endangered species. This is a Category 2 issue.

IMPACTS OF OPERATION

- It is not possible to reach a conclusion about the significance of potential impacts to threatened and endangered species at this time because (1) the significance of impacts on such species cannot be assessed without site- and project-specific information that will not be available until the time of license renewal and (2) additional species that are threatened with extinction and that may be adversely affected by plant operations may be identified between the present and the time of license renewal. This is a Category 2 issue.

- The staff examined nine aspects of water quality that might be affected by power plant operations: current patterns at intake and discharge structures, salinity gradients, temperature effects on sediment transport, altered thermal stratification of lakes, scouring from discharged cooling water, eutrophication, discharge of biocides, discharge of other chemical contaminants (e.g., metals), and discharge of sanitary wastes. Open-cycle cooling systems are more likely than other cooling systems to have such effects because they withdraw and discharge very large volumes of water; however, the impacts for each of these effects were found to be of small significance for all plants, regardless of cooling system type. For each type of impact, the staff considered potential mitigation measures but found that none were warranted because they would be costly and would have very small environmental benefits. These are Category 1 issues.

- The staff found no potential for water use conflicts or riparian plant and animal community impacts of moderate or large significance for plants with open-cycle cooling systems because they are used on large water bodies. Because the potential mitigation measures are costly and because the potential benefits are small, the staff does not consider mitigation to be warranted. These are Category 1 issues.

- The staff found that water use conflicts and the effects of consumptive water use on in-stream aquatic and riparian terrestrial communities could be of moderate significance at some plants that employ cooling-tower or cooling-pond systems because they are often located near smaller water bodies. For plants with these cooling systems, these are Category 2 issues.

- The staff examined 12 potential effects that nuclear power plant cooling systems may have on aquatic ecology: (1) impingement of fish; (2) entrainment of fish (early life stages); (3) entrainment of phytoplankton and zooplankton; (4) thermal discharge effects; (5) cold shock; (6) thermal plume barriers to migrating fish; (7) premature emergence of aquatic insects; (8) stimulation of nuisance organisms; (9) losses from predation, parasitism, and disease among organisms exposed to sublethal stresses; (10) gas supersaturation; (11) low dissolved oxygen in the discharge; and (12) accumulation of contaminants in sediments or biota. Except for three potential impacts (entrainment of fish and shellfish, impingement of fish and shellfish, and thermal discharge effects), each of these was found to be of small significance at all plants. Because mitigation would be costly and provide little environmental benefit, no additional mitigation measures beyond those implemented during the current license term are warranted. These are Category 1 issues. The other three impacts would be of small significance at all plants employing cooling-tower cooling systems. Because mitigation would be costly and provide little environmental benefit, no additional mitigation measures beyond those implemented during the current license term are warranted. For those plants, these are Category 1 issues. However, the impacts may be of greater significance at some plants employing open-cycle or cooling-pond systems; and these are Category 2 issues for those plants.

- The staff found that groundwater use of less than 0.0063 m^3/s (100 gal/min) is of small significance because the cone of depression will not extend beyond the site boundary. Conflicts might result from several types of groundwater use by nuclear power plants. If groundwater conflicts arose, they could be resolvable by deepening the affected wells, but no such mitigation is warranted because sites producing less than 0.0063 m^3/s (100 gal/min) would not have a cone of depression that extends beyond the site boundary. This is a Category 1 issue. Plants that extract more than 0.0063 m^3/s (100 gal/min), including plants using Ranney wells, may have groundwater use conflicts of moderate or large significance. Groundwater use is a Category 2 issue for such plants.

- Cooling system makeup water consumption may cause groundwater use conflicts. During times of low flow, surface water withdrawals for cooling tower makeup from small rivers can reduce groundwater recharge. Because the significance of such impacts cannot be determined generically, this is a Category 2 issue.

- Groundwater withdrawals could cause adverse effects on groundwater quality by inducing intrusion of lower-quality groundwater into the aquifer. The staff found that the significance of these potential impacts is of small significance in all cases. Because all plants except Grand Gulf use relatively small quantities of groundwaters and surface water intrusion at Grand Gulf would not preclude current water uses, the staff found that mitigation was not warranted. This is a Category 1 issue.

- Cooling ponds leak an undetermined quantity of water through the pond bottom. Because the water in cooling ponds is elevated in salts and metals, such leakage may contaminate groundwater. The staff found that groundwater quality impacts of ponds that are located in salt marshes would be of small significance in all cases because salt marshes already have poor water quality. This is a Category 1 issue. Cooling ponds that are not located in salt marshes may have groundwater quality impacts of small, moderate, or large significance. This is a Category 2 issue.

- Small amounts of ozone and substantially smaller amounts of oxides of nitrogen are produced by transmission lines; however, ozone concentrations generated by transmission lines are too low to cause any significant effects. The minute amounts of oxides of nitrogen produced are also insignificant. Thus, air quality impacts associated with the operational transmission lines during the renewal term are expected to be of small significance at all sites. Potential mitigation measures would be very costly and are not warranted. This is a Category 1 issue.

- The potential impact of cooling tower drift on crops and ornamental vegetation arising from operations during the license renewal term is expected to be of small significance for all nuclear plants. No mitigation measures beyond those implemented during the current license term are warranted because there have been no measurable effects on crops or ornamental vegetation from cooling tower drift. This is a Category 1 issue.

- The impact of cooling towers on natural plant communities should continue not to result in measurable degradation as a result of license renewal and will therefore be of small significance. Because the impacts of cooling tower drift on native plants are expected to be small and because potential mitigation measures would be costly, no mitigation measures beyond those during the current term license would be warranted. This is a Category 1 issue.

- Bird mortality from collision with power lines associated with nuclear plants is of small significance for all plants because bird mortality is expected to remain a small fraction of total collision mortality associated with all types of man-made objects. Because the numbers of birds killed from collision with cooling towers are not large enough to affect local population stability or species function within the ecosystem, consideration of further mitigation is not warranted. Both bird collision with power lines and bird collision with cooling towers are Category 1 issues.

- Because no threat to the stability of local wildlife populations or vegetation communities is found for any cooling pond, the impacts are found to be of small significance. Potential mitigation measures would include excluding wildlife (e.g., birds) from contaminated ponds, converting to a dry cooling system, or reducing plant output during fogging or icing conditions. The impacts are found to be so minor that consideration of additional mitigation measures is not warranted. These effects of cooling ponds are so minor and so localized that cumulative impacts are not a concern. This is a Category 1 issue.

- Maintaining power-line right-of-ways (ROWs) causes fluctuations in wildlife populations, but the long-term effects are of small significance. The staff found that bird collisions with transmission lines are of small significance. Also, transmission line maintenance and repair would have impacts of only small significance on floodplains and wetlands. In each case, the staff found that potential mitigation measures beyond those implemented during the current license term would be costly and provide little environmental benefit, and thus are not warranted. These are Category 1 issues.

- Wildlife, livestock, and plants residing in power-line electromagnetic fields (EMF) apparently grow, survive, and reproduce as well as expected in the absence of EMF. The potential impact of EMF on terrestrial resources during the license renewal term is considered to be of small significance for all plants. Because the impact is of small significance and because mitigation measures could create additional environmental impacts and would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

- Land use restrictions are necessary within transmission-line ROWs. The staff found these impacts to be of small significance at all sites. Mitigation beyond that imposed when ROWs were established might include relocating the transmission line. The staff concluded that such mitigation would not be warranted because it would be very costly and provide little environmental benefit. This is a Category 1 issue.

- During the license renewal term, the radiation dose commitment to the total worker population is projected to increase less than 5 percent at nuclear power plants under the typical scenario and less than 8 percent at any plant under the conservative scenario. The present operating experience results in about 30,000 person-rem/year for all licensed plants combined. After the period of refurbishment, routine operating conditions are expected to result in 32,000 person-rem/year for all plants combined. The risk associated with occupational radiation exposures after license renewal is expected to be of small significance at all plants. No mitigation measures beyond those implemented during the current license term are warranted because the existing ALARA process continues to be effective in reducing radiation doses. This is a Category 1 issue.

- Among the 150 million people who live within 50 miles of a U.S. nuclear power plant, about 30 million will die of spontaneous cancer unrelated to radiation exposure from nuclear power plants. This number is compared with approximately 5 calculated fatalities associated with potential nuclear-power-plant-induced cancer. The estimated annual cancer risk to the average individual is less than 1×10^{-6}. Public exposure to radiation during the license renewal term is of small significance at all sites, and no mitigation measures beyond those implemented during the current license term are warranted because current mitigation practices have resulted in declining public radiation doses and are expected to continue to do so. This is a Category 1 issue.

- The significance of potential for electrical shock from charges induced by transmission lines that may occur during the license renewal term cannot be evaluated generically because no National Electric Safety Code (NESC) review was performed for some of the earlier licensed plants. For those that underwent an NESC review, a change in the transmission line voltage may have been made since issuance of the initial operating license, or changes in land use since issuance of the original license could have occurred. This is a Category 2 issue.

- There is no consensus among scientists on whether 60-Hz EMF have a measurable human health impact. Because of inconclusive scientific evidence, the chronic effects of EMF would be not be categorized as either a Category 1 or 2 issue. If NRC finds that a consensus has been reached that there are adverse health effects, all license renewal applicants will have to address EMF effects in the license renewal process.

- Occupational health questions related to thermophilic organisms like *Legionella* are currently resolved using proven industrial hygiene principles to minimize worker exposures to these organisms in mists of cooling towers. Adverse occupational health effects associated with microorganisms are expected to be of small significance at all sites. Aside from continued application of accepted industrial hygiene procedures, no additional mitigation measures beyond those implemented during the current license term are warranted. This is a Category 1 issue.

- Thermophilic organisms may or may not be influenced by operation of nuclear power plants. The issue is largely unstudied. However, NRC recognizes a potential health problem stemming from heated effluents. Public health questions require additional consideration for the 25 plants using cooling ponds, lakes, canals, or small rivers because the operation of these plants may significantly enhance the presence of thermophilic organisms. The data for these sites are not now at hand, and it is impossible with current knowledge to predict the level of thermophilic organism enhancement at any given site. Thus, the impacts are not known and are site specific. Therefore, the magnitude of the potential public health impacts associated with thermal enhancement of *N. fowleri* cannot be determined generically. This is a Category 2 issue.

- The principal noise sources at power plants (cooling towers and transformers) do not change appreciably during the aging process. Because noise impacts have been found to be small and generally not noticed by the public, noise impacts are expected to be of small significance at all sites. Because noise reduction methods would be costly, and given that there have been few complaints, no additional mitigation measures are warranted for license renewal. This is a Category 1 issue.

- The staff examined socioeconomic effects of nuclear power plant operations during a license renewal period. Five of these would be of small significance at all sites: education, public safety, social services, recreation and tourism, and aesthetics. Because mitigation measures beyond those implemented during the current license term are costly and would offer little benefit, no additional mitigation measures are warranted. These are Category 1 issues. Four of the socioeconomic effects were found to have moderate or large significance at some sites: housing, transportation, public utilities (especially water supply), and off-site land use. These are Category 2 issues. In addition, the statute (National Historic Preservation Act) requires consultation; thus historic and archaeological resources are Category 2 issues.

ACCIDENTS

- The environmental impacts of postulated accidents were evaluated for the license renewal period in GEIS Chapter 5. All plants have had a previous evaluation of the environmental impacts of design-basis accidents. In addition, the licensee will be required to maintain acceptable design and performance criteria throughout the renewal period. Therefore, the calculated releases from design-basis accidents would not be expected to change. Since the consequences of these events are evaluated for the hypothetical maximally exposed individual at the time of licensing, changes in the plant environment will not affect these evaluations. Therefore, the staff concludes that the environmental impacts of design-basis accidents are of small significance for all plants. Because the environmental impacts of design basis accidents are of small significance and because additional measures to reduce such impacts would be costly, the staff concludes that no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

- The staff concluded that the generic analysis of severe accidents applies to all plants and that the probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to groundwater, and societal and economic impacts of severe accidents are of small significance for all plants. However, not all plants have performed a site-specific analysis of measures that could mitigate severe accidents. Consequently, severe accidents are a Category 2 issue for plants that have not performed a site-specific consideration of severe accident mitigation and submitted that analysis for Commission review.

URANIUM FUEL CYCLE AND MANAGEMENT OF WASTE

- The radiological and nonradiological environmental impacts of the uranium fuel cycle have been reviewed. The review included a discussion of the values presented in Table S-3, an assessment of the release and impact of ^{222}Rn and of ^{99}Tc, and a review of the regulatory standards and experience of fuel cycle facilities. For the purpose of assessing the radiological impacts of license renewal, the Commission uses the standard that the impacts are of small significance if doses and releases do not exceed permissible levels in the Commission's regulation. Given the available information regarding the compliance of fuel-cycle facilities with applicable regulatory requirements, the Commission has concluded the actual impacts of the fuel cycle are at or below existing regulatory limits. Accordingly, the Commission concludes that individual radiological impacts of the fuel cycle (other than the disposal of spent fuel and high-level waste) are small. With respect to the nonradiological impact of the uranium fuel cycle, data concerning land requirements, water requirements, the use of fossil fuel, gaseous effluent, liquid effluent, and tailings solutions and solids, all listed in Table S-3, have been reviewed to determine the significance of the environmental impacts of a power reactor operating an additional 20 years. The nonradiological environmental impacts attributable to the relicensing of an individual power reactor are found to be of small significance. The individual radiological and the nonradiological effects of the uranium fuel cycle are Category 1 issues.

  The radiological impacts of the uranium fuel cycle on human populations over time (collective effects) have been considered within the framework of Table S-3. The 100-year environmental dose commitment to the U.S. population from the fuel cycle, high-level-waste and spent-fuel disposal excepted, is calculated to be about 14,800 man-rem, or 12 cancer fatalities, for each additional 20-year power-reactor operating term. Much of this, especially the contribution of radon releases from mines and tailing piles, consists of tiny doses summed over large populations. This same dose calculation can theoretically be extended to include many tiny doses over additional thousands of years as well as doses outside the United States. The result of such a calculation would be thousands of cancer fatalities from the fuel cycle, but this result assumes that even tiny doses have some statistical adverse health effect that will not ever be mitigated (for example, no cancer cure in the next thousand years) and that these dose projections over thousands of years are meaningful. However, these assumptions are questionable. In particular, science cannot rule out the possibility that there will be no cancer fatalities from these tiny doses. For perspective, the doses are very small fractions of regulatory limits and even smaller fractions of natural background exposure to the same populations. No standards exist that can be used to reach a conclusion as to the significance of the magnitude of the collective radiological effects. Nevertheless, some judgment as to the regulatory NEPA implication of this issue should be made, and it makes no sense to repeat the same judgment in every case. The Commission concludes that these impacts are acceptable in that these impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the collective effects of the fuel cycle, this issue is considered Category 1.

There are no current regulatory limits for off-site releases of radionuclides from high-level-waste and spent-fuel disposal at the current candidate repository site at Yucca Mountain. If we assume that limits are developed along the lines of the 1995 National Academy of Sciences report and that, in accordance with the Commission's Waste Confidence Decision, a repository can and likely will be developed at some site that will comply with such limits, peak doses to virtually all individuals will be 100 mrem/year or less. However, while the Commission has reasonable confidence that these assumptions will prove correct, there is considerable uncertainty since the limits are yet to be developed, no repository application has been completed or reviewed, and uncertainty is inherent in the models used to evaluate possible pathways to the human environment. The National Academy report indicates that 100 mrem/year should be considered as a starting point for limits for individual doses but notes that some measure of consensus exists among national and international bodies that the limits should be a fraction of the 100 mrem/year. The lifetime individual risk from 100-mrem/year dose limit is about 3×10^{-3}. Doses to populations from disposal cannot now (or possibly ever) be estimated without very great uncertainty. Estimating cumulative doses to populations over thousands of years is more problematic. The likelihood and consequences of events that could seriously compromise the integrity of a deep geologic repository have been evaluated by the Department of Energy (DOE) and the NRC, and other federal agencies have expended considerable effort to develop models for the design and for the licensing of a high-level-waste repository, especially for the candidate repository at Yucca Mountain. More meaningful estimates of doses to population may be possible in the future as more is understood about the performance of the proposed Yucca Mountain repository. Such estimates would involve very great uncertainty, especially with respect to cumulative population doses over thousands of years. The standard proposed by the NAS is a limit on maximum individual dose. The relationship of potential new regulatory requirements, based on the NAS report, and cumulative population impacts has not been determined, although the report articulates the view that protection of individuals will adequately protect the population for a repository at Yucca Mountain. However, EPA's generic repository standards in 40 CFR Part 191 generally provide an indication of the order of magnitude of cumulative risk to population that could result from the licensing of a Yucca Mountain repository, assuming the ultimate standards will be within the range of standards now under consideration. The standards in 40 CFR Part 191 protect the population by imposing "containment requirements" that limit the cumulative amount of radioactive material released over 10,000 years. The cumulative release limits are based on EPA's population impact goal of 1,000 premature cancer deaths worldwide for a 100,000-metric tonne (MTHM) repository.

Nevertheless, despite all the uncertainty surrounding the effects of the disposal of spent fuel and high-level waste, some judgment as to the regulatory NEPA implications of these matters should be made, and it makes no sense to repeat the same judgment in every case. Even taking the uncertainties into account, the Commission concludes that these impacts are acceptable in that these impacts would not be sufficiently large to require the NEPA conclusion, for any plant, that the option of extended operation under 10 CFR Part 54 should be eliminated. Accordingly, while the Commission has not assigned a single level of significance for the impacts of spent-fuel and high-level-waste disposal, this issue is considered Category 1.

- The radiological and nonradiological environmental impacts from the transportation of fuel and waste attributable to license renewal of a power reactor have been reviewed. Environmental impact data for transportation are provided in Table S-4. The estimated radiological effects are within the Commission's regulatory standards. Radiological impacts of transportation are therefore found to be of small significance when they are within the range of impact parameters identified in Table S-4. The nonradiological impacts are those from periodic shipments of fuel and waste by individual trucks or rail cars and thus would result in infrequent and localized minor contributions to traffic density. These nonradiological impacts are found to be small when they are within the range of impact parameters identified in Table S-4. Programs designed to reduce risk, which are already in place, provide for adequate mitigation. Table S-4 should continue to be the basis for case-by-case evaluations of transportation impacts of spent fuel until such time as detailed analysis of the environmental impacts of transportation to the Yucca Mountain repository becomes available. Transportation of fuel and waste is a Category 2 issue.

- The radiological and nonradiological environmental impacts from the storage and disposal of low-level radiological waste attributable to license renewal of a power reactor have been reviewed. The comprehensive regulatory controls that are in place and the low public doses being achieved at reactors ensure that the radiological impacts to the environment will remain small during the term of the renewed license. The maximum additional on-site land that may be required for low-level waste storage during the term of a renewed license and associated impacts will be small. Nonradiological environmental impacts on air and water will be negligible. The radiological and nonradiological environmental impacts of long-term disposal of low-level waste from any individual plants at licensed sites are small. The need for the consideration of mitigation alternatives within the context of renewal of a power reactor license has been considered, and the Commission concludes that its regulatory requirements already in place provide adequate mitigation incentives for on-site storage of low-level waste and that, for off-site disposal, mitigation would be a site-specific consideration in the licensing of each facility. In addition, the Commission concludes that there is reasonable assurance that sufficient low-level waste disposal capacity will be made available when needed for facilities to be decommissioned consistent with NRC decommissioning requirements. Low-level waste is a Category 1 issue.

- The radiological and nonradiological environmental impacts from the storage and disposal of mixed waste attributable to license renewal of a power reactor have been reviewed. The comprehensive regulatory controls and the facilities and procedures that are in place ensure proper handling and storage, as well as negligible doses and exposure to toxic materials for the public and the environment at all plants. License renewal will not increase the small, continuing risk to human health and the environment posed by mixed waste at all plants. The radiological and nonradiological environmental impacts of long-term disposal of mixed waste from any individual plant at licensed sites are small. The maximum additional on-site land that may be required for mixed waste is a small fraction of that needed for low-level waste storage during the term of a renewed license, and associated impacts will be small. Nonradiological environmental impacts on air and water will be negligible. The radiological and nonradiological environmental impacts of long-term disposal of mixed waste from any individual plants at licensed sites are small. The need for the consideration of mitigation alternatives within the context of renewal of a power reactor license has been considered, and the Commission concludes that its regulatory requirements already in place provide adequate mitigation incentives for on-site storage of mixed waste and that, for off-site disposal, mitigation would be a site-specific consideration in the licensing of each facility. In addition, the Commission concludes that there is reasonable assurance that sufficient mixed waste disposal capacity will be made available when needed for faculties to be decommissioned consistent with NRC decommissioning requirements. Mixed waste is a Category 1 issue.

- The Commission's waste confidence finding at 10 CFR 51.23 leaves only the on-site storage of spent fuel during the term of plant operation as a high-level waste storage and disposal issue at the time of license renewal. The Commission's regulatory requirements and the experience with on-site storage of spent fuel in fuel pools and dry storage have been reviewed. Within the context of a license renewal review and determination, the Commission finds that there is ample basis to conclude that continued storage of existing spent fuel and storage of spent fuel generated during the license renewal period can be accomplished safely and without significant environmental impacts. Radiological impacts will be well within regulatory limits; thus radiological impacts of on-site storage meet the standard for a conclusion of small impact. The nonradiological environmental impacts have been shown to be not significant; thus they are classified as small. The overall conclusion for on-site storage of spent fuel during the term of a renewed license is that the environmental impacts will be small for each plant. The need for the consideration of mitigation alternatives within the context of renewal of a power reactor license has been considered, and the Commission concludes that its regulatory requirements already in place provide adequate mitigation incentives for on-site storage of spent fuel. On-site storage of spent fuel during the term of a renewed operating license is a Category 1 issue.

- The environmental impacts from the storage and disposal of nonradiological waste attributable to the license renewal of a power reactor have been reviewed. Regulatory and operational trends suggest a gradual decrease in quantities generated annually and the impacts during the terms of renewed licenses. Facilities and procedures are in place to ensure continued proper handling and disposal at all plants. Consequently, the generation and management of solid nonradioactive waste during the term of a renewed license is anticipated to result in only small impacts to the environment. Because the facilities and procedures that are in place are expected to ensure continued proper handling and disposal at each plant, additional mitigative measures are not a consideration in the context of a license renewal review. Nonradiological waste is a Category 1 issue.

DECOMMISSIONING

- Decommissioning after a 20-year license renewal would increase the occupational dose no more than 0.1 person-rem (compared with 7,000 to 14,000 person-rem for DECON decommissioning at 40 years) and the public dose by a negligible amount. License renewal would not increase to any appreciable extent the quantity or classification of LLW generated by decommissioning. Air quality, water quality, and ecological impacts of decommissioning would not change as a result of license renewal. There is considerable uncertainty about the cost of decommissioning; however, while license renewal would not be expected to change the ultimate cost of decommissioning, it would reduce the present value of the cost. The socioeconomic effects of decommissioning will depend on the magnitude of the decommissioning effort, the size of the community, and the other economic activities at the time, but the impacts will not be increased by decommissioning at the end of a 20-year license renewal instead of at the end of 40 years of operation. Incremental radiation doses, waste management, air quality, water quality, ecological, and socioeconomic impacts of decommissioning due to operations during a 20-year license renewal term would be of small significance. No mitigation measures beyond those provided by ALARA are warranted within the context of the license renewal process. The impacts of license renewal on radiation doses, waste management, air quality, water quality, ecological resources, and socioeconomics impacts from decommissioning are Category 1 issues.

1. INTRODUCTION

1.1 PURPOSE OF THE GEIS

This Generic Environmental Impact Statement (GEIS) for license renewal of nuclear plants was undertaken to assess what is known about the environmental impacts that could be associated with license renewal and an additional 20 years of operation of individual plants. That assessment is summarized in this GEIS. This GEIS provides the technical basis for an amendment to the Commission's regulations, 10 CFR Part 51, Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions, with regard to the renewal of nuclear power plant operating licenses. The rule amendment and this document were initiated with the objective that the efficiency of the license renewal process be improved by documenting in this GEIS and codifying in the Commission's regulations the environmental impacts that are well understood. Thus, repetitive reviews of those impacts may be avoided. The Commission's decision to undertake a generic assessment of the environmental impacts associated with the renewal of a nuclear power plant operating license was motivated by its belief in the following:

(1) License renewal will involve nuclear power plants for which the environmental impacts of operation are well understood as a result of data evaluated from operating experience to date.
(2) Activities associated with license renewal are expected to be within this range of operating experience, thus environmental impacts can be reasonably predicted.
(3) Changes in the environment around nuclear power plants are gradual and predictable with respect to characteristics important to environmental impact analyses.

1.2 RENEWAL OF A PLANT OPERATING LICENSE—THE PROPOSED FEDERAL ACTION

Under NRC's environmental protection regulations in 10 CFR Part 51, renewal of a nuclear power plant operating license is identified as a major federal action significantly affecting the quality of the human environment, and thus an environmental impact statement (EIS) is required for a plant license renewal review. The EIS requirements for a plant-specific license renewal review are specified in 10 CFR Part 51. NRC's public health and safety requirements that must be met for the renewal of operating licenses for nuclear power plants are found in 10 CFR Part 54. Operating licenses may be renewed for up to 20 years beyond the 40-year term of the initial license. No limit on the number of renewals is specified. Part 54 requires license renewal applicants to perform specified types of evaluations and assessments of their facility and to provide sufficient information for the NRC to determine whether or not continued operation of the facility during the renewal term will endanger public health and safety or the environment. Specifically, licensees will be required to assess the effect of age-related degradation on certain long-lived, passive systems, structures, and components that are within the scope of Part 54. The assessment results will determine what activities and modifications are necessary at the time of license renewal and throughout the renewal term to ensure continued safe operation of the plant. Most utilities are expected to begin preparation for license renewal about 10 to 20 years before expiration of their original operating licenses. The inspection, surveillance, test, and maintenance programs for license renewal would be integrated gradually into plant operations over a period of years. For the purpose of the analysis in this GEIS, NRC anticipates that plant refurbishment undertaken specifically for license renewal would probably be completed within normal plant outage cycles beginning 8 years before the original license expires and one longer outage, if a major refurbishment item is involved. Activities associated with license renewal and operation of a plant for an additional 20 years are discussed in Chapter 2.

1.3 PURPOSE AND NEED FOR THE ACTION

The Commission will act on an applications for license renewal submitted by a licensee of an operating nuclear power plant. Although a licensee must have a renewed license to operate a plant beyond the term of the existing operating license, the possession of that license is just one of a number of conditions that must be met for the licensee to continue plant operation during the term of the renewed license. State regulatory agencies and the owners of the plant would ultimately decide whether the plant will continue to operate based on factors such as need for power or other matters within the State's jurisdiction or the purview of the owners. Economic considerations will play a primary role in the decision made by State regulatory agencies and the owners of the plant.

Thus, for license renewal reviews, the Commission has adopted the following definition of purpose and need:

> The purpose and need for the proposed action (renewal of an operating license) is to provide an option that allows for power generation capability beyond the term of a current nuclear power plant operating license to meet future system generating needs, as such needs may be determined by State, utility, and, where authorized, Federal (other than NRC) decision makers.

This definition of purpose and need reflects the Commission's recognition that, absent findings in the safety review required by the Atomic Energy Act of 1954, as amended, or findings in the NEPA environmental analysis that would lead the NRC to reject a license renewal application, the NRC has no role in the energy planning decisions of State regulators and utility officials as to whether a particular nuclear power plant should continue to operate. From the perspective of the licensee and the State regulatory authority, the purpose of renewing an operating license is to maintain the availability of the nuclear plant to meet system energy requirements beyond the term of the plant's current license. The underlying need that will be met by the continued availability of the nuclear plant is defined by various operational and investment objectives of the licensee. Each of these objectives may be dictated by State regulatory requirements or strongly influenced by State energy policy and programs. In cases of interstate generation or other special circumstances, Federal agencies such as the Federal Energy Regulatory Commission (FERC) or the

Tennessee Valley Authority (TVA) may be involved in making these decisions. The objectives of the various entities involved may include lower energy cost, increased efficiency of energy production and use, reliability in the generation and distribution of electric power, improved fuel diversity within the State, and environmental objectives such as improved air quality and smaller land use impacts.

1.4 ALTERNATIVES TO THE PROPOSED ACTION

In Chapter 8, the Commission has considered the environmental consequences of the no action alternative (i.e., denying a license renewal application) and the environmental consequences of the various alternatives available for replacing the lost generating capacity that would be available to a utility and other responsible energy planners. No conclusions are made in this document about the relative environmental consequences of license renewal or the construction and operation of alternative facilities for generating electric energy. The information in the GEIS is available for use by the NRC and the licensee in performing the site-specific analysis of alternatives. This information will be updated periodically, as appropriate. For individual plant reviews, information codified in the rule, information developed in the GEIS, and any significant new information introduced during the plant-specific review, including any information received from the State or members of the public, will be considered in reaching conclusions in the supplemental EIS. For an individual plant review, the environmental impacts of license renewal are to be compared with those of alternative energy sources so as to determine whether the adverse environmental impact of license renewal are so great that preserving the option of license renewal for energy planning decision makers would be unreasonable.

1.5 ANALYTICAL APPROACH USED IN THE GEIS

The GEIS summarizes the approach and findings of a systematic inquiry into the potential environmental consequences of renewing the licenses and operating individual nuclear power plants an additional 20 years. The inquiry identified the attributes of the nuclear power plants, such as major features and plant systems, and the ways the plants can affect the environment. The inquiry also identified the possible refurbishment activities and modifications to maintenance and operating procedures that might be undertaken given the requirements of the safety review as provided for in the Commission's regulations 10 CFR Part 54 or given a utility's motivation for increased economic efficiency. To identify possible initiators of environmental impacts, two scenarios were developed from the possible set of refurbishment activities and continuation of plant operation during the renewal term. One scenario was developed as a typical but somewhat conservative scenario for license renewal, intended to be representative of the type of programs that many licensees seeking license renewal might implement. The other scenario is highly conservative, encompassing considerably more activities, and is intended to characterize a reasonable upper bound of impact initiators that might result from license renewal. These scenarios are discussed in Chapter 2 and in more detail in Appendix B. The linkages between the impact initiators and the environment and the potential environmental impact consequences are developed in the other chapters of the GEIS.

Previous experience with nuclear power plant operation and refurbishment was reviewed in developing the possible scope of environmental impacts that complemented the identification of impact initiators and linkages to the environment. This experience is found in a variety of sources. A list of possible impacts is found in NUREG-0099, Regulatory Guide 4.2, Rev. 2 (July 1976) and in NUREG-0555, "Environmental Standard Review Plans for the Environmental Review of Construction Permit Applications for Nuclear Power Plants" (May 1979). Information was gathered from the environmental impact statements prepared for individual plants at the construction permit and operating license stages. A survey of individual plant operating and refurbishment experience was designed by Oak Ridge National Laboratory (ORNL) and the NRC staff and was administered by the Nuclear Energy Institute (NEI), formerly the Nuclear Utility Management and Resources Council (NUMARC). ORNL analysts reviewed the literature relevant to nuclear power plant impacts on the environment and surveyed by telephone and letter federal, state, and local authorities who have responsibilities that would make them cognizant of the environmental impacts of individual nuclear power plants. The information gathered for this GEIS was supplemented at several stages by comments and information provided by various interests groups at public workshops and by written comments in response to information noticed in the Federal Register. The NRC staff's responses to comments are provided in NUREG-1529, *Public Comments on the Proposed 10 CFR Part 51 Rule for Renewal of Nuclear Power Plant Operating Licenses and Supporting Documents; Review of Concerns and NRC Staff Response.*

The general analytical approach to each environmental issue was to (1) describe the activity that affects the environment, (2) identify the population or resource that is affected, (3) assess the nature and magnitude of the impact on the affected population or resource, (4) characterize the significance of the effect for both beneficial and adverse effects, (5) determine whether the results of the analysis applies to all plants, and (6) consider whether additional mitigation measures would be warranted for impacts that would have the same significance level for all plants.

A standard of significance was established for assessing environmental issues; and, because significance and severity of an impact can vary with the setting of a proposed action, both "context" and "intensity" as defined in the Council on Environmental Quality regulations (40 CFR 1508.27) were considered. With these standards as a basis, each issue was assigned to one of the three following significance levels:

> Small: For the issue, environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the Commission has concluded that those impacts that do not exceed permissible levels in the Commission's regulations are considered small.
>
> Moderate: For the issue, environmental effects are sufficient to

alter noticeably but not to destabilize important attributes of the resource.

Large: For the issue, environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

The discussion of each environmental issue in the GEIS includes an explanation of how the significance category was determined. For issues in which probability of occurrence is a key consideration (i.e., accident consequences), the probability of occurrence has been factored into the determination of significance. In determining the significance levels it was assumed that ongoing mitigation measures would continue and that mitigation measures employed during plant construction would be employed during refurbishment, as appropriate. The potential benefits of additional mitigation measures were not considered in determining significance levels.

In addition to determining the significance of environmental impacts associated with an issue for that issue, a determination was made whether the analysis in the GEIS could be applied to all plants and whether additional mitigation measures would be warranted. The categories to which an issue may be assigned follow.

Category 1: For the issue, the analysis reported in the Generic Environmental Impact Statement has shown:

(1) the environmental impacts associated with the issue have been determined to apply either to all plants or, for some issues, to plants having a specific type of cooling system or other specified plant or site characteristics;
(2) a single significance level (i.e., small, moderate, or large) has been assigned to the impacts (except for collective off-site radiological impacts from the fuel cycle and from high-level waste and spent fuel); and
(3) mitigation of adverse impacts associated with the issue has been considered in the analysis and it has been determined that additional plant-specific mitigation measures are likely not to be sufficiently beneficial to warrant implementation.

The generic analysis of the issue may be adopted in each plant-specific review.

Category 2: For the issue, the analysis reported in the GEIS has shown that one or more of the criteria of Category 1 cannot be met, and therefore, additional plant-specific review is required.

If, for an environmental issue, the three Category 1 criteria apply to all plants, that issue is Category 1, and the generic analysis should be used in a license renewal review for all plant applications and supplemental environmental impact statements. If the three Category 1 criteria apply to a subset of plants that are readily defined by a common plant characteristic, notably the type of cooling system, the population of plants is partitioned into the set of plants with the characteristic and the set without the characteristic. For the set of plants with the characteristic, the issue is Category 1, and the generic analysis should be used in the license renewal review for those plants. For the set of plants without the characteristic, the issue is Category 2, and a site-specific analysis for that issue will be performed as part of the license renewal review. The review of a Category 2 issue may focus on the particular aspect of the issue that causes the Category 1 criteria not to be met. For example, severe accident mitigation design alternatives under the issue "severe accidents" is the focus for a plant-specific review because the other aspects of the issue, specifically the off-site consequences, have been adequately addressed in the GEIS.

1.6 SCOPE OF THE GEIS

This final GEIS assesses 92 environmental issues. Sixty-eight of these issues are found to be Category 1 and are identified in 10 CFR Part 51 as not requiring additional plant-specific analysis. Guidance on the analyses required for each of the other 24 issues is provided in 10 CFR Part 51. A summary of the findings for the 92 environmental issues is provided in Table 9.1 of this GEIS. That table has been codified in Appendix B to Subpart A of 10 CFR Part 51 (Table B-1).

Preparing the plants for an additional 20 years of operations is an important factor in assessing the type and extent of environmental impacts. Consequently, Chapter 2 describes (1) the two scenarios that were developed to characterize refurbishment activities to prepare the plant for operations during the license renewal term and (2) the possible differences between past operations and anticipated operations during the license renewal period. With Chapter 2 as a basis, Chapter 3 projects and assesses the potential environmental impacts associated with refurbishment; and Chapter 4 examines the potential environmental impacts associated with operations during the license renewal period. In most ways, the environmental effects of license renewal are found to be similar to those of normal operations.

The implications for license renewal on the environmental impacts associated with accidents, the uranium fuel cycle and waste management, and decommissioning are discussed in separate chapters. Chapter 5 addresses the ways in which the impacts of potential design basis and severe accidents may be affected by operation of the plants for an additional 20 years. Chapter 6 discusses the extent to which license renewal and an additional 20 years of operation will affect the environmental impacts related to the uranium fuel cycle and the management (storage and disposal) of nonradioactive solid waste, low-level radioactive waste, mixed waste (radioactive and chemically hazardous), spent fuel, and transportation of radioactive wastes as generated at a plant. Chapter 7 assesses the extent to which the license renewal and an additional 20 years of operation would affect the environmental impacts of decommissioning a plant.

Chapter 8 describes the potential environmental effects of terminating plant operations at the end of the current license term and the effects that would be associated with various alternative sources of energy. Because many environmental impacts of energy technologies are site specific, this chapter reaches no conclusions about the significance of these effects nor does it reach any conclusions about the preferability of license renewal or any alternative to it. The information in this chapter is intended to serve as an aid for preparers of plant-specific license renewal impact assessments.

Finally, Chapter 9 summarizes the analytical findings reached in this GEIS.

1.7 IMPLEMENTATION OF THE RULE

1.7.1 General Requirements

The regulatory requirements for performing a NEPA review for a license renewal application are similar to the NEPA review requirements for other major plant licensing actions. Consistent with the current NEPA practice for major plant licensing actions, an applicant is required to submit an environmental report that analyzes the environmental impacts associated with the proposed action, considers alternatives to the proposed action, and evaluates any alternatives for reducing adverse environmental effects. Additionally, the NRC staff is required to prepare a supplemental environmental impact statement for the proposed action, issue the statement in draft for public comment, and issue a final statement after considering public comments on the draft. These requirements are found in the Commissions regulations at 10 CFR Part 51.

The review requirements for license renewal deviates from NRC's traditional NEPA review practice in some areas. First, the amendment codifies certain environmental impacts associated with license renewal that are analyzed in this GEIS. Accordingly, additional analyses for certain impacts codified by this rulemaking need not be presented in an applicant's environmental report for license renewal nor in the Commission's (including NRC staff, adjudicatory officers, and the Commission itself) draft and final SEIS and other environmental documents developed for the proceeding. Secondly, the amendment reflects the Commission's decision to limit its NEPA review for license renewal to a consideration of the environmental effects of the proposed action and alternatives to the proposed action. Finally, the amendment contains a decision standard that the Commission will use in determining the acceptability of the environmental impacts of individual license renewals.

The Commission and the applicant will also in some cases (e.g., severe accident consequences) consider alternatives to reduce or mitigate environmental impacts. The Commission has concluded that, for license renewal, the issues of need for power and utility economics should be reserved for State and utility officials to decide. Accordingly, the NRC will not conduct an analysis of these issues in the context of license renewal or perform traditional cost-benefit balancing in license renewal NEPA reviews. Finally, the rule does not codify any conclusions regarding the subject of alternatives. Consideration of and decisions regarding alternatives will occur at the site-specific stage.

1.7.2 Applicant's Environmental Report

The applicant's environmental report must contain an analysis of the environmental impacts of renewing a license, the environmental impacts of alternatives, and mitigation alternatives. In preparing the analysis of environmental impacts contained in the environmental report, the applicant should refer to the data provided in 10 CFR Part 51, Appendix B. The applicant is not required to provide an analysis in the environmental report of those issues identified as Category 1 issues in Table B-1 in Appendix B. For those issues identified as Category 2 in

Table B-1, the applicant must provide a specified additional analysis beyond that contained in Table B-1. Section 10 CFR 51.53(c)(3)(ii) specifies the subject areas of the analysis that must be addressed for the Category 2 issues.

Pursuant to 10 CFR 51.45(c), 10 CFR 51.53(c)(2) requires the applicant to consider possible actions to mitigate the adverse impacts associated with the proposed action. This consideration is limited to designated Category 2 matters. Pursuant to 10 CFR 51.45(d), the environmental report must include a discussion of the status of compliance with applicable Federal, State, and local environmental standards. Also, 10 CFR 51.53(c)(2) specifically excludes from consideration in the environmental report the issues of need for power, the economic costs and benefits of the proposed action, economic costs and benefits of alternatives to the proposed action, or other issues not related to environmental effects of the proposed action and associated alternatives. In addition, the requirements in 10 CFR 51.45 are consistent with the exclusion of economic issues in 10 CFR 51.53(c)(2).

Pursuant to 10 CFR 51.45(c), 10 CFR 51.53(c)(2) requires the applicant to consider the environmental impacts of alternatives to license renewal in the environmental report. The treatment of alternatives in the environmental report should be limited to the environmental impacts of such alternatives. The amended regulations do not require a discussion of the economic costs and benefits of these alternatives in the environmental report for the operating license renewal stage except as necessary to determine whether an alternative should be included in the range of alternatives considered or whether certain mitigative actions are appropriate. The analysis should demonstrate consideration of a reasonable set of alternatives to license renewal. In preparing the alternatives analysis, the applicant may consider information regarding alternatives in this GEIS.

The Commission has developed a new approach to making decisions for environmental impact statements for license renewal. This decision standard differs from past Commission practice. The amended regulations for license renewal do not require applicants to apply this decision standard to the information generated in their environmental report (although the applicant is not prohibited from doing so if it desires). Under NEPA, the Commission has the final authority and responsibility for making such a decision regarding the environmental acceptability of the proposed renewal license. However, the NRC staff will use the information contained in the environmental report in preparing the environmental impact statement upon which the Commission will base its final decision.

Consistent with the NRC's current NEPA practice, an applicant must include alternatives to reduce or mitigate adverse environmental impacts in its environmental report. However, for license renewal, the Commission has generically considered mitigation for environmental issues associated with renewal and has concluded that no additional site-specific consideration of mitigation is necessary for many issues. The Commission's consideration of mitigation for each issue included identification of current activities that adequately mitigate impacts and an assessment as to whether certain impacts are so insignificant that mitigation is not warranted. The Commission has considered mitigation for all impacts designated as Category 1 in Table B-1. Therefore, a license renewal applicant need not address mitigation for Category 1 issues in Table B-1.

1.7.3 The NRC's Supplemental Environmental Impact Statement

The Commission is required to prepare a supplemental environmental impact statement (SEIS), consistent with 10 CFR 51.20(b)(2). This statement will serve as the Commission's independent analysis of the environmental impacts of license renewal as well as a comparison of these impacts to the environmental impacts of alternatives. This document will also present the preliminary recommendation by the NRC staff regarding the proposed action. The provisions in 10 CFR 51.71 and 51.95 to reflect the Commission's approach to addressing the environmental impacts of license renewal in an SEIS.

The issues of need for power, the economic costs and benefits of the proposed action and economic costs and benefits of alternatives to the proposed action are specifically excluded from consideration in the supplemental environmental impact statement for license renewal by 10 CFR 51.95(c), except as these costs and benefits are either essential for a determination regarding the inclusion of an alternative in the range of alternatives considered or relevant to mitigation. The environmental report does not need to discuss issues related to other than environmental effects of the proposed action and associated alternatives. The requirements in 10 CFR 51.71(d) and (e) are consistent with the exclusion of economic issues in 10 CFR 51.95(c). Additionally, 10 CFR 51.95 allows information from previous NRC site-specific environmental reviews, as well as NRC final generic environmental impact statements, to be referenced in supplemental environmental impact statements.

1.7.4 Public Scoping and Public Comments on the SEIS

Consistent with NRC's NEPA practice, the NRC staff will hold a public meeting in order to inform the local public of the proposed action and receive comments. In addition, the SEIS will be issued in draft for public comment in accordance with 10 CFR 51.91 and 51.93. In both the public scoping process and the public comment process, the Commission will accept comments on all previously analyzed issues and information codified in Table B-1 of 10 CFR Part 51, Appendix B, and will determine whether these comments provide any information that is new and significant compared with that previously considered in the GEIS. If the comments are determined to provide new and significant information bearing on the previous analysis in the GEIS, these comments will be considered and appropriately factored into the Commission's analysis in the SEIS. Public comments on the site-specific additional information provided by the applicant regarding Category 2 issues will be considered in the SEIS.

1.7.5 Commission's Analysis and Preliminary Recommendation

The Commission's draft SEIS will include its analysis of the environmental impacts of the proposed license renewal action and the environmental impacts of the alternatives to the proposed action. The Commission will utilize and integrate the codified environmental impacts of license renewal as provided in Table B-1 of 10 CFR Part 51, Appendix B (supplemented by the underlying analyses in the GEIS), and the appropriate site-specific analyses of Category 2 issues and any new issues identified during the scoping and public comment process, to arrive at a conclusion regarding the sum of the environmental impacts associated with license renewal. These impacts will then be compared, quantitatively or qualitatively as appropriate, with the environmental impacts of the considered alternatives. The analysis of alternatives in the SEIS will be limited to the environmental impacts of these alternatives and will be prepared in accordance with 10 CFR 51.71 and of 10 CFR Part 51, Subpart A, Appendix A. The analysis of impacts of alternatives provided in the GEIS may be referenced in the SEIS as appropriate. The alternatives discussed in the GEIS include a reasonable range of different methods for power generation. The analysis in the draft SEIS will consider mitigation actions for designated Category 2 matters and will consider the status of compliance with Federal, State, and local environmental requirements as required by 10 CFR 51.71(d). Consistent with 10 CFR 51.71(e), the draft supplemental environmental impact statement must contain a preliminary recommendation regarding license renewal based on consideration of the information on the environmental impacts of license renewal and of alternative energy sources contained in the SEIS. To reach its recommendation, the NRC staff must determine whether the adverse environmental impacts of license renewal are so great that preserving the option of license renewal for energy planning decision makers would be unreasonable. This requirement is contained in 10 CFR 51.95(c)(4).

1.7.6 Final Supplemental Environmental Impact Statement

The Commission will issue a final supplemental environmental impact statement for a license renewal application in accordance with 10 CFR 51.91 and 51.93 after considering the public comments related to new issues identified from the scoping and public comment process, Category 2 issues, and any new and significant information regarding previously analyzed and codified Category 1 issues. Pursuant to 10 CFR 51.102 and 51.103, the Commission will provide a record of its decision regarding the environmental impacts of the proposed action. In making a final decision, the Commission must determine whether the adverse environmental impacts of license renewal (when compared with the environmental impacts of other energy generating alternatives) are so great that preserving the option of license renewal for energy planning decision makers would be unreasonable.

All comments on the applicability of the analyses of impacts codified in the rule and the analysis contained in the draft supplemental EIS will be addressed by NRC in the final supplemental EIS in accordance with 40 CFR § 1503.2, regardless of whether the comment is directed to impacts in Category 1 or 2. Such comments will be addressed in following manner:

a. NRC's response to a comment regarding the applicability of the analysis of an impact codified in the rule to the plant in question may be a statement and explanation of its view that the analysis is adequate including, if applicable, consideration of the significance of new information. A commenter dissatisfied with such a response may file a petition for rulemaking under 10 CFR § 2.802. Procedures for the submission of petitions for rulemaking are explained in Appendix I. If the commenter is successful in persuading the Commission that the new information does indicate that the analysis of an impact codified in the rule is incorrect in significant respects (either in general or with respect to the particular plant), then a rulemaking proceeding will be initiated.

b. If the commenter provides new information that is relevant to the plant and is also relevant to other plants (i.e., generic information) and that information demonstrates that the analysis of an impact codified in the final rule is incorrect, the NRC staff will seek Commission approval either to suspend the application of the rule on a generic basis with respect to the analysis or to delay granting the renewal application (and possibly other renewal applications) until the rule can be amended. The updated GEIS would reflect the corrected analysis and any additional consideration of alternatives as appropriate.

c. If a commenter provides new, site-specific information that demonstrates that the analysis of an impact codified in the rule is incorrect with respect to the particular plant, then the NRC staff will seek Commission approval to waive the application of the rule with respect that analysis in that specific renewal proceeding. The supplemental EIS would reflect the corrected analysis as appropriate.

1.8 REFERENCES

NUREG-1529, *Public Comments on the Proposed 10 CFR Part 51 Rule for Renewal of Nuclear Power Plant Operating Licenses and Supporting Documents; Review of Concerns and NRC Response*, U.S. Nuclear Regulatory Commission, Washington, D.C., to be published.

2. DESCRIPTION OF NUCLEAR POWER PLANTS AND SITES, PLANT INTERACTION WITH THE ENVIRONMENT, AND ENVIRONMENTAL IMPACT INITIATORS ASSOCIATED WITH LICENSE RENEWAL

2.1 INTRODUCTION

Currently, 118[1] commercial nuclear power plants are located at 74 sites in 33 of the contiguous United States. Of these, 57 sites are located east of the Mississippi River, with most of this nuclear capacity located in the Northeast (New England states, New York, and Pennsylvania); the Midwest (Illinois, Michigan, and Wisconsin); and the Southeast (the Carolinas, Georgia, Florida, and Alabama). No commercial nuclear power plants are located in Alaska or Hawaii. Approximately half of these 74 sites contain two or three nuclear units per site. Three of the 118 plants have been shut down and will be decommissioned. The plant characteristics and environmental settings for these nuclear power plant sites are provided in Appendix A. Table 2.1 provides a summary overview of the plants considered in preparing this Generic Environmental Impact Statement (GEIS).

The total capacity of generating U.S. commercial nuclear power plants is approximately 99 GW(e), with plant generating capacities ranging from 67 MW(e) to 1270 MW(e). In 1992, the U.S. electric utility industry generated about 2.8×10^{12} kWh, 21.6 percent of which was supplied by nuclear power. The range of annual electricity production for these plants is approximately 390×10^{6} kWh/year to 6900×10^{6} kWh/year using an assumed annual capacity factor of 62 percent. It is anticipated that the electric utility industry will seek to operate many of these nuclear power plants beyond the current operating license term of 40 years. This GEIS examines how these plants and their interactions with the environment would change if such plants were allowed to operate (under the proposed license renewal regulation 10 CFR Part 54) for a maximum of 20 years past the term of the original plant license of 40 years.

The purpose of this section is to provide an orientation from the perspective of environmental considerations and assessments. Section 2.2 describes commercial nuclear power plants and their major features and plant systems. Section 2.3 describes the ways nuclear power plants interact with and affect the environment. The license renewal rule, particularly its requirements that may result in changes to nuclear plant environmental impacts, is discussed in Section 2.4. Section 2.5 reviews the generation of particular environment impacts, or precursors to such impacts, that are typical of current nuclear plant operation. It discusses the "baseline" values to be used in comparing incremental effects resulting from license renewal. Section 2.6 describes major refurbishment activities and changes that could occur at nuclear power plants during license renewal refurbishment and the extended years of operation. This section provides the background for more thorough evaluations and environmental impact assessments discussed in Sections 3 through 10.

2.2 PLANT AND SITE DESCRIPTION AND PLANT OPERATION

2.2.1 External Appearance and Setting

Nuclear power plants generally contain four main buildings or structures:

- Containment or reactor building. A massive containment structure that houses the reactor vessel, the suppression pool [boiling-water reactors (BWRs) only], steam generators, pressurizer [pressurized-water reactors (PWRs) only], pumps, and associated piping. The building is generally designed to withstand such disasters as hurricanes, earthquakes, and aircraft collisions. The containment's ability to withstand such disasters, as well as the effects of accidents initiated by system failures, is the principal deterrent to release of radioactive materials to the environment.
- Turbine building. Plant structures that house the steam turbine and generator, condenser, waste heat rejection system, pumps, and equipment that supports those systems.
- Auxiliary buildings. Buildings that house such support systems as the ventilation system, the emergency core cooling system, the water treatment system, and the waste treatment system, along with fuel storage facilities and the plant control room.
- Cooling towers. Structures designed to remove excess heat from the condenser without dumping such heat directly into water bodies.

A plant site also contains a large switchyard, where the electric voltage is stepped up and fed into the regional power distribution system, and may also include various administrative and security buildings. During the operating life of a plant, its basic appearance remains unchanged.

Typically, nuclear power plant sites and the surrounding area are flat-to-rolling countryside in wooded or agricultural areas. More than 50 percent of the sites have 80-km (50-mile) population densities of less than 200 persons per square mile, and over 80 percent have 80-km (50-mile) densities of less than 500 persons per square mile. The most notable exception is the Indian Point Station, located within 80 km (50 miles) of New York City, which has a projected 1990 population density within 80 km (50 miles) of almost 2000 persons per square mile.

Site areas range from 34 ha (84 acres) for the San Onofre Nuclear Generating Station in California to 12,000 ha (30,000 acres) for the McGuire Nuclear Station in North Carolina. As shown in Table 2.1, 28 site areas range from 200 to 400 ha (500 to 1000 acres), and an additional 12 sites are in the 400- to 800-ha (1000- to 2000-acre) range. Thus, almost 60 percent of the plant sites encompass 200 to 800 ha (500 to 2000 acres). Larger land-use areas are associated with plant cooling systems that include reservoirs, artificial lakes, and buffer areas.

2.2.2 Reactor Systems

U.S. reactors employed for domestic electric power generation are conventional (thermal) light-water reactors (LWRs), using water as moderator and coolant. The two types of LWRs are PWRs (Figure 2.1) and BWRs (Figure 2.2). Of the 118 power reactors in the United States, 80 are PWRs and 38 are BWRs.

Table 2.1 Nuclear power plant baseline information

Plant	Unit	Operating license	License expiration	Electrical rating [MW(e)]	Reactor type[a]	Steam supply system vendor[b]	Cooling system[c]	Cooling water source	Condenser flow rate (10^3 gal/min)	Intake structure	Discharge structure	Total site area (acres)	Nearest city	Transmission corridor (acres)	1990 population (50 miles)
Arkansas Nuclear One	1	1974	2014	850	PWR	B&W	OT	Dardanelle	765	3220-ft	520-ft	1,160	Little Rock,	3,700	200,000
	2	1978	2018	912	PWR	CE	NDCT	Reservoir	422	canal	canal		Ark.		
Beaver Valley	1	1976	2016	835	PWR	WEST	NDCT	Ohio River	480	At river	At river	501	Pittsburgh	Uses	3,740,000
	2	1987	2027	836	PWR	WEST	NDCT		480	edge	edge			existing corridor	
Bellefonte Nuclear	1	—	—	1,213	PWR	B&W	NDCT	Guntersville	410	Intake	Submerged	1,500	Huntsville,	2,900	1,070,000
Plant	2	—	—	1,213	PWR	B&W	NDCT	Lake	410	channel	diffuser		Ala.		
Big Rock Point Nuclear Plant	1	1962	2002	72	BWR	GE	OT	Lake Michigan	49	Underwater crib	Open discharge canal	600	Sault Ste. Marie, Canada	—	200,000
Braidwood Station	1	1987	2027	1,120	PWR	WEST	CCCP	Kankakee	730	At lake	Surface flume	4,457	Joliet, Ill.	2,376	4,510,000
	2	1988	2028	1,120	PWR	WEST	CCCP	River	730	shore					
Browns Ferry Nuclear	1	1973	2013	1,065	BWR	GE	OT with	Tennessee	630	In small	Diffuser pipes	840	Huntsville,	1,350	760,000
Power Station	2	1974	2014	1,065	BWR	GE	towers	River	630	river			Ala.		
	3	1976	2016	1,065	BWR	GE			630	inlet					
Brunswick Steam	1	1976	2016	821	BWR	GE	OT	Cape Fear	675	3-mile canal	6-mile canal	1,200	Wilmington,	3,500	230,000
Electric Plant	2	1974	2014	821	BWR	GE	OT	River	675	from river	to Atlantic Ocean		N.C.		
Byron Station	1	1985	2025	1,120	PWR	WEST	NDCT	Rock River	632	On river	Discharge to	1,398	Rockford, Ill.	2,000	1,000,000
	2	1987	2027	1,120	PWR	WEST	NDCT		632	bank	river				
Callaway Plant	1	1984	2024	1,171	PWR	WEST	NDCT	Missouri River	530	From river	To river	3,188	Columbia, Mo.	1,140	400,000
Calvert Cliffs Nuclear	1	1974	2014	845	PWR	CE	OT	Chesapeake	1,200	560 ft from	850 ft from	1,135	Washington,	1,990	3,030,000
Power Plant	2	1976	2016	845	PWR	CE	OT	Bay	1,200	shore	shore		D.C.		
Catawba Nuclear	1	1985	2025	1,145	PWR	WEST	MDCT	Lake Wylie	660	Skimmer	Cove of lake	391	Charlotte,	584	1,590,000
Station	2	1986	2026	1,145	PWR	WEST	MDCT		660	wall			N.C.		
Clinton Power Station	1	1987	2027	933	BWR	GE	OT	Salt Creek	569	Shoreline of creek	3-mile flume	14,090	Decatur, Ill.	906	730,000
Comanche Peak Steam	1	1989	2029	1,150	PWR	WEST	OT	Squaw Creek	1,030	Shore of	Canal to	7,669	Ft. Worth,	458	1,130,000
Electric Station	2	—	—	1,150	PWR	WEST	OT	Reservoir	1,030	reservoir	reservoir		Tex.		

See footnotes at end of table

Table 2.1 (continued)

Plant	Unit	Operating license	License expiration	Electrical rating [MW(e)]	Reactor type[a]	Steam supply system vendor[b]	Cooling system[c]	Cooling water source	Condenser flow rate (10^3 gal/min)	Intake structure	Discharge structure	Total site area (acres)	Nearest city	Transmission corridor (acres)	1990 population (50 miles)
Donald C. Cook Nuclear Power Plant	1 2	1974 1977	2014 2017	1,030 1,100	PWR PWR	WEST WEST	OT OT	Lake Michigan	800 800	2,250 ft from shore	1,250 ft from shore	650	South Bend, Ind.	3,300	1,250,000
Cooper Nuclear Station	—	1974	2014	778	BWR	GE	OT	Missouri River	631	At shoreline	At shoreline	1,090	Lincoln, Neb.	6,862	180,000
Crystal River Nuclear Plant	3	1977	2017	825	PWR	B&W	OT	Gulf of Mexico	680	16,000 ft from shore	13,000 ft canal	4,738	Gainesville, Fla.	2,140	440,000
Davis-Besse Nuclear Power Station	1	1977	2017	906	PWR	B&W	NDCT	Lake Erie	480	Submerged 3,000 ft off shore	Submerged 900 ft off shore	954	Toledo, Ohio	1,800	1,920,000
Diablo Canyon Nuclear Power Plant	1 2	1984 1985	2024 2025	1,086 1,119	PWR PWR	WEST WEST	OT OT	Pacific Ocean	863 863	At shore with break wall	Surface to ocean	750	Santa Barbara, Calif.	6,000	300,000
Dresden Nuclear Power Station	2 3	1969 1971	2010 2011	794 794	BWR BWR	GE GE	Cooling lake and spray canal	Kankakee River	471 471	Canal from Kankakee River	Cooling lake to Illinois River	953 + 1,274 cooling pond	Joliet, Ill.	2,250	6,820,000
Duane Arnold Energy Center	1	1974	2014	538	BWR	GE	MDCT	Cedar River	290	Shoreline	Canal to shoreline	500	Cedar Rapids, Iowa	1,160	620,000
Joseph M. Farley Nuclear Plant	1 2	1977 1981	2017 2021	829 829	PWR PWR	WEST WEST	MDCT MDCT	Chatta-hoochee River	635 635	River to storage pond	At river bank	1,850	Columbus, Ga.	5,300	390,000
Enrico Fermi Atomic Power Plant	2	1985	2025	1,093	BWR	GE	NDCT	Lake Erie	837	At edge of lake	Pond to lake	1,120	Detroit	180	5,370,000
James A. FitzPatrick Nuclear Power Plant	—	1974	2014	816	BWR	GE	OT	Lake Ontario	353	From lake	To lake	702	Syracuse, N.Y.	1,000	820,000
Fort Calhoun Station	1	1973	2013	478	PWR	CE	OT	Missouri River	360	At shore	At shore	660	Omaha, Neb.	186	770,000
Robert Emmett Ginna Nuclear Power Plant	1	1969	2009	470	PWR	WEST	OT	Lake Ontario	356	Lake bottom	Open canal	338	Rochester, N.Y.	280	1,140,000
Grand Gulf Nuclear Station	1	1984	2024	1,250	BWR	GE	NDCT	Mississippi River	572	Collector wells	Discharge via barge slip	2,100	Jackson, Miss.	2,300	350,000

See footnotes at end of table.

Table 2.1 (continued)

Plant	Unit	Operating license	License expiration	Electrical rating [MW(e)]	Reactor type[a]	Steam supply system vendor[b]	Cooling system[c]	Cooling water source	Condenser flow rate (10^3 gal/min)	Intake structure	Discharge structure	Total site area (acres)	Nearest city	Transmission corridor (acres)	1990 population (50 miles)
Haddam Neck (Connecticut Yankee)	—	1967	2007	582	PWR	WEST	OT	Connecticut River	372	Shoreline	Canal to river	525	Meridian, Conn.	985	3,630,000
Shearon Harris Nuclear Power Plant	1	1987	2027	900	PWR	WEST	NDCT	Buckhorn Creek	483	Reservoir on creek	To reservoir	10,744	Raleigh, N.C.	3,500	1,430,000
Edwin I. Hatch Nuclear Plant	1 2	1974 1978	2014 2018	776 784	BWR BWR	GE GE	MDCT	Altamaha River	556	Edge of river	120 ft from shore	2,244	Savannah, Ga.	4,691	330,000
Hope Creek Generating Station	1	1986	2026	1,067	BWR	GE	NDCT	Delaware River	552	Edge of river	10 ft from shore	740	Wilmington, Del.	912	4,850,000
Indian Point Station	2 3	1973 1976	2013 2016	873 965	PWR PWR	WEST WEST	OT	Hudson River	840	At river bank	Channel to river	239	White Plains, N.Y.	10	15,190,000
Kewaunee Nuclear Power Plant	—	1973	2013	535	PWR	WEST	OT	Lake Michigan	420	1,750 ft from shore	At shoreline	908	Green Bay, Wisc.	1,066	640,000
La Salle County Station	1 2	1982 1984	2022 2024	1,078 1,078	BWR BWR	GE GE	Cooling pond	Illinois River	645	From cooling pond	To cooling pond	3,060	Joliet, Ill.	2,278	1,160,000
Limerick Generating Station	1 2	1985 1990	2025 2030	1,055 1,055	BWR BWR	GE GE	NDCT NDCT	Schuylkill River	450	From river	To river	595	Reading, Pa.	7	6,970,000
Maine Yankee Atomic Plant	—	1973	2013	825	PWR	CE	OT	Back River	426	River bank	Bay on Back River	740	Portland, Maine	220	640,000
William B. McGuire Nuclear Station	1 2	1981 1983	2021 2023	1,180 1,180	PWR PWR	WEST WEST	OT	Lake Norman	675	Submerged and surface at shoreline	2,000-ft canal discharge	30,000	Charlotte, N.C.	62	1,750,000
Millstone Nuclear Power Plant	1 2 3	1970 1975 1986	2010 2015 2026	660 870 1,154	BWR PWR PWR	GE CE WEST	OT OT OT	Long Island Sound	420 523 907	Niantic Bay	Via holding ponds	500	New Haven, Conn.	927	2,760,000
Monticello Nuclear Generating Plant	—	1970	2010	545	BWR	GE	OT with towers	Mississippi River	280	Canal	Canal	1,325	Minneapolis, Minn.	1,454	2,170,000
North Anna Power Station	1 2	1978 1980	2018 2020	907 907	PWR PWR	WEST WEST	OT	Lake Anna	940	Lake shore	Via cooling pond	18,643	Richmond, Va.	3,528	1,150,000

See footnotes at end of table.

Table 2.1 (continued)

Plant	Unit	Operating license	License expiration	Electrical rating [MW(e)]	Reactor type[a]	Steam supply system vendor[b]	Cooling system[c]	Cooling water source	Condenser flow rate (10^3 gal/min)	Intake structure	Discharge structure	Total site area (acres)	Nearest city	Transmission corridor (acres)	1990 population (50 miles)
Nine Mile Point Nuclear Station	1 2	1968 1987	2008 2027	620 1,080	BWR BWR	GE GE	OT NDCT	Lake Ontario	250 580	Pipelines 1,000 ft off shore	Diffuser pipe	900	Syracuse, N.Y.	1,640	820,000
Oconee Nuclear Station	1 2 3	1973 1973 1974	2013 2013 2014	887 887 887	PWR PWR PWR	B&W B&W B&W	OT	Lake Keowee	680	710-ft deep skimmer wall	765 ft deep	510	Greenville, S.C.	7,800	990,000
Oyster Creek Generating Station	1	1969	2009	650	BWR	GE	OT	Barnegat Bay	460	Forked River from bay	Forked River to bay	1,416	Atlantic City, N.J.	322	4,030,000
Palisades Nuclear Plant	1	1972	2012	805	PWR	CE	MDCT	Lake Michigan	405	Crib 3,300 ft from shore	108-ft canal	487	Kalamazoo, Mich.	2,250	1,170,000
Palo Verde Generating Station	1 2 3	1985 1986 1987	2025 2026 2027	1,270 1,270 1,270	PWR PWR PWR	CE CE CE	MDCT	Phoenix City Sewage Treatment Plant	560	35-mile pipe	Evaporation ponds	4,050	Phoenix, Ariz.	16,600	1,180,000
Peach Bottom Atomic Power Station	2 3	1973 1974	2013 2014	1,065 1,065	BWR BWR	GE GE	OT with towers	Conowingo Pond	750	Small intake pond	5,000-ft canal	620	Lancaster, Pa.	1,030	4,660,000
Perry Nuclear Power Station	1	1986	2026	1,205	BWR	GE	NDCT	Lake Erie	545	Multiport 2,250 ft off shore	Diffuser 1,650 ft off shore	1,100	Euclid, Ohio	1,500	2,480,000
Pilgrim Nuclear Power Station	1	1972	2012	655	BWR	GE	OT	Cape Cod Bay	311	Edge of bay	850-ft canal	517	Brockton, Mass.	174	4,440,000
Point Beach Nuclear Plant	1 2	1970 1972	2010 2012	497 497	PWR PWR	WEST WEST	OT	Lake Michigan	350	1,750 ft from shore	Flumes 150 ft from shore	2,065	Green Bay, Wisc.	3,321	610,000
Prairie Island Nuclear Generating Plant	1 2	1973 1974	2013 2014	530 530	PWR PWR	WEST WEST	MDCT or OT	Mississippi River	294	Short canal	Basin to towers and/or river	560	Minneapolis, Minn.	973	2,290,000
Quad-Cities Station	1 2	1972 1972	2012 2012	789 789	BWR BWR	GE GE	OT	Mississippi River	471	Edge of river	14,000-ft spray canal	784	Davenport, Iowa	1,400	740,000
Rancho Seco Nuclear Station	1	1974	2014	918	PWR	B&W	NDCT	Folsom Canal	446	3.5-mile pipe	1.5-mile pipe to reservoir	2,480	Sacramento, Calif.	870	2,010,000

See footnotes at end of table.

Table 2.1 (continued)

Plant	Unit	Operating license	License expiration	Electrical rating [MW(e)]	Reactor type[a]	Steam supply system vendor[b]	Cooling system[c]	Cooling water source	Condenser flow rate (10^3 gal/min)	Intake structure	Discharge structure	Total site area (acres)	Nearest city	Transmission corridor (acres)	1990 population (50 miles)
River Bend Station	1	1985	2025	936	BWR	GE	MDCT	Mississippi River	508	At river bank	Into river	3,342	Baton Rouge, La.	1,014	800,000
H. B. Robinson Plant	2	1970	2010	700	PWR	WEST	OT	Lake Robinson	482	Edge of lake	4.2-mile canal	5,000	Columbia, S.C.	1,024	740,000
Salem Nuclear Generating Station	1 2	1976 1981	2016 2021	1,115 1,115	PWR PWR	WEST WEST	OT	Delaware River	1,100	Edge of river	500 ft into river	700	Wilmington, Del.	3,900	4,810,000
San Onofre Nuclear Generating Station	1 2 3	1967 1982 1983	2007 2022 2023	436 1,070 1,080	PWR PWR PWR	WEST CE CE	OT	Pacific Ocean	341 797 797	3,200 to 3,400 ft off shore	2,600 to 8,500 ft from shore	84	Oceanside, Calif.	1,100	5,430,000
Seabrook Station	1	1990	2032	1,198	PWR	WEST	OT	Atlantic Ocean	399	7,000 ft off shore	5,500 ft off shore	896	Lawrence, Mass.	1,545	3,760,000
Sequoyah Nuclear Plant	1 2	1980 1981	2020 2021	1,148 1,148	PWR PWR	WEST WEST	OT and/or NDCT	Chickamauga Lake	522	From lake	To lake	525	Chattanooga, Tenn.	1,260	930,000
Shoreham Nuclear Power Station	—	—	—	819	BWR	GE	OT	Long Island Sound	574	Intake canal	Diffuser system	499	New Haven, Conn.	39	5,390,000
South Texas Project	1 2	1988 1989	2028 2029	1,250 1,250	PWR PWR	WEST WEST	CCCP	Colorado River	907	Bank of river	Bank of river	12,350	Galveston, Texas	4,773	270,000
St. Lucie Plant	1 2	1976 1983	2016 2023	830 830	PWR PWR	CE CE	OT	Atlantic Ocean	491	1,200 ft off shore	>1,200 ft off shore	1,132	West Palm Beach, Fla.	760	690,000
Virgil C. Summer Nuclear Station	1	1982	2022	900	PWR	WEST	OT	Lake Monticello	485	Intake at shoreline	Discharge pond to lake	2,200	Columbia, S.C.	1,576	910,000
Surry Power Station	1 2	1972 1973	2012 2013	788 788	PWR PWR	WEST WEST	OT	James River	840	1.7-mile canal	2900-ft canal	840	Newport News, Va.	4,420	1,900,000
Susquehanna Steam Electric Station	1 2	1982 1984	2022 2024	1,050 1,050	BWR BWR	GE GE	NDCT	Susquehanna River	448	River bank	240 ft from bank	1,075	Wilkes-Barre, Pa.	1,800	1,500,000
Three Mile Island Nuclear Station	1	1974	2014	819	PWR	B&W	NDCT	Susquehanna River	430	At river bank	At shoreline	472	Harrisburg, Pa.	1,790	2,170,000

See footnotes at end of table.

Table 2.1 (continued)

Plant	Unit	Operating license	License expiration	Electrical rating [MW(e)]	Reactor type[a]	Steam supply system vendor[b]	Cooling system[c]	Cooling water source	Condenser flow rate (10^3 gal/min)	Intake structure	Discharge structure	Total site area (acres)	Nearest city	Transmission corridor (acres)	1990 population (50 miles)
Trojan Nuclear Plant	1	1975	2015	1,130	PWR	WEST	NDCT	Columbia River	429	At river bank	350 ft from bank	635	Portland, Ore.	1,260	1,850,000
Turkey Point Plant	3 4	1972 1973	2012 2013	693 693	PWR PWR	WEST WEST	Closed-cycle canal	Biscane Bay	624	Intake canal and barge canal	Canal system	24,000	Miami	817	2,70[illegible],000
Vermont Yankee Nuclear Power Station	1	1973	2013	540	BWR	GE	OT and towers	Connecticut River	366	Edge of river	Edge of river	125	Holyoke, Mass.	1,550	1,510,000
Vogtle Electric Generating Plant	1 2	1987 1989	2027 2029	1,101 1,160	PWR PWR	WEST WEST	NDCT	Savannah River	510	At river bank	Near shoreline	3,169	Augusta, Ga.	—	630,000
Waterford Steam Electric Station	3	1985	2025	1,104	PWR	CE	OT	Mississippi River	975	At river bank	At river bank	3,561	New Orleans	280	1,970,000
Watts Bar Nuclear Plant	1 2	— —	— —	1,170 1,170	PWR PWR	WEST WEST	NDCT NDCT	Chickamauga Lake	410	At lake bank	Holding pond to lake	1,170	Chattanooga, Tenn.	3,165	950,000
Washington Nuclear Project (WNP)	2	1984	2024	1,100	BWR	GE	MDCT	Columbia River	550	Offshore	175 ft from shoreline	Department of Energy, Hanford Reservation	Richland, Wash.	Hanford Reservation	280,000
Wolf Creek Generation Station	1	1985	2025	1,170	PWR	WEST	CCCP	Wolf Creek	500	Cooling lake	Cooling lake to embayment	9,818	Topeka, Kansas	2,900	200,000
Yankee Nuclear Power Station	1	1960	2000	175	PWR	WEST	OT	Deerfield River	140	Sherman Pond, 90 ft below surface	Sherman Pond	2,000	Pittsfield, Mass.	—	1,720,000
Zion Nuclear Plant	1 2	1973 1973	2013 2013	1,040 1,040	PWR PWR	WEST WEST	OT OT	Lake Michigan	735	2600 ft off shore	760 ft off shore	250	Waukegan, Ill.	145	7,480,000

[a]PWR = pressurized-water reactor; BWR = boiling-water reactor.
[b]B-W = Babcock and Wilcox; GE = General Electric; WEST = Westinghouse; C-E = Combustion-Engineering.
[c]OT = once through; NDCT = natural draft cooling tower; MDCT = mechanical draft cooling tower; CCCP = closed cycle cooling pond, lake, or reservoir.

ORNL-DWG95-7681

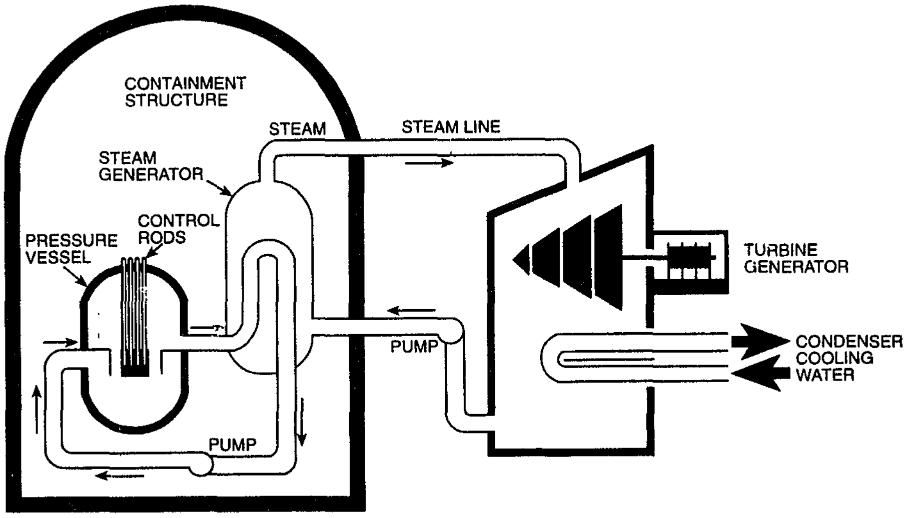

Figure 2.1 Pressurized-water-reactor power generation system.

ORNL-DWG95-7682

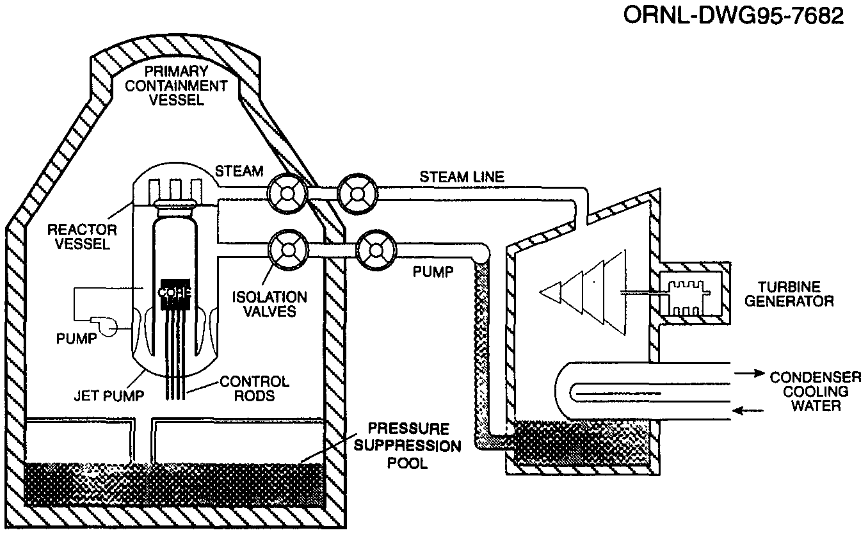

Figure 2.2 Boiling-water-reactor generating system.

In the PWR, reactor heat is transferred from the primary coolant to a secondary coolant loop that is at a lower pressure, allowing steam to be generated in the steam generator. The steam then flows to a turbine for power production. In contrast, the BWR generates steam directly within the reactor core, which passes through moisture separators and steam dryers and then flows to the turbine.

All domestic power reactors employ a containment structure as a major safety feature to prevent the release of radionuclides in the event of an accident. PWRs employ three types of containments: (1) large, dry containments; (2) subatmospheric containments; and (3) ice condenser containments. Of the 80 U.S. PWRs, 65 have large, dry containments; 7 have subatmospheric containments; and 8 have ice condenser containments. BWR containments typically are composed of a suppression pool and dry well. Three types of BWR containments (Mark I, Mark II, and Mark III) have evolved. There are 24 Mark I, 10 Mark II, and 4 Mark III containment designs in the United States.

NUREG/CR-5640 provides a comprehensive overview and description of U.S. commercial nuclear power plant systems.

2.2.3 Cooling and Auxiliary Water Systems

The predominant water use at a nuclear power plant is for removing excess heat generated in the reactor by condenser cooling. The quantity of water used for condenser cooling is a function of several factors, including the capacity rating of the plant and the increase in cooling water temperature from the intake to the discharge. The larger the plant, the greater the quantity of waste heat to be dissipated, and the greater the quantity of cooling water required.

In addition to removing heat from the reactor, cooling water is also provided to the service water system and to the auxiliary cooling water system. The volume of water required for these systems for once-through cooling is usually less than 15 percent of the volume required for condenser cooling. In closed-cycle cooling, the additional water needed is usually less than 5 percent of that needed for condenser cooling.

Of the 118 nuclear reactors, 48 use closed-cycle cooling systems (see Table 2.2, which groups the 74 plant sites into three broad categories according to environment). Most closed-cycle systems use cooling towers. Some closed-cycle system units use a cooling lake or canals for transferring heat to the atmosphere. Once-through cooling systems are used at 70 units. A few of these systems are augmented with helper cooling towers to reduce the temperature of the effluent released to the adjacent body of water.

In closed-cycle systems, the cooling water is recirculated through the condenser after the waste heat is removed by dissipation to the atmosphere, usually by circulating the water through large cooling towers constructed for that purpose. Several types of closed-cycle cooling systems are currently used by the nuclear power industry. Recirculating cooling systems consist of either natural draft or mechanical draft cooling towers, cooling ponds, cooling lakes, or cooling canals. Because the predominant cooling mechanism associated with closed-cycle systems is evaporation, most of the water

Table 2.2 Types of cooling systems used at nuclear power sites

Plant site	State	Cooling system[a]
	Coastal or estuarine environment	
Diablo Canyon Nuclear Power Plant	California	Once through
San Onofre Nuclear Generating Station	California	Once through
Millstone Nuclear Power Plant	Connecticut	Once through
Crystal River Nuclear Plant	Florida	Once through
St. Lucie Plant	Florida	Once through
Turkey Point Plant	Florida	Cooling canal
Maine Yankee Atomic River Plant	Maine	Once through
Calvert Cliffs Nuclear Power Plant	Maryland	Once through
Pilgrim Nuclear Power Plant	Massachusetts	Once through
Seabrook Station	New Hampshire	Once through
Hope Creek Generating Station	New Jersey	Towers (natural draft)
Oyster Creek Generating Station	New Jersey	Once through
Salem Nuclear Generating Station	New Jersey	Once through
Indian Point Station	New York	Once through
Shoreham Nuclear Power Station	New York	Once through
Brunswick Steam Electric Plant	North Carolina	Once through
South Texas Project	Texas	Cooling pond
Surry Power Station	Virginia	Once through
	Great Lakes shoreline environment	
Zion Nuclear Plant	Illinois	Once through
Big Rock Point Nuclear Plant	Michigan	Once through
Donald C. Cook Nuclear Power Plant	Michigan	Once through
Enrico Fermi Atomic Power Plant	Michigan	Towers (natural draft) and pond
Palisades Nuclear Plant	Michigan	Towers (mechanical draft)
James A. FitzPatrick Nuclear Power Plant	New York	Once through
Robert Emmett Ginna Nuclear Power Plant	New York	Once through
Nine Mile Point Nuclear Station	New York	Once through and towers
Davis-Besse Nuclear Power Station	Ohio	Towers (natural draft)
Perry Nuclear Power Station	Ohio	Towers (natural draft)
Kewaunee Nuclear Power Plant	Wisconsin	Once through
Point Beach Nuclear Plant	Wisconsin	Once through
	Freshwater riverine or impoundment environment	
Bellefonte Nuclear Plant	Alabama	Towers (natural draft)
Browns Ferry Nuclear Power Plant	Alabama	Once through and helper towers
Joseph M. Farley Nuclear Plant	Alabama	Towers (mechanical draft)
Palo Verde Generating Station	Arizona	Towers (mechanical draft)
Arkansas Nuclear One	Arkansas	Once through and towers
Rancho Seco Nuclear Station	California	Towers (natural draft)
Haddam Neck Plant (Connecticut Yankee)	Connecticut	Once through
Edwin I. Hatch Nuclear Plant	Georgia	Towers (mechanical draft)
Vogtle Electric Generating Plant	Georgia	Towers (natural draft)
Braidwood Station	Illinois	Cooling pond
Byron Station	Illinois	Towers (natural draft)
Clinton Power Station	Illinois	Cooling pond

Table 2.2 (continued)

Plant site	State	Cooling system[a]
	Freshwater riverine or impoundment environment (continued)	
Dresden Nuclear Power Station	Illinois	Spray canal and cooling pond
La Salle Country Station	Illinois	Cooling pond
Quad Cities Station	Illinois	Once through
Duane Arnold Energy Center	Iowa	Towers (mechanical draft)
Wolf Creek Generation Station	Kansas	Cooling pond
River Bend Station	Louisiana	Towers (mechanical draft)
Waterford Steam Electric Station	Louisiana	Once through
Yankee Nuclear Power Station	Massachusetts	Once through
Monticello Nuclear Generating Plant	Minnesota	Variable (mechanical draft)
Prairie Island Nuclear Generating Plant	Minnesota	Variable (mechanical draft)
Grand Gulf Nuclear Station	Mississippi	Towers (natural draft)
Callaway Plant	Missouri	Towers (natural draft)
Cooper Nuclear Station	Nebraska	Once through
Fort Calhoun Station	Nebraska	Once through
Shearon Harris Nuclear Power Plant	North Carolina	Towers (natural draft)
William B. McGuire Nuclear Station	North Carolina	Once through
Trojan Nuclear Plant	Oregon	Towers (natural draft)
Beaver Valley	Pennsylvania	Variable (natural draft)
Limerick Generating Station	Pennsylvania	Towers (natural draft)
Peach Bottom Atomic Power Station	Pennsylvania	Once through and towers (mechanical draft)
Susquehanna Steam Plant Station	Pennsylvania	Towers (natural draft)
Three Mile Island Nuclear Station	Pennsylvania	Towers (natural draft)
Catawba Nuclear Station	South Carolina	Towers (mechanical draft)
Oconee Nuclear Station	South Carolina	Once through
H. B. Robinson Plant	South Carolina	Cooling pond
Virgil C. Summer Nuclear Station	South Carolina	Cooling pond
Sequoyah Nuclear Plant	Tennessee	Variable (natural draft)
Watts Bar Nuclear Plant	Tennessee	Towers (natural draft)
Comanche Peak	Texas	Once through
Vermont Yankee Nuclear Power Station	Vermont	Once through and helper towers
North Anna Power Station	Virginia	Once through
Washington Nuclear Project-2	Washington	Towers (mechanical draft)

[a]Of the 48 plants with closed-cycle cooling systems, 15 use mechanical draft cooling towers, 25 use natural draft cooling towers, 4 use a canal system, and 4 use a cooling lake. Of the 70 plants with once-through cooling systems, 24 discharge to a river, 11 discharge to the Great Lakes, 19 discharge to the ocean or an estuary, and 16 discharge to a reservoir or lake. Five of the once-through plants can also switch to cooling towers.

used for cooling is consumed and is not returned to a water source.

In a once-through cooling system, circulating water for condenser cooling is drawn from an adjacent body of water, such as a lake or river, passed through the condenser tubes, and returned at a higher temperature to the adjacent body of water. The waste heat is dissipated to the atmosphere mainly by evaporation from the water body and, to a much smaller extent, by conduction, convection, and thermal radiation loss.

All sites with two or three reactors use the same cooling system for all reactors, except for two sites: Arkansas Nuclear One in Arkansas and Nine Mile Point in New York. These two sites use once-through cooling for one unit and closed-cycle for the other.

For both once-through and closed-cycle cooling systems, the water intake and discharge structures are of various configurations to accommodate the source water body and to minimize impact to the aquatic ecosystem. The intake structures are generally located along the shoreline of the body of water and are equipped with fish protection devices (ORNL/TM-6472). The discharge structures are generally of the jet or diffuser outfall type and are designed to promote rapid mixing of the effluent stream with the receiving body of water. Biocides and other chemicals used for corrosion control and for other water treatment purposes are mixed with the condenser cooling water and discharged from the system.

In addition to surface water sources, some nuclear power plants use groundwater as a source for service water, makeup water, or potable water. Other plants operate dewatering systems to intentionally lower the groundwater table, either by pumping or by using a system of drains, in the vicinity of building foundations.

2.2.4 Radioactive Waste Treatment Systems

During the fission process, a large inventory of radioactive fission products builds up within the fuel. Virtually all of the fission products are contained within the fuel pellets. The fuel pellets are enclosed in hollow metal rods (cladding), which are hermetically sealed to further prevent the release of fission products. However, a small fraction of the fission products escapes the fuel rods and contaminates the reactor coolant. The primary system coolant also has radioactive contaminants as a result of neutron activation. The radioactivity in the reactor coolant is the source of gaseous, liquid, and solid radioactive wastes at LWRs.

The following sections describe the basic design and operation of PWR and BWR radioactive-waste-treatment systems.

2.2.4.1 Gaseous Radioactive Waste

For BWRs, the sources of routine radioactive gaseous emissions to the atmosphere are the air ejector, which removes noncondensable gases from the coolant to improve power conversion efficiency, and gaseous and vapor leakages, which, after monitoring and filtering, are discharged to the atmosphere via the building ventilation systems.

The off-gas treatment system collects noncondensable gases and vapors that are exhausted at the condenser via the air ejectors. These off-gases are processed through a series of delay systems and filters to remove airborne radioactive particulates and halogens, thereby minimizing the quantities of the radionuclides that might be released. Building ventilation system exhausts are another source of gaseous radioactive wastes for BWRs.

PWRs have three primary sources of gaseous radioactive emissions:

- discharges from the gaseous waste management system;
- discharges associated with the exhaust of noncondensable gases at the main

condenser if a primary-to-secondary system leak exists; and

- radioactive gaseous discharges from the building ventilation exhaust, including the reactor building, reactor auxiliary building, and fuel-handling building.

The gaseous waste management system collects fission products, mainly noble gases, that accumulate in the primary coolant. A small portion of the primary coolant flow is continually diverted to the primary coolant purification, volume, and chemical control system to remove contaminants and adjust the coolant chemistry and volume. During this process, noncondensable gases are stripped and routed to the gaseous waste management system, which consists of a series of gas storage tanks. The storage tanks allow the short-half-life radioactive gases to decay, leaving only relatively small quantities of long-half-life radionuclides to be released to the atmosphere. Some PWRs are using charcoal delay systems rather than gas storage tanks (e.g., Seabrook).

2.2.4.2 Liquid Radioactive Waste

Radionuclide contaminants in the primary coolant are the source of liquid radioactive waste in LWRs. The specific sources of these wastes, the modes of collection and treatment, and the types and quantities of liquid radioactive wastes released to the environment are in many respects similar in BWRs and PWRs. Accordingly, the following discussion applies to both BWRs and PWRs, with distinctions made only where important differences exist.

Liquid wastes resulting from LWR operation may be placed into the following categories: clean wastes, dirty wastes, detergent wastes, turbine building floor-drain water,[1] and steam generator blowdown (PWRs only). *Clean wastes* include all liquid wastes with a normally low conductivity and variable radioactivity content. They consist of reactor grade water, which is amenable to processing for reuse as reactor coolant makeup water. Clean wastes are collected from equipment leaks and drains, certain valve and pump seal leaks not collected in the reactor coolant drain tank, and other aerated leakage sources. These wastes also include primary coolant. *Dirty wastes* include all liquid wastes with a moderate conductivity and variable radioactivity content that, after processing, may be used as reactor coolant makeup water. Dirty wastes consist of liquid wastes collected in the containment building sump, auxiliary building sumps and drains, laboratory drains, sample station drains, and other miscellaneous floor drains. *Detergent wastes* consist principally of laundry wastes and personnel and equipment decontamination wastes and normally have a low radioactivity content. *Turbine building floor-drain wastes* usually have high conductivity and low radionuclide content. In PWRs, *steam generator blowdown* can have relatively high concentrations of radionuclides depending on the amount of primary-to-secondary leakage. Following processing, the water may be reused or discharged.

Each of these sources of liquid wastes receives varying degrees and types of treatment before storage for reuse or discharge to the environment under the site National Pollutant Discharge Elimination System (NPDES) permit. The extent and types of treatment depend on the chemical and radionuclide content of the waste; to increase the efficiency of waste processing, wastes of similar characteristics are batched before treatment.

The degree of processing, storing, and recycling of liquid radioactive waste has steadily increased among operating plants. For example, extensive recycling of steam generator blowdown in PWRs is now the typical mode of operation, and secondary side wastewater is routinely treated. In addition, the plant systems used to process wastes are often augmented with the use of commercial mobile processing systems. As a result, radionuclide releases in liquid effluent from LWRs have generally declined or remained the same.

2.2.4.3 Solid Radioactive Waste

Solid low-level radioactive waste (LLW) from nuclear power plants is generated by removal of radionuclides from liquid waste streams, filtration of airborne gaseous emissions, and removal of contaminated material from various reactor areas. Liquid contaminated with radionuclides comes from primary and secondary coolant systems, spent-fuel pools, decontaminated wastewater, and laboratory operations. Concentrated liquids, filter sludges, waste oils, and other liquid sources are segregated by type, flushed to storage tanks, stabilized for packaging in a solid form by dewatering, slurried into 55-gal steel drums, and stored on-site in shielded Butler-style buildings or other facilities until suitable for off-site disposal (NUREG/CR-2907). These buildings usually contain volume reduction facilities to reduce the volume of LLW requiring off-site disposal (EPRI NP-5526-V1).

High-efficiency particulate filters are used to remove radioactive material from gaseous plant effluents. These filters are compacted in volume reduction facilities that have volume reduction equipment and are disposed of as solid wastes.

Solid LLW consists of contaminated protective clothing, paper, rags, glassware, compactible and noncompactible trash, and non-fuel-irradiated reactor components and equipment. Most of this waste comes from plant modifications and routine maintenance activities. Additional sources include tools and other material exposed to the reactor environment (EPRI-NP-5526-V1; EPRI NP-5526-V2). Before disposal, compactible trash is usually taken to on- or off-site VR facilities. Compacted dry active waste is the largest single form of LLW disposed from nuclear plants, comprising one-half and one-third of total average annual volumes from PWRs and BWRs, respectively (EPRI NP-5526V1).

Volume reduction efforts have been undertaken in response to increased disposal costs and the passage of the 1980 Low Level Radioactive Waste Policy Act and the 1985 Low Level Radioactive Waste Policy Amendments Act (LLRWPAA) (Pub. L. 96-573; Pub. L. 99-240), which require LLW disposal allocation systems for nuclear plants (see Section 6.3). Volume reduction is performed both on- and off-site. The most common on-site volume reduction techniques are high-pressure compacting of waste drums, dewatering and evaporating wet wastes, monitoring waste streams to segregate wastes, minimizing the exposure of routine equipment to contamination, and decontaminating and sorting radioactive or nonradioactive batches before off-site shipment. Off-site waste management vendors compact compactible wastes at ultra-high pressure (supercompaction); incinerate dry active waste; separate and incinerate oily, organic wastes; solidify the ash; and occasionally undertake waste crystallization and asphalt solidification of resins and sludges

(EPRI NP-6163; EPRI NP-5526-V1; EPRI NP-5526-V2; DOE/RW-0220).

Spent fuel contains fission products and actinides produced when nuclear fuel is irradiated in reactors, as well as any unburned, unfissioned nuclear fuel remaining after the fuel rods have been removed from the reactor core. After spent fuel is removed from reactors, it is stored in racks placed in storage pools to isolate it from the environment. Delays in siting an interim monitored retrievable storage (MRS) facility or permanent repository, coupled with rapidly filling spent-fuel pools, have led utilities to seek other storage solutions, including expansion of existing pools, aboveground dry storage, longer fuel burnup, and shipment of spent fuel to other plants (Gerstberger 1987; DOE RW-0220).

Pool storage has been increased through (1) enlarging the capacity of spent-fuel racks, (2) adding racks to existing pool arrays ("dense-racking"), (3) reconfiguring spent fuel with neutron-absorbing racks, and (4) employing double-tiered storage (installing a second tier of racks above those on the pool floor).

Efforts are under way to develop dry storage technologies; these include casks, silos, dry wells, and vaults (DOE December 1989). Dry storage facilities are simpler and more readily maintained than fuel pools. They are growing in favor because they offer a more stable means of storage and require relatively little land area (less than 0.2 ha—half an acre in most cases) (Johnson 1989). Dry storage is currently in use at about 5 percent of the sites.

2.2.4.4 Transportation of Radioactive Materials

There are four types of radioactive material shipments to and from nuclear plants: (1) routine and refurbishment-generated LLW transported from plants to disposal facilities, (2) routine LLW shipped to off-site facilities for volume reduction, (3) nuclear fuel shipments from fuel fabrication facilities to plants for loading into reactors (generally occurring on a 12- to 18-month cycle), and (4) spent-fuel shipments to other nuclear power plants with available storage space (an infrequent occurrence usually limited to plants owned by the same utility).

Workers and others are protected from exposure during radioactive material transport by the waste packaging. Operational restrictions on transport vehicles, ambient radiation monitoring, imposition of licensing standards (which ensure proper waste certification by testing and analysis of packages), waste solidification, and training of emergency personnel to respond to mishaps are also used (NUREG-0170; O'Sullivan 1988). Additional regulations may be imposed by states and communities along transportation corridors (Pub. L. 93-633; OTA-SET-304).

A typical PWR makes approximately 44 shipments of LLW per year; an average BWR makes 104 shipments per year (EPRI NP-5983). Most of this LLW is Class A waste packaged in 55-gal drums or other "Type A" containers and shipped to disposal facilities on flatbed trucks (DOE August 1989). (A "Type A" container permits no release of radioactive material under normal transportation conditions and must maintain sufficient shielding to limit radiation exposure to handling personnel).

LLW shipments require manifests that describe the contents of the packages to permit inspection by state, local, and facility personnel and to ensure that the waste is suitable for a particular disposal facility (NUREG-0945).

Currently, the only spent-fuel shipments from nuclear plants are to other plants. A few spent-fuel shipments have, in the past, been made to fuel reprocessing plants. These shipments are packaged in "Type B" casks designed to retain the highly radioactive contents under normal and accident conditions. These containers range in size from 23–36 metric tons (25–40 tons) for truck shipment (each cask is capable of holding seven fuel assemblies) to 109 metric tons (120 tons) for rail transport (with a capacity for 36 assemblies) (DOE/RW-0065). The casks are resistant to both small-arms fire and high-explosive detonation (NUREG-0170).

2.2.5 Nonradioactive Waste Systems

Nonradioactive wastes from nuclear power plants include boiler blowdown (continual or periodic purging of impurities from plant boilers), water treatment wastes (sludges and high saline streams whose residues are disposed of as solid waste and biocides), boiler metal cleaning wastes, floor and yard drains, and stormwater runoff. Principal chemical and biocide waste sources include the following:

- Boric acid used to control reactor power and lithium hydroxide used to control pH in the coolant. (These chemicals could be inadvertently released because of pipe or steam generator leakage.)
- Sulfuric acid, which is added to the circulating water system to control scale.
- Hydrazine, which is used for corrosion control. (It is released in steam generator blowdown.)
- Sodium hydroxide and sulfuric acid, which are used to regenerate resins. (These are discharged after neutralization.)
- Phosphate in cleaning solutions.
- Biocides used for condenser defouling.

Other small volumes of wastewater are released from other plant systems depending on the design of each plant. These are discharged from such sources as the service water and auxiliary cooling systems, water treatment plant, laboratory and sampling wastes, boiler blowdown, floor drains, stormwater runoff, and metal treatment wastes. These waste streams are discharged as separate point sources or are combined with the cooling water discharges.

2.2.6 Nuclear Power Plant Operation and Maintenance

Nuclear power reactors are capable of generating electricity continuously for long periods of time. However, they operate neither at maximum capacity nor continuously for the entire term of their license. Plants can typically operate continuously for periods of time ranging from 1 year to 18 months on a single fuel load. Scheduled and unscheduled maintenance outages and less than peak power generation resulting from diminished consumer demand, or operational decisions, have reduced the power output for the U.S. nuclear power industry as a whole to an average annual capacity of between 58 and 73 percent of the maximum capability for the years 1975 through 1993, inclusive (NUREG-1350, vol. 6).

Maintenance activities are routinely performed on systems and components to help ensure the safe and reliable operation of the plant. In addition, inspection, testing, and surveillance activities are conducted throughout the operational life of a nuclear power plant to maintain the current licensing basis of the plant and ensure compliance with federal, state, and local requirements regarding the environment and public safety.

Nuclear power plants must periodically discontinue the production of electricity for refueling, periodic in-service inspection (ISI), and scheduled maintenance. Refueling cycles occur approximately every 12 to 18 months. The duration of a refueling outage is typically on the order of 2 months. Enhanced or expanded inspection and surveillance activities are typically performed at 5- and 10-year intervals. These enhanced inspections are performed to comply with Nuclear Regulatory Commission (NRC) and/or industry standards or requirements such as the American Society of Mechanical Engineers Boiler and Pressure Vessel Code. Five-year ISIs are scheduled for the 5th, 15th, 25th, and 35th years of operation, and 10-year ISIs are performed in the 10th, 20th, and 30th years. Each of these outages typically requires 2 to 4 months of down time for the plant. For economic reasons, many of these activities are conducted simultaneously (e.g., refueling activities typically coincide with the ISI and maintenance activities).

Many plants also undertake various major refurbishment activities during their operational lives. These activities are performed to ensure both that the plant can be operated safely and that the capacity and reliability of the plant remain at acceptable levels. Typical major refurbishments that have occurred in the past include replacing PWR steam generators, replacing BWR recirculation piping, and rebuilding main steam turbine stages. The need to perform major refurbishments is highly plant-specific and depends on factors such as design features, operational history, and construction and fabrication details. The plants may remain out of service for extended periods of time, ranging from a few months to more than a year, while these major refurbishments are accomplished. Outage durations vary considerably, depending on factors such as the scope of the repairs or modifications undertaken, the effectiveness of the outage planning, and the availability of replacement parts and components.

Each nuclear power plant is part of a utility system that may own several nuclear power plants, fossil-fired plants, or other means of generating electricity. An on-site staff is responsible for the actual operation of each plant, and an off-site staff may be headquartered at the plant site or some other location. Typically, from 800 to 2300 people are employed at nuclear power plant sites during periods of normal operation, depending on the number of operating reactors located at a particular site. The permanent on-site work force is usually in the range of 600 to 800 people per reactor unit. However, during outage periods, the on-site work force typically increases by 200 to 900 additional workers. The additional workers include engineering support staff, technicians, specialty craftspersons, and laborers called in both to perform specialized repairs, maintenance, tests, and inspections and to assist the permanent staff with the more routine activities carried out during plant outages.

2.2.7 Power-Transmission Systems

Power-transmission systems associated with nuclear power plants consist of switching stations (or substations) located on the plant site and transmission lines located primarily off-site. These systems are required to transfer power from the generating station to the utility's network of power lines in its service area.

Switching stations transfer power from generating sources to power lines and regulate the operation of the power system. Transformers in switching stations convert the generated voltage to voltage levels appropriate for the power lines. Equipment for regulating system operation includes switches, power circuit breakers, meters, relays, microwave communication equipment, capacitors, and a variety of other electrical equipment. This equipment meters and controls power flow; improves performance characteristics of the generated power; and protects generating equipment from short circuits, lightning strikes, and switching surges that may occur along the power lines. Switching stations occupy on-site areas generally two to four times as large as areas occupied by reactor and generator buildings, but are not as visible as the plant buildings.

The length of power transmission lines constructed for nuclear plants varies from a few miles for some plants to hundreds of miles for others. Power line systems include towers (structures), insulator strings, conductors, and ground wires strung between towers. Power lines associated with nuclear plants usually have voltages of 230 kV, 345 kV, 500 kV, or 765 kV (see Section 4.5.1). They operate at a low frequency of 60 Hz (60 cycles per second) compared with frequencies of 55–890 MHz for television transmitters and 1000 MHz and greater for microwaves.

Most power line towers are double wooden poles ("H-frame" structure) or metal lattice structures that support one or two sets of conductors (three conductors per set; see Section 4.5.1). Tower height, usually between 21 and 51 m (70 and 170 ft), increases with line voltage. Strings of insulators connect the conductors to the towers. The tops of the towers support two ground wires that transmit the energy of lightning strikes to the ground. Thus, the ground wires prevent lightning strikes to the conductors, minimize the occurrence of power system outages, and protect vital power system components that could be damaged by lightning-caused power surges on the conductors.

2.3 PLANT INTERACTION WITH THE ENVIRONMENT

This section describes how nuclear plants interact with the environment. Nuclear power plants are sited, designed, and operated to minimize impacts to the environment, including plant workers. Land that could be used for other purposes is dedicated to electric power production for the life of the plant. The aesthetics of the landscape are altered because of the new plant structures; the surface and groundwater hydrology and terrestrial and aquatic ecology may be affected; the air quality may be affected; and, finally, the community infrastructure and services are altered to accommodate the influx of workers into the area. The environmental impact from plant operation is determined largely by waste effluent streams (gaseous, liquid, and solid); the plant cooling systems; the exposure of plant workers to radiation; and plant expenditures, taxes, and jobs.

Operational activities associated with nuclear power plants, including maintenance actions, often produce liquid discharges that are released to the surrounding environment. The major liquid effluent occurs in once-through cooling systems which discharge heat and chemicals into a receiving body of water, but all nuclear power plants have liquid effluents to some extent. To operate, power plants must obtain an NPDES permit that specifies discharge standards and monitoring requirements, and they are required to be strictly in compliance with the limits set by the permit. NPDES permits are issued by the Environmental Protection Agency (EPA) or a designated state water quality agency. They must be renewed every 5 years.

Any gaseous effluents generated are similarly controlled by the EPA and state permitting agencies, which require compliance with the Clean Air Act and any amendments added by the states. On-site incineration of waste products is controlled in this manner.

2.3.1 Land Use

Nuclear power plants are large physical entities. Land requirements generally amount to several hundred hectares for the plant site, of which 20 to 40 ha (50 to 100 acres) may actually be disturbed during plant construction. Other land commitments can amount to many thousands of hectares for transmission line rights-of-way (ROWs) and cooling lakes, when such a cooling option is used.

Nuclear power plants that began initial operation after the promulgation of the National Environmental Policy Act of 1969 (Pub. L. 91-190) or the Endangered Species Act of 1973 (Pub. L. 93-205) are sited and operate in compliance with these laws. Any modifications to the plants after the effective dates of these acts must be in compliance with the requirements of these laws. The Endangered Species Act applies to both terrestrial and aquatic biota. The individual states may also have requirements regarding threatened and endangered species; the state-listed species may vary from those on the federal lists.

2.3.2 Water Use

Nuclear power plants withdraw large amounts of mainly surface water to meet a variety of plant needs (Section 2.2.3). Water withdrawal rates are large from adjacent bodies of water for plants with once-through cooling systems. Flow through the condenser for a 1,000-MW(e) plant may be 45 to 65 m^3/s (700,000 to 1,000,000 gal/min). Water lost by evaporation from the heated discharge is about 60 percent of that which is lost through cooling towers. Additional water needs for service water, auxiliary systems, and radioactive waste systems account for 1 to 15 percent of that needed for condenser cooling.

Water withdrawal from adjacent bodies of water for plants with closed-cycle cooling systems is 5 to 10 percent of that for plants with once-through cooling systems, with much of this water being used for makeup of water by evaporation. With once-through cooling systems, evaporative losses are about 40 percent less but occur externally in the adjacent body of water instead of in the closed-cycle system. The average makeup water withdrawals for several recently constructed plants having closed-cycle cooling, normalized to 1,000 MW(e), are about 0.9 to 1.1 m^3/s (14,000 to 18,000 gal/min). Variation results from cooling tower design, concentration factor of recirculated water, climate at the site, plant operating conditions, and other plant-specific factors.

Consumptive loss normalized to 1,000 MW(e) is about 0.7 m^3/s (11,200 gal/min), which is about 80 percent of the water volume taken in. Consumptive water losses remove surface water from other uses downstream. In those areas experiencing water availability problems, nuclear power plant consumption may conflict with other existing or potential closed-cycle uses (e.g., municipal and agricultural water withdrawals) and in-stream uses (e.g., adequate in-stream flows to protect aquatic biota, recreation, and riparian communities). The environmental impacts of consumptive water use are considered in Sections 4.2.1 and 4.2.2.

As discussed in Section 2.2.3, some nuclear power plants use groundwater as an additional source of water. The rate of usage varies greatly among users. Many plants use groundwater only for the potable water system and require less than 0.006 m^3/s (100 gal/min); however, withdrawals at other sites can range from 0.02 to 0.2 m^3/s (400 to 3000 gal/min). Impacts associated with groundwater use are discussed in Sections 4.2.2, 4.3.2, and 4.4.3.

Nuclear plant water usage must comply with state and local regulations. Most states require permits for surface water usage. Groundwater usage regulations vary considerably from state to state, and permits are typically required.

2.3.3 Water Quality

Water quality is impacted by the numerous nonradioactive liquid effluents discharged from nuclear power plants (Section 2.1.6). Discharges from the heat dissipation system account for the largest volumes of water and usually the greatest potential impacts to water quality and aquatic systems, although other systems may contribute heat and toxic chemical contaminants to the effluent. The relatively small volumes of water required for the service water and auxiliary cooling water systems do not generally raise concerns about thermal or chemical impacts to the receiving body of water. However, because effluents from these systems contain contaminants that could be toxic to aquatic biota, their concentrations are regulated under the power plant's NPDES discharge permit. The quality of groundwater may also be diminished by water from cooling ponds seeping into the underlying groundwater table.

Sewage wastes and cleaning solvents, including phosphate cleaning solutions, are treated as sanitary wastes. They are treated before release to the environment so that, after release, their environmental impacts are minimized. In cases where nonradioactive sanitary or other wastes cannot be processed by on-site water treatment systems, the wastes are collected by independent contractors and trucked to off-site treatment facilities. Water quality issues relate to the following: NPDES permit system for regulating low-volume wastewater, adequate wastewater treatment capacity to handle increased flow and loading associated with operational changes to the plant and discharges of wastes through emission of phosphates from utility laundries, suspended solids and coliforms from sewage treatment discharges, and other effluents that cause excessive biological oxygen demand.

Many power plants are periodically treated with biocidal chemicals (most commonly some form of chlorine) to control fouling and bacterial slimes. Discharge of these chemicals to the receiving body of water can have toxic effects on aquatic organisms. The biological and water quality impacts of discharges from the discharge systems are considered in Sections 4.2, 4.3, and 4.4.

Chlorine is used widely as a biocide at nuclear power plants and represents the largest potential source of chemically toxic release to the aquatic environment. Chlorine application as a cooling system biocide is typically by injection in one of several different forms, including chlorine gas or sodium hypochlorite. It may be injected at the intake or targeted at various points (such as the condensers) on an intermittent or continuous basis. Such treatments control certain pest organisms such as the Asiatic clam or the growth of bacterial or fungal slime (TVA 1978). The control of biological pests or growths is critical to maintaining optimum system performance and minimizing operating costs (EPRI CS-3748).

Because of the evolution of the guidelines pertaining to chlorine and changes in biocide technologies over the past 15 years, the potential for any adverse impacts of chlorine has been decreasing. Improvements in dechlorination technologies are likely to significantly reduce the level of chlorine in the aquatic environment. Given the critical need for controlling biofouling in the cooling system, both alternative and chlorine treatment technologies are expected to keep pace with regulatory requirements.

All effluent discharges are regulated under the provisions of the Clean Water Act and the implementing effluent guidelines, limitations, and standards established by EPA and the states. Conditions of discharge for each plant are specified in its NPDES permit issued by the state or EPA.

2.3.4 Air Quality

Transmission lines have been associated with the production of minute amounts of ozone and oxides of nitrogen. These issues are associated with corona, the breakdown of air very near the high-voltage conductors. Corona is most noticeable for the higher-voltage lines and during foul weather. Through the years, line designs have been developed that greatly reduce corona effects.

The effluents created and released from the incineration of any waste products must comply with EPA and state requirements regarding air quality. Permits for release of controlled amounts of these effluents to the atmosphere are controlled by state permitting agencies. Because nuclear power plants generally do not produce gaseous effluents, the impact on air quality is minimal.

2.3.5 Aquatic Resources

Operation of the once-through (condenser cooling) system requires large amounts of water that are withdrawn directly from surface waters. These surface waters contain aquatic organisms that may be injured or killed through their interactions with the power plant. Aquatic organisms that are too large to pass through the intake debris screens, which commonly have a 1-cm (0.4-in.) mesh, and that cannot move away from the intake, may be impinged against the screens. If the organisms are held against the screen for long periods, they will suffocate; if they receive severe abrasions, they may die. Impingement can harm large numbers of fish and large invertebrates (e.g., crabs, shrimp, and jellyfish).

Aquatic organisms that are small enough to pass through the debris screens will travel through the entire condenser cooling system and be exposed to heat, mechanical, and pressure stresses, and possibly biocidal chemicals, before being discharged back to the body of water. This process, called entrainment, may affect a wide variety of small plants (phytoplankton), invertebrates (zooplankton), fish eggs, and larvae (ichthyoplankton). Entrainment mortality is variable. Conditions at some plants with once-through cooling may result in relatively low levels of mortality, although at such plants the volumes of water (and numbers of entrained organisms) are often high. On the other hand, generally no aquatic organisms survive at plants with closed-cycle cooling that recirculate water through cooling towers, although the volumes of water withdrawn are relatively low. Biological effects of entrainment and impingement are considered in Section 4.2.3.

Discharges from the plant heat rejection system may affect the receiving body of water through heat loading and chemical contaminants, most notably chlorine or other biocides. Heated effluents can kill aquatic organisms directly by either heat shock or cold shock. In addition, a number of indirect or sublethal stresses are associated with thermal discharges that have the potential to alter aquatic communities (e.g., increased incidence of disease, predation, or parasitism, as well as changes in dissolved gas concentrations).

As stated in Section 2.3.3, all effluent discharges are regulated by the Clean Water Act and standards established by the EPA and the individual states. Conditions of discharge for each plant are specified in the NPDES permit issued for that plant.

2.3.6 Terrestrial Resources

A number of ongoing issues associated with terrestrial resources can arise in the immediate area around the plant or its power transmission lines. Most power lines are located on easements (or ROWs) that the utility purchased from the landowner. Land uses on the easements are limited to activities compatible with power-line operation. In areas with rapidly growing vegetation, utilities must periodically cut or spray the vegetation to prevent it from growing so close to the conductors that it causes short circuits and endangers power line operation. Other terrestrial resource issues can result from changes in local hydrology. Such changes can occur from altered contouring of the land, reduced tree cover, and increased paving. These changes can reduce the value of land and contribute to local erosion and flooding. Additional impacts can include the effects of cooling tower effluent drift, reduced habitat for plants and animals, disruption of animal transit routes, and bird collisions with cooling towers and transmission lines.

Each plant planning to apply for license renewal will need to consult with the appropriate agency administering the Endangered Species Act of 1973 about the presence of threatened or endangered species. Compliance with the Endangered Species Act will be a necessary part of each plant's environmental documentation at the time of license renewal.

2.3.7 Radiological Impacts

2.3.7.1 Occupational Exposures

Plant workers conducting activities involving radioactively contaminated systems or working in radiation areas can be exposed to radiation. Most of the occupational radiation dose to nuclear plant workers results from external radiation exposure rather than from internal exposure from inhaled or ingested radioactive materials. Experience has shown that the dose to nuclear plant workers varies from reactor to reactor and from year to year. Since the early 1980s, when NRC regulatory requirements and guidance placed increased emphasis on maintaining nuclear power plant occupational radiation exposures as low as reasonably achievable, there has been a decreasing trend in the average annual dose per nuclear plant worker.

The effect of plant refurbishment on occupational doses is evaluated in Sections 3.8.2 and in Appendix B. Similarly, the effect of continued operation associated with license renewal on occupational doses is evaluated in Section 4.6.3.

2.3.7.2 Public Radiation Exposures

Commercial nuclear power reactors, under controlled conditions, release small amounts of radioactive materials to the environment during normal operation. These releases result in radiation doses to humans that are small relative to doses from natural radioactivity. Nuclear power plant licensees must comply with NRC regulations (e.g., 10 CFR Part 20, Appendix I to 10 CFR Part 50, 10 CFR Part 50.36a, and 40 CFR Part 190) and conditions specified in the operating license.

Potential environmental pathways through which persons may be exposed to radiation originating in a nuclear power reactor include atmospheric and aquatic pathways. Radioactive materials released under controlled conditions include fission products and activation products. Fission product releases consist primarily of the noble gases and some of the more volatile materials like tritium, isotopes of iodine, and cesium. These materials are monitored carefully before release to determine whether the limits on releases can be met. Releases to the aquatic pathways are similarly monitored. Radioactive materials in the liquid effluents are processed in radioactive waste treatment systems (Section 2.2.4). The major radionuclides released to the aquatic systems are tritium, isotopes of cobalt, and cesium.

When an individual is exposed through one of these pathways, the dose is determined in part by the exposure time, and in part by the amount of time that the radioactivity inhaled or ingested is retained in the individual's body. The major exposure pathways include the following:

- inhalation of contaminated air,
- drinking milk or eating meat from animals that graze on open pasture on which radioactive contamination may be deposited,
- eating vegetables grown near the site, and
- drinking (untreated) water or eating fish caught near the point of discharge of liquid effluents.

Other less important exposure pathways include external irradiation from surface deposition; consumption of animals that drink irrigation water that may contain liquid effluents; consumption of crops grown near the site using irrigation water that may contain liquid effluents; shoreline, boating, and swimming activities; and direct off-site irradiation from radiation coming from the plant.

Radiation doses to the public are calculated in two ways. The first is for the maximally exposed person (that is, the real or hypothetical individual potentially subject to maximum exposure). The second is for average individual and population doses. Doses are calculated using site-specific data where available. For those cases in which site-specific data are not readily available, conservative (overestimating) assumptions are used to estimate doses to the public.

2.3.7.3 Solid Waste

Both nonradioactive and radioactive wastes are generated at nuclear power plants. The nonradioactive waste is generally not of concern unless it is classified as Resource Conservation and Recovery Act (RCRA) waste. All waste that is hazardous, that is, classified as RCRA waste, is packaged and disposed of in a licensed landfill consistent with the provisions of RCRA.

Hazardous chemicals, properly handled and controlled, do not present a major health risk to personnel at nuclear power plants, but they must be understood and treated carefully. Hazardous chemicals may be encountered in the work environment during adjustments to the chemistry of the primary and secondary coolant systems, during biocide application for fouling of heat removal equipment, during repair and replacement of equipment containing hazardous oils or other chemicals, in solvent cleaning, and in the repair of equipment. Exposures to hazardous chemicals are minimized by observing good industrial hygiene practices. Disposal of essentially all of the hazardous chemicals used at nuclear power plants is regulated by RCRA or NPDES permits.

Solid radioactive waste consists of LLW, mixed waste, and spent fuel. LLW is generated by removal of radionuclides from liquid waste streams, filtration of airborne gaseous emissions, and removal of contaminated material from the reactor environment.

Mixed waste is LLW that contains chemically hazardous components as defined under RCRA. Mixed waste consists primarily of decontamination wastes and ion exchange resins. The volume of mixed wastes produced at nuclear power plants is typically a small fraction of their overall waste stream, accounting for less than 3 percent by volume of the annual LLW discharged.

Spent fuel is produced during reactor operations. The buildup of fission products and actinides during normal operation prevents the continued use of the fuel assembly. Spent fuel is stored at the reactor site. Uncertainty exists as to when an MRS or permanent spent-fuel repository may become available. However, NRC has examined this issue and determined that licensees may, without significant impact on the environment, store spent fuel on-site for 80 years after ceasing reactor operation (55 FR 38474).

Four major considerations must be addressed when managing solid radioactive waste: (1) the adequacy of interim storage on-site in lieu of permanent off-site disposal, (2) transport of the radiological wastes to disposal sites over the nation's highways and railways, (3) worker and public radiation exposure resulting from handling and processing operations and transportation, and (4) final disposal.

LLW is normally temporarily stored on-site before being shipped to licensed LLW disposal facilities. Previously these facilities were at Barnwell, South Carolina; Beatty, Nevada; and Hanford, Washington. Under the Low Level Radioactive Waste Policy Act of 1980 and the LLRWPAA of 1985, states must secure their own disposal capacity for LLW generated within their boundaries after 1992 by forming waste compacts that are responsible for siting regional disposal facilities, or by siting their own disposal facilities.

For disposal purposes, mixed waste is principally regulated by NRC (10 CFR Part 61). Although the LLRWPAA of 1985 required states to certify they are capable of providing storage and disposal of mixed wastes in an NRC/EPA-licensed facility by 1992, there are currently no licensed disposal facilities accepting commercially generated mixed waste. Because these facilities are not yet available, mixed waste is currently stored on-site.

Originally, disposal of spent fuel in a deep-geological repository was contemplated. However, because of delays in siting a permanent repository on the part of the Department of Energy and delays in developing an interim MRS facility, as required by the Nuclear Waste Policy Act of 1982, nuclear power plants are storing their spent fuel on-site.

LLW is compacted and packaged, typically in 55-gal drums, then transported via truck or railcar. The packaging and transportation of both LLW and mixed waste must comply with EPA requirements. NRC specifications for reviewing the environmental effects of the transport of spent fuel are contained in the Table S-4 Rule (54 FR 187; 10 CFR Part 51.52). States and communities along transportation corridors may impose additional restrictions on the transport of nuclear waste.

Workers receive radiation exposure during the storage and handling of radioactive waste and during the inspection of stored radioactive waste. However, this source of exposure is small compared with other sources of exposure at operating nuclear plants. Members of the general public are also exposed when the LLW is shipped to a disposal site. No other type of radioactive waste is currently being transported from the reactor sites. The public radiation exposures from radioactive material transportation have been addressed generically in Table S-4 of 10 CFR Part 51. Table S-4 indicates that the cumulative dose to the exposed public from the transport of both LLW and spent fuel is estimated to be about 0.03 person-sievert (3 person-rem) per reactor year.

2.3.8 Socioeconomic Factors

2.3.8.1 Work Force

Although the size of the work force varies considerably among U.S. nuclear power plants, the on-site staff responsible for operational activities generally consists of 600 to 800 personnel per reactor unit. The average permanent staff size at a nuclear power plant site ranges from 800 to 2400 people, depending on the number of operating reactors at the site. In rural or low population communities, this number of permanent jobs can provide employment for a substantial portion of the local work force. Table 2.3 depicts mean employment during normal operations in the 1975–1990 period, grouped by the number of reactors.

In addition to the work force needed for normal operations, many nonpermanent personnel are required for various tasks that occur during outages, for example, refueling outages, ISIs, or major refurbishments. Between 200 and 900 additional workers may be employed during these outages to perform the normal outage maintenance work. These are work force personnel who will be in the local community only a short time, but during these periods of extensive maintenance activities, the additional personnel will have a substantial effect on the locality. Table 2.4 indicates the levels of additional personnel typically required for different types of outages.

A substantial portion of the regular plant work force is normally involved in many of the efforts listed in Table 2.4, supplemented as needed by contractor personnel for support during specialized projects. Peak crew sizes are greatly affected by the specific requirements at each plant, utility decisions to make major repairs to systems and components to improve or sustain plant performance, and the relative phasing (schedule overlap) of these activities. Exact crew sizes can, therefore, vary widely from plant to plant.

2.3.8.2 Community

Typically, the immediate environment in which a nuclear power plant is located is rural, but the population density of the larger area surrounding the plant and the distance from a medium- or large-sized metropolitan center varies substantially across sites. Most sites, however, are not extremely remote [i.e., not more than about 30 km (20 miles) from a community of 25,000 or 80 km (50 miles) from a community of 100,000]. The significance of any given nuclear power plant to its host area will depend to a large degree on its location, with the effects generally being most concentrated in those communities

Table 2.3 Changes in mean operations-period employment at nuclear power plants over time

Operations period	One-unit plants[a]	Two-unit plants[a]	Three-unit plants[a]
Current[b]	832 (34)	1247 (28)	2404 (4)
1985-1989	841 (30)	1094 (26)	2095 (4)
1980-1984	447 (19)	946 (21)	1078 (3)
1975-1979	233 (17)	515 (16)	699 (3)

[a]Number in parentheses indicates number of plants providing data.
[b]Approximately half the respondents reported data for 1989 and half for 1990.

Table 2.4 Mean additional employment per reactor unit associated with three outage types at nuclear power plants

Outage type[a]	Number of workers
Typical planned (58)	783
In-service inspection (23)	734
Largest single (45)	1148

[a]Number in parentheses indicates number of plants providing data for the survey (NUMARC).

closest to the plant. Major influences on the local communities include the plant's effects on employment, taxes, housing, off-site land use, economic structure, and public services.

As noted in Section 2.3.8.1, the average nuclear power plant directly employs 800 to 2400 people. Many hundreds of additional jobs are provided through plant subcontractors and service industries in the area. In rural communities, industries that provide this number of jobs at relatively high wages are major contributors to the local economy. In addition to the beneficial effect of the jobs that are created, local plant purchasing and worker spending can generate considerable income for local businesses.

Nuclear power plants represent an investment of several billion dollars. Such an asset on the tax rolls is extraordinary for rural communities and can constitute the major source of local revenues for small or remote taxing jurisdictions. Often, this revenue can allow local communities to provide higher quality and more extensive public services with lower tax rates. In general, capital expenditures and large changes in public services are seldom necessitated by the presence of the plant and its operating workers, particularly after local communities have adapted to greater and more dynamic changes experienced during plant construction.

As this discussion indicates, nuclear power plants can have a significant positive effect on their community environment. These effects are stable and long term. Because these socioeconomic effects generally enhance the economic structure of the local community, nuclear power plants are accepted by the community, and indeed, become a major positive contributor to the local environs.

2.4 LICENSE RENEWAL—THE PROPOSED FEDERAL ACTION

This section provides a brief overview of the most significant requirements of the proposed revision to 10 CFR Part 54, "Nuclear Power Plant License Renewal" (FR 59, no. 174, p. 46574).

Under the license renewal rule (10 CFR Part 54), nuclear power plant licensees would be allowed to operate their plants for a maximum of 20 years past the terms of their original 40-year operating licenses provided that certain requirements are met (Section 1.1). The rule requires licensees submitting license renewal applications to perform specified types of evaluations and assessments of their facilities, and to provide sufficient information for the NRC to determine whether continued operation of the facility during the renewal term would endanger public safety or the environment.

License renewal will be based on ensuring plant compliance with its current licensing basis (i.e., the original plant licensing basis as amended during the initial license term). In addition, licensees will be required to demonstrate for certain important systems, structures, and components (SSCs) that the effects of aging will be managed in the renewal period in a manner so that the important functions of these SSCs will be maintained. The SSCs of concern in the renewal period are those which traditionally do not have readily monitorable performance or condition characteristics and include most passive, long-lived plant SSCs. Therefore, the NRC's license renewal rule requires a systematic review of, at least, passive, long-lived SSCs that support safety or other critical functions of a nuclear power plant (as delineated in the rule). To make these determinations regarding these SSCs, it is expected that licensees will implement aging management activities for SSCs for which current programs may not be adequate to ensure continued functionality in the renewal term. These aging management activities are expected to include surveillance, on-line monitoring, inspections, testing, trending, repair, refurbishment, replacement, and recordkeeping, as appropriate.

The license renewal rule seeks to ensure that the effects of aging in the period of extended operation are adequately managed. The rule allows credit for existing programs and regulatory requirements that continue to be applicable in the period of extended operation and that provide adequate management of the effects of aging for SSCs. This provision includes credit for rules or requirements, such as those incorporated in the maintenance rule, which could impact license renewal activities performed to detect and mitigate age-related functionality degradation.

The rule requires an integrated plant assessment (IPA). License renewal applicants must perform an IPA to determine which SSCs will be subject to additional review. The IPA would then determine whether additional programs, over and above the current operational and maintenance programs, are required to manage the effects of aging so that equipment function is maintained.

In addition, the license renewal rule requires licensees submitting an application for license renewal to provide the following:

- information noting any changes in the current licensing basis that occur during NRC's review of the submittal; and
- an evaluation of time-limited aging analyses (i.e., issues such as fatigue, equipment qualification, and reactor-vessel neutron embrittlement which have inherent time limits associated with them).

Key aspects of 10 CFR Part 54 could result in environmental impacts because of the requirements imposed. These key aspects are (1) the enhanced surveillance, on-line monitoring, inspections, testing, trending, and recordkeeping (SMITTR) on SSCs identified in the IPA and (2) the resulting actions taken to ensure that aging would be effectively managed and that the functionality of these SSCs would be maintained throughout the term that the new license would be in effect.

Note that the license renewal rule does not require any specific repairs, refurbishments, or modifications to nuclear facilities, but only that appropriate actions be taken to ensure the continued functionality of SSCs in the scope of the rule.

2.5 BASELINE ENVIRONMENTAL IMPACT INITIATORS ASSOCIATED WITH CONTINUED OPERATION OF NUCLEAR POWER PLANTS

The previous sections identified the various types of environmental impacts associated with current nuclear power plant operation. Before discussing incremental impacts associated with license renewal, it is useful to first establish a baseline from which to evaluate incremental effects. This baseline is provided by current experience with nuclear power plant operation and the related interactions with the environment. This section presents quantitative information on selected environmental "impact initiators." The term "impact initiators" is defined, followed by estimates of the quantities of each initiator currently generated by typical nuclear power plant operation.

2.5.1 Definition of Environmental Impact Initiators

The terms "environmental impact initiators" and "impact initiators" as used here refer to the precursors to possible environmental impacts. For example, the incremental work force needed to accomplish license renewal activities is not an environmental impact, but the associated effects on housing, transportation, schools, etc., are environmental or socioeconomic impacts. The environmental impact initiators that need to be quantified to estimate overall environmental effects resulting from license renewal are as follows:

- Labor hours and work force size associated with on-site craft workers, engineering and administrative personnel, and health physics personnel are needed to estimate socioeconomic impacts to communities affected by personnel employed temporarily at nuclear plants.
- Labor costs are used to estimate both economic impacts to affected communities and economic viability of extended plant operation through license renewal.
- Occupational radiation exposure is used to estimate radiation-related impacts to workers.
- Capital costs of hardware, materials, and equipment are used both to estimate tax-base-related impacts to affected communities and to provide information related to the overall economics of license renewal.
- Radioactive waste types, volumes, and disposal costs are used to estimate environmental impacts related to the disposal of such wastes.

These impact initiators are the key elements expected to change, relative to current nuclear plant operation, as a result of actions taken to support license renewal. Other environmental considerations, including water usage, land usage, chemical usage/discharges, and air quality, are not anticipated to change significantly as a result of license renewal activities.

The impact initiators assessed—labor force, labor costs, capital costs, occupational radiation exposure, and radioactive waste volumes—help determine most of the potential changes in environmental impacts resulting from license renewal. For example, estimates of refurbishment labor and capital cost, together with a description of the types of refurbishment activities that might be undertaken, help define potential environmental impacts related to refurbishment period land use, water use, air quality, socioeconomics, nonradiological solid wastes, etc. The impact initiators assessed form a sufficient set from which to assess most license renewal-related environmental impacts. Also, the focus is on changes in impact initiators originating from plant activities, as opposed to changes in the plant environs or receptors (e.g., changes in the population affected by the plant).

2.5.2 Baseline Environmental Impact Initiator Estimates

The following discussions provide estimates of the baseline quantities for each of the foregoing impact initiators. These baseline quantities are typical of current nuclear plant operation.

2.5.2.1 Baseline Work Force Size and Expenditures for Labor

Table 2.3 indicates that the current work force at nuclear plant sites is typically in the range of 830 to 2400 permanent staff, depending on the number of operating reactors at a site. On-site personnel responsible for operational activities generally number between 600 and 800 per reactor unit. The average number of permanent staff per reactor unit is estimated to be about 700 people, and this number is approximately the same for both BWRs and PWRs. Assuming a normal 40-hour work week for most on-site staff, this staffing translates into an annual labor effort of about 1.5 million labor hours per unit. The permanent staff is augmented by temporary workers called in to assist with outage activities and special projects. The associated expenditures for labor, including an allowance of roughly 20 percent for temporary staff to support outages and special projects, is estimated to be about $77,000,000 annually per unit.

2.5.2.2 Baseline Capital Expenditures

Nuclear power plants incur expenditures for three major types of capital additions. There are (1) major plant retrofits needed to satisfy NRC requirements to ensure safe plant operation (e.g., changes required as a result of resolution of a generic safety issue), (2) major repairs needed to keep the plant operational (such as main turbine-generator repairs), and (3) discretionary activities undertaken to improve plant performance and labor productivity (DOE/EIA-0547). Expenditures for capital additions have varied widely from plant to plant and from one year to another. In 1989, the average expenditure for capital additions was about $24 per kilowatt, or roughly $24 million for a 1000-MW(e) plant (1989 dollars). These expenditures equate to about $28 million per year per 1000-MW(e) plant in 1994 dollars.

2.5.2.3 Baseline Occupational Radiation Exposure

Occupational radiation exposures vary considerably from plant to plant and from year to year at a given plant. The long-term trends indicate that overall worker exposure has been decreasing on a per-plant basis. The average occupational exposure for the year 1989 was roughly 4.4 person-sievert (440 person-rem) per plant at BWRs and about 3 person-sievert (300 person-rem) per plant at PWRs. For the years 1991 to 1993, the average exposure for all U.S. nuclear plants was about 2.5 person-sievert (250 person-rem) per plant (NUREG-1350, v.6). Significant deviations from these averages are routinely experienced, depending largely on whether a given plant had an outage during a given year and the nature and extent of refurbishment or repair activities undertaken during outages.

2.5.2.4 Baseline Radioactive Waste Generation

Section 2.2.4.3 discussed the different types of radioactive wastes typically generated at nuclear power plants. The type of waste generated in the greatest volumes is LLW. The volume of LLW disposed of annually has shown a decreasing trend over the past several years. Most recently, the amount of LLW disposed of at PWRs has been about 250 m^3/year (8800 ft^3/year); in contrast, the amount disposed of at BWRs has been about 560 m^3/year (19,700 ft^3/year).

Small volumes of mixed wastes are also generated by nuclear plant operation. However, any such waste that cannot be treated to eliminate the chemical hazards is currently stored on-site at the nuclear plants and not shipped for disposal.

U.S. reactors generate high-level wastes, primarily in the form of spent fuel. The quantities of spent fuel generated on a per-reactor-year basis is not expected to change with license renewal.

2.6 ENVIRONMENTAL IMPACT INITIATORS ASSOCIATED WITH LICENSE RENEWAL AND CONTINUED OPERATION

2.6.1 Scope and Objectives of Section 2.6

A major objective of the GEIS is to support the proposed changes to 10 CFR Part 51 by defining the issues that need to be addressed by the NRC and the applicants in plant-specific license renewal proceedings. First, the environmental issues are defined by characterizing and evaluating the actions and activities that may be undertaken by licensees in pursuit of license renewal and extended plant life. These actions and activities are then used to characterize their associated potential environmental impacts.

This section discusses potential actions nuclear power plant licensees may undertake to achieve license renewal and an extended plant life. This section also estimates the extent of the environmental initiators associated with these actions during license renewal and the extended term of operation.

The preceding section noted that the license renewal rule requires that the functionality of important SSCs be maintained throughout the period of the renewed license. To provide this assurance, licensees will likely undertake enhanced SMITTR activities on SSCs identified in the IPA and, based on the findings of these efforts, take appropriate action to ensure that aging is effectively managed and that the functionality of these SSCs is maintained. Incremental repair, refurbishment, and/or replacement of SSCs, as well as related changes to plant operations and maintenance, may be performed to ensure that this objective is achieved. These actions, either directly or indirectly, will produce incremental impacts to the local environment. These incremental effects are over and above those expected if plants were simply to continue to operate as at present.

Licensees may also choose to undertake various refurbishment and upgrade activities at their nuclear facilities to better maintain or improve reliability, performance, and economics of power plant operation during the extended period of operation. These are activities which would be performed at the option of the licensee and which are in addition to those performed to satisfy the license renewal rule requirements.

The set of activities undertaken is expected to vary widely from plant to plant. Some plants may require little refurbishment and upgrading. Other plants may require considerable refurbishment and upgrading. For purposes of the GEIS, two types of license renewal programs were considered for which the environmental impact initiators were developed:

- a "typical" or "mid-stream" license renewal program, intended to be representative of the type of program that many plants seeking license renewal might implement, and
- a "conservative" or "bounding" program encompassing considerably more activities by licensees, intended to characterize an upper bound, or near upper bound, of the impacts that could be generated at a nuclear power plant.

Each program applies to both BWRs and PWRs. Thus, there are four separate cases or scenarios considered: a typical BWR, an upper bound or conservative BWR, a typical PWR, and a conservative PWR.

The typical scenarios can be used to estimate environmental impacts from an "average" license renewal program and to estimate the nationwide impacts of the total nuclear power plant population. The bounding license renewal scenarios, being much more conservative, are intended to address what might occur for those plants whose impacts will be considerably greater than is typical of the nuclear power reactor population as a whole.

Section 2.6.2 presents the bases and assumptions used in developing the different license renewal scenarios. Section 2.6.3 describes and characterizes the typical license renewal scenarios and the resulting environmental impact initiators. The conservative scenario program is described in Section 2.6.4.

2.6.2 Bases, Assumptions, and Approach

2.6.2.1 Structures, Systems, and Components of Interest

The SSCs of interest for assessing license renewal-related environmental impacts are those that are critical to the safe operation of the plant and that traditionally do not have readily monitorable performance characteristics, which means that the effects of aging may go undetected and lead to the loss of SSC functionality. Many structures and components in currently-licensed LWRs are subject to programs such as the maintenance rule, periodic surveillances, and periodic replacement and refurbishment and have readily monitorable performance or condition characteristics so that these programs can reveal the effects of aging in sufficient time to prevent loss of SSC functionality. However, many other nuclear plant components, such as passive, long-lived structures and components, may not be subject to programs which reveal the effects of aging in sufficient time to ensure their functionality. Therefore, these passive, long-lived structures and components are the items that may need new or incremental aging management activities. The SSCs used in the current evaluation are discussed in Sections 2.6.3.1 and 2.6.4.1 for the typical and conservative programs, respectively.

2.6.2.2 Definition of Candidate Aging Management Activities

A comprehensive list of possible license renewal-related activities with potential environmental impacts was developed. Emphasis was placed on defining those activities clearly associated with license renewal, that is, those activities which would not be included in a continuation or extrapolation of the activities that occurred during the original licensing term. The types of activities considered ranged from enhanced inspection programs to component replacement. In turn, the potential environmental impacts of each identified activity were examined and analyzed.

Following the identification of candidate SSCs and the related aging management activities for each of the different license renewal programs, quantitative estimates of potential environmental impact initiators were developed. The estimates apply to a particular approach to aging management.

The data needed to characterize aging management activities were developed in the context of the four major license renewal programs previously identified: a typical BWR, a conservative BWR, a typical PWR, and a conservative PWR. Each program consisted of the following:

- lists of SSCs for which incremental activities would be performed to ensure that safe and economical operation could be achieved throughout the extended life of the plant;
- lists of the activities performed on each SSC to manage aging;
- the number of times each activity would be performed, accounting for repetitive actions on individual SSCs and the number of similar items in the plant subject to these activities; and
- the specific times during which each activity is performed.

The generic license renewal programs utilized in this evaluation were based on similar schedules for carrying out the selected aging management activities. Any major refurbishment work called for by the programs was assumed to start shortly after a renewed license had been granted. In these example programs, this would occur in roughly year 30 of the original 40-year license term. This work was assumed to be completed over several successive outages, including one at the end of the 40th year of plant operation. Incremental SMITTR actions, and the installation of enhanced or additional surveillance and monitoring equipment and systems, were also assumed to be initiated at this time. The SMITTR actions continue throughout the remaining life of the plants. This is true for both the typical and conservative case scenarios.

2.6.2.3 Incremental Effects Only

All aging management programs of interest to the current effort deliberately omit, to the extent possible, current practice as it has evolved and is expected to evolve in the license renewal period. The programs also exclude any changes in the basic design or technology of the plant. Rather, they include only those activities that would constitute a discrete change in the plant's operation and maintenance program and would be implemented only after issuance of the renewal license. In particular, all normal repair activities, as well as any activities undertaken to satisfy recently enacted requirements such as the Maintenance Rule, are considered to fall within the scope of current practice and were excluded from consideration. Therefore, the impact initiators considered here are incremental to those resulting from the extension of current practice.

2.6.2.4 Reference Plant Size and Characteristics

All assessments presented here reflect design features and quantities consistent with 1000-MW(e) plant designs. For the PWRs, the features and sizing chosen were consistent with those for a four-loop Westinghouse plant design with a large dry containment. The BWR features used were representative of designs utilizing internal jet pumps and two recirculation loops. Mark III containment features were used.

2.6.2.5 Reference SMITTR Program

The generic BWR and PWR aging management programs used in the present evaluations for both the typical and conservative scenarios were based on the safety-centered SMITTR programs that were used in the regulatory analysis for 10 CFR Part 54 (NUREG-1362). These basic SMITTR programs were supplemented by activities planned for the Lead Plant programs (Sciacca 1/3/93 and Sciacca 1/13/93). In addition, the aging management programs used as the basis for the current impact initiator estimates included actions anticipated for non–safety-related systems and equipment, but which licensees may undertake to maintain or enhance plant availability and performance. The conservative case scenarios, in particular, assumed considerable expansion of the basic Part 54 programs to include actions on many balance-of-plant SSCs. The inclusion of activities directed toward non–safety-related SSCs considerably expanded the number of times given activities would be performed and significantly increased the variety of activities performed, compared with those considered for the 10 CFR Part 54 Regulatory Analysis. The inclusion of aging management activities beyond those characterized for safety-centered SMITTR programs enhances the comprehensiveness and conservatism of the estimates used in the preparation of the GEIS conservative cases. The typical license renewal program scenarios also include more SMITTR actions than those used for the 10 CFR Part 54 assessments, but to a lesser degree than the conservative case scenarios. The typical program SMITTR activities incremental to those anticipated under Part 54 were included to allow for voluntary actions on the part of licensees to better manage aging of balance-of-plant SSCs. All typical program activities were reviewed for possible overlap with the Maintenance Rule activities; any activities perceived to fall within the scope of the Maintenance Rule or other rules were eliminated from the programs.

2.6.2.6 Major Refurbishments and Replacements

The major refurbishment/replacement class of activities included in the license renewal programs characterized here is intended to encompass actions which typically take place only once in the life of a nuclear plant, if at all. Replacement of BWR recirculation piping and PWR steam generators falls into this category of activities. Many such activities were included in the conservative case license renewal scenarios. The items making up this category include both activities which have already been performed at some operating LWRs and activities which have not yet been performed, at least not to the extent assumed for the purpose of defining potential environmental impacts. The inclusion of activities which have already been performed on some existing nuclear plants is based on the premise that there are certain plants in the reactor population that will not have to perform these activities during the current license term, but that would elect to perform these major activities to enable safe and economic operation for the incremental term allowed with license renewal. In addition, major refurbishment activities included in these example license renewal programs encompass all areas of a nuclear power plant (e.g., structures, mechanical and electrical systems, fluid systems). This approach further ensures that the impacts characterized for the conservative case scenarios have a high probability of bounding the impacts likely to accrue to any individual plant seeking license renewal and extended plant operation.

The typical scenarios, in contrast, included fewer major refurbishment activities of this type. For these scenarios the assumption was made that most plants will have ongoing effective maintenance and refurbishment programs that preclude the need for refurbishment/replacement of all but a few components and structures.

2.6.2.7 Prototypic License Renewal Schedule

Figure 2.3 shows representative timelines for the license renewal process of a nuclear plant. The timelines shown were judged to be reasonable by the NRC staff. The schedule is applicable to both the typical and conservative license renewal scenarios. The upper timeline shows the relationship of the new license period to the initial license period. The lower line indicates the various outage types and their assumed timing over the period covered by a renewed license. The key underlying assumption for the timelines is that the licensee should be assured by the NRC 10 years before the expiration of its current operating license that the plant in question is suitable for license renewal. These 10 years are required for the licensee to arrange for alternative sources of power should a renewed license not be granted. The license renewal process is presumed to start with the licensee initiating a number of studies and analyses to support the license renewal application 3 years before submitting the application to the NRC. The NRC would then perform a detailed review of the application and, in the successful cases, issue a new license (with conditions) within 2 years after the application is received. The new license would go into effect at that point, covering the balance of the original 40-year term, as well as the additional 20-year term.

It was assumed that licensees would initiate incremental aging detection and management activities as soon as the new license was granted, as called for by 10 CFR Part 54. Discretionary major refurbishment activities might also be undertaken early into the license renewal term.

2.6.2.8 Schedule for Performing Major Refurbishment Activities

The reference schedule assumes that major refurbishment activities associated with

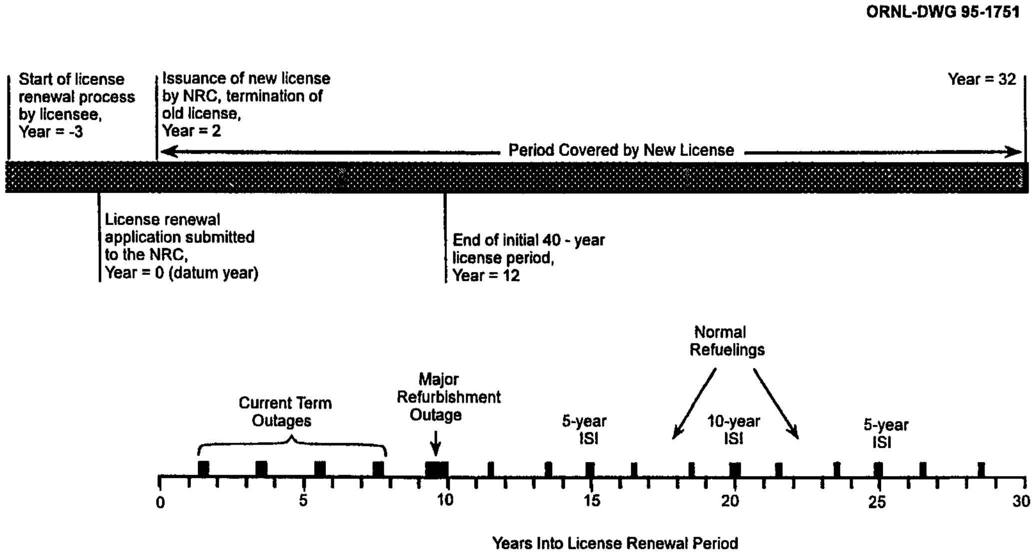

Figure 2.3 License renewal schedule and outage periods considered for environmental impact initiator definition.

license renewal are started shortly after the new license is granted, and that these are accomplished over several successive outages. They are completed by the time the plant completes its 40th year of operation, which is about 10 years into the new license term. The schedule for performing any major refurbishment activities will undoubtedly be highly plant specific, and such activities could well be spread throughout the term of the renewed license. Earlier timing of these activities provides the utilities with more time to recover the cost of the investment through the sale of energy produced. Thus, the schedules utilized for the present evaluations are reasonable, but alternative schedules are also possible.

The schedules utilized were similar for both the BWR and PWR programs. However, the typical programs have little need for an extended outage because the extent of major refurbishment activities is relatively modest. The "major refurbishment outage" duration for the typical programs was reduced compared with that deemed necessary for the conservative case scenarios.

2.6.2.9 Outage Types and Durations

Activities carried out in support of license renewal and extended plant life were assumed to be performed primarily during selected outages. Five types of outages were used: normal refuelings, 5-year ISI outages, 10-year ISI outages, current term refurbishment outages, and major refurbishment outages. Figure 2.3 illustrates when these outages are assumed to occur. The current term outages fall within the 40-year period initially covered by the plant's current license, but with license renewal they occur during the period covered by the new license.

Outage types and durations were established to allow estimation of the rates at which environmental impacts might be generated as a result of license renewal activities. For example, the number of workers required at a site for a given outage is dependent on the amount of work to be performed (labor hours), the time available to accomplish the work, and the number of labor hours expended per person-week or person-day. The number of workers so identified, in turn, allows estimation of potential socioeconomic and other impacts to affected communities.

Table 2.5 summarizes the different outage types and durations for both reactor types and for both the typical and conservative license renewal scenarios. Additional discussion of the basis used in selecting outage durations is provided in Appendix B.

2.6.3 Typical License Renewal Scenario

The characteristics of the typical license renewal program are discussed briefly in Section 2.6.3.1. Listings of the SSCs likely to be subject to incremental aging management activities are provided. Listings of the types of SMITTR actions and major refurbishment activities that may be performed as part of a typical license renewal program are reviewed and discussed in Appendix B. Section 2.6.3.2 summarizes the impact initiator quantities expected to be generated by such a program. Section 2.6.3.2 compares the impact initiator quantities for the typical program scenarios with the impactor initiator quantities currently produced from routine reactor operation.

2.6.3.1 Characterization of Typical License Renewal Programs

The characterization of license renewal programs required that three key types of information be developed: (1) identification of the SSCs likely to be subject to incremental aging management activities, (2) candidate lists of the activities to be performed on these systems and components to suitably manage aging effects that could have potential environmental consequences, and (3) identification of environmental attributes (impact initiators) associated with those activities. The typical programs are intended to be representative of the typical or "average" plant's activities in support of license renewal. However, the typical programs are still somewhat conservative; that is, some plants will not require all of the actions identified in the typical programs. The typical license renewal scenarios were based on the following.

- The Monticello and Yankee Rowe lead plant life extension (PLEX) programs were carefully reviewed. Activities included in either program were, with some exceptions, incorporated into the typical license renewal scenarios. The information obtained from the lead plants was also used to establish both the numbers of SSCs subject to a given activity and the schedule for performing such activities.
- All activities included in the Part 54 Regulatory Analysis which were pertinent to passive, long-lived SSCs and which were not likely to be implemented because of other rules or regulations were retained as incremental actions. The Part 54 activities were retained both to maintain consistency with the updated Part 54

Regulatory Analysis and to allow for a modest amount of conservatism in the typical scenarios.

- As noted previously, recently enacted rules and regulations, in particular the Maintenance Rule, were taken into account in developing typical license renewal or PLEX-related activities.
- Surveys were made to help establish the likelihood that certain major activities would be performed by typical licensees seeking license renewal. In particular, assessments were made relative to steam generator replacement and reactor vessel annealing for PWRs, and for recirculation piping replacement for BWRs. These assessments reviewed the fraction of the affected reactor population that has already performed these refurbishment/replacement activities and ascertained whether such activities might need to be repeated for extended plant life. Based on the results of these reviews, it was assumed that typical license renewal programs will not need to include many such major activities.

Table 2.5 Outage duration summary

Outage type	Outage duration (months)	
	Conservative	Typical
Refueling	2	2
5-Year in-service inspection	3	3
10-Year in-service inspection	4	3
Current-term outage (refurbishment)	4	3
Major refurbishment outage	9	4

Typical program structures, systems, and components subject to incremental activities

Tables 2.6 and 2.7 list the SSCs used in the typical program evaluations for which incremental activities are assumed to be conducted during license renewal and extended life. Table 2.6 lists the items subject to incremental SMITTR actions; Table 2.7 lists items subject to major refurbishment/replacement activities. Table 2.6 includes SSCs subject to the addition of new or improved condition monitoring systems, as well as those subject to incremental SMITTR activities. Most of the items in these tables are common to both BWRs and PWRs.

Although the specific numbers of components and design features may be different for these two reactor types, they are similar enough that the environmental impacts resulting from aging management

Table 2.6 Typical program structures and components subject to incremental SMITTR[a] activities in support of license renewal

Item	BWR/PWR[b]
AC or DC busses	Both
Actuation and instrumentation channels	Both
Bellows	BWR
Building cranes and hoists	Both
BWR control rod drive mechanisms	BWR
BWR recirculation pumps and motors	BWR
Check valves	Both
Compressed air system	Both
Containment	Both
Emergency diesel generators	Both
Fan coolers	Both
Fuel pool	Both
Heat exchangers	Both
Heating, ventilation, and air conditioning	Both
Hydraulic or air operated valves	Both
Main condensor	Both
Main generator	Both
Main turbine	Both
Metal containment, including suppression chamber	BWR
Motor-operated valves	Both
Motor-driven pumps and motors	Both
Nuclear steam supply system supports	Both
PWR critical concrete structure—containment	PWR
PWR reactor coolant pump	PWR
Reactor pressure vessel	Both
Reactor pressure vessel internals	Both
Turbine-driven pumps and turbines	Both

[a]SMITTR = surveillance, on-line monitoring, inspections, testing, trending, and recordkeeping.
[b]BWR = boiling-watert reactor; PWR = pressurized-water reactor.

Table 2.7 Typical program systems, structures, and components subject to major refurbishment or replacement activities

Item	BWR/PWR[a]
BWR safe ends and recirculation and feedwater piping inside containment	BWR
Compressed air system	Both
Containment	Both
Emergency diesel generators	Both
Main generator	Both
Major structures, including buildings and pipe enclosures	Both
Motor-operated valves	Both
Piping sections	Both
Reactor containment building	Both
Reactor pressure vessel	Both
Reactor pressure vessel internals	Both
Steam generators	PWR
Storage tanks	Both

[a]BWR = boiling-water reactor; PWR = pressurized-water reactor

activities on these items will be reasonably similar for both reactor types. Differences in the numbers of like items employed in each plant design were taken into account in assessing impacts.

Certain SSCs such as the reactor recirculation piping for BWRs and steam generators for PWRs are unique to the plant design type. Potential impacts from aging management activities on such items were treated separately for the two major plant categories.

Definition of aging management activities

The incremental aging management activities carried out to allow operation of a nuclear power plant beyond the original 40-year license term will be from one of two broad categories: (1) SMITTR actions, most of which are repeated at regular intervals, and (2) major refurbishment or replacement actions, which usually occur fairly infrequently and possibly only once in the life of the plant for any given item.

Most of the SMITTR activities included in the present assessment were taken from the Safety-Centered Aging Management program defined previously and utilized for the 10 CFR Part 54 License Renewal Regulatory Analysis (NUREG-1362). However, the current effort includes additional items and activities, because the previous analysis focused only on SSCs important to safety, whereas for the current efforts it has been assumed that licensees will also perform actions aimed at ensuring reliable and efficient electrical power production. Thus, many balance-of-plant SSCs are included here which were not included in the 10 CFR Part 54 evaluations.

In certain cases a SMITTR activity could involve replacement or refurbishment of the SSC being addressed. Any such SMITTR replacement/refurbishment activities for a particular item typically occur more than once in the extended life of the plant.

Table B.1 of Appendix B lists the incremental SMITTR actions used as the basis for estimating license renewal environmental impacts. It indicates the specific aging detection and mitigation actions performed on each SSC of concern. These activities include some which are undertaken only to improve reliability or economic performance; thus, Table B.1 includes several active components in addition to the passive, long-lived SSCs that are the focus of 10 CFR Part 54.

Table B.2 of Appendix B lists the major refurbishment or replacement activities used to estimate environmental impacts. The table indicates the fractions or portions of the SSCs involved which are subject to the stated actions. Unless otherwise noted, 100 percent of an SSC was assumed to be replaced or refurbished. As with the list of actions cited in Table B.1, the quantities assumed were based in part on the information provided in the industry pilot and lead plant studies and from reported existing industry experience on major refurbishments (Sciacca 1/3/93 and 1/13/93). In other cases engineering judgment provided the basis for the portions of the systems or structures being replaced or refurbished. The extent of major refurbishments envisioned for typical license renewal programs is fairly modest.

2.6.3.2 Typical Program Incremental Initiator Quantities

Table 2.8 summarizes the typical program impact initiator quantities resulting from the incremental SMITTR and major refurbishment/replacement activities assumed to be carried out in support of license renewal and extended plant life. Estimates of the amounts generated are shown for each of the outage types previously discussed, during which these impact initiators are expected to be generated from license renewal activities. Separate estimates are provided for BWRs and PWRs. All figures are shown on a per-plant basis (i.e., for a single nuclear plant).

A comparison of the figures shown in Table 2.8 with current reactor experience as discussed in Section 2.5.2 indicates that, for the typical license renewal scenario, incremental license renewal effects are expected to be relatively modest. For example, with current nuclear plant operation, roughly 1.5 million person-hours are expended each year for on-site operations and maintenance activities. The incremental efforts associated with license renewal-related activities are estimated to add between 500,000 and 700,000 person-hours for all such activities over the remaining

Table 2.8 Typical license renewal program environmental impact initiators

Outage type	Labor hours	Additional on-site personnel	Waste volumes (as-shipped) (m^3)	Occupational rad exps (person-sieverts)	Waste disposal costs (1994$)[a]	Labor costs (1994$)[a]	Capital costs (1994$)[a]	Total on-site costs (1994$)[a]	Off-site costs (1994$)[a]	Total costs (1994$)[a]
Boiling-water reactors										
Full power operation (20 yrs)	0	0	0	0.00	0	0	0	0	0	0
Normal refueling[b]	4,148	10	2	0.04	23,000	196,940	215,460	435,400	47,751	483,151
5-yr ISI[c] refueling[d]	38,675	63	17	0.71	244,000	1,789,900	314,100	2,348,000	0	2,348,000
10-yr ISI refueling[e]	62,208	110	30	0.91	424,000	3,082,450	589,550	4,096,000	0	4,096,000
Current term refurbishments[f]	45,294	71	17	0.10	245,000	1,715,040	579,360	2,539,400	177,347	2,716,747
Major refurbishment outage[g]	298,375	361	69	1.53	976,000	12,585,040	57,589,360	71,150,400	13,804,688	84,955,088
Total all occurrences	660,000	—	220	4.57	3,052,000	27,700,000	62,800,000	93,600,000	14,900,000	108,500,000
Pressurized-water reactors										
Full power operation (20 yrs)	0	0	0	0.00	0	0	0	0	0	0
Normal refueling[b]	3,488	8	1	0.03	18,000	166,265	145,635	329,900	27,179	357,079
5-yr ISI refueling[d]	20,935	33	11	0.30	153,000	953,750	185,250	1,292,000	13,886	1,305,886
10-yr ISI refueling[e]	37,482	60	22	0.51	313,000	1,691,600	309,400	2,314,000	831	2,314,831
Current term refurbishments[f]	45,924	72	18	0.11	272,000	1,741,880	580,920	2,594,800	176,530	2,771,330
Major refurbishment outage[g]	219,018	264	44	0.79	1,631,000	9,108,830	49,380,970	60,120,800	12,068,028	72,188,828
Total all occurrences	510,000	—	170	2.61	3,482,000	21,000,000	53,500,000	78,000,000	13,000,000	91,000,000

Notes:

[a]All cost figures are undiscounted 1994 dollars
[b]8 occurrences, 2-month duration each
[c]ISI = in-service inspection
[d]2 occurrences, 3-month duration each
[e]1 occurrence, 4-month duration
[f]4 occurrences, 4-month duration each
[g]1 occurrence, 9-month duration

To convert m^3 to ft^3, multiply by 35.32.
To convert person-sievert to person-rem, multiply by 100.

Source: Science and Engineering Associates, Inc., January 1995.

life of a typical plant. Thus, the license renewal activities would add roughly 20,000 person-hours per year, which is a small increment compared to the 1.5 million person-hours per year typical of current reactor operation.

Table 2.8 indicates that the number of additional on-site personnel needed to accomplish license renewal-related activities is quite modest for most periods when such activities will be performed. The exception is the major refurbishment outage, when an average of between 200 and 400 additional personnel may be needed. Note that these personnel are in addition to the 700- to 800-person temporary work force typically called in to assist with current outages at nuclear power plants (see Table 2.4). The estimates of additional personnel presented in Table 2.8 are based on the assumption that the incremental work efforts are spread uniformly over the entire duration of the associated outages. In reality, some peaking of staffing requirements will occur during each outage. Additional analyses were performed to evaluate the extent of such peaking, and these analyses are discussed in Appendix B. For the typical BWR license renewal scenario, these analyses indicated that the on-site temporary work force would peak at about 1000 personnel. This peak occurs during the major refurbishment outage, and it includes the temporary work force needed to accomplish refueling and routine outage activities (e.g. routine maintenance and ISI activities) as well as license renewal-related activities. For the PWR, the corresponding temporary worker requirements reach a peak at about 900 additional staff. This peak requirement occurs during the current term outages.

The incremental occupational radiation exposure estimated to accrue because of license renewal activities is between 2.5 and 5 person-sievert (250 and 500 person-rem). On an annualized basis, this represents an increase in annual exposures of about 3 to 4 percent relative to current reactor operation experience.

LLW generation resulting from license renewal activities is projected to be between 185 and 220 m^3 (6,000 and 8,000 ft^3) of as-shipped LLW over the remaining life of the plants. Currently, PWRs typically generate about 250 m^3/year (8800 ft^3/year); the amount disposed of at BWRs has been about 560 m^3/year (19,700 ft^3/year). Thus, the amount of LLW expected to be added because of license renewal activities is roughly the equivalent of one-half to one year's production of waste under current operating conditions. This represents an increment over the remaining life of the plants of about 1 to 3 percent relative to what would be produced with continued present-basis plant operation.

Table 2.8 presents several types of costs associated with license renewal and extended plant life. These include incremental costs associated with additional labor, waste disposal, capital costs, and off-site costs (off-site engineering and administrative support). For the typical BWR license renewal program, the total incremental costs are estimated to be almost $110 million; those for the typical PWR program are estimated to be about $90 million. Although these costs will be incurred over the remaining life of a plant, more than half of these costs might well be incurred in the first few years after a renewed license is granted. For comparison purposes, recent non-fuel operations and maintenance (O&M) costs at U.S. nuclear plants have averaged about $75 million per year for a 1000-MW(e) plant, and capital additions have averaged about $28 million per year (1994 dollars). Thus, the estimated labor and capital expenditures associated with incremental license renewal activities over the remaining life of a plant with a renewed license are the equivalent of roughly a year's expenditures for O&M and capital additions currently experienced by LWRs, or less than a 5 percent increase for such expenditures on an annualized basis.

2.6.4 Conservative License Renewal Scenario

The characteristics of the conservative case license renewal programs are discussed briefly in Section 2.6.4.1. As was done in Section 2.6.3.1 for the typical programs, listings are provided of the SSCs likely to be subject to incremental aging management activities. Listings of the types of SMITTR actions and major refurbishment activities that may be performed as part of a conservative license renewal program are reviewed and discussed in Appendix B. Section 2.6.4.2 summarizes the impact initiator quantities expected to be generated by such programs and compares the impact initiator quantities for the conservative program scenarios with the impactor initiator quantities currently produced in routine reactor operation.

2.6.4.1 Characterization of the Conservative Program

The conservative license renewal scenarios are intended to capture what might occur for those outlier plants whose impacts will be considerably greater than what is typical of the reactor population as a whole. Because these conservative, or bounding, programs are quite comprehensive, they subsume impacts from more atypical plants.

The conservative case license renewal scenario uses a conservative basis for projecting activities and impacts. The primary bases and assumptions are as follows.

- In contrast with the typical programs, the recently enacted rules and regulations, in particular the Maintenance Rule, were not taken into account in revising license renewal or PLEX-related activities. This simplified approach was taken because accounting for such effects would have a negligible impact on the estimates of environmental impact initiator quantities.
- All activities included in the Part 54 Regulatory Analysis were retained as incremental actions. In many instances, the number of SSCs subjected to particular SMITTR activities was increased to reflect optional actions on the part of licensees to better ensure reliable and economical service for balance-of-plant systems and components.
- The major refurbishment and replacement activities included in the programs are quite expansive and encompass all aspects of the plant designs (e.g., structural, mechanical, and electrical). Similarly, the extent of such activities for particular SSCs is considerable in most cases and is more extensive than that anticipated for the average plant seeking license renewal.
- As was previously noted, several of the major refurbishment activities included in the present estimates have already occurred at many nuclear plants. These are activities such as steam generator replacement in PWRs and recirculation piping replacement in BWRs. These activities are included in the conservative case scenarios to encompass those plants that must perform such activities to achieve the desired extended plant life and efficiency, but that have not already done so or that might have to repeat such actions.

License renewal program definition

Conservative program SSCs subject to incremental activities. The conservative program SSCs assumed to be subject to incremental SMITTR activities included all of the SSCs identified in Table 2.6 for the typical program. In addition, the conservative program included the items listed in Table 2.9. The conservative program, in most instances, also included a greater number of a given type of SSC subject to SMITTR actions than did the typical programs. For example, the conservative programs included roughly twice the number of motor-operated valves subject to incremental aging detection and mitigation actions as did the typical programs. This approach was taken with the conservative programs to encompass what might occur at outlier plants.

Both the SSCs subject to incremental SMITTR activities and those subject to major refurbishment activities for the conservative program are more inclusive than those included in the typical program scenarios. A comparison of Tables 2.6 and 2.7 with Tables 2.9 and 2.10 readily demonstrates the more comprehensive nature of the conservative program compared with the typical program scenarios.

Table 2.9 Conservative program additional structures and components subject to incremental SMITTR[a] activities in support of license renewal

Item	BWR/PWR[b]
BWR control rod drive mechanism	BWR
Compressed air system	Both
Emergency diesel generator	Both
Fan cooler	Both
Main turbine	Both

[a]SMITTR = surveillance, on-line monitoring, inspections, testing, trending, and recordkeeping.
[b]BWR = boiling-water reactor; PWR = pressurized-water reactor.

Table 2.10 lists items subject to major refurbishment/replacement activities. Most of the items in these tables are common to both BWRs and PWRs.

Definition of conservative program aging management activities. As for the typical programs, the incremental aging management activities carried out for the conservative license renewal scenarios to allow operation beyond the original 40-year license term will include both SMITTR activities and major refurbishment activities.

The SMITTR activities associated with the conservative programs are quite similar to those developed for the typical programs, except that they cover additional types and numbers of SSCs. The scenarios developed

Table 2.10 Conservative program systems, structures, and components subject to major refurbishment or replacement activities

Item	BWR/PWR[a]
Building crane	Both
BWR recirculation pump and motor	BWR
BWR safe ends and recirculation and feedwater piping	BWR
Concrete imbedments	Both
Condensate storage tank	Both
Control room communication systems	Both
Electrical cables in and out of containment	Both
Electrical raceways	Both
Emergency diesel generator	Both
Feedwater heater	Both
Heating, ventilation, and air conditioning	Both
Main generator	Both
Main turbine	Both
Major structures, including buildings and pipe enclosures	Both
Metal containment, including suppression chamber	BWR
Nuclear steam supply system supports	Both
Pressurizer and surge line	PWR
Piping section	Both
PWR coolant and feedwater piping inside containment	PWR
Radioactive waste processing system	Both
Reactor containment building	Both
Reactor pressure vessel	Both
Reactor pressure vessel internals	Both
Steam generator	PWR
Steam valve	Both
Switchyard	Both
Turbine pedestal	Both
Ultimate heat sink structures	Both

[a]BWR = boiling-water reactor; PWR = pressurized-water reactor.

for the conservative programs assumed that many balance-of-plant SSCs would be subject to license renewal-related activities to better ensure reliable and economical operation for the extended life of the plant.

Table B.1 of Appendix B lists the incremental SMITTR actions used as the basis for estimating license renewal environmental impacts. It indicates the specific aging detection and mitigation actions performed on each SSC of concern.

Table B.1 indicates the specific SMITTR activities included in each type of program, but it does not indicate the number of SSCs subject to a particular activity. The programs defined for the conservative case scenarios in all instances match or exceed the number of SSCs included in the corresponding typical license renewal programs.

The list of major replacement and refurbishment activities included here was derived largely from areas of concern identified in the industry pilot and lead NP-5181M, EPRI NP-5289P, EPRI NP-5002). This is true for both the conservative and typical scenarios. Those studies did not necessarily indicate that all of the items addressed should be replaced or undergo major overhauls. However, for all items addressed, there was sufficient concern over their long-term integrity that investigators thought, as a minimum, that additional analysis was warranted.

Although replacement may not have been indicated for the pilot and lead plants, at least a few plants may well face extensive actions of this type to ensure safe and economical operation throughout the renewal term. Therefore, regardless of the specific determinations for the pilot and lead plants, the SSCs of concern identified in those studies form a representative list of candidate items for inclusion in major replacement and refurbishment actions for outlier plants, and thus for the conservative scenarios. Other items included in this list were drawn from actions that have already occurred at one or several operating power plants. BWR recirculation piping replacement and PWR steam generator replacement fall into this category. Although many plants will undertake the replacement of such items during the current license term, there may be other plants which would undertake such tasks only to allow for extended plant operation. Inclusion of these activities in the conservative scenario evaluations provides for an upper bound estimate of what at least a few plants may undertake for license renewal.

Table B.2 of Appendix B lists the major refurbishment or replacement activities used to estimate environmental impacts for the conservative case scenarios. Unless otherwise noted, 100 percent of an SSC was assumed to be replaced or refurbished.

2.6.4.2 Conservative Program Incremental Initiator Quantities

Table 2.11 summarizes the conservative program impact initiator quantities resulting from the incremental SMITTR and major refurbishment/replacement activities assumed to be carried out in support of license renewal and extended plant life. A comparison with the estimates provided for the typical programs (Table 2.8) indicates that the conservative program scenario estimates of impact initiator quantities are factors of four to six greater than those for the typical programs. The type of information provided in Table 2.11 is identical to that provided in Table 2.8. Separate estimates are provided for BWRs and PWRs, and all figures are shown on a per-plant basis.

Table 2.11 Conservative license renewal program environmental impact initiators

Outage type	Labor hours	Additional on-site personnel	Waste volumes (as-shipped) (m^3)	Occupational rad exps (person-sieverts)	Waste disposal costs (1994$)[a]	Labor costs (1994$)[a]	Capital costs (1994$)[a]	Total on-site costs (1994$)[a]	Off-site costs (1994$)[a]	Total costs (1994$)[a]
Boiling-water reactors										
Full power operation (20 yrs)	49,900	1	0	0.00	0	2,089,856	0	2,089,856	0	2,089,856
Normal refueling[b]	11,352	27	5	0.10	64,182	556,407	612,043	1,232,632	131,856	1,364,488
5-yr ISI[c] refueling[d]	48,406	78	21	0.27	290,508	2,258,137	712,251	3,260,896	0	3,260,896
10-yr ISI refueling[e]	101,308	122	38	1.08	537,102	4,585,522	1,250,536	6,373,160	0	6,373,160
Current term refurbishments[f]	732,280	866	233	1.91	3,303,684	28,170,043	10,843,605	42,317,332	3,122,803	45,440,135
Major refurbishment outage[g]	1,642,760	867	814	15.61	11,525,736	73,719,268	119,968,099	205,213,104	28,546,104	233,759,207
Total all occurrences	4,910,000	—	1,900	26.66	26,372,000	202,000,000	170,900,000	399,300,000	42,100,000	441,400,000
Pressurized-water reactors										
Full power operation (20 yrs)	49,900	1	0	0.00	0	2,089,856	0	2,089,856	0	2,089,856
Normal refueling[b]	8,733	21	3	0.07	46,166	406,936	410,540	863,642	79,897	943,539
5-yr ISI refueling[d]	28,550	46	13	0.35	185,790	1294,224	451,076	1,931,090	50,734	1,981,824
10-yr ISI refueling[e]	62,295	75	29	0.66	416,620	2,867,021	845,401	4,129,042	74,282	4,203,324
Current term refurbishments[f]	768,460	909	264	2.00	2,889,204	29,607,382	9,687,766	43,184,352	2,821,826	46,006,178
Major refurbishment outage[g]	3,241,260	1,713	1,324	13.80	20,204,944	139,806,842	110,947,895	270,959,681	26,185,773	297,145,454
Total all occurrences	6,550,000	—	2,500	23.74	36,919,300	269,000,000	154,700,000	460,700,000	38,300,000	499,000,000

Notes:

[a]All cost figures are undiscounted 1994 dollars
[b]8 occurrences, 2-month duration each
[c]ISI = in-service inspection
[d]2 occurrences, 3-month duration each
[e]1 occurrence, 4-month duration
[f]4 occurrences, 4-month duration each
[g]1 occurrence, 9-month duration

To convert m^3 to ft^3, multiply by 35.32
To convert person-sievert to person-rem, multiply by 100

Source: Science and Engineering Associates, Inc., January 1995.

A comparison of the figures shown in Table 2.11 with current reactor experience as discussed in Section 2.5.2 indicates that, for the conservative license renewal scenario, incremental license renewal effects are expected to be fairly significant. The incremental efforts associated with license renewal-related activities are estimated to add between 5 million and 7 million person-hours for all such activities over the remaining life of a conservative plant. These increments for license renewal can be compared with the roughly 1.5 million person-hours expended annually with current reactor operation.

If the license renewal efforts were uniformly spread over the 30-year period that a renewed license would be in effect, they would increase annual labor requirements by 10 to 15 percent. The effect of the incremental license renewal labor will be even more significant for certain periods. For example, the number of additional workers needed to accomplish the major refurbishment activities during the major refurbishment outage could potentially double or triple the number needed during a normally scheduled outage. The projected number of additional workers needed for the BWR major refurbishment outage is almost 900, averaged over the entire outage. For certain periods during this outage, the number of additional workers is estimated to be about 1200. For the PWR, the outage average increment in additional personnel needed for the major refurbishment outage is about 1700, and the number is expected to peak at about 2300 for certain periods during this outage. Note that these estimates of peak incremental personnel include the 700- to 800-person temporary work force typically called in to assist with current outages at nuclear power plants (see Table 2.4).

Appendix B provides additional discussion of license renewal-related incremental staffing requirements.

The overall occupational radiation exposure estimated to accrue because of conservative program license renewal activities is between 23 and 24 person-sievert (2300 and 2400 person-rem). The large increase compared with the exposures anticipated for the typical programs is largely a result of the extensive major refurbishment activities expected to be undertaken with the conservative program scenarios. On an annualized basis, this is equivalent to an increase in annual exposures of about 20 to 30 percent relative to current reactor operation experience.

LLW generation from license renewal activities is projected to be between 1,900 and 2,500 m^3 (65,000 and 90,000 ft^3) of as-shipped LLW over the remaining life of the plants. Currently, PWRs typically generate about 250 m^3/year (8800 ft^3/year); the amount disposed of at BWRs has been about 560 m^3/year (19,700 ft^3/year). Thus, the amount of LLW expected to be added because of conservative program license renewal activities represents several years worth of production of waste under current operating conditions. This represents an increment over the remaining life of the plants of about 11 percent annually for the BWRs and about 30 percent annually for the PWRs relative to what would be produced with present-basis, continued plant operation. The larger percentage of PWR LLW results primarily from the large volume of the steam generators, which it is assumed will be replaced for the conservative program.

Table 2.11 indicates that the overall incremental costs associated with conservative program license renewal activities are projected to be in the range of $450 million to $500 million per plant (1994 dollars). With current nuclear plant operation, annual expenditures for fuel, O&M, and capital costs are in the range of $150 million to $250 million, depending on individual plant conditions. Thus, the license renewal expenditures represent 2 to 4 years of current overall operating costs.

2.6.5 Impact Initiator Estimate Uncertainties

The NRC staff believes that the license renewal scenarios presented in Section 2.6.4 reasonably characterize both the nature and magnitude of licensee activities that may be undertaken in support of license renewal and extended plant life. Both the typical and conservative programs include some discretionary activities that are assumed to be undertaken by licensees to better ensure economical and reliable plant operation, and that are in addition to those activities performed to meet the requirements of 10 CFR Part 54. The licensee actions in response to the 10 CFR Part 54 requirements, believed to be fairly modest, consist of a considerably smaller set of activities than those characterized for the typical license renewal scenarios. Appendix B presents estimates of impact initiator quantities strictly related to meeting the requirements of the license renewal rule. Thus, a broad spectrum of license renewal programs are possible, and the license renewal-related environmental impacts can vary widely from one plant to another, depending on specific plant conditions and on discretionary activities undertaken by each licensee/applicant. This variability in program characteristics, coupled with uncertainties in parameter values used to estimate specific initiator quantities, results in a considerable degree of uncertainty in the estimates presented in Tables 2.8 and 2.11. Although a rigorous uncertainty analysis has not been performed, the estimates of individual impact initiators provided in Table 2.8 for the typical programs are judged to have uncertainties in the range of ±30 percent. The more bounding assumptions employed for the conservative scenarios reduce the likelihood that the actual impact initiators experienced could be much higher than those presented in Table 2.11. The uncertainty range for the Table 2.11 estimates, therefore, is judged to be on the order of +10 percent to -30 percent.

2.7 SUMMARY

This chapter described operating U.S. nuclear power plants and described the nature of their interactions with the environment. The basic requirements of the license renewal rule, 10 CFR Part 54, were reviewed with the focus on aspects which may result in incremental environmental impacts. Chapter 2 also described both typical and conservative license renewal programs characterized for the purpose of estimating license renewal-related environmental impacts. Estimates were provided of environmental impact initiators associated with these programs. These impact initiators are used in the balance of this document to identify and quantify anticipated environmental impacts associated with nuclear power plant license renewal.

2.8 ENDNOTES

1. Construction of nuclear units Grand Gulf Unit 2, Perry Unit 2, and Washington Nuclear Project Units 1, 3, 4, and 5 has been suspended; therefore,

these units are not considered in this GEIS.

2. This category is generally discussed as a separate source of liquid waste primarily for PWRs in which the water has a different radionuclide content and chemistry from primary coolant.

2.9 REFERENCES

DOE (U.S. Department of Energy), *Transporting Radioactive Materials: Answers to Your Questions*, U.S. Department of Energy, Washington, D.C., August 1989a.

DOE (U.S. Department of Energy), *Annual Report to Congress*, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, D.C., December 1989b.

DOE/RW-0065, *Transporting Spent Nuclear Fuel: An Overview*, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, D.C., March 1986.

DOE/RW-0220, *Final Version Dry Cask Storage Study*, U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Washington, D.C., February 1989.

EPRI CS-3748, *Dechlorination Technology Manual*, Electric Power Research Institute, Palo Alto, California, 1984.

EPRI NP-3765, Project 2062-11, W. J. Bailey, et al., *Surveillance of LWR Spent Fuel in Wet Storage, Final Report*, prepared by Battelle, Pacific Northwest Laboratories, Richland, Washington, for the Electric Power Research Institute, Palo Alto, California, October 1984.

EPRI NP-5002, Virginia Power Company et al., *LWR Plant Life Extension,* Electric Power Research Institute, Palo Alto, California, January 1987.

EPRI NP-5181SP and EPRI NP-5181M, Northern States Power Company, *BWR Pilot Plant Life Extension Study at the Monticello Plant: Phase 1,* Electric Power Research Institute, Palo Alto, California, May 1987.

EPRI NP-5289P, Virginia Power Company et al., *PWR Pilot Plant Life Extension Study at Surry Unit 1: Phase 1,* Electric Power Research Institute, Palo Alto, California, July 1987.

EPRI NP-5526-V1, Project 1557-26, *Radwaste Generation Survey Update,* Volume 1: *Boiling Water Reactors: Final Report*, prepared by Analytical Resources, Inc., Sinking Spring, Pennsylvania, for the Electric Power Research Institute, Palo Alto, California, February 1988.

EPRI NP-5526-V2, Project 1557-26, *Radwaste Generation Survey Update,* Volume 2: *Pressurized Water Reactors: Final Report*, prepared by Analytical Resources, Inc., Sinking Springs, Pennsylvania, for the Electric Power Research Institute, Palo Alto, California, February 1988.

EPRI NP-5983, Project 2412-6, *Assessing the Impact of NRC Regulation 10 CFR 61 on the Nuclear Industry: Final Report*, prepared by Vance and Associates, Ruidoso, New Mexico, for the Electric Power Research Institute, Palo Alto, California, August 1988.

EPRI NO-6163, Project 2724-3, *On-Site Storage of Low-Level Radioactive Waste at Power Reactors: An International Scoping Study, Final Report*, prepared by Science Applications International Corporation, Inc., for the Electric Power Research Institute, Palo Alto, California, December 1988.

Gerstberger, C., Jr., "Westinghouse At-Reactor Consolidation Program," *Journal of Nuclear Materials Management*, 15(3), 30–31, April 1987.

Johnson, E. R., *Trip Report—Attendance at IAEA Technical Committee Meeting on Methods for Expanding Spent Fuel Storage Facilities*, prepared by E. R. Johnson, Associates, Oak Ridge, Tennessee, for Martin Marietta Energy Systems, Inc., under Contract 41X-SD841V, Task 10, July 3, 1989.

NUMARC (Nuclear Management Resources Council), Survey of U.S. utility-owned nuclear power plants, Oak Ridge National Laboratory, Oak Ridge, Tennessee, and NUMARC, Washington, D.C., June 1990.

NUREG-0170, *Vols. 1 and 2, Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes, Volumes 1 and 2*, U.S. Nuclear Regulatory Commission, Office of Standards Development, December 1977.

NUREG-0945, "Licensing Requirements for Land Disposal of Radioactive Waste," *Final Environmental Impact Statement on 10 CFR Part 61, Vol. 1*, U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguard, November 1982.

NUREG-1362, *Regulatory Analysis for Proposed Rule on Nuclear Power Plant License Renewal,* U.S. Nuclear Regulatory Commission, Washington, D.C., July 1990.

NUREG/CR-2907, J. Tichler, et al., *Radioactive Materials Released from Nuclear Power Plants, Annual Report 1987*, prepared by Brookhaven National Laboratory, Upton, New York, for the U.S. Nuclear Regulatory Commission, 1989.

NUREG/CR-5640, *Overview and Comparison of U.S. Commercial Nuclear Power Plant, Nuclear Power Plant System Source Book*, U.S. Nuclear Regulatory Commission, September 1990.

ORNL/TM-6472, J. B. Cannon, et al., *Fish Protection at Steam-Electric Power Plants: Alternative Screening Devices*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 1979.

O'Sullivan, R. A., "International Consensus for the Safe Transport of Radioactive Materials: An Experience to Imitate," *IAEA Bulletin*, **30**(3), 31–34, 1988.

OTA-SET-304, *Transportation of Hazardous Materials*, Office of Technology Assessment, U.S. Congress, Washington, D.C., July 1986.

Sciacca, F. W., Science and Engineering Associates, Inc., letter to D. Cleary, U.S. Nuclear Regulatory Commission, "Letter Report Presenting Base Case and Typical License Renewal Program Impact Driver Summaries," January 3, 1993.

Sciacca, F. W., Science and Engineering Associates, Inc., letter to D. Cleary, U.S. Nuclear Regulatory Commission, "Bases and Assumptions Used in Developing Updated Base Case and Typical License Renewal Program Scenarios," January 13, 1993.

TVA (Tennessee Valley Authority), *Summary of Added Chemicals and Resulting End Product Chemicals*, U.S. Nuclear Regulatory Commission, 1978.

3. Environmental Impacts from Nuclear Power Plant Refurbishment

3.1 INTRODUCTION

This chapter addresses the environmental impacts of refurbishment activities at an operating nuclear power plant in anticipation of license renewal. Section 2.4 describes the activities to be undertaken to prepare a nuclear power plant for operation following license renewal (see Tables 2.6 and 2.7). These activities will include (1) enhanced inspection, surveillance, testing, and maintenance and (2) repair, replacement, modification, and refurbishment of plant systems, structures, and components. For some plants, replacement of large components of the nuclear steam supply system (e.g., steam generator or pressurizer) is conceivable, as is repair or replacement of pumps, pipes, control rod systems, electronic circuitry, electrical and plumbing systems, or motors. Upgrading radioactive waste storage facilities could also be required because of increased low-level radioactive waste (LLW) generation and because a permanent high-level-waste repository is not yet available. Construction of new transmission lines is not expected to occur in conjunction with license renewal, although repair or replacement of structures may be needed occasionally. For example, wooden-pole structures may need rebuilding or replacement every 50–60 years. If construction of new lines is proposed, the impacts would be reviewed in accordance with the requirements of 10 CFR Part 51.

Refurbishment activities could result in environmental impacts beyond those that occur during normal plant operation. For example, site excavation and grading associated with construction of new waste storage facilities could result in fugitive dust emissions, localized air quality impacts, erosion, sedimentation, and disturbance of both aquatic and terrestrial ecosystems. Moreover, refurbishment could (1) require a sizable addition to the work force, (2) increase the radiation exposure to workers, and (3) generate increased quantities of LLW. These potential impacts are evaluated in the sections that follow.

3.2 ON-SITE LAND USE

Farming and other types of land use occur on some nuclear plant sites. Some utilities have designated portions of their nuclear plant sites for land uses such as recreation, management of natural areas, and wildlife conservation. Changes in on-site land use at a nuclear plant could result if additional new spent fuel and interim LLW storage facilities were required. (Waste generation, handling, and disposal are discussed in Chapter 6.) Incremental land use resulting from license renewal-related activities, even major refurbishments, is expected to be modest. The greatest land use needs for such activities are projected to occur during the major refurbishment outages of the conservative license renewal scenarios. Major activities such as steam generator replacement in pressurized-water reactors (PWRs), recirculation piping replacement in boiling-water reactors (BWRs), replacement of some reactor vessel internal structures, main turbine repairs, and general structural refurbishments are projected to occur for a few reactor plants during these outages.

Incremental land use associated with license renewal activities can be estimated from prior related experience within the U.S. nuclear industry. For example, a recent steam generator replacement at a U.S. PWR required about 1 ha (~2.5 acres) of land area to accommodate laydown, staging, handling, temporary storage, personnel processing, mockup and training, and related needs. The major activities projected to occur for the conservative license renewal scenarios are expected to require temporary land use for activities such as staging of new components and removing old components. In addition, the large number of temporary workers needed to accomplish the major refurbishment activities will likely require that temporary facilities be installed for on-site parking, training, site security access, office space, change areas, fabrication shops, mockups, and related needs. Based on previous experience with major refurbishments at nuclear power plants, it is expected that ~1–4 ha (~2.5–10 acres) of land may be needed to accommodate these refurbishment activities. Once these major activities and the major outages are completed, this land might be returned to its prior uses. Alternatively, the land could be used for on-site storage of LLW, spent fuel, and contaminated components such as steam generators until final off-site disposal is possible. Thus, some or all of the same land may be used both for the temporary major refurbishment needs and for the longer-term needs associated with on-site storage of waste materials. However, radioactive wastes are stored in remote parts of the site by some utilities in order to minimize worker radiation exposure and to avoid interference with routine activities. Typical license renewal scenario incremental land use requirements are bounded by those projected for the conservative scenarios.

The site is already owned by the utility and any land used for refurbishment activities will likely be within the exclusion area. Even if the land used for dry storage of spent fuel is on a remote part of the site, the impacts will be small. The U.S. Nuclear Regulatory Commission (NRC) has written a number of environmental assessments for on-site dry cask storage facilities and has reached a "finding of no significant impact" (FONSI) for each. The FONSI was reached considering the amount of land actually disturbed, the range of possible environmental impacts, and alternative uses of the land. On-site land use impacts are expected to be of small significance at all sites. Temporary disturbance of land may be mitigated by restoration to its original condition after refurbishment, or after site decommissioning. This is a Category 1 issue.

3.3 AIR QUALITY

Most plant refurbishment activities associated with license renewal would be performed on equipment inside existing buildings and would not generate atmospheric emissions. The only potential sources of impacts to air quality would be (1) fugitive dust from site excavation and grading for construction of any new waste storage facilities and (2) emissions from motorized equipment and workers' vehicles.

Air quality impacts from these sources would be minor and of short duration. The disturbed area for the waste storage facilities and laydown areas, if required, is expected to be 4 ha (10 acres) or less (Section 3.2). During site excavation and grading, some particulate matter in the form of fugitive dust would be released into the atmosphere, but fugitive dust consists primarily of large particles that settle quickly and thus have minimal adverse public health effects. Because construction would probably occur within an existing plant yard, much less site preparation would be necessary than for a previously undisturbed site. Because of the (1) small size of the disturbed area, (2) relatively short construction period, (3) availability of paved roadways at existing facilities, and (4) use of the best management practices (such as seeding and wetting), fugitive dust resulting from these construction activities should be minimal.

Heavy construction vehicles and other construction equipment would generate exhaust emissions (which would include small amounts of carbon monoxide, oxides of nitrogen, volatile organic compounds, and particulate matter). These would be temporary and localized. Additional emissions would result from the vehicles of up to about 2300 construction, refurbishment, and refueling personnel during most of the 9-month refurbishment outage (Figure B.6). For refurbishment occurring in geographical areas of poor or marginal air quality, these vehicle exhaust emissions could be cause for some concern. The 1990 Clean Air Act Amendments include a provision that no federal agency shall support any activity that does not conform to a state implementation plan designed to achieve the National Ambient Air Quality Standards for criteria pollutants (sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and particulate matter less than 10 μm in diameter). On November 30, 1993, the U.S. Environmental Protection Agency (EPA) issued a final rule (58 FR 63214) implementing the new statutory requirements, effective January 31, 1994. The final rule requires that federal agencies prepare a written conformity analysis and determination for each pollutant where the total of direct and indirect emissions caused by a proposed federal action would exceed established threshold emission levels in a nonattainment or maintenance area. An area is designated as nonattainment for a criteria pollutant if it does not meet National Ambient Air Quality Standards for the pollutant. A maintenance area is one that a state has redesignated from nonattainment to attainment.

Based on EPA's interpretation that mobile emissions from workers' vehicles should generally be considered as indirect emissions in a conformity analysis, a screening analysis was performed which indicated that the emissions from 2300 vehicles may exceed the thresholds for carbon monoxide, oxides of nitrogen, and volatile organic compounds (the latter two contribute to the formation of ozone) in nonattainment and maintenance areas. In addition, the amount of road dust generated by the vehicles traveling to and from work would exceed the threshold for particulate matter less than 10 μm in serious nonattainment areas. However, the assumption of adding 2300 workers' vehicles to existing traffic forms an upper bound of potential emissions; in reality, some workers would carpool to the refurbishment sites, while others would be driving to other construction sites if the proposed refurbishment activities were not occurring. In addition, EPA suggests that there may be some flexibility in the rigor of a conformity analysis, particularly with regard to the specific site, the extent of refurbishment, the pollutants which are in nonattainment, the severity of the nonattainment, the state regulatory agency, and the federal agency's control over workers' vehicles. In summary, vehicle exhaust emissions could be cause for some concern, but a general conclusion about the significance of the potential impact cannot be drawn without considering the compliance status of each site and the number of workers expected to be employed during the outage. This is a Category 2 issue.

3.4 SURFACE WATER AND GROUNDWATER QUALITY

3.4.1 Surface Water

Refurbishment could impact surface water quality as a result of the effects of (1) refurbishment- or construction-related discharges to surface water and (2) project-related surface water consumption. Changes in water quality could affect aquatic biota and water uses (fishing, recreation, and water supply).

Because most refurbishment activities would be conducted indoors (Section 2.6), discharges would be readily controlled, thereby minimizing the potential for impacts on surface water quality. The construction of new structures for storage of spent fuel or LLW could require modest amounts of site excavation and grading, but there are no features unique to the refurbishment that would require unusual construction practices. Procedures for the control of nonpoint-source pollution from construction activities as mandated by Section 319 of the Clean Water Act are well known. Mitigative measures were developed at each nuclear power plant site to control impacts during original plant construction. These measures, which are listed in the environmental statements related to the issuance of construction permits, include controlling drainage by ditches, berms, and sedimentation basins; prompt revegetation to control erosion; stockpiling and reusing excavated topsoil; and various other techniques used to control soil erosion and water pollution. These same types of site-specific mitigation measures (often referred to as best management practices) are expected to be implemented during refurbishment to minimize impacts on surface water quality and aquatic biota. Therefore, the potential impacts of refurbishment on surface water quality are expected to be negligible (small) for all plants. Impacts of refurbishment on surface water quality and aquatic biota could be further reduced by additional mitigative measures, such as more stringent construction control techniques. However, because the effects of refurbishment are considered to be of small significance and potential mitigation measures are likely to be costly, the staff does not consider the implementation of mitigation measures beyond "best management practices" to be warranted. This is a Category 1 issue.

Water consumption during refurbishment would not change from pre-refurbishment requirements unless the plant were temporarily shut down. If refurbishment activities resulted in more or longer plant outages than are typical for the facility, both cooling water withdrawals and routine permitted discharges of heat, biocides, or other chemical contaminants in the cooling system effluent would be reduced. The additional quantities of water required during construction for mixing, cleaning, and dust suppression would be negligible. For these reasons, water consumption impact during refurbishment is expected to be of small significance or beneficial for all plants. The only potential mitigation for any increase in water consumption would be to acquire the additional water from some other source. However, because this approach would provide very little, if any, environmental benefit and would be costly, the staff does not consider implementation of additional mitigation to be warranted. This is a Category 1 issue.

3.4.2 Groundwater

No liquid wastes were discharged to groundwater during construction of nuclear power plants, and none is expected to occur during refurbishment. During construction, liquid construction wastes were either temporarily retained in lined evaporation ponds or stored in drums for shipment to off-site disposal facilities. Because liquid construction wastes would be handled similarly during refurbishment no impacts to groundwater quality is expected.

The only impacts on groundwater quality reported during nuclear plant construction resulted from groundwater dewatering associated with deeply excavated building foundations and cooling water canals at sites close to the ocean. Groundwater dewatering at sites near the ocean can adversely affect groundwater quality by inducing saltwater intrusion. Deep excavations and site dewatering would not be required at any plant so no saltwater intrusion or groundwater quality impacts would occur.

Because refurbishment would not affect groundwater quality in any way, refurbishment would neither cause nor contribute to impacts on groundwater at any site. While there are several ways of mitigating adverse impacts to groundwater quality, no mitigation measures are warranted because there would be no adverse impacts to mitigate. This is a Category 1 issue.

3.5 AQUATIC ECOLOGY

Aquatic biota could be affected by adverse changes in water quality caused by construction or by changes in plant operation; however, if mitigative measures developed for the site during and since original construction are used, adverse effects on water quality and thus on aquatic biota would be minimal (Section 3.4.1). Potential impacts on aquatic biota from changes in operating conditions of the plant during refurbishment are expected to be small at all sites.

Effects of refurbishment on aquatic organisms are considered to be of small significance if plant-induced changes are localized and populations of aquatic organisms in the receiving waterbody are not reduced. During a major refurbishment outage there would be a reduction or elimination of cooling water withdrawals and discharges of heat, biocides, or other permitted chemicals in the cooling effluent. No adverse effects on aquatic biota would be caused at any power plant by reduced entrainment of organisms into the cooling system, reduced impingement against the intake screens, or reduced discharges of chemicals from any power plant site. Because no adverse effects on aquatic organisms are anticipated during refurbishment, the effects are considered to be of small significance for all plants. Since any effects would be minor and localized, they would not contribute to cumulative impacts. Water quality impacts could be readily controlled using current mitigative measures, and the reduction in cooling system operation during major refurbishment outages would reduce the number of aquatic organisms impacted by entrainment, impingement, and nonradiological discharges. Hence, no mitigation measures beyond those already implemented in the current license period would be needed. The effect of refurbishment on aquatic biota is a Category 1 issue.

3.6 TERRESTRIAL ECOLOGY

The potential loss of plant and animal habitat resulting from laydown areas and possible construction of new waste storage facilities during refurbishment at nuclear power plant sites would be the principal terrestrial ecology concern. The amount of on-site land that could be disturbed would be expected to be ~1–4 ha (2.5–10 acres). No off-site habitat loss would be expected to occur except to the extent that refurbishment may cause increased residential and commercial growth in nearby communities (see Section 3.7.5). No off-site power-line expansions (construction of new lines, upgrading of existing lines, or right-of-way expansion) are expected as part of license renewal; licensees must notify the NRC of such major modifications. Rebuilding wooden pole structures, however, may be necessary about every 50–60 years.

The significance of lost habitat depends on the importance of the plant or animal community involved. Particularly important habitats are wetlands, riparian habitats, staging or resting areas for large numbers of waterfowl, rookeries, restricted wintering areas for wildlife (e.g., winter deer yards), communal roost sites, strutting or breeding grounds of gallinaceous birds, and areas containing rare plant communities (e.g., Atlantic white cedar swamps). Such habitats are uncommon and are unlikely to occur on most plant sites. However, if such resources do occur on plant sites, refurbishment activities should be planned to avoid them to the extent feasible. If no important resource would be affected, the impacts would be considered minor and of small significance. If important resources could be affected by refurbishment activities, the impacts would be potentially significant. Because the significance of ecological impacts cannot be determined without considering site-specific and project-specific details, and because mitigation may be warranted, this is a Category 2 issue.

3.7 SOCIOECONOMIC IMPACTS

3.7.1 Introduction

This section describes the socioeconomic impacts associated with nuclear power plant refurbishment. Based on a literature search and citation review, the following plant-induced socioeconomic impacts were chosen for in-depth evaluation: changes to local housing (i.e., availability, costs, and characteristics); the magnitude of new nuclear plant tax payments in relation to total revenues in host communities; disruptions of local public services (i.e., education, transportation, public safety, social services, public utilities, and tourism and recreation); changes of local land use and development patterns; local employment levels; and disturbances to historic and aesthetic resources at and around the plant site. Of these socioeconomic impacts only those directly affecting the natural and built environment are carried forward to the decision whether to renew an operating license. The regional economic impact—including income, employment, and taxes—is not considered in the license renewal decision. The impacts discussed in this chapter are only those *new* impacts expected to be caused by refurbishment-related activities. Impacts are discussed for each plant's "impact" or "study" area, which includes those jurisdictions in which the most pronounced socioeconomic impacts are expected. Plant-induced population growth, while not an impact itself, was studied as a potential influence on a number of the impacts listed above.

For this analysis, the socioeconomic impacts that occurred during construction of seven case study nuclear plants were identified and used to forecast refurbishment-related impacts at the same seven plants. Differences between the construction and refurbishment periods in terms of key impact predictors such as work force size, population, and community infrastructure conditions were factored into the impact analysis. The analysis assumes that no other major construction projects will occur concurrently with plant refurbishment. If other large construction projects are ongoing during refurbishment, the socioeconomic impacts could be greater than those predicted. Because the case study plants (Figure 3.1) were representative of the range of U.S. nuclear plants in terms of a number of key factors (remoteness, population density, geographic region, age of plant), the impacts projected for the seven sites provide upper and lower bounds for the range of impacts that will occur at all plants.

Socioeconomic impacts are site-specific in nature. Therefore, simultaneous relicensing of several nuclear power plants will not have cumulative regional or national impacts. However, if two plants within 80 km (50 miles) of each other are refurbished simultaneously, worker in-migration and the related impacts might be larger. An overview of the socioeconomic research methods used is provided in Appendix C.

Socioeconomic impact analyses, particularly of resources affected by changes in population, are based on work force estimates presented in Chapter 2, Appendix B, and SEA (1995). The conservative scenario work force represents the upper bound of work force requirements for a typical plant. The primary socioeconomic impact analyses are based on the largest estimated work force (i.e., the PWR work force of 2273 persons).[1] This peak work force would occur during the 9-month major refurbishment outage immediately before the expiration of the initial operating license (see Appendix B).

After the refurbishment work force has peaked, refueling will be undertaken to prepare for continued plant operation during the license renewal term. Because of uncertainty surrounding the work force numbers, a sensitivity analysis was performed wherein socioeconomic impacts were predicted in response to a work force roughly 50 percent larger than the projected bounding case PWR refurbishment work force (i.e., 3400 workers). The discussion of conclusions for each socioeconomic topic states whether or not the category of impacts expected with the original estimate would change in response to the larger work force.

The estimates for the conservative case and typical case BWR peak work forces are 1500 and 1017, respectively.[2] The peak

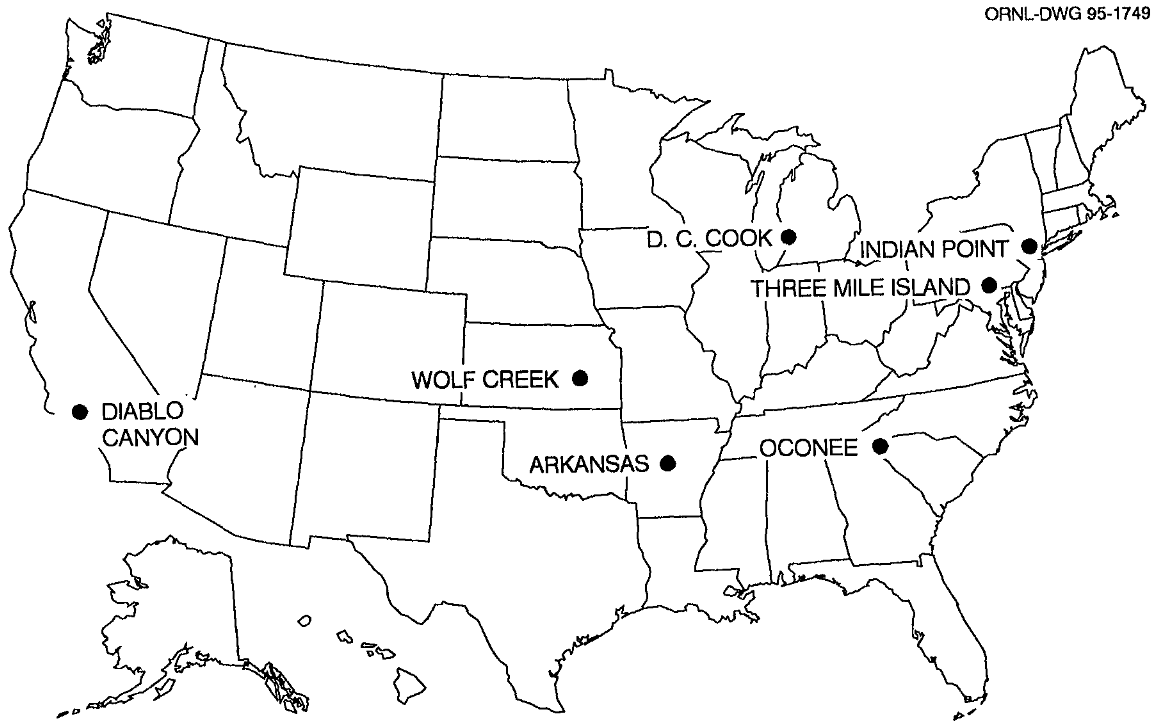

Figure 3.1 The seven case study nuclear plants.

on-site work force associated with the conservative BWR refurbishment scenario would occur during the current-term outages that will begin up to 10 years before the expiration of the original operating license. Because the current-term outages will last only 4 months, refueling and refurbishment workers will be on-site simultaneously. Both types of workers are included in the estimated peak work force of 1500. Under the BWR typical refurbishment scenario, the peak work force (1017) would occur during the final refurbishment period, projected to last 4 months. Because the outage would be brief, refueling workers will be on-site at the same time as refurbishment workers and are therefore included in the total work force estimate.

Limited additional analyses were conducted to determine if these smaller work forces would cause smaller impacts. These analyses were conducted only for resources found to be subject to potential moderate or large impacts with a work force of 2273 and known not to experience moderate or large impacts with smaller work forces (e.g., associated with refueling/maintenance activities). These analyses are discussed in the education and land use sections (i.e., those resources which, at certain case-study sites, fit the above description).

Population growth is important because it is one of the main drivers of socioeconomic impacts. The population increases resulting from construction-related in-migration at the seven case study plants varied (Table 3.1). Of all U.S. nuclear power plants, Indian Point has the highest combination of population density and proximity to urban centers, whereas Wolf Creek has one of the lowest combinations of the same variables. Consequently, Indian Point and Wolf Creek serve as the lower and upper bounds, respectively, of construction-related growth as a percentage of the case study areas' total populations.

Both the absolute and relative population growths associated with the refurbishment of the case study plants would be less than were experienced during original construction (see Table 3.1). The absolute growth would be smaller because the scale of refurbishment activities would be smaller than original construction. Relative growth would also be smaller because existing populations of the host communities are expected to be larger than during original construction (see Appendix C). The levels of refurbishment-related growth projected for the case study sites are expected to bound the levels of growth that would occur at all other plants.

Table 3.1 Past and projected population growth associated with the peak construction and refurbishment work forces at the seven case study nuclear power plants[a]

Plant	Past population growth caused by original plant construction	Past population growth as a percentage of study area's total population during peak construction years	Projected population growth caused by refurbishment	Projected population growth (refurbishment) as a percentage of study area's projected total population
Arkansas Nuclear One	2756	8.3	2355	3.7
D. C. Cook				
Bridgman—Lake Township	175	4.6	141	3.1
Berrien County	2193	1.3	1825	1.0
Diablo Canyon	3308	2.6	3631	0.8
Indian Point				
Dutchess County	390	0.2	367	0.1
	309	<0.1	290	<0.1
Oconee	701	1.7	496	0.7
Three Mile Island	301	2.2	189	1.0
Wolf Creek	2329	20.5	798	9.1

[a]Includes both direct and indirect workers and their families.
Source: The staff.

Refurbishment-related growth is expected to represent between less than 0.1 percent and 9.1 percent of the local areas' total populations for all plants (Table 3.1). As a result, for most U.S. nuclear power plants, refurbishment would result in only small population increases and correspondingly small population-driven impacts. Rural areas that are more than 80 km (50 miles) from an urban center (i.e., a population of at least 100,000) and that have low population densities would experience greater population-driven impacts.

3.7.2 Housing

The impacts on housing are considered to be of small significance when a small and not easily discernible change in housing availability occurs, generally as a result of a very small demand increase or a very large housing market. Increases in rental rates or housing values in these areas would be expected to equal or slightly exceed the statewide inflation rate. No extraordinary construction or conversion of housing would occur where small impacts are foreseen.

The impacts on housing are considered to be of moderate significance when there is a discernible but short-lived reduction in available housing units because of project-induced in-migration. Rental rates and housing values would rise slightly faster than the inflation rate, but prices should realign quickly once new housing units became available or once project-related demand diminished. The new housing units added to the market during construction are easily absorbed into the market once project-related demand diminishes. Minor or temporary conversions of nonliving space to living space, such as converting garages to apartments, may occur. Also, there may be a temporary addition of new mobile home parks or expansions of existing parks.

The impacts on housing are considered to be of large significance when project-related demand for housing units would result in very limited housing availability and would increase rental rates and housing values well above normal inflationary increases in the state. Such increases could make housing unavailable or less affordable to nonproject personnel. Substantial conversions of housing units, such as single-family houses to apartments, as well as substantial overbuilding so that these units cannot be absorbed into the housing market once project demand diminishes are also considered indicative of large impacts.

Housing impacts were evaluated by comparing refurbishment-related housing demand to the projected local housing market (number of units and vacancies). The housing impacts that occurred during original plant construction were considered, as were current housing characteristics (e.g., the existence of multifamily units in the local and neighboring housing markets) and the presence of any growth control measures that limit housing development. The size of the future housing market during the refurbishment period was estimated based on historical housing growth rates in the study areas. Housing demand unrelated to refurbishment was estimated based on the projected population at refurbishment time and the 1990 household size. A complete discussion of these assumptions is provided in Section C.4.1.2. Information concerning original construction-related housing impacts and current housing markets at the seven case study sites was obtained from site-specific NUREG reports, the U.S. Census Bureau, local housing authorities, and interviews with realtors and community development officials (see references in Appendix C).

Table 3.2 summarizes the housing impacts that resulted from original construction of the seven case study plants and lists construction-related housing demand relative to the local housing market, which is one of several factors that influence significance. In most cases, project-related housing demand was so small or the local and regional housing markets were so large that no large impacts resulted. The large housing impacts experienced at Wolf Creek were evidenced by (1) limited or no housing availability, (2) the occupation of previously abandoned housing units and of structures that were not originally intended for residential use, and (3) drastically increased rental costs. At this and other sites, local mobile home parks expanded to meet increased demand. None of the case study plant areas experienced substantial new construction of housing units that were built solely in response to project-related demand for housing. Construction of new housing units was noted at some sites during and before plant construction, but all new units were readily absorbed into the market once project-related demand diminished. The smallest work force that induced large impacts occurred with 640 on-site workers at Wolf Creek during operations-period refuelings (Section 4.7.2). Consequently, a work force as small as 640 may cause large impacts in low population areas but less significant impacts in higher population areas.

Potential refurbishment impacts on housing at each of the case study sites are summarized in Table 3.3. Table 3.3 also includes information about peak housing demand and housing demand relative to the projected number of housing units in each study area, although there is no simple direct relationship between these numbers and significance levels. Projected refurbishment impacts at the case study sites range from small to large. Declining economic conditions in the host communities would not increase the severity of the impact because public revenues are not used to build or maintain the dwellings that plant workers would occupy and because economic decline often is accompanied by a loss of population, which could increase the number of available housing units.

Moderate and large impacts are possible at sites located in rural and remote areas, at sites located in areas that have experienced extremely slow population growth (and thus slow or no growth in housing), or where growth control measures that limit housing development are in existence or have recently been lifted. Because impact significance depends on local conditions that cannot be predicted at this time, housing is a Category 2 issue.

3.7.3 Taxes

Plant-induced increases to local tax receipts are considered beneficial. The benefits of plant refurbishment to local tax structures were considered by examining the magnitude of potential new tax payments by the nuclear power plants in relation to total revenues in the host community. The new payments could be made directly to local government jurisdictions or indirectly to local government jurisdictions through state tax and revenue sharing programs. A more detailed discussion of the methods used to predict tax impacts is provided in Section C.4.1.3.

The benefits of taxes are considered to be small when new tax payments by the

Table 3.2 Summary of housing impacts during construction of seven nuclear power plants in case study

Site	Peak housing demand in study area	Housing demand as a percentage of the total number of housing units in the study area	Factors affecting housing impact	Impact on housing
Arkansas Nuclear One	858	6.25	Construction-related demand caused temporary housing shortages and increased rents, expansion of housing stock	Moderate
D. C. Cook				
Berrien County	902	1.8	Existing housing stock and housing growth adequate to meet demand	Small
Diablo Canyon	1297	2.7	Impact increased by rapidly increasing demand for housing unrelated to project	Moderate
Indian Point				
Westchester County	194	0.28	Very large housing market	Small
Dutchess County	143	0.04		Small
Oconee	167	1.2	Duke power provided on-site housing for 150 workers	Small
Three Mile Island	146	2.8	Substantial growth in housing stock occurred unrelated to project demand	Small
Wolf Creek	713	18	Low vacancy rate in a small housing market; very large construction-related demand	Large

Source: The staff.

Table 3.3 Projected housing impacts of refurbishment at the seven case study nuclear power plants

Plant	Peak housing demand in the study area	Housing demand as a percentage of housing units in the study area	Projected impacts
Arkansas Nuclear One	976	3.8[a]	Small
D. C. Cook			
Berrien C.	811	1.1	Small to moderate
Diablo Canyon	1388	0.9	Moderate to large[b]
Indian Point			
Dutchess County	158	0.1	Small
Westchester County	124	0.02	Small
Oconee	260	0.6	Small
Three Mile Island	124	1.7	Small
Wolf Creek	355	9.2	Large

[a]If the rapid growth in housing that occurred during 1986–1990 continues, demand as a percentage of total housing units would be 3.2 percent. The more conservative estimate is presented in this table and used to determine potential impacts.
[b]Because of current growth control measures, a slower growth scenario for San Luis Obispo County (see Appendix C) is used. If these growth control measures remain in effect, the impact to housing would be moderate to large. However, if these growth control measures were removed, impacts would be small.
Source: The staff.

nuclear plant constitute less than 10 percent of total revenues for local taxing jurisdictions. The additional revenues provided by direct and indirect plant payments on refurbishment-related improvements result in little or no change in local property tax rates and the provision of public services. The benefits of taxes are considered moderate when new tax payments by the nuclear plant constitute 10 to 20 percent of total revenues for local taxing jurisdictions. The additional revenues provided by direct and indirect plant payments on refurbishment-related improvements result in lower property tax levies and increased services by local municipalities. The benefits of taxes are considered to be large when new tax payments by the nuclear plant represent more than 20 percent of total revenues for local taxing jurisdictions. Local property tax levies can be lowered substantially, the payment of debt for any substantial infrastructure improvements made in the past can easily be made, and future improvements can continue.

Property taxes paid to the municipalities and taxing school districts surrounding the seven case study plants were very small at the start of original plant construction, and income and residential-related property taxes, although increasing rapidly throughout the construction period, were usually not large. Generally, as construction progressed, the assessed value of the nuclear plants increased dramatically; therefore, the property tax payments based on these assessments also increased greatly.

Capital improvements made to plants during the final refurbishment outage very likely would have no effect on taxes until they have been completed; thus, they should cause no tax impacts until the license renewal term. However, the assessed value of the plant is expected to increase before that time because of refurbishment-related capital improvements that occur during current-term outages.

Based on the benefits that occurred as a result of original plant construction, benefits resulting from the increase in direct and indirect tax payments to local jurisdictions during refurbishment would be small to moderate at the case study sites. The magnitude of current tax payments provides an indication of the magnitude of new tax payments. Where existing tax payments account for only a small or moderate share (< 20 percent) of total revenue (see Table 4.13), the new additional tax payments will have only small benefits, especially if the increase in assessed value from capital improvements is small. At sites where the plants currently contribute significantly (> 20 percent) to their respective local jurisdictions' total revenues (see Table 4.13) and where substantial capital improvements greatly increase the assessed value, the new benefits may be moderate.

3.7.4 Public Services

The projected impacts of refurbishment on public services were considered for education, transportation, public safety, social services, level of demand for public utilities, and tourism and recreation.

For most public services, future impacts were projected based on the estimated number of in-migrating workers and on the projected state of the local infrastructure. To predict impacts to local educational systems, the number of in-migrating workers accompanied by their families and their associated family sizes also are important. In the area of transportation, the total number of workers is important whether or not they are new to the host community, because they will use local roads to access the project site. Assumptions about the above-mentioned variables were based on patterns observed during original plant construction. Additional information on the calculation of public service impacts is provided in Sections C.1.5.3 and C.4.1.4. Information concerning construction-related public service impacts and current services at the case study sites was obtained from site-specific reports and interviews with local officials (see references in Appendix C).

Because projections of infrastructure capacity were based on current conditions, it is appropriate to ask whether future deterioration of host community infrastructure could invalidate the conclusions about impact significance presented below. Infrastructure deterioration is unlikely because these facilities and services generally have been maintained (and in many instances improved) during the period of plant operations. In addition, continued plant operations will ensure continued revenues for those local jurisdictions currently taxing the plant, providing a measure of protection for communities in which economic decline might otherwise result in infrastructure deterioration. Also, in communities where the quality and quantity of public services have declined, a population decrease has often occurred, reducing the demand for these services. Finally, the sensitivity analysis discussed in Section 3.7.1 revealed that local public services could accommodate the growth associated with a work force 50 percent larger than the bounding case refurbishment work force without increasing the significance level of the impacts. As a result, for those elements of the infrastructure projected to experience only small impacts, the capacity of the existing infrastructure in impact area communities could decline and still be adequate to support projected refurbishment-induced growth.

3.7.4.1 Education

Impact determinations depend on the baseline conditions of the potentially affected school system (e.g., whether it is below, at, or exceeding maximum allowed student/teacher ratio). In general, small impacts are associated with project-related enrollment increases of 3 percent or less. Impacts are considered small if there is no change in the school systems' abilities to provide educational services and if no additional teaching staff or classroom space is needed. Moderate impacts generally are associated with 4 to 8 percent increases in enrollment. Impacts are considered moderate if a school system must increase its teaching staff or classroom space even slightly to preserve its pre-project level of service. Any increase in teaching staff, however small (e.g., 0.5 full-time equivalent), that occurs from hiring additional personnel or changing the duties of existing personnel (e.g., a guidance counselor assuming classroom duties) may result in moderate impacts, particularly in small school systems. Large impacts are associated with project-related enrollment increases above 8 percent. Education impacts are considered large if current institutions are not adequate to accommodate the influx of students or if the project-related demand can be met only if additional resources (e.g., new teachers and/or classrooms) are acquired.

Impacts to education that resulted from plant construction depended upon the number of in-migrating workers (and, thus, school-aged dependents) and the size of the existing school system (and thus its ability to absorb additional students). School districts were affected for a short period of time, and disruption to existing institutions was small in most cases. However, some schools had to set up temporary classrooms to accommodate the influx of children. At the case-study sites, impacts to education during plant construction ranged from small to moderate (see Table 3.4). Once construction was well under way, positive monetary impacts began to be experienced by some school districts where plants were located.

Projected impacts to education during the refurbishment period would be potentially large at Wolf Creek where school enrollment is projected to increase 9 percent because of the in-migration of the refurbishment work force (see Table 3.5). At the Arkansas Nuclear One site, a projected 4 percent increase in

Table 3.4 Original construction-induced public service impacts at the seven case study nuclear power plant sites

Service	Arkansas Nuclear One	Diablo Canyon	D. C. Cook	Indian Point	Oconee	Three Mile Island	Wolf Creek
Education	Small	Small to moderate	Small	Small	Small	Small	Moderate
Transportation	Small	Small	Small to moderate	Small	Small	Moderate	Large
Public safety	Small	Small	Small	Small	Small	Small	Small
Social services	Small	Small	Small	Small	Small to moderate	Small	Small
Public utilities	Small to moderate	Small	Small	Small	Small	Small	Moderate
Tourism and recreation	Small	Small	Small	Small	Small	Small	Small to moderate

Source: The staff.

Table 3.5 Projected refurbishment-induced public service impacts at seven nuclear plant sites in case study

Service	Arkansas Nuclear One	D. C. Cook	Diablo Canyon	Indian Point	Oconee	Three Mile Island	Wolf Creek
Education	Moderate	Small	Small	Small	Small	Small	Moderate to large
Transportation	Small	Moderate	Small	Small	Small	Moderate	Large
Public safety	Small	Small	Small	Small	Small	Small	Small
Social services	Small	Small	Small	Small	Small	Small	Small
Public utilities	Small	Small	Small to moderate	Small	Small	Small	Small to moderate
Tourism and recreation	Small	Small	Small	Small	Small	Small	Small

Source: The staff.

enrollment could cause moderate impacts to education. At all other sites, impacts would be small.

Analyses of the smaller projected work forces associated with BWR conservative and BWR typical scenarios were conducted at case-study sites where impacts induced by the PWR conservative scenario work force were projected to be moderate or large. The analyses determine whether these smaller work forces would induce smaller impacts to education. At the most sparsely populated case study site (Wolf Creek), impacts to education would be moderate even with the smaller work forces. At the other site (Arkansas Nuclear One), impacts would be moderate with the 1500-person BWR bounding case work force but small with the 1017-person BWR typical case work force.

Based on the case-study analysis of the PWR bounding-case work force, refurbishment impacts on education at all plant sites would range from small to large, although most sites will experience only small new impacts to education. Analyses of the work forces associated with the BWR bounding- and typical-case scenarios conclude that moderate impacts to education could be induced by these smaller work forces but only at sites that are remotely located and sparsely populated. Because site-specific and project-specific factors determine the significance of impacts to education and the potential value of mitigation measures, this is a Category 2 issue.

3.7.4.2 Transportation

Significance levels of transportation impacts are related to the Transportation Research Board's level of service (LOS) definitions (Transportation Research Board 1985). LOS is a qualitative measure describing operational conditions within a traffic stream and their perception by motorists. LOS data, when available, can be obtained from local planners, county engineers, or local or state departments of transportation. Using LOS data describing existing conditions, the staff projected LOS conditions that would arise from the additional traffic associated with refurbishment (or continued operations). The LOS at each site was examined during shift change times when plant- and non-plant-related traffic is heaviest. A general definition of each LOS is provided below.

LOS A and B are associated with small impacts because the operation of individual users is not substantially affected by the presence of other users. At this level, no delays occur and no improvements are needed. LOS C and D are associated with moderate impacts because the operation of individual users begins to be severely restricted by other users and at level D small increases in traffic cause operational problems. Consequently, upgrading of roads or additional control systems may be required. LOS E and F are associated with large impacts because the use of the roadway is at or above capacity level, causing breakdowns in flow that result in long traffic delays and a potential increase in accident rates. Major renovations of existing roads or additional roads may be needed to accommodate the traffic flow.

Impacts to local transportation networks during construction of the case study plants were large only at Wolf Creek (Table 3.4) because of the inadequacy of the main local access roads to accommodate plant-related traffic. Large transportation impacts also are anticipated at Wolf Creek during refurbishment. In this case, current operations workers would contribute to the

Level of service	Conditions
A	Free flow of the traffic stream; users are unaffected by the presence of others.
B	Stable flow in which the freedom to select speed is unaffected but the freedom to maneuver is slightly diminished.
C	Stable flow that marks the beginning of the range of flow in which the operation of individual users is significantly affected by interactions with the traffic stream.
D	High-density, stable flow in which speed and freedom to maneuver are severely restricted; small increases in traffic will generally cause operational problems.
E	Operating conditions at or near capacity level causing low but uniform speeds and extremely difficult maneuvering that is accomplished by forcing another vehicle to give way; small increases in flow or minor perturbations will cause breakdowns.
F	Defines forced or breakdown flow that occurs wherever the amount of traffic approaching a point exceeds the amount which can traverse the point. This situation causes the formation of queues characterized by stop-and-go waves and extreme instability.

magnitude of those impacts. The magnitude of impacts experienced at this and the other case study sites depends primarily on the state of the existing road network rather than on the host area population density.

Refurbishment impacts to transportation would be small at most sites, but a few sites would experience moderate or large impacts. Because impacts are determined primarily by road conditions existing at the time of the project and cannot be easily forecast, a site-specific review will be necessary to determine whether impacts are likely to be moderate or large and whether mitigation measures may be warranted. Transportation is a Category 2 issue.

3.7.4.3 Public Safety

Impacts on public safety are considered small if there is little or no need for additional police or fire personnel. Impacts are considered moderate if some permanent additions to the police and fire protection forces or some new capital equipment purchases are needed. Impacts are considered to be large if there is a substantial increase in the permanent manpower of police and fire protection forces and in the need to purchase additional vehicles.

No serious disruption of public safety services occurred as a result of original construction at the seven case study sites (Table 3.4). Most communities showed a steady increase in expenditures connected with public safety departments. Tax contributions from the plant often enabled expansion of public safety services in the purchase of new buildings and equipment and the acquisition of additional staff.

Public safety services may experience some benefit from any increase in tax revenue generated by plant improvements during current term outages. Past adverse impacts at the case study sites were found to be small, and nothing in the literature review indicated reason to expect moderate or large impacts. Accordingly, any adverse public safety impacts associated with future plant refurbishment at case study sites would be small.

Based on the case-study analysis, it is determined that there would be little or no need for additional police or fire personnel. Therefore, adverse public safety impacts at all sites would be small. Sensitivity analysis indicated that this conclusion would be true even with a peak work force of 3400 workers. Some minor positive impacts might result because of increased tax payments. Because the impacts are small and the implementation of additional mitigation measures (e.g., additional personnel or capital equipment) would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. Therefore, public safety is a Category 1 issue.

3.7.4.4 Social Services

The impacts on social services are considered small if no change in the current level of service occurs. Impacts are considered moderate if some additional personnel are needed to administer existing service programs. Impacts are considered large if new programs and additional personnel are required.

Impacts to local social services associated with the original construction of the case study plants generally were small (Table 3.4), but some areas did see a small increase in both the amount of dollars spent for new or existing programs and the demand for service during the construction period.

Based on original construction experience at case study plants, the staff anticipates that refurbishment-related population increases would lead to no change in the current levels of social service provided (Table 3.5). Consequently, the impacts of refurbishment on social services would be small at all sites. Because there would be no change in the levels of service and because mitigation measures (e.g., hiring additional social service personnel) beyond those implemented during the current term license would be costly, no mitigation measures would be warranted. This is a Category 1 issue. Sensitivity analysis indicates that this conclusion would be true even with a peak of 3400 workers.

3.7.4.5 Public Utilities

Impacts on public utility services are considered small if little or no change occurs in the ability to respond to the level of demand and thus there is no need to add to capital facilities. Impacts are considered moderate if overtaxing of facilities during peak demand periods occurs. Impacts are considered large if existing service levels (such as the quality of water and sewage treatment) are substantially degraded and additional capacity is needed to meet ongoing demands for services.

In general, small to moderate impacts to public utilities were observed as a result of the original construction of the case study plants (Table 3.4). While most locales experienced an increase in the level of demand for services, they were able to accommodate this demand without significant disruption. Water service seems to have been the most affected public utility.

Public utility impacts at the case study sites during refurbishment are projected to range from small to moderate. The potentially moderate impact at Diablo Canyon is related to water availability (not processing capacity) and would occur only if a water shortage occurs at refurbishment time.

Because the case studies indicate that some public utilities may be overtaxed during peak periods, the impacts to public utilities would be moderate in some cases, although most sites would experience only small impacts. This is a Category 2 issue.

3.7.4.6 Tourism and Recreation

Impacts on tourism and recreation are considered small if current facilities are adequate to handle local levels of demand. Impacts are considered moderate if facilities are overcrowded during peak demand times. Impacts are considered large if additional recreation areas are needed to meet ongoing demands.

In most of the case study areas, the original construction of a nuclear power plant had positive effects on tourism and recreation facilities. For example, some locales have been able to build new recreation facilities because of plant-related tax revenues. Some improvement to recreation facilities and programs may be possible if additional tax revenue is available as a result of current-term refurbishment at the plant. Increased demand associated with the refurbishment work force and in-migrating population is expected to cause only small impacts to recreation at the case-study sites.

Based on the case study analysis, the beneficial impacts of refurbishment would continue at most sites. Sensitivity analysis indicates that this conclusion would be true even with a peak work force of 3400 workers. Current facilities would continue to be adequate to handle local levels of demand at all sites, and developing additional facilities would be costly. Therefore, no mitigation measures (e.g., improving or expanding existing facilities) beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

3.7.5 Off-Site Land Use

The issue evaluated in this section concerns refurbishment-induced changes to local land use and development patterns. Because the value attributed to land-use changes can vary for different individuals and groups, this analysis does not attempt to conclude whether such changes have positive or negative impacts. The methodology used to define impact significance and project impacts is discussed briefly in the introduction to Section 3.7 and is detailed in Section C.4.1.5.

The impacts to off-site land use are considered small if population growth results in very little new residential or commercial development compared with existing conditions and if the limited development results only in minimal changes in an area's basic land-use pattern.

Land-use impacts are considered to be moderate if plant-related population growth results in considerable new residential or commercial development and the development results in some changes to an area's basic land-use pattern. The impacts are considered to be large if population growth results in large-scale new residential or commercial development and the development results in major changes in an area's basic land-use pattern.

Although it is difficult to predict the exact nature of land-use impacts that will result from any nuclear plant's refurbishment, the original construction experience at the case study plants provides some key predictors of impacts. Generally, if plant-related population growth is less than 5 percent of the study area's total population, off-site land-use changes would be small, especially if the study area has established patterns of residential and commercial development, a population density of at least 60 persons per square mile (2.6 km^2), and at least one urban area with a population of 100,000 or more within 80 km (50 miles).

If refurbishment-related growth is between 5 and 20 percent of the study area's total population, moderate new land-use changes can be expected. Such impacts would most likely occur when the study area has established patterns of residential and commercial development, a population density of 30 to 60 persons per square mile (2.6 km^2), and one urban area within 80 km (50 miles).

Small, moderate, and large off-site land-use impacts resulted from the original construction at the study sites. Large impacts resulted during construction at the two sites where lakes were created. Because no major off-site land use conversion would be needed to support the refurbished plants, only small impacts of this sort are expected. Large impacts were not induced at any site by population growth (see Table 3.6 and Appendix C).

Because the residential settlement pattern of the refurbishment work force is expected to be comparable to that of the original construction work force at many nuclear plants, population-driven land-use impacts that have resulted from the original construction can be used to predict some of the off-site land-use impacts of refurbishment. Thus, the staff expects that refurbishment-related population increases will result in small to moderate new off-site land-use impacts for socioeconomic case study plants (see Table 3.6 and Appendix C).

For the case study site where the staff anticipates moderate land-use changes associated with population in-migration, the staff has conducted additional analyses to determine whether smaller work forces would induce smaller impacts. This analysis shows that at this case-study site moderate impacts are possible with the BWR conservative scenario construction work force (1500 persons), but only small impacts are anticipated with the BWR typical scenario construction work force (1017 persons).

Based on predictions for the case study sites, refurbishment at all nuclear plants is expected to induce small or moderate land-use changes. There will be new impacts; but for almost all plants, refurbishment-related population growth would typically represent a much smaller percentage of the local areas' total population than did original construction-related growth. Moderate land use changes are also possible under the BWR conservative scenario, but only small impacts would be

Table 3.6 Significance levels for original construction and refurbishment-related off-site land-use impacts at seven case study nuclear power plants

Plant	Construction	Refurbishment
Arkansas Nuclear One	Moderate	Small
D. C. Cook	Moderate	Small
Diablo Canyon	Small	Small
Indian Point	Moderate	Small
Oconee	Large[a]	Small
Three Mile Island	Small	Small
Wolf Creek	Large[a]	Moderate

[a]Large impact because lake construction was associated with site development, not because of population growth (see Appendix C).
Source: The staff.

associated with the BWR typical scenario. Because future impacts are expected to range from small to moderate, and because land-use changes could be considered beneficial by some community members and adverse by others, this is a Category 2 issue. A sensitivity analysis shows that large changes in land use would not occur even with a 3400-person work force.

3.7.6 Economic Structure

The issue evaluated in this section concerns the impact of plant refurbishment on local employment and income levels.

Economic effects are considered small if peak refurbishment-related employment accounts for less than 5 percent of total study area employment. Effects are considered moderate if peak refurbishment-related employment accounts for 5 to 10 percent of total study area employment. Effects are considered large if peak refurbishment-related employment accounts for more than 10 percent of total study area employment. In this context, "plant-related employment" refers to area residents employed at the nuclear power plant or at indirect jobs resulting from a nuclear plant's presence. Employees who live outside the study area and work at the plant are not included.

The study of economic structure examines employment because of its preeminent role in determining the economic well-being of an area. Economic impacts at the case study plants were predicted by comparing the number of direct and indirect jobs created by a plant's refurbishment with the total employment of the local study area at the time of refurbishment. These impacts are considered positive. The potential economic impacts of plant refurbishment at all sites were projected based on the seven case study plants.

During original construction, plant-related employment represented 0.3–25.6 percent of total employment in the communities near the case study plants. Table 3.7 shows the past effects associated with the construction work force and the projected effects of the refurbishment work force for all seven case study sites. The impacts to economic structure of both direct and indirect employment were included in this assessment.

Based on the findings at the case study sites, refurbishment-related economic effects would range from small benefits to moderate benefits at all nuclear plant sites. No adverse effects to economic structure would result from refurbishment-related employment. This conclusion would apply in the event of a much larger refurbishment work force because the associated impacts are beneficial.

3.7.7 Historic and Archaeological Resources

For this discussion and that in Section 4.7.7, historic resources are considered to be any prehistoric or historic archaeological site or historic property, district, site, or landscape in or eligible for inclusion in the *National Register of Historic Places* or having great local importance.

Sites are considered to have small impacts to historic and archaeological resources if (1) the State Historic Preservation Office (SHPO) identifies no significant resources on or near the site; or (2) the SHPO identifies (or has previously identified) significant historic resources but determines they would not be affected by plant refurbishment, transmission lines, and license-renewal-term operations and there are no complaints from the affected public about altered historic character; and (3) if the conditions associated with moderate impacts do not occur. Moderate impacts may result if historic resources, determined by the SHPO not to be eligible for the *National Register*, nonetheless are thought by the SHPO or local historians to have local historic value and to contribute substantially to an area's sense of historic character. Sites are considered to have large impacts to historic resources if resources determined by the SHPO to have significant historic or archaeological value would be disturbed or otherwise have their historic character altered through refurbishment activity, installation of new transmission lines, or any other construction (e.g., for a waste storage facility). Determinations of significance of impacts are made through consultation with the SHPO.

Any new construction activity, including building new waste storage facilities, new parking areas, new access roads to existing transmission lines, or new transmission lines, is particularly important to an analysis of impacts to historic and archaeological resources. Therefore, a refurbishment plan detailing areas of land disturbance is necessary to assess the potential impacts. Historic and archaeological resources vary widely from site to site; there is no generic way of determining their existence or significance. Also, additional resources (e.g., an archaeological site) may be identified before refurbishment begins or their historic significance may be newly established (e.g., a historic building). For these reasons, it is not possible to conclude that only small impacts would occur at the case study sties.

In addition, conclusions with respect to potential impacts to historic resources at the case study sites can be drawn only through consultation with the SHPO. The National Historic Preservation Act of 1966,

Table 3.7 Past construction-related and projected refurbishment-related employment effects at seven case study nuclear plants

	Construction			Refurbishment	
Nuclear plant	Plant-related employment[a]	Percentage of total study area employment	Magnitude of impact	Percentage of total study area employment in peak refurbishment year	Magnitude of impact
Arkansas Nuclear One	964	6.4	Moderate	5.8	Moderate
D. C. Cook					
Bridgman-Lake Township	140	8.8	Moderate	7.5	Moderate
Berrien County	2569	6.5	Small	3.3	Small
Diablo Canyon	3153	3.6	Moderate	1.8	Small
Indian Point					
Westchester County	966	0.3	Small	0.2	Small
Oconee	706	3.3	Small	1.9	Small
Three Mile Island	259	2.1	Small	6.0	Small
Wolf Creek	1361	25.6	Large	6.8	Small

[a]Includes both direct and indirect employment and income for study area residents.
Source: The staff.

especially Section 106, requires consultation with the SHPO and possibly the Advisory Council on Historic Preservation to determine whether historic and archaeological resources (either in or eligible for inclusion in the *National Register of Historic Places*) are located in the area and whether they will be affected by the proposed action.

It is unlikely that moderate or large impacts to historic resources occur at any site unless new facilities or service roads are constructed or new transmission lines are established. However, the identification of historic resources and determination of possible impact to them must be done on a site-specific basis through consultation with the SHPO. The site-specific nature of historic resources and the mandatory National Historic Preservation Act consultation process mean that the significance of impacts to historic resources and the appropriate mitigation measures to address those impacts cannot be determined generically. This is a Category 2 issue.

3.7.8 Aesthetic Resources

The issues evaluated in this section concern the impacts of construction and refurbishment activities on aesthetic resources at and around nuclear power plants. Primarily, aesthetic impacts would be temporary, would be limited both in terms of land disturbance and the duration of activity, and would have characteristics similar to those encountered during industrial construction: dust and mud around the construction site, traffic and noise of trucks, and construction disarray on the site itself. If severe, these effects could have implications for the economic and social institutions and functions of communities. Aesthetic resources are the physical elements that are pleasing sensory stimuli and include natural and manmade landscapes and the way the two are integrated. In this evaluation, the staff considers aesthetic resources to be primarily visual.

Levels of impacts for aesthetic resources are defined largely by the impact of the proposed changes as perceived by the public, not merely the magnitude of the changes themselves. The potential for significance arises with the introduction (or continued presence) of an intrusion into an environmental context resulting in measurable changes to the community (e.g., population declines, property value losses, increased political activism, tourism losses).

Sites are considered to have small impacts on their host communities' aesthetic resources if there are (1) no complaints from the affected public about a changed sense of place or a diminution in the enjoyment of the physical environment and (2) no measurable impact on socioeconomic institutions and processes. Sites are considered to have moderate impacts on their host communities' aesthetic resources if there are (1) some complaints from the affected public about a changed sense of place or a diminution in the enjoyment of the physical environment and (2) measurable impacts that do not alter the continued functioning of socioeconomic institutions and processes. A site is considered to have large impacts on its host community's aesthetic resources if there are (1) continuing and widely shared opposition to the plant's continued operation based solely on a perceived degradation of the area's sense of place or a diminution in the enjoyment of the physical environment and (2) measurable social impacts that perturb the continued functioning of community institutions and processes.

Because refurbishment would not result in substantial physical changes to existing plants and because the duration of these activities is expected to be short, new aesthetic impacts are expected to be limited to temporary effects. Based on projections for the case study sites, noticeable impacts on aesthetic resources from refurbishment activities could occur only at those sites where well-recognized aesthetic resources have been identified and protected by community organizations. Insignificant levels of impact on aesthetic resources are likely to be experienced in most host communities where (1) no scenic protection organizations are active, (2) active organizations view refurbishment activities as nonthreatening to such resources, or (3) either few or no distinctive aesthetic resources exist or refurbishment activities are not perceived to be threatening to local resources.

Refurbishment activities will be conducted on-site and primarily within existing buildings. Other than a possible increase in local traffic, due to refurbishment workers, refurbishment activities are not expected to be readily noticeable from off-site viewpoints at any plant. Thus, without a visual intrusion within the physical environment there is no stimulus that could lead to complaints from the public about a changed sense of place or a diminution in the enjoyment of the physical environment and measurable impact on socioeconomic institutions and processes. For these reasons, the impact on aesthetic resources is found to be small. Because there will be no readily noticeable visual intrusion, consideration of mitigation is not warranted. Aesthetic impacts of refurbishment is a Category 1 issue.

3.8 RADIOLOGICAL IMPACTS

Radiological impacts include off-site dose to members of the public and on-site dose to the work force. Each of these impacts is generic to all light-water reactors (LWRs). Section 2.6 and Appendix B identify the changing out of steam generators at PWRs and the replacement of recirculation piping at BWRs as the major anticipated refurbishment activities. Public radiation exposures and occupational radiation exposures from refurbishment activities for license renewal can be evaluated on the basis of information derived from past occurrences and projections for other repairs. Effluents anticipated during major refurbishment events were estimated on the basis of historical information derived for steam generator changeouts at PWRs and replacements of recirculation piping at BWRs, refurbishment tasks that have already taken place several times within the LWR power reactor industry. From these estimates, the maximum individual and average doses to members of the public were compared with the design objective of Appendix I to 10 CFR Part 50 and with baseline effluents produced during normal reactor operations. Occupational exposures were similarly estimated on the basis of detailed reports of major refurbishment or replacement actions. The radiological significance of the doses caused by refurbishment was compared with doses from normal operation, and risks from occupations not associated with ionizing radiation. Major historical refurbishment actions are referred to in Section 2.6 and are described in detail in Appendix B. Radiological impacts of transportation are discussed in Chapter 6.

A detailed discussion is provided in Chapter 6 of the radiological impacts of low-level waste, mixed waste, and spent fuel generated by power reactors during the renewal period; the impacts attributable to the uranium fuel cycle; and the impacts of the transportation of fuel and waste.

In response to comments on the draft generic environmental impact statement (GEIS) and the proposed rule, the standard defining a small radiological impact has changed from a comparison with background radiation to sustained compliance with the dose and release limits applicable to the activities being reviewed. This change is appropriate and strengthens the criterion used to define a small environmental impact for the reasons that follow. The Atomic Energy Act requires NRC to promulgate, inspect, and enforce standards that provide an adequate level of protection of the public health and safety and the environment. These responsibilities, singly and in the aggregate, provide a margin of safety. The definitions of the significance level of an environmental impact (small, moderate, or large) applied to most other issues addressed in this GEIS are based on an ecological model that is concerned with species preservation, ecological health, and the condition of the attributes of a resource valued by society. Generally, these definitions place little or no weight on the life or health of individual members of a population or an ecosystem. However, health impacts on individual humans are the focus of NRC regulations limiting radiological doses. A review of the regulatory requirements and the performance of facilities provides the bases to project continuation of performance within regulatory standards. For the purposes of assessing radiological impacts, the Commission has concluded that impacts are of small significance if doses and releases do not exceed permissible levels in the Commission's regulations. This definition of "small" applies to occupational doses as well as to doses to individual members of the public. Accidental releases or noncompliance with the standards could conceivably result in releases that would cause moderate or large radiological impacts. Such conditions are beyond the scope of regulations controlling normal operations and providing an adequate level of protection. Given current regulatory activities and past regulatory experience, the Commission has no reason to expect that such noncompliance will occur at a significant frequency. To the contrary, the Commission expects that future radiological impacts from the fuel cycle will represent releases and impacts within applicable regulatory limits.

3.8.1 Public Exposures

This section addresses the impacts on members of the public of radiation doses caused by refurbishment activities, including doses from effluents as well as from direct radiation. This issue is generic to all 118 nuclear power plants. To determine the relative significance of the estimated public dose for refurbishment, the staff compared dose projections for refurbishment with the historical (baseline) doses experienced at PWRs and BWRs. The dose estimates were based on reports evaluating effluent releases during refurbishment efforts (projected and measured).

Evaluating and analyzing public exposures to radioactive emissions associated with refurbishment was done in light of the regulatory requirements for nuclear power plants, methods for calculating doses from gaseous and liquid effluents, the levels of risk that authoritative agencies have determined to be associated with radiation exposure, and baseline radiation exposure data.

3.8.1.1 Regulatory Requirements

Nuclear power reactors in the United States must be licensed by the NRC and must comply with NRC regulations and conditions specified in the license in order to operate. NRC regulations in 10 CFR Part 20 include requirements that apply to all licenses such as individual nuclear power plants. In particular, maximum allowable concentrations of radionuclides in air and water above background at the boundary of unrestricted areas are specified to control radiation exposures of the public and releases of radioactivity. These concentrations are based on an annual total effective dose equivalent of 0.1 rem to individual members of the public. (A discussion of the International System of units used in measuring radioactivity and radiation dose is given in Appendix E, Section E.A.3.) In addition, design criteria and technical specifications concerning releases from the plant are required to minimize the radiological impacts associated with plant operations to levels as low as reasonably achievable (ALARA).

In 10 CFR Part 50.36a, conditions are imposed on licensees in the form of technical specifications on effluents from nuclear power reactors. These specifications are intended to keep releases of radioactive materials to unrestricted areas during normal operations, including expected operational occurrences, to ALARA levels. Appendix I to 10 CFR Part 50 provides numerical guidance on dose-design objectives and limiting conditions for operation of LWRs to meet the ALARA requirement. All licensees have provided reasonable assurance that the dose-design objectives are being met for all unrestricted areas. The design objective doses for Appendix I are summarized in Table 3.8.

In addition to NRC limitations, nuclear power plant releases to the environment must comply with EPA standards in 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations." These standards specify limits on the annual dose equivalent from normal operations of uranium fuel-cycle facilities (except mining, waste disposal operations, transportation, and reuse of recovered special nuclear and byproduct materials). The standards are given in Table 3.8. Radon and its daughters are excluded from these standards.

EPA standards in 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants; Regulation of Radionuclides," apply only to airborne releases. The EPA specified an annual effective dose equivalent limit of 10 mrem for airborne releases from nuclear power plants; however, no more than 3 mrem can be caused by any isotope of iodine. However, EPA has stayed the rule for NRC-licensed commercial nuclear power reactors based on its finding that NRC's program for power reactor air effluents protects and is likely to continue to protect the public health and safety with an ample margin of safety.

Experience with the design, construction, and operation of nuclear power reactors indicates that compliance with the design objectives of Appendix I to 10 CFR Part 50 will keep average annual releases of radioactive material in effluents at small percentages of the limits specified in 10 CFR Part 20 and 40 CFR Part 190. At the same time, the licensee is permitted the flexibility of operation, compatible with considerations of health and safety, to ensure that the public is provided a dependable source of power, even under unusual operating conditions that may temporarily result in releases higher than such small percentages but still well within the regulatory limits.

A major revision of 10 CFR Part 20 became effective in 1991. A significant change is the explicit requirement that the sum of the external and internal doses (total effective dose equivalent) for a member of the public may not exceed 100 mrem/year. This value is an annual limit and is not intended to be applied as a long-term average goal. Summations are to be performed using the methodology in International Commission on Radiological Protection (ICRP) Publication 26 (1977). The revised airborne effluent limits are based on 50 mrem/year. Therefore, with regard to radiation levels at any unrestricted area, the limit of 100 mrem in 7 consecutive days is eliminated, while the limit of 2 mrem in any 1 h is retained. Licensees may comply with the 100-mrem limit by demonstrating (1) by measurement or calculation that the individual likely to receive the highest dose from sources under the licensee's control does not

Table 3.8 Design objectives and annual limits on doses to the general public from nuclear power plants[a]

Tissue	Gaseous	Liquid
Design objectives, 10 CFR Part 50, Appendix I		
Total body, mrem	5[b]	3
Any organ (all pathways), mrem		10
Ground-level air dose[b], mrad	10 (gamma) 20 (beta)	
Any organ[c] (all pathways), mrem	15	
Skin, mrem	15	
Dose limits, 40 CFR Part 190, Subpart B		
Total body[d], mrem	25	
Thyroid[d], mrem	75	
Any other organ[d], mrem	25	

[a]Calculated doses.
[b]The ground-level air dose has always been limiting because an occupancy factor cannot be used. The 5-mrem total body objective could be limiting only in the case of high occupancy near the restricted area boundary.
[c]Particulates, radioiodines.
[d]All effluents and direct radiation except radon and its daughters.

exceed the limit or (2) that the concentrations of radioactive material released in gaseous and liquid effluents averaged over 1 year do not exceed the new levels at the unrestricted area boundary and that the dose in an unrestricted area exceeds neither 2 mrem in any given hour nor 100 mrem in 1 year. It is difficult to judge how federal regulations and industry standards will change between the present time and the license renewal period, which, for the newest reactors, may be 40 years from now. Some indications of future trends can be summarized, however. Two changes are discussed that could significantly affect radiation protection programs at the 118 power plants:

- New ICRP recommendations. ICRP-60 (1991) has recommended an occupational dose limit of 10-rem effective dose equivalent, accumulated over defined periods of 5 years. They have further specified that the effective dose should not exceed 5 rem in any single year. The NRC has carefully reviewed the recommendations of the ICRP and is reviewing the comments of the scientific community and others on these recommendations, and the ICRP response to inquiries. In addition, NRC staff will review the recommendations of other expert bodies, such as the National Council on Radiation Protection and Measurements (NCRP), and participate in the deliberations of the U.S. Committee on Radiation Research and Policy Coordination and any interagency task force convened by the EPA to consider revised federal radiation guidance. Any future reductions in the dose limits by NRC would be the subject of a future rulemaking proceeding.

- NCRP lifetime dose recommendation. NCRP has recommended that a worker's dose in rem should not exceed his age in years. The recommendation was not accepted for the 1991 revision of 10 CFR Part 20. NRC considers that if the magnitude of the annual dose is limited, there is a *de facto* limitation on the lifetime dose that can be received. The annual dose limit is preferable to an actual cumulative lifetime dose limit because the cumulative limit could act to limit employment, raising questions concerning the right of an individual to pursue employment in a chosen profession. Nonetheless, the Institute of Nuclear Power Operations has expressed considerable interest in the recommendation, and at many plants records are being examined to determine whether the more experienced workers meet this criterion. For those who do not, the utilities may face decisions involving worker protection and liability considerations from a viewpoint favoring restrictions and the need for skilled and experienced workers during the process leading up to and extending throughout the license renewal period.

3.8.1.2 Effluent Pathways for Calculations of Dose Commitment to the Public

When an individual is exposed to radioactive materials through air or water pathways, the dose is determined in part by the amount of time spent in the vicinity of the source or the amount of time the radionuclides inhaled or ingested are retained in the individual's body (exposure). The consequences associated with this exposure are evaluated by calculating the dose commitment. The total effective dose equivalent is the sum of the deep dose from external sources and the committed effective dose equivalent for internal exposures. This latter dose is that which would be received over a 50-year period following the intake of radioactive materials for 1 year under the conditions existing at the midlife of the station operation (typically 15 years).

Radioactive effluents can be divided into several groups based on physical characteristics. Among the airborne effluents, the radioisotopes of the noble gases krypton, xenon, and argon neither deposit on the ground nor are absorbed and accumulated within living organisms; therefore, the noble gas effluents act primarily as a source of direct external radiation emanating from the effluent plume. For these effluents, dose calculations are performed for the site boundary where the highest external-radiation doses to a member of the general public are estimated to occur.

A second group of airborne radioactive effluents—the fission-product radioiodines, as well as carbon-14 and tritium—are also gaseous but some can deposit on the ground or be inhaled during respiration. For this class of effluents, estimates are made of direct external radiation doses from ground deposits (as well as exposure to the plume). Estimates are also made of internal radiation doses to total body, thyroid, bone, and other organs from inhalation and from vegetable, milk, and meat consumption.

A third group of airborne effluents consists of particulates and includes fission products, such as cesium and strontium, and activated corrosion products, such as cobalt and chromium. These effluents contribute to direct external radiation doses and to internal radiation doses through the same pathways as described above for the radioiodine. Doses from the particulates are combined with those from the radioiodines, carbon-14, and tritium for comparison with one of the design objectives of Appendix I to 10 CFR Part 50.

The liquid effluent constituents could include fission products such as strontium and iodine; activation and corrosion products, such as sodium, iron, and cobalt; and tritiated water. These radionuclides contribute to the internal doses through pathways described above from fish consumption, water ingestion (as drinking water), and consumption of meat or vegetables raised near a nuclear plant and using irrigation water, as well as from any direct external radiation from recreational use of the water near the point of a plant's discharge.

The release of each radioisotope and the site-specific meteorological and hydrological data serve as input to radiation-dose models that estimate the maximum radiation dose that would be received outside the facility by way of a number of pathways for individual members of the public and for the general public as a whole. These models and the radiation-dose calculations are discussed in Revision 1 of Regulatory Guide 1.109, "Calculation and Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I."

Doses from all airborne effluents except the noble gases are calculated for individuals at the location or source point (for example, the site boundary, garden, residence, milk cow or goat, and meat animal) where the highest radiation dose to a member of the public has been established from each applicable pathway (such as ground deposition, inhalation, vegetable consumption, milk consumption, or meat consumption). Only those pathways associated with airborne effluents that are known to exist at a single location are combined to calculate the total maximum exposure to an exposed individual. Pathway doses associated with liquid effluents are combined without regard to any single location but are assumed to be associated with maximum exposure of an individual.

A number of possible exposure pathways to humans are evaluated to determine the impact of routine releases from each nuclear facility on members of the general public living and working outside the site boundaries. A detailed listing of these exposure pathways would include external radiation exposure from the gaseous effluents, inhalation of iodines and particulate contaminants in the air, drinking milk from a cow or goat or eating meat from an animal that grazes on open pasture near the site on which iodines or particulates may be deposited, eating vegetables from a garden near the site (that may be contaminated by similar deposits), and drinking water or eating fish or invertebrates caught near the point of liquid effluent discharge. Other, less important exposure pathways may include external irradiation from surface deposition; eating of animals and crops grown near the site and irrigated with water contaminated by liquid effluents; shoreline, boating, and swimming activities; drinking potentially contaminated water; and direct irradiation from within the plant itself. Calculations for most pathways are limited to a radius of 80 km (50 miles). Beyond 80 km, the doses to individuals are smaller than 0.1 mrem/year, which is far below the average natural-background dose of 300 mrem/year.

For this study, effluent and population dose information was collected from a series of documents that have resulted from ongoing NRC programs. Source-term data (normal effluent releases from nuclear power plants) are assembled annually at Brookhaven National Laboratory (NUREG/CR-2907), and calculations of radiation dose to the public are performed at Pacific Northwest Laboratory. Documentation is given in a series of reports titled *Population Dose Commitments Due to Radioactive Releases from Nuclear Power Plant Sites* (NUREG/CR-2850). The source terms (measured in effluents) are used to estimate dose commitments to those persons assumed to be living in a region between 2 and 80 km (1.2 and 50 miles) from the reactor sites. Atmospheric transport factors (annual average dilution and annual average deposition) were calculated for the region around each site using appropriate meteorological data supplied by either the NRC or the utility. Site-specific parameters other than releases, meteorology, and population were obtained from environmental impact statements or updates in environmental monitoring reports. Parameter values include the total population drinking contaminated water, fish and invertebrate harvest for the region, and dilution factors. For those cases in which site-specific data were not readily available and the particular pathway was not expected to result in a large dose, assumptions intended to be conservative were used to estimate doses. The use of more realistic data should decrease dose estimates in most cases. To this end, each licensee has the opportunity to provide site-specific data. Doses were calculated using models approved by the NRC (NUREG/CR-2850).

3.8.1.3 Risk Estimates from Radiation Exposure

In estimating the health effects resulting from both off-site and occupational radiation exposures as a result of refurbishment of nuclear power facilities, the staff used normal probability coefficients for stochastic effects recommended by the ICRP (ICRP 1991). The coefficients consider the most recent radiobiological and epidemiological information available and are consistent with the United Nations Scientific Committee on the Effects of Atomic Radiation. The coefficients used in this GEIS (Table 3.9) are the same as those recently published by ICRP in connection with a revision of its recommendations (ICRP 1991). Excess hereditary effects are listed separately in this GEIS because radiation-induced effects of this type have not been observed in any human population, as opposed to excess malignancies that have been identified among populations receiving instantaneous and near-uniform exposures in excess of 10 rem. Details regarding the risk of radiation-induced health effects are provided in Appendix E.